10-5.1 Dielectric Rod BOR-MoM Analysis

The BOR-MoM code CHAMP (TICRA) can analyze the dielectric rod by feeding it from a circular waveguide using mode-matching and by using the BOR-MoM portion to compute its pattern. Figure 10-5.1.1 shows the model of a 5λ long dielectric rod. Equally spaced dielectric segments along the rod (shown as rings around the rod) are mostly the same diameter with an initial taper from the waveguide and an end taper to reduce wave reflection. We need to increase the diameter of the initial portion to transition from the waveguide to the rod so that P = 1.2 to 1.3. However, the dielectric loaded waveguide provides a good transition. A reflected wave on the dielectric rod produces a second beam and increases the backlobe. The CHAMP model specifies a series of rod diameter variables so that we can use the optimization portion of CHAMP to improve performance. We increase the number of segments to improve optimization, but what is possible is limited by the total rod length. We support the rod by a single dielectric cylinder in the waveguide starting with an input taper. The model includes the taper length and support length as variables to enable optimization of return loss, Figure 10-5.1.2.

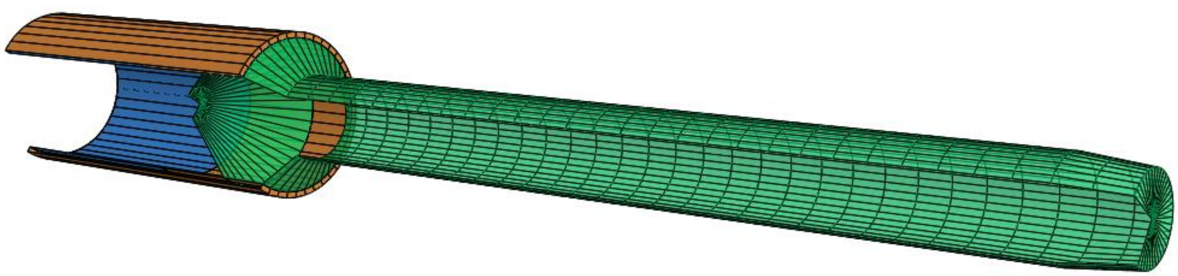

Figure 10-5.1.1 5λ Long Dielectric Rod Fed by Circular Waveguide

The mode-matching waveguide aperture ends a short axial distance from the tapered dielectric rod. This model used a distance of twice the waveguide wall thickness. The circular outer surface of the dielectric support is specified as metal. The model uses separate scatterers of the tapered dielectric rod, the waveguide wall to the end of the dielectric taper, and the exterior of the waveguide feeder where "snap-to-aperture" has been turned off. The waveguide feeder will have significant outer wall currents due currents from the sum of inner waveguide wall currents flowing down the outside and a second component due to the backward wave radiation of the dielectric rod.

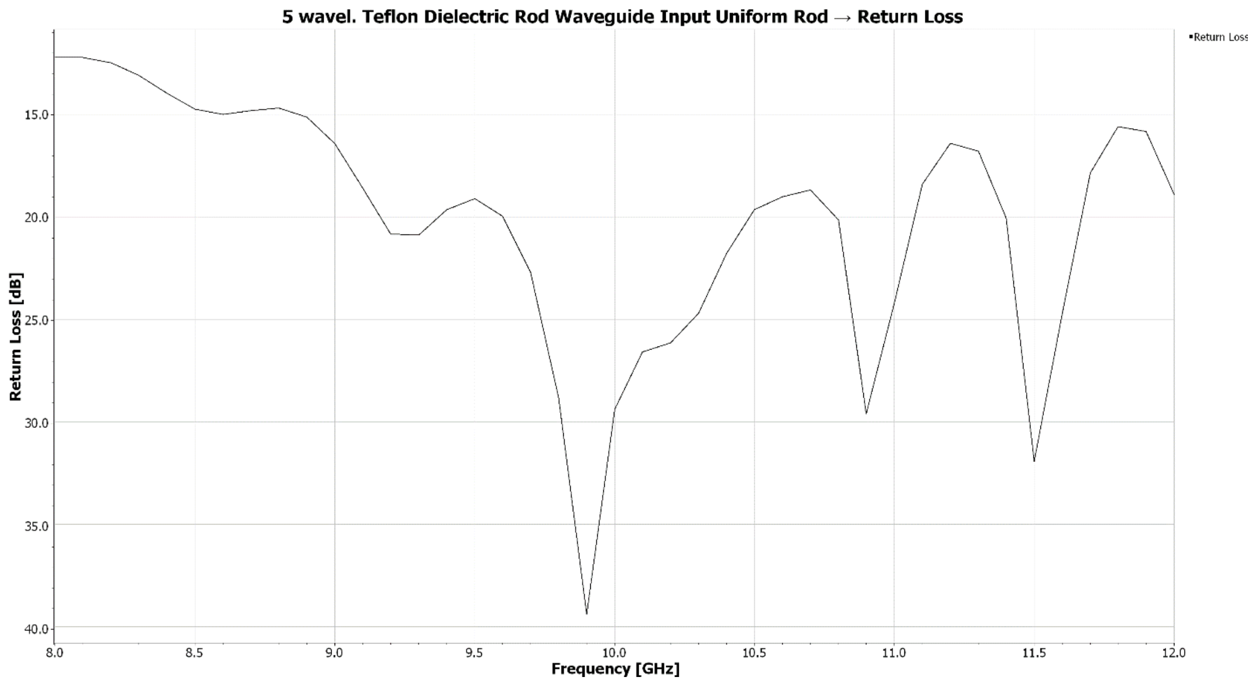

Figure 10-5.1.2 5λ Long Dielectric Rod Fed by Circular Waveguide - Return Loss w/o optimization

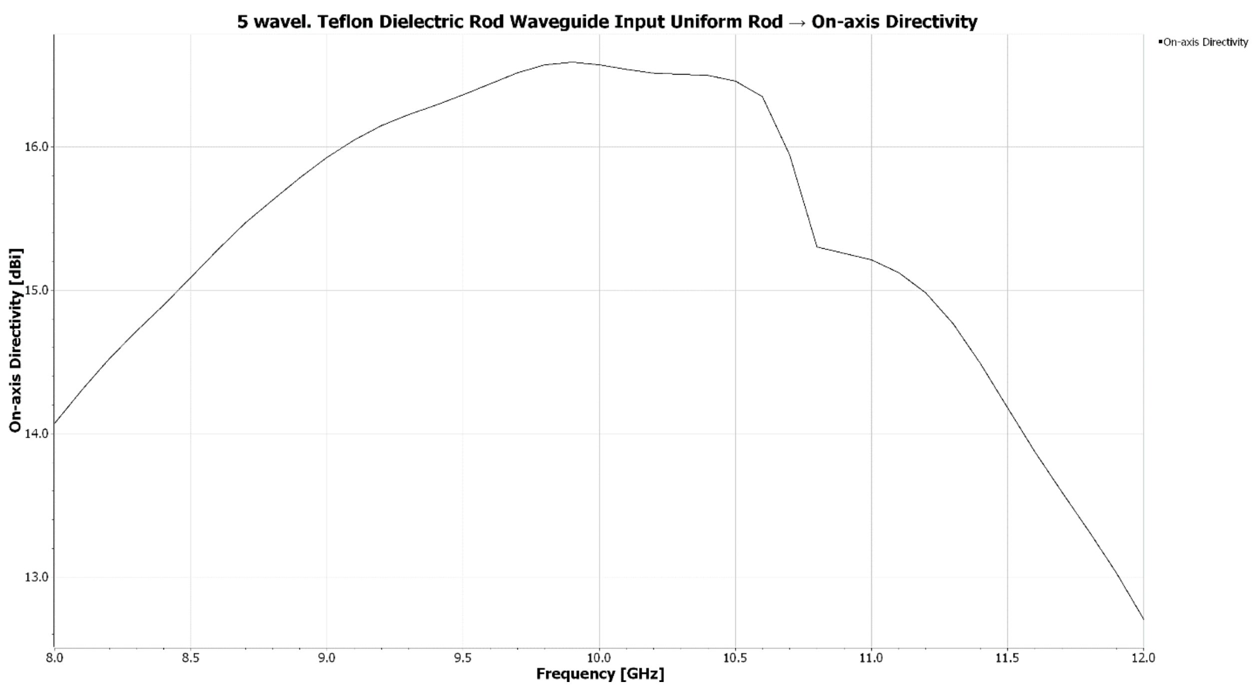

Figure 10-5.1.3 Directivity of 5λ Long Dielectric Rod Fed by Circular Waveguide

The center frequency directivity 16.6 dB matches the value given on Figure 10.2 within a few tenths of a dB for a uniformly fed traveling wave structure. We achieve a uniform distribution by making most of the segments the same diameter. Figure 10-5.1.4 of the pattern shows that the first sidelobes are similar to those given in Figure 10-16 of the uniform distribution dielectric rod. The front/back of 26 dB can be improved either by optimizing dielectric diameters or by adding structure on the feeding waveguide end to block outer wall currents on the waveguide feeder.

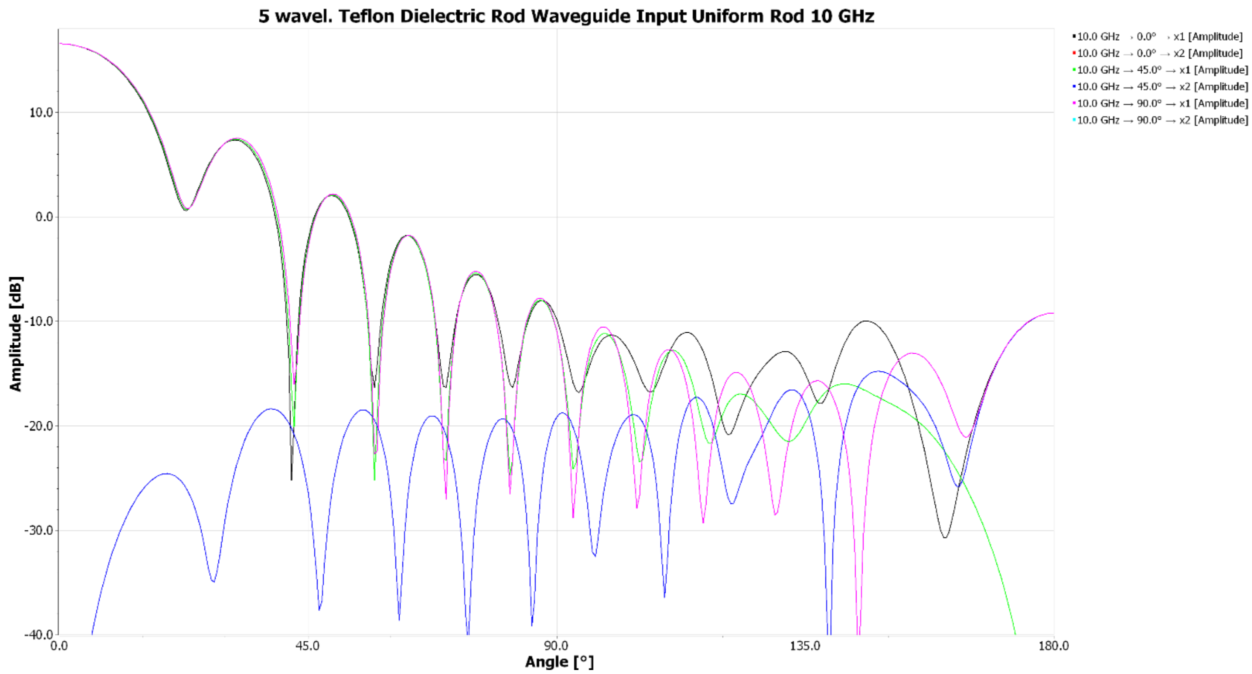

Figure 10-5.1.4 Center Frequency Pattern of 5λ Long Dielectric Rod Fed by Circular Waveguide

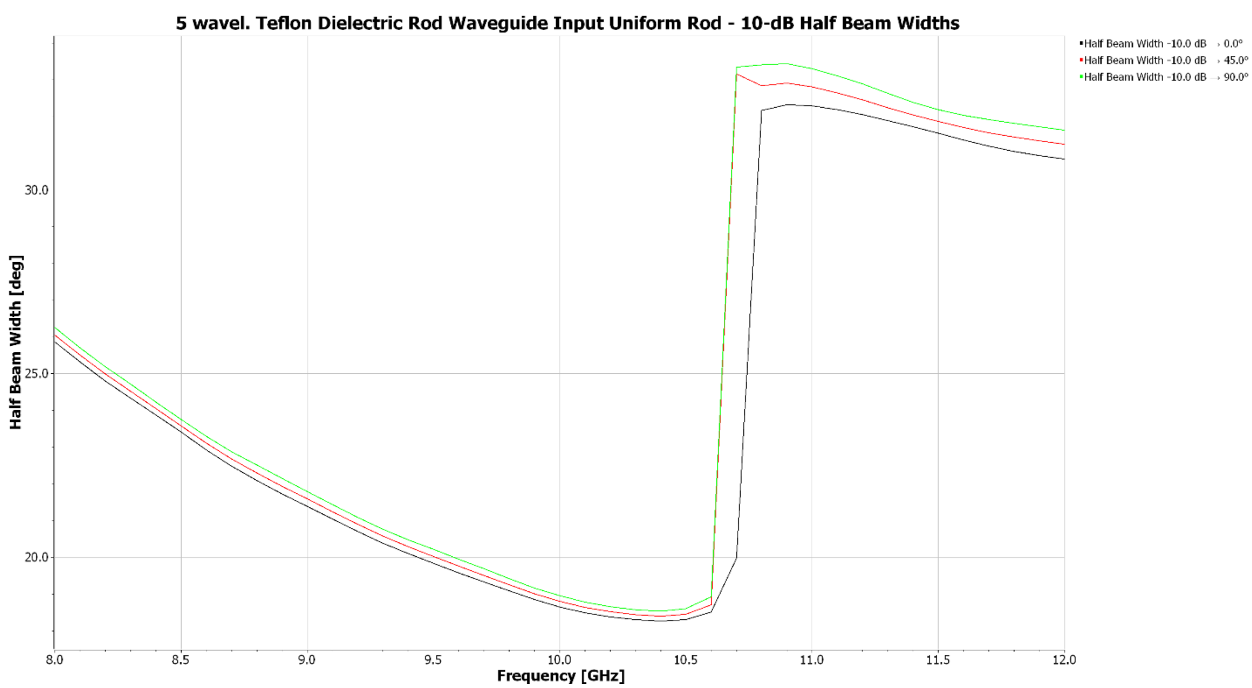

Figure 10-5.1.5 10-dB Half Beamwidth of 5λ Long Dielectric Rod Fed by Circular Waveguide

Figure 10-5.1.5 shows that the beamwidth decreases as frequency increases but has a discontinuity at about 10.7 GHz where the depth of the first null (dip) rises above 10-dB below the peak.

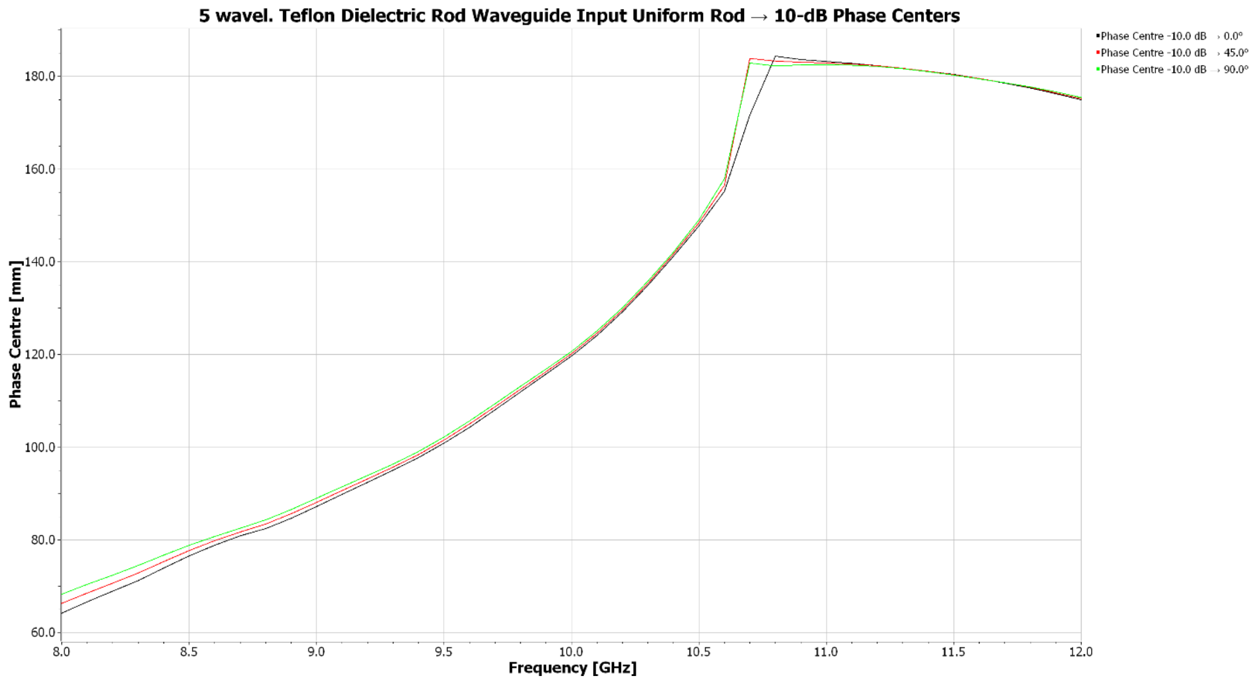

Figure 10-5.1.6 Phase Center using 10-dB beam of 5λ Long Dielectric Rod Fed by Circular Waveguide

CHAMP computes the location of phase center which we need if we use this antenna as a reflector feed. CHAMP measures the phase center distance from the mode-matching aperture. The equivalent model waveguide is located at about 27 mm. When we subtract 27 mm from the values on Figure 10-5.1.6, we compute the center frequency phase center as 93 mm along the 150 mm dielectric rod. By reading the half 10-dB beamwidth from Figure 10-5.1.5 (~19°) and by reading Scale 8-1, we would have a good feed for a reflector with an effective *f/D* = 1.5 (probably a dual reflector).

One method of reducing the backlobe is to use a small horn at the input to the dielectric rod, Figure 10-5.1.7. Figure 10-5.1.8 illustrates that the center frequency directivity increases by about 0.2 dB compared to the design without the small horn. A comparison of the sidelobes between the pattern with the small horn (Figure 10-5.1.9) and without (Figure 10-5.1.4) shows that sidelobes at angles greater than 60° are reduced by the small horn. Front/back has decreased by about 4 dB to 22-dB. The beamwidth and phase center shows little change.

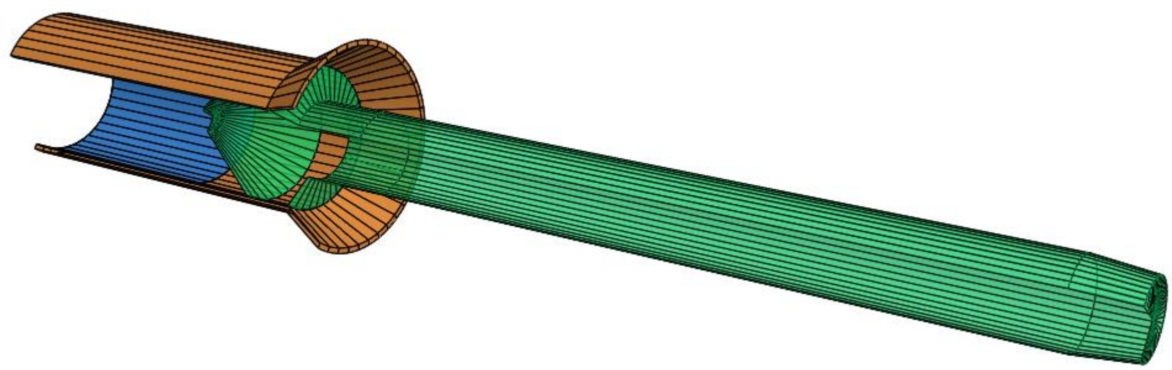

Figure 10-5.1.7 5λ Long Dielectric Rod Fed by Circular Waveguide with Small Horn

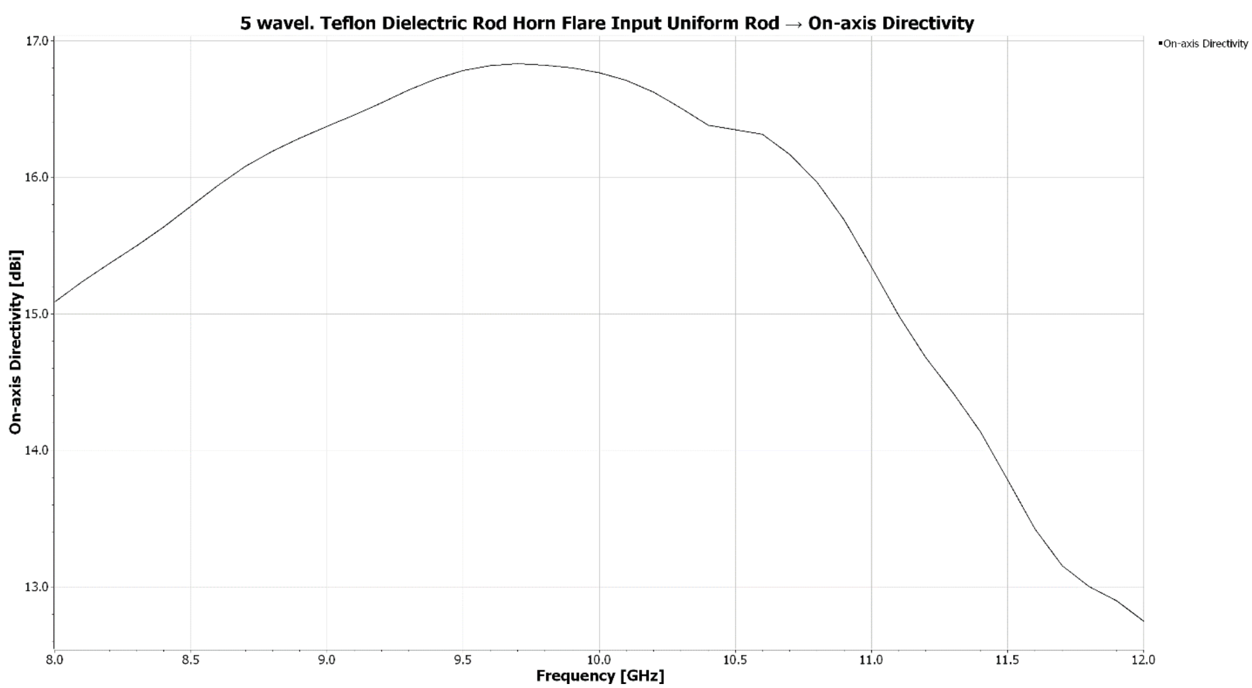

Figure 10-5.1.8 Directivity of 5λ Long Dielectric Rod Fed by Circular Waveguide with Small Horn

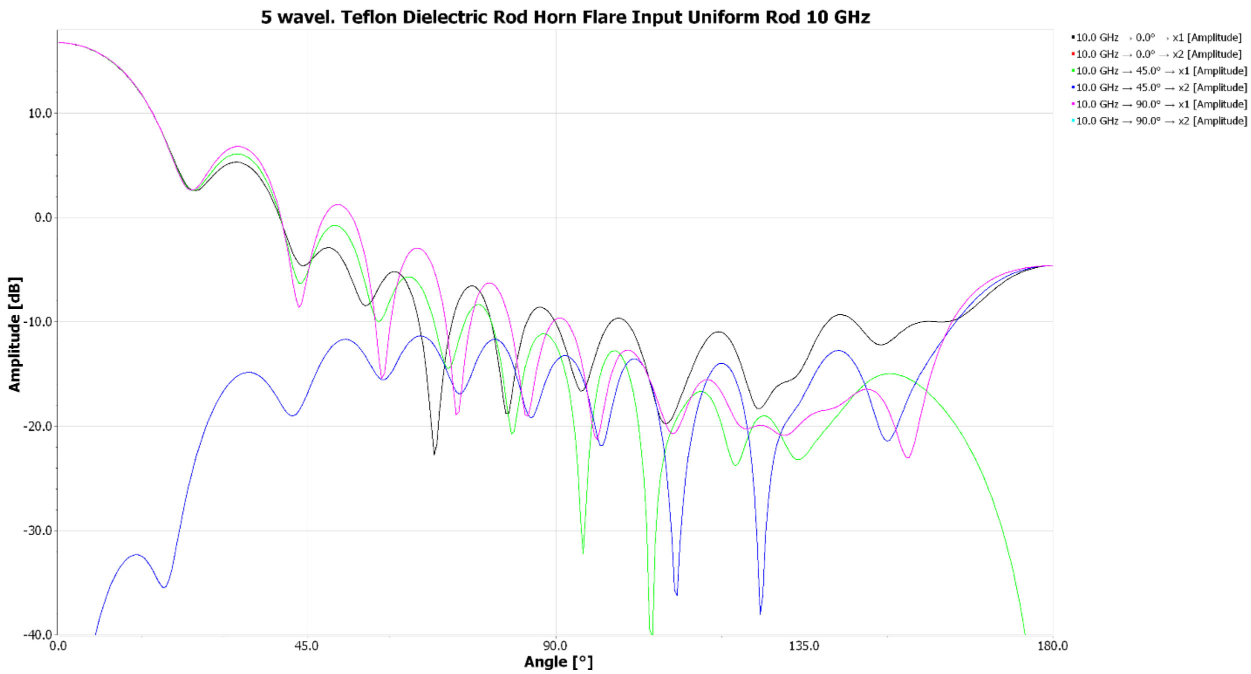

Figure 10-5.1.9 Center Frequency Pattern of 5λ Long Dielectric Rod Fed by Circular Waveguide with Small Horn

A second method of reducing the backlobe is to add a series of circular chokes on the feeding waveguide (Figure 10-5.1.10).

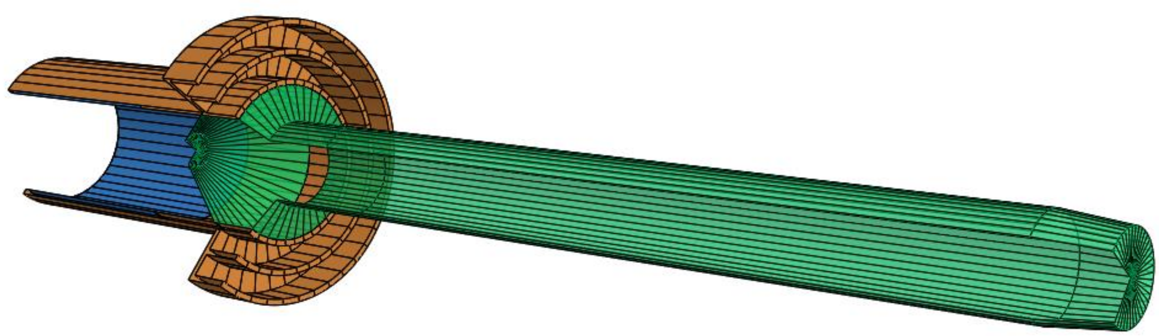

Figure 10-5.1.10 5λ Long Dielectric Rod Fed by Circular Waveguide with 2 Circular Chokes

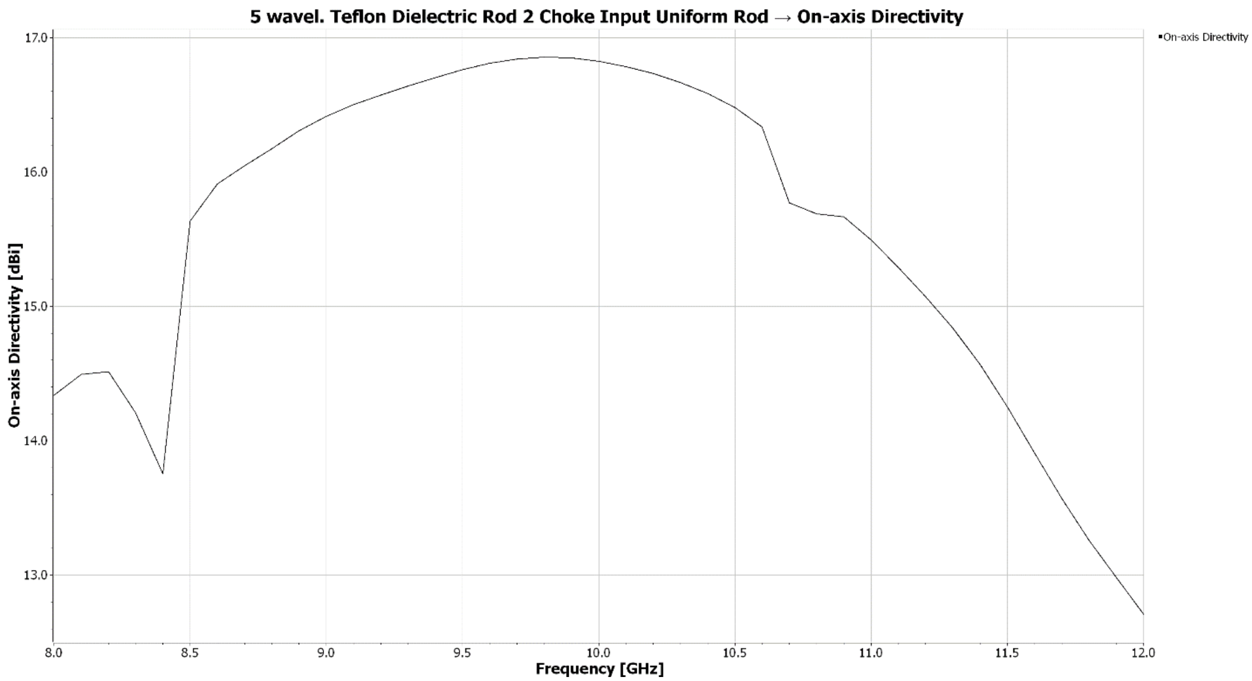

Figure 10-5.1.11 Directivity of 5λ Long Dielectric Rod Fed by Circular Waveguide with 2 Circular Chokes

The chokes increase the center frequency directivity by about 0.2 dB (Figure 10-5.1.11) compared to a design without the chokes (Figure 10-5.1.3).

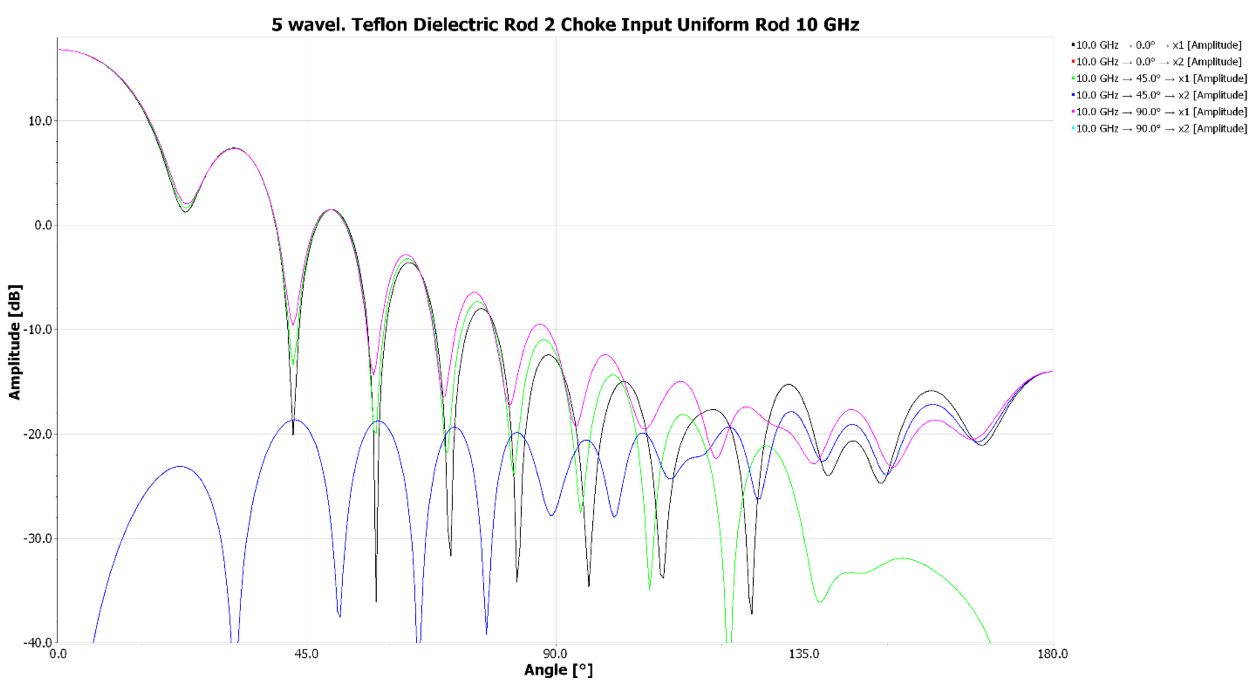

Figure 10-5.1.12 Center Frequency of 5λ Long Dielectric Rod Fed by Circular Waveguide with 2 Circular Chokes

The 2 circular chokes reduce Front/Back by an additional 10 dB to 31 dB compared to using a small horn input feeder as well as all sidelobes beyond 60° of the design using a simple waveguide feed.

2λ Long Dielectric Rod Antenna

Decreasing the length of the dielectric rod reduces directivity and increases the pattern beamwidth. Figure 10-5.1.13 shows the short rod fed from a simple waveguide.

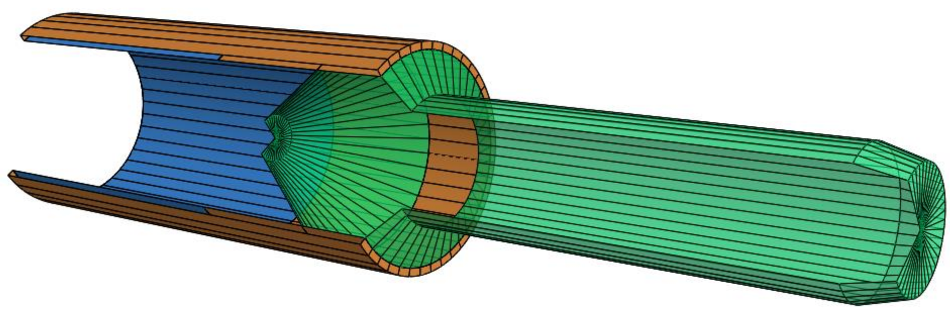

Figure 10-5.1.13 2λ Long Dielectric Rod Fed by Circular Waveguide

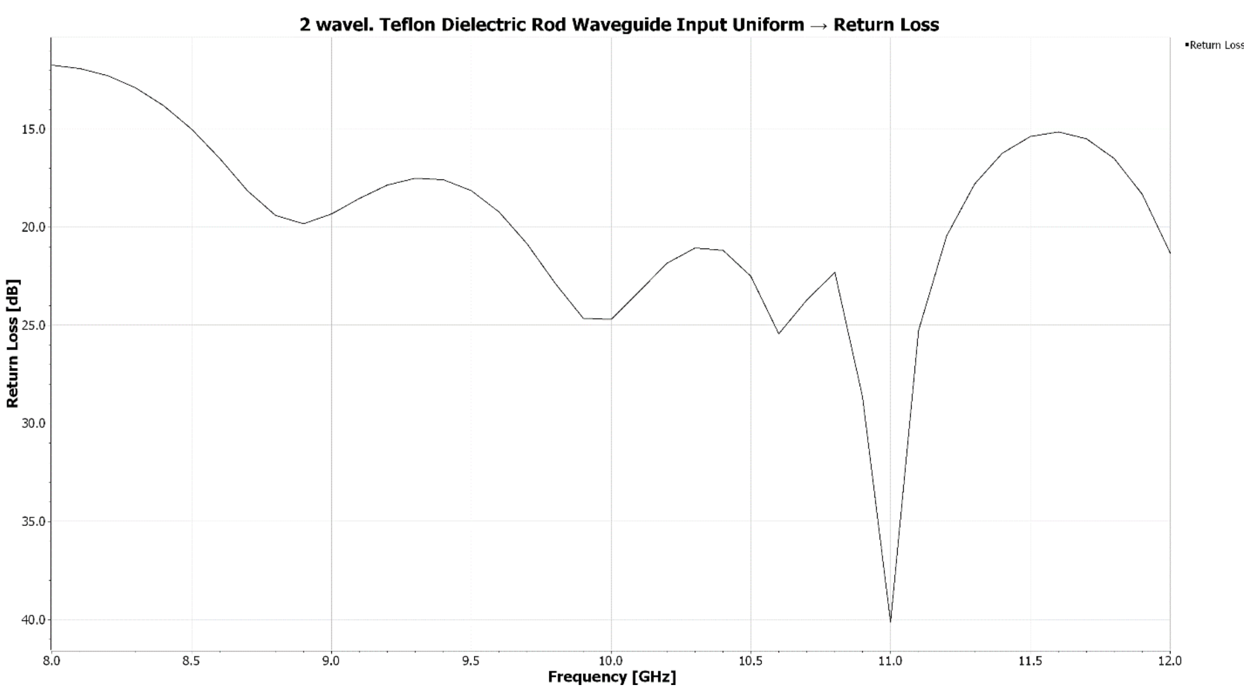

Figure 10-5.1.14 Return Loss of 2λ Long Dielectric Rod Fed by Circular Waveguide

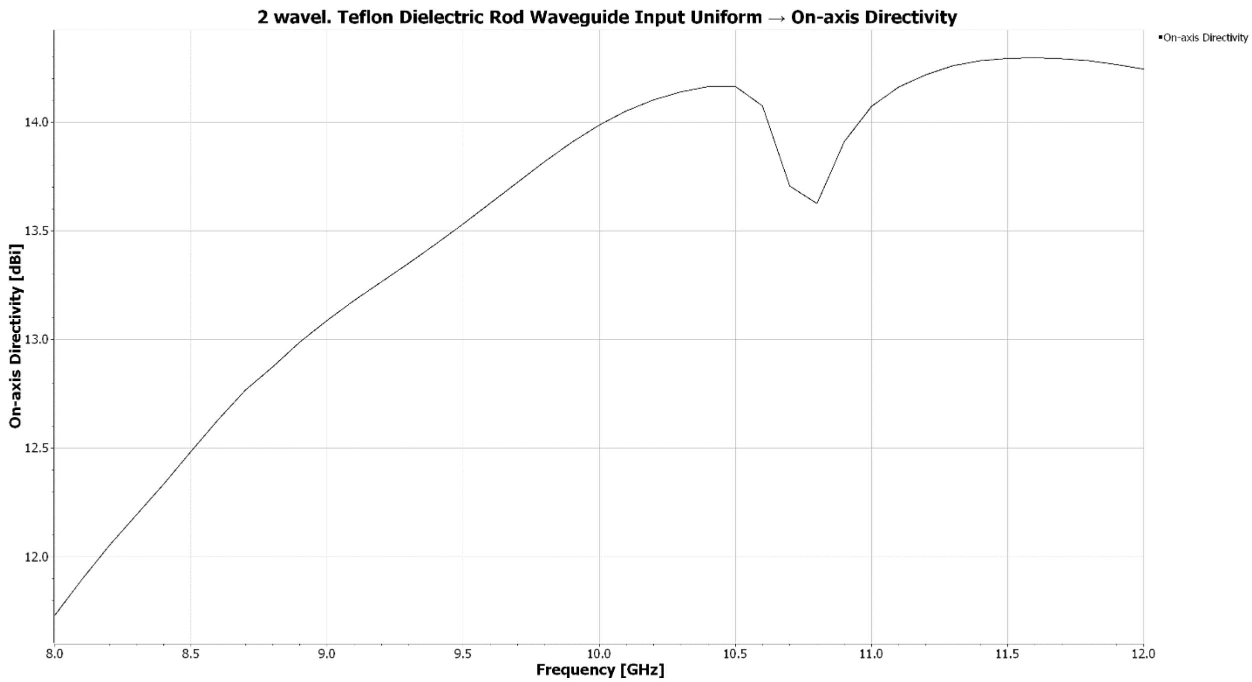

Figure 10-5.1.15 Directivity of 2λ Long Dielectric Rod Fed by Circular Waveguide

Directivity exceeds Figure 10-2 by a few 10ths of a dB for a 2λ length antenna.

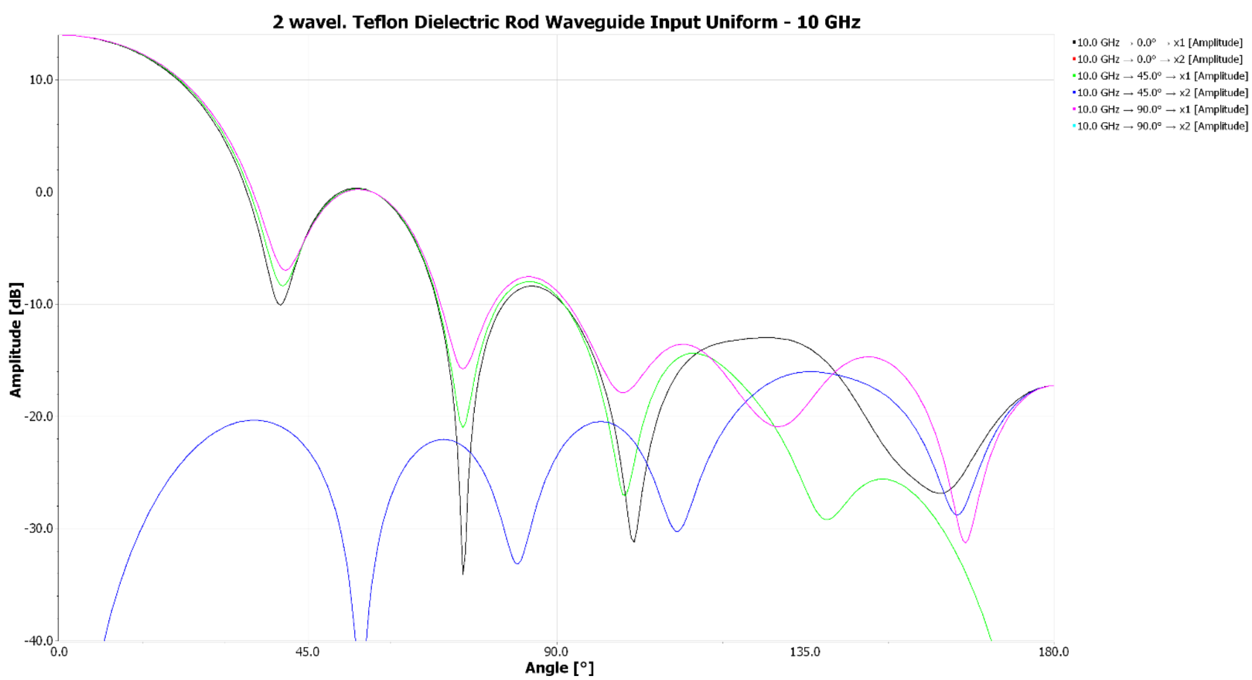

Figure 10-5.1.16 Center Frequency of 2λ Long Dielectric Rod Fed by Circular Waveguide

A front/back of 31 dB is quite good.

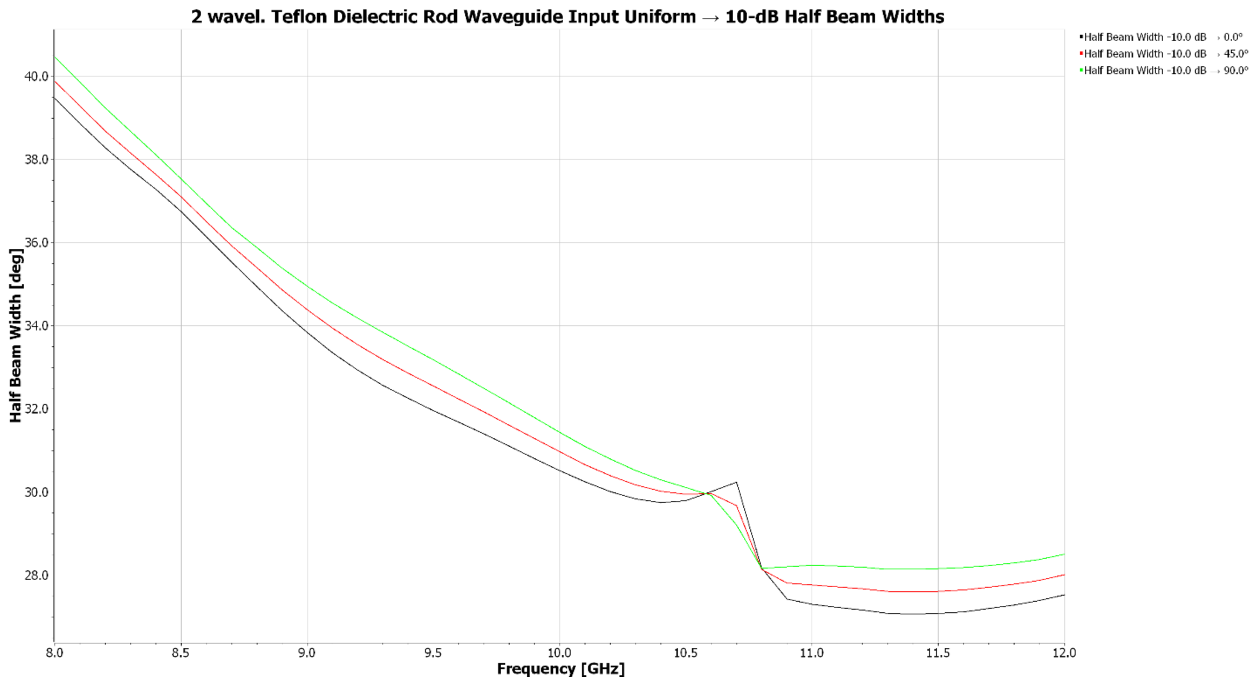

Figure 10-5.1.17 10-dB Half BW of 2λ Long Dielectric Rod Fed by Circular Waveguide

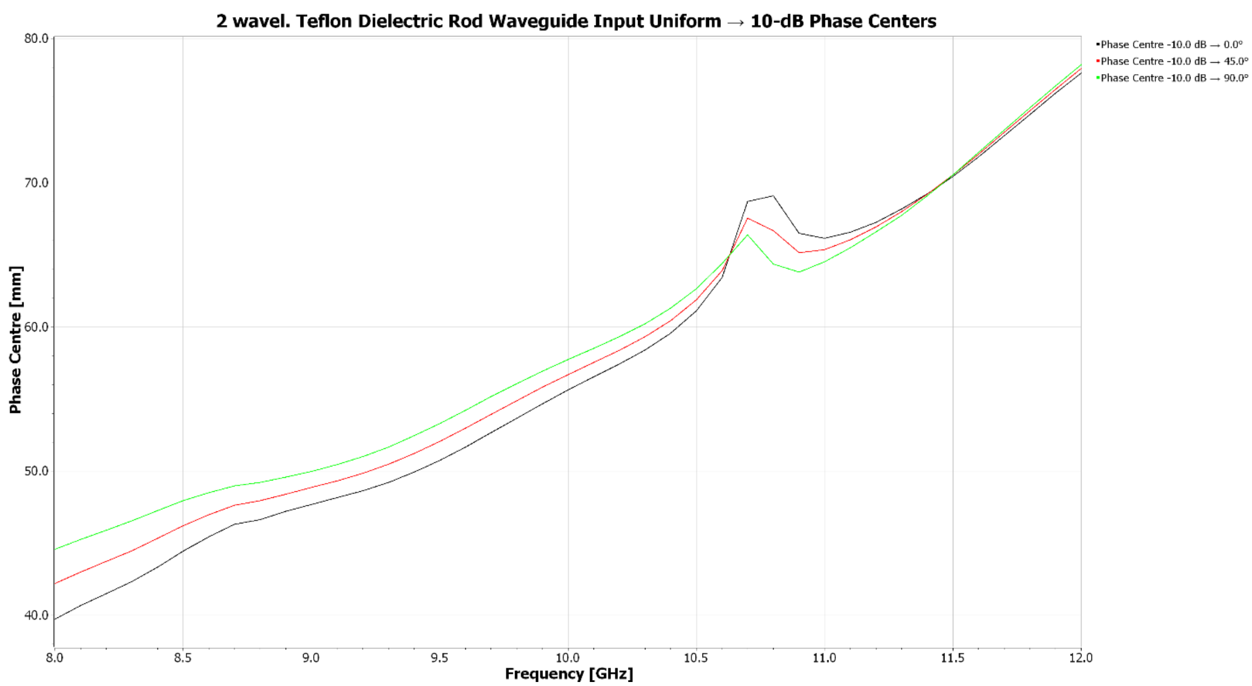

Figure 10-5.1.18 10-dB Half BW of 2λ Long Dielectric Rod Fed by Circular Waveguide

The phase center scale includes 27 mm of the internal waveguide parts which when subtracted locates it 30 mm along the rod (~ halfway).

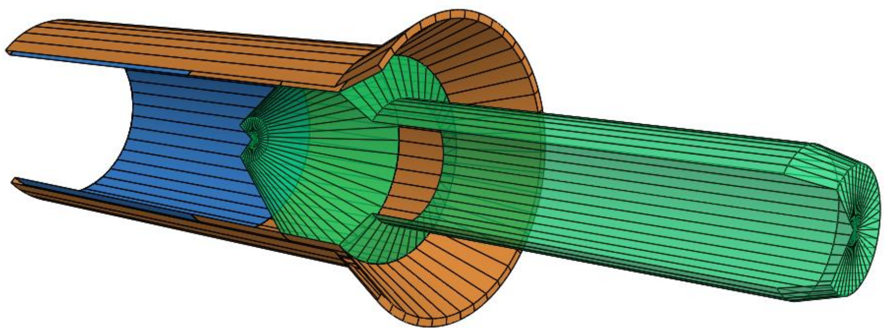

Figure 10-5.1.19 2λ Long Dielectric Rod Fed by Circular Waveguide and Small Horn

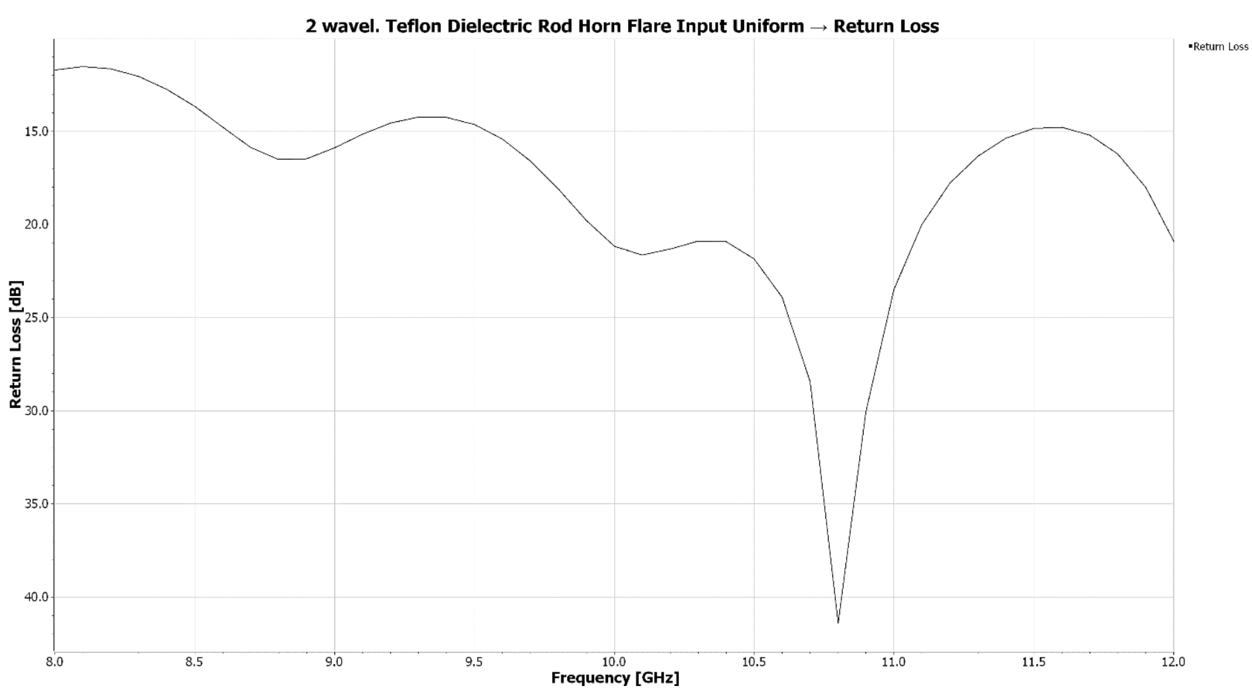

Figure 10-5.1.20 Return Loss of 2λ Long Dielectric Rod Fed by Circular Waveguide and Small Horn

The short horn feed reduces antenna directivity by about 0.3 dB (Figure 10-5.1.21) compared to the dielectric rod fed from a simple waveguide. The small horn excitation of the 2λ long dielectric rod reduces front/back to ~18 dB (Figure 10-5.1.22) reduced compared to the straight waveguide feed with 31-dB. By applying optimization of the horn and end taper of the rod in CHAMP, the front/back could be improved.

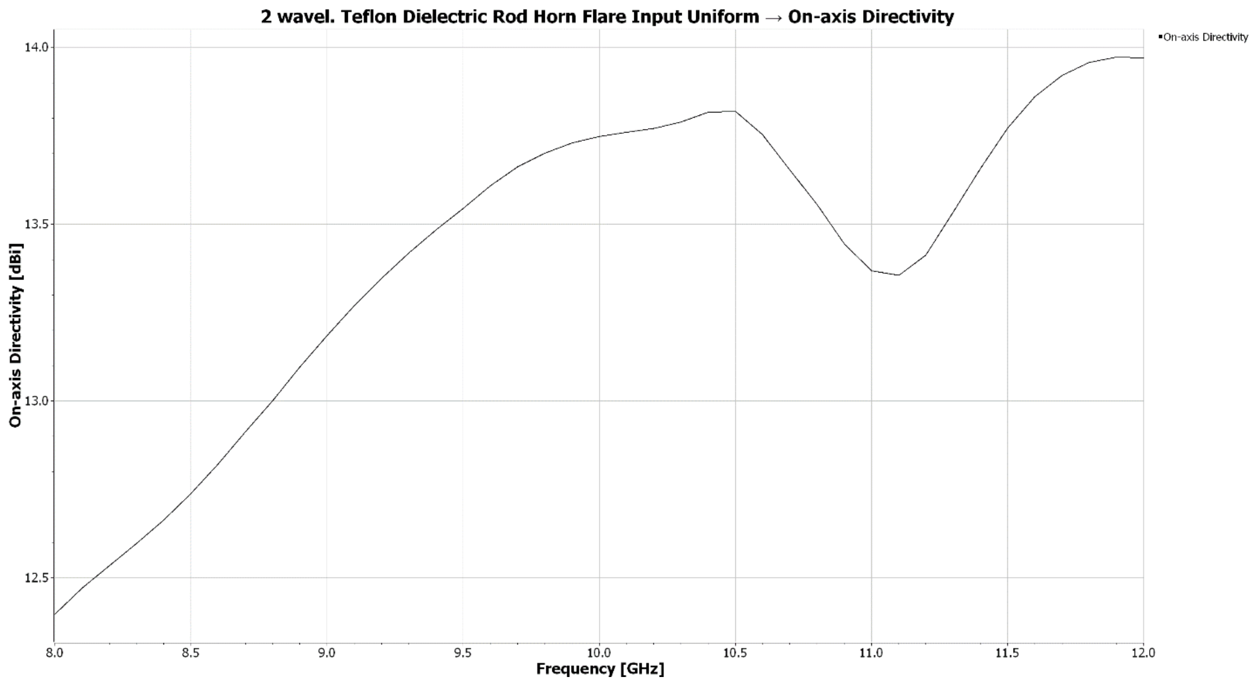

Figure 10-5.1.21 Directivity of 2λ Long Dielectric Rod Fed by Circular Waveguide and Small Horn

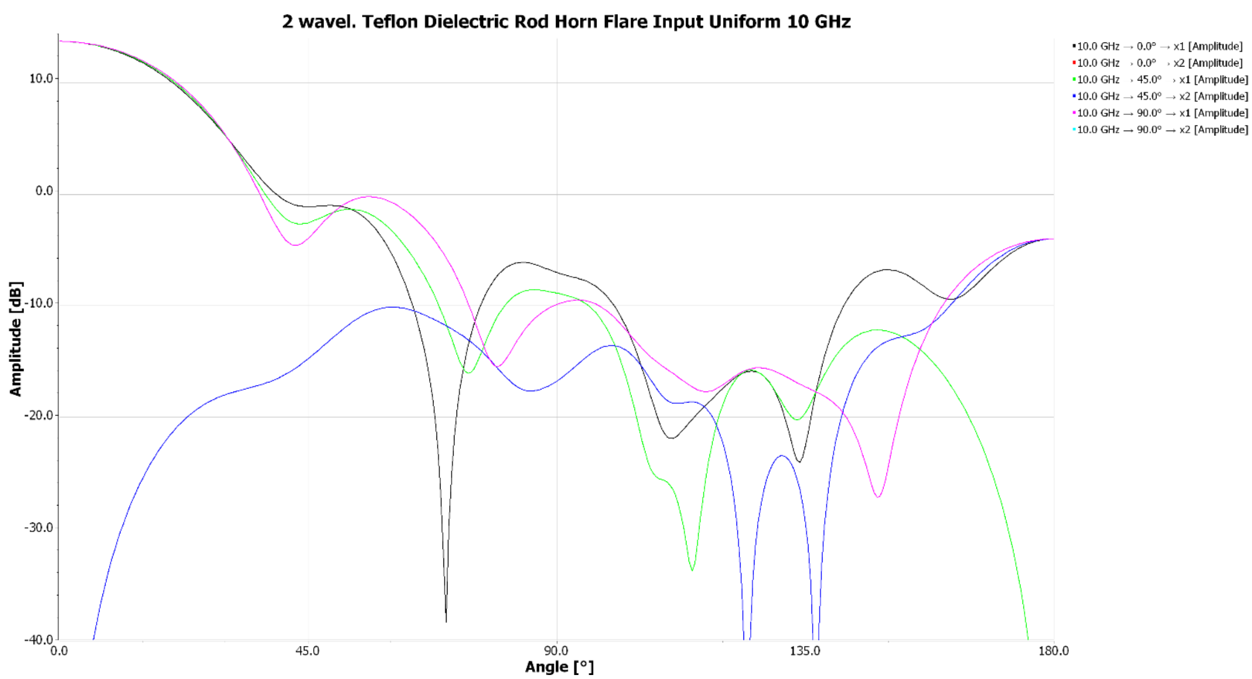

Figure 10-5.1.22 Center Frequency of 2λ Long Dielectric Rod Fed by Circular Waveguide and Small Horn

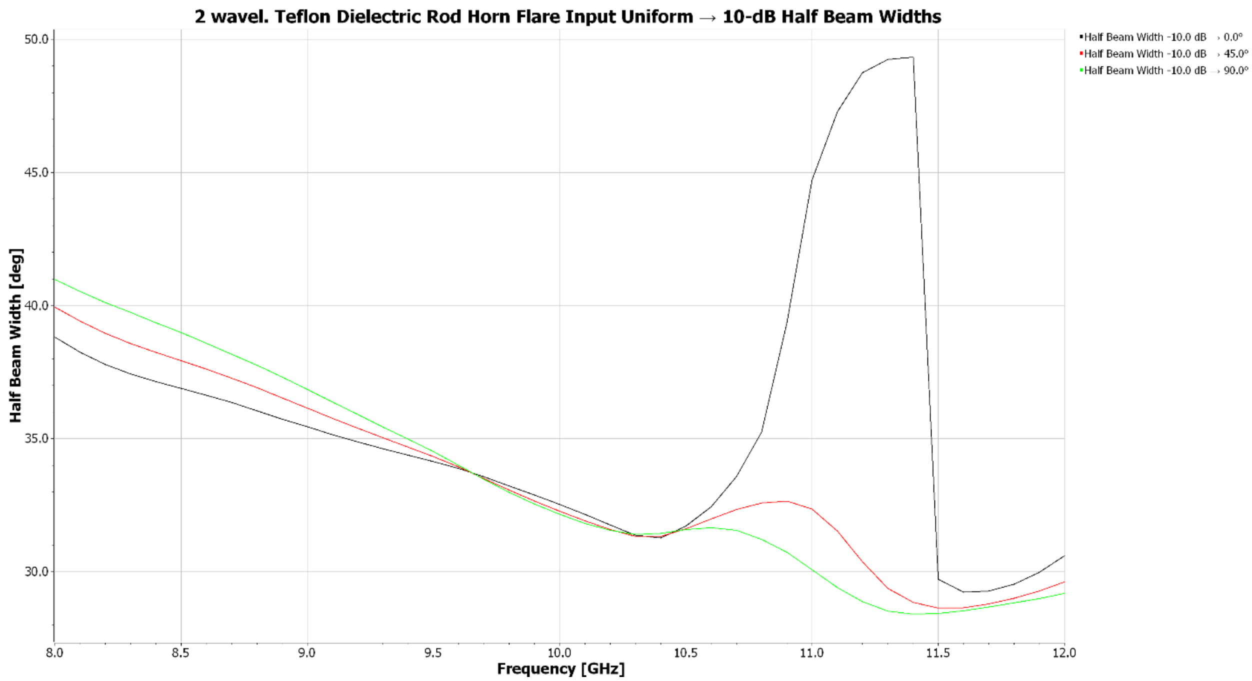

Figure 10-5.1.23 10-dB Half BW of 2λ Long Dielectric Rod Fed by Circular Waveguide and Small Horn

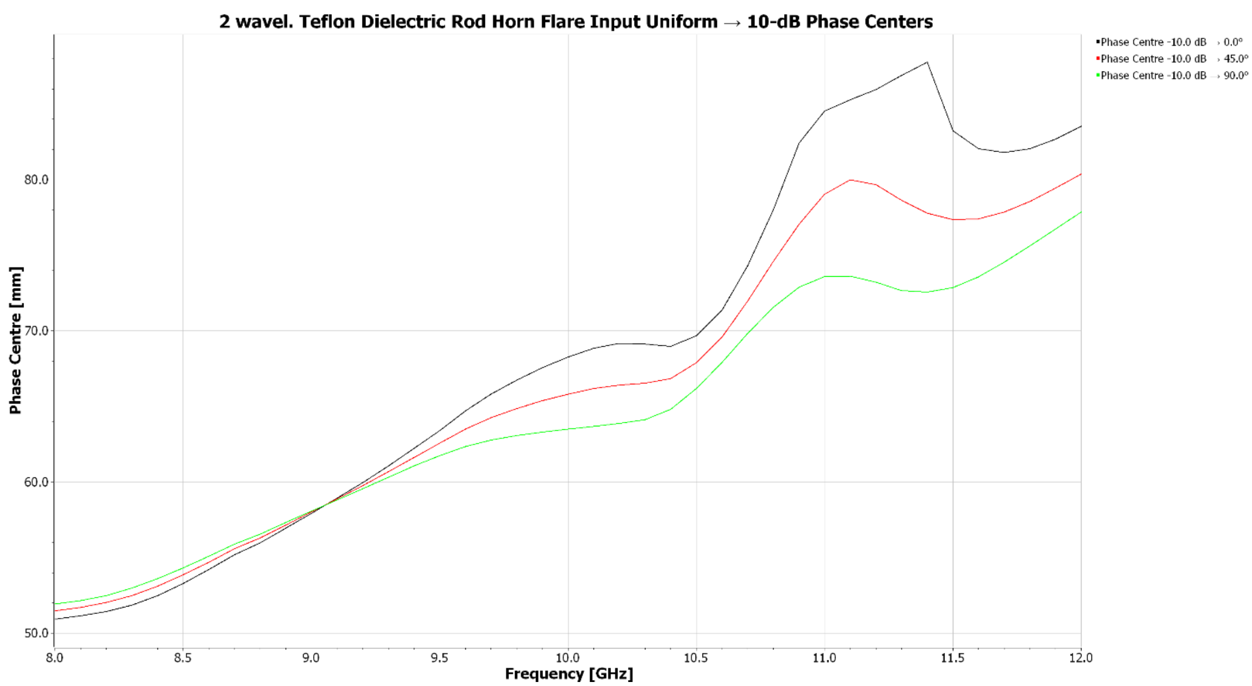

Figure 10-5.1.24 10-dB Phase Center of 2λ Long Dielectric Rod Fed by Circular Waveguide and Small Horn

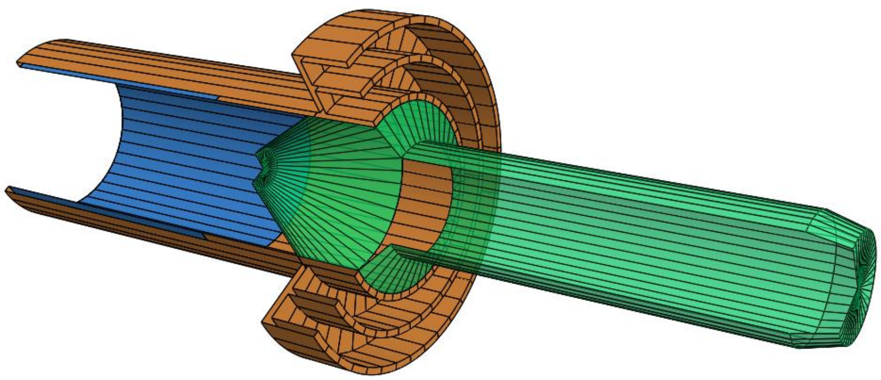

Figure 10-5.1.25 2λ Long Dielectric Rod Fed by Circular Waveguide w/ 2 Chokes

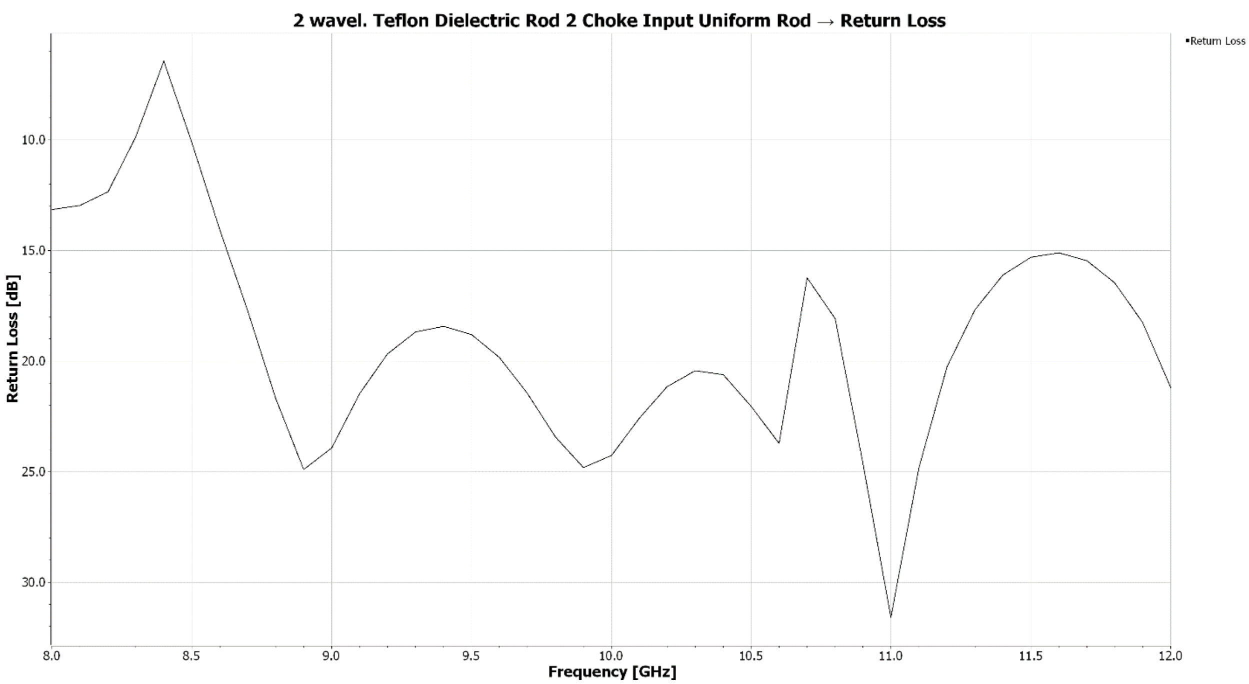

Figure 10-5.1.26 Return Loss of 2λ Long Dielectric Rod Fed by Circular Waveguide w/ 2 Chokes

When we add the two chokes to the feed region, directivity (Figure 10-5.1.27) increases by about 0.2 dB compared to the simple waveguide feed (Figure 10-5.1.15). The chokes fail to increase front/back.

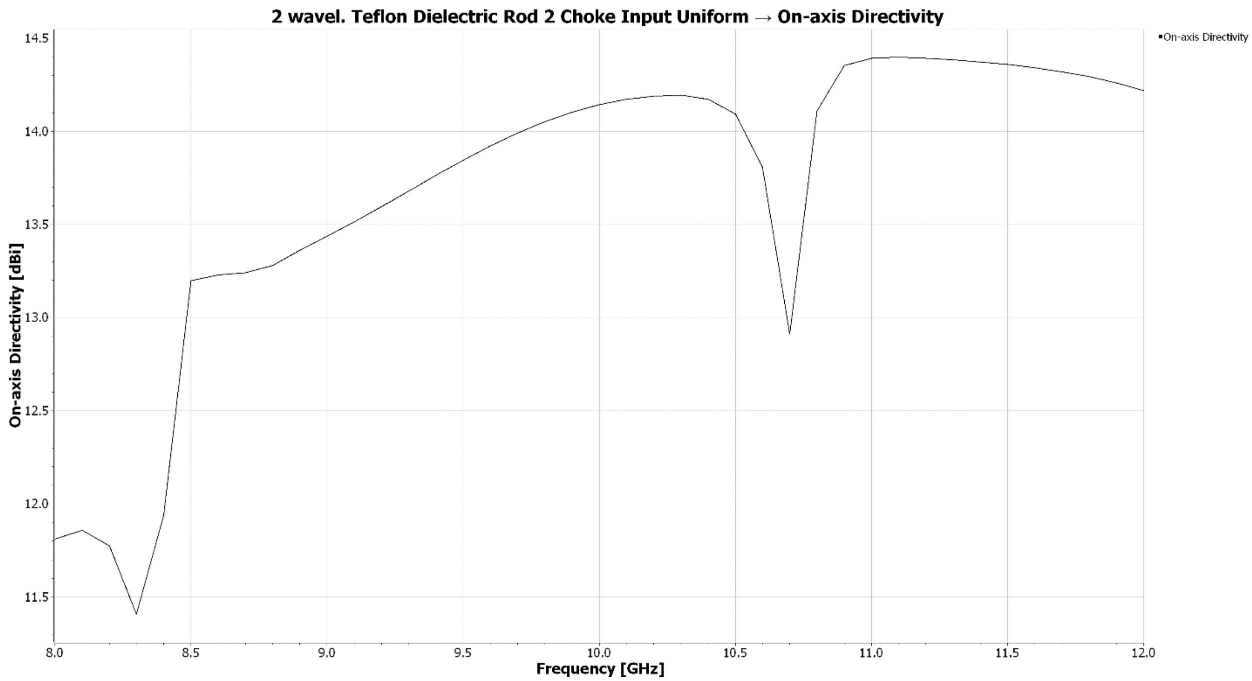

Figure 10-5.1.27 Directivity of 2λ Long Dielectric Rod Fed by Circular Waveguide w/ 2 Chokes

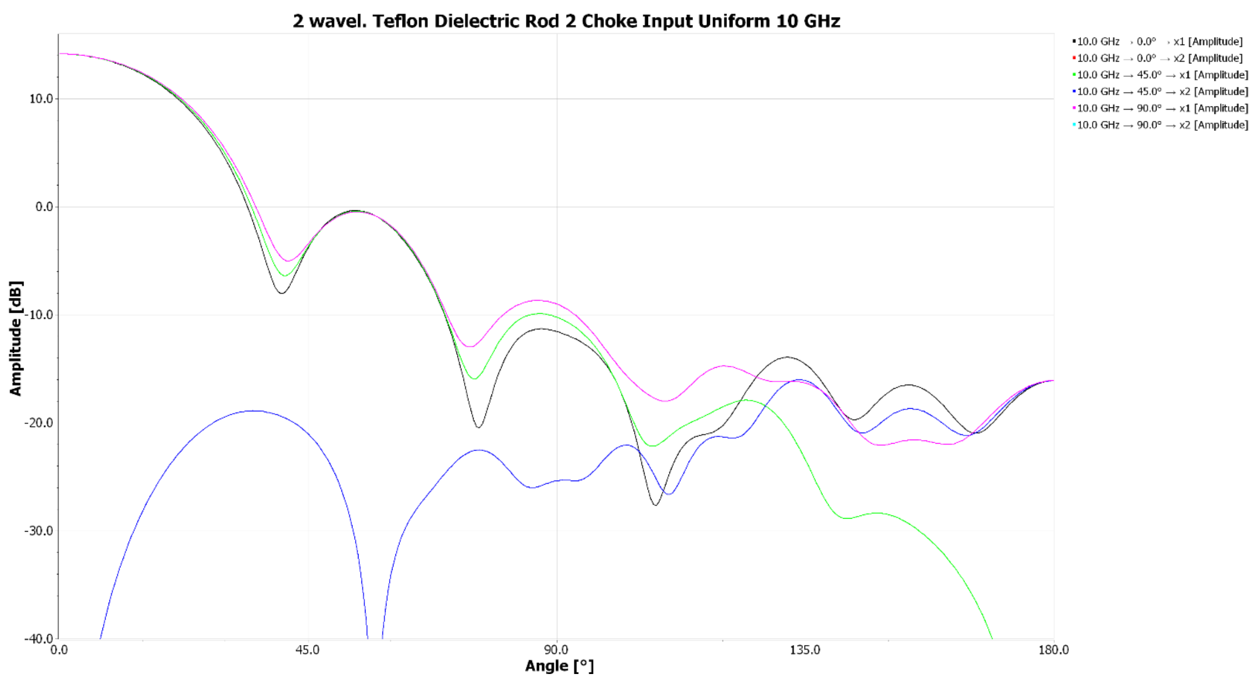

Figure 10-5.1.28 Center frequency of 2λ Long Dielectric Rod Fed by Circular Waveguide w/ 2 Chokes

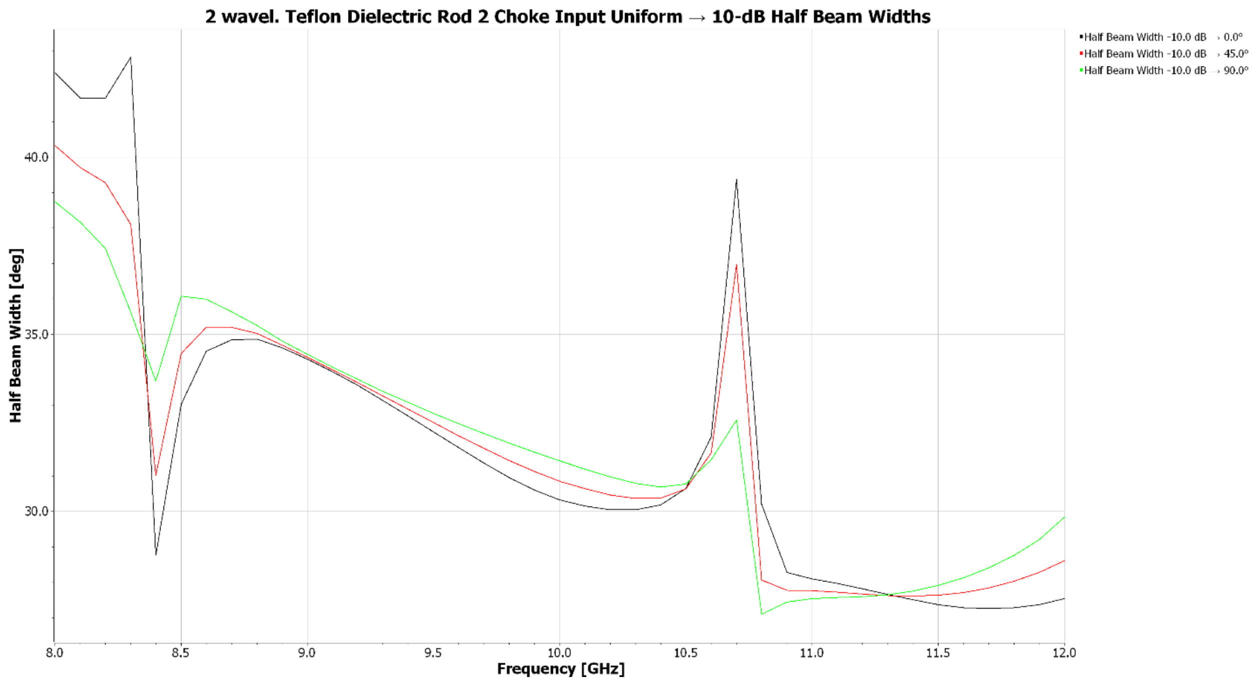

Figure 10-5.1.29 10-dB Half BW 2λ Long Dielectric Rod Fed by Circular Waveguide w/ 2 Chokes

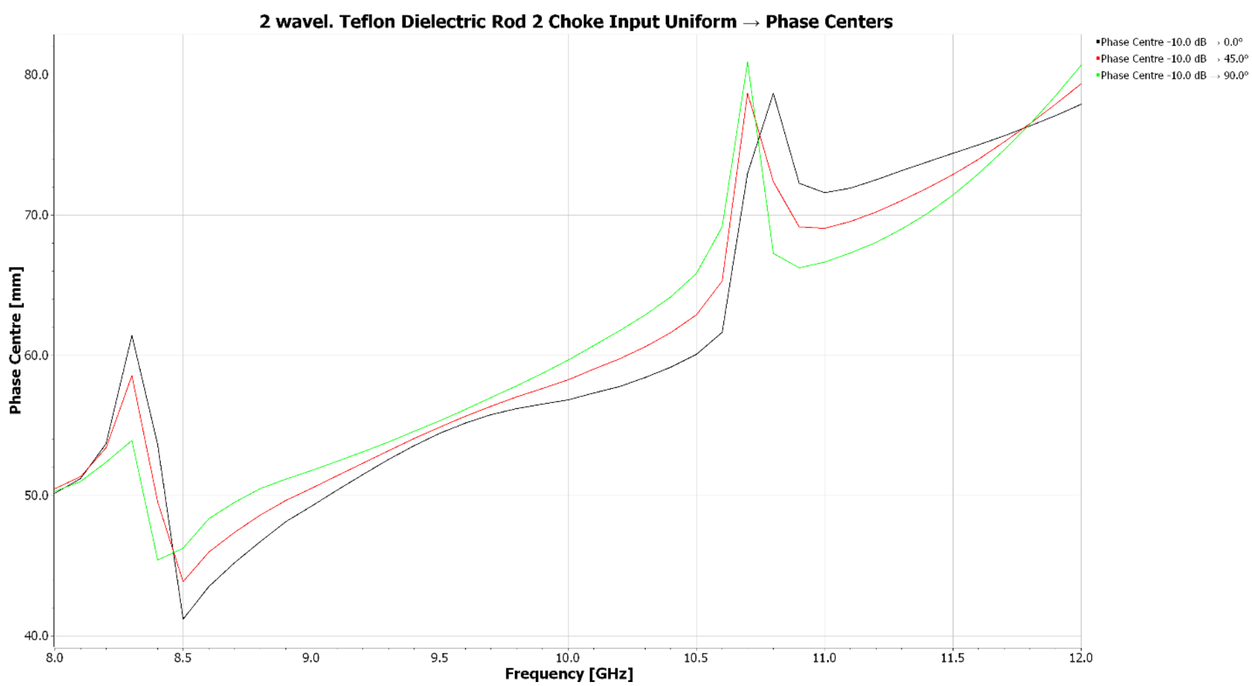

Figure 10-5.1.30 10-dB Phase Center of 2λ Long Dielectric Rod Fed by Circular Waveguide w/ 2 Chokes

λ Long Dielectric Rod Antenna

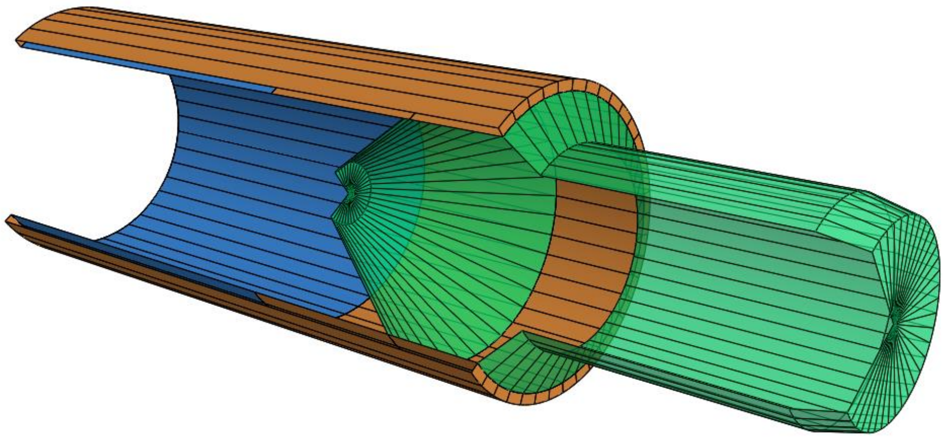

Figure 10-5.1.31 λ Long Dielectric Rod Fed by Circular Waveguide

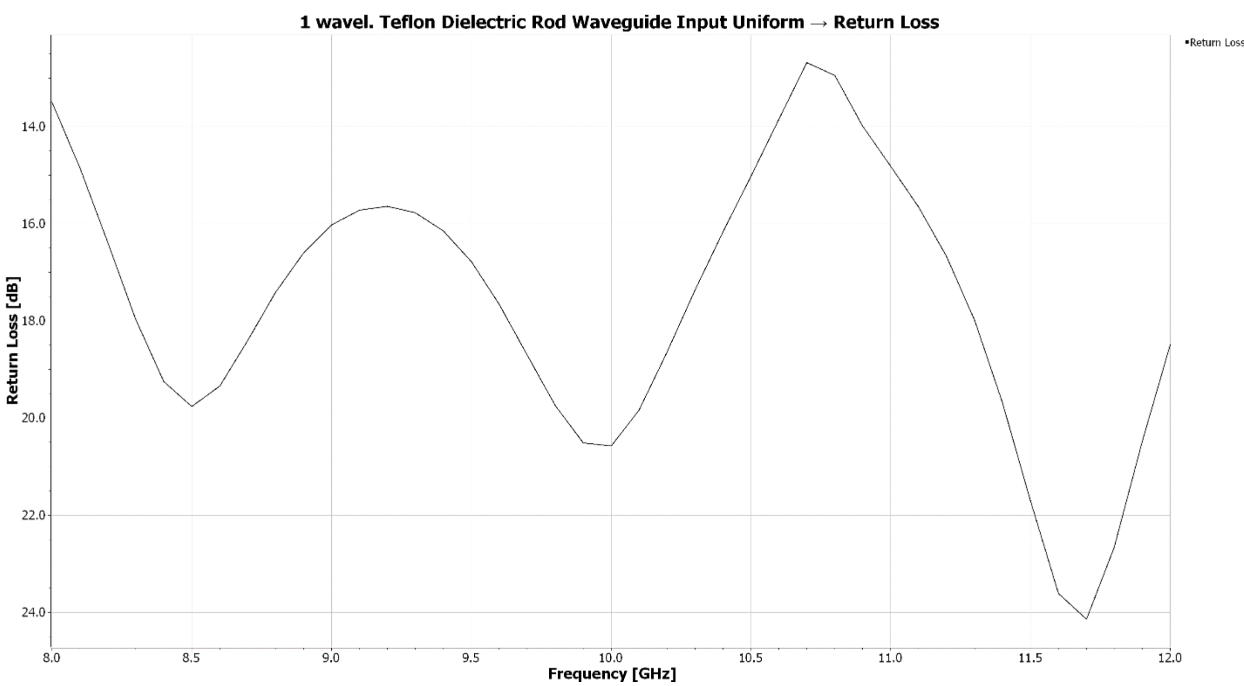

Figure 10-5.1.32 Return Loss of λ Long Dielectric Rod Fed by Circular Waveguide

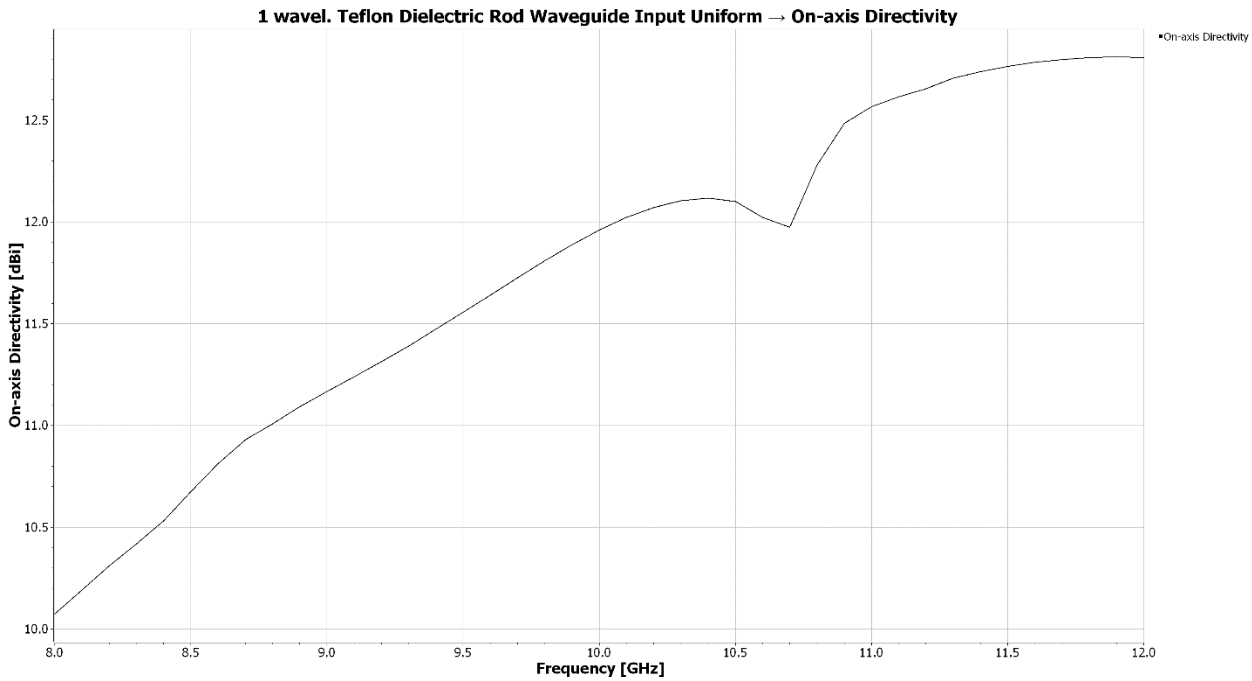

Figure 10-5.1.33 Directivity of λ Long Dielectric Rod Fed by Circular Waveguide

Figure 10-5.1.34 Center Frequency of λ Long Dielectric Rod Fed by Circular Waveguide

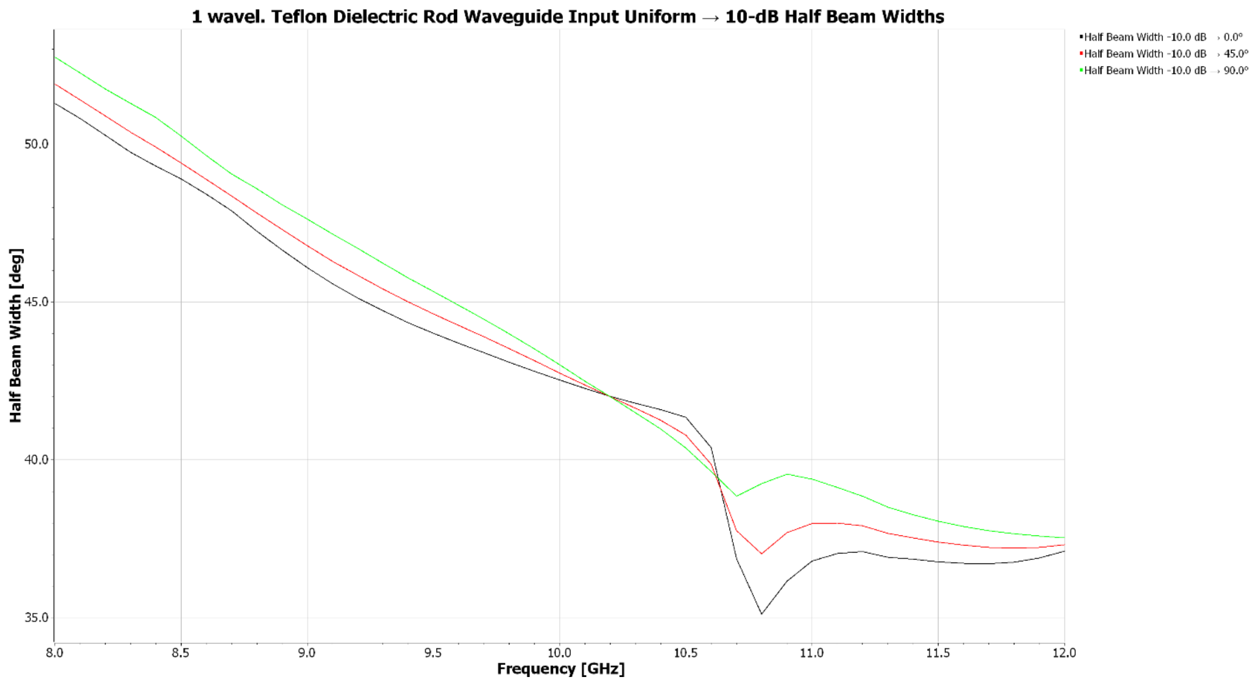

Figure 10-5.1.35 10-dB Half BW of λ Long Dielectric Rod Fed by Circular Waveguide

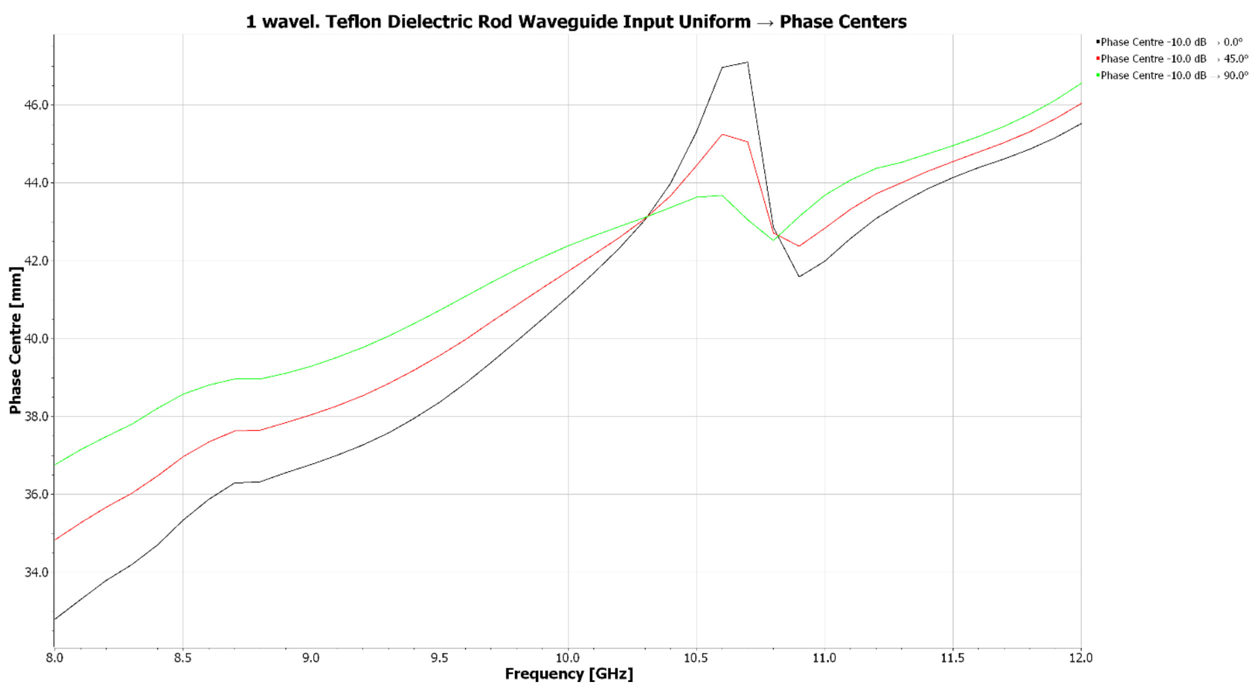

Figure 10-5.1.36 10-dB Phase Center of λ Long Dielectric Rod Fed by Circular Waveguide

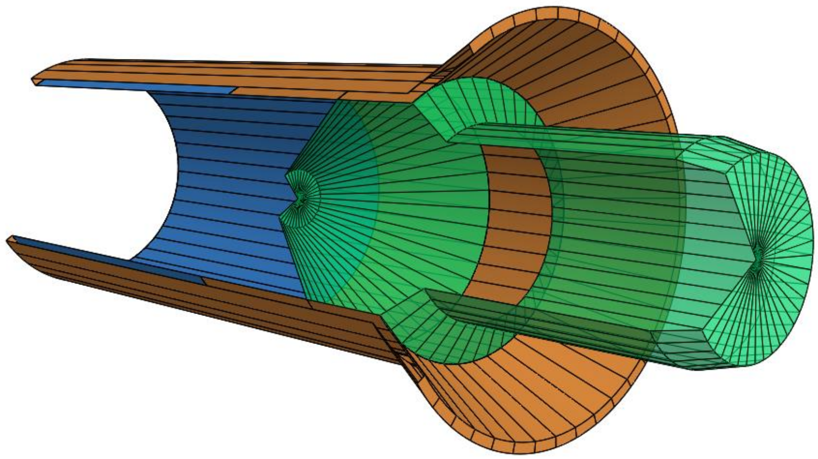

Figure 10-5.1.37 λ Long Dielectric Rod Fed by Circular Waveguide and Small Horn

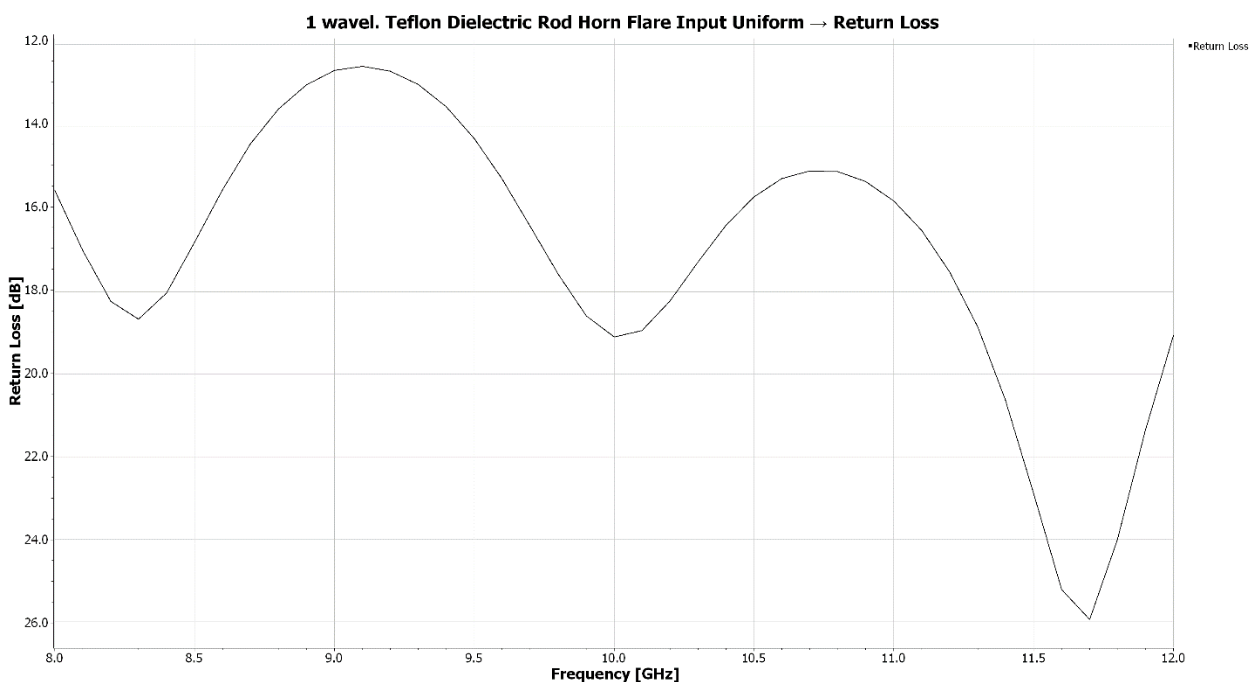

Figure 10-5.1.38 Return Loss of λ Long Dielectric Rod Fed by Circular Waveguide and Small Horn

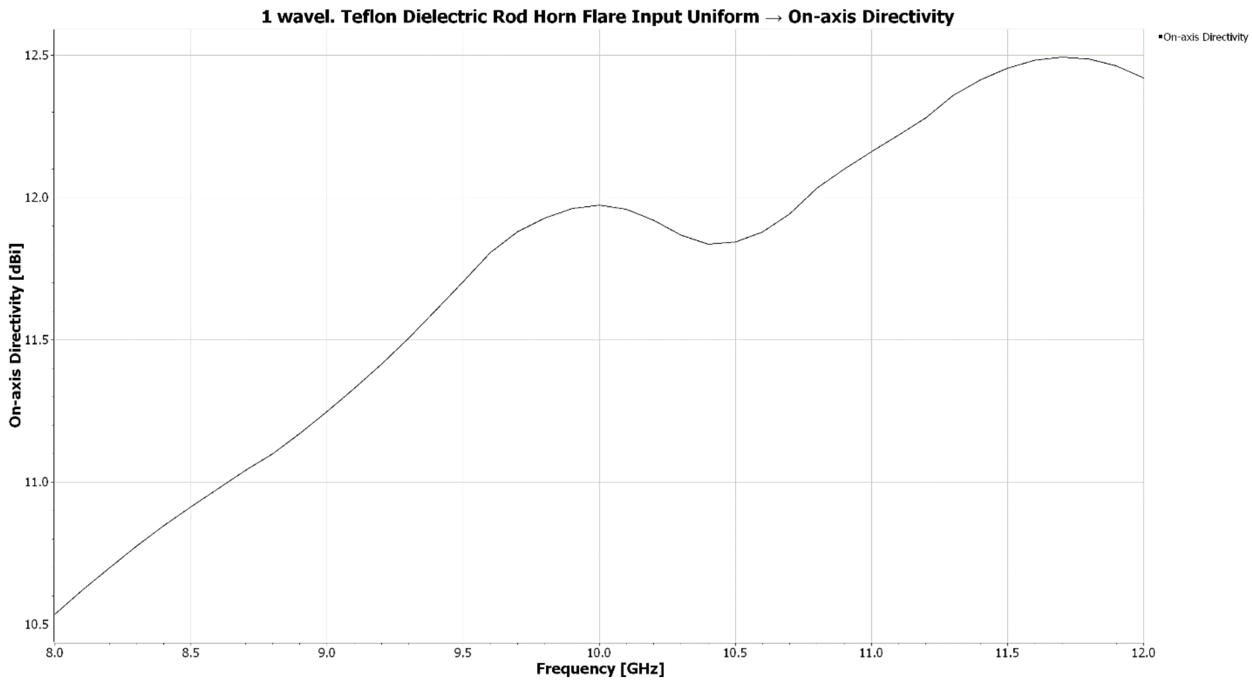

Figure 10-5.1.39 Directivity of λ Long Dielectric Rod Fed by Circular Waveguide and Small Horn

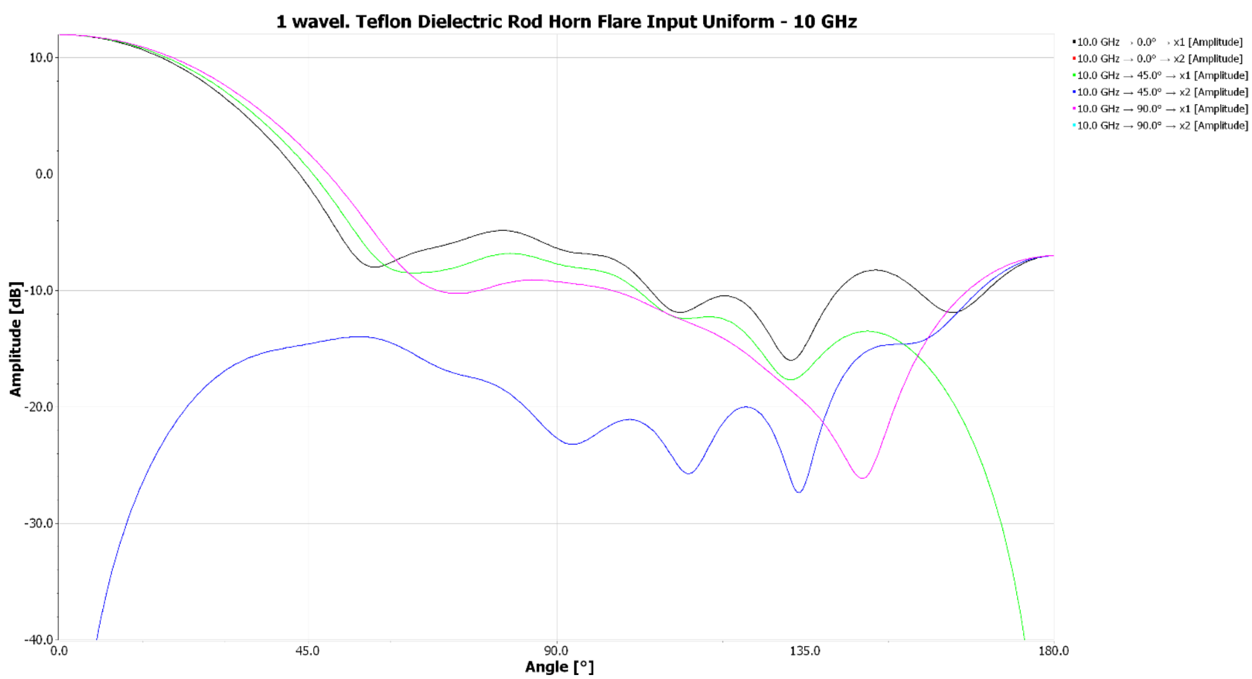

Figure 10-5.1.40 Center Frequency of λ Long Dielectric Rod Fed by Circular Waveguide and Small Horn

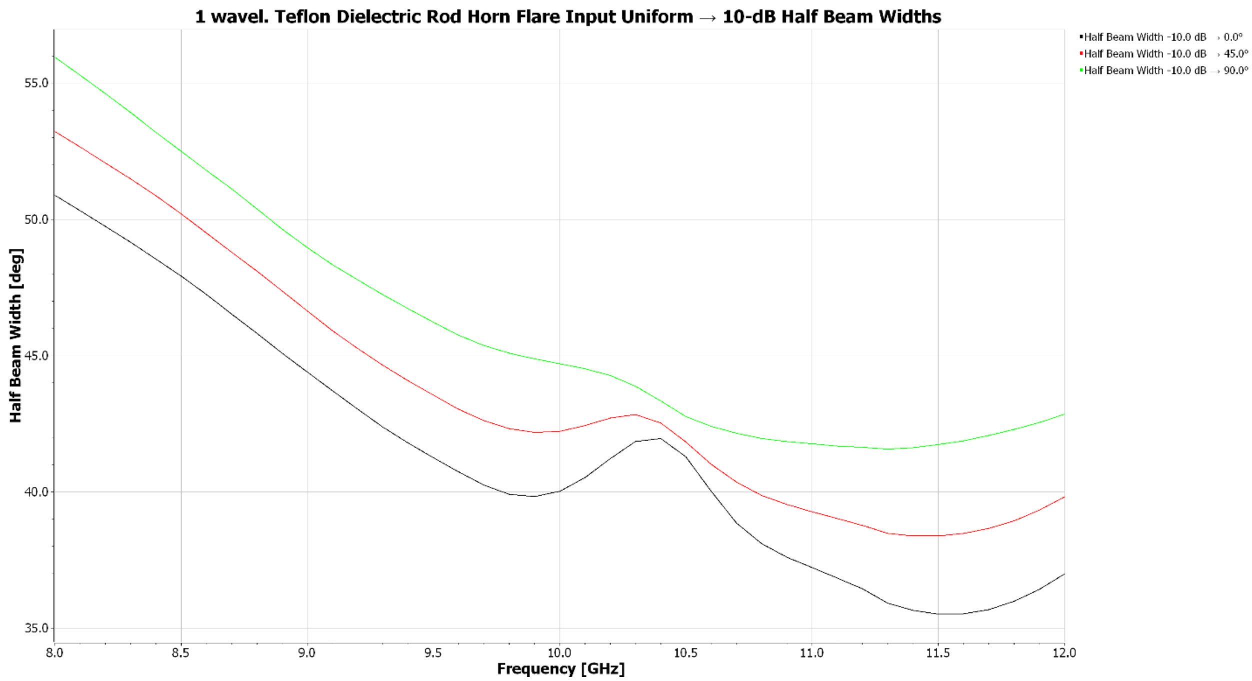

Figure 10-5.1.41 10-dB Half BW of λ Long Dielectric Rod Fed by Circular Waveguide and Small Horn

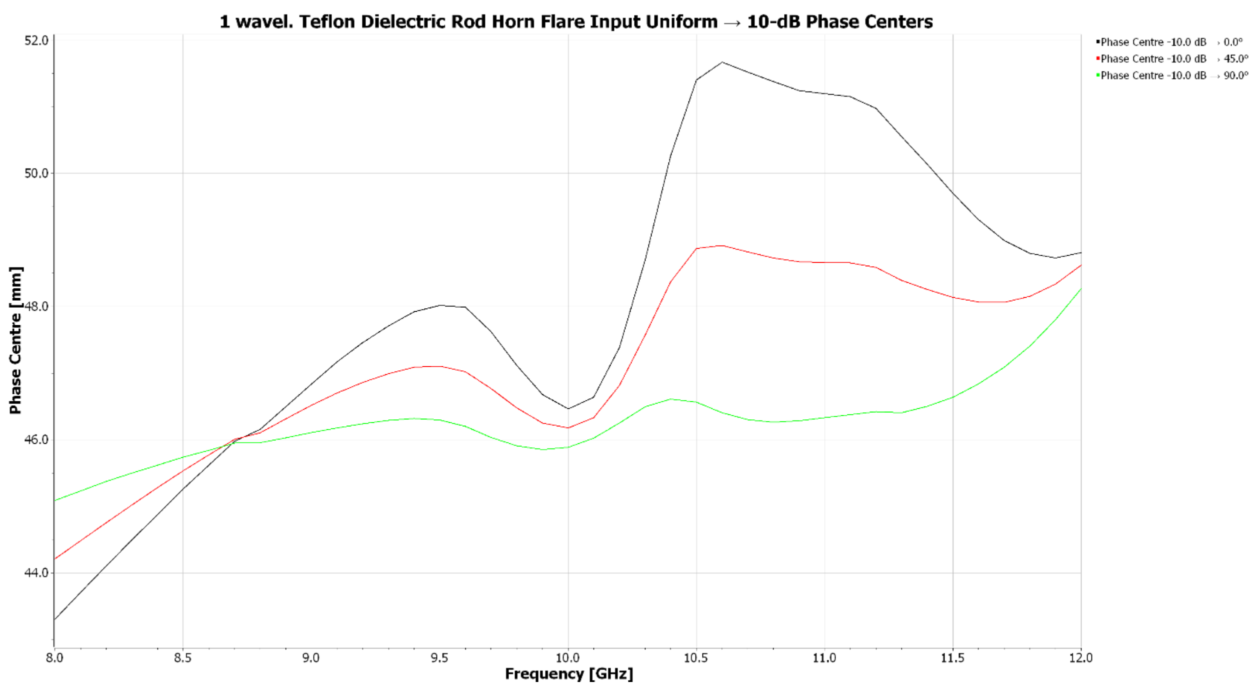

Figure 10-5.1.42 10-dB Phase Center of λ Long Dielectric Rod Fed by Circular Waveguide and Small Horn

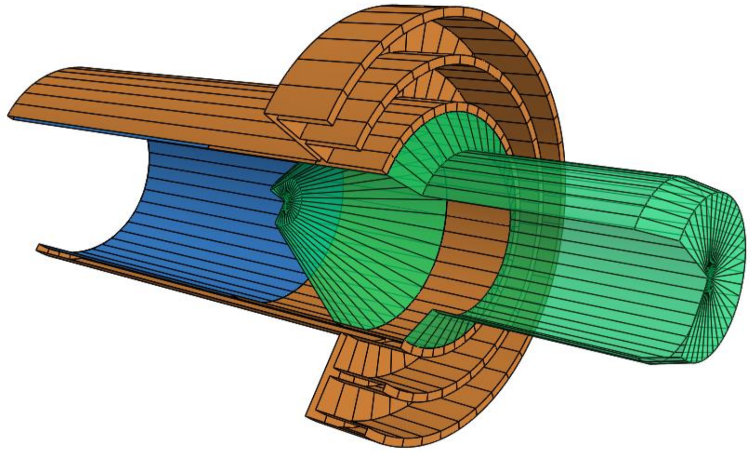

Figure 10-5.1.43 λ Long Dielectric Rod Fed by Circular Waveguide w/ 2 Chokes

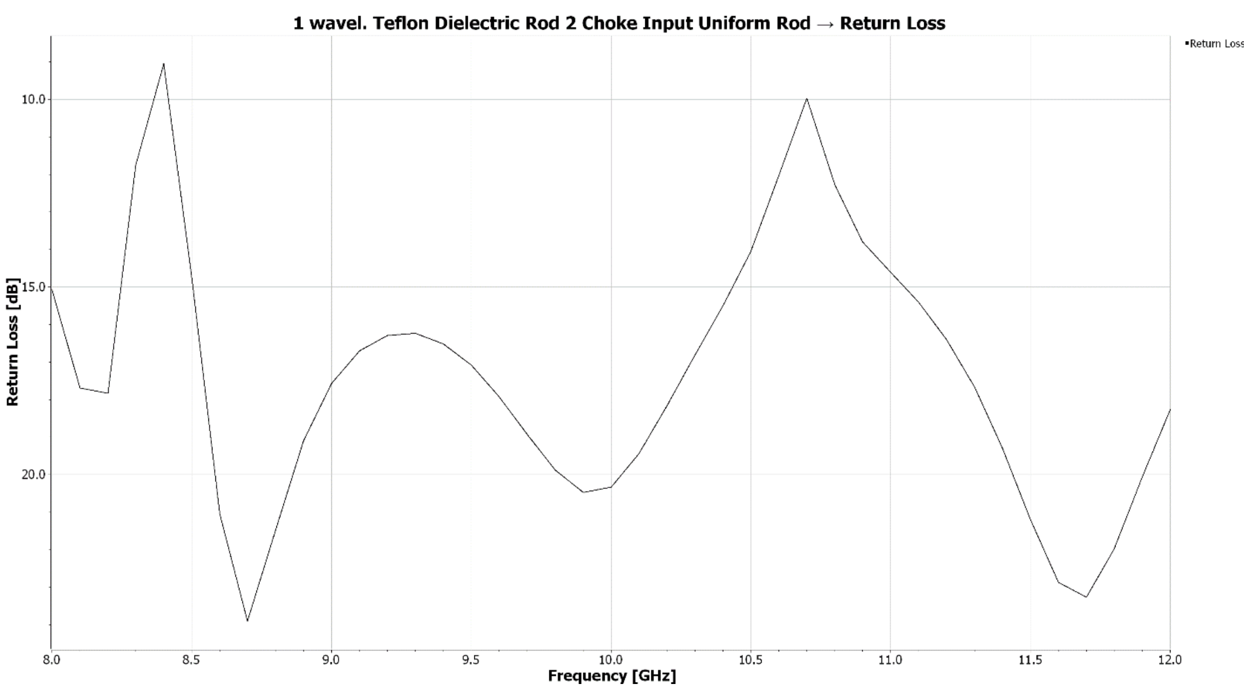

Figure 10-5.1.44 Return Loss of λ Long Dielectric Rod Fed by Circular Waveguide w/ 2 Chokes

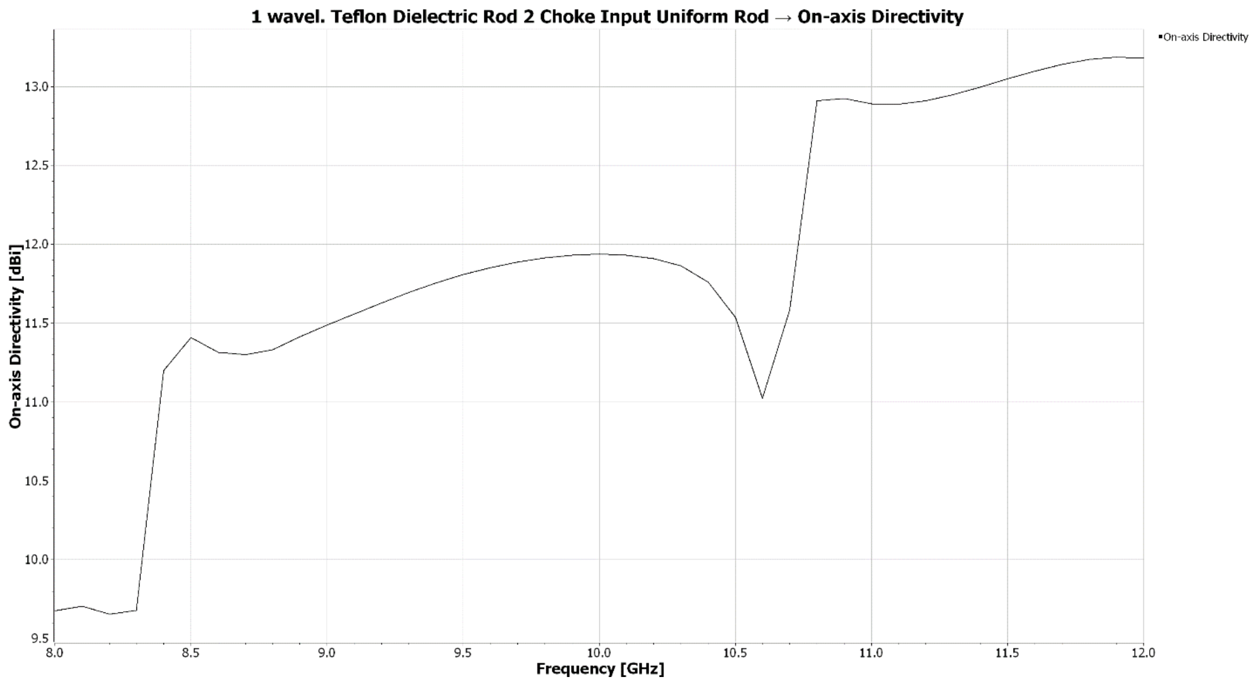

Figure 10-5.1.45 Directivity of λ Long Dielectric Rod Fed by Circular Waveguide w/ 2 Chokes

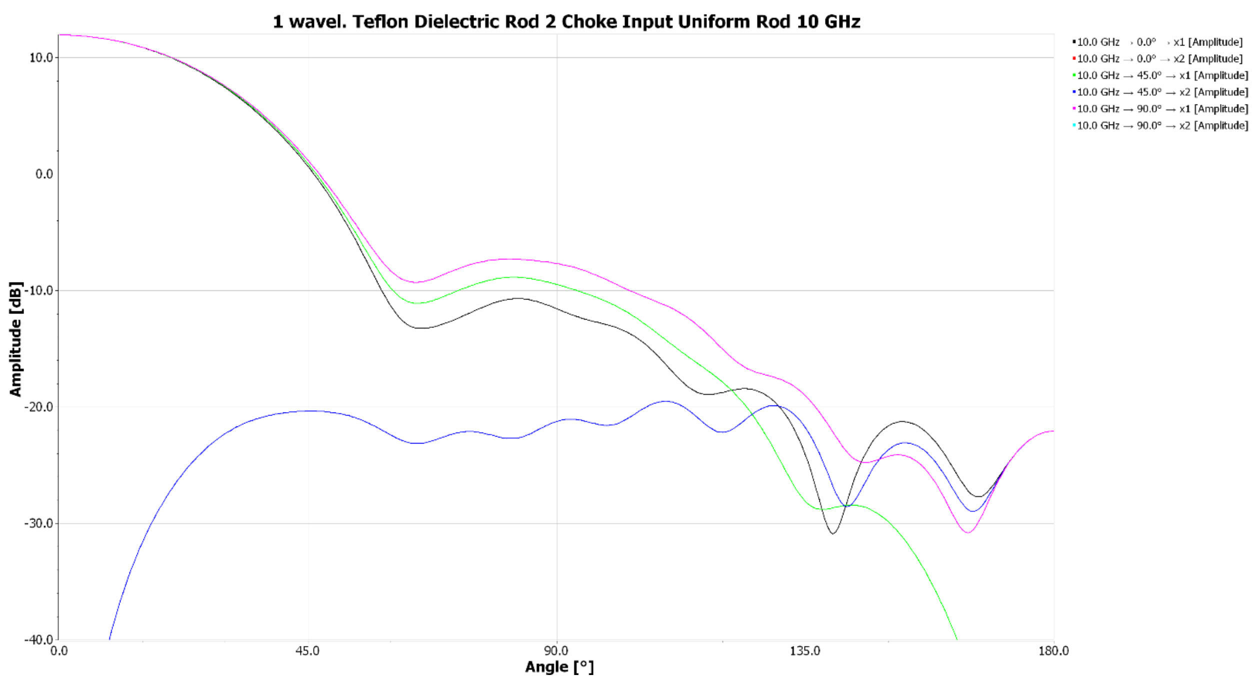

Figure 10-5.1.46 Center Frequency of λ Long Dielectric Rod Fed by Circular Waveguide w/ 2 Chokes

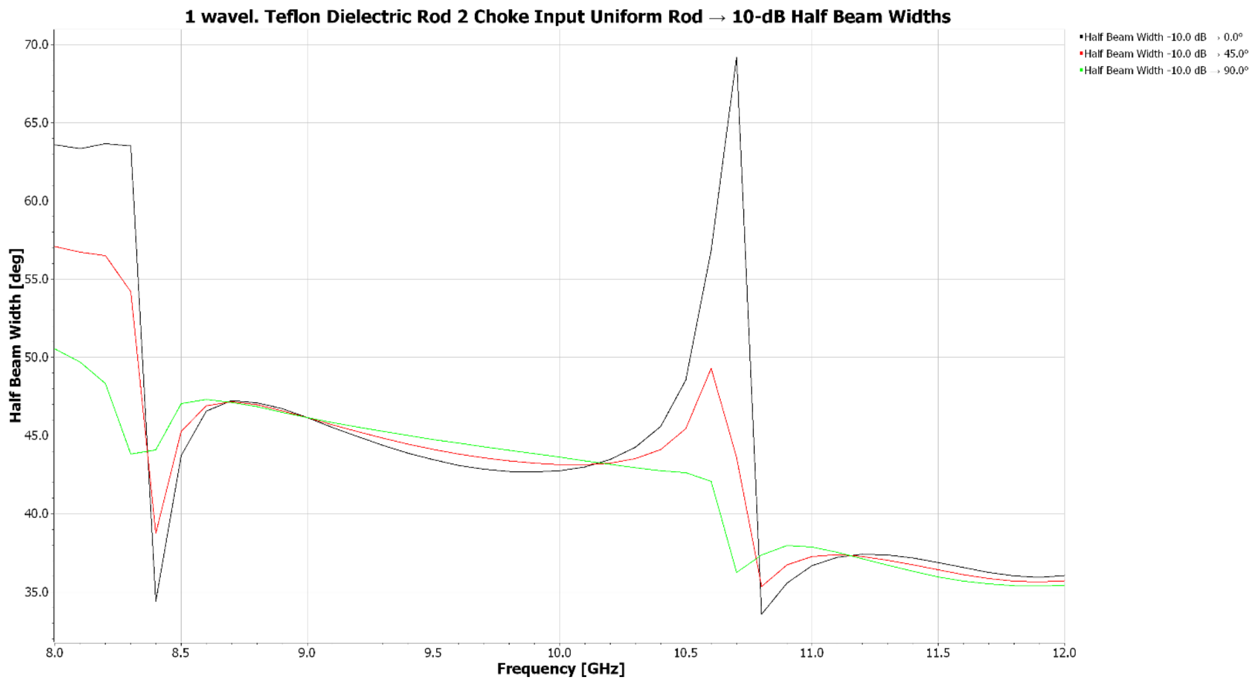

Figure 10-5.1.47 10-dB Half BW of λ Long Dielectric Rod Fed by Circular Waveguide w/ 2 Chokes

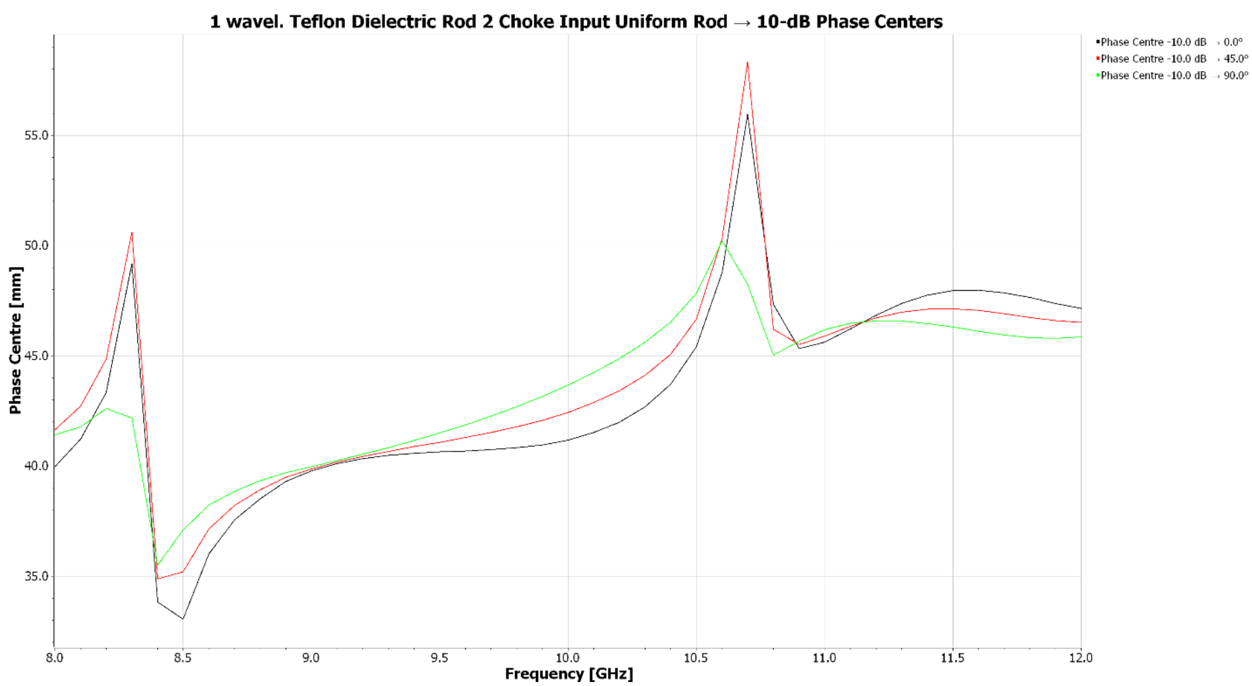

Figure 10-5.1.48 10-dB Phase Center of λ Long Dielectric Rod Fed by Circular Waveguide w/ 2 Chokes

12.2λ Long Dielectric Rod Antenna

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Figure 10-5.1.49 12.2λ Long Uniform Amplitude Dielectric Rod w/ end tapers Fed by Circular Waveguide w/ 2 Chokes

Section 10-3.3 Yagi-Uda programs has an example of a 50-element dipole antenna whose axial length is approximately 12.2λ. We compare this to a dielectric rod the same length where the diameter is nearly constant along the rod. The diameters on both ends of the dielectric rod are tapered. The input end starts with P = 1.2 and the rod end has been tapered to reduce the reflected wave. The clean response of this antenna illustrates that the wave amplitude along the rod is nearly uniform with the proper progressive phase to form a beam peak at zero.

The frequency response of the return loss of the long antenna (Figure 10-5.1.50) matches the response of the 5λ-(Figure 10-5.1.2) and the 2λ-(Figure 10-5.1.14) antenna. This shows that the bandwidth is independent of length similar to the long Yagi-Uda dipole element antennas. Figure 10-5.1.51 of peak directivity shows that the rod is slightly too large since its peak is below center frequency. The center frequency (10 GHz) directivity matches the Figure 10-2 curve of a theoretical traveling-wave endfire antenna.

The center frequency pattern (Figure 10-5.1.52) has the expected 10 dB first sidelobe of a uniform distribution traveling wave with a phase distribution for peak gain. The long antenna produces a Front/Back of about 27-dB. The depth of chokes could be tuned using CHAMP optimization to reduce the Front/Back to a lower level, but this was not done. Uniform diameter gave sufficient variables to produce a desired specified pattern through optimization, instead of peak gain using in this example to match section 10-3.3.

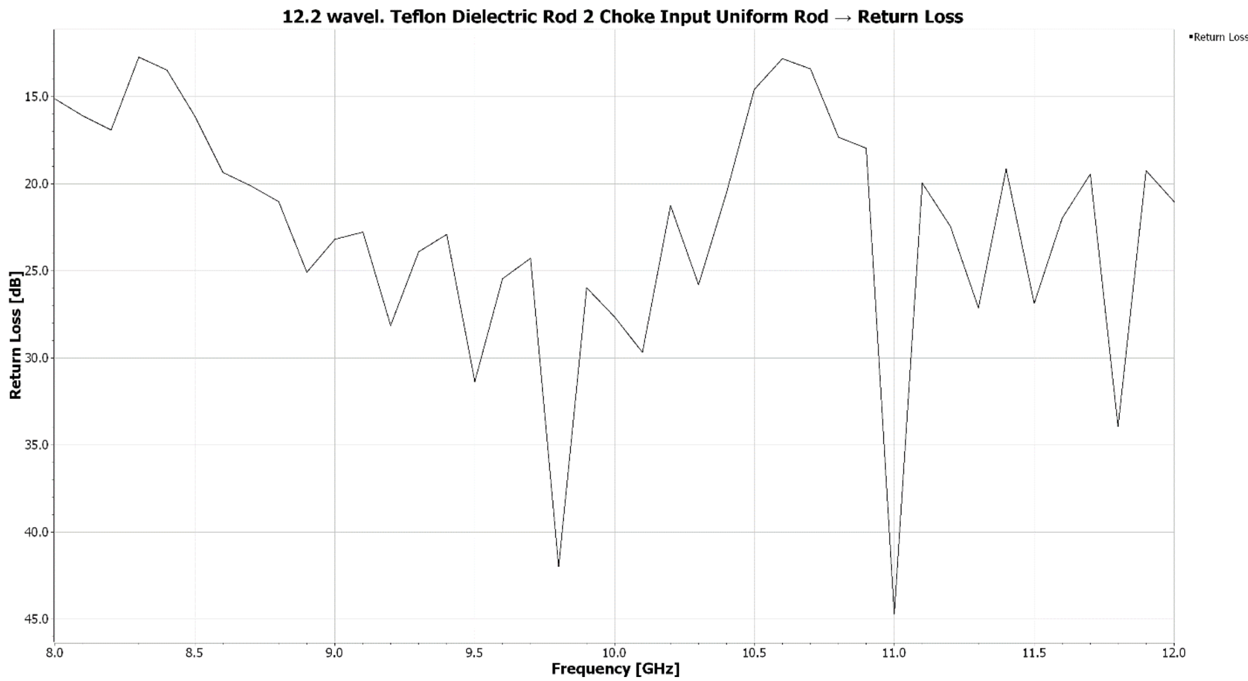

Figure 10-5.1.50 Return Loss of 12.2λ Long Uniform Amplitude Dielectric Rod w/ end tapers Fed by Circular Waveguide w/ 2 Chokes

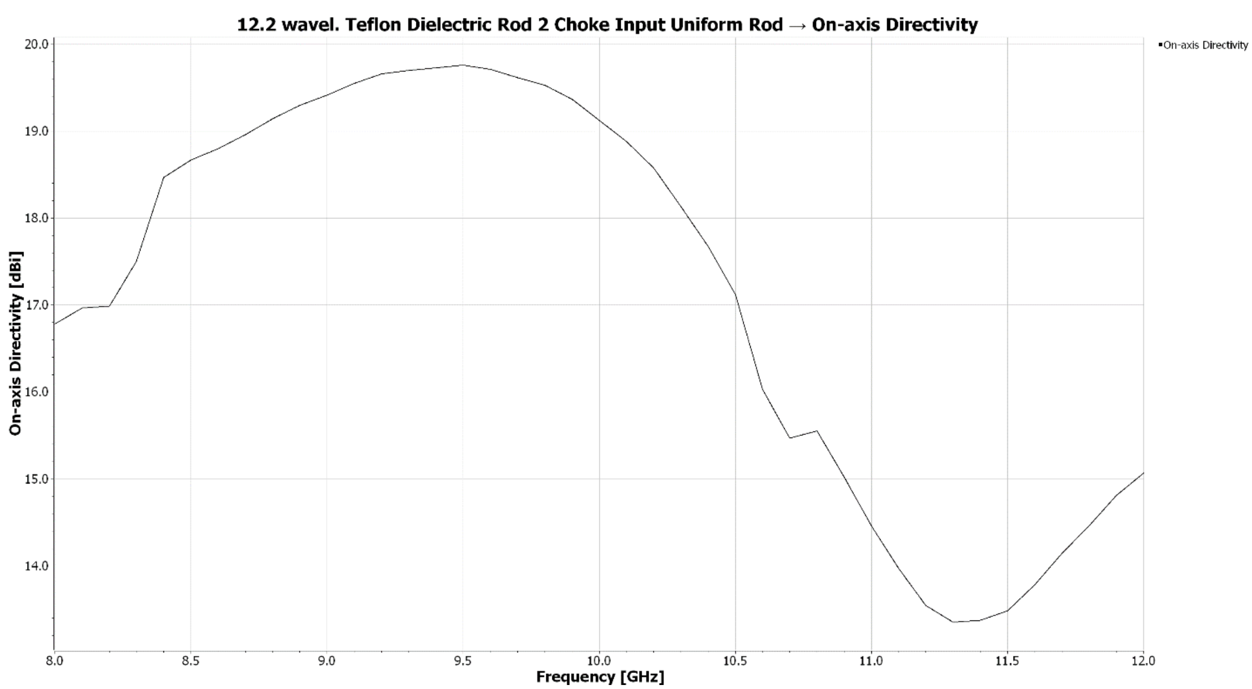

Figure 10-5.1.51 Directivity of 12.2λ Long Uniform Amplitude Dielectric Rod w/ end tapers Fed by Circular Waveguide w/ 2 Chokes

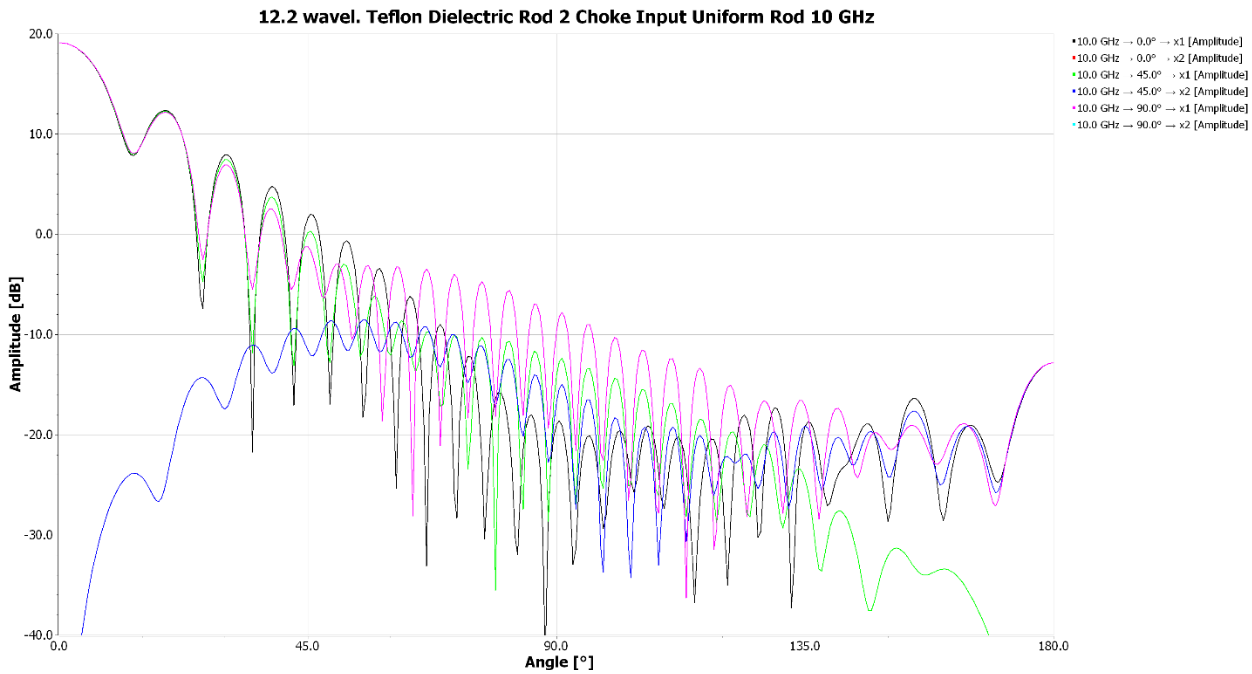

Figure 10-5.1.52 Center Frequency of 12.2λ Long Uniform Amplitude Dielectric Rod w/ end tapers Fed by Circular Waveguide w/ 2 Chokes

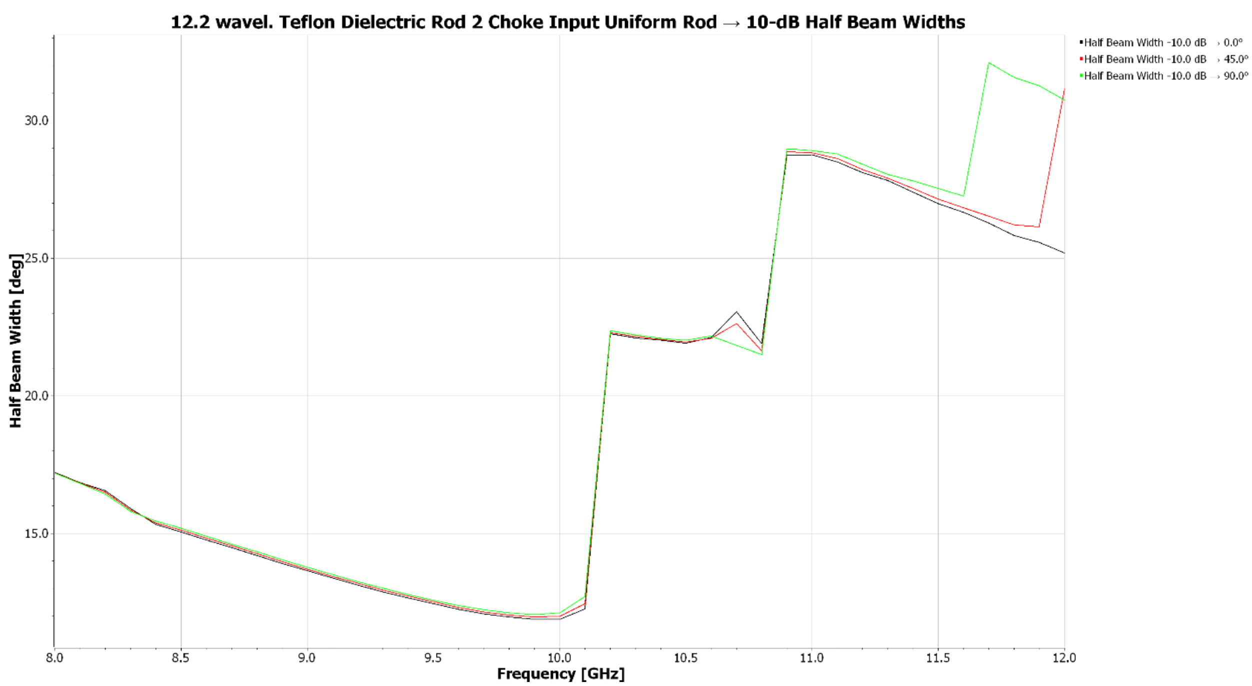

Figure 10-5.1.53 10-dB Half BW of 12.2λ Long Uniform Amplitude Dielectric Rod w/ end tapers Fed by Circular Waveguide w/ 2 Chokes

Phase center, Figure 10-5.1.54, 350 – 27 mm (mode matching aperture to start of dielectric rod) locates it near half way along the rod.

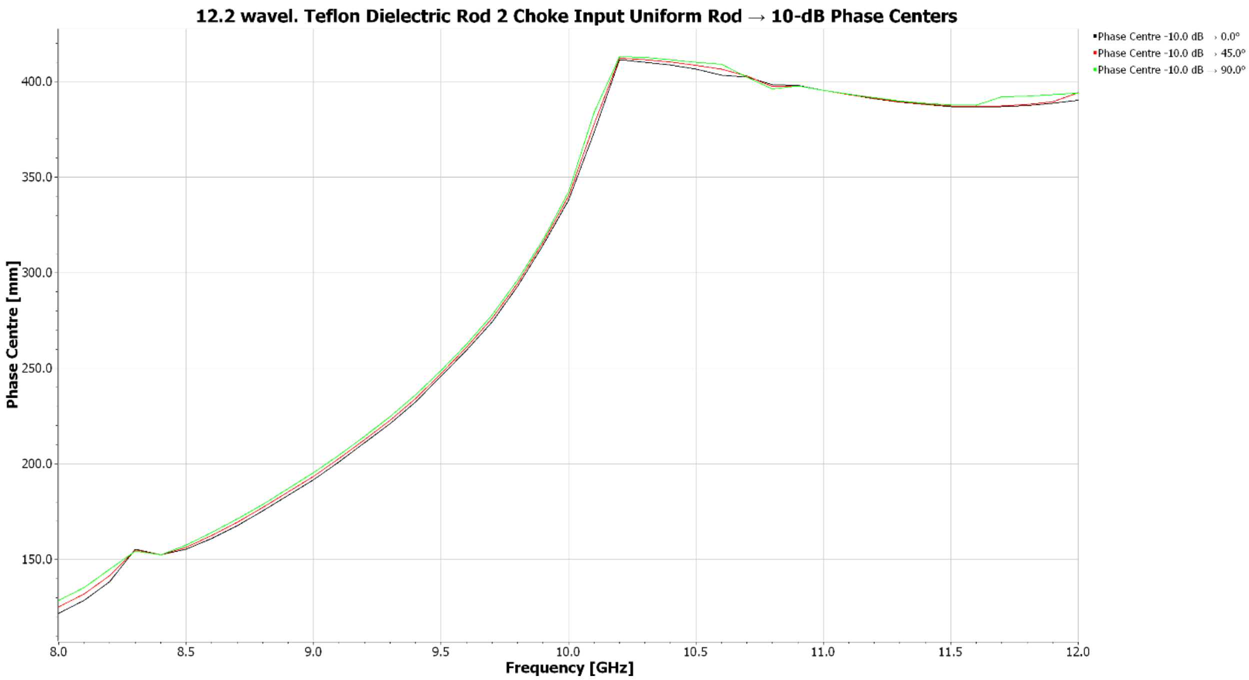

Figure 10-5.1.54 10-dB Phase Center of 12.2λ Long Uniform Amplitude Dielectric Rod w/ end tapers Fed by Circular Waveguide w/ 2 Chokes