A NEW REFLECTOR ANTENNA DESIGN PROVIDING TWO DIFFERENT PATTERNS

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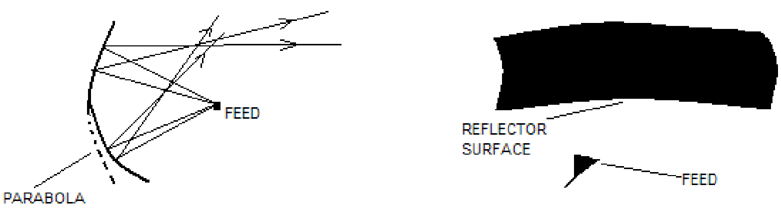
Abstract

Antennas with cosecant squared pattern are designed for air-surveillance radar systems. These permit an adapted distribution of the radiation in the beam and causing a more ideal space scanning. In the practice a cosecant squared pattern can be achieved by a deformation of a parabolic reflector. Moreover, it can be achieved by using multiple feed antennas with normal parabolic reflector surfaces. A fan beam antenna which is a directional antenna producing a main beam having a narrow beamwidth in one dimension and a wider beamwidth in the other dimension can also be used for similar purposes. This pattern can be achieved by a truncated parabolic reflector or a circular parabolic reflector. Frequency selective surfaces (FSSs) have been used in the reflector antenna designs in recent years. A FSS is an array of periodically arranged patches or apertures, showing a particular filtering behavior. Its selectivity in frequency is obtained by the design and allows the transmission of signals in a certain frequency range only. This work is proposed to design a reflector antenna that provides both fan beam and cosecant squared pattern by using a FSS. For the simulation and optimization of the antenna, high frequency simulation software (HFSS) and SUPERNEC antenna simulation programs are used.

Keywords: Cosecant squared pattern, fan beam antenna, beamwidth, frequency selective surface, reflector antenna, simulation, optimization, HFSS, SUPERNEC.

1.Introduction

Reflector antennas are probably the most widely used antennas for high-frequency and high-gain applications in radio astronomy, radar, microwave and millimeter wave communications and satellite tracking and communications [1]. Although reflector antennas can take various geometrical configurations, the most popular shape is the paraboloid because of its excellent ability to produce a high gain with low side lobes and good cross-polarization characteristics in the radiation pattern [1]. Because of its narrow beamwidth, radiating patterns of reflector antennas is defined as “pencil beam”. A reflector antenna consists of one reflector surface and a feed antenna. Reflector designs can be planar, have a parabolic arc, or incorporate a design that uses neither of the aforementioned designs. Feed structures can be placed in front of the reflector or be fed from the back, depending on the reflector technology being implemented [2]. While reflector antennas have high gain and are very directive making them well suited for satellite - earth stations also reflector antennas with different patterns such as cosecant squared are widely used in radar systems. In practice a cosecant squared pattern can be achieved by a deformation of a parabolic reflector (Figure 1.1-a). Moreover, it can be achieved by multiple feed antennas with normal parabolic reflector surfaces. Also another important reflector antenna type for radars is fan beam antennas [3]. They produce a main beam having a narrow beamwidth in one dimension and a wider beamwidth in the other dimension. This pattern can be achieved by a truncated parabolic reflector or a circular parabolic reflector (Figure 1.1-b).



(a) (b)

Figure 1.1 (a) Deformation of parabolic reflector to obtain a cosecant squared pattern, (b) A Fan beam antenna

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In recent years, frequency selective surfaces (FSSs) have been used in reflector antenna designs as reflector surfaces (Figure 1.2). An example of that is Marconi and Franklin's reflector. This reflector is very much similar to the most famous FSS design, an array of half-wave dipoles. A large reflector antenna is constructed by using wire-grids [4]. Also, FSSs have been considered in design of multi-frequency reflector antennas for data communication links. FSS structures are periodic arrays of special elements printed on a substrate [4]. In general, the FSS structures can be categorized into two major groups: patch-type elements and aperture-type elements. FSSs have different behaviors as low pass, high pass, band pass or band stop filter characteristics [5]. The waves are transmitted or reflected according to the properties of the incident waves and the structure of FSS. Because of their frequency selective behavior, FSS have found many filtering applications in microwave and millimeter-wave engineering. Some examples are radome design, polarizers, beam splitters and reflector antennas [6].

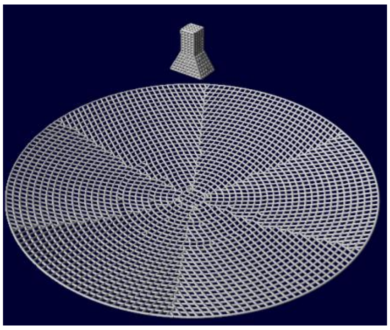


Figure 1.2 A parabolic reflector antenna that has a grid reflector surface

In this work, FSS structures are used for a new reflector antenna design. For this purpose FSS structures are inserted to a fan beam reflector antenna to obtain a cosecant squared antenna form. Thus, the new designed reflector antenna can provide both a fan beam pattern in a frequency band and a cosecant squared pattern in another frequency band.

2.Frequency Selective Surface (FSS)

FSSs are periodic structures which have different behaviors as low pass, high pass, band pass or band stop filter characteristics. They have been widely used in broadband communications, radar systems, and antenna technology in a long time [5]. Generally, FSSs can be categorized into two major groups: patch – type elements and aperture – type elements. For patch – type elements, conducting materials are used in frequency selective surfaces. The patches are placed on a dielectric material. FSS structures provide different electromagnetic filter behaviors by different design styles. For example, a square patch array performs as a low pass filter while a conducting grid performs as a high pass filter (Figure 2.1) [7].

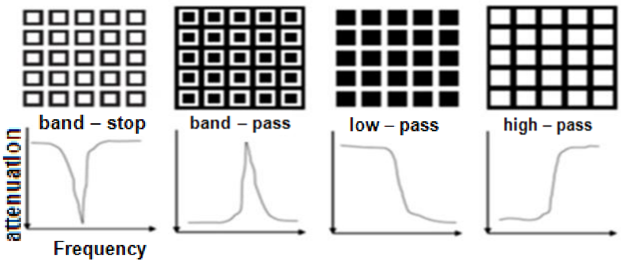


Figure 2.1 Electromagnetic filter behaviors of FSS structures that are differently designed

For analyzing the electromagnetic behavior of frequency selective surface, finite element method, finite difference method or method of moments are commonly used [8]. Despite their accuracy in analysis, these techniques require time consuming simulations and do not allow the designer to have a good insight into the physics behind the structures. Equivalent circuit representations are useful for quickly predicting the performance of frequency selective surface and allow performing a very simple model able to describe every kind of shape after a full-wave computer simulation. These equivalent circuit models also provide useful physical insight into the performance of the FSS. The equivalent circuit model can also be employed in the design of the multilayered frequency selective surfaces [9].

3. Antennas with Cosecant Squared Pattern

Antennas with cosecant squared pattern are special designed for air-surveillance radar sets. These permit an adapted distribution of the radiation in the beam and causing a more ideal space scanning. There are a couple of variation possibilities, to get a cosecant squared pattern in practice as deformation of a parabolic reflector or a stacked beam by more horns feeding a parabolic reflector.

In this work, one feed antenna is used and some modifications are made on the parabolic reflector. First of all, a normal reflector antenna that has a pencil beam pattern is represented in figure 3.1. For the simulation, SUPERNEC antenna simulation program is used.

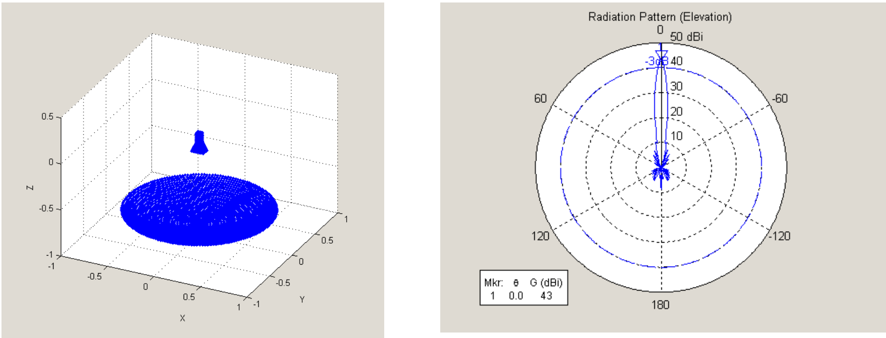


Figure 3.1 A parabolic reflector antenna with pencil beam pattern

In figure 3.2, a reflector antenna with cosecant squared pattern that has been traditionally designed is represented. For the design, a part of reflector surface is cut and the cut side is bowed to feed antenna. For the simulation, SUPERNEC antenna simulation program is used.

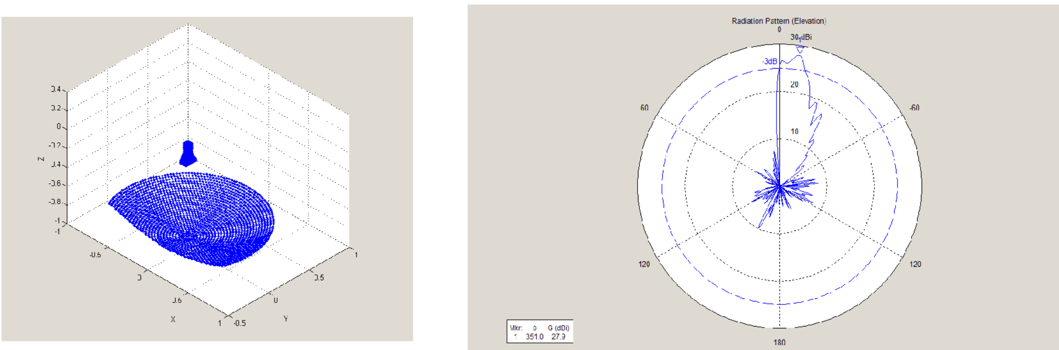


Figure 3.2 An antenna with cosecant squared pattern

4.Design Procedure of a Reflector Antenna that Provides both Fan Beam and Cosecant Squared Pattern in Different Frequency Bands

First of all, a fan beam antenna is constructed (Figure 4.1). Then a FSS structure that has same geometric form with a part of parabola is inserted to the fan beam antenna to obtain a cosecant squared antenna form such as figure 3.2. Thus in a frequency band, the FSS structures reflect electromagnetic waves and as a result, a cosecant squared pattern can be obtained. However in another frequency band, the FSS structures transmit electromagnetic waves and thus a fan beam pattern can be obtained. For this design is required two feed antennas. If we want to use one feed antenna, different two polarizations can be used in a feed antenna. However for getting a good cosecant squared pattern with one feed antenna, a FSS structure is used in the feed antenna. The FSS structure is inserted to inside of the horn antenna's radial flange with an angle. The FSS structure has same geometric form with a side of the horn antenna's radial flange (Figure 4.2).

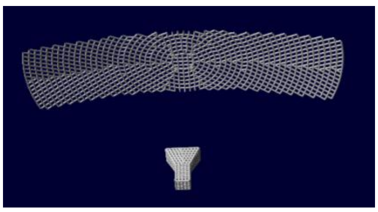


Figure 4.1 A fan beam antenna

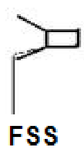
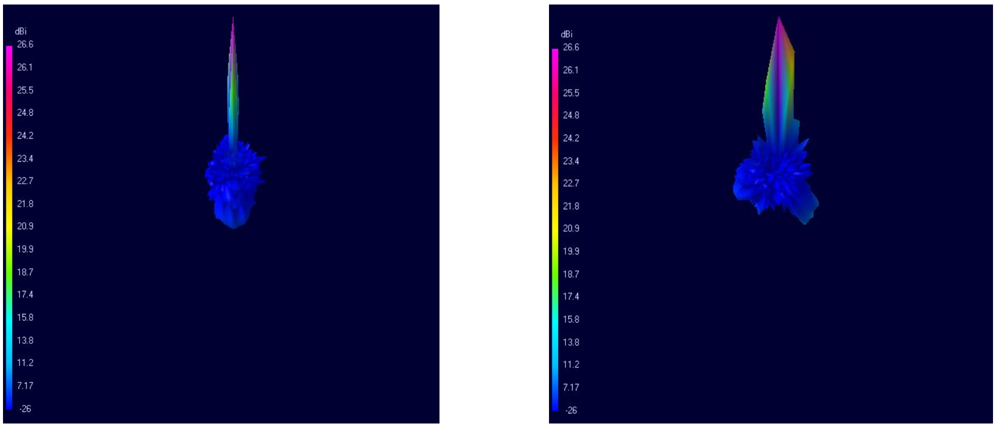


Figure 4.2 A horn antenna with a FSS structure

In figure 4.3, fan beam patterns are represented for a frequency band. In figure 4.4, cosecant squared pattern is represented for another frequency band by using the same antenna.



(a) (b)

Figure 4.3 (a) Sight of the pattern in Theta: 90 and Phi: 90, (b) Sight of the pattern in Theta: 90 and Phi: 180

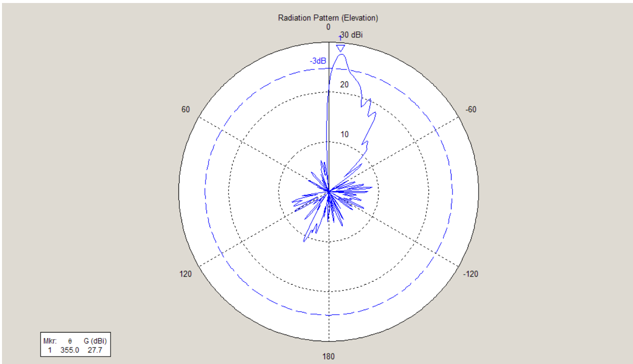


Figure 4.4 Cosecant squared pattern of the antenna

5. Conclusion

In this paper, a novel design for reflector antennas has been introduced. Frequency selective surfaces have been just used as reflector surfaces for reflector antennas in many years. However in the design, frequency selective surfaces are used for a different purpose on the antennas. In this work, it is proposed that two different important radiating patterns are obtained with an antenna in two different frequency bands by using frequency selective surfaces. In future, we will try to obtain the two patterns in a same frequency band by using different polarizations.

References

1. Huang, Y. ve Boyle, K., (2008), Antennas From Theory to Practice, John Wiley & Sons Ltd. Publication, United Kingdom.
2. Volakis, J.L., Yo, D.M.K.A., Emrick, R., (2007), Antenna Engineering Handbook, The McGraw-Hill Companies, Chapter-2.
3. Cooley, M.E. and Davis, D., (2008), Radar Handbook, The McGraw-Hill Companies, Chapter-12 Reflector Antennas.
4. Bayatpur, F., (2009), "Matematerial – Inspired Frequency – Selective Surfaces", Thesis for The Degree of Doctor, The University of Michigan Electrical Engineering.
5. Munk, B.A., (2000), Frequency Selective Surfaces -Theory and Design, John Wiley and Sons Inc., New York.
6. Fallahi, A., Mishrikey, M., Hafner, C., Vahldieck, R., (2009), "Analysis of Multilayer Frequency Selective Surface on Periodic and Anisotropic Substrates", ELSEVIER Metamaterials, Number 3, p.63-74.
7. Döken, B., (2011), "Design for the Structural Surface Material Enabling Signal Transmit Appropriate for the Function in Wireless Communication within the Building", Thesis for The Master's Degree, İTÜ, İstanbul.
8. Mittra, R., Chan, C. H., Cwik, T., (1988), "Techniques for analyzing frequency selective surfaces a review", Proc. IEEE, Vol. 76, No. 12. 1593-1615.
9. Kent, E.F., Döken, B., Kartal, M., (2010), "A New Equivalent Circuit Based FSS Design Method by Using Genetic Algorithm", ENGOPT, Lisbon, Portugal.