P3C.11 # CALIBRATION EFFORTS AT CAMAGUEY MRL-5 RADAR STATION

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1. INTRODUCTION

There are many topics in which radar meteorologists do not agree, but radar calibration seems to be "the apple of discord" among all discrepancies (perhaps a close call together with DSD and Z-R). In fact, weather radars are one of the most complex instruments used in Meteorology and no unique method of calibration is globally recognized. Even the word "calibration" has different meanings to different groups. Nevertheless, everybody agree in the strong necessity of good radar calibration.

Having seven operational weather radars, the Cuban Institute of Meteorology is not free from this necessity. Our case is aggravated by the fact that four of our radars are Russian-made MRL-5 and the rest Japan-made RC-32B. These models are different in construction, but we want them to perform similarly.

The Technical Development Laboratory decided to begin our calibration effort in our insignia Camagüey Radar Station (MRL-5), the only one used for both operational and research purposes. This is the sole station where a "sphere calibration" has been performed in the past (Koloskov and Rodriguez, 1986).

The MRL-5 is a powerful dual-wavelength radar (S- and X-band) with both channels collinearly mounted in the same antenna. Its parameters are briefly summarized in Table 1.

Table 1. MRL-5 parameters.

Parameters	
S Band Transmitter Power [kW]	No more than 850
S Band Receiver Sensitivity [dBm]	Better than -106
S Band Beam width [degrees]	1.5
X Band Transmitter Power [kW]	No more than 250
X Band Receiver Sensitivity [dBm]	Better than -104
X Band Beam width [degrees]	0.5 or 1.5
S and X Band PRF [Hz]	250 or 500
S and X Band Pulse durat. [microsec]	2 or 1

Signals are acquired by a high-speed PCI card (two channels running at 2MHz) controlled by the VESTA-RDA software. This software receives the logarithmic video output from both the S- and X-Band receivers and performs signal averaging and code to power conversion. (Perez *et al.,* 1999).

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2. RADAR EQUATION

In operational practice we use the following variant of the radar equation for distributed targets:

$$z_e = \left(\frac{2^{10} \cdot \ln 2 \cdot c}{0.93 \cdot \pi^3}\right) \cdot \left(\frac{1}{p_{ave} \cdot T_r \cdot f_t^2}\right) \cdot \left(\frac{1}{l_r}\right) \cdot \left(\frac{1}{g^2 \cdot \Theta \cdot \Phi \cdot l_{wg}}\right) \cdot \left(p_r \cdot r^2\right)$$

The first term of the equation contains only numeric constants. In the second term we find parameters related to the average transmitted power, pulse repetition frequency and microwave frequency. The third term represents the receiver losses. The fourth term is related to wave-guide losses and antenna gain and beam width. The last term is related to the target itself: received power and range.

In order to produce good estimates of the Radar Reflectivity Factor (z_e) we need to measure all the elements in the second and fourth terms. We also need to calculate the receiver losses (third term) and to calibrate the received power (last term).

3. MEASUREMENTS

3.1 Transmitter measurements.

The average transmitted power, pulse repetition period and microwave frequency, are routinely checked in our radar with high precision. So, they do not represent a serious problem.

3.2 Antenna measurements.

As with most radar systems, in our case, the major problem is measuring the characteristics of the antenna.

In this work, we started by measuring our wave-guide losses. Transmitting losses were measured using two wave-guide sections with thermo-pairs, one right at the magnetron output, the other near the antenna feed horn. Losses were found to be, in average, 1.15dB for the X-band channel and 0.9dB for the S-band channel. Receiving losses were measured by injecting signals from a standard signal generator. The generator was connected first to the antenna feed horn and later directly to the receiver input. The difference was found to be, in average, 1.2dB for the X-band channel and 1.1dB for the S-band channel.

Unfortunately, we lack the equipment to measure the antenna gain. Instead, we use the original value supplied by the vendor. A nice test was made using a signal generator connected to an MRL-5 antenna (from an old radar), located 4 km north of our radar station. The problem is that the gain of this antenna is not known either. However, it was a good practice!

Our biggest surprise came when we started measuring the antenna beam-width for both channels.

For this we used the echo from a distant tower. Both beam patterns were supposed to be equal and collinear, but they were not. In addition, the level of the X-band signal was very low compared to the S-band (see fig. 1). This indicated that the small X-band reflector (mounted inside the big S-band dish) was not in the right position.

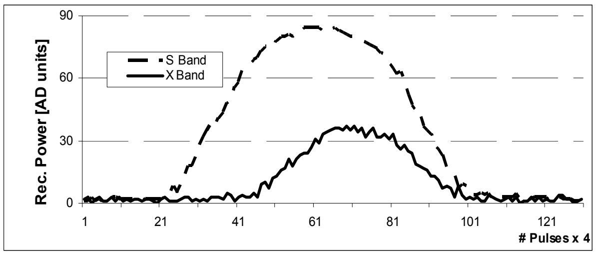

Fig. 1: Signal from a distant tower, misaligned antennas.

After a long and tedious procedure, the small reflector was set in the correct position. Now both X- and S-band patterns are collinear and they have the same 1.5° beam-width (see fig.2).

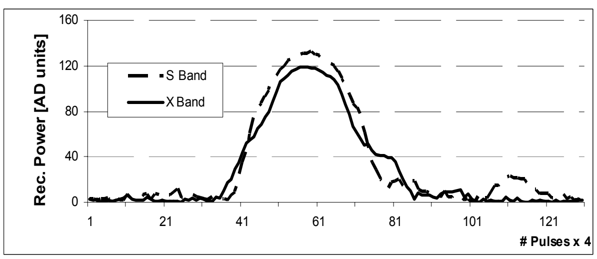

Fig. 2: Signal from a distant tower, aligned antennas.

Everything seemed to be OK, but when we used some other (closer) targets to repeat the beam-width measurements we got the puzzling result shown in fig. 3. The patterns are not completely matched, even though they seemed to be so for the previous target.

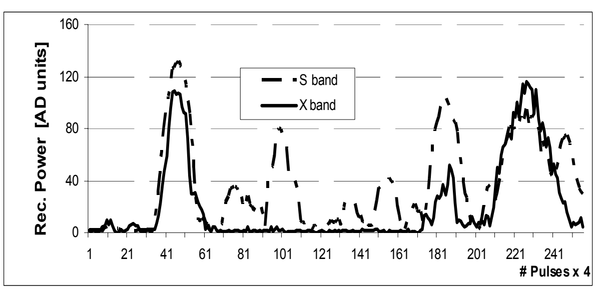

Fig. 3: Signal returned from closer targets showing pattern mismatch.

At this point we must remember Rinehart and Tuttle (1982): side lobe patters must also be matched to get perfect dual-wavelength processing. However, nothing is perfect in reality!

3.2 Receiver calibration

Receiver losses were calculated according to Doviak and Zrnic (1979). For long pulse (2µS) receiver losses are -1.33dB while for short pulse (1µS) they are -2.87dB. In both cases our receiver bandwidth is 1MHz.

Receiver calibration is routinely made by injecting signals of known power and reading the output code from the receiver in order to correct and/or verify the look up table for the signal processing procedure. The look up table converts the A-D code units from the receiver into Received Power values expressed in dB.

In the modernized version of the MRL-5, the same master clock generates range gates as well as transmitter triggers. In this way, synchronization is very easy to check. Distances measured by our radar agree within the expected accuracy with those given by geodesic coordinates.

4. CONCLUSIONS

A group of simple, yet effective, checks were performed on the Camagüey Radar Station. They showed that the radar is working reasonably well. These procedures are now being introduced into operational practice to the whole Cuban Weather Radar Network.

Taking into account that the MRL-5 radar at Camagüey is also dedicated to research purposes, the co-linearity of both beams was measured and corrected. Nevertheless, this subject deserves further research.

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