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Reflector Shape Optimization for Wideband Uni-directional of CPW-fed Slot Antenna

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Abstract

The size and shape of the reflectors conductor of CPW-fed slot antennas using loading metallic strips and a widened tuning stub (CPW-FSLW) have been observed. By shaping the reflector, noticeable enhancements in both radiation pattern which provides uni-directional and bandwidth can be achieved while maintaining the easy fabrication and installation. Comparing each shapes for the same width reflector, the Λ-and inverted-Λ shape reflectors with a horizontal plate structure have noticeable enhancement both radiation pattern and impedance bandwidth.

1. Introduction

In the past few years, printed circuit slot antennas have been extensively investigated. They have the advantages of being able to provide wide impedance bandwidth. Various feeding mechanisms have been proposed in the literature to improve the slot antenna's bandwidth. Many slot antennas fed by microstrip have been reported [1]. Another importance candidate which may complete favorably with microstrip for the many applications is coplanar waveguide (CPW). CPW transmission structures have several attractive features including low radiation, less dispersion, easy integration for MMIC and without the need for vias or holes through the substrate. One of the main issues with CPW-fed slot antennas is to provide an easy impedance matching to the CPW-line. CPW-fed antennas have been increasingly studied in recent years because of their large bandwidth operation. In order to obtain wideband CPW-fed slot antennas, several impedance tuning techniques have been reported in the literature based on a change of slot dimensions in bow-tie slots, a wide rectangular slot, coupling mechanism, dielectric resonator coupling, and other techniques. Their main drawback, however, is essentially a bi-directional radiator, with the back radiation being undesirable, which not only directs half of the power in potentially undesired directions but also increases the sensitivity of the antenna to its surrounding environment and prohibits the placement of such slot antennas on the platforms. Therefore, there are limit its use to a small number of applications.

The antenna should efficiently focus the RF/microwave signal towards the target and collect the back-scattered energy such as the base station antenna of mobile systems and point to point communications. A wideband antenna with uni-directional radiation pattern required for these applications. There are several techniques to reduce the level of back radiation from antennas using reflector[2]-[6]. However, they have a narrow bandwidth. Unfortunately, wideband printed circuit slot antennas with uni-directional radiation pattern have a small literature.

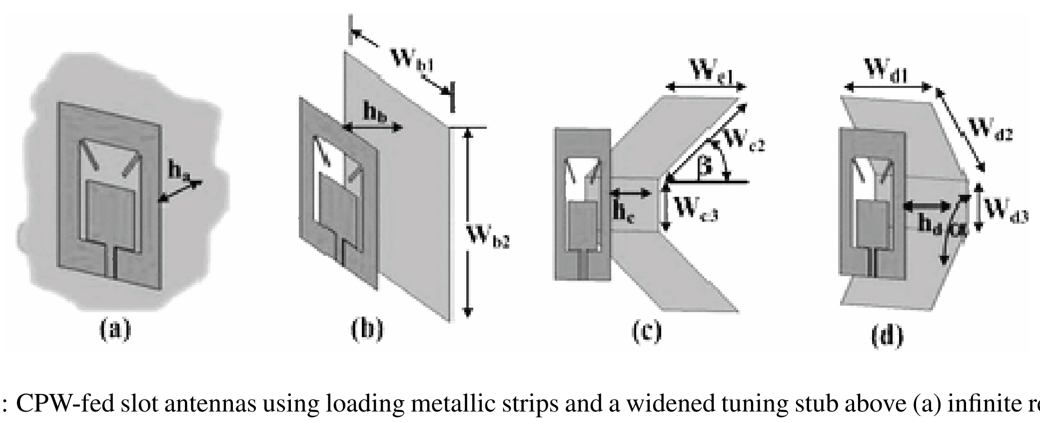

Figure 1: CPW-fed slot antennas using loading metallic strips and a widened tuning stub above (a) infinite reflector, (b) finite reflector, (c) Λ-shape reflector with a horizontal plate, and (d) inverted-Λ-shape reflector with a horizontal plate.

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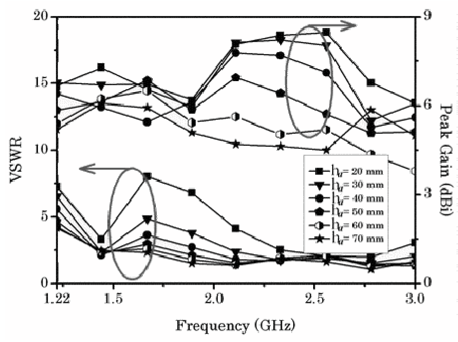


Figure 2: Computedd VSWR and peak-gain of antenna above infinite reflector with different reflector distances.

This paper presents the enhancement of a uni-directional pattern and impedance bandwidth by optimizing the several types of reflector shape including infinite reflector, flat reflector, Λ-shape reflector with a horizontal plate and inverted-Λ-shape reflector with a horizontal plate. The goal in this study is the achievement on a uni-directional all frequencies in operating band and maintain impedance bandwidth equally an antenna without reflector. By shaping the reflector, noticeable enhancements in both radiation pattern which provides uni-directional and bandwidth can be achieved while maintaining the easy fabrication and installation.

2. CPW-FSLW above Various Types of Reflectors

In this study, the radiation element is an unbacked CPW-fed slot antennas using loading metallic strips and a widened tuning stub (CPW-FSLW) [7]. It is etched in the ground on the substrate FR-4 (ϵ_r=4.4) with a thickness 1.6 mm. This structure without a reflector radiates a bi-directional pattern and a low gain. Several types of reflector shape are considered in this paper including infinite reflector, finite reflector, Λ and inverted-Λ-shape reflectors with a horizontal plate. By changing the parameters of each reflector such as size of reflector, the distance between radiation element and reflector, and the angle between horizontal plate and the two sides slope reflector of Λ-and inverted-Λ shape reflectors with a horizontal plate are found to affect the impedance bandwidth, resonant frequency and radiation characteristics. These parameters are optimized to enhance the performance antenna. First, the CPW-FSLW located above an infinite reflector plane [Fig. 1(a)] is analyzed. As an example, we considered a CPW-FSLW above an infinite reflector plane with h_a. An infinite sized reflector is not possible, and small reflector is necessary for base station and point-to-point antennas installation. Thereafter, the same CPW-FSLW antenna is analyzed above a flat finite reflector conductor.The reflector has dimensions of $W_{b1}\times W_{b2}$ and distance between the reflector and radiation element is h_b in Fig. 1(b). The case for a simple bent conductor ground or corner ground was proposed in [4]. The Λ-shape reflector with the horizontal plate, which is a useful modification of the corner reflector. To reduce the overall dimensions of a large corner reflector the vertex can be cut off and replaced with a horizontal flat reflector ($W_{c1}\times W_{c3}$). The geometry of the proposed broadband CPW-FSLW with a Λ-shape reflector with the horizontal plate as shown in Fig. 1(c). The Λ-shape reflector, having a horizontal flat section dimensions of $W_{c1}\times W_{c3}$, is bent with a bent angle of β. The width of the bent section of the Λ reflector is W_{c2}. The distance between the antenna and the flat section is h_c. For the last reflector, we modified the shape of the conductor reflector. Instead of a Λ-shape reflector, we took the conductor reflector to have the form of a inverted-Λ-shape reflector Fig. 1(d)]. The geometry of the inverted-Λ-shape reflector with the horizontal plate is shown in Fig. 1(d). The Λ-shape reflector, having a horizontal flat section dimensions of $W_{d1}\times W_{d3}$, is bent with a bent angle of α. The width of the bent section of the inverted-Λ reflector is W_{d2}. The distance between the antenna and the flat section is h_d.

3. Characteristics of Antenna by Reflector Conductor Shapes

In order to obtain the uni-directional radiation, a plane reflector is placed parallel to the slot surface on the side of the dielectric substrate. The VSWRs and peak-gains of the CPW-FSLW antenna above infinite are calculated for different distances between the radiation element and an infinite reflector, as shown in Fig. 2. It can be seen that the matching of the antennas are affected by the distance between the reflector and radiation element. The matching of the antenna above infinite reflector gets worse when the distance between reflector and radiation element (h_a) is increased. Comparisons of the simulated gain obtained by six different distances h_a from 20 mm to 70 mm are also presented in Fig. 2. In these examples, the gain of the antenna increases as the reflector is positioned closer to the radiator element.

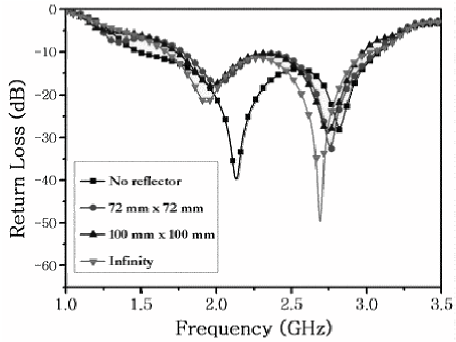
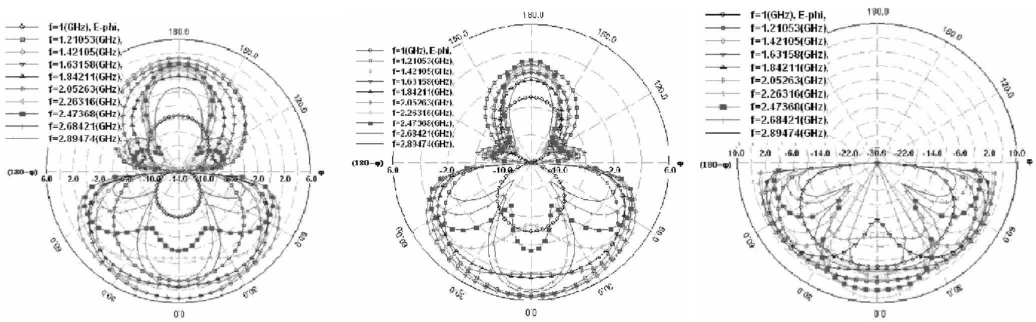


Figure 3: Return loss of the CPW-FSLW antenna with different sizes of reflector plates: $h_a = h_b$ = 70 mm.

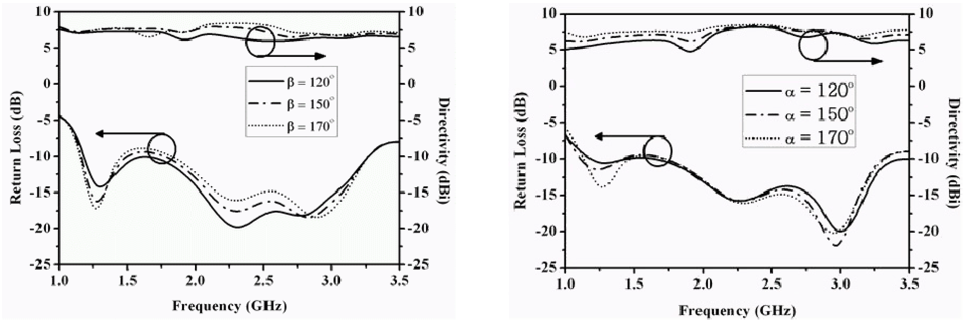


(a) (b) (c)

Figure 4: Simulated radiation patterns in E-plane with different sizes reflector (a) 72 mm ×72 mm, (b) 100 mm × 100 mm, and (c) infinite size reflector.

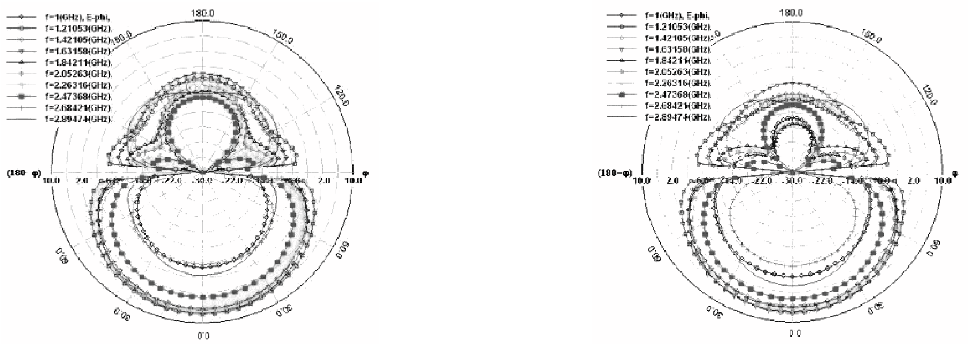
The return loss performance of the CPW-FSLW antenna for difference sizes of a finite reflector plate are simulated. IE3D is used to simulate the return loss of all antennas with finite reflector plates. Simulated return loss and directivity results of the CPW-FSLW antenna with different sizes of a reflector plate, including no-reflector, 72 mm×72 mm, 100 mm×100 mm, and infinite size reflector, are shown in Fig. 3. It can be seen that the resonant frequencies will shift lower when the reflector plate size increases. The 10-dB return loss bandwidth is about 1390 MHz for all antennas withwithout reflectors, which is 59% of the center frequency 2.355 GHz. The E- plane patterns of the CPW-FSLW antenna with different sizes of a reflector plate have been calculated and given in Fig. 4. It can be seen that from Fig.4 that the backside lobe level decreases when the size of the reflector plate increases. The main lobe of both E- plane patterns of the two antennas change slightly when the size of the reflector plate increases from 100×100 mm^2 to infinity. It is obvious that there is no backward radiation in the case of an infinite reflector plate.It can be seen that the bandwidth and the peak gain change slightly when the size of the reflector plate increases from 72 mm ×72 mm size to 100 mm×100 mm. It is also noticed that the front-to-back ratio becomes higher when the size of the reflector size increases, as we expected.

The cases for varying the angle β in the proposed design are also studied and the results of the simulated return loss are shown in Fig. 5 (a). Here, the size of the flat reflector is fixed at 72 mm (W_{c1}) × 44 mm (W_{c3}) and the rectangular slope reflectors (W_{c2}×W_{c1}) are 40 mm×72 mm. For obtaining maximum enhanced antenna gain, results indicate that $\beta = 170^o$ is the optimal angle between the flat section and rectangular slop reflectors with h_c = 30 mm. On the other hand, it is seen that the decreases in β decreases the impedance bandwidth. This behavior is probably because the decrease in β corresponds to the lowering in the effective average substrate thickness in the proposed design, resulting in a smaller impedance bandwidth obtained. Fig. 5(b) shows the simulated return loss for the CPW-FSLW above an inveted-Λ reflector with various of α. The flat reflector has dimensions of 44 mm × 72 mm ($W_{d3} \times W_{d1}$) and the rectangular slope reflectors ($W_{d2} \times W_{d1}$) are 40 mm × 72 mm. The distance h_d from the radiator element to the flat reflector is fixed to be 30 mm. The impedance bandwidth is significantly increased by increasing in the bent angle from 120^o to 170^o. When the bent angles are 150^o and 170^o, the antenna's impedance bandwidth reaches about 38%. It can seen that the peak gain change slightly. The radiation properties are computed for h_c and h_d = 30 mm with the same angle β and $\alpha = 170^o$ are shown in Fig. 6. It is interesting to observe that a uni-directional beam can be achieved all frequency operating band.



(a) (b)

Figure 5: Simulated return losses and directivities for the proposed antenna as a function β and α; $h_c = h_d = 30$ mm with $W_{c1} = W_{d1} = 72$ mm, $W_{c2} = W_{d2} = 40$ mm, and $W_{c3} = W_{d3} = 44$ mm.



(a) (b)

Figure 6: Simulated radiation patterns in E-plane with different sizes reflector when $h_c = h_d = 30$ mm (a) $\beta = 170^o$ and (b) $\alpha = 170^o$.

4. Conclusion

This paper presented the investigations of a uni-directional CPW-fed slot antennas using loading metallic strips and a widened tuning stub of four different reflector shapes, namely infinite, finite, inverted-Λ and Λ-shape reflectors. By proper selection of reflector parameters, specially reflector distances, shaped, size, and angle of reflector, a wide impedance bandwidth and uni-directional can be achieved. Both Λ and inverted-Λ reflectors are the achievement on a uni-directional all frequencies in operating band and maintain good impedance bandwidth.

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