資料３－３

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高速電力線搬送通信に関する研究会

ＩＴＵ－Ｒでの検討状況紹介

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「ＩＴＵ－Ｒ　ＷＰ１Ａに提案されたＰＬＣから短波放送に対する妨害に関する検討資料」

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Working Party 6E

REPLY TO THE LIAISON STATEMENT FROM WP 1A REQUESTING TECHNICAL CHARACTERISTICS ON BROADCAST RECEIVERS, ANTENNA TYPES AND GAIN

Working Party 6E thanks WP 1A for its liaison statement contained in Document 6E/40, describing progress towards a PDNR and studies of compatibility between radiocommunication systems and high data rate telecommunication systems using electricity power supply or telephone distribution wiring. WP 1A is now requesting information on technical characteristics of broadcast receivers and antennas so that work may be completed.

To assist WP 1A in this regard, WP 6E offers the following preliminary reference material in Annex 1 on antennas, analogue and digital receivers typical of broadcast service use, to be used in further analysis of system requirements and characteristics.

Annex 1

Contents

Technical Characteristics of Broadcast Receivers and Antennas

1 Analogue Receiver sensitivity

For AM sound broadcast receivers operating frequencies below 30 MHz (LF, MF, and HF bands), receiver sensitivity is defined in Rec. ITU-R BS.703 (Reference receivers for planning purposes). Besides that, receiver sensitivity of the low-cost receivers for MF band is defined in Rec. ITU-R BS.415. In both cases, receiver sensitivity is defined as the minimum usable field strength, using built-in antenna even if a terminal for external antenna connection is provided, and for the receiving quality of: 26 dB AF S/N, with 30% modulation, in condition where external noise is absent. These values are as follows:

LF: 66 dB(μV/m)

MF: 60 dB(μV/m), (75 dB(μV/m) for low-cost receivers)

HF: 40 dB(μV/m)

Above values are shown in Fig. 5 with the lines, *e, f, h*, and *g,* respectively.

These are defined for the maximum receiving direction of the built-in-antenna. For a short whip antenna widely used in HF band, it is omni-directional for the horizontal directions.

However, for a loop or a ferrite lode antenna widely used in LF and MF band, it has 8-character pattern for the horizontal directions, and the maximum receiving gain is given when the axis of loop or ferrite lode is in the right angle with the radio path direction. Even for the angle considerably different from the right angle, antenna gain reduction is not significant. However, it presents sharp null when the axis is in the direction of radio path.

2 Receiver Noise Level and Acceptable Interference Level

For estimation of receiver sensitivity deterioration by co-channel interference, or for estimation of acceptable co-channel interference level, it is important to know the receiver noise level rather than the receiver sensitivity, since it is considered that receiver sensitivity is deteriorated due to increase of receiver noise by co-channel interference power. For example, if the co-channel interference receiving power is the same level as the original receiver noise, resultant noise power increases to 2-times (3 dB) (neglecting the difference of noise waveforms), and the sensitivity deterioration is 3 dB.

Receiver external noise level and interference wave level are usually expressed by field strength. Accordingly, it is convenient to express the receiver internal noise also by equivalent field strength for ease of comparison. (In place of actual noise existing in the receiver, it is assumed that as if an equivalent noise were received through the antenna with noise-less receiver.)

Receiver noise level corresponds to the receivers, whose sensitivities are specified in the previous paragraph 1, can be assumed by the follow way:

$$\text{AF S/N (dB)} = \text{RF C/N (dB)} + \text{modulation (dB)}$$

Substituting the conditions: AF S/N = 26 dB, and modulation = 30 % (-10.5 dB), RF C/N which corresponds to the minimum usable field strength is estimated as 36.5 dB. Accordingly, the field strength equivalent to the receiver noise is estimated as; 36.5 dB below the minimum usable field strength. That is:

LF: 29.5 dB(μV/m)

MF: 23.5 dB(μV/m), (38.5 dB(μV/m) for low-cost receivers)

HF: 3.5 dB(μV/m)

Each value is indicated in Fig. 5, by the line i, j, and k respectively (excepting low-cost receivers). Although this receiver noise is estimated using analogue receiver sensitivity, these results also apply to digital receivers when bandwidth differences are taken into account.

The above receiver noise estimation is made on condition that external noise is absent. However, receiver noise usually includes external noise that is received through receiving antenna besides receiver internal (intrinsic) noise, which is generated in the receiver. The external noise for receivers operating at below 30 MHz includes atmospheric, man-made, and cosmic noise.

Recommendation ITU-R P.372 expresses each of average strength of atmospheric noise, man-made noise, and cosmic noise comparing with the thermal noise level (kTo) when they are received through a loss-less short vertical monopole with perfectly grounded plane. Therefore, it is convenient to make conversion of the receiver internal noise level into equivalent field strength (Eri), mentioned above, based on the identical antenna.

Equivalent field strength of the receiver (overall) noise (*Ert*) is expressed by the field strength corresponds to the power sum of the above Ert and average field strength of the external noise (*Ere*). That is:

$$Ert^2 = Eri^2 + Ere^2 \qquad (1)$$

When a co-channel interference of field strength E*u* superposes to this *Ert*, equivalent field strength of the receiver noise power increases up to *Ertu* that corresponds to the power sum of *Ert* and *Eu*. That is:

$$Ertu^2 = Ert^2 + Eu^2 \qquad (2)$$

For example:

– When *Eu* is equal to *Ert*, overall receiver noise increases by 3 dB, that is, receiver sensitivity deteriorates by 3 dB.

– When *Eu* is 6 dB lower than *Ert*, receiver sensitivity deteriorates by 1 dB.

– When *Eu* is 10 dB lower than *Ert*, receiver sensitivity deteriorates by 0.5 dB.

– When *Eu* is 20 dB lower than E*rt*, receiver sensitivity deteriorates by 0.05 dB.

That is, in order to limit receiver sensitivity deterioration due to co-channel interference (*Eu*) within 0.05 dB, *Eu* should be 20 dB lower than equivalent field strength of the receiver (overall) noise (*Ert*).

Above receiver noises are estimated from the receiver sensitivity. The receiver noise estimated from the characteristics of the receiver and antenna is shown in the following paragraphs.

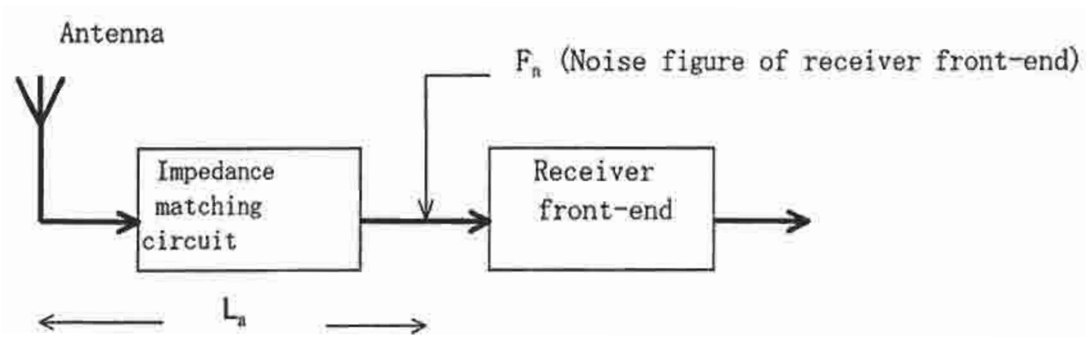
3 Receiver intrinsic noise

3.1 Field strength equivalent to receiver intrinsic noise

In Fig. 1, *La* is the overall antenna circuit loss that includes loss in the antenna, antenna matching circuit loss, and antenna mis-match loss.

FIGURE 1

Noise equivalent circuit of receiver input circuit



From Fig. 1, field strength equivalent to the receiver intrinsic noise (*Eri*) is expressed by:

$$E_{ri} = E(k\,T_o\,b) + L_a + F_n \;\; \mathrm{dB(\mu V/m)} \tag{3}$$

Where:

$E(k\,T_o\,b)$: Equivalent field strength of the ideal receiver noise (= thermal noise: $k\,T_o\,b$) (F_n: 0 dB) based on loss-less antenna (L_a; 0 dB): dB(μ V/m)

k : Boltzmann's constant= 1.38×10^{-23} J / K

T_o : Reference temperature ; 288K,

b : Receiver effective noise bandwidth (Hz)

$k\,T_o\,b$: –165 dBW (for b = 8000 Hz)*

L_a : Overall antenna circuit loss (dB)

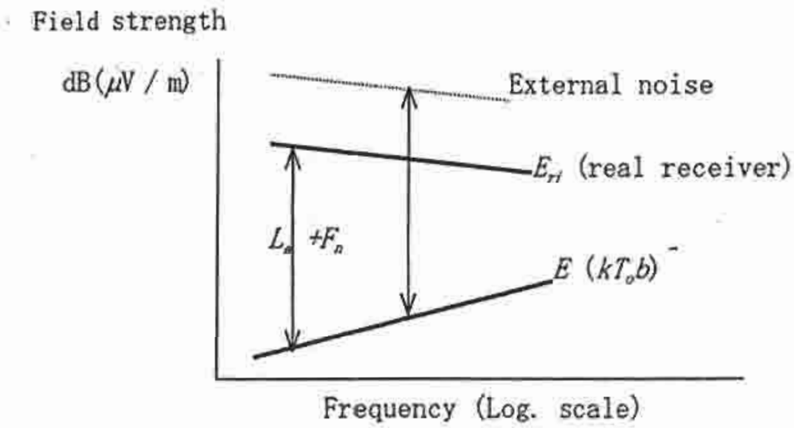
F_n : Receiver front-end noise figure (dB)

* the bandwidth is to be adjusted in accordance with the necessary bandwidth of the transmitter system.

Above relationship is shown in Fig. 2. Figure 2 shows the case that external noise field strength is higher than the equivalent field strength of receiver intrinsic noise.

FIGURE 2

Equivalent field strength of receiver intrinsic noise (*Eri*)



On the other hand, received power (P_r) by an loss-less antenna located in field strength; E is expressed by:

– With vertical short monopole antenna located on a perfectly conductive ground:

$$P_r = E^2\,\lambda^2 / (640\,\pi^2) \tag{4}$$

– With small loop antenna:

$$P_r = E^2\,\lambda^2 / (320\,\pi^2) \tag{5}$$

Where:

P_r: Maximum available received power (W)

E: Field strength (V/m)

λ: Wave length (m) = $3 \times 10^2 / f$

f: Frequency (MHz)

Substituting $kT_o b$ (–165 dBW) into the above P_r, $E(kT_o b)$ for (b = 8 000 Hz) is expressed by:

– With vertical loss-less short monopole antenna located on a perfectly conductive ground:

$$E(kT_o b) = 20 \log f - 56.5 \text{ dB } (\mu \text{V/m}) \quad (6)$$

– With small loss-less loop antenna:

$$E(kT_0 b) = 20 \log f - 59.5 \text{ dB } (\mu \text{V/m}) \quad (7)$$

3.2 Overall antenna circuit loss (L_a)

When an antenna matches to the wavelength is used, La can be reduced within some dB.

However, broadcast receivers use built-in-antenna whose size is much smaller than the wavelength. Although, theoretical antenna gain or maximum available antenna received power is independent of the antenna size itself, actual received power reduces by La that increases for smaller size of antenna. It is of the order of 30-60 dB in HF band and 70-90 dB in MF band.

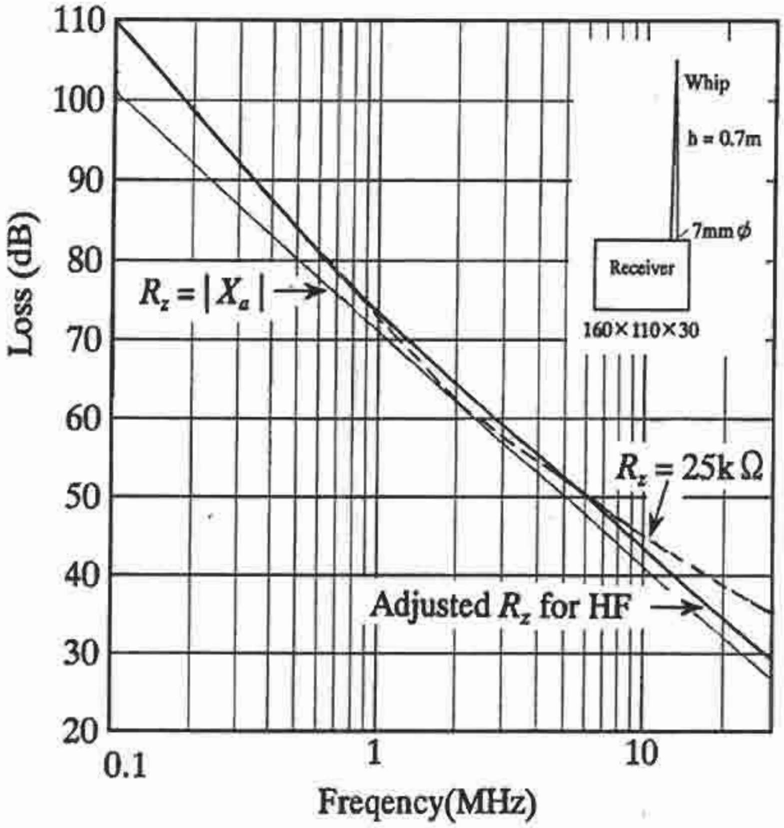
The following are examples of La in broadcast receivers.

(1) *La* for 0.7m whip antenna

Radiation impedance of a whip antenna, whose length is extremely shorter than the wavelength as shown in Fig. 3, is equivalent to series connection of a very small radiation resistance of much less than 1 ohm and a very small capacity (Reactance: Xa) of the order of 3 pF (53 kohm at 1 MHz). Since its Q is extremely high, impedance matching to the receiver input circuit is quite difficult. Fig. 3 shows miss-mach loss when the antenna is loaded by pure resistance Rz = 25 kohm. It also shows the case that Rz is reduced for higher frequencies than 7 MHz for lower loss (additional loss due to adjusting error of 2 dB is included).

FIGURE 3

Matching loss when a 0.7m whip antenna is terminated by a pure resister load: *Rz*



(2) *La* for loop antenna or ferrite rod antenna

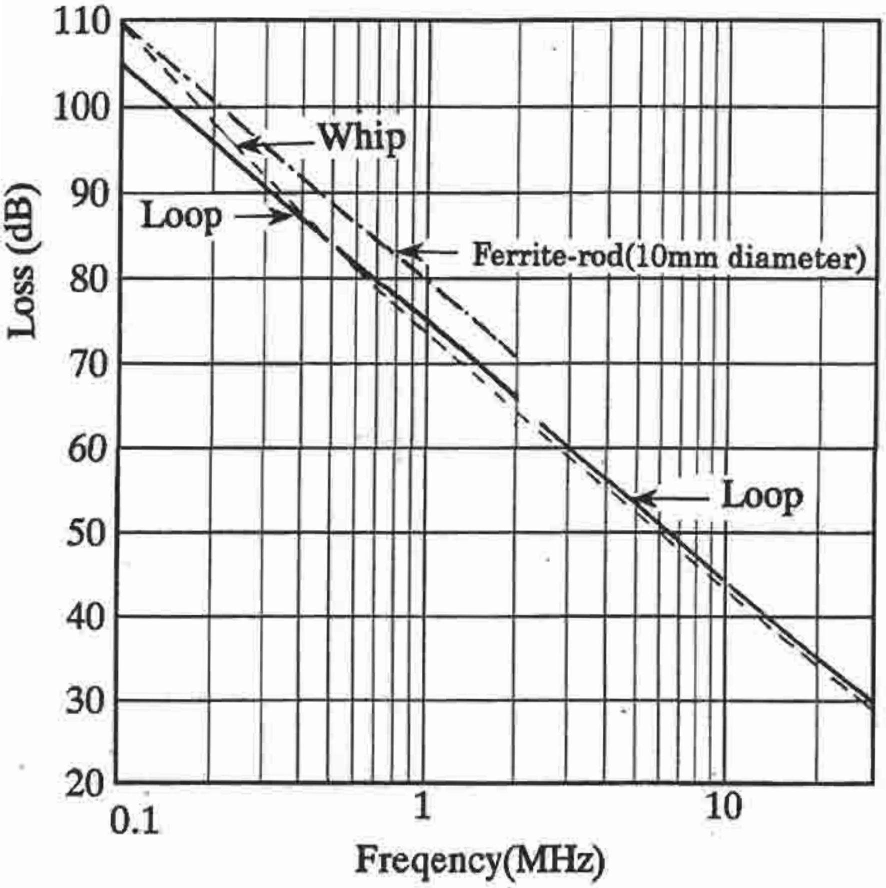
For a loop antenna, impedance match is easily made by tuning the loop inductance with a capacity, and matching loss is not an issue. However, loss resistance of the loop which is much bigger than the antenna radiating resistance, generated in series with the loss resistance, causes a big loss.

Figure 4 shows estimated loss for a loop antenna with loop area of 135 cm^2, Q of 120 (LF), 150 (MF, HF). In this estimation, additional 5 dB loss due to metal material near the loop and miss match loss is included. This estimation results approximates to the case of whip antenna in Fig. 3.

In order to reduce the loop size, a ferrite rod antenna is usually used. Loss estimation for the effective relative permeability of 60, and diameter of 10 mm, is also included in Fig. 4.

FIGURE 4

Loop antenna loss: Loop antenna: 135 cm^2
Ferrite rod: diameter: 10 mm



3.3 Equivalent field strength of the receiver intrinsic noise using built-in-antenna in the above (1), (2)

Assuming that:

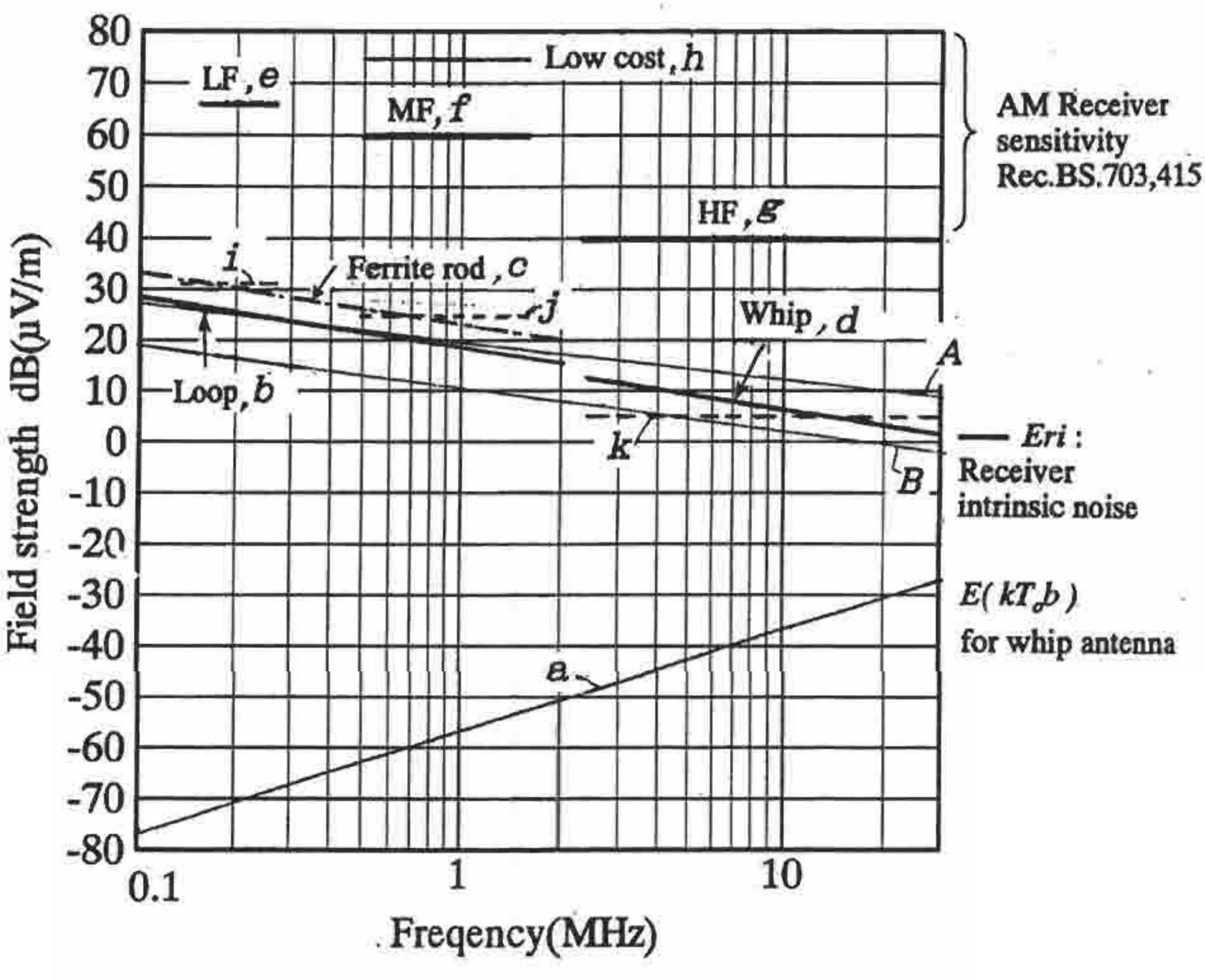
$$b = 8000 \text{ Hz}$$

$$F_n = 5 \text{ dB},$$

and using the above antenna circuit loss, and $E(k\,T_o\,b)$ obtained by equation (6), equivalent field strength of the receiver intrinsic noise (*Eri*) is obtained as shown in Fig. 5.

FIGURE 5

Equivalent field strength of receiver intrinsic noise with built-in antenna



$E(k\,T_o\,b)$: (curve *a*)

Equivalent field strength of receiver intrinsic noise (*Eri*)

LF · MF: loop antenna (curve *b*)

ferrite rod antenna (curve *c*)

HF: whip antenna (curve *d*)

3.4 Receiver intrinsic noise of Digital (DRM) receiver

Receiver intrinsic noise of Digital (DRM) receiver and antenna characteristics are basically the same as that of AM receivers, except for RF bandwidth difference. (No difference when the noise par unit bandwidth is considered.)

4 External noise

Recommendation ITU-R P.372 expresses each of average strength of atmospheric noise, man-made noise, and cosmic noise comparing with the thermal noise level (F_{am} dB relative to kT_o) when they are received through a loss-less short vertical monopole with perfectly grounded plane.

4.1 Man-made noise

Figure 6A shows the summary of man-made noise. Their equivalent field strength are shown in Fig. 6B. (for b = 6 kHz)

4.2 Atmospheric noise

Converted to equivalent field strength for Tokyo and New York as shown in Fig. 7 (for b = 6 kHz).

(When the atmospheric noise is below the man-made noise of Category D, man-made noise level is used.)

4.3 Comparison between man-made noise and atmospheric noise

The minimum level of external noise is determined by the man-made noise.

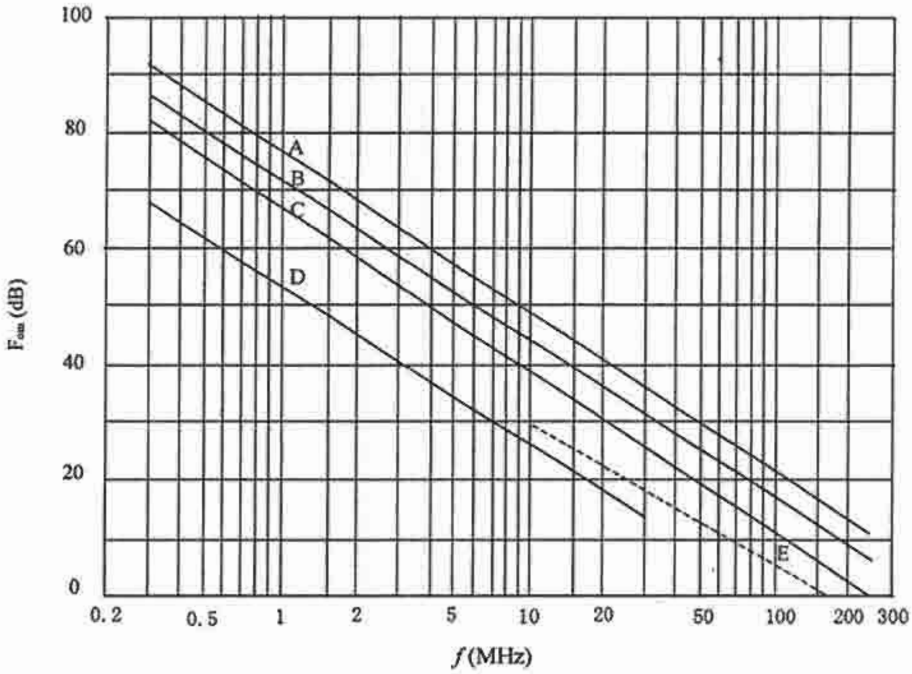
5 Permissible interference field strength

From the above, it is concluded that:

- When an external antenna is used, external noise is the major receiver noise.
- For broadcast receivers with built-in-antenna, external noise is the major noise in business and residential areas. Even in rural areas external noise is significant.
- The minimum value of external noise is determined by the man-made noise.
- In conclusion, it can be said that permissible interference field strength is determined by man-made noise.
- And it is preferable to consider man-made noise in quiet rural area for example situation.
- That is, in order to limit receiver sensitivity deterioration due to a co-channel interference (*Eu*) within 0.05 dB, *Eu* should be 20 dB lower than equivalent field strength of the man-made noise for quiet rural area shown in Fig. 6B.

FIGURE 6A

Relative Medium Man-made noise level comparing with the thermal noise level (F_{am} dB relative to kT_0) when they are received through a loss-less short vertical monopole with perfectly grounded plane



Environmental categories:

A: Business
B: Residential
C: Rural
D: Quiet rural
E: Cosmic noise

FIGURE 6B

Equivalent field strength of man-made noise (b: 6 kHz)

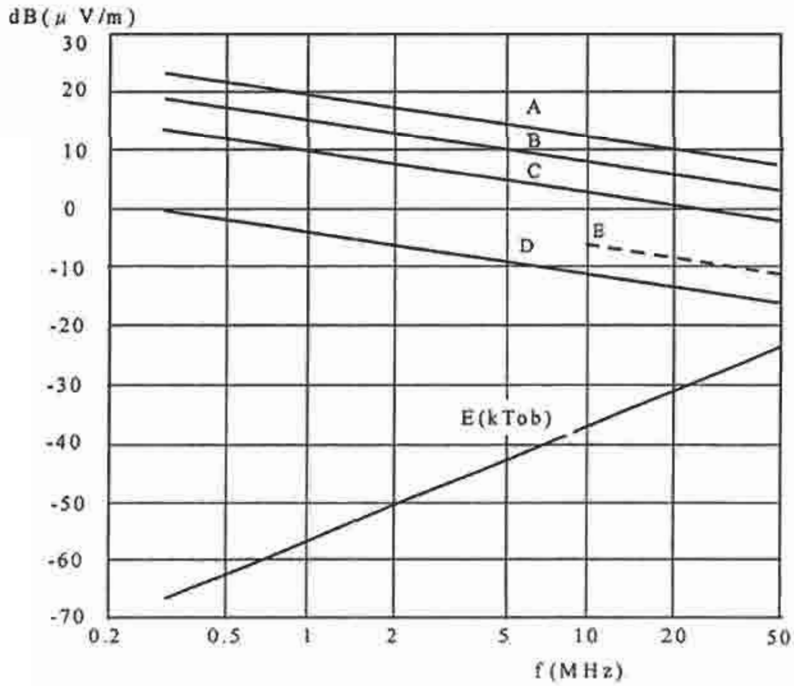
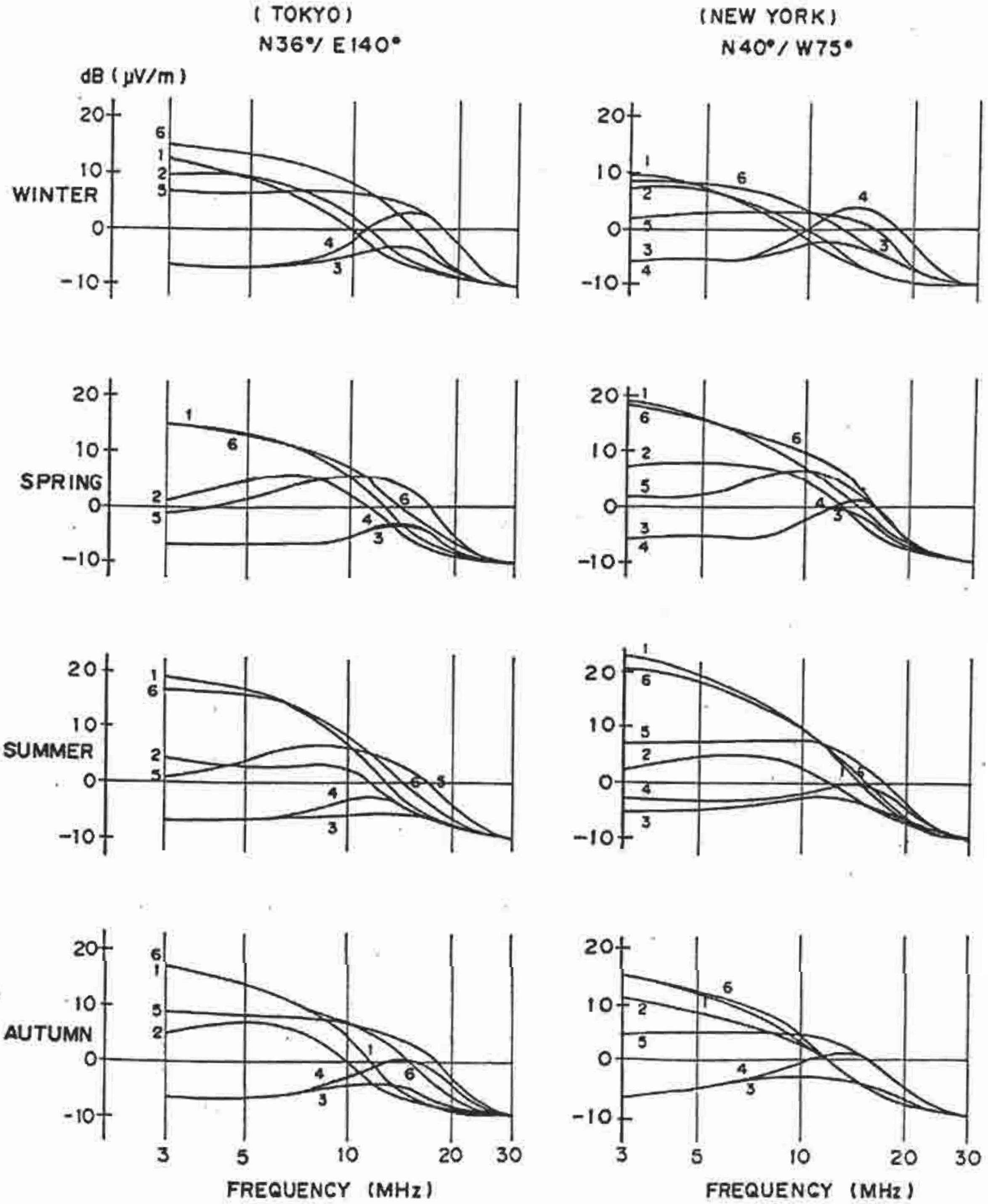


FIGURE 7

Examples of atmospheric noise field strength (Tokyo, New York)



Bandwidth (b) : 6kHz

1 0000-0400LT
2 0400-0800LT
3 0800-1200LT
4 1200-1600LT
5 1600-2000LT
6 2000-2400LT