# Beam-steerable Flat-panel Reflector Antenna

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## Introduction

Many space applications require a high-gain antenna that can be easily deployable in space. Currently the most common high-gain antenna for space-born applications is an umbrella-type reflector antenna that can be folded while being lifted to the Earth orbit. There have been a number of issues to be resolved for this type of antenna. The reflecting surface of a fine wire mesh has to be light in weight and flexible while opening up once in orbit. Also the mesh must be a good conductor at the operating frequency. In this paper, we propose a different type of high-gain antenna for easy space deployment. The proposed antenna is similar to reflector antennas except the curved main reflector is replaced by a flat reconfigurable surface for easy packing and deployment in space. Moreover it is possible to steer the beam without moving the entire antenna system.

## Flat-Panel Reflector Antenna

The proposed antenna is shown in Figure 1. The major difference between the proposed antenna and conventional reflector antennas is that the main reflector in the proposed antenna system is flat. A number of waveguides are placed on the flat surface so that the effective surface impedances at the waveguide openings are configured to give a focused beam. The length of each waveguide is adjusted so that after the incident wave is reflected from the back conducting plate, the reflected wave has a phase at the open waveguide end such that the beam will be focused in the predetermined direction. In other words the law of reflection does not apply at the reconfigured surface. Also the beam steering can be achieved by adjusting the waveguide heights. Since the height of each waveguide is always less than a half of a wavelength, all the waveguide plates are relatively short. If the waveguide heights are controlled with an electronic means, an electronically beam-steerable antenna results.

## Theoretical Approaches

The feed radiation will be simulated with the well known formulars as given below:

$$\vec{E} \;=\; \left[\hat{\theta}\, C_E(\theta)\cos\phi \;-\; \hat{\phi}\, C_H(\phi)\sin\phi\right]\sqrt{Z}\,\frac{e^{-jkr}}{r}$$

where $C_E(\theta) = \cos^{n_E}\theta, \quad C_H(\phi) = \cos^{n_H}\phi$

Here (r, θ, ϕ) are in feed coordinates, Z is the free-space impedance of 377 Ω, and k is the wavenumber. The parameters of $n_E$ and $n_H$ depend on radiation patterns of the feed horn. Once the incident field strength is known at each of the waveguide openings, the scattered fields are computed using the physical optics method with the Kirchhoff's approximation for the waveguide coupling [1].

## Numerical Results

The detailed antenna geometry for theoretical analysis is shown in Figure 2 for a typical offset reflector antenna at 9.4 GHz. Also the arrangement of the parallel plate waveguides on the reflector surface is shown in Figure 3. The waveguide heights near the vertical centerline for various scanning angles are shown in Figure 4. The resultant E-plane radiation patterns are shown in Figure 5. Note that when the beam is directed without scanning, the overall shape of waveguide heights is parabolic. When the direction of the main beam shifts, the overall shape is skewed as shown in Figure 4. The gain of the reflector-array antenna degrades very rapidly when the main beam is steered beyond 30 degrees away from the boresight of the reflector plate due to reduced aperture area as the beam is steered. In the numerical computation, the blockage of the feed assembly was not considered for the negative values of the scan angle. With a feed taper of 6 dB ($n_E = n_H = 2$), the sidelobe levels are under –15 dB. If a lower sidelobe level is desired, a higher feed taper is needed at the expenses of reduced gain.

## Concluding Remarks

A new concept of reconfigurable surface is applied to a flat-reflector antenna system, in which the equivalent surface impedance is adjusted by varying the height of an individual waveguide at a location on the flat reflector surface. The theoretical results have demonstrated the beam-focusing effect with the reconfigured reflector surface. It is also shown that the beam can be scanned when the waveguide heights are changed accordingly.

## References:

[1] C.S. Lee and S.W. Lee, "RCS of a Coated Circular Waveguide Terminated by a Perfect Conductor," *IEEE Trans. Antennas Propagat.*, Vol. AP-35, pp. 391-398, April 1987.

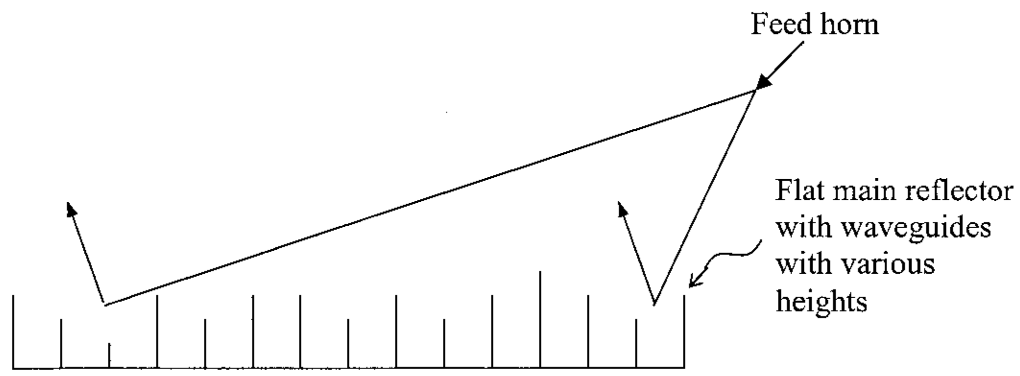


Figure 1. Flat-panel reflector antenna.

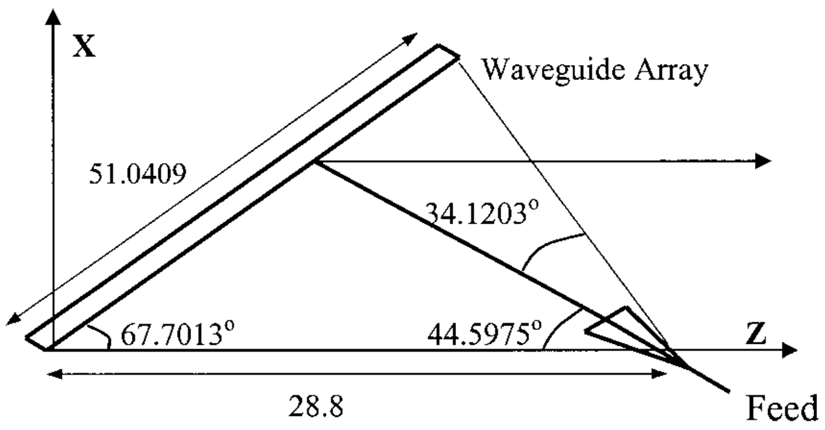


Figure 2. Flat high-gain antenna geometry at 9.4 GHz. All lengths are in cm.

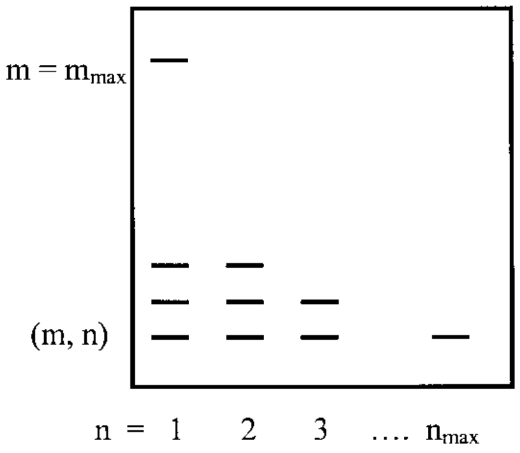


Figure 3. Distribution of parallel-plate waveguides. The periodic spacing is 2 cm. The cross-sectional area of the waveguide is 1.9 cm x 1.9 cm and the gap between the neighboring cells is 0.1 cm. The array size is (24, 24).

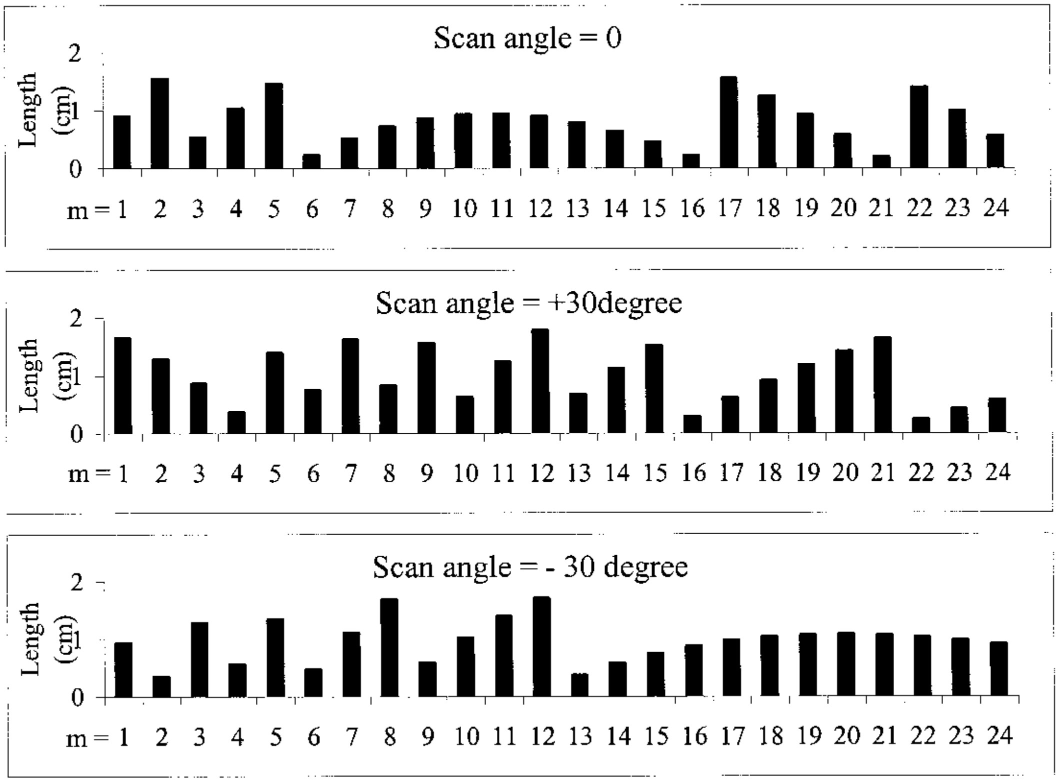


Figure 4. Height of each of the waveguide plates as a function of m with n = 12 (as in Figure 3) for various beam directions.

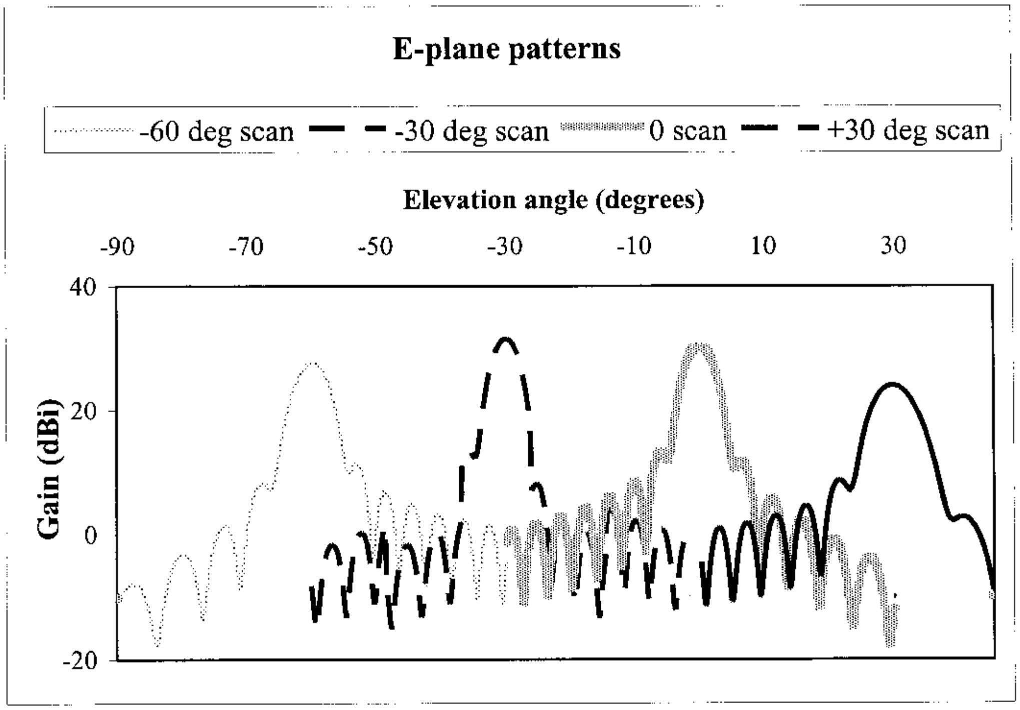


Figure 5. E-plane radiation patterns for various scan angles with $n_E = n_H = 2$.