International Telecommunication Union

ITU-R
Radiocommunication Sector of ITU

Recommendation ITU-R M.1179
(10/1995)

Procedures for determining the interference coupling mechanisms and mitigation options for systems operating in bands adjacent to and in harmonic relationship with radar stations in the radiodetermination service

M Series

Mobile, radiodetermination, amateur and related satellite services

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2010

RECOMMENDATION ITU-R M.1179[*, **]

PROCEDURES FOR DETERMINING THE INTERFERENCE COUPLING MECHANISMS AND MITIGATION OPTIONS FOR SYSTEMS OPERATING IN BANDS ADJACENT TO AND IN HARMONIC RELATIONSHIP WITH RADAR STATIONS IN THE RADIODETERMINATION SERVICE

(1995)

Scope

This Recommendation provides administrations with measurement procedures to identify the interference coupling mechanism(s), receiver front-end overload or radar spurious emissions, and methods to mitigate the interference from radar stations in the radiodetermination service to fixed radio-relay stations and fixed-satellite earth stations.

The ITU Radiocommunication Assembly,

considering

a) that both fixed and mobile radar stations in the radiodetermination service are widely implemented in bands adjacent to and in harmonic relationship with the 4, 5 and 6 GHz bands used by the fixed and fixed-satellite services;

b) that fixed radio-relay stations and fixed-satellite earth stations are vulnerable to interference from radar stations that have fundamental (necessary) and spurious emissions with high peak power levels;

c) that fixed radio-relay stations have largely adopted digital modulation and fixed-satellite earth stations are rapidly moving towards the use of digital modulations which may be more susceptible to interference from radar pulsed type emissions;

d) that fixed radio-relay stations and fixed-satellite earth stations use low-noise amplifiers which have inherent wide bandwidths and gains of 10-20 dB for fixed radio-relay stations and 50-65 dB for earth stations;

e) that under the conditions stated in a) through d), interference to stations in the fixed and fixed-satellite services may be caused by radar station necessary emissions causing receiver front-end overload;

f) that high levels of radar spurious emissions may cause interference to fixed radio-relay stations in the 4, 5 and 6 GHz bands and fixed-satellite earth stations in the 4 GHz band;

g) that Radiocommunication Study Group 9 has proposed interference mitigation options to enhance compatibility between radar stations in the radiodetermination service and fixed radio-relay stations (Recommendation ITU-R F.1097);

h) that measurement procedures to positively identify the interference coupling mechanisms and mitigate the interference are not widely known,

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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 Maritime Radio Association (CIRM), the World Meteorological Organization (WMO) and Radiocommunication Study Groups 4 and 9.

[**] Radiocommunication Study Group 5 made editorial amendments to this Recommendation in 2009 in accordance with Resolution ITU-R 1.

recommends

1 that in cases of radar interference to earth stations operating in the 4 GHz band and fixed radio-relay stations operating in the 4, 5 and 6 GHz bands, the following action(s) should be taken:

– the procedures described in Annex 1 should be used to identify the interference coupling mechanism (see Notes 1 and 2);

– after the interference coupling mechanism has been identified, one of the interference mitigation options described in Annex 2 for the interference coupling mechanism identified should be applied.

NOTE 1 – If the receiving system does not have a bandpass (preselector) filter ***ahead*** of the low-noise amplifier, it may be more cost-effective to install a bandpass (preselector) filter ***ahead*** of the low-noise amplifier prior to performing the tests in Annex 1. If the interference continues after the installation of the filter, the Annex 1 measurements to identify the interference coupling mechanism must be performed.

NOTE 2 – If the interference coupling mechanism is identified as radar transmitter spurious emissions, the radar will need to be identified if it is desirable to filter the radar transmitter output. Installation of filters in the radar transmitter may not be achievable if the radiodetermination station is mobile and there are numerous radars such as the case of radionavigation radars operated under licences of many administrations. Also, the installation of a filter in a radar may not be achievable due to the type of output device, size, weight and performance trade-offs.

ANNEX 1

Determination of interference coupling mechanism

1 Introduction

Interference mitigation measures will be ineffective unless the correct interference coupling mechanism (receiver front-end overload or radar transmitter spurious emissions) is identified. This Annex describes methods by which the interference mechanism may be determined, so that appropriate mitigation measures may be implemented as reliably as possible. It should be noted that the tests and measurements required to determine the interference mechanism are not necessarily easy to perform, even if personnel at the facility has access to the necessary test equipment (a spectrum analyser and digital oscilloscope are recommended, at a minimum). (In carrying out measurements on radar emissions, care should be taken to ensure that overload of the measurement equipment does not occur as damage may be caused to measuring equipment.)

Commercially available RF front-end bandpass filters are relatively inexpensive and can be installed relatively quickly. Installation of such a filter ***ahead*** of the first LNA/LNB/LNC (low noise amplifier/mixer/downconverter) in the receiver RF front-end is recommended as a first step when the interfering radar signal is outside the normal allocated receive band for the fixed radio-relay or earth station. If the only interference mechanism is receiver front-end overload and the radar signal is occurring outside the receive band, then the filter should mitigate the problem.

It is also possible for receiver front-end overload interference and radar spurious emission interference to occur simultaneously. In that case, installation of a bandpass filter on the receive station will only eliminate the front-end overload interference component; the station will still experience interference effects due to the radar spurious emissions. Because of this possibility, the installation of a bandpass filter on the receive station ***ahead*** of the LNA/LNB/LNC is recommended before tests for radar spurious emission interference are attempted. If no such filter is installed, then the absence of receiver front-end overload must be verified through tests described below.

Finally, it should be noted that a receiver front-end amplifier which also incorporates a mixer/downconverter (LNB or LNC) may generate undesired products in the desired receive band when it is in an overload condition, as shown in Annex 2. These products may be easily mistaken for radar spurious emissions in the earth station band. Thus, it is critical that the possibility of receiver front-end overload be eliminated by installation of a front-end bandpass filter before tests for spurious emissions are performed.

2 Measurement procedures

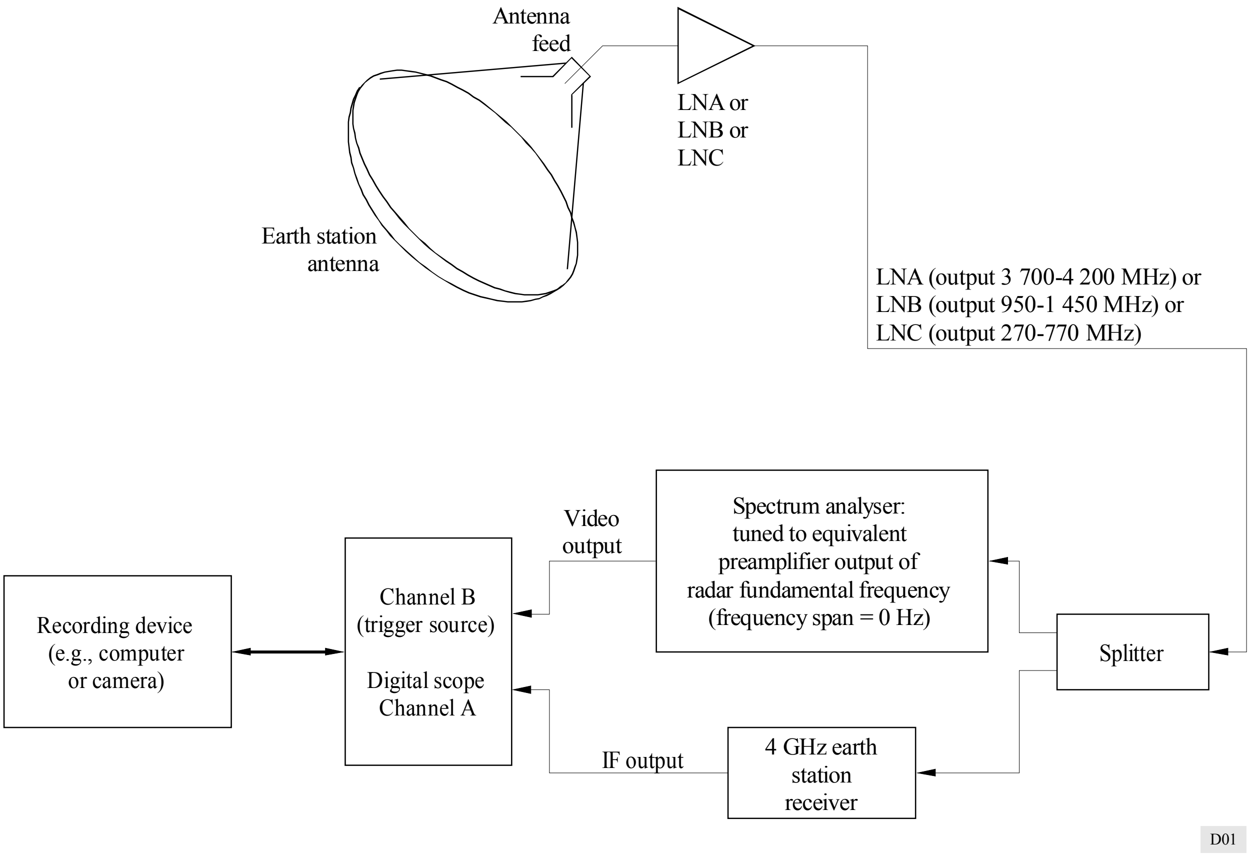
2.1 Determination of front-end overload

There are several steps in the process of determining whether or not front-end overload is occurring in a receiver. The first and most obvious step is to physically examine the RF front-end of the system, usually at the antenna, and determine if any preselection already exists. It is important not to be misled by schematic diagrams, which may indicate the presence of filters which may not have actually been installed, or by narrow frequency ranges which are specified on an amplifier case (e.g. "3.7-4.2 GHz"); the actual amplifier response may be much wider than the label indicates. If RF bandpass filtering ***ahead*** of the first preamplifier is verified as being present, then it is very unlikely that the coupling mechanism is receiver front-end overload. If no such filtering is present, then such a filter should be installed. If the installation results in elimination of the problem, then the mechanism is probably front-end overload.

If a bandpass filter for the earth station is unavailable, or for any other reason the presence of front-end overload must be independently verified, then the following measurement procedure can be performed through the front-end of the receive station during an interference event. The goal of this measurement is to determine the extent, if any, to which the amplifier is gain-compressing when energy from the radar is received. In order to document this effect clearly, it is necessary to simultaneously monitor the radar energy at the radar fundamental frequency, as well as the response of the earth station to that energy. A block diagram for the hardware arrangement to be used in this test is shown in Fig. 1.

FIGURE 1

Block diagram for determination of interference coupling mechanism. Characteristics of either front-end overload or radar spurious emissions are observed in coincidence with radar pulses



With reference to Fig. 1, this test is performed with the antenna feed horn connected directly into the earth station's front-end amplifier (LNA/LNB/LNC). THERE SHOULD *NOT* BE ANY BANDPASS FILTER AHEAD OF THE LNA/LNB/LNC DURING THIS TEST UNLESS IT IS NORMALLY A PART OF THE SYSTEM. The signal out of the amplifier is then split into two paths. One side of the split is sent to a spectrum analyser, and the analyser video output is in turn routed to one channel of an oscilloscope (see Note 1). The analyser should be tuned to the equivalent preamplifier output of the radar fundamental frequency and the analyser frequency span should be set to 0 Hz. (If two or more radar fundamentals are produced, any one of them will suffice.) The analyser IF bandwidth should be set to 1 MHz, and analyser trace sweeping should be suspended.

NOTE 1 – Documentation of these measurements is important. Either a digital oscilloscope that can transfer data to a magnetic medium or an analogue oscilloscope with a camera can be used for this purpose.

The other side of the split is routed to the earth station receiver, and the receiver's IF output is routed to a second channel of the oscilloscope. The oscilloscope should be triggered from the radar pulse train coming out of the spectrum analyser. Thus, both the radar pulse train and the receiver response to that pulse train may be simultaneously observed on the oscilloscope. If the radar is overloading the earth station front-end, then gain compression should be observed on the IF trace when pulses from the radar are observed on the other oscilloscope trace. Examples of such responses are shown for an LNA and an LNB in Figs. 2-5.

A variation on this technique can be implemented on an antenna that incorporates two cross-polarized feeds: install a bandpass filter ***ahead*** of the preamplifier on one feed. If interference subsequently occurs on the unfiltered feed but not on the filtered feed, then the problem is receiver front-end overload. As a caveat, however, it should be noted that interference may be polarization-dependent, and the cross polarization between feeds can unintentionally produce a filtering effect of its own. So it is critical, if this technique is attempted, that both feeds are known to have previously been affected by the interference simultaneously.

2.2 Simultaneous occurrence of front-end overload and spurious emission interference

As stated at the beginning of this section, it is entirely possible for both receiver front-end overload and radar spurious emission interference to occur simultaneously. This would be the case if a radar produced strong spurious emissions at the receive station's centre frequency, while the receive station was being operated with an unpreselected front-end. However, before the spurious emission interference problem can be addressed, the possibility of front-end overload must first be eliminated by installing an RF filter on the earth station.

2.3 Determination of radar spurious emissions

If tests for receiver front-end overload are negative or interference persists when a bandpass filter has been installed ahead of the first RF amplifier in the receive station, then the interference is probably occurring as a result of radar transmitter spurious emissions in the receive band of the station.

It must be emphasized that, if the tests for radar spurious emission interference are to utilize unpreselected earth station RF front-ends, as shown in Fig. 1, then the possibility that interference is caused by receiver front-end overload **must** be eliminated before these tests are conducted. While the use of a bandpass filter on the earth station front-end is not absolutely required under these circumstances, the presence of such a filter during the tests increases the confidence that no receiver front-end overload is occurring.

FIGURE 2

Channels A and B of oscilloscope when test arrangement of Fig. 1 is used and LNB front-end is not overloaded

Note that time axis is much faster, due to faster expected recovery time of LNB

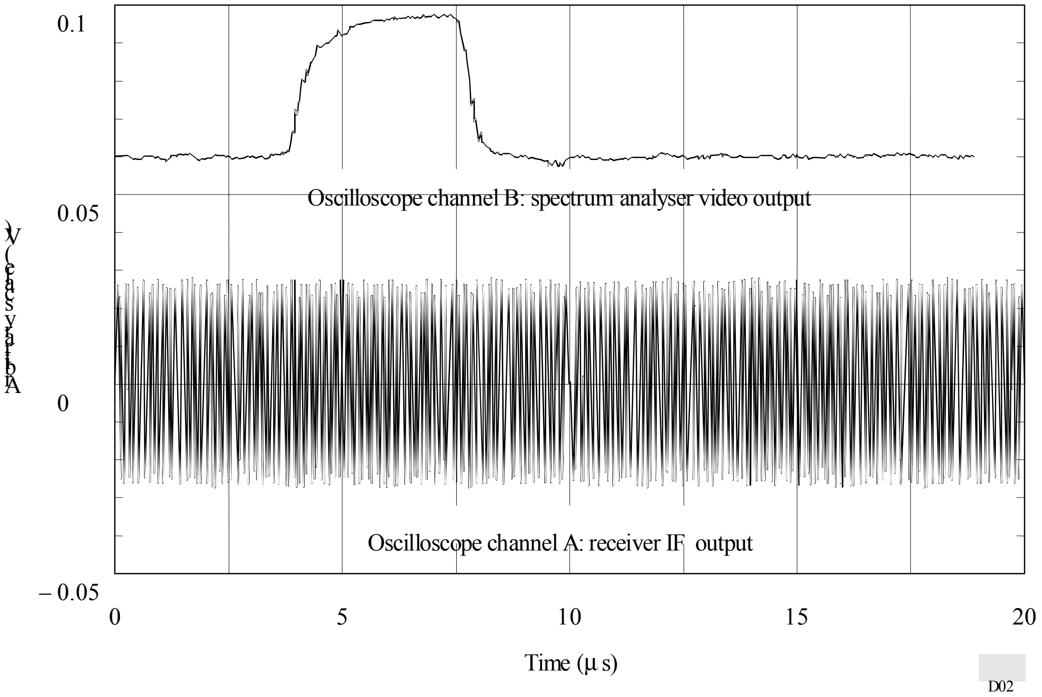


FIGURE 3

Channels A and B of oscilloscope when test arrangement of Fig. 1 is used and LNB front-end is overloading

Note faster recovery time of LNB than of LNA (interval the same as pulse width)

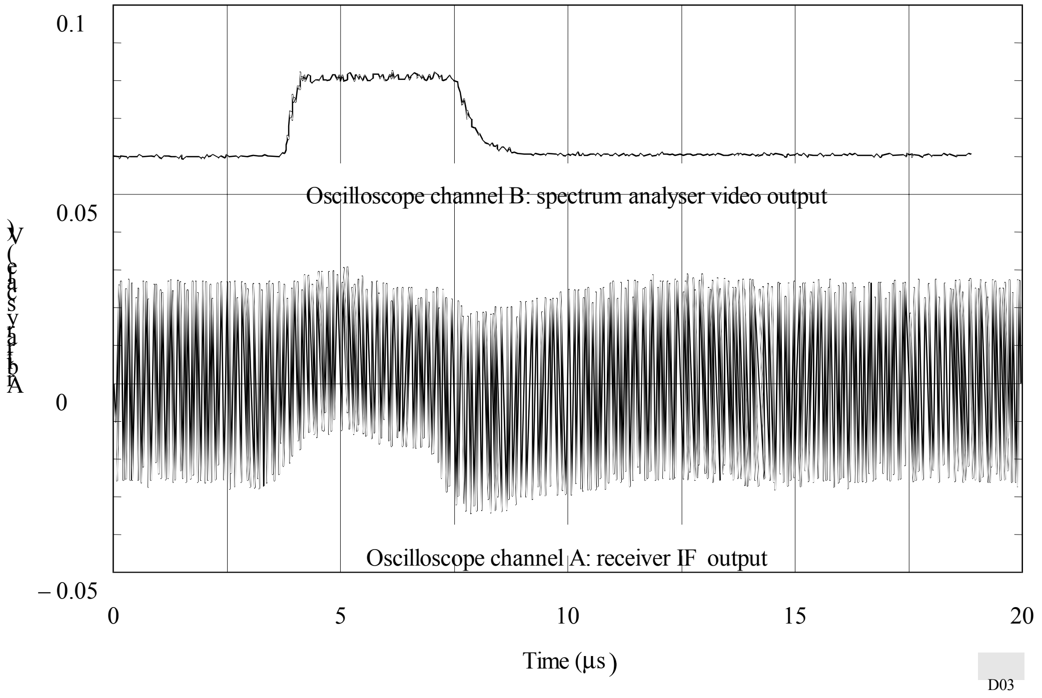


FIGURE 4

Channels A and B of oscilloscope when test arrangement of Fig. 1 is used and radar pulses are not overloading LNA front-end

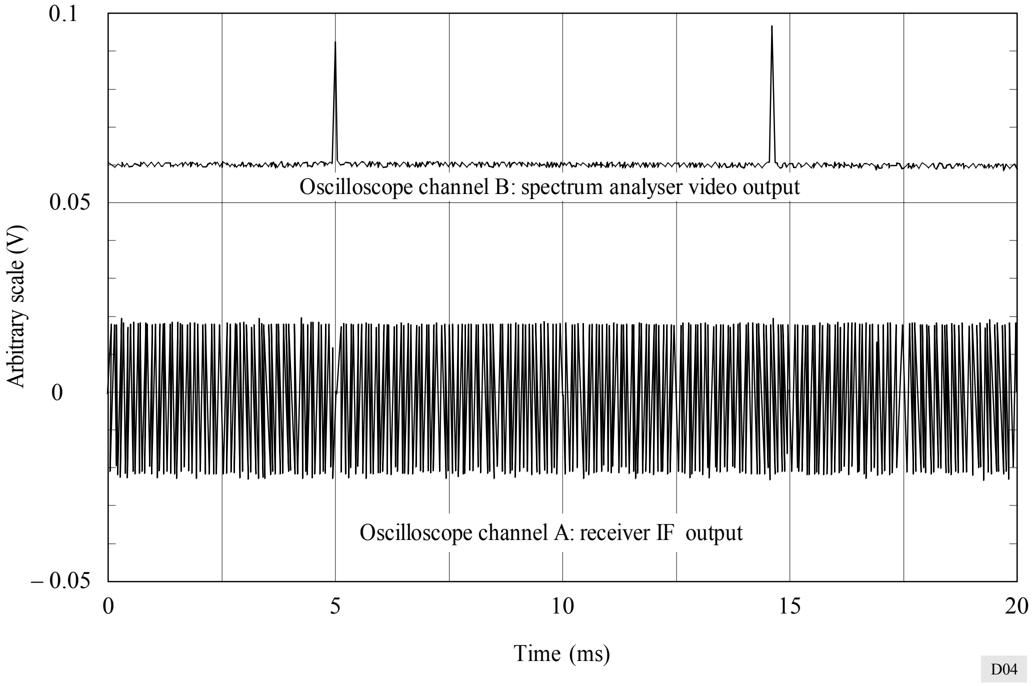
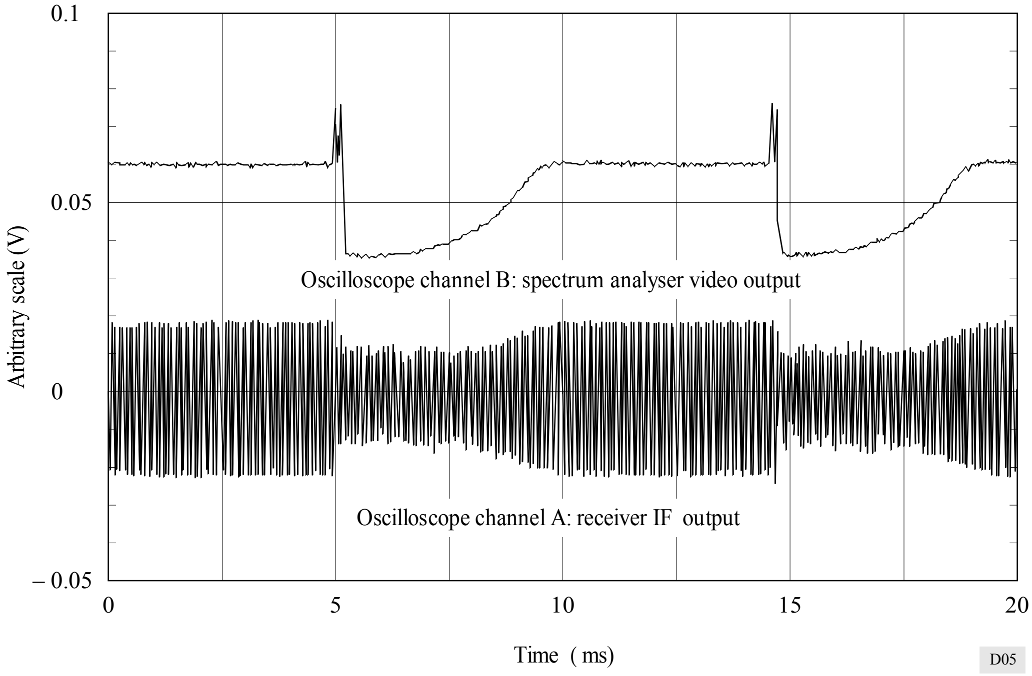


FIGURE 5

Channels A and B of oscilloscope when test arrangement of Fig. 1 is used and LNA front-end is overloading

Note long LNA recovery interval relative to the radar pulse width

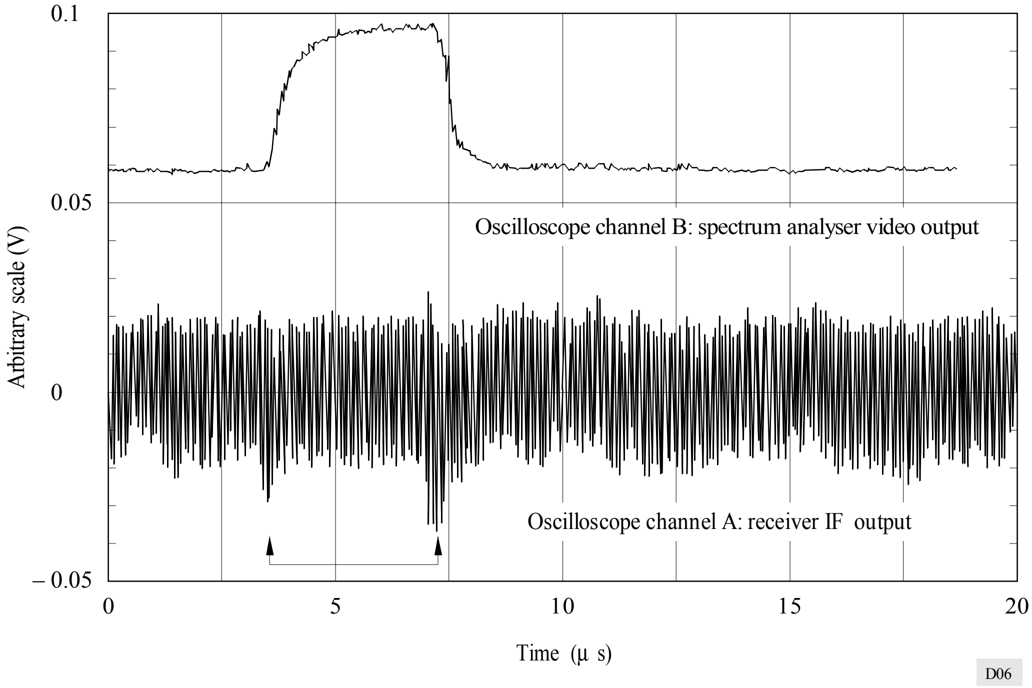


The observations may be accomplished in two ways. One method uses the same block diagram arrangement as shown in Fig. 1 (but preferably with a bandpass filter inserted ***ahead*** of the LNA/LNB/LNC). The result will be to observe the radar spurious emission pulses superimposed on the desired signal, as shown in Fig. 6. The spurious emission radar pulses will usually be observed as pairs of high leading and trailing edges (rabbit ears); the time-domain spacing will be the same as the nominal pulse width. It is also possible for spurious emissions to appear as noise-like pulses. A disadvantage to this method is that the presence of the desired earth station signal may have the effect of masking the radar spurious emissions.

FIGURE 6

Channels A and B of oscilloscope when test arrangement of Fig. 1 is used and spurious emissions occur at received frequency

Desired signal must be eliminated to perform this test



The second observation technique eliminates the desired signal, thus reducing possible masking of the radar spurious emission pulses. With reference to Fig. 1, this is accomplished for fixed radio-relay stations by turning off the desired signal and for earth stations by substituting an omnidirectional antenna for the receiver parabolic antenna (and again, preferably with a bandpass filter inserted ***ahead*** of the LNA/LNB/LNC). The omnidirectional antenna used for earth stations must have a frequency response of at least 2 700 to 4 400 MHz. This method may be most practical if the earth station has a spare receiver system already available, to which the omni antenna can be attached.

If radar spurious emissions are established as causing interference to an earth station, then the radar that is involved must be identified. The radar spurious emission levels must be quantified so that steps can be taken to resolve the problem.

2.4 Alternative measurement procedures

Although the following measurements are not as conclusive as the above measurement procedure in determining the interference coupling mechanism, they may be used to indicate the possible interference coupling mechanism.

The severity of the interference on each of the channels can be an indication of the coupling mechanism. If the interference affects all (or most) of the channels, front-end overload could be indicated. If only specific channels are affected, spurious emissions would be indicated.

Another method of identifying the interference mechanism would be to measure the radiated field intensity of the radar's spurious emissions in the receive band at the approximate location of the receive station feedhorn. This could be performed using an omni antenna or portable directional antenna, coaxial filter and an LNA. The filters used on fixed radio-relay and earth stations are waveguide filters which may not be immediately available. Tuneable bandpass and band reject filters may already be at hand and could be used with coaxial LNAs and receivers to provide a sensitive measurement system. While the measurement antenna would not have the same gain as the receive station, the choice of omni or directional antenna properly oriented could simulate the antenna gain of the receive station in the direction of the radar. Therefore, the gain of the test antenna would approximate the receive station antenna in the direction of radar, making the two systems approximately equal in the ability to detect the radar spurious emissions.

ANNEX 2

Interference coupling mechanisms and mitigation options

1 Introduction

This Annex describes how energy radiated from radar stations may cause degradation to fixed radio-relay and earth station receiver performance (interference coupling mechanisms) and methods to enhance compatibility between the stations (interference mitigation options). Investigations of several interference cases have identified two interference coupling mechanisms that have occurred between radar stations operating around 3 and 5 GHz and fixed-satellite service earth stations operating in the 4 GHz band and fixed radio-relay stations operating in the 4 and 6 GHz bands. These interference coupling mechanisms are receiver front-end overload and radar transmitter spurious emissions.

2 Receiver front-end overload

Receiver front-end overload coupling occurs when energy from the fundamental frequency of an undesired signal saturates the receiver front-end (e.g. LNA), resulting in gain compression (reduction in output signal level) of the desired signal sufficient to degrade performance. Receiver front-end overload generally occurs from high-power signals in adjacent bands.

The input threshold at which receiver front-end overload occurs is a function of the 1 dB output gain compression level (saturation level) and the gain of the front-end low-noise amplifier:

$$T = C - G \tag{1}$$

where:

T : input threshold at which receiver front-end overload occurs (dBm)

C : 1 dB gain compression level of the LNA (dBm)

G : low-noise amplifier gain at the radar fundamental frequency (dB).

A typical 1 dB output gain compression level for a LNA is +10 dBm. Earth station receiver systems typically use LNAs with 50 to 65 dB gain in the 4 GHz band. The 4 and 6 GHz radio-relay receiver systems typically use LNAs with 10-15 dB gain. Therefore, the input threshold at which receiver front-end overload may be expected to occur is approximately in the range of –55 to – 40 dBm for fixed-satellite earth stations and 0 to –5 dBm for fixed radio-relay stations.

2.1 Preamplifier gain response

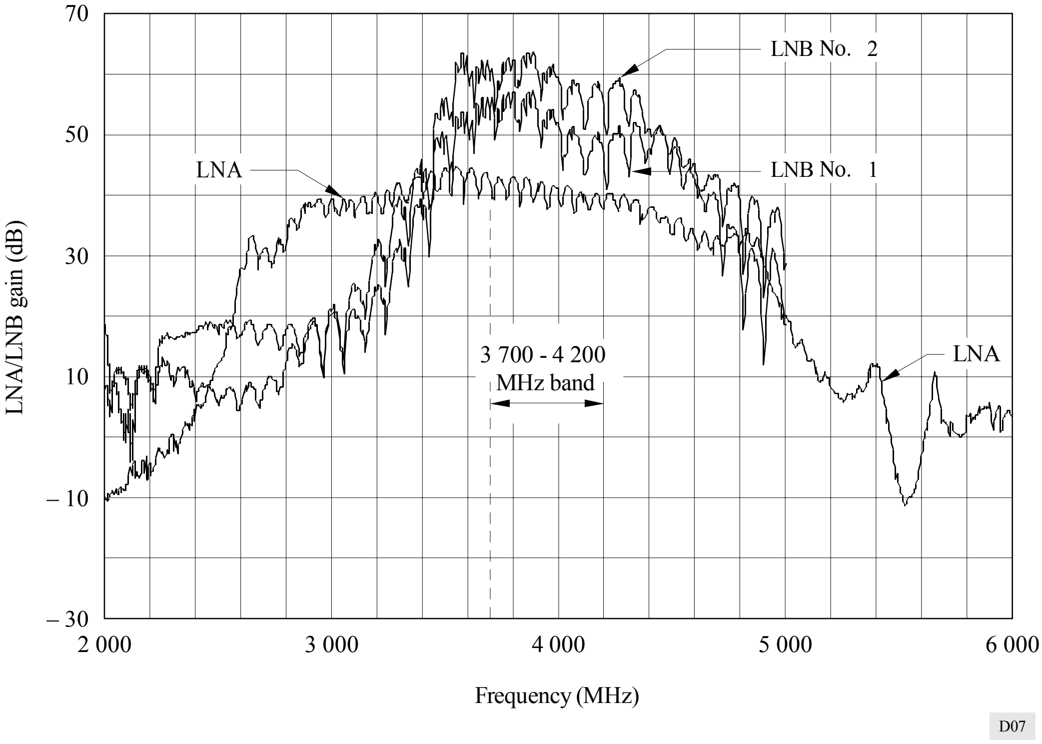
Fixed-satellite earth station and fixed radio-relay receiver systems typically employ a low-noise, high-gain preamplifier at the antenna feed. The preamplifier may produce output at the same frequencies in which case it is designated an LNA. Or, the preamplifier may incorporate a mixer which downconverts the signal to a lower frequency band near 1 000 MHz (e.g. 950-1 450 MHz), in which case it is designated an LNB, or an LNC which downconverts frequencies from the 4 GHz band to a few hundred MHz (e.g. 270-770 MHz) output.

The purpose of a front-end preamplifier is to provide sensitivity to a weak input signal (which requires that the noise figure of the preamplifier be low) and to produce an output with enough gain to compensate for both the line loss between the antenna and the receiver and the noise figure of the receiver. Ideally, the frequency response range of such a preamplifier would be the same as the assigned operational band of the receiver (i.e., 3 700-4 200 MHz). If the frequency response of a preamplifier is wider than the allocated band of the receiver, then the likelihood of overloading the preamplifier by emissions from transmitters outside the allocated band is increased.

Measurements of the frequency response of an LNA and two LNBs (LNB No. 1 and LNB No. 2) are shown in Fig. 7. All three preamplifiers are commercially available and are in use in 4 GHz earth stations. The LNA shows significant gain over 40% of the spectrum below 5 GHz (2.8 to 4.8 GHz). The LNB which incorporates some filtering does not have significant gain below 3 400 MHz. LNB No. 2 incorporates a bandpass filter in its design.

FIGURE 7

Gain of LNA, LNB No. 1 and LNB No. 2



The response ranges of the three amplifier devices include part or all of every radiolocation band between 2 700 and 3 700 MHz, as well as the 4 200-4 400 MHz aeronautical radionavigation band. This broadband frequency response of LNAs used in 4 GHz earth stations makes these systems vulnerable to front-end overload by radars operating outside the 4 GHz band.

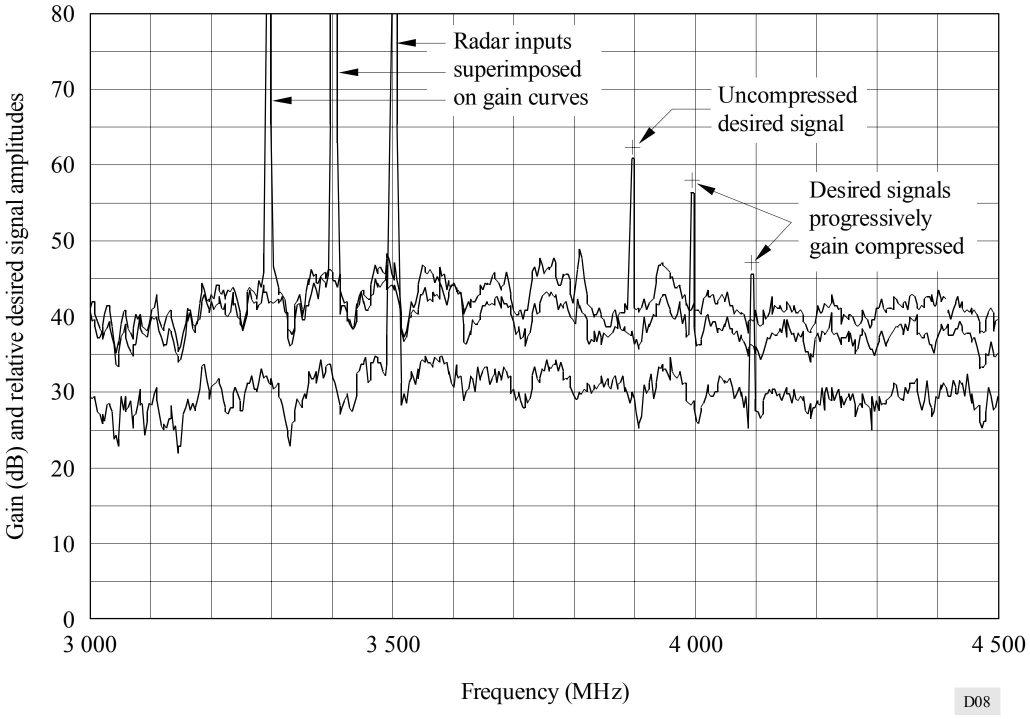
2.2 Gain compression

If the input signal level at the preamplifier does not exceed the threshold value (see equation (1)), then the output gain of the front-end preamplifier will remain at its nominal design value. However, if the input signal level to the device exceeds a critical threshold, then the gain characteristic of the amplifier will be reduced. A significant feature of this degradation is that gain will be reduced across the entire frequency response range of the amplifier (e.g. 2 800-4 800 MHz), even if the overload occurs at a single frequency (e.g. 3 300 MHz).

Figures 8 and 9 show a measured gain characteristics of the previously characterized LNA and LNB No. 1 in overload conditions, respectively. Both preamplifiers were tested for overload characteristics at three input power levels of a simulated radar signal (1 µs pulses at a rate of 1 000 pulses/s). To achieve graphical clarity, the input frequencies at the three power levels were adjusted successively to 3 300, 3 400, and 3 500 MHz. The in-band (desired) signals were similarly adjusted to 3 900, 4 000, and 4 100 MHz. The desired input level in each figure is that of the desired signal at 3 900 MHz; the decrease in desired signal levels at 4 000 MHz and 4 100 MHz is due to gain compression caused by front-end overload. At the lowest radar input level (–50 dBm peak power) in each of Figs. 8 and 9, the amplifiers are not overloaded and the amplifier gain and the power level of the in-band (desired) signals are normal. For a –30 dBm radar signal at 3 500 MHz, the desired signal at 4 100 MHz was reduced by 15 dB for the LNA and over 25 dB for LNB No. 1.

FIGURE 8

LNA response as a function of simulated radar inputs at 3 300 MHz (– 50 dBm, no gain compression), 3 400 MHz (– 40 dBm) and 3 500 MHz (– 30 dBm). Desired (in-band) signals are marked at 3 900, 4 000 and 4 100 MHz



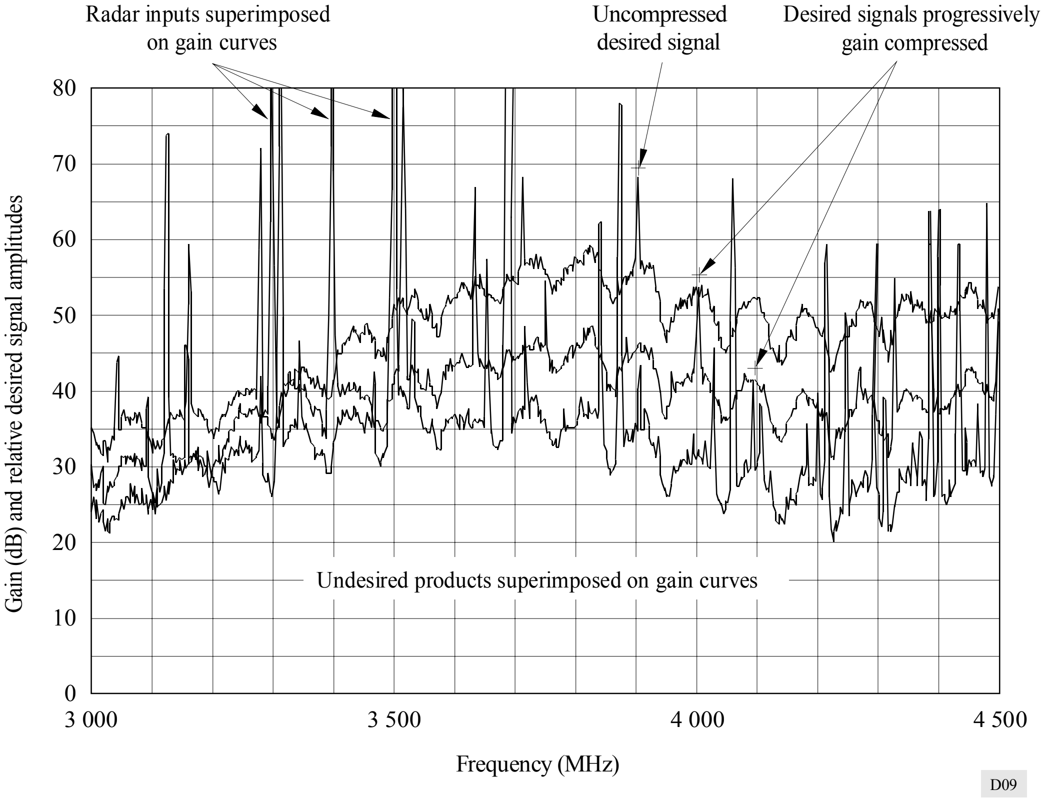
2.3 Other overload responses

Gain compression may not be the only result of receiver front-end overload; mixing products to the input signal can be generated as part of the device output. Such products are especially likely to occur if the device incorporates a mixing stage (downconversion), as is the case for an LNB or an LNC. A device lacking such stages, such as an LNA, would be expected to be less susceptible to this phenomenon.

Measurements showed that such mixing products were not observed for the LNA, but were observed in the LNB device (see Fig. 9) at peak input power levels of – 40 dBm and –30 dBm. It is critical to note that some of the undesired products in the LNB devices occurred at frequencies within the 4 GHz receive band. Such responses could result in interference in a receiver system if they were to coincide with the frequencies of desired in-band signals. Also, such responses may easily be misinterpreted by measurement personnel as spurious signals generated by the radar, rather than being correctly identified as a response generated within the LNB.

FIGURE 9

LNB No. 1 response as a function of simulated radar inputs at 3 300 MHz (– 50 dBm, no gain compression), 3 400 MHz (– 40 dBm) and 3 500 MHz (– 30 dBm). Desired (in-band) signals are marked at 3 900, 4 000 and 4 100 MHz



2.4 Gain compression interval

The interval of overload gain compression of an amplifier is finite. The length of the compression interval is one of the factors which determines the amount of data that a receiver system may lose as a result of overload. Table 1 shows measurements conducted on three devices to determine their overload compression intervals. For each device, the overload signal was applied at four different peak power levels, which were adjusted to produce gain compressions of 10, 20, 30 and 40 dB in a simulated in-band (desired) signal at 4 000 MHz. The input overload signal was pulsed to simulate an out-of-band radar, as had been done during the earlier gain compression tests, with a pulse width of 1 µs, pulse repetition rate of 1 000/s, and radar fundamental frequency of 3 500 MHz.

The compression intervals for the LNA were found to be on the order of several hundred microseconds, whereas the compression intervals for the LNB devices were about two orders of magnitude shorter, on the order of a few microseconds. For the LNA, the interval resulting from a compression of 40 dB was 900 µs, which approached the 1 000 µs interval between simulated radar pulses. The reason for the difference in gain compression intervals between the LNA and the two LNB devices is not known, and was not pursued as part of the study.

TABLE 1

Gain compression intervals of LNA and LNB devices

	10 dB compression interval (µs)	20 dB compression interval (µs)	30 dB compression interval (µs)	40 dB compression interval (µs)
LNA	150	200	650	900
LNB No. 1	1[(1)]	1.5	2.5	3
LNB No. 2	1.5	2.5	3	3.5

(1) The compression interval was equal in length to the duration of the input pulse: 1 µs.

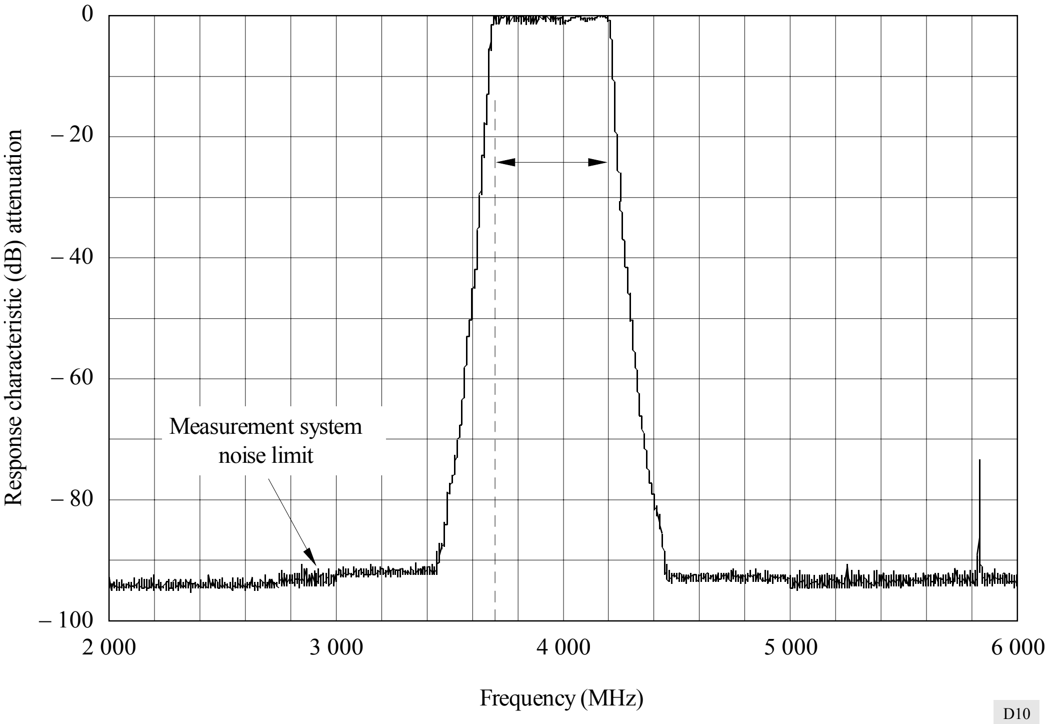
2.5 Front-end overload interference mitigation options

The most viable and economic option to mitigate receiver front-end overload in earth stations and fixed radio-relay stations is the installation of a filter on the front-end of the receiver. The filter must be installed ***ahead*** of the LNA (LNA/LNB/LNC); intermediate frequency (IF) filtering will ***not*** solve the problem. The filter must attenuate energy at the receiver's frequency to a minimal extent, but must substantially attenuate energy at the radar fundamental frequency. Ideally, the filter should have a bandpass characteristic for the entire portion of spectrum allocated for use by the receiver and high attenuation characteristic outside the receiver's allocated band.

The frequency response curve shown in Fig. 10 is a commercially available filter used to mitigate front-end overload in 4 GHz earth stations and fixed radio-relay stations. The in-band (3 700 to 4 200 MHz) insertion loss ranges between 0 and 1 dB, and is typically about 0.5 dB. Out-of-band attenuation is approximately 25 dB within 50 MHz of the band edges, and is in excess of 45 dB within 100 MHz of the band edges.

FIGURE 10

Frequency response curve of a commercially procured 3 700 to 4 200 MHz bandpass filter



3 Radar transmitter spurious emissions

Radar spurious emission coupling occurs when energy from the radar transmitter spurious emissions in the earth station or fixed radio-relay station band causes degradation to the receiver system performance. The predominant factor that governs the level of spurious emissions from radars is the transmitter output device (also referred to as an output tube).

It is important to know the inherent spurious emission levels and variances for the different types of transmitter output devices in order to assess the potential for interference from radars utilizing these output devices. Microwave radar output devices inherently generate spurious emission noise that generally dominates spectral emissions at frequency separations greater than 50 MHz from the radar fundamental frequency. (Such emissions are often referred to as transmitter noise.) Thus, at frequency separations of greater than 50 MHz, the radar emission spectrum is independent of radar system characteristics such as the pulse modulation parameters (e.g. pulse width, pulse modulation, and pulse rise/fall times). Radiocommunication Study Group 8 has been studying the spurious emission characteristics of radar output devices to improve efficient use of the spectrum and enhance compatibility with services in adjacent bands.

3.1 Radar spurious emissions interference mitigation options

The following is a discussion of options to mitigate interference from radar stations due to radar transmitter spurious emissions.

3.1.1 Radar station interference mitigation options

RF waveguide filters can be used in some radiodetermination stations to reduce interference to fixed radio-relay and earth stations receivers to acceptable levels. Measurements have shown (see Figs. 11 and 12) that RF waveguide filters will suppress radar spurious emissions in the 4 GHz band by at least 40 to 50 dB. In Fig. 11, note that the filter is characterized by attenuation in excess of 80 dB at frequencies immediately above the upper cutoff at 3 700 MHz, but that this attenuation decreases to as little as 15 dB at frequencies above 4 300 MHz. This demonstrates that, while filter installation on a radar station may reduce the potential for interference in one band, it may not provide a solution for other bands even farther removed in the spectrum.

When interference is caused by spurious emissions from a radar transmitter, the installation of an RF filter for the appropriate band at the radar transmitter is considered a practicable solution provided that it is technically, operationally, and economically feasible. Although most radar systems can accept the installation of an output filter to reduce spurious emissions, some radar systems utilize distributed phased-array transmitters and thus cannot be effectively output filtered.

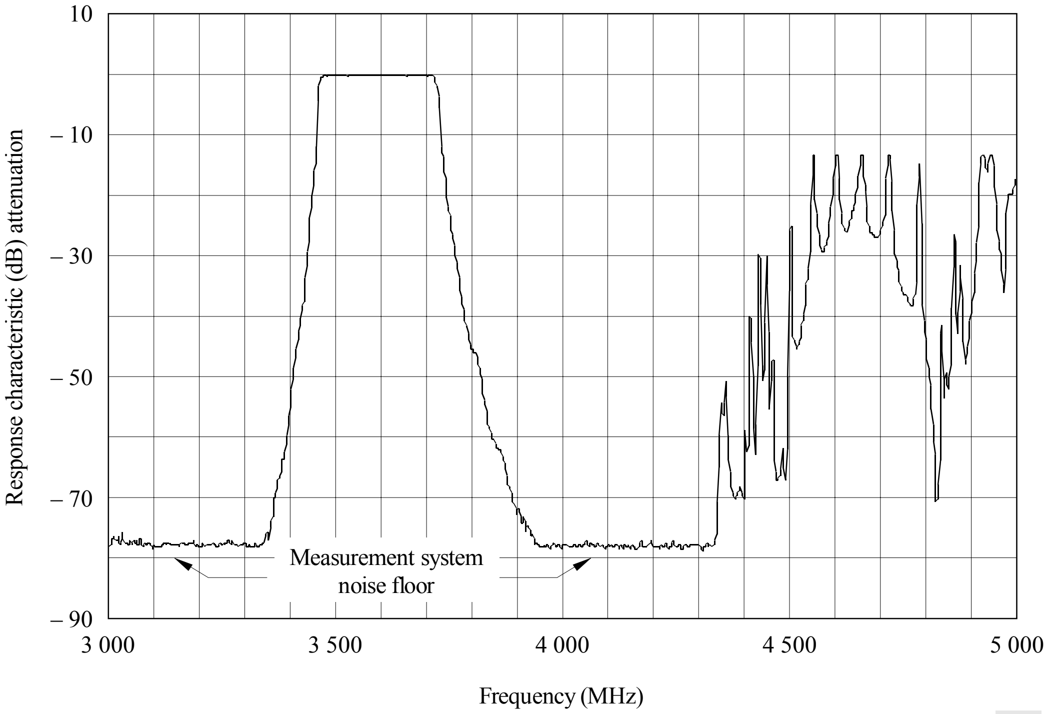
Other options to mitigate radar transmitter spurious emission interference are replacement of radar transmitter output device and selection or adjustment of radar transmitter frequency. There are variations in the spurious emission levels of the same type output device as a function of an individual device and the operating frequency. In some cases replacement of the output device or a change in the operating frequency have mitigated the interference. These interference mitigation options are discussed in Recommendation ITU-R F.1097 – Interference mitigation options to enhance compatibility between radar systems and digital radio-relay systems.

3.1.2 Fixed radio-relay station interference mitigation options

Interference mitigation options to enhance compatibility between fixed radio-relay stations and radars operating in adjacent bands when interference is due to radar transmitter spurious emissions in the fixed service band are discussed in Recommendation ITU-R F.1097. The options for fixed radio-relay stations include: space diversity, angle diversity, forward error correction (FEC) coding, alternate channel use, alternate band deployment, path routing, increased transmitter power and antenna selection (characteristics).

FIGURE 11

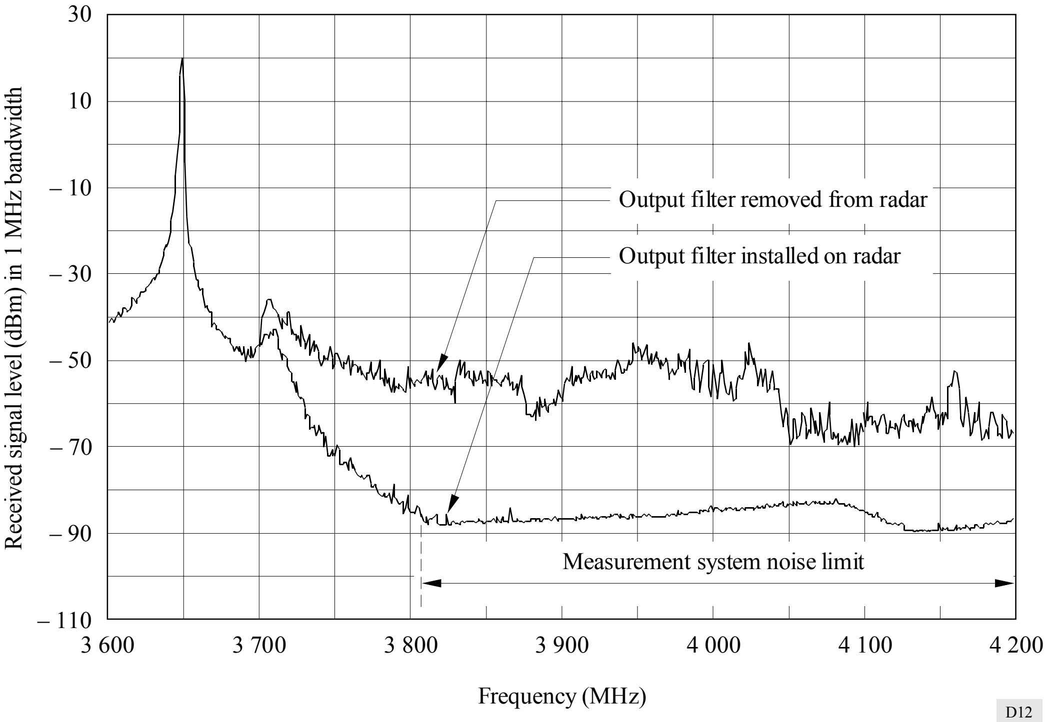
Measured frequency response curve of a bandpass filter installed on a radar



D11

FIGURE 12

Spectrum of a radar showing effect on spectrum when bandpass filter is installed on radar output



D12

3.1.3 Fixed-satellite earth stations interference mitigation options

The following is a discussion of options for fixed-satellite earth stations to enhance compatibility when interference is due to radar transmitter spurious emissions in the fixed-satellite service band.

3.1.3.1 Antenna selection

Antenna discrimination, the response of an antenna to signals arriving from various azimuths, varies widely among antenna types. In some situations, it may be possible to take advantage of those characteristics to reduce the response of a system to interference arriving from a particular direction. Currently, the vast majority of earth stations use standard parabolic antennas with prime focus feeds. Other types of antennas used which have lower sidelobe levels include those incorporating cassegrain reflector, gregorian reflector, offset-fed reflector and horn antennas. Antenna manufacturers have stated that shrouded parabolic antennas used for radio-relay systems can also be used by earth stations operating in the 4 GHz band. Each type has a different response to off-axis signals. At off-axis angles in excess of 10°, shrouded parabolic and conical horn reflector antennas can provide 10 to 20 dB of additional suppression of an interfering signal and 20 to 50 dB of suppression for off-axis angles greater than 50°.

3.1.3.2 Site selection

Site selection can be used during the design phase of new earth stations to avoid potential interference exposures to operational radar stations. There are many factors that determine the site selection of earth stations. When possible, one of the factors should be the electromagnetic environment. For site selection 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 on site selection may significantly impact the economics of the earth station construction. The key to mitigation of radar interference in selection of a site is electromagnetic shielding by surrounding terrain.