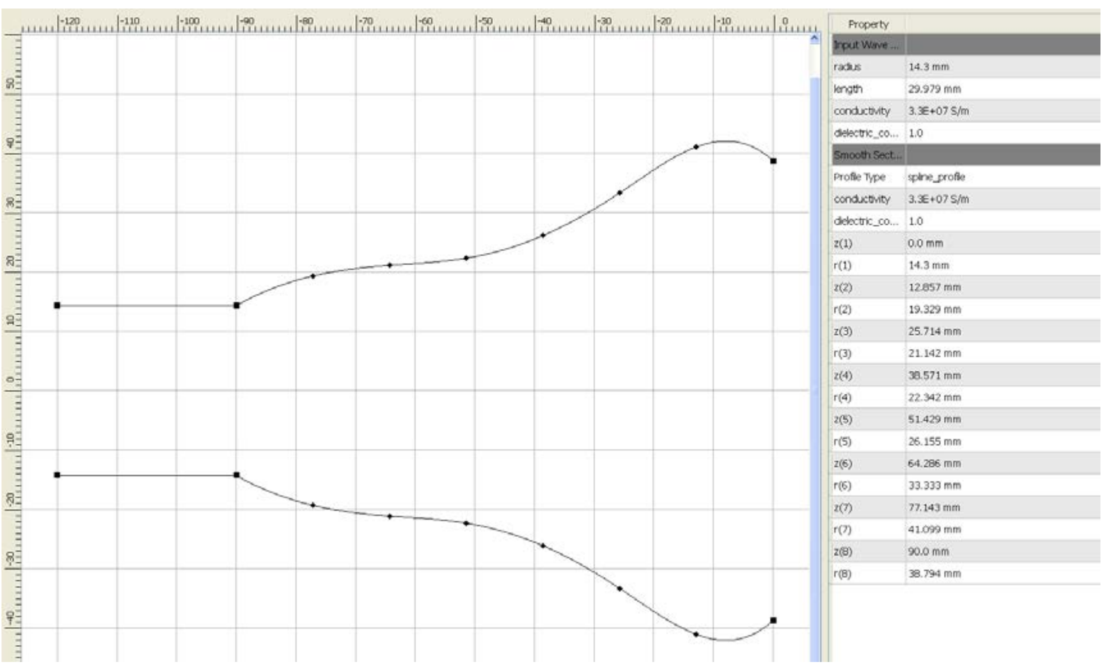
## 7-3.4 Spline Profile Horn for Corrugated Horn Performance [1]

A cubic spline of the radius versus length can generate the hybrid mode in the aperture of a smooth-wall circular horn. This will have the characteristics of a corrugated horn: equal beamwidths in all planes, low cross polarization in the diagonal plane, low sidelobes, and excellent return loss. This has a great advantage at high frequencies where the corrugations are difficult to machine and with careful design the horn may be formed on a mandrel that can be pulled from the horn.

We use a mode matching analysis program that includes optimization for design, such as, CHAMP (TICRA) to design these horns. One option is to use a spline for the horn profile and the knots of the spline become the optimization variables. Figure 1 shows the cross-section of a spline profile horn designed for a 54° -12-dB beamwidth at 10 GHz.

[1] Christophe Granet, et al, A Smooth-Walled Spline-Profile Horn as an Alternative to the Corrugated Horn for Wide Band Millimeter-Wave Applications, *IEEE AP-S Trans.*, vol. 54, No. 3, March 2004, pp. 848 – 854.




-12 dB beamwidth

The spline has 6 internal knots and we see it has a radius overshoot near the aperture. The cubic spline causes the overshoot with so few points although we see that the radius of the last internal knot is larger than the aperture radius. This means that power exists in higher order modes internal to the bell than propagate to the aperture. In Figure 2 we see a narrow frequency region in the return loss plot where these trapped modes cause poor performance. This horn has a 6 dB return loss at 8.6 GHz and the pattern is greatly distorted.

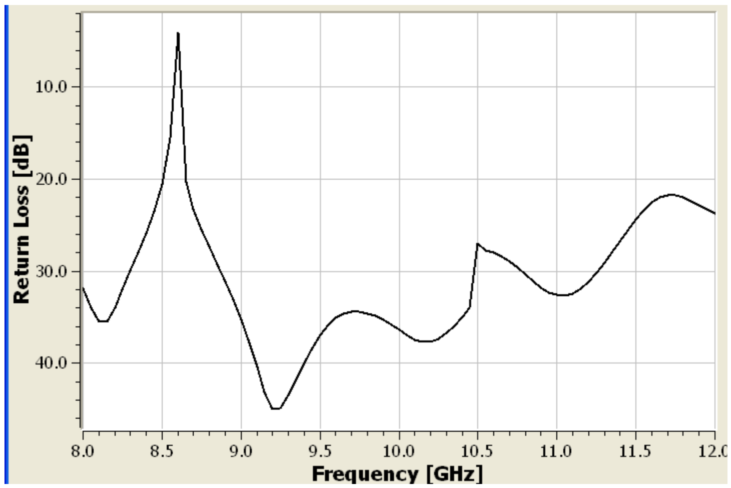



Figure 2  Trapped Mode Causes Narrowband Return Loss Resonance and Poor Performance

Four design goals were used in the optimization:

1) -12 dB beam point is 27° from 9.75 to 10.25 GHz: weight of 5.
2) The pattern variation with azimuth is zero at 25° from 9.75 to 10.25 GHz: weight of 1.
3) Maximum cross-polarization is -30 dB from 0° to 60° 9.0- to 11-GHz: weight of 1.
4) Return loss 30 or more 9.0- to 11-GHz: weight of 1.

Optimization is an art and by using various paths to the best design, we can obtain different designs. Figure 3 shows a second design for the same requirements, but this one monotonically increases radii along the spline. Eight internal knots were used and we use the differential radius as optimization variables.  At each knot the radius is the sum of previous radii and the optimization variables are restricted to be greater than zero. No trapped modes occur in the bell and the design response has no unusual patterns across a wide frequency range or narrow resonances in the return loss response. The second important characteristic is that this horn could be built on an electroform mandrel that can be pulled out of the bell.

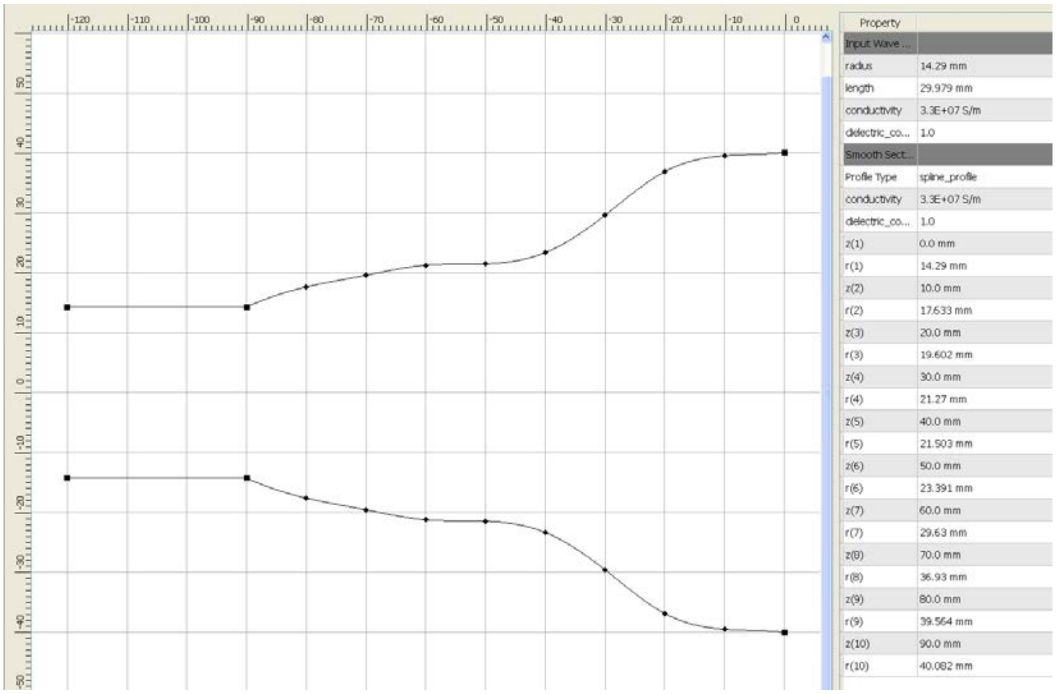



Figure 3 Cross section of spline horn with 8 knots with monotonic radial increase designed for 54° -12 dB beamwidth

A spline contour design produced a similar 22-dB gain horn as the combined axially and vertically directed corrugated horn given in section 7-3.3. Figure 4 shows its profile. The axially and radial corrugated horn has a length of about 5.7λ while this horn has a length of 6.67λ. This spline contour horn has an aperture radius of about 2.74λ while the axially and radial corrugated horn designs have a radius 2.69λ for 6 axial slots and 2.37λ for 8 axial slots. The 6 axial slots design has a similar vestigial to the lobe as the spline contour horn while the 8 axial slot design has a more uniform aperture distribution with a smaller aperture than the 6 axial slot design that produces the higher vestigial lobe. The optimization of the axial slots was able to produce a design with lower diagonal plane cross polarization because less degrees of freedom were needed to produce hybrid mode than in the spline contour design. The phase center lies near the mouth of the waveguide and has about 1.9λ astigmatism that is still insignificant if the antenna was used as a feed for an effective shallow reflector. Although the horn performance does not match the combined axially and vertically directed corrugated horn, its performance is remarkable and much simpler to produce.

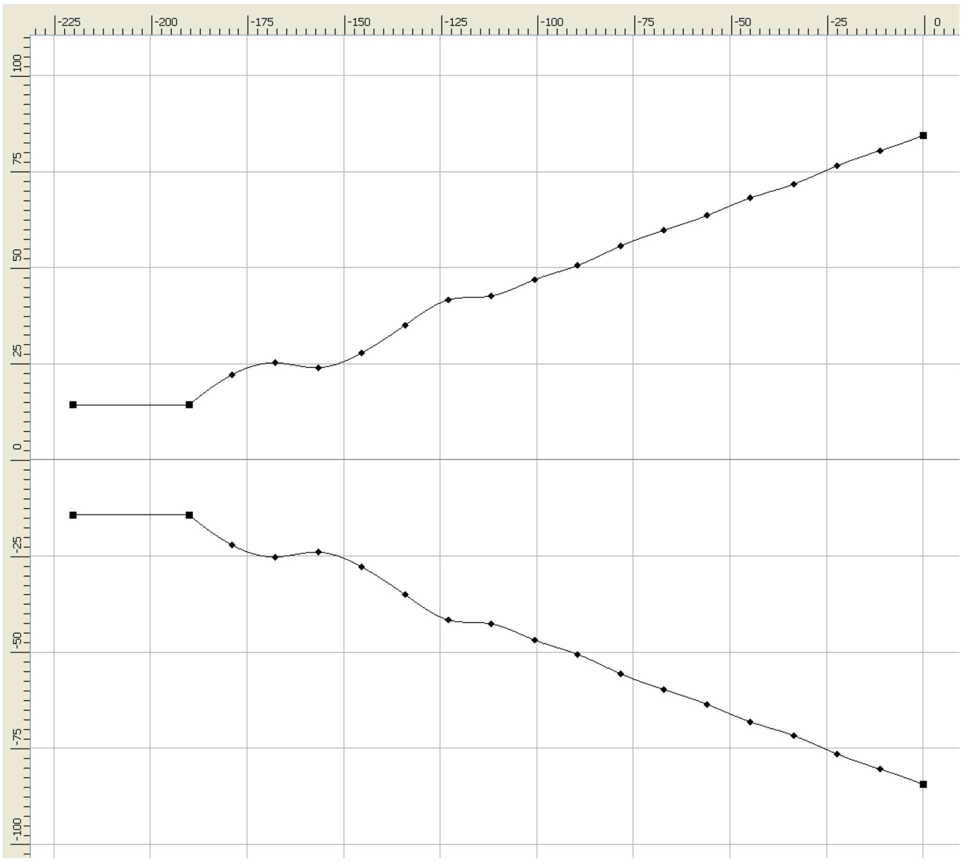



Figure 4 Spline Contour Horn Designed for 22 dB Gain with monotonic increasing radius with 6.67λ Axial Length

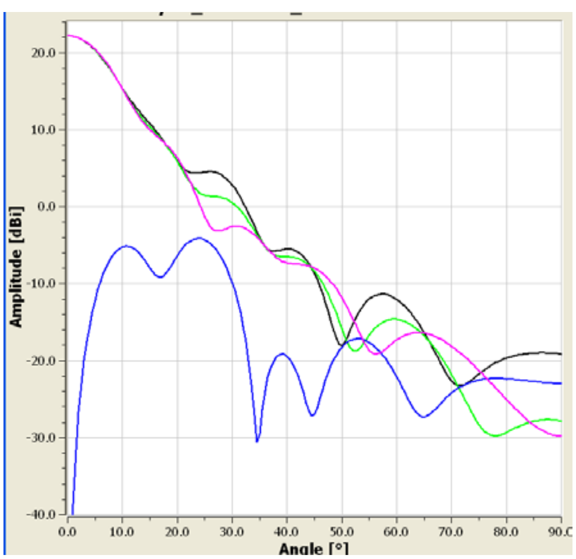



Figure 5 Center Frequency Response of Short Spline Contour Horn for 22 dB Gain

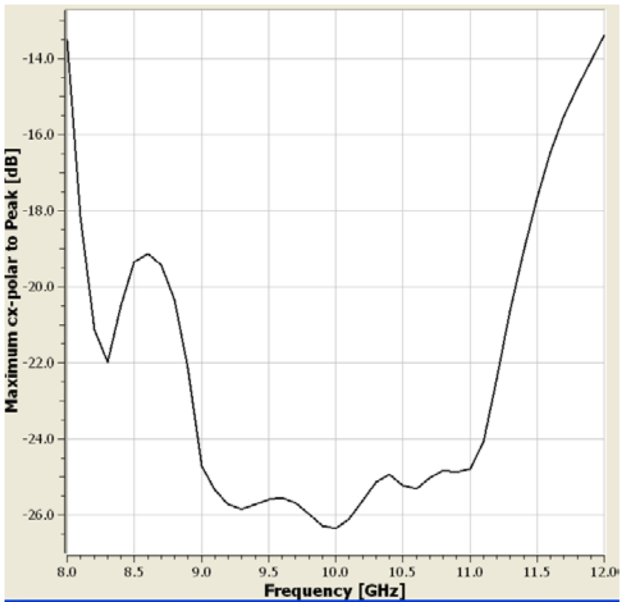



Figure 6 Maximum Cross Polarization Response of Short Spline Horn for 22 dB