Progress In Electromagnetics Research Letters, Vol. 47, 125–129, 2014

A Dual Beam Scanning Microstrip Antenna

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Abstract—A dual-beam scanning microstrip antenna is proposed in this letter. The well-known characteristic of the conventional leaky wave antenna is the beam scanning with operating frequency variation. Here, two L-shaped slots are applied on the ground plane of the conventional leaky wave antenna structure to obtain the dual-beam scanning characteristic. The results show that this will work with relatively simple structure radiatng not only in the upper half-plane, but also in the lower half-plane. The upper half-plane main lobe scans from 356° (−4°) to 24° (scanning region is 28°). Meanwhile, the lower half-plane main lobe scans form 190° (−170°) to 161° (scanning region is 29°). The 7-dB return loss bandwidth is 600 MHz from 3.4 GHz to 4 GHz. In addition, the measured average antenna gain is about 5.3 dBi in the operating frequency.

1. INTRODUCTION

In recent years, surveillance application systems have been developed rapidly as security issues become more significant. Therefore, the applications such as radar sensors, automobile collision avoidance systems and traffic management systems have become considerably more popular in wireless communications. This is especially evident in the application of the automotive collision avoidance radar. In these wireless applications, the directional antenna and multi-beam antenna play important roles [1]. For this reason, a leaky wave antenna becomes a suitable candidate in these applications. However, the conventional microstrip leaky wave antenna only has one main-beam to scan when it is operating. Therefore, some design methods for dual-beam scanning applications have been demonstrated [2–7]. As mentioned, many design methods have been proposed. Nevertheless, some of them are array structure, which means that these methods need more than one antenna element.

In this letter, we demonstrate an antenna with a simple structure for dual-beam scanning application. Based on the beam scanning characteristics of the conventional leaky wave antenna, the upper half plane can be scanned since the proposed antenna is similar to the leaky wave antenna structure. In addition, two L-shaped slots are added on the ground plane at a particular position to obtain the scanning radiation pattern in the lower half plane. Finally, the proposed antenna has dual-beam radiation pattern and scanning characteristics when operating. The proposed antenna is suitable for directional communication system or scanning application.

2. ANTENNA DESIGN

The structure of the proposed antenna is shown in Figure 1, and detailed dimensions of the slots are listed in Table 1. This work is implemented on an FR-4 printed circuit board with dielectric constant of $\epsilon_r = 4.4$, loss tangent of $\tan\delta = 0.02$ and thickness of $h = 1.6$ mm. The length and width of the substrate are 135 mm and 45 mm. This work is based on the conventional leaky wave antenna with two L-shaped slots embedded on the ground plane. Therefore, the feeding network of this work also

Received 31 May 2014, Accepted 19 July 2014, Scheduled 8 August 2014
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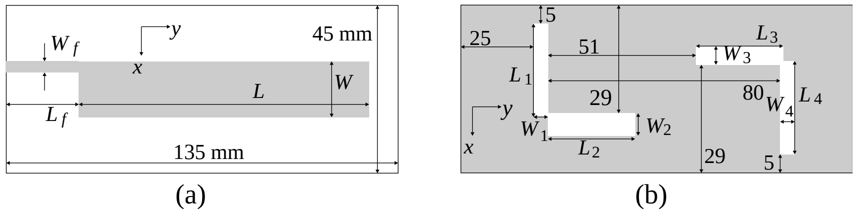

Figure 1. Structure of the proposed antenna. (a) Top view. (b) Bottom view.

Table 1. Detailed dimensions of the proposed antenna structure.

Parameter	L	L_f	L_1	L_2	L_3	L_4
Value (mm)	100	25	25	35	30	25
Parameter	W	W_f	W_1	W_2	W_3	W_4
Value (mm)	15	3	5	6	5	5

adopts an asymmetrical feed line to excite the 1st higher order mode. As shown in Figure 1(a), the structure is the same as the conventional leaky wave antenna structure. However, the ground plane of this work is quite different, as shown in Figure 1(b). The design concept which involved adding slots on the ground plane for the conventional leaky wave antenna was also utilized in [8]. In the work, the slot element array is etched on the ground plane of the conventional LWA. This method can change the current distribution on the ground to reduce the frequency of the first higher order mode. Meanwhile, the operating frequency band shifts to the lower frequency band since the propagation constants are varied. However, the side lobe radiation which is beneath the ground plane is also induced.

Here, two L-shaped slots which can be seen in a set of antenna arrays are embedded on the ground plane. Likewise, the antenna structure is similar to the conventional leaky wave antenna in this work. The left-hand side L-shaped slot is beneath the position which is the feeding structure of the proposed antenna. The right-hand side L-shaped slot is under the end edge of the proposed antenna.

The width and length of the proposed antenna main structure are 15 mm and 100 mm, respectively. In the case of no slots, the operating frequency band is from 4.2 GHz to 5 GHz of the conventional leaky wave antenna. However, the operating frequency is shifted to a lower frequency band with two L-shaped slots embedded on the ground plane.

Because of the two L-shaped slots and the similarity to the conventional leaky wave antenna configuration, this work has beam scanning capability. Moreover, this work enhances the side lobe radiation which is beneath the ground plane. Since there are two slots on the ground plane, the radiation pattern of this work has the pattern not only above the ground plane, but also beneath the ground plane. Compared to the conventional leaky wave antenna, the efficiency is improved by more than 70%. The simulation and measurement results are demonstrated in the following section.

3. MEASUREMENT RESULTS

The proposed antenna was fabricated as shown in Figure 2. The simulated and measured normalized radiation patterns are shown in Figure 3, where the simulated data are obtained by Ansoft HFSS.

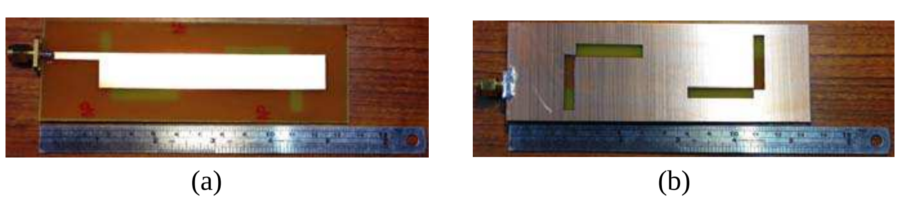

Figure 2. The fabricated proposed antenna. (a) Top layer. (b) Bottom layer.

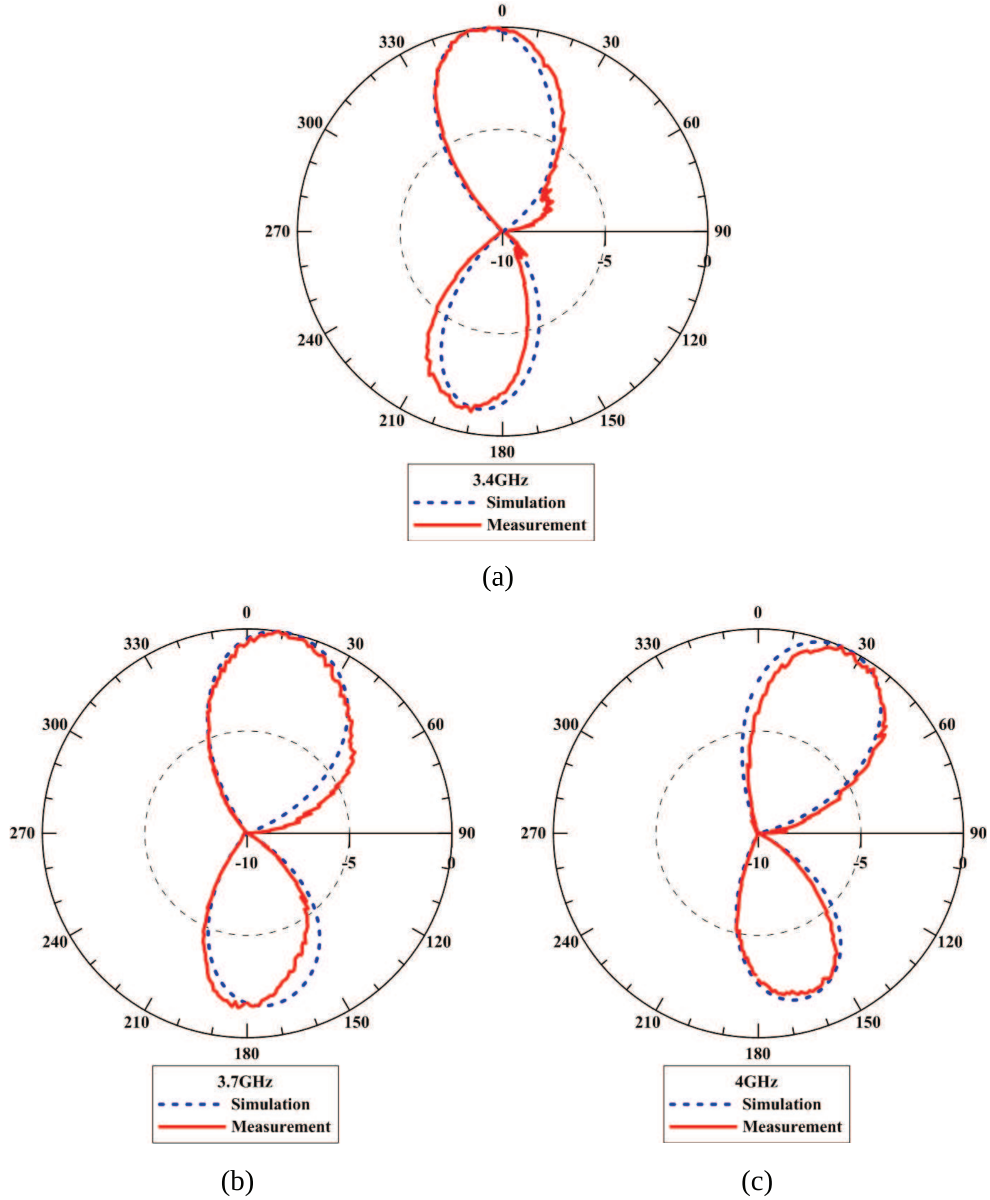

Figure 3. Normalize simulated and measured radiation patterns in yz-plane, where the simulated data is obtained by Ansoft HFSS. (a) At 3.4 GHz. (b) At 3.7 GHz. (c) At 4 GHz.

According to the results, the measured results are in good agreement with the simulation. As shown in Figure 3(a), the radiation pattern of dual beam are close to 356° (−4°) and 189° (−171°) when operating frequency is 3.4 GHz. In Figure 3(c), the dual main beam radiates toward 24° and 160°. As demonstrated in Figure 3, the scanning range in the upper plane is from 354° (−6°) to 25° and in the lower plane is 190° (−170°) to 161°. According to these measured results, the scanning range is 28° in the upper plane and 29° in the lower plane.

In Figure 4, the simulated and measured return loss results are demonstrated, where the simulated data are also obtained by Ansoft HFSS. Simulated to the radiation pattern results, the measured return loss is also in good agreement with the results from the simulation. From Figure 4, the 7-dB impedance bandwidth is 600 MHz from 3.4 GHz to 4 GHz.

The measured peak gains of the upper and lower planes are shown in Figure 5(a). According to the results, the average peak gain of the upper plane is about 5.31 dBi. Meanwhile, in the lower plane case, it

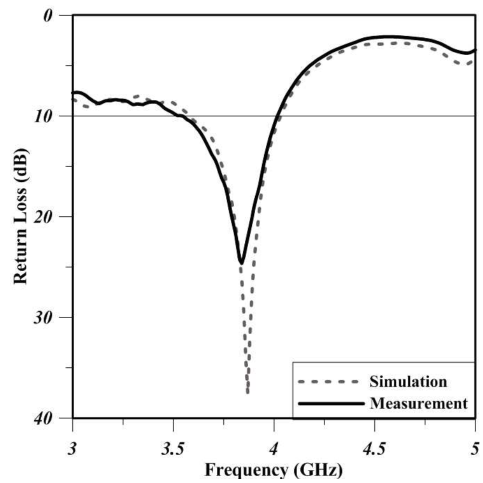

Figure 4. Simulation and measurement return losses, where the simulation result is obtained by Ansoft HFSS.

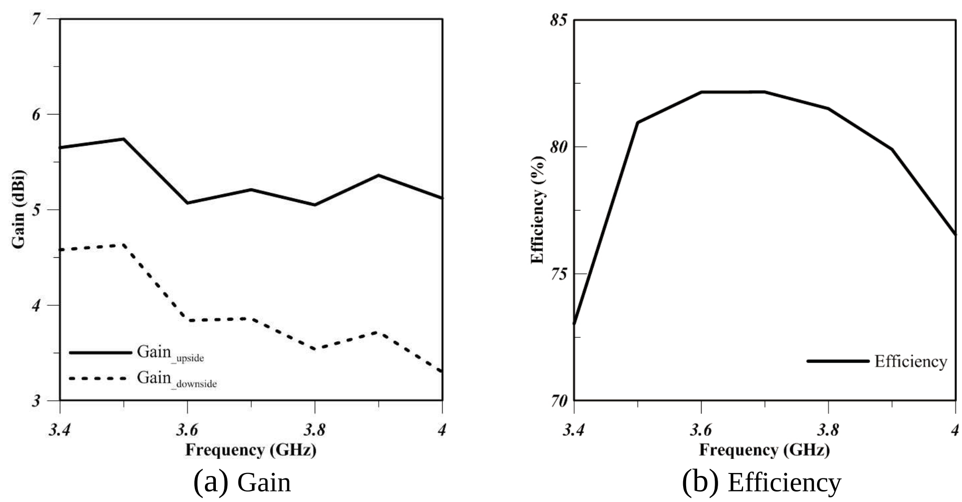

Figure 5. Measured results. (a) Peak gain of upside and downside. (b) Measured efficiency.

is about 3.92 dBi. Although the peak gain of the lower plane is smaller than that of the upper plane, the radiation pattern still has good directivity. From these results, the proposed antenna can radiate both in the upper and lower planes with beam scanning characteristics. In addition, the simulated radiation efficiency is shown in Figure 5(b). All the simulated data as a whole of the operating frequency are better than 70%, which have a good efficiency quality.

4. CONCLUSION

A dual-beam frequency scanning microstrip antenna is presented in this letter. The dual-beam radiation pattern characteristic is obtained by adding slots applied on the ground plane. According to the measurement results, the scan range of the main beam in the upper half plane is from 356° (−4°) to 24° and from 190° (−170°) to 161° for the lower half plane when the operating frequency is from 3.4 GHz to 4 GHz. The scanning region is 28° for upper plane and 29° for lower plane. The average measured peak gains are 5.31 dBi and 3.92 dBi for upper and lower planes, respectively. This design can be a good candidate for radar sensors, automobile collision avoidance systems and traffic management systems.

ACKNOWLEDGMENT

The authors are grateful to the National Center for High performance Computing and the Chip Implementation Center (CIC) of the National Applied Research Laboratories, Taiwan, for support with regard to simulation software and facilities. Meanwhile, this work was supported in part by the National Science Council (NSC), R.O.C., under contract NSC 102-2221-E-009-028.

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