RECOMMENDATION ITU-R F.1190*

PROTECTION CRITERIA FOR DIGITAL RADIO-RELAY SYSTEMS TO ENSURE COMPATIBILITY WITH RADAR SYSTEMS IN THE RADIODETERMINATION SERVICE

(Question ITU-R 159/9)

(1995)

The ITU Radiocommunication Assembly,

considering

a) that radar systems can produce interference to digital radio-relay systems (DRRS), which gives rise to regular bursts of errors related to the operational characteristics of the radar e.g. the radar antenna rotation rate;

b) that the importance of radar systems is recognized worldwide, but that nevertheless efforts should be made to reduce the levels of spurious emissions from such systems;

c) the importance of DRRS in telecommunication networks;

d) that it is necessary to establish the criteria for ensuring compatibility between radar systems and DRRS;

e) that the effects of interference from radar systems are different depending on the type of radar systems;

f) that although the effect of radar interference on DRRS is different depending on the modulation methods employed in the interfered-with systems, provisionally it seems appropriate to define the protection threshold in terms of interference-to-thermal noise ratio in order to make the criteria applicable to any modulation method,

recommends

1 that the interference power should be evaluated in terms of peak envelope power over the entire necessary bandwidth of a radio channel of the interfered-with system;

2 that in the case of interference from fixed and transportable land based radar systems;

2.1 the interference-to-thermal noise ratio (referred to in *recommends* 1) should be no greater than 0 dB (see NOTES 1 and 2);

2.2 the interference should be evaluated in an actual or planned operational situation;

2.3 for the case of the main beam radio-relay antenna intercept of the interference, the power flux-density at a receiving station of radio-relay systems due to unwanted emissions should be no greater than –127 dB(W/m^2) in any 40 MHz band in the 3 400-4 200 MHz and 4 400-5 000 MHz ranges or –130 dB(W/m^2) in any 20 MHz band in the 5 925-6 425 MHz range (see Annex 2);

3 that in the case of interference from maritime and land mobile radar systems (see NOTE 3);

3.1 the interference-to-thermal noise ratio (I/N) (referred to in § 1) should be no greater than 10 dB (NOTES 1, 2 and 5);

3.2 the interference should be evaluated in an actual or planned operational situation. However, the condition of 20 km distance direct exposure in line-of-sight and free space propagation, should be considered representative of the maritime mobile radars for many cases;

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* This Recommendation should be brought to the attention of Radiocommunication Study Group 8 (WP 8C), the International Maritime Organization (IMO) and the International Maritime Radio Association (CIRM).

3.3 the power flux-density at a receiving station of radio-relay systems due to unwanted emissions should be no greater than –117 dB(W/m^2) in any 40 MHz band in the 3 400-4 200 MHz and 4 400-5 000 MHz ranges or –120 dB(W/m^2) in any 20 MHz band in the 5 925-6 425 MHz range (see NOTE 4);

4 that the guidance contained in Annex 1 should be taken into consideration for evaluation of interference power into digital radio-relay systems due to unwanted emissions from radar systems.

NOTE 1 – This value was derived from the assumption that the interference from radar systems has an intermittent nature and occurs only with low probability. This requires further studies and tests to validate these assumptions.

NOTE 2 – For the time being, this criteria should apply only to radar interference in the frequency bands below about 7 GHz. Further studies are required.

NOTE 3 – Maritime mobile does not include high power naval radiolocation.

NOTE 4 – The power flux-density values in § 3.3 above are equivalent to the unwanted emission e.i.r.p. of a radar system of –20 dBW in a 40 MHz band and –23 dBW in a 20 MHz band, respectively, assuming a 20 km separation distance (see Annex 2).

NOTE 5 – The I/N value was derived from the assumption that the interference from mobile radar systems is temporary in nature.

ANNEX 1

Evaluation of interference power into digital radio-relay systems due to unwanted emissions from radar systems

The interference power due to unwanted emissions from radar systems into DRRS should be evaluated in terms of peak envelope power over the necessary bandwidth of a radio channel of the interfered-with system (see *recommends* 1 of this Recommendation). In evaluating the total power over the necessary bandwidth, the following factors should be taken into account:

– it is not always possible to evaluate the peak envelope power of the interference in time domain;

– when measured in frequency domain, interfering components appear with a frequency spacing equal to an inverse of the pulse width of a radar system;

– there is more or less coherence among such interfering components and, therefore, the peak envelope power of the aggregate interference depends on the degree of coherence among interfering components;

– in general, it is appropriate in the evaluation of the second or third harmonic spurious emission to assume a perfect coherence among interfering components (i.e. voltage sum);

– in general, it is appropriate in the evaluation of non-harmonic unwanted emissions to assume a partial coherence among interfering components (i.e. 1.5th power sum).

Based on the above considerations, the following methods should be employed for evaluation of interference power:

– Preferably the peak envelope power of radar interference over the entire bandwidth of a radio channel of the interfered-with system should be evaluated in time domain.

– If the data is available only in frequency domain, consisting of n interference components w_i (i = 1, 2, .., n) expressed in power unit, the overall peak envelope power W should be evaluated as follows:

$$W = (\Sigma \, w_i^{1/k})^k$$

where k should be assumed as 2.0 for the evaluation of the second or third harmonic spurious emission and 1.5 for the evaluation of non-harmonic unwanted emission. Further study of the validity of these values is required.

ANNEX 2

Derivation of the maximum allowable levels

1 Introduction

In order to facilitate the understanding of the subsequent calculation examples, a brief description of an interference scenario is given. In addition some of the concepts and the parameter values commonly used in high capacity radio-relay links are explained.

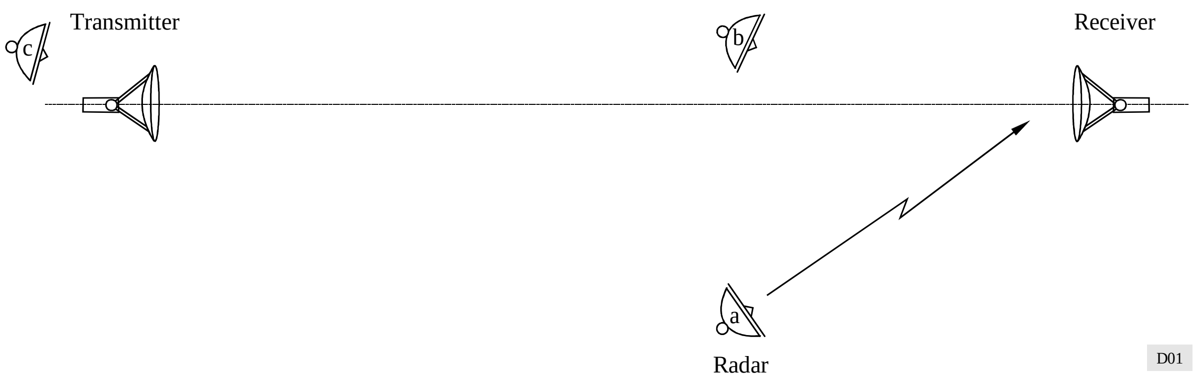
The radio-relay links are line-of-sight (LOS) systems requiring an unobstructed path between transmitter and receiver antennas. The path length is usually 40-60 km, and in some cases even longer.

Antennas are high gain narrow beam types, normally parabolic, or in some cases similar designs (horn reflector etc.).The emphasis is on low side-lobe levels. Usually the main beam 3 dB width is of the order of 1.5°-2°, and the gain at beam centre is about 40-43 dBi.

If a radar transmitter designed for operation with f_0 near 3 GHz is in use near a radio-relay path, and if it emits unintentionally generated spurious energy from the radar antenna, some portion of this may be intercepted by the radio-relay antenna. In many cases the spurious emission may enter the radio-relay receiving antenna through the side lobes, but in unfortunate situations main beam intercept may happen. A radio-relay hop with three possible locations of an interfering radar is shown in Fig. 1. Location a will result in radio-relay side-lobe entry. Location b is near the LOS between radio-relay transmitter and receiver, resulting in main beam intercept. Location c is near the extension of the LOS behind the transmitter, also resulting in main beam intercept.

FIGURE 1

Plan view, radio-relay path and possible radar positions



The radio-relay link is used to transport a high speed bit stream known as the payload. It may consist of many multiplexed telephone channels or digitized TV video signals. Typically the capacity is 155.52 Mbit/s (STM-1), or 311 Mbit/s (2 × STM-1). The Telecommunication Standardization Sector (ITU-T) has issued strict transmission quality requirements. These are expressed in terms of maximum permitted number of errored seconds (ES) and maximum permitted number of severely errored seconds (SES) (see ITU-T Recommendation G.826).

During ES the telephone or video transmission quality is noticeably degraded and during SES the radio channel is unusable.

Any spurious emission from a radar which is intercepted by a radio-relay antenna and which ingresses into a radio-relay receiver will result in a certain interference power level, *I*. This must be compared to the receiver background noise level, *N*. The radio-relay system design assumes that a receiver will operate correctly with a certain minimum desired signal level, *C* and thus with a minimum *C*/*N* value. Any interference is perceived as additional noise degrading *C*/*N* and thus resulting in transmission errors. If intermittent interference (pulsed spurious emission) is received, it may be particularly troublesome if certain parts of the formatted bit stream are affected. This may result in loss of synchronism and thus in wholesale loss of transmission capability.

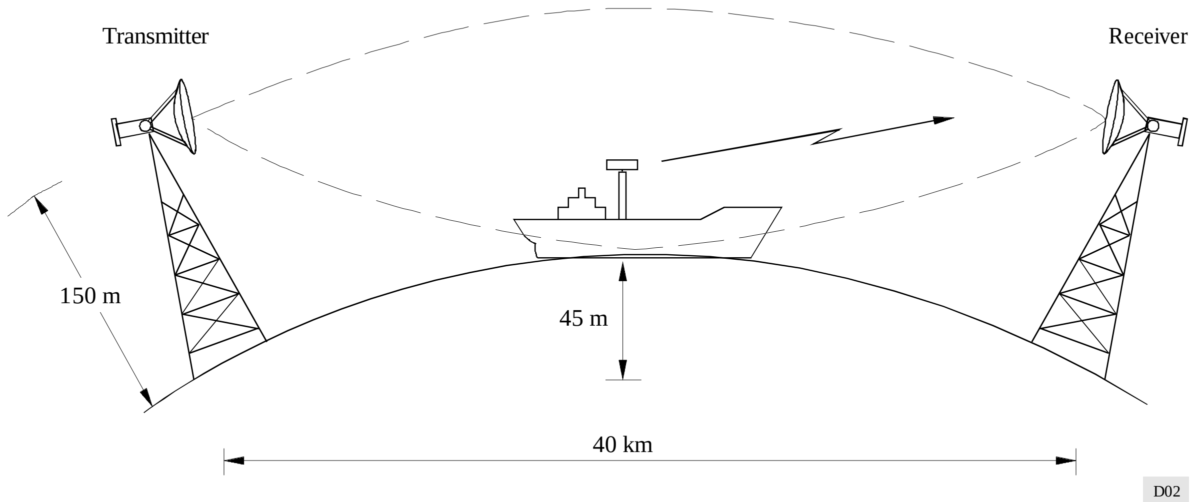
In the following examples several assumptions are made concerning the scenario and the *I*/*N* required.

The situation depicted in Fig. 2 is assumed where the radio-relay main beam intercept occurs. The distance from the interfering radar is assumed to be 20 km and the path from the radar antenna to the radio-relay antenna is assumed to be unobstructed. Thus the propagation path loss for spurious emissions in the 4 GHz band is about 130 dB.

The *I*/*N* requirements are derived for a high capacity radio-relay link using an advanced high level modulation scheme. The receiver needs a certain RF signal-to-noise ratio *C*/*N*. This is achieved in the system design by providing adequate transmitter power and antennas with suitable gain.

FIGURE 2

Side view, radio-relay path; ship crossing near LOS



2 Non-harmonic unwanted emission

The assumed parameters of the interfered-with system are:

Operating frequency band: 3 400-4 200 MHz

Receiver bandwidth: 40 MHz (see Note 1)

Receiver antenna gain: 36 dB (after subtracting feeder loss)

Receiver noise figure: 4 dB

Free space loss: 130 dB (20 km)

Thermal noise: –140 dB(W/MHz)

Thus the maximum allowable level of interference corresponding to the interference-to-thermal noise ratio of 10 dB is –114 dB(W/40 MHz) at the receiver input of the interfered-with system. For a 36 dB receiver antenna gain, this equates to a power flux-density of –117 dB(W/m^2). For a free space loss of 130 dB and a 36 dB antenna gain, this also equates to an unwanted emission e.i.r.p. of a radar system of –20 dBW.

It should be noted that many mobile radar systems may not meet this requirement and further efforts are needed to improve such radar systems. It should also be noted that in the case of a radar system employing a magnetron, the levels of unwanted emissions are different depending on the elapse of operational time, and in general the levels of non-harmonic unwanted emissions become higher as it approaches its life end.

For the 4 400-5 000 MHz range, the assumed parameters (in particular, antenna gain and free space loss) of the interfered-with system may be slightly different. However, calculations result in the same limit of the unwanted emission, because the increased antenna gain is just offset by the increased free space loss.

NOTE 1 – The receiver bandwidth is different depending on systems. If coherence among the interfering components is taken into account (see Annex 1), a system with wider receiver bandwidth is more susceptible to non-harmonic emissions from a radar system, which generally have bandwidth broader than that of the interfered-with receiver. Thus, 40 MHz is chosen as representing a system with wide receiver bandwidth.

3 Second harmonic spurious emission

Assumed parameters of the interfered-with system are:

Operating frequency band:	5 925-6 425 MHz
Receiver bandwidth:	20 MHz (see Note 2)
Receiver antenna gain	40 dB (after subtracting feeder loss)
Receiver noise figure:	4 dB
Free space loss:	134 dB (20 km)
Thermal noise:	–140 dB(W/MHz)

Thus the maximum allowable level of interference corresponding to the interference-to-thermal noise ratio of 10 dB is –117 dB(W/20 MHz) at the receiver input of the interfered-with system. This equates to a power flux-density of –120 dB(W/m^2) and an unwanted e.i.r.p. of a radar system of –23 dBW.

It should be noted that many mobile radar systems may not meet this requirement and further efforts are needed to improve such radar systems in this case as well.

NOTE 2 – Generally the bandwidth of second harmonic spurious emission is narrower than that of the interfered-with receiver. Therefore, the interference-to-thermal noise ratio is higher at a receiver of narrower bandwidth. Thus, 20 MHz is chosen as representing a system with narrow receiver bandwidth.