

REPORT ITU-R M.2050

Test results illustrating the susceptibility of maritime radionavigation radars to emissions from digital communication and pulsed systems in the bands 2 900-3 100 and 9 200-9 500 MHz

(2004)

1 Introduction

Tests have been performed to assess the effects that emissions from digital communication systems have on three maritime radionavigation radars that operate with a primary allocation in the 2 900-3 100 MHz band and two radars that operate with primary allocation in the 9 200-9 500 MHz band. The radars were International Maritime Organization (IMO) SOLAS¹ compulsory carriage category maritime radionavigation radars that employ scan rates, pulse widths, PRFs, IF bandwidth, noise figure, and antenna beamwidths typical of those identified in Recommendation ITU-R M.1313. These radars are representative of the types being used by the United States Coast Guard for shipboard navigation, by the commercial shipping industry, and recreational boaters as well. The radars operating in the 2 900-3 100 MHz band are identified as Radars A, B and C in this Report and the 9 200-9 500 MHz radars are identified as Radars D and E.

Radars identified in Recommendation ITU-R M.1313 typically employ interference mitigation techniques/processing methods identified in Recommendation ITU-R M.1372 to allow them to operate in the presence of other radionavigation and radiolocation radars. Techniques of that kind are very effective in reducing or eliminating low duty-cycle asynchronous pulsed interference between radars. All of the radars that were tested have some type of interference rejection circuitry/processing, which by default was enabled. Recommendation ITU-R M.1461 contains protection criteria for radars operating in the radiodetermination service.

These tests investigated the effectiveness of each of the radar's interference suppression circuitry/software to reduce or eliminate interference due to the emissions from a communication system employing a digital modulation scheme. Additional tests were also performed using low duty-cycle pulsed emissions as an interference source.

The tests were performed with the assistance of the radar manufactures and experienced mariners. Their guidance was used to properly set up and to operate the radars.

The tests were performed with non-fluctuating targets generation which were inserted into the radar receivers.

This Report describes the conduct of the findings to date.

2 Objectives

The objectives of the testing were:

- to quantify the capability of each of the five maritime radionavigation radar's interference-rejection processing to mitigate unwanted emissions from digital communication systems as a function of their power level;

¹ International Convention for Safety of Life at Sea.

- to develop I/N protection criteria that would mitigate the unwanted digital communication systems emissions in maritime radionavigation radars;
- to observe and quantify the effectiveness of each of the maritime radionavigation radar's interference rejection techniques to reduce the number of false targets, radial streaks (strokes), and background noise or "speckle".

3 Radars under test

3.1 Radar A

Maritime radionavigation Radar A, which was introduced circa 2000 and is still being refined, is designed for commercial applications and is an IMO category radar that operates in the 2 900-3 100 MHz band. Nominal values for the principal parameters of this radar were obtained from regulatory type-approval documents, sales brochures and technical manuals. These are presented in Table 1.

TABLE 1
Radar A transmitter and receiver parameters

Parameter	Value			
Frequency (MHz)	3 050 ± 30			
Pulse power (kW)	30			
Range (nmi) (km)	0.375-1.5 0.7-2.8	3-6 5.6-11.1	12 22.2	24-96 44.5-177.8
Pulse width (µs)	0.08	0.30	0.60	1.2
PRF (Hz)	2 200		1 028	600
IF bandwidth (MHz)	28	3	3	3
Spurious response rejection (dB)	60			
System noise figure (dB)	4			
RF bandwidth (MHz)	Unknown			
Antenna scan rate (rpm)	26			
Antenna scan time (s)	2.31			
Antenna horizontal beamwidth (degrees)	1.9			
Antenna vertical beamwidth (degrees)	22			
Polarization	Horizontal			

The radar uses a multistage logarithmic IF amplifier/detector. This type of receiver design is very common in marine radionavigation radars since they have to detect targets that have very small and large returns. A logarithmic amplifier increases the range of target returns that can be handled by the radar receiver without it becoming saturated.

The noise figure of the radar was measured and was found to be 5.3 dB, which was consistent with the nominal value of 4 dB. The 3 dB IF bandwidth is about 3 MHz for the range scale used for the tests. Using those parameters the noise power of the radar receiver is calculated to be about -104 dBm.

Radar A has extensive signal processing and target tracking capabilities, including an adaptive local constant-false-alarm-rate (CFAR) feature and a scan-to-scan correlation feature. The local CFAR (acting within a small fraction of one range sweep) is known as an ordered-statistic CFAR, which is a type that permits the desensitizing effect of interfering pulses to be lessened or avoided. This is done by discarding a selectable number of background signal samples that would otherwise be used in establishing the detection threshold. The process discards the samples having the greatest amplitude. As more samples are discarded which contain the higher amplitude interfering pulses, the less influence they are likely to have on the sensitivity of valid target detection.

Radar B can also perform a scan-to-scan correlation process that provides an additional means for discriminating between signals that are present consistently, such as a valid target, and signals that appear at random times, such as asynchronous pulsed interference.

3.2 Radars B and D

Radars B and D are maritime radionavigation IMO category type of radars produced by the same manufacturer and are designed for commercial applications. Radar B operates in the 2 900-3 100 MHz band while Radar D operates in the 9 200-9 500 MHz band. Radars B and D locate their transmitter/receiver below deck and use waveguide to send/receive signals from the antenna. They use different antennas and receiver front-ends, but have a common display along with common receiver elements including the interference rejection processing and IF circuitry. The radars use a multistage logarithmic IF amplifier and a separate video detector. Radars B and D also use pulse jitter. The transmitted pulse PRF can be jittered to prevent second time around echoes and also to reduce the interference from other transmitters in the vicinity. This function is automatically set in the transceiver and provides up to $\pm 25\mu\text{s}$ jitter about the nominal value.

Nominal values for the principal parameters of these radars were obtained from regulatory type-approval documents, sales brochures and technical manuals. They are presented in Table 2.

TABLE 2
Radars B and D transmitter and receiver parameters

Parameter	Value			
Frequency (MHz)	3 050 ± 10		9 410 ± 30	
Pulse power (kW)	30			
Range (nmi)	0.125-1.5	3-24	48	96
Pulse width (μs)	0.070	0.175	0.85	1.0
PRF (Hz)	3 100	1 550	775	390
IF bandwidth (MHz)	22	22	6	6
Spurious response rejection (dB)	Unknown			
System noise figure (dB)	5.5			
RF bandwidth (MHz)	Unknown			
Antenna scan rate (rpm)	24/48			
Antenna horizontal beamwidth (degrees)	2.8		1.2	
Antenna vertical beamwidth (degrees)	28		25	
Polarization	Horizontal			

The values of pulse width and PRF in Table 2 are the default settings for that particular range. The operator can, for some ranges, select other pulse widths and PRFs that are under or over the default values.

Pulse-to-pulse and scan-to-scan correlators are used by Radars B and D to mitigate interference which may be caused from other radars operating nearby. For the pulse-to-pulse correlator, returns are compared on a pulse-to-pulse basis to reduce interference. A signal is only displayed if it is present on two consecutive pulses. This interference rejection function is most effective if the transceiver has been set to provide PRF jitter. For the scan-to-scan correlator, a target is only displayed if it is present on two consecutive scans. These radars do not have CFAR processing. A complete discussion of these radar interference mitigation techniques can be found in Recommendation ITU-R M.1372.

3.3 Radars C and E

Radars C and E are maritime radionavigation IMO category type of radars produced by the same manufacturer and are designed for commercial applications. Radar C operates in the 2 900-3 100 MHz band while Radar E operates in the 9 200-9 500 MHz band. Radars C and E are a topmast design. The receiver/transmitter (R/T) is encapsulated in a metal housing located directly below the rotating antenna. The video from the R/T unit is sent to the ppi located below deck via cables. They use different antennas and receiver front-ends, but have a common display along with common receiver elements including the interference rejection processing and IF circuitry. Both of the radars use an eight-stage successive approximation logarithmic IF amplifier/detector.

Nominal values for the principal parameters of these radars were obtained from regulatory type-approval documents, sales brochures and technical manuals. They are presented in Table 3.

TABLE 3
Radars C and E transmitter and receiver parameters

Parameter	Value		
Frequency (MHz)	3 050 ± 10	9 410 ± 30	
Pulse power (kW)	30		
Range (nmi)	0.125-3	6-24	48-96
Pulse width (μs)	0.050	0.25	0.80
PRF (Hz)	1 800		785
IF bandwidth (MHz)	20	20	3
Spurious response rejection (dB)	Unknown		
System noise figure (dB)	4		
RF bandwidth (MHz)	Unknown		
Antenna scan rate (rpm)	25/48		
Antenna scan time (s)	2.31		
Antenna horizontal beamwidth (degrees)	2.0		
Antenna vertical beamwidth (degrees)	30		
Polarization	Horizontal		

The values of pulse width and PRF in Table 3 are the default settings for that particular range. The operator can, for some ranges, select other pulse widths and PRFs that are under or over the default values.

Radars C and E use pulse-to-pulse and scan-to-scan correlators to mitigate interference from other radars. A description of these techniques is provided in § 3.2. These radars do not have CFAR processing.

3.4 Radar video displays

Radar A, due to its enhanced signal processing capabilities, has the ability to display various types of targets in different combinations. The radar is able to display amorphous raw-video “blips” (known as the image display), synthetic targets that appear as an “o”, and/or tracked targets that appear as an “x”. The brightness of the video image targets corresponds to the level of the target return. Targets that have a brighter “blip” have a greater return echo. The synthetic targets required about 2-3 dB of additional desired power compared to the raw-video targets to obtain the same probability of detection, P_d , when operating at minimum detectable signal (MDS) level but do not change their brightness in correspondence to the reflected signal strength.

Radars B and D (from the same manufacturer) use a colour CRT to display targets and radar information to the user such as PRF, pulsewidth, and range rings among other parameters. These radars do not show synthetic targets and only display raw-video “blips”. Likewise, Radars C and E (from another manufacturer) only display raw-video “blips”. However, the display used with radars C and E is monochromatic raster scan type. Besides targets, this display also indicates various radar parameters. Like Radar A, for these radars the raw-video “blip” is brighter for targets that have a greater return echo.

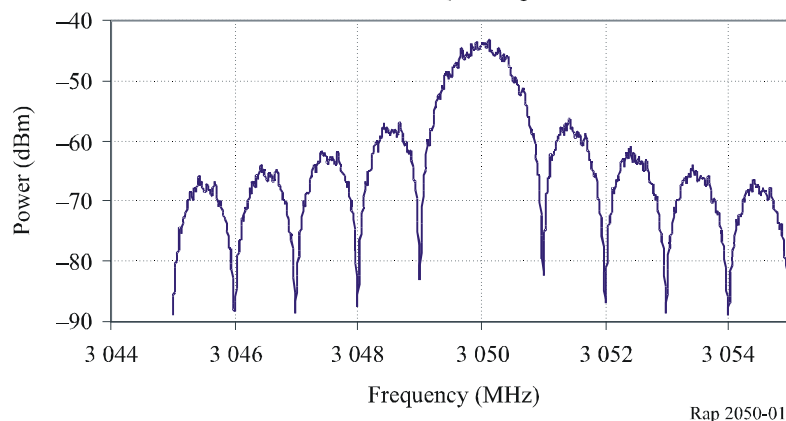
4 Unwanted signals

Radar A was tested with a 2 Mbit/s quadrature phase shift keyed (QPSK) waveform as an interference source. Radars B and C were tested with 64 quadrature amplitude modulation (QAM), 16-QAM, code division multiple access2000 (cdma2000), and wideband CDMA (WCDMA) signals as interference sources. Radars D and E were only tested with the cdma2000 and WCDMA signals. All interfering signals were on-tune with the radars. The QPSK signal injected into Radar A was continuous, occurring for a full 360°.

The unwanted CDMA signals that were injected into Radars B, C, D and E were gated to occur at the same time of the target generation within the same azimuth. The gate time was equal to the length of time that a stationary interference source would be within the radar’s antenna 3 dB horizontal beamwidth as it rotates. The QAM signals were not gated.

The measured emission spectrum of the continuous QPSK signal is shown in Fig. 1.

FIGURE 1
Emission spectra of QPSK waveform
2 Mbit/s QPSK signal

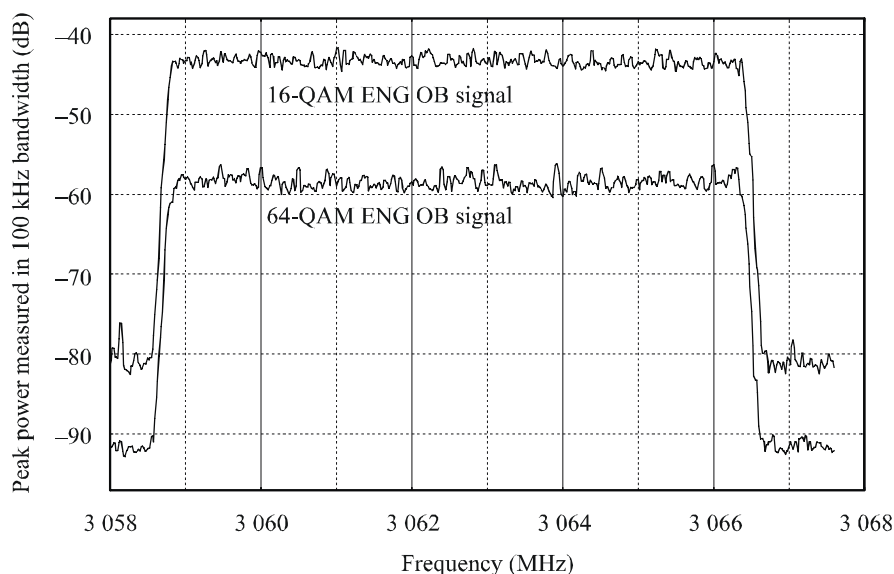


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Communication test sets were used to generate the DVB-T 16-QAM, DVB-T 64-QAM, cdma2000 and WCDMA signals. Spectrum shots of each of the unwanted signals are shown in Figs. 2 and 3. The cdma2000 signal was for the reverse link (mobile-to-base) standard according to the IS-95 format for cellular mobile telephones. The WCDMA signal was for the uplink standard according to the 3GPP 3.5 format.

The 16 and 64 DVB-T QAM signals in Fig. 2 represent the type of modulation scheme that is used by digital cameras for electronic news gathering (ENG OB) purposes.

FIGURE 2
QAM signal used in ENG OB
ENG OB signal spectra



Note 1 – The spectrum curves are offset in amplitude for graphical clarity.

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