



ENGLISH TRANSLATION

RADIOFREQUENCY-EXPOSURE
PROTECTION

ARIB STANDARD

RCR STD-38

Version 3.0

Version 1.0 September 9th 1993

Version 3.0 July 30th 2019

Association of Radio Industries and Businesses

General Notes to the English Translation of ARIB Standards and Technical Reports

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Foreword

The Association of Radio Industries and Businesses (ARIB) investigates and summarizes the basic technical requirements for various radio systems in the form of “ARIB Standards”. These standards are developed with the participation of and through discussions amongst radio equipment manufacturers, telecommunication operators, broadcasting equipment manufacturers, broadcasters and users.

ARIB Standards include “government technical regulations” (mandatory standard) that are set for the purpose of encouraging effective use of frequency and preventing interference with other spectrum users, and “private technical standards” (voluntary standards) that are defined in order to ensure compatibility and adequate quality of radio equipment and broadcasting equipment as well as to offer greater convenience to radio equipment manufacturers, telecommunication operators, broadcasting equipment manufacturers, broadcasters and users.

This ARIB standard is developed for “Radiofrequency-exposure Protection”. In order to ensure fairness and transparency in the defining stage, the standard was set by consensus at the ARIB Standard Assembly with the participation of both domestic and foreign interested parties from radio equipment manufacturers, telecommunication operators, broadcasting equipment manufacturers, broadcasters and users.

ARIB sincerely hopes that this ARIB Standard will be widely used by radio equipment manufacturers, telecommunication operators, broadcasting equipment manufacturers, broadcasters and users.

Foreword for the first edition

This standard was compiled as radio wave protection standards that gave quantitative evaluation standards about safety when the human body was exposed to an electric wave based on the “Radio-Radiation Protection Guidelines for Human Exposure to Electromagnetic Fields” reported by the Telecommunications Technology Council of the Ministry of Posts and Telecommunications in June 1990. This standard was based on the principle of human protection considering an adequate safety factor according to administrative guidelines of the Council report and exceeding this standard alone does not necessarily affect the human body. Also, the measurement methods adopted in this standard are described in the measurement methods of the Council report.

Foreword for the second edition

Since the first edition of this standard was developed, the Telecommunications Technology Council report “Radio-Radiation Protection Guidelines for Human Exposure to Electromagnetic Fields” to respond to Inquiry 89 was published in April 1997 and the partial-body absorption guidelines, that was excluded in the Council report issued in 1990 to apply when there was a radio wave emission source in the vicinity of the body, was clearly defined.

Also, on October 1, 1998 a ministerial ordinance amending part of the Regulations for Enforcement of the Radio Law was promulgated and the establishment of a “safety facilities for electromagnetic field strength” had become mandatory for places where electromagnetic field strength had possibility of exceeding the electromagnetic field strength guideline value under general environment. In addition, on November 30, 1998 a report “Measurement and calculation methods of radio wave strength to confirm compliance with radio wave protection guideline” was submitted by the Telecommunications Technology Council to respond to Inquiry No. 104

On the other hand, in April 1998 within the Research Subcommittee of the Electromagnetic Environment Committee in ARIB, a Radio protection confirming working group was established to research estimation methods and latest measurement methods to evaluate the conformity to the protection standards targeting a radio station installed at a specific location, and the "Examination Report on Compliance with the Guidelines on the Protection of Radio Waves" was compiled in September 1998. The results of this study are reflected in the report responding to the Inquiry No. 104 of the above-mentioned Telecommunications Technology Council. Considering these situations, the “Radio Frequency Protection Standard RCR STD-38 (version 1.0) was revised as version 2.0.

Foreword for the third edition

Subsequently, in May 2011 “Ideal State of Partial-Body Absorption Guidelines” was issued to respond to Inquiry No. 2030, and in March 2015 “Ideal State of Radio Protection Guidelines in the Low Frequency Range (10 kHz to 10 MHz)” and in September 2018 “Ideal State of Radio Protection Guidelines in the High Frequency Range” among “Ideal State of Radio Protection Guidelines” were issued to respond to Inquiry No. 2035 by the Council for Information and Communication. Considering these situations, the “Radio Frequency Protection Standard RCR STD-38 (version 2.0) was revised as version 3.0.

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Chapter 1 General Matters

1.1 Outline

This Radiofrequency-exposure Protection Standard (hereinafter referred to as “the standard”) prescribes standard limit levels of the electromagnetic field strength and the specific ratio absorption rate which are allowable levels to be considered as not causing undesirable electromagnetic phenomenon to the human body (such as a temperature rise in inner body, an electric shock, a high frequency burn, etc.) when the human body is exposed to the electromagnetic fields in using electromagnetic waves. In addition, the standard prescribes estimation methods (calculation methods, experiment methods and so on) of electromagnetic strength and measurement methods necessary for evaluation. However, when confirming the conformity to this standard for a specific radio station in detail, ARIB Technical Report “Methods of evaluating compliance for radiofrequency-exposure protection standard” (ARIB TR-T11), ARIB Technical Report “Measurement and calculation methods to evaluate electro-magnetic field and SAR emitted from mobile base station antenna with regard to radiofrequency-exposure protection” (ARIB TR-T21) or ARIB Standard “Specific absorption rate (SAR) estimation for cellular phone” (ARIB STD-T56) shall apply.

In addition, this standard is based on the following:

Relevant 1: Excerpts from “Radio-Radiation Protection Guidelines for Human Exposure to Electromagnetic Fields” (1990), a report by the Telecommunications Technology Council,

Relevant 2: Excerpts from “Radio-Radiation Protection Guidelines for Human Exposure to Electromagnetic Fields” (1997),

Relevant 3: Excerpts from “Measurement method and calculation method of the strength of radio waves to confirm conformity to the radio wave protection guidelines” (November 1998) ,

Relevant 4: Ideal state of partial-body absorption guidance (May 2011) ,

Relevant 5: Ideal state of radio protection guidelines in the low frequency range (from 10 kHz to 10 MHz) (March 2015) ”as a part of “Ideal state of radio protection guidelines,

Relevant 6: Ideal state of radio protection guidelines in the high frequency range (September 2018)” as a part of “Ideal state radio protection guidelines.

Wireless device manufacturers, telecommunications carriers, users, etc. should consider the

safety of the human body based on this standard in general radio wave usages.

1.2 Scope of application

This standard applies to radio wave utilization in electromagnetic fields with frequency range of 10 kHz to 300 GHz. However, it does not apply to artificial electromagnetic radiation to patients for the purpose of medical treatment (see Note in Section 2.5).

In addition, the standard values under general environment in the electromagnetic field strength standard of this standard are the same as the strength value of the electric wave requiring safety facilities specified in Article 21-3 of Regulations for Enforcement of the Radio Law (Safety facilities for the strength of the electric wave). Therefore, the radio facilities meeting the standard values under general environment are considered as satisfying the condition of safety facilities specified in the article of Regulations for Enforcement of the Radio Law.

For reference, the correspondence with the provisions specified in this standard and those specified in Notification 309 (2017) of the Ministry of Internal Affairs and Communications based on the provisions specified in Regulations for Enforcement of the Radio Law 21-3 and Attached Table 2-2-2 Note 3 is shown in Appendix 4.

1.3 Standards on contact current and induced current

Contact current and induced current, which are described in the report by the Telecommunications Technology Council and are treated in this standard, are excluded from the Regulations for Enforcement of Radio Law. The reason is described as follows in Chapter 2 of the report responding to the Inquiry No.104 shown in Appendix 3.

Radio Radiation Protection Guidelines to be applied shall be electromagnetic field strength guidelines and supplementary guidelines under general environment. However, for the following reasons it is desirable that Note 1, Note 2 and the supplementary guidelines concerning induced current and contact current are excluded from subject of standardization and should be used as voluntary guidelines.

- ① The measurement method and the measurement instrument for inducted and contact current have not yet been established well.
- ② Regarding guidance values of induced current, there is not a reasonable definition of the non-grounded condition of the human body and it is difficult to determine whether the induced current value meets guidance values.
- ③ The guideline value of the contact current is based on a perceivable threshold level and even if the contact current level exceeds the guideline value, the level is deemed not to immediately affect the health of persons.
- ④ Even with the same electric field strength, the current value flowing into the human body is different due to the size of the intended metal object and the electromagnetic field strength considering the contact current cannot be determined uniquely.
- ⑤ In the United States and Australia where the introduction of institutionalization has been considered, no regulation under general environment exists.

Therefore, although this voluntary standard incorporates the standard for contact current and induced current, they are not mandatory in the actual radio wave protection evaluation.

Chapter 2 Radiofrequency-Exposure Protection Standard

2.1 Outline

2.1.1 Structure of radiofrequency-exposure protection standard

Figure 2.1-1 shows a structure of radiofrequency-exposure protection standard. This standard consists of an electromagnetic field strength standard, a supplementary standard and a partial-body absorption standard. The electromagnetic field strength standard and the partial-body absorption standard are further divided into standards in the general environment and the controlled environment. As shown in Appendix 1, the basic guideline is provided as a guideline for the basis of these standards and strict evaluation of these standards. In addition, as shown in Appendix 2, there is a basic restriction that can be used positively to confirm compliance compared to the basic guideline in the frequency range from 10 kHz to 10 MHz,

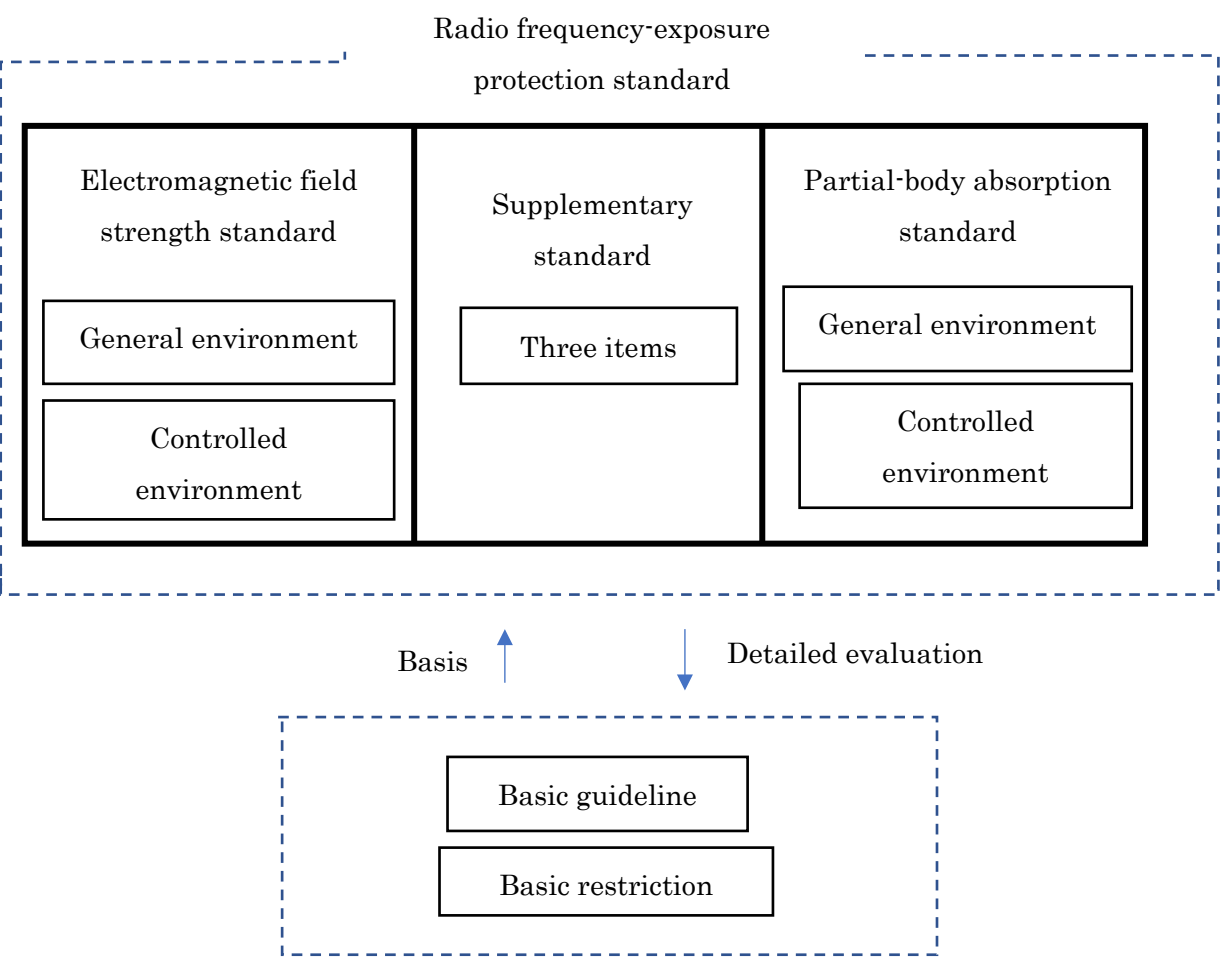


Figure 2.1-1 Structure of radiofrequency-exposure protection standard

2.1.2 Application procedure of radiofrequency-exposure protection standard

This standard is applied by the following procedures.

Procedure 1: Determination of a standard to be applied

Whether the source of the intended radio wave is near or far from the human body should be determined and the frequency of the source is confirmed. If the distance exceeds 20 cm, the electromagnetic field strength standard should be applied. In this case, the standard for thermal effects should be applied to the frequency range of 100 kHz to 300 GHz, and the standard for the stimulation effects should be applied to the frequencies of 10 MHz or less, and the both standards should be applied to the frequency range of 10 kHz to 10 MHz. If the distance is within 20 cm, the partial-body absorption standard should be applied to the frequency range of 10 kHz to 6 GHz. However, the application of the electromagnetic field strength standard or supplementary standard in the frequencies of not less than 300 MHz and in the distance between 10 cm and 20 cm is not excluded.

Procedure 2: Determination of the intended space environment

In situation where the environment of the intended space is exposed to radio waves in daily life and thorough management of the electromagnetic environment is difficult, the value of the general environment is applied, and in situation where the electromagnetic environment is controlled in such a case of being exposed to radio waves on business, the value of the controlled environment is applied.

Procedure 3: Determination of safety I

By comparing with the standard values applied to the intended space, safety should be determined.

Procedure 4: Determination of safety II

When the distance between the radio wave emission source and the intended space exceeds 20 cm and the electromagnetic field strength standard is not satisfied, the supplementary standard should be applied to determine the safety. The supplementary standard is composed of the following three items.

- ① Standard applied to the cases of non-uniform or partial body exposure to the electromagnetic field,
- ② Standard concerning contact current,
- ③ Standard concerning induced current.

2.2 Electromagnetic field strength standards

2.2.1 General environment

Table 2.2-1 (a) and Table 2.2-1 (b) show electromagnetic field strength standards under the general environment. If the electromagnetic field strength in a measurement space does not partially satisfy the values in these tables, the supplementary standard in Section 2.3 should be applied.

Figure 2.2-1 and Figure 2.2-2 are graphical representations of the standard values in Table 2.2-1 (a) and Table 2.2-1 (b).

Table 2.2-1(a) Electromagnetic field strength standards under the general environment (average value over 6 minutes)

Frequency f	Effective value of electric field strength E [V/m]	Effective value of magnetic field strength H [A/m]	Power density S [mW/cm ²]
Above 100 kHz to 3 MHz	275	$2.18f[\text{MHz}]^{-1}$ (21.8-0.728)	
Above 3 MHz to 30 MHz	$824f[\text{MHz}]^{-1}$ (275-27.5)	$2.18f[\text{MHz}]^{-1}$ (0.728-0.0728)	
Above 30 MHz to 300 MHz	27.5	0.0728	0.2
Above 300 MHz to 1.5 GHz	$1.585f[\text{MHz}]^{1/2}$ (27.5-61.4)	$f[\text{MHz}]^{1/2}/237.8$ (0.0728-0.163)	$f[\text{MHz}]/1500$ (0.2-1)
Above 1.5 GHz to 300 GHz	61.4	0.163	1

Table 2.2-1(b) Electromagnetic field strength standards in low frequency range
under general environment

Frequency f	Effective value of electric field strength E [kV/m]	Effective value of magnetic field strength H [A/m]	Effective value of magnetic flux density [T]
Above 10 kHz to 10 MHz	8.3×10^{-2}	21	2.7×10^{-5}

Note 1: If contact hazard is not prevented at 15 MHz or less, protection from the contact current can be ensured by applying the supplementary standard 2.3.2. This note is not a mandatory evaluation item as described at the end of Section 1.3.

Note 2: In the case where the non-grounding condition of the human body is not satisfied, the effective value of the electric field strength (average value over 6 minutes) should be $1,430f \text{ (MHz)}^{-3/2} \text{ V/m}$ (i.e. 275 V/m to 9 V/m) or less in the frequency range from 3 MHz to 30 MHz, 9V/m or less in the frequency range from 30 MHz to 100 MHz and $0.09f \text{ (MHz)} \text{ V/m}$ or less (i.e. 9V /m to 27 V / m) in the frequency range from 100 MHz to 300 MHz. However, even if the effective value does not meet these limits, the supplementary standard 2.3 can apply if the value is below the guideline value in Table 2.2-1 (a). This note is not a mandatory evaluation item as described at the end of Section 1.3.

Note 3: When the electric field strength or magnetic field strength changes within the average time shown in Table 2.2-1 (a), root mean square value of the effective value within the average time should be used, and when the power density changes, the average value within the average time should be used.

Note 4: In Table 2.2-1 (a) when the electromagnetic field consists of multiple frequency components and the strength of each component cannot be ignored with respect to each standard value, the sum of the square of ratio of the strength to the standard values of electric field strength and magnetic field strength in each frequency component are calculated. Regarding power density, the sum of the ratios of the density to the standard value in each frequency component is calculated. As the result all these sums should not exceed 1.

In Table 2.2-1 (b), when the electromagnetic field consists of multiple frequency components and the strength of each component cannot be ignored with respect to

each standard value, the sum of the ratios of electric field strength, magnetic field strength and magnetic flux density to the standard values in each frequency component is calculated or the appropriate weighted average with respect to the ratios according to the frequency characteristics of the standard value is calculated. As the result all these sums should not exceed 1.

Note 5: The values in parentheses in the column of the effective value of magnetic field strength in Table 2.2-1 (a) should be calculated by using 2.185f instead of 2.18f.

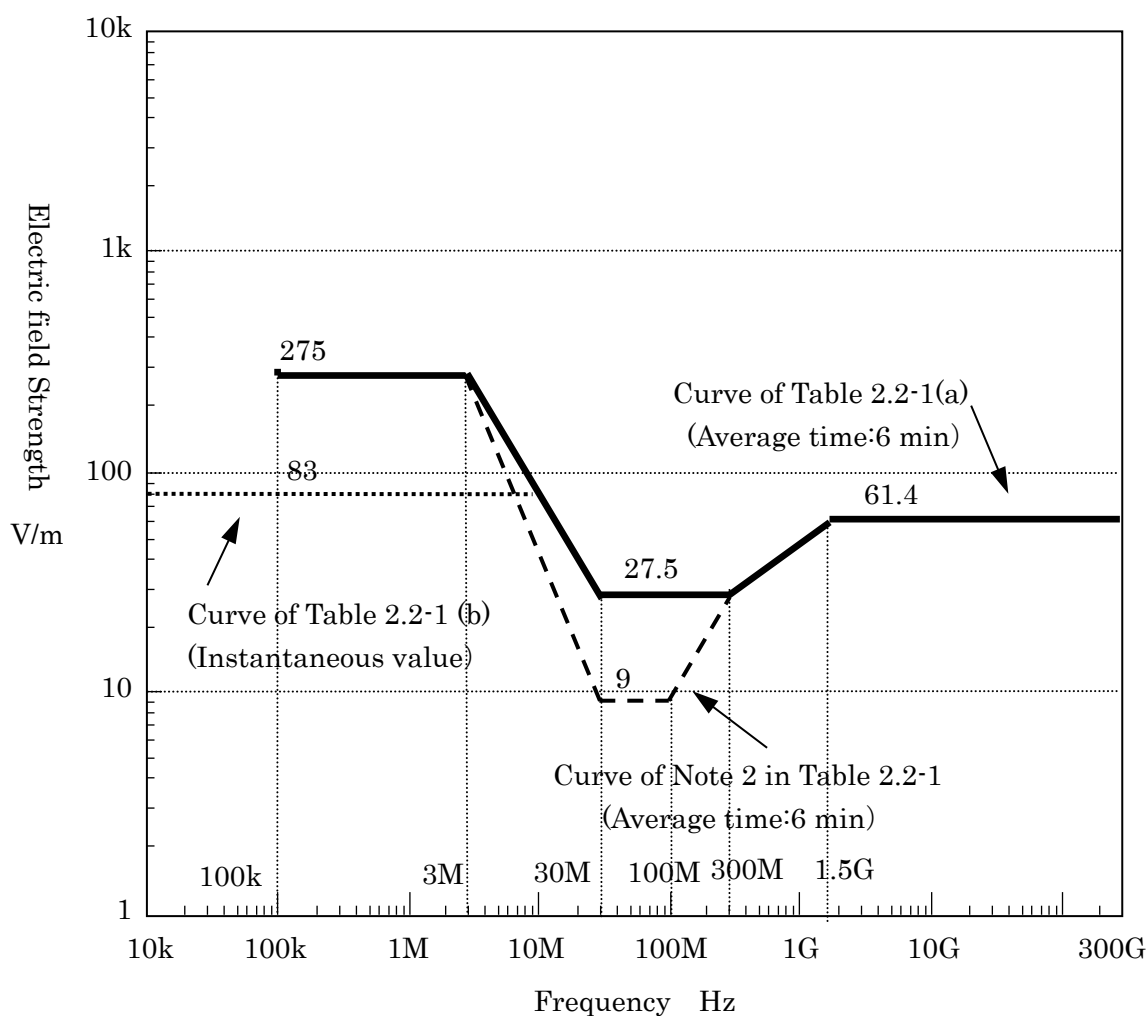


Figure 2.2-1 Electric field strength standard (General environment)

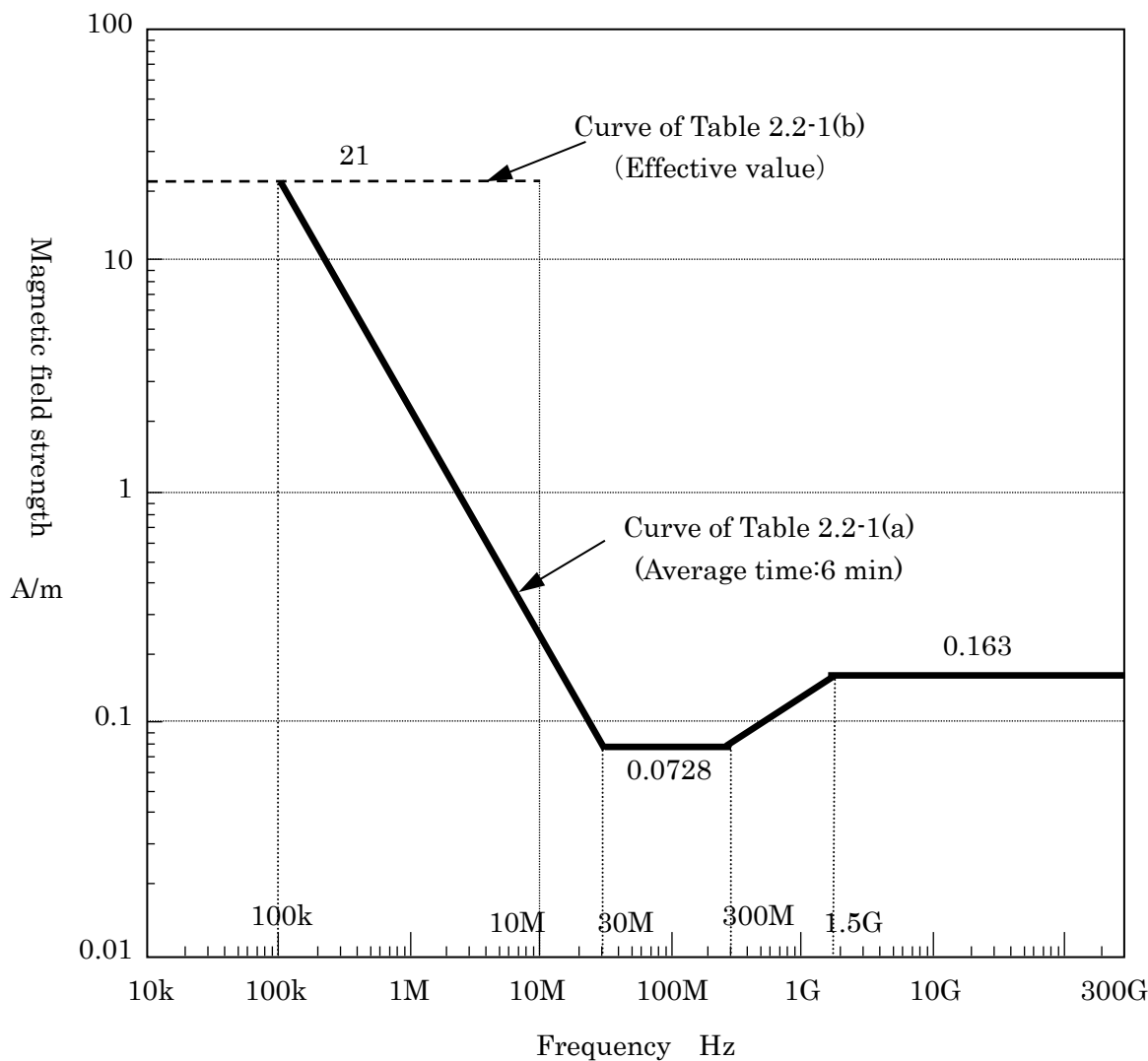


Figure 2.2-2 Magnetic field strength standard (General environment)

2.2.2 Controlled environment

Table 2.2-2 (a) and Table 2.2-2 (b) show the electromagnetic field strength standards under the controlled environment. If the electromagnetic field strength in a measurement space does not partially satisfy the values in these tables, the supplementary standard in Section 2.3 should be applied.

Figure 2.2-3 and Figure 2.2-4 are graphical representations of the standard values in Table 2.2-2 (a) and Table 2.2-2 (b).

Table 2.2-2(a) Electromagnetic field strength standards under the controlled environment (average value over 6 minutes)

Frequency f	Effective value of electric field strength E [V/m]	Effective value of magnetic field strength H [A/m]	Power density S [mW/cm ²]
Above 100 kHz to 3 MHz	614	$4.9f[\text{MHz}]^{-1}$ (49-1.63)	
Above 3 MHz to 30 MHz	$1,842f[\text{MHz}]^{-1}$ (614-61.4)	$4.9f[\text{MHz}]^{-1}$ (1.63-0.163)	
Above 30 MHz to 300 MHz	61.4	0.163	1
Above 300 MHz to 1.5 GHz	$3.54f[\text{MHz}]^{1/2}$ (61.4-137)	$f[\text{MHz}]^{1/2}/106$ (0.163-0.365)	$f[\text{MHz}]/300$ (1-5)
Above 1.5 GHz to 300 GHz	137	0.365	5

Table 2.2-2(b) Electromagnetic field strength standards in low frequency range
under controlled environment

Frequency f	Effective value of electric field strength E [kV/m]	Effective value of magnetic field strength H [A/m]	Effective value of magnetic flux density [T]
Above 10 kHz to 10 MHz	1.7×10^{-1}	80	1×10^{-4}

Note 1: If the contact hazard is not prevented at 15 MHz or less, protection from the contact current can be ensured by applying the supplementary standard 2.3.2. This note is not a mandatory evaluation item as described at the end of Section 1.3.

Note 2: In the case where the non-grounding condition of the human body is not satisfied, the effective value of the electric field strength (average value per 6 minutes) should be $3,200f(\text{MHz})^{-3/2}$ V/m (i.e. 614 V/m to 20 V/m) or less in the frequency range from 3

MHz to 30 MHz, 20 V/m or less in the frequency range from 30 MHz to 100 MHz and $0.2f$ (MHz) V/m or less (i.e. 20 V/m to 61.4 V/m) in the frequency range from 100 MHz to 300 MHz. However, even if the effective value does not meet these limits, the supplementary standard 2.3.3 can be applied if the value is below the guideline value in Table 2.2-2 (a). This note is not a mandatory evaluation item as described at the end of Section 1.3.

Note 3: When the electric field strength or magnetic field strength changes within the average time shown in Table 2.2-2 (a), root mean square value of the effective value within the average time should be used, and when the power density changes, the average value within the average time should be used.

Note 4: In Table 2.2-2 (a) when the electromagnetic field consists of multiple frequency components and the strength of each component cannot be ignored with respect to each standard value, the sum of the square of ratios of the strength to the standard value of electric field strength and magnetic field strength in each frequency component are calculated. Regarding power density, the sum of the ratios of the density to the standard value in each frequency component is calculated. As the result all these sums should not exceed 1.

In Table 2.2-2 (b), when the electromagnetic field consists of multiple frequency components and the strength of each component cannot be ignored with respect to each standard value, the sum of the ratios of electric field strength, magnetic field strength and magnetic flux density to the standard values in each frequency component is calculated or the appropriate weighted average with respect to the ratios according to the frequency characteristics of the standard value is calculated. As the result all these sums should not exceed 1.

Note 5: In Table 2.2-2 (a) and Note 2 when the values obtained by using equations $3.54f^{1/2}$, $3200f^{3/2}$ and $0.2f$ are different from values in the parentheses after the equations, the values obtained by using these equations should be applied.

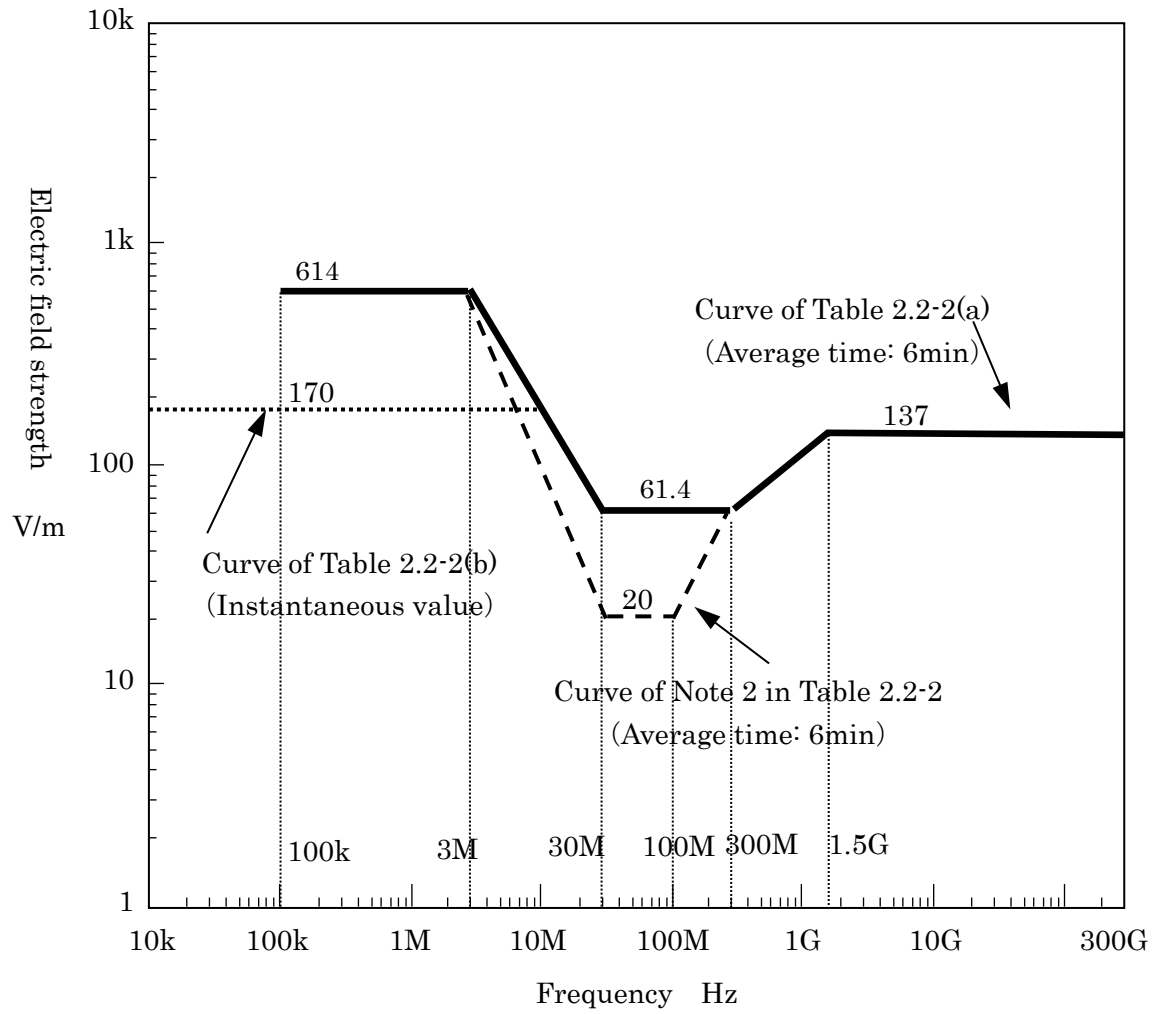


Figure 2.2-3 Electric field strength standard (Managed environment)

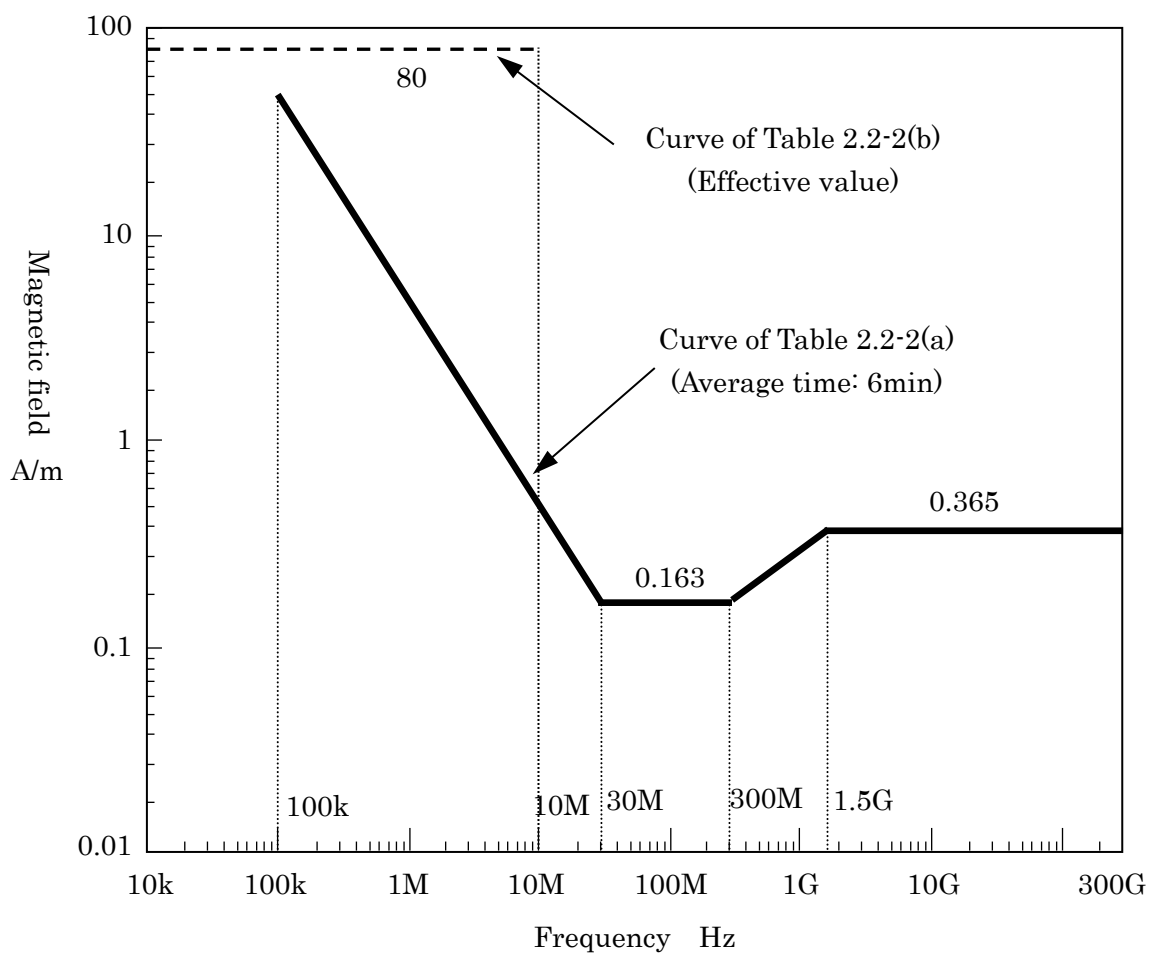


Figure 2.2-4 Magnetic field strength standard (Managed environment)

2.3 Supplementary standard

2.3.1 Standard in the case where the human body is exposed non-uniformly or partially to electromagnetic field

Even if the electromagnetic field strength standard specified in Section 2.2 is exceeded, it is considered that the radio wave protection standard is satisfied if all the applicable conditions are satisfied according to the frequency classification shown below.

With regards to (1), (2) a) and b), (3) a) and b), and (4) a), b) and c), if the intended frequencies exist across the following sections and the sum of the ratio of the field strength in each frequency component to the standard value (in the case of electric field strength or magnetic field strength, the sum of square of the ratio of the strength to the standard value) does not exceed 1, it is considered that the radiofrequency-exposure protection standard is satisfied.

For equipment used within 20 cm from the human body (10 cm in the frequencies of 300 MHz or above from the human body), individual judgment is required for each situation. If there is a possibility of exceeding the basic guidelines, evaluation based on the partial-body absorption standard should be conducted.

(1) The case where the frequency is less than 300 MHz:

- a) With regards to protection from stimulation effects from the electromagnetic wave of 10 kHz to less than 10 MHz, in a space more than 20 cm away from the electromagnetic radiation source or a metal object, the spatial average value (simple average value) of the electric field strength or magnetic field strength in the entire space corresponding to the space occupied by the human body should be or less than the electromagnetic field strength standard specified in Section 2.2 applicable to the corresponding environment (controlled environment or general environment). In that case, local exposure may exceed the electromagnetic field strength standard, but should not exceed the basic restriction. Notes 1 and 4 in Table 2.2-1 or Table 2.2-2 should be also applied to this case.
- b) With regard to protection (an electromagnetic field strength average value over 6 minutes) from thermal effects from 100 kHz to less than 300 MHz, in a space more than 20 cm away from the electromagnetic radiation source or a metal object, the spatial average value of the power density distribution (the square root of the mean square value in the case of electric field strength or magnetic field strength) in the entire space corresponding to the space occupied by the human body should be or less than the electromagnetic field strength standard value (Table 2.2-1 (a) or Table 2.2-2 (a) of Section 2.2.1) applicable to the corresponding environment (general environment or controlled environment). Note 1 to Note 4 in Table 2.2-1 or Table 2.2-2 should be also applied to this case.

(2) The case where the frequency is 300 MHz to less than 1 GHz

- a) In a space more than 10 cm away from an electromagnetic radiation source or a metal object, the spatial average value of the power density distribution (the square root of the

- mean square value in the case of electric field strength or magnetic field strength) in the entire space corresponding to the space occupied by the human body should be or less than the electromagnetic field strength standard value (Section 2.2) applicable to the corresponding environment (general environment or controlled environment). Notes 3,4 and 5 in Tables 2.2-1 and 2.2-2 should be also applied to this case.
- b) The maximum spatial power density in the area occupied by the human body excluding the limbs should be 4 mW/cm² or less (as an average value over 6 minutes) in the general environment and 20 mW/cm² or less (as an average value over 6 minutes) in the controlled environment. However, only the case where the space is at least 10 cm away from an electromagnetic radiation source or a metal object should be considered. Notes 3,4 and 5 in Tables 2.2-1 and 2.2-2 should be also applied to this case.
- (3) The case where the frequency is 1 GHz to less than 3 GHz
- a) In a space more than 10 cm away from an electromagnetic radiation source or a metal object, the spatial average value of the power density distribution (the square root of the mean square value in the case of electric field strength or magnetic field strength) in the entire space corresponding to the space occupied by the human body should be or less than the electromagnetic field strength standard value (Section 2.2) applicable to the corresponding environment (general environment or managed environment). Notes 3,4 and 5 in Tables 2.2-1 and 2.2-2 should be also applied to this case.
 - b) The maximum spatial power density in the area occupied by the human body excluding the limbs should be 4 mW/cm² or less (as an average value over 6 minutes) in the general environment and 20 mW/cm² or less (as an average value over 6 minutes) in the controlled environment. However, only the case where the space is at least 10 cm away from an electromagnetic radiation source or a metal object is considered. Notes 3,4 and 5 in Tables 2.2-1 and 2.2-2 should be also applied to this case.
 - c) The maximum spatial power density incident on the head shall be 2 mW/cm² or less (as an average value over 6 minutes) in the general environment and 10 mW/cm² or less (as an average value over 6 minutes) in the controlled environment. However, only the case where the space is at least 10 cm away from an electromagnetic radiation source or a metal object is considered. Notes 3,4 and 5 in Tables 2.2-1 and 2.2-2 should be also applied to this case.
- (4) The case where the frequency is 3 GHz or more

- a) In a space more than 10 cm away from an electromagnetic radiation source or a metal object, the spatial average value of the power density distribution (the square root of the mean square value in the case of electric field strength or magnetic field strength) in the entire space corresponding to the space occupied by the human body should be or less than the electromagnetic field strength standard value (Section 2.2) applicable to the corresponding environment (general environment or controlled environment). Notes 3,4 and 5 in Tables 2.2-1 and 2.2-2 should be also applied to this case.
- b) In a space more than 10 cm away from an electromagnetic radiation source or a metal object, the spatial maximum value of the power density incident to the human body should be 50 mW/cm² or less (as an average value over 6 minutes) in the controlled environment and 10 mW/cm² or less (as an average value over 6 minutes) in the general environment. Notes 3,4 and 5 in Tables 2.2-1 and 2.2-2 should be also applied to this case.
- c) In a space more than 10 cm away from an electromagnetic radiation source or a metal object, the spatial maximum value of the power density incident to the human eye should be 10 mW/cm² or less (as an average value over 6 minutes) in the controlled environment and 2 mW/cm² or less (as an average value over 6 minutes) in the general environment. Notes 3,4 and 5 in Tables 2.2-1 and 2.2-2 should be also applied to this case.

The conditions described above are summarized in Table 2.3-1.

Table 2.3-1 Supplementary standard in the case where the human body is exposed non-uniformly or partially to electromagnetic field

	10kHz ~ 100kHz	100kHz ~ 10MHz	10MHz ~ 300MHz	300MHz ~ 1GHz	1GHz ~ 3GHz	3GHz ~ 300GHz
Simple average value of electro-magnetic field strength (Stimulation effects)	General environment: Less than or equal to the electro-magnetic field strength standard in Table 2.2-1 (b) (Note 1 and Note 4 also apply) Controlled environment: Less than or equal to the electromagnetic field strength standard in Table 2.2-2 (b) (Note 1 and Note 4 also apply)		Not applicable			
Spatial average value of electro-magnetic field strength (Thermal effects)	Not applicable	General environment: Less than or equal to the electromagnetic field strength standard in Table 2.2-1 (a) (Notes 1 to 4 also apply) Controlled environment: Less than or equal to the electromagnetic field strength standard in Table 2.2-2 (a) (Notes 1 to 4 also apply)				
Spatial maximum value of electromagnetic field strength (Power density)	Not applicable			Parts other than limb: General environment: 4mW / cm ² Controlled	Body surface: General environment: 10 mW / cm ²	

		environment: 20 mW / cm ²		Controlled environment: 50 mW / cm ²
		Not applicable	Head: General environment: 2 mW / cm ² Controlled environment: 10 mW / cm ²	Eye: General environment: 2 mW / cm ² Controlled environment: 10 mW / cm ²
Applicable space	Space occupied by human body more than 20 cm away from electromagnetic radiation source or metal object	Space occupied by human body more than 10 cm away from electromagnetic radiation source or metal object		

2.3.2 Standard on contact current

As described in the last paragraph of Section 1.3, this standard is not mandatory.

(1) The case where contact hazard is not prevented in the general environment

a) In the frequency range of 10 kHz to 10 MHz, if the measured contact current level meets the following conditions, Note 1 in Table 2.2-1 is not needed to be met.

- 0.2f (kHz) mA or less (as effective value) in the frequency range of 10 kHz to 100 kHz
- 20 mA or less (as effective value) in the frequency range of 100 kHz to 10 MHz

However, if the contact current consists of multiple frequency components with a level that cannot be ignored against this standard value, the sum of the ratio of each frequency component level to the standard value should be calculated or the average of the values which are calculated by weighting the ratio to the standard value of each frequency component should be calculated. The sum of the ratio or the sum of the average value related to weighting should not exceed 1.

b) In the frequency range of 100 kHz to 15 MHz, when the measured contact current level (as an average value over 6 minutes) is 45 mA or less, Note 1 in Table 2.2-1 is not needed to be met. However, if the contact current consists of multiple frequency components with a level that cannot be ignored with respect to this standard, the sum of square of the ratio to the standard value of each frequency component is calculated and the sum should not exceed 1.

※ In the frequency range of 100 kHz to 10 MHz, both standards described in a) and b) above should be met.

(2) The case where contact hazard is not prevented in the controlled environment

a) In the frequency range of 10 kHz to 10 MHz, if the measured contact current level meets the following conditions, Note 1 in Table 2.2-1 is not needed to be met.

- 0.4f (kHz) mA or less (as effective value) in the frequency range of 10 kHz to 100 kHz
- 40 mA or less (as effective value) in the frequency range of 100 kHz to 10 MHz

However, if the contact current consists of multiple frequency components with a level that cannot be ignored against this standard value, the sum of the ratio of each frequency component level to the standard value should be calculated or the average of the values which are calculated by weighting the ratio according to the standard value of each frequency component should be calculated. The sum of the ratio or the sum of the average value related to weighting should not exceed 1.

b) In the frequency range of 100 kHz to 15 MHz, when the measured contact current level (as an average value over 6 minutes) is 100 mA or less, Note 1 in Table 2.2-1 is not needed to be met. However, if the contact current consists of multiple frequency components with a level

that cannot be ignored with respect to this standard, the sum of square of the ratio to the standard value of each frequency component is calculated and the sum should not exceed 1.

※ In the frequency range of 100 kHz to 10 MHz, both standards described in a) and b) above should be met.

2.3.3 Standard on induced current to human ankle

As described in the last paragraph of Section 1.3, this standard is not mandatory.

(1) The case where non-grounding condition is not met in the general environment

In the frequency range of 3 MHz to 300 MHz, when the measured current level (as an average value over 6 minutes) induced to an ankle is 45 mA or less per foot, Note 2 in Table 2.2-1 is not required to be met. However, if the induced current to the ankle consists of multiple frequency components with a level that cannot be ignored with respect to this standard, the sum of square of the ratio to the standard value of each frequency component should not exceed 1.

(2) The case where non-grounding condition is not met in the controlled environment

In the frequency range of 3 MHz to 300 MHz, when the measured induced current level (as an average value over 6 minutes) to an ankle is 100 mA or less per foot, Note 2 in Table 2.2-2 is not needed to be met. However, if the induced current to the ankle consists of multiple frequency components with a level that cannot be ignored with respect to this standard, the sum of square of the ratio to the standard value of each frequency component should not exceed 1.

2.4 Partial-body absorption standard

2.4.1 Scope of application

This standard is applicable in the frequency range of 100 kHz to 300 GHz.

The main target of the partial-body absorption standard is a small wireless device such as a mobile phone terminal and it is assumed that the antenna and the housing that contribute to electromagnetic radiation source are used very close to a human body.

This standard is applied to the case where the distance between an electromagnetic radiation source (mainly antenna) or a metal (such as a housing) involved in the radiation and the human body is within 20 cm. At other distance, if any one of the electromagnetic field strength standard, supplementary standard, or partial-body absorption standard is satisfied, it can be

determined that the basic guideline is satisfied. However, the application of electromagnetic field strength guideline or supplementary guideline at distances between 10 cm and 20 cm in a frequency range of 300 MHz to 300 GHz is not excluded.

At the boundary point where the distance between an electromagnetic radiation source (mainly antenna) or a metal (housing, etc.) and the human body is 20 cm in a frequency range of 100 kHz to 300 MHz and 10 cm in a frequency range of 300 MHz to 300 GHz, the partial-body absorption standard should be applied preferentially instead of the electromagnetic field strength standard although being not specified in the report of the Information and Communication Technology Subcommittee.

2.4.2 General environment

The following all requirements should be satisfied.

- (1) Any 6-minute average value of a whole-body averaged SAR should be 0.08 W/kg or less.
- (2) In the frequency range of 6 GHz or less, the partial-body SAR (average value over 6 minutes) per any tissue of 10 g should not exceed 2 W/kg (4 W/kg for limb).
- (3) In the frequency range of 6 GHz to 30 GHz, the incident power density (average value over 6 minutes) per 4 cm² on any human body surface (any area in the region corresponding to the space occupied by the human body) should not exceed 2 mW/cm².
- (4) In the frequency range of above 30 GHz to 300 GHz, the incident power density (average value over 6 minutes) per 1 cm² on any human body surface (any area in the region corresponding to the space occupied by the human body) should not exceed 2 mW/cm².
- (5) When the human is exposed to multiple frequency radio waves at the same time, the sum of the ratio of each frequency component in the preceding paragraphs (2), (3) and (4) to the standard value should not exceed 1.
- (6) In the case where contact hazard is not prevented, the contact current level should be 20 mA or less (as an effective value) in the frequency range of 100 kHz to 10 MHz and 45 mA or less (average value over 6 minutes) in the frequency range of 100 kHz to 100 MHz.

However, if the contact current consists of multiple frequency components with a level that cannot be ignored against this standard value, in the frequency range of 100 kHz to 10 MHz the sum of the ratio of each frequency component level to the standard value (20 mA: effective value) should be obtained. Or regarding the ratio of each frequency component to the standard value, appropriate weighting is applied to the ratio according to the frequency characteristics of the standard value and the average value of the weighted values is calculated. The sum of the ratio or the sum of the average value should not exceed 1. In

addition, in the frequency range of 100 kHz to 100 MHz, the sum of square of the ratio to the standard value (45 mA: average value over 6 minutes) of each frequency components should not exceed 1.

(7) In the frequency range of 100 kHz to 10 MHz, the electric field strength inside a body should not exceed $1.35 \times 10^{-4} \times f(\text{Hz}) \text{V/m}$. However, if the electric field strength inside a body consists of multiple frequency components with a level that cannot be ignored with respect to this standard, the sum of the ratio of each frequency component level to the standard value should be obtained. Or regarding the ratio of each frequency component to the standard value, appropriate weighting is applied to the ratio according to the frequency characteristics of the standard value and the average value of the weighted values is calculated. The sum of the ratio or the sum of the average value should not exceed 1.

It should be noted that the evaluation according to (6) above for radio stations operating in the frequency range of 100 MHz or above is not needed and the evaluation according to (7) above for radio stations operating in the frequency range of 10 MHz or above is not needed

The conditions described above are summarized in Table 2.4-1.

2.4.3 Controlled environment

The following all requirements should be satisfied.

- (1) Any 6-minute average value of a whole-body averaged SAR should be 0.4 W/kg or less.
- (2) In the frequency range of 6 GHz or less, the partial-body SAR (average value over 6 minutes) per any tissue of 10 g should be 10 W/kg (20 W/kg for limb) or less.
- (3) In the frequency range of 6 GHz to 30 GHz, the incident power density (average value over 6 minutes) per 4 cm² on any human body surface (any area in the region corresponding to the space occupied by the human body) should not exceed 10 mW/cm².
- (4) In the frequency range of above 30 GHz to 300 GHz, the incident power density (average value over 6 minutes) per 1 cm² on any human body surface (any area in the region corresponding to the space occupied by the human body) should not exceed 10 mW/cm².
- (5) When the human is exposed to multiple frequency radio waves at the same time, the sum of the ratio of each frequency component in the preceding paragraphs (2), (3) and (4) to the standard value should not exceed 1.
- (6) In the case where contact hazard is not prevented, the contact current level should be 40 mA or less (effective value) in the frequency range of 100 kHz to 10 MHz and 100 mA or less (average value over 6 minutes) in the frequency range of 100 kHz to 100 MHz.

However, if the contact current consists of multiple frequency components with a level that cannot be ignored against this standard value, in the frequency range of 100 kHz to 10 MHz, the sum of the ratio of each frequency component level to the standard value (40 mA: effective value) should be obtained. Or regarding the ratio of each frequency component to the standard value, appropriate weighting is applied to the ratio according to the frequency characteristics of the standard value and the average value of the weighted values is calculated. The sum of the ratio or the sum of the average value should not exceed 1. In addition, in the frequency range of 100 kHz to 100 MHz, the sum of square of the ratio to the standard value (100 mA: average value over 6 minutes) of each frequency component should not exceed 1.

- (7) In the frequency range of 100 kHz to 10 MHz, the electric field strength inside a body should not exceed $2.7 \times 10^{-4} \times f(\text{Hz}) \text{V/m}$. However, if the electric field strength inside a body consists of multiple frequency components with a level that cannot be ignored with respect to this standard, the sum of the ratio of each frequency component level to the standard value should be obtained. Or regarding the ratio of each frequency component to the standard value, appropriate weighting is applied to the ratio according to the frequency characteristics of the standard value and the average value of the weighted values is calculated. The sum of the ratio or the sum of the average value should not exceed 1.

It should be noted that the evaluation according to (6) above for radio stations operating in the frequency range of 100 MHz or above is not needed and the evaluation according to (7) above for radio stations operating in the frequency range of 10 MHz or above is not needed

The conditions described above are summarized in Table 2.4-1.

Table 2.4-1 Excerpts from partial-body absorption standard

Applicable range: This standard value applies to frequencies from 100 kHz to 300 GHz.

Target: Applicable to small wireless devices used close (within 20 cm) to a body.

Frequency range	Requirement	General environment	Controlled environment
100 kHz – 300 GHz	Whole-body averaged SAR	0.08 W/kg	0.4 W/kg
100 kHz – 6 GHz	Partial-body SAR	For any 10g tissue: 2 W/kg	For any 10g tissue 10 W/kg

		4 W/kg (limb)	20 W/kg (limb)
6 GHz – 30 GHz	Incident power density	For any 4 cm ² body surface: 2 mW / cm ²	For any 4 cm ² body surface: 10 mW / cm ²
30 GHz – 300 GHz		For any 1 cm ² surface: 2 mW / cm ²	For any 1 cm ² surface: 10 mW / cm ²

Note 1: Average for any 6 minutes

2.5 Note

This standard is related to the upper limit of the electromagnetic field quantity that does not cause an unwanted biological effect on the human body. When an electromagnetic wave is used for medical purposes, the following matters should be paid attention because this standard does not cover the effect on medical electrical equipment such as a pacemaker.

(1) For medical purpose

When an electromagnetic wave is used for a medical purpose, this standard is applicable to the medical personnel exposed to an electromagnetic field. On the other hand, as the usage of the electromagnetic wave to a patient is needed to be judged in consideration of the medical effect, this standard is not applicable as long as a doctor uses the electromagnetic wave with full awareness of the safety limit indicated in this standard. However, for example, radio waves that are effective in treating knee joints may be harmful to other parts. Therefore, it is necessary to avoid irradiating an electromagnetic wave in a wider area unnecessarily and to be careful about the leakage of the electromagnetic wave.

(2) Pacemaker wearer, etc.

This standard does not cover the effect on a pacemakers and other medical electrical equipment. The mechanism that causes interference to a pacemaker, etc. is due to the malfunction of an electronic circuit caused by a signal induced in the electronic circuit inside the equipment by a radio wave. Therefore, the interference effect on the medical equipment should not be dealt with the same way as the effect of a radio wave on the human body.

In the case where a person wearing a medical electrical device such as a pacemaker uses a radio wave, the instruction of the doctor in charge should be followed.

(3) Person with metal embedded in the body

If a metal is embedded in the body, the metal may cause unexpected local heat, even if an electromagnetic field is below the specified value. Therefore, special care should be taken.

(4) Person wearing metal

When a person is wearing a metal, especially close to an induction heating furnace, the metal may cause heat even in an electromagnetic field below the specified value. Therefore, special care should be taken.

Chapter 3 Conformity confirmation methods

This chapter outlines general issues related to calculation and measurement methods to be used for confirming conformity to this Radiofrequency-Exposure Protection Standard.

Regarding specific calculation methods which can be easily used by persons who want to establish specific radio stations and standard measurement methods using general measuring equipment which is available generally to the persons, when confirmation of the conformity to the electromagnetic field strength standard is intended, ARIB technical reports “Methods of Evaluating Compliance for Radiofrequency-Exposure Protection Standard” (ARIB TR-T11) and “Measurement and Calculation Methods to Evaluate Electro-Magnetic Field and SAR Emitted from Mobile Base Station Antenna with regard to Radiofrequency-Exposure Protection” (ARIB TR-T21) should be applied. When confirmation of conformity to partial-body absorption standard is intended, ARIB standard “Specific Absorption Rate (SAR) Estimation and Power Density Estimation for Cellular Phone” (ARIB STD-T56) should be applied.

3.1 Basic concept of confirmation method

It is easily imagined that to confirm conformity of electromagnetic environment around radio stations by measurement is not easy work and requires a lot of time and effort. There are many factors that impair the accuracy and reproductivity of measurement results; for example, the radio station itself has a variety of specifications, the characteristics in the near-field region are complex, the emitted radio wave itself fluctuates over time and is greatly affected by the surrounding environment, and there are errors associated with the measuring instrument itself. For these reasons even for a radio station using a single frequency, to understand the surrounding electromagnetic environment spatially and temporally, and to confirm the conformity require specialized knowledge of various measuring instruments, measurement techniques and experience in measurement. In the environment where multiple frequencies coexist, for example shared radio towers and large transmitting stations, the difficulty of measurement is increased further and it places a heavy burden on a radio station constructor.

For the electromagnetic field strength, basically, the conformity is confirmed by the calculation method, and Section 3.2 shows the basis of the calculation method. For actual confirmation, ARIB technical report ARIB TR-T11 or TR-T21 should be used. When the conformity can be confirmed by this, no further measurement is required. Especially, in establishing a new radio station, as emission of radio wave cannot be allowed, it is impossible to conduct the

measurement and there is no choice but to confirm conformity by calculation. When the confirmation is performed only by calculation, in using the standard calculation method it is required that the level of the electromagnetic field calculated is not lower than the actual level. If the conformity cannot be confirmed by a specific calculation method, measurement should be performed by using the measurement method specified in ARIB technical report ARIB TR-T11 or TR-T21. In this case, the measurement results are given priority. However, it is necessary to clarify the reason for the difference between the results obtained by the calculation and the measurement, and to make a comprehensive determination based on both results.

Regarding the partial-body absorption standard, the basic concept is described in Section 3.3. In confirming the conformity, ARIB STD-T56 should be used for both SAR and power density.

3.2 Calculation method of electric field strength

3.2.1 Outline

Approximate values of power density (S), electric field strength (E) and magnetic field strength (H) of the exposed electromagnetic field can be calculated by using known information such as antenna input power (P), absolute antenna gain (G) or relative antenna gain (G_h), equivalent isotropic radiated power (EIRP) or equivalent radiated power (ERP), antenna directivity and modulation method and the distance from the antenna (R).

In a far-field region of an antenna, the conversion to power density (S[W/m²]) from electric field strength (E[V/m]) or magnetic field strength (H[A/m]) can be made using Equation (1).

$$S = \frac{E^2}{377} = 377H^2 \quad (1)$$

The conversion to power density (S[mW/cm²]) can be made using Equation (2)

$$S = \frac{E^2}{3770} = 37.7H^2 \quad (2)$$

These equations are applied in a far-field region in principle. Although these equations can be applied also in a near-field region, the results obtained would be over-estimated values.

There are some kinds of equations. A kind of equation is simple and applicable to many cases but the approximation accuracy is low. Another kind of equation is applicable only to limited cases but the approximation accuracy is high. There is also a method using numerical calculation program such as Numerical Electromagnetic Code. However, as higher knowledge is required, this method is not included.

The simple and standard equation provides accurate results in a far-field region. However, over-estimated results are obtained in a near-field region. Therefore, in a near-field region this equation can be also used to calculate the worst case (conservative) values.

3.2.2 Simplified calculation method

(1) Simplified calculation method to be applied to free space and far-field region

A calculation method which can be applied in a far-field region under the free space where no ground and metals exist nearly is shown below.

In an ideal isotropic antenna, antenna input power (P) is radiated radially in all directions. Therefore, the power density (S) at the point of the distance R can be obtained by dividing the antenna input power (P) by the surface area of a sphere of radius R as follows.

$$S = \frac{P}{4 \pi R^2} \quad (3)$$

In the case of a directional antenna the maximum power density (S) at the point of the distance R can be obtained as follows. Where, G is the absolute antenna gain in the direction to which the maximum power is radiated.

$$S = \frac{PG}{4 \pi R^2} \quad (4)$$

When the G is given in decibel (it is expressed as GdB or GdBi), GdB is transformed to G by using Equation (5).

$$G = 10^{(GdB/10)} \quad (5)$$

In the case where equivalent isotropic radiated power (EIRP) is given instead of antenna input power (P) and an antenna absolute gain (G), as $EIRP = PG$, Equation (4) can be expressed as shown in Equation (6)

$$S = \frac{EIRP}{4 \pi R^2} \quad (6)$$

In the case where a relative gain (G_h) is given instead of an absolute gain (G), as G_h is the antenna gain relative to the antenna gain in the direction to which the maximum power of a standard half-wavelength antenna is radiated, to obtain the power density (S) needs to multiply 1.64 of the absolute gain of the half-wavelength antenna as shown in Equation (7).

$$S = 1.64 \frac{PG_h}{4\pi R^2} = 0.41 \frac{PG_h}{\pi R^2} \quad (7)$$

In the case where equivalent radiated power (ERP) is given instead of antenna input power (P) and an antenna relative gain (G_h), Equation (7) can be expressed as shown in Equation (8).

$$S = 1.64 \frac{ERP}{4\pi R^2} = 0.41 \frac{ERP}{\pi R^2} \quad (8)$$

(2) The case where reflection effect is considered

In general, when reflection is expected, the electric field strength becomes double in the worst case, and the power density becomes quadruple by using Equation (1). Therefore, Equation (4) becomes as follows.

$$S = 2^2 \frac{PG}{4\pi R^2} = \frac{PG}{\pi R^2} \quad (9)$$

In an individual case such as the case where the reflection is assumed only from the ground, other values based on an actual measurement may be used. For example, for FM radio and television broadcasting antennas, the US Environmental Protection Agency (EPA) has established a model that predicts field strength and power density on the ground based on a large amount of measured data. In the EPA model, the increase rate of the electric field strength due to actual ground reflection is estimated to be about 1.6 times. Therefore, when this model is used, the increase in power density becomes 2.56 (1.6×1.6) times. Therefore, equation (9) can be modified as follows.

$$S = 2.56 \frac{PG}{4\pi R^2} = 0.64 \frac{PG}{\pi R^2} \quad (10)$$

Accordingly, when EIRP is known, Equation (10) becomes as follows.

$$S = 0.64 \frac{EIRP}{\pi R^2} = 0.2037 \frac{EIRP}{R^2} \quad (11)$$

When ERP is known, Equation (10) becomes as follows.

$$S = 0.64 \times 1.64 \frac{ERP}{\pi R^2} = 1.05 \frac{ERP}{\pi R^2} \quad (12)$$

In some cases, to use $\mu W/cm^2$ rather than mW/cm^2 as a unit expressing power density is convenient. In the case where power density is expressed by $\mu W/cm^2$, Equation (12) becomes more concise.

$$S = 334 \frac{ERP}{R^2} \quad (13)$$

Where, S is power density ($\mu W/cm^2$), ERP is equivalent radiated power (W) and R is

distance (m).

(3) The case where directivity is considered.

The equations described in the previous sections are used to evaluate the power density in the maximum radiation direction and give overestimated results in other directions. When the directivity is known, the use of it provides a realistic evaluation result. In the case where the directivity of the angle θ is given, assuming that power density directivity is $D(\theta)$, $S(\theta)$ can be given as follows.

$$S(\theta) = \frac{PG}{4\pi R^2} D(\theta) \quad (14)$$

In the case where $F(\theta)$ of electric field strength directivity is given, as $D(\theta) = F(\theta)^2$, $S(\theta)$ can be given as follows.

$$S(\theta) = \frac{PG}{4\pi R^2} F(\theta)^2 \quad (15)$$

The directivity is usually given in normalized value by the gain of the maximum radiation direction which sets to 1. When the decrease rate of the directivity is expressed by decibel (dB), the power density should be recalculated in the same way as equation (5).

(4) Space to be calculated

Basically, it is necessary to calculate the maximum value in the space occupied by the human body. Therefore, the maximum electromagnetic field level within the range of 0 to 2 m height should be calculated and the calculated value is compared with the standard value. Usually, as an antenna is often installed at a high position such as a rooftop of a building, a steel tower, etc., the evaluation in the worst case is often given by calculating at a height of 2m.

If the intended space is non-uniform due to the vicinity of the antenna or the influence of reflected waves from the ground, the spatial average value of the power density distribution (the square root of the mean square value in the case of electric field strength or magnetic field strength) over the entire area corresponding to the space occupied by the human body should be calculated and the calculated result may be compared with the standard value to estimate the conformity.

(5) The case where time average value is needed (radar pulse, digital modulation, etc.).

In the case where the radiation is made intermittently and the duty ratio (d) is known in such as radar waves and digital modulation waves, the time average value $\langle S \rangle$ of power density is

calculated as follows. However, in the case where the cycle period is longer than 6 minutes, it is necessary to obtain the maximum value in the time average over 6 minutes.

$$\langle S \rangle = \frac{PGd}{4\pi R^2} \quad (16)$$

(6) The case where multiple waves exist.

If there are multiple waves, it is necessary to calculate the ratio of the calculated power density to the standard value at each frequency and if the sum of the ratio is less than 1, it is determined that the power density conforms to the standard.

3.2.3 Aperture antenna

An aperture antenna is used for satellite earth stations, fixed microwave links, various radars, and so on. In general, an aperture antenna has a parabolic surface, and the aperture surface has a circular cut shape in many cases. Power is transmitted by a pencil beam with a sharp beam angle and high gain. An aperture antenna is used in a microwave band system (typically 900 MHz and above).

Since these aperture antennas have very sharp directivity, the possibility of being exposed to strong microwaves in directions other than the main beam direction is greatly reduced. Usually, the power density at a place where people can be exposed to microwaves is much lower than that of the main beam (on the axis). Factors to be considered in evaluating the possibility of being exposed include the direction of the main beam, the height of the antenna from the ground, the positional relationship between the antenna and the place where the person lives or works and the procedure of operation being performed at the facility.

In order to calculate the power density of the microwave from an aperture antenna, an experimental model based on antenna theories and actual measurements has been created. For a parabolic aperture antenna having a cut plane of circular, the power density around the system can be calculated using the following information and calculation formula obtained from this experimental model.

(1) Antenna surface

The maximum power density S_{surface} on the antenna surface can be calculated by the following equation:

$$S_{\text{surface}} = \frac{4P}{A} \quad (17)$$

Where, P is the antenna input power, and A is the physical area of the aperture antenna.

(2) Near-field region

In the near-field region (Fresnel region) of the main beam, there is a possibility that the power density reaches the maximum value once before the power density begins decreasing with distance. The range of the near-field region is given by the following equation (D and λ have the same unit).

$$R_{nf} = \frac{D^2}{4\lambda} \quad (18)$$

Where, R_{nf} is a range of the near-field region, D is the maximum the antenna size (diameter for circular aperture) and λ is wavelength.

The magnitude of the power density on the main beam axis depends on the distance R . However, the maximum value S_{nf} of the power density on the axis in the near-field region does not depend on the distance and can be expressed by the following equation.

$$S_{nf} = 16 \frac{\eta P}{\pi D^2} \quad (19)$$

Where, η is aperture efficiency (typically 0.5 to 0.75), P is antenna input power, and D is the maximum antenna size (diameter).

The approximate value of the aperture efficiency η of the circular surface is obtained as follows using the ratio of the effective antenna aperture and the physical area.

$$\eta = \frac{\frac{G \lambda^2}{4\pi}}{\frac{\pi D^2}{4}} \quad (20)$$

Where, G is the absolute antenna gain, λ is wave-length and D is the maximum antenna size (diameter).

In the case where the absolute antenna gain G is unknown, the G can be obtained by the following equation using the actual or estimated aperture efficiency.

$$G = 4\pi \eta A / \lambda^2 \quad (21)$$

Where, η is aperture efficiency, λ is wave-length and A is the physical area of the antenna.

(3) Transitional region

The power density in the transitional region decreases inversely proportional to the distance

from the antenna and the power density in the far-field region (Fraunhofer region) decreases inversely proportional to the square of the distance from the antenna. In the evaluation when being exposed to microwaves, the distance R_{ff} to the start point of the far-field region (the limit point of the transitional region) can be predicted by the following equation.

$$R_{ff} = 0.6D^2 / \lambda \quad (22)$$

Where, D is the maximum antenna size (diameter), and λ is the wavelength.

The transitional region is a range from R_{nf} calculated by Equation (18) to R_{ff} calculated by Equation (22). When the evaluation point is within this transitional region, the power density S_L on the main beam axis is calculated by the following equation.

$$S_L = S_{nf} \times \frac{R_{nf}}{R} \quad (23)$$

Where, S_{nf} is the maximum power density of the near-field region calculated by Equation (19), R_{nf} is the range of the near-field region calculated by Equation (18) and R is the distance from the antenna.

(4) Far-field region

The power density in the far-field region (Fraunhofer region) of the antenna decreases inversely proportional to the square of the distance from the antenna. The power density S_{ff} in the far-field region can be calculated by the simple calculation formula described above. That is,

$$S_{ff} = \frac{PG}{4\pi R^2} \quad (24)$$

Where, P is the antenna input power, G is the absolute antenna gain and R is the distance from the antenna.

In the far-field region, the power density on the main axis obtained from the above equation (24) is the maximum exposure level that is generated by the system. The power density out of the main axis is greatly reduced.

Regarding the power density calculations out of the main axis in the near-field and transitional regions, if the evaluation point is away from the central of the main beam by the distance at least equivalent to diameter of the antenna or more, the power density at that point is at least one hundredth (-20 dB) of the value calculated at the equivalent distance on the main beam direction.

(*) In order to predict the actual electromagnetic fields out of the main axis near the aperture antenna, it is effective to use the radiation pattern of the antenna.

3.2.4 Collinear antenna

According to Tell, the use of a cylindrical model is useful for evaluating RF electromagnetic fields in the vicinity of a vertical collinear dipole antenna used in base stations of mobile phone systems, PHS, pagers, and MCA.

This model can be also used to predict the exposure in the near-field of an antenna used at television or FM radio stations where workers may approach while working on the tower. In general, this model can predict the exposure level in the immediate vicinity region of the antenna relatively accurately in the case where the RF environment is overestimated when a theoretical formula for the far-field region such as equation (4) is used. However, with the increase of the distance from the antenna, the evaluation by the cylindrical model gives overestimation and the use of the theoretical formula applied in the far-field region gives more accurate evaluation. The boundary of which formula should be used depends on the characteristics of the antenna such as the size (D) and gain (G) of the antenna.

However, according to the result of comparison with actual measurement values, the boundary may be approximately set to $R_{ff} = 0.6D^2/\lambda$ (see ARIB TR-T11 Part 2).

(1) Near-field region

The Tell's cylindrical model can predicts the spatial average value of the power density equivalent to a plane wave parallel to the antenna by dividing the net antenna input power by the imaginary cylindrical surface area surrounding the length of the radiating antenna. The actual power density varies along the height direction of the antenna, but the average value S of the power density along the length of the antenna can be obtained by the following equation.

$$S = \frac{P_{net}}{2\pi Rh} \quad (25)$$

Where, P_{net} is the net antenna input power, R is the distance from the antenna and h is the height of the aperture of the antenna.

For the sector type antenna, the power density can be calculated by dividing the net antenna input power by the portion of the cylindrical surface area corresponding to the antenna beam angle. For example, if the azimuth of the beam is 120 °, the surface area corresponds to

one-third of the complete cylindrical surface area. For this reason, the power density near the sector type antenna is three times that in the case of a purely omnidirectional antenna. Mathematically, this can be expressed by equation (26). The beam angle θ_{BW} can be regarded as the approximate “power dispersion” angle of the reflector. For example, for a certain sector antenna, the predicted power density (S) can be obtained as an excessive value by using the beam azimuth angle of -3 dB (half power).

$$S = \frac{180}{\theta_{BW}} \times \frac{P_{net}}{\pi Rh} \quad (26)$$

Where, P_{net} is the net antenna input power, θ_{BW} is the antenna beam width, R is the distance from the antenna and h is the height of the antenna aperture corresponding to D of equation (18)

Equation (26) can be applicable to any vertical collinear antenna including an omnidirectional antenna. In the case of an omnidirectional antenna, θ_{BW} is 360 degrees and Equation (26) becomes the simpler Equation (25).

When a reflected wave from the ground or the like is expected near the evaluation point, to multiply a coefficient to the right side of Equations (25) and (26) is needed. This coefficient is 2.56 when the reflected wave from the ground needs to be considered at 76 MHz or higher and in other cases it is 4.

(2) Far-field region

Similar to an aperture antenna, a simple calculation Equation (4) or Equations (6) to (8) can be used.

$$S = \frac{P_{net}G}{4\pi R^2} \quad (27)$$

Where, P_{net} is the net antenna input power, G is the absolute antenna gain, R is the distance from the antenna.

3.3 Estimation and measurement methods of specific absorption rate and power density

As described in Section 2.4, the partial-body absorption standard applies mainly to an electromagnetic field radiated from radio terminals used in close vicinity of the body such as mobile phones. Therefore, in measuring the specific absorption rate and power density necessary for confirming conformity to the partial-body absorption standard in this standard, the Standard “Specific Absorption Rate (SAR) Estimation and Power Density Estimation for

RCR STD-38

Cellular Phone” (ARIB STD-T56) established separately by this Association should be used.

Chapter 4 Terms and definitions

- Electromagnetic wave

It is a general term for waves of which an electric field and a magnetic field propagate through a vacuum or material medium by vibrating. The electromagnetic waves include low frequency electromagnetic fields, so-called radio waves used for communications, light emitted from the sun (infrared rays, visible rays, ultraviolet rays), and radioactive rays applied to medical treatments (X-rays, γ-rays). Electromagnetic waves having a shorter or longer wavelength than ultraviolet rays are classified generally as ionizing radiation or non-ionizing radiation, respectively.

- Radio wave

It is an electromagnetic wave of frequency of 3 000 GHz or lower specified in Article 2 of the Radio Law. This Radiofrequency-exposure protection standard applies to the frequency range of 10 kHz to 300 GHz.

- Radio wave protection confirmation method

It is a method for confirming whether the electromagnetic environment at an evaluation point or area conforms to the standard value of this Radiofrequency-exposure protection standard. The method consists of a radio wave protection standard calculation method and a radio wave protection standard measurement method.

- Radio wave protection standard calculation method

It is a standard calculation method for confirming that the electromagnetic environment of the evaluation point or area conforms to the standard value of this Radiofrequency-exposure protection standard

- Radio wave protection standard measurement method

It is a standard measurement method for confirming that the electromagnetic environment of the evaluation point or area conforms to the standard value of this Radiofrequency-exposure protection standard.

- Basic guideline

It is a guideline for evaluating the safety of the human body based on various body phenomena (thermal stress accompanying the increase of body temperature, high-frequency burn, etc.) that occur inside the human body in the case where the human body is exposed to an electromagnetic field.

- Basic restriction

It is a limit value on physical quantities directly related to in vivo phenomena due to a radio wave exposure that may lead to harmful health effects.

- Electromagnetic field strength standard

It is a standard for evaluating the safety of the space by using the electric field strength, magnetic field strength, power density and magnetic flux density in the evaluation space. Different numerical values are selected depending on the general environment and the controlled environment.

- Partial-body absorption standard

It is a standard used for detailed evaluation in accordance with a basic guideline in the case where part of the body is exposed to an electromagnetic field intensively due to an electromagnetic wave emitted mainly from a wireless device used in the close vicinity of the body.

- Supplementary standard

It is a standard used for a detailed evaluation in accordance with the basic guideline in the case where the electromagnetic field strength standard is not satisfied. If the situation of exposure to electromagnetic fields (non-uniform, local, surface, etc.), body phenomena (contact current or induced current) and attributes of radio wave emission sources (antenna input power and frequency band) are known, this standard is expressed in a form that relaxes or excludes the application of the electromagnetic field strength standard according to these situations.

- General environment

It is a case (environment) where the recognition of situation that a human body is exposed to the electromagnetic wave and a proper control are not expected and there is an uncertain factor. This is a case where residents are exposed to electromagnetic fields in a general living environment. For this reason, the guideline values to be applied are more stringent in the general environment than in the controlled environment. This general environment corresponds to the condition G of the Radio Wave Protection Guidelines published in 1990.

- Controlled environment

It is a case where the exposure of a human body to an electromagnetic field is recognized, a radio wave radiation source is specified, and appropriate control can be performed accordingly. For example, this is applied to a situation where an operator in an environment where a radio wave is handled daily (broadcast transmitter, a high frequency processing plant, etc.) is exposed to an electromagnetic field. This controlled environment corresponds to the condition P of the Radio Wave Protection Guidelines published in 1990.

- Uniform exposure

It is a case where the electromagnetic field in the space region where a human body exists can be regarded as almost uniform, and the whole body is exposed to the electromagnetic field. This also includes the case where the free space impedance is not $120\pi [\Omega]$. In the free space, if the

distance from the wave source is sufficiently long compared to the height of the human, for example 15 m or more for frequencies of 0.3 MHz or less, 10 m or more for frequencies of from 0.3 MHz to 300 MHz, 5 m or more for frequencies of 300 MHz or above, the electromagnetic field is considered uniform.

- Non-uniform exposure

It is a case where the exposure is not considered to be uniform.

- Partial body exposure

It is a case where a part of the body is intensively exposed to an electromagnetic field. This includes the case of emission in the vicinity of the antenna smaller than the size of the human body or the spot emission with short wavelength radio waves, etc.

- Whole body exposure

It is a case where a whole body is exposed to an electromagnetic field without being biased locally. The whole-body exposure is not necessarily uniform, but it corresponds to the case of non-partial-body exposure.

- Average time

It means the duration time for measurement set based on the focused body phenomena in order to evaluate the conformity to the standard. The average time used in this standard is instantaneous for stimulating phenomena and 6 minutes for thermal phenomena.

- Specific absorption rate (SAR)

It is defined as electromagnetic power absorbed per unit time and unit mass of the tissue when a tissue is exposed by an electromagnetic wave. The average of the SAR over the whole body is called “whole body average SAR”, and the SAR averaged within an arbitrary 1 g or 10 g organization is called “partial-body SAR”.

- Contact current

It is electric current that flows through a contact point when a grounded human body touches an ungrounded conductive object placed in an electromagnetic field.

- Contact hazard

It is a potential situation causing a contact current.

- Induced current

It is an electric current caused by electromagnetic induction. It is also an electric current induced inside the human body when the human body is exposed to an electromagnetic field.

- Non-grounding condition

It is a condition where the influence of the ground can be ignored so that the induced current does not flow into the ground.

- Electromagnetic field

It is a general term to express an electric field and a magnetic field.

Except for the static case where the electric and magnetic fields do not change with time, both always exist at the same time and their relationship can be defined by the Maxwell's equations.

- Electric field strength

It is a vector value obtained by dividing the force acting on arbitrary point by quantity of a static micro positive electric charge when such charge is placed at that point in the electric field.

If the force is F and the quantity of the electric charge is q , the electric field strength E is given by $E=F/q$ [V/m]. In this standard, the magnitude of the electric field strength is simply referred to as the electric field strength.

- Magnetic field strength

It is a vector value whose rotation becomes a current density and a displacement current density.

It is equal to the quantity obtained by dividing magnetic flux density by the magnetic permeability of the medium. The unit is given in A/m. In this standard, the magnitude of the magnetic field strength is simply referred to as the magnetic field strength.

- Power density (Power flux density)

It is the passing power per unit area perpendicular to the direction of electromagnetic wave propagation. In principle, the evaluation of the incident power density should be made over the entire space where there is a possibility of the existing of a person in the absence of a person.

For example, the power density S [W/m²] in the case of a plane wave is expressed as $S=E^2/120\pi$ when the electric field strength is E [V/m] and the magnetic field strength is H [A/m]. Where, 120π [Ω] is the free space impedance.

- Far-field

It is an electromagnetic field in a state where the distance from the electromagnetic wave source is in a region farther than $2D^2 / \lambda$ or $\lambda / (2\pi)$, and there is no reflection or scattering.

Where, D is the maximum size of the antenna and λ is the free space wavelength.

- Near-field

It is an electromagnetic field in a region that is not far-field.

- Effective value

It is a value obtained by taking the square root of the average of the square of the wave pattern over the one period of the frequency wave pattern. The effective values of the electric field strength and magnetic field strength of the electromagnetic field that periodically change are values related to Joule heat.

- Time average value

In the case of the electric field strength or magnetic field strength, it is the root mean square

value of an instantaneous effective value indication over the average time. In the case of power density, it is the average value of an instantaneous effective value indication over the average time.

- Duty cycle

In a pulse having a periodicity, it is the ratio of the pulse width to the pulse period, and in an intermittent wave having a periodicity, it is the ratio of the emission time of the intermittent wave to the intermittent period.

- Antenna power

It is peak power, average power, carrier power or standard power.

- Antenna input power

It is net antenna input power obtained by subtracting the antenna feeder loss and mismatch loss from a transmitter output power.

- Peak power

It is average power supplied from a transmitter to an antenna feeder during one radio frequency cycle at the highest peak of the modulation envelope under a normal operating condition.

- Average power

It is the power obtained by averaging the power which is supplied to a feeder of an antenna over a long time period in comparison with the cycle of the lowest frequency used for the modulation. Usually the average time is one-tenth second of the duration when the average power keeps the maximum.

- Carrier power

It is mean power supplied from a transmitter to a feeder line of an antenna system during one radio frequency cycle without modulation. However, this definition does not apply to the emission of a pulse modulation carrier.

- Standard power

It is value of the output standard of a transmitter under the usage of a final stage vacuum tube (amplifier).

- Equivalent Isotropic Radiated Power (EIRP)

It is the product of the power supplied to the antenna and the absolute gain of the isotropic antenna in a given direction. (Approximately 1.64 times the effective radiation power.)

- Effective Radiated Power (ERP)

It is the product of the power supplied to the antenna and the relative gain for the half-wavelength dipole antenna in a given direction.

- Antenna gain

It is the ratio of the power to be supplied to the input of a reference antenna in order to produce the same electric field at the same distance in a given direction to the power supplied to the input of the given antenna. In this case, unless otherwise specified, the numerical value representing the gain of the antenna indicates the gain in the direction of main radiation.

- Absolute gain of antenna

It is an antenna gain in a given direction when the reference antenna is an isotropic antenna isolated in space.

- Relative gain of antenna

It is an antenna gain in a given direction when the reference antenna is a half-wave lossless dipole that is isolated in space and whose vertical bisector plane includes the given direction.

Appendix 1 Basic guideline

The basic guidelines are shown in Appendix Table 1.1. The basic guidelines are concepts on which the radio wave protection standard is based, and also provides a basis for judging the possibility of occurrence of biological effects.

Appendix Table 1.1 Basic guidelines

- ① The average value of the whole-body average SAR for any 6-minute period shall be 0.4W/kg or less.
- ② (Deleted)
- ③ At frequencies from 100kHz to 100MHz, the inflow current from outside such as contact current should be 100mA or less (average time 6 minutes).
- ④ In addition to ①, ② and ③ above, the followings shall be considered as precautions.
 - (a) Even if any of 6 min average among average power SAR is 0.4 W/kg or less, local SAR at any of 1 gram tissue (6 min average) is desirably not to exceed 8W/kg (for body surface and limbs 25 W/kg).
 - (b) For 3 GHz or higher frequency irradiating power density into eyes (6 min average) is desirably 10 mW/cm² or less.

Appendix 2 Basic restrictions

The basic restrictions are shown in Appendix Table 2-1. The basic limit is radio wave exposure that can have harmful health effects.

It is defined as a limit value for physical quantities that are directly related to the in-vivo phenomenon caused by. Conformity confirmation by basic guidelines

However, while it is positioned as an exceptional measure when conformity cannot be confirmed according to the management guidelines, it is a basic restriction.

Is expected to be actively used for conformity confirmation.

Appendix Table 2-1 The basic restrictions

Exposure characteristics	frequency range	Managed environment	General environment
		Electric field in the body (V/m)	Electric field in the body (V/m)
All tissues of the head and body	10 kHz~10 MHz	$2.7 \times 10^{-4} \times f$	$1.35 \times 10^{-4} \times f$

(Note 1) f is the frequency 【Hz】

(Note 2) In the frequency range above 100 kHz, it is necessary to consider the guideline value of thermal action.

(Note 3) When the electromagnetic field consists of multiple frequency components that cannot be ignored with respect to the guideline value, the sum of the ratios of each frequency component (10 kHz or more and 10 MHz or less) to the guideline value with respect to the electric field strength, magnetic field strength, and magnetic flux density. Obtain or obtain an appropriate weighted average of the ratio of each frequency component to the guide value according to the frequency characteristics of the guide value. The sum of these must not exceed 1.

Appendix 3 Safety management

Appendix 3.1 Overview

We will outline the method for ensuring the safety of the human body when there is a risk of electromagnetic field irradiation exceeding the numerical value of this standard in the situation of operating or using radio wave utilization equipment.

Appendix 3.2 Safety management method

There are four basic means that can be used as a safety management method: shielding / insulation, distance limitation, time limitation, and power limitation. It is important to combine them for more effective safety management.

Appendix 3.2.1 Shielding / insulation

Measures are taken by electromagnetically shielding or insulating the electromagnetic radiation source and the human body.

For leaked electromagnetic waves, etc., a method of shielding the electromagnetic radiation source or the space containing the electromagnetic radiation source by covering it with an electromagnetic shielding material, etc., reducing the electromagnetic field strength by using a metal plate or a radio wave absorbing material, etc. There is a method.

For the contact current, there are methods such as covering the metal body with a non-inductive material or grounding the metal body, and for the ankle induced current, the human body is in an insulated state on the floor surface. There is a way to ensure the non-grounding condition of.

For special situations such as maintenance of electromagnetic radiation sources, it is possible to reduce the electromagnetic field strength by using protective equipment (protective clothing, protective glasses, insulating shoes, insulating gloves). In this case, it is necessary to use protective equipment evaluated based on the basic guidelines. However, although the evaluation methods for protective materials are currently quite advanced, the evaluation methods for protective clothing, etc. composed of these are still in the research stage, and their effects have not been retested in Japan.

Appendix 3.2.2 Distance limit

This is a method of managing the distance between the electromagnetic radiation source and the human body so that it is separated by a certain distance or more. Basically, electromagnetic radiation sources such as antennas should be installed sufficiently away

from the human body's existing space, but by installing fences or displaying signs to prevent people from entering areas that exceed this standard. It can also be handled.

Appendix 3.2.3 time limit

The transmission time or operating time of the power source is reduced, and measures are taken in consideration of the evaluation of the average time.

There are methods such as reducing the duty cycle of the equipment used intermittently and controlling the operation (operation) time within the average time (6 minutes). In addition, since the basis of the basic restriction on human body protection from stimulating action is based on an instantaneous (typically 100 msec or less) biological reaction, the standard value for human body protection from stimulating action is not included. The pointer value is shown as an instantaneous value.

Appendix 3.2.4 Power limit

This is a countermeasure by reducing the amount of radiant power to the target space.

There are methods such as arranging a plurality of radioactive sources so as not to be locally concentrated, using an antenna radiation pattern, and preventing the antenna system from pointing in a specific direction.

For special situations such as maintenance of the electromagnetic radiation source, there is a method of temporarily reducing or stopping the output of the electromagnetic radiation source.

Appendix 3.2.5 Safety management manual

Measures are taken by clearly indicating necessary information regarding protection in safety management manuals, equipment operation manuals, etc., and by enforcing appropriate actions by the operator or operator based on this information.

The following items can be considered as information on the safety management manual.

- ① Possibility of failure and avoidance behavior
- ② Setting off-limits areas, posting signs, displaying cautionary notes
- ③ Secure an appropriate distance from the wave source
- ④ Restrictions on wearing metal objects
- ⑤ Use of electromagnetic field strength monitor, etc.
- ⑥ Prior confirmation of electromagnetic field strength by measurement, estimation, etc.
- ⑦ Unique situation of pacemaker users, etc.

Appendix 4 Correspondence between regulations such as the Radio Law Enforcement Regulations and this standard

Appendix 4-1 Article 21-3 of the Radio Law Enforcement Regulations, 2017 (2017) Ministry of Internal Affairs and Communications Notification No. 309 and Correspondence to this Standard

No.	Enforcement rules, etc.	This standard	remarks
1	Article 21-3, Paragraph 1 Restricted places are usually limited to places where people usually gather, pass, and go in and out.	Equivalent to general environment	The contents are the same.
2	Article 21-3, Paragraph 1 Exemption from radio equipment of the following radio stations ① Radio station of 20 mW or less ② Moving radio station ③ Temporary radio station in case of emergency ④ Radio station separately announced by the Minister of Posts and Telecommunications	The subject of this standard is the electromagnetic field generated by the radio equipment, except when irradiating for medical purposes, and the radio equipment is not specified.	The same applies to the electromagnetic field strength standard.
3	Attached Table No. 2-2-2 Values specified in "Table of signal strength values" * Partially revised by the Ordinance No. 65 of the Ministry of Internal Affairs and Communications (2017)	2.2 General environment values of electromagnetic field strength standard (Table 2.2-1 (a))However, Note 1 and 2 are excluded.	The contents are the same.
4	Table 1 of Notification No. 309 Spatial average at frequencies above 100 kHz and below 300 MHz	2.3 Auxiliary standard 2.3.1 Standard for non-uniform exposure to electromagnetic fields (1) b) However, Note 1 and 2 are excluded.	

5	Table 1 of Notification No. 309 Spatial average of electric field strength, magnetic field strength, and power flux density at frequencies above 300 MHz and below 300 GHz (The value is the same as the value in item 3)	2.3 Auxiliary standard 2.3.1 Standards for non-uniform exposure to electromagnetic fields (2) a), (3) a), (4) a) However, Note 1 and 2 are excluded.	
6	Table 1 of Notification No. 309 Spatial maximum power flux density at frequencies above 300 MHz and below 1 GHz	2.3 Auxiliary standard 2.3.1 Value of general environment of standard (2) b) when exposed to non-uniform electromagnetic field However, Note 1 and 2 are excluded.	
7	Table 1 of Notification No. 309 Spatial maximum value of power flux density at frequencies above 1 GHz and below 300 GHz	2.3 Auxiliary standard 2.3.1 General environment values of standards (3) c) and (4) c) when exposed to non-uniform electromagnetic fields However, Note 1 and 2 are excluded.	
8	Table 2 of Notification No. 309 Spatial average at frequencies above 10 kHz and below 10 MHz	2.3 Auxiliary standard 2.3.1 Standard for non-uniform exposure to electromagnetic fields (1) a) However, Note 1 and 2 are excluded.	
9	Table 3 of Notification No. 309 Effective value of electric field in the body at frequencies above 10 kHz and below 10 MHz	Appendix 2 Basic limit general environment values	

Relevant report 1

Report from Telecommunications Technology Council, Inquiry No. 38 "Human Body Protection Guideline in using Radio Waves", June 1990 (Excerpt)

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Foreword

With remarkable evolution in recent social and economic activities and also computerization, demand in the field of radio wave utilization is growing over time.

Wireless telecommunications as communication media utilizing radio wave taking maximum advantage of radio wave characteristics, which allows overcoming obstacles of time and distance to transfer information instantly and thus ranked as one of the important infrastructures for life and industry in modern society. Most wide utilization among wireless communication is field of broadcasting, assorting various broadcasting services with short wave, FM, TV, and satellite communications, it gives richness to people's lives by providing information on culture and amusement and also varieties of audio and visual cultures to not only family life but every scene in the nation as well. Besides it transfers multiplicities of information of telephone, facsimile, and data communication by utilizing broadband micro wave or satellite transmission paths, throughout not only in Japan but also all the world over instantaneously, and thus it is considered as essential means for the advanced information age. In daily life or on occasions of natural disaster, at national government, local government or other public institutions for emergency care center, fire department, police department, and many public welfares for medical service, sea traffic or transportation, it plays important role as quick information transmission means. Recently radio wave utilization is conspicuously increasing in private applications especially cordless telephone for home use, portable wireless phone in urban area for enhancing mobility in urban area, personal radio equipment accepted in the field of hobby and leisure become conveniently used according to individual lifestyle as no technical knowledge required.

Similarly, use case utilizing radio wave as energy supply means also becomes essential to people's lives and industrial activities, for example, microwave oven for home use, dehydration of ceramics and woods, thermoforming of plastic and vinyl, and so on. Likewise, medical technology utilizing electromagnetic wave as medical treatment spreads widely for broken bone, neuralgia, cancer, and so on.

Despite these social tendencies of uncertainty and question that radio wave may affect unlikable influence to living body, which is radiated from radio wave utilization facilities, comes to arise. When living body is exposed to strong electromagnetic field, some living body action such as rise of body temperature in a deep part by energy of electromagnetic field or excitement of nerve or muscle by stimulation of flow of electricity are proved to cause, in the outcome from research and survey. For this point radio wave radiation from various utilizing facilities, wireless telecommunication facilities and the like, shows quite feeble energy distribution in the

region of daily lives and thus is considered not to cause serious effect to living body action. However, in future there may be various situations of radio wave utilization, which are never experienced before may come into practice and it is expected that there may arise unnecessary confusion to people, who may have misunderstanding or anxiety about radio wave facilities for their large scale and strange appearance due to unfamiliarity with radio wave utilization. Hence, it is important to clarify the correlation quantitatively between energy amount of radio wave and its affection to living body action, and also, in order to development of healthy utilization of radio wave, it is demanded to enact radiofrequency-exposure protection guideline.

Concerning interactions between electromagnetic field and living body, in addition to the effect by heat and current stimulation, some research reports suggest possibilities that relatively feeble electromagnetic field may affect living body into cell and cause harmful influence, it is the fact that there still be several research topics remain unsolved. On the other side research on the interaction activities between electromagnetic field and living body have been carried out over 40 years, providing many outcomes available, moreover recent years remarkable progress in systematization of methodology of research accumulated and available.

In this report standing on the correct understanding on radiofrequency-exposure protection in order to promote the desirable progress provides protection guideline for human body in use of radio wave. In future observing the intended purpose actively utilize the guideline for reference when configure voluntary operation standard.

Chapter 1 Purpose and Scope

Radiofrequency-exposure protection guideline is aimed to promote sound growth of radio wave utilization for increasing social and economic demand, by harmonizing safety of human body and operation of radio wave utilization facilities. For this purpose, the guideline shows fundamental ways and specific values to judge whether the electromagnetic energy, exposed through using radio wave, is within safe state and not to cause disagreeable electromagnetic influences to human body (temperature increasing in deep part, electric shock, high-frequency heating injury, etc.), and measurement method and estimation method of electromagnetic field strength in the vicinity of radio wave utilization facilities and also basic protection method to mitigate the electromagnetic field energy radiated to human body, moreover provides guideline to define safety standard, recommendation, operation procedures, etc. The value indicated here assumes human body protection with sufficient safety factor and exceeding the value does not mean directly to cause bad influence to human body.

Although the target frequency range of electromagnetic field to be stipulated in radiofrequency-exposure protection guideline should cover the full range of article 2 of Radio Law ("Radio wave" refers to electromagnetic wave in 3000 GHz or lower frequency), considering the present situation of frequency allocation and the movement of radio wave utilization technology, it is focused from 10 kHz to 300 GHz.

Radiofrequency-exposure protection guideline shall be applied to the whole radio wave utilization. Typical examples are occupational exposure in work, ordinary exposure in daily life and the like, and when applying the radiofrequency-exposure protection guideline it is important to appropriately take into practice through careful examination on various conditions such as specification of electromagnetic wave source, situation of being exposed, etc., and based on the concept of the guideline.

Radiofrequency-exposure protection guideline in this report is described based on the facts approved as common understanding among specialists, while still includes some temporary aspects. For this situation, as examination and study in this field will progress, and when another scientifically proven basis or new concept will be presented, the details of the radiofrequency-exposure guideline should be revised according to the situation of radio wave utilization in the public, etc.

Chapter 3 Protection Guideline

3.1 Positioning and Constitution of Protection Guideline

3.1.1 Living body effect in electromagnetic field as the basis of Protection Guideline

Tissues within human body can be interpreted electromagnetically as inductive substance having a certain electric constant. On interaction between electromagnetic field and living body, logical analysis in electrical characteristic of living body is carried out and also experimental analyzing methodology using virtual ma model composed in appropriate permittivity and conductivity is established. According to the outcomes from these analyses living body effect can be generally classified into heat effect, stimulus effect and other effect as shown in Table 1.

Table 1: Relationship between electromagnetic wave and living body effect

Category of effect		Mutation factor of organism	Object amount of effect assessment	Relation with electromagnetic wave
Heat effect	Whole body effect	Heat adjustment response against temperature increasing by heat stress in deep part	Temperature increasing for whole body averaged SAR (in deep part)	Macroscopic interaction (exposure evaluation technique)
	Local body effect	Tissue heating	Temperature increasing for local averaged SAR (local tissue temperature)	
Stimulus effect		Nerve and muscle excitement by flow of electricity	Induced current (density)	
Others		Unknown	Electromagnetic field strength, etc. (modulation frequency)	Microscopic interaction

Among these living body effect, there is a lot of accumulation of study on heat and stimulus effects, in which the cause-and-effect relationship with electromagnetic field strength are quantitatively grasped. It shows a distinct tendency that stimulus effect is dominant in lower frequency range and heat effect in higher frequency range of 100 kHz.

However, for other effect than stimulus or heat, no effect has been observed relating with living body or no fact causing to human health has been shown.

Therefore, the target effect to be observed by the radiofrequency-exposure protection guidelines is focused on heat and stimulus effects. This includes pulse wave effect and modulation wave effect, which is ordinarily interpreted in heat and stimulus effects, and also includes pulse wave effect and modulation wave effect suffering directly living body in electromagnetic field. In addition, contact current effect caused due to electromagnetic energy is also assessed though it is not direct effect from electromagnetic field.

In the meantime, many countries stipulate their own protection guideline based on the similar approach and within their guidelines any facts of undesirable influence caused concerning not only heat effect and stimulus effect but other effect are not yet disclosed so far.

3.1.2 Objective Quantity Problem of evaluation in Protection Guideline

Heat effect from electromagnetic energy to living body appears as temperature rise of body or tissue by Joule heat occurs within tissue. This temperature rise closely relates to energy quantity absorbed into tissue, thus is evaluated with energy quantity absorbed in unit mass during unit time, that is specific absorption rate (SAR). On the other hand, stimulus effect relates current density induced within human body tissue. Specific absorption rate and induced current are both recognized as observable phenomena depending on electric field strength within human body tissue and conductivity of tissue.

As described above, living body effect in electromagnetic field closely relates to electric field strength within tissue. However, as it is impossible to measure electric field within tissues directly, electromagnetic state taking place within human body needs to be estimated by some means. At present any estimation procedure for this case has not been formalized yet. Only some research institutes deal with this kind of estimation (evaluation) as their own subject. Therefore, at the present stage it can be said it is not common practice to deal with electromagnetic state within human body as measurement object itself.

Radiofrequency-exposure protection guidelines is required to provide methodology for speedy evaluation on the safety in various situations where people may concern with radio utilizing equipment, hence it is insufficient to satisfy the realistic demand as the guideline if it is described using expression of quantity on electromagnetic state which is not directly measurable. Therefore, evaluation on safety needs to be done by converting the electromagnetic state within human body to measurable quantity (electromagnetic field strength or current) and using the result obtained through the conversions.

3.1.3 Organization of Protection Guideline

Situations that protection guideline needs to be applied are generally categorized into three standpoints below.

- ① Environment evaluation of spatial area affected with electromagnetic energy
- ② Condition evaluation of radiation from radio wave utilizing equipment and its usage
- ③ Protection means evaluation against electromagnetic field

For ① the evaluation target is aerial space with no human body occupying. If human body locates sufficiently far from radio wave radiation source with no metallic object dispersing radio wave at a close range, then electromagnetic state within human body can be regarded to have a certain correlation with electric and magnetic field values measured without human body. In such a restricted condition protection guideline can be established referring to electromagnetic field strength in the space without human body. This is called electromagnetic field strength guideline. Target electromagnetic field of protection guideline is generally near-field or non-uniform, hence electromagnetic field strength guideline, as it is, can be applied to situations with very limited conditions. If those limited conditions are not satisfied, this space evaluation without human body is not suitable. In those situations evaluation of ② is applied.

For ② evaluation target is relationship between electromagnetic radiation source and human body. If there resides a certain correlation between electromagnetic radiation source and human body, the evaluation can be regarded as evaluation on electromagnetic radiation source itself. That is, particularly in case that the radiation source is sufficiently far, it can be regarded as category ① evaluation, but in general the evaluation must be done based on electromagnetic state occurs within human body. The guideline for evaluation based on electromagnetic state within human body is called base guideline.

However, the base guideline includes description in immeasurable quantity and it is difficult to handle all cases with base guideline and also it is not reasonable to expect its practical operation. To cope practically with this kind of problem of ② another guideline needs to be arranged with measurable evaluation value, which is called supplementary guideline. The supplementary guideline is arranged to fill up the electromagnetic field strength guideline in accordance with the base guideline and its evaluation is composed of following four items.

- (1) Non-uniformly or locally exposed to electromagnetic energy
- (2) Contact current
- (3) Induced current

(4) Low-power radiation source

Note that the supplementary guideline is arranged characterized as simplified evaluation for electromagnetic state within human body and thus it should be kept in mind that the evaluation ② should be handled originally with the base guideline.

For ③ there reside some issues which cannot be judged without direct evaluation of electromagnetic state within human body. That is, the evaluation should be carried out with base guideline, for which careful estimation and evaluation are required by some expert institutes.

As described above protection guideline is composed of electromagnetic field strength guideline, supplementary guideline and base guideline. Among these, electromagnetic field strength guideline and supplementary guideline provide methodologies to be applied practically to the actual situation. These two guidelines are called managing guideline. Base guideline is the foundation of managing guideline and characterized to provide judging reference for safety in particular case which is unable to handle with managing guideline.

Protection guideline is stipulated at the present time based on the latest study outcomes and actual situation of radio wave utilization. Hence as the situation would change after this, the guideline should be complemented or revised accordingly. The study progress on influence of electromagnetic energy to living body will be chiefly reflected to base guideline, while any alteration of compatibility with actual daily life along with the progress on measurement and estimation methodologies and change of radio wave utilization will be reflected to managing guideline. For this positioning base guideline needs not be revised quite often, while managing guideline should be revised appropriately when needed.

3.1.4 Managing Guideline in two-step composition

For evaluation based on protection guideline to be reliable, protection guideline needs to be appropriately applied and useful to inspect whether any change arises in the condition of electromagnetic environment when needed. If it is the case, managing guideline (electromagnetic field strength guideline and supplementary guideline), which is based on converted values from base guideline, can be applied. On the other hand, if the radio wave utilizing condition is not be recognized correctly there may arise some situation unconsciously not to satisfy condition of base guideline and no behavior can be expected being aware of existence of electromagnetic field. Therefore, in order to secure sufficient safety even in those situations, another appropriate guideline with additional safety factor, as adopted to be rational practice in other countries, should be established.

Consequently, managing guideline is categorized into condition P, in which evaluation target is the situation that the purpose of protection guideline is effectively reflected and the environment is well managed, and condition G, in which protection guideline and radio wave utilizing situation are not well recognized. In condition G, considering uncertainty due to insufficiently managed electromagnetic field compared to condition P, generally five times of additional safety factor of condition P in power density is heaped up.

3.1.5 Procedure to apply Protection Guideline

Procedure to apply protection guideline composed of managing guideline (electromagnetic field strength guideline and supplementary guideline) and base guideline is as follows.

To start evaluation, regardless conditions of radiation source, etc., apply electromagnetic field strength guideline first. Then for the evaluation target, where the actual situation of radio wave utilization is well recognized and also it is possible to utilize radio wave based on the purpose of protection guideline, condition P is applied, otherwise condition G instead. When electromagnetic field strength guideline is satisfied through the whole target spatial area (location), the spatial area (location) is judged as being safe.

Electromagnetic field in the target space is mostly non-uniform or near-field, therefore it is generally evaluated as higher value than the actual electromagnetic field strength. In such situations when electromagnetic field strength guideline is not satisfied safety is judged through further evaluation based on supplementary guideline.

If the result of evaluation in above-mentioned procedure managing guideline in condition G is not yet satisfied, then the target should be managed corresponding to condition P or appropriate measure for satisfying the guideline should be taken. If it is proved that the guideline in condition P is not satisfied there is possibility not to satisfy base guideline, then another measure to satisfy the base guideline has to be taken or in order to directly judge the possibility of damage to human body, returning to the base guideline, evaluation with base guideline needs to be done.

Evaluation stipulated in base guideline includes some values for which definite methodologies of measurement and estimation are not fully established yet. Therefore, in this guideline only some actual evaluation is illustrated. To evaluate for such cases evaluation can be done according to the methodology approved by research institutes, etc.

3.2 Managing Guideline

Managing guideline is stipulated based on the base guideline and actual evaluation of electromagnetic environment is carried out mainly using managing guideline. This guideline is composed of electromagnetic field strength guideline and supplementary guideline and is applied based on measurement method and electromagnetic field strength estimation method described in Chapter 4 and Chapter 5 respectively.

3.2.1 Electromagnetic Field Strength Guideline Value

(1) Condition P

Guideline value corresponding to condition P is shown in Table 2 (a) and Table 2 (b). If evaluation target space does not locally satisfy values in this table, supplementary guideline described in 3.2.2 (1).

Guideline values in Table 2 (a) and Table 2 (b) are graphed in Figure 1 and Figure 2.

Table 2 (a) Guideline value of electromagnetic field strength (6 min average)
in condition P

Frequency f	r.m.s. value of electric field strength E [V/m]	r.m.s. value of magnetic field strength H [A/m]	Electric power density S [mW/cm ²]
10 kHz - 30 kHz	614	163	
30 kHz - 3 MHz	614	$4.9f \text{ (MHz)}^{-1}$ (163 - 1.63)	
3 MHz - 30 MHz	$1842f \text{ (MHz)}^{-1}$ (614 - 61.4)	$4.9f \text{ (MHz)}^{-1}$ (1.63 - 0.163)	
30 MHz - 300 MHz	61.4	0.163	1
300 MHz - 1.5 GHz	$3.54f \text{ (MHz)}^{1/2}$ (61.4 - 137)	$f \text{ (MHz)}^{1/2}/106$ (0.163 - 0.365)	$f \text{ (MHz)}/300$ (1 - 5)
1.5 GHz - 300 GHz	137	0.365	5

Table 2 (b) Guideline value of electromagnetic field strength for low-frequency range
(averaging time < 1 sec) in condition P

Frequency f	r.m.s. value of electric field strength E (V/m)	r.m.s. value of magnetic field strength H (A/m)
10 kHz - 100 kHz	2.00	163

Note 1: The r.m.s. value of electric field with no prevention means taken against contact current shall be 137V/m or less for 15 MHz or lower frequency

(Averaging time < 1 sec). However even if the evaluation value does not satisfy this reference value, when it is less than guideline value in Table 2 (a) and Table 2 (b) then guideline 3.2.2 (2) can be applied.

Note 2: The r.m.s. value of electromagnetic field strength (averaging time: 6 min) when non-grounded condition with human body is not satisfied shall be $3,200f(\text{MHz})^{-3/2}\text{V/m}$ for frequency range from 3 MHz to 30 MHz (i.e. 614V/m – 20V/m), 20 V/m from 30 MHz to 100 MHz, $0.2f(\text{MHz})\text{V/m}$ from 100 MHz to 300 MHz (i.e. 20V/m – 61.4V/m) or less. However even if the evaluation value does not satisfy this reference value, when it is less than guideline value in Table 2 (a) then guideline 3.2.2 (2) can be applied.

Note 3: If electric field strength or magnetic field strength fluctuates during averaging time in Table 2 (a), root mean square of effective value through averaging time shall be used, and if power density is not stable mean value through averaging time shall be used.

Note 4: In case that electromagnetic field is composed of multiple frequency component at non-ignorable level to the guideline value electric field strength and magnetic field strength shall be summed up with square values of proportion to guideline value of each frequency component and power density shall be summed up the values of proportion to the guideline value of each frequency component. The sum total of these values shall exceed 1.

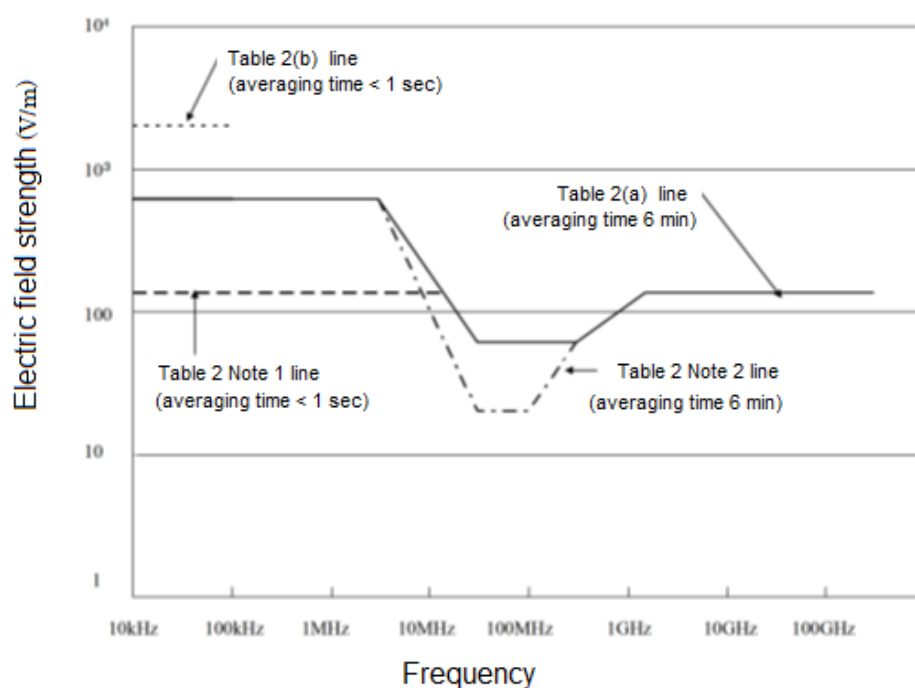


Figure 1 Electric field guideline value (condition P)

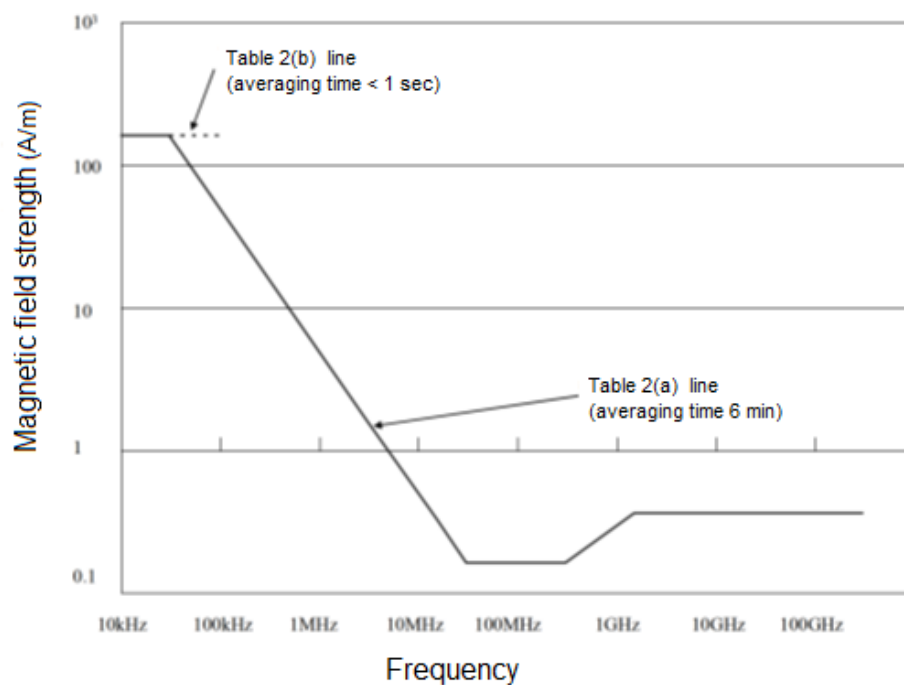


Figure 2 Magnetic field strength guideline value (condition P)

(2) Condition G

Guideline value corresponding to condition G is shown in Table 3 (a) and Table 3 (b).

If evaluation target space does not locally satisfy values in this table, supplementary guideline described in 3.2.2 (1).

Guideline values in Table 3 (a) and Table 3 (b) are graphed in Figure 3 and Figure 4.

Table 3 (a) Guideline value of electromagnetic field strength (6 min average)
in condition G

Frequency f	r.m.s. value of electric field strength E [V/m]	r.m.s. value of magnetic field strength H [A/m]	Electric power density S [mW/cm ²]
10 kHz - 30 kHz	275	72.8	
30 kHz - 3 MHz	275	$2.18f \text{ (MHz)}^{-1}$ (72.8 - 0.728)	
3 MHz - 30 MHz	$824f \text{ (MHz)}^{-1}$ (275 - 27.5)	$2.18f \text{ (MHz)}^{-1}$ (0.728 - 0.0728)	
30 MHz - 300 MHz	27.5	0.0728	0.2
300 MHz - 1.5 GHz	$1.585f \text{ (MHz)}^{1/2}$ (27.5 - 61.4)	$f \text{ (MHz)}^{1/2}/237.8$ (0.0728 - 0.163)	$f \text{ (MHz)}/1500$ (0.2 - 1)
1.5 GHz - 300 GHz	61.4	0.163	1

Table 3 (b) Guideline value of electromagnetic field strength for low-frequency range
(averaging time < 1 sec) in condition G

Frequency	r.m.s. value of electric field strength E (V/m)	r.m.s. value of magnetic field strength H (A/m)
10 kHz - 100 kHz	894	72.8

Note 1: The r.m.s. value of electric field with no prevention means taken against contact current shall be 61.4V/m or less for 15 MHz or lower frequency (averaging time < 1 sec). However even if the evaluation value does not satisfy this reference value, when it is less than guideline value in Table 3 (a) and Table 3 (b) then guideline 3.2.2 (2) can be applied.

Note 2: The r.m.s. value of electromagnetic field strength (averaging time: 6 min) when non-grounded condition with human body is not satisfied shall be $1,430f \text{ (MHz)}^{-3/2} \text{ V/m}$ for frequency range from 3 MHz to 30 MHz (i.e., 275V/m - 9V/m), 9 V/m from 30 MHz to 100 MHz, $0.09f \text{ (MHz)} \text{ V/m}$ from 100 MHz to 300 MHz (i.e.,

9V/m – 27V/m) or less. However even if the evaluation value does not satisfy this reference value, when it is less than guideline value in Table 3 (a) then guideline 3.2.2 (3) can be applied.

Note 3: If electric field strength or magnetic field strength fluctuates during averaging time in Table 3 (a), root mean square of effective value through averaging time shall be used, and if power density is not stable mean value through averaging time shall be used.

Note 4: In case that electromagnetic field is composed of multiple frequency component at non-ignorable level to the guideline value electric field strength and magnetic field strength shall be summed up with square values of proportion to guideline value of each frequency component and power density shall be summed up the values of proportion to the guideline value of each frequency component. The sum total of these values shall exceed 1.

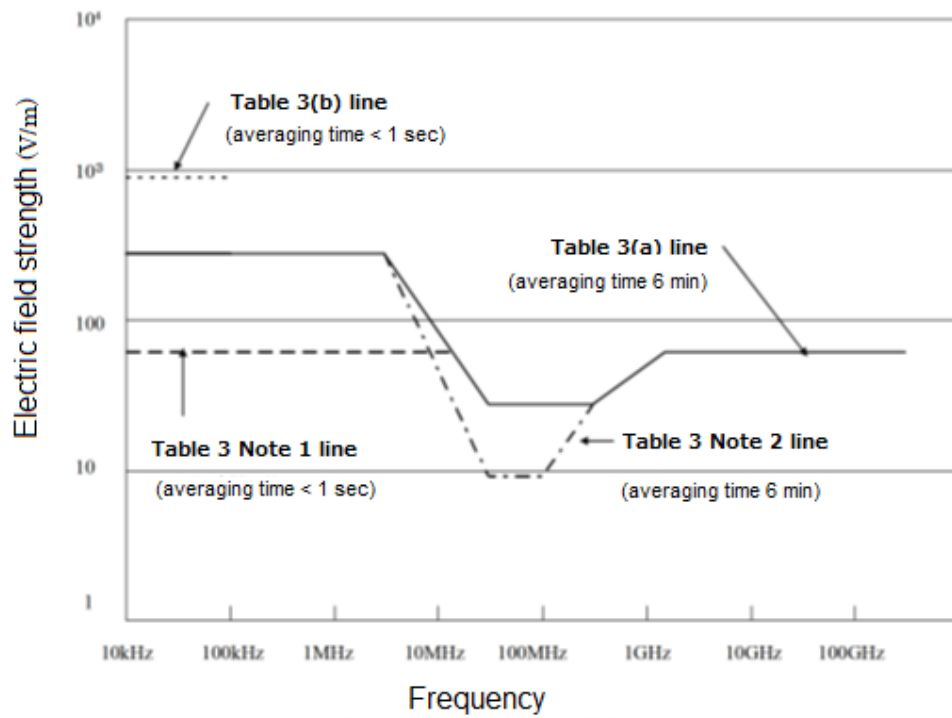


Figure 3 Electric field guideline value (condition G)

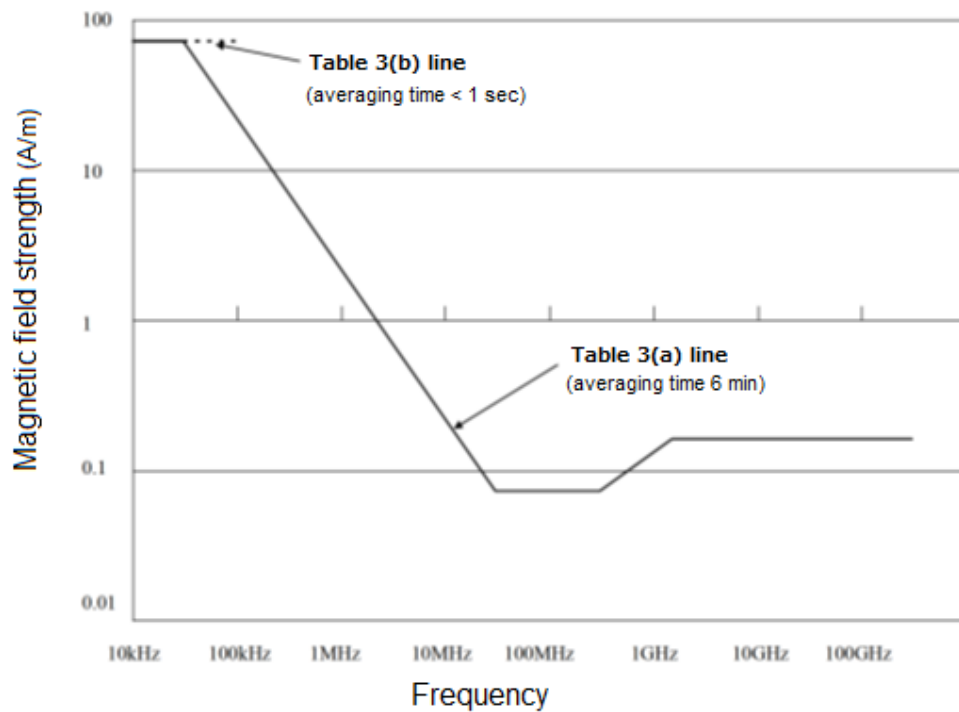


Figure 4 Magnetic field strength guideline value (condition G)

3.2.2 Supplementary Guideline

This supplementary guideline, in case that it is impossible to prove the target satisfying the protection guideline with electromagnetic guideline-based evaluation alone, provides more strict evaluation methodology, observing the situation of human body exposed to electromagnetic energy or living body effect to be counted.

(1) Guideline applied for cases of human body non-uniformly or locally exposed to electromagnetic field

When the conditions are fully satisfied for the specified frequency range, it is considered being conformed to guideline.

In case of target frequency ranges extend over the multiple divisions listed below, for the ranges ①, ② (a) & (b) and ③ (a) & (b), calculate the sum of square values of proportion at each frequency component to the guideline value, which shall not exceed 1.

Exceptionally, equipment used in the spatial area within 20 cm of human body (within 10 cm for frequency range 300 MHz or higher) needs to be judged separately for each particular situation. When the energy may exceed the base guideline value, base guideline must be adequate to that evaluation.

① For frequency range lower than 300 MHz

Spatially averaged value of power density distribution through the whole area corresponding to the space occupied by human body, at spatial area 20 cm or more apart from electromagnetic radiation source or metallic object (root mean square for strength of electric field or magnetic field), shall be the guideline value of corresponding conditions (P or G) in electromagnetic field guideline (clause 3.2.1) or less.

Note 1 through Note 4 below Table 2 or Table 3 shall be applied to this clause as well.

② For frequency range from 300 MHz to 1 GHz

(a) Spatially averaged value of power density distribution through the whole area corresponding to the space occupied by human body, at spatial area more than 10 cm apart from electromagnetic radiation source or metallic object (root mean square for electric or magnetic field strength), shall be the guideline value of corresponding conditions (P or G) in electromagnetic field strength guideline (clause 3.2.1) or less.

Note 1 through Note 4 below Table 2 or Table 3 shall be applied to this clause as well.

(b) Spatial maximum value of power density within the space occupied by human body excluding limbs shall be 20 mW/cm² or less (6 min average), where the evaluation

target shall be limited to the space 10 cm or more apart from electromagnetic radiation source or metallic object.

Note 3 and Note 4 below Table 2 or Table 3 shall be applied to this clause as well.

③ For frequency range from 1 GHz to 3 GHz

(a) Spatially averaged value of power density distribution through the whole area corresponding to the space occupied by human body, at spatial area more than 10 cm apart from electromagnetic radiation source or metallic object (root mean square for electric or magnetic field strength), shall be the guideline value of corresponding conditions (P or G) in electromagnetic field strength guideline (clause 3.2.1) or less

Note 1 through Note 4 below Table 2 or Table 3 shall be applied to this clause as well.

(b) Spatial maximum value of power density within the space occupied by human body excluding limbs shall be 20 mW/cm² or less (6 min average), where the evaluation target shall be limited to the space 10 cm or more apart from electromagnetic radiation source or metallic object.

Note 3 and Note 4 below Table 2 or Table 3 shall be applied to this clause as well.

(c) Spatial maximum value of power density irradiating into head area shall 10 mW/cm² or less (6 min average), where the evaluation target shall be limited to the space 10 cm or more apart from electromagnetic radiation source or metallic object.

Note 3 and Note 4 below Table 2 or Table 3 shall be applied to this clause as well.

④ For frequency 3 GHz or higher

(a) Spatially averaged value of power density distribution through the whole area corresponding to the space occupied by human body, at spatial area more than 10 cm apart from electromagnetic radiation source or metallic object (root mean square for electric or magnetic field strength), shall be the guideline value of corresponding conditions (P or G) in electromagnetic field strength guideline (clause 3.2.1) or less.

Note 1 through Note 4 below Table 2 or Table 3 shall be applied to this clause as well.

(b) Spatial maximum value of power density irradiating on body surface, at spatial area more than 10 cm apart from electromagnetic radiation source or metallic object shall be 50 mW/cm² or less in condition P, and 10 mW/cm² or less in condition G (both in 6 min average).

Note 3 and Note 4 below Table 2 or Table 3 shall be applied to this clause as well.

(c) Spatial maximum value of power density irradiating into eyes shall be 10

mW/cm² or less (6 min average).

Note 3 and Note 4 below Table 2 or Table 3 shall be applied to this clause as well. Conditions described above are sorted out in Table 4.

Table 4 Guideline applied for cases of human body non-uniformly or locally exposed

	10 kHz - 300 MHz	300 MHz - 1 GHz	1 GHz - 3 GHz	3 GHz - 300 GHz
Spatial average of electromagnetic	Managed environment: Table 1 applied General environment: Table 2 applied			
Spatial maximum of electromagnetic strength		Except limbs: Managed: 20 mW/cm ² General: 4 mW/cm ²		Body surface: M: 50mW/cm ² G: 10 mW/cm ²
			Head: M: 10mW/cm ² G: 2 mW/cm ²	Eyes: M: 10mW/cm ² G: 2 mW/cm ²
Applied space	Body occupying space 20 cm or more apart from radiation source or metallic object	Body occupying space 10 cm or more apart from radiation source or metallic object		
Averaged time	6 min.			

(2) Guideline concerning contact current

(a) In case of no prevention means taken against contact hazard in condition P

Measured contact current (averaging time < 1 sec) shall be $10^{-3}f(\text{Hz})\text{mA}$ or less for frequency range from 10 kHz to 100 kHz, if 100 mA or less for frequency range from 100 kHz to 15 MHz, then unnecessary to satisfy Note 1 of Table 2.

In case that contact current is composed of multiple frequency component at non-ignorable level to this criterion, contact current shall be summed up with square values of proportion the criteria of each frequency component, which shall not exceed 1.

(b) In case of no prevention means taken against contact hazard in condition G

Measured contact current (averaging time < 1 sec) shall be $4.5 \times 10^{-4}f(\text{Hz})\text{mA}$ or less for frequency range from 10 kHz to 100 kHz, if 45 mA or less for frequency range from 100 kHz to 15 MHz, then unnecessary to satisfy Note 1 of Table 3.

In case that contact current is composed of multiple frequency component at non-ignorable level to this criterion, contact current shall be summed up with square values of proportion the criteria of each frequency component, which shall not exceed 1.

(3) Guideline concerning induced current

(a) In case of deviation of non-grounded condition in condition P

If measured induced current at ankle for frequency range from 3 MHz to 300 MHz (6 min average) is less than 100 mA each leg, unnecessary to satisfy Note 2 of Table 2.

In case that ankle induced current is composed of multiple frequency component at non-ignorable level to this criteria, induced current shall be summed up with square values of proportion to the criteria for each frequency component, which shall not exceed 1.

(b) In case of deviation of non-grounded condition in condition G

If measured induced current at ankle for frequency range from 3 MHz to 300 MHz (6 min average) is less than 45 mA each leg, unnecessary to satisfy Note 2 of Table 3.

In case that ankle induced current is composed of multiple frequency component at non-ignorable level to this criteria, induced current shall be summed up with square values of proportion to the criteria for each frequency component, which shall not exceed 1.

(4) Guideline concerning low-power radiation source

Electromagnetic wave radiation source, with rated power 7 W or lower for frequency range from 100 kHz to 3 GHz, shall be considered to meet the base guideline in the ordinary using condition and no evaluation according to managing or other supplementary guidelines is needed. However, if radiation source is very close to human body or radiation energy is concentrated to some particular direction, enormous SAR value may be locally observed, hence to those situations some care should be desirably taken.

3.3 Base Guideline

Base guideline is shown in Table 5. Base guideline is the foundation of managing guideline and characterized to provide judging reference for the possibility of occurrence of living body effect.

Table 5 Base Guideline

1 Any of each 6 min average extracted from whole body averaged SAR shall be 0.4 W/kg or lower.
2 Induced current in the tissue for frequency range from 10 kHz to 100 kHz shall be $0.35 \times 10^{-4}f[\text{Hz}]\text{mA}/\text{cm}^2$ or less (averaging time < 1 sec).
3 Incoming current like contact current for frequency range from 10 kHz to 100 kHz shall be $10^{-3}f[\text{Hz}]\text{mA}$ or less (averaging time < 1 sec), for frequency range from 100 kHz to 100 MHz 100 mA or less (averaging time 6 min).
4 In addition to (1), (2) and (3) above, the following shall be considered as advisable conditions.
(a) Even if any of 6 min average among average power SAR is 0.4 W/kg or less, local SAR at any of each 1 gram tissue (6 min average) is desirably not to exceed 8W/kg (for body surface and limbs 25 W/kg).
(b) Irradiating power density into eyes for 3 GHz or higher frequency (6 min average is desirably to be 10 mW/cm ² or less.

3.4 Point to Notice

(1) Medical purpose

When electromagnetic wave is used for medical purpose person in operation being exposed to electromagnetic energy is to be applied with this guideline while patient is excluded as far as conducted by the doctor who fully recognizes the reliability of safety factor indicated in this guideline. However, for example, even efficacious radio wave as medical care to knee joint may cause harm to eyes, hence careful handling to avoid wider area of irradiation than needed and careful observing the leakage of electromagnetic energy are required.

(2) Pacemaker wearer

Pacemaker wearer should consult the doctor in charge when using radio wave, who is excluded from the target of this guideline.

(3) Person with metallic object embedded inside the body

Metal embedded inside the body may yield unexpected heat locally with even lower

electromagnetic field strength than guideline value, careful treatment needed.

(4) Person wearing metal on the body

Metal worn on the body may generate heat, particularly within short range of induction heating furnace or the like, with even lower electromagnetic field strength than guideline value, careful treatment needed.

Annex 1 Foundation for Radiofrequency-Exposure Protection Guidelines

1 Foundation for base guideline

1.1 Foundation for base guideline ①

When living body exposed to electromagnetic energy, body temperature (tissue temperature) increasing due to whole body heating will be seen as short-term biological effect. This effect may be seen in behavioral pattern change most sensitively observed in animal experiment. Such behavioral pattern changes regardless variety of animal and condition of irradiating electromagnetic field when the electromagnetic field strength exceeds a certain level of whole body averaged SAR, as is explicated by many researchers. Based on this fact whole body averaged SAR is adopted as the reference on this effect.

Some threshold examples are announced for whole body effect observed by the behavioral pattern change based on the result of animal experiment e.g., rat, such as, 4 – 8 W/kg by ANSI (American National Standards Institute) (AM82), 1 – 2 W/kg in study report by EPA (United States Environmental Protection Agency) (EI84). The electromagnetic energy of 1 – 2 W/kg of whole body averaged SAR corresponds approximately 1 °C rise of body temperature in deep part considering basal metabolism.

Consequently, the value range 1 – 4 W/kg as threshold can be considered being accepted. Based on this fact, the guideline value is defined as 0.4 W/kg in whole body averaged SAR. The guideline value allows 2.5 – 10 of safety factor. This is because the value is estimated based on the animal experiment and there still remains some uncertainty in straightforward extrapolation to human body. According to the result of animal experiment, the threshold value would not change depending on varieties of animals such as mouse, ape, etc., at the same time bigger animals, assuming their heat regulation mechanism are equivalent, are apt to be suffered more, thus a coordination is proposed as “4 S/kg for rat corresponds to 0.57 W/kg for human body” (Go86). A lot of criticism arise to this proposal because human body has advanced perspiration thus straightforward coordination is not adequate. Even assuming such a coordination has its reason at some extent, introducing above-mentioned safety factor is effective to avoid troubles. This guideline value is estimated good enough to protect human body suffering from heat effect with whole body being exposed to electromagnetic energy.

ANSI standard, IRPA (international Radiation Protection Association) guideline, Australian Standards, and so on stipulate their guideline values, etc. in the same way based on the value “whole body averaged SAR = 0.4 W/kg”, thus the appropriateness of this value is widely accepted.

Since heat time constant for human body is estimated approximately 0.1 hour or longer,

this guideline value shall be applied to averaged value during any 6 minute period (0.1 hour).

1.2 Foundation for base guideline 2

According to Bernhardt (Be79), etc. the lowest threshold of current density exciting nerves or muscle cells is estimated approximately as $J = 0.35 \times 10^{-4}f(\text{Hz})\text{mA/cm}^2$ [10 kHz – 100 kHz]. This value is adopted as guideline value of induced current density.

If current density in almost equal to the stimulus threshold level is assumed within human body around heart, more safety factor should be counted for this significant effect. However, since induced current caused by external electromagnetic energy at frequency of 10 kHz or higher tends to flow mostly upper layer of body surface, hence if current density stays within this guideline value on the body surface, only far smaller current density than the stimulus threshold is caused at vitally important part within human body. Consequently, with this guideline value is sufficient to protect human body.

Since stimulus effect is a phenomenon within 1 second time constant, the guideline value shall be applied to averaged value within this time frame.

1.3 Foundation for base guideline 3

The threshold of thermal injury by contact current is reported as “200 mA” (NC86, Ro81). The contact current “200 mA” is equivalent to detectable extent when grasping something at frequency 100 kHz or higher. At lower frequency than 100 kHz sensible threshold of contact current becomes lower in proportion to frequency. In touching with fingertips, the current gathers densely in a small point and the detectable threshold becomes lower than this level (Ch 86). For this point the contact current lower than this threshold must have possibility to be sensed depending on contact manner.

In the meantime, IEC (International Electrotechnical Commission) and JIS (Japanese Industrial Standards), incoming current from outside into human body is stipulated as “1 mA or less extracorporeal current (at commercial frequency)”. It is reported that threshold of stimulus effect by current is proportional to frequency for 1 kHz or higher, while has uniform dependency on frequency at lower than 1 kHz (Sa88). The current value corresponding to the threshold of stimulus effect is extrapolated for frequency range from 10 kHz to 100 kHz as $10^{-3}f[\text{Hz}]\text{mA}$ (10 mA – 100 mA). This value is a half of the threshold for grasping contact. Counting the compatibility with specification of commercial frequency and lower sensing threshold as in contact with fingertip, this value is adopted as guideline value for contact current like incoming current from outside into human body. This value, estimating stimulus effect, is applied to averaged value within 1 second.

For frequency range from 100 kHz to 10 MHz effect by current appears not as stimulus effect but mostly as heat effect. The threshold of this effect is almost fixed at any frequency. Hence to keep continuity with aforementioned value the base guideline value concerning incoming current from outside into body at this frequency range shall be 100 mA. This value is a half of the threshold for high frequency thermal injury and is considered sufficient to protect human body in safety. For this frequency range it appears principally as heat effect and the guideline value shall be applied to 6 minutes averaged value.

1.4 Foundation for base guideline 4(a)

It is pointed out not agreeable that the large SAR is concentrated at some local part of the body even if base guideline 1 stipulation is satisfied.

For the maximum value of local SAR (peak SAR), exposed to electromagnetic field in free space at lower 1 GHz frequency, in such a situation power absorption is concentrated to the neck and limbs, in the worst case it is approximately twenty times of that of whole body averaged SAR. It means that power absorption is, if peak SAR is controlled less than 8 W/kg, which is twenty times of whole body averaged SAR, seems at safe side regardless the SAR distribution. But as there is no data implying injurious when exceeding this value, it is left as remarks.

In the meantime, Gandhi et al. (Ga86a) and others point out ankle SAR exceeds far more than estimation with ground connection at around resonance frequency. Because induced current is maximum at ankle with ground connection. But there are no important organs at ankle or limbs, and tolerable enough to temperature rise, thus local SAR at ankle is allowable even 8 W/kg or more. In study carried out from viewpoint of temperature the amount of temperature rises per 1 minute with thermal insulation is reported as 0.0045 times of local SAR value [W/kg] at ankle, 0.0048 times at wrist (Ch88). It means with 25 W/kg the ankle temperature will rise approximately 0.7 °C during 6 minutes at worst ($0.0045 \times 25 \times 6$). In experimental report the ankle temperature rise will be up to 40 °C in the normal temperature (Si89). Counting cooling effect on the ankle surface and comparing with local heating by other estimation, the assumption for body surface and limbs peak SAR value = 25 W/kg seems to be appropriate value.

In case of certain part exposed to electromagnetic field locally, influence especially to eye is an object of concern. For cataract, Guy (Gu75) and others report the threshold 138 W/kg (irradiation longer than 20 minutes). On the other hand, recently the threshold 2.6 W/kg (2.45 GHz, 10 mW/cm²), which brings reversible change to a cornea, is reported (Ku85). Accordingly in Canadian drafted revision peak SAR for eye is stipulated as less than 0.4 W/kg.

However, this report was resulted using pulse wave, and there are several objections raised, that is, the threshold will be twice or more when using continuous wave, it was observed with repeating a set of four-hour continuous irradiation every day, which is not observed with short-time irradiation, and more, it has not been confirmed with any follow-up experiment yet, so the reported result has not won any consensus as confirmable phenomenon so far. Consequently, assuming to resume discussion when the validity of this phenomenon will be confirmed based on some follow-up experiment in the future, at this stage no particular value is stipulated as peak SAR guideline for eye, 8 W/kg or lower is temporarily adopted, which is the same value as those for other tissues.

This value is of sufficient safety factor (17 times) of the threshold for cataract.

At higher frequency power absorption is apt to be concentrated only to the quite thin layer on the surface, and tissue temperature in the deep part will not rise so high as peak SAR, thus tissue temperature on the surface is estimated to rather saturate at microwave or millimeter wave frequency regions. Consequently, averaged value “per 1 gram tissue” within 1 cm cube is adopted for local SAR.

1.5 Foundation for base guideline 4(b)

At frequency range 3 GHz or higher problems are influence to eye and temperature sensation due to irradiation to wide area on the body surface. At frequencies 35 GHz and 107 GHz irradiation of 10 – 50 mW/cm² causes transient trouble to epithelial cell of rabbit cornea, and irradiation of more than 100 mW/cm² may cause intransient influence (Ro76). Transient trouble is of insignificant one, which can be observed without irradiation with electromagnetic wave so needs not taken seriously. Based on these reports, it is desirable to control irradiating power density 10 mW/cm² or less, and this item is added as supplementary notice.

For another problem temperature sensation at frequency range of millimeter wave, according to Gandhi (Ga86b) and others the threshold of temperature sensation radiated to wide area on body surface is estimated 8.7 mW/cm². If the exposure to whole body with this level of radiation exceeds base guideline 1. The threshold for local radiation is much higher than for wide area, e.g., perceptive threshold of temperature sensation on inner arm is reported 26.7 mW/cm² (2.45 GHz, 10 second radiation), threshold of heat pain 2,500 mW/cm² (3 GHz, 30 second radiation) (E184). Estimated from these facts if base guideline 1 and base guideline 4(a) are satisfied, then any problem on temperature sensation will not arise

2 Foundation for managing guideline

2.1 Foundation for electromagnetic field strength guideline

Based on each item shown in base guideline, electromagnetic field strength guideline is stipulated as follows.

Yet, thresholds of living body effect considered to determine electromagnetic field strength guideline and its value sorted in condition P and condition G are graphed in Figure 6 through Figure 9.

2.1.1 Condition P

(1) Table 2 (a)

a) Frequency range 3 MHz or higher

Based on guideline 1, electric field strength values equivalent to those causing $SAR = 0.4$ W/kg when human body is exposed to electromagnetic field in a plane wave were determined assuming human body with various height, and based on the envelope curve, guideline value of electric field strength, not exceeding these values, were determined (Du79, Am82). The guideline value of magnetic field strength is determined as magnetic field strength corresponding to that in a plane wave.

In this conversion worst situations are assumed, that is, concerning electromagnetic exposure field distribution, whole body is uniformly exposed to electromagnetic field in a plane wave instead of local part, concerning polarized wave, direction in which power absorption into human body shows maximum value. And more, absorbed power has its own proper resonance characteristic depending on body size or shape, hence the guideline value is determined by tying the resonance envelope curve. Therefore, when some of these conditions change actual absorbed power may become smaller accordingly. In other words, most cases except worst situation include sufficient safety factor to base guideline.

Yet, if the radio wave is other than plane wave, since the ration of electric field strength to magnetic field strength is not equal to 120π , if conditions for both electric field strength and magnetic field strength are satisfied, then it is at safe side.

b) Frequency range 3 MHz or lower

At low frequency region the trouble caused by big electric shock and induced current in unexpected situation will be prevented by introducing the approach of base guideline 2 and 3 into 6 min average. For this reason, 6 min average of electric field strength at frequency 3 MHz or lower shall be “614 V/m (equivalent to 100 mW/cm²)” at maximum.

(2) Table 2 (b)

According to Hill (Hi85b) when grounded human body is exposed to electric field at low

frequency parallel to its longer axis the amount of current flowing within human body is represented in equation below.

$$I = 275 \times 10^{-9} f(\text{Hz}) E(\text{V/m}) \text{ mA} \quad [60 \text{ Hz} - 200 \text{ kHz}]$$

where assuming the current $I \leq 10^{-3} f(\text{Hz}) \text{ mA}$ as in base guideline ③, electric field strength is represented in equation below.

$$E \leq 3,636 \text{ V/m} \quad [10 \text{ kHz} - 100 \text{ kHz}]$$

Based on this, counting uncertainty in measuring the upper limit of electric field strength in effective value is determined as 2,000 V/m (safety factor 1.8). Averaging time is within 1 second according base guideline.

Even more, assuming induced current density $J \leq 0.35 \times 10^{-4} f(\text{Hz}) \text{ mA/cm}^2$, corresponding magnetic field strength to this is, according to Bernhardt (Be79),

$$H \leq 800 \text{ A/m} \quad [10 \text{ kHz} - 100 \text{ kHz}]$$

Based on this, similarly to electric field strength, counting uncertainty in measuring the upper limit of magnetic field strength in effective value is determined as 163 A/m (safety factor 1.7).

(3) Table 2 Note 1

Contact current flows if grounded human body touches non-grounded object, which is placed in electromagnetic field with high-frequency voltage induced. The relationship between flowing current and electric field strength depends on various conditions such as non-grounded object size, and does not indicate a certain relativity. Therefore, contact current, essentially as in supplementary guideline (2), should be evaluated itself, but to allow simplified evaluation even with electromagnetic field strength, according to base guideline 3, with several objects assumed, the guideline value is provided hereinafter.

According to study report the threshold of electromagnetic field strength, at which an adult female perceives electric shock when grasping doorknob on truck or bus, is about 170 V/m (7.7 mW/cm²) for 10 kHz – 3 MHz (Ch86). This corresponds to 220 mA current for 100 kHz or higher. The threshold is interpreted about 200 V/m (260 mA) for a male, about 105 V/m (180 mA) for a child. Likewise, the threshold of electromagnetic field strength, perceived by touching with fingertips, is about 70 V/m (35 mA) for females, about 85 V/m (40 mA) for males, and about 60 V/m (25 mA) for children.

In condition P the situation that an adult female touches door knob on bus or truck is defined as typical target and 137 V/m corresponding to 5 mW/cm², which is slightly less than the threshold of electric shock of this case, is selected as guideline value. Averaging time is concluded 1 second or shorter.

This stipulation is not applied to situations with contact hazard prevented.

(4) Table 2 Note 2

According to 4 (a) it is determined as follows.

In frequency range 100 MHz or lower, electric field strength corresponding to $SAR = 25$ W/kg or less at ankle of grounded adult, varies with frequencies and appears “20 V/m (frequency 40 MHz)” at worst (Ga86a). In this case temperature rise during the first 6 min period is less than $0.7\text{ }^{\circ}\text{C}$ (Ch88) and converged temperature is less than $40\text{ }^{\circ}\text{C}$ (Si89). Note that this guideline value includes heat time constant and is applied to 6 min average.

This constraint with ankle SAR is excluded when human body is regarded as non-grounded (more 10 cm apart from ground). Still more by wearing shoes flowing induced current can be reduced by several tens of percent.

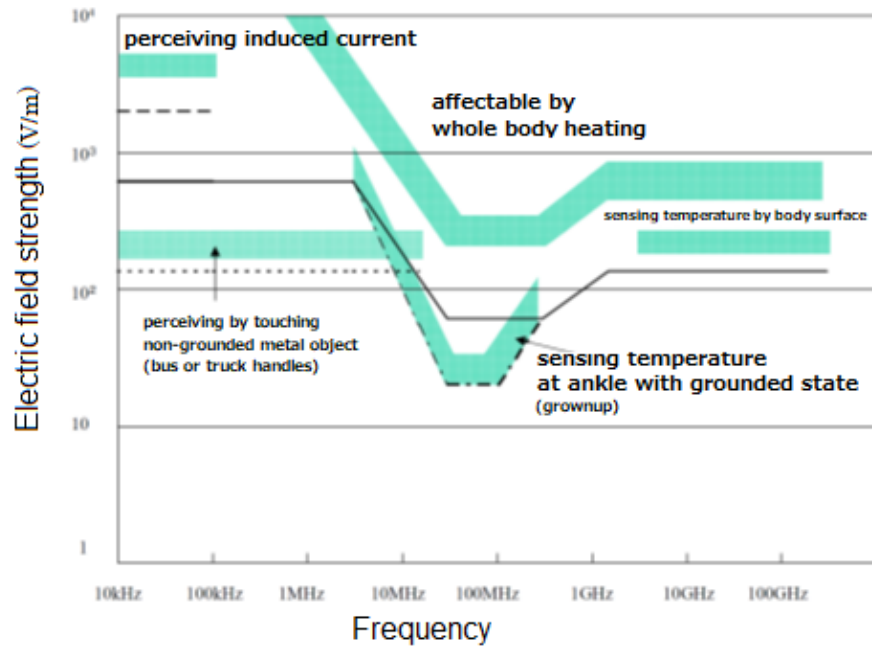


Figure 6 Electric field strength guideline value with considered threshold of living body effect (condition P)

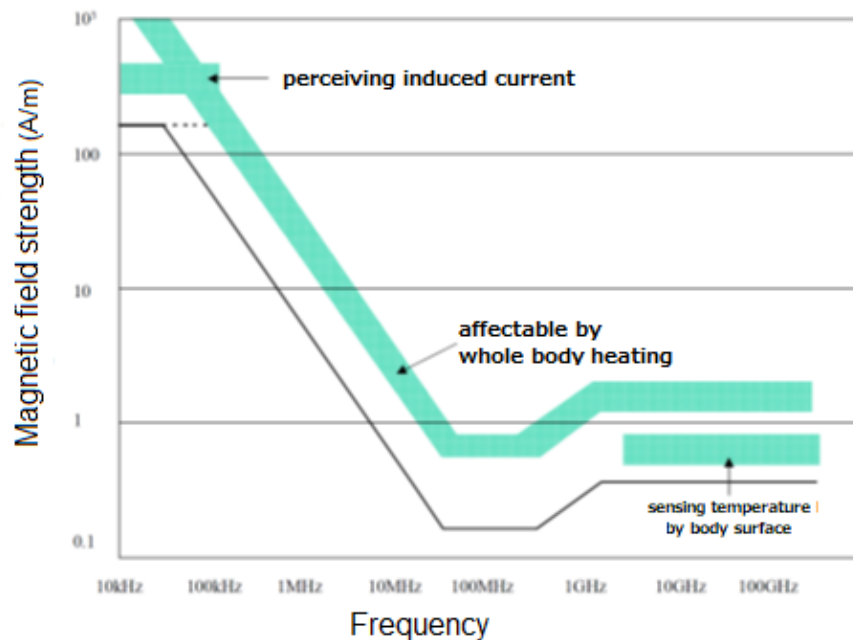


Figure 7 Magnetic field strength guideline value with considered threshold of living body effect (condition P)

2.1.2 Condition G

(1) Table 3 (a) and Table 3 (b)

Condition G includes situations that management is not necessarily made observing protection guideline. In such situations, measuring occasion is not so frequent, measuring point is not comprehensively covered, or circumstances such as surrounding objects or buildings, which disperse radio wave, may vary, and there may be other fluctuating factor, hence electromagnetic field strength is supposed to vary as much as twice even radiation sources do not vary. In condition G, counting these uncertainties, includes additional 5 times of safety factor in power density (2.23 times in electric field strength or magnetic field strength). IRPA guideline also includes 5 times of additional safety factor of exposure limit for general public compared to occupational exposure.

(2) Table 3 Note 1

In the same way as condition P based on base guideline 3 it is determined as follows.

According to study report the threshold at which a child perceives electric shock when touching some big metallic object such as truck or bus with fingertip (point contact) is the lowest, in such a case the threshold which is about 60 V/m in electric field strength (Ch86). Based on this typical situation guideline value with no contact hazard prevention is determined as “61.4 V/m (1 mW/cm²)” The electric field strength is interpreted 25 mA in contact current, which is equivalent to perceiving threshold when an adult male touches a school bus with fingertip, considering the reason for condition G lower threshold for children is selected. Based on base guideline 3 averaging time is determined within 1 second.

This stipulation is not applied to situation with contact hazard prevented in advance.

(3) Table 3 Note 2

Compared to condition P root 5 times of safety factor considered it is determined as 9 V/m (frequency 30 MHz – 100 MHz) at worst. This value means, in worst case for children, that SAR at ankle of grounded human body is 12 W/kg or less for frequency 62.5 MHz (a half of condition P) (Ga86a). In this case temperature rise during the first 6 min period is less than 0.3 °C (Ch88) and converged temperature is less than 38 °C (Si89). This guideline value, according to heat time constant, is applied to 6 min average.

This constraint with ankle SAR is excluded when human body is regarded as non-grounded (more 10 cm apart from ground). Still more by wearing shoes flowing induced current can be reduced by several tens of percent.

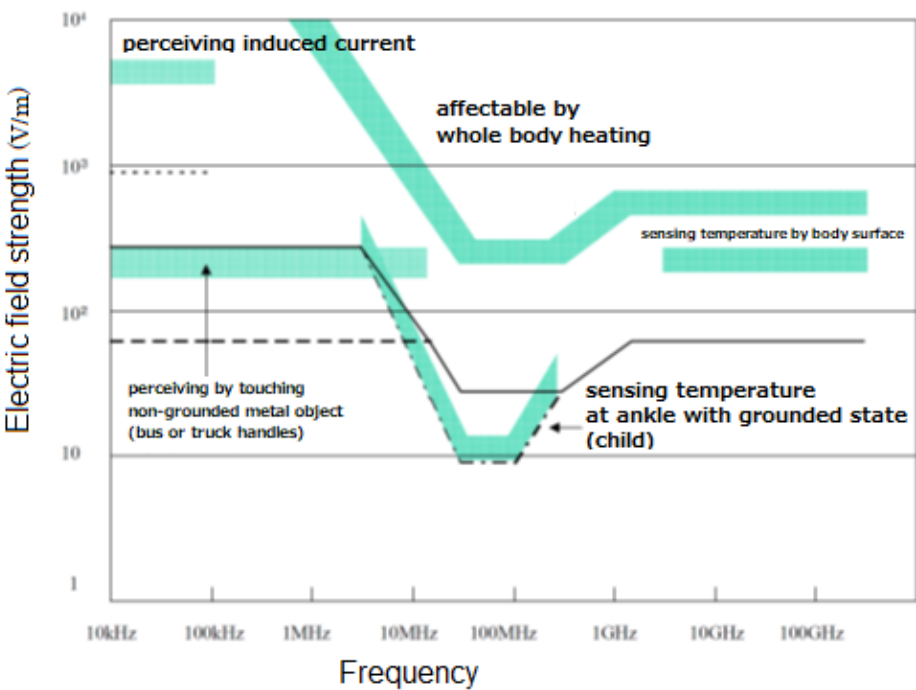


Figure 8 Electric field strength guideline value with considered threshold of living body effect (condition G)

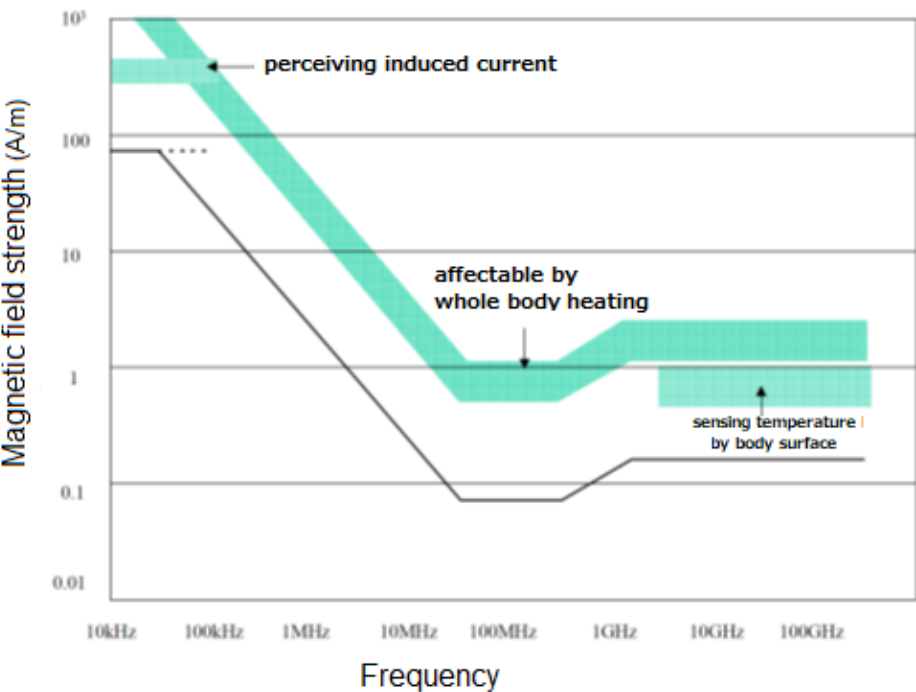


Figure 9 Magnetic field strength guideline value with considered threshold of living body effect (condition G)

2.2 Foundation for supplementary guideline

(1) Foundation for guideline on non-uniform exposure and local exposure

Electromagnetic field strength guideline is derived from base guideline (1), assuming whole body exposed to electromagnetic energy uniformly. However, in case of non-uniform exposure, even if at certain point exposure exceeds the guideline value, the guideline (1) may be sufficiently satisfied.

Essentially there may be some correlation in level at each point between irradiating electromagnetic field and SAR distribution but no correlation in positional distribution map. Even uniformly exposed to electromagnetic field SAR positional distribution may spread in complicated pattern (SAR is apt to be concentrated to narrow part such as neck, wrist, ankle, etc.). Non-uniform local exposure will show another different distribution pattern. But assuming spatial (square) mean strength in non-uniform electromagnetic field as equivalent uniform electromagnetic field strength it is at some extent understandable approach and quite effective to simplify complicated problem. However, there must remain some riskiness of unavoidable SAR concentration, which is distinctively observed in local exposure, with this restriction alone. Therefore a provision is added to restrict local power density irradiation into human body for frequency range 300 MHz or higher of shorter wavelength compared to human body.

To apply this guideline managing distance between human body and radiation source is crucial and careful operation is required when human body is approaching in closer distance than 20 cm (10 cm for frequency 300 MHz or higher) from radiation source settled with restriction of measuring condition. Especially if there may be possibility of interaction with radiation source, evaluation plan should be reconsidered with base guideline (4)(a).

a) (1), (2)(a), (3)(a) and (4)(a)

Above-mentioned discussion and electromagnetic field strength guideline are considered.

b) (2)(b), (3)(b) and (3)(c)

There is no uniform correlation between irradiating power density locally exposed to electromagnetic field and local SAR value. But according to study report at some extent correlation can be seen. Local SAR by radiation sources in close distance has tendency to concentrate to a local part of human body more remarkably at higher frequency. The maximum of local SAR is estimated 8 W/kg with 10 mW/cm² or so in power density at frequency range from 1 GHz to 3 GHz and with several times of power density at 300 MHz or higher. If baseline guideline notice (4)(a) applied as it is the restriction with this value in power density may be adequate, but at frequency range from 1 GHz to 3 GHz energy is

absorbed at quite limited region, that is, mostly body surface or limbs, except eyes and head, and thus there is no possibility of serious harm. Therefore, it is reasonable to determine irradiating power density into local area as 20 mW/cm² at frequency range from 300 MHz to 3 GHz. But as there is some comments by expert saying absorption on the head should be carefully managed, counting the restriction of 8 W/kg the guideline value is determined as 10 mW/cm² or less at frequency range from 1 GHz to 3 GHz.

c) (4)(b)

Based on guideline (4)(a) equivalent plane wave power density, with 25 W/kg or less of averaged SAR in thin layer within 1 cm from the surface, is about 50 mW/cm² at frequency 3 GHz or higher. In condition G 5 times of additional safety factor counted. The value in condition P, with which there may be a slight sense of warmth by long time irradiation, is far more less than threshold of heat pain. Especially considering other clause of guideline only quite narrow limited area can be allowed as much as 50 mW/cm².

d) (4)(c)

Based on guideline (4)(b) power is limited irradiating into eyes at 3 GHz or higher frequency.

(2) Foundation for guideline on contact current.

Base guideline (3) is considered. In condition G $1/\sqrt{5}$ times of additional safety factor is counted. The reason of this additional safety factor is the same as that of electromagnetic field strength guideline. Also as perceiving threshold for point contact with fingertip is $1/\sqrt{5}$ times of that for grasping contact as base guideline foundation, this additional safety factor is valuable to avoid perceiving with point contact.

(3) Foundation for guideline concerning induced current

The relation between local SAR and current density is given with the equation below.

$$\text{Local SAR} = J^2 / \sigma \rho$$

where $\rho = 1000 \text{ kg/m}^3$, σ is 0.4 – 1.25 S/m at frequency 3 MHz – 300 MHz. Assuming ankle cross section $A = 10 \text{ cm}^2$, induced current corresponding to SAR = 25 W/kg (base guideline (4)(a)) is shown in the equation below.

$$I = A (\text{SAR} \cdot \sigma \rho)^{1/2} = 100 - 176 \text{ [mA]}$$

For both legs: 200 mA, multiplied by 2. In condition G $1/\sqrt{5}$ times of additional safety factor counted.

(4) Foundation for guideline concerning low-power electromagnetic irradiation source

Assuming a half of radiation power is absorbed in whole body, for body weight 75 kg whole body averaged SAR exceeds 0.4 W/kg at more than 60 W of radiation power, even for body weight 10 kg tolerable radiation power is 8 W or higher. Assuming 1/5 of radiation power absorbed in head 4kg, head averaged SAR exceeds 0.4 W/kg exceeds 0.4 W/kg at radiation power more than 8 W.

The experiment by Balzano et al. using 800 MHz band portable radio equipment the peak SAR was 0.4 – 0.9 W/kg per watt (Ba78b). Another similar experiment by Chatterjee et al. obtained 0.6 – 0.8 W/kg per watt (Ch85), and more Cleveland et al. 0.7 – 1.1 W/kg per watt (Cl89). Referring to these results “Rated output 7 W or lower” satisfies local SAR 8 W/kg or less of base guideline (4)(a).

Still more, with experiment using homogeneous sphere model up to 3 GHz the observed value at 7 cm or longer apart was confirmed not to exceed base guideline value.

In case of portable radio equipment in limited time by normal usage there must be no problem with “3 GHz, 7 W or less”. But in use mode with radiation source almost touching body or close to eyes, adequate caution should be arisen.

3 Safety Factor

3.1 Safety Factor in base guideline

The concept of base guideline for safety factor is to cover the uncertainty in applying the threshold estimated from animal experiment data to human body. In case that it is estimated from human experimentation uncertainty must be comparatively less, so the threshold is determined as lower limit of estimated value (base guideline (2), (3)). For whole body averaged SAR (base guideline (1)) as the threshold is extrapolated from animal experiment, counting the different characteristics between human body and animal, appropriate safety factor (2.5 – 10) is determined.

The values suggested as advisable conditions (base guideline (4)) are provided with insufficient quantitative analysis hence the concept of safety factor is not clear.

3.2 Safety Factor in managing guideline

The concept of managing guideline for safety factor is to cover the uncertainty in conversion and measurement from base guideline.

When converting whole body averaged SAR into electric field strength or magnetic field strength, most obtained values are undoubtedly at safer side except the worst conditions, so no additional safety factor is provided.

When converting induced current (density) into electric field strength or magnetic field strength, conversion may include uncertainty in conversion so safety factor is doubled.

Concerning advisable conditions, the suggested values themselves are provided along with their standpoint of voluntariness and include less uncertainty in conversion, thus obtained values themselves are adopted.

In condition G counting that measuring point is not comprehensively covered, 5 times of safety factor, compared to condition P, in power density (2.23 times in electromagnetic field strength) is adopted. This is because electromagnetic field strength may become as much as double value in standing wave.

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Relevant report 2

Report from Telecommunications Technology Council, Inquiry No. 89 “The State of Human Body Protection in using Radio Waves”, April 1997 (Excerpt)

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1 Introduction

Recent remarkable progress in scientific and information technologies boosts more and more applications of radio wave. Especially mobile communications utilizing radio waves become rapidly widespread into daily life and thus cordless telephones and portable telephones, similar to home electrical appliances, become familiar in the closest scene.

Our lives have been surrounded by radio waves, those from the sun, of TV broadcasting, radio broadcasting, satellite broadcasting, all the time, up to now. As the utilization of radio waves advances, concerns by ordinary users about impacts on human health due to radio waves increase year by year. While some commentary articles of poor understanding on radio or electromagnetic waves might cause confusion to ordinary users.

Various studies on influence of electromagnetic waves have been done over forty years so far and international consensus has been built on many items. In Japan, based on these outcomes, report from Telecommunications Technology Council “The State of Human Body Protection in using Radio Waves”, 1990 (commonly known as Radiofrequency-Exposure Protection Guidelines) has been published, which includes the energy levels as guideline to control to avoid undesirable influence to human body. The values of the guideline are defined to protect human body which includes enough margin for safety factor. Also based on this report, in 1993 Research and Development Center for Radio Systems (RCR) (reorganized as present Association of Radio Industries and Businesses (ARIB)) enacted “Radiofrequency-Exposure Protection Standard” which is put to practical use as nongovernmental guideline.

Recent rapid growth of mobile communications depends on heavily on widespread of portable terminal because of downsizing of radio equipment, and thus configuration of radio wave utilization varies drastically. When mobile terminal is in use its antenna as main radiation source of radio wave is used to be isolated from human body in some distance, while at present during mobile terminal in use its antenna is kept closer position to human body. Therefore, as described in “Report of Investigation and Research concerning The State of Radiofrequency-Exposure Protection”, March, 1996 it is important that in the state of radiofrequency-exposure protection considers

characteristics of radio wave propagation in the near-field of radiation source and absorption quantity in the local part of human body and then on the ground of above standpoint it is required that the guideline is put into effect.

Radio waves, radiated from various utilization apparatuses such as radio station, are quite feeble energy distribution in the daily life environment and are considered not to cause any anxious harmful influences to human body and thus even safe. For through outcomes from many animal experiments or epidemiology examinations which have been investigating so far, there has been no evidence observed that radio waves within the range which meet radiofrequency-exposure protection guidelines would not cause any harmful influences including cancer to human health.

However, the fact is that there still remain unknown phenomena concerning some influences caused to human body by radio waves, although considerable experiment in the field of nerves or immunity, which could not have explicated clearly, hence it is indispensable to clarify essential items for coming studies and proceed studies continuously in cooperation internationally.

This report, on the ground of recent study outcomes and overseas actions, etc., provides protection guidelines for situations that human body is locally exposed by electromagnetic waves, etc. and provides viewpoint to put guidelines into practice as well. Also, this report lists items to be studied next. It is desirable to support establishment of human body safety and progress of radio wave utilization simultaneously according to the purpose of this report.

2 Purpose and Scope

Radiofrequency-exposure protection guideline is aimed to promote sound growth of radio wave utilization for increasing social and economic demand, providing the fundamentals for judging whether the strength of electromagnetic wave is within the safe level not to cause disagreeable electromagnetic influences to human body and the guideline based standard value and measurement and estimation methods of the electromagnetic field strength in surrounding area of radio wave utilization establishment

This report, among guidelines above-mentioned, focused on further concrete guideline embodiment concerning radio equipment used in near-field of human body, rearrange of organization of guidelines, reorganize guideline system accordingly, applying procedure of rearranged guideline and clarified measurement and estimation methods of energy absorption quantity of radio wave for its base value and studied in applying guidelines. For example, among managing guidelines, studied revising supplementary guideline and relevant evaluation method.

In addition, concluded positioning of the radiofrequency-exposure protection guideline after this, and items concerning radio wave influence to human body needed to be studied in the future.

Although target frequency range of electromagnetic wave needs to cover basically full range defined in Radio Law Article No.2 (“Radio wave” is an electromagnetic wave of frequency of 3,000,000 MHz (3,000 GHz) or lower), this report focuses on the range from 10 kHz through 3000 GHz, considering the present state of assigned frequency, future trend of technology of radio wave utilization technology. (Examples of relationship between radio wave frequencies and their application is shown in Figure 1.)

Guidelines in this report are prepared basically grounded on analysis and evaluation of enormous study reports and common understanding between specialists belonging to international council. Guideline values disclosed here are determined on the human body protection anticipating sufficient safety factor, and thus it is noted that the fact of exceeding the value does not result directly harmful influences to human body.

However, when scientifically corroborative evidence or reassessment will be provided in further progress of investigation or research, etc. the guideline needs to be revised according to the situation of radio wave utilization.

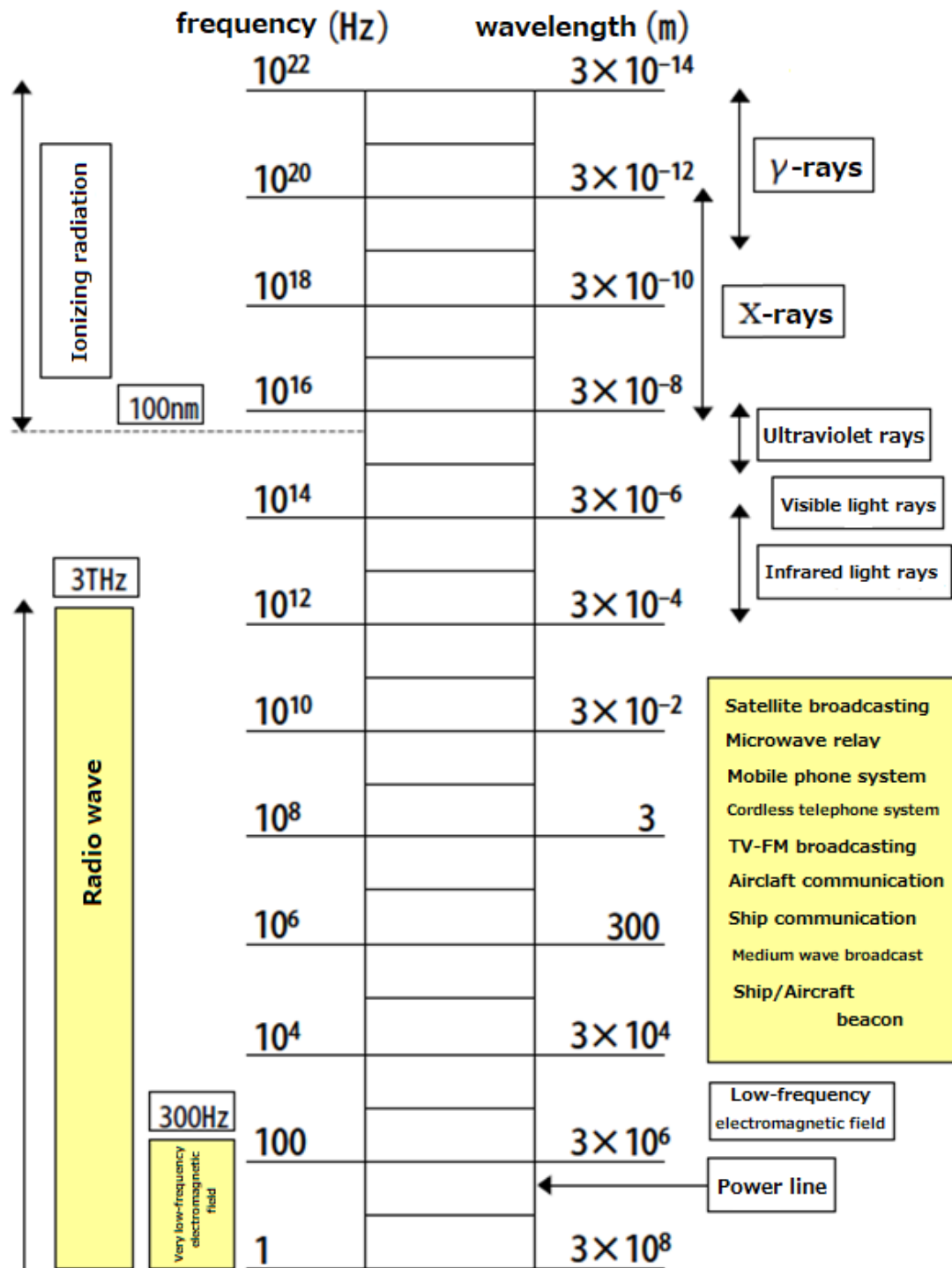


Figure 1 Radio frequencies and exemplary applications

3 Definitions

- (1) The term “Electromagnetic waves” is a generic name of wave motion, that is, vibration of electric field or magnetic field propagating in a vacuum or in substances. Electromagnetic wave includes low frequency electromagnetic field, what is called “radio wave” utilized for wireless telecommunication, light wave (infrared light rays, visible light rays, ultraviolet rays) radiated from the sun, radiologic rays (X-rays, γ-rays) utilized for medical treatment, etc. Electromagnetic waves are classified by wavelength into two categories, ionizing radiation with shorter than ultraviolet and non-ionizing radiation with longer than ultraviolet.
- (2) “Radio wave” is an electromagnetic wave of frequency of 3,000,000 MHz (3,000 GHz) or lower specified in Article 2 of the Radio Law. In the radiofrequency-exposure protection guidelines, frequency range from 10 kHz to 300 GHz is applied.
- (3) “Radiofrequency-exposure protection guidelines” is a recommendation for keeping the human body in a safety state that does not exert biological action considered unfavorable to the human body when human body is exposed to a radio wave (limited to the range of 10 kHz to 300 GHz) in the use of radio waves.
- (4) “Base guideline” is a criterion to be used in safety evaluation of human body, when exposed to an electromagnetic field effect, based on the various biological action exerted to human body (fever stress accompanied with rise of body temperature, electric current stimulation, high-frequency heating injury, etc.).
- (5) “Managing guideline” is a practical criterion to satisfy the base guideline to be used in actual evaluation illustrated with measurable physical quantity (electric field strength, magnetic field strength, electric power density, electric current, and specific absorption rate). Managing guideline is further organized and specialized into electromagnetic field strength guideline, supplementary guideline, and localized specific absorption rate guideline.
- (6) “Electromagnetic field strength guideline” is intended for safety evaluation of the target space, with electric field strength, magnetic field strength, electric power density.
- (7) “Localized specific absorption rate guideline” is prepared for detailed evaluation according to the base guideline when a local portion of human body is intensively exposed by the radio wave radiated from radio equipment used within a very short range to human body.
- (8) “Supplementary guideline” is prepared to proceed to further evaluation according to the base guideline when evaluation result does not meet with the criteria of

electromagnetic field strength guideline. It is applicable to the case that the actual circumstance of exposure to the radio wave (non-uniformly, locally, superficially, etc.), objective biological action (contact current and induced current), and specifications of radiation source (antenna power, frequency range) are obvious, by relaxing or exempting the guideline less strict.

- (9) “Managed environment” is a condition that the state of human body exposed to the electromagnetic field is recognized and the radiation source of radio wave can be identified, and besides the appropriate management of environment for those situations can be taken accordingly.
- (10) “General environment” is an environment that (in which, where) understanding of the exposed level and appropriate management cannot be expectable and there resides some uncertain factor. Typical case is general residential environment where residents are exposed to electromagnetic field, and so on. For this standpoint guideline provides severer criteria for this general environment than for managed environment. General environment corresponds to condition G in Radiofrequency-Exposure Protection Guidelines, 1990.
- (11) “Specific Absorption Rate (SAR)” is electromagnetic power absorbed per unit of mass of the tissue when a tissue is irradiated by electromagnetic waves. SAR averaged over the whole body is called “Whole body averaged SAR”, SAR averaged within an arbitrary 1 g or 10 g organization is called “Localized SAR”.
- (12) “Electromagnetic field” is a generic name of electric field and magnetic field.
- (13) “Electric field strength” is defined as the strength of electric field.
- (14) “Magnetic field strength” is defined as the strength of magnetic field.
- (15) “Electric power density” is defined as the radiated unit passing through an element of surface normal to the direction of propagation of an electromagnetic wave.
- (16) “Induced current” is current caused by electromagnetic induction. Particularly it means induced current inside human body when exposed to electromagnetic field.
- (17) “Contact current” is current running via contact point of grounded human body by touching non-grounded conducting object placed in electromagnetic field.
- (18) “Contact hazard” is hazardous situation that can potentially cause contact current.
- (19) “Non-grounded condition” is situation that no induced current can cause to the ground and thus ground influence can be ignored.
- (20) “Low power radiation source” is an electromagnetic radiation source that uses frequency range from 100 kHz to 3 GHz with low output power.
- (21) “Phantom” is a virtual man model used for experimentally estimating SAR inside

human body.

- (22) “Equivalent Isotropic Radiated Power (EIRP)” is a product of antenna fed power and absolute gain at given direction of isotropic antenna. (About 1.64 times of effective radiated power)
- (23) “Effective radiated power (ERP)” is a product of antenna fed power and relative gain at given direction of half-wavelength dipole antenna.

4 Guideline for human body locally exposed to electromagnetic wave, etc.

4.1 Needs of clarifying guideline for low-power radiation source such as portable telephone terminal, etc.

Since Telecommunication Technology Council reported Human Body Protection Guideline in using Radio Waves, 1990, radio equipment such as portable telephone terminal has rapidly evolved in downsizing and is coming into universal use. Consequently, there will have more and more occasions of local exposure typically in the head, etc. to electromagnetic wave from low-power radiation source. However no clear guideline appropriate to such cases has been described so far.

On the other hand, as well as downsizing of portable telephone, SAR measurement technology with artificial model of human body (phantom) is rapidly progressing, enabling to measure radio wave in the deep part of human body, which was formerly available limited to very distinguished and specialized institution and yet not enough precision in measuring result. Hence, it is required to prepare more concrete and comprehensible guideline for low-power radiation source as quickly as possible to release ordinary user from needless fear and misunderstanding.

4.2 Partial revision of Managing Guideline

Considering recent research outcomes, international trend and remarkable popularization of portable phones and the like, managing guideline provided in “Radiofrequency-Exposure Protection Guidelines”, reported in 1990 shall be partially revised as described below.

The existing managing guideline, currently consisting of electromagnetic field strength guideline and supplementary guideline, considering coordination with international standards by International Commission on Non-Ionizing Radiation Protection (ICNIRP), etc. and in order to clarify guideline more comprehensible for low-power radiation source such as portable phones, “Localized Specific Absorption Rate Guideline” shall be newly laid down. “Guideline for low-power electromagnetic radiation source” shall be included in localized specific absorption rate guideline, and current description in supplementary guideline will be deleted accordingly. As a result, renovated managing guideline consists of electromagnetic field strength guideline, supplementary guideline, and localized specific absorption rate guideline.

(1) Electromagnetic field strength guideline

As reported in “Radiofrequency-Exposure Protection Guidelines”, 1990.

(2) Supplementary guideline

Existing supplementary guideline shall be partially revised because of localized specific absorption rate guideline to be laid down. Revised supplementary guideline is shown in Annex 1.

(3) Localized specific absorption rate guideline(3-1) Scope of application

This guideline is applied to frequency range of 100 kHz to 3 GHz.

Main target of localized specific absorption rate guideline is small radio equipment such as portable telephone terminal, assuming being used with its antenna or case, acting as electromagnetic radiation source, quite close to human body.

This guideline shall be applied in principle to situation characterized by distance, which is defined between electromagnetic radiation source (mostly antenna) or metal substance (case, etc.) to human body, and frequency range, that is, 20 cm or closer for frequency range from 100 kHz to 300 MHz, and 10 cm or closer from 300 MHz to 3 GHz. For distance other than above it shall be considered that the base guideline is satisfied, if either one of former managing guideline (electromagnetic field strength guideline and supplementary guideline) and localized specific absorption rate guideline is satisfied.

(3-2) Managed environment

All the following criteria are mandatory.

<1> Any of 6 min average extracted from whole body averaged SAR is 0.4 W/kg or less.

<2> Localized SAR at any 10 gram tissue (6 min average) does not exceed 10 W/kg (20 W/kg at upper and lower limbs).

<3> Contact current is 100 mA or less (6 min average) at frequency from 100 kHz to 100 MHz, with no prevention means taken against contact hazard.

In case that contact current is composed of multiple frequency component at non-ignorable level to this criterion, contact current shall be summed up with

square values of proportion to the criteria at each frequency component, which shall not exceed 1.

For radio equipment using frequency from 100 MHz or higher, the evaluation described in <3>, based on criteria concerning contact current, is not mandatory.

(3-3) General environment

All the following criteria are mandatory.

<1> Any of 6 min average extracted from whole body averaged SAR is 0.08 W/kg or lower

<2> Localized SAR at any 10 gram tissue (6 min average) does not exceed 2 W/kg (4 W/kg at upper and lower limbs).

<3> Contact current is 45 mA or less (6 min average) at frequency from 100 kHz to 100 MHz, with no prevention means taken against contact hazard.

In case that contact current is composed of multiple frequency component at non-ignorable level to this criterion, contact current shall be summed up with square values of proportion to the criteria at each frequency component, which shall not exceed 1.

For radio equipment using frequency from 100 MHz or higher, the evaluation described in <3>, based on criteria concerning contact current, is not mandatory

4.3 Point to notice

For the utilization of medical purpose, notice to person wearing cardiac pacemaker or person with metal made substance embedded in the body is the same as that described in radiofrequency-exposure protection guideline, reported in 1990.

Recently some mass media report that radio wave influence affected to cardiac pacemaker and that to human body are regarded to be identical, but it is recognized mistakenly. The mechanism that radio wave affects interference to electronic device for medical care such as cardiac pacemaker and the like is that induced signal in electric circuit by radio wave cases malfunction to electric device, hence it shall not be handled in the same way as influence to human body. For guideline to prevent electric device for medical care from influence affected by radio equipment such as portable telephone terminal, consult “Guidelines for Use of Mobile Phones and other Devices to prevent

influence affected by electric devices for medical care”, announced in March 1997 by Council for countermeasure against unnecessary radio wave problem.

I Electromagnetic field strength guideline (summary) [same as existing guideline (no change)]

Table 1: Guideline values of electromagnetic field strength (6 min average) in managed environment (condition P)

Frequency f	r.m.s. value of electric field strength E [V/m]	r.m.s. value of magnetic field strength H [A/m]	Electric power density S [mW/cm ²]
10 kHz - 30 kHz	614	163	
30 kHz - 3 MHz	614	$4.9f \text{ [MHz]}^{-1}$ (163 - 1.63)	
3 MHz - 30 MHz	$1842f \text{ [MHz]}^{-1}$ (614 - 61.4)	$4.9f \text{ [MHz]}^{-1}$ (1.63 - 0.163)	
30 MHz - 300 MHz	61.4	0.163	1
300 MHz - 1.5 GHz	$3.54f \text{ [MHz]}^{1/2}$ (61.4 - 137)	$f \text{ [MHz]}^{1/2}/106$ (0.163 - 0.365)	$f \text{ [MHz]}/300$ (1 - 5)
1.5 GHz - 300 GHz	137	0.365	5

Table 2: Guideline values of electromagnetic field strength (6 min average) in general environment (condition G)

Frequency f	r.m.s. value of electric field strength E [V/m]	r.m.s. value of magnetic field strength H [A/m]	Electric power density S [mW/cm ²]
10 kHz - 30 kHz	275	72.8	
30 kHz - 3 MHz	275	$2.18f \text{ [MHz]}^{-1}$ (72.8 - 0.728)	
3 MHz - 30 MHz	$824f \text{ [MHz]}^{-1}$ (275 - 27.5)	$2.18f \text{ [MHz]}^{-1}$ (0.728 - 0.0728)	
30 MHz - 300 MHz	27.5	0.0728	0.2
300 MHz - 1.5 GHz	$1.585f \text{ [MHz]}^{1/2}$ (27.5 - 61.4)	$f \text{ [MHz]}^{1/2}/237.8$ (0.0728 - 0.163)	$f \text{ [MHz]}/1500$ (0.2 - 1)
1.5 GHz - 300 GHz	61.4	0.163	1

II Supplementary guideline (summary) [clarification of general environment (partial)]

(1) Guideline applied for cases of human body non-uniformly or locally exposed to electromagnetic field

	10 kHz - 300 MHz	300 MHz - 1 GHz	1 GHz - 3 GHz	3 GHz - 300 GHz
Spatial average of electromagnetic strength	Managed environment: Table 1 applied General environment: Table 2 applied			
Spatial maximum of electromagnetic strength		Except limbs: Managed: 20 mW/cm ² General: 4 mW/cm ²		Body surface: M: 50mW/cm ² G: 10 mW/cm ²
			Head: M: 10mW/cm ² G: 2 mW/cm ²	Eyes: M: 10mW/cm ² G: 2 mW/cm ²
Applied space	Body occupying space 20 cm or more apart from radiation source or metallic object	Body occupying space 10 cm or more apart from radiation source or metallic object		
Averaged time	6 min.			

(2) Guideline for contact current

Frequency	Contact current
10 kHz - 100 kHz	$10^{-3}f$ [Hz] mA (averaging time < 1 sec.)
	$4.5 \times 10^{-4}f$ [Hz] mA (averaging time < 1 sec.)
100 kHz - 15 MHz	100 mA or less (averaging time < 6 min.)
	45 mA or less (averaging time < 6 min.)

Upper: Managed environment Lower: General environment

(3) Guideline for ankle induced current

Frequency	Contact current
3 MHz - 300 MHz	100 mA or less (averaging time < 6 min.)
	45 mA or less (averaging time < 6 min.)

Upper: Managed environment Lower: General environment

III Localized specific absorption rate (SAR) guideline (summary) [newly defined]

Scope of application: This guideline can be applied for frequency range from 100 kHz to 3 GHz

Applied object: Small radio devices, etc. used close to human body.

Mostly,

20 cm or closer from radiation source for frequency range from 100 kHz to 300 MHz

10 cm or closer from radiation source for frequency range from 300 MHz to 3 GHz

	Managed environment	General environment
Whole body averaged SAR	0.4 W/kg	0.08 W/kg
Localized SAR	For any 10 g tissue: 10 W/kg 20 W/kg (limbs)	For any 10 g tissue: 2 W/kg 4 W/kg (limbs)
Contact current	No prevention means taken against contact hazard: 100 mA for frequency range from 100 kHz to 100 MHz	No prevention means taken Against contact hazard: 45 mA for frequency range from 100 kHz to 100 MHz

(any of 6 min averaged value)

※ In case that contact current is composed of multiple frequency component at non-ignorable level to this criteria, contact current shall be summed up with square values of proportion to the criteria of each frequency component, which shall not exceed 1.

5 Measurement method and estimation method of electromagnetic environment caused by electromagnetic radiation source such as portable telephone terminal and the like

This chapter surveys the situation of technical development of measurement method and estimation method with calculation for conformity evaluation to localized SAR guideline in case that human body is locally exposed to electromagnetic wave from low-power radiation source such as portable phone terminal, etc. and considers feasibility of those method to evaluation of actual equipment. Exemplary study target is evaluation of localized absorption in the situation where electromagnetic radiation source is used close to human head like a handy type of portable radio device.

However, all evaluation for low power radiation source shall not be necessarily practiced with specific absorption rate (SAR), yet some cases with electromagnetic field strength guideline value are efficacious. The evaluation method of electromagnetic field strength with electric field probe and the like, detailed description is included in measurement method and estimation of radiofrequency-exposure guideline (Report from Telecommunication Technology Council 1990), thus omitted here.

5.1 Measurement method

(1) Technological development state

Since measuring SAR of inner living body is difficult to practice, experimentally estimating SAR using virtual man model (referred as phantom) is used as general substitution. There are many determining factors to be considered for SAR, such as shape of phantom, electrical characteristics of material, form of electromagnetic radiation source, especially form and radiation characteristics of antenna, furthermore positional relationship between phantom and antenna. It is important to simulate actual exposing situation as exact as possible.

For measurement of SAR on local exposure from portable terminal and the like, setting up electromagnetic radiation and phantom simulating actual exposed condition, measure some physical quantity relating SAR value inside phantom. To evaluate conformity to localized SAR, maximum values of whole body averaged SAR and localized SAR are needed, both can be obtained by measuring SAR distribution through phantom interior.

However, to conduct measurement described above special equipment or apparatuses are required, consequently measurement had been carried out at a few particular research institutes. It is only recently electric field probe or phantom, etc. have been developed and have become available on the market, and that allows measurement to be practiced easier.

Actual SAR measurement method ever applied to portable telephone terminal and suggested are the followings.

(a) Measurement method via measuring electric field strength

Derive SAR distribution from measured electric field strength through phantom interior.

(b) Measurement method via measuring temperature

Derive SAR distribution from measured temperature through phantom interior.

(c) Measurement method via measuring surface magnetic field strength

Derive SAR distribution on phantom surface from magnetic field on near surface of phantom.

(2) Applicability

Principles of these measurement methods are approved by academic societies in Japan and several foreign countries, and are also introduced in documents on measurement method by ANSI/IEEE and CENELEC, etc. However, detailed specification of measurement, and clarification and standardization for measuring condition are still under consideration, hence measuring service by public institution is not yet available. Recently SAR measurement system via electromagnetic field strength has been put on the market but it is still unclear whether or not it could be verified as a standard measurement system.

(3) Establishment of measurement method and treatment of measurement error

In order to standardize these measurement methods, it is important to clarify not only uncertainty and error reside in measurement apparatus such as tolerance of rated power but also individual uncertainty and error factor such as uncertainty caused from uniform phantom or error factor due to container used for liquid phantom. Nevertheless, there still remain some miscellaneous unremovable measurement error, and the treatment of tolerance on those errors. At ANSI/IEEE, CENELEC, and ARIB are presently working on standardizing process for measurement method, for clear methodology, outcomes from the work are awaited.

5.2 Estimation method

(1) Technological development state

SAR or electric current density caused inner human body exposed electromagnetic energy can be estimated through logical analysis and numerical simulation. Accurate estimation requires appropriate man model and estimation system for respective exposure conditions.

Typical methods of logical SAR estimation are the followings.

- (a) Applying an exact solution to a flat board, a round column and sphere models.
- (b) Applying an approximate solution to rotating ellipsoid model.
- (c) Applying numerical simulation to block shaped man model.

(2) Applicability

For electromagnetic radiation source used in near-field to human body, estimation is required considering coupled with human body. Moreover, for electromagnetic radiation source like portable phone used in near-field of human head, estimation is required with model simulating shape of head and medium distribution in detail. Consequently, for these exposure conditions numerical simulation with block shaped man model is advisable. Specially because of recent improvement of computational capacity, the most suitable method of numerical simulation can be said as Finite Difference Time Domain (FDTD) (or the similar differential solution method).

(3) Establishment of estimation method and treatment of estimation error

Estimation method using numerical simulation like FDTD has wide range of application scope but may cause unexpected increase of error without appropriate numerical modeling and calculation conditioning of electromagnetic radiation source like portable telephone. From the practical standpoint estimation method for safety evaluation of living body against electromagnetic radiation source like portable telephone should be limitedly handled by particular experts who have thorough knowledge of calculation methodology or specifying portable telephone. Therefore, in order to establish such an estimation methodology as universal estimation method

unrestrictedly available in public there is a need to promote study on appropriateness of estimated value and assessment of error range and standardizing man model.

6 Promotion of Radiofrequency-Exposure Protection Guidelines hereafter

6.1 Background of Radiofrequency-Exposure Protection Guidelines

Study on interaction between electromagnetic wave and living body has been carried out over forty years in the meantime many outcome reports and scientific knowledge have been accumulated. Radio wave radiated from the radio wave utilization facilities show generally quite feeble energy distribution in our daily life environment and, according to the accumulated scientific viewpoint so far, a consensus that radio wave energy should be controlled under a certain level in the daily life environment is reaching to be agreeable internationally.

For example International Commission on Non-Ionizing Radiation Protection (ICNIRP), unifying the outcomes of studies carried out so far, announces their statement (opinion, view) “Health issue concerning utilization of portable wireless telephone and base station”, in which ICNIRP claims (declares, states) “There is no evidence (symptom) that electromagnetic wave may cause harmful influences to human health including cancer as far as the electromagnetic energy does not exceed the guideline value for whole body averaged SAR and for localized SAR provided by ICNIRP.”

The recent growth of the number of radio stations in the daily life boosts concern among people rapidly on health influence affected by radio wave radiated from radio stations. Consequently, the possibility that obscure uneasiness or misunderstanding may be increasing against radio wave according to the large scale and strange appearance. It is desired that sooner measure to solve this uneasiness and misunderstanding in advance.

For the protection guideline concerning radio wave radiated from radio wave utilization facilities, it is common practice in the past that some protection guidelines have been laid down, just like in Japan “Radiofrequency-Exposure Protection Guidelines” enacted by Association of Radio Industries and Business (ARIB). However recent trend is to reform such guidelines as official regulations enforced by government. As the first action in August, 1996, Federal Communications Commission (FCC) of the United States of America had revised their FCC rule and accomplished to broaden the scope of control

target in order to secure safety of human body against radio wave from cellular base stations or wide range of radio stations.

Likewise in Europe introducing safety regulations against radio wave from radio stations, etc. are being considered. In Germany in November, 1996, the Federal House of Councilors (Deutscher Bundesrat) approved the order on electromagnetic wave drafted by federal government with their partially modifying suggestion, thus introducing regulation is anticipated to be finalized shortly. Similarly in Australia since January, 1997 Telecommunications Act requires those who are involved in radio wave industries to report the conformity with radio wave protection guideline provided as private standard, to local government or the similar practices. In addition, proposed amendment currently being processed includes articles the Spectrum Management Agency (SMA) shall be authorized to stipulate standards on radiofrequency-exposure protection guidelines for human body.

Considering these world situations, in our country sooner consideration is needed to introduce regulations to radio wave to avoid disagreeable influences to human health by radio wave radiated from radio utilization facilities such as radio stations.

6.2 Advantages and disadvantages with introducing regulation

Concerning introducing regulations to secure safety against radio waves radiated from radio wave utilization facilities such as radio stations, there may be positive factor and negative factor. Positive factors can be:

- (1) Introducing restrictive standard facilitates appropriate protective and preventive measures, if needed, based on the latest and reliable scholarly supported knowledge, although the strength of radio wave exceeding the guideline does not affect directly human health.
- (2) While technological evolution in radio wave has brought varieties of possible use cases, appropriate regulation secures safety and allows propelling development of innovative radio wave utilization system.

- (3) In the circumstance that governmental regulations are introduced or going to be introduced in the United States, Germany, etc., introducing regulation is considered as assured practice in international coordination hereafter,
- (4) Introducing restrictive standard, which is based on the latest and reliable scholarly supported knowledge, also provides relieves to people having concern in safety in using radio wave,

On the contrary increasing number of radio station licensees and work volume at government office may be negative factors. However, human body safety is serious concern and office work for dealing with inquiry or confirmation on radio safety are increasing recently for which enormous load is required, hence regulation, if introduced, may bring rather burden reduction instead of another obstacle or load.

As a result, introducing regulation must be the realistic step to protect human body from radio wave radiated from radio stations or radio wave utilization facilities.

6.3 Items to be considered in introducing regulation

For the strength of radio wave radiated from radio stations or radio wave utilization facilities, measurement method and estimation method are established in general condition. While for absorption rate of electromagnetic energy from portable radio station used in short range of human body, technologies for measurement and estimation methods are still under development, and particularly the current stage of Japan is that discussion of standardization conducted by private standardization body has just started.

In addition, even in case that electromagnetic field strength guideline can be applied with established methods, care must be taken that some among radio station licensees or the like may not be acquainted enough with those methods.

Moreover, regulation scheme concerning human body protection guideline shall be organized in practical way, in which work volume at radio station licensees and government office shall be minimized.

6.4 Regulation target and Radiofrequency-Exposure Protection Guidelines values to be applied

To secure effectiveness of regulation to protect human body from radio wave, it is essential to establish definite methodologies of measurement and estimation. Therefore, introducing regulation should be started with the field where the sure methodologies for measurement and estimation are already established, hence in the meantime introducing regulation for human body safety should be focused on radio wave utilization facilities, excluding portable radio stations which is used in short range to human body

On the other hand, for the local absorption rate guideline among radiofrequency-exposure protection guidelines, for SAR as physical quantity to be measured or estimated, definitely established methodology is not recognized at present. Hence, for portable radio stations used in short range to human body, regulation should be introduced after the measuring or estimating methodologies will have been definitely established, considering the actual condition of regulation in other countries.

Concerning guideline values to be used for the regulation shall be based on the Report from the Council “Human Body Protection Guideline in using Radio Waves”, June 1990 and localized specific absorption rate guideline described in chapter 4 of this report, which is prepared aiming actualization of the preceding report. Both of “Human Body Protection Guideline in using Radio Waves”, June 1990 and localized specific absorption rate guideline described in chapter 4 of this report are prepared to meet with whole body averaged SAR and localized SAR presented by ICNIRP, etc., thus observing on the basis of these guidelines will secure safety supported by the latest and scholarly knowledge. Practicing regulation should be grounded the following items.

(1) Guideline value to be applied

“Human Body Protection Guideline in using Radio Waves”, June 1990 provides three categories of guideline values for electromagnetic field strength, r.m.s. value of electric field strength, r.m.s. value of magnetic field strength, and electric power density. These three physical quantities can be mutually exchangeable by converting, for frequency 30 MHz or higher and considered as far-field. Particularly to confirm the observance to the guideline value with measurement in the area where electromagnetic field strength guideline value is applicable, only measurable one out of three must be sufficient.

(2) Radio stations that confirmation duty of guideline observance may be exempted

Many radio stations can be estimated obviously meeting the guideline since their installed condition or low power of antenna. Imposing the confirmation duty of guideline observance to all radio stations unconditionally brings increase of useless work of radio station licensee and government office, hence exempting confirmation duty to those radio stations must be realistic measure (practice). (Installation condition for radio stations to be exempted shall be defined referring to the example shown in Annex 2 of this report.)

(3) Operation of guideline in managed environment

In the managed environment participants have sufficient knowledge on electromagnetic wave and observance of guideline particularly in the situation where electromagnetic field strength guideline value can be applied, with propagating and enlightening knowledge and information concerning radio wave protection, it may be possible practice that the management operation would be entrusted on a voluntary basis of participants themselves.

(4) Sufficient technological information required

Sufficient technological information is required to avoid confusion due to lack of technological understanding when introducing rules concerning guideline.

6.5 Providing information concerning radio waves radiated from radio stations

Lack of expertise on radio wave radiated from radio stations or radio wave utilizing facilities may cause obscure uneasiness or misunderstanding for radio waves. To prevent these, it is important to provide information continually concerning radio wave strength radiated from radio stations or radio wave utilizing facilities.

On the other hand, some portable radio station is assumed to be used with its radiation source in a certain distance from human body. For these radio stations for further safety, it is important to provide safety information against radio wave to users, for example suggestions of usage such as secure distance to be taken from body to antenna, etc. included in the users' manual.

Supplementary Guideline incorporating Localized Specific Absorption Rate GuidelineSupplementary guideline (1): guideline in case that human body is exposed non-uniformly or locally to electromagnetic energy

When the conditions are fully satisfied for the specified frequency range, it is considered being conformed to managing guideline. In case of target frequency ranges extend over the multiple divisions listed below, for the ranges <1>, <2> (a) & (b), <3> (a) & (b), and <4> (a), (b) & (c), calculate the sum of square values of proportion at each frequency component to the guideline value, which shall not exceed 1.

Exceptionally, equipment used in the spatial area within 20 cm of human body (within 10 cm for frequency range 300 MHz or higher) needs to be evaluated (judged) separately for each particular situation. When the energy may exceed the basic guideline value, local absorption rate guideline must be adequate to that evaluation.

<1> For frequency range lower than 300 MHz

Spatially averaged value of power density distribution through the whole area corresponding to the space occupied by human body, at spatial area 20 cm or more apart from electromagnetic radiation source or metallic object (root mean square for strength of electric field or magnetic field), shall meet the guideline value.

<2> For frequency range from 300 MHz to 1 GHz

(a) Spatially averaged value of power density distribution through the whole area corresponding to the space occupied by human body, at spatial area more than 10 cm apart from electromagnetic radiation source or metallic object (root mean square for electric or magnetic field strength), shall be less than the electromagnetic field strength guideline value of the corresponding (managed or general) environment. (ref. former guideline clause 3.2.1)

Note 1 through Note 4 below Table 2 or Table 3 of the former guideline shall still be applied to this clause.

- (b) Spatial maximum value of power density within the space occupied by human body excluding limbs shall be less than 20 mW/cm² (6 min average) in managed environment or less than 4 mW/cm² (6 min average) in general environment, where the evaluation target shall be limited to the space 10 cm or more apart from electromagnetic radiation source or metallic object.

Note 3 and Note 4 below Table 2 or Table 3 of the former guideline shall still be applied to this clause.

<3> For frequency range from 1 GHz to 3 GHz

- (a) Spatially averaged value of power density distribution through the whole area corresponding to the space occupied by human body, at spatial area more than 10 cm apart from electromagnetic radiation source or metallic object (root mean square for electric or magnetic field strength), shall be less than the electromagnetic field strength guideline value of the corresponding (managed or general) environment. (ref. former guideline clause 3.2.1)

Note 1 through Note 4 below Table 2 or Table 3 of the former guideline shall still be applied to this clause.

- (b) Spatial maximum value of power density within the space occupied by human body excluding limbs shall be less than 20 mW/cm² (6 min average) in managed environment or less than 4 mW/cm² (6 min average) in general environment, where the evaluation target shall be limited to the space 10 cm or more apart from electromagnetic radiation source or metallic object.

Note 3 and Note 4 below Table 2 or Table 3 of the former guideline shall still be applied to this clause.

- (c) Spatial maximum value of power density irradiating into head area shall be less than 10 mW/cm² (6 min average) in managed environment or less than 2 mW/cm² (6 min average) in general environment, where the evaluation target shall be limited to the space 10 cm or more apart from electromagnetic radiation source or metallic object.

Note 3 and Note 4 below Table 2 or Table 3 of the former guideline shall still be applied to this clause.

<4> For frequency 3 GHz or higher

- (a) Spatially averaged value of power density distribution through the whole area corresponding to the space occupied by human body, at spatial area more than 10 cm apart from electromagnetic radiation source or metallic object (root mean square for electric or magnetic field strength), shall be less than the electromagnetic field strength guideline value of the corresponding (managed or general) environment. (ref. former guideline clause 3.2.1)

Note 1 through Note 4 below Table 2 or Table 3 of the former guideline shall still be applied to this clause.

- (b) Spatial maximum value of power density irradiation on body surface, at spatial area more than 10 cm apart from electromagnetic radiation source or metallic object shall be less than 50 mW/cm² in managed environment or less than 10 mW/cm² in general environment (both in 6 min average).

Note 3 and Note 4 below Table 2 or Table 3 of the former guideline shall still be applied to this clause.

- (c) Spatial maximum value of power density irradiating into eyes shall be less than 10 mW/cm² (6 min average) in managed environment or less than 2 mW/cm² (6 min average) in general environment.

Note 3 and Note 4 below Table 2 or Table 3 of the former guideline shall still be applied to this clause.

Conditions described above are sorted out in Table 4-1.

Supplementary guideline (2): guideline concerning contact current

- (a) In case of no prevention means taken against contact hazard in managed

environment

Measured contact current shall be less than $10^{-3}f$ [Hz] mA for frequency range from 10 kHz to 100 kHz (averaging time < 1 sec), less than 100 mA for frequency range from 100 kHz to 15 MHz (averaging time 6 min).

In case that contact current is composed of multiple frequency component at non-ignorable level to this criterion, contact current shall be summed up with square values of proportion the criteria of each frequency component, which shall not exceed 1.

(b) In case of no prevention means taken against contact hazard in general environment

Measured contact current shall be less than $4.5 \times 10^{-4}f$ [Hz] mA for frequency range from 10 kHz to 100 kHz (averaging time < 1 sec), less than 45 mA for frequency range from 100 kHz to 15 MHz (averaging time 6 min).

In case that contact current is composed of multiple frequency component at non-ignorable level to this criterion, contact current shall be summed up with square values of proportion the criteria of each frequency component, which shall not exceed 1.

Supplementary guideline (3): guideline concerning ankle induced current

(a) In case of deviation of non-grounded condition in managed environment

Measured induced current at ankle for frequency range from 3 MHz to 300 MHz (6 min average) shall be less than 100 mA each leg.

In case that ankle induced current is composed of multiple frequency component at non-ignorable level to this criteria, induced current shall be summed up with square values of proportion to the criteria for each frequency component, which shall not exceed 1.

(b) In case of deviation of non-grounded condition in general environment

Measured induced current at ankle for frequency range from 3 MHz to 300 MHz (6 min average) shall be less than 45 mA each leg.

In case that ankle induced current is composed of multiple frequency component at non-ignorable level to this criteria, induced current shall be summed up with square values of proportion to the criteria for each frequency component, which shall not exceed 1.

Annex 1 Background and foundation for local absorption rate guideline

1. Background for revising guideline concerning low-power radiation source

In the existing protection guideline, a clause on portable radio equipment stipulates guideline for low-power electromagnetic radiation source (supplementary guideline (4)) stating “Electromagnetic wave radiation source, with rated power 7 W or lower for frequency range from 100 kHz to 3 GHz, shall be considered to meet the base guideline in the ordinary using condition and no evaluation according to managing or other supplementary guidelines is needed.”

This is because that experiment with head phantom using portable radio equipment for frequency band 800 MHz proves the conformity to the local SAR value 8 W/kg or less of base guideline 4(a) at ordinary using distance, and also experiment with homogeneous sphere phantom for frequency 3 GHz or less proves the conformity to the guideline 4(a) at 7 cm or more apart from antenna. Even closer than 7 cm between body and antenna if lower frequency than 3 GHz or short communication duration and more if limited rated power less than 7 W energy can be controlled not to exceed guideline 4(a) value. But for this point the former guideline, 1990 included only informative notice instead of concrete description.

Recent downsizing and popularization produces completely different situation. Accordingly, there might have difficulty to apply the existing guideline to the low-power radiation source.

On the other hand (in the meantime) U.S. ANSI, referring to fresh knowledge grounded on research outcomes in the field of dosimetry or biology from various countries, had revised significant portion of their standard (ANSI/IEEE C95.1(1992)), in which an exceptive clause is stipulated to be applied to the distance 2.5 cm at the shortest between radiation source and body for low-power equipment by lowering the power as higher frequency than 450 MHz. And more, unlike the former ANSI recommendation evaluation environment are classified into two grades, managed and non-managed, in the managed environment upper output limit is one-fifth of that of managed environment. According to the latest research portable telephone these days is assessed to meet one-fifth of base guideline 4(a) value.

However, in a range of 2.5 or shorter between antenna and human body coupling conditions would vary in big extent for each equipment model and could not be generally assessed. Thus, as the recent progress of SAR measurement technologies, methodologies of local SAR for every model itself are considered in various countries

and going to be adopted as compulsory standard.

Grounded on these facts also in Japan in place of supplementary guideline (4) another guideline for local SAR in the managing guideline needs to be stipulated urgently.

2 Establishment of localized specific absorption rate guideline and reorganization of guidelines

Delete the existing guideline on low-power radiation source (supplementary guideline (4)) and newly establish “Localized SAR guideline” based on local SAR technology. This guideline will cover broader scope than supplementary guideline (4) and will be ranked abreast with existing managing guidelines (electromagnetic field strength guideline, supplementary guideline).

In the newly introduced “Localized specific absorption rate guideline” target evaluation categories are divided into two (managed environment, general environment) (Figure 8), similarly to the classification (condition G) in the existing managing guideline with better safety factor.

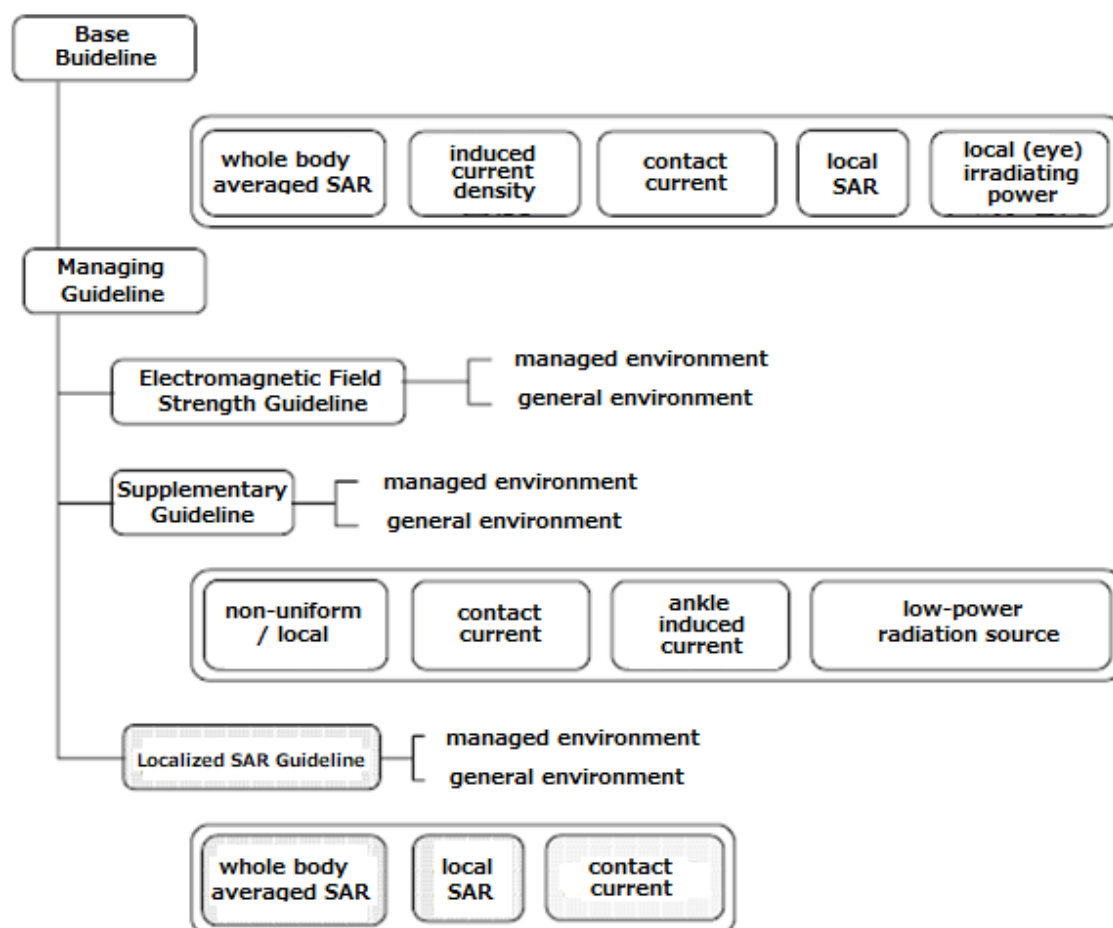


Figure 8 Organization of Radiofrequency-Exposure Protection Guideline (draft)

3 Foundation of “Localized Specific Absorption Rate Guideline”

(a) Managed environment

Foundation of <1>

The value is equivalent to the guideline value of the existing base guideline 1 and also that of whole body averaged SAR as base limitation in occupational exposure in IRPA/INIRC (1988).

Foundation of <2>

For local SAR the base guideline states as informative notice “local SAR at any 1 g tissue (6 min average) does advisably not exceed 8 W/kg (25 W/kg at body surface and limbs).” But to bring items of the base guideline into practice, feasibility with measurement technique must be taken into account.

The proclamation on “Health problem relating portable telephone” at International Commission on Non-Ionizing Radiation Protection (ICNIRP), April 1996 states the basis is not definite for high resolution measurement required for any 1 gram tissue block, and concludes measurement for any 10 gram tissue block must be appropriate from physiological standpoint and many options of measurement.

In the meanwhile, although various studies are being carried out including animal experiment according to the guideline value of ICNIRP, any scientifically proven evidence is not yet shown that bad influence to health including cancer may be caused by electromagnetic energy at lower level than this guideline value.

Accepting these facts, the localized SAR guideline value recommended in the proclamation of ICNIRP is adopted as the localized specific absorption rate guideline value of Japan.

Moreover, the recent study clarifies that the maximum value of averaged local SAR per 1 gram tissue excluding skin (1 gram averaged value excluding skin in base guideline) and the maximum value of averaged local SAR for any 10 gram tissue through whole head area including skin (10 gram averaged value excluding limbs in specific absorption rate guideline) are almost equivalent.

Consequently, there must be no essential difference between the adopted value in this revision and the value in the existing protection guideline.

Note that the local SAR evaluation should be seriously considered as it is essential for equipment such as portable phone used closely to human body and to endeavor international coordination on guideline value, as far as no essential difference resides, should be regarded as important to secure study infrastructure on

measurement technique and to expedite free distribution of equipment internationally.

Foundation of <3>

The value is that of base guideline 3 for frequency range from 100 kHz to 100 MHz.

(b) General environment

General environment includes managing situations insufficiently observing the protection guideline. In general environment counting variations of users or usages above, additional margin of $1/5$ in power and SAR ($1/\sqrt{5}=1/2.24$ in current) as safety factor is included. This is because the guideline and proclamation of ICNIRP include, comparing to occupational exposure, additional safety factor of $1/5$ in power /SAR for the exposure limit of the general public.

Foundation of <1>

Safety factor of $1/5$ in SAR compared to managed environment considered.

Foundation of <2>

Safety factor of $1/5$ in SAR compared to managed environment considered.

Foundation of <3>

Safety factor of $1/5$ in current compared to managed environment considered.

4. Supplement to “applicable scope of localized SAR guideline”

The note “The distance between electromagnetic radiation source (antenna) or metallic object (case, etc.) and human body is 20 cm or closer for frequency lower than 300 MHz, 10 cm or closer for frequency range from 300 MHz to 3 GHz” is originally derived from the measurement limitation in the electromagnetic field strength and supplementary guidelines. It depends on the size of wavelength and measuring antenna or measuring probe.

For portable phone even if minute probe can measure electromagnetic energy in very near range, the radiation condition still differs from that with human body within a few cm and thus accurate exposure evaluation is difficult.

(Reference)

Base guideline

- (1) Any of each 6 min average extracted from whole body averaged SAR shall be 6.4 W/kg or lower.
- (2) Induced current in the tissue for frequency range from 10 kHz to 100 kHz shall be $0.35 \times 10^{-4} f$ [Hz] mA/cm² or less (averaging time < 1 sec).
- (3) Incoming current like contact current for frequency range from 10 kHz to 100 kHz shall be $10^{-3} f$ [Hz] mA or less (averaging time < 1 sec), for frequency range from 100 kHz to 100 MHz 100 mA or less (averaging time 6 min).
- (4) In addition to (1), (2) and (3) above, the following shall be considered as advisable conditions.
 - (a) Even if any of 6 min average among average power SAR is 0.4 W/kg or less, local SAR at any of each 1 gram tissue (6 min average) is desirably not to exceed 8W/kg (for body surface and limbs 25 W/kg).
 - (b) Irradiating power density into eyes for 3 GHz or higher frequency (6 min average is desirably to be 10 mW/cm² or less.

Relevant report 3

Telecommunication Technical Council Report (Oct. 11, 1998)

Inquiry Number 104 [Measurement method and calculation method of radio wave strength for evaluating compliance with radiofrequency-exposure protection guidelines] (Excerpt)

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1 Forward

Regarding the radio wave effect against the human body, various studies have been conducted on the influence of radio waves on the human body for more than 40 years, and there are many items that have gained international consensus. In Japan, based on the above research results the Telecommunication Technical Council reported the radiofrequency-exposure protection guidelines regarding radio waves (so called 'Radiofrequency-exposure protection guidelines') in June, 1990 regarding to the guidelines which regulate the volume of radio wave energy and other related items for the prevention the radio wave energy affects unfavorably to the human body. These values of the radiofrequency-exposure protection guidelines are assumed with the consideration of enough safety factors. And, based on this report RCR (present ARIB) formulated the Standard of the radiofrequency-exposure protection guidelines in 1993, since then it is being utilized as the civilian level guidelines.

On the other hand, as wireless facilities such as mobile phones, etc. are equipped inside and around the area in which people live and work, compared to before, the expansion of radio waves used and the antenna existing on the closer to the human body due to the spread of portable terminals. As the interest to the health effects of radio waves radiated from radio stations rises, and the concern that radio waves emitted by this radio equipment causes an undesirable affect raises social anxiety, the possibility of misunderstanding against radio waves are increasing.

Ensuring safety on radio use is an important matter related to the essential value of human health. Therefore, the Telecommunication Technical Council examined the handling of radio frequency exposure protection guidelines and presented the human body exposure protection guidelines when the human body is exposed to electromagnetic waves in the report of [How to protect human body in radio wave use] issued in April, 1997 from the viewpoint of protecting the health of the people regarding to the safety in radio wave use. Moreover, in order to push the civil guidelines, it is proposed that regulations of the area in which the measurement method and the estimation method are already established thoroughly should be introduced and regulations considered the safety of the general public should be introduced for radio use facilities except mobile radio stations which is near the human body in use for the time being.

Considering this status and situation, the Ministry of Post and Telecommunication decided to establish institutionalization in which [the licensee was obligated to establish the facilities for the person without operators of the radio equipment not to easily enter the area in which the strength of radio waves radiated from the radio equipment exceeded the regulated value], as

the radio wave exposure protection had been employed as the non-governmental guidelines hitherto.

The measurement method and calculation method are presented in this report on this occasion of institutionalization for standardization of radio frequency-exposure protection for the procedure of license application and inspection for radio stations and while the conformity with the radiofrequency-exposure protection guidelines can be confirmed easily as possible on the unified procedure. The measurement method and calculation method in this report are based on the widely recognized knowledge at this stage including overseas information. It is desirable that these measurement methods and calculation-based methods on this report shall be utilized widely hereafter and raise awareness of safety ensuring for the licensee to undertake further thorough use of safe radio waves.

2 Purpose and scope

2.1 Purpose

The method of measuring and calculating the strength of radio waves to confirm compliance with the radiofrequency-exposure protection guidelines (the confirmation procedure of radiofrequency-exposure protection guidelines or simplified 'the confirmation procedure') thereby aims to contribute to the smooth operation of radiofrequency-exposure protection guidelines by showing a standard method for confirming that radio waves emitted from radio stations conform to the radiofrequency-exposure protection guidelines as to reduce the burden on licensees due to the establishment of a standard system for radio wave protection, simplify the examination work, and improve the reproducibility of conformity check results.

2.2 Radio stations subject to verification methods and applicable radiofrequency-exposure protection guidelines

The radio stations objected by the confirmation procedure shall be the radio stations objected by the institutionalization of radio frequency-exposure protection standard.

(Note) Radio stations not objected by the institutionalization of radio frequency-exposure protection standard.

- ① Radio stations less than 20mW average power
- ② Mobile radio stations
- ③ Radio stations temporally established for the state of emergencies such as earthquakes, typhoons, floods, tsunami, fires, public disturbances and other emergency situations, or are anticipated to occur.

The radio frequency-exposure protection guidelines to be applied are the electromagnetic field strength guidelines (Table 2.1) in general environment (Condition G) and the supplementary guidelines (Table2.2). But the supplementary guidelines regarding to note 1, note 2, conductive current and catalytic current shall not take as the objects to be the institutionalization of radio frequency-exposure protection standard with following the reasons shown below and is desirable to carry on as non-governmental guidelines.

- ① The measurement method and measurement equipment have not yet established regarding to the induced current and the contact current.

- ② Regarding the guideline value of the induced current, the rational definition of ground non-contact condition with the human body cannot be found, as well as the determination of whether it satisfies actually seems to be difficult.
- ③ The guideline value of contact current is based on the perceptive threshold, but it is commonly accepted that exceeding the value does not affect the human health immediately.
- ④ The current value of flowing into the human body is changeable according to the size of the metal object even in the same electric field, it is difficult to evenly decide the electromagnetic field strength considered with the contact current.
- ⑤ There is no regulation for general environments in USA and Australia who introduce the institutionalization and is under discussion to take the institutionalization.

Hereafter, the measuring method, etc. continuously shall be studied and this Council shall review on this theme at the stage when these items are established regarding overseas countries.

Reference material Electromagnetic field strength guidelines in a general environment
(Condition G) and supplementary guidelines

(Items with ※symbol shall be excluded from this report.)

1 Electromagnetic field strength guidelines

Table 2.1(a) Electromagnetic field strength (average time 6 minutes) guideline values

Frequency f	r.m.s. value of electric field strength E [V/m]	r.m.s. value of magnetic field strength H [A/m]	Electric power density S [mW/cm ²]
10kHz -- 30kHz	275	72.8	
30kHz – 3 MHz	275	$2.18f[\text{MHz}]^{-1}$ (72.8-0.728)	
3MHz -- 30MHz	$824f[\text{MHz}]^{-1}$ (275-27.5)	$2.18f[\text{MHz}]^{-1}$ (0.728-0.0728)	
30MHz – 300MHz	27.5	0.0728	0.2
300MHz – 1.5GHz	$1.585f[\text{MHz}]^{1/2}$ (27.5-61.4)	$f[\text{MHz}]^{1/2}/237.8$ (0.0728-0.163)	$F[\text{MHz}]/1500$ (0.2-1)
1.5GHz – 300GHz	61.4	0.163	1

Table 2.1(b) Electromagnetic field strength in low frequency regions (average time <1 sec)
guideline values

Frequency f	r.m.s. value of electric field strength E [V/m]	r.m.s. value of magnetic field strength H [A/m]
10kHz – 100kHz	894	72.8

※Note 1: The r.m.s. value of electric field strength not prevented with the contact hazard should be below 61.4V/m (average time < 1 sec). However, supplementary guidelines related to the contact current shall be permitted to apply when the above said condition is not satisfied and they go lower than the guideline values of Table 2.1(a) and Table 2.1(b) at the same time.

※Note 2: The r.m.s. value of electric field strength (6 min. average time) which does not satisfy the ungrounded condition of human body should be $1,430f[\text{MHz}]^{-3/2}\text{V/m}$ (i.e., 275V/m~9V/m) between 3MHz and 30MHz, 9V/m between 30MHz and 100MHz, less than $0.09f[\text{MHz}]\text{V/m}$ (i.e., 9V/m~27V/m). However, the supplementary guidelines of induced current can be applied in the case that the values do not satisfy and when above values are below the guideline values in Table 2.1(a).

Note 3: When the electric field strength or the magnetic field strength are changeable, the values which are r.m.s. values within the average time should be used and when the electric power density is changeable, the average value in the average time should be used within the average time shown in Table 2.1 (a).

Note 4: In the case that the electromagnetic field contains multiple frequency components which cannot be ignored in levels against guideline values, it is required to calculate the sum of the squares which is derived from the percentage of each frequency component ratio to the guideline value regarding the electric field strength and magnetic field strength, and to calculate the sum of the percentage of each frequency component ratio to the guideline value regarding the electric power density. This total sum shall not exceed more than 1.

2 Supplementary guidelines

(1) Table 2.2 Supplementary guidelines when the human body is exposed unevenly or locally in the electromagnetic field

	10kHz—300M Hz	300MHz—1G Hz	1GHz—3GHz	3GHz—300G Hz
Spatial RMS value of electromagnetic field strength	Less than the guideline value of electromagnetic field strength in Table 2.1(a)			
Spatial maximum value of electromagnetic field strength		Without limb: 4mW/cm ²		Body surface: 10mW/cm ²
			Head: 2mW/cm ²	Eye: 2mW/cm ²
Applied space	The space occupied of the human body which is separated more than 20cm from the metal object of electromagnetic radiation source	The space occupied of the human body which is separated more than 10cm from the metal object of electromagnetic radiation source		
Average time	6 minutes			

※(2) Supplementary guidelines related to the contact current when the contact hazard is not prevented

The r.m.s. value of electric field strength which are not prevented with the contact hazard does not have to be met Note 1 of Table 2.1, when the measured contact current (average time < 1 sec) in the frequency between 10kHz and 100kHz is less than $4.5 \times 10^{-4}f[\text{Hz}]\text{mA}$, and is less than 45mA in the frequency between 100kHz and 15MHz.

However, in the case that the contact current contains multiple frequency components which cannot be ignored in level against guideline value, it is required to calculate the sum of squares which is derived from the percentage of each frequency component ratio to guideline value. This total sum shall not exceed more than 1.

- ※(3) Supplementary guidelines related to the induced current without satisfying the non-contact ground conditions

The induced current measured at the ankle in the frequency band between 3MHz and 300MHz (average time 6 minutes) shall not satisfy Note 2 of Table 2.1, if the current is less than 45mA / one leg.

However, in the case that the induced current contains multiple frequency components which cannot be ignored in level against guideline value, it is required to calculate the sum of squares which is derived from the percentage of each frequency component ratio to guideline value. This total sum shall not exceed more than 1.

3 Definitions and terms

- “Electromagnetic wave” is the generic name of wave motions which vibrations in electric fields and magnetic fields propagate in a vacuum or in materials. Electromagnetic waves cover the low frequency electromagnetic fields, so-called radio waves which are used for communication, lights radiated from the sun (infrared, visible lights, ultraviolet rays), radiations applied for the medical care (X-rays, γ -rays), etc. Electromagnetic waves which are shorter than ultraviolet rays in wavelength are divided roughly as ionizing radiation and longer ones are non-ionizing radiation.
- “Radio waves” are electromagnetic waves of frequencies not exceeding 3000GHz as defined by the Radio Act Article 2. The frequency band between 10kHz and 300GHz shall be set to target in the radio frequency-exposure protection guidelines.
- “Radio frequency-exposure protection guidelines” are prepared for the upper limit value that the amount of electromagnetic field shall not affect the unnecessary biological effects to the human body, when the human body is exposed in the electromagnetic field (Frequency range is between 10kHz and 300GHz.). Enough safety ratio is added. The guidelines consist of the electromagnetic field strength guidelines and supplementary guidelines and these are edited with terms of the measurable physical quantities (Electric field strength, magnetic field strength, power density and current) which satisfy the basic guidelines.
- “Basic guidelines” are the guidelines for evaluating the security of human body based on various biological effects caused in the human body (deep body temperature rise, current stimulation, high frequency burn, etc.) when the human body is exposed in electromagnetic field. This is positioned as the basis of radio frequency-exposure protection guidelines and is written by SAR, induced current, contact current, etc.
- “Electromagnetic field strength guidelines” are the guidelines to evaluate the safety of concerned space with electric field strength, magnetic field strength and power flux density in the objected space. These items will take different values according to two conditions of P and G.
- “Supplementary guidelines” are the guidelines which are applied for executing the detail evaluations in the case that electromagnetic field strength guidelines are not satisfied.

Supplementary guidelines are expressed in the style of mitigation or exclusion to be applied with electromagnetic field strength guidelines according to these situations as follows that exposed situations in the electromagnetic field (uneven, local, surface, etc.), objected biological effects (contact current and induced current) and attribution of radio wave emission source are evident.

- “Managed environment” (Condition P) covers that recognition of status that the human body is exposed in the electromagnetic field, identifying the radio wave emission source and appropriate management is available according to these above situations. For example, this managed environment shall be applied to the case that workers in the environment of handling radio waves on a daily basis with being exposed in the electromagnetic field (Broadcasting station, high frequency processing plant, etc.)
- “General environment (Condition G)” is the case (environment) of indeterminate factors existed without the recognition of status that the human body is exposed in the electromagnetic field and proper management, etc. The cases that residents in general living environment are exposed in the electromagnetic field are applicable. Therefore, specific values of general environment are stricter than of managed environment in applying guidelines.
- “Uniform exposure” is the exposure of whole body in the electromagnetic field regarded as the spatial domain of electromagnetic field in which the human body exists can be considered almost uniform. In this case, it includes the case that the wave impedance in free space is not $120\pi [\Omega]$. It shall be considered as uniform when the distance from the wave source enough longer than the height of human (for example, higher than 15m in below 0.3MHz band, higher than 10m in between 0.3MHz and 300MHz, higher than 5m in above 300MHz band) in free space.
- “Average time” is the measurement time based on the focused biological effects for the evaluation of compatibility to the guideline values. Average time stipulated in this guideline is within 1 second for the stimulating effect and 6 minutes for the thermal effect.
- “Specific absorption rate (SAR)” is absorbed power per unit mass arisen with the exposure of living body in the electromagnetic field.
- “Contact current” is the current flown through the contact point with touching the

non-grounded conductive object put in the electromagnetic field by the grounded human body.

- “Contact hazard” is the potential situation which likely causes the contact current.
- “Induced current (density)” is the current (density) induced inside the human body as the result of the human body exposure in the electromagnetic field.
- “Ungrounded condition” is the condition that the influence of ground such as the induced current does not flow to the ground can be ignored. For example, the status of above 10 cm separation is required for bare feet.
- “Electromagnetic field” is the generic term of electric field and magnetic field. Both fields exist inevitably at the same time and their relation can be defined with Maxwell’s equations except the static case that electric field and magnetic field do not change temporally.
- “Electric field strength” is defined with the vector quantity shown with the force of point charge divided by the amount of charge when a static minute positive charge is placed on the point which is given. Electric field strength E is given by $E=F/q$, when force is F and charge amount is q . The amount of electric field strength is simply called electric field strength in this guideline.
- “Magnetic field strength” is defined with the vector quantity that its rotation is the current density and displacement current density. It is equal to the amount of magnetic flux density divided with the permeability of medium. The unit is given A/m. The amount of magnetic field strength is simply called magnetic field strength.
- “Power flux density” is the radiant power per vertical unit area toward the propagation direction. For example, the power flux density $S[W/m^2]$ in the case of plane wave is associated with $S = E^2/120 \pi = 120 \pi \cdot H^2$ as the wave impedance $120 \pi [\Omega]$ in free space assuming that the electric field strength is $E[V/m]$ and the magnetic field strength is $H[A/m]$
- “Far-field” is the electromagnetic field of region (far region) in which the electromagnetic field strength of electromagnetic wave attenuates inverse-proportionally to distance.

- “Near-field” is the electromagnetic field of region (near region) which is not far-field.

- “Frequency asynchronous type measurement system” is the measurement system which is available to measure the wide frequency range (for example 10kHz~300MHz) in almost flat sensitivity without tuning the measurement equipment of receiving frequency for the frequency of objected electromagnetic wave.

- “Frequency tuning type measurement system” is the measurement system which is available to measure the electromagnetic field with each frequency component by tuning the measurement receiver to the objected frequency of the electromagnetic wave. Normally, measurement range is quite wide (for example 10KHz~18GHz) and the response time is short with high sensitivity.
- “Electromagnetic probe” is the antenna system which has broadband characteristics with using a physically minute dipole antenna or loop antenna and is improved interference characteristics with using high resistance wire, etc. This is mainly used for the broadband isotropic electromagnetic strength meter, and a probe which is provided by small antennas on three orthogonal axes to make it isotropic is called an isotropic electromagnetic field probe.
- The term “isotropic” refers to a characteristic of a probe (or antenna) that gives the same designated value if the electromagnetic field strength is the same in an arbitrary incident direction of an electromagnetic wave.
- “Response time” is the time which the indication value of measurement system reaches to 90% of final value, when the measurement target is applied to the electromagnetic field strength measurement system.
- “r.m.s. (RMS)” is the value which is the square root of the mean square throughout whole one cycle of periodic wave form. The RMS of electric field strength and magnetic field strength of the electromagnetic field which changes periodically is the value related to Joule heat.
- “Time average value” is the square root mean value over the mean time while RMS indication is treated as the instantaneous value in the case of electric field or magnetic field and the average value over mean time while RMS indication is treated as instantaneous value in the case of power density.
- “Duty cycle” is the percentage of pulse width against pulse periodicity on the pulse with periodicity and the percentage of emission time against intermittent periodicity on the intermittent wave with periodicity.
- “Radiofrequency-exposure protection guideline compatibility confirmation method” is the method to confirm that the electromagnetic environment of objected point and region conforms

the radiofrequency-exposure protection guidelines and is constituted with the standard calculation method and the standard measurement method.

- “Standard calculation method” is the standard calculation method to confirm that the electromagnetic environment of objected point and region conforms the radiofrequency-exposure protection guidelines.
- “Standard measurement method” is the standard measurement method to confirm that the electromagnetic environment of objected point and region conforms the radiofrequency-exposure protection guidelines.
- “Antenna input power” is the net power supplied to the antenna where the loss of antenna power supply system and the inconsistency loss are extracted from the output power of transmitter.
- “Peak power” is the average power supplied with the transmitter to the antenna feeder during one cycle of radio frequency at the highest peak of modulation envelope in normal operation state.
- “Average power” is the power which is supplied with the normally operating transmitter to the feeder of antenna system and is averaged in the enough long time (normally about one tenth second when the average power is maximum) compared with the period of the lowest frequency used in modulation.
- “Carrier power” is the average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle taken under the condition of no modulation. However, this definition shall not be applied for the radiation of pulse modulation.
- “EIRP: Equivalent isotopically radiated power” is the product of the power supplied to an antenna and the absolute gain of isotropic antenna in the given direction. (this is about 1.64 multiplied of effective radiated power.)
- “ERP: Effective radiated power” is the product of the power supplied to the antenna and the relative gain of half-wavelength dipole antenna in the given direction.

- “Antenna gain” is the power ratio between the power supplied with input part of a given antenna and the power to supply into the input part of the reference antenna in the same distance to acquire the same electric field strength in the given direction. In this case, the figure which expresses the gain of antenna is the gain in the direction of main radiation.
- “Absolute gain of antenna” is the gain of antenna in the situation that the reference antenna is isolated isotropic antenna in space.
- “Relative gain of antenna” is the antenna gain when the reference antenna is isolated in space and half wave non-loss dipole including the vertical bisector direction in the given direction.

4 Basic concept of confirmation procedure

4.1 The relationship between calculation and measurement

The confirmation that the strength guideline value of radio wave emitted by the radio equipment conforms to the guideline value is understood to adopt the calculation basically. However, it is required to proceed conformity check by measurement, when the strong reflections are expected as there exists reflective object in the vicinity and the calculated result is lower than -6dB or more against the guideline value.

The reason for the calculation is based on the fact of anticipation that the measurements of the radio wave intensity performed to confirm the conformity to the guideline value requires a lot of time and labor with accompanying difficulties. As the causes are that specifications of radio station itself are various, characteristics in near field are complicated, emitted radio waves fluctuate on the time scale and it is liable to be influenced strongly with the ambient environment. Adding these, there are lots of factors which spoil the accuracy and reproducibility of measured results such as errors accompanied with the measurement equipment itself. Therefore, various measurement equipment, expertise regarding to measuring technologies and experience of measurements are required to proceed conformity check with grasping the electromagnetic environment in space and time even in the radio station of using a single frequency. The difficulty increases more at the environment in which multiple frequency are of mixed use whereas on the shared radio tower and in the large-scale sending station, licensees forced to take more heavier burden. Also, there is no way but to proceed conformity check by the calculation method in the case of a new license application, as it is not yet licensed the actual measurement is impossible because the radio wave is not allowed to transmit.

For this reason, the compatibility shall be confirmed by the standard calculation method described in Chapter 5. It shall be acceptable to skip the actual measurement if the compatibility is confirmed with the said method in the preamble.

It is necessary to keep the strength of the radio wave calculated in the standard method not lower than the actual value for this application, and it is noted to satisfy this condition on the way to define the standard calculation method. When there is a reflective obstacle in near-field and strong reflections are expected, the measurement shall be performed by the standard measurement method shown in Chapter 6 according to the calculated result which is than 6dB

lower.

(in the case that the calculated result in the standard calculation method is lower than 6dB against the guideline value)

In addition, regarding to other methods which are different from the method shown in this Report, they shall not be excluded necessarily to apply if they are based on the proper engineering technologies, and it is desirable to review the standard measurement method if necessary, according to the progress of technologies.

4.2 Physical quantities to be confirmed

Physical quantities to be confirmed are classified into two categories according to the targeted area of far-field region or near-field region. For the indication of far-field region, the nearest distance from the antenna structure which contributes to the emission of radio wave is farther region more than either $2D^2/\lambda$ or $\lambda/2\pi$ while D is the maximum dimension of antenna structure which contributes the emission of radio wave and λ is free space wavelength.

4.2.1 When the area to be confirmed objectively is far-field region

The following relational expression can be held among the electric field strength E[V/m], the magnetic field strength H[A/m] and electric power density S[W/m²] in far-field region. Here, 377 (=120 π) is wave impedance in free space.

$$S = E^2/377 = 377H^2 \quad (4.1)$$

The other two physical quantities can be converted with (4.1) formula if any one quantity is decided in far-field region among above physical quantities.

On the other hand, relations of each physical quantity are shown as follows below in guidelines of Table 2.1 in Chapter 2.

- Less than 3MHz

The guideline value of electric field strength and that of magnetic field strength have no fixed relationship as the ground of guidelines are different. The guideline values of electric field strength are always equal or smaller value, when the guideline value of electric field strength and the equivalent value converted with conversion relationship from the guideline value of electromagnetic field strength are compared.

- 3MHz or more

The guideline values of electric field strength and magnetic field strength hold the conversion relationship on (4.1) formula in far-field region. Regarding frequencies more than 30MHz the guideline value of electric power density is specified in addition to values of electric field strength and magnetic field strength and the conversion relationship as shown in (4.1) formula is consisted among these values.

Therefore, the confirmation of compatibility for the guideline value is proceeded on the electric field strength only, as the converted electromagnetic field strength is to satisfy the guideline value if the electric field strength satisfies the guideline value regarding to the frequency less than 3MHz.

It is enough to confirm the compatibility with the guideline value on either the electric field strength or the electromagnetic field strength after calculation or measurement regarding to the frequency above 3MHz.

It is enough to confirm the compatibility with the guideline value on among the electric field strength, the electromagnetic field strength or the electric power density after calculation or measurement at the frequencies above 30MHz.

4.2.2 When the region to be confirmed is near-field region

There is not a certain relationship between the electric field strength and the magnetic field strength in near-field region, therefore each quantity shall be calculated or measured and then will confirm the compatibility to each corresponding guideline value.

However, when the proper formula for the near-field region is not found, the formula for far-field region shall be applied and be calculated. This is because that the formula for far-field region is considered in general to result an excessive value in near-field region. (Refer to Annex 1) In this case, the physical quantity to calculate is one enough among the electric field strength, the electromagnetic field strength or the electric power density, as they are mutually convertible. The way to confirm the compatibility to the guideline value shall be treated as same as the case in far-field region.

Also, when the measurement is required in the frequency higher than 1GHz, it exceeds the measurement range of the available measurement equipment of electromagnetic field strength at this moment, and it is agreed that only the electric field strength shall be measured and confirmed.

5 Standard calculation method

5.1 Characteristics and composition of standard calculation method

The calculation method presented here is considered to achieve that the calculation operation can be easily done and the calculated result will not be lower than the level of the actual electromagnetic field. In this clause the basic calculation formula is shown in 5.2. The basic calculation formula conducts the accurate result in far-field region, but generally does the excessive result in the near-field region. Therefore, it may use the formula to calculate in the near-field region, but the user is required to notice it may result in too much excessive value. When the result calculated with the basic calculation formula exceeds the guideline value, it is possible to evaluate the result by using more detailed calculation methods for each antenna shown in the 5.3 clause. In addition, it may use other methods if they are based on the proper technologies regarding to calculation methods of individual antennas.

5.2 Basic calculation formula

This calculation formula is the calculation formula applied for far-field region basically. It may be possible to apply this calculating formula in near-field region, but it generally brings an oversized result. In addition, this calculation formula is adopted in the literature [1] FCC USA recommends for the confirmation of guideline compatibility.

While antenna input power is $P[W]$ and antenna absolute gain in maximum emission direction is G , electric power density $S[W/m^2]$ at the distance $R[m]$ is calculated below.

$$S = \frac{P G}{4\pi R^2} \quad (5.1)$$

R is defined that R is the distance between the observation point and the point which is the nearest on the antenna structure.

While the unit of electric power density calculated in (5.1) formula is $[W/m^2]$, the unit in the guideline is $[mW/cm^2]$ and the conversion from $[W/m^2]$ to $[mW/cm^2]$ is available with the calculated result multiplying 1/10.

When the absolute gain G is expressed in decibel (dB or dBi) as written G_{dB} , the power ratio rate is converted with the formula (5.2).

$$G = 10^{(G_{dB}/10)} \quad (5.2)$$

The above calculation formula is prepared for the direction of maximum radiation angle, and is

possible to apply to the other directions, but leads to the overestimation. When the directivity of antenna is definite, it can achieve more detailed evaluation.

For example, the electric power density $S(\theta)$ for an angle θ is expressed to the next line, when the directivity of electric power density normalized for the angle θ is $D(\theta)$.

$$S(\theta) = \frac{PG}{4\pi R^2} D(\theta) \quad (5.3)$$

The formula (5.3) is applied for the calculations in the horizontal planes and the vertical planes. When the electric power density of the near-field region in the direction of $D(\theta)=0$ is calculated, the mentioned electric power density shall be calculated with the realization that the directivity of concerned direction is shown approximately by the envelope of directional pattern. (For example, lines which link the peaks of them when plural side lobes exist.)

When the evaluation with considering the vertical plane directivity except the main beam direction is undertaken, it is available to proceed the simple evaluation without the strict consideration of directivity by the way as below.

The calculated result by this way makes the excessive result compared with the actual strength of the radio wave.

- ① When the vertical plane directivity which is out of the main beam direction is put under the consideration, the calculated result can be overestimated by using the gain of first side lobe.
- ② Regarding the antennas which are piled up with more than two elements equipped in the radio equipment of FM and television broadcast station, it is accepted to evaluate that the attenuation amount of vertical plane directivity is uniformly 10dB in the elevation angle of more than 45 degree. This is because that the attenuation amount of vertical plane directivity outside the main beam of antennas which are used in domestic can be looked at in the elevation angle of more than 10dB. (Refer to Annex 2)

When the reflection is supposed to be, the maximum electric field strength will be approximately double and the electric power density will be four times larger than when is not supposed. The calculation is operated in the style that the result of (5.1) formula is multiplied with the coefficient which indicates the effect of the earth reflection, when the reflector is limited of the earth or so.

Regarding to the coefficient which indicates the effect of earth reflection, the Model[2] which US Environmental Protection Agency (EPA) has prepared on transmission antennas of the FM

broadcasting station and the television broadcasting station is referred. EPA recommends more realistic prediction of earth reflection with assuming that the increase of electric field is maximum of 1.6 times. The earth cannot be regarded as a complete conductor generally as the frequency goes up higher. Therefore, as the influence of the earth reflection grows smaller, it is recommended in this report when referring the EPA model, the increase of the electric field caused by the earth reflection in the frequency band of FM broadcasting stations or more (76MHz or more) that coefficient of the earth's reflection in the above frequency band of FM broadcasting stations is fixed for 1.6 in the calculation.

The electric power density S at this time is expressed as below.

$$S = 1.6^2 \frac{PG}{4\pi R^2} \quad (5.4)$$

The increase of the electric field strength by the earth reflection is considered larger, as the earth can be regarded as the perfect conductor with accompanying of operating frequency descent generally, and the increase of electric field strength shall be 2 times larger in the frequency region of below FM broadcasting frequency (Less than 76MHz) as evaluating on excessive side. The electric power density is expressed as the following formula shown below.

$$S = 2^2 \frac{PG}{4\pi R^2} \quad (5.5)$$

5.3 Calculation formula for an individual antenna

5.3.1 Collinear array antenna

This calculation formula is available to be applied for the antenna neighborhood inside the main beam of the general-use collinear antenna which is used at the mobile communication base station. It is said that the use of cylindrical model is useful for the evaluation of electromagnetic field in the vicinity of such antennas. This calculation formula is the calculation formula that indicates the relatively accurate electromagnetic level very close to the antenna with the use of cylindrical model in the case when the basic formula is occupied, it might be overestimated. This calculating formula might result overestimated if the basic calculation formula is used, however the calculation formula expresses relatively accurate level of electromagnetic field very close to the antenna with the use of cylindrical model. But as calculated value goes overestimated as moves away from the antenna and therefore the basic

calculation formula leads to the more accurate evaluation. It goes to the overestimation with more detail comparison of calculation models, when the distance from the antenna is far more than $0.6D^2/\lambda$. (Refer to Annex 3)

The spatial average value of electric power density equivalent to the plane wave can be predicted by dividing the antenna input power $P[W]$ with the surface area of the imaged cylindric which surrounds the length of radiation antenna. Where R is the distance from antenna [m] and D is the length of opening surface [m], the electric power density $S[W/m^2]$ is calculated as below.

$$S = \frac{P}{2\pi RD} \quad (5.6)$$

The electric power density can be calculated by the antenna input power divided with the surface area equivalent to the power half width $\Theta_{BW}[\text{degree}]$ regarding to the sector type antenna.

$$S = \frac{P}{2\pi RD} \left(\frac{360}{\Theta_{BW}} \right) \quad (5.7)$$

5.3.2 Aperture array antenna

The aperture array antenna is the antenna applied for earth satellite stations, fixed micro wave links and various kinds of radar. The aperture array antenna has a paraboloid face (so called “Parabola”) normally, and the majority of cutting end is circular. The power is transmitted with the pencil beam of sharp angle which brings high gain. The aperture array antenna is occupied in the system of microwave band (normally higher than 900MHz).

These aperture array antennas have very sharp directivity so that the serious risk of microwave exposure is drastically low except in the main beam direction. The electric power density at the point which the human is possibly exposed is quite lower than comparing with the electric power density on the main beam axis.

Regarding to the calculation out of axis in the near-field region and transition region, the electric power density at that point is at least 1/100 (-20dB) compared with the calculated value on the equivalent distance in the main beam if one point is at least separated more than the diameter of the antenna from the center of main beam.

The experimental model based on the antenna theory and actual measurements is under preparation for calculating the microwave electric power density from the aperture array

antenna. Regarding to the parabolic aperture array antenna which has a circular cut end, the electric power density surrounding the relevant system is calculated with using the information below obtained from the experimental model and with using calculation formulas.

(1) Antenna surface

The maximum

electric power density on the antenna surface

$$S_{\text{surface}} = \frac{4P}{A} \quad (5.8)$$

is calculated by the formula below.

Here, P is antenna input power and A is the physical area of aperture array antenna.

(2) Near-field region

There is a possibility that once the electric power density reaches to the maximum value before the electric power density starts to decay according to the distance as it goes. Here, the range of near-field regions are defined within the neighborhood area of R_{nf} which is the distance from the antenna surface plain given by the formula below (D and λ are of the same unit.).

$$R_{\text{nf}} = D^2/4\lambda \quad (5.9)$$

Here, D is the maximum antenna size (diameter if circle) and λ is wave length.

The value of the electric power density on the axis (of main beam) depends on the distance R. But the maximum value of electric power density on the axis S_{nf} does not depend on the distance can be expressed with the following formula below.

$$S_{\text{nf}} = 16 \frac{\eta P}{\pi D^2} \quad (5.10)$$

Here, η is aperture efficiency (normally 0.5~0.75), P is antenna input power and D is the maximum antenna size (diameter).

The approximate value of aperture efficiency η on the circle aperture plain is calculated as below with the ratio of the effective aperture area and the physical area.

$$\eta = \frac{\frac{G \lambda^2}{4\pi}}{\frac{\pi D^2}{4}} = \frac{G \lambda^2}{(\pi D)^2} \quad (5.11)$$

Here, G is absolute gain of antenna, λ is wave length and A is physical area of antenna.

When the antenna absolute gain G is unknown, it can be calculated by the formula below with using the actual or guessed aperture efficiency.

$$G = 4 \pi \eta A / \lambda^2 \quad (5.12)$$

Here, η is aperture efficiency, λ is wave length and A is physical area of antenna.

(3) Transition region

The electric power density in the transition region decreases in inverse proportion to the distance from antenna and the electric power density in far-field region (Fraunhofer region) decreases in inverse proportion to a square of distance from antenna. The distance to the start point of far-field (the limit point of transition region) R_{ff} can be calculated by the equation below in the evaluation of microwave exposure.

$$R_{ff} = 0.6 D^2 / \lambda \quad (5.13)$$

Whereas D is the maximum antenna size (Diameter) and λ is wave length.

The transition region stays in the range between R_{nf} which is calculated by the formula (5.9) and R_{ff} which is calculated by the formula (5.13). When the point to know is in this transition region, the electric power density on axis shall be calculated by the formula below.

$$S_L = S_{nf} \times \frac{R_{nf}}{R} \quad (5.14)$$

Here, S_{nf} is the maximum electric power density in near-field region calculated by the formula (5.10), R_{nf} is the range of near-field region and R is the distance from antenna.

5.3.3 Monopole antenna for the medium wave broadcasting

The electromagnetic field strength in near-field of top-hat monopole antenna which is most adopted for the medium wave broadcast stations can be calculated by the formula derived with referring to Document [3] and Document [4].

It is decided then, to evaluate with adapting the proper numeric to s of the antenna wavelength reduction rate and κ of the top hat correction factor for the application of this formula. s and κ

shall be compared with the measured values and be selected among the most matched ones for adaptation. However, when the comparisons are impossible, the provisional values of $s = 0.88$ and $\kappa = 0.7$ shall be used for the evaluations.

(1) Equivalent length of the top-hat antenna

The equivalent length of the top-hat is shown in the formula below.

$$l' = \frac{\tan^{-1}(\omega C Z_0)}{k_a} \quad (5.15)$$

Here, Z_0 is the characteristic impedance of cylindrical column and C is the capacitance of top-hat to the ground.

κ normally takes the value of 0.6~0.8 as for the correction factor with the nonmetal disc of the top-hat on employing

$$Z_0 = 60 \left(\ln\left(\frac{2l}{d}\right) - \ln\sqrt{3} \right) \quad (5.16)$$

$$C = 4 \kappa \epsilon_0 D \quad (5.17)$$

symbols of Figure 1 (Antenna and coordinate system).

Also, s is the coefficient which decides k_a of the propagation constant on the antenna and the relation is $k_a = k_0/s$. Normally its value is 0.85~0.9.

(2) Antinode current value of the antenna

The current at ξ of the random point on the z axis is expressed in the formula as below.

$$I(\xi) = I_0 \sin(ka(lt - |\xi|)) \quad (5.18)$$

$$I_0 = \frac{\sqrt{\left(\frac{P_t}{R_f}\right)(R_f^2 + X_f^2)}}{Z \cos(kl - \theta)} \quad (5.19)$$

Here, I is the full length of the antenna ($=I+I'$). And I_0 is the antinode current value which is calculated with the input impedance of feeding point at the antenna base $Z_f (=R_f + jX_f)$ and the

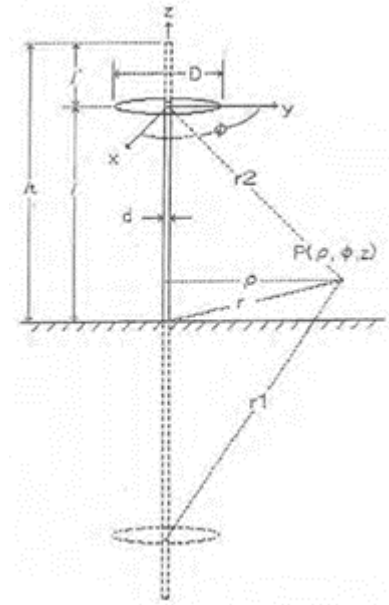


Figure 1 Antenna and coordinate system

antenna power P_t .

The input impedance is expressed in the following formula with using α_1 , α_2 , β_1 , β_2 (Reference document [8]) of Hellen's coefficients, as $\Omega = 2 I_n (4 I_t/d)$.

$$Z_f = -j30 \frac{\Omega \cos(ka \cdot lt) + \alpha_1 + \alpha_2/\Omega}{\sin(ka \cdot lt) + \beta_1/\Omega + \beta_2/\Omega^2} \quad (5.20)$$

(3) The representing formula of electric field strength

When the current of formula (5.18) flows on the antenna, A of the vector potential on the observation point $P(\rho, \phi, z)$ is expressed in the next formula as it consists of the z component only.

$$A_z = \frac{\mu_0}{4\pi} \int_{-l}^l \frac{I(\xi) e^{-jk_0 r}}{r} d\xi \quad (5.21)$$

$$\text{where } r = \sqrt{\rho^2 + (z - \xi)^2}$$

The electromagnetic field is generally related with the vector potential A shown below on the other hand.

$$\begin{aligned} E &= -j\omega A + \left(\frac{1}{j\omega \epsilon_0 \mu_0} \right) \nabla (\nabla \cdot A) \\ H &= \left(\frac{1}{\mu_0} \right) \nabla \times A \end{aligned} \quad (5.22)$$

Therefore, each component of the radiated electromagnetic field derived from A_z is expressed in the following formulas.

$$\begin{aligned} E_z &= -j\omega A_z - j \frac{(\omega/k_0^2) \partial^2 A_z}{\partial z^2} \\ E_\rho &= -j \frac{(\omega/k_0^2) \partial^2 A_z}{\partial \rho \partial z} \\ H_\phi &= - \frac{(1/\mu_0) \partial A_z}{\partial \rho} \\ E_\phi &= H_z = H_\rho = 0 \end{aligned} \quad (5.23)$$

The radiated electromagnetic field strength is available to be acquired by substituting (5.21) for (5.23) in the formulas, but the calculation will be extremely difficult and complicated because the propagation constant in the formula (5.21) accordingly takes ka of the antenna in $I(\xi)$ and k_0 of free space in the index division. Therefore, substituting formula (5.21) for formula (5.23),

each component of the electromagnetic field added with the differential operation shall be transferred to the integral type expression, and then the electromagnetic field strength shall be calculated in the numerical integration method.

The integral type expressions of each electromagnetic field component are shown below.

$$E_z = -j \frac{\omega \mu_0 I_0}{4\pi k_0} \int_{-l}^l \sin k_a (lt - |\xi|) \left[\left\{ \frac{k_0}{r} - \frac{1}{k_0 r^3} - \frac{k_0 (\xi - z)^2}{r^3} + \frac{3(\xi - z)^2}{k_0 r^5} \right\} (\cos k_0 r - j \sin k_0 r) d\xi \right. \\ \left. + j \left\{ -\frac{1}{r^2} + \frac{3(\xi - z)^2}{r^4} \right\} \right] \quad (5.24)$$

$$E_\rho = -j \frac{\omega \mu_0 I_0}{4\pi k_0} \int_{-l}^l \sin k_a (lt - |\xi|) \rho (Z - \xi) \left\{ \left(-\frac{k_0}{r^3} + \frac{3}{k_0 r^5} \right) + j \frac{3}{r^4} \right\} (\cos k_0 r - j \sin k_0 r) d\xi \quad (5.25)$$

$$H_\phi = \frac{I_0}{4\pi} \int_{-l}^l \sin k_a (lt - |\xi|) \rho \left\{ \frac{1}{r^3} + j \frac{k_0}{r^2} \right\} (\cos k_0 r - j \sin k_0 r) d\xi \quad (5.26)$$

r is the distance from the antenna and be defined with the formula below. (ξ is any point on the antenna.)

$$r = \sqrt{\rho^2 + (z - \xi)^2} \quad (5.27)$$

The composite value of the electric field and the magnetic field is brought by the formulas below.

$$\begin{aligned} E_c &= \sqrt{(|E_z|^2 + |E_\rho|^2)} \\ H_c &= |H_\phi| \end{aligned} \quad (5.28)$$

The following conversions shall be carried by PC with the integral computation and generate the program code.

$$\begin{aligned} d\xi &\rightarrow \nabla \xi = \frac{2l}{n} \\ \xi &\rightarrow \xi_i = -l + \nabla \xi \cdot i \quad (i = 1, 2, \dots, n) \\ r &\rightarrow r_i = \sqrt{\rho^2 + (z - \xi_i)^2} \end{aligned} \quad (5.29)$$

When the measured data of near electric field exists, the data which match well among the on-site measured data shall be selected with changing the coefficient up and down slightly at the calculation and generating distance-to-electromagnetic characteristic curve on each assumed coefficient.

As the coefficient of the concerned antenna can be decided with this, the electromagnetic field other than measurement points is available to be estimated by the calculation.

When it is not the case of cylindrical column type antenna like truss type or so, the electromagnetic field strength is estimated by the above formula with deriving the radius equivalent to cylindrical column from Z_f found by calculation.

5.3.4 Curtain antenna (for the short-wave international broadcasting)

The electromagnetic field strength of the curtain antenna which is used for the short-wave international broadcasting is synthesized by the electromagnetic field strength of each radiation component which constitutes the curtain antenna.

For the calculation of synthesized electromagnetic field,

it is necessary to consider the reflection from the earth and the reflection from the reflector if the reflector is occupied and the synthesized electromagnetic field can be calculated, while each reflection is treated as a complete reflection.

Each radiation element is accordingly replaced with a half-wave length equivalent dipole antenna and each element is assumed to feed in the same phase and equal power.

Here, the electromagnetic field of one half-wave dipole is expressed in the following formula below.

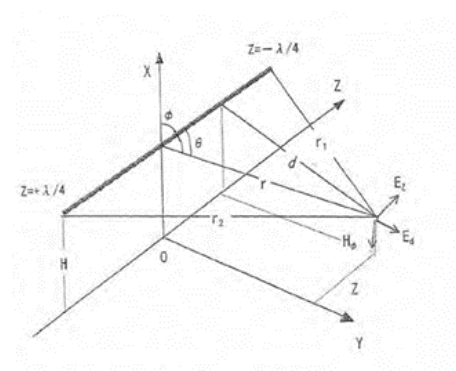


Figure 2 Coordinate system of horizontal dipole

$$E_z = \frac{-jkI}{4\pi\omega\epsilon} \left\{ \frac{\exp(-jkr_1)}{r_1} + \frac{\exp(-jkr_2)}{r_2} \right\} \quad (5.30)$$

$$E_d = \frac{-jkI}{4\pi\omega\epsilon d} \left\{ \left(Z + \frac{\lambda}{4} \right) \frac{\exp(-jkr_1)}{r_1} + \left(Z - \frac{\lambda}{4} \right) \frac{\exp(-jkr_2)}{r_2} \right\} \quad (5.31)$$

$$H_{\Phi} = \frac{jI}{4\pi d} \{ \exp(-jkr_1) + \exp(-jkr_2) \} \quad (5.32)$$

Where ω : Angular frequency, k : Phase constant and ϵ : Dielectric constant

$r_1, r_2, d, Z, E_z, E_d, H_\phi$ are shown in Figure 2.

It is obtained from the antenna power, the number of elements, the input impedance of each element and the like.

5.4 Confirming check methods using calculation formula

5.4.1 Space to be calculated

The target places are the places people normally gather, pass, come and go. The height is the range between 0 and 2m. Usually, the antenna is often installed at a high position such as the rooftop of a building or a steel tower, so that the worst-case evaluation is often given by calculating at a position of 2 m.

5.4.2 How to take a spatial average

When the electromagnetic field strength in objective space is uneven derived from the position in near-field of antenna, the influence of surrounding reflection waves or so, after calculating the spatial average value of electric power density in all region equivalent to the space occupied by the human body (root-mean-square value in case of electric field strength or magnetic field strength), the compatibility can be confirmed with comparing this to the guideline value as defined in the supplementary guidelines.

5.4.3 Cases requiring the time average (radar pulse, digital modulation, etc.)

When the radiation format is intermittent as radar wave, or so, it is available to evaluate by the time average of antenna input power with occupying the duty factor instead of the antenna input power.

As the pulse width is τ and the pulse repetition frequency is f_p , the duty factor F is expressed as shown below.

$$F = \tau \cdot f_p \quad (5.33)$$

The time average $\langle P \rangle$ corresponding to the peak value of antenna input power at this time is expressed as shown below.

$$\langle P \rangle = P \cdot F \quad (5.34)$$

However, it is necessary to seek the maximum value in the 6-minute time average when the repeated period is longer than 6 minutes.

5.4.4 The case to consider antenna rotation

The antenna input power which is time-averaged with the considered coefficient of the antenna rotation shall be applied for the radio equipment with rotating antenna as radar.

The compensated coefficient of antenna rotation K is defined as below.

$$K = \theta_{BW}/360 \quad (5.35)$$

As the electric power density is concentrated within the range of antenna diameter in near-field region and transition region, the compensated coefficient shall be calculated with using the prospective angle of antenna diameter ψ at the distance R instead of the width of antenna beam. The compensated coefficient of the antenna rotation K is expressed as below.

$$K = \psi/360 \quad (5.36)$$

$$\text{where } \psi = 2 \tan^{-1} (D/2R) \quad (5.37)$$

The time-averaged antenna input power $\langle P \rangle$ considered with the duty factor and compensated coefficient averaged with the antenna rotation for the peak value of antenna input power is expressed as below.

$$\langle P \rangle = P \cdot F \cdot K \quad (5.38)$$

5.4.5 Cases of multiple waves with different frequencies

When the incident wave consists of multiple frequency components in the level which cannot be ignored against the guideline value, the electric power density of each incident wave, the electric field strength of each incident wave and electromagnetic field strength of each incident wave are calculated and the percentage of the guideline value are individually calculated for acquiring the sum of them. (The sum of squares shall be calculated regarding to the electric field strength and the electromagnetic field strength.) It shall be evaluated to fulfill the guideline value, if the value of sum is lower than one.

6 Standard measurement method

6.1 Characteristics and composition of standard measurement methods

The standard measurement methods shown in this chapter explain the methods with using normally-obtainable and general measurement equipment as well as the measurement to achieve conveniently. It is acceptable to adopt other methods which are different from methods described here if they are based on proper engineering technologies.

This measurement method is targeted to measure the electromagnetic field strength of any direction and polarization radio wave exactly, therefore it is the base to measure the r.m.s. (root-sum-square) value of orthogonal 3 axis components in an incident wave.

There are two kinds of methods to measure this value as roughly classified as below.

- The method to use the dedicated isotropic electromagnetic field probe
- The method to use the general-purpose measuring instrument

The isotropic electromagnetic field probe has the features shown in 6.2.1 and is possible to execute above measurement conveniently. The method which uses the general-purpose measuring instrument can compensate the cases that the isotropic electromagnetic field probe is difficult to achieve the enough measurement (Refer to 6.2.3) and to measure the outer-range frequencies which commercially available probe cannot measure.

(Refer to Annex 4 Electric field: 10kHz—50GHz, Magnetic field: 300kHz—1GHz)

6.2 Method by isotropic electromagnetic field probe

6.2.1 Composition and features of isotropic electromagnetic field probe

The isotropic electromagnetic field probe is composed of the antenna, detector, indicator etc. The antenna consists of orthogonal 3-axis elements (minute dipole or minute loop) and the responses of each element shall be compositing processed to acquire the characteristics which do not depend on the polarization and arrival direction. The detection methods are the diode detection type and the thermocouple detection type. It is said that the diode detection type has not quick response performance against the large amplitude fluctuation range such as pulse waves and it may not necessarily indicate the right power (r.m.s.), as it deviates from the square detection characteristics. The thermocouple detection type is available to indicate the pulse power (r.m.s.), however there is a possibility that it may be destroyed by the excessive

input, as its allowable input range is narrow. The indicator type is classified into two types. One is become one with the sensor part (antenna, detector), and the other is the separated type which the separated parts are connected with the optical fiber.

The isotopic electromagnetic field probe has the features shown below,

- ① the spatial resolution is high.
- ② the connectivity with the wave source is small.
- ③ it is available to measure conveniently and accurately the maximum value even if the polarization is unknown.

and is conveniently useful for the measurement in the narrow space and near-field region of radiation source.

6.2.2 Terms of isotopic electromagnetic field probe

(1) Isotopic

The fluctuation of response for the incident direction of electromagnetic wave is within 3dB in the frequency range of the objected radio station.

(2) Frequency characteristics

The response of amplitude characteristics for the frequency should be flat in the frequency range of the objected radio station. (This is normally shown in the style of response deviation.) And the response for the electromagnetic wave which is out of the frequency range should be made clear.

(3) Amplitude characteristics

It should be made clear that the range of the electromagnetic field level which is available to be measured accurately in the frequency range of the objected radio station. And, the probe and its accessory, etc. should not respond to the physical quantities beside the objected physical quantity. (For example, the probe with using the minute loop should not respond to the electric field.)

(4) Response time

Within 1 second

6.2.3 Measurement method

(1) Basic measurement procedure

- To seek the maximum value with scanning the probe over the space occupied by the human body at the measurement point to be objected for the confirmation.
- The average time at the measurement point is 6 minutes in principle. (Less than 1 second at below 100 kHz) It may reduce the average time on following to the situation, when the value

of 6-minute average time is acquired within shorter time than 6 minutes considering to the modulation characteristics of radio wave at the objected radio station.

- The spatial averaged value in the space which satisfies the condition specified by the supplementary guideline shall be treated as the measured value, when the measured value in this method exceeds the value of the guideline. The point to take the spatial average is basically 20cm interval in the frequency of less than 300MHz and 10cm interval in the frequency of more than 300MHz. Then, the maximum value at the place equivalent to the space that the human body occupies shall be measured and be compared with the minimum value which the supplementary guideline specifies.
- The measurement should be performed in the targeted region according to procedures of above each section in at least a 45-degree interval around the transmission antenna including the maximum radiation direction when the directivity of antenna is broad, or when the antenna directivity is narrow, the measurement should be done in the direction of main lobe and side lobe.

(2) Important points on using the isotropic electromagnetic field probe

It is required to hold the probe isolated so that it is not affected by the human body or polarization. For example, the antenna part and the high-register line part of probe are prohibited to hold by hand. And, the probe axis of the electric field and the electric field should not be parallel.

The minimum distance between the measurement probe and the electromagnetic source, the earth, metal objects, etc. should be basically kept more than 20cm in the frequency of less than 300MHz and more than 10cm in the frequency of higher than 300MHz to avoid the connection.

(3) Important points on the measurement in the environment of multiple-wave existence

The electromagnetic field probe should not be used at the place where it cannot ignore the influence of radio wave from other radio station as it is generally very broadband. In this case, it is necessary to adopt the frequency tuning measurement system described in Clause 6.3.

(4) Important point for the pulse wave

The thermocouple type electromagnetic field probe should be used, when the electromagnetic field probe is occupied for the pulse wave measurement.

6.3 Method by the general-purpose measurement equipment

6.3.1 Composition and features of measurement system

The measurement will be promoted with combining the antenna unit (including feeder cable) and the general-purpose measuring instrument same as the general measurement of electromagnetic field strength.

The measurement systems are classified into the frequency tuning type measurement system and the frequency non-tuning type measurement system.

The frequency tuning type measurement system is the system which tunes the specific frequency and responds only to the electromagnetic field within the bandwidth of the centered specific frequency. There is the spectrum analyzer, the interference wave measuring instrument, the electric field strength measuring instrument, etc. as the frequency tuning type measuring instrument.

These measuring systems have features of very wide tuning-frequency range (for example, 10kHz ~ 18GHz), high receiving sensitivity and very quick response-time.

And moreover, they are suitable to measure the multiple waves, as each frequency component is separated and its level is measurable.

In addition, it is necessary to pay attention that the indicated level is not correct, when the occupied bandwidth like the pulse wave is wider than the bandwidth of measuring instrument resolution ability.

The frequency non-tuning type measurement system is the measurement system which shows the flat response of the output value for the electromagnetic field over a wide frequency range. The broadband antenna and the measuring instrument which has the broadband characteristics shall be occupied as the basic components.

The combination of the diode detector, the time-wave observation like the oscilloscope and power sensor & power meter, etc. is used as the practical measuring instruments. The former is available to measure the envelope time waveform of the electromagnetic field, and the latter is available to measure the r.m.s. value of the electromagnetic field. The frequency non-tuning type measurement system is suitable to measure the electromagnetic field which fluctuates over time as for the pulse wave measurement. However, the sensitivity is inferior to that of the frequency tuning type measurement system.

6.3.2 Conditions for the measurement system

(1) Antenna

The appropriate antenna should be applied according to the radio station of measurement target, but its antenna coefficient should be known.

(2) Measuring instrument

The measurable frequency range, the frequency-resolution bandwidth (Frequency tuning type measurement system only), the input sensitivity, the detection method and the maximum allowable input of measuring instrument should be known. The input impedance is matched with the measuring cable. The measuring instrument and cable should have enough shielding characteristics as the measurement is set to target in the strong electromagnetic field. The measuring instrument should not be influenced with the high-frequency electromagnetic field and the low-frequency electromagnetic field except the measurement target.

6.3.3 Measurement method

(1) Basic measurement procedure

- The maximum value shall be sought with scanning the measurement antenna over the space occupied with the human body at the point to be objected for the confirmation.
- The direction and polarization plane of the antenna shall be deployed to maximize the received voltage in this case and be measured. For example, when the characteristics of the polarization, etc. is known, the measurement shall be proceeded with matching the polarization plane of the measurement antenna to that of the transmitter antenna. And the following correction values should be added with considering the polarization loss.
 - ① 3dB shall be added, when the linear polarization antenna is used for the wave source and the circularly polarized antenna is used for the measurement antenna.
 - ② 3dB shall be added, when the circularly polarized antenna is used for the wave source and the linear polarization antenna is used for the measurement antenna.
- The average time at each measurement point is 6 minutes (less than 1 second in lower than 100kHz) in principle. However, the average time is available to be reduced as appropriate, if the value of less than 6-minute average time is anticipated equivalent to the value of 6-minute average time considering the modulation characteristics for the radio wave of the target radio station.
- The spatial-averaged value in the space which satisfies conditions specified by the supplementary guidelines shall be the measured value, when the measured value by this method exceeds the guideline value. The point to take the spatial average is basically 20cm interval in the frequency of lower than 300MHz and 10cm interval in the frequency of higher than 300MHz. Then, the maximum value at the place equivalent to the space that the human body occupies shall be measured and be compared with the minimum value which the

supplementary guideline specifies.

- The measurement should be performed in the targeted region according to procedures of above each section in at least 45-degree interval around the transmission antenna including the maximum radiation direction when the directivity of antenna is broad, or when the antenna directivity is narrow, the measurement should be done in the direction of main lobe and side lobe.

(2) Important points on using measuring instrument

It should be confirmed that the level of the measurement equipment when terminated with the matched load is negligible small compared to the level when the measurement antenna is connected at the measurement point.

The distance between the measurement antenna and the electromagnetic source, the earth, metal objects, etc. should be basically kept more than 20cm in the frequency of lower than 300MHz and more than 10cm in the frequency of higher than 300MHz to avoid the connection. The note is required that the size of the measurement antenna is larger than that of the dedicated electromagnetic field probe, so that the coupling with the electromagnetic wave source, the ground, and a metal object is increased.

The scanning action should be carefully done to minimize the influence of the human body when the measurement antenna is scanned.

(3) Important points for multi wave measurement

The measurement system of the frequency tuning type shall be used. The maximum value of the incident wave at each frequency component shall be measured according to the method of 6.3.3 (1). (It is focused on that the maximum point and the maximum direction do not match necessarily.) It shall be evaluated to fulfill the guideline value if the sum of them is less than 1 after calculating the percentage of guideline for each frequency component.

(4) Important points for pulse wave measurement

The measurement system of the non-tuning type shall be used. The average value is required to be calculated from time waveform when the diode detector and the oscilloscope are occupied.

6.4 Notes on measurement

(1) It is important to secure the safety of measurers so that the electromagnetic field strength shall be presumed in advance when the measurers enter the measurement location.

(2) It is necessary not to select the unsuitable measurement system. For example, it is possible to underestimate the electromagnetic field strength, when the radar wave is measured with using the diode detector type isotropic magnetic probe.

(3) When the reflective object exists in the inside or near-field of measurement space, it needs to

pay attention to the selection of the measurement point as the electromagnetic field strength changes complicatedly and happens to become bigger locally according to the slight change of the measurement point.

(4) When the directive antenna is used, the influence of the incident wave which comes from other directions than the main radiation direction should be considered.

(5) It should be considered to avoid the electromagnetic field disturbance caused by measurers and measurement system as much as possible at the time of measurement. Particularly, measurers, antenna and surrounding objects should not move, while the electromagnetic field which is changing over time is under measuring. The measurement should be performed by slowing the scanning time with paying enough attention as the fluctuation of electromagnetic field caused with scanning measurement is to distinguish whether spatial fluctuation or time one.

(6) It should be careful that the measurement equipment might be affected by environmental conditions (temperature, humidity, vibration, electromagnetic field, etc.).

(7) The measurement system should be calibrated one and it is desirable to perform calibration regularly according to the age of component equipment and the frequency of use.

(8) It is desirable to keep the model numbers and characteristics of measurement equipment as records.

7 Issues to consider

The present situation of the measurement method and measuring instrument has not been established yet thoroughly regarding to the measurement of the induced current and the contact current as there exist various technical tasks. It is strongly expected that the research and development of the measurement method and measuring instrument shall be continuously promoted and the measurement technologies of the induced current and the contact current shall be established.

The development of the electromagnetic field probe (the magnetic field probe for higher than 1 GHz, the probe for multiple waves) for the conformity check of the radio-frequency exposure protection guidelines is expected to promote as well as the fulfillment of the domestic calibration system.

Annex 1 Study on calculated results of electromagnetic field strength when the calculation formula for far-field region is applied to the near-field region

1 Purpose

The near-field electromagnetic field is calculated and compared in the three different ways, and the result shows that the approximate expression of far-field region indicates a more excessive-side result rather than the result of strict calculation method in near-field region in taking a half-wave dipole antenna for an example.

2 Calculation method

Figure 1 shows the coordinate system.

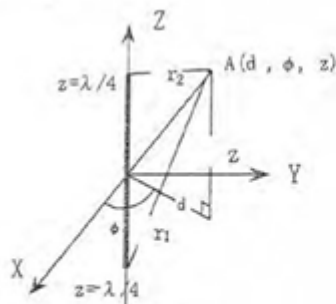


Figure 1 Cylindrical coordinate system

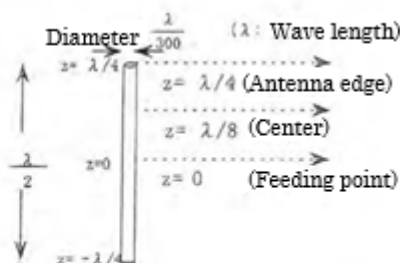


Figure 2 Calculation range of distance characteristics

(1) Approximate expression (Formula of far-field region)

Electric field strength

$$E = \frac{\sqrt{30PG}}{d} (V/m)$$

P: Antenna input power (W)

G: Antenna absolute gain (1.64)

d: Distance from antenna (m)

Magnetic field strength

$$H = \frac{E}{120\pi} (A/m)$$

Additionally, above formulas are equivalent to the formula of electric power density (Basic

calculation

$$S = \frac{PG}{4\pi d^2} (W/m^2) \quad \text{formula)}$$

(2) Numerical calculation method

The numerical electromagnetic field analysis program (NEC2) by the method of moments Document [5] is used.

(Division number: 11, Wire diameter: $\lambda/300$)

(3) Theoretical formula of ideal half wavelength antenna (thickness is 0, loss is 0, sinusoidal current distribution) Document [7]

The electromagnetic field at the Point A in Figure 1 is given by the following formula below.

Where I is the current at the feeding point and ϵ is the permittivity of space. And, $\omega = 2\pi f$, $k = 2\pi/\lambda$ (f: frequency, λ : wavelength)

$$\begin{cases} Ez = -\frac{jkI}{4\pi\omega\epsilon} \left(\frac{e^{-jkr_1}}{r_1} + \frac{e^{-jkr_2}}{r_2} \right) \\ Ed = \frac{jkI}{4\pi\omega\epsilon d} \left\{ \left(Z + \frac{\lambda}{4} \right) \frac{e^{-jkr_1}}{r_1} + \left(Z - \frac{\lambda}{4} \right) \frac{e^{-jkr_2}}{r_2} \right\} \\ H\varphi = \frac{jI}{4\pi d} (e^{-jkr_1} + e^{-jkr_2}) \end{cases}$$

3 Calculation result

Figure 2 shows the calculation range, Figure 3 and Figure 4 show the distance characteristics of the electric field and magnetic field normalized with the wavelength corresponding to each point.

3.1 Electric field

(1) Feeding point ($z = 0$)

The electric field is always the same value in any method at one wavelength or more separation. The value of the far-field formula is bigger than the value of other methods at below one wavelength. In addition, as the theoretical formula does not consider the thickness of the line, the method of moments (NEC2) is anticipated correct in the very near-field region.

(2) Center point ($z = \lambda/8$)

When the distance of more than one wavelength is taken, the result always comes to the same value. When the distance is below one wavelength, the result calculated by the formula of far-field region has a larger value than that of other method.

(3) Edge of antenna ($z = \lambda/4$)

Any method comes to the same value when the distance is taken for more than one wavelength. When under one wavelength, the result calculated by the formula of far-field region is larger value than that of other method. However, only the result by method of moments (NEC2) is

larger than the result calculated by the formula of far-field region. It is limited within only the very near region (nearer than $\lambda / 500$) which is almost the same thickness of the antenna. Additionally, the result by method of moments (NEC2) is not always exclusively correct.

3.2 Magnetic field

(1) Feeding point ($z = 0$)

3 methods arrive to the same result. The approximate expression is correct in near-field in this case.

(2) Center point ($z = \lambda / 8$)

3 methods arrive to the same result when about one wavelength or more distance is separated. The result of the approximate expression formula in near-field gives the largest one.

(3) Antenna edge ($z = \lambda / 4$)

The same result is gotten as (2) Center point ($z = \lambda / 8$).

4 Conclusion

The value calculated by the approximate expression (the formula of far-field region) shows the excessive result compared with the calculated value by more strict method in near-field region regarding to the half wavelength dipole antenna.

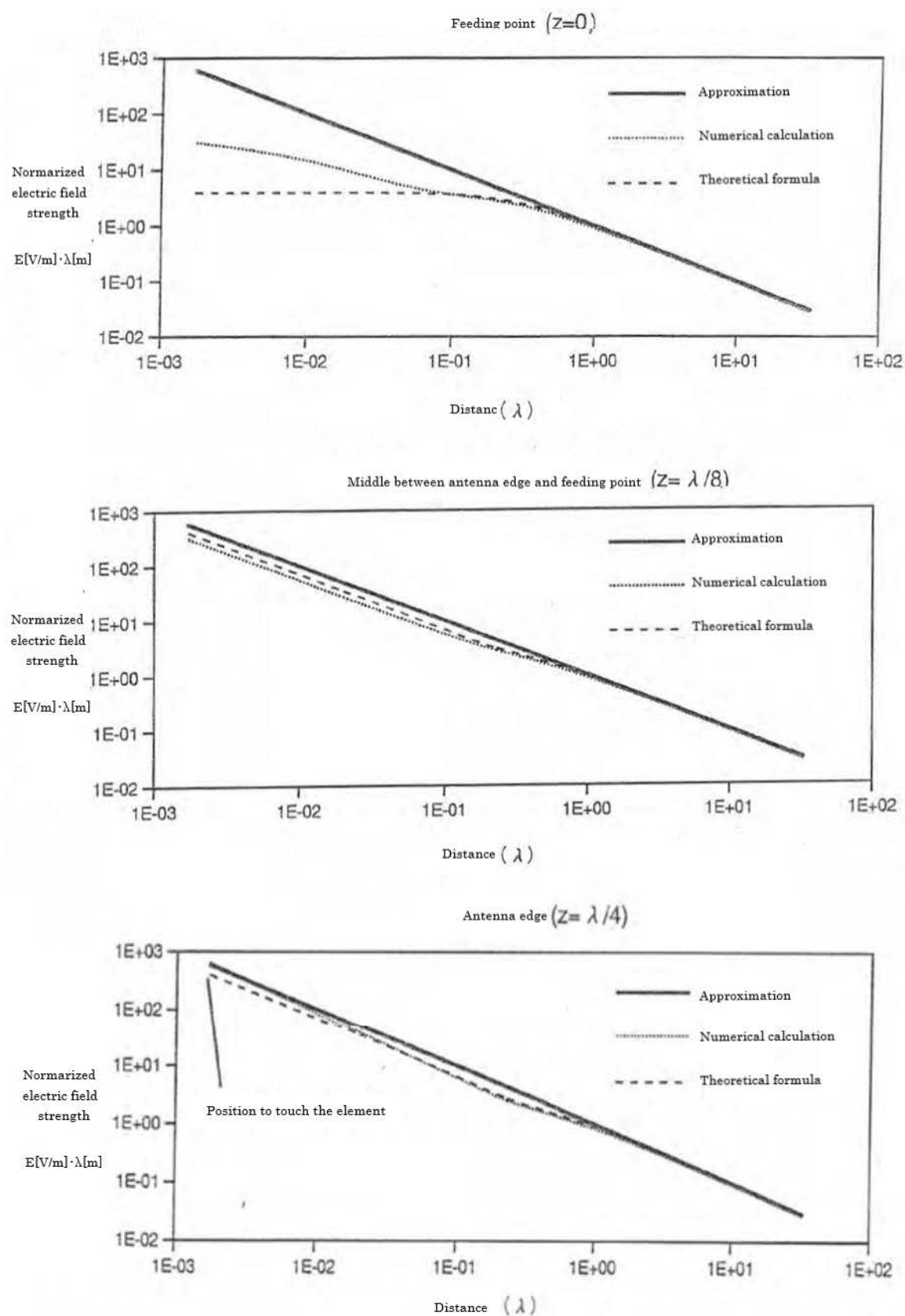


Figure 3 Distance characteristics of electric field strength at each point
Half wave-length dipole antenna Antenna input power : 20mW

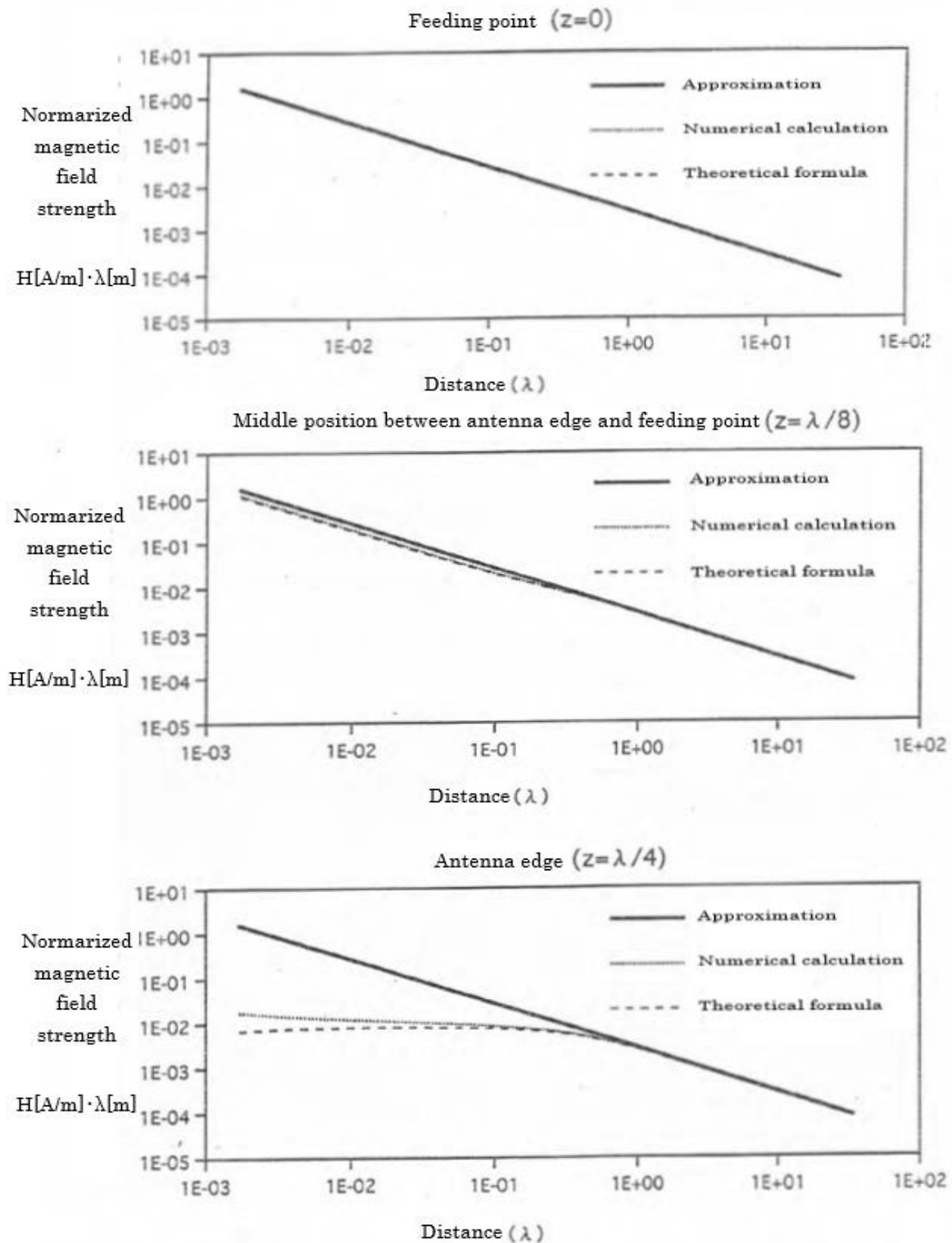


Figure 4 Distance characteristics of magnetic field strength at each position
Half wavelength dipole antenna Antenna input power: 20mW

Annex 2 Attenuation of vertical-plane and directional antenna for FM and television broadcasting stations

Typical antennas occupied in domestic FM and television broadcasting stations are listed as followed below.

- ① Yagi antenna
- ② Super gain antenna
- ③ Twin loop antenna
- ④ Corner antenna
- ⑤ Two-dipole antenna
- ⑥ Super turn style antenna (Horizontal polarization only)
- ⑦ Frame antenna (Horizontal polarization only)

Regarding the evaluation result of the acquired values of vertical-plane directional characteristics listed on above antennas, the attenuation of vertical-plane direction is interpreted impartially 10dB, as the vertical-plane directional attenuation is more than 10 dB at the elevation angle of higher than 45 degrees on more than 2 stage layered antennas. The following charts shown below are typical vertical-plane directional characteristics.

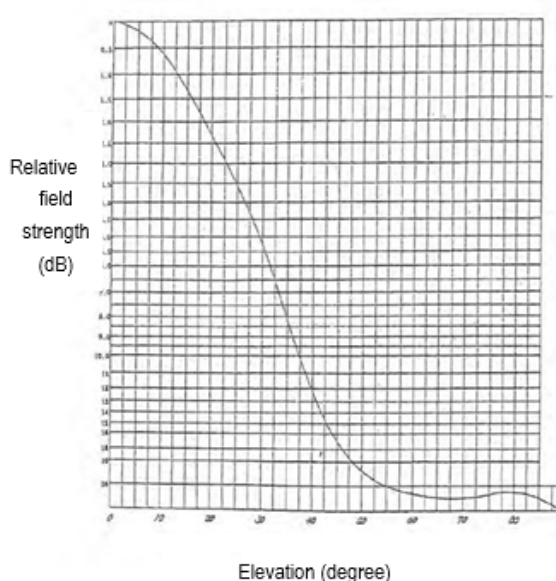


Fig. 1 2-stage 5 element Yagi antenna (horizontal)

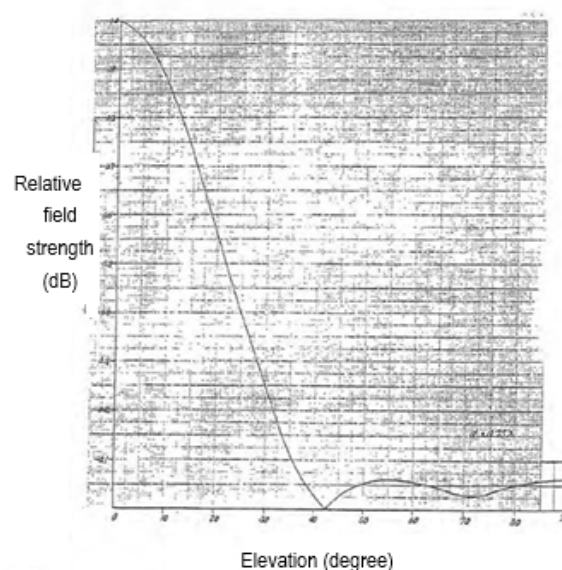


Fig. 2 2-stage 5 element Yagi antenna (vertical)

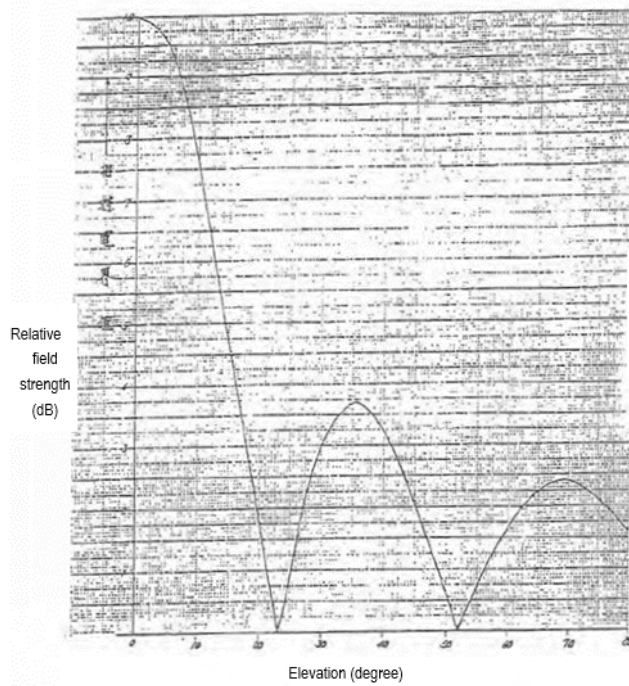


Fig. 3 3 stage super gain antenna (horizontal)

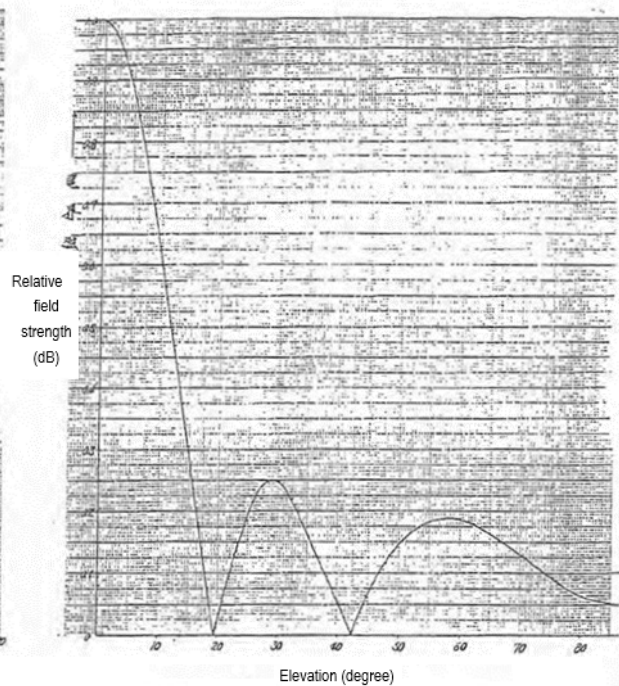


Fig. 4 3 stage super gain antenna (vertical)

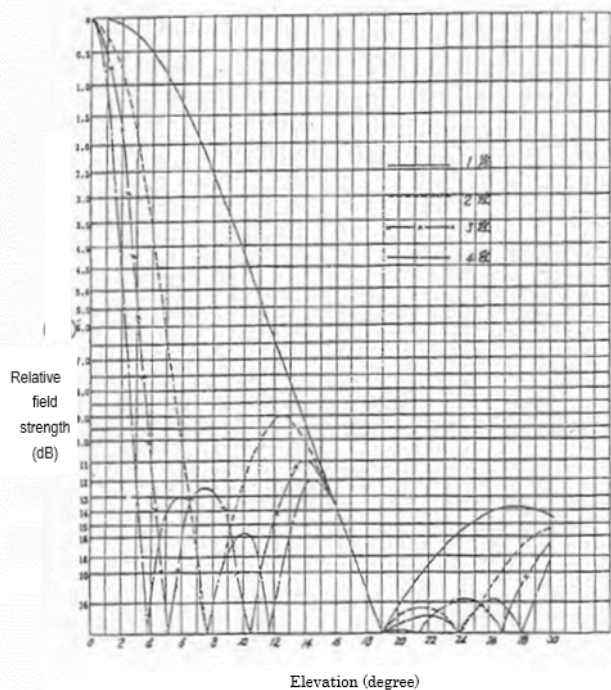


Fig. 5 Twin loop antenna (horizontal)

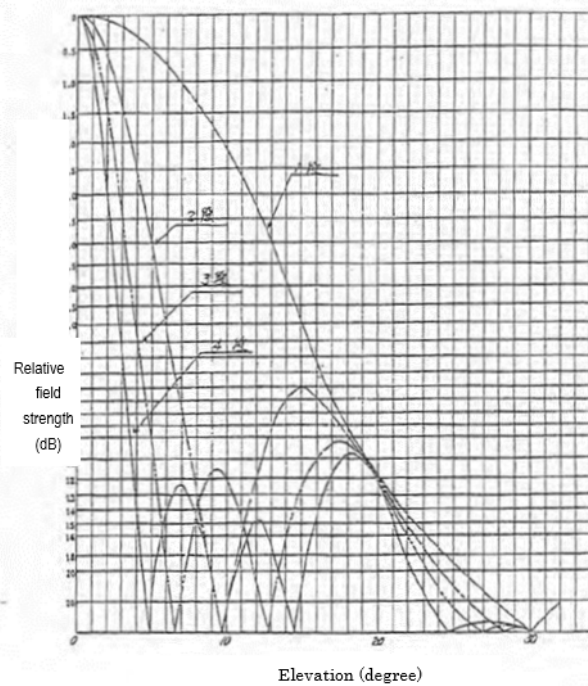


Fig. 6 Twin loop antenna (vertical)

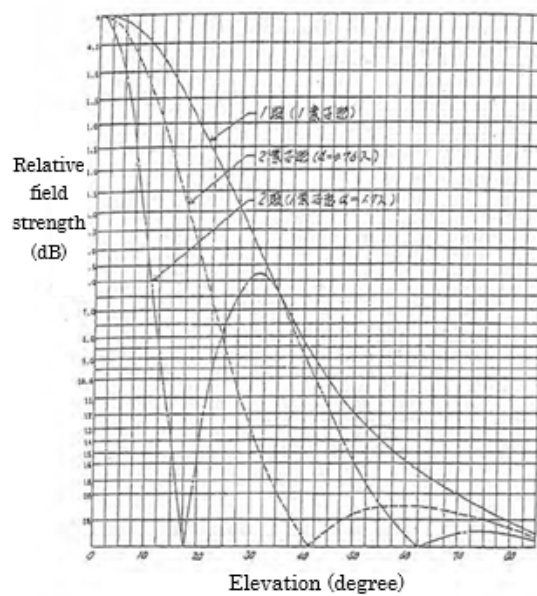


Fig. 7 Corner antenna (horizontal)

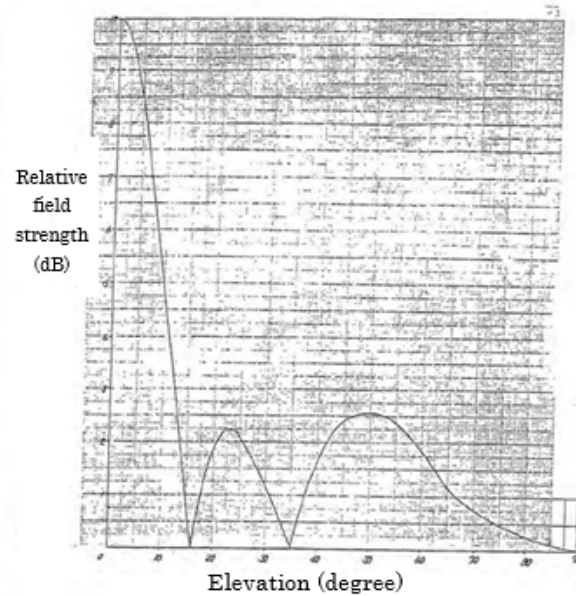


Fig. 8 3 stage coner antenna (vertical)

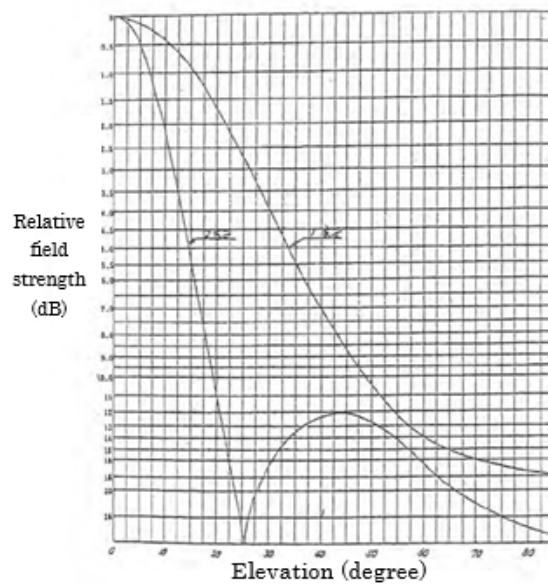


Fig. 9 2 dipole antenna (horizontal)

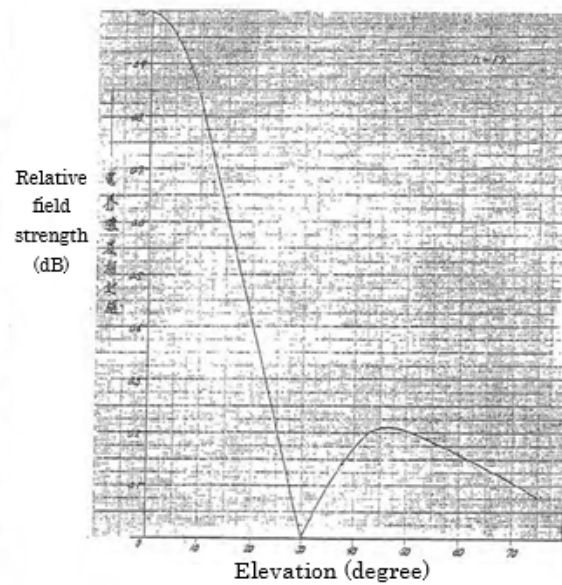


Fig. 10 2 dipole antenna 2 stage (vertical)

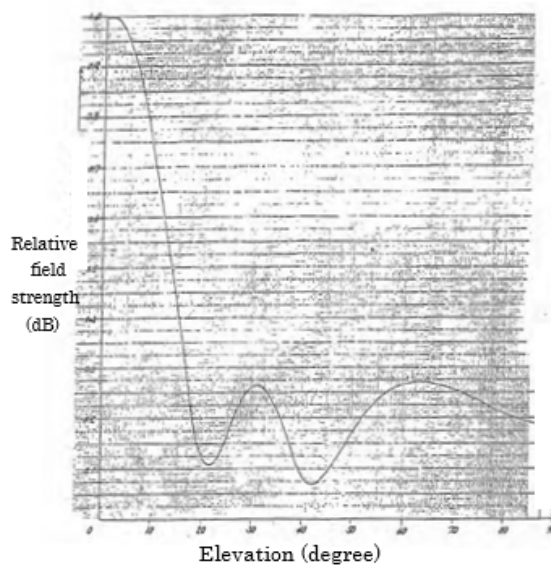


Fig. 11 3 stage super turn style antenna
(horizontal)

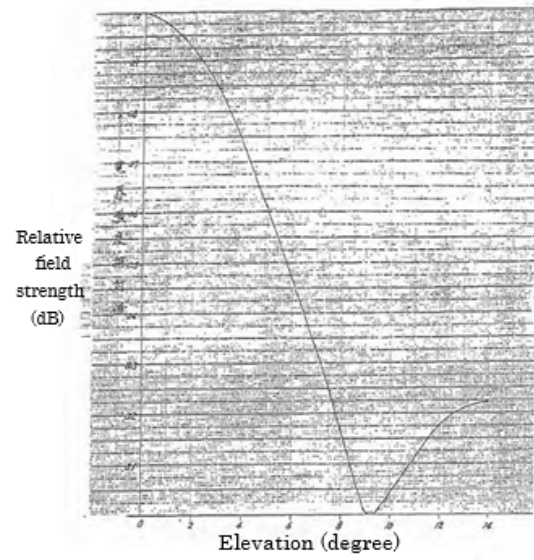


Fig. 12 8 stage framed antenna
(horizontal)

Annex 3 Applicable range of calculation formula for collinear array antenna

The ball model and the cylindrical model shall be applied for evaluating the compatibility with the value of the radiofrequency-exposure protection guidelines by the simple calculation method regarding the electromagnetic field strength in the surrounding area of mobile base stations (mobile phone, car phone, pager, PHS base station) which occupy the collinear array antenna.

Here, the theoretical values led by the strict analytical methods as the method of moments [5] and the excitation coefficient method [6], and these simple calculated results are put into the comparison. It is targeted to clarify that the evaluation of compatibility can be achieved in relatively better accuracy by applying either the ball model for far-field region or the cylindrical model for near-field region with taking a certain distance from the antenna ($0.6D^2/\lambda$) as the border.

1 The border between the long-distance region and the short-distance region

The cylindrical model is applied to the near-field region and the ball model is applied to the far-field region respectively, and the border of applied region shall be calculated with the formula written in FCC OET65 (Reference [1]) in this presumption. The formula of OET65 is originally applied to the aperture antenna, however the validity shall be confirmed on this decision method of the border using the concrete example of collinear antenna

Two methods are used that are the general moment method (Reference [5]) and the strict calculation method of the collinear array antenna (It is called the excitation coefficient method.) written in Reference [6] as the exact solutions.

1.1 Method of moments

The calculation is done on the method of Reference [5] regarding to the antenna model which arrays N-piece antenna elements in linear shown in Figure 1. The calculation is carried with considering the mutual connection among each antenna element.

However, as the basic model is non-directional, the calculated value of the electromagnetic field strength is multiplied with $\sqrt{3}$ for the directivity of the sector composition when it is a 120° beam.

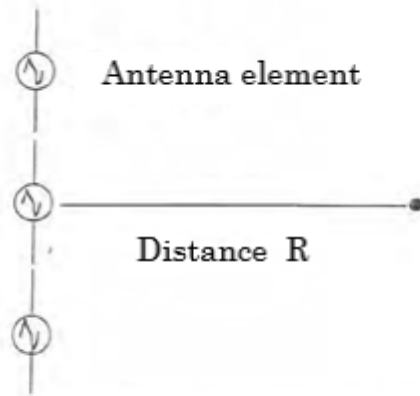


Figure 1 Arrangement of dipole antenna in linearity

1.2 Excitation coefficient method

The model of this calculation method is shown in Figure 2 with the next formula.

There is a method with presuming the antenna element as a point wave source for the method to estimate the electromagnetic field strength in the near-field of collinear array antenna. (It is called 'Excitation coefficient method' in this reference.) [6]

This method seeks the electric field strength F at the point A from any j -th point wave source among point wave sources arrayed linearly in the following formula below.

$$\hat{F} = a_j f_E(\theta_j) f_H(\phi_j) \frac{e^{-jk r_j}}{r_j} \hat{\theta}_j \quad (1)$$

Where

a_j : Excitation coefficient of element j

$f_H(\theta)$: H-plane radiation pattern of element j

$f_E(\phi)$: E-plane radiation pattern of element j

k : Phase constant in free space

r_j : Distance from element j

$\hat{\theta}_j$: Unit vector in θ direction for element j

Therefore, the overall electric field strength E_A composed with N elements is calculated as the result of vector addition from the electric fields of each wave source as below.

$$E_A = 7 \sqrt{\frac{G_d LP}{N \sum_{j=1}^N |a_j|^2}} \sqrt{\sum_{k=x,y,z} \left| \sum_{j=1}^N F_{jk} \right|^2} \quad (2)$$

where

G_d : Relative gain

P : Antenna input power

L : Feeder loss

However, as the basic model is non-directional, the calculated value of the electromagnetic field strength is multiplied with $\sqrt{3}$ for the directivity of the sector composition when it is 120° beam.

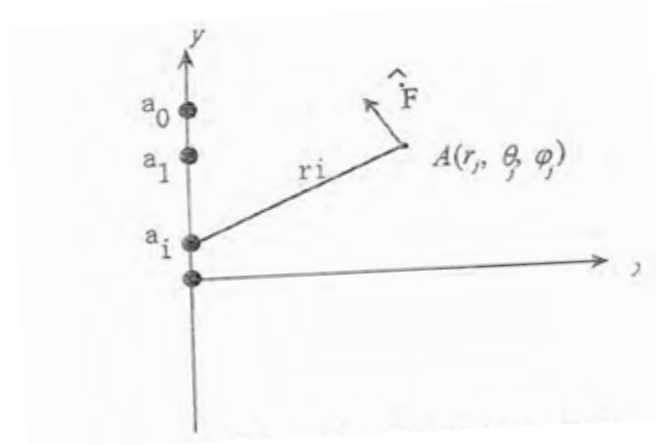


Figure 2 Point wave source arranged linearly

1.3 Calculation example of mobile and car phone base station

As a typical example, the electromagnetic field strength in the main beam of the collinear array antenna shown in Figure 3 of the overview and the specifications in Table 1 was obtained by a sphere model, a cylindrical model, method of moments and an excitation coefficient method. The results are shown in Figure 4 and Figure 5.

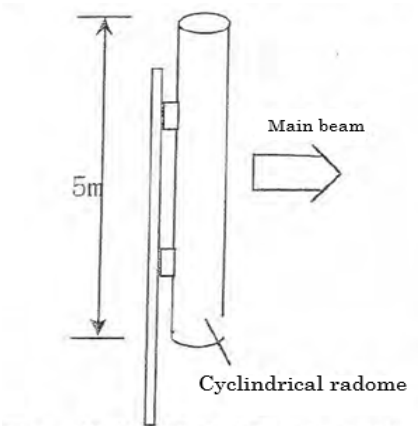


Figure 3 Antenna example of mobile phone base station

Table 1 Example of antenna specifications used for the estimation of mobile phone base station

Item	Numerical values, etc.
Basic configuration	Collinear array with reflective plate
Frequency	900MHz
Antenna aperture height h	5m
Main beam maximum absolute gain G	17dBi
First secondary beam absolute gain	-3dBi
Horizontal direction directional characteristics	120° beam

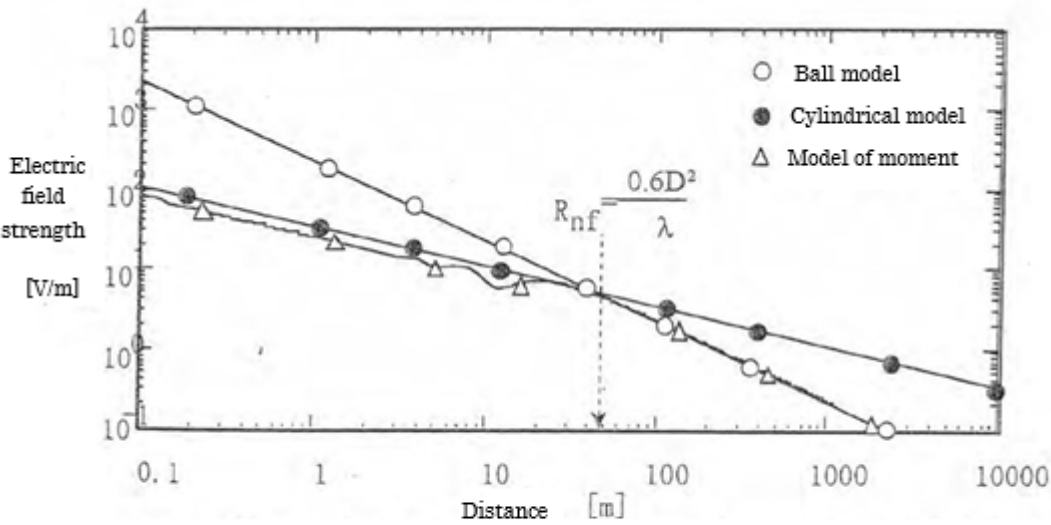


Figure 4 Calculated result of electric field strength in the main beam direction using 26 element array antenna
(Comparison among method of moment, ball model and cylindrical model)

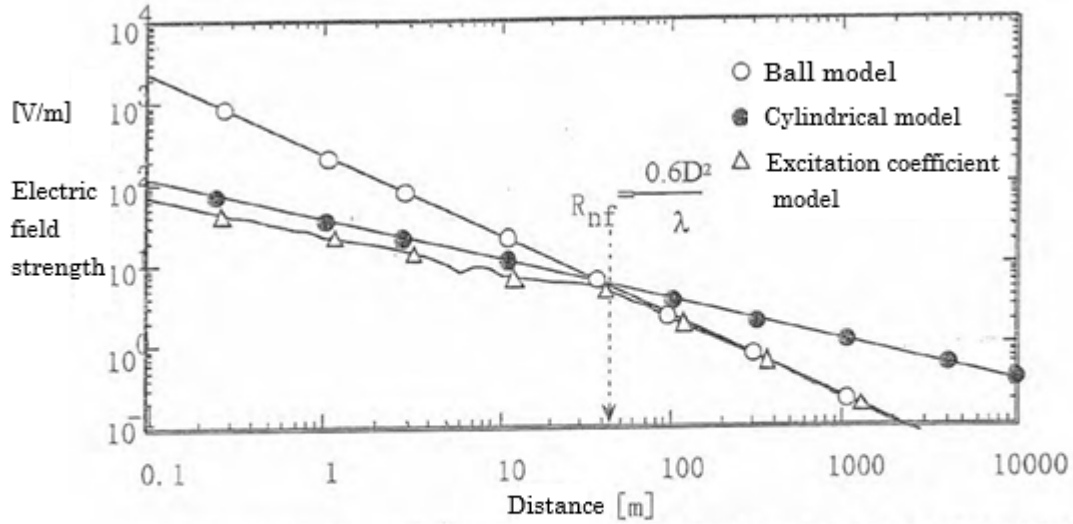


Figure 5 Calculated result of electric field strength in the main beam direction using 900MHz 26 element array antenna
(Comparison among excitation coefficient model, ball model and cylindrical model)

The following matters are found according to Figure 4 and Figure 5.

- (1) An electric field strength curve in which a cylindrical model is continuously connected in the near-field and a sphere model is connected in the far-field is in good agreement with the two electric field strength curves obtained by strict calculations with the intersection of the two electric field strength curves obtained by the cylindrical model and the spherical model as the boundary.
- (2) Regarding this intersection, the starting point R_{nf} in far-field region where the electric power density on the aperture antenna decreases in inverse proportion to the square based on the Reference [1] is led below.

$$R_{nf} = \frac{0.6D^2}{\lambda} \quad (3)$$

Here, D is the physical diameter of antenna aperture. $R_{nf} = 45\text{m}$ assuming that this D is equal to h of the collinear antenna length in Table 1 parameters. This R_{nf} almost matches with the intersection of the ball model and the cylindrical model. Therefore, it is available to apply Formula (3) described on FCC OET65 for the R_{nf} calculation.

1.4 Calculation example of pager base station

As the typical example, the calculated results same as in Clause 1.3 are shown in Figure 7 and Figure 8, while the overview of the collinear array antenna is in Figure 6 and the specifications of collinear antenna in table 2.

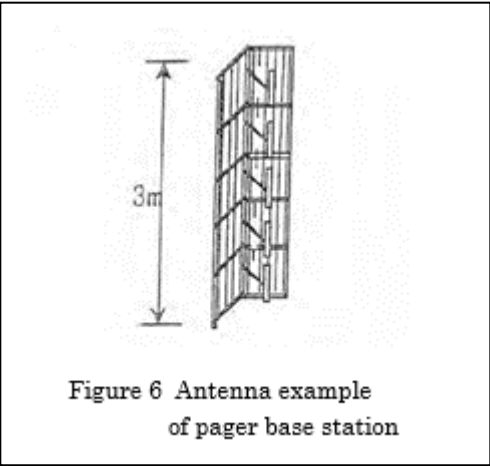


Table 2 Example of antenna specifications used for the estimation of pager base station

Item	Numerical values, etc.
Basic configuration	Collinear array with reflective plate
Frequency	280MHz
Antenna aperture height h	3m
Main beam maximum absolute gain G	10dBi
First secondary beam absolute gain	-3dBi
Horizontal direction directional characteristics	120° beam
Antenna input power P	2000W

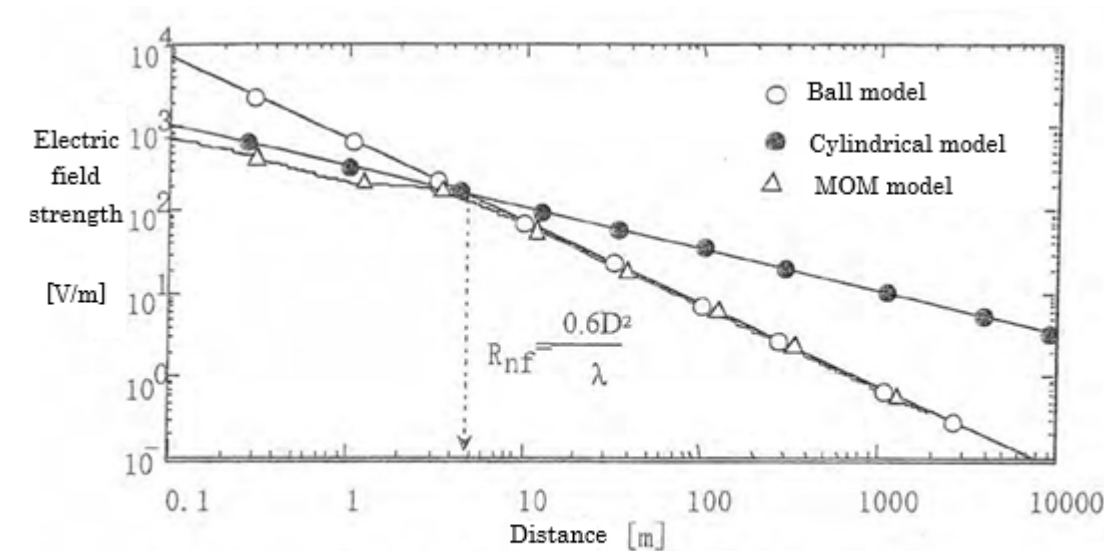


Figure 7 Calculated result of electric field strength in the main beam of 280MHz, 5 elelment array antenna (Comparison of MOM model, ball model and cylindrical model)

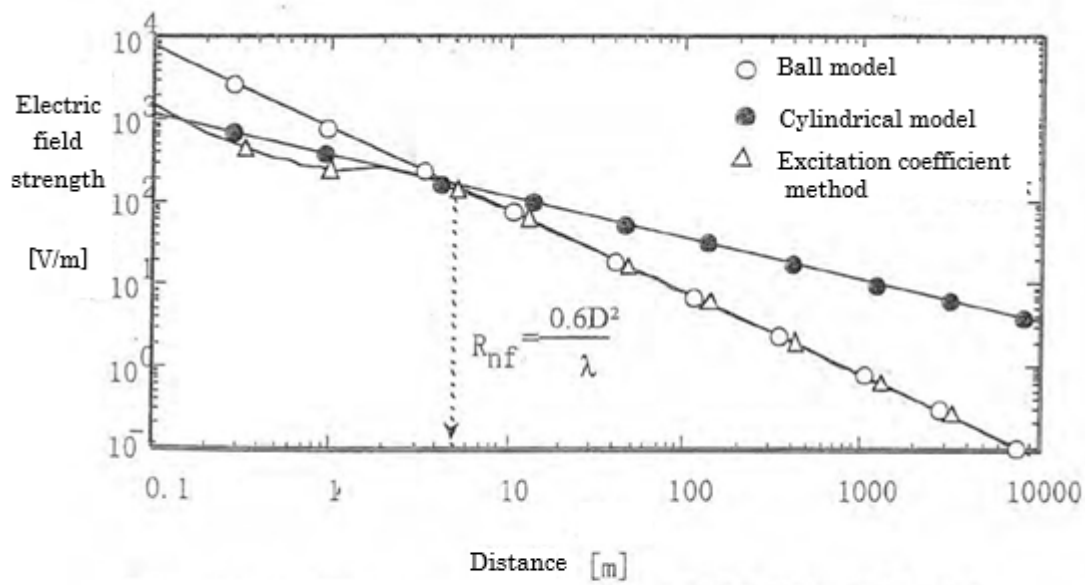
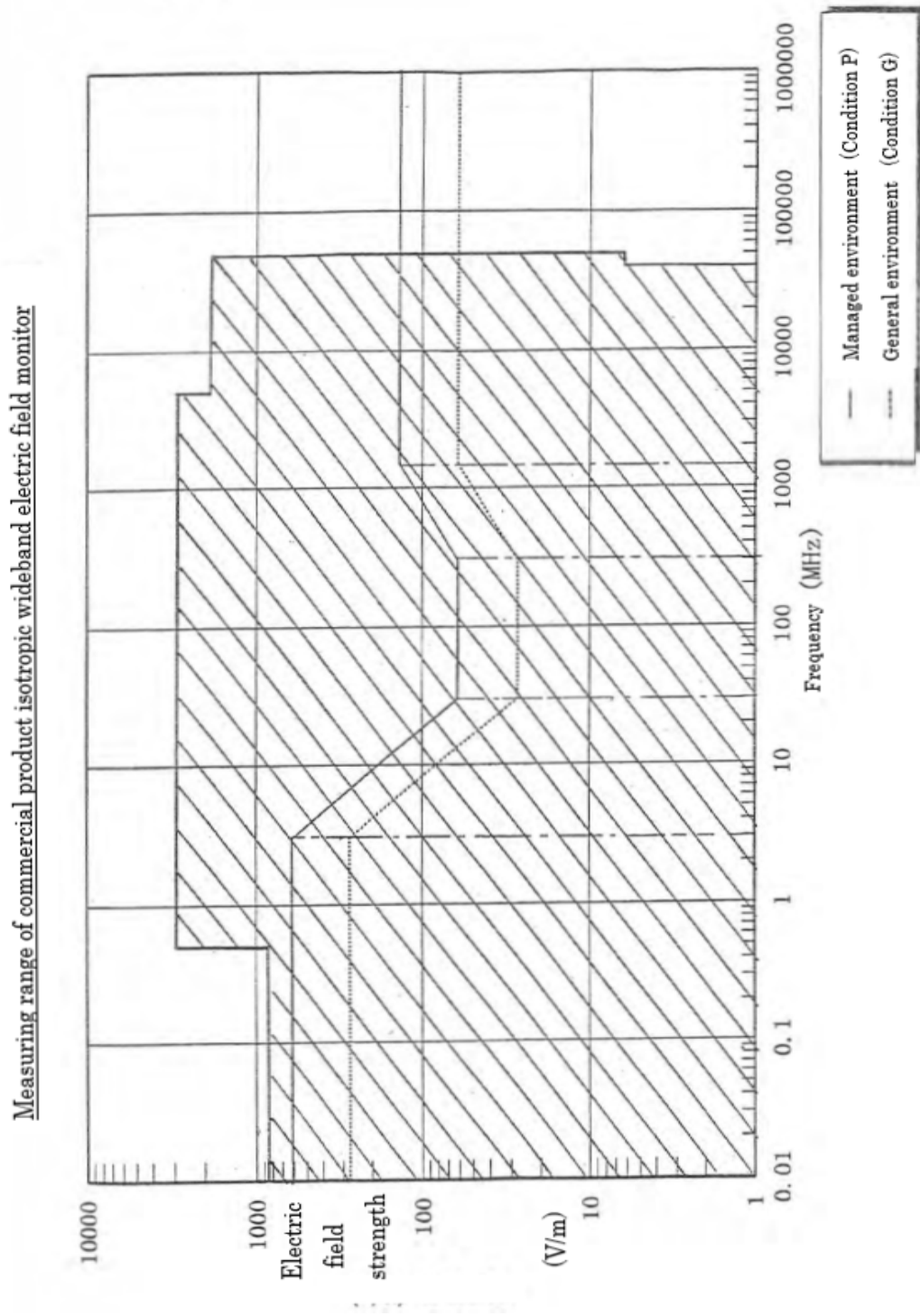


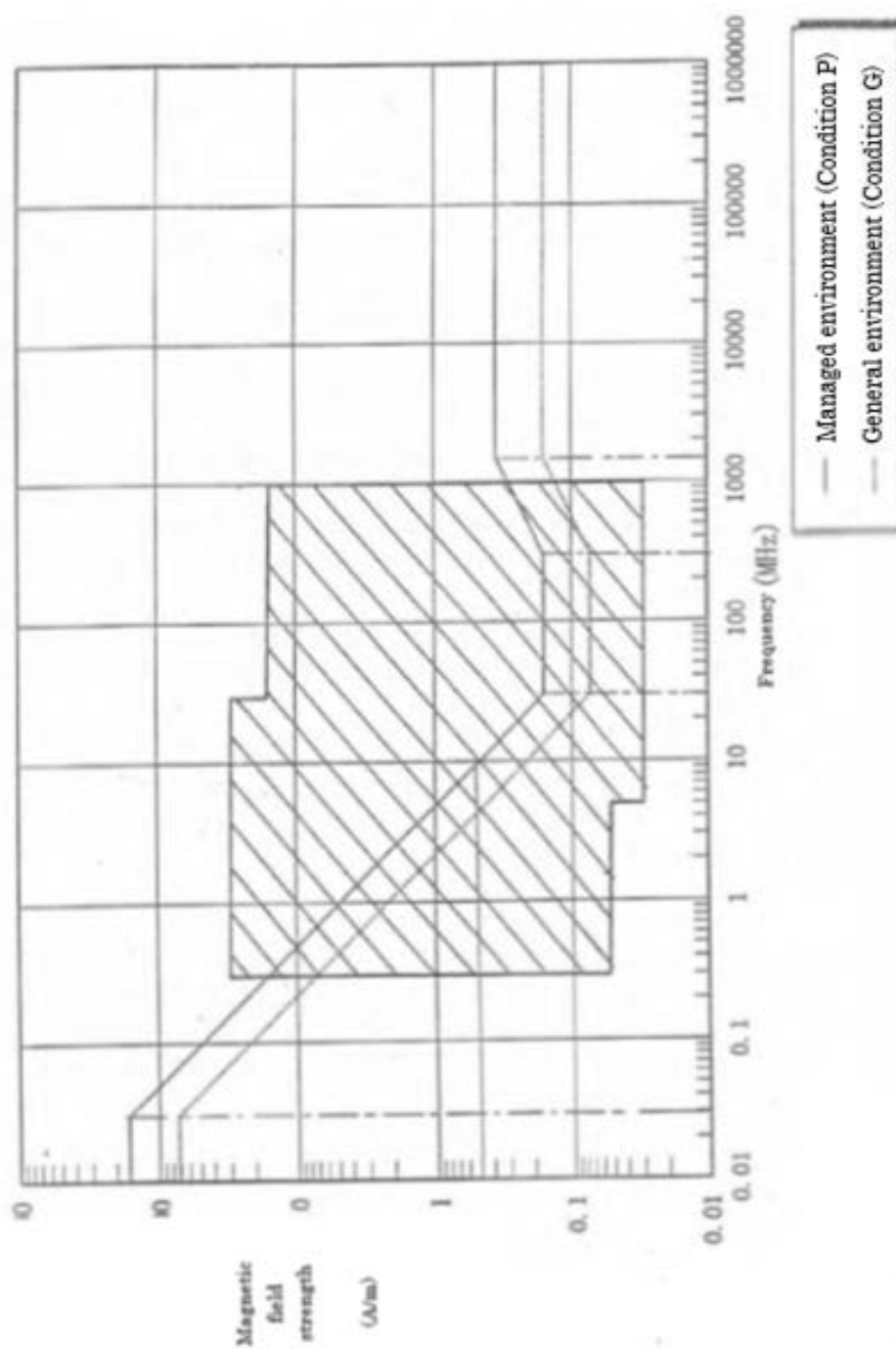
Figure 8 Calculated result of electric field strength in the main beam of
280MHz, 5 element array antenna
(Comparison of excitation coefficient method, ball model and cylindrical model)

From this calculation, the similar result as in Section 1.3 was obtained.

Annex 4 Measurable range and level of obtainable electromagnetic field probe



Measuring range of commercial product isotropic magnetic field monitor



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Relevant report 4

Information and Communication Council report (May, 2012) Inquiry No. 2030

[The state of local absorption guidelines]

This is the Report of No. 2030 inquiry [The state of local absorption guidelines]

It is adequate to revise the coverage of the guidelines as shown below regarding to the local absorption guidelines (4.2(3)) on the Telecommunication Technology Council Report for Inquiry No. 89 [The state of body protection on radiowave use](April 24,1997)

(3-1) Scope of application

The said guidelines cover the range of frequency from higher than 100kHz to less than 6GHz. The main object of this local absorption guidelines is the small radio equipments of mobile telephone terminals, etc. on the supposed cases that the antenna and housing which contribute to the electromagnetic radiation are used in very close distance to the human body.

Specifically, these guidelines (Local absorption guidelines) are expected to apply to the distance of within 20cm between electromagnetic radiator (mainly antenna), metals (housing , etc.) and the human body. In other cases without the above distance, it can be interpreted to satisfy the basic guidelines if one of three guidelines as the electromagnetic field strength guidelines, supplementary guidelines or local absorption guidelines.

But application of the electromagnetic field strength guidelines or supplementary guidelines shall not be excluded in a frequency band of more than 300MHz and less than 300GHz, as well as in the distance from more than 10cm to less than 20cm.

Moreover, regarding radio stations which are less than 20mW of average antenna power, they shall be considered no necessity of evaluation, as this case satisfies the local SAR radiofrequency-protection guidelines even if all the output power of the radio station is absorbed into the narrow part of human body. And under the managed environment it is also considered no necessity of evaluation for the radio stations of less than 100mW as the same above.

Relevant report 5

[The state of radiofrequency-exposure protection guidelines for low frequency region] in the report of Inquiry Number 2035 [The state of radiofrequency-exposure protection guidelines] of Information and Communications Council partial report (March, 2015)

Partial report

December 13, 2013 Inquiry Number 2035

[The state of radiofrequency-exposure protection guidelines for low frequency region (more than 10kHz, less than 10MHz)]

in

[The state of radiofrequency-exposure protection guidelines]

[The state of Radio frequency-exposure protection guidelines for low frequency region (more than 10kHz, less than 10MHz)] Report

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1 Definition

It is required to follow the definition of each issue regarding to the interpretation of radio frequency-exposure protection guidelines.

(1) “Electromagnetic waves” are the generic name of wave motions which vibrations in electric fields and magnetic fields propagate in a vacuum or in materials. Electromagnetic waves cover the low frequency electromagnetic field, so-called radio waves which are used for communication, lights radiated from the sun (infrared, visible lights, ultraviolet rays), radiations applied for the medical care (X-rays, γ -rays), etc. Electromagnetic waves which are shorter than ultraviolet rays in wavelength are divided roughly as ionizing radiation and longer ones are non-ionizing radiation.

(2) “Radio waves” are the electromagnetic waves of frequencies not exceeding 3,000,000MHz (3,000GHz) as defined in the Radio Act Article 2. The frequency band between 10kHz and 300GHz shall be set to target in the radio frequency-exposure protection guidelines.

(3) “Radio frequency-exposure protection guidelines” are the guidelines to be recommended for acquiring the safety situation in which the electromagnetic waves do not have any biological effects that are considered undesirable to the human body when the human body is exposed to an electromagnetic field (frequency range is from 10kHz to 300GHz) in the use of radio waves.

(4) “Basic guidelines” are the guidelines for evaluating the safety of the human body based on various biological effects caused in the human body (deep body temperature rise, current stimulation, high frequency burn, etc.) when the human body is exposed in the electromagnetic field.

(5) “Basic restrictions” are the restriction values on physical quantity directly related to the biological phenomenon by the radio wave exposure which possibly leads to the harmful effect on health.

(6) “Managed guidelines” are the guidelines used for actual evaluations expressed in measurable physical quantities (electric field strength, magnetic field strength, magnetic flux density, power density, current and specific absorption rate) which meet the basic guidelines and the basic restrictions. Managed guidelines are composed with electromagnetic field strength guidelines, supplementary guidelines and local absorption guidelines.

(7) “Electromagnetic field strength guidelines” are the guidelines that evaluate the safety of concerned space with electric field strength, magnetic field strength, power flux density and magnetic flux density in the objected space.

(8) “Local absorption guidelines” are the guidelines to be applied for detail evaluation according to basic guidelines, when some part of the body is exposed intensively in electromagnetic field by the electromagnetic wave radiated from the radio equipment which are occupied very close

to the body.

(9) “Supplementary guidelines” are the guidelines which are applied for executing the detail evaluations when electromagnetic field strength guidelines are not satisfied. Supplementary guidelines are expressed in the style of mitigation or exclusion to be applied with electromagnetic field strength guidelines according to these situations as follows; when exposed situations in the electromagnetic field (uneven, local, surface, etc.), objected biological effects (contact current and induced current) and attribution of radio wave emission source are evident, the guidelines are presented in a form that relaxes or excludes the application of the electromagnetic field strength guidelines based on these situations.

(10) “Managed environment” covers that recognition of status that the human body is exposed in the electromagnetic field, identifying the radio wave emission source and performing appropriate management according to these above situations. For example, this managed environment shall be applied to the case that workers in the environment of handling radio waves on a daily basis with being exposed in the electromagnetic field (broadcasting station, high frequency processing plant, etc.). The managed environment is equivalent to the condition P of radio frequency-exposure protect guidelines in 1990.

(11) “General environment” are the cases (environment) of indeterminate factors existed without the recognition of status that the human body is exposed in the electromagnetic field and proper management, etc. The cases that residents in general living environment are exposed in the electromagnetic field are applicable. Therefore, specific values of general environment are stricter than of managed environment in the applying guidelines. General environment is equivalent to the condition G of radio frequency-exposure protect guidelines in 1990.

(12) “Specific absorption rate (SAR)” is absorbed power per unit mass arisen with the exposure of the living body in the electromagnetic field. It is called “the whole body average SAR” which is a SAR averaged over the whole body and “Local SAR” which is SAR averaged within arbitrary 1 g or 10 g organization.

(13) “Electromagnetic field” is a general term of electric and magnetic fields.

(14) “Electric field strength” is the electric field strength of electromagnetic field.

(15) “Magnetic field strength” is the magnetic field strength of electromagnetic field.

(16) “Electric power density” is the radiant power per vertical unit area toward the propagation direction.

(17) “Induced current” is the current flowing by electromagnetic induction. Here, it includes the current induced inside the human body as the result that human body is exposed to electromagnetic fields.

- (18) “Contact current” is the current flown through the contact point with touching the non-grounded conductive object put in the electromagnetic field by the grounded human body.
- (19) “Contact hazard” is the potential situation which likely causes the contact current.
- (20) The “Ungrounded condition” is the condition that the influence of ground such as the induced current does not flow to the ground can be ignored.
- (21) “Uniform exposure” is the exposure of the whole body in the electromagnetic field regarded as the spatial domain of electromagnetic field in which the human body exists can be considered almost uniform. In this case, it includes the case that the wave impedance in free space is not $120\pi[\Omega]$. It shall be considered as uniform when the distance from the wave source enough larger than the height of human (for example, more than 15m in less than 0.3MHz band, more than 10m in between 0.3MHz and 300MHz, more than 5m in more than 300MHz) in free space.
- (22) “Uneven exposure” is cases which cannot be considered of uniform exposure.
- (23) “Local exposure” is when a part of the body is intensively exposed to electromagnetic fields. This refers to the case where irradiation is performed in the vicinity of an antenna smaller than the size of a human body or spot-like irradiation using radio waves having a short wavelength.
- (24) The “whole body exposure” is the case where the whole body is exposed to an electromagnetic field regardless of location. It is not necessarily uniform, but corresponds to the case of non-local exposure.
- (25) “Average time” is the measurement time based on the focused biological effects for the evaluation of compatibility to the guideline values. Average time used in the radio frequency-exposure protection guidelines is 6 minutes for the thermal effect.
- (26) “Far-field” is an area of an electromagnetic field in a region where the distance from the electromagnetic wave source is farther than either $2D^2/\lambda$ or $\lambda/2\pi$ and there is no reflection or scattering. Here, D is the maximum dimension of the antenna, and λ is the free space wavelength.
- (27) “Near-field” is the electromagnetic field of region (near region) which is not far-field.
- (28) “r.m.s.” is the value which is the square root of the mean square throughout whole one cycle of periodic wave form. The r.m.s. of electric field strength and magnetic field strength in electromagnetic field which changes periodically is the value related to Joule heat.

2.1 The feature and composition of the protection guidelines

2.1.1 Biological effects of electromagnetic fields as a basis of protection guidelines

Each tissue in the human body is considered a derivative with electrical constants electromagnetically. The theoretical analysis is performed in terms of electrical characteristics on this living body regarding to the interaction between the electromagnetic field and living

body, besides above the experimental analytical method is also established by the simulated human body composed with the proper dielectric constant and conductivity. The biological effects of electromagnetic fields can be roughly classified to thermal effect, stimulation and other effects according to the research results based on these as shown in Table 1.

Table 1 Relationships between electromagnetic waves and biological effects

Classification of effect		Factors of biological change	Evaluation amount of effect	Relationship to electromagnetic waves
Thermal effect	Whole body heating	Heat adjustment response Deep body-temperature heating Heat stress	Whole body average SAR Rising temperature (core body temperature)	Macro interaction (Dosimetry approach is available)
	Local heating	Tissue heating	Local average SAR Rising temperature	
Stimulation		Nerve and muscle excitement by current stimulation	Electric field strength inside body (Local tissue temperature)	
Other effects		Unknown	Electromagnetic field strength (Modulation frequency)	Micro interaction

There has been a great deal of researches conducted on the thermal effect and the stimulating effect among these biological effects and the causal relationship with the electromagnetic field strength has been grasped almost quantitatively. According to them, impacts of the stimulus in the low frequency region of less than 10MHz and thermal effect in the high frequency region of more than 100kHz are mainly observed. But, other effects beside the stimulus and thermal effect are not recognized as the status related to the phenomenon in the living body. Therefore, the fact that they disturb human health has not shown yet.

For this reason, target electromagnetic field biological effects in the radiofrequency-exposure protect guidelines are limited to thermal effect and stimulus. Effects by pulse wave and modulated wave captured in the category of thermal effect and stimulus are included in these. Also, the contact current caused by electromagnetic field is considered, although it is not the direct effect from electromagnetic field.

In foreign countries radiofrequency-exposure protect guidelines are enacted on a similar idea, however, a fact that a health effect has occurred regarding to thermal effect and stimulus as well as other effects has not yet recognized to date within range of the guidelines.

2.1.2 Problems with the target quantity of protection guidelines

Thermal effect to living body by electromagnetic field is described as the rise of body temperature or tissue temperature due to the generation of Joule heat in tissue. This temperature rise is closely related to the tissue absorbed energy so that amount of energy absorbed by the unit mass of tissue per unit time in other words, specific absorption rate (SAR) is used as the evaluation amount. On the other hand, the stimulation (effect) is related to the electric field strength induced in tissue inside the human body. The specific absorption rate (SAR) can be caught as the phenomenon which depends on the electric field strength induced in tissue inside the human body and tissue conductivity. The biological effect in electromagnetic fields has a close relationship to the electric field strength inside tissue. But as it is impossible to measure electric field strength directly inside tissue, it is required to estimate electromagnetic phenomenon inside the human body in some way. At the present time, standard measurement methods for this estimation procedure are prepared for only some wireless devices. Therefore, it is uncommon to specify the measurement target quantities of electromagnetic phenomenon inside the human body at the present time.

As the radiofrequency-exposure protection guidelines is required to evaluate the safety of radio equipment quickly in many occasions when we get involved with them, the guidelines are not enough to play its realistic role with only describing expressions of the amount related to electromagnetic phenomenon which are unmeasurable directly inside human body. Therefore, it is necessary to convert electromagnetic phenomenon inside human body to measurable quantity (electromagnetic field strength, etc.) and safety should be assessed.

2.1.3 Composition of protection guidelines

Situations that require protection guidelines are generally classified into 3 cases as shown below.

- ① Aspects of evaluating the spatial electromagnetic environment
- ② Aspects of radiation emission from radio equipment and evaluation of how the equipment is used.
- ③ Aspects of evaluating protective measures against the electromagnetic field.

The electromagnetic field in a space where no human body exists is subject to evaluation in case①. The radio emission source is far enough, and if there is no object that scatters radio waves, such as metal, in the close distance of the space where the human body is located the electromagnetic phenomena inside the human body at that position can be regarded as having a substantially constant relationship with the electric field intensity and the magnetic field

intensity measured when no human body exists in that space. Under these conditions, protection guidelines can be set using the electromagnetic field strength in a space where no human body exists. This guideline is called the electromagnetic field strength guideline. Since the electromagnetic field covered by the protection guidelines is usually near-field or non-uniform, the situation where the field strength guidelines can be applied as it is whole-body limited. Electromagnetic environment that does not satisfy such conditions is the case where evaluation of the real of space is not appropriate. In this case, consider case②.

In ②, the correlation between the electromagnetic radiation source and the human body is the subject of evaluation. If the relationship between the electromagnetic radiation source and the human body is constant, it can be regarded as an evaluation for the electromagnetic radiation source itself. In other words, the case where the radiation source is far away can be regarded as the matter of the case ①, but it is generally necessary to perform the evaluation based on the electromagnetic phenomenon inside the human body. The guideline for such evaluation based on electromagnetic phenomena inside the human body (excluding the evaluation related to protection from stimulation effects) is called the basic guidelines. In addition, in the protection from stimulating effects in the low frequency range (10kHz to 10MHz),” the restriction limits on physical quantities directly related to in vivo phenomena due to radio wave exposure that may lead to harmful effects on health" are called basic limits.

However, since the basic guidelines and basic restrictions include expressions using quantities that cannot be easily measured, it is not practical to evaluate all of the problems in ② by the basic guidelines or basic restrictions. It cannot be expected to be used. Therefore, in order to practically address the problem ②, it is necessary to provide a guideline based on measurable evaluation quantities. In addition, it is necessary to provide a guideline for the contact current in the case where the contact hazard is not prevented in the electromagnetic field strength guideline. These guidelines are called supplementary guidelines.

The supplementary guidelines are shown in a form supplementing the guidelines for electromagnetic field strength based on the basic guidelines or basic limits and international guidelines on contact current, and consist of the following three items.

- (1) When exposed to uneven or localized electromagnetic fields
- (2) Contact current
- (3) Ankle induced current

In addition, (1) and (3) of the supplementary guidelines have the character as a simple evaluation method of the electromagnetic phenomena inside the human body instead of the basic guidelines and basic restrictions, and should be dealt with in the basic guidelines or basic

restrictions. In addition, (1) and (3) of the supplementary guidelines have the character as a simple evaluation method of the electromagnetic phenomena inside the human body instead of the basic guidelines and basic restrictions, and it is necessary to keep in mind that they should be originally dealt with in the basic guidelines or basic restrictions.

In the case of ③, there are cases where it is impossible to judge without directly evaluating the phenomenon inside the human body. In this case, in particular, under conditions where the human body and the electromagnetic radiation source are closer to each other than 20 cm (10 cm for 300 MHz or more), which is 100 kHz or more, the evaluation is basically performed according to the local absorption guidelines. When the local absorption guidelines cannot be applied, it is necessary to perform evaluation based on the basic guidelines or basic restrictions, and it is necessary to carefully estimate and evaluate them at research institutions. As described above, the protection guidelines are composed of the electromagnetic field strength guidelines, supplementary guidelines, local guidelines, basic guidelines, and basic restrictions. Among them, the electromagnetic field strength guideline, the supplementary guideline, and the local absorption guideline are guidelines for specifically applying to actual problems. These three guidelines are called managed guidelines. The basic guidelines and basic restrictions are the basis of the managed guidelines, and have the property of providing a basis for determining safety when conformity with the managed guidelines cannot be evaluated. The protection guidelines are based on the current research results and the actual situation of radio wave use. Therefore, it is necessary to supplement or revise according to changes in these situations. The progress of research on the biological effects of electromagnetic fields is mainly reflected in basic guidelines or basic restrictions, and the progress of research on measurement and estimation methods for electromagnetic phenomena in living bodies and consistency with the real world due to changes in the use of radio waves is reflected in the managed guidelines. In view of this position, the basic guidelines and basic restrictions are not easily amended, but the managed guidelines are subject to change depending on environments.

2.1.4 Two-stage structure consisting of basic restrictions and managed guidelines

For the evaluation by the protection guidelines to be reliable, it is necessary that the protection guidelines are used properly and that it can be checked if necessary that the electromagnetic environment situation does not change. If such a situation can be ensured, the managed guidelines (electromagnetic field strength guidelines and supplementary guidelines) based on figures converted from the basic guidelines or basic restrictions shall be applied. However, if the situation of radio wave use is not correctly recognized, situations that do not satisfy the basic guidelines or basic restrictions may occur unconsciously, and actions that are conscious of the

existence of electromagnetic fields cannot be also expected. Therefore, in order to ensure sufficient safety even in such a situation, it is necessary to take appropriate safety factors into consideration, as in the methods adopted as reasonable countermeasures in foreign protection guidelines, appropriate guidelines need to be established taking into account additional safety factors.

From the above viewpoints, a managed environment that targets the situation where the electromagnetic environment is managed with the gist of the protection guidelines and the general environment which covers the situation where the protection guidelines and use of radio wave are not confirmed are classified. Considering the uncertainty due to insufficient management of the electromagnetic field compared to the managed environment, the general environment has an additional safety factor of approximately 5 times converted to the power density from the managed environment.

In addition, as for basic restrictions on protection from stimulating action in the low frequency range (10kHz ~ 10MHz), guide values for the general environment are set in addition to the managed environment.

2.1.5 Application procedure of protection guidelines

The procedure for applying the managed guidelines (electromagnetic field strength guidelines, supplementary guidelines and local absorption guidelines) and the protection guidelines consisting of basic guidelines and basic restrictions is as follows.

When actually conducting an evaluation, the guidelines for electromagnetic field strength are applied first regardless of the conditions of the radiation source and the like. If the subject to be evaluated is to be able to use the radio wave based on the gist of the protection guidelines by recognizing the actual conditions of radio wave use, the managed environment is applied. If such conditions are not satisfied, the general environment shall be applied. If the electromagnetic field strength is satisfied in all the target spaces (places), it is determined that the spaces (places) are safe.

The electromagnetic field in the target space is generally non-uniform or near-field in many cases, and is evaluated as a value larger than the true electromagnetic field strength. If the electromagnetic field strength is not satisfied in such a situation, it is determined whether it is safe or not by performing a detailed evaluation based on the supplementary guidelines. In addition, if the supplemental guidelines cannot be applied and the human body and the electromagnetic radiation source are close to each other, the evaluation is performed using the local absorption guidelines.

As a result of the evaluation by such a procedure, if the managed guidelines of the general

environment are not satisfied, the management corresponding to the managed environment is performed or a measure is taken to satisfy the guidelines. If it is shown that the managed guidelines are not satisfied, there is a possibility that the basic guidelines or basic restrictions may not be satisfied, and measures shall be taken to satisfy them, or the possibility of injury to the human body will be determined more directly. In order to do so, it is necessary to conduct an evaluation that reverts to the basic guidelines or basic restrictions.

In the evaluation based on the basic guidelines or basic restrictions, the specified amount may include an amount for which a specific measurement method or estimation method is not sufficiently established. The evaluation in this case is performed in accordance with a method deemed appropriate by the research institution.

2.2 Managed guidelines

The managed guidelines are based on the basic guidelines and basic restrictions, and the evaluation of the actual electromagnetic environment is mainly performed with using the managed guidelines. The guidelines consist of an electromagnetic field strength guidelines, supplementary guidelines and local absorption guidelines.

2.2.1 Electromagnetic field strength guidelines

(1) Managed environment

Tables 2(a) and 2(b) show the guideline values of the electromagnetic field strength in the case of managed environment. In the frequency range from 100kHz to 10MHz, it is necessary to satisfy both Table 2 (a) and Table 2 (b). If the measurement target space does not locally satisfy values in this table, the supplementary guidelines in 2.2.2 (1) shall be applied.

Figure 1 and Figure 2 show graphs of guideline values in Tables 2 (a) and 2 (b).

Table 2 (a) Electromagnetic field strength (6 minute average value) guideline value of managed environment

Frequency f	r.m.s. value of electric field strength E [V/m]	r.m.s. value of magnetic field strength H [A/m]	Electric power density S [mW/cm ²]
100kHz — 3MHz	614	$4.9f(\text{MHz})^{-1}$ (49—1.63)	
3MHz — 30MHz	$1.842f(\text{MHz})^{-1}$ (614—61.4)	$4.9f(\text{MHz})^{-1}$ (1.63—0.163)	
30MHz — 300MHz	61.4	0.163	1
300MHz — 1.5GHz	$3.54f(\text{MHz})^{1/2}$ (61.4—137)	$f(\text{MHz})^{1/2}/106$ (0.163—0.365)	$f(\text{MHz})/300$ (1—5)
1.5GHz — 300GHz	137	0.365	5

Table 2 (b) Electromagnetic field strength guideline value related to human body protection by stimulation in managed environment

Frequency f	r.m.s. value of electric field strength E (kV/m)	r.m.s. value of Magnetic field strength H (A/m)	r.m.s. value of magnetic flux density (T)
10kHz — 10MHz	1.7×10^{-1}	80	1×10^{-4}

Note 1: If contact hazard is not prevented below 15MHz, the protection from the contact current can be ensured by applying the supplementary guidelines 2.2.2 (2).

Note 2: The effective value of the electromagnetic field strength (average time 6 minutes) when the non-grounding condition of human body is not satisfied must be $3.200 f \text{ (MHz)}^{-3/2}$ V/m (that is, 614V/m to 20V/m) at frequencies from 3MHz to 30MHz, 20V/m at frequencies from 30MHz up to 100MHz and $0.2f \text{ (MHz)}$ V/m (that is 20V/m~61.4V/m) or less. However, if this is not satisfied and the value is below the guideline value in Table 2 (a), the supplementary guidelines 2.2.2 (3) may be applied.

Note 3: If the electric field strength or magnetic field strength changes within the average time shown in Table 2 (a), the effective value within the average time which is the root mean square value within the average time should be used and if the power density changes, the averaged value within the average time should be used.

Note 4: Regarding Table 2(a), if the electromagnetic field consists of multiple frequency components that cannot be ignored with respect to the guideline value, the sum of squares of the ratio of each frequency component to the guideline value is obtained for the electric field strength and magnetic field strength, and the sum of the ratio of each frequency component to the guideline value is also obtained as for the power density. Their sum must not exceed one.

Regarding Table 2(b), if the electromagnetic field consists of multiple frequency components at a level that cannot be ignored with respect to the guideline value, the ratio of each frequency component to the guideline value for the electric field strength, magnetic field strength and magnetic flux density is calculated, or an appropriate weighted average is calculated for the ratio of each frequency component to the guideline value according to the frequency characteristic of the guideline value (Refer to Attachment). Their sum must not exceed one.

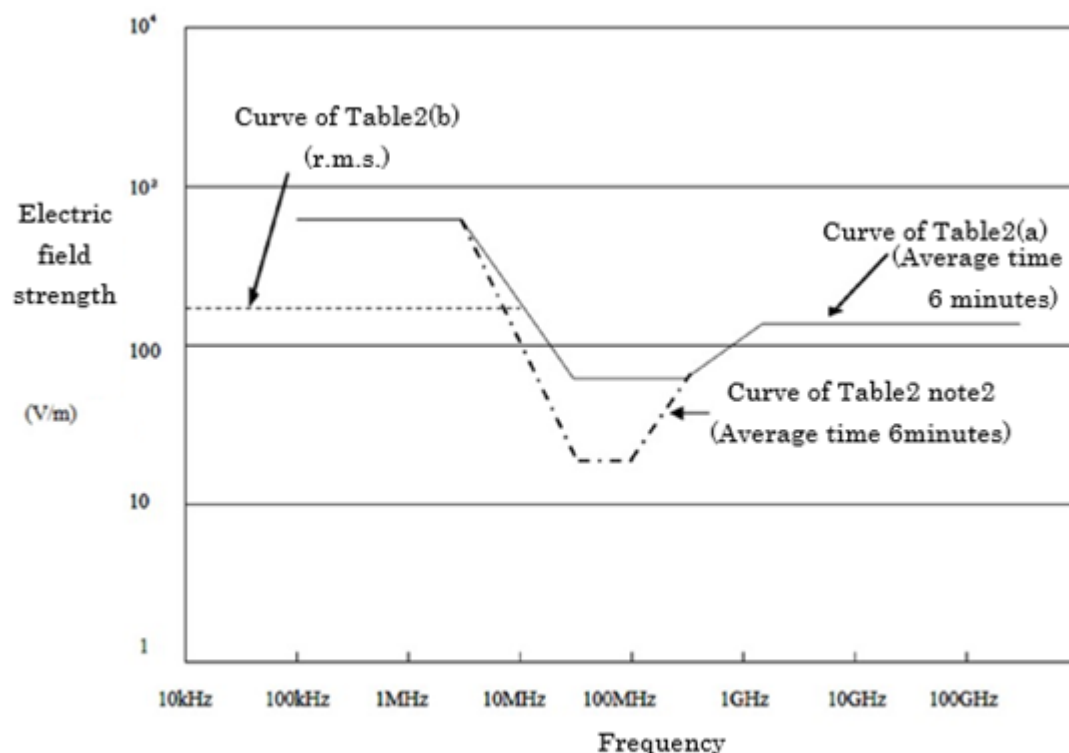


Figure 1 Indication value of electric field strength
(Managed environment)

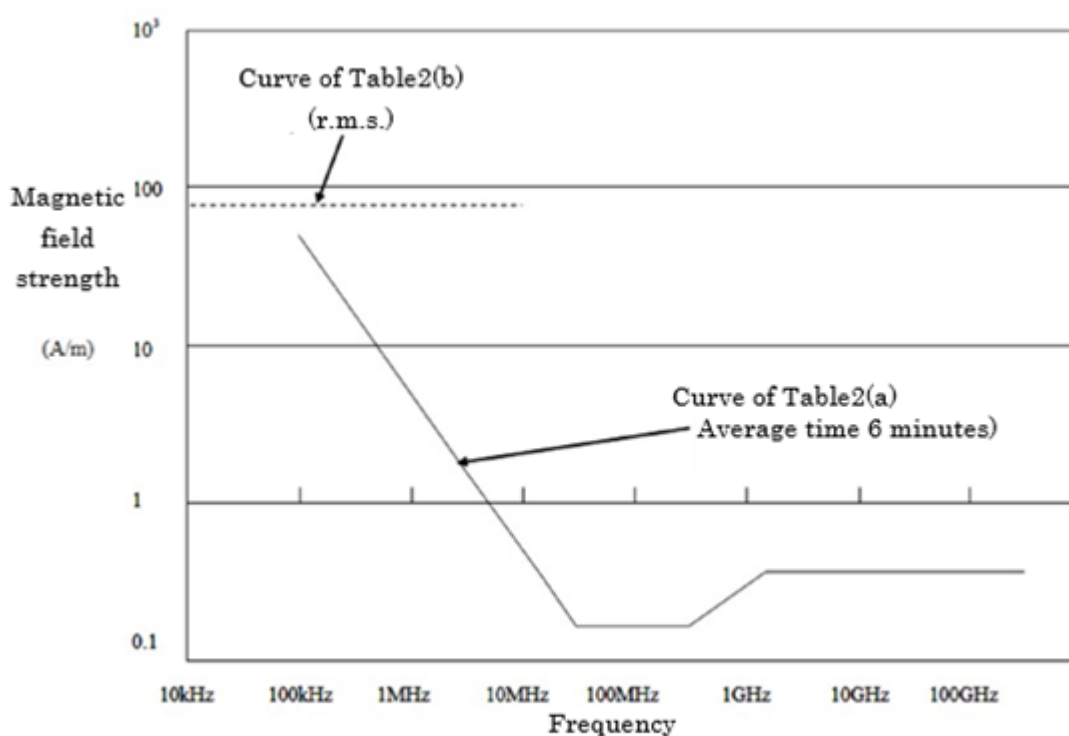


Figure 2 Indication value of magnetic field strength
(Managed environment)

(2) General environment

Tables 3 (a) and 3 (b) show the guideline values for electromagnetic field strength in the general environment. In the frequency range from 100kHz to 10MHz, it is necessary to satisfy both Table 3 (a) and Table 3 (b). If the measurement target space does not locally satisfy the values in this table, the supplementary guidelines in 2.2.2 (1) shall be applied.

Figure 3 and Figure 4 are graphs of the guideline values in Tables 3 (a) and 3 (b).

Table 3(a) Guideline value of electromagnetic field strength in general environment (6 minute average value)

Frequency f	r.m.s. value of electric field strength E[V/m]	r.m.s. value of magnetic field strength H[A/m]	Electric power density S[mW/cm ²]
100kHz — 3MHz	275	$2.18f \text{ (MHz)}^{-1}$ (21.8—0.728)	
3MHz — 30MHz	$824f \text{ (MHz)}^{-1}$ (275—27.5)	$2.18f \text{ (MHz)}^{-1}$ (0.728—0.0728)	
30MHz — 300MHz	27.5	0.0728	0.2
300MHz — 1.5GHz	$1.585f \text{ (MHz)}^{1/2}$ (27.5—61.4)	$f \text{ (MHz)}^{1/2}/237.8$ (0.0728—0.163)	$f \text{ (MHz)}/1500$ (0.2—1)
1.5GHz — 300GHz	61.4	0.163	1

Table 3(b) Electromagnetic field strength guideline value related to human body protection by stimulation in general environment

Frequency f	r.m.s. value of electric field strength (kV/m)	r.m.s. value of magnetic field strength (A/m)	r.m.s. of magnetic flux density (T)
10kHz — 10MHz	8.3×10^{-2}	21	2.7×10^{-5}

Note 1: If contact hazard is not prevented below 15MHz, the protection from contact current can be ensured by applying the supplementary guidelines 2.2.2 (2).

Note 2: The effective value of the electromagnetic field strength (average time 6 minutes) when the non-grounding condition of the human body is not satisfied must be $1.430 f \text{ (MHz)}^{-3/2}$ V/m (that is, 275V/m to 9V/m) at frequencies from 3MHz to 30MHz, 9V/m at frequencies from 30MHz up to 100MHz and $0.09 f \text{ (MHz)}$ V/m (that is 9V/m~27V/m) or less. However, if this is not satisfied and the value is below the guideline value in Table 3 (a), the supplementary guidelines 2.2.2 (3) may be applied.

Note 3: If the electric field strength or magnetic field strength changes within the average time shown in Table 3(a), the effective value within the average time which is the root mean square value within the average time should be used and if the power density changes, the averaged value within the average time should be used.

Note 4: Regarding Table 3(a), if the electromagnetic field consists of multiple frequency components that cannot be ignored with respect to the guideline value, the sum of squares of the ratio of each frequency component to the guideline value is obtained for the electric field strength and magnetic field strength, and the sum of the ratio of each frequency component to the guideline value is also obtained as for the power density. Their sum must not exceed one.

Regarding Table 3(b), if the electromagnetic field consists of multiple frequency components at a level that cannot be ignored with respect to the guideline value, the ratio of each frequency component to the guideline value for the electric field strength, magnetic field strength and magnetic flux density is calculated, or an appropriate weighted average is calculated for the ratio of each frequency component to the guideline value according to the frequency characteristic of the guideline value (Refer to Attachment). Their sum must not exceed one.

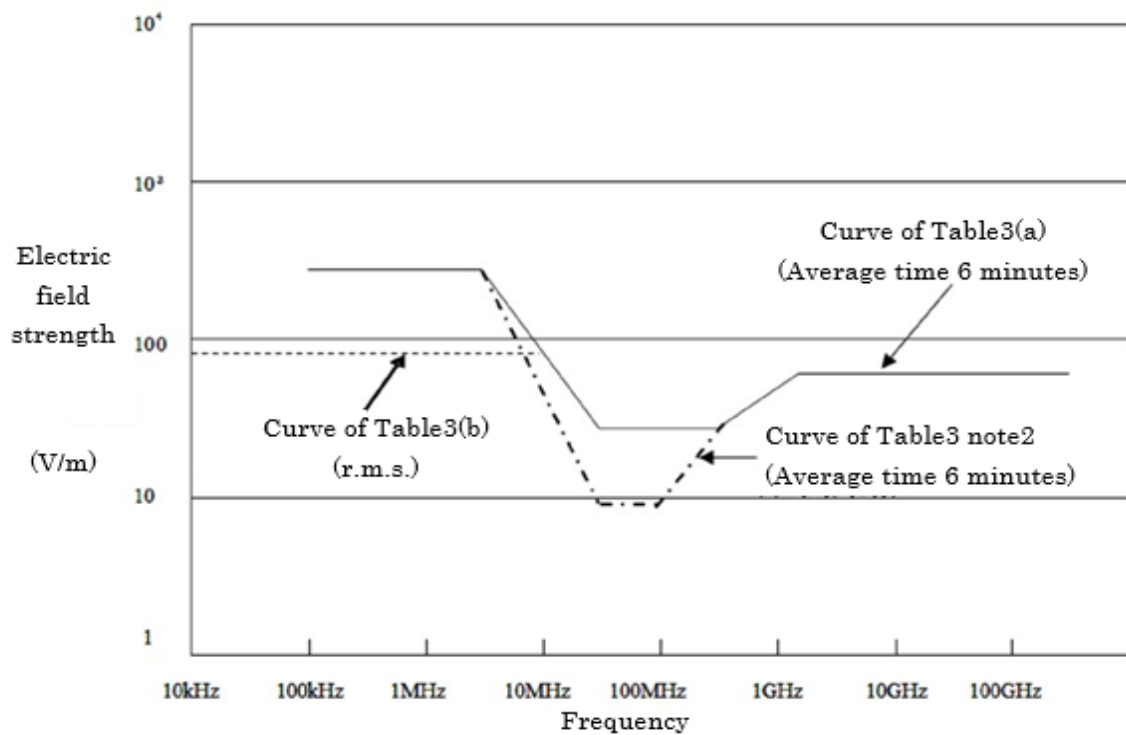


Figure 3 Indication value of electric field strength
(General environment)

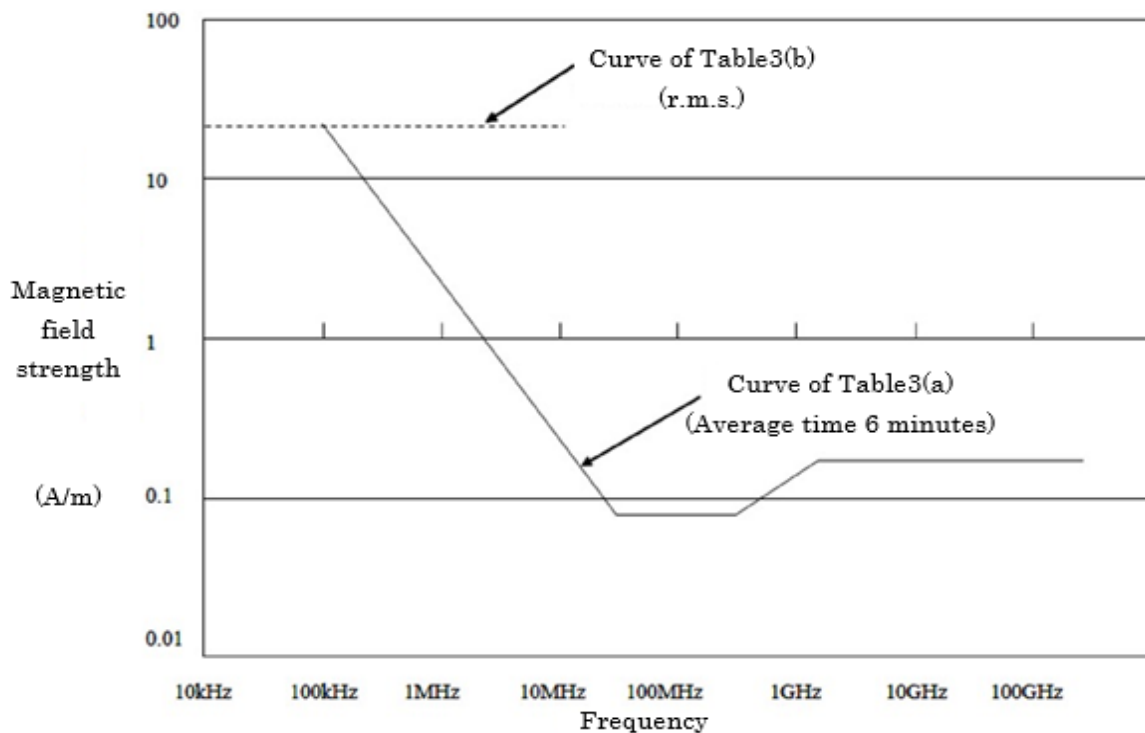


Figure 4 Indication value of magnetic field strength
(General environment)

2.2.2 Supplementary guidelines

The supplementary guidelines are guidelines for more strict evaluation by focusing on a situation where the human body is exposed to the electromagnetic wave and a biological effect, etc. to be considered, when the electromagnetic field strength guidelines alone cannot show that the protection guidelines are satisfied.

(1) Guidelines for non-uniform or local exposure of the human body to electromagnetic fields

If all applicable conditions are satisfied according to the frequency, it is considered that the managed guidelines are satisfied. When the target frequency exists over the following categories, for ①(b), ②(a) and ②(b), ③(a) and ③(b), ④(a), (b) and (c), the sum of the squares of the ratio of each frequency component to the guideline value for the electric field strength and the magnetic field strength is calculated and as for the power density, the sum of the ratio of each frequency component to the guideline value is obtained. Their sum must not exceed one. It should be noted that for equipment used in a space within 20cm from the human body (within 10 cm at a frequency of 300MHz or more), individual judgment is required for each situation. If there is a risk of exceeding the basic guidelines, it is desirable to conduct an evaluation based on the local absorption guidelines.

① When the frequency is 300MHz or less

(a) For protection from stimulating effects at 10kHz to less than 10MHz, in a space 20cm or more away from electromagnetic radiation sources and metal objects, guidelines for the electromagnetic field strength of the environment (managed environment or general environment) to which the average value (simple average value) of the electric field strength or magnetic field strength of the entire area corresponding to the space occupied by the human body (Table 2 (b) in Section 2.2.1 or Table 3 (b)).

Note that Notes 1 and 4 in Table 2 or Table 3 also apply in this section.

(b) For protection from thermal effects at 100kHz to less than 300MHz (electromagnetic field strength guideline value of 6-minute average time), in a space 20cm or more away from electromagnetic radiation sources, the spatial average value of the power density distribution in the entire area corresponding to the space occupied by the human body (in the case of electric field strength or magnetic field strength, the square root of the root mean square) must be less than or equal to the electromagnetic field guideline value (Table 2(a) or Table 3(a) in Section 2.2.1) of the corresponding environment (managed environment or general environment).

Note that Notes 1 to 4 in Table 2 or Table 3 also apply in this section.

② when the frequency range is 300MHz to 1GHz or less

(a) In a space at least 10cm away from electromagnetic radiation sources and metal objects, the spatial average value of the power density distribution in the entire area corresponding to the space occupied by the human body (in the case of electric field strength or magnetic field strength, the square root of the root mean square) shall be equal to or less than the electromagnetic field strength guideline (Section 2.2.1) of the corresponding environment (managed environment or general environment).

Note that Notes 3 and 4 in Table 2 or Table 3 also apply in this section.

(b) The spatial maximum value of the power density in the area occupied by the human body excluding limbs is 20mW / cm² or less (average for 6 minutes) in the managed environment, and 4mW / cm² or less (average for 6 minutes) in the general environment. However, only the space at least 10cm away from the electromagnetic radiation source and the metal object is covered.

Note that Notes 3 and 4 in Table 2 or Table 3 also apply in this section.

③ when the frequency range is 1GHz to 3GHz or less

(a) In a space at least 10cm away from electromagnetic radiation sources and metal objects, the spatial average value of the power density distribution in the entire area corresponding to the space occupied by the human body (in the case of electric field strength or magnetic field strength, it is the square root of the root mean square value.) must be lower than electromagnetic field strength guideline value (Section 2.2.1) of the corresponding environment (managed environment or general environment).

Note that Notes 3 and 4 in Table 2 or Table 3 also apply in this section.

(b) The spatial maximum value of the power density in the area occupied by the human body excluding limbs is 20mW / cm² or less (average for 6 minutes) in the managed environment, and 4mW / cm² or less (average for 6 minutes) in the general environment. However, only the space at least 10cm away from the electromagnetic radiation source and the metal object is covered.

Note that Notes 3 and 4 in Table 2 or Table 3 also apply in this section.

(c) The spatial maximum value of the power density incident on the head should be 10mW / cm² or less (average value for 6 minutes) in the managed environment, and 2mW / cm² or less (average value for 6 minutes) in the general environment.

Note that Notes 3 and 4 in Table 2 or Table 3 also apply in this section.

④ When the frequency is 3GHz or more

(a) In a space at least 10cm away from electromagnetic radiation sources and metal objects, the spatial average value of the power density distribution in the entire area corresponding to the space occupied by the human body (in the case of electric field strength or magnetic field

strength, the square root of the root mean square) shall be equal to or less than the electromagnetic field strength guideline (Section 2.2.1) of the corresponding environment (managed environment or general environment).

Note that Notes 3 and 4 in Table 2 or Table 3 also apply in this section.

(b) The spatial maximum value of the power density incident on the body surface in a space at least 10 cm away from electromagnetic radiation sources and metal objects is 50mW / cm² or less in a managed environment and 10mW / cm² or less in a general environment (all of them are averages for 6 minutes).

Note that Notes 3 and 4 in Table 2 or Table 3 also apply in this section.

(c) The power density incident on the eye in a space at least 10cm away from electromagnetic radiation sources and metal objects is 10mW / cm² or less (average value for 6 minutes) in a managed environment, and 2mW / cm² or less in a general environment (average value for 6 minutes).

Note that Notes 3 and 4 in Table 2 or Table 3 also apply in this section.

Table 4-1 shows the above conditions.

Table 4-1 Supplementary guidelines for uneven or local exposure

	10kHz~ 100kHz	100kHz~ 10MHz	10MHz~ 300MHz	300MHz ~ 1GHz	1GHz~ 3GHz	3GHz~ 300GHz
Electromagnet ic field strength Simple average Value (Stimulation effect)	Managed environment: under electromagnetic field strength guideline value of Table 2(b) (Note 1 and Note 4 are applied.) General environment: under electromagnetic field strength guideline value of Table 2(b) (Note 1 and Note 4 are applied.)					
Spatial average value of Electromagnet ic field strength (Thermal effect)		Managed environment: under electromagnetic field strength guideline value (Note1 to Note4 also apply) of Table 2(a) General environment: under electromagnetic field strength guideline value (Note1 to Note4 also apply) of Table 3(a)				
Spatial maximum value of Electromagnetic field strength				Excluding limbs: Managed environment: 20mW/cm ² General environment: 4mW/cm ²		Body surface: Manage- ment environ- ment: 50mW/cm ² General environ- ment: 10mW/cm ²
					Head: Mana- ged environ- ment: 10mW/c m ² Gener- al environ- ment: 2mW/c m ²	Eye: Manage- d environ- ment: 10mW/c m ² General environ- ment: 2mW/cm ²

Space to apply	The space occupied by human body 20cm or more away from electromagnetic radiation source and metal object.	The space occupied by human body 10cm or more away from electromagnetic radiation source and metal object.
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(2) Guidelines for contact current

(a) When contact hazards are not prevented in a managed environment

① The measured contact current shall satisfy the following conditions for frequencies from 10kHz to 10MHz.

- 0.4f (kHz) mA or less (effective value) at frequencies from 10kHz to 100kHz.
- 40mA or less (effective value) at frequencies from 100kHz to 10MHz.

However, when the contact current is composed of a plurality of frequency components of a level that cannot be ignored with respect to the guidelines, the sum of the ratio of each frequency component to the guideline value is calculated, or alternatively, an appropriate weighted average (see Appendix) is calculated for the ratio of each frequency component to the guideline value according to the frequency characteristics of the guideline value. Their sum must not exceed one.

② At frequencies from 100kHz to 15MHz, the measured contact current shall be 100mA or less (average time: 6 minutes). However, when the contact current is composed of a plurality of frequency components at a level that cannot be ignored with respect to the guideline, the sum of squares of the ratio of each frequency component to the guideline value is calculated. Their sum must not exceed one.

※ Both ① and ② must be satisfied from 100kHz to 10MHz.

(b) When contact hazards are not prevented in a general environment

① When a current is induced in an extremely large non-grounded metal body, or when contact current due to the influence of a magnetic field is assumed, the measured contact current must satisfy the following conditions at frequencies from 10kHz to 100kHz.

- 0.2f (kHz) mA or less (effective value) at frequencies from 10kHz to 100kHz.
- 20mA or less (effective value) at frequencies from 100kHz to 10MHz.

However, when the contact current is composed of a plurality of frequency components of a level that cannot be ignored with respect to the guideline, the sum of the ratio of each frequency component to the guideline value is calculated, or alternatively, an appropriate weighted average (see Appendix) is calculated for the ratio of each frequency component to the guideline value according to the frequency characteristics of the guideline value. Their sum must not exceed one.

② At frequencies from 100kHz to 15MHz, the measured contact current shall be 100mA or less (average time: 6 minutes). However, when the contact current is composed of a plurality of frequency components at a level that cannot be ignored with respect to the guideline, the sum of squares of the ratio of each frequency component to the guideline value is calculated. Their sum must not exceed one.

※ Both ① and ② must be satisfied from 100kHz to 10MHz.

(3) Guidelines for ankle induced current

(a) When the non-grounding condition is not satisfied in the managed environment

Induced current (average time 6 minutes) at the ankle measured at a frequency between 3MHz and 300MHz should be less than 100mA per foot.

However, when the ankle induced current is composed of a plurality of frequency components at a level that cannot be ignored with respect to the guidelines, the sum of squares of the ratio of each frequency component to the guideline value is obtained. Their sum must not exceed one.

(b) When the non-grounding condition is not satisfied in the general environment

Induced current (average time 6 minutes) at the ankle measured at a frequency between 3MHz and 300MHz should be less than 45mA per foot.

However, when the ankle induced current is composed of a plurality of frequency components at a level that cannot be ignored with respect to the guidelines, the sum of squares of the ratio of each frequency component to the guideline value is obtained. Their sum must not exceed one.

2.2.3 Local absorption guidelines

(a) Scope of application

These guidelines apply to frequencies from 100kHz to 6GHz.

The main target of the local absorption guidelines is a small wireless device such as a mobile phone terminal, and it is assumed that an antenna or a housing that contributes to an electromagnetic radiation source is used very close to a human body.

Specifically, these guidelines (local absorption guidelines) are applied when the distance between the human body and the electromagnetic radiation source (antenna as a species) or metal (housing, etc.) involved in radiation is within 20cm. Also, at other distances, if any one of electromagnetic field strength guidelines, supplementary guidelines and local absorption guidelines is satisfied, it can be determined that the basic guidelines is satisfied. However, the

application of the electromagnetic field strength guidelines or supplementary guidelines at a frequency between 300MHz and less than 300GHz and a distance between 10cm and 20cm is not excluded.

For radio stations with an average antenna power of 20mW or less, even if the entire output of the radio station is absorbed by only a small part of body, it meets the local SAR radio frequency protection guidelines, and it is thought that there is not the necessity of evaluation to be required. In the managed environment, it is considered that there is no need to evaluate radio stations with the power of 100mW or less.

(b) Managed environment

All the following requirements shall be met.

<1> The average value of the whole-body average SAR for any 6-minute period shall be 0.4W/kg or less.

<2> The local SAR (average value for 6 minutes) per 10g of any tissue should not exceed 10W/kg (20W/kg for limbs).

<3> If contact hazard is not prevented, the contact current shall be 40mA or less (r.m.s. value) in the frequency range from 100kHz to 10MHz, and the contact current shall be 100mA or less (average time: 6 minutes) in the frequency range from 100kHz to 100MHz.

However, if the contact current consists of multiple frequency components of a level that cannot be ignored with respect to this guideline, for frequencies from 100kHz to 10MHz, the sum of the sums derived from the ratio of each frequency component to the guideline value (40mA (r.m.s. value)) shall be calculated, or an appropriate weighted average is calculated for the ratio of each frequency component to the guideline value according to the frequency characteristic of the guideline value. Their sum must not exceed one. Further, for frequencies from 100kHz to 100MHz, the sum of squares of the ratio of each frequency component to the guideline value (100mA (average time: 6 minutes)) is calculated. Their sum must not exceed one.

<4> The electric field strength in the body should not exceed $2.7 \times 10^{-4} \times f$ (Hz) V/m from 100kHz to 10MHz.

However, when the in-vivo electric field strength is composed of a plurality of frequency components at a level that cannot be ignored with respect to the guideline value, the sum of the ratio of each frequency component to the guideline value is calculated, or for the ratio of each frequency component to the guideline value, an appropriate weighted average (refer to Appendix) according to the frequency characteristics of the guideline value shall be calculated. Their sum must not exceed one.

It is not necessary for a radio station having a frequency of 100MHz or more to perform

evaluation based on the guideline regarding contact current described in <3>. In addition, a radio station having a frequency of 10MHz or higher does not need to perform the evaluation based on the guideline regarding the electric field strength in the body described in <4>.

(c) General environment

All the following requirements shall be met.

<1> The average value of the whole-body average SAR for any 6-minute period shall be 0.08W/kg or less.

<2> The local SAR (average value for 6 minutes) per 10g of any tissue should not exceed 2W/kg (4W/kg for limbs).

<3> If a contact hazard is not prevented, the contact current shall be 20mA or less (r.m.s. value) in the frequency range from 100kHz to 10MHz, and the contact current shall be 45mA or less (average time: 6 minutes) in the frequency range from 100kHz to 100MHz.

However, if the contact current consists of multiple frequency components of a level that cannot be ignored with respect to this guideline, for frequencies from 100kHz to 10MHz, the sum of the sums derived from the ratio of each frequency component to the guideline value (20mA (r.m.s. value)) shall be calculated, or An appropriate weighted average is calculated for the ratio of each frequency component to the guideline value according to the frequency characteristic of the guideline value. Their sum must not exceed one. Further, for frequencies from 100kHz to 100MHz, the sum of squares of the ratio of each frequency component to the guideline value (45mA (average time: 6 minutes)) is calculated. Their sum must not exceed one.

<4> The electric field strength in the body should not exceed $1.35 \times 10^{-4} \times f$ (Hz) V/m from 100kHz to 10MHz.

However, when the in-vivo electric field strength is composed of a plurality of frequency components at a level that cannot be ignored with respect to the guideline value, the sum of the ratio of each frequency component to the guideline value is calculated, or for the ratio of each frequency component to the guideline value, an appropriate weighted average (refer to Appendix) according to the frequency characteristics of the guideline value shall be calculated. Their sum must not exceed one.

It is not necessary for a radio station having a frequency of 100MHz or more to perform an evaluation based on the guideline regarding contact current described in <3>. In addition, a radio station having a frequency of 10MHz or higher does not need to perform an evaluation based on the guideline regarding the electric field strength in the body described in <4>.

2.3 Basic guidelines

The basic guidelines are shown in Table 5-1. The basic guidelines are concepts that serve as bases for the managed guidelines regarding protection of the human body from thermal effects and provide bases for judging the possibility of occurrence of biological effects.

Table 5-1 Basic guidelines

1	The average value of the whole-body average SAR for any 6-minute period shall be 0.4W/kg or less.
2	(Deleted)
3	At frequencies from 100kHz to 100MHz, the inflow current from outside such as contact current should be 100mA or less (average time 6 minutes).
4	In addition to the above (1), (2) and (3), the following points should be considered as precautions.
	(a) Even if the average value of the whole-body average SAR for any 6-minute period is 0.4W/kg or less, the SAR (average value for 6 minutes) per gram of any tissue is expected to exceed 8W/kg (25W/kg for the body surface and limbs).
	(b) At frequencies above 3GHz, the incident power density on the eye (6-minute average) is 10mW / cm ² .

2.4 Basic restrictions

Table 5-2 shows the basic restrictions on protection of the human body from stimulation effects in the low frequency range. Basic limits are defined as limits on physical quantities that are directly related to in-vivo phenomena due to exposure to radio waves that can lead to harmful effects on health.

Table 5-2 Basic restrictions on the protection of human body from stimulation (r.m.s. value)

Exposure characteristics	Frequency range	Managed environment	General environment
		Electric field in the body (V/m)	Electric field in the body (V/m)
All head and body tissues	10kHz – 10MHz	$2.7 \times 10^{-3} \times f$	$1.35 \times 10^{-3} \times f$

(Note 1) f is frequency [Hz].

(Note 2) It is necessary to consider the guideline value of thermal effect in the frequency range higher than 100kHz.

(Note 3) If the electromagnetic field consists of multiple frequency components that cannot be ignored relative to the guideline value, the sum of the ratio of each frequency component (from 10kHz to 10MHz) to the guideline value for the electric field strength, magnetic field strength, and magnetic flux density calculated, or an appropriate weighted average is calculated for the ratio of each frequency component to the guideline value according to the frequency characteristic of the guideline value (refer to Attachment). Their sum must not exceed one.

2.5 Precautions

(1) For medical purposes

When electromagnetic waves are used for medical purposes, the conditions under which medical personnel are exposed to electromagnetic fields are covered by these guidelines. But, for patients, it is a matter that should be determined in consideration of the medical effects, therefore, it is not applicable only when a medical doctor uses it after fully understanding the safety limitations shown in these guidelines. However, for example, radio waves that are effective in treating knee joints can also be harmful to the eyes. Therefore, it is necessary to avoid irradiating electromagnetic waves over a wider area than necessary and to pay close attention to leakage electromagnetic fields.

(2) Pacemaker wearer

If a pacemaker wearer uses radio waves, the instructions of the medical doctor in charge should be followed, and therefore this guideline does not cover pacemaker wearers.

(3) People with metal implants in their bodies

When a metal is implanted in the body, even an electromagnetic field lower than the guideline value may cause unexpected local heat generation, and caution is required.

(4) People who wear metal on their body

If metal is worn, especially near an induction heating furnace, the metal may generate heat even with an electromagnetic field less than the guideline value, so care must be taken.

Attachment Exposure to non-sinusoidal wave

It is available to treat as following below regarding to the exposure to non-sinusoidal wave in the frequency range of between more than 10kHz and less than 10MHz.

Electromagnetic waves in low frequencies are distorted by the high frequency components distributed in a wide frequency band. As the result, the wave forms of electric field and magnetic field show complicated (sometimes pulse shaped) patterns. Such electric fields and magnetic fields for example with applying Fourier transform method (FT) can be decomposed into discrete spectral component, it is always possible to apply the previously mentioned rule for multiple frequencies. This method is described that spectral components are to be added in the same phase, that is, it assumes that all the maximum values come out at the same time. As a result, one sharp peak value arises. This assumption is realistic if the number of spectral components is limited and their phases are not coherent, i.e., random.

If the phase is fixed coherently, this assumption is an unnecessarily conservative estimate. Moreover, there is a possibility to artificially increase the linear sum of exposure ratio because of spurious frequencies generated by sampling in the FT spectrum analysis and the window function.

There are techniques for the induced electric field to be weighted with the external electric field and for the induced magnetic field to be weighted with the external magnetic field (ICNIRP 2003 : Jokela 2000) using the basic restriction or the filter function related to reference level as the choice instead of spectrum method.

The restriction imposed by filtering is expressed mathematically as follows below in the electric field and magnetic field which are compose with harmonics components.

$$\left| \sum_i \frac{A_i}{E_{Li}} \cos(2\pi f_i t + \theta_i + \phi_i) \right| \leq 1$$

Here, t is time, E_{Li} is exposure limit value at i^{th} harmonic frequency f_i , A_i , θ_i and ϕ_i are the amplitude of electric field and magnetic field, phase angle and phase angle of filter at i^{th} harmonic frequency. The detailed guidance related to the practical method of weighting (Decision of weighting peak-value exposure) will be referred in the attachment of ICNIRP guidelines [Guidelines (1Hz ~ 10Hz) related to the exposure restrictions of electric field and magnetic field which change over time] (2010)

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Relevant report 6

Partial Report from Information and Communications Council, “The State of Radiofrequency-Exposure Protection Guidelines in the high-frequency range”, September 2018 among Inquiry No. 2035 “The State of Radiofrequency-Exposure Protection Guidelines”

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Partial Report concerning “The State of Radiofrequency-Exposure Protection Guidelines in the high-frequency range” among Inquiry No. 2035 “The State of Radiofrequency-Exposure Protection Guidelines”

In Partial Report from Information and Communications Council, “The State of Radiofrequency-Exposure Protection Guidelines in the low-frequency range (from 10 kHz to 10 MHz)”, March 12, 2015 among Inquiry No. 2035 “The State of Radiofrequency-Exposure Protection Guidelines”, it shall be appropriate that “1. Definitions” and “2.2.3 Localized specific absorption rate guidelines” are to be revised as follows.

1 Definitions

Interpretation on radiofrequency-exposure protection guideline shall comply with definitions of the following items.

- (1) The term “Electromagnetic waves” is a generic name of wave motion, that is, vibration of electric field or magnetic field propagating in a vacuum or in substances. Electromagnetic wave includes low frequency electromagnetic field, what is called “radio wave” utilized for wireless telecommunication, light wave (infrared light rays, visible light rays, ultraviolet rays) radiated from the sun, radiologic rays (X-rays, γ -rays) utilized for medical treatment, etc. Electromagnetic waves are classified by wavelength into two categories, ionizing radiation with shorter than ultraviolet and non-ionizing radiation with longer than ultraviolet.
- (2) “Radio wave” is an electromagnetic wave of frequency of 3,000,000 MHz (300 GHz) or lower specified in Article 2 of the Radio Law. In the radiofrequency-exposure protection guideline, frequency range from 10 kHz to 300 GHz is applied.
- (3) “Radiofrequency-Exposure Protection guideline” is a recommendation for keeping the human body in a safety state that does not exert biological action considered unfavorable to the human body when human body is exposed to a radio wave (limited to the range of 10 kHz to 300 GHz) in the use of radio waves.
- (4) “Base guideline” is a criterion to be used in safety evaluation of human body, when exposed to an electromagnetic field effect, based on the various biological action exerted to human body (fever stress accompanied with rise of body temperature, high-frequency heating injury, etc.).
- (5) “Basic limitation” is limit value for physical quantity having direct relation with inner phenomenon of living body caused by radiofrequency-exposure, which may possibly become hazardous influence to health.
- (6) “Managing guideline” is a practical criterion to satisfy base guideline and basic limitation to be used in actual evaluation illustrated with measurable physical quantity (electric field strength, magnetic field strength, magnetic flux density, electric power density, electric current, and specific absorption rate). Managing guideline is further organized and specialized into electromagnetic field strength guideline, supplementary guideline, and localized specific absorption rate guideline.
- (7) “Electromagnetic field strength guideline” is intended for safety evaluation of the target space, with electric field strength, magnetic field strength, electric power density, and magnetic flux density.

- (8) “Localized specific absorption rate guideline” is prepared for detailed evaluation according to the base guideline when a local portion of human body is intensively exposed by the radio wave radiated from radio equipment used within a very short range to human body.
- (9) “Supplementary guideline” is prepared to proceed to further evaluation according to the base guideline when evaluation result does not meet with the criteria of electromagnetic field strength guideline. It is applicable to the case that the actual circumstance of exposure to the radio wave (non-uniformly, locally, superficially, etc.), objective biological action (contact current and induced current), and specifications of radiation source (antenna power, frequency range) are obvious, by relaxing or exempting the guideline less strict.
- (10) “Managed environment” is a condition that the state of human body exposed to the electromagnetic field is recognized and the radiation source of radio wave can be identified, and besides the appropriate management of environment for those situations can be taken accordingly. For example, it can be applied to the case that a workman is exposed to electromagnetic field in the work environment to handle electromagnetic wave on a daily basis (broadcasting transmitting station, high-frequency fabrication plant, and so on). Managed environment is equivalent to condition P in Radiofrequency-Exposure Protection Guidelines, 1990.
- (11) “General environment” is an environment that (in which, where) understanding of the exposed level and appropriate management cannot be expectable and there resides some uncertain factor. Typical case is general residential environment where residents are exposed to electromagnetic field, and so on. For this standpoint guideline provides severer criteria for this general environment than for managed environment. General environment corresponds to condition G in Radiofrequency-Exposure Protection Guidelines, 1990.
- (12) “Specific Absorption Rate (SAR)” is electromagnetic power absorbed per unit of mass of the tissue when a tissue is irradiated by electromagnetic waves. SAR averaged over the whole body is called “Whole body averaged SAR”, SAR averaged within an arbitrary 1 g or 10 g organization is called “Localized SAR”.
- (13) “Electromagnetic field” is a generic name of electric field and magnetic field.
- (14) “Electric field strength” is defined as the strength of electric field.
- (15) “Magnetic field strength” is defined as the strength of magnetic field.
- (16) “Electric power density” is defined as the radiated unit passing through an element of surface normal to the direction of propagation of an electromagnetic wave.

- (17) “Induced current” is current caused by electromagnetic induction. Particularly it means induced current inside human body when exposed to electromagnetic field.
- (18) “Contact current” is current running via contact point of grounded human body by touching non-grounded conducting object placed in electromagnetic field.
- (19) “Contact hazard” is hazardous situation that can potentially cause contact current.
- (20) “Non-grounded condition” is situation that no induced current can cause to the ground and thus ground influence can be ignored.
- (21) “Uniform exposure” is the situation that whole body is exposed to electromagnetic field in the spatial region where electromagnetic field can be considered almost uniform. This situation includes the case that free space impedance is less than $120\pi [\Omega]$. The free space, where the distance from the radiation source is longer enough than height of human body (ex. 15 m or more for frequency range lower than 0.3 MHz, 10 m or more from 0.3 MHz to 300 MHz, 5m or more for 300 MHz or higher), shall be considered uniform.
- (22) “Non-uniform exposure” is the situation that exposure cannot be considered uniform exposure.
- (23) “Localized exposure” is the situation that a particular part of human body is intensively exposed to the electromagnetic field, including being radiated from a relatively smaller antenna than human body in its near-field or spot radiation by radio wave of short wavelength.
- (24) “Whole body exposure” is the situation that exposure is not focused on a particular part but spreads over whole body, which is not necessarily uniform and not typical localized exposure.
- (25) “Averaging time” is the period for measurement to evaluate conformity to a guideline value determined based on targeted living effect. Average time used in radiofrequency-exposure protection guideline is one second for stimulating and six minutes for heating.
- (26) “Far-field” is the electromagnetic field where the distance from electromagnetic source is more than both of $2D^2/\lambda$ and $\lambda/2\pi$ with neither reflection nor dispersion. Where D is maximum length, and λ is free space wavelength.
- (27) “Near-field” is the electromagnetic field of the region which is not considered far-field.
- (28) “root mean square (r.m.s.)” is defined as a value obtained by calculating square root of mean square on periodic waveform through whole single period. Root mean square value of electric strength and magnetic strength of periodically fluctuating electromagnetic field is correlating value with Joule heat.

2.2.3 Localized absorption guideline

(a) Scope of application

This guideline shall be applied to frequency range from 100 kHz to 300 GHz.

The main objective of localized absorption guideline is small radio equipment such as portable telephone terminal, whose antenna or case as electromagnetic radiation source and which is assumed being used very close to human body.

For instance, this guideline shall be applied to the situation when the distance between electromagnetic radiation source (mostly antenna) or relating metal substance (case, etc.) and human body is 20 cm or closer. For distance other than above it shall be considered that the base guideline is satisfied if either one of electromagnetic field strength guideline, supplementary guideline, or localized absorption guideline is satisfied. However, for frequency range from 300 MHz to 300 GHz, electromagnetic field strength guideline or supplementary guideline in the distance between 10 cm and 20 cm shall not be exempted.

For frequency range from 100 kHz to 6 GHz, radio station with 20 mW or less averaged antenna power satisfies radiofrequency-exposure protection guideline for localized SAR even when whole power of radio station is absorbed in a particular portion of human body, and thus there assumed no evaluation needed. Yet in managed environment those radio station with 100 mW or less, no evaluation needed.

For frequency range from 6 GHz to 30 GHz, radio station with 8 mW or less averaged antenna power satisfies radiofrequency-exposure protection guideline for irradiating power density even when whole power of radio station is absorbed in a particular portion of human body, and thus there assumed no evaluation needed. Yet in managed environment those radio station with 40 mW or less, no evaluation needed.

For frequency range from 30 GHz to 300 GHz, radio station with 2 mW or less averaged antenna power satisfies radiofrequency-exposure guideline for irradiating power density even when whole power of radio station is absorbed in a particular portion of human body, and thus there assumed no evaluation needed. Yet in managed environment those radio station with 10 mW or less, no evaluation needed.

(b) Managed environment

All the following criteria are mandatory.

<1> Any of 6 min average extracted from whole body averaged SAR shall be 0.4 W/kg or lower.

<2> For frequency 6 GHz or lower localized SAR at any 10 gram tissue (6 min average) shall not exceed 10 W/kg (20 W/kg at upper and lower limbs).

<3> For frequency range from 6 GHz to 30 GHz irradiating power density (6 min average) at any 4 cm² body surface (any area among equivalent space region occupied by human body) shall not exceed 10 mW/cm².

<4> For frequency range from 30 GHz to 300 GHz irradiating power density (6 min average) at any 1 cm² body surface (any area among equivalent space region occupied by human body) shall not exceed 10 mW/cm².

<5> When exposed to radio wave in multiple frequencies at the same time, the sum total of proportions to the guideline value of each frequency component in preceding clauses <2>, <3>, and <4> shall not exceed 1.

<6> With no prevention means taken against contact hazard, contact current shall be 40 mA or less (r.m.s.) at frequency from 100 kHz to 100 MHz and also 100 mA or less (6 min average) at 100 kHz to 100 MHz.

In case that contact current is composed of multiple frequency component at non-ignorable level to this criterion, for frequency range from 100 kHz to 10 MHz the sum total shall be calculated with the proportion of contact current to the guideline value (40 mA (r.m.s.)) at each frequency component, or the average shall be calculated for the proportion to the guideline value at each frequency component with proper weighting corresponding to frequency characteristic. These sums shall not exceed 1. Moreover, for frequency range from 100 kHz to 100 MHz, the sum total of square values of proportion to the guideline value (100 mA (6 min average)) at each frequency component. The sum shall not exceed 1.

<7> For frequency range from 100 kHz to 10 MHz, electric field strength of internal body shall not exceed $2.7 \times 10^{-4} \times f$ (Hz) V/m.

In case that electric field strength of internal body is composed of multiple frequency component at non-ignorable level to this guideline value, the sum total shall be calculated with the proportion to the guideline value at each frequency component, or the average shall be calculated for the proportion to the guideline value at each frequency component with proper weighting (refer to Attachment) corresponding to frequency characteristic. These sums shall not exceed 1.

For radio station using frequency 100 MHz or higher, evaluation according to contact current guideline described in <6> is not needed. For radio station using frequency range 10 MHz or higher, evaluation according to electric field strength of internal body guideline described in <7> is not needed.

(c) General environment

All the following criteria are mandatory.

- <1> Any of 6 min average extracted from whole body averaged SAR shall be 0.08 W/kg or lower.
- <2> For frequency 6 GHz or lower localized SAR at any 10 gram tissue (6 min average) shall not exceed 2 W/kg (4 W/kg at upper and lower limbs).
- <3> For frequency range from 6 GHz to 30 GHz irradiating power density (6 min average) at any 4 cm² body surface (any area among equivalent space region occupied by human body) shall not exceed 2 mW/cm².
- <4> For frequency range from 30 GHz to 300 GHz irradiating power density (6 min average) at any 1 cm² body surface (any area among equivalent space region occupied by human body) shall not exceed 2 mW/cm².
- <5> When exposed to radio wave in multiple frequencies at the same time, the sum total of proportions to the guideline value of each frequency component in preceding clauses <2>, <3>, and <4> shall not exceed 1.
- <6> With no prevention means taken against contact hazard, contact current shall be 20 mA or less (r.m.s.) at frequency from 100 kHz to 100 MHz and also 45 mA or less (6 min average) at 100 kHz to 100 MHz.

In case that contact current is composed of multiple frequency component at non-ignorable level to this criterion, for frequency range from 100 kHz to 10 MHz the sum total shall be calculated with the proportion of contact current to the guideline value (20 mA (r.m.s.)) at each frequency component, or the average shall be calculated for the proportion to the guideline value at each frequency component with proper weighting corresponding to frequency characteristic. These sums shall not exceed 1. Moreover, for frequency range from 100 kHz to 100 MHz, the sum total of square values of proportion to the guideline value (45 mA (6 min average)) at each frequency component. The sum shall not exceed 1.

- <7> For frequency range from 100 kHz to 10 MHz, electric field strength of internal body shall not exceed $1.35 \times 10^{-4} \times f \text{ (Hz) V/m}$.

In case that electric field strength of internal body is composed of multiple frequency component at non-ignorable level to this guideline value, the sum total shall be calculated with the proportion to the guideline value at each frequency component, or the average shall be calculated for the proportion to the guideline value at each frequency component with proper weighting (refer to Attachment) corresponding to frequency characteristic. These sums shall not exceed 1.

For radio station using frequency 100 MHz or higher, evaluation according to contact current guideline described in <6> is not needed. For radio station using frequency range 10 MHz or higher, evaluation according to electric field strength of internal body guideline described in <7> is not needed.

To: Secretariat of Standard Assembly Meeting of the Association of Radio Industries and Businesses
 FAX: +81-3-3592-1103 E-mail:std@arib.or.jp
 Nittochi Bldg. 11th Floor, 1-4-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-0013, Japan

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RADIOFREQUENCY-EXPOSURE PROTECTION

ARIB STANDARD

RCR STD-38 Version 3.0

Version 1.0	September	1993
Version 2.0	October	1999
Version 3.0	July	2019

Published by

Association of Radio Industries and Businesses

Nittochi Bldg. 11F
1-4-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-0013, Japan

TEL 03-5510-8590
FAX 03-3592-1103

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