REPORT ITU-R M.2136*

Theoretical analysis and testing results pertaining to the determination of relevant interference protection criteria of ground-based meteorological radars

(2008)

The present Report provides theoretical analysis and testing results pertaining to the determination of relevant interference protection criteria of ground based meteorological radars with the key objective to establish the maximum interference level that meteorological radar systems can withstand before their forecasting capability is compromised.

The analysis and related test results as in Annex 1 are related to meteorological radars operating in the frequency band 2 700-2 900 MHz and support the requirement for a protection value that could be as low as –9 dB I/N for the base reflectivity data. Calculations show that the I/N value at which the spectrum width performance is degraded beyond the system requirements (bias ≥ 1 m/s) is even lower (–14.4 dB) but measurements only support an I/N of –10 dB for spectrum width.

The test results performed with a meteorological radar operating in the frequency band 5 600-5 650 MHz as in Annex 2 confirm the analysis described in Annex 1 for meteorological radar operating in the frequency band 2 700-2 900 MHz and support the requirement for a protection value that could be as low as –12.75 dB I/N for the base reflectivity, i.e. for products that are related to signal power. For meteorological products not related to signal power (such as Doppler of differential phase modes) lower sensitivity thresholds would likely be necessary.

As an overall conclusion, this Report provides elements that confirm that, in order that most meteorological radars and their corresponding products be protected, a minimum I/N = –10 dB should be used.

* This Report should be brought to the attention of the World Meteorological Organization (WMO).

Annex 1

Results of tests with a meteorological radar operating in the frequency band 2 700-2 900 MHz

Executive summary

The key objective of the work contained in this Annex 1 was to establish the maximum interference level that meteorological radar systems can withstand before their forecasting capability is compromised.

Based upon the radar's technical specifications, mathematical models have been derived for key products (base reflectivity, mean radial velocity and spectrum width) that indicate what these expected levels should be. In order to physically validate this analysis, a test and data analysis methodology has been defined through which data were collected and analysed.

The analysis of the data supports the calculated value required for protection of the reflectivity measurements. Current limitations in the radar calibration and noise removal process performed by the low-level data processor limit the measurement of the necessary protection criteria for the spectrum width measurements. However, correction of the data for the limitations of this processing results in values that support the calculated protection values.

1 Introduction

Tests were run on a modern meteorological radar (noted as radar 1 in Annex 2 of Recommendation ITU-R M.1849) to determine the appropriate criteria necessary for protection from continuous wave (CW) and interference signals in the 2 700-2 900 MHz band. The tests were comprised of injecting a CW signal and six different digital modulation schemes into the radar receiver while it was scanning the atmosphere. Low-level or base meteorological products (base reflectivity, mean radial velocity and spectrum width) were recorded while conducting a series of antenna rotations at a single antenna elevation. Interference signals were injected with I/N ratios ranging from +6 dB to −15 dB.

2 Theoretical calculation of necessary protection criteria

The radar generates three base products that are used by the signal processing system to derive the meteorological products that are used by the meteorologist. These base products are:

– volume reflectivity, Z (mm^6/m^3) which for rain is a measure of total water in the radar sample volume;

– mean radial velocity, V (m/s) which is the power weighted mean radial motion of the targets in the sample volume;

– spectrum width, W (m/s) which is a measure of the radial velocity dispersion of the targets in the sample volume.

2.1 Minimum signal level

Signal processing removes the radar system noise effects from the reflectivity and spectrum width products so that the system can provide these products when the signal level is below the receiver noise level. The S/N threshold, i.e. the lowest level for which the return signal is processed, is selectable by the radar operator between the limits of −12 dB S/N and +6 dB S/N. With the present signal processing, the lower values are generally not used due to limitations with noise removal but the system provides useful products down to −3 dB *S/N*. The interference level that compromises the system is related to the minimum signal level of −3 dB *S/N* and the product characteristics themselves, as described below. Excessive interference will impact data quality, degrade the meteorological products, and compromise the system's ability to accomplish its mission of providing data necessary for public weather forecasting, severe weather warning, and rainfall measurement for flash flood prediction and water management.

2.2 Reflectivity maximum *I/N*

Reflectivity is used in multiple applications; the most important of which is rainfall rate estimation. Reflectivity is calculated from a linear average of return power and is subject to contamination by interference as an unknown increase in the measured reflectivity. Reflectivity is seriously contaminated if the bias exceeds the system specifications[1]. Given the radar systems dB bias and *S/N*, the following equations can be used to calculate the *I/N* that is required in order to protect the integrity of the reflectivity product.

Bias in terms of *I/S* is given by:

$$\text{dB bias} = 10 \log \frac{S+I}{S}$$

Solving for *I/S* yields:

$$I/S = \left[10\wedge\left(\frac{\text{dB bias}}{10}\right)\right] - 1$$

I/N is then equal to:

$$I/N = 10 \log (I/S) + S/N$$

Example calculation for a 1 dB bias and an *S/N* of –3 dB:

$$I/S = \left[10\wedge\left(\frac{1}{10}\right)\right] - 1$$

$$I/S = 0.26$$

$$10 \log I/S = -5.8 \text{ dB}$$

Therefore, reflectivity is biased 1 dB at an interference level 5.8 dB below the signal.

Since the minimum signal level has an *S/N* of −3 dB and the maximum *I/S* level for the reflectivity product is −5.8 dB, the maximum *I/N* is:

$$(-3 \text{ dB}) + (-5.8 \text{ dB}) = -8.8 \text{ dB } I/N$$

[1] The dB bias is a function of the radars calibration accuracy and equal to the standard deviation of the reflectivity estimate as specified in the radar technical requirements.