Pour an Antenna for X-Band

20–20 vision for your microwave system!

by John M. Franke WA4WDL

Ever heard of anyone pouring an antenna? This idea isn't as silly as it sounds, and it's quite easy.

What I am referring to is casting lenses—microwave lenses. It turns out that optical lenses above 3 GHz actually help correct aberrations in the wavefront coming out of a horn antenna, thereby reducing sidelobes. A lens collects and collimates the energy coming out of the horn which results in an increase in gain.

Some time ago, Bill Hoisington K1CLL described a simple X-band (10 GHz) crystal set using a 1N23 detector and a hemisphere of wax as the antenna. (See "The World of X-Band" by Bill Hoisington K1CLL, *73*, March 1975.) He cast ordinary kitchen paraffin to make several short focal length lenses about 0.64cm and 12.7cm in diameter. Paraffin is not optically transparent, but microwaves do not know that. The wax is very clear to microwave energy. Also, the lens surface does not have to be optically smooth. As long as the imperfections are less than an eighth wavelength (0.142 inches), there should not be any noticeable effects. Lenses are much more tolerant of surface errors than are reflector or "dish" antennas. A surface error on a reflector is doubled upon reflection. For example, a tenth-wave bump or dent produces a fifth-wave distortion in the wavefront. A microwave lens with an index of refraction of 1.5 and having a tenth-wave bump or dent produces a wavefront distortion of one-tenth times 1.5 minus 1, or one twentieth wave. In other words, the distortion is less than the physical defect.

Designing and Building the Lens

I can't go into detailed lens design, but I can relate some personal experience in casting lenses. After all, most of us started in microwaves by using dish or horn antennas we found through surplus sales or hamfests. Then, as special needs arose, we designed and constructed custom antennas. The majority of dish and horn antennas used by amateurs fall into the found or purchased category. Few of us actually build them. I have built a couple of special purpose dishes, but will opt for an already-built one any chance I get—I'm basically lazy. (See "The Amazing Cylindrabola" by John M. Franke WA4WDL, *73*, September 1983.)

Several years ago I came across a large glass lens at an antique flea market. I've been keeping it for use as an optical receiver antenna. It is 6 inches in diameter, about 1½ inches thick, and quite heavy. It has a focal length of about 6 inches. The lens is flat on one surface and convex on the other, so it is known as a "planoconvex." Such a large fat lens is poor for optical imaging, but it's a great light collector. However, I needed two antennas. So, I decided to try to cast epoxy resin replicas of the glass lens.

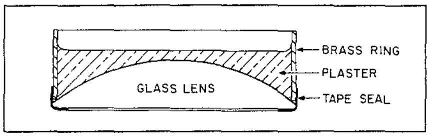

Figure 1. Forming the plaster mold.

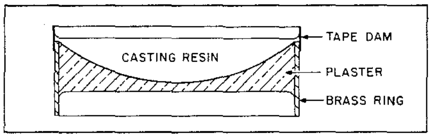

Figure 2. Casting the replica lens.

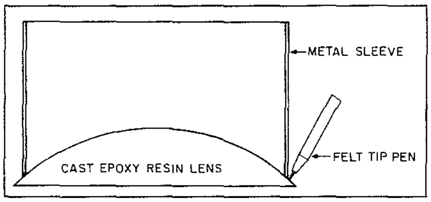

Figure 3. Marking the cast lens for edging. Note that the marking sleeve or cylinder must be perpendicular to this rear surface of the lens.

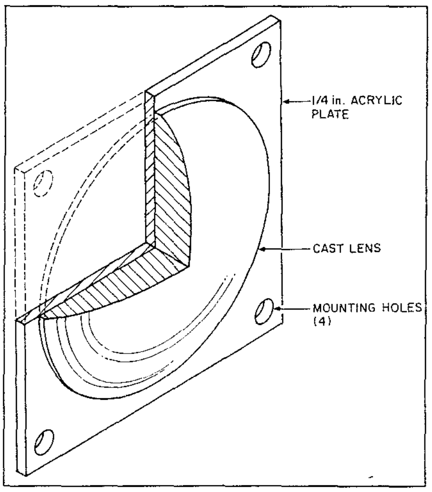

Figure 4. Cast lens epoxied to acrylic support plate.

In my junk box I found a couple of brass rings 6 inches in diameter and 2 inches tall. If I had not had the rings, I could have made suitable rings or sleeves by forming strips of aluminum flashing into a band and taping it to hold its shape. I placed the glass lens on the first ring, curved surface down, then taped the glass to the metal edge with plastic electrical tape, forming a watertight seal. (See Figure 1.)

Next, I mixed plaster, poured it into the mold, and let it harden for several hours. (See Figure 2.) Once the plaster had hardened, I removed the tape, separated the glass lens from the first ring, and taped it to the second ring. Then I poured the second mold and let it harden. (I let both plaster castings dry thoroughly for two days before doing any more work.)

In Photo A you can see several screws protruding through the sides of the brass rings into the plaster. The screws are there to plug existing threaded holes in the rings. They have no other real function, but they may be helpful in holding the ring and plaster mold together.

Once the plaster had dried, it was time to cast the lenses. One mold would have been sufficient, but I wanted to mix the epoxy resin only once. So, I made two molds to have added assurance against having to throw out the mixed resin if I dropped or chipped a mold after the resin was mixed. I placed the molds on a level surface with their smooth cast surfaces up. (If the molds are not level, the rear surfaces of the lenses will be wedged.) A strip of plastic electrical tape was used to form a straight wall lip at the top of each mold. I mixed the hobby casting resin using the least amount of catalyst recommended. This lengthens the curing time, but reduces the

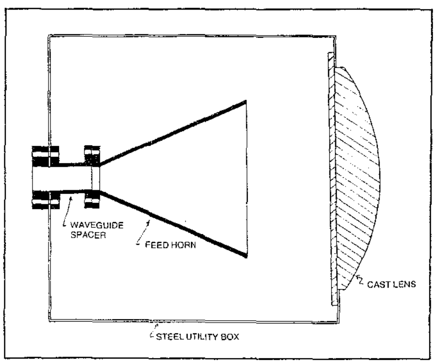

Figure 5. Completed antenna mounted in a 6-inch cube utility box.

chances of uneven curing and cracking due to rapid heat build-up. Next, I poured the resin and allowed it to cure overnight. The curing site should be outside to eliminate any problems with the smelly fumes.

The next day, I separated the cast lenses from their molds. The molds survived and could be used again. The edges of the lenses were rough and chipped, so I decided to trim or "edge" the lenses. I used a cylinder with an outside diameter of 5 inches—the hood from an old oscilloscope—to mark the lenses. (See Figure 3.) The actual edging was done with a disk sander and only took a couple of minutes for each lens. After the edging, the next task was to mount the lenses. Normally, lenses are mounted in a finely-machined barrel with a threaded retaining ring. I can operate a lathe and chase threads, but let's be reasonable! Instead, I epoxied a 5½-inch-square piece of ¼-inch acrylic to the flat surface of each of the epoxy lenses. (See Figure 4.) Then I drilled four mounting holes in each acrylic square.

Light sanding of each lens, followed by a couple of coats of clear acrylic spray, finished the lenses. The sanding is for two reasons. First, although the lenses are of poor optical quality, they can still produce a very hot spot when aimed at the sun, unless their surfaces receive a ground scattering finish. Second, they look better with an even, frosted appearance.

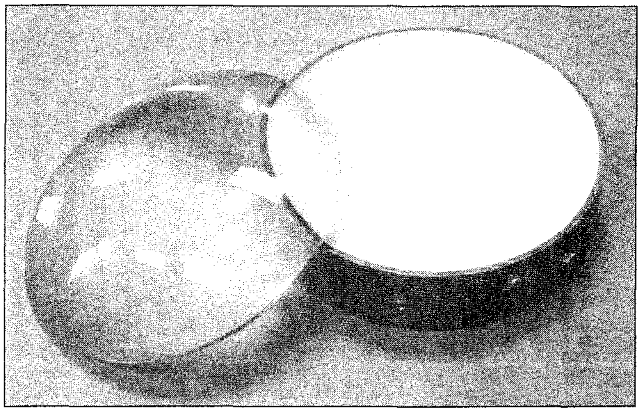

Photo A. Original glass lens and plaster mold.

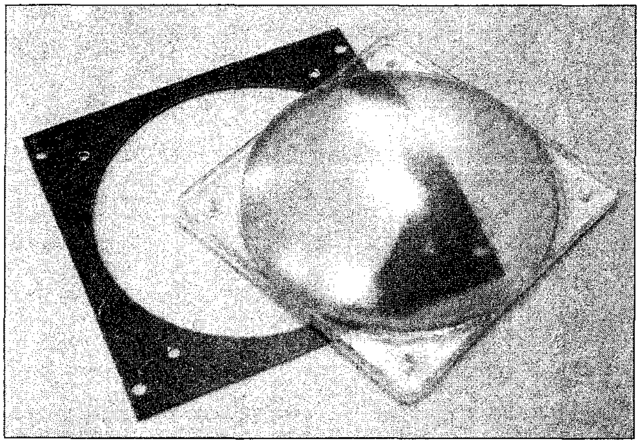

Photo B. Cast lens epoxied to acrylic plate and lens mounting plate.

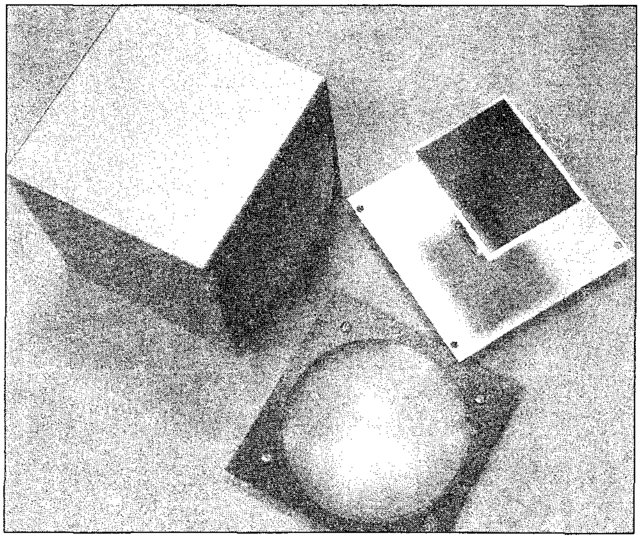

Photo C. Mounted lens, mounted horn and complete antenna.

Testing the Lens

One nice thing about small aperture microwave antennas is that you can set up a test range in a short distance. For example, with a small horn source antenna and the cast lenses, a distance of 20 feet is more than adequate. For a source, I used a surplus 2K25 klystron that had its cavity stretched to operate on 10.4 GHz. (See "A Complete X-Band Transmitter" by Stirling M. Olberg W1SNN, *73*, August 1978.) People may shun vacuum tubes, but I can only respect a tube that, like me, is over 40 years old and still working. Besides, have you priced a Gunn diode lately? I would very much like to hear from anyone with a supply of Solfan Gunn diode units. Anyway, the 2K25 puts out about 25mW when used with an old surplus klystron power supply that I got at a hamfest many years ago. The receiving portion of my antenna range is a 0–40 dB attenuator and a tunable detector mount. For metering, I now use a circuit published by Chuck Houghton WB6IGP. (See "Microwave Test Equipment for 10 GHz" by Chuck L. Houghton WB6IGP, *73*, October 1988) I did have to reverse the polarity of the detector diode to get it to work, probably due to a misprint. His circuit is very compact and very sensitive. You cannot go wrong reading his many articles, and he now has a superb column, "Above and Beyond," in *73* every month.

I placed a standard gain horn on both the transmitter source and the receiving setup, and tuned the detector mount for maximum response. Then I set the S-meter to midscale by adjusting the variable attenuator. The attenuator setting at this point became my reference reading. Substituting other antennas on the receiver setup, the attenuator is changed to maintain a midscale meter deflection. The reference reading is subtracted from the new setting. The result is added to the gain of the reference antenna to yield the gain of the new antenna.

Sound more complicated than it actually is? Say you have a reference antenna of 16 dB gain and with it you get a reference attenuator setting (reference reading for midscale meter deflection) of 8.5 dB. Putting your test antenna on the receiving setup, you get a midscale meter deflection with the attenuator changed to a setting of 12 dB. Then, subtracting the reference reading (12 − 8.5 = 3.5 dB), you find that the test antenna has a gain 3.5 dB greater than the reference. You have to attenuate the signal from the test antenna to make it equal to the reference signal. The gain of the test antenna is the difference added to the gain of the reference antenna (16 + 3.5 = 19.5 dB). If the midscale deflection had required an attenuator setting of 4 dB for the test antenna, then subtracting the reference reading (4−8.5 = -4.5 dB) tells you that the test antenna has a gain of 4.5 dB less than the reference, or a net gain of 16 − 4.5 = 11.5 dB.

You do not need to know the absolute gain of an antenna to use this technique. As long as you use the same antenna as a reference, you can measure the relative gain of your other antennas to it. After all, we are more interested in reducing losses or improving gains than we are in knowing what the absolute levels are.

Back to the lenses. The lenses, having a focal ratio (or F#) of about 1, should be fed with some sort of small horn antenna. I used the only one I had at the time—a Microwave Associates metalized plastic 17 dB gain horn. The addition of the epoxy lens increased the gain by 4.5 dB, or a factor of 2.8. With a unit at each end of a path, the net system gain is 9 dB, allowing the usable separation to be increased by 2.8 for equal signal strength. I was able to mount the lenses on one face of a 6-inch cube steel utility box and mount the horn with a spacer on the opposite face of the box. The result is a compact, easy-to-handle unit that can be readily mounted on a tripod for field work, or on a tower for point-to-point applications. (See Figure 5.)

I am now looking for a larger lens to cast, or perhaps I can find a large bowl to serve as a mold. 73

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