

## SEPTUM FEED REVISITED

*by Rastislav Galuscak, OM6AA*

### Introduction

A septum feed was evaluated when I considered new feed configurations for my larger dish antenna. Frantisek Strihavka - OK1CA, developed and Zdenek Samek - OK1DFC [1], described septum feed for hams working on 23 and 13 cm. Computer analysis of this feed configuration performed by Paul Wade - W1GHZ [2], gave good results. Paul's analysis inspired me to improve the efficiency of my septum feed by adding "multi-collar rings," also referred to as a "choke." This type of modified circular feed is known as "Chaparral" style feed [3].

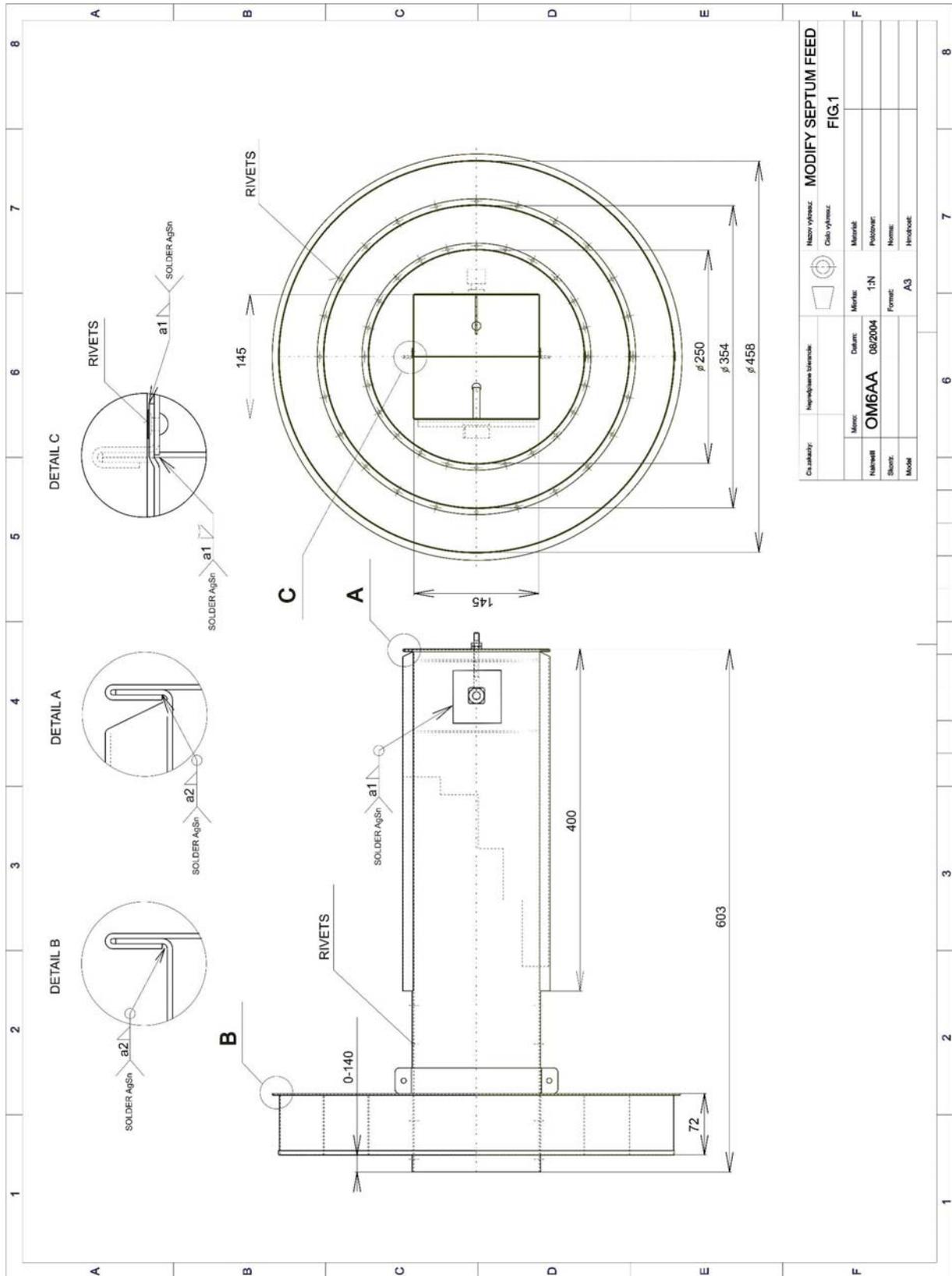
According to this reference, I have added three rings with minimal spacing between rings of  $0.22\lambda$ , so as not to block a relatively small dish diameter of  $16.4\lambda$ . Dimensions of the resulting modified feed assembly for 23 cm are shown in Fig. 1. The feed assembly was made from 0.8mm thick polished stainless steel plate. Stainless steel was chosen for its superior anticorrosive properties, unlike those of copper or aluminum. Incremental loss is minor; only a few thousandths of a dB on 23 cm compared to copper. However, at higher frequencies a material with higher conductivity should be used.

Inside the feed assembly, the septum is soldered to the feed body on both sides and is attached by rivets to the plate at the closed end. The end plate is also soldered to the feed body. The area around the connectors is mechanically reinforced by a second plate formed in a "U" shape on which the coaxial connectors are mounted. The rings are affixed with rivets and the widest one is soldered from the outer side as well. The Tx port employs a 7/16" female connector and its probe is a 6mm diameter silver plated brass rod. Minimum VSWR is adjusted by the probe length and also with a tuning screw that is perpendicular to the probe. The Rx port employs a male, "N" type, connector and its probe is a 2.3mm diameter rod, also of silver plated brass. Minimum VSWR here is adjusted by the probe length only.

My interest in studying the performance of the modified septum feed led me to Czech Technical University (CTU) in Prague, where I was able to take advantage of their interest in this device. Thanks to Prof. Miloš Mazánek, head of the Department of Electromagnetic Fields, I was able to perform and publish these measurements. All measurements were performed in an anechoic chamber at CTU. The feed assembly being tested was placed on a rotating turntable as a receiving antenna, for all pattern measurements.

A wide-band horn was used as the transmitting antenna. The measurement configuration is shown in Fig. 2. Both antennas were able to rotate 90 degrees longitudinally for specific measurements. The feed assembly probe orientation (vertical or horizontal) was used to define elevation and azimuth planes. Similarly, v or h polarization defines the orientation of the transmitting antenna.

"FEEDPATT" software, written by Paul Wade - W1GHZ [4], was used to evaluate the feed efficiency in a dish antenna. The "ANT-PC" program package, developed by Miroslav Procházka [5] And "PARPACUP.for" software, developed by Thomas Milligan [6] and modified by Miroslav Procházka, were used to calculate the dish antenna's resulting radiation pattern and directivity.

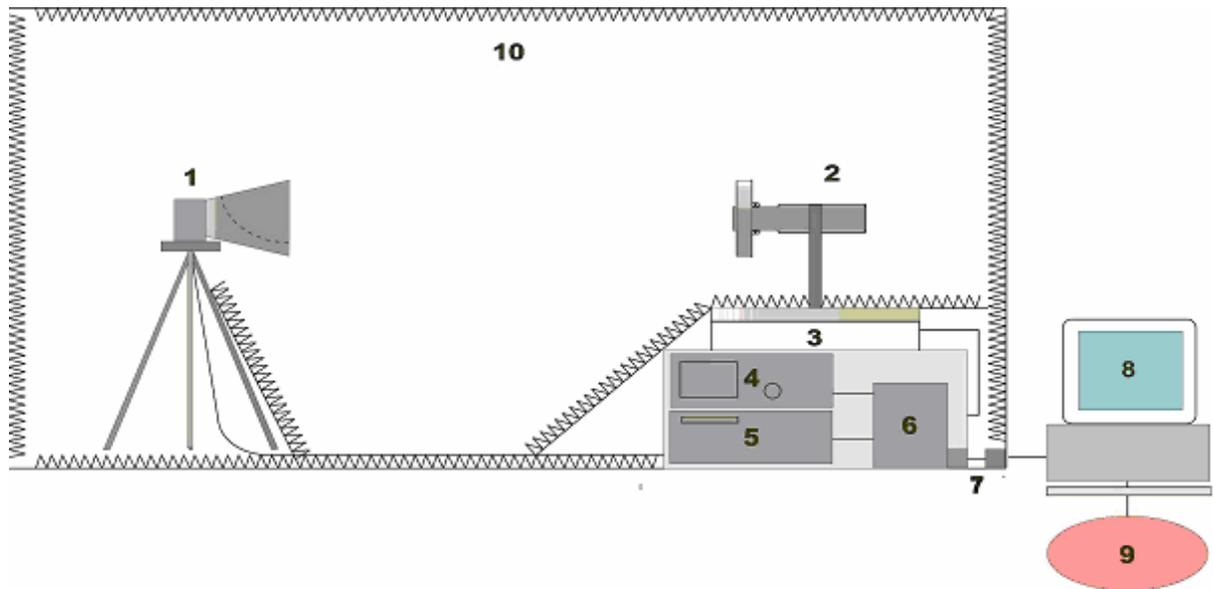


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Hlavní výkres		MODIFY SEPTUM FEED		FIG.1	
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Fig. 1 - Modify septum feed.

The following measurements have been performed:

- I. Impedance Match at Rx and Tx Ports
- II. Impedance Match Changes against a Conductive Plate
- III. Comparison of Radiation Characteristics at Rx and Tx Ports
- IV. Radiation Patterns at both Ports with Various Choke Positions
- V. Feed Pattern Frequency Dependency
- VI. Isolation Between Ports
- VII. Phase Center Position

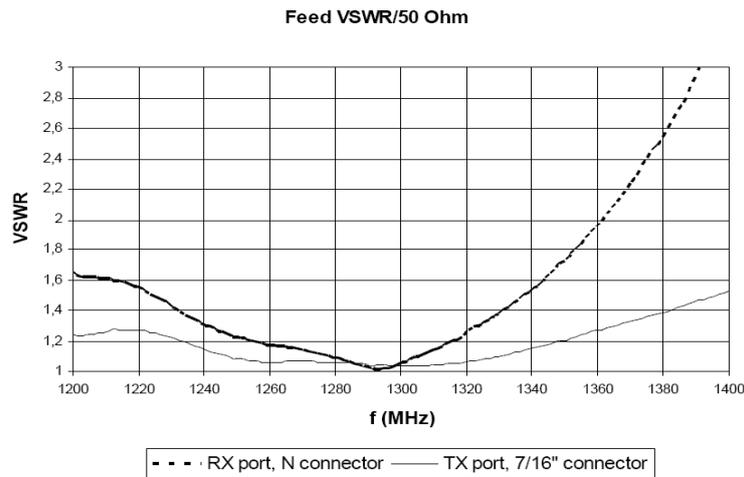


1- TX ANTENNA, 2- RX ANTENNA, 3- ROTATOR, 4- HP 8564E SPEKTRUM ANALYZER, 5- HP 8350B SIGNAL GENERATOR, 6- PC, 7- AC FILTERS, 8- CONTROL COMPUTER, 9- INTERNET, 10- ANECHOIC CHAMBER.

Fig . 2 - The anechoic chamber layout.

### I. Impedance Match at Rx and Tx Ports

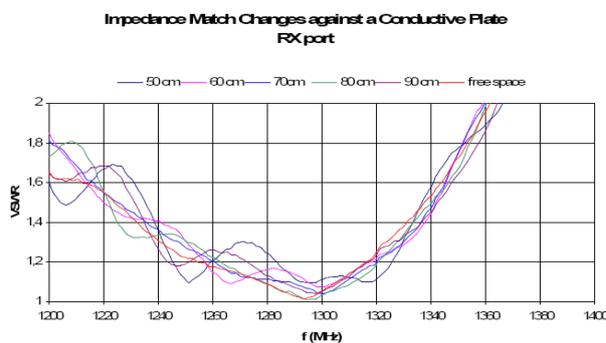
*Measurement condition: Choke flush, free space.* An ANRITSU S400A Site Master transmission line and antenna analyzer was used for these measurements. Results are shown in Fig. 3. The return loss at the Rx port is about 40 dB. This very good impedance match can be viewed as a trade-off for narrower bandwidth. A return loss 33 dB was achieved at the Tx port, with wider bandwidth.



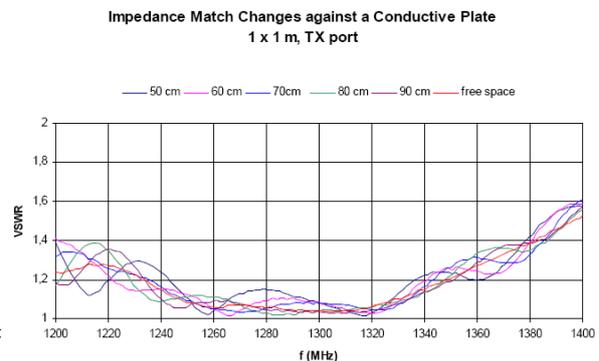
**Fig. 3 - Feed VSWR/50 Ohm.**

## II. Impedance Match Changes against a Conductive Plate

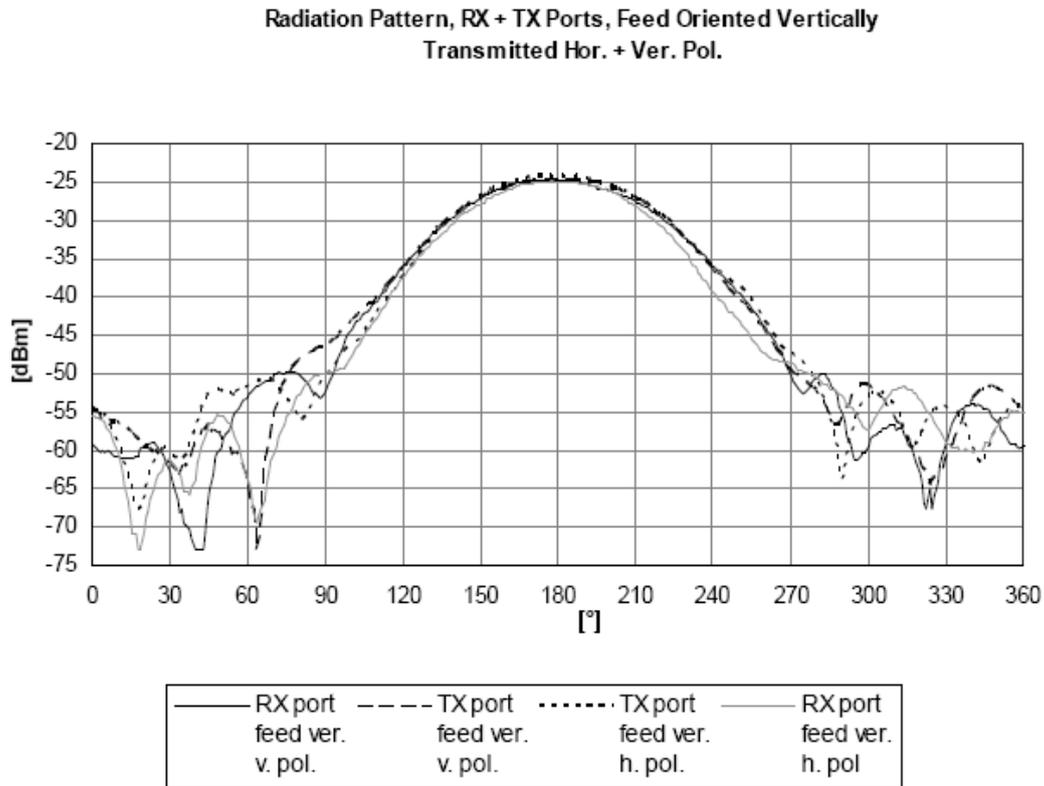
*Measurement condition: Choke flush.* These measurements were made to investigate VSWR changes that may be encountered when assembling the feed to a dish. A 1m x 1m conductive plane plate positioned normal to the feed's longitudinal axis was used to simulate the dish. The distance between the feed and plate was varied from 50 cm to 90 cm. The resulting VSWR performance is shown in Fig. 4 and Fig. 5. At distances over 90 cm, VSWR changes were negligible. Shorter distances between the feed and conductive plane simulate the effects of a deeper and smaller dish. At these shorter distances, VSWR ripple was observed. This indicates that when assembling the feed to a deeper and smaller dish, probe length adjustments may be necessary.



**Fig. 4 - Impedance match changes against a conductive plate. Rx port.**



**Fig. 5 - Impedance match changes against a conductive plate. Tx port.**



**Fig. 6** – Radiation pattern, Rx + Tx ports. Feed oriented vertically, transmitted hor. + ver. polarization.

### III. Comparison of Radiation Characteristics at Rx and Tx Ports

*Measurement condition: Choke flush.* These measurements, which compare radiation patterns at both ports, gave the first indication of feed circularity. Radiation patterns were measured with vertical feed orientation and both horizontal and vertical transmitting antenna polarizations. Initially, the feed's vertical axis of rotation was placed at the geometrical center of the feed assembly, midway between the closed end and the open end or aperture. With the axis located there, the observed radiation pattern was narrower than it actually was. For all further pattern measurements, the feed's vertical axis of rotation was placed at the feed's aperture, where the phase center position is expected. Results are shown in Fig. 6. Essentially identical radiation patterns were observed between the angles of 125 and 235 degrees with very good axial ratio, so good circularity is achieved at 180 degrees. The difference between ports is a maximum of only 0.7 dB at 180 degrees. From the graph, it is obvious that levels at the Rx and Tx ports are equivalent and the choke in this position does not degrade the circularity of the feed.

### IV. Radiation Patterns at both Ports with Various Choke Positions

*Measurement condition: The choke position was varied along the feed body toward the closed end according to Fig. 7.*

Feed radiation patterns were measured at both ports for the following choke positions:

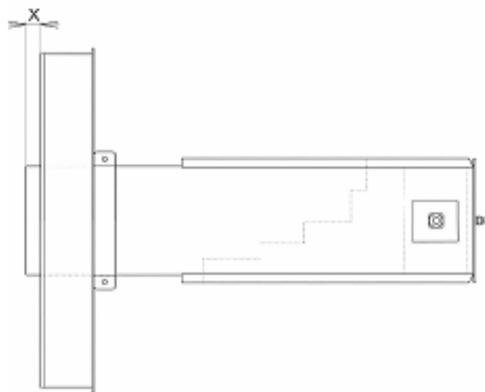
1. Flush with open end,  $x = 0$
2. Choke 30 mm back,  $x = 30$

### 3. Choke 60 mm back, $x = 60$

#### 4. Bare feed, no choke

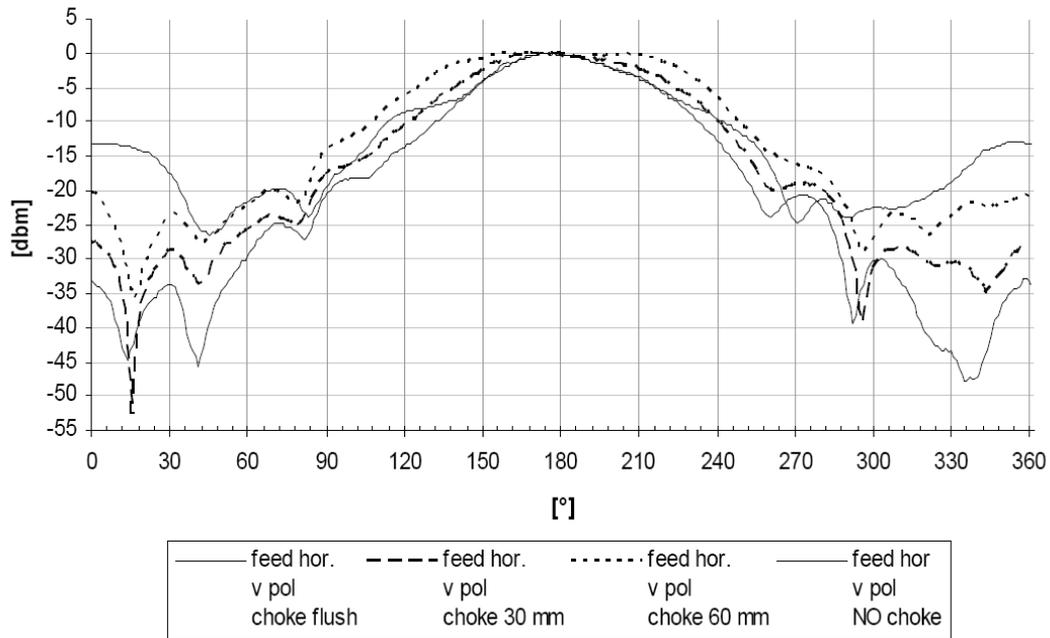
Normalized radiation patterns at the Rx port for vertical and horizontal feed orientations and for vertical and horizontal transmitting antenna polarizations are shown in Fig's. 8 through 11. Patterns were normalized to their respective maximums. We can see how the choke position affects the beam width as well. Moving the choke back toward the closed end of the feed assembly makes the beam wider, but differences between the polarizations increase. The resulting dish antenna efficiency for the Rx port with various choke positions was calculated using FEEDPATT software. These results are shown in Fig's. 12 through 15. These calculations are based on average values from vertical and horizontal polarization measurements for the appropriate plane with adjustments made for variations in symmetry, since both software programs assume symmetrical radiation patterns. From these figures it is apparent that the ring choke improves the efficiency of a dish of this size. Additionally, the use of a choke gives us the opportunity to tailor the feed's beam width appropriately for a given dish. For very deep dishes, good efficiency may be achieved, but with some associated degradation of circularity.

The dish antenna's directivity,  $Dir$  and resulting radiation pattern were calculated using ANT-PC and PARPACUP.for software. The PARPACUP.for program does not use actual measured values, but calculates the approximate radiation pattern using  $\cos^N \theta$ . The exponent,  $N$ , is based on dish edge illumination. Fig. 16 shows calculated results for the bare feed configuration where the dish aperture is partially blocked by the square waveguide supported by four 14 mm diameter struts. In Fig. 17, calculated results for the feed configuration having the choke 30 mm back and the same dish aperture blockage are shown. The program does not perform calculations using feed efficiency. Similar results were obtained at the Tx port. This port generates opposite, left-turn circular polarization. Radiation patterns are shown in Fig's. 18 and 19. As the patterns are nearly identical with those obtained at the Rx port, only one plane was measured. Also, because of only minor differences between ports, antenna efficiency for the Tx port was not calculated. For all calculations, a phase center position at the feed's aperture was assumed.



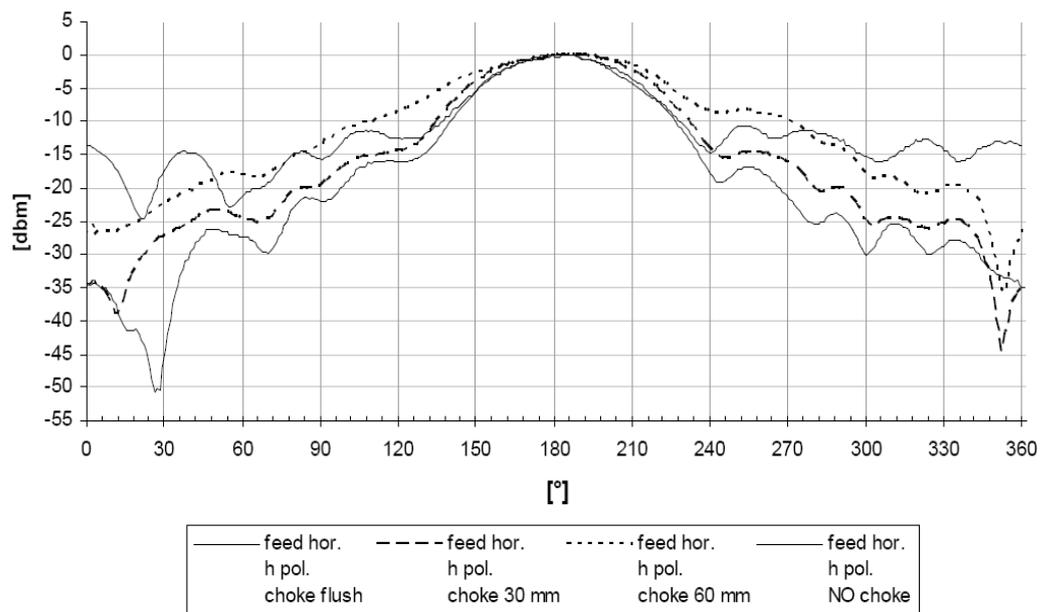
**Fig. 7** - Definition of parameter  $x$ .

**Radiation Pattern, RX Port, Feed Oriented Horizontally  
Transmitted Vert. Pol.**



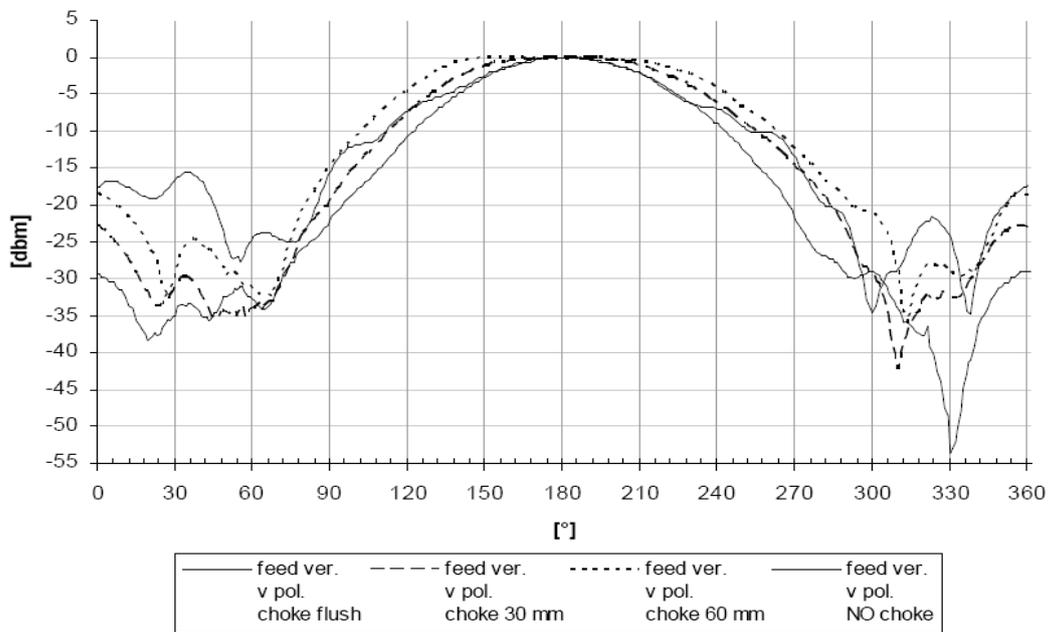
**Fig. 8** – Radiation pattern Rx port. Feed oriented horizontally, transmitted vert. polarization.

**Radiation Pattern, RX Port, Feed Oriented Horizontally  
Transmitted Hor. Pol.**



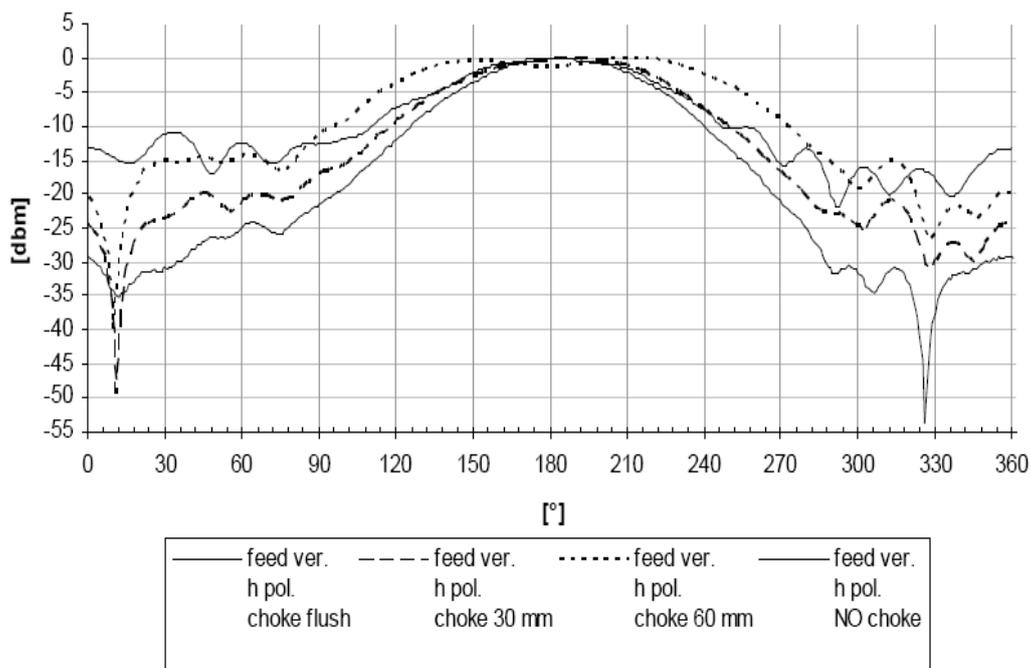
**Fig. 9** – Radiation pattern Rx port. Feed oriented horizontally, transmitted hor. polarization.

**Radiation Pattern, RX Port, Feed Oriented Vertically  
Transmitted Vert. Pol.**



**Fig. 10** – Radiation pattern, Rx port. Feed oriented vertically, transmitted vert. polarization.

**Radiation Pattern, RX Port, Feed Oriented Vertically  
Transmitted Hor. Pol.**



**Fig. 11** – Radiation pattern, Rx port. Feed oriented vertically, transmitted hor. polarization.

Septum Feed, OM6AA modification, Choke flush

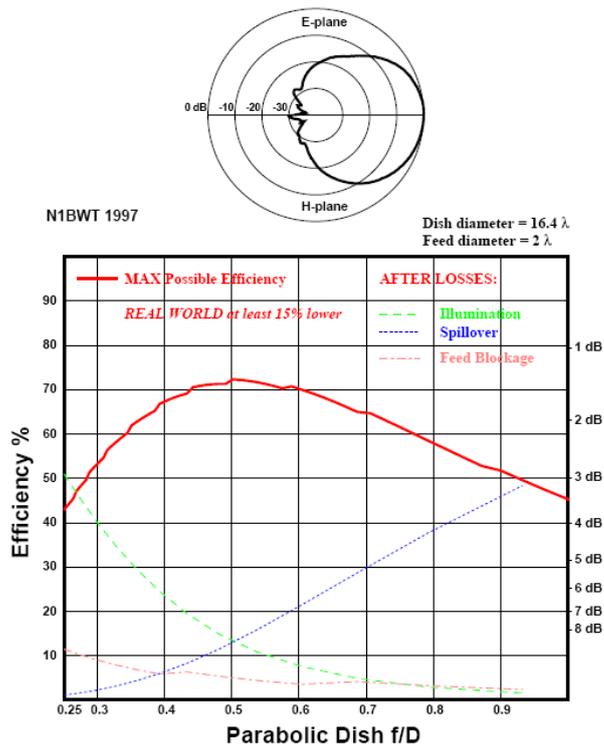


Fig . 12 - Antenna efficiency with choke in flush position.

Septum Feed, OM6AA modification, Choke 30mm back

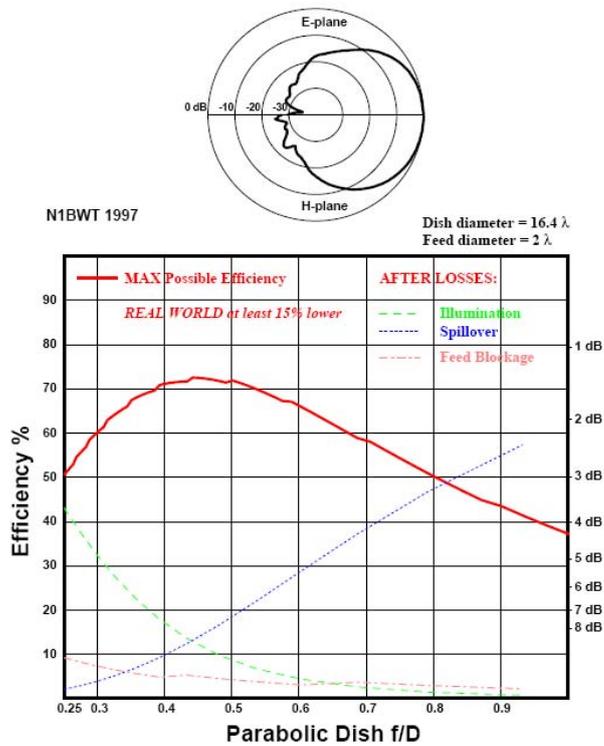


Fig. 13 - Antenna efficiency with choke 30mm back.

Septum Feed, OM6AA modification, Choke 60mm back

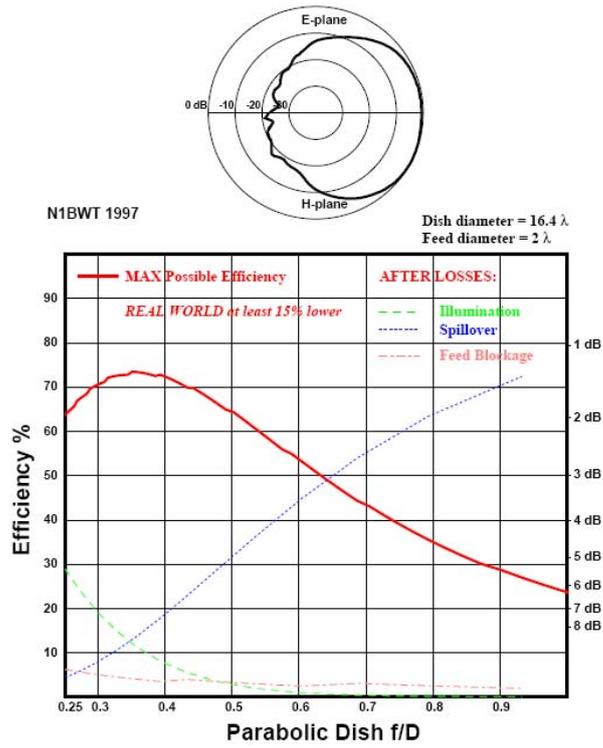


Fig. 14 - Antenna efficiency with choke 60mm back.

Septum Feed, RX port, NO Choke

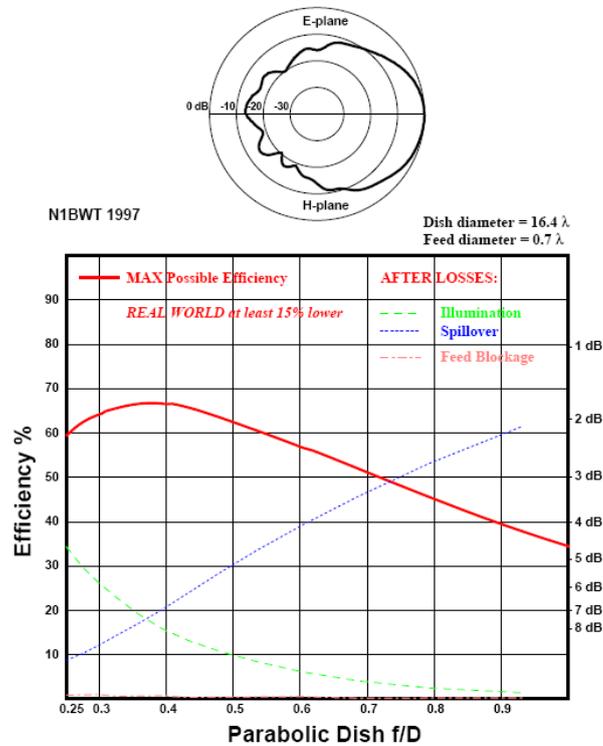
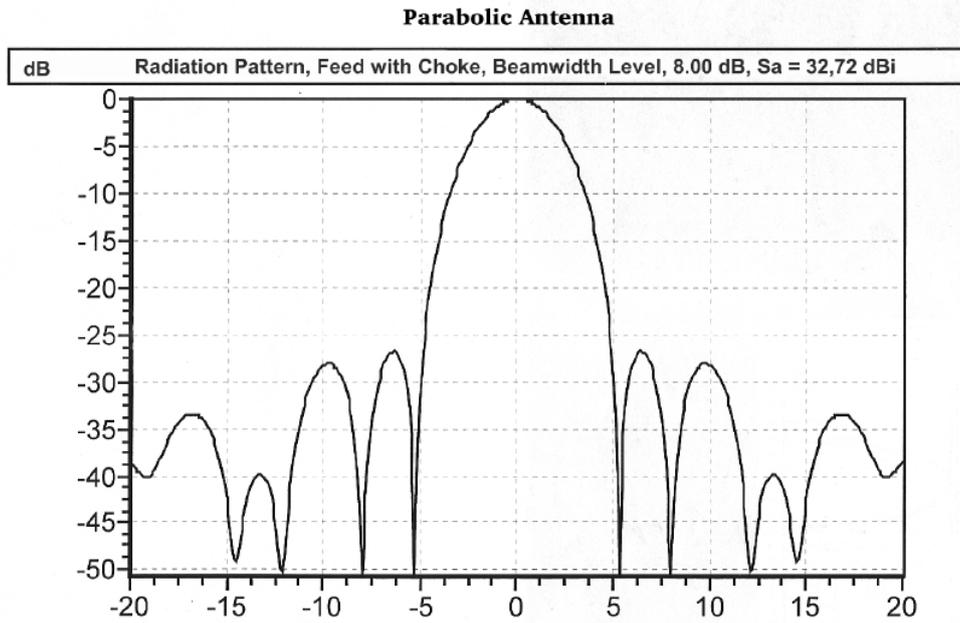
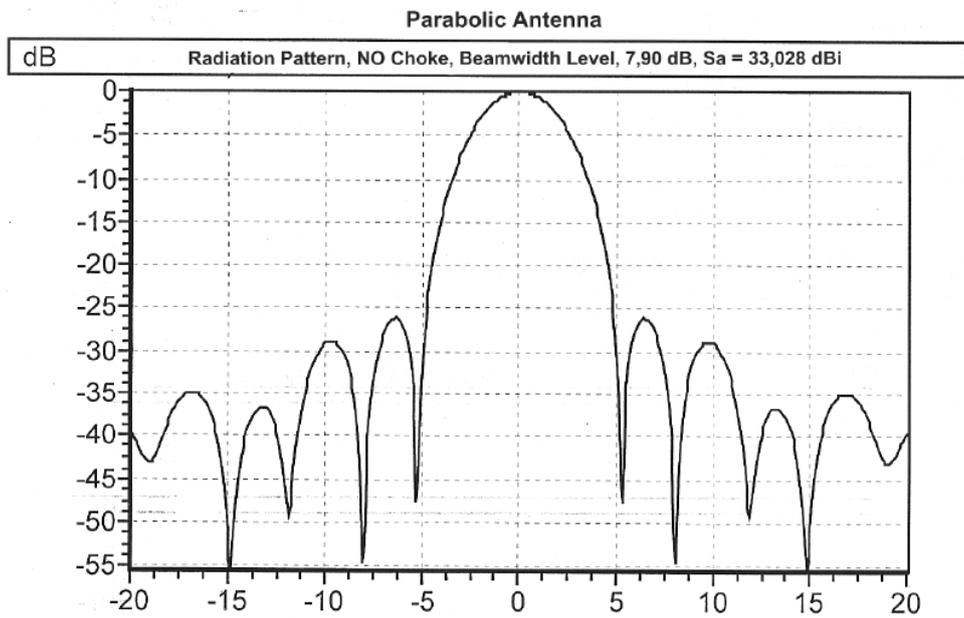


Fig. 15 - Antenna efficiency, no choke.

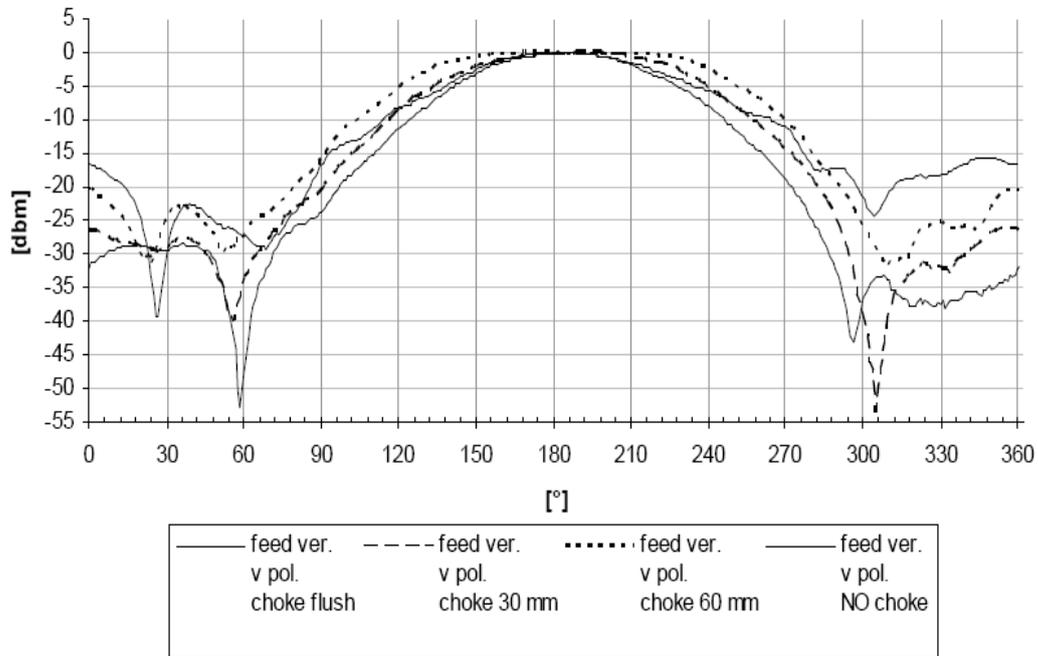


**Fig. 16** - Calculated radiation pattern for antenna configuration equipped with bare feed and four struts blockage.



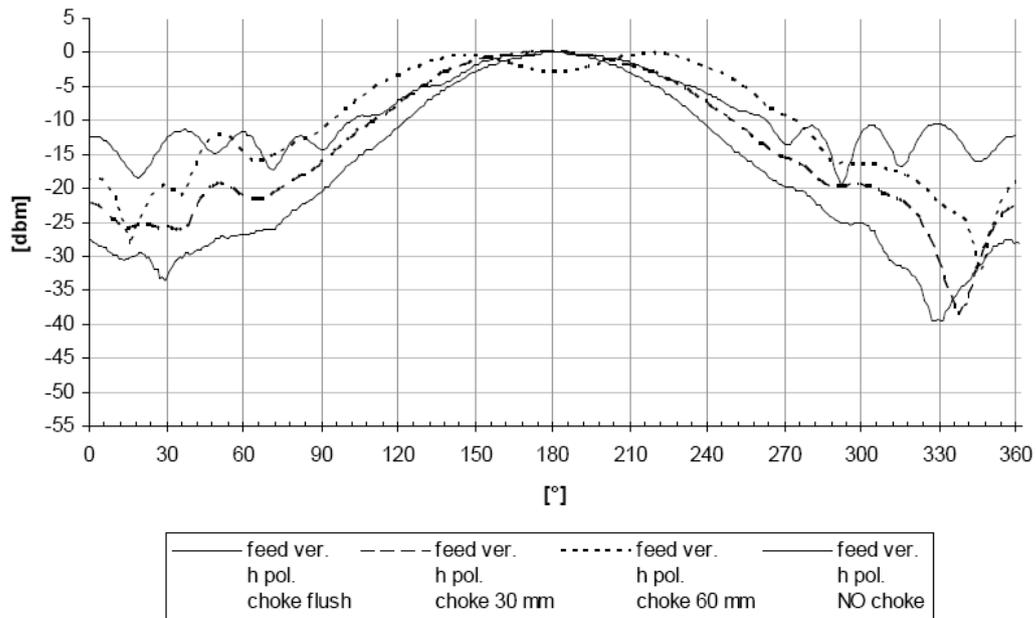
**Fig. 17** - Calculated radiation pattern for antenna configuration with feed including choke 30mm back and four struts blockage.

**Radiation Pattern, TX Port, Feed Oriented Vertically  
Transmitted Ver. Pol.**



**Fig. 18** - Radiation pattern, Tx port. Feed oriented vertically, transmitted ver. polarization.

**Radiation Pattern, TX Port, Feed Oriented Vertically  
Transmitted Hor. Pol.**



**Fig. 19** - Radiation pattern, Tx port. Feed oriented vertically, transmitted hor. polarization.

## V. Feed Pattern Frequency Dependency

*Measurement condition: Choke flush* This test provides information on how the feed radiation pattern depends on frequency. These measurements are useful for the 13 and 3 cm bands, where split frequency EME operation is common. Feed dimensions scaled according to frequency should not have an influence on the radiation pattern. The feed pattern's response to frequency is shown in Fig. 20 and Fig. 21. Only a small enlargement of the pattern is observed, especially on the Tx port at higher frequencies.

## VI. Isolation Between Ports

*Measurement condition: Tx port driven by HP 8350 B signal generator, Rx port analyzed with HP 8564 E spectrum analyzer.* Very good isolation between ports, 31 dB, was measured on a bare feed assembly beaming to free space. This isolation decreased to 21 dB when a choke in the flush position was added. Mounting the feed assembly onto a dish resulted in a further reduction in isolation between the ports. This is due to a portion of the reflected signal, which exhibits opposite rotational polarization, radiating back into the feed assembly. Dish antenna efficiency is reduced by approximately this amount. This is not a problem unique to septum feed, but in general, to most feed configurations that work with reversed polarization. To investigate this, a feed assembly having a choke in the flush position was tested against a conductive plate, which was again used to simulate a dish. Isolation was seen to vary with the feed-to-plate distance and isolation ripple of between 16 and 30 dB was measured. A worst-case isolation of 16 dB was measured with short distances between the feed assembly and the plate. A diagram of this is not available.

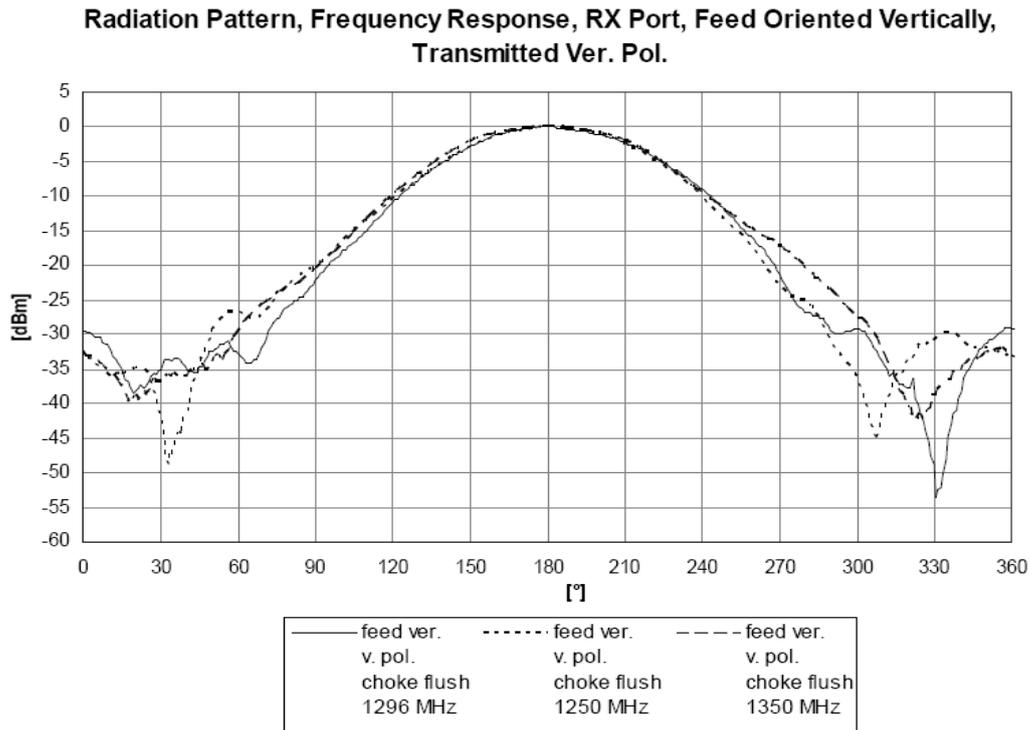
In the case of high transmitting power, such as 1kW for example, a signal of about 25W may appear on the Rx port. Because of this, a good isolation switch with adequate power handling capability must be used in front of the LNA.

## VII. Phase Center Position

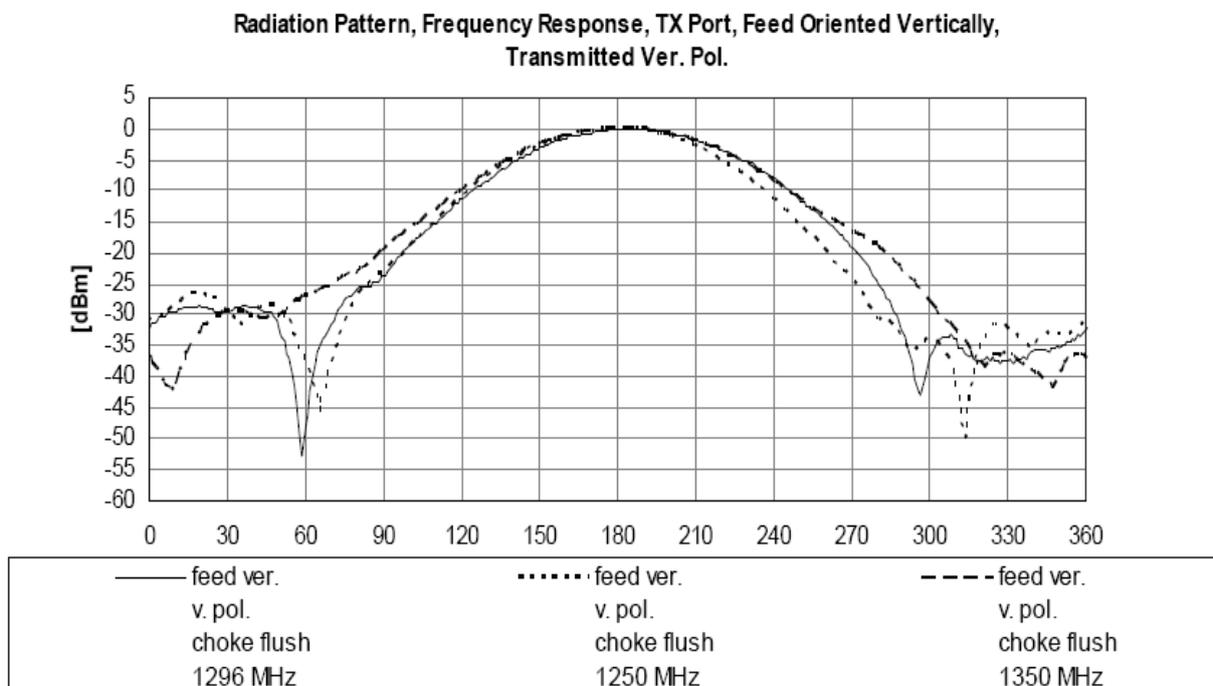
*Measurement condition: Choke 15mm back.* Two methods were applied to locate the feed's phase center. The first was based on relative changes in radiation patterns with various distances between the feed's aperture end and its vertical axis of rotation and the geometry of appropriately positioned antennas. This method yielded somewhat imprecise results. Some of the calculations indicated that the phase center position for this feed configuration is located about 2 cm inside the feed's open aperture.

To confirm this, a second method based on constant phase was applied. An Agilent Technologies E8364A network analyzer was used, but no special antennas for circular polarization were available at that time. Consequently, the second measurement also yielded an imprecise result.

Phase center position measurement is very complex and requires special equipment. Perhaps the best method is to use a "sun noise measurement." Regardless, previous measurements indicate that the overall efficiency of the dish assembly is less sensitive to phase center position than to adjustments made for reflected power of reversed polarization.



**Fig. 20** - Radiation pattern. Frequency response, Rx port. Feed oriented vertically, transmitted ver. polarization.



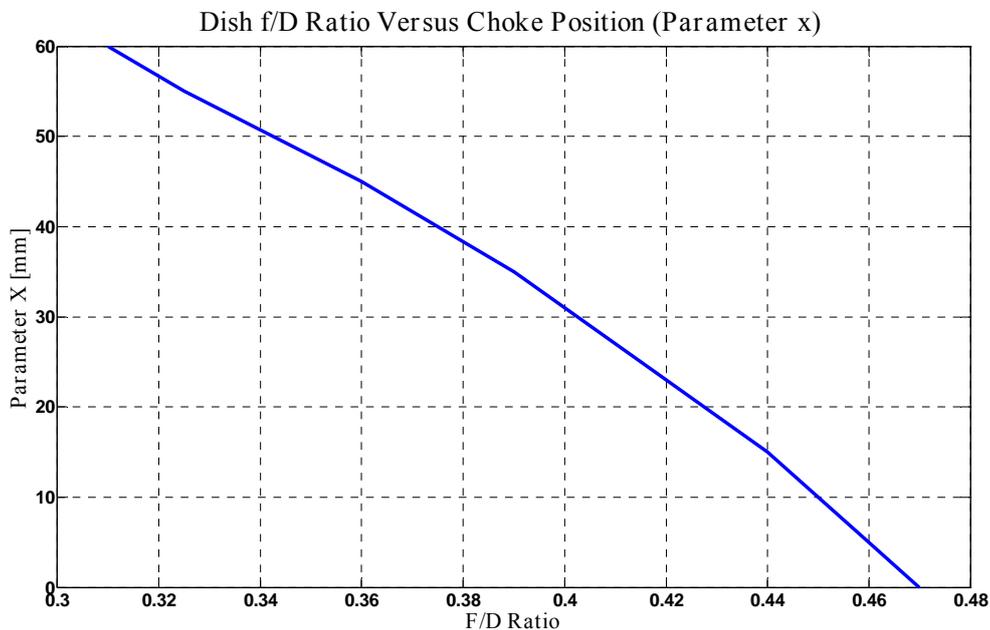
**Fig. 21** - Radiation pattern. Frequency response, Tx port. Feed oriented vertically, transmitted ver. polarization.

## Summary and Conclusion

Despite favorable computer analysis, some asymmetry between azimuth and elevation planes was detected and investigated. Neglecting manufacturing inaccuracy and measurement error, this property of the feed assembly is most likely inherent to the square shape of the waveguide. To improve the axial ratio and phase characteristics, some authors report using a series of tuning screws following the septum. Performance is controlled by adjusting the depth of these screws [7]. Others report controlling circularity with additional corner brackets and stiffeners employing a small ground plane [8]. Another solution, mounting a dielectric slab of Teflon behind the septum, was also described [9]. For higher frequencies, a solution employing a corrugated waveguide section following the septum was published [10]. To reduce the asymmetry problem, a circular feed assembly with septum polarizer can be used. This is an area open to further experimentation.

In spite of these problems, septum feed has many advantages for deep-dish applications. A multi-collar ring choke improves efficiency for dishes  $10\lambda$  and larger. To find the optimum choke position for a dish, the graph of Fig. 22 was compiled. This graph, for EME use, is based on “low noise” edge illumination of 13 dB. I regret that because of my time schedule, I am unable to discuss practical experience with this feed configuration or to compare it to my present VE4MA style feed at this time.

I plan to place all measurement data on my web site, [www.webpark.sk/om6aa](http://www.webpark.sk/om6aa), in Excel format. Until this time, measurement data can be obtained by sending me an e-mail request at [OM6AA@martinet.sk](mailto:OM6AA@martinet.sk).



**Fig. 22** - Optimum choke position.

## References

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**Fig. 23** - Preparation of the feed for measurement in anechoic chamber.