10 & 24 GHz Dual-band Feedhorn Alignment

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The Dual-band feed for 10 & 24 GHz can provide excellent performance with common offset dishes but requires careful setup to get it right. The most important parts are to get the phase center of the feedhorn exactly at the dish focus, and to aim the horn correctly at the dish.

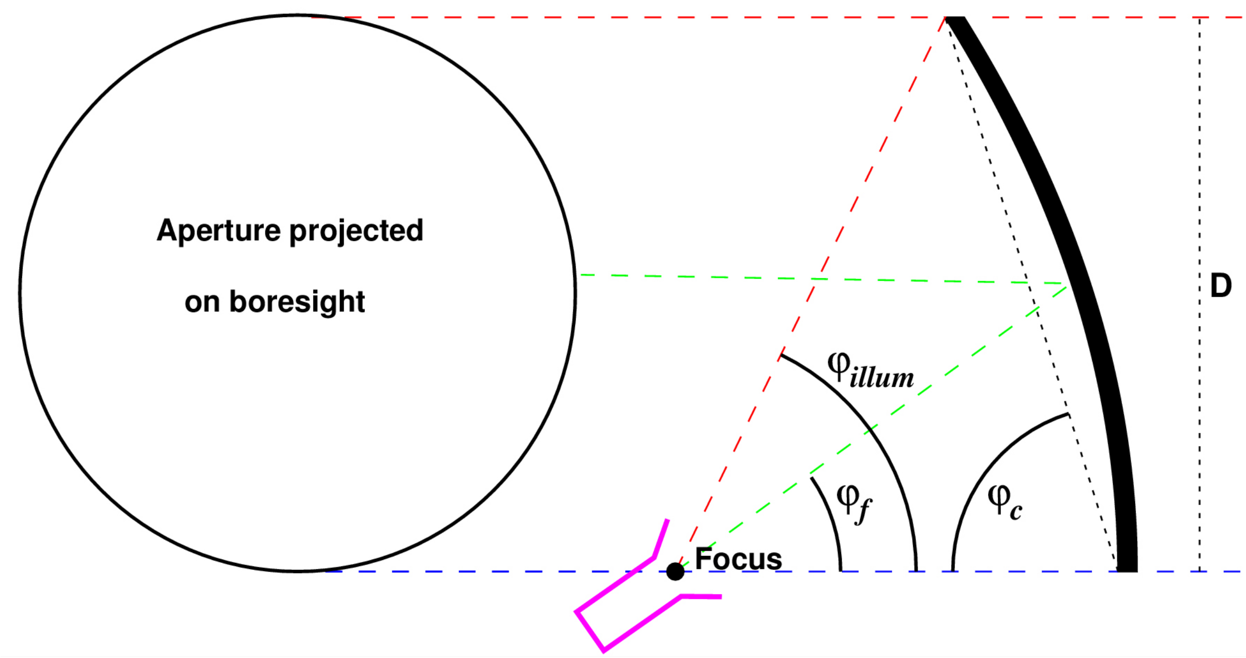

Figure 1 – Offset dish sketch

Most common offset dishes are designed so that the bottom of the dish is level with the focus when pointed at the horizon, as shown in Figure 1. The dish focal length f can be calculated using the HDL_ANT2_WinForms[1] program (thanks to W3SZ). I recommend using the string method to locate the focus in space – the program will calculate string lengths, from the top and bottom rim to the focus. Some of the available offset dishes are tabulated at http://w1ghz.org/antbook/app-5a.pdf

Figure 2 – Finding dish focus using string method

The illumination angle $\emptyset_{illum}$, the angle that the feedhorn must illuminate, is:

$$\emptyset_{illum} = \tan^{-1}\left(\frac{D}{2f}\right)$$

The feedhorn should be aimed at the center of the projected circular aperture, according to Milligan[2], at a feed angle $\emptyset_f$ calculated by:

$$\emptyset_f = 2 \cdot \tan^{-1}\left(\frac{D}{4f}\right)$$

You will probably find that this is close to the center of the dish -- for small dishes it isn't that critical and I just eyeball the center of the dish.

The phase center is quite a distance inside the dual-band feedhorn, 23.6 mm at 24 GHz, making it difficult to see the exact location and place it right at the focus.

For 10 GHz only, just eyeball the phase center location with the string and get it on the air. Don't fret about fancy mechanics, zip-ties and clamps are fine (see Figure 5) – after you make some contacts and operate a few times, you will probably want to make some changes anyway. A small error will only cause a very small decrease in gain. Find the proper elevation tilt angle by peaking on a distant signal to set your tilt indicator. I use a simple RV tilt indicator stuck to the side of the rig when roving.

The 24 GHz port may be covered, or left open for water to drain out. 10 GHz energy will not propagate through the 24 GHz waveguide.

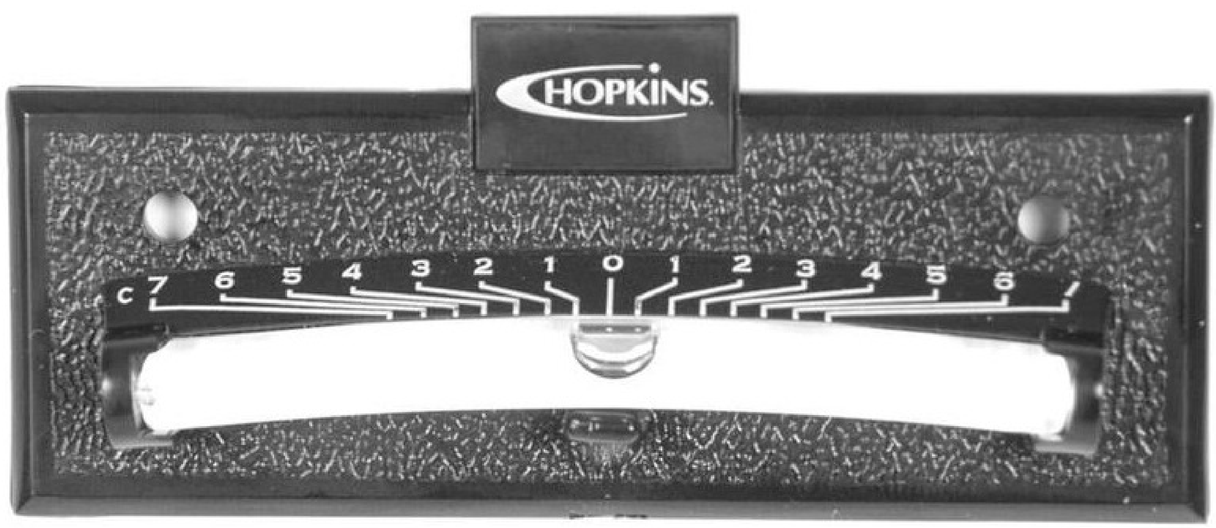

Figure 3 – Simple RV tilt indicator for quick elevation alignment of offset dish

Two-band Adjustment

At 24 GHz, where the dish is much sharper, the real value of the dual-band feed is being able to line up the dish on 10 GHz so that you have a chance of finding a weak 24 GHz signal. The beamwidth on 24 GHz is only about 40% of the beamwidth at 10 GHz – the 18-inch dish in Figure 2 has a beamwidth of about 4° at 10 GHz but only about 1.7° at 24 GHz, so you must be within < 2 dB of the peak at 10 GHz, in both azimuth and elevation, if you hope to find a very weak signal on 24 GHz. You can't do that with an S-meter or by ear. Signals are typically much stronger on 10 GHz, so you might not expect to have to find a weak signal on 24 GHz. I've heard folks claiming they have no trouble finding signals with a big, sharp dish; perhaps they need to try weaker signals.

With the dual-band feed, if the phase center is not at the focus, the elevation tilt will change, and be different on the two bands (see w1ghz.org for details[3]). If the phase center is too close to the dish, the beam will be tilted upward, while too far away will tilt the beam downward, with different tilt angles on the two bands and more tilt on the higher band. To get the phase center at the focus, I recalculate the string lengths to align at the center of the horn aperture, as shown in Figure 4.

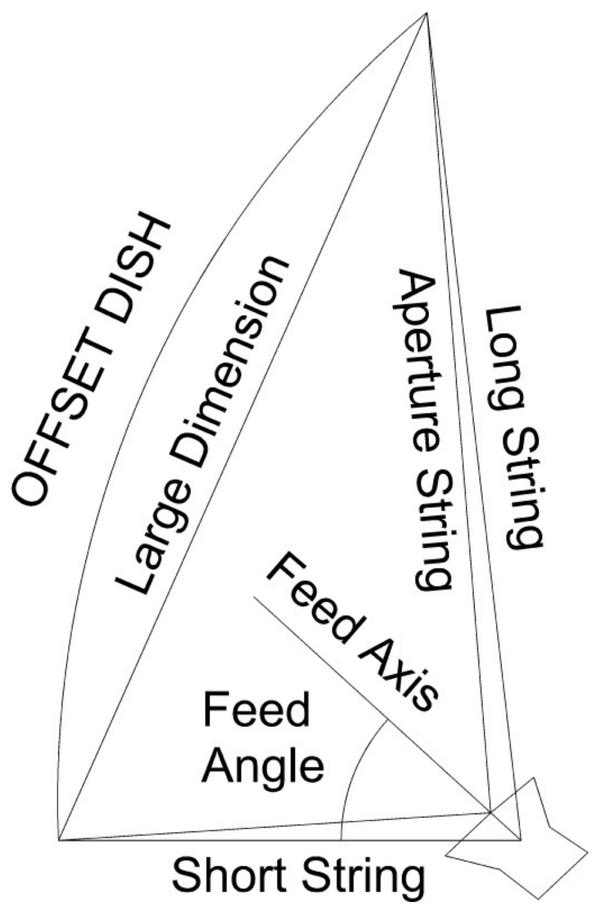

Figure 4 – String lengths to align with center of aperture

The difference between the phase center and aperture, ΔPC = 23.6 mm for the dual-band feedhorn, is along the feed axis, at an angle φ_f from the short string. The center of the aperture is then:

$\Delta x = \Delta PC \sin \varphi_f$ toward the bottom of the dish and $\Delta y = \Delta PC \cos \varphi_f$ in the vertical direction.

The new aperture string dimensions are easily calculated using the triangles formed by the original strings and ΔPC:

Short aperture string = $\sqrt{ShortString^2 - \Delta PC^2}$

Long aperture string = $\sqrt{LongString^2 - \Delta PC^2}$

Figure 5 – Using modified string lengths to align feed at center of aperture

Checking the Alignment

If the dish is properly aligned, it will peak at the same heading on both bands.

This requires a properly long antenna range, several times the Rayleigh distance, with no ground reflection, since ground reflection will likely be different on the two bands. A range with one end significantly elevated will move ground reflections well out of the beam -- perhaps with the sources placed on a tower. I set up the slant range in Figure 6, with the system on the deck about 15 feet above ground level and the sources on the second floor of the barn about 50 feet lower.

Figure 6 – Slant antenna range for testing tilt alignment on the two bands

Peaking the dish for this test requires high resolution of signal strength, to fractions of a dB - a tiny S-meter won't do. I use the sun noise meter at the lower right in the photo, which displays a range of 5 dB on the large meter from a defunct HP power meter. Once it is peaked, I measure the elevation tilt with a digital level; the tilt is where the two bands are more likely to differ.

A better test is to peak on sun noise -- a decent system should see several dB of sun noise. I measure at the transverter IF output with the sun noise meter. It has a wide bandwidth, ~1 MHz, and a slow meter time constant to give stable readings and allow peaking. See w1ghz.org for more.

Sun noise may also be measured with with a computer, if you don't have a dedicated sun noise meter. Bob Atkins, KA1GT, has a good description[4] using **WSJT-X** or **Spectravue** software for sun noise measurement.

Figure 7 – Measuring sun noise and calibrating elevation tilt

Figure 8 – Feed shadow marked on dish

An additional advantage to sun noise is that the difference between measured elevation tilt on the digital level and the known sun elevation tells you exactly how far to tilt the offset dish to be on the horizon.

I also mark the feed shadow on the reflector with a Sharpie, for quick alignment with the sun at a new location. Of course, it will be cloudy when I need it.

Summary

With the two bands aligned together, you will make more contacts with less frustration.

<u>Notes:</u>

1. http:/w1ghz.org/software/HDL_ANT2_WinForms.zip
2. Thomas A.Milligan, *Modern Antenna Design, Second Edition*, IEEE Press, 2005, p.400.
3. http://w1ghz.org/antbook/conf/Parabolic_Dish_Focus_Zoom_and_Tilt.pdf
4. http://www.bobatkins.com/radio/sun_noise_measurement.htm