# Further Evaluation of the W5LUA & W5ZN Dual Band Feeds

By

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During the past few years, Al Ward and I have previewed a series of dual band feedhorns[1,2,3] for use on parabolic reflectors in the amateur microwave frequency range. Our acquired data on the horns consisted primarily of return loss, isolation between ports, and gain measurements on parabolas of various diameters.

In late 1997, our friend Paul Wade, W1GHZ, presented material on feedhorn pattern measurements in an excellent article on feedhorns and parabolic reflectors[4,5]. Paul also presented a software program called "*FEEDPATT*", which graphically plots a variety of factors for various parabolic f/D ratios from actual feedhorn data. Paul's articles prompted me to take the next step in our dual band feed design and analyze each section of the dual band feedhorns.

Armed with these tools, I set out to investigate and, if needed, optimize the dual band feeds Al and I had produced. No such work had previously been performed on these particular horns.

**Data Objective**

The data collected from each horn was used to answer three basic questions:

1. What dish f/D is each section of the feedhorn optimum for?
2. Is the phase center the same for each section of the feedhorn?
3. Does each section's measured gain compare to estimates and actual measurements of single band feedhorns?

Selecting a feedhorn to properly illuminate a dish is important in realizing the maximum gain from an antenna system. Matching the horn to the dish f/D ratio is a key element to success.

When dealing with dual band feedhorns of this particular design, it is imperative that the phase center be the same for each section or a considerable decrease in efficiency and gain will be experienced on one of the sections. My evaluation consisted of setting up the feedhorn and associated dish on my antenna range and adjusting the horn in front of the dish at the focal point for maximum gain on the lower frequency section. I would then adjust the horn to verify the peak amplitude location for the higher frequency section. Of course, a feedhorn's phase center can be accurately determined utilizing a network analyzer arrangement, but it is a more complicated process and not practical or necessary for this work.

The gain measurements were conducted on my antenna range utilizing a WA5VJB configuration and setup.

## Feed Pattern Measurement Range

My mission was to construct a range capable of obtaining accurate pattern data. This required assembling the necessary equipment and auxiliary apparatus, beginning with a support structure. The necessity of the support structure is only to provide some height above the ground. Just about any wooden table will work, but I chose to construct one that could have holes drilled in it to mount the test horn support at multiple distances from the source antenna to allow measurement of different frequency horns. Figure 1 shows the table I constructed which is made from a 1"x 12" 10 ft long, laid horizontally on a 2"x 4" supporting rib. The legs are 2"x 4".

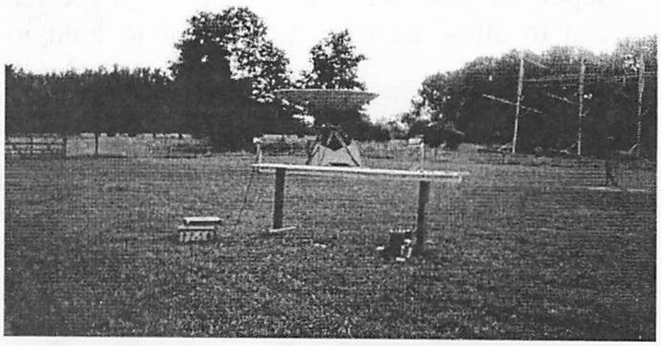

Figure 1

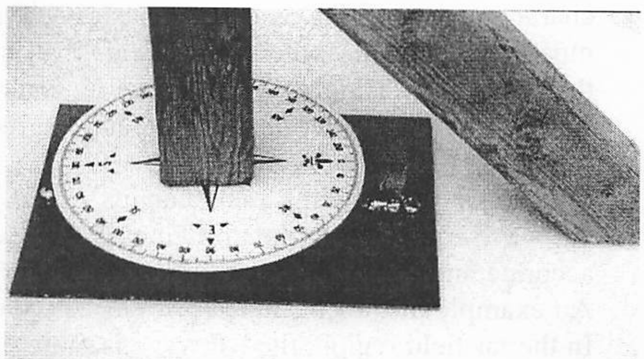

Figure 2

The structure for the test horn must be capable of physically supporting the horn, and also capable of rotation with a means of identifying the degree of rotation from a given point. I purchased an 8 ft. long 1"x 1" piece of lumber at the local home supply house. While there, I began searching for something inexpensive that could have one end attached stationary to the table top, and the other end attached to a 12" length of the 1"x 1" to allow it to rotate. During my stroll, I located a display of replacement garage door rollers. These specific ones were made by Genie. I drilled two holes in the round "roller" section to allow mounting to the table. A hole was drilled in one end of the 12" length of 1"x1" wood. This permits insertion of the axle part of the roller into the wood. In order to determine the degree of rotation, I used an azimuth scale I had acquired in the Dayton Flea Market a few years ago for about a quarter. One can easily be constructed. All that is required are markings to 10° or 15° as this is the incremental measurement you will need to make. The test feed horn can be mounted to the top of the 12" long 1"x 1" wooden piece.

Since the azimuth indicator covers an area larger in diameter than the roller, I had to attach an extension to the roller in order to facilitate mounting of the assembly at various locations on the table. I used a piece of circuit board material that extended further than the radius of the azimuth indicator. The roller was mounted to the circuit board, then two wood screws were used to mount this base plate to the wood table surface. While I was at it, just to add a touch of "fanciness" to the assembly, I soldered a piece of ½" brass strip to the base plate as a mark for my azimuth position. The azimuth indicator and base mounting plate are shown in Figure 2, and the entire assembly is shown in Figure 3. The only purpose of the 1"x 1" wooden piece extending at a 45° angle is to provide lateral support to the vertical section for larger feedhorns and to allow an easy attachment to hold to while rotating.

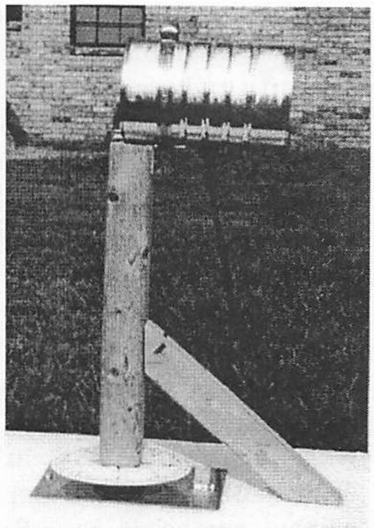

**Figure 3**

Figure 4 shows the attachment for the source antenna. I simply drilled a hole through the rib section of the table sufficient to pass a U-bolt through in order to clamp another section of 1"x 1" wood. This piece is approximately 2 ft long in order to allow vertical adjustment for centering with the test horn. The source horn is then mounted atop this wooden piece.

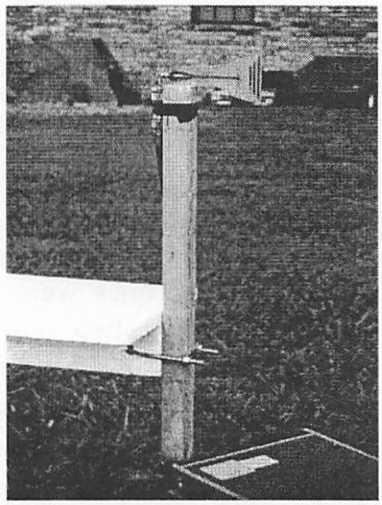

**Figure 4**

## Separation distance

The separation distance between the source and test antennas is determined by the individual characteristics of the two antennas. Each antenna must be out of the others near field. Paul suggests that generally, a higher gain source antenna farther away will give a better phase front, and I agree.

The reason for avoiding each antenna's near field is that the density of the energy in the RF wave contained in the near field is very complex and can vary drastically, making an accurate and repeatable pattern measurement (as well as gain measurement) impossible. An example of the calculated power density within the near field is depicted in Figure 5. In the far field region, the RF wave is more uniform with regard to density and decreases in strength in accordance with the Inverse Square Law. From this, it can be quickly concluded that knowing the nominal origination point of the far field is desirable. The location from the antenna where the near field ends and the far field begins is dependant on the antenna type and can be mathematically calculated. I have listed the formulas in Table 1, along with pertinent information about the feedhorn types that are the subject of this article.

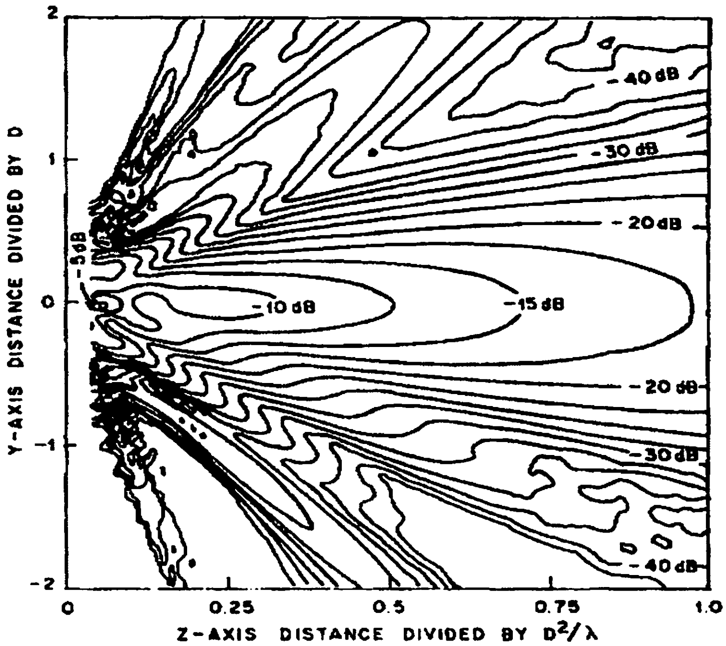


**Figure 5:** Calculated power density contours in the near field zone of a parabolic antenna.

## Antenna Range

The antenna range is a basic layout capable of placing test antennas at a distance of up to 500 ft from the source antenna.

## Test & Measurement Equipment

The equipment on the source end consists of a signal generator modulated with a 1000 Hz tone. For the 2.3, 3.4, and 5.7 GHz measurements, a WA3RMX Tri-band feed was used as a source antenna. For 10 and 24 GHz, a small horn antenna was used. The test horn end consists of an HP415E with an amplified speaker and detector connected to the horn.

## The W5LUA Dual Band 2.3 GHz / 3.4 GHz Coffee Can – Soup Can Feed

### Pattern Evaluation

Pattern measurements were performed on a single coffee can feed and a single soup can feed, as well as the dual band version. In addition, I performed measurements on a coffee can and soup can in an offset arrangement. I use a 6 ft dish on 2.3 and 3.4 GHz from my home installation. A single soup can feed is mounted in the center of the dish at the focal point and a coffee can is mounted to the side of the soup can, centered vertically but offset horizontally with respect to the dish. This is a mounting technique sometimes used for single band feeds, but it requires you to offset the azimuth direction from the 3.4 GHz signal amplitude peak to obtain a 2.3 GHz signal peak. My interest was the effect on the wave pattern caused by this arrangement.

The actual measurement data is contained in Table 2 and Table 3, with W1GHZ *FEEDPATT* plots contained in Figure 6, 7, and 8.

Figure 6 depicts the pattern for the individual feeds with f/D plots. Each indicates optimum performance on a parabolic reflector with an f/D of .35.

Figure 7 shows the comparison of the two feeds when placed in an offset scenario. The 3.4 GHz feed exhibits practically no change, but the soup can appears to cause some effect to the coffee can pattern such that the optimum f/D is lower.

When comparing the sections of the dual band feed in Figure 8, the same condition is seen. The 2.3 GHz section indicates a lower optimum f/D, but a change to the 3.4 GHz section is also noted. The optimum location increases to an f/D of approximately .48, and exhibits a broader range. Interestingly enough, the two patterns indicate good efficiency on an f/D of approximately .35 with a decrease of only about 5% from the maximum calculated efficiency peak for each section in the dual band arrangement as well as the single feedhorns.

Phase Center/Focal Point Evaluation

No difference was noted in the location of the phase center for each section of the dual band feed. The location of the feedhorn for maximum gain was the same for each section. The focal point was recorded to be at 10.375 inches, 0.25 inches closer toward the dish from the calculated position, indicating the actual phase center is approximately 0.25 inches inside the opening of the coffee can, confirming previous estimates. It is concluded that no efficiency degradation occurs relative to feedhorn phase center.

Gain Measurements

This feedhorn was used on a .3 f/D dish 3 ft in diameter. The estimated gain at 55% efficiency and the actual gain measurements are contained in Table 6. The reduction in gain for the 3.4 GHz section is attributed to the low f/D of this dish, as the optimum f/D for this section of the feedhorn is higher.

## The W5LUA Dual Band 5.7 GHz / 10.368 GHz Feedhorn

Pattern Evaluation

The actual measured data is contained in Table 4, with W1GHZ *FEEDPATT* plots contained in Figure 9. Maximum efficiency for both feedhorn sections is indicated to occur at an f/D of approximately .45. The interesting point about these data plots is that they exhibit a rather broad f/D response, suggesting reasonable performance of both sections from .4 to .6. A unique feature of this horn is the sharp null in the E plane of the 10 GHz section. This occurred at an offset of 40°. I acquired pattern measurements on a single 10 GHz feedhorn constructed from the same ¾" copper pipe material as the 10 GHz section of this feed horn. This null was not present on the single band feed.

Phase Center/Focal Point Evaluation

No difference was recorded in the location of the phase center for each section of the dual band feed. The location of the feedhorn for maximum gain was the same for each section. The focal point was recorded to be at 10.5 inches, 0.125 inches closer toward the dish from the calculated position. This would indicate the phase center to be just at the opening of the 1.5" copper pipe section of the feedhorn. It is concluded that no efficiency degradation occurs relative to feedhorn phase center.

Gain Measurements

This feedhorn was used on a .45 f/D dish 2 ft in diameter. The estimated gain at 55% efficiency and the actual gain measurements are contained in Table 6. I concluded that this feed works quite well and efficiently at the optimum f/D indicated by the test results.

## **The W5ZN Dual Band 10 GHz / 24 GHz Feedhorn**

Pattern Evaluation

The measured data is contained in Table 5 with W1GHZ *FEEDPATT* plots in Figure 10. The 10 GHz section, which is constructed from the same ¾" copper pipe material as the W5LUA 5/10 GHz feed exhibits a similar broad f/D optimization range. The 24 GHz section indicates an optimum point at approximately .43. Given the broad range of the 10 GHz section, this feed would perform well on both bands using a dish with an f/D of approximately .45. At this point, the plots indicate a difference of only about 2% in efficiency.

Phase Center/Focal Point Evaluation

No difference was noted in the location of the phase center for each section of this dual band feed. The location of the feedhorn for maximum gain on my range was the same for each section. The focal point was recorded to be at 10.625 inches, the location of the estimated focal point. It is concluded that no efficiency degradation occurs relative to the feedhorn phase center.

One interesting bit of Rover field data needs to be interjected at this point. I was in Germany this summer and had an occasion to chat with my friend Erhard, DC4RH, about recent 24 GHz activity. Erhard said it is common practice for them to arrange the feed so as to permit adjustment relative to the focal point during operation. After peaking the amplitude of the 10 GHz signal and switching to 24 GHz, the 24 GHz signal is further peaked by adjusting the feed relative to the focal point. I assumed this was to ensure you were at the exact focal point required for the 24 GHz section, as this was before I had conducted any phase center measurements. In preparing for the ARRL 10 GHz and Up Cumulative Contest this year I arranged my feed to permit such an adjustment. While on my antenna range I verified the feedhorn was at the focal point of the dish for both bands. At two roving locations working W5LUA on 24 GHz, I adjusted the feedhorn location relative to the focal point and was quite shocked to see the peak amplitude of the 24 GHz signal occur at a point different from the 10 GHz peak. The 10 GHz amplitude peak occurred at the point I had marked during my antenna range measurement, but the 24 GHz signal amplitude peaked closer toward the dish! The peak relative to azimuth and elevation remained the same. Upon returning home, I went to the antenna range and obtained an amplitude peak on both bands at the same point. We'll be investigating this interesting phenomenon in the coming months!

Gain Measurements
This feedhorn was used on a .45 f/D dish 2 ft in diameter. The estimated gain at 55% efficiency and the actual gain measurements are contained in Table 6.

## Conclusion

Additional work is required on the 2.3 GHz / 3.4 GHz feed to bring the optimum f/D points closer together. This does not, however, inflict degradation sufficient to render one band inferior to the other. This horn has been employed on numerous rover expeditions and home installations utilizing shallow dishes and has performed very well.

The W5LUA 5.7 GHz/10 GHz dual band feed provides excellent performance on dishes with an f/D of around .45. At lower f/D ratios, the feedhorn performs well with only a slight reduction in efficiency. I use this feed in my home and rover installations. I have consistently worked W5LUA at 230 miles from Mt. Nebo, Arkansas while roving. From home, W5LUA is worked consistently at 320 miles and WA8WZG has been worked on both bands at 645 miles. The antenna in the home installation is a 1 meter, .35 f/D dish. The rover antenna is a 2 ft, .45 f/D dish.

The W5ZN 10 GHz/24 GHz dual band feed provides excellent performance with an f/D of approximately .45. At lower f/D ratios, the efficiency is reduced on the 24 GHz section but not for the 10 GHz section. For this reason, it is recommended to utilize this feedhorn on a dish of approximately .45 to maintain optimum conditions. This horn provides the luxury of peaking a signal on 10 GHz, then moving to 24 GHz where the beamwidth is considerably smaller and not having to worry about hunting the other station by re-peaking azimuth or elevation. I have used this feedhorn extensively in rover operation and have worked W4HHK consistently at 70 miles on 10 GHz (Paul runs 1 watt in the shack and a 1 ft. dish). W5LUA is consistently worked at 175 miles on 10 GHz and 29 miles on 24 GHz. There has not been an opportunity to attempt greater distances with this feed to date.

Just as this paper was going to print, Paul has published another paper in QEX[7] titled "Parabloic Dish Feeds – Phase and Phase Center". Additional phase center data on these feeds will be presented during my presentation of this paper at Microwave Update '99 in Plano, TX.

Are you limited to one dish? Try one of these feeds and get on a new band. Al and I will be waiting for you!

## Acknowledgements

I want to again acknowledge and thank my friends Al Ward, W5LUA, and Paul Wade, W1GHZ. The completion of this project would not have been possible without their advice.

Paul's compilation and presentation of antenna data, specifically regarding parabolic antennas, is a "must read" for anyone involved in or considering microwave operation. He has provided an extremely valuable tool, the *FEEDPATT* program, which permits one to easily examine and optimize their microwave antenna system.

Al's (and most important, Emily's) tolerance of my late night and early morning ranting and faxes on this subject are appreciated. Thanks for keeping me calibrated Al!

**References:**


1. Horns for the Holidays; Joel Harrison, W5ZN – Proceedings of Microwave Update, 1997 or http://users.ipa.net/~wb5igf
2. Dual Band Feedhorns for 2304/3456 MHz and 5760/10368 MHz; Al Ward, W5LUA – Proceedings of Microwave Update, 1997
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5. W1GHZ Microwave Antenna Book; Paul Wade, W1GHZ – { HYPERLINK http://www.qsl.net/~n1bwt }
6. The ARRL UHF/Microwave Experimenters Manual; American Radio Relay League, Newington CT
7. QEX – Forum for Communications Experimenters; American Radio Relay League, Newington, CT

## W5ZN Feedhorn Data Compilation

| Amateur Band Data | | | Feedhorn Data | | | | Near Field Data $\frac{2D^2}{\lambda}$ |
|---|---|---|---|---|---|---|---|
| Frequency GHz | λ Centimeters | λ Inches | Feed Type | Diameter λ | Diameter Inches | Length Inches | Near Field / Far Field Boundary |
| 2.304 | 13.02 | 5.125" | Coffee Can | 0.76λ | 4.0" | 5.3" | 6.24" |
| 3.456 | 8.68 | 3.42" | Soup Can | 0.76λ | 2.65" | 3.8" | 4.10" |
| 5.760 | 5.21 | 2.05" | 1½" Copper Pipe | 0.73λ | 1.5" | 4.9" | 2.20" |
| 10.368 | 2.89 | 1.14" | ¾" Copper Pipe | 0.70λ | 0.75" | 2.0" | 1.00" |
| 24.192 | 1.24 | 0.49 | Open WR42 | a = 0.857λ | a = 0.420" | Waveguide | 0.72" |
| | | | ¾" Copper Pipe | 1.53λ | 0.75" | 2.0" | 2.3" |

**Near Field Formulas**

**Feedhorns:** $nf = \frac{2D^2}{\lambda}$

Where D = Horn Diameter in inches
λ = Wavelength in inches

**Waveguide:** $nf = \frac{2a^2}{\lambda}$

a = Waveguide Open End
Where sides a , b ($a \geq b$)

**Table 1**

# 2.304 GHz Feedhorn Pattern Measurements

| E Plane (Horizontal) | | | | H Plane (Vertical) | | | |
|---|---|---|---|---|---|---|---|
| Offset Angle in Deg. | Amplitude Difference Single Coffee Can | Dual Band Coffee / Soup Can | Offset Coffee / Soup Can | Offset Angle in Deg. | Amplitude Difference Single Coffee Can | Dual Band Coffee / Soup Can | Offset Coffee Coffee / Soup Can |
| 0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0.0 |
| 10 | 0.0 | 0.0 | 0.5 | 10 | 0.2 | 0.0 | 0.0 |
| 20 | 0.8 | 0.5 | 1.0 | 20 | 1.0 | 0.5 | 0.8 |
| 30 | 2.0 | 1.5 | 1.0 | 30 | 1.5 | 1.5 | 1.5 |
| 40 | 3.0 | 3.0 | 2.0 | 40 | 3.0 | 4.0 | 3.0 |
| 50 | 4.0 | 4.5 | 3.0 | 50 | 5.0 | 6.0 | 4.5 |
| 60 | 5.0 | 6.0 | 5.0 | 60 | 7.0 | 7.0 | 7.0 |
| 75 | 8.5 | 7.0 | 6.0 | 70 | 10.0 | 8.0 | 8.0 |
| 90 | 11.0 | 10.0 | 9.0 | 90 | 11.0 | 13.0 | 10.0 |
| 110 | 13.0 | 11.0 | 12.0 | 110 | 15.0 | 20.0 | 14.0 |
| 135 | 11.0 | 14.0 | 12.0 | 130 | 25.0 | 25.0 | 18.0 |
| 145 | 14.0 | 11.0 | 14.0 | 145 | 25.0 | 20.0 | 18.0 |
| 160 | 14.0 | 15.0 | 20.0 | 155 | 25.0 | 25.0 | 20.0 |
| 170 | 16.0 | 17.0 | 14.0 | 170 | 15.0 | 20.0 | 20.0 |
| 180 | 12.0 | 12.0 | 12.0 | 180 | 13.0 | 13.0 | 20.0 |

**Table 2**

# 3.456 GHz Feedhorn Pattern Measurements

| E Plane (Horizontal) | | | | H Plane (Vertical) | | | |
|---|---|---|---|---|---|---|---|
| Offset Angle in Deg. | Amplitude Difference | | | Offset Angle in Deg. | Amplitude Difference | | |
| | Single Soup Can | Dual Band Coffee / Soup Can | Offset Coffee / Soup Can | | Single Soup Can | Dual Band Coffee / Soup Can | Offset Coffee Coffee / Soup Can |
| 0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0.0 |
| 10 | 0.5 | 0.5 | 0.5 | 10 | 0.5 | 0.4 | 0.2 |
| 20 | 1.0 | 2.0 | 1.5 | 20 | 1.2 | 1.0 | 1.5 |
| 30 | 2.5 | 4.0 | 1.0 | 30 | 2.0 | 3.0 | 2.0 |
| 40 | 3.5 | 6.0 | 2.0 | 40 | 3.5 | 5.0 | 3.0 |
| 50 | 6.0 | 9.0 | 3.0 | 50 | 5.0 | 8.0 | 4.0 |
| 60 | 7.0 | 11.0 | 5.0 | 60 | 7.0 | 12.0 | 7.0 |
| 75 | 10.0 | 14.0 | 9.0 | 70 | 10.0 | 15.0 | 9.0 |
| 90 | 13.0 | 16.0 | 14.0 | 90 | 12.0 | 25.0 | 12.0 |
| 110 | 18.0 | 20.0 | 12.0 | 110 | 20.0 | 25.0 | 20.0 |
| 135 | 20.0 | 18.0 | 25.0 | 130 | 25.0 | 25.0 | 15.0 |
| 145 | 20.0 | 20.0 | 13.0 | 145 | 25.0 | 25.0 | 25.0 |
| 160 | 18.0 | 25.0 | 14.0 | 155 | 25.0 | 25.0 | 15.0 |
| 170 | 20.0 | 10.0 | 25.0 | 170 | 25.0 | 25.0 | 25.0 |
| 180 | 20.0 | 25.0 | 25.0 | 180 | 20.0 | 25.0 | 25.0 |

**Table 3**

# W5LUA Dual Band 5/10 GHz Feedhorn Pattern Measurements

| E Plane (Horizontal) | | | | H Plane (Vertical) | | | |
|---|---|---|---|---|---|---|---|
| Offset Angle in Deg. | Amplitude Difference 5.760 GHz Section | | 10.368 GHz Section | Offset Angle in Deg. | Amplitude Difference 5.760 GHz Section | | 10.368 GHz Section |
| 0 | 0.0 | | 0.0 | 0 | 0.0 | | 0.0 |
| 10 | 0.0 | | 0.2 | 10 | 0.0 | | 0.6 |
| 20 | 0.8 | | 3.0 | 20 | 0.5 | | 2.5 |
| 30 | 2.0 | | 13.0 | 30 | 1.2 | | 6.0 |
| 40 | 3.5 | | 20.0 | 40 | 2.5 | | 10.0 |
| 50 | 5.0 | | 11.0 | 50 | 5.0 | | 13.0 |
| 60 | 9.0 | | 15.0 | 60 | 9.0 | | 15.0 |
| 70 | 10.0 | | 15.0 | 70 | 9.0 | | 17.0 |
| 80 | 10.8 | | 15.0 | 80 | 9.5 | | 17.0 |
| 90 | 13.0 | | 15.0 | 90 | 13.0 | | 16.0 |
| 100 | 13.0 | | 19.0 | 100 | 18.0 | | 16.0 |
| 120 | 13.0 | | 20.0 | 120 | 20.0 | | 18.0 |
| 140 | 15.0 | | 20.0 | 140 | 20.0 | | 18.0 |
| 160 | 20.0 | | 17.0 | 160 | 20.0 | | 18.0 |
| 180 | 18.0 | | 20.0 | 180 | 20.0 | | 18.0 |

**Table 4**

# W5ZN Dual Band 10/24 GHz Feedhorn Pattern Measurements

| E Plane (Horizontal) | | | | H Plane (Vertical) | | | |
|---|---|---|---|---|---|---|---|
| | Amplitude Difference | | | | Amplitude Difference | | |
| Offset Angle in Deg. | 10.368 GHz Section | | 24.192 GHz Section | Offset Angle in Deg. | 10.368 GHz Section | | 24.192 GHz Section |
| 0 | 0.0 | | 0.0 | 0 | 0.0 | | 0.0 |
| 10 | 0.2 | | 0.2 | 10 | 0.2 | | 0.6 |
| 20 | 1.0 | | 1.5 | 20 | 0.8 | | 2.5 |
| 30 | 2.0 | | 2.5 | 30 | 2.0 | | 6.0 |
| 40 | 4.5 | | 4.0 | 40 | 5.0 | | 10.0 |
| 50 | 7.0 | | 5.0 | 50 | 8.0 | | 13.0 |
| 60 | 9.0 | | 8.0 | 60 | 10.0 | | 15.0 |
| 70 | 10.0 | | 11.5 | 70 | 11.0 | | 17.0 |
| 80 | 14.0 | | 13.5 | 80 | 15.0 | | 17.0 |
| 90 | 14.0 | | 15.0 | 90 | 20.0 | | 16.0 |
| 100 | 14.0 | | 17.0 | 100 | 18.0 | | 16.0 |
| 120 | 15.0 | | 20.0 | 120 | 25.0 | | 18.0 |
| 140 | 18.0 | | 20.0 | 140 | 25.0 | | 18.0 |
| 160 | 20.0 | | 20.0 | 160 | 25.0 | | 18.0 |
| 180 | 25.0 | | 20.0 | 180 | 25.0 | | 18.0 |

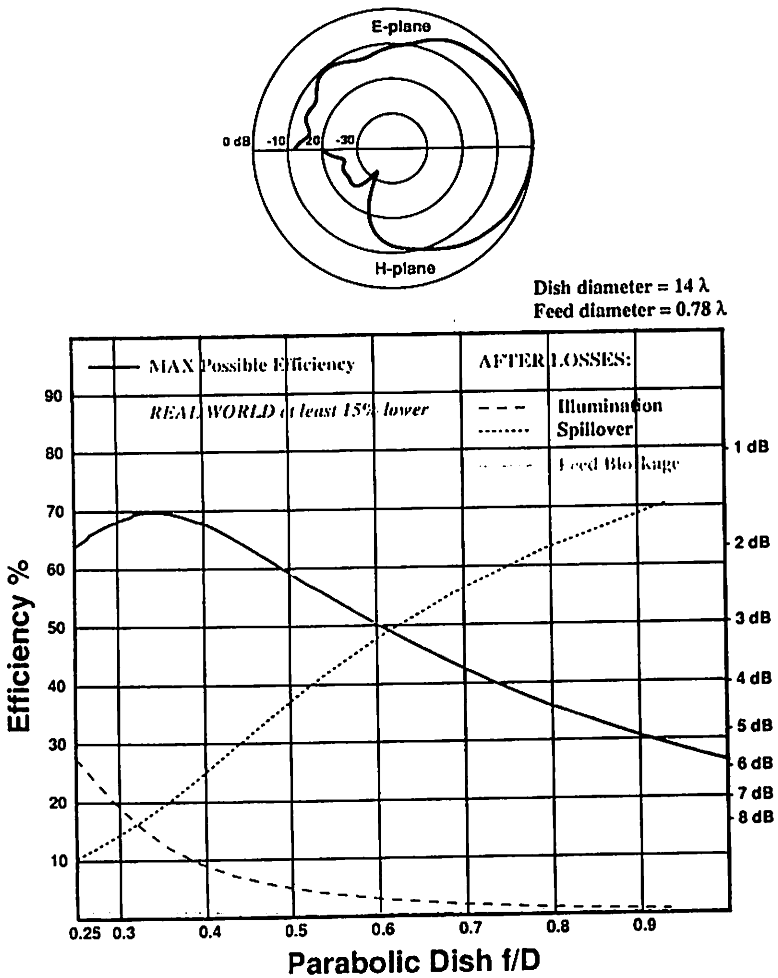
**Table 5**

# Gain Measurements by W5ZN

| Frequency MHz | Antenna Diameter | Dish f/D | Gain Estimate 55% Efficiency | Feedhorn Type | W5ZN Measured Gain |
|---|---|---|---|---|---|
| 2304 | 3 ft | 0.30 | 24.0 dB | W5LUA | 22.5 dB |
| 3456 | 3 ft | 0.30 | 27.5 dB | W5LUA | 26.0 dB |
| 5760 | 2 ft | 0.45 | 28.5 dB | W5LUA | 28.5 dB |
| 10368 | 2 ft | 0.45 | 33.5 dB | W5LUA | 32.5 dB |
| 10368 | 2 ft | 0.45 | 33.5 dB | W5ZN | 33.0 dB |
| 24192 | 2 ft | 0.45 | 41.0 dB | W5ZN | 40.0 dB |

**Table 6**

**Single Coffee Can Feed - 2.304 GHz**




**Single Soup Can Feed - 3.456 GHz**

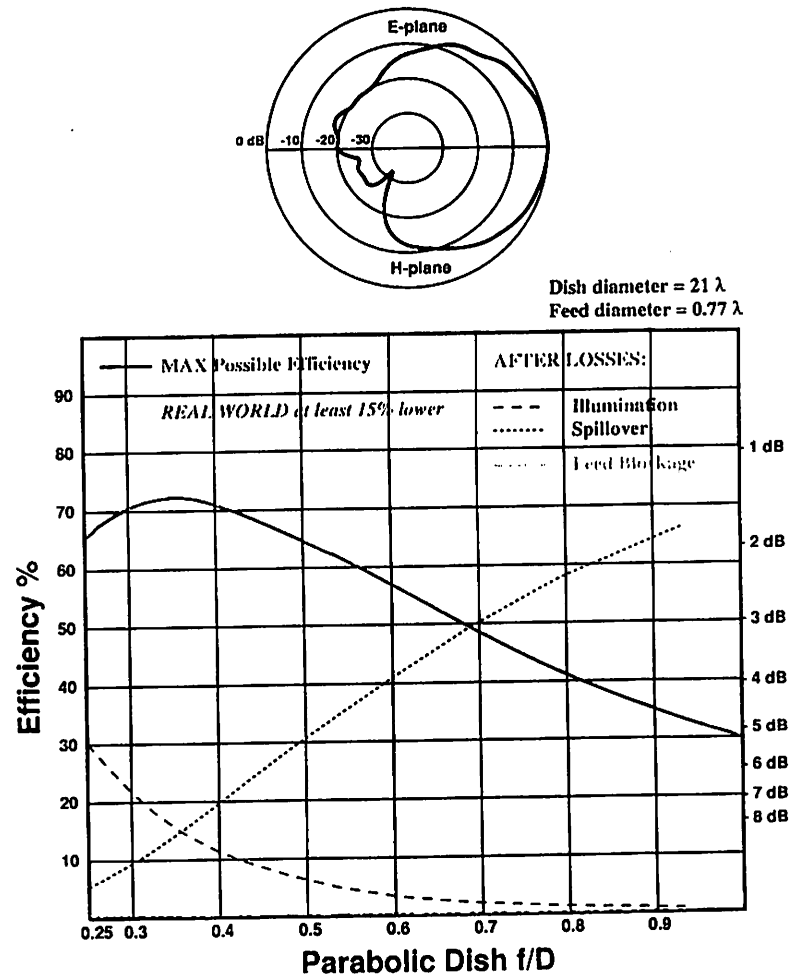
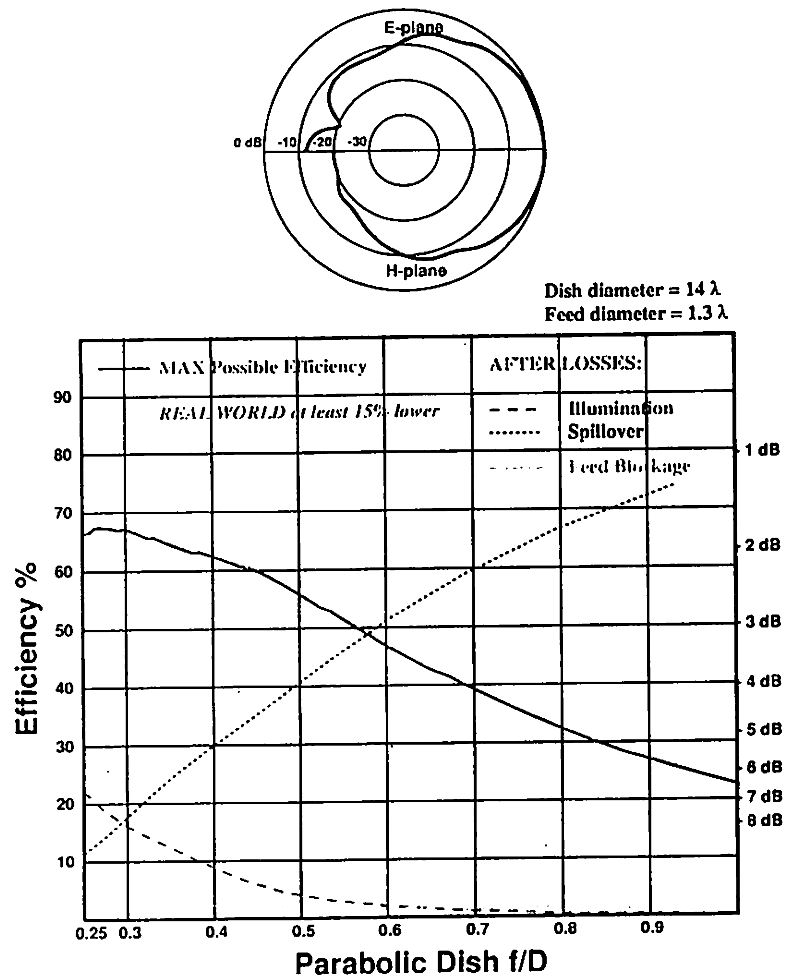



Figure 6

## Offset Feeds - 2.304 GHz Coffee Can Section




## Offset Feeds - 3.456 GHz Soup Can Section

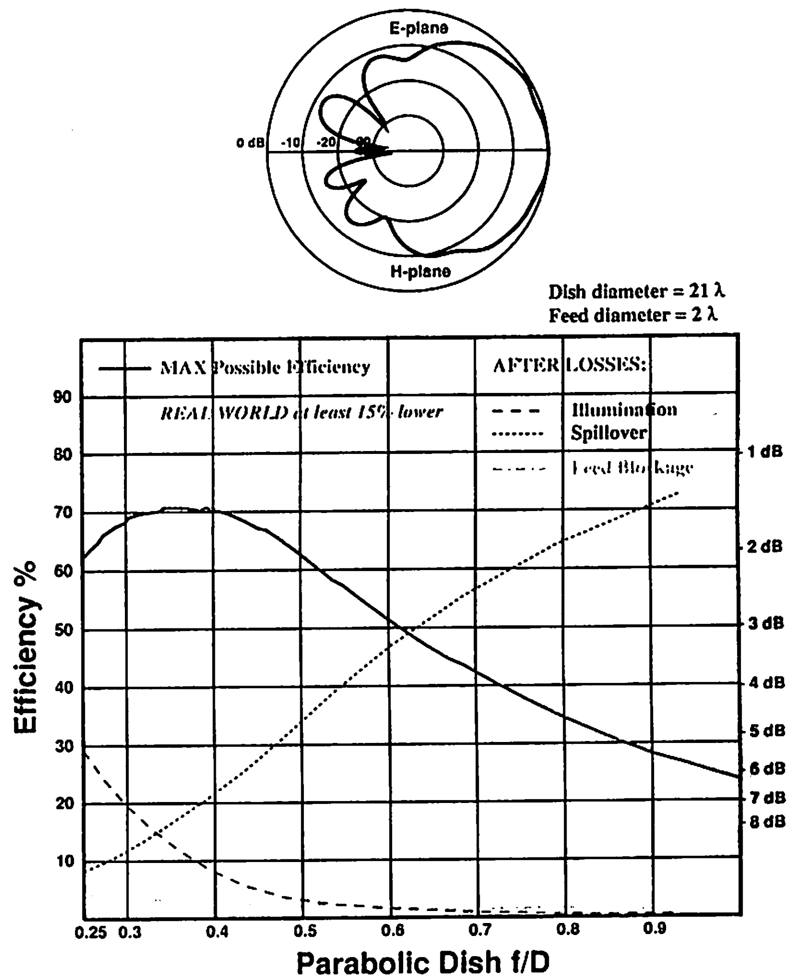
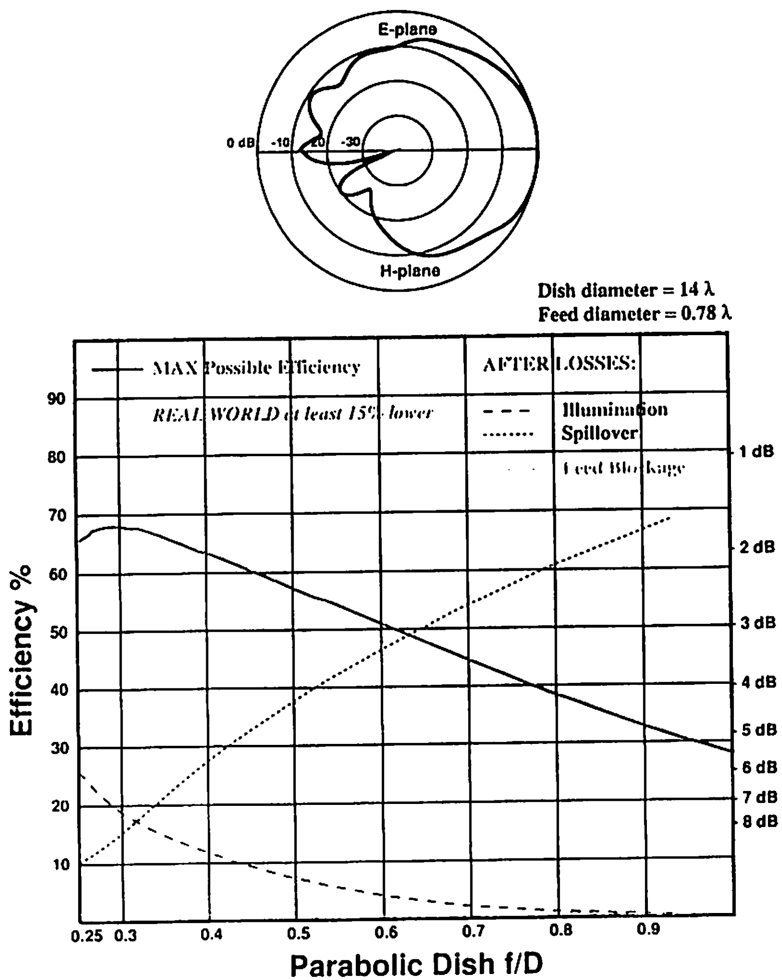



Figure 7

## W5LUA Dual Band Feed - 2.304 GHz Coffee Can Section




## W5LUA Dual Band Feed - 3.456 GHz Soup Can Section

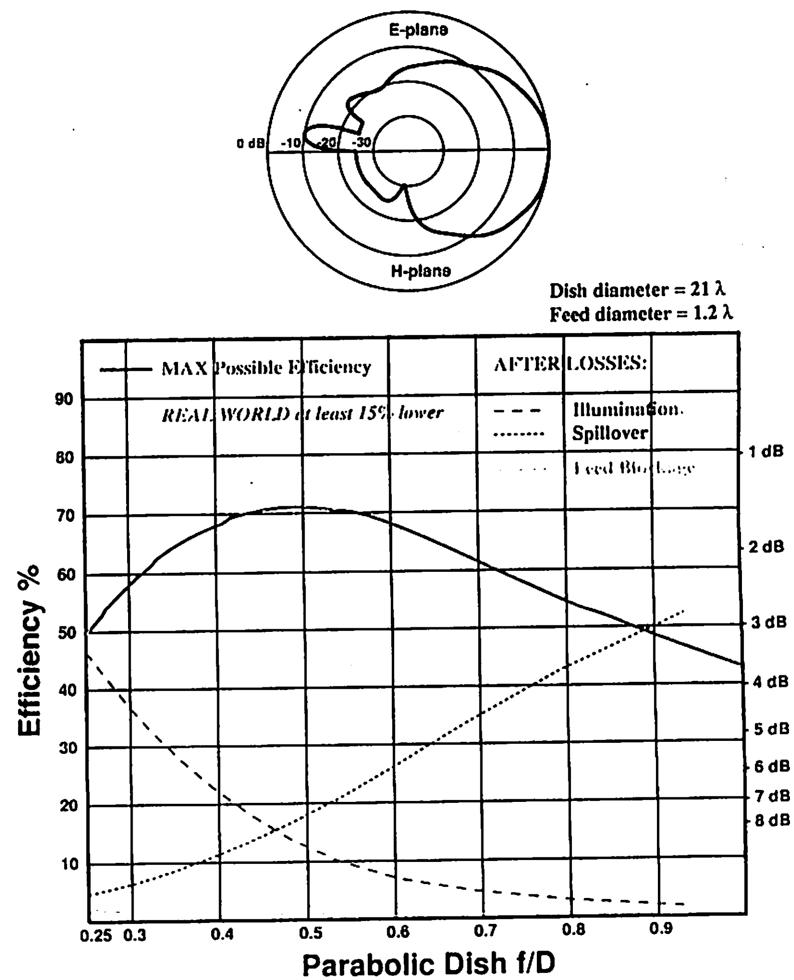
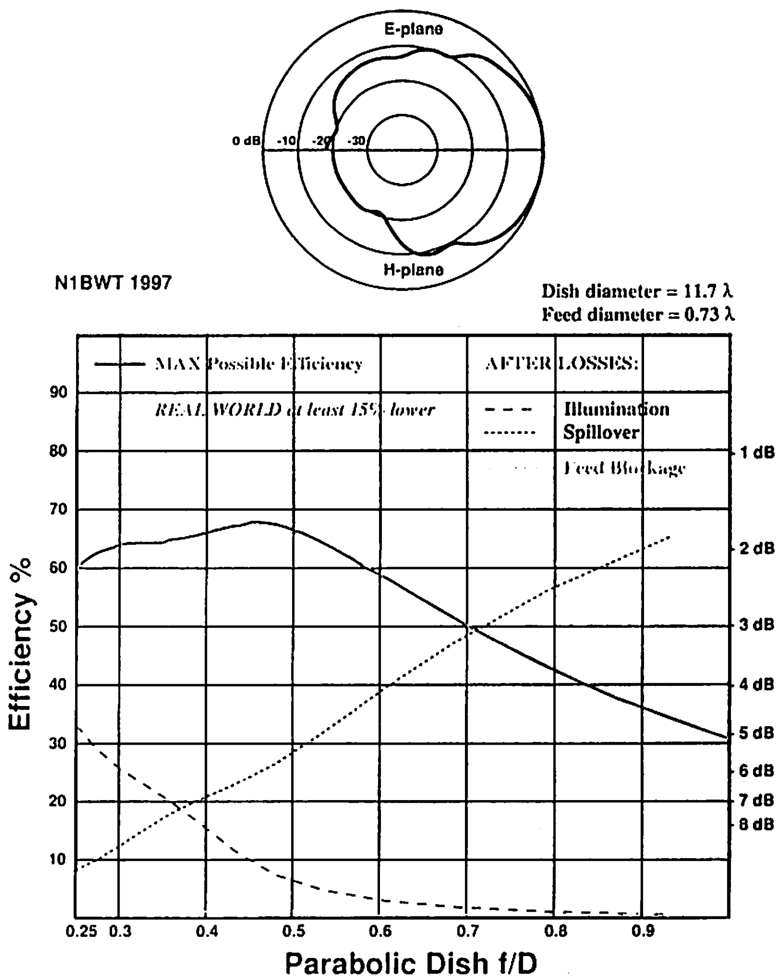



Figure 8

## W5LUA Dual Band Feed - 5.7 GHz Section




## W5LUA Dual Band 5/10 GHz Feed - 10 GHz Section

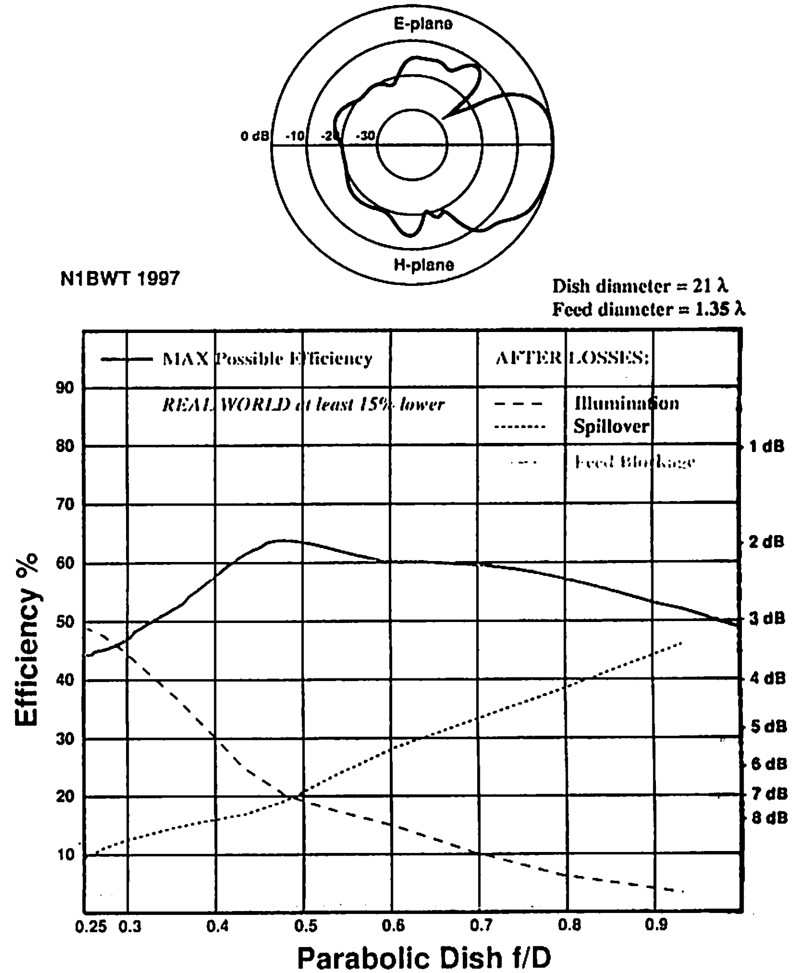
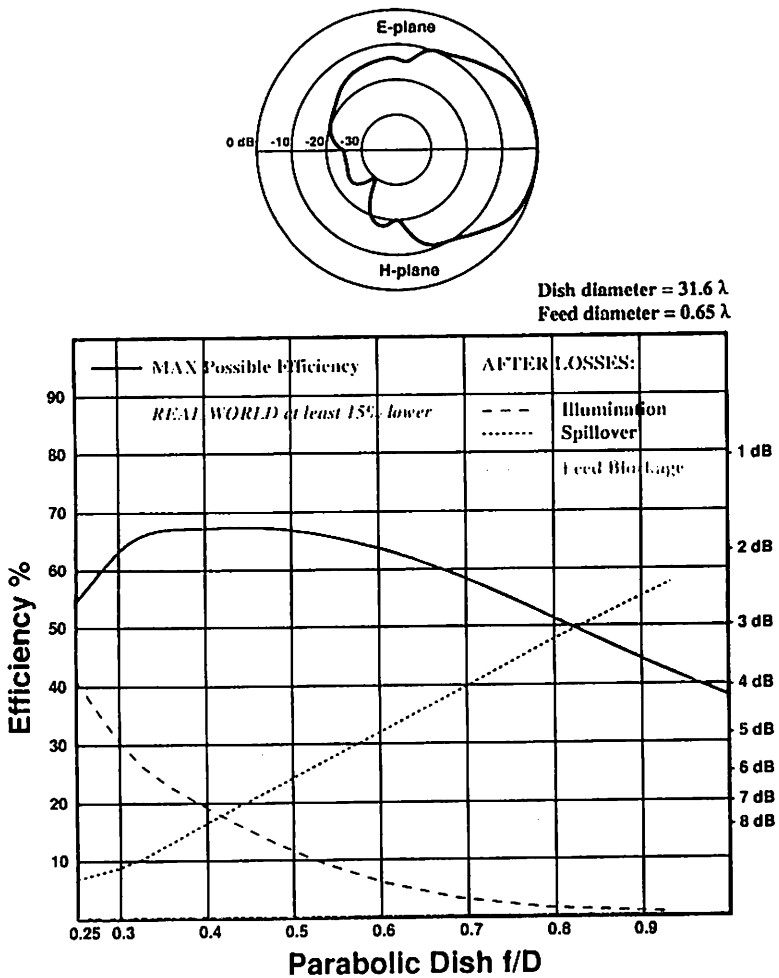



Figure 9

## W5ZN Dual Band Feed - 10.368 GHz Section




## W5ZN Dual Band Feed - 24.192 GHz Section

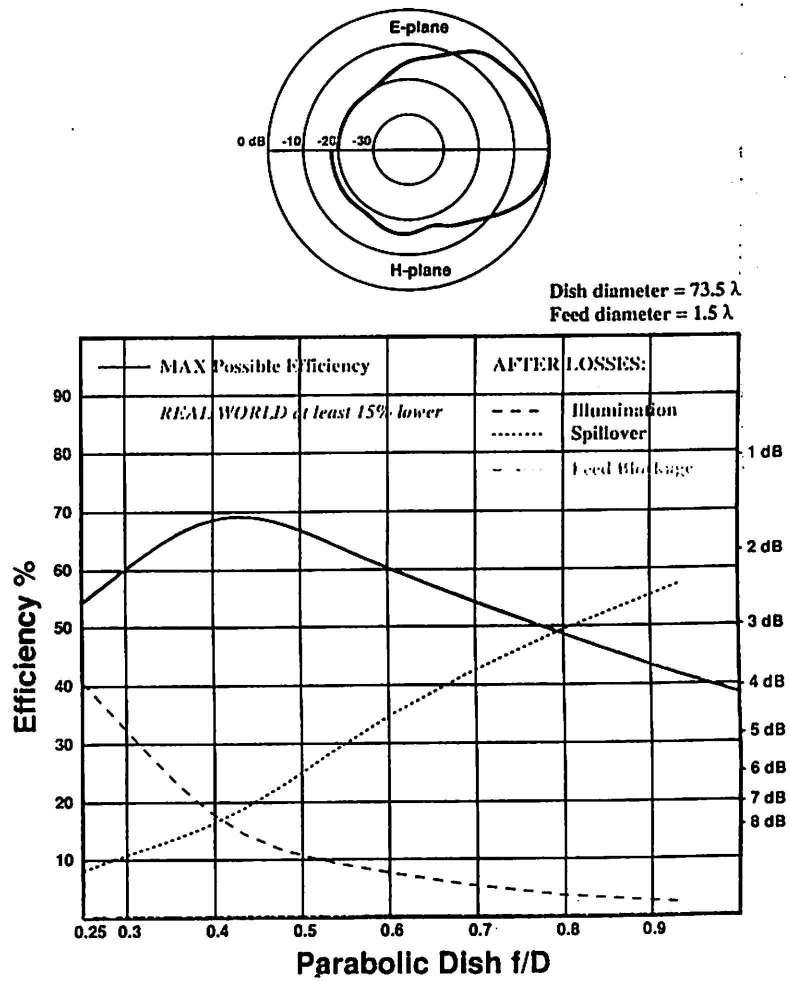



Figure 10