Chapter 19

S-band Reflector Antenna for LIA 400 System

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Ray optics techniques are in general employed for design of lenses and reflectors at microwave frequencies, in similar way they are employed at light frequencies. Corner reflector and plane reflectors were the earliest form of reflectors which were used for directing electromagnetic energy in particular direction. Parabolic reflectors in different configurations are quiet commonly used in high power microwave systems worldwide.

19.1. Choice of Antenna

High power microwave systems radiate power in the form of burst of microwave signal on a single frequency/ a narrow band of frequency for very short period of time. Narrowband single frequency antennas can be used for antenna design of these systems. For gain range of typically up to 23-24 dB, horn antennas are used. In case of rectangular waveguides with TE_{10} mode excitation, pyramidal horn antennas are used very commonly. For circular waveguides with

TM_{01}/TE_{11} mode excitation conical horn antennas are used. If gain of the antenna is more than 30 dB, reflector antennas are typically used for high power microwave systems. Further front fed classical reflector antenna, dual reflector antenna (Cassegrain/Gregorian) can be used depending on system requirements.

19.2. Basic Configuration of Reflector Antenna

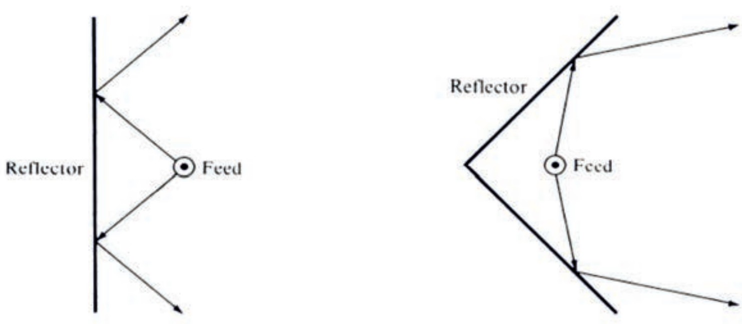
From the basic properties of parabola, if beam of parallel rays is incident upon a parabolic dish reflector, then this beam will converge at a single point known as the focus of parabola. Similarly if a point source is placed at focal point of parabola, outgoing electromagnetic waves coming after reflection from parabolic reflector will emerge in the form of a parallel beam. Simple reflector antenna is a reflector antenna along with a smaller feed antenna which is placed at the focal point of main reflector. Some more complex constructions like offset reflector antenna and dual reflector antenna are also very commonly used. Dual reflector antenna involves a secondary reflector (a sub-reflector) at the focal point, which is illuminated by a primary feed. The most common main reflector is the parabolic one, though other type of reflector shapes are also used in different systems. We will limit our discussion to simple reflector antenna in this article. Configurations of different type of reflector antennas are shown in Figure 19.1.

19.3. Gain of Reflector Antenna:

Reflector antennas are analyzed as aperture antennas. Maximum achievable gain G_{max} of an aperture antenna is given by following equation:

$$G_{max} = \frac{4\pi}{\lambda^2} A_p \tag{19.1}$$

Where λ is wavelength of operation and A_p is physical aperture area. It signifies that maximum achievable gain by an aperture antenna is limited by physical size of aperture and wavelength of operation. Achieving this gain is not practically possible; this gain can be achieved only if the following is true: uniform amplitude and phase distribution, no spillover, no ohmic losses. In practice the effective antenna aperture is less than its physical aperture. Actual gain G for an antenna in general is given by following equation.



(a) Plane (b) Corner

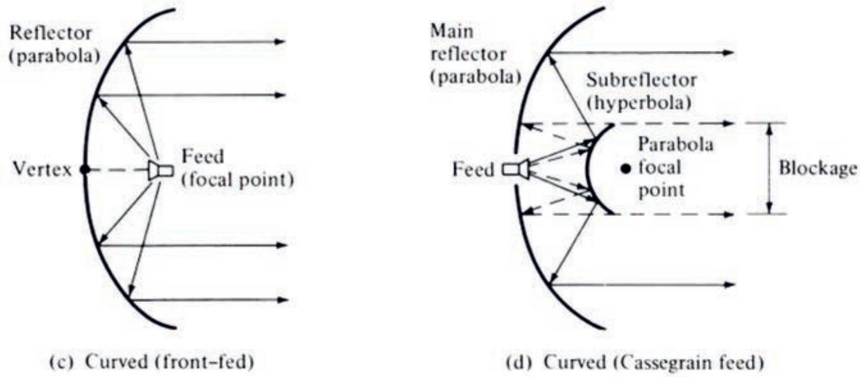


Figure 19.1. Different type of reflector Antennas [2].

$$G_{max} = \frac{4\pi}{\lambda^2}\epsilon_{ap}A_p \qquad (19.2)$$

Here ϵ_{ap} is aperture efficiency of antenna. Aperture efficiency is defined as a product of all other efficiencies.

$$\epsilon_{ap} = e_r\epsilon_t\epsilon_s\epsilon_a \qquad (19.3)$$

Here:

e_r is the radiation efficiency (loss),

ϵ_t is the aperture taper efficiency, which is due to the tapering of feed pattern.

ϵ_s is the spillover efficiency, which is due to spill over of beam beyond parabolic dish.

ϵ_a is the achievement efficiency. Achievement efficiency is an integral factor including losses due to: random surface error, cross-polarization loss, aperture blockage, reflector phase error (profile accuracy), feed phase error.

In general aperture efficiency of 0.5-0.75 is achieved. A well designed reflector antenna can have aperture efficiency of 0.65 or better.

19.4. Design Parameters for S band Reflector Antenna:

This antenna was designed for a S band Microwave source namely LIA 400, which was generating a microwave power of 250-300 MW, at 3 GHz frequency. System was earlier having a pyramidal horn antenna as a radiating antenna with an effective range of source to be approximately 125 m. It was planned to achieve 1 km effective range with the same source, for which the need of higher gain antenna was eminent. It was decided to use classical parabolic reflector antenna with a pyramidal feed.

Required gain for antenna was calculated from effective range requirement and following parameters were fixed for S band reflector antenna.

Power Rating: 300 MW, Frequency: 3 GHz, Gain: In excess of 34 dB.

Based on these parameters F/D ratio for this reflector antenna was fixed at 1. Diameter of reflector was chosen to be 3 m. Also the optimum dimensions of feed 17 cm × 24 cm aperture were chosen after optimization. All this work was done using CST Microwave studio.

19.5. Results of S band High Gain Reflector Antenna

Model of S band high gain reflector antenna in CST Microwave Studio is shown in Figure 19.2 along with its actual photograph.

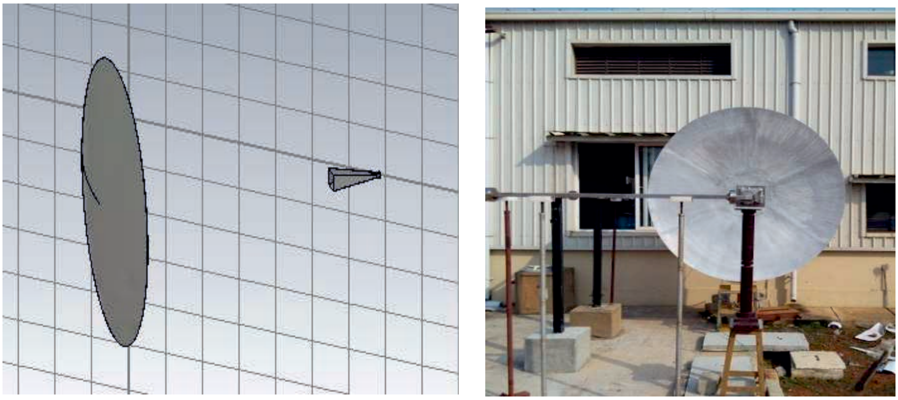


Figure 19.2(a) Model of reflector antenna in CST Microwave Studio and (b) S band high gain reflector antenna.

Antenna modeling was done in CST microwave studio. In simulation a gain of 37.4 dB at 3 GHz has been achieved, reflection loss better than -25 dB has been achieved. These results are shown in Figures 19.3, 19.4 and 19.5. After this, antenna has been actually tested for 1 km range with LIA-400 system. Actual gain of antenna has been better than 36 dB in field testing of system. As shown in Figure 19.6, electric field signal of > 5 kV/m at 3 GHz frequency has been recorded at 904 m distance from source. Disruption of computer has been successfully established at 1 km range with a truck mountable system.

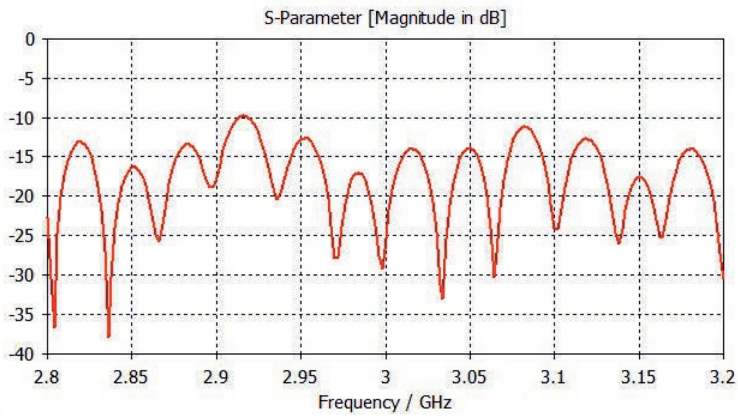


Figure 19.3. Reflection Loss S11 performance of antenna.

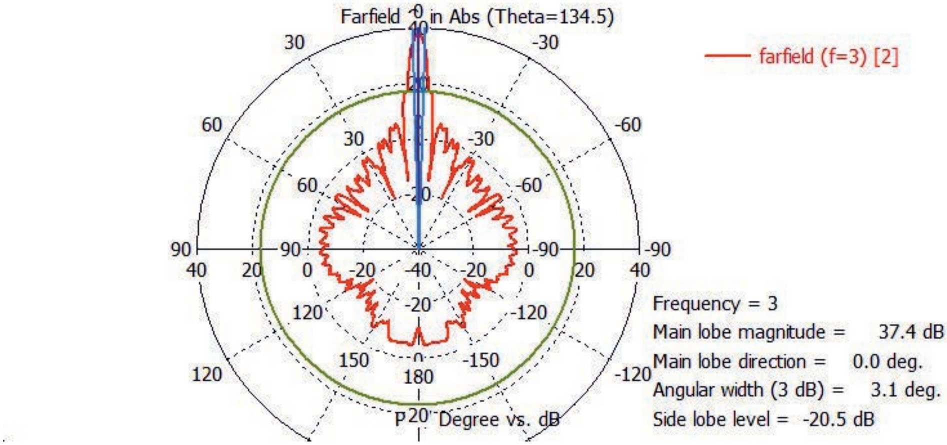


Figure 19.4. 2 D pattern of reflector Antenna.

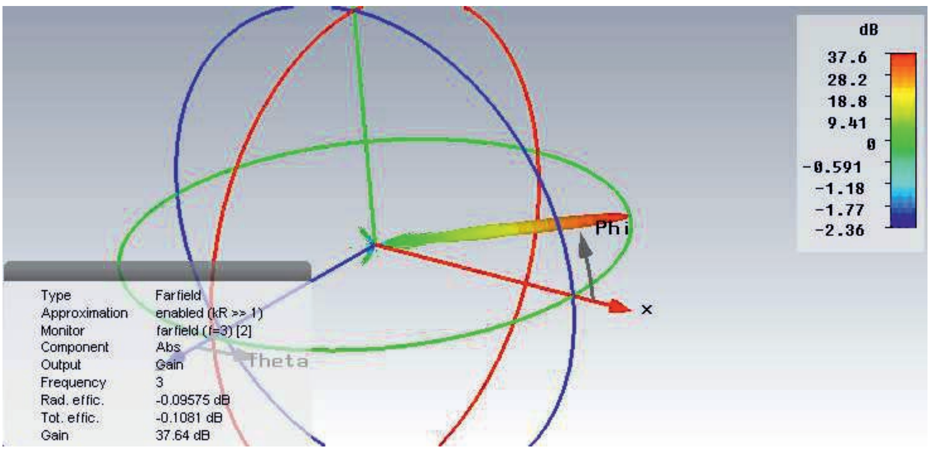


Figure 19.5. 3 D radiation pattern of Reflector Antenna.

19.6. Conclusion

A simple parabolic reflector antenna of 3 m diameter has been designed and developed for S-band operation. This antenna was designed to achieve 1 km range for personal computer disruption, which has been successfully achieved. Also field values recorded at 904 m are in excess of 5 kV/m which indicates a gain better than 36 dB. Though exact value of gain can't be determined due to infeasibility of field mapping at such a large distance. This antenna has achieved its required performance; also it has established feasibility of reflector antennas for HPM sources.

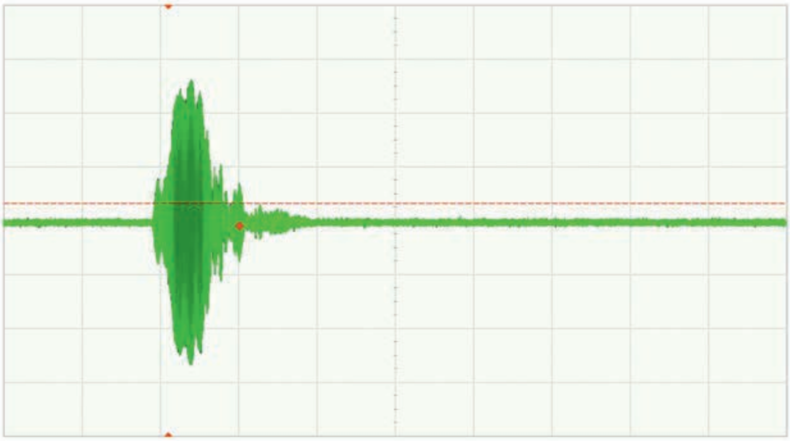


Figure 19.6. Electric Field Signal at 904 m from source.

References

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