RECOMMENDATION ITU-R P.1147-4

Prediction of sky-wave field strength at frequencies between about 150 and 1 700 kHz

(Question ITU-R 225/3)

(1995-1999-2003-2005-2007)

Scope

This Recommendation provides a prediction procedure for the frequency range between about 150 and 1700 kHz, for path length between 50 to 12 000 km.

The ITU Radiocommunication Assembly,

considering

a) that there is a need to give guidance to engineers in the planning of broadcast services in the LF and MF bands;

b) that it is important, for stations working in the same or adjacent frequency channels, to determine the minimum geographical separation required to avoid interference resulting from long-distance ionospheric propagation;

c) that portions of this frequency range are being shared by broadcasting and other services in different Regions, an accurate method for predicting interference levels is needed to maintain efficient and orderly utilization of those portions of the spectrum,

recommends

that the following method should be adopted for use, taking particular note of the discussion on accuracy given in Annex 1.

1 Introduction

This method predicts values of the night-time sky-wave field strength for a given power radiated from one or more vertical antennas, when measured by a loop antenna at ground level aligned in a vertical plane along the great-circle path to the transmitter. The method has been based on measurements made in the frequency bands allocated to broadcasting and applies for paths of length 50 to 12 000 km for those LF and MF bands in particular. For a discussion on daytime propagation, see Annex 2.

Figures 1, 2 and 3 are an essential part of the prediction method. Geomagnetic maps are included for convenience in Figs. 5, 6 and 10. The remaining Figures and Appendix 1 provide additional information to simplify the use of the method.

2 Annual median night-time field strength

The predicted sky-wave field strength is given by:

$$E = V + E_0 - L_t = V + G_S - L_p + A - 20 \log p - L_a - L_t - L_r \qquad (1)$$

where:

E: annual median of half-hourly median field strengths (dB(µV/m)) for a given transmitter cymomotive force, V, and at a given time, t, relative to sunset or sunrise as appropriate

E_0: annual median of half-hourly median field strengths (dB(µV/m)) for a transmitter cymomotive force of 300 V at the reference time defined in § 2.1

V: transmitter cymomotive force (dB above a reference cymomotive force of 300 V) (see § 2.2)

G_S: sea-gain correction (dB) (see § 2.3)

L_p: excess polarization-coupling loss (dB) (see § 2.4)

A: a constant. At LF, $A = 110.2$. At MF, $A = 107$ except for propagation paths whose midpoints are situated in the part of Region 3 south of parallel 11° S. In those cases, $A = 110$

L_a: loss factor incorporating effects of ionospheric absorption and related factors (see § 2.6)

L_t: hourly loss factor (dB) (see § 2.7)

L_r: loss factor incorporating effect of solar activity (§ 2.8).

Figure 4 shows E_0 as a function of ground distance, d, for various geomagnetic latitudes when G_S, L_p and R are all zero; where R is the twelve-month smoothed international relative sunspot number.

2.1 Reference time

The reference time is taken as six hours after the time at which the Sun sets at a point S on the surface of the Earth. For paths shorter than 2 000 km, S is the mid-point of the path. On longer paths, S is 750 km from the terminal where the Sun sets last, measured along the great-circle path.

2.2 Cymomotive force

The transmitter cymomotive force V (dB(300 V)) is given as:

$$V = P + G_V + G_H \qquad (2)$$

where:

P: radiated power (dB(1 kW))

G_V: transmitting antenna gain factor (dB) due to vertical directivity, given in Fig. 1

G_H: transmitting antenna gain factor (dB) due to horizontal directivity. For directional antennas, G_H is a function of azimuth. For omnidirectional antennas, $G_H = 0$.

2.3 Sea gain

The sea gain G_S is the additional signal gain when one or both terminals is situated near the sea, but it does not apply to propagation over fresh water. G_S for a single terminal is given by:

$$G_S = G_0 - c_1 - c_2 \qquad \text{for} \quad (c_1 + c_2) < G_0 \tag{3}$$

$$G_S = 0 \qquad \text{for} \quad (c_1 + c_2) \geq G_0 \tag{4}$$

where:

G_0: sea gain when the terminal is on the coast and the path is unobstructed by further land (dB)

c_1: correction to take account of the distance between the terminal and the sea

c_2: correction to take account of the width of one or more sea channels, or the presence of islands.

If both terminals are near the sea, G_S is the sum of the values for the individual terminals.

G_0 is given in Fig. 2 as a function of d for LF and MF. At MF, $G_0 = 10$ dB when $d > 6\,500$ km; and at LF $G_0 = 4.1$ dB when $d > 5\,000$ km, where d is the ground distance between the two terminals.

The correction c_1 is given by:

$$c_1 = \frac{s_1}{r_1} G_0 \tag{5}$$

where:

s_1: distance of terminal from sea, measured along great-circle path (km)

$r_1 = 10^3 G_0^2 / Q_1 f$ km

f: frequency (kHz)

$Q_1 =$ 0.30 at LF and 1.4 at MF.

The correction c_2 is given by:

$$c_2 = \alpha\, G_0 \left(1 - \frac{s_2}{r_2} \right) \qquad \text{for} \quad s_2 < r_2 \tag{6}$$

$$c_2 = 0 \qquad \text{for} \quad s_2 \geq r_2 \tag{7}$$

where:

s_2: distance of terminal from next section of land, measured along the great-circle path (km)

$r_2 = 10^3 G_0^2 / Q_2 f$ km

$Q_2 =$ 0.25 at LF and 1.2 at MF

α: proportion of land in the section of path between r_2 and s_2 $(0 < \alpha \leq 1)$.