ID 079

Metal Plate Lenses for A High Power Microwave Zoom Antenna

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***Abstract*—A high power microwave antenna with true zoom capability was designed with the use of metal plate lenses. Proof of concept was achieved through experiment as well as simulation. This concept comprises a horn feed antenna and two metal plate lenses. Good agreement was found between experiment and simulation. This antenna provides true zoom capability in the TEM mode with continuously variable diameter pencil beam output and approximately 10% bandwidth.**

I. INTRODUCTION

The metal plate lens was proposed by W.E. Koch in the 1940's [1] but has seen little use since. Some design considerations are presented in [2]. This paper presents results of experiment and simulation exploring application of metal plate lenses to a high power microwave zoom antenna concept. This antenna consists of three elements: a pyramidal horn feed antenna and two appropriately designed metal plate lenses that can be translated along the boresight axis relative to each other and to the feed horn. The output of this antenna system is a variable diameter (TEM) pencil beam output. The bandwidth is on the order of 10%.

The metal plate lens antenna, shown conceptually in (1) is essentially a waveguide array antenna that works only in the TEM mode.

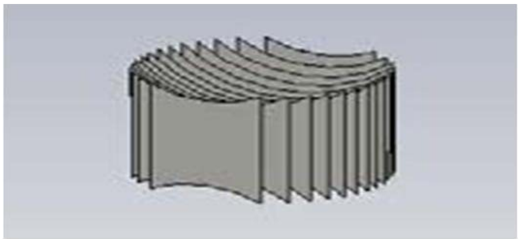


Fig. 1. Conceptual illlustration of metal plate lens.

It consists of an array of parallel metal plates with constant spacing "a". The index of refraction of the structure, n, is less than 1 and is determined by

$$n = \sqrt{1 - (\frac{\lambda}{2a})^2} \qquad (1)$$

where λ is the wavelength. The front and back faces of the metal plate array can then be shaped to provide the desired focal length,f, according to the lensmaker's equation:

$$\frac{1}{f} = (n-1)\left(\frac{1}{R1} - \frac{1}{R2}\right) \qquad (2)$$

Positioning of the lenses to achieve a collimated (pencil beam output) is governed by

$$\frac{1}{f} = \frac{1}{S1} + \frac{1}{S2} \qquad (3)$$

where S1 is the distance from the phase center of the pyramidal horn antenna and S2 is the distance from the center of lens 1 to the center of lens 2, as shown in (2).

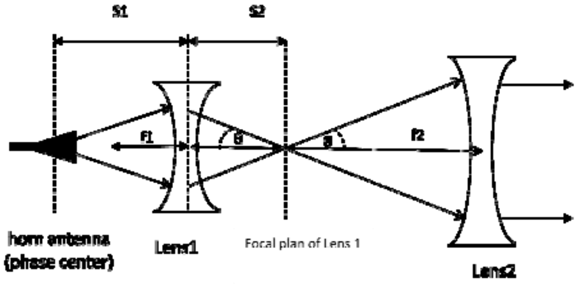


Fig. 2. Zoom antenna concept – broad collimated beam output.

Reducing the diameter of the collimated beam output of the zoom antenna is achieved by repositioning the lenses such that lens one is closer to the phase center of the horn antenna (while still being greater than a focal length, f1, away) and such that lens 2 is again one focal length, f2, from the new location of the focal plane of lens 1. This is illustrated graphically in (3).

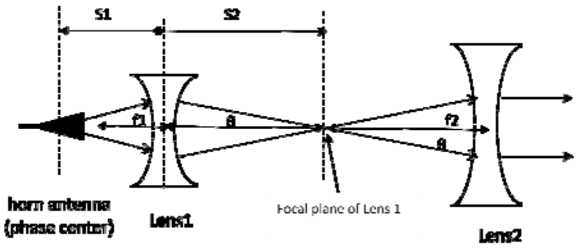
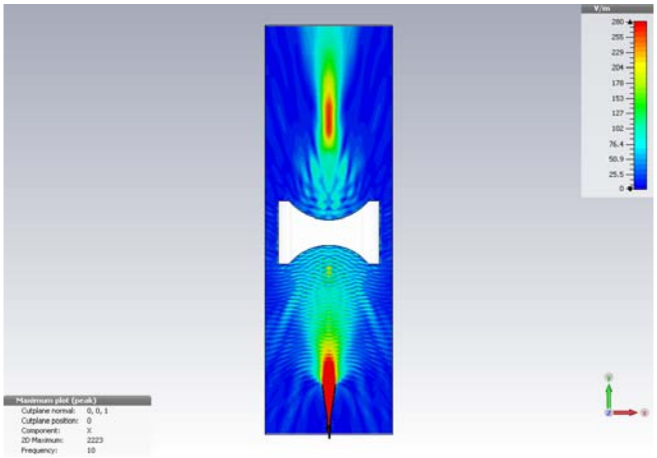


Fig. 3. Zoom antenna concept – narrow collimated beam output.

II. EXPERIMENTAL AND SIMULATED RESULTS

To demonstrate the concept, a pair of 10-GHz metal plate lenses were designed and built: one with a diameter of 40.6 cm and a focal length of 25.4 cm and the other with a diameter of 81.3 cm and a focal length of 139.7 cm. The plate spacing of the lenses was 1.9 cm, resulting in an index of refraction of 0.6. A 15dBi horn antenna was appropriately placed and driven by port 1 of a network analyzer. The lenses were positioned to achieve a collimated beam output. Low power S21 measurements were made with a small receive horn antenna connected to port 2 of the network analyzer across the focal plane of the first lens in the E- and H- planes as well as at the output of the antenna. The entire system (including the horn antenna and both lenses) was simulated and the results showed good agreement.

Point focus, achieved by placing a single lens greater than a focal length from the phase center of the horn antenna is illustrated by the simulated results shown in (4).



Maximum plot (peak)
Cutplane normal: 0, 0, 1
Cutplane position: 0
Component: X
2D Maximum: 2223
Frequency: 10

Fig. 4. Focus of TEM beam radiated from a pyramidal horn antenna achieved with a single metal plate lens

The beam is not focused to a single point, but rather to an Airy disc, whose diameter is diffraction limited to greater than a wavelength.

The simulated boresight electric field corresponding to (4) is shown in (5).

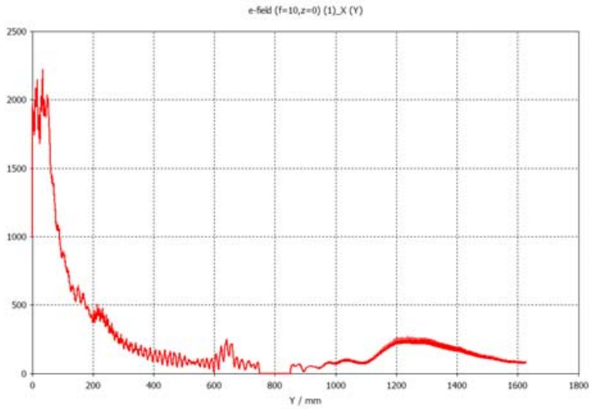


Fig. 5. Simulated boresight electric field (aperture of antenna at y=200mm)

Focus of the beam occurs at approximately y=1200mm; the electric field falls off as 1/r2 as one moves further away from the focal plane. A second metal plate lens, with focal length f', if placed a distance f' from the focal plane of this lens will collimate the beam. The diameter of the collimated beam is then varied by re-positioning the lenses, resulting in a true zoom capability.

Experimental and simulation results indicated focusing of the beam in the focal plane of the first lens to an Airy disc whose diameter is diffraction limited about 1.5*λ. Simulated results also reveal beam collimation when the lenses were correctly positioned relative to each other and relative to the phase center of the horn antenna, as well as variability in the collimated beam diameter.

Experiment and simulation revealed the feasibility of designing, constructing and implementing a high power microwave zoom antenna using metal plate lenses to guide the electromagnetic waves radiated from a horn antenna into a pencil beam output of continuously variable diameter. Air breakdown in the focal plane determines the maximum power handling capability of the system. Analysis reveals an exponential decrease in maximum power with increasing frequency; from several gigwatts at 1 GHz, to almost 40 megawatts at 10 GHz.

REFERENCES

[1] W.E. Koch, "Metal-Lens Antennas," Proceedings of the I.R.E. (34) 11 , pp. 828–836, November 1946.

[2] C.J. Sletten, Reflector and Lens Antennas: Analysis and Design Using Personal Computers, 1st ed., MA: Artech House, 1988, pp. 262–272.