

Computer Optimized Dual Mode Circularly Polarized Feedhorn

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1 - Introduction

This paper presents a high efficiency horn antenna intended to illuminate a passive parabolic reflector. The design utilizes the dual-mode method developed by the late Dick Turrin, W2IMU, by which two guided waves with different modes cancel each other at the rim of the feed in order to provide an exceptionally clean radiation pattern. The feedhorn also incorporates a 5-step septum polarizer in a circular waveguide, which provides excellent circularity and isolation between the right and left circularly polarized coaxial feedpoints. Complete dimensions are presented for 1296 MHz, although they can be easily scaled to other frequencies.

2 - Literature review

The dual mode feedhorn was presented in the professional literature [1] by W2IMU and later in his famous "*The Crawford Hill VHF Club Technical Reports*" [2] in 1970. Dick was an outstanding engineer and his dual-mode feed is still among the best ways to efficiently feed a dish with a focus to diameter (f/d) ratio between 0.5 and 0.6. In 1971 [3], he presented a method to generate circular polarization for EME that consisted in a series of screws that could be adjusted in order to introduce a phase shift and achieve right and left circular polarization.

In 2000, Zdenek Samek, OK1DFC, introduced the septum polarizer to the amateur community, based on previous work published in the professional literature [4]. This polarizer was developed in square waveguide, and its performance is very good.

There were attempts to utilize the square-section septum polarizer in circular waveguide feedhorns, like the W2IMU dual-mode, by scaling its dimensions, but the performance of the polarizer was not as good as compared to the original square-waveguide design.

Dmitry Dimitriev, RA3AQ, obtained better results with a combination of a square septum polarizer and a round feedhorn [5]. His dual-mode feed performs very well and has been successfully used by a number of stations to date.

Finally, Rasto Galuscak, OM6AA, developed an outstanding 5-step septum polarizer in circular waveguide [6]. He achieved excellent circularity and isolation over a bandwidth wide enough that allowed operation across the entire 13 cm band. However, the dimensions of the septum were not made public, so it could not be easily duplicated.

3 - Dual mode, circularly polarized feedhorn design

I decided to make an attempt to fill the gap between the square septum polarizer and the W2IMU dual mode feedhorn by developing a 5-step septum polarizer in circular waveguide that could match the W2IMU feedhorn, achieving good performance in terms of isolation, circularity and bandwidth.

I used HFSS [7], an electromagnetic simulation software that can also optimize dimensions based on specific goals, to design a 5-step septum polarizer. As a starting point, I took the dimensions of the 4-step septum that OK1DFC made popular, and added one more step for a maximum septum height of 184 mm, which is the diameter that OM6AA used for his circular 5-step septum. Once I obtained the dimensions for the septum by running an optimization, I designed a W2IMU feedhorn and re-optimized both pieces together again.

The results obtained at this point were very good, but the feedhorn was much longer than a regular W2IMU, even with the screw polarizer. The isolation was good, but not outstanding. I suspected that most of the problems with the isolation were related to a mismatch between the polarizer and the feedhorn, so I decided to sweep the length of the polarizer's waveguide to investigate the issue. Surprisingly, I noticed a marked change in isolation that repeated itself every half waveguide wavelength, as shown in Fig. 1. As a consequence, I decreased the length of the polarizer's waveguide until I reached a maximum in isolation. I re-simulated the entire feed, and the results were excellent.

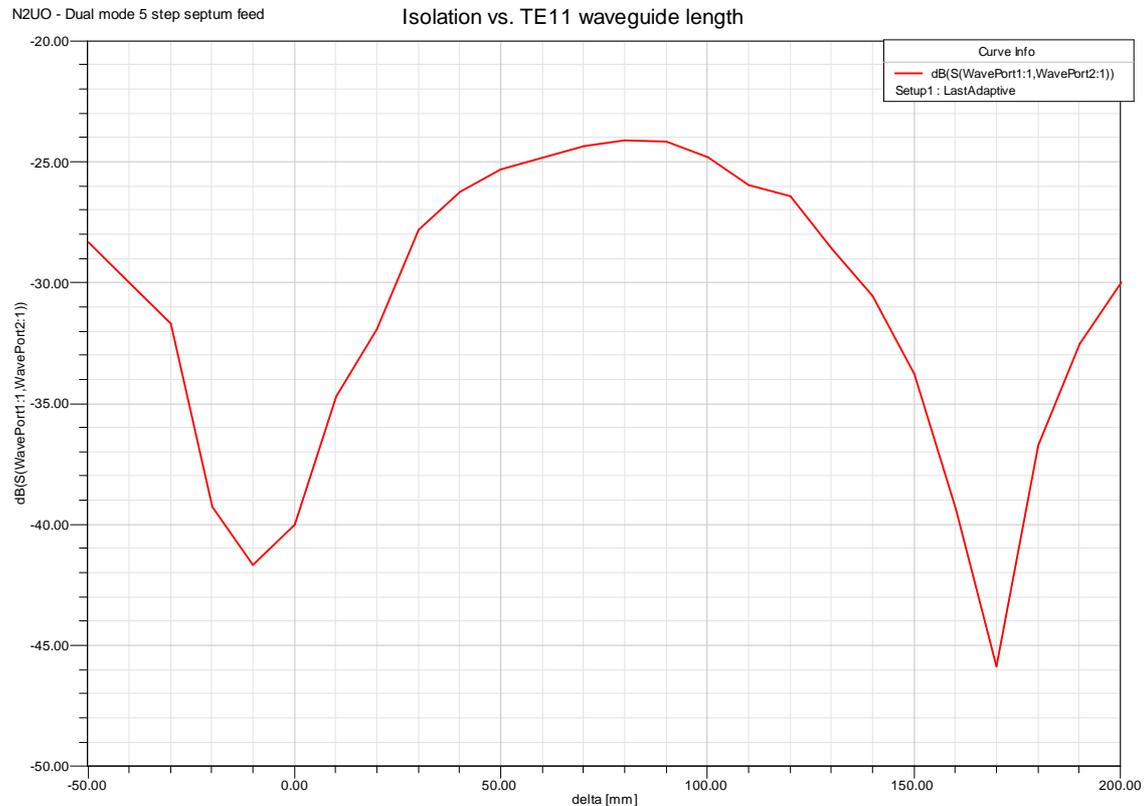


Fig. 1 – Isolation between ports as a function of the length of the feed

3 - Optimization and simulation results for 1296 MHz

Fig. 2 shows a 3-D view of the dual mode feedhorn, and Fig. 3 and 4 provide the dimensions of the key parts. The material used is copper. The dimensions of all the hollow parts are internal in order to avoid the need to use a specific copper sheet thickness, except for the septum, which must be 1 mm thick.

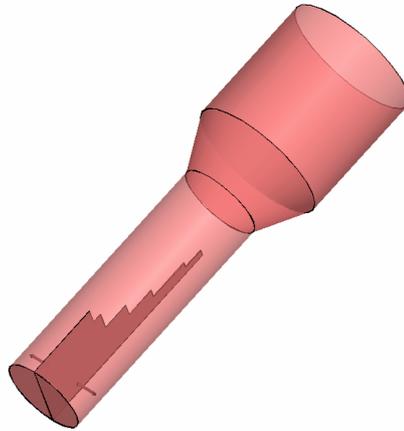


Fig. 2 – 3-D view of the dual-mode feed

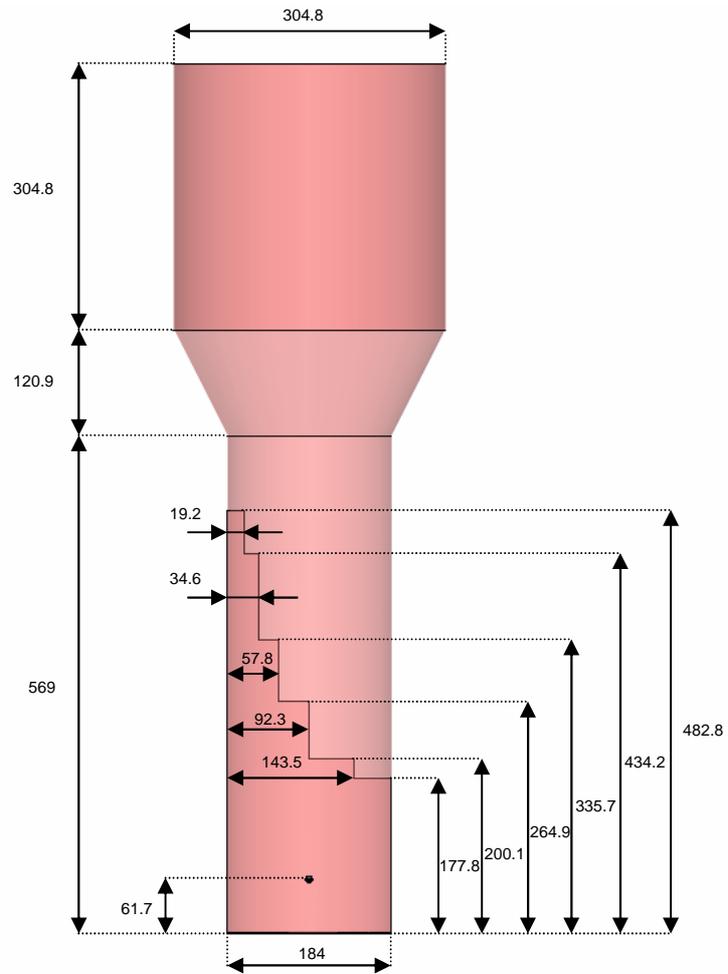
Fig. 5 shows the feed inside the radiation boundary, and the two probes connected to 50 ohm coaxial cables that extend the feed point to the edge of the radiation boundary. The effects of these coaxial cables was taken into account and de-embedded after the simulation.

Fig. 6 shows the maximum theoretical efficiency achievable with a prime focus parabolic reflector by using this dual mode feed. The calculation was done with Matlab [8] based on a paper by Bob Larkin W7PUA [9], and it does not include diffraction or feed blockage losses. The maximum efficiency is achieved with a 0.55 focus to diameter ratio (f/d) dish.

The radiation pattern is shown in Fig. 7, 8 and 9. It can be appreciated its cleanness and low sidelobe level, typical of the dual-mode feed. The opposite polarization rejection is approximately 50 dB with respect to the maximum gain at the bore sight, and it holds reasonably well across the entire aperture.

The axial ratio, which serves as a measure of the circularity of the antenna, is shown in Fig. 10. It is just a tenth of a dB at the bore sight, and it only degrades to about 1 dB at the 50 degree points, which approximately correspond to the edge of the dish; the rest is spillover and the axial ratio does not matter.

The simulated isolation between ports is shown in Fig. 11. The feed performs well across a 50 MHz bandwidth, which means that it is expected to cover the entire 13 cm band if it is scaled properly. The return loss is also acceptable across the same bandwidth, as shown in Fig. 12. The length of the probes is very critical, and most likely they will need to be trimmed to achieve a good match. The probes position respect to the back of the feed is also critical for isolation and impedance match to the coaxial line.



**Fig. 3 – N2UO dual mode 5 step septum feedhorn for 1296 MHz - all dim. in mm
Septum: 1 mm thick. All dimensions are internal. Material: copper**

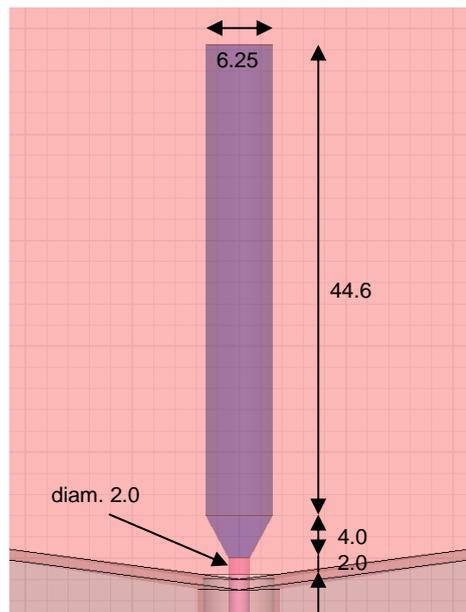


Fig. 4 – Probe detail for 1296 MHz - all dimensions in mm. Material: copper

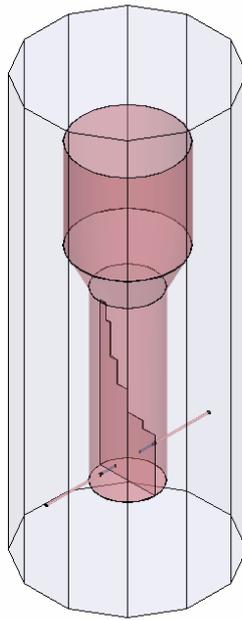


Fig. 5 – Dual-mode feed inside the radiation boundary with extended coaxial feedpoints

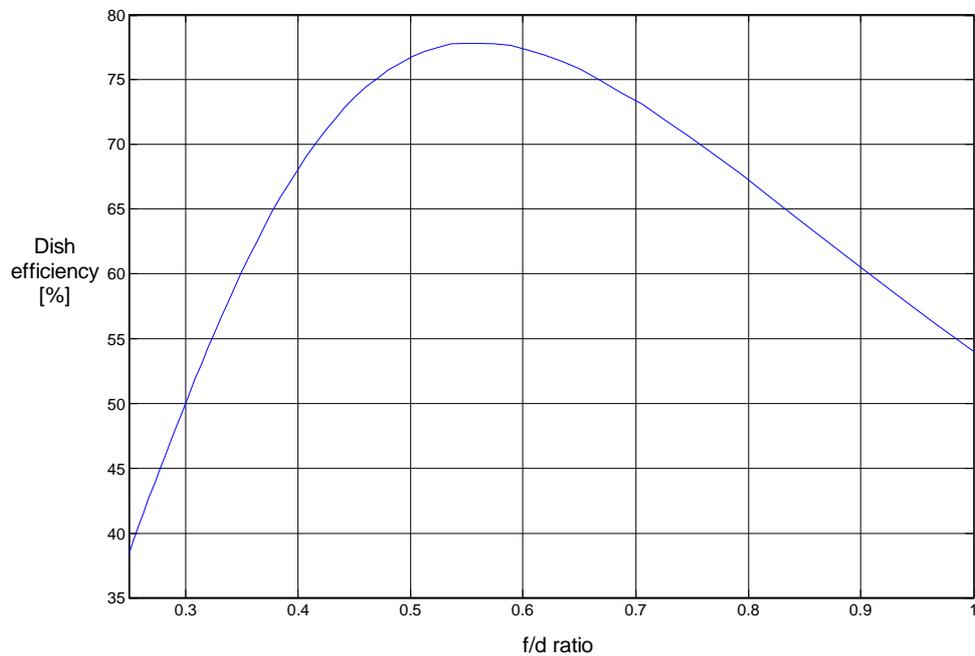


Fig. 6 – Theoretical parabolic reflector efficiency

Fig. 13, 14 and 15 show the performance of the feed as a function of frequency. It can be seen that the axial ratio is approximately maintained below 2 dB across 100 MHz, and that the radiation pattern and the cross polarization do not suffer major degradations.

Finally, Fig. 16 shows the electric and magnetic fields inside the feed. Careful inspection will reveal clear TE₁₁ and TM₁₁ mode patterns, which give name to this dual-mode feed.

4 - Conclusion

This dual mode feedhorn with a 5-step septum polarizer offers a very clean radiation pattern, high efficiency optimized for a parabolic reflector with an f/d of 0.55, and excellent circularity and isolation between ports.

The septum dimensions, as well as the probe position, are very critical. The probe length should be trimmed to achieve resonance at the operating frequency, but the value of the feed impedance is mostly determined by the probe position respect to the back of the feed.

Simulations of other types of feeds intended for deeper dishes (smaller f/d) did not yield the same type of results in terms of spillover, circularity and isolation between ports. It is quite possible that this feed will still be a good choice for deeper dishes in spite of the slightly lower efficiency, which could be compensated by its remarkable clean pattern, and as a consequence, a lower antenna noise temperature.

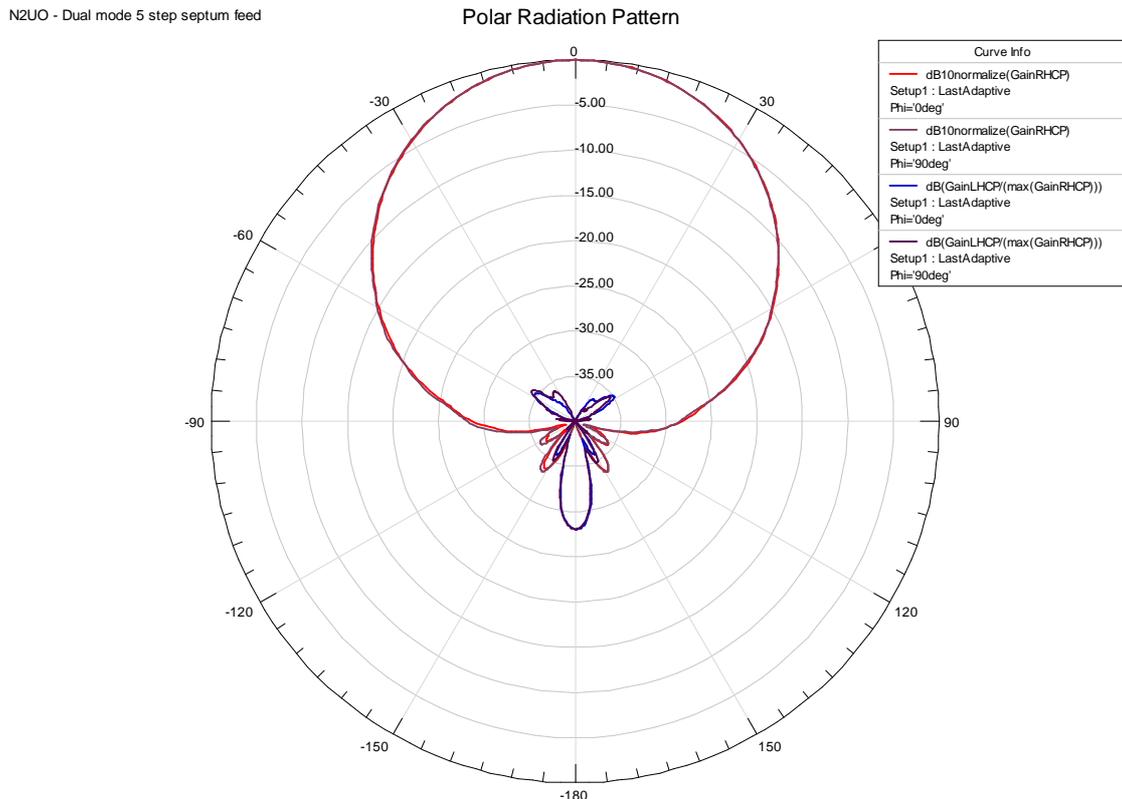


Fig. 7 – Polar radiation pattern at 1296 MHz

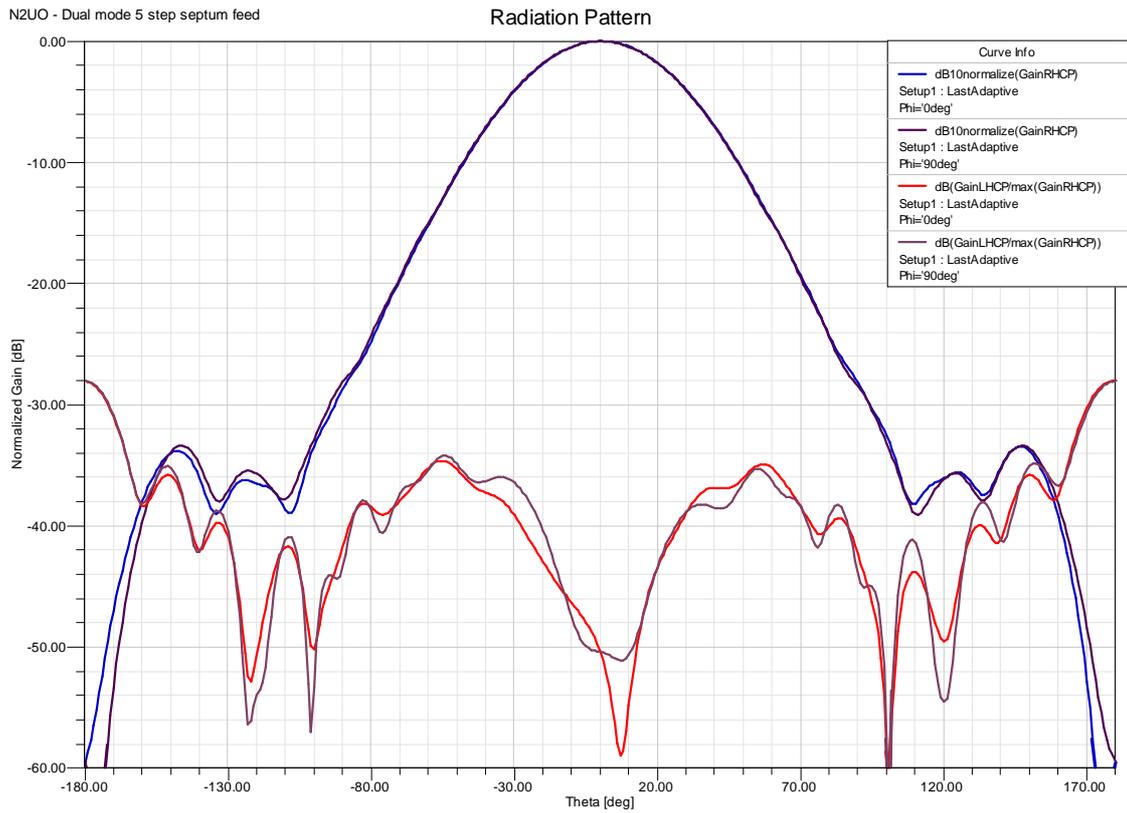


Fig. 8 – Right and left-hand circular radiation pattern at 1296 MHz

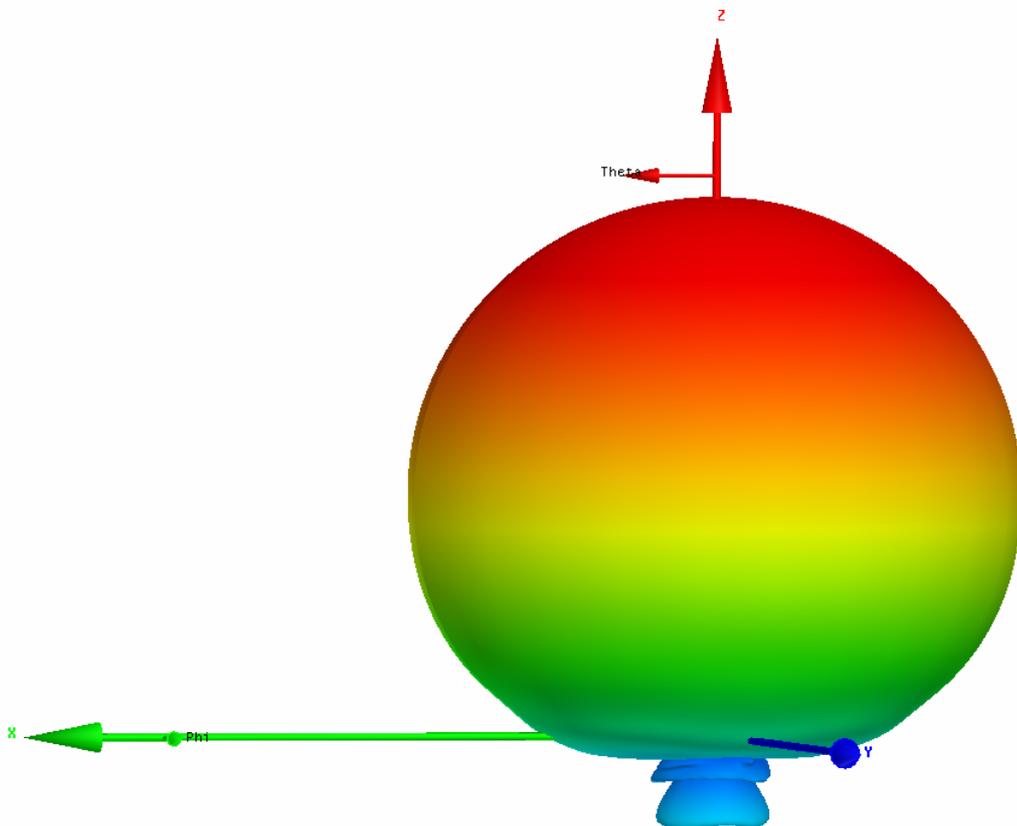


Fig. 9 – Three-dimensional radiation pattern at 1296 MHz

Axial Ratio

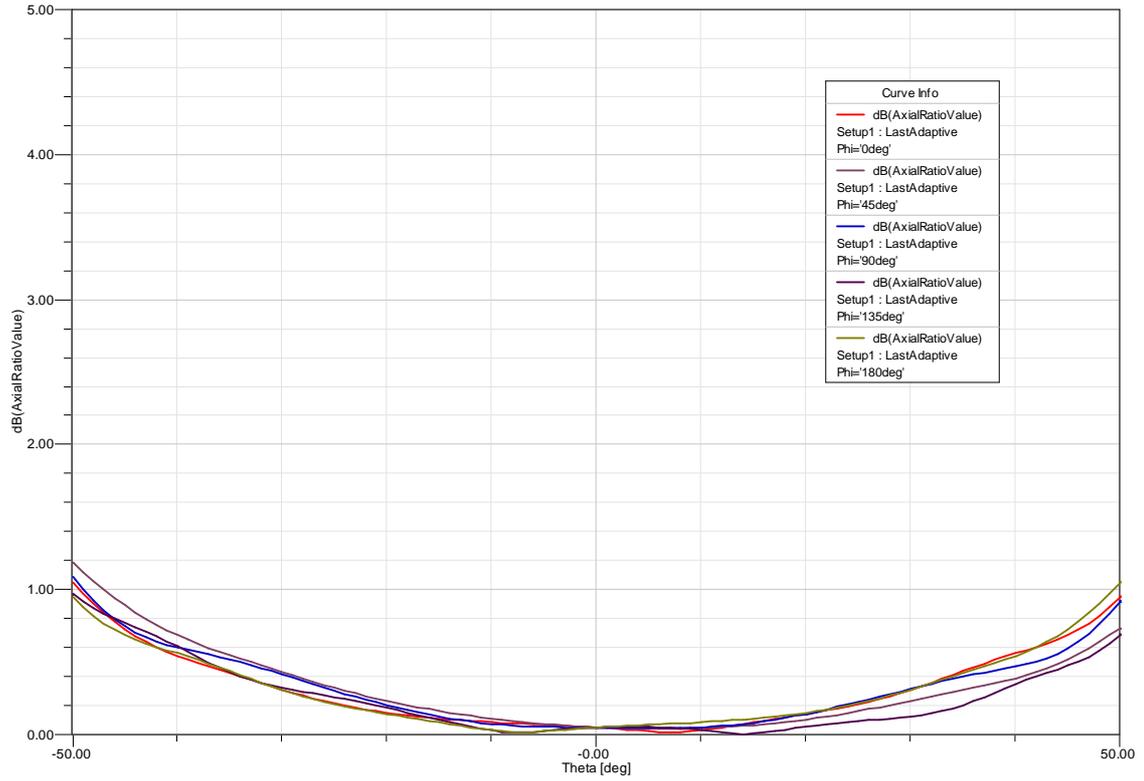


Fig. 10 – Axial ratio at 1296 MHz

Isolation

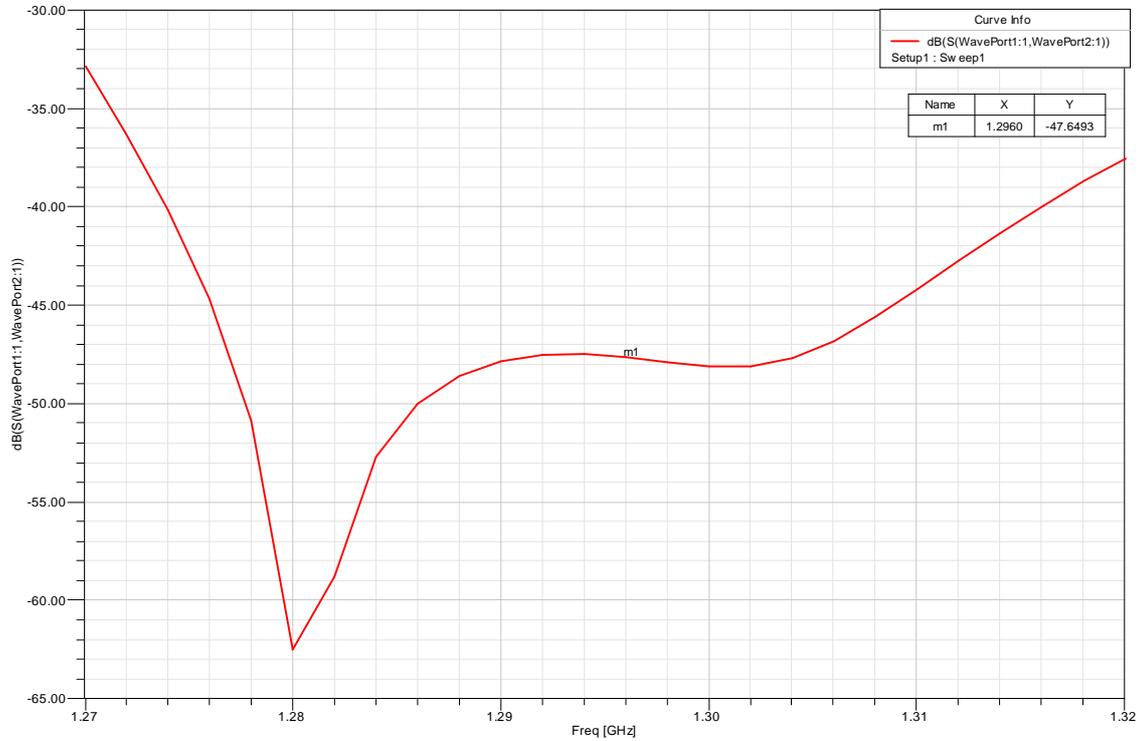


Fig. 11 – Isolation between ports

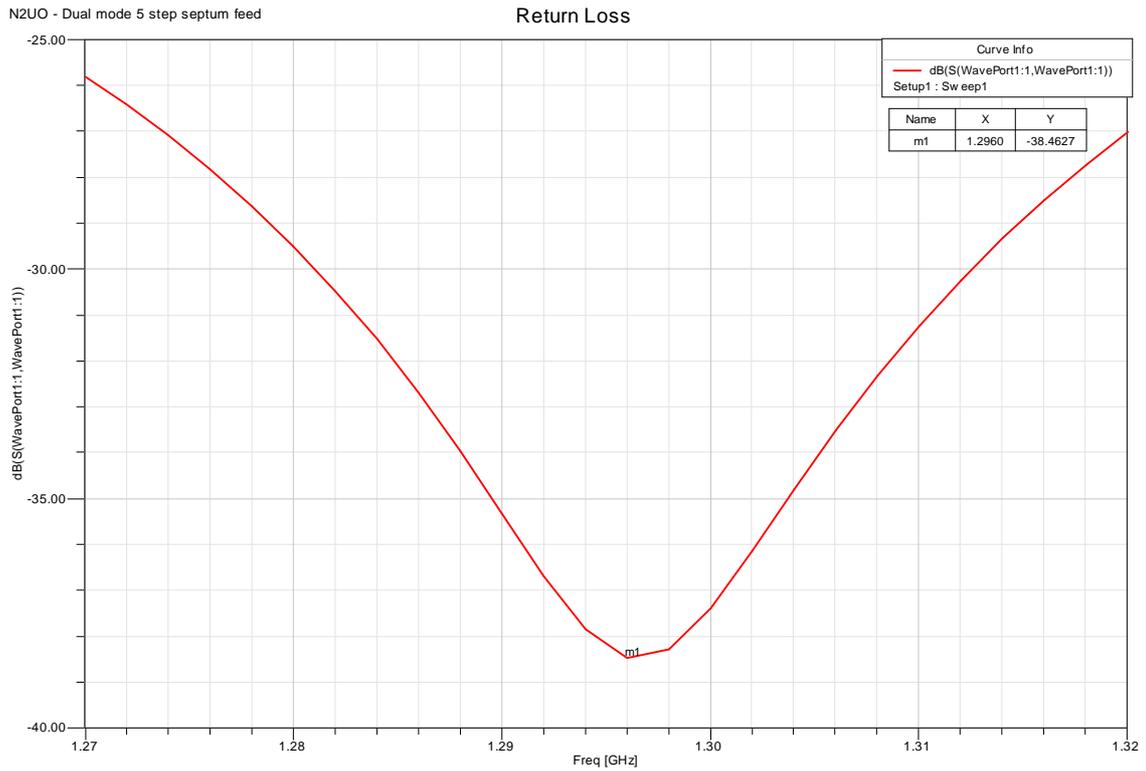


Fig. 12 – Return loss

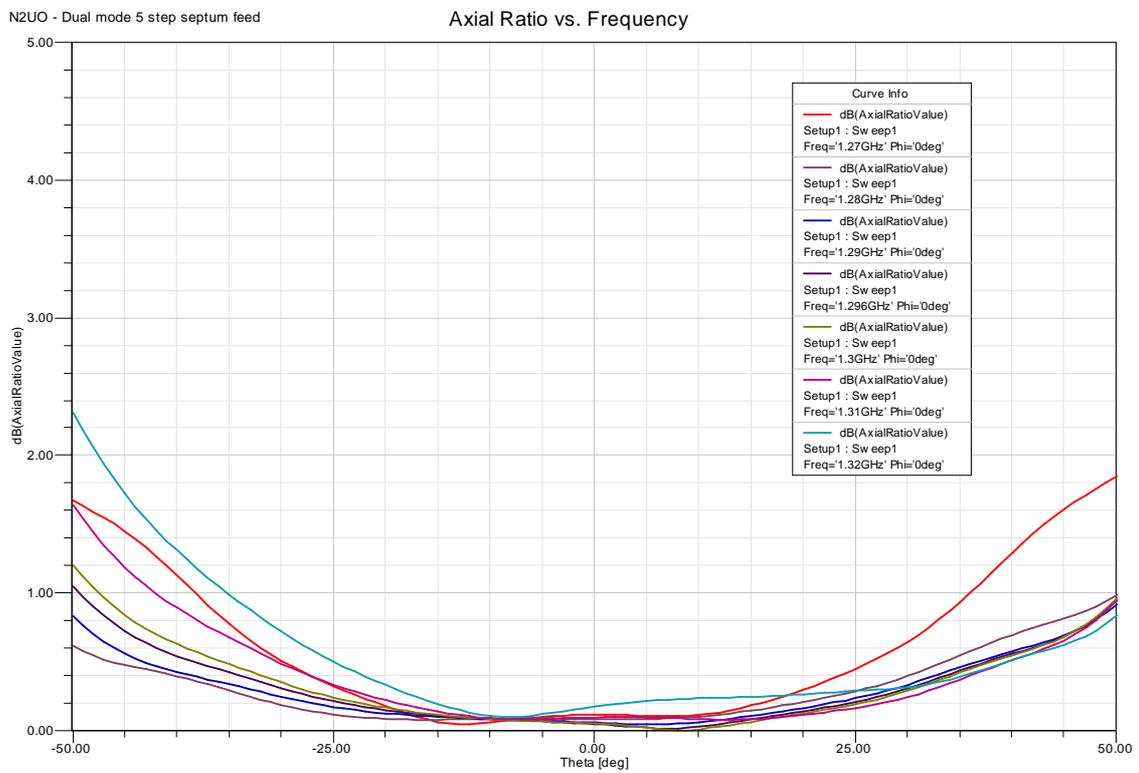


Fig. 13 – Axial ratio vs. frequency

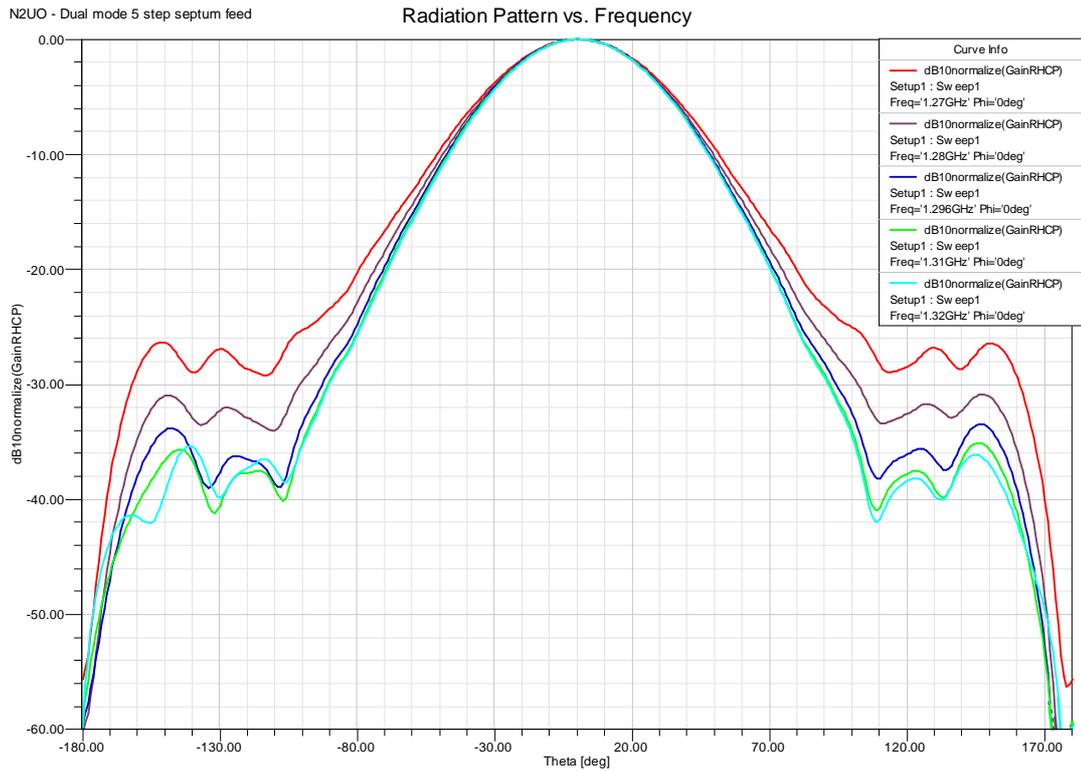


Fig. 14 – Right hand circular radiation pattern vs. frequency

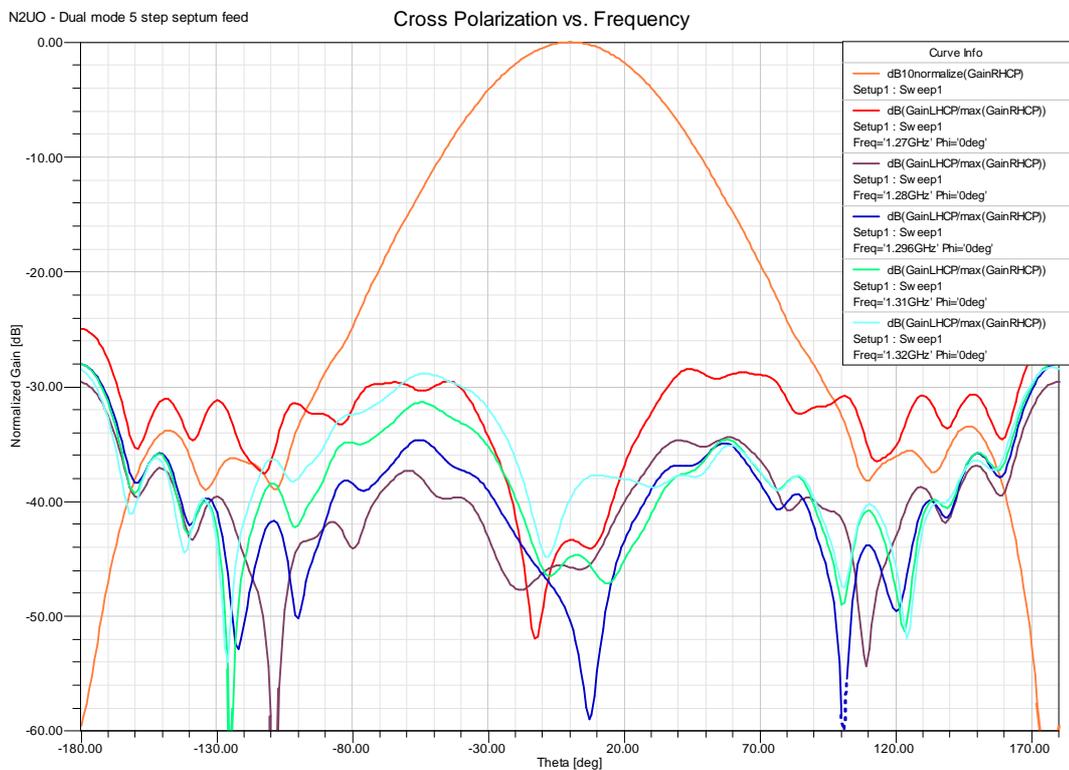


Fig. 15 – Cross-polarization vs. frequency (1296 MHz used for reference)

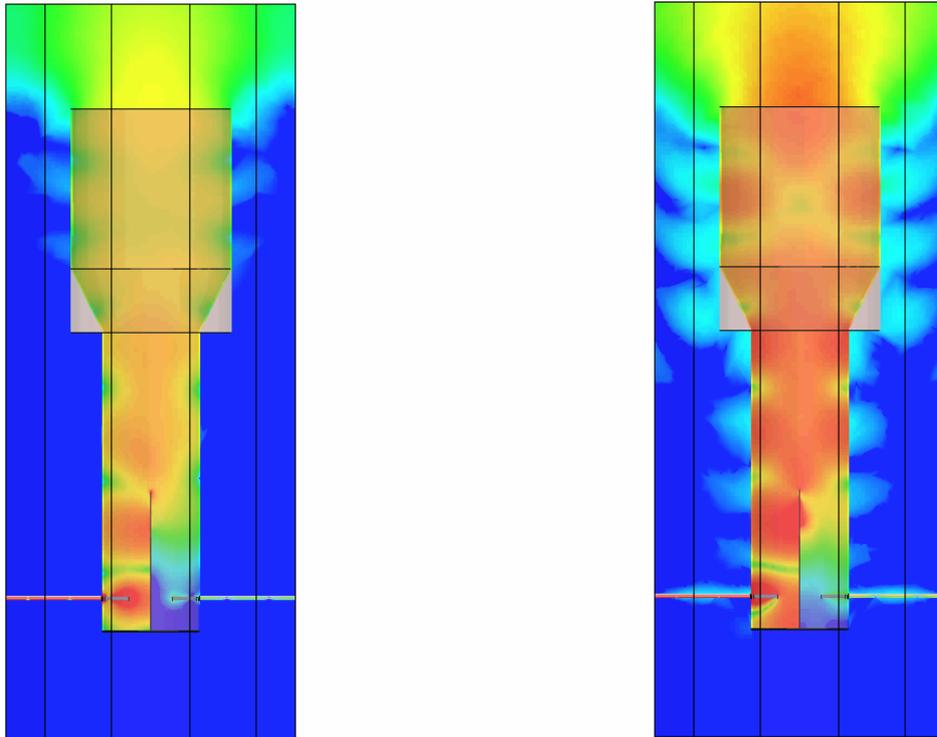


Fig. 16 – Electric field (left) and magnetic field (right)

5 - References

- [1] – Turrin, R., “*Dual Mode Small-Aperture Antennas*”, IEEE Transactions on Antennas and Propagation, March 1967.
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- [3] - Dick Turrin, “*Technical Report #9*”, The Crawford Hill VHF Club, W2NFA, 1971.
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- [5] - <http://www.ok1dfc.com/eme/technic/septum/ra3aq.pdf>
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- [9] - Bob Larkin, W7PUA, “*Dipole-Reflector Parabolic Dish Feeds for F/D of 0.24 to 0.4*”, QEX, February 1996.

6 - Acknowledgment

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