Dual-Band 10/24 GHz Feedhorns for Shallow Dishes

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Introduction

While there have been many dual-band feedhorn designs published over the last several years [1,2,3,4,] few of these designs have been optimized for use on shallow dishes. With the abundance of offset feed dishes with f/d ratios of .6 to .7 that are now available it becomes interesting to try to design a dual-band feed that is optimized for these dishes. Over the last year we've developed a series of 10/24 GHz dual band feeds optimized for offset feed reflectors with f/d ratios of .7.

Both of our dual band radios use the feed described here to great advantage. We are able to line up our dishes on 10 GHz where signal levels are stronger and then switch to 24 GHz to make a QSO. Our experience is that no repositioning of the dish is required on 24 GHz once the initial peaking is done on 10 GHz. The dual band feed has made it much easier to complete QSOs on 24 GHz.

Design Ideas

We both started by using the W5ZN dual band feed on our radios. While this feed is a fairly good match to dishes with f/d ratios of around 0.4 it isn't a good match to offset dishes that typically have higher f/d ratios. AA6IW modified this feed for improved performance on 10 GHz [4] while AD6FP performed modifications to improve the 24 GHz performance. The 10 GHz improvement was the addition of "Chaparral 11 GHz superfeed" on the end of the W5ZN feedhorn. The 24 GHz improvement was to change from a step horn as in the W5ZN feed to a "stepless" or W2IMU style horn for the 24 GHz section.

The obvious approach was to combine the modifications that we had each done into a single dual band feed. The first combination put a "Chaparral 11 GHz Superfeed" on the 24 GHz IMU horn. The performance of this combination is very good on 24 GHz due to the extremely clean pattern of the IMU dual mode section. On 10 GHz it is still sub-optimal, the pattern is a bit too broad to efficiently illuminate a .7 f/d dish. The natural path to follow was to look for a higher gain section to add to the end of the 24 GHz IMU feed. Two 10 GHz gain sections were simulated and built: 1) a conical horn sized for a .7 f/d dish and 2) a surplus 11 GHz corrugated horn designed for a .7 f/d dish. The surplus corrugated horn was made by Chaparral.

The names used in the rest of the paper to refer to the various feedhorns are:

- **W5ZN**: Joels original dual band feedhorn [2]
- **W5ZN/Chaparral**: the W5ZN feedhorn with a Chaparral 11 GHz Superfeed on the end
- **IMU**: a 24 GHz W2IMU feed for a .7 f/d dish with a 10 GHz probe in the drift section
- **IMU/Chaparral**: the 24 GHz IMU feed with a Chaparral 11 GHz Superfeed on the end.
- **IMU/conical**: the 24 GHz IMU feed for a .7 f/d, 10 GHz conical horn on the end
- **IMU/corrugated**: the 24 GHz IMU feed for a .7 f/d, 10 GHz corrugated horn on the end

The goal was to achieve the same beamwidth on both 10 and 24 GHz suitable to illuminate a .7 f/d dish while having the 10 and 24 GHz phase centers reasonably close to each other.

Simulation Tools

Two commercial 3D field simulators were used to verify and improve the operation of the succession of feedhorns. AA6IW used CST Microwave Studio to model and simulate the feedhorns and AD6FP independently used Agilent HFSS to verify the results. CST uses a time domain algorithm while HFSS uses a frequency domain algorithm. For the feedhorn simulations we found excellent agreement between the two simulators.

Simulation Results

Simulation results for the two best designs will be presented: IMU/conical and IMU/corrugated. The other designs were also simulated and constructed but since they don't perform as well we won't cover them in detail. The basic IMU/conical design is shown in Figure 1 and the IMU/corrugated version is shown in Figure 2. Dimensions for the IMU/corrugated version are the same except for the 10 GHz corrugated horn section which are omitted since it is a commercial surplus part. Since the IMU/conical feedhorn performs almost as well as the IMU/corrugated and it is easy to build from readily available material we will focus on that design.

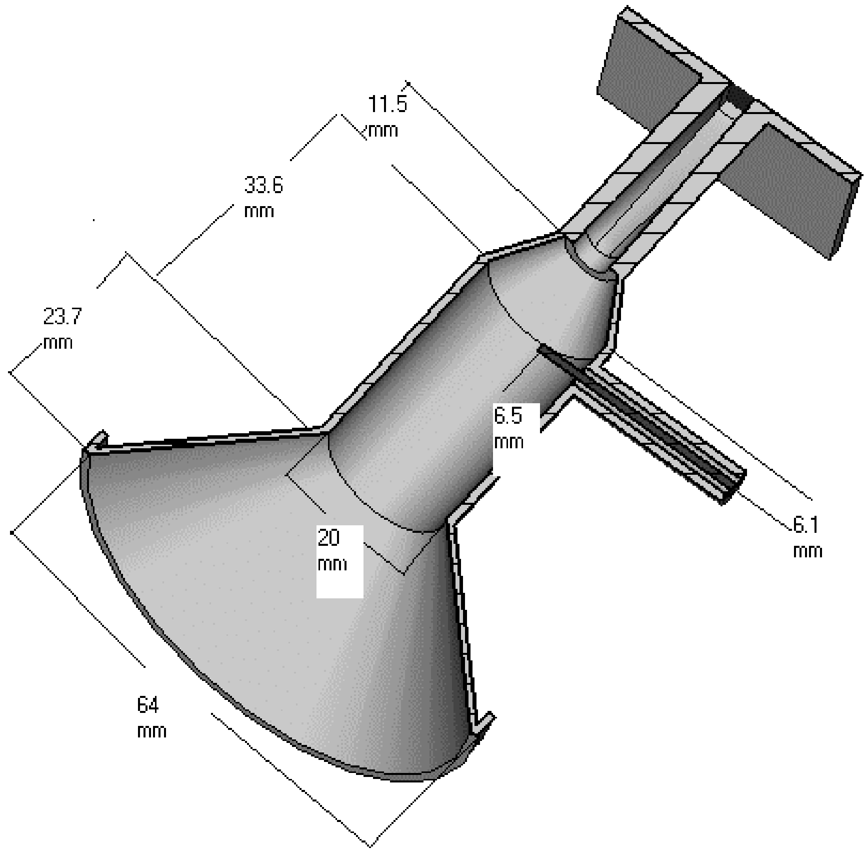


Figure 1 – IMU/conical cutaway view and dimensions

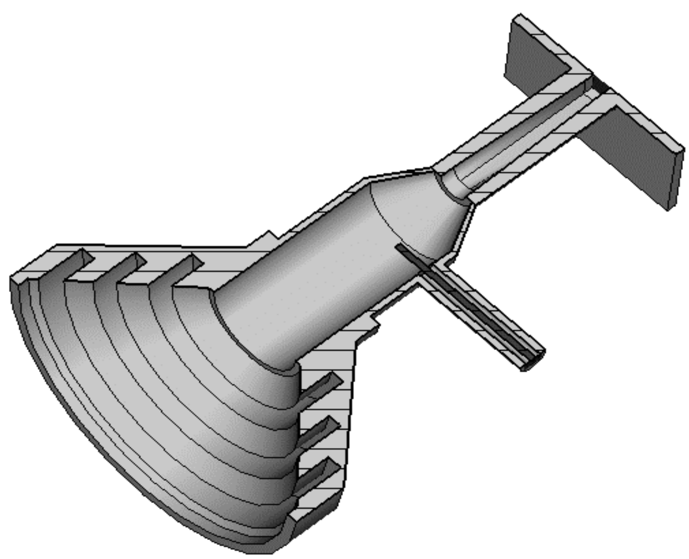


Figure 2 – IMU/corrugated cutaway view

The simulation results include far-field E and H plane plots for each band and S(1,1) (vswr) and S(2,1) (port-to-port isolation). Figure 3 shows the 10 GHz E and H plane plots for the IMU/conical feed. As expected there is some asymmetry between the E and H planes, this is typical for conical horns.

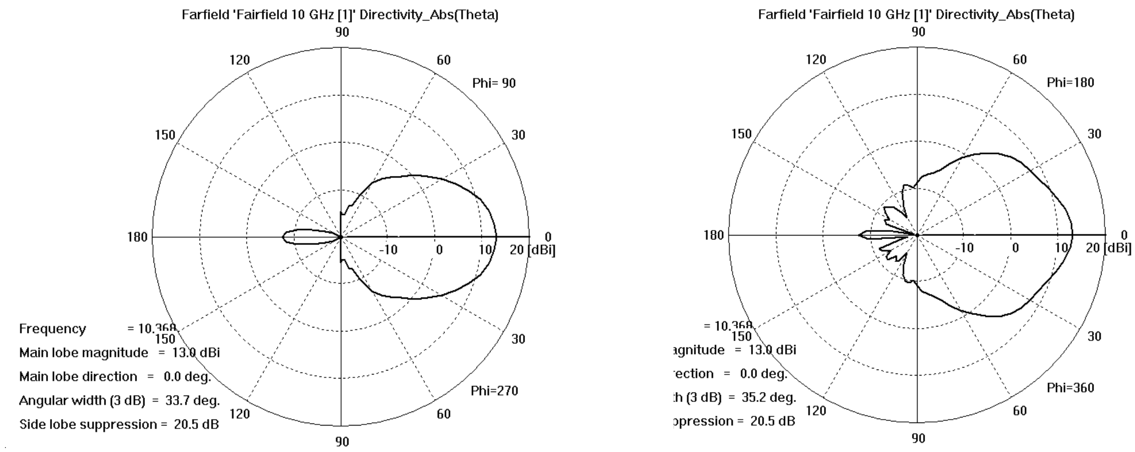


Figure 3 – E and H plane far-field, 10 GHz IMU/conical

Comparing this to the corrugated 10 GHz horn as shown in Figure 4 we see that the corrugated horn has a more symmetrical E and H plane although still not perfect.

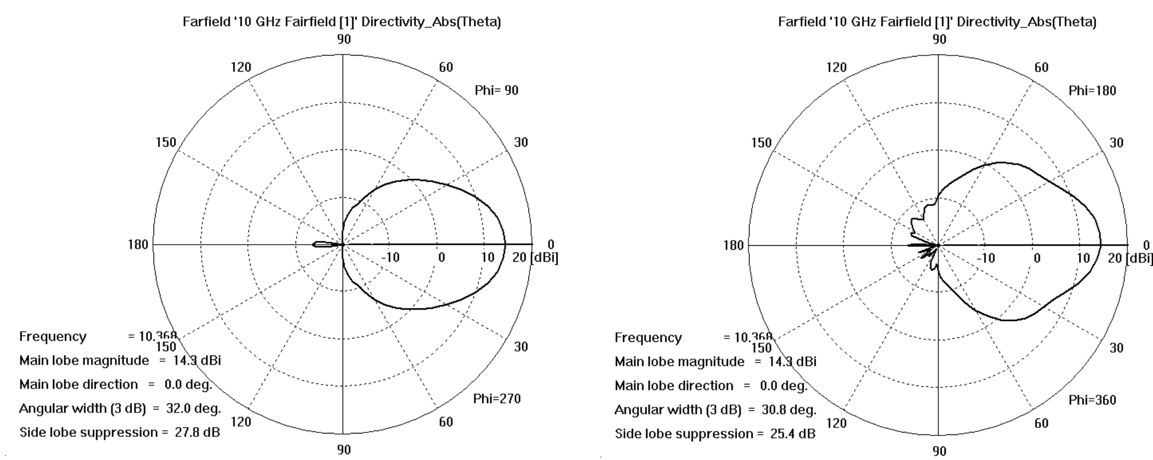


Figure 4 – E and H plane far-field, 10 GHz IMU/corrugated

Figures 5 and 6 show the E and H planes at 24 GHz for each feed. The performance of the IMU dual mode is quite evident on the IMU/corrugated feed, the patterns are very clean and symmetrical between the E and H planes. The 10 GHz horn does disturb the 24

GHz pattern a bit on the IMU/conical feed, this is also noticeable later in the sun noise measurements.

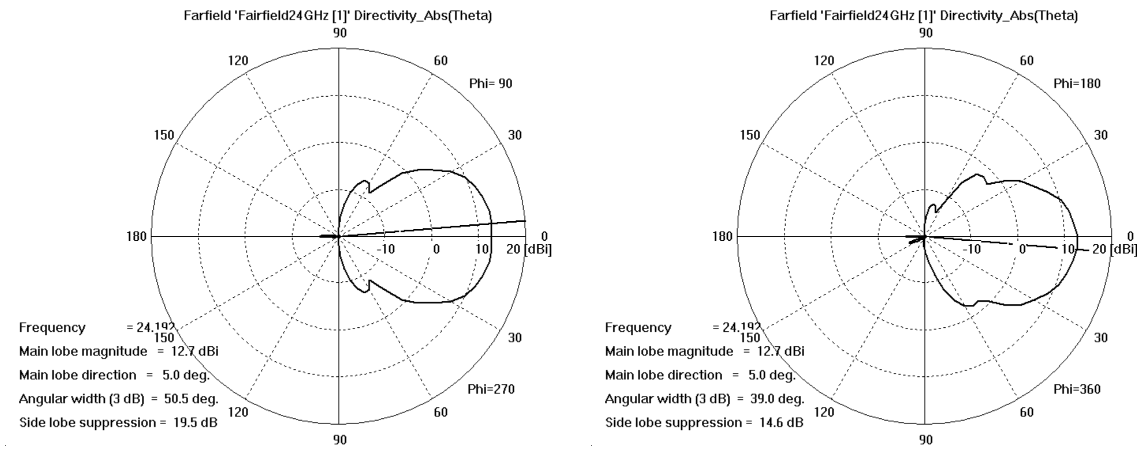


Figure 5 – E and H plane far-field, 24 GHz IMU/corrugated feed

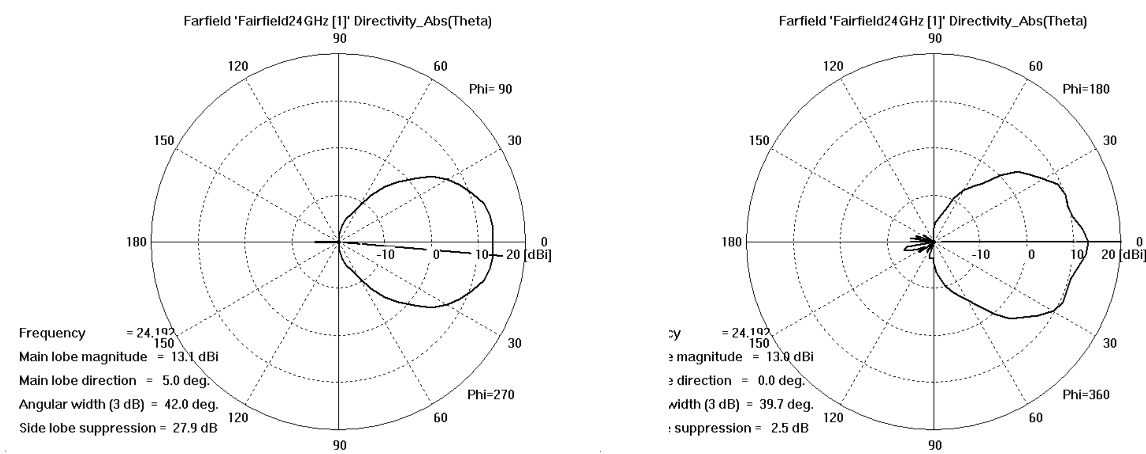


Figure 6 E and H plane far-field, 24 GHz IMU/conical feed

For both of these feeds we optimized the 10 GHz probe position and length for best swr. We also attempted to improve the 24 GHz to 10 GHz isolation by repositioning the 10 GHz probe, unfortunately we weren't able to make significant improvements. The 24 GHz to 10 GHz isolation is marginal, it's OK for low power 24 GHz operation but with higher powers on 24 GHz protection of the 10 GHz LNA will become important. Figures 7 and 8 show the swr plots and port-to-port isolation.

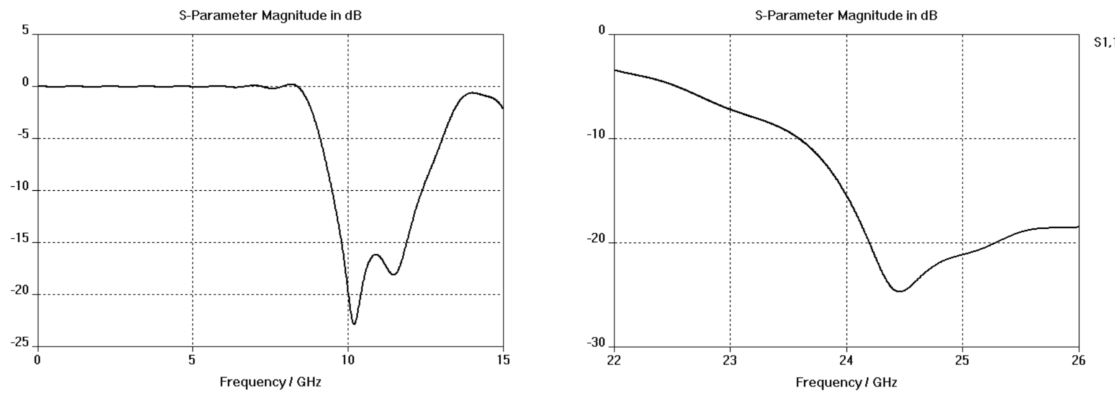


Figure 7 – 10 and 24 GHz SWR

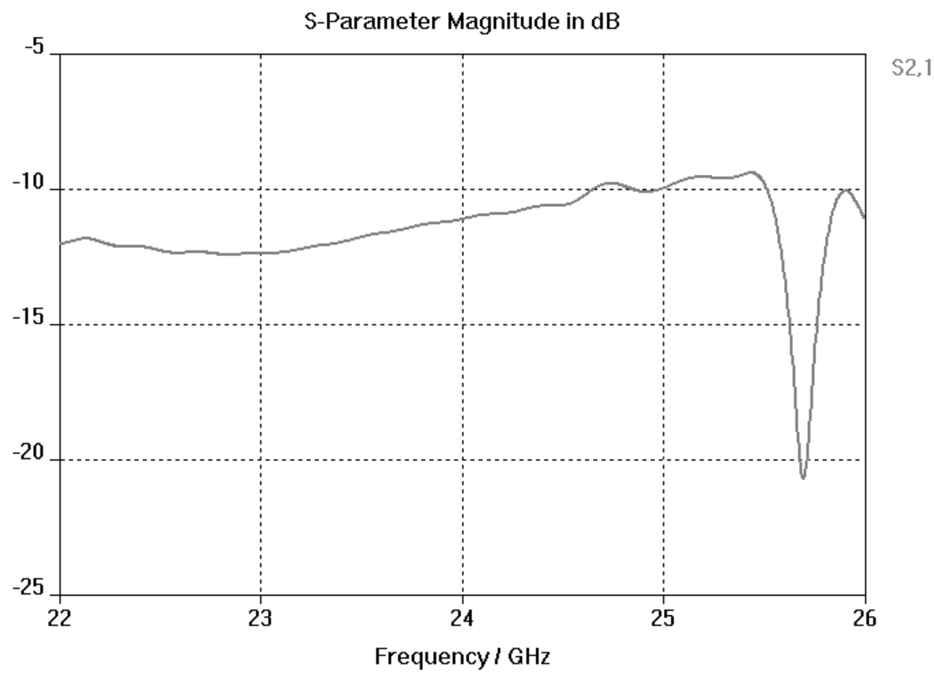


Figure 8 – 24 GHz to 10 GHz isolation

There are a couple of solutions to the isolation problem that don't involve any changes to the feed design:

- A low pass filter could be put on the 10 GHz port
- The 10 GHz T/R switch can be switched to the transmit position while transmitting on 24 GHz, the 24 GHz feed-through would be safely handled by the 10 GHz power amplifier.

Sun Noise Measurements

To verify the improvements that were seen in the simulations we used sun noise measurements. Using a setup similar to the one described in [6] we have measured the following sun noise ratios on the various horns:

Feed	**10 GHz**	**24 Ghz**
W5ZN	2.8 db	3.2 db
W5ZN/ Chaparral	5.5 db	3.0 db
IMU	3.1 db	6.7 db
IMU/Chaparral	5.5 db	6.7 db
IMU/conical	7.3 db	6.2 db
IMU/corrugated	7.3 db	6.7 db

All sun noise measurements were made on a four foot diameter Prodelin [7] offset reflector with a .7 f/d ratio. All of the measurements were made at an SFU of 143 and with system noise figures of 3.7 db on 24 GHz and 1.4 db on 10 GHz. While the sun noise improvements for the IMU/conical and IMU/corrugated look impressive keep in mind that these are G/T improvements and the actual gain improvement is considerably less

Construction Hints

The horns in the pictures below were made from copper plumbing tubing, brass hobby tubing and brass hobby sheet stock. All of the joints were soldered with 60/40 soft solder using a 60W soldering iron. Paul Wade' s HDL_ANT program [8] is very useful to produce templates for each of the flare sections. The flare sections are cut from 10 mil hobby brass using a pair of heavy scissors.

The HDL_ANT parameters used to generate each template are as follows:

- 10 GHz conical horn:
  - “G”enerate optimal horn
  - 10368 MHz
  - 13 dbi gain
  - 20mm input waveguide size

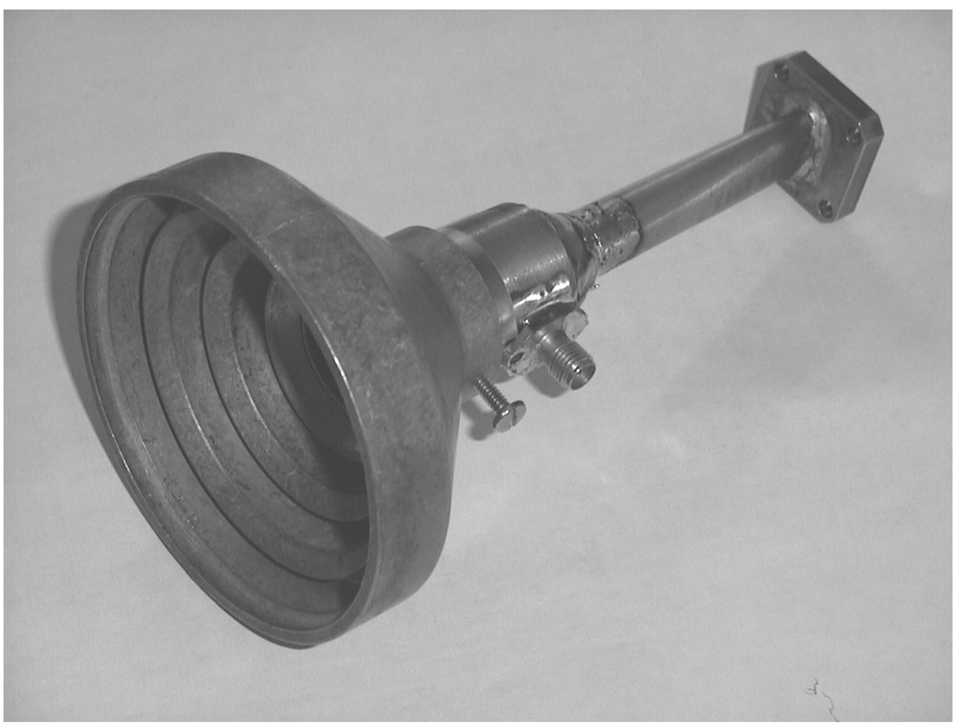
- 24 GHz IMU horn:
  - “W”2imu horn
  - 24192 MHz
  - “N”o suggestion for aperture
  - 9.5 mm input wg diameter
  - 20 mm output wg diameter

In each case HDL_ANT can generate a template for the horn which can be printed and used to cut out hobby brass sheet to make the flares.

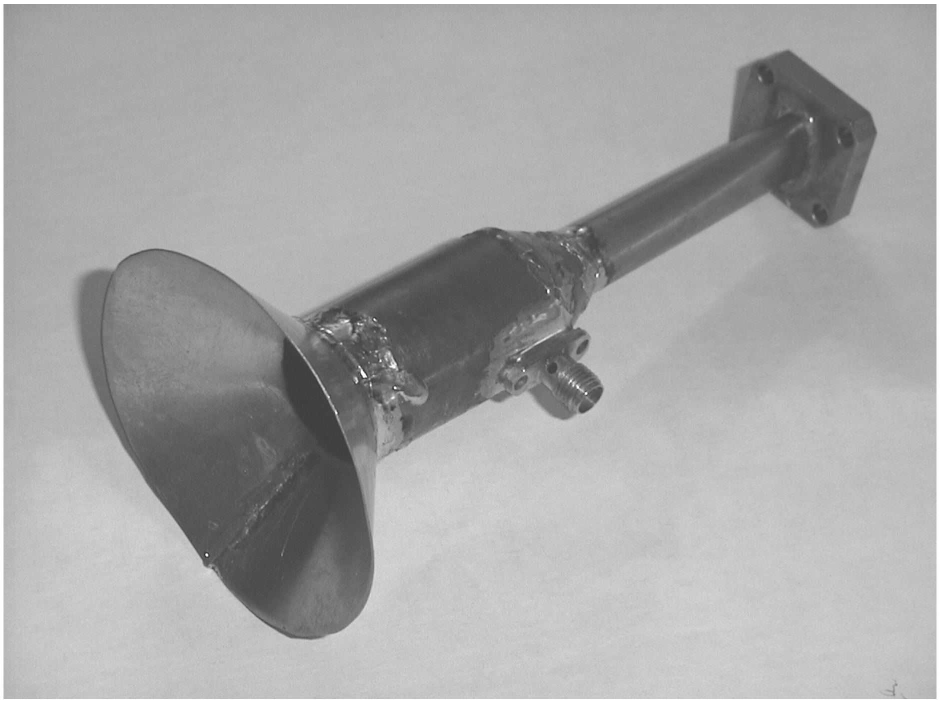
The order of construction that was used is:

- Cut to length and form the 24 GHz WG section, one end is formed into a rectangle to fit a wr-42 flange, use 3/8" (9.5mm) hobby brass
- Cut the 24 GHz drift section to length from ¾" "type L" copper pipe
- Drill the drift section for the 10 GHz probe 6.1mm from one end
- Cut out and form the IMU flare section
- Solder the IMU flare section to the drift section
- Solder the 24 GHz WG section to the IMU flare section
- Cut out and form the 10 GHz conical horn
- Solder the 10 GHz horn to the 24 GHz drift section
- Solder the 24 GHz WG section to a wr-42 flange
- Solder on the 10 GHz probe, probe length = 6.5mm

The last step of soldering on the wr-42 flange is done with the assistance of a hot plate. The temperature of the hot plate is set below the melting point of the soft solder so that the 60W iron can be used to provide spot heating to complete the joint. The 10 GHz probe is made from a gold-plated sma connector with a long center pin. The body of the connector is simply soldered to the 24 GHz drift section using the 60W iron. The process is simpler than it sounds, a complete feedhorn can be made in less than one hour.



IMU/corrugated Feedhorn



IMU/conical feedhorn

Conclusions

A high performance dual band feed for 10 and 24 GHz has been described and detailed simulation results were presented. This dual band feed is very useful in helping to complete QSOs on 24 GHz. The conical horn version of the feed is easily reproducible from readily available tubing and brass sheet stock.

References

[1] "Dual Band Feedhorns for 2304/3456 MHz and 5760/10368 MHz", Al Ward W5LUA, Proceedings of Microwave Update 1997, pp 158-163

[2] "W5ZN Dual Band 10 GHz / 24 GHz Feedhorn", Joel Harrison W5ZN, Proccedings of Microwave Update 1998, pp 189-190

[3] "Further Evaluation of the W5LUA & W5ZN Dual Band Feeds", Joel Harrison W5ZN, Proccedings of Microwave Update 1999, pp 66-73

[4] “W1GHZ Microwave Antenna Book”, Paul Wade W1GHZ, Chapter 6.9 “Multiband Feeds”, http://www.tiac.net/users/wade/10g_home.htm

[5] “W1GHZ Microwave Antenna Book”, Paul Wade W1GHZ, Part 3/11 “Parabolic Dish Feeds – Performance Analysis”, http://www.tiac.net/users/wade/10g_home.htm

[6] "More on Parabolic Dish Antennas", Paul Wade W1GHZ, QEX, Dec. 1995, pp. 14-22.

[7] http://www.prodelin.com/

[8] “HDL_ANT”, http://www.tiac.net/users/wade/10g_home.htm