A BROADBAND POLARIZATION SELECTABLE FEED FOR COMPACT RANGE APPLICATIONS

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Abstract

Many aircraft radome structures are designed to operate simultaneously over multiple RF bands and incident polarizations. Critical parameters must be measured over the electrical apertures of the radome and across each operating band. Automated measurement techniques are required to efficiently collect the large volume of test data required. A modular broadband feed assembly has been developed to allow the simultaneous collection of multi-band, multi-polarization data on a compact range without the need to mechanically change feeds. The feed assembly utilizes a sinuous antenna as the radiating element and is capable of operation from 2-18 GHz with electronically selectable polarization states.

Feed design criteria as they relate to compact range antenna and radome measurements are discussed. Of primary importance are reflector illumination pattern, linear polarization cross-polarization level, and circular polarization axial ratio. Polarization switching requirements for a specific test application are defined and the physical implementation of the integrated feed assembly is described. Measured feed and quiet zone performance data is presented for this application. The polarization switching configuration can be readily modified to support other applications.

Keywords: Compact Range Feed, Radome Measurements, Sinuous Antenna.

1. Introduction

Many radome measurements require the acquisition of amplitude/phase data over wide or multiple frequency ranges and differing polarizations. The volume of data required to fully evaluate a test article is sufficiently large that high levels of measurement system automation are required to minimize test times and maximize test facility usage. Broadband or multi-band compact range feeds with electronic polarization selection are required for these applications.

Designing a broadband antenna compact range feed requires a careful trade-off of feed beamwidth, cross-polarization level, and phase center stability. Further, if polarization of the antenna is to be automatically selectable, the radiating element must be embedded in a switching network, which will also affect feed performance. The impact of these compromises on range performance must be considered in the selection of the type of broadband radiating element to be used.

Radome testing in general involves determining how the radome degrades specified characteristics of the electromagnetic field from free space levels. Most tests are comparative in nature: measurements are taken with and without the radome in place, and the results are compared to determine the level of degradation. Moderate quiet zone polarization purity is generally sufficient to obtain high quality comparison measurements, thus allowing polarization to be somewhat compromised in favor of frequency range. Directivity of the feed must be selected to properly illuminate the compact range reflector.

A broadband feed assembly was developed to illuminate an MI Technologies 5708 reflector. This reflector will produce a 12'W x 8'H x 12'L Quiet Zone if illuminated properly, and is capable of testing large radome structures. Primary feed design characteristics are:

Frequency Range:	2-18 GHz
Gain:	2 dBi min
HPBW:	60 deg nom
Linear Cross-Polarization Ratio:	-25 dB min
Circular Axial Ratio:	±1 dB nom
Polarization States:	H, V, RHC, LHC

2. Radiating Element

Antennas capable of broadband operation include log periodics, ridged horns, spirals and sinuous structures. Spirals exhibit moderate levels of beam squint and are limited to circular operation in the microwave range and were not considered for this application. Primary characteristics of the other structures are compared in Table 1.

	Antenna Type		
	Ridged Horn	Log Periodic	Sinuous
freq range	2-18 GHz	1-18 GHz	2-18 GHz
dual pol	yes	yes	yes
gain range	5- 15 dBi	2 - 6 dBi	5 dBi
beamwidth	25-100 deg	70-130 deg	65-95 deg
cross-pol	-20/25 dB	-15/20 dB	-20/25 dB
axial ratio	N/A	N/A	±1 dB
backlobes	-25 dB	-15/20 dB	-25 dB

Table 1. Broadband Feed Antenna Characteristics

The profile of the MI 5708 reflector (Ref 1) is shown in Figure 1 with the Quiet Zone extent and feed pattern angles superimposed. The feed 0.25 dB beamwidth must be approximately 50 degrees in the horizontal plane and 30 degrees in the vertical plane to optimally illuminate the reflector. Sidelobes and backlobes should be as low as possible to avoid illuminating other chamber surfaces.

Ridged horns can be designed to provide optimum illumination of the reflector over a narrow band of frequencies (Ref 2). Beamwidth varies widely with frequency however, usually resulting in over-illumination of the reflector at low frequencies in multi-octave applications. Further, the axial location of the phase center of the radiation pattern can vary with frequency, resulting in slight defocusing of the Quiet Zone field.

Log Periodic antennas (Ref 3) have reasonably constant beamwidth (30%) over multi-octave bands, but beamwidth may vary 50 – 75% between the E and H planes. Pyramidal designs have equal beamwidth in both E and H planes, but are single polarized. And, like ridged horns, the phase center location varies somewhat with frequency. In addition, log periodics have higher backlobe energy than the other types considered for this application.

The Sinuous antenna (Ref 4) exhibits reasonably constant beamwidth over multi-octave bands (30%), equal beamwidth in both the E and H planes, a stable phase center and low beam squint. It does have one potential drawback: the polarization tilt angle varies with frequency. This polarization WOW is on the order of ± 5 deg.

3. Polarization Considerations

Airborne radar and avionics systems make wide use of circular as well as linear polarization, and some systems switch between the two in different modes of operation. The ability to electronically switch between polarizations during a radome measurement sequence is mandatory for automated measurement systems.

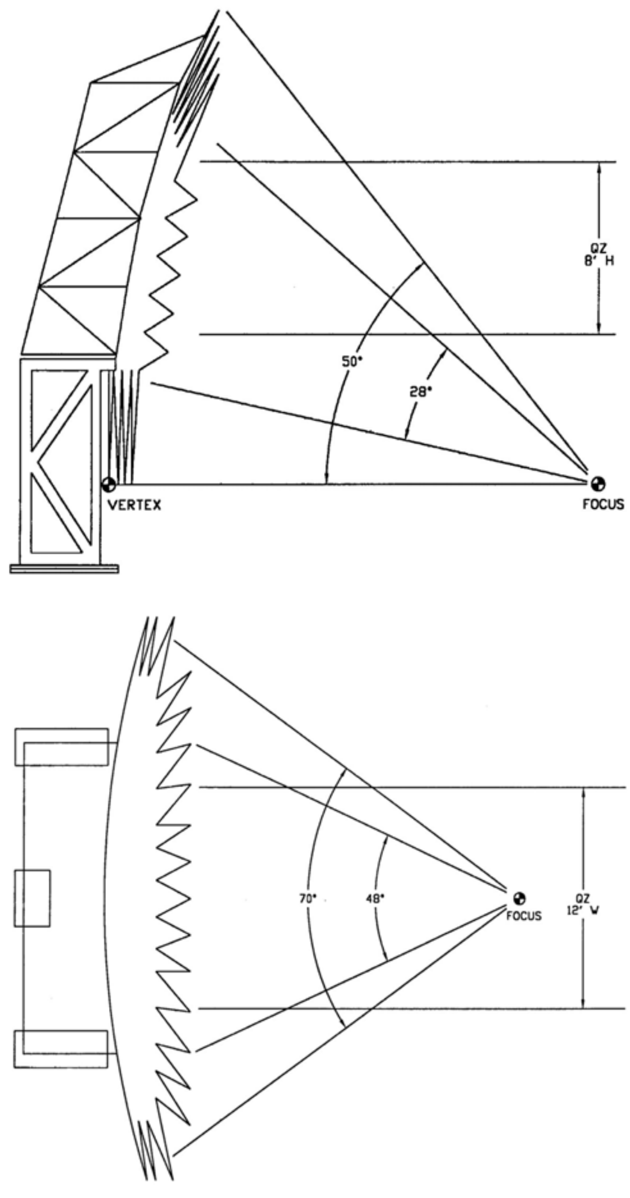

Figure 1. MI 5708 Feed Pattern Angles

Circular polarization can be generated from a dual linear polarized antenna by feeding both ports from a quadrature hybrid. Electronic polarization selection can then be accomplished by integrating these components in an appropriate switching network. The polarization purity of the circular polarized energy is dependent on the inherent linear polarization purity of the antenna and the phase/amplitude balance of the hybrid and transmission lines connecting to the antenna ports. A perfect dual polarized linear radiator (equal transmit amplitudes in spatial quadrature and no cross polarization) will produce an 0.75 dB axial ratio if the input ports are driven 5 degrees out of time phase quadrature. If cross-polarization decreases to –25 dB, axial ratio can degrade to 1.25 dB

Achievable polarization purity is ultimately dependent on the quality of the hybrid used to drive the feed antenna. In general, broader band hybrids have poorer phase/amplitude balance and isolation than narrow band devices. Still, broadband devices are available with amplitude balance of 0.5 dB and phase balance of better than ±5 deg. If the connecting transmission lines are balanced in amplitude to within 0.1 dB and phase to within 5 deg, overall axial ratios of 2 dB are achievable.

Spatial stability of the polarization vector must also be considered in the feed design. If tilt angle variations are significant to the measurement being made, then the variation may need to be characterized and data correction applied to raw measured data.

4. Integrated Feed Assembly

A prototype compact range feed was designed and fabricated for use in testing the multi-band radome used on the Combat Talon II MC-130H aircraft. This radome is tested with a highly automated measurement system requiring minimal operator intervention. The test sequence requires high speed electronic switching between X and Ku-band frequencies, H and V polarizations or RCP and LCP polarizations. A block diagram of the feed subsystem switching network is shown in Figure 2. The system uses electromechanical switches to select linear or circular polarization and a high speed Agilent Technologies 4-port PIN switch to select H-V or R-L. The switches were selected to provide a direct interface to an Agilent 8530 based data acquisition system controlled by Orbit/FR 959 acquistion software.

The radiating element used in this feed is a 2.4 inch dual linear Sinuous antenna. Feed performance was optimized for X- and Ku-band operation, but the feed is capable of operation from 2-18 GHz. Simulation of the required radome measurements showed that small variations in polarization tilt angle would not significantly degrade the accuracy of the reduced data.

The feed assembly was configured as a compact package designed to mount on a standard MI Technologies feed positioner and place the phase center of the Sinuous antenna at the focal point of the MI 5708 reflector. A photograph of the integrated feed assembly is shown in Figure 3.

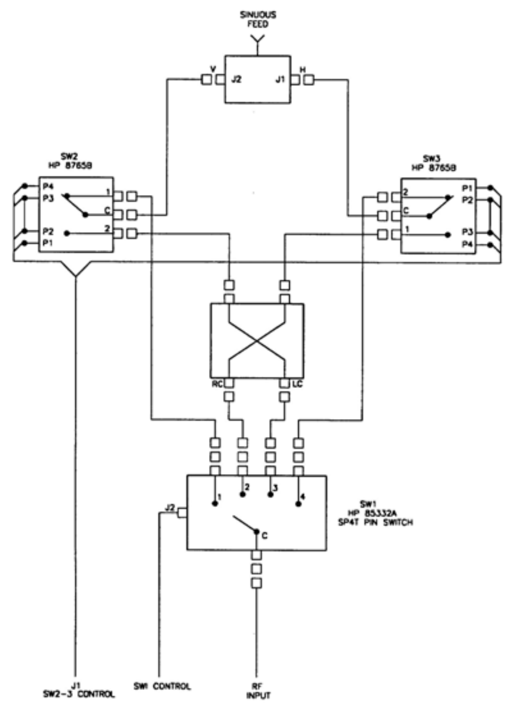

Figure 2. Broadband Feed Block Diagram

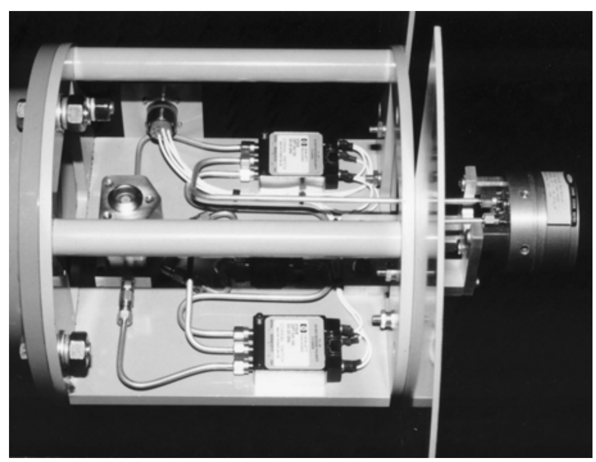

Figure 3. Broadband Feed on Feed Positioner

The prototype feed assembly was designed to support a specific test application. However, the construction of the feed was designed to allow easy configuration of different switching arrangements and the addition of phase and amplitude trimming networks to further optimize circular polarization characteristics over specific frequency ranges.

5. Measured Performance

The primary characteristics of the prototype feed were measured prior to installation in the compact range to quantify feed performance. Figure 4 shows typical linear polarization principal plane radiation patterns at X- and Ku-Band. 3 dB beamwidth is 70 - 80 deg. Figure 5 shows measured axial ratio for the feed at X- and Ku-Band. Axial ratio is 1 – 1.5 dB at 9.36 GHz and 2 – 4 dB at 16.5 GHz.

The Quiet Zone performance of the MI 5708 reflector using the prototype feed was evaluated. The reflector was installed in a 40'W x 30'H x 75'L chamber; the chamber surfaces were covered with 12" pyramidal absorber. Figure 6 shows horizontal and vertical field probe traces at X-band. Figure 7 shows performance at Ku-band. Quiet Zone ripple was typically 0.2 dB at X-band and 0.5 dB at Ku-band. Taper was less than 1.0 dB. Phase variation was less than 10 degrees.

Combat Talon II Radome performance measurements made with conventional single band compact range feeds have been compared with measurements using the broadband feed assembly and found to overlay very closely. The broadband feed assembly is presently being used to evaluate these radomes.

6. Conclusions

A broadband compact range feed has been designed for operation with an MI Technologies 5708 compact range reflector. The feed was designed to support automated high speed polarization selection (H,V,RCP,LCP) and uses a Sinuous antenna as the radiating element. A prototype feed with a switching network configured specifically for testing Combat Talon II MC-130H nose radomes was fabricated and tested. Operating frequency range of the feed is 2-18 GHz, optimized for X- and Ku-band. Typical circular polarization axial ratio is 1.5 – 4 dB.

Radome test results made using conventional single-band compact range feeds were compared to test results made using the broadband feed, and the data compares favorably.

The feed construction is modular in nature and can be easily modified to support alternative polarization switching requirements and switch drive instrumentation.

7. Acknowledgements

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8. References

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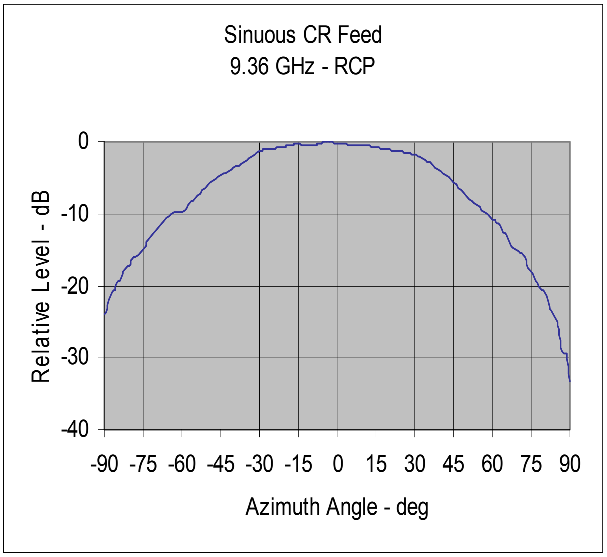
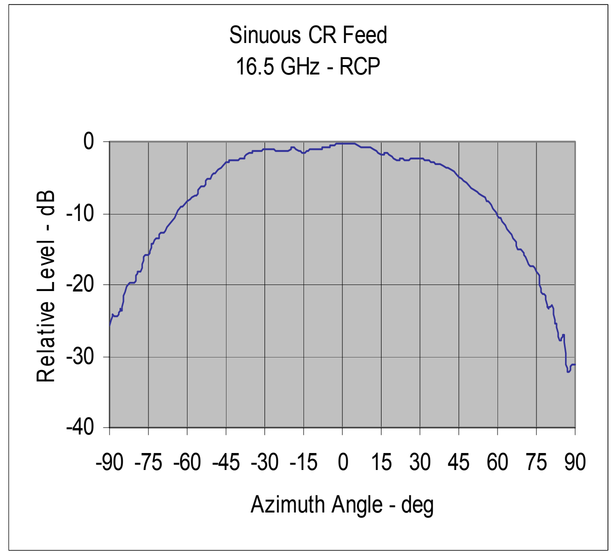
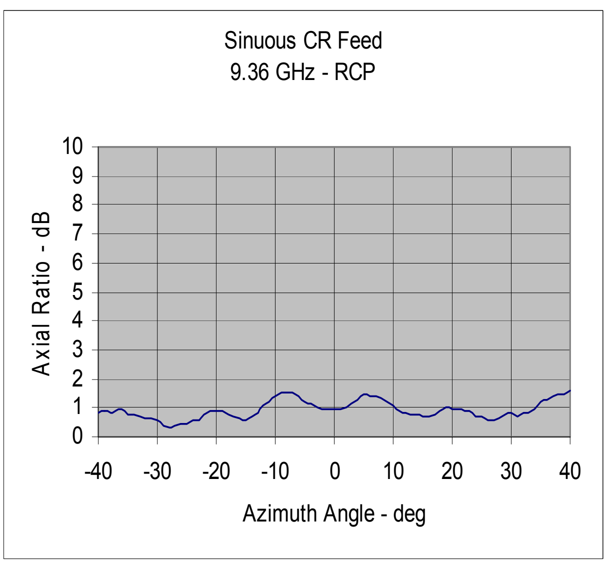


a) X-Band RCP Azimuth Pattern

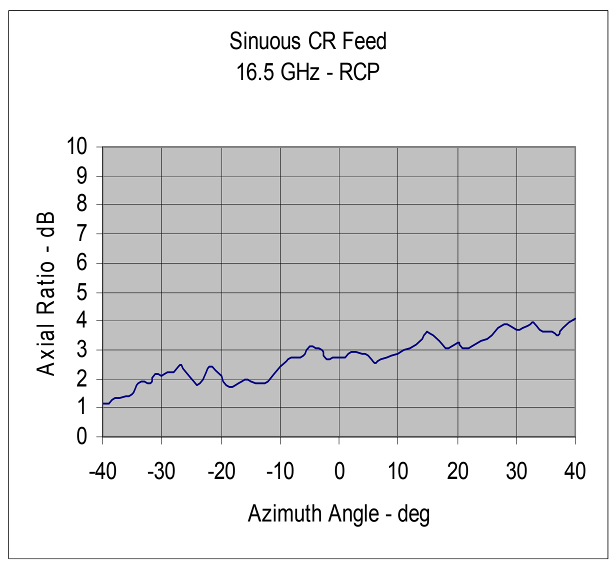


b) Ku-Band RCP Azimuth Pattern

Figure 4. Sinuous Feed Primary Patterns

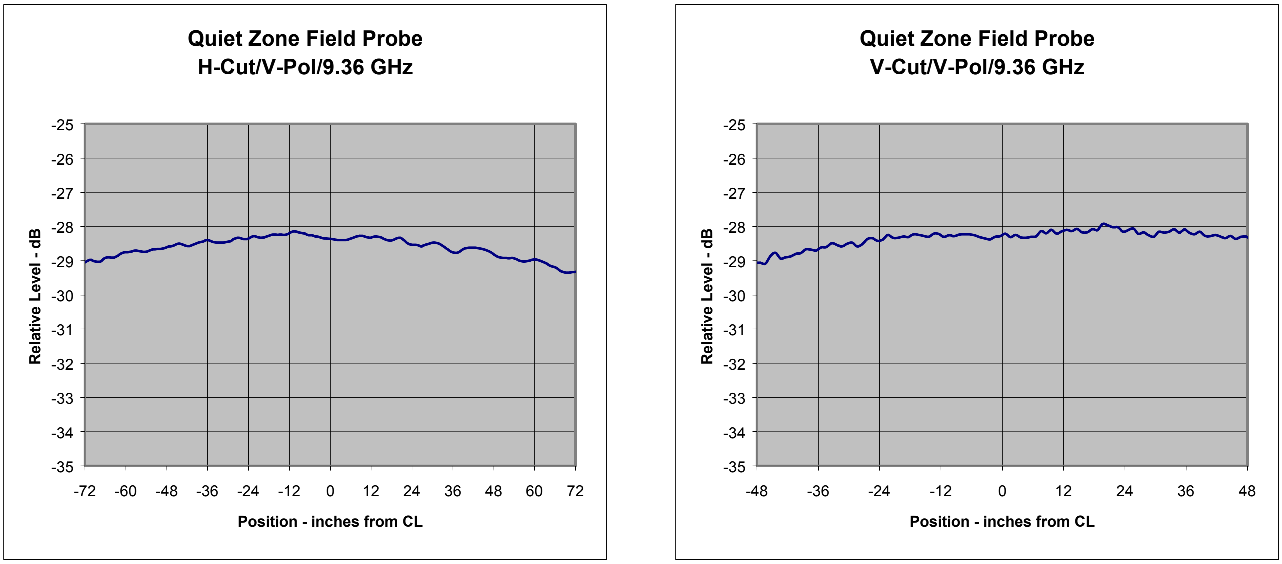


a) X-Band RCP Axial Ratio



b) Ku-Band RCP Axial Ratio

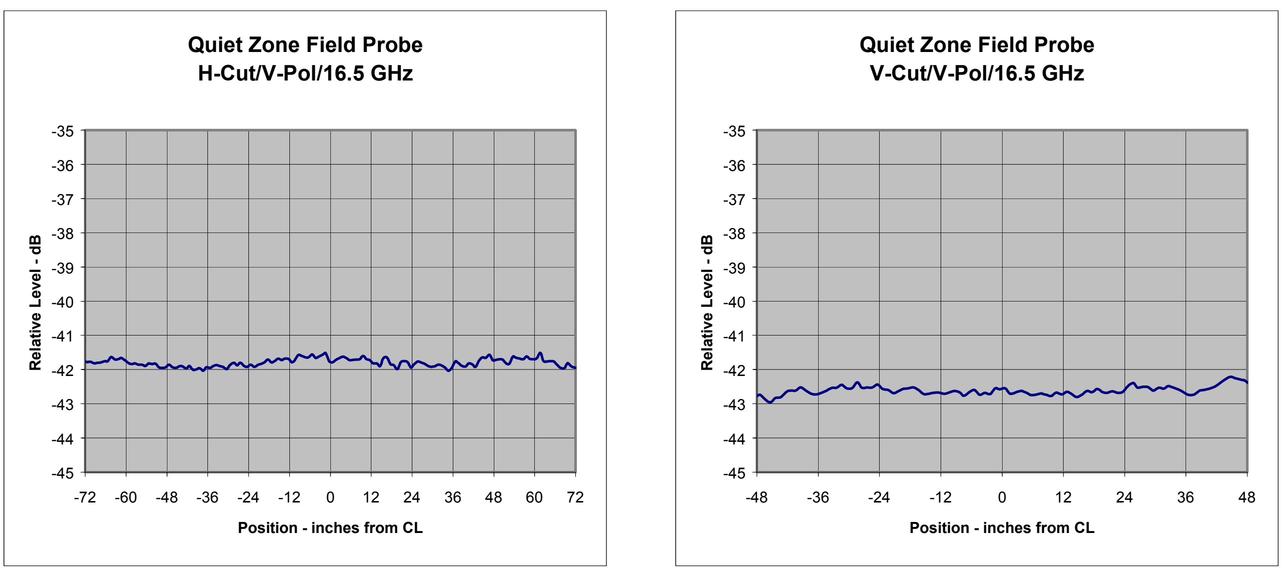
Figure 5. Sinuous Feed Axial Ratio



a) Horizontal Cut/Vertical Polarization

b) Vertical Cut/Vertical Polarization

Figure 6. X-band Field Probe Cuts – 5708/Sinuous



a) Horizontal Cut/Vertical Polarization

b) Vertical Cut/Vertical Polarization

Figure 7. Ku-band Field Probe Cuts – 5708/Sinuous