Effects of rain on performance of maritime radars

Vladimir Stoiljkovic, Easat, Stoke-on-Trent, UK

Maritime radars are required to have a very good target detection capability. Detection and tracking of small targets in harsh weather conditions can help authorities in efficient monitoring of illegal activities.

It is well known that rain can significantly reduce detection ranges of maritime radars, especially on small targets. This paper explains the causes for this and how adverse effects of rain can be reduced by proper choice of radar scanner parameters.

Introduction

Raindrops absorb and scatter radar signals, so less energy reaches the target and even less returns to radar as an echo. Hence, precipitation (rain, snow, hail etc.) in general and rainfall in particular affect the propagation of electromagnetic (EM) waves (radar signals) in two ways: first, there is absorption of electromagnetic energy by water drops and vapour which causes radar signal attenuation (loss). Second, there is a returned signal from the rain which 'clutters' the radar return and can mask targets. This phenomenon is known as rain clutter.

Precipitation losses

The absorption of the EM energy is mainly dependent on precipitation rate, its type and extent, radar operating frequency and its polarisation. The attenuation increases with both frequency and the rainfall rate and is usually expressed in decibels per kilometre. Table 1 gives representative values for rain attenuation at S- and X-bands of frequencies, customarily used in maritime radars.

TABLE 1. TWO-WAY RADAR SIGNAL ATTENUATION IN RAIN, dB/km

Frequency /GHz/	Rainfall rate /mm/hour/		
	1	4	16
	- light rain -	-moderate rain -	- heavy rain -
3	0.0009	0.004	0.019
10	0.025	0.13	0.66

The numbers shown indicate that the loss at 10GHz is one to two orders of magnitude higher than at 3GHz, and that a long path in heavy rain at higher frequency could produce large attenuation.

Rainfall rates along the radar/target path cannot be easily determined, partly because the rainfall is not uniform along the path. For example, the rainfall over the ground, where the radar station is based, is usually different from the rainfall out at the sea, where the target is (offshore rates tend to be lower). Furthermore, heavy rainfall mainly occurs in areas occupying only a part of the total radar/target path length. Having said that, one should bear in mind that heavy rain represents very high navigational hazard and the radar performance calculations should be based on the worst-case assumption of the whole-path precipitation. Whether this assumption is being used or not should be clearly stated, as the effect on long range detection performance can be considerable, especially for small targets.

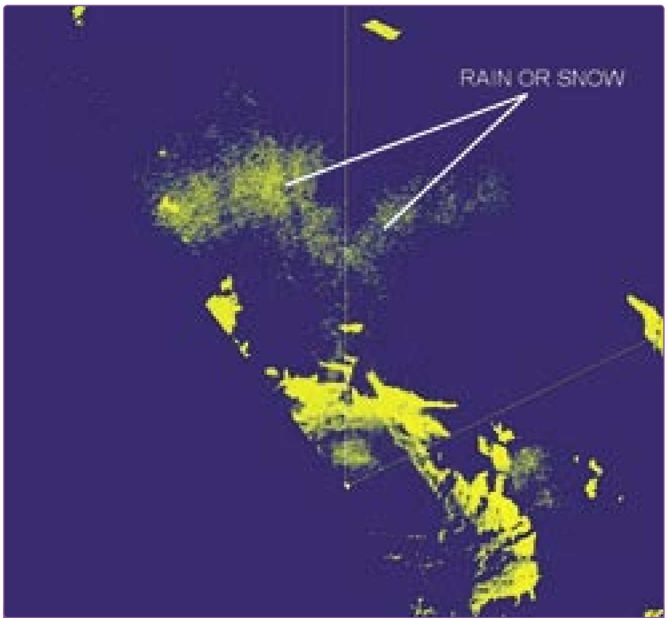

Figure 1. Radar picture clearly showing precipitation.

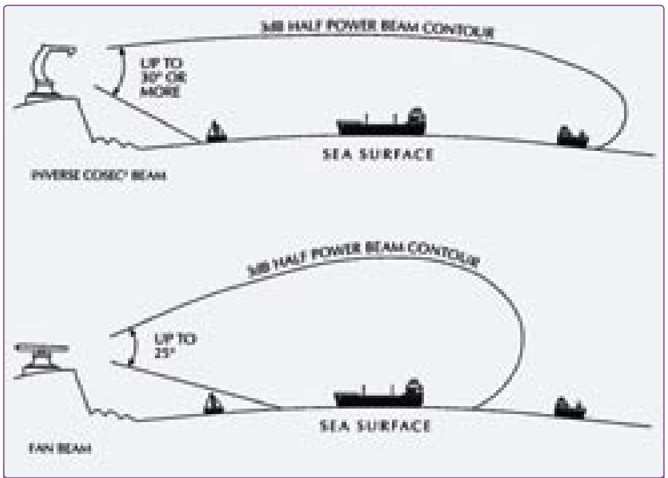

Figure 2. The shaped radar beam reduces rain clutter returns and increases radar ranges.

The world-wide statistics on precipitation intensity is available from International Telecommunications Union (www.itu.int): ITU-R Recommendation P.837-4, 'Characteristics of precipitation for propagation modelling'. The document describes a numerical model which can estimate the rainfall rate exceeded for a given percentage of time a year. For example, there is probability of 0.01% (about one hour a year) of precipitation exceeding 40mm/hour on the coast of Portugal.

Rain clutter

Rain reflects some of the energy transmitted by radar back to the radar receiver as rain clutter (Figure 1). The rain clutter is a volumetric phenomenon so the amount of clutter returned back to the radar will be directly proportional to the volume of rain illuminated by the radar beam (Figure 2). Obviously, the narrower the radar beam the smaller the clutter. The beam should be narrow in both azimuth and elevation. The reduction in the clutter returns as function of elevation and azimuth beamwidths is given in Table 2.

When circularly polarised radar scanner illuminates rain, internal reflections within perfect spheres of water would return the circularly polarised signal of the opposite hand, which perfectly polarised scanners would reject. The raindrops are not perfect spheres, however, and neither the scanners have perfect circular polarisation. Even so, good circularly polarised radar scanners reduce rain clutter by about 20dB, which enables substantial improvement of radar performance in rain (Figure 3).

Unfortunately, radar cross section of targets is slightly reduced for circular polarisation (hence, slightly reduced radar ranges), so for optimum detection the operator should have a capability of polarisation switching: circular polarisation in rain and linear polarisation in clear weather.

The pulse duration which the radar transmits also affects the level of rain clutter returns: the longer the pulse duration, the more clutter is received by the radar scanner. Reducing the pulse duration lowers the clutter energy but the energy on target is also reduced and the situation when the energy is not sufficient to ensure detection has to be avoided.

Practical steps in reducing rain clutter

Based on the above described considerations, the practical steps to reduce rain clutter in heavy rainfall are:

1. Use of circular polarisation in rain and linear polarisation in clear weather
2. Use of radar scanners with narrow azimuth and elevation beamwidths
3. Use of dual S- and X-band radar scanners
4. Reduction in the pulse widths

TABLE 2. NARROWER RADAR BEAMS REDUCE RAIN CLUTTER RETURNS

Azimuth 3dB beamwidth	0.37°	0.43°	0.33°
Elevation 3dB beamwidth	11.0°	4.0°	1.8°
Reduction of rain clutter power level	**0dB**	**3.7dB**	**8.4dB**

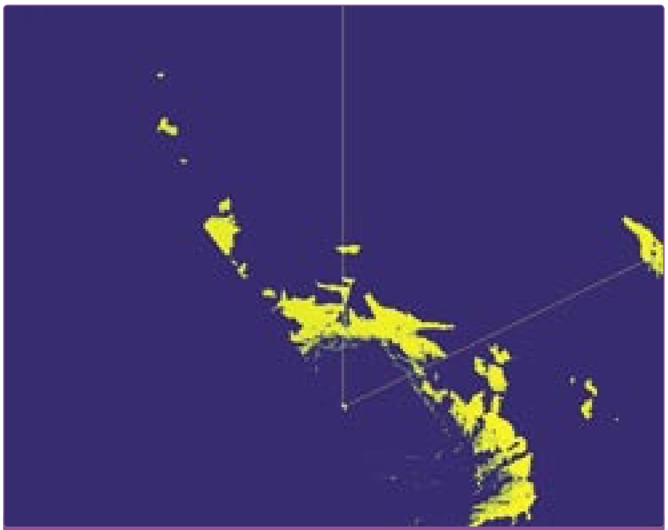

Figure 3. By switching the antenna polarization rain and snow disappear from the radar picture (Figure 1), enabling better detection and visibility of small targets.

Conclusion

Detection performance of maritime radars can deteriorate significantly in rainy weather, particularly on small targets. Simple ways of reducing adverse effects of rain have been described. Proper choice of radar scanner parameters is essential in improving detection and tracking performance in harsh weather conditions.

ABOUT THE COMPANY

Formed in 1987, Easat is a subsidiary of Goodwin plc, a British privately owned engineering group established in 1883. Easat is a giant exporter having its components and systems installed in over 30 countries around the world. Easat supplies high specification radar sensors for coastal surveillance and security critical applications. The sensors combine high gain antenna technology with the state of the art transceiver equipment enabling integrated surveillance of sea and air targets.

Easat specialises in long range coastal surveillance radars. The coastal radar equipment is capable of detecting small targets at short and long ranges in severe weather conditions hence reducing the risks posed by terrorism, illegal immigration, arms and drugs trafficking, etc. Other applications include long range Vessel Traffic Management Systems (VTMS), home land security, search and rescue, fisheries management, pollution management, etc. Radars can be configured for the detection of sea surface targets only or for combined air and sea surveillance. The wide range of radar sensor models enables Easat to meet technical, operational and budgetary constraints by delivering tailored solutions for the coastal surveillance applications.

The radars consist of a modular family of specially developed antennas, transceivers and radar processors. Each of these is chosen from a range of high performance, proven sub-systems, either designed by Easat or built to Easat specifications. Easat can provide customers with radar performance predictions and recommendations in the choice and architecture of radar sensor systems. These can comprise antennas, transceivers, towers, foundations, equipment cabins and other equipment necessary to provide a complete radar sensor system including full civil engineering works.

ENQUIRIES

Easat
Goodwin House
Leek Road
Hanley
Stoke-on-Trent
ST1 3NR
UK

Tel: +44 (0) 1782 208028
Fax: +44 (0) 1782 208060
Email: vstoiljkovic@easat.co.uk
Website: www.easat.co.uk