



K.18

PROTECTION AGAINST INTERFERENCE

CALCULATION OF VOLTAGE INDUCED INTO TELECOMMUNICATION LINES FROM RADIO STATION BROADCASTS AND METHODS OF REDUCING INTERFERENCE

ITU-T Recommendation K.18

(Extract from the *Blue Book*)

NOTES

1 ITU-T Recommendation K.18 was published in Volume IX of the *Blue Book*. This file is an extract from the *Blue Book*. While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Recommendation, the expression “Administration” is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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Recommendation K.18

CALCULATION OF VOLTAGE INDUCED INTO TELECOMMUNICATION LINES FROM RADIO STATION BROADCASTS AND METHODS OF REDUCING INTERFERENCE

Geneva, 1980, modified at Malaga-Torremolinos, 1984 and at Melbourne, 1988)

1 Introduction

Although inductive interference from radio waves is seldom observed on circuits in underground cables, many examples of such interference have been reported in circuits carried by open wires, aerial cables or cables inside buildings.

Interference on voice-frequency circuits occurs because the induced radio wave is detected and demodulated by the nonlinear components in a telephone set or by metal oxide layers formed at conductor joints. This interference is mostly intelligible noise and may occur up to 5 km from a radio station whose radiating power is more than several tens of kilowatts.

On carrier or video transmission circuits, the induced radio wave impairs circuit performance when the radio-wave frequency is within the operating frequency of the transmission system. The interference usually consists of a single frequency tone within a telephone channel and is unintelligible. It reduces the signal-to-noise ratio (SNR) for the transmission system. This interference may occur within a wide area around a radio station. Interference on video transmission circuits has been reported in only a few cases, but it is expected to cause serious problems when video transmission services increase in number in the future.

An unusual example of interference may arise in which outside plant maintenance personnel receive burns due to radio frequency currents. Such problems have been reported only in the immediate vicinity of a radio station antenna.

2 Analysis of interference

In the theoretical analysis of the voltage induced from a radio wave, the following conditions are assumed:

- Earth resistivity is homogeneous and uniform.
- A cable or a wire is supported in a straight line at a constant height above the earth's surface.
- The metallic screen of a cable is earthed at both ends.
- The radio-wave electric field has a constant intensity and a constant incidence angle, and phase change along the cable is uniform.
- The radio wave is originally polarized vertically. However, while it propagates along the surface of the earth, a horizontal component is generated due to the finite conductivity of the earth.

Constants and variables used for theoretical analysis are shown in Annex A.

2.1 For telecommunication lines without a metallic screen, the horizontal component of the radio-wave electric field acts directly as an electromotive force on the telecommunication line. This causes induced noise at terminals when the circuit has an impedance unbalance with respect to earth. Induced longitudinal voltages at the ends of a telecommunication line without a metallic screen are given by Equations (B-1) and (B-2).

2.2 For telecommunication cables with a metallic screen, the horizontal component of the radio-wave electric field acts as an electromotive force, causing induced current to flow in the earth return circuit composed of the metallic screen of the cable and the earth. Due to the current in the screen, an electromotive force is induced in the conductors through the transfer impedance between the conductors and the metallic screen. This electromotive force may cause disturbance to metallic circuits in the cable, according to the degree of their unbalance with respect to the metallic screen (or the earth).

Induced longitudinal voltages at the ends of a telecommunication cable with a metallic screen are given by Equations (B-3) and (B-4). In reference [1] the values obtained by using these equations are shown to agree with measured values.

2.3 The equations in Annex B are very complicated and involve many parameters. It is therefore useful to estimate the approximate value of the maximum induced longitudinal voltage by the following simplified equation:

$$\begin{aligned} V_2(0) \text{ dB} \left[\approx V_2(l) \right] &= 20 \log_{10} V_2(0) \\ &= 20 \log_{10} \frac{PE_v(\cos \theta) Z_K}{4Z_{01}} - 30 \log_{10} f - 20 \log_{10} \alpha_{20} + 300 \end{aligned} \quad (2-1)$$

where

$$l \geq \frac{1.5 \beta_0}{f \cdot \beta_2} \times 10^8 \quad (2-2)$$

$$20 \Omega < |Z_{1R}|, |Z_{1L}| \leq |Z_{01}| \quad (2-3)$$

$$\gamma_2 = \alpha_2 + j\beta_2$$

$$\alpha_2 = \alpha_{20} \sqrt{f} \times 10^{-3} \text{ (dB / km)}$$

α_{20} is the attenuation coefficient at 1 MHz (dB/km)

f is the radio-wave frequency expressed in Hz.

Other constants and variables are shown in Annex A.

Equation (2-1), which gives the maximum induced longitudinal voltage in dB (0 dB = 0.775 V), is obtained on the basis of the following:

The induced longitudinal voltage calculated by the equations in Annex B reaches an initial peak value when cable length

$$l = \frac{1.5 \beta_0}{f \cdot \beta_2} \times 10^8$$

and subsequently describes a series of peak values. Its maximum value occurs at one of the earliest peak values along the cable length.

$$l \geq \frac{1.5 \beta_0}{f \cdot \beta_2} \times 10^8.$$

The induced longitudinal voltage reaches its maximum at one of the earliest peak values due to the attenuation of the induced radio wave along the cable (Figure 3/K.18).

The errors involved in using Equation (2-1) instead of the full equations of Annex B are described in detail in Annex C.

2.4 If the line configuration is very complicated, it is necessary to divide the line into several segments and to estimate the induced longitudinal voltage for each segment by Equations (B-1) to (B-4). Estimated induced voltages for each segment are then combined to obtain the overall induced voltage, taking into account the transmission characteristics and the boundary conditions of the line involved.

When the simplified equation (2-1) is applied to a complicated line, a straight line model may be used to estimate the maximum induced longitudinal voltage. Calculations should commence at the point nearest to the radio station and the smallest value of radio wave incidence angle should be used.

2.5 When field measurement of the radio-wave electric field strength is carried out, the measured value may be used for E_v in Equation (2-1).

When the measured value is not available, the radio-wave electric field strength E_v can be calculated by Equation (2-4), taking into account the distance from the radio station and the power of the radio station transmitter (see [2]).

$$E_v = \frac{1}{r} \sqrt{\frac{1.5 P Z_0}{2\pi}} \quad (2-4)$$

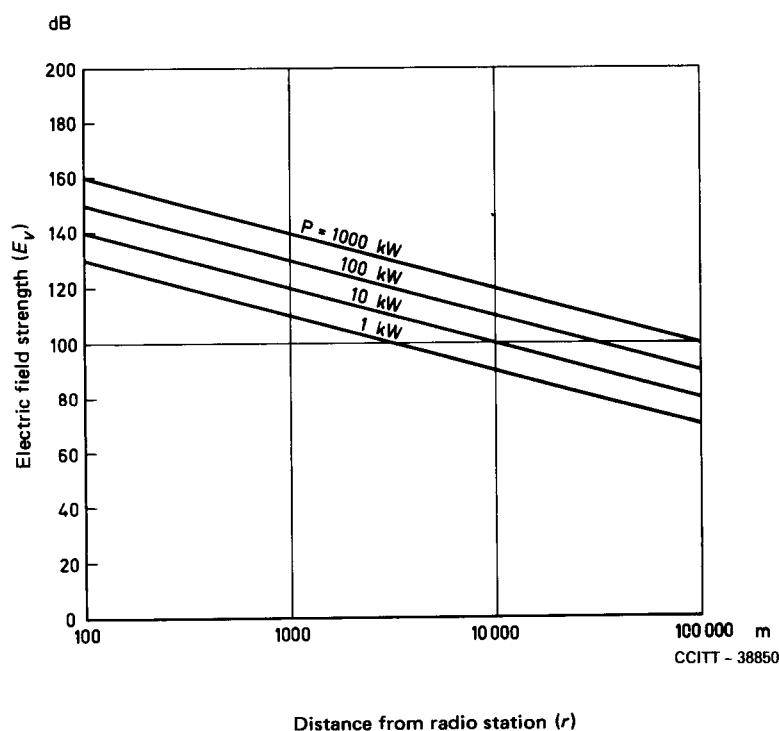
where

P is the radio station transmitting power (W)

r is the distance from radio station (m)

Z_0 is the intrinsic impedance of free space ($\approx 377 \Omega$)

Figure 1/K.18 shows values of E_v obtained from Equation (2-4) using various values of P .



Note – E_v is expressed in dB (0dB = 1 μ V/m).

FIGURE 1/K.18
Radio-wave electric field strength related to the distance from the radio station

2.6 The angle of incidence made by the radio wave onto the telecommunication line may vary according to circumstances.

When the telecommunication line is installed in open country, either a measured value of the incidence angle or a value calculated from the relative location of the radio station and the telecommunication line may be used.

When the telecommunication line is installed near structures which obstruct radio wave propagation, the incidence angle may be taken as zero and the severest condition assumed.

2.7 The induced longitudinal voltage at the ends of the telecommunication cable shown in Figure 2/K.18 may be estimated using the simplified method which follows.

Inserting the values for parameters P , f , α_{20} , β_2 and θ given in Figure 2/K.18 together with calculated values for E_v and Z_K into Equations (2-1) and (2-2), the following results are obtained:

$$V_2(0) \approx V_2(l) = -35.0 \text{ dB}$$

$$l \geq 210 \text{ m}$$

Moreover, using $\theta = 0^\circ$ as the most severe value, the following is obtained:

$$V_2(0) \approx V_2(l) = -32.0 \text{ dB}$$
$$l \geq 210 \text{ m}$$

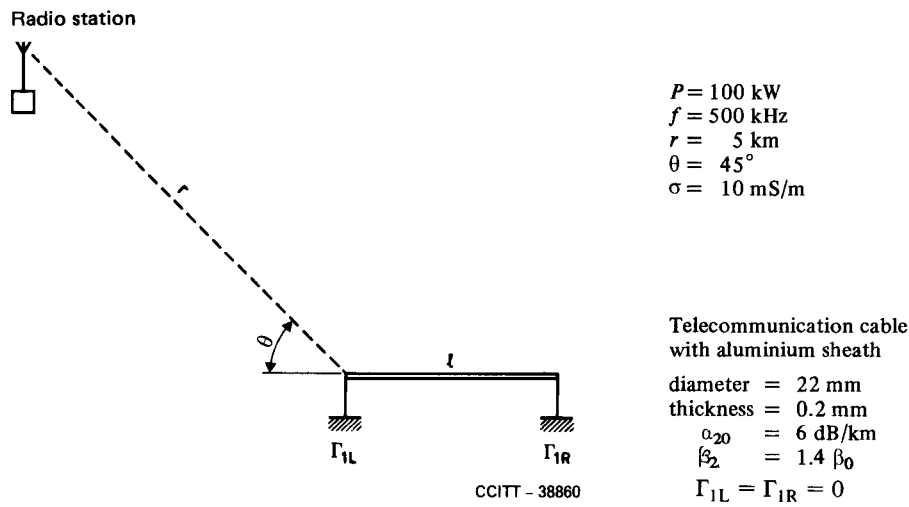


FIGURE 2/K.18
Relative position of radio station and telecommunication line

In Figure 3/K.18 the results obtained by using the simplified calculations are compared with others derived from using the more rigorous methods described in Annex B, in which values of V_2 related to cable length are expressed. It is apparent that the simplified method is adequate for estimating the most severe interference likely to be experienced.

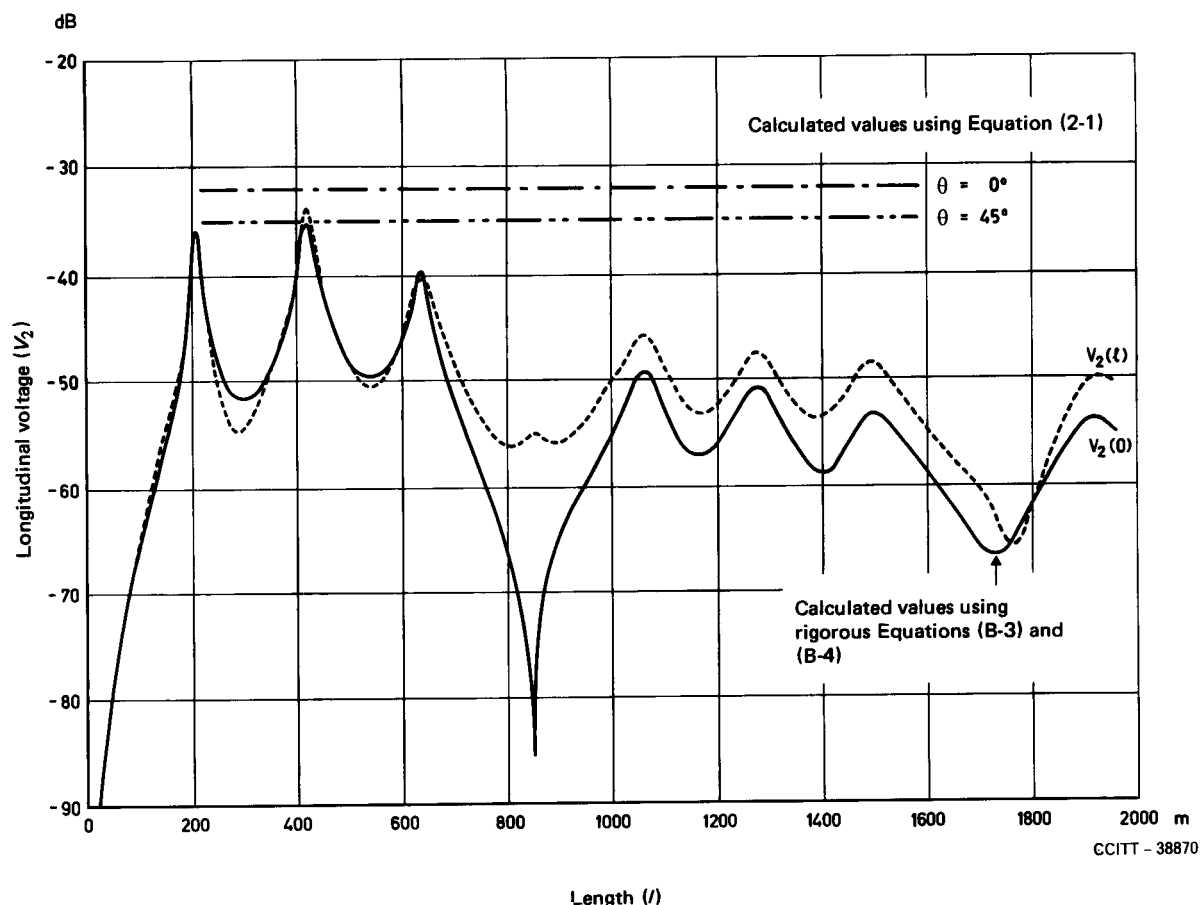


FIGURE 3/K.18
Calculated induced longitudinal voltage at ends of cable shown in Figure 2/K.18

2.8 Transverse voltages which cause noise arise due to the imperfect balance of the circuit with respect to the metallic screen (or earth). If a ratio, λ is used to related longitudinal and transverse voltages, noise levels may be obtained from calculated or measured values of the induced longitudinal voltage:

$$V = \lambda \cdot V_2$$

where

V_2 [$V_2(0)$ or $V_2(l)$] is the longitudinal voltage at the ends of the longitudinal circuit under open circuit conditions,

V [$V(0)$ or $V(l)$] is the transverse voltage at the ends of the circuit when terminated with its characteristic impedance at both ends.

For example, in the case shown in Figure 2/K.18 and λ equal to -40 dB, the noise level, V is obtained as follows:

(in this case, $V_2 = -35$ dB [0 dB = 0.775 V])

$$V = -35 - 40 \text{ dB} = -75 \text{ dB}$$

3 Reduction of interference

The following measures may be taken to minimize interference:

3.1 Interference to a voice-frequency circuit can be reduced by inserting a $0.01 \sim 0.05 \mu\text{F}$ capacitor between conductors and the earth at the input terminal or at the telephone set, to bypass induced radio-wave currents.

3.2 Interference to carrier and video transmission systems can be reduced by the following measures: