SEPTUM FEED OPTIMIZATION FOR PARABOLIC DISHES WITH A FOCAL DISTANCE f/D IN THE RANGE OF 0.4.

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For the simplicity of its design and performance the septum polarizer feed is one of the best options available for illuminating a dish with an f/D of around 0.4, but with such f/D the dish has a total subtended aperture angle of about 130 deg., while a typical septum feed with choke-ring has a total beam-width at – 10 dB of about 144 deg. on the E and H plane, and 160 deg. at a 45 deg. pattern cut (Ref. 1), so that the main lobe itself is generating a good amount of spillover toward the ground, in addition to the spillover generated by side and back lobes, with an equivalent noise temperature of 25 deg. K in the best case, and comparable to the one produced by a good LNA for 1296 MHz (VK3UM EME Calculator).

By considering that spillover to the ground is usually the main contributor to the antenna noise temperature, to get an increase in the system's G/T I have decided to test a Flared Horn, as an adaptor, to be combined with a square septum polarizer with the purpose of shaping the main lobe to attain a total av. nominal beam-width of 120 deg. at – 10 dB. Flared horns have a complex behavior, so that their physical dimensions must be carefully selected. They may be adjusted to the desired f/D by varying the horn aperture size. Design data have been derived from classic textbooks and other papers in the References.

A dimensional cut of this Horn Adaptor is shown in Fig. 1. Practical waveguides have an aperture d larger than the operating half wavelength, and less than 1 wavelength to suppress higher order modes, so that the flare aperture of the horn should be less than 1 lambda to prevent the generation of higher order modes. If the flare angle is small enough, the higher mode field components are also small enough when compared with the dominant mode. Large flare angles show loss in gain, broadening of the radiation pattern and an increase of sidelobe levels in the 45 deg. pattern cuts (Ref. 2). A small flare half angle of 10 deg. has been chosen to provide a soft transition from the septum waveguide to the free space.

To verify that the formula given by A.W. Love (Ref. 2) will closely match the values of ½ beam-width measured on a septum polarizer with a square aperture of 150 x 150 mm.:

Beam-width at -10 dB = 101 x Lambda / d = 101 x 0.231/0.150 = 155.54 deg.

½ Beam-width = 77.77 deg. (av. measured values: 72 deg. on the E and H plane, 80 deg. at a 45 deg. pattern cut).

To get a nominal av. value for ½ beam-width B of 60 deg. at – 10 dB when illuminating a dish with f/D = 0.4, and a subtended aperture angle of 130 deg.:

d = 101 Lambda / 2B = 101 x 0.231 / 120 = 194 mm. (horn aperture).

With an ½ beam-width of 60 deg. at -10 dB we are under illuminating the last 5 deg. sector at the dish edge by putting the beam-width 12.2 dB down at 65 deg., by considering its low contribution to the dish gain vs. the antenna temperature.

If, as in Fig. 2:

θ = 65 deg. = ½ subtended aperture angle of the dish at - X dB.
θ_1 = 60 deg. = ½ subtended aperture angle of the dish at – 10 dB.

Since the beam ratio is proportional to the square root of the dB ratio (Ref. 4):

$\theta/\theta_1 = \sqrt{XdB/10}$; X dB = $10\,(\frac{\theta}{\theta_1})^2$ = 11.73 dB.

+ calculated increase in $\frac{1}{(R)2}\ taper\ loss =$ 0.47 dB = 12.20 dB.

By giving a half flare angle α of 10 deg. to provide a soft transition from the septum waveguide to the free space, and to limit the side lobes in the 45 deg. pattern cuts:

β = 80 deg. ; cos. β= 22 / h ; 0.173 = 22 / h ; h = 127 mm.

sin β= l / h ; 0.984 = l / 127 ; l = 125 mm.

As you can see, physical dimensions are related to the dish f/D and size of the septum polarizer aperture, so that my calculation is valid for an f/D of around 0.4, and for a septum waveguide with an aperture of 150 x 150 mm.

By testing this flared horn on my 5 m. dish, to be combined with a square septum polarizer with an aperture of 150 x 150 mm., it has been providing about the same performance of a choke-ring, with an additional sensible reduction in spillover, clean main beam pattern with the 1st sidelobes well below -18 dB over a Sy normalized linear plot, same or better Sy readings, and by offering a minimum feed blockage on small dishes. It is also easy to build, with a low weight and wind resistance.

It has been made in one piece from a folded sheet of aluminum cal. # 20. A flange is providing the overlap to insert the Horn over the septum. The junction between the septum and the Horn has to be kept tight.

Despite its axial symmetry, the calculated beam-widths of this horn in the principal planes are unequal (Ref. 4). The symmetry could be improved by adjusting the height d of the flare aperture on the E or H plane, with perhaps an additional G/T improvement of a few tenths of a dB.

The field in the flare changes from a plane wave front to a curved one, which is desirable for feeding a parabolic dish (Ref. 2). The measured displacement of the phase center outside the horn aperture has been 35 mm., and it has to be taken into account when adjusting the feed focal distance.

References:

(1) Paul Wade - Enhancing the OK1DFC Square Septum Feed with a Choke Ring. www.w1ghz.org
(2) A.W. Love – Electromagnetic Horn Antennas. CH 14-7, 14-23.
(3) Technical Report #5 – The Crawford Hill VHF Club. Page 2.
(4) H. Jasik – Antenna Engineering Handbook. CH. 10.