

RECOMMENDATION 498-2

IONOSPHERIC CROSS-MODULATION IN THE LF AND MF BROADCASTING BANDS

(Question 44/10, Study Programme 44E/10)

(1974-1978-1990)

The CCIR,

CONSIDERING

that excessive radiation towards the ionosphere may result in ionospheric cross-modulation and hence harmful interference,

UNANIMOUSLY RECOMMENDS

that the maximum permissible radiation at any angle of elevation should be such that annoyance due to ionospheric cross-modulation does not exceed that agreed for co-channel interference (see Recommendation 560).

ANNEX I*

The effects of ionospheric cross-modulation in bands 5 (LF) and 6 (MF) may become a problem of increasing severity as the power of transmitters continues to increase.

1. Detailed experiments on this subject have been carried out within the framework of the EBU in several countries, notably in the United Kingdom, in the Federal Republic of Germany [Haberkant and Vogt, 1966; Haberkant *et al.*, 1971] and in the People's Republic of China [CCIR, 1986-90]. From these experiments which were carried out with conventional amplitude-modulation double-sideband transmissions, the following results may be deduced:

1.1 The percentage of cross-modulation increases practically linearly with the power of the interfering transmitter and also increases with the depth of modulation.

Note – The percentage of cross-modulation is the percentage by which the carrier of the wanted transmitter is modulated by the modulating frequencies of the interfering transmitter.

1.2 Cross-modulation depends primarily on the power radiated by the interfering transmitter in the direction of the reflection point of the wanted signal in the ionosphere.

Cross-modulation of percentages less than 10% are directly proportional to the power [Knight, 1973]; an increase of 3 dB in the interfering transmitter power therefore, increases the cross-modulation levels by 6 dB. The percentage of cross-modulation is also directly proportional to the depth of modulation of the interfering transmitter [Knight, 1973].

1.3 The percentage of cross-modulation decreases as the modulating frequency of the interfering transmitter increases. Laboratory experiments [Whyte and Reed, 1973] have shown that the subjective effect of cross-modulation can be related to co-channel interference. To produce a given subjective grade of impairment, interference resulting from ionospheric cross-modulation requires 6 dB less input signal-to-interference ratio than does co-channel interference, providing that the cross-modulation is referred to a modulation frequency of 300 Hz.

1.4 It should be noted that the studies on the problem of ionospheric cross-modulation carried out by Study Group 6 are summarized in Report 574.

2. Figure 1 shows the percentages of cross-modulation measured in many experiments [Knight, 1973]. Each measurement has been standardized to the value which would have been observed if the interfering transmission had been radiated from a short vertical antenna with a carrier power of 100 kW and amplitude modulated at 300 Hz to a depth of 80%.

* This Annex is given for information.

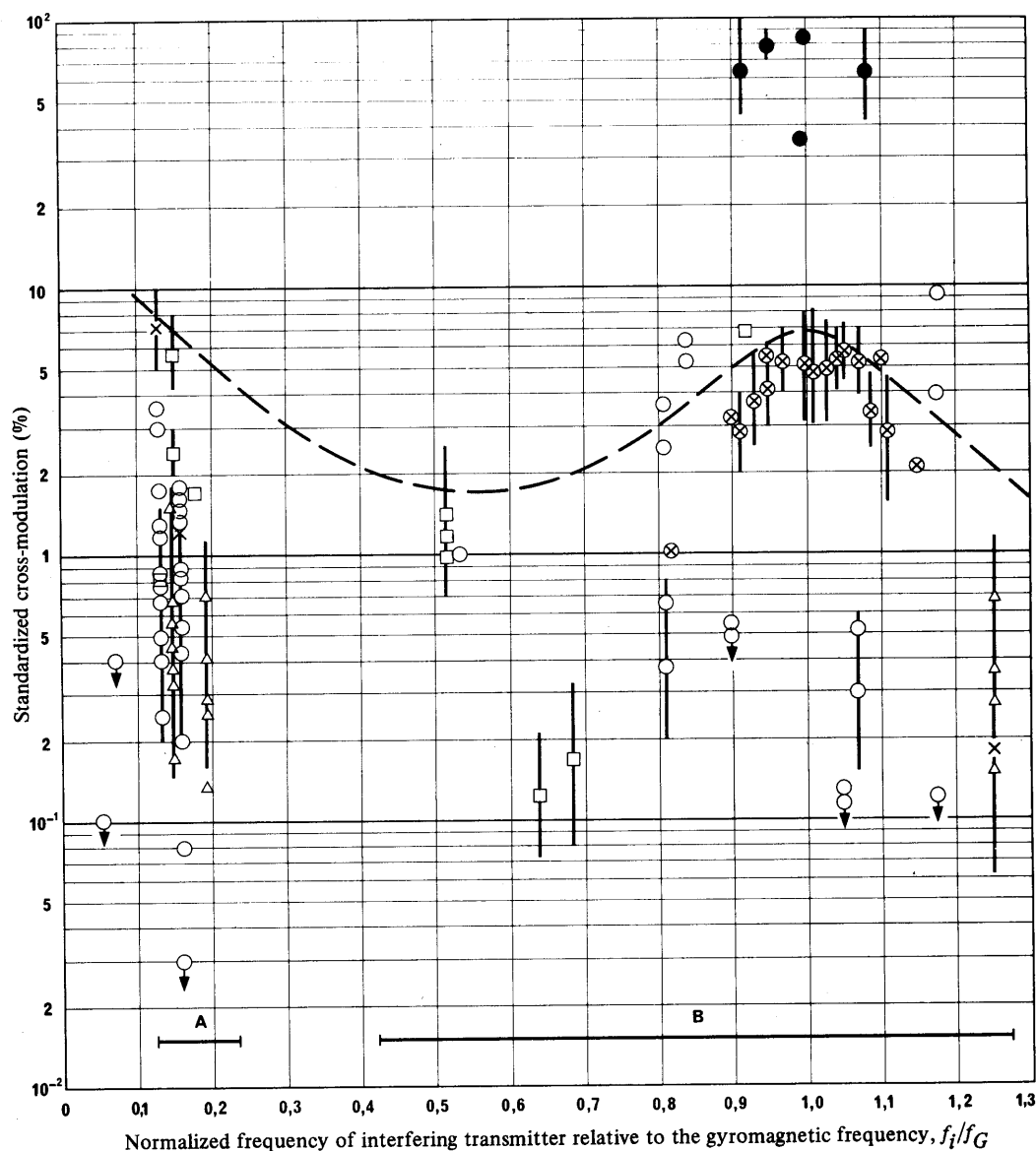


FIGURE 1 – Measurements of ionospheric cross-modulation at medium latitudes

□ : measurements before 1945

○ : measurements at Cambridge and Birmingham

● : measurements in Italy

⊗ : measurements in Australia

△ : measurements in Western Europe after 1945

× : other measurements

— — — : semi-empirical upper limit

A : band 5 (LF)

B : band 6 (MF)

[van der Pol and van der Mark, 1935; Bäumler and Pfitzer, 1935; Bailey, 1937; Grosskopf, 1938]

[Huxley *et al.*, 1947; Ratcliffe and Shaw, 1948; Huxley *et al.*, 1948; Huxley, 1950; Shaw, 1951; Bell, 1951]

[Cutolo and Ferrero, 1948 and 1949; Cutolo *et al.*, 1950; Cutolo, 1952]

[Bailey *et al.*, 1952; Hibberd, 1964]

[Haberkant and Vogt, 1966; Haberkant *et al.*, 1971]

Note – The vertical lines represent a range of median values measured during the course of a night, or on different nights. The arrows pointing downwards indicate measured values which are less than the value indicated.

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Figure 1 includes a semi-empirical curve which shows the greatest percentage of cross-modulation, averaged over a short period, likely to be observed; the condition for this is that the wanted signal should traverse the region of the ionosphere most strongly illuminated by the interfering transmitter. Figure 1 shows that cross-modulation rises to a second maximum when the frequency of the interfering transmitter is close to the gyro-magnetic frequency. Figure 5 shows a map giving the value of the gyro-magnetic frequency for different parts of the world [Laitinen and Haydon, 1950].

3. The effects of cross-modulation should be taken into account not only for sky-wave reception, but also for ground-wave reception at the edge of the service area when at night the sky-wave is no longer negligible. However, the effect of cross-modulation is reduced approximately in the ratio of the wanted signal levels, ground-wave to sky-wave, at the receiving point.

4. The percentages of ionospheric cross-modulation have been calculated for LF and MF and their dependence on the powers of the wanted and unwanted transmitter has been determined. Results of theoretical studies and practical experiments have been compared. [Shluyger *et al.*, 1976].

5. Preliminary conclusions

On the basis of measurements [Haberkant and Vogt, 1966; Haberkant *et al.*, 1971] examples may be given of the power-flux levels, or the transmitter power as a function of the angle of elevation, which can cause disturbance to wanted transmissions.

For this purpose, an assumption is first made regarding the tolerable level of the percentage of cross-modulation. According to Recommendation 560 and Report 575, a radio-frequency protection ratio of approximately 30 dB is agreed for 10% of the time in the case of a fluctuating unwanted signal. Ignoring the effect mentioned in § 1.3, the same disturbing effect is produced by 3% cross-modulation for 10% of the time. It has been shown [Haberkant *et al.*, 1971] that for frequencies at the upper end of the MF broadcasting band 6 (MF) this level of cross-modulation may be produced by a power flux within the E region of the ionosphere of about $2 \mu\text{W}/\text{m}^2$ ($-57 \text{ dB}(\mu\text{W}/\text{m}^2)$), which corresponds to a maximum field strength of 27 mV/m ($89 \text{ dB}(\mu\text{V}/\text{m})$).

Assuming a height of 100 km of the reflecting layer (E region), it is possible to calculate the power radiated from various types of antenna which would produce this power flux within the E region. The vertical transmitting antennas that are commonly used show a vertical radiation pattern which depends in a well-defined fashion on the height (expressed in fractions of the wavelength, λ). In particular, such vertical antennas do not radiate at an angle of elevation of 90° . Table I [Haberkant *et al.*, 1971] indicates, for a number of vertical transmitting antennas at different heights the transmitter powers to be fed into these antennas to meet the above-mentioned requirements.

TABLE I

Length of vertical antenna	$< 0.25 \lambda$	0.25λ	0.5λ	0.55λ	0.64λ	$0.64 \lambda^{(1)}$
Transmitter carrier power (kW)	320	340	560	670	370	840

⁽¹⁾ First side lobe compensated.

It is possible to calculate the dependence of the radiated power on the angle of elevation required to produce the same power flux, covering the whole range from 0° (horizontal radiation) to 90° (vertical radiation). The results are given in Table II.

Tables I and II give only approximate values because it is known, from theory, that ionospheric cross-modulation may be influenced by several parameters, such as the frequencies of the wanted and of the interfering transmitter (in particular seen in their relationship to the gyro-frequency) and the polarization of emission.

The powers given in Tables I and II are examples based on a small number of measurements at a frequency near the top end of band 6 (MF); they make no allowance for the change of cross modulation with carrier frequency of the disturbing signal, nor do they include the effect of reduced cross-modulation at the higher audio frequencies which permits interfering-transmitter powers to be increased by 3 dB.