

A NEW WIDEBAND DUAL LINEAR FEED FOR PRIME FOCUS COMPACT RANGES

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ABSTRACT

Performance trade-offs are investigated between the use of clustered waveguide bandwidth feeds and the use of one multi-octave bandwidth single aperture feed in a prime focus compact range for dual linear polarization. The results show that feed structure may be used for advantage for the particular test requirements of compact range systems for Radar Cross Section Measurement.

Keywords: Compact Range, Feed Clustering, Microstrip, Polarization, Quiet Zone, Radar Cross Section, RCS, Sinuous and Spiral.

1. INTRODUCTION

The prime focus compact range has been successfully used for many years to provide antenna and RCS measurements. It is advantageous to provide as large a test zone as possible for a given reflector size and hardware investment. Johnson^[1] addressed the relationship of the diameter of the test zone to the beamwidth of the feed pattern and to the focal length of the reflector of a point-source compact range. Jones^[2] and Baggett^[3] have shown in many cases increasing the beamwidth (and therefore lowering the reflector illumination taper) will increase the quiet zone size with no further reflector or structural changes. The taper of the feed limits the quiet zone extent more than diffraction effects for all but the lowest frequencies. Typical feeds for compact range illumination offer only an octave or less bandwidth. Usual aperture type radiators have beamwidths that vary with frequency and attempts to make the radiators more broadbeamed typically results in degraded VSWR and energy storage problems (i.e.: ringing).

Several general requirements for a compact range feed are:

- Minimum amplitude taper across the reflector
- Stable beamwidth patterns
- Constant phase center
- Low cross-polarization
- Low side and back lobes
- Broadband to reduce fabrication, mounting, and operational costs. Broadband measurements are also required for high spatial resolution measurements.
- Have low resistive loss to improve dynamic range
- Small physical size to reduce mutual coupling and diffraction effects
- Absence of model resonances and energy storage

2. FEED CONFIGURATION ALTERNATIVES

There are two feed configuration alternatives for broadband operation of a point source compact range, a cluster of high performance, narrowband feeds and a single broadband feed. The cluster feed approach (Baggett and Swamer^[3]) offers advantages over single, narrowband feeds since it allows broadband frequency data collection of RCS targets, but the cluster approach

introduces some limitations in the operation of the compact range. The offset feeds shift the beam axis relative to the chamber and cause a reduction in the quiet zone. The beam shift can be easily compensated by the data extraction and processing software but the quiet zone reduction cannot be recovered. The polarization purity of the individual narrowband cluster feeds is desirable and mandatory for some measurement requirements. The broadband feed approach has not been a viable approach until recently as former broadband feeds have exhibited modal resonances and the resultant energy storage that produces ringing in pulsed RCS measurements.

Single polarized antennas with broadband and broadbeam performance are available for compact range feeds including slotline antennas^[4] for linear polarization and multi-octave spiral-mode antennas^[5] for circular polarization. Today's testing environment necessitates dual polarization performance so the maximum amount of radiation data may be obtained during a given time interval. For example, the Scientific-Atlanta Model 1795 Microwave Receiver offers the antenna test engineer the capability of multiple measurement channels with rapid frequency agility and the measurement of up to 5000 data points per second. Therefore, an antenna with the capability of providing multi-octave frequency operation, near constant beamwidths and simultaneous dual linear or dual circular polarization is desirable. Furthermore, the antenna must not contain energy storing devices within its structure that prevent RCS measurements with pulsed radar techniques.

3. SINUOUS ANTENNA

Two relatively new types of dual polarized antennas provide broad-beam patterns with minimal sidelobes and backlobes over a multi-octave frequency range. Both antennas are variations of the DuHamel^[6] sinuous antenna. The cavity-backed sinuous antenna^[7,8] contains in a single aperture two orthogonal linear polarized radiating elements that resemble the cavity-backed spiral antenna. The sinuous microstrip antenna^[9] is a planar, low profile antenna whose outer element rings terminate in an absorbing medium that eliminates end currents and does not require a cavity for proper operation.

The sinuous antenna is a planar, broadband, dual polarized structure that is functionally similar to a LPA. The sinuous design, patented in 1987 by R.H. DuHamel^[6], is used primarily to replace single polarized flat planer spiral antennas in electronic warfare applications. The detailed design of the sinuous radiating element is described by Chu^[7], and Scherer^[8]. The sinuous antenna meets most of the desired characteristics discussed above for optimum compact range operation. The antenna is available with an integrated 90 degree hybrid for dual circular polarization if desired.

The 1 dB beamwidth of a commercially available off-the-shelf cavity backed sinuous antenna nominally varies from 35 to 55 degrees over a frequency range of 2 to 18 GHz. In comparison, a typical corrugated flange feed operates over a waveguide bandwidth and has a nominal 1 dB beamwidth of 27 to 37 degrees. A comparison of 1 dB and 10 dB beamwidths for the sinuous and corrugated

flange feeds is shown in Figures 1A-2B respectively. It is advantageous to keep the beamwidth of the feed as broad as possible, consistent with the combined ripple and taper specifications. Figure 3 is a typical quiet zone field calculation for a Scientific-Atlanta Model 5706 Compact Range Reflector with a sinuous cavity backed antenna feed and a Scientific-Atlanta Model 31 corrugated flange feed. The minimum quiet zone size is advertised as six feet in width. The quiet zone in Figure 3 shows that the quiet zone width is more than ten feet in the horizontal plane at 3.0 GHz.

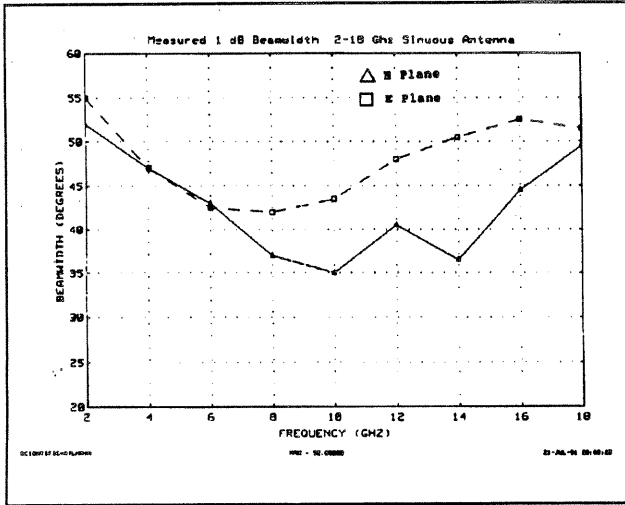


Figure 1A: Sinuous Cavity Antenna 1 dB Beamwidth

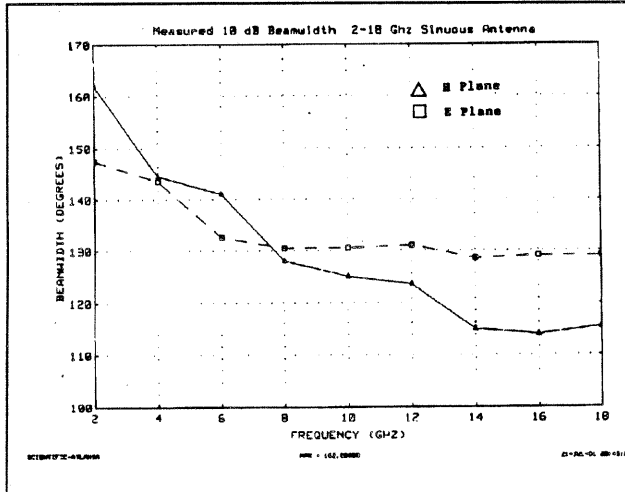


Figure 1B: Sinuous Cavity Antenna 10 dB Beamwidths

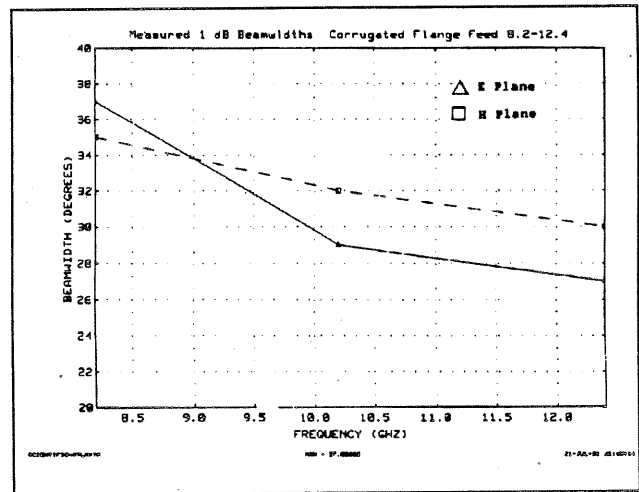


Figure 2A: Scientific-Atlanta Corrugated Flange Feed 1 dB Beamwidths

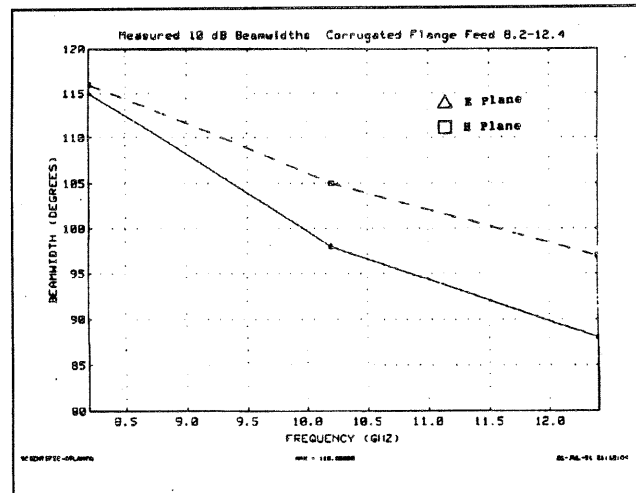


Figure 2B: Scientific-Atlanta Corrugated Flange Feed 10 dB Beamwidths

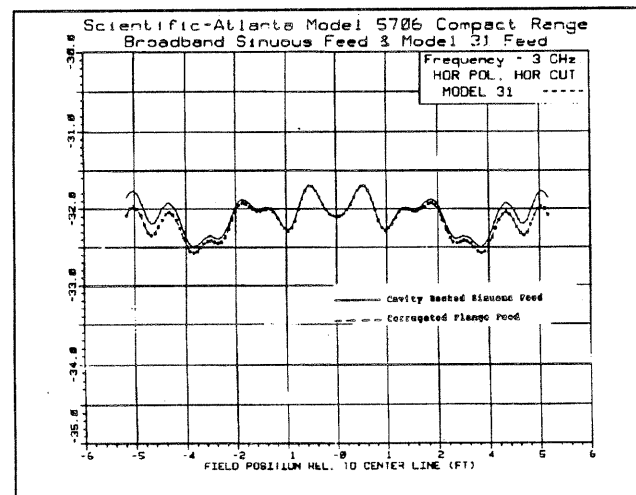


Figure 3: Scientific-Atlanta Model 5706 Quiet Zone Calculation with a Corrugated Flange Feed and a Broadband Cavity Sinuous Feed

Although the sinuous antenna is functionally similar to the LPA, it does not exhibit extreme axial phase center change with frequency that is characteristic of the LPA. Phase center measurements suggest negligible phase center change for axes transverse to boresight, and less than 1 cm change in the axis along boresight from 2-18 GHz. If multi-octave frequency operation is desired with conventional waveguide bandwidth horns, the horns must be clustered around the reflector focal point. This leads to a secondary wavefront tilt proportional to the amount of feed offset. Since the sinuous antenna has essentially a single point phase center, this problem is reduced.

The polarization performance of the sinuous antenna is affected by any anomalies in the symmetry of the structure. Anomalies can cause the tilt angle of the polarization to rotate vs frequency and/or cause a change in the ellipticity of the polarization. Chu^[7] reports that the worst case polarization ellipticity is 20 dB across the 2 to 18 GHz band for the cavity backed sinuous antenna. Preliminary measurements on the microstrip sinuous antenna suggest that the polarization approaches a 15 dB ellipticity across a five-to-one frequency band. The sinuous antenna polarization tilt angle does not remain constant with frequency. For example, the high frequency polarization characteristics are dominated by the size of the coaxial feed at the center of the structure that causes the ellipticity to change. Variations as much as ± 5 degrees over the frequency range have been reported. In comparison, the typical polarization isolation for a Scientific-Atlanta corrugated flange horn is greater than 40 dB and its tilt angle is invariant with frequency.

Recent measurements^[10] show an improvement in cross-polarization levels using a 2 inch diameter 2-18 GHz cavity backed sinuous antenna. The worst case cross-polarization level within ± 20 degrees from boresight is shown in Figure 4. It is anticipated that the relatively poor cross-polarization levels at 2 GHz will be alleviated by an upcoming 6 inch diameter design.

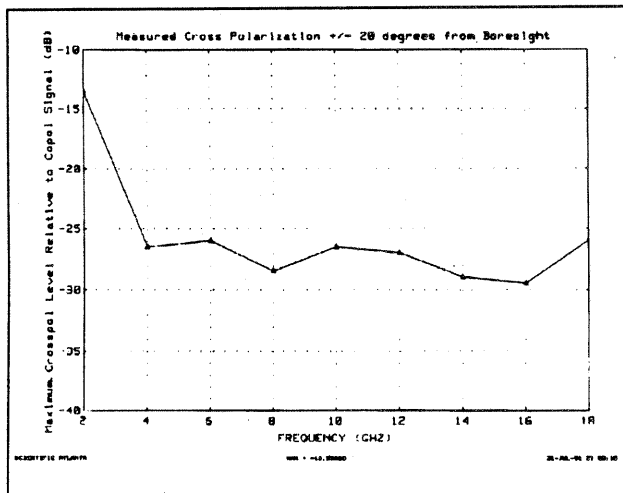


Figure 4: Measured Worst Case Cross-Polarization Levels Over a \pm Degree Angular Extent Using Cavity Backed Sinuous Antenna

Typical E- and H- plane patterns for the 2-18 GHz cavity backed sinuous antenna are shown in Figure 5A and 5B. The sidelobes and backlobe are typically down at least 25 dB from the main beam. This is primarily achieved by using of an absorber loaded cavity. The wide-angle radiation performance of this antenna is helpful in maintaining a uniform test field in the quiet zone. A typical pattern for the sinuous microstrip antenna is shown in Figure 6.

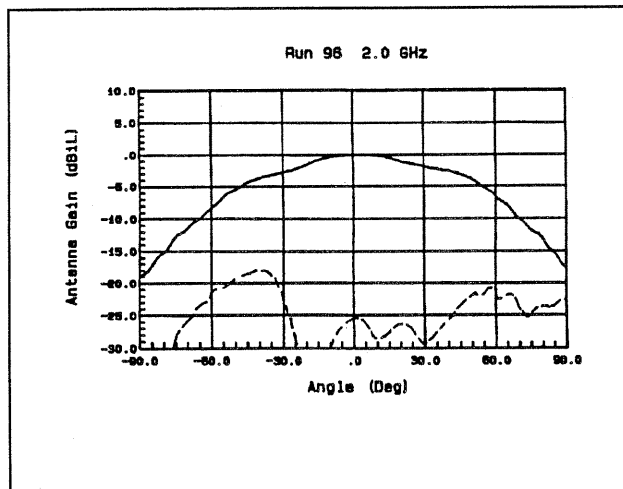


Figure 6: Microstrip Sinuous Antenna Radiation Pattern

Ringdown tests were made by Scientific-Atlanta to determine the suitability of using a sinuous antenna as a feed for RCS applications. It was determined that the ringdown response for a 35 nsec pulse exceeds 2 dB/ns for the 2-18 cavity-backed sinuous feed. Figure 7A shows a measured empty chamber response for a standard product Scientific-Atlanta feed with a measured ringdown response of better than 2 dB/ns. Figure 7B shows the same empty chamber response with the wideband cavity-backed sinuous feed. Although usual LPA structures are not noted for having a quick ringdown response, it is suggested that the absorber loading in the cavity section and attention to balun design may be responsible for the favorable ringdown performance. The VSWR of the cavity backed sinuous antenna is 3:1 maximum; it is unusual for a waveguide bandwidth dual polarized corrugated horn to exceed 2:1. The additional VSWR may cause excessive losses and transmission line ringing if the RF source/receiver is far from the antenna.

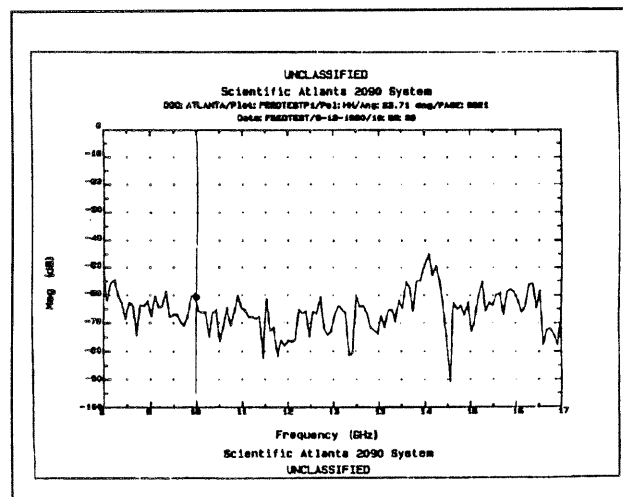


Figure 7A: Measured Empty Chamber RCS Response with a Corrugated Flange Feed

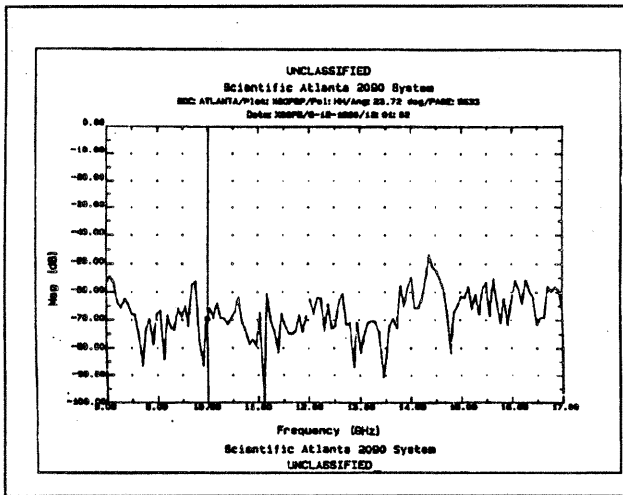


Figure 7B: Measured Empty Chamber RCS Response with 2-18 GHz Cavity Sinuous Feed

The intricate balun and feed network limits the power handling capability of the sinuous antenna. The size of the coaxial cable feeding the sinuous elements is limited by the desired high frequency radiation requirements mentioned above. The necessary small diameter cable (0.046" diameter) limits the power handling capability of the antenna to 10 watts CW. The power handling capability of a dual polarized waveguide bandwidth horn is rated at 20 watts for 18 GHz operation.

The small size of the sinuous antenna is advantageous in reducing mutual coupling effects and scattering. The 2-18 GHz cavity backed sinuous antenna has a diameter of 2.4 inches which is smaller than a 2 GHz corrugated flange feed. The blockage is considerably less than that obtained by using a clustered array of waveguide bandwidth feeds to cover the same frequency range. The 2-12 GHz microstrip sinuous antenna is approximately 3" in diameter but requires a ground plane diameter of between 6" and 15".

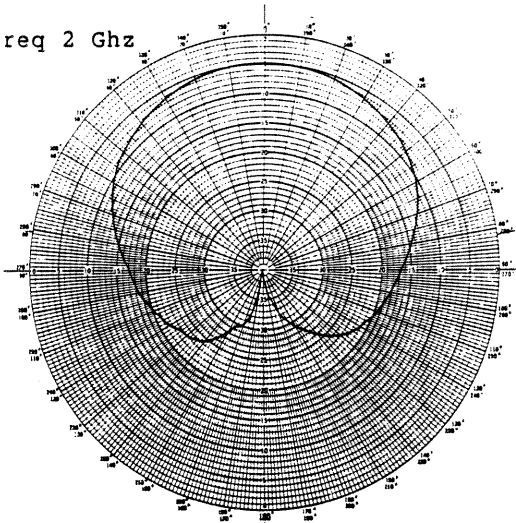
In conclusion, the cavity backed sinuous antenna and the microstrip sinuous antenna are capable of providing dual polarized, broadband, multi-octave bandwidth performance as feeds for a point source, RCS compact range without the detrimental pulse ringing characteristics of other multi-octave feeds. The polarization characteristics of the sinuous antenna may exclude its use for some compact range applications. The bandwidth performance will allow the sinuous feeds to replace from four to six waveguide bandwidth feeds with the following advantages /disadvantages compared to corrugated flange feeds.

SINUOUS ADVANTAGES	SINUOUS DISADVANTAGES
More broadband	Relatively poor cross-polarization
Small physical size	Polarization axis rotation with frequency
Reduced illumination across reflector	Resistive losses greater
Faster set-up than using individual waveguide feeds	VSWR greater
Lower cost	Lower power handling capability
No wavefront tilt caused by off axis feed phase center	Lower Gain
No switching network need as when using a feed cluster array	

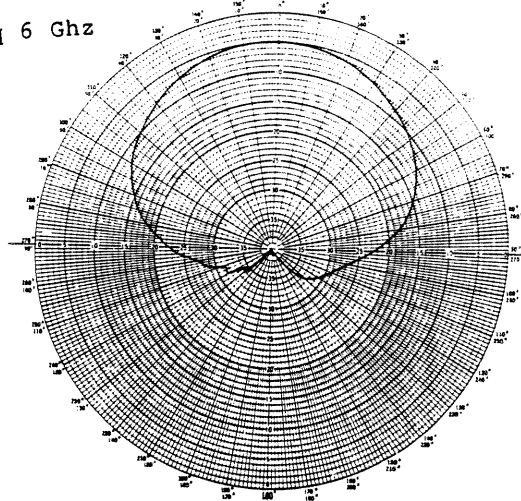
REFERENCE:

- [1] Richard C. Johnson, "Some Design Parameters for Point-Source Compact Ranges," IEEE Trans. AP, Vol. Ap-34, No. 6, pp 845-847, June 1986.
- [2] J.R. Jones, "Prime Focus Feeds for the Compact Range," AMTA Eighth Symposium, pp. 117-122, September 1986.
- [3] Marion C. Baggett and William G. Swamer, "Use of Clustered Feeds in a Compact Range for RCS Measurements," AMTA Twelfth Symposium, Philadelphia, PA., pp 2-19 to 2-22, 1990.
- [4] Albert Lai, W.D. Burnside and E.H. Newman, "Broad Band Antenna for Compact Range Use," AMTA Eleventh Symposium, pp.15-19 to 15-23, 1989.
- [5] Johnson J.H. Wang and Victor K. Tripp, "Design of Multi-octave Spiral-mode Microstrip Antennas," IEEE Trans A&P, Vol. 39, No. 3, March 1991, pp 332-335.
- [6] R.H. DuHamel, U.S. Patent #4658262, April 14, 1987.
- [7] T.T. Chu and H.G. Oltman, Jr. "The Sinuous Antenna," Microwave System News, June 1988.
- [8] J.P. Scherer, "The Dual Polarized Sinuous Antenna," Journal of Electronic Defense, August 1991.
- [9] V.K. Tripp and J.J.H. Wang, "A Sinuous Microstrip Antenna," IEEE International APS Symposium, London, Ontario, Canada, Vol. 1, pp 52-55, June, 1991.
- [10] Private Communications with J.P. Scherer, Randtron Industries.

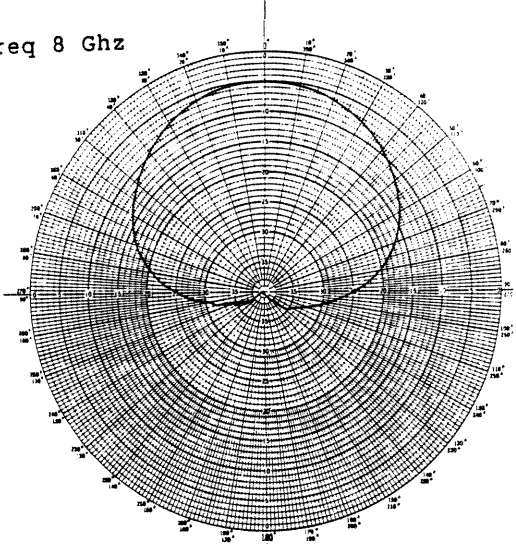
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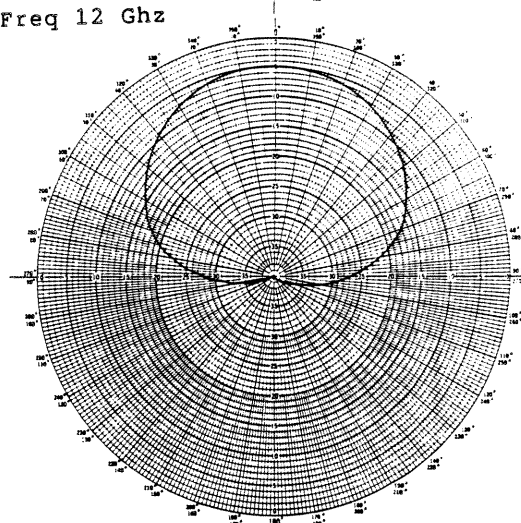
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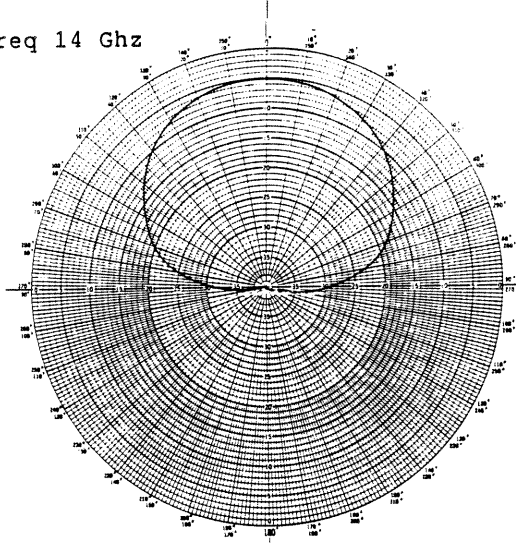
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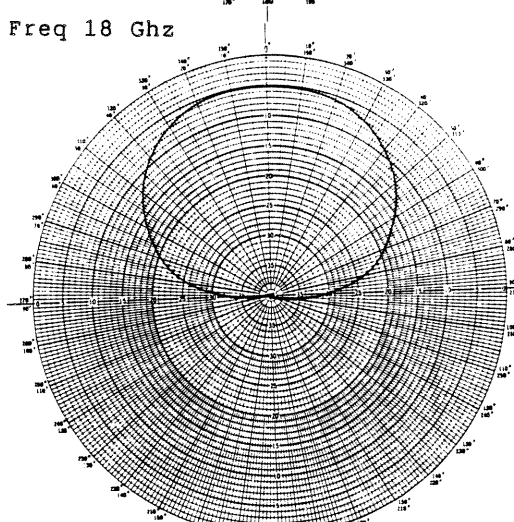
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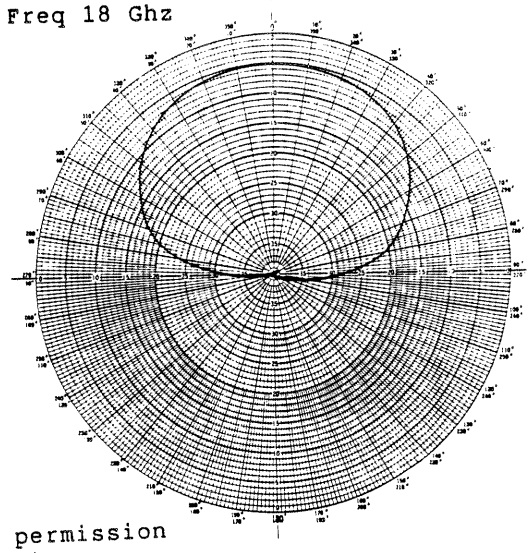
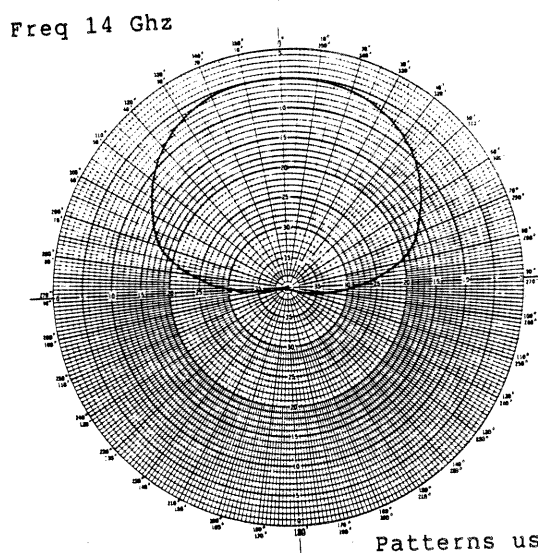
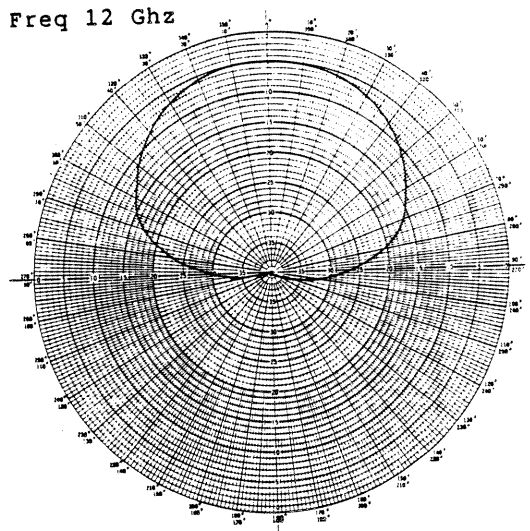
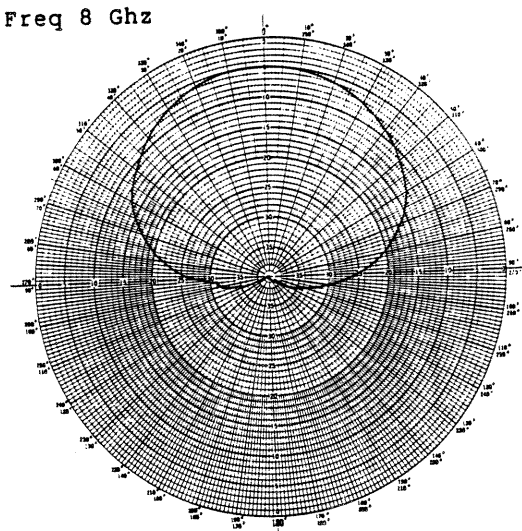
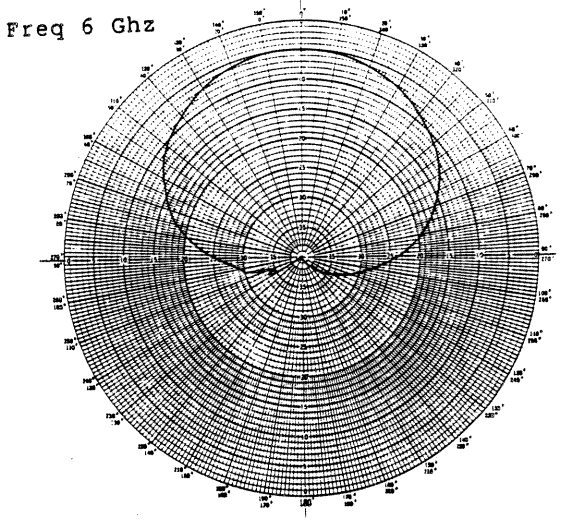
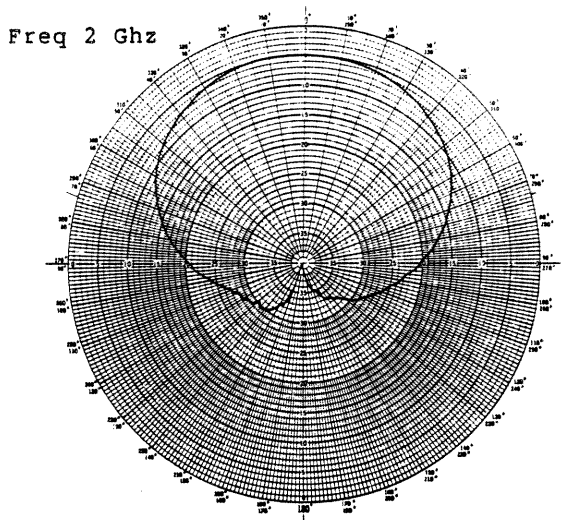


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Figure 5A: 2-18 GHz Cavity Sinuous Antenna E Plane Radiation Patterns



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Figure 5B: 2-18 GHz Cavity Sinuous Antenna H Plane Radiation Patterns