DESIGN FOR AN AMATEUR RADIO SATELLITE COMMUNICATIONS ANTENNA

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Abstract

This paper describes the design for a parabolic antenna system which can be used for communications with GEO satellites at the assigned amateur radio frequencies in S-Band and X-Band. A coaxial waveguide feed is used in this design which provides excellent performance in both bands. The concept for this type of feed is shown in Figure 1.

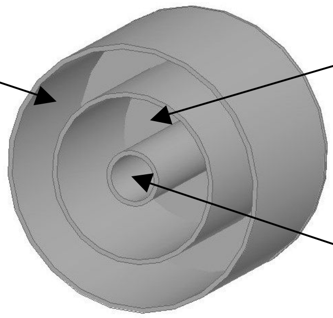


Figure 1. Coaxial feed configuration for multi-band operation

Background

Coaxial waveguide was analyzed and described in the M.I.T. Radiation Laboratory Waveguide Handbook, Vol. 10, published in 1950; however, subsequent to this publication, use of coaxial waveguide as an antenna feed has not been common. Its earliest use was in the design of a dual band (VHF/UHF) high power radar system deployed at White Sands Missile Range in 1963 shown in Figure 1.

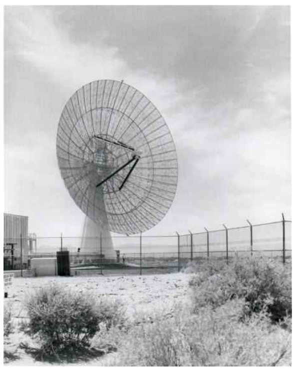


Figure 1. VHF/UHF radar system

It was recognized that this new approach was superior to the multi-band feed systems then deployed and showed that a parabolic reflector with a multi-band coaxial feed could perform the work of several reflectors using single band feeds without sacrificing performance.

A mobile tri-band SATCOM system, using a coaxial waveguide feed (Figure 2), was developed for the U.S. Army on an SBIR contract in 1999.

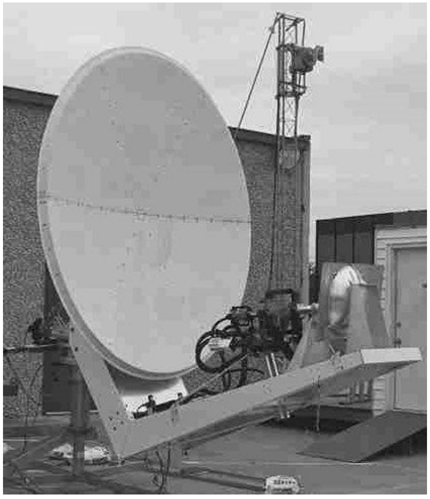


Figure 2. Tri-band SATCOM antenna

Antennas of this type were subsequently produced and deployed for both commercial and military SATCOM applications. Examples are shown below:

Large Tri-band SATCOM Ground Station

Transportable Tri-band SATCOM Antenna

Tri-band Programmed Track Antenna

Principle of Operation

To function as a prime focus feed, circular waveguide must operate in the $TE_{1,1}$ mode. The field distribution for this mode is shown in Figure 3.

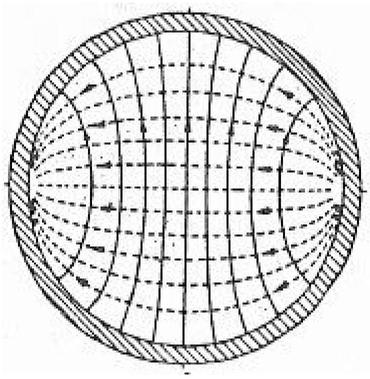


Figure 3. Electro-magnetic fields in circular waveguide for $TE_{1,1}$ Mode

$TE_{1,1}$ propagation in this waveguide is possible when the cavity diameter is $> 0.6\lambda$.
Likewise, coaxial waveguide must be operated in the $TE_{1,1}$ mode. The field distribution for this mode is shown in Figure 4.

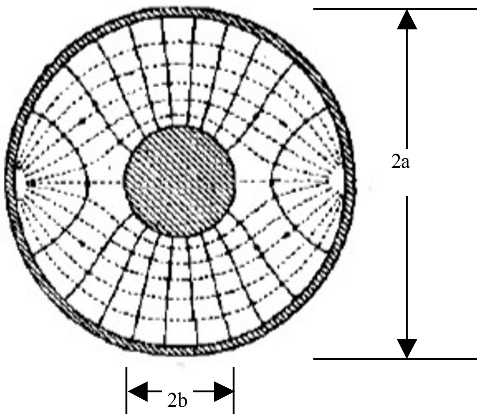


Figure 4. Electro-magnetic fields associated with $TE_{1,1}$ mode in coaxial waveguide

$TE_{1,1}$ propagation is possible when the mean circumference is greater than 1 wavelength. The cutoff wavelength is therefore given by the formula:

$$\lambda_{co} = \pi(a+b)$$

An open-ended waveguide of this type radiating into space produces an on-axis pattern as shown in Figure 5. Quadrature phased orthogonal $TE_{1,1}$ modes can be simultaneously excited in the waveguide to produce circular polarization.

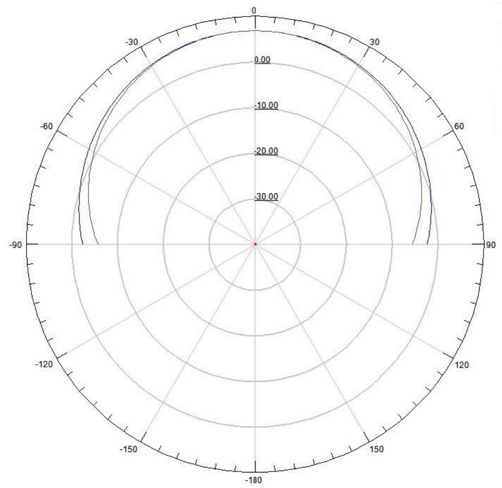


Figure 5. $TE_{1\,1}$ Pattern produced by open-ended coaxial waveguide

As seen in this figure, the pattern produced by open ended coaxial waveguide is near optimum for use in a parabolic reflector.

Antenna Design

The design shown in Figure 6 provides the desired performance while being a cost effective, conventional approach. It consists of an OEM parabolic reflector with a prime focus, dual band coaxial feed.

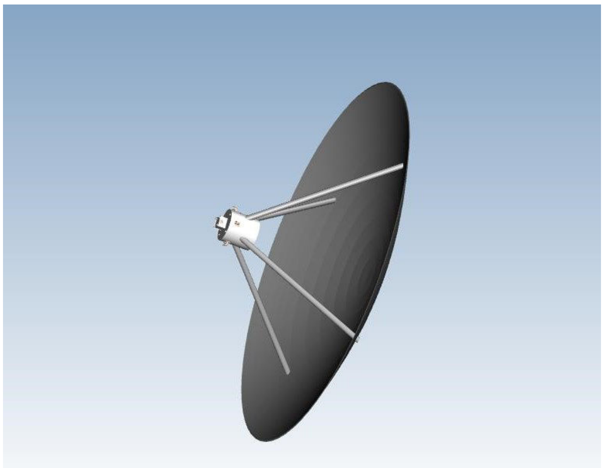


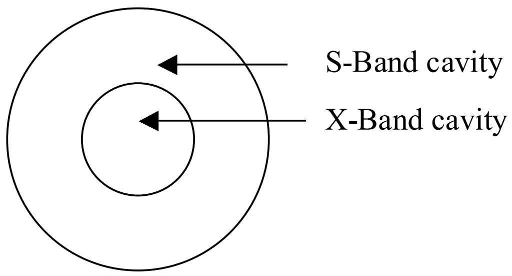
Figure 6. Antenna system for amateur band satellite communications

The feed is designed to operate over the following frequencies:

S-Band: 2404.775 MHz ± 4.725 MHz
X-Band: 10,494.275 MHz ± 4.725 MHz

Polarization shall be RHCP (from the reflector) for S-Band and dual linear polarization for X-Band.

It is implemented with two concentric coaxial waveguide cavities arranged as shown below.



The inner cavity is a conventional open ended circular waveguide covering X-Band; the outer is coaxial waveguide covering S-Band.

The outer cavity is fed with four orthogonally placed probe transitions as shown in Figure 7. The feed excitation network to produce circular polarization is shown in Figure 8.

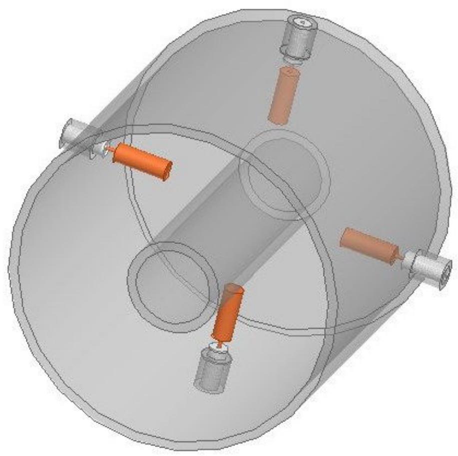


Figure 7. S-Band feed excitation

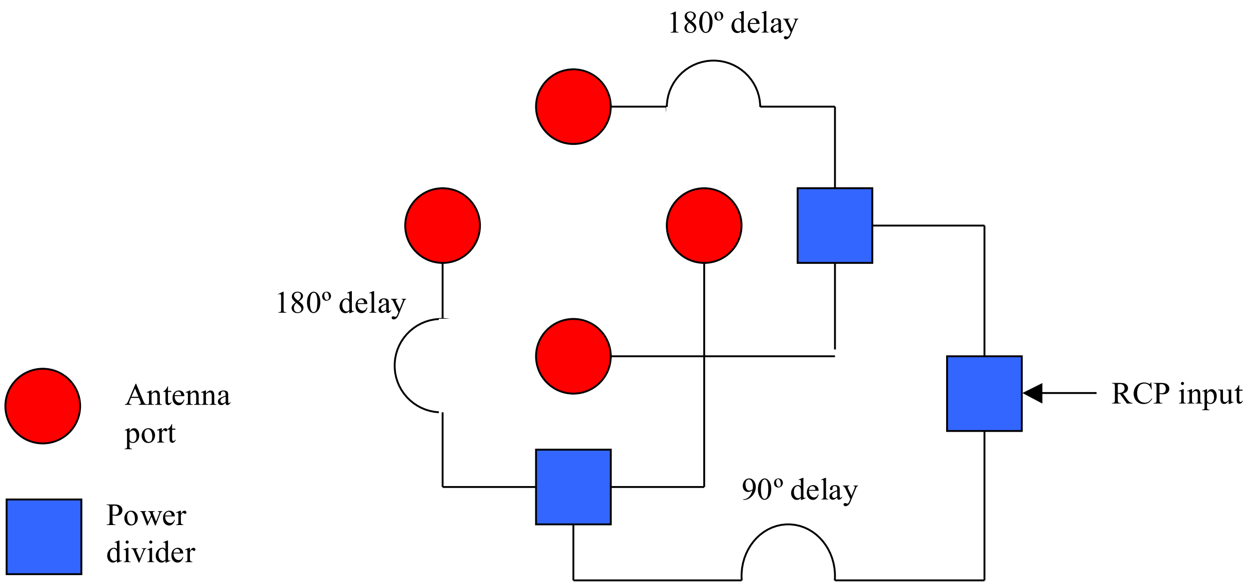


Figure 8. Network for producing circular polarization

The inner (X-Band) waveguide cavity is fed with dual probes as shown in Figure 9.

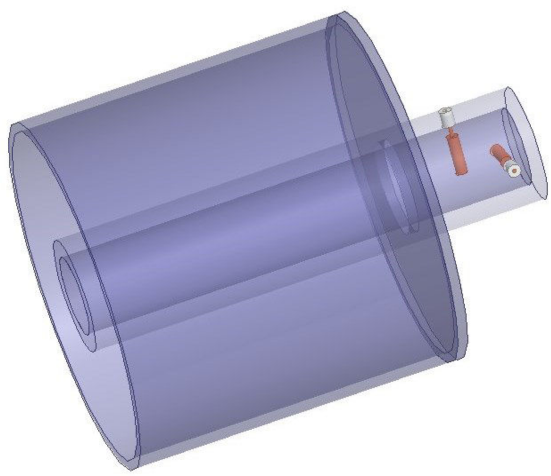


Figure 9. X-Band feed excitation

HFSS (High Frequency Structure Simulator) software was used to design and evaluate the feed shown in Figure 10.

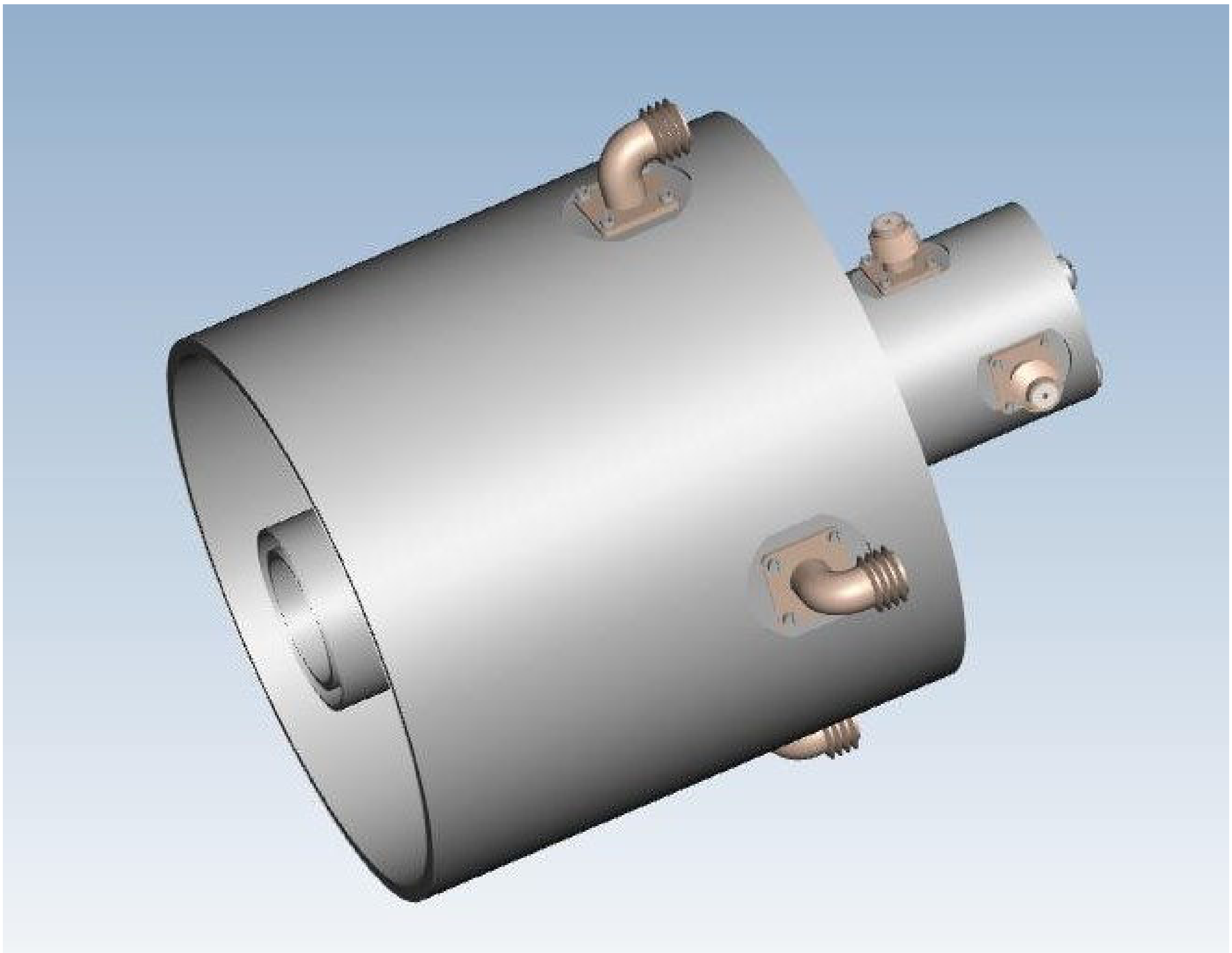
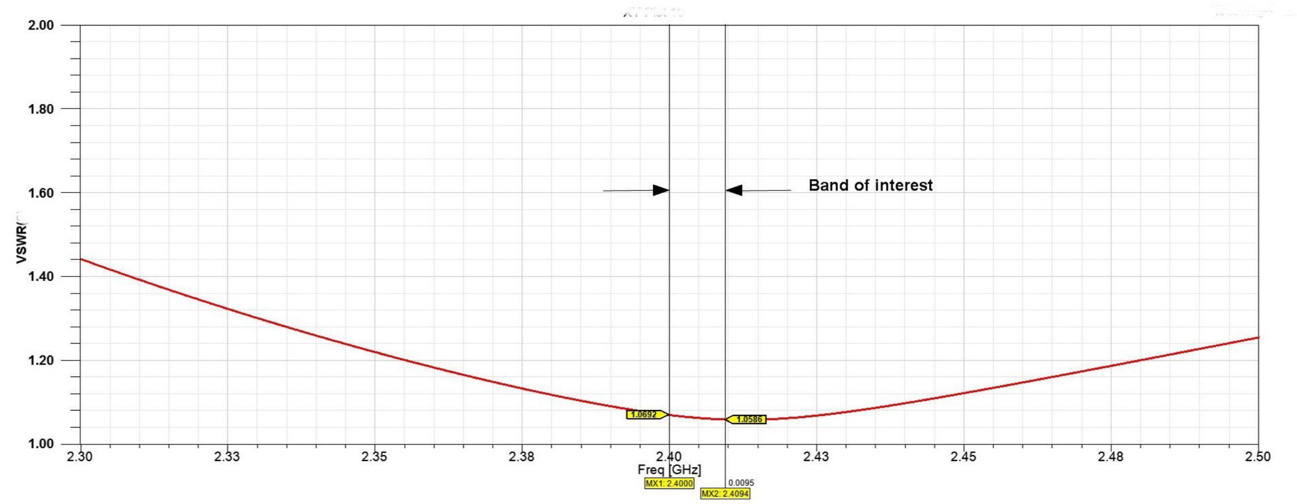
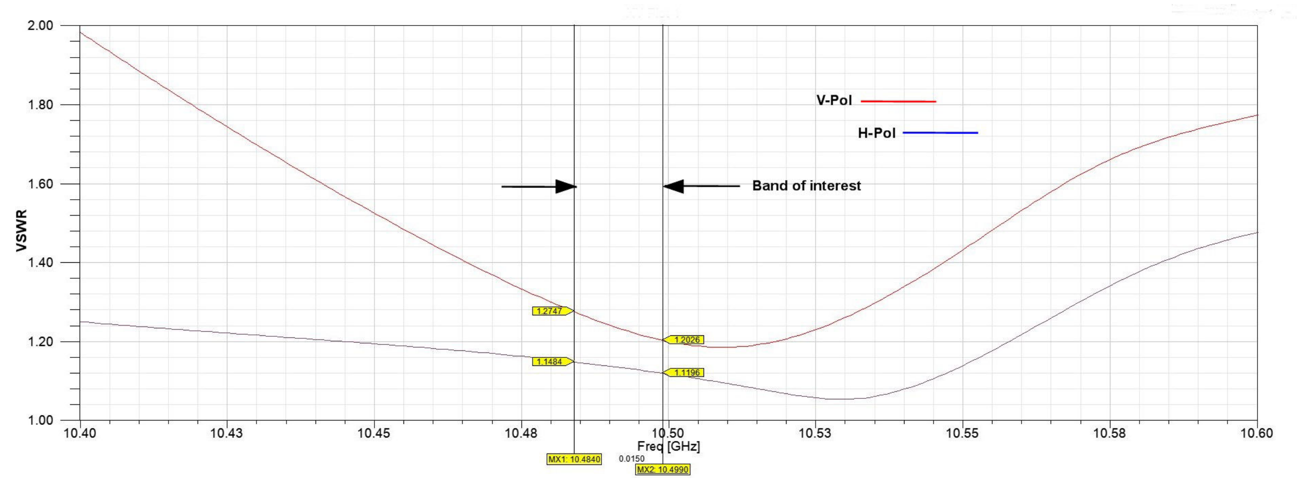


Figure 10. S/X-Band feed

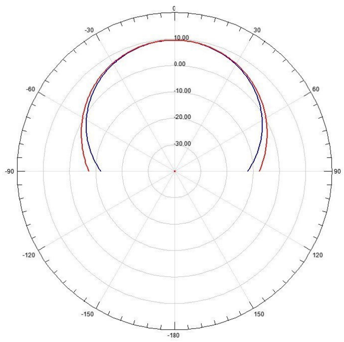
Computed Performance

VSWR

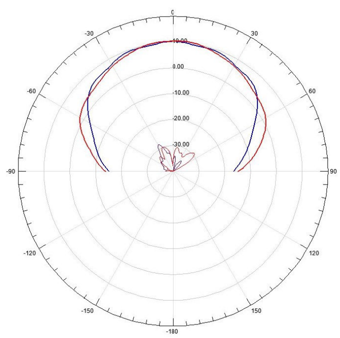




Primary Patterns

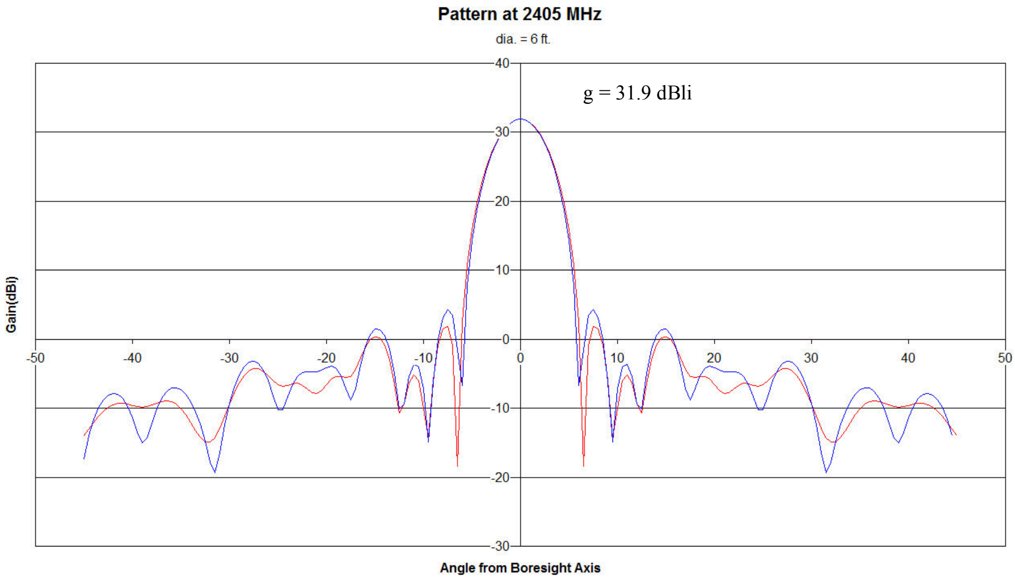


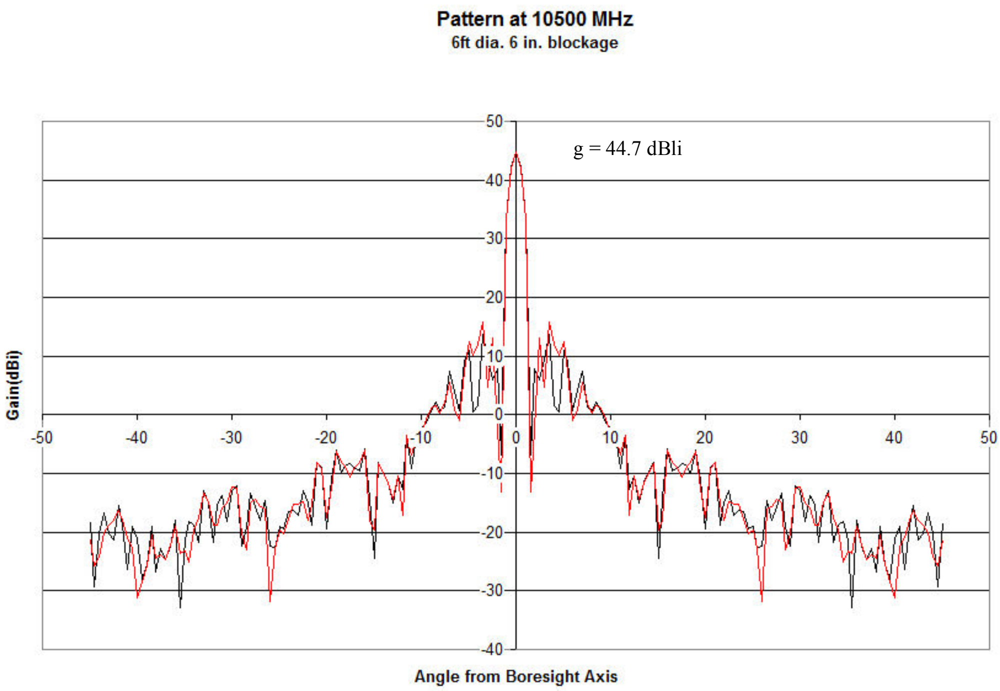
S-Band



X-Band

Secondary Patterns





The computed gain shows an illumination efficiency of 72% for S-Band and 70% for X-Band. Sidelobes are down more than 20 dB below the main beam.

Conclusion

The antenna described above meets the amateur band system requirements with near text book perfect performance. Several designs of this type have been fielded and performance predicted by HFSS simulation has been repeatedly confirmed by testing.

Additional features of the coaxial feed is that it can operate simultaneously in all bands, it can be configured to operate in any set of dual simultaneous polarizations and, importantly, it remains focused at all frequencies.