RECOMMENDATION ITU-R F.1097*

INTERFERENCE MITIGATION OPTIONS TO ENHANCE COMPATIBILITY BETWEEN RADAR SYSTEMS AND DIGITAL RADIO-RELAY SYSTEMS

(Question ITU-R 159/9)

(1994)

The ITU Radiocommunication Assembly,

considering

a) that radar systems can produce interference to digital radio-relay systems in some situations;

b) that there are two coupling mechanisms by which radiated energy from radar stations may be coupled into radio-relay systems: radio-relay system front-end overload (receiver desensitization) caused by the radar fundamental frequency and radar spurious emission in the radio-relay bands;

c) that many of the techniques employed by radio-relay system designers to enhance system performance are expected to reduce the susceptibility of these systems to interference from radar transmitters;

d) that in other cases the most desirable method of mitigating the interference may be to reduce the spurious emissions at the radar transmitter,

recommends

1. that the interference mitigation options listed below should be taken into consideration in the design and implementation of digital radio-relay systems in order to enhance compatibility with radar systems:

– microwave RF filters,
– space diversity,
– angle diversity,
– forward error correction (FEC) coding,
– alternate channel use,
– alternate band deployment,
– path routing,
– increased transmitter power,
– antenna selection (characteristics),
– other possible techniques;

2. that the interference mitigation options for radar systems listed below should be taken into consideration in order to enhance compatibility with digital radio-relay systems:

– RF filters,
– replacement of transmitter device,
– selection or adjustment of transmitter frequency,
– other possible techniques;

3. that Annex 1 should be referred to for the additional guidance relating to this Recommendation.

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* This Recommendation should be brought to the attention of the International Maritime Organization (IMO), the International Civil Aviation Organization (ICAO), the International Radiomaritime Committee (CIRM) and Radiocommunication Study Groups 1 (WP 1A) and 8 (WP 8C).

ANNEX 1

Options to enhance compatibility between radar systems and radio-relay systems

1. Radio-relay system options

1.1 Microwave RF filters

When interference from a radar system is observed in a radio-relay system, one of the first steps in attempting to reduce the interference is to determine if the coupling mechanism is front-end overload caused by the radar fundamental frequency. If front-end overload of the low-noise preamplifier (LNA) by the radar signal is the coupling mechanism, an RF blocking filter ahead of the waveguide run may be used to protect the LNA from radar interference.

Front-end LNA overload from 5 GHz ground-based radars has been observed in some administrations in digital radio-relay systems operating in the 6 GHz or the upper 4 GHz band. Receiver RF filters will not be effective against interference on, or near to, the radio-relay receiver frequencies.

1.2 Space diversity

The space diversity systems installed in most digital radio-relay systems tend to decrease system susceptibility to interference, and are effective in cases where the radar causes interference during the time the radio route is involved in a multipath fade condition. This is because space diversity reduces the total fade time by providing a second receive path which is only partially correlated with the primary receive path. If the interfering signal causes system performance degradation all the time, space diversity will work as a protection for the fade margin reduction due to the interference, compared with the systems without diversity.

Also, in the case of maritime mobile radar interference, space diversity may provide certain performance improvements considering the path differences between two desired/undesired radio waves each received by both the antennas.

1.3 Angle diversity

A method which employs a similar technique to space diversity, where signals from a second receive path may be available to the system when the primary signal has faded, employs a single antenna capable of providing outputs for two separate receive patterns. Separate waveguide ports are provided for each pattern at each polarization. These “angle diverse” signals are then compared and the best signal is selected, as happens with signals from two different antennas in a space diversity system. Employment of this technique has the potential to reduce the total time that the desired received signal is below the radar interference level, thereby decreasing the impact of the radar interference along with the impact of multipath fading. Angle diversity is sometimes employed by radio-relay system designers in lieu of space diversity.

1.4 Forward error correction

Forward error correction (FEC) coding is a method used in most digital microwave systems to improve the BER performance, particularly when the system is power limited. The utilization of FEC coding techniques permits a limited number of errors to be corrected at the receiving end by means of special coding and software (or hardware) implemented at both ends of the circuit. Measurements have shown that for a double-error correcting code, the threshold for errors breaking through to the payload is improved by approximately 10 dB when the interfering pulse duration is 1 Bd interval (i.e. the interference produces a receiver impulse response).

Use of an FEC technique which is effective against burst errors as well as random errors would be most helpful. This method using a bit-shuffling technique is now under study.

1.5 Alternate channel use

The level of radar spurious emissions in radio-relay bands varies somewhat less predictably across bands. Measurements (at 30 MHz IF bandwidth) have shown a variation of 15-20 dB depending on the channel frequency. Therefore, when interference from a radar system into a digital radio-relay system is encountered, one method to temporarily reduce the interference is to use alternate channels.

Alternate channel use may only be a viable solution when unused channels are available. In any case, alternate channel use should only be considered as a temporary solution since the radar spurious emission levels at various frequencies are a function of matching of the impedance of the radar transmitter line and tube output, age of the radar output tube and the pulse shaping (filtering) network.

1.6 Alternate band deployment

When designing a new radio-relay link or modifying an existing radio-relay link (i.e. conversion from analogue to digital), various factors must be considered in selecting an appropriate frequency band. One of the factors should be the electromagnetic environment in the area of deployment. If a ground-based radar is operating in the vicinity, the selection of a band for deployment of the radio-relay system is likely to affect the potential for radar interference. The selection of an appropriate band is dependent on the type of output device used in a radar which determines the radar spurious emission levels.

In any case, such alternation in the frequency band usage should be done under careful consideration of interference environments within the radio-relay networks.

1.7 Path routing

Where possible, path routing selections can be used during the design phase of new routes to avoid potential interference exposures to operational or planned ground-based radar stations. There are many factors that determine the site selection of stations in a radio-relay route. One of the factors should be the electromagnetic environment. For path routing to be successful as an interference mitigation option, knowledge of the location of radar stations is necessary. It should be recognized, however, that additional constraints or site selections may have a significant impact on the economics of the radio-relay route construction.

However, this path routing selection is a temporary solution to the overall interference problem and is not considered a preferred option with regard to effective frequency use.

1.8 Transmitter power

Increase of transmitter power is effective when mutual interference problems within the radio-relay network can be coordinated. However, it does not always seem to be the best way from the viewpoint of frequency sharing with other services.

1.9 Antenna characteristics

1.9.1 Antenna selection

Antenna discrimination, the response of the antenna to signals arriving from various azimuths, varies widely among antennas. In some situations, it may be possible to take advantage of these characteristics to reduce the response of a system to interference arriving from a particular direction.

When the estimated level of unwanted emission from a radar system is known and the path geometry between the radar system and the digital radio-relay system is given, one can calculate the maximum permissible radio-relay antenna gain in order to keep the interference-to-thermal noise ratio within a level still under consideration. Then, Recommendation ITU-R F.699 (or the actual radiation pattern of the radio-relay antenna to be used) may be used to establish the required off-axis angle. If this angle is larger than the actual (or planned) off-axis angle, an antenna with better radiation characteristics should be selected, which may satisfy the requirement.

Depending on the distance and angular separation between the radio-relay system and the ground-based radar system, and the radar nomenclature/device involved, the required off-axis angle may not be achievable.

1.9.2 Antenna site shielding

One method to reduce the peak pulsed power of a radar entering the radio-relay system is to shield (or screen) the radio-relay antenna from the radar transmitted beam, if practicable. Shielding may be available from the topography between the radar and the radio-relay antennas or it may be man-made.

2. Radar system options

2.1 Radar RF filters

Radio frequency (RF) waveguide filters have been used in several radars to reduce interference to radio-relay systems to acceptable levels. To date, RF bandpass filters have only been used in fixed 5 GHz ground-based radars to mitigate interference into the 6 GHz radio-relay common carrier band. Measurements have shown (Fig. 1) that RF waveguide filters will suppress radar spurious emissions by approximately 40 to 50 dB.

When radar interference into digital radio-relay systems is caused by spurious emissions from radars, the installation of an RF filter at the radar transmitter is considered a practicable solution provided that it is technically and/or economically possible.

2.2 Replacement of transmitter device

Variations in ground-based radar spurious emission levels have been observed in radars using coaxial and conventional magnetron tubes. These variations may be attributed to changes in modulating pulse shaping networks, anode voltage and current and arcing in the tube due to age. The ground-based radar users, on a routine basis, may need to perform periodic checks of the radar transmitter to determine whether these transmitters have, because of age, developed spurious components that were not present when the transmitter was new. In some reported cases, interference problems have been corrected by replacing the output device.

The means discussed in § 2.1 and 2.2 can, in principle, be applied also to maritime mobile radar systems. However, it should be taken into account that in future consideration of mitigation options, such systems are a safety service of the Safety of Life at Sea (SOLAS) Convention of the IMO, and therefore the introduction of such options should be compatible with not producing significant decrease in performance.

2.3 Selection or adjustment of transmitter frequency

In some types of fixed radar systems it may be possible to select or adjust the fundamental frequency of the radar transmitter within the frequency range allowed for the radar system so that the second or third harmonic spurious emissions will not be received by the interfered-with radio-relay systems. This kind of mitigation option has already been undertaken in some countries resulting in a successful coordination.

FIGURE 1

Radiated spectrum measurements of a 5 GHz radar without and with an RF filter