A Broad-Beam Antenna Using Nonuniform MSA Parasitic Array Excited by Cavity-Backed Slot

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Abstract

This paper presents a broad-beam antenna using the techniques of nonuniform microstrip patches parasitic array, which is excited by the cavity-backed slot. To achieve broad-beam antenna, phase of each element of the microstrip array has been designed to emulate the reflection of waves on the surface of parabolic backscatter by adjusting the parasitic patches size. In order to increase the efficiency of this array antenna, the back-slot cavity with an exciting probe will be used for coupling the electromagnetic waves to the back of this array. The proper sizes and locations of patches and the optimized position of cavity have been investigated by computer simulation technology (CST) software. Finally, the optimized parameters of this antenna are chosen and the simulation results show the maximum gain and half-power beamwidth of 4 dBi and 120º, respectively.

Keywords: Broad-beam Antenna Cavity-backed Slot Parasitic Array Slot Coupling

1. Introduction

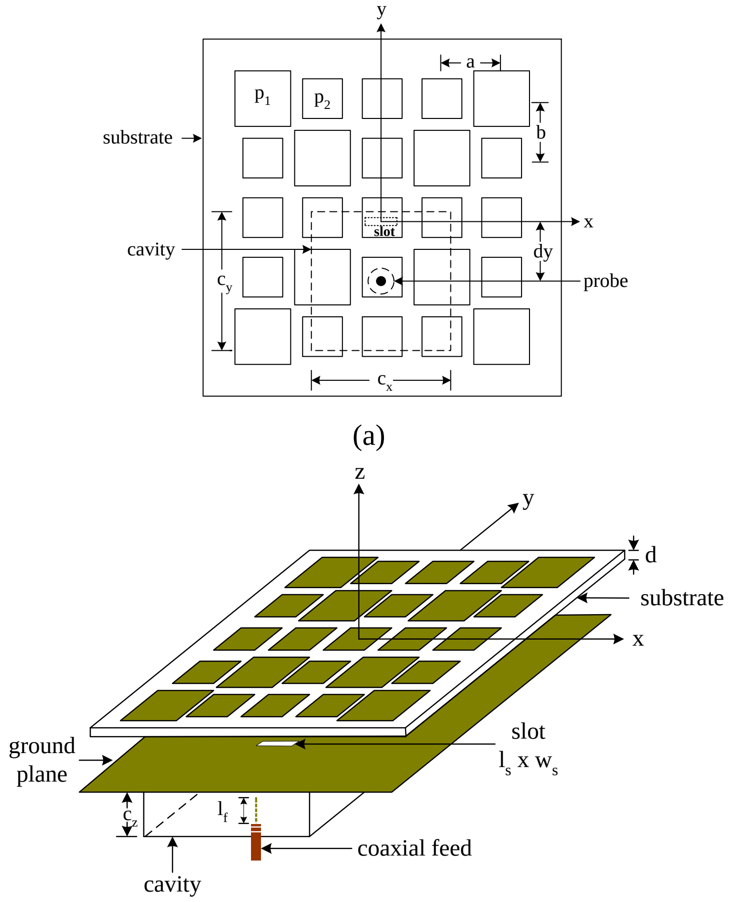
The antennas technology for space and Geographical Information System (GIS), especially, Low-Earth Orbit (LEO) satellite communication systems have been popularly to investigate. The parabolic reflector antenna is the most widely used in satellite communication due to high gain and narrow-beam. However, the feed horn and their arm are placed at the front of the reflector causing obstruct the aperture and its efficiency is degraded, while the large curvature is generally affected to the aerodynamic of the satellite when launching into the orbit. To solve these problems the novel type of the microstrip array is designed [1], [2]. Essentially, this microstrip array has no limitation in its dimensions and has much less distortion in its planar shape. This operation is similar to the parabolic reflector that naturally forms a planar phase front when a feed is placed at its focus. Besides, the advantaged of the microstrip array are low cost, small size, light weight and easy installation.

To overcome the limitations of time requirement for an earth station communicates with LEO satellite that moves in very high-speed. The shaped reflector antenna [3], and microstrip reflectarray [4], [5], which are duplicated the same radiating aperture as parabolic backscatters were designed. Nevertheless, the shaped reflector and reflectarray antennas are used the feed horn place at the front of the reflector causing obstruct the aperture, and its efficiency is degraded.

In this paper, the half-power beamwidth of parasitic array antenna from [8] has been extended by adjusting the sizes (nonuniform patch sizes) and positions of some elements on such array. In addition, we propose the simulation results for installing the cavity-backed slot to the proper position on the back of new parasitic patches array for enhancement its efficiency. The structure of this cavity-backed slot is excited by a linear electric probe, which is located at the center of inner surface of the rectangular cavity [6]-[8]. To achieve the broad-beam antenna, phase of each array element in the microstrip array antenna is specifically designed to emulate the function of curvature of the parabolic backscatter by modifying the parasitic patches size around the radiation patch. Finally, the numerical results are provided by computer simulation technology (CST) software. The frequency response of return losses (S_{11}) and the radiation patterns with various patch sizes and cavity positions have been investigated. After the optimized parameters are chosen, it is found that at the operating frequency of 10 GHz, the proposed array antenna yields the maximum gain around 4 dBi and the half-power beamwidth (HPBW) around 120º.

2. Antenna Design

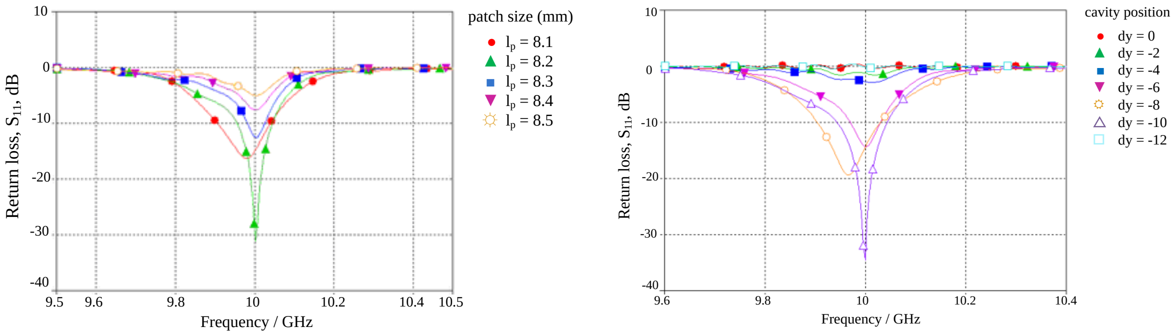
The modified geometry of 5x5 nonuniform microstrip patches parasitic array using cavity-backed slot is shown in Fig. 1. The various sizes of square-shaped microstrip arrays of the optimal designed are etched on the Taconic substrate of thickness $d = 0.767$ mm and dielectric constant $\varepsilon_r = 2.33$. The antenna parameters and the position of each patch element have been simulated using CST-microwave studio simulation to achieve the best return loss and the widest beam radiation. The dimensions of the broad-beam configuration have been designed for the operating frequency 10 GHz. In Fig. 2(a), the frequency response of return losses are illustrated for patches size variation. The minimum return loss of the operating frequency is occurred at -30 dB when the dimensions of a square patch has the length $P_1 = P_2 = 8.2$ mm. The rectangular slot is etched in the center of the antenna ground plane and covered with the metallic cavity. The slot itself must not resonate over the operating frequency band of the antenna because of the radiation from this slot interfering to the radiation from the patches, thus it has the length $l_s = 5.2$ mm and width $w_s = 0.5$ mm. The dimensions and installing position of the rectangular cavity are an important parameter, which were designed and also simulated by using CST-microwave studio. To realize the resonant frequency at 10 GHz, thus the length, the width, and the height of cavity are $c_x = 20.9$ mm, $c_y = 20.9$ mm, and $c_z = 5$ mm, respectively. The installing position of cavity to achieve the best return loss is appeared at dy = 10 mm and shifted from the center of slot along y–axis as shown in Fig. 2(b), while the exciting probe of the length $l_f = 1.5$ mm is installed at the cavity center.



(b)

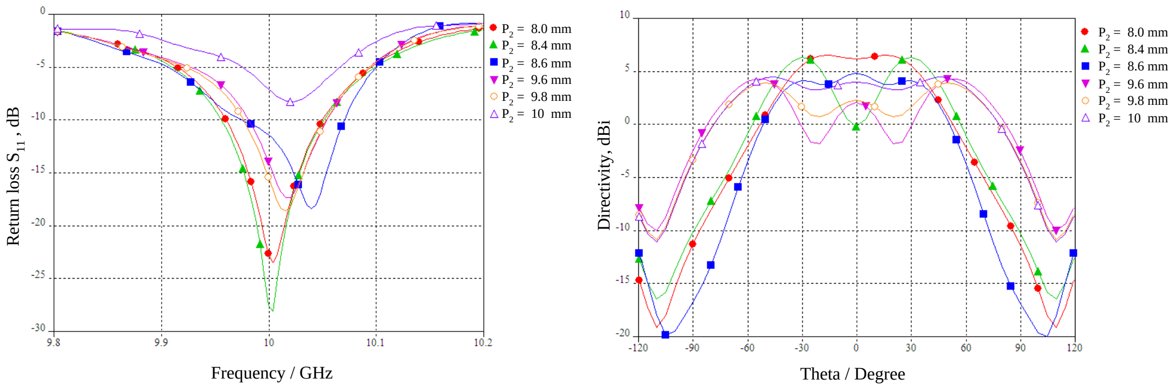
Figure 1: Geometry of the proposed antenna (a) Top view and (b) perspective view, where $P_1 = 9.8$ mm, $P_2 = 8.2$ mm, $l_S = 5.2$ mm, $w_S = 0.5$ mm, $c_X = c_Y = 21.9$ mm, $c_Z = 5$ mm, $l_f = 1.5$ mm, $a = b = 0.34\lambda_0$

To obtain the widest beam radiation and the minimum return loss, the sizes of square patch for microstrip element P_2 are varied from 8 mm to 10 mm, while the simulated results of the radiation patterns are shown in Fig. 3. The resonant frequencies (at minimum S_{11}) for different patch sizes (P_2) are slightly different. The widest beam radiation and the good return loss (< –10 dB) are occurred when the dimension of the square parasitic patches have the length P_1 and P_2 equal to 8.2 mm and 9.8 mm, respectively, and the spacing between microstrip patches (a and b) are $0.34\lambda_0$.



(a) (b)

Figure 2: (a) Simulated return loss (S_{11}) of the proposed antenna for the various patch sizes., (b) Simulated return loss (S_{11}) when the cavity positions are varied along y-axis.

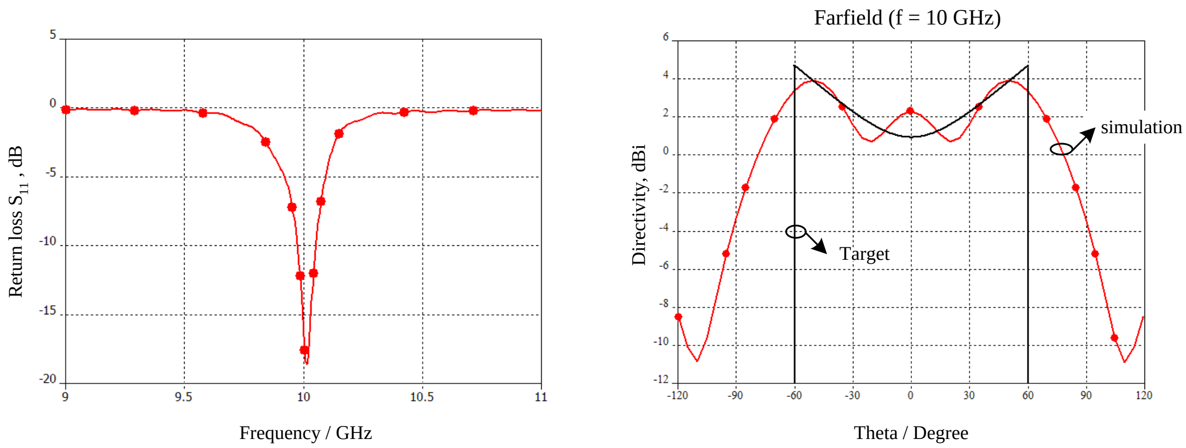


(a) (b)

Figure 3: Simulation results of the proposed antenna: (a) return losses (S_{11}), (b) radiation patterns when the parasitic patch sizes (P_2) are varied (fixed P_1 = 8.2 mm) and the spacing between patches a = b = $0.34\lambda_0$.

3. Results

In order to optimize the half-power beamwidth of broad-beam antenna, the patch sizes of array elements, P_1 and P_2, are selected at 8.2 mm and 9.8 mm, respectively, and spacing between the elements, both a and b, are around $0.34\lambda_0$. The computed return loss and radiation pattern of this antenna that such parameters were optimized and compared to the target line of parabolic backscatter function in cartesian coordinate with the parameters in Fig. 1, are illustrated in Fig. 4. Evidently after the patch sizes and its locations were modified, the broad-beam pattern is achieved. The return loss of antenna at the operating frequency 10 GHz is about – 19 dB, while its radiation pattern has the half-power beamwidth around 120° (wider than before modified [8] about 20°) with the S_{11} criteria with more than –10 dB. While the maximum directive gain of this antenna is about 4 dBi.



(a) (b)

Figure 4: Simulation results of the proposed antenna: (a) Return loss (S_{11}), (b) Radiation pattern at 10 GHz of the proposed antenna compare with parabolic backscatter function in cartesian coordinate.

4. Conclusion

A broad-beam antenna using nonuniform microstrip patches parasitic array, which is excited by the cavity-backed slot has been proposed in this paper. The CST software was used for simulation the key characteristics, especially, the return loss and radiation pattern of antenna. From the simulation results, we found that the half-power beamwidth extension of uniform microstrip patches parasitic array can be achieved by adjusting the patch sizes of its elements. This modified antenna has proven a better radiation pattern and gain comparing to the parabolic backscatter function design for the operating frequency at 10 GHz. After this, the proposed antenna will be realized by fabrication and will be measured to validate the technique in the future.

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