ROTATED FEED HORNS IN A COMPACT RANGE FOR RCS MEASUREMENTS

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Introduction

A way has been found to utilize the reflector return in a compact range as a source of continuous drift compensation. This is performed by translating receive polarizations 45 degrees with respect to the transmit polarizations to ensure returns in co- and cross-polarizations. An added benefit is the simplicity of alignment for the polarization calibration standard.

Reference Source

When performing any type of measurement, an increase in accuracy can be obtained if a continuous ratioing of data can be performed. If data can be measured for an unknown quantity and compared against a known quantity, accuracy and repeatability can be enhanced. In the performance of RCS measurements, usually a calibration measurement is performed at the start of a series of measurements. Because of this, the accuracy of the later measurements are dependent on the stability of the measurement system. If a continuous reference target level can be found that is present at both calibration and target measurement times, a ratio of measurements from these two times would cancel system amplitude and phase drift. For this measurement and calibration to be realizable, four measurements must be made and a theoretical model for the calibration target must exist. For a dual range gate system this equates to two measurements of target pairs. The calibrated RCS for a target can be determined by the equation in Figure 1.

Several methods were investigated. At first it was thought that a dihedral, located farther in range and to the side of the target, if positioned in a small absorber lined tunnel would satisfy the requirement. This was not pursued because there was concern that the target would still interact with the dihedral, due to diffraction off the edges of the tunnel, and would contaminate the reference. For this reason the dihedral was abandoned. The next course of action was to see if there were other sources of reflection already present on the range that could be used as a reference. This reflector was a prime focus reflector with no offset, so it was thought the energy coming off of the reflector on the way to the target could be used. Since the system was a pulsed system, range gating could be applied to separate the target reflection from the reflector reflection.

The reflector level equivalent in dBsm can be calculated by comparing it to a known target level. For the reflector level, the ratio of power received to power transmitted can be represented in Figure 2.

Figure 1.

$$\sqrt{\text{TargetSigma}} = (\text{target/Ref@Target})\ (\text{Ref@Cal/Cal}) \times \sqrt{\text{CalSigma[theory]}}$$

where:

TargetSigma	= Calibrated RCS of Target
target	= Receiver Voltage for Target
Ref@Target	= Reflector Voltage during Target Measurement
Ref@Cal	= Reflector Voltage during Cal Measurement
Cal	= Receiver Voltage for Calibration
CalSigma[theory]	= Mathematical Model for Cal theoretical

Figure 2.

$$\frac{P_R}{P_T} = \frac{A_{eff}\, G}{4\pi R^2} = \left(\frac{G \text{ Lambda}}{4\pi R}\right)^2$$

where:

G = gain of the reflector feed
Aeff = the effective area of the feed
R = the focal length of the reflector in meters
Sigma = the cross-section in square meters
Lambda = the wavelength in meters

The target level ratio of received power to transmitted power can also be represented in a similar vein:

$$\frac{P_R}{P_T} = \frac{G^2 \text{ Lambda}^2 \text{ Sigma}}{(4\pi)^3 R^4}$$

If the target sigma is set at 1 square meter, the ratio becomes:

$$\frac{P_R}{P_T} = \frac{G^2 \text{ Lambda}^2}{(4\pi)^3 R^4}$$

Ratioing the reflector level to the 1 square meter target level, we obtain:

$$\frac{\left[\frac{P_R}{P_T}\right]_{Ref}}{\left[\frac{P_R}{P_T}\right]_{Targ}} = \frac{\left(\frac{G \text{ Lambda}}{4\pi R}\right)^2}{\frac{(G \text{ Lambda})^2}{(4\pi)^3 R^4}} = 4\pi R^2$$

So the final dBsm level of the reflector is only a function of the reflector focal length. For a 12 foot focal length, the equivalent dBsm is 22 dBsm. In a more practical view, the reflector is only a half reflector so that the main energy from the vertex area is slightly reduced. Measurements of this level for the prime focus reflector, show it to be +18 dBsm. This is easily within the dynamic range of the system.

Reference Polarization

While the reflector reflection meets all the requirements for range location and signal level, it is only useful for maintaining a reference in co-polarized channels. If vertical polarization is transmitted, the reflector will return a significant level only as a vertical component. There is no strong signal return in a horizontal component for vertical transmission. This problem can be overcome by making use of the property that any orthogonal set of polarizations can provide full polarization data. If the transmit polarizations are vertical/horizontal and the receive polarizations are -45 degrees/+45 degrees relative to vertical, there will always be a return from the reflector in both receive channels for either transmit polarization. The ratioing against the reflector is performed first and then the polarizations are combined to yield vertical or horizontal on receive. For the ratioing the process is shown in Figure 3.

The ratioing of reflector terms taken at the time of the cal measurement and then at the time of the target measurement will cancel out system drift. For the two range gate system, both target and reflector or Cal and reflector are measured off of the same transmit pulse so that drift is accounted for on a pulse by pulse basis. If we combine the previous receive terms we obtain the following: (See Figure 4.)

Based on a coherent summation of pairs of orthogonal polarizations, the desired vertical and horizontal components can be obtained. In summary, we have a system that can compensate for drift on a pulse to pulse basis using the reflector reflection as a reference level.

Effect on Calibration

There is one additional benefit of using this mode of polarization combining. Most systems using a simple means of polarization calibration, rely on the alignment of a 45 degree rod or 22.5 degree dihedral to give equal returns in both vertical and horizontal receive channels. This means that every time a polarization calibration is to be performed, the calibration target angle must be aligned. This can be time consuming. For this system, since the receive ports are tilted 45 degrees with respect to vertical, there will be equal returns in both ports for a sphere calibrator. This level can be related to the theoretical value for the sphere by the following:

$$\text{SigmaSphere}[v/-45] = \text{SigmaSphere}[vv]/\sqrt{2}$$

The same type of relationship holds for the other combinations. The important point to be made is the sphere is insensitive to alignment problems. The only alignment to be done is when the antennas are first aligned to each other.

In summary a system has been designed for full polarization matrix drift compensation and for ease of polarization calibration.

Figure 3.

$$R[v/-45] = \frac{Targ[v/-45]}{Ref[v/-45@Targ]} \; \frac{Ref[v/-45@Cal]}{Cal[v/-45]} \; \sqrt{SigmaTheory[v/-45]}$$

$$R[v/+45] = \frac{Targ[v/+45]}{Ref[v/+45@Targ]} \; \frac{Ref[v/+45@Cal]}{Cal[v/+45]} \; \sqrt{SigmaTheory[v/+45]}$$

$$R[h/-45] = \frac{Targ[h/-45]}{Ref[h/-45@Targ]} \; \frac{Ref[h/-45@Cal]}{Cal[h/-45]} \; \sqrt{SigmaTheory[h/-45]}$$

$$R[h/+45] = \frac{Targ[h/+45]}{Ref[h/+45@Targ]} \; \frac{Ref[h/+45@Cal]}{Cal[h/+45]} \; \sqrt{SigmaTheory[h/+45]}$$

Figure 4.

$$R[vv] = (R[v/+45] + R[v/-45]) \times \frac{1}{\sqrt{2}}$$

$$R[vh] = (R[v/+45] - R[v/-45]) \times \frac{1}{\sqrt{2}}$$

$$R[hh] = (R[h/+45] - R[h/-45]) \times \frac{1}{\sqrt{2}}$$

$$R[hv] = (R[h/+45] + R[h/-45]) \times \frac{1}{\sqrt{2}}$$