REPORT 401-6

TRANSMITTING ANTENNAS IN LF AND MF BROADCASTING

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

(1966-1970-1974-1978-1982-1986-1990)

1. Antenna with reduced vertical radiation

A high-efficiency anti-fading antenna should be of sectionalized construction and have a total electrical height of 2 λ/3 to λ, to produce the necessary rapid rise of sky-wave field-strength near the point where it equals that of the ground-wave. The effect of the resistive component of the antenna current on the vertical radiation pattern of a sectionalized tower can be reduced or compensated by multiple feeding. It should be noted that the location and extent of the fading zone varies due to changes in the properties of the reflecting ionospheric layers.

In practice, the fading zone is somewhat larger than that calculated. This might be due, on the one hand, to variations of the E-layer reflection, and on the other hand, to F-layer reflections. The design of antennas should take care of these effects.

2. Influence of ground conductivity on the vertical radiation pattern (including ground system)

[CCIR, 1970-74a] gives the results of a theoretical study into the influence of ground conductivity on the vertical radiation patterns of typical vertical antennas. The study takes account of the diffraction of waves around the curvature of the Earth.

Ground loss may be defined as the reduction in field strength which occurs above a curved Earth when land replaces sea water. The corresponding increase which occurs when land is replaced by sea water is known as "sea gain".

[CCIR, 1966-69a] gives the results of field-strength measurements carried out to determine the effects of ground conductivity on low angle radiation over a relatively long transmission path of 1400 km. Transmissions from Rome at 845 kHz were measured simultaneously at coastal and inland sites along a radial extending 100 km inland from a coastal site in Southern England. Because of the principle of reciprocity it is immaterial whether the antenna transmits or receives. Figure 1 shows the results of measurements in terms of field strength at the inland sites. B to K. relative to the coast site A.

It is concluded that a transmitter operating in the MF band (band 6) will radiate sky-waves more efficiently at low angles of radiation if it is situated on a coastline facing the area to be served and that the ground loss does not reach its limiting value until the antenna is at least 50 km inland. To obtain maximum advantage open sea must extend from the coastline for a distance of at least 100 wavelengths in the direction of propagation.

Ground loss applies equally to transmitting and receiving antennas. For further information see Recommendation 435.

Measurements of the effect of sea gain have been reported by Italy [CCIR 1966-69b] and by the USSR [CCIR 1970-74b] in LF and MF. The results are in good agreement with the calculated theoretical values.

Studies carried out in Italy [CCIR, 1982-86a] have shown the combined influence of a soil of finite conductivity and of a ground system on the sky-wave vertical radiation pattern of MF transmitting antennas. By the use of a computer-based procedure, a correction factor has been derived which is applied to the radiation pattern of a single mast antenna over flat and perfectly conducting ground.

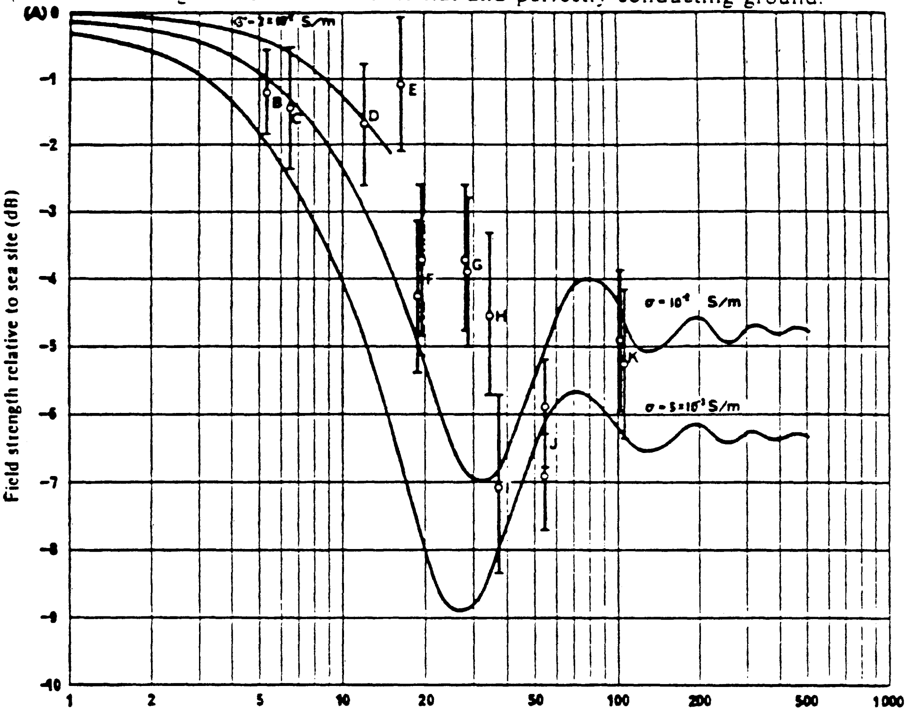


FIGURE 1 – *Theoretical and measured ground loss*

——————— : theoretical ground loss

o : measured ground loss

(Vertical lines indicate confidence limits)

Figure 1 shows how ground loss varies with distance from the sea at the frequency 845 kHz for an angle of arrival of about 4°. Also shown in Fig. 1 are theoretical curves for ground conductivities of 5×10^{-3} S/m and 10^{-2} S/m which are believed to be the limits for most of the area. Part of the theoretical curve for 2×10^{-2} S/m is also included since the first 10 km inland was known to be of about this value. Figure 1 clearly demonstrates the large ground loss at sites well inland from the coast.

3. High-efficiency transmitting antennas

It should be emphasized that the capital and maintenance costs of a high-efficiency transmitting antenna should not be considered in isolation, but rather with regard to the cost and effectiveness of the broadcasting station as a whole. For example, for a broadcasting station with a transmitter output power of 100 kW or more, the cost of a simple antenna may be a relatively small part of the total expenditure.

3.1 LF anti-fading antennas

[CCIR 1966-69c] gives information on experience gained with the broadcasting ring antenna for use in band 5 at Motala (191 kHz). The antenna is a stationary field ring antenna consisting of one central element (a vertical radiator of height 250 m) and five vertical radiators with a height of 200 m, equally spaced on a radius of 630 m (0.4 λ). The measurements of field strengths at distances of up to 300 km from the antenna show a substantial extension of the fading-free zone.

3.2 MF anti-fading antennas

[CCIR, 1970-74c] describes a double half-wave cage-type antenna for use in band 6 (MF). This antenna consists of four cages of copper or aluminium wires. The cages are suspended on an earthed, non-divided mast, each cage (λ/4) being galvanically connected with the mast at its upper end and insulated from the mast at its lower end (see Fig. 2).

By appropriate selection of the ratio and phase of the currents in the two dipoles, the vertical radiation pattern can be shaped within a wide range. This enables selection of the optimum operating conditions for both day-time and night-time conditions.

[CCIR, 1970-74d] reports on the existence of a high-gain band-6 (MF) broadcasting antenna at Lille-Camphin on a frequency of 1376 kHz. This antenna is of the full-wave type and is designed to increase the horizontal gain by reducing radiation in directions other than that of the horizon. It is centre-fed, but its quarter-wave skirt structure avoids cutting the tower with insulators. There is also no insulator at the base of the tower. Feeder matching is effected without the classical antenna unit, inductance or capacitance. The radiation diagram was regulated with the help of measurements made using a helicopter. A detailed description of the antenna is available [Lacharnay, 1969].

[CCIR, 1970-74e] describes the design of an antenna, the radiation pattern of which can be regulated in the vertical plane. The upper part of the antenna is a normal vertical radiator whilst the lower part is a vertical radiator with a reactance in the form of a short circuit loop connected to the base. To reduce its characteristic impedance, inclined wires are suspended from the upper part of the antenna. A vertical wire screen is fixed to the lower part of the antenna, reaching from the ground to a height of $H_1 = 0.4\ H$.

Regulation of the radiation pattern in the vertical plane is provided by adjusting the current distribution by means of distributed constant impedance lines. The antenna possesses anti-fading properties in a wide frequency band and has a gain of up to twice that of a base driven half-wave antenna.

3.3 MF Directional antennas

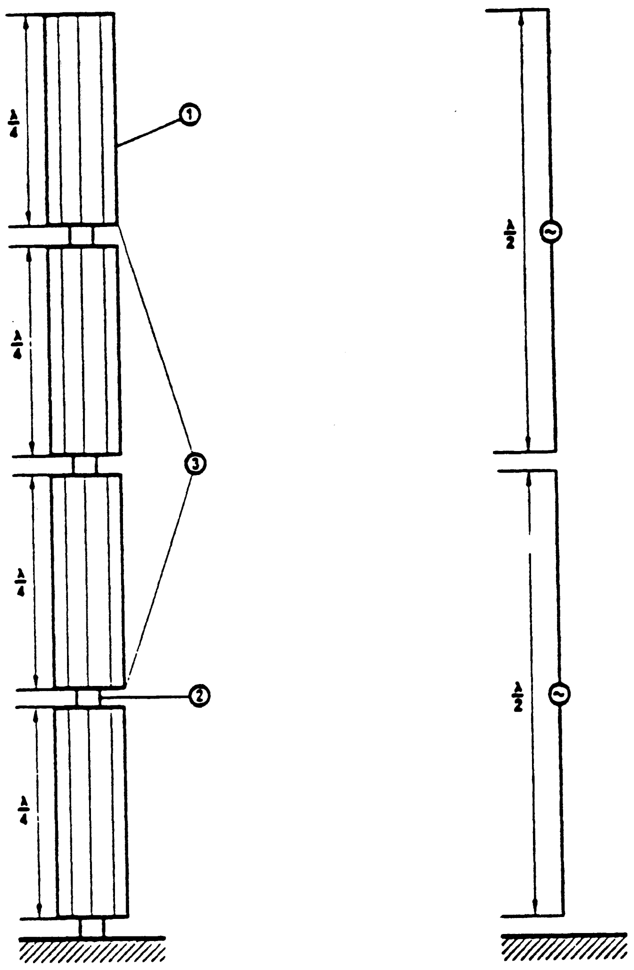
[CCIR, 1970-74f] describes a switchable transmitting antenna for optimized day and night service in band 6 (MF). Two antennas of this type were in use at two broadcasting stations (Ismaning, 1 602 kHz and Langenberg, 1 586 kHz). The antenna consists of three insulated sections and this permits very flexible adjustment of the current distribution and allows changes in the vertical radiation pattern over a wide range. A suitable combination of parameters results in an improvement in the co-channel radio-frequency wanted-to-interfering signal ratio of between 3 dB and 10 dB.

[CCIR, 1974-78a] describes a band 6 (MF) directional antenna with a controlled horizontal radiation pattern [Timonina, 1971].

The antenna consists of four radiators located at the corners of a square of side D. Two of the radiators are active whilst the other two act as passive reflectors tuned by means of a short-circuited stub. The radiation pattern in the horizontal plane is controlled over the sector 0° to 360°. The direction of maximum radiation may be changed in steps of 90°. Assuming $D = 0.25\,\lambda$ to $0.28\,\lambda$ then the back radiation level is -18 dB to -20 dB relative to the main beam, whilst over an angular sector of 100° this level averages about -14 dB.

A four-mast antenna with an adjustable current distribution [Bielousov, 1974; Bielousov *et al.*, 1976] and height $H = \lambda$ with $D = 0.28\,\lambda$ has a gain of 10 dB when tuned for maximum radiation in the forward direction.

[CCIR, 1974-78b] refers to a published article [Lacharnay, 1976] which describes various directional transmitting antennas employing vertical mast-radiators for LF and MF broadcasting, characterized by very low radiation over wide sectors, both in elevation and azimuth. Such antennas render it possible to reduce the interference in overcrowded frequency bands. Some practical installations are described and details are given of the attenuation that can be obtained (30 dB at present) as well as the stability of the antenna adjustments, verified over several years.



a) Distribution of cages along the mast

b) Equivalent circuit

FIGURE 2 – *Double half-wave cage-type antenna*

4. Methods of prediction of the re-radiation effects

The problem of the re-radiation effects from structures, such as power transmission lines, metallic masts, buildings with metallic structure and buried metallic installations is a serious one since such structures may modify the desired radiation pattern. The elimination of the undesired effects is closely related to the knowledge of the current distribution along the antenna structure in the presence of such surrounding structures.

A number of the methods for determining the current distribution along the antenna structure has been reported. A simple method, the so-called "point matching method", a variant of "the moment method" [Harrington, 1968] has been developed in Yugoslavia [Popovic, 1970] and has been successfully applied in the treatment of the related applications [Surutka and Mitic, 1975].

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[1970-74]: a. 10/188 (United Kingdom); b. 10/294 (USSR); c. 10/62 (Poland (People's Republic of)); d. 10/73 (France); e. 10/292 (USSR); f. 10/28 (Germany (Federal Republic of)).

[1974-78]: a. 10/108 (USSR); b. 10/272 (France).

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