Design and Simulation of a Concentrated Luneberg Antenna

Z. Briqech, and M. Abousetta

***Abstract*—** Luneberg lens is a new generation of antennas that is developed in the last few years and inserts itself strongly in Microwaves, Communications and Telescopes area. The idea of this research is to improve the radiation pattern by decreasing the side lobes and increasing the main lobe. The new design is proposed to work in the X-band. The simulated result and analysis are presented.

***Keywords*—**Communications, Microwaves, lens Antenna, Lunberg Lens Antenna.

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I. Introduction

THE lens antenna has been known and researched for many years. The motivation of this work is to search for an applicable antenna for multibeam scanning and high gain at microwave frequencies in satellite communication systems, remote sensing. A topic of much interest lately is satellite communication to vehicles, where a roof-mounted antenna is required. The satellite microwave link may typically operate at X band (8.5GHz-12GHz).[1,2] A multi-beam antenna is required to steer independent beams to any area in space. The main contribution of this research is the reduction of side lobe level from -15dB to -21dB and with no increase of the 3dB beamwidth.

II. Spherical Luneburg Lens

The design of a spherical Luneburg lens is such that, if a point source is located on the surface, the lens transforms the resulting spherical waves into a plane wave with the propagating vector aligned along the diameter passing through the feed point shown in Fig.1.

The variation of the relative dielectric constant (ε_r) as a function of the normalized radius (r/R), with the position of the feed (r_o/R) as the parameter, can be expressed by the following equation:

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$$\varepsilon_r = 2 - \left(\frac{r}{R}\right)^2 \tag{1}$$

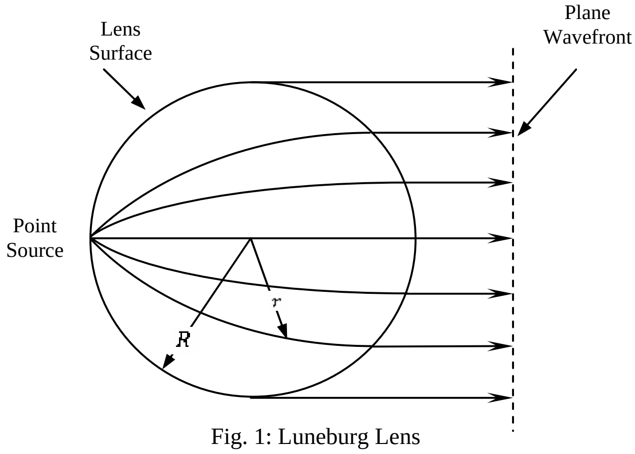

Fig. 1: Luneburg Lens

The refractive index of the lens is given by [3]:

$$n(r) = n_R\left[2 - \left(\frac{r}{R}\right)^2\right]^{1/2} \tag{2}$$

Where n_R is the refractive index at $r = R$. In order to avoid reflection at the surface of the lens, it is usual to choose n_R = 1 [3]. Equation (2) is also valid for a cylindrical lens with a circular cross section. The index of refraction is maximum at the center, where it is equals to $\sqrt{2}$, and decreases to a value of unity on the periphery. In practice, it is difficult to construct an antenna with a point-source feed placed directly on the surface of the lens. If the feed is away from the surface the required refractive-index variation in the lens is different from that given by Equation (2). [3]

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III. Design Procedure

Parabolic antennas are widely used, especially in the commercial (Satellite Receiver Antenna). However main drawback arises with the need for simultaneous reception from more than one satellite at a fixed position.

Recently there are series of serious research on Luneberg lens antenna properties for handling separate multiple beams. For satellite multiple receptions and more sophisticated tracking radars.

There are two kinds of parabolic antenna namely: conventional feeding parabolic antenna, illustrated in Fig. 2 and cassegrain feeding parabolic antenna, illustrated in Fig. 3. In conventional method the feeder, is installed in the center of dish as shown below and it is used for applications such as home satellite reception, while in the cassegrain method the feeding is installed in the middle of the dish with a second reflector in the center of in the dish. They have given further reductions in side lobe level and more gain.

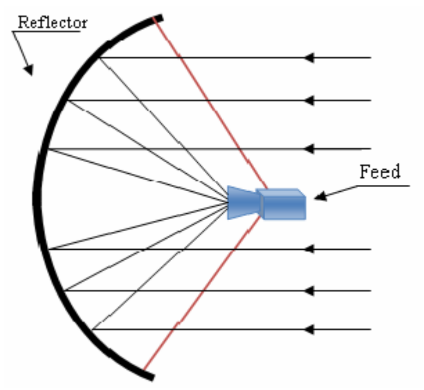

Fig. 2 Conventional Parabolic

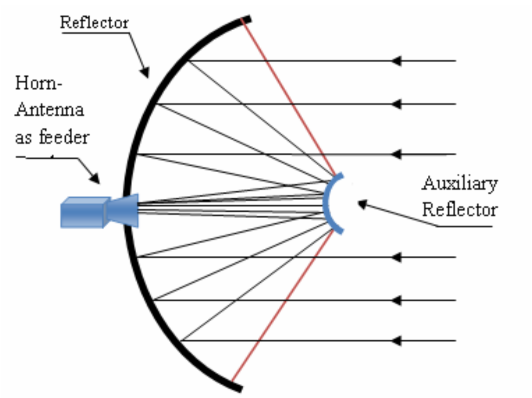

Fig. 3 The cassegrain feeding parabolic

IV. The Theory behind the New Design

The thought is to reduce sidelobes without sacrificing the main gain. From Luneberg lens antenna as in cassegrain feeding parabolic antenna we suggested adding a second sphere adjacent to the main sphere, a lens in front of the feeding point (focal point) illustrated in Fig. 5. The main lens congregates the rays and the sublens concentrates the rays into the focal point, Fig. 4 illustrates the conventional Luneberg lens antenna (CLLA).

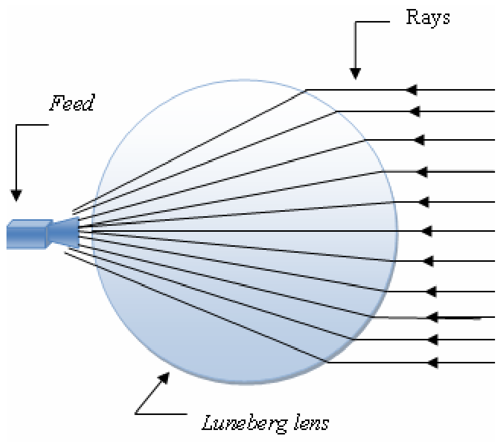

Fig. 4 The Conventional Luneberg lens antenna (CLLA)

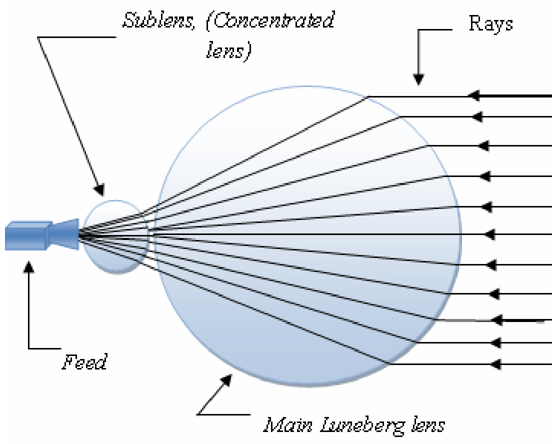

Fig. 5 Luneberg lens with *Concentrating* lens antenna

V. Simulation

The implementation of this technique is simulated by using FDTD (Finite Difference Time Domain) Simulation program. This simulation program has potential to handle the new design of Luneberg lens antenna. A comparison between many type of conventional Luneberg lens antenna (LLA) as well as with the new design of the proposed multiple feed Luneberg antenna has been made and results are tested against conventional type.

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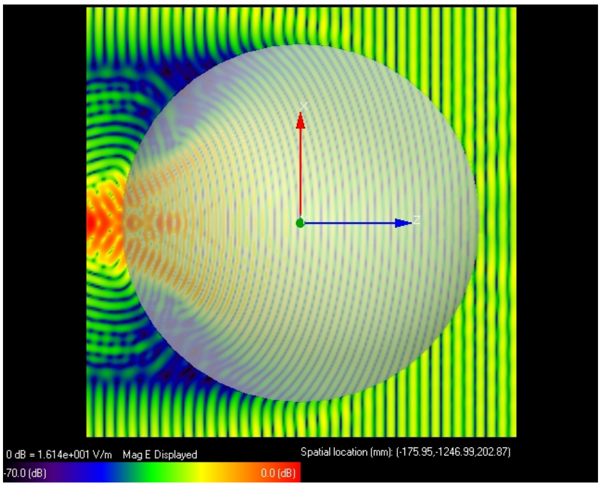

Fig. 6 Illustrates the radiation electromagnetic field xz-axis in the Luneberg lens antenna (LLA)

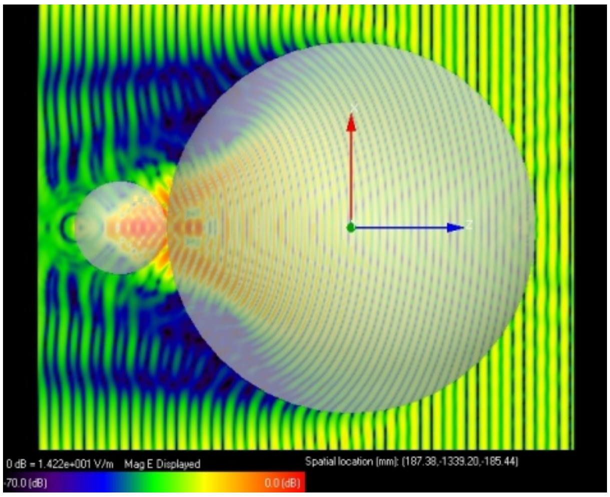

Fig. 7 Illustrates the radiation electromagnetic field xz-axis in the Concentrating Luneberg lens antenna (CLLA)

The radiation pattern in 3-D of both LLA and CLLA is illustrated in Fig. 8 and Fig. 9. The difference is so noticeable in the main lobe, CLLA has more gain than LLA. This is due to the concentration of both lenses. Also the sidelobe are much smaller in the CLLA.

Testing procedure. The antenna is composed of two spheres. The main Sphere has a diameter of 40cm and the auxiliary (sublens) has a diameter of 10cm. Both have a uniform relative permittivity of $\varepsilon_r = 2.0$, and $n = 1.414$. A uniform plane wave at frequency 12GHz impinges on the larger one as shown in Fig. 6, and Fig. 7.

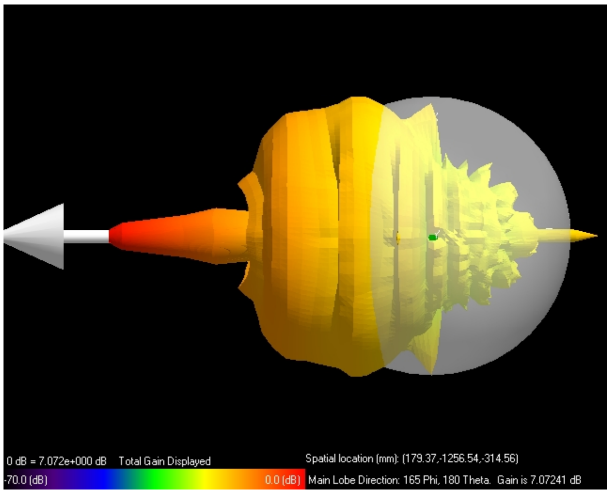

Fig. 8 The 3-D radiation pattern of the (LLA) in xz-axis display

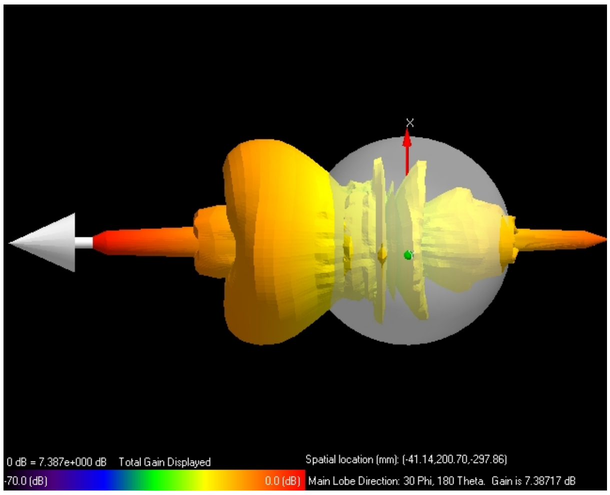

Fig. 9 The 3-D radiation pattern of the (CLLA) in xz-axis display

The far field of both antennas is shown in Fig. 10 for the LLA and Fig. 11 for the CLLA.

VI. Summary and Conclusions

Quiet useful investigation of Luneberg antenna has been achieved, based on the behavior of a Luneberg Lens with a feeder at the focus. Then the work has been advanced to a more fruitful configuration where another smaller size Luneberg lens is placed at the focal point of the main Luneberg. The horn feeder of course is at the focal point of the auxiliary lens.

Results from this new design are very encouraging where considerable reduction in side lobe level is obtained accompanied with a small increase in gain. This is at the expense of the increase in the back lobe (dependent on the material). At other materials results are very optimistic regarding gain and side lobes with suppressed backlobe.

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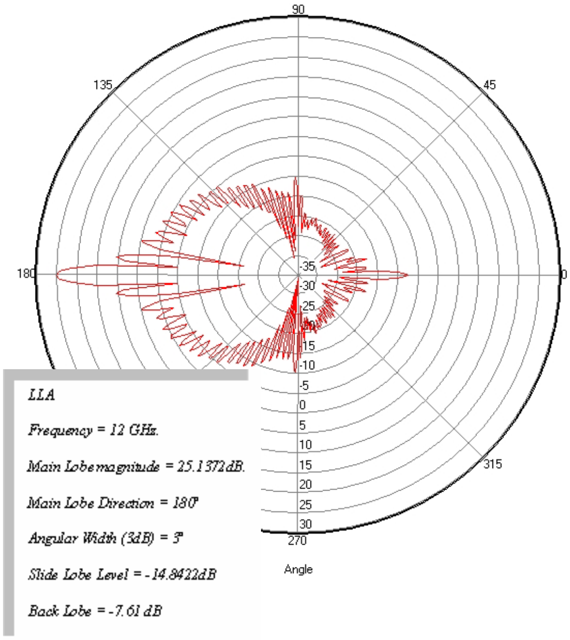

Fig. 10 The Radiation pattern of the LLA

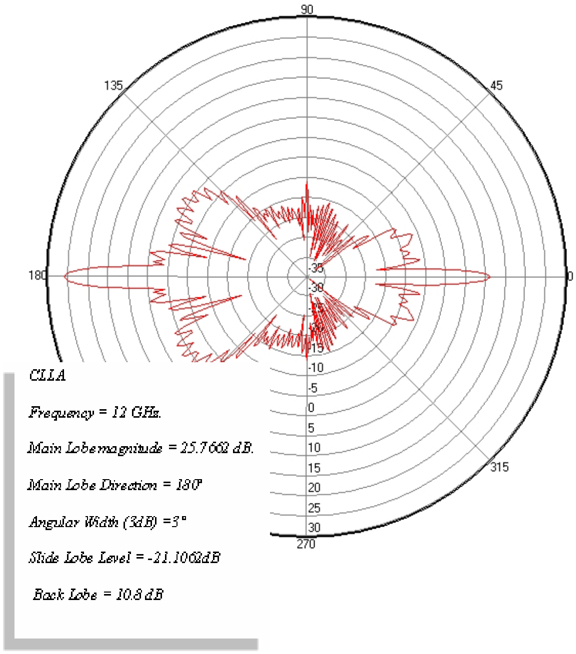

Fig. 11 The Radiation pattern of the CLLA

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