

Horns for the Holidays

by
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INTRODUCTION

What do feedhorns have in common with the holidays? Absolutely nothing! But it makes the point that constructing efficient feedhorns is so easy you can build one while lounging out over just about any holiday!

It has long been proven that the most effective antenna for amateur microwave communications is the parabolic reflector. Their efficiency, however, lies directly with proper feed methods. Numerous articles have appeared in recent times discussing techniques for proper illumination of parabolic reflectors to increase gain & efficiency, most notably those written by Paul Wade, N1BWT. I strongly recommend these articles for review and retention in your personal library.

What I'll deal with in this paper are the practical applications of constructing efficient feeds for single band and multi-band applications.

A BRIEF HISTORY OF FEEDHORN DESIGN

Types of feeds

Feedhorns come in a variety of shapes, sizes, and designs ranging from rectangular, tapered, circular, cassegrain, sectoral, dipole, and dual-mode W2IMU versions. The type of feed to be used really depends on the intended mode of operation and parabolic reflector geometry.

I'll be reviewing circular designs and construction in this paper.

Circular design dimensions

A circular feedhorn is basically a piece of circular waveguide, or material constructed to act like a circular waveguide. When working with waveguide, or any antenna component for that matter, it is well understood that dimensions are frequency specific. Figure 1 identifies the critical dimensions.

For a round material to act like a waveguide and propagate a radio wave properly, its diameter (D) must exceed 0.58λ in air. The preferred range is 0.65λ to 0.70λ .

The length of the material (L) must be greater than 1 guide wavelength (λ_g).

A guide wavelength is the wavelength of the RF signal in the waveguide. The velocity of a radio wave in a waveguide will not be the same as in air or free space.

The length of the radiating probe (PL) inside the horn will be approximately $1/4\lambda$. This will vary slightly based on several different parameters.

The distance of the radiating element from the closed end of the feedhorn (s) is theoretically $1/4\lambda$. Several factors affect this distance, most notably diameter and length of the horn. My experience has been to place the radiating element about 0.4λ from the closed end.

The phase center of a circular waveguide feedhorn will be approximately $1/4''$ inside the opening.

Scalar Rings

Scalar rings have been successfully used to improve the efficiency of a parabolic antenna. Basically the ring, which is placed around the feedhorn, improves the RF pattern to better illuminate the reflecting surface of the dish. We all know that the better the dish is illuminated, the greater the efficiency and gain of the system. The previously mentioned articles by Paul Wade provide an excellent explanation of dish illumination. I do not use scalar rings on my 2.3, 3.4, and 5.7 GHz terrestrial antennas because no performance increase has been recorded in antenna measurement tests. The parabolic reflectors I use on these bands are relatively deep, with an f/D of 0.3. A dish with a larger f/D may notice improvements utilizing a scalar ring.

FEEDHORNS FOR TERRESTRIAL COMMUNICATIONS

2.3 GHz Linear Polarization Feedhorn

Probably the simplest feedhorn to construct is a circular waveguide style for 13 cm. It just so happens you probably have the materials right under your nose every morning. A one pound coffee can with a $1/4$ wavelength probe makes an excellent horn. Use an "N" chassis panel mount and some $1/8''$ brass or copper tubing for the element. You should be able to locate small diameter tubing at the same place you

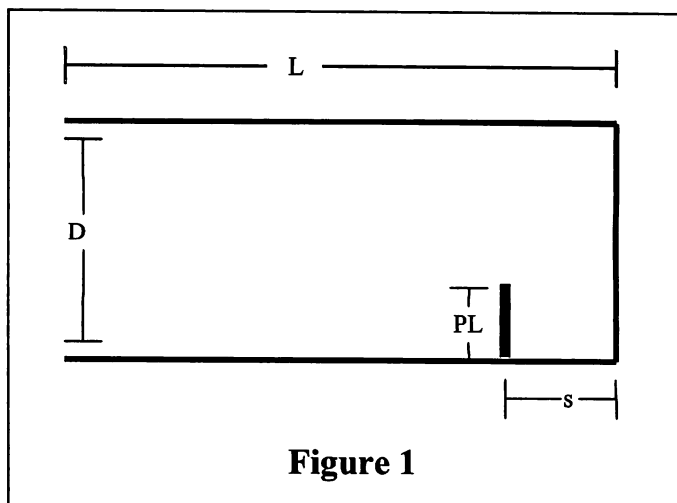


Figure 1

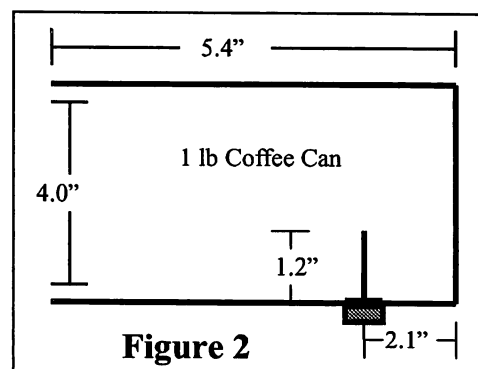


Figure 2

purchase brass strips at a local hobby store. The tubing will slide over the N center pin. Al Ward prefers to use two pieces of tubing, one smaller than the other. The smaller piece to be soldered to the center pin and the other telescoping over and soldered to the smaller one. This will allow increasing or decreasing the length of the probe for tuning.

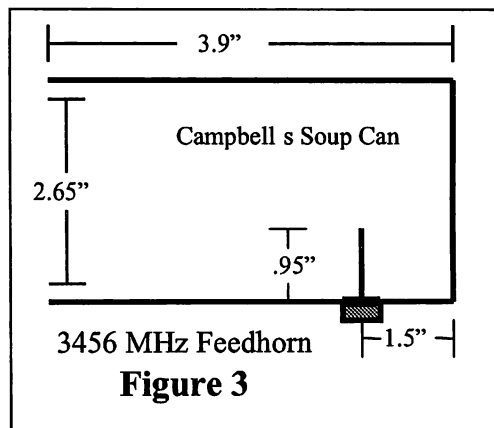
Exactly opposite from the probe element (180°) drill a hole large enough for a #6 or #8 brass screw. Solder a brass nut over the hole and insert the screw. This will permit additional tuning for best return loss (minimum SWR).

Refer to the coffee can dimensions in Figure 2 for construction details.

CONSTRUCTION TIME = 30 Minutes with Tuning

3.4 GHz Linear Polarization Feedhorn

9 cm is another band that offers easy feedhorn construction. Just like 2304 MHz, you probably have the materials sitting right under your nose. After emptying that coffee can and finishing your cup of coffee, lunch probably comes to mind (or at least it does for me!). What could be better with a nice sandwich than a hot bowl of soup. Wait a minute! Don't throw that can away. A soup can just happens to be the right size for a 3456 MHz feedhorn. Follow the same guidelines as with the 2304 MHz version and you're in business.



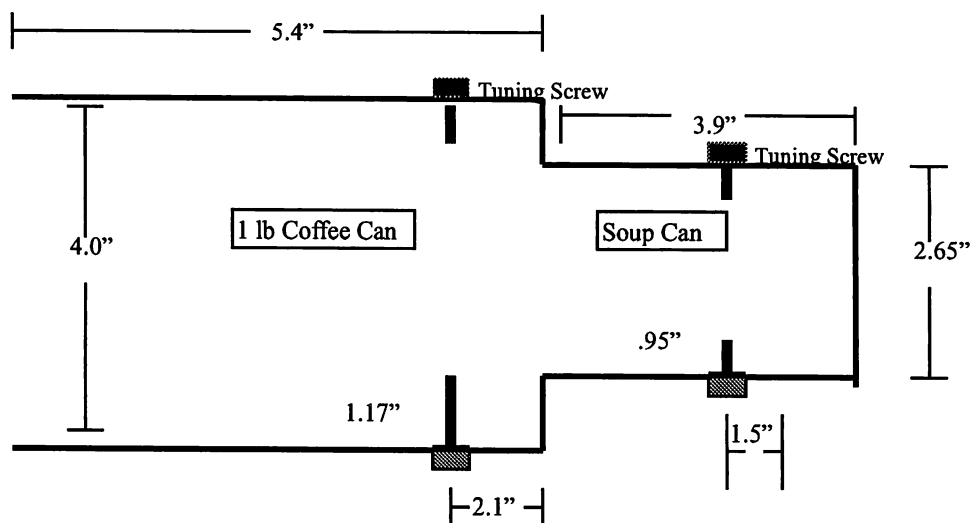
CONSTRUCTION TIME = 30 Minutes with tuning.

Dual Band 2304/3456 Linear Polarization Feedhorn

If you're a "single band man", then optimizing your antenna system is not that difficult. Radio amateurs are always striving, though, to have as much possible, as best possible, for the least possible! Hence the drive for maximum utilization from one antenna system. I use a 6 ft. dish for some of my microwave work. My first feed was the WA3RMX Tri-Band Feed. This worked until I decided to optimize the antenna system. I made the decision to use the 6 ft. dish for 2304 MHz and 3456 MHz, and a separate dish for 5760 MHz. Al Ward reminded me of a feed he designed a few years ago that employed a soup can attached to the back of a coffee can, with a relay used to switch the active port. The design is shown in Figure 4, and uses the exact same materials as the individual horns for 2304 MHz and 3456 MHz previously mentioned. The only addition is to attach the soup can to the coffee can.

2304/3456 Dual Band Feedhorn

FEEDHORN DESIGN BY AL WARD, WB5LUA 8/10/89



Measured Parameters

2304 MHz Return Loss ≥ 23 dB
 3456 MHz Return Loss ≥ 20 dB when 2304 port is "Open"

Measurements have been performed on several different size dishes with an f/d of .3 to .4, and approximately 55% efficiency has been achieved each time.

Measured Parameters with a 32" dish:

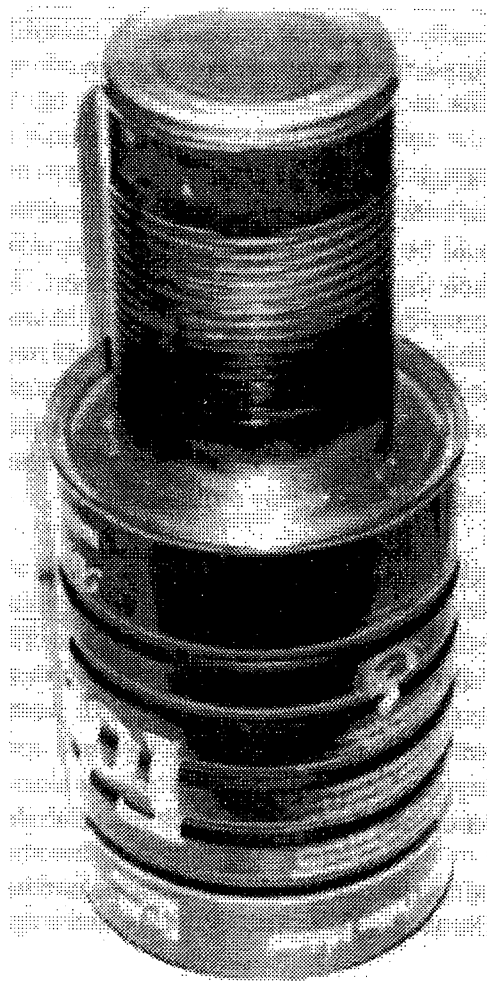
Frequency MHz	Theoretical Gain 55% Efficiency	Measured Gain At CSVHF	dB Below Theoretical
2304	23.3 dB	22.7 dB	-0.6 dB
3456	26.8 dB	25.8 dB	-1.0 dB

Figure 4

Start by preparing the soup can and coffee can for N connector/probe and tuning screw mounting. Next, cut a hole the diameter of the soup can, centered in the bottom of the coffee can. The hole should NOT be large enough for the soup can to freely slide into the coffee can, but just large enough for the outer edge of the soup can to “catch on the opening. I place the soup can centered on the bottom of the coffee can and trace a circle on the coffee can bottom around the soup can edge with a felt pen. Punch or drill a hole in the center of this circle. Go to Wal-Mart and buy a pair of small cuticle scissors (or steal your wife s!) and cut from this hole to the trace of the drawn circle, then just around the inside of the trace. Cuticle scissors are “curved” and will provide a very smooth circular cut in the thin metal of a coffee can. Now place the soup can over this new hole. It should be almost perfect to expose the entire opening of the soup can when viewed from the front of the coffee can, but just catch on the outer rim.

Now place the coffee can top down with the new hole facing up. Use solder flux around the edge of the coffee can hole and rim of the soup can. Center the opening of the soup can over the hole in the coffee can.

At this point, it helps to place a light weight on top of the soup can so it doesn't move around when the flux is heated. Take enough solder (not the real small kind you use on circuit boards, but something larger) to wrap around the soup can 2 or 3 times, and slide this down to the rim of the soup can where it mates with the coffee can. Use a small propane torch (forget soldering guns) and begin evenly heating around the circumference of the soup can/coffee can attachment area. As the temperature increases, the solder will flow and blend a



very uniform transition. Be easy with the heat, but use enough to produce an even solder flow.

Don't touch things for 2 or 3 minutes. The solder won't set for a while. I've destroyed perfect solder transitions on these by moving too fast! After cooling, inspect the transition. There should not be any holes. Now look into the assembly from the open end of the coffee can. The entrance from the soup can into the coffee can should be symmetrical. If part of the coffee can bottom at the opening into the soup can extends into the opening, use a round file to remove the excess.

Now attach the probe assemblies, starting with the 3456 MHz soup can. I recommend using 4-40 screws and nuts. The screw should be flush with the nut on the inside. Do NOT allow the screw to extend into the can past the nut. I use UT-141 from the feedpoint to the relay. Even if you run high power, UT-141 is rated at 150 watts at 2304 MHz. Just make sure your relay is capable of handling the RF. I use a relay with N connectors, but an SMA relay will work fine in most applications. I mount the relay on what will be the bottom of the 2304 MHz horn when mounted horizontally. I bend heavy brass shim stock to form a 90° angle and drill holes in one end. Solder the un-drilled end to the 2304 MHz feed and use screws to attach the relay to the other ends. If you use a relay with a normally open (NO) and normally closed (NC) action, I recommend connecting the 2304 MHz port to the NC side of the relay.

Tune-up

With both ports connected to the relay, measure the return loss (SWR) on 2304 MHz. It should be greater than 20 dB. If not, adjust the tuning screw for minimum SWR. Now switch the relay to the 3456 MHz port. The return loss should be around 20 dB. If not, try adjusting the tuning screw. A second adjustment would be to move the probe slightly toward the front of the horn. If return loss improves, then move the probe forward a little more. If not, move it back. Now re-check the 2304 MHz port again. If the return loss is not at least 20 dB, adjust the tuning screw and/or probe position. If none of these adjustments produce a return loss of at least 20 dB, vary the length of the probe and re-adjust as previously outlined.

Final Assembly

After tuning, remove the relay and clean the horn assembly of any flux, dirt, grease, etc. I use an Exacto knife to scrape the flux off the solder areas, then use Resin Flux Remover (available from Radio Shack) to clean the solder area to a nice shiny finish. Now take the assembly to the sink and wash with warm soapy water. Rinse thoroughly. After drying, cover the N connectors with tape and spray paint the outside with your favorite color. I spray the inside of the horn with a clear Krylon paint. Once this has completely dried, remount the relay and recheck the return loss. Everything should still be fine.

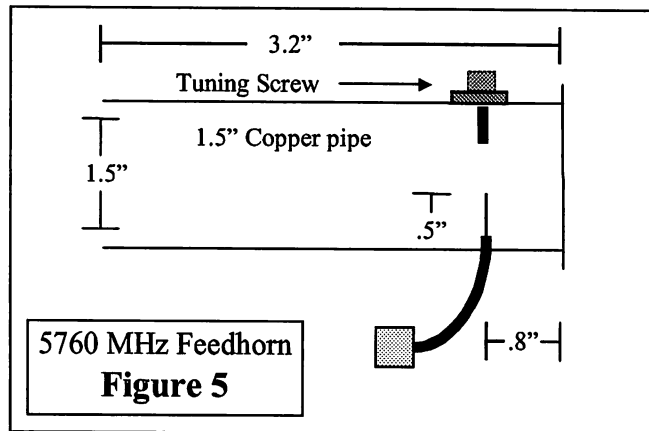
During antenna gain measurements, we have concluded that the phase center of this feed is the same as the others, just inside the opening of the coffee can.

Mount the horn at the focal point of your favorite dish and you're in business with a very effective dual band feed!

CONSTRUCTION TIME = 2 hours (not counting paint drying time)

5.7 GHz Linear Polarization Feedhorn

I haven't found anything in the kitchen (yet) that is suitable to provide materials for a 5760 MHz feedhorn. 1.5" diameter copper pipe works great, though! This is a common size, so you'll be able to find some at a local plumbing supply house. The basic design is similar to the other single band feeds, with dimensions shown in Figure 5.



The most complicated decision to make with this feed is how to assemble the probe and port connection. The simplest approach is to use a length of UT-141. Remove the outer copper shield to expose a 0.5" length of the inner conductor. Drill a hole in the pipe 0.8" from the end of the pipe where the probe will be placed and a second hole on the opposite side (180°) for a tuning screw. The diameter of the first hole should just be large enough for the UT-141 cable to fit snugly into, and the second large enough for a #6 brass screw.

Obtain a piece of PC board (preferably double sided) and cut it to a length sufficient to cover the back end of the pipe and also to allow for dish mounting. Apply flux to both components and set the pipe on the PC board. Place 2 or 3 rings of solder around the pipe at the base where it mates with the PC board. Using a propane torch, heat the pipe evenly around the circumference until the solder flows forming a uniform joint. Allow this assembly to cool for a few minutes.

Now place a brass 6-32 nut over the hole where the tuning screw will go. Apply a small amount of flux to the area and evenly heat with a propane torch, applying solder as needed. You may find that placing the screw into the nut and allowing it to extend into the pipe will help hold the assembly in place during soldering, just be careful in applying the solder so as not to affix the screw solidly to the nut!

Next, insert the UT-141 into the probe hole. The outer copper shield should be flush with the inside surface of the pipe, exposing the entire 1/2" length of inner conductor into the pipe. On the outside of the pipe, place a small amount of flux around the hole and on the outer shield of the UT-141. Place 1 or 2 turns of solder around the UT-141 at the pipe surface. Use a small propane torch to heat the pipe evenly around the hole (do not put the

flame directly on the UT-141) until the solder flows to form a uniform joint. As the joint begins to heat up, your “snug” UT-141 may become loose and could move. I recommend securing the assembly during the soldering phase. Allow the assembly to cool for a few minutes.

Inspect the joint on the outside and inside. It should be a solid even joint. Make sure you haven't used excessive solder and have a blob that has collected on the inside. Some of the dielectric between the inner and outer conductor may have moved into the pipe cavity. If so, don't worry about removing it as this should not be a problem. Place an appropriate connector on the other end of the UT-141 (N, SMA, etc.).

Tune-up is simple, adjust the tuning screw for best return loss. After tuning, secure the screw by either soldering it in place or using a second nut for locking purposes. I have built over 30 of these feeds, and all had a return loss of 25 to 30 dB.

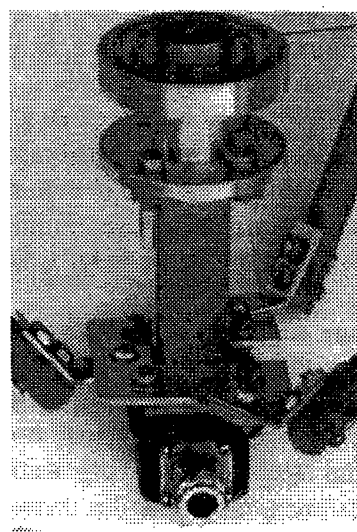
I recommend painting the completed assembly. Remove excess flux, dirt, and grease in the manner previously mentioned in this article, wash with warm soapy water and rinse thoroughly. After drying, spray paint with your favorite color. Again, I spray the inside of the assembly with clear Krylon.

One word of caution about this assembly; The solder joint of the UT-141 and copper pipe won't take an excessive amount of flexing. Once you mount the feedhorn in your dish, secure the cable in a manner that will prevent flexing of the UT-141 cable.

CONSTRUCTION TIME = 30 Minutes with Tuning

10 GHz Linear Polarization Feedhorns

There are a couple of different options for simple 10 GHz feedhorns. The one I use utilizes an N to waveguide transition attached to a short length (about 3 inches) of waveguide connected to a Chapparral scalar feed (see photo). All of these items can be picked up in the flea market at some of the major hamfests or microwave conferences. All that is required for construction is to use some screws & nuts and attach the individual pieces. Without any tuning or adjustment, I obtained a 20 dB return loss. I use this feed with a 2 ft dish which produces a measured gain of 32.5 dB.



Another approach is to use an 1 1/4" diameter copper pipe the same way as in the 5.7 GHz feed. This design was described by Chuck Steer, WA3IAC, in Microwave Update '91, and later in the ARRL UHF Microwave Projects Manual. I have not constructed or tested this particular feed, but it should perform very well.

Al Ward has developed a dual band 5.7/10 GHz feed using a 1.5" to 3/4" copper pipe transition. This design will be presented by Al in a separate article.

24 GHz Linear Polarization Feedhorns

Feeds for this band are scarce. My experience has been limited to commercial "button hook" feeds that can, on a rare occasion, be found at the Dayton type flea markets, or out on the west coast.

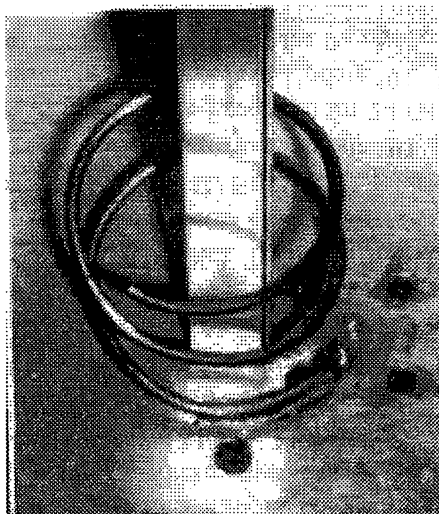
The only homebrew design I m aware of is a W2IMU version designed by Kent Britain, WA5VJB, described in Microwave Update '91, and later in the ARRL UHF/Microwave Projects Manual. Others are certainly possible.

FEEDHORNS FOR SATELLITE COMMUNICATIONS

Having been active on the Oscar Satellites for several years, coupled with my interest in the amateur microwave bands, finally convinced me to try Mode S, Oscar 13 s 435 MHz uplink/2400 MHz downlink. Of course at the time I knew very little about this mode. During a stop at an AMSAT booth while at a hamfest, I purchased a copy of "Mode S - The Book", written by my good friend Ed Krome, KA9LNV. Ed has spent a considerable amount of time experimenting with Mode S antennas. I strongly recommend this book for those interested in not only Mode S, but the forthcoming new satellite microwave bands as well.

Mode S (2.4 GHz) Circular Polarization Feeds

Ed s book describes a small three turn helix antenna for 2400 MHz, placed at the focal point of and facing a dish. The photo shows the one I have in use. I hesitated building one of these feeds, fearing that it wouldn t work properly. After actually getting started on the project, construction of the feed was extremely easy, and the feed worked great. Signals were "armchair" copy from Oscar 13. Guess who the second station was I work? That s right, Ed!



Phase 3D Circular Polarization Feeds

The bad news about Mode S on Oscar 13 is that A0-13 is no more. The good news is Phase 3D is on the horizon and promises to be an absolute gem of a satellite with not only an S band transponder, but several others as well.

While we don t have any actual experience to report at this time prior to P3D s launch, there are some interesting preliminary options to consider. Ed had envisioned offset single band feeds (feeds placed side by side at the dish focal point) to cover all of the new bands. At the Dayton Hamvention® this year I was conducting a forum on feedhorns and

describing Al's dual band 2.3/3.4 GHz feedhorn when Ed had an idea to use a version of that feed. Although it is linearly polarized, it offers encouraging possibilities. If you are planning to operate on the P3D μ wave bands, give that configuration a try and let us know how it works. Ed and I will be doing the same!

Give 'em a Try

I hope this will encourage you to try some of these designs and become active on a new band, or improve an existing one. These microwave antennas can be constructed and tested in less time than it takes to assemble an HF antenna and most VHF/UHF antennas.

I'll be looking for you on the bands!

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