Novel Circularly Polarized Substrate Integrated Waveguide SLOT Antanna

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Abstract

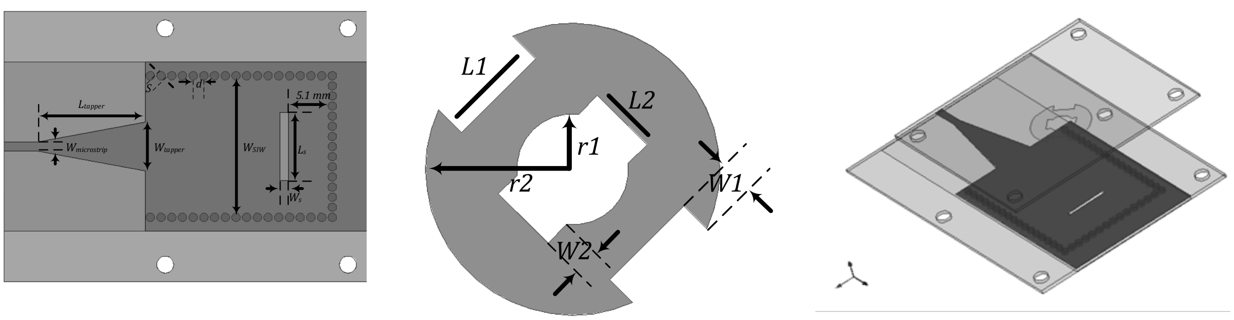
Circularly-polarized antenna is built based on a new SIW (substrate integrated waveguide) structure which contains cavity-backed resonator and a conventional polarized ring with two square slits in inner and outer ring that differ 90° at position and is proposed for right-handed circular polarization (RHCP) and fabricated in two separate layers. A broadband impedance bandwidth of 13.9% and a RHCP axial ratio of 0.5GHz have been obtained under the condition of less than VSWR ≤2 and axial ratio≤ 3 dB, respectively.

Keywords: PCB, SIW, HMSIW, QMSIW, HFSS, RHCP

1- Introduction

Circular polarization is widely used in current radar and satellite wireless communication systems, due to provide better mobility and weather penetration. Circular polarization is formed by two orthogonal filed components with two identical amplitudes but with 90° of phase difference. In recent years, there has been rapid development of wireless communication technologies. The demand for high performance and a small size has also increased steadily. To meet this demand, micro strip antennas, which have a low weight, a low profile, a compact size, and many commercial advantages, are used in many of applications. The substrate integrated waveguide (SIW), also called the laminated waveguide [1] or the post-wall waveguide [2], is composed of two rows of conductive cylinders on a printed circuit board (PCB). The Via holes are embedded in a substrate that connect two parallel metal plates. Therefore, a synthetic rectangular metallic waveguide filled with dielectric material, is constructed in the planar form, thus allowing complete integration with other planar transmission-line circuits (such as micro strip or coplanar waveguides) on the same substrate [3]. The advantage of SIW is that it is low-loss, compaction volume, low profile, and it can make a simple integration with other planar circuits. Therefore, research into SIW circuit sand antennas is gaining interest. For instance, a low profile, cavity-backed planar SIW slot antenna is presented in [4]. Because of the back cavity, it has 5.4dBi gain with 1.7% bandwidth. A slotted leaky-wave antenna was implemented in the

SIW technology [5]. In this device, leakage occurs on the periodic structure of transverse slots on top of the SIW. This leaky-wave antenna provides a beam-scanning range from broadside to end fire. An SIW feeding network is used in a 4x4 array in a Yagi antenna [6]. Additionally, the SIW technology has been applied to realize circularly polarized (CP) antennas. In [7], an SIW cavity-backed, crossed-slot antenna is presented. The CP wave is generated in TE_{12}mode. The CP operation is realized by different lengths of the two arms of the crossed slot to create a90 phase difference. A low profile, cavity-backed planar slot CP antenna has been developed using a half-mode substrate integrated waveguide (HMSIW) technique [8]. The CP wave is generated in TE_{12}mode. A 90° phase difference is achieved by the incorporated micro strip line, in which two orthogonal quarter-wavelength patch modes are excited. ACP SIW antenna was designed using a quarter-mode substrate integrated waveguide (QMSIW) technique [9]. The CP wave is generated in TE_{22} mode. A 90 phase difference is achieved by adjusting the length of the two edges of the QMSIW cavity. Results and discussions of proposed antenna are presented in the following section.



(a) (b) (c)

Fig. 1. Proposed antenna configuration (a). bottom layer, (b). top layer, (c). two layered

2- Antenna Configuration

We considered the proposed cavity-backed slot antenna using SIW technology as shown in Fig. 1. The proposed antenna is mainly composed of three parts: a conventional polarized ring with two square slits inside and out of "b" the ring, a SIW-based cavity-backed resonator "c" and "a" a slot antenna, and feeding network, respectively. The total occupied area is 32(W) × 43(L) mm^2 in Fig. 1a with FR4 substrate, which has a thickness "h" of 0.5 mm, relative permittivity of3.8, and loss tangent of 0.022. The optimized parameter values for generating CP, are listed in Table 1. In order to attain CP, a ring with two square slit in inside and out of it, is used that have 90° difference at position on FR4 substrate with 0.5mm thickness and 4.4 relative permittivity, as shown in Fig. 1b. The ring is located in a distance of 1 mm from lower substrate and the distance between the two substrates is filled with air.

Table.1. Design parameter values of proposed antenna

Parameter(s)	Value	Parameter(s)	value
L_s	8 mm	L_{tapper}	12.6 mm
W_s	1 mm	r_1	1.6 mm
W_{siw}	16.8 mm	r_2	4.2 mm
d	1.259 mm	L_1	3 mm
s	1 mm	L_2	2 mm
W_{tapper}	5.85 mm	W_1	0.923 mm
$W_{microstrip}$	1.1 mm	W_2	0.751 mm

Experimental results sand discussion

A measured return loss of the proposed antenna is shown in Fig. 2, which shows a good agreement between data and the simulated results, using commercially available software (HFSS). Photograph of the fabricated antenna is shown in Fig. 4.

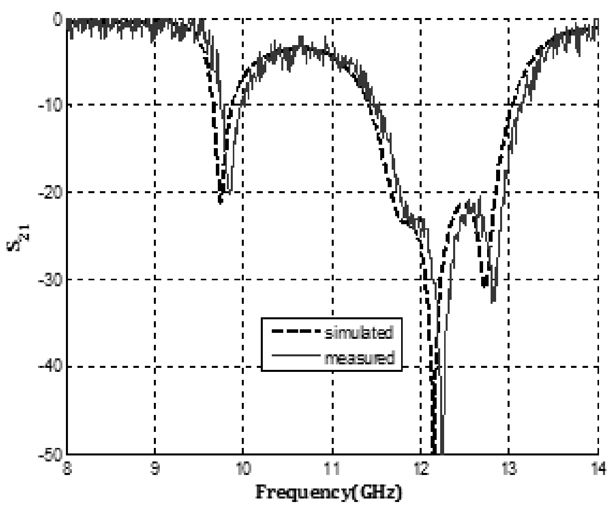


Fig. 2. Simulated and experimental return loss characteristics with photograph of fabricated antenna

It can be evaluated from Fig. 2 that the input impedance bandwidths are 13.9% from 11.4to 13.1GHz. From Fig. 3, which shows the gain and axial ratio (AR), it is seen that the proposed antenna has 8.75 dBi as maximum gain within 11 to 13 GHz, a very stable 3 dB gain band width of 0.5 GHz, and axial ratio bandwidth of 2.3% from 11.7 to 12.3 GHz for less than 3dB. The measured radiation patterns in two orthogonal cutting planes shown in Fig. 5, imply that the proposed antenna satisfies the RHCP generation with a lower cross-polarization at broad sight direction.

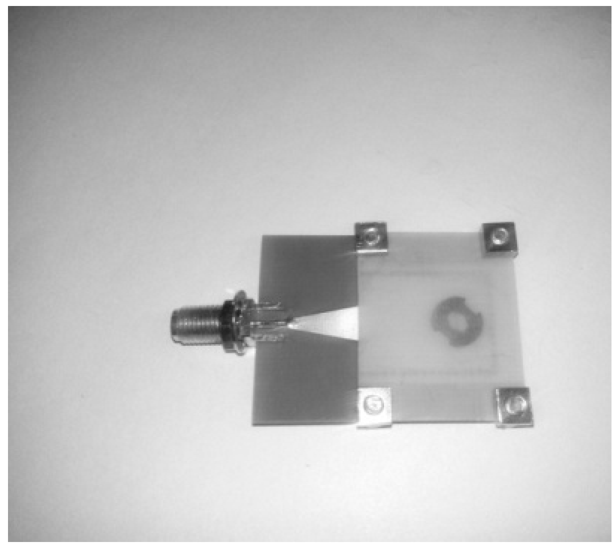


Fig. 3. Photograph of the fabricated antenna

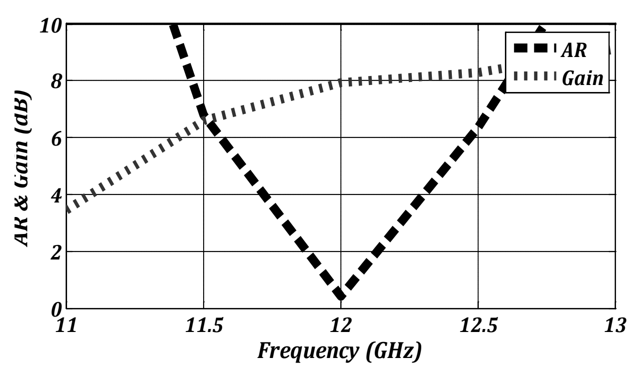


Fig. 4. Gain and axial ratio characteristics against frequency

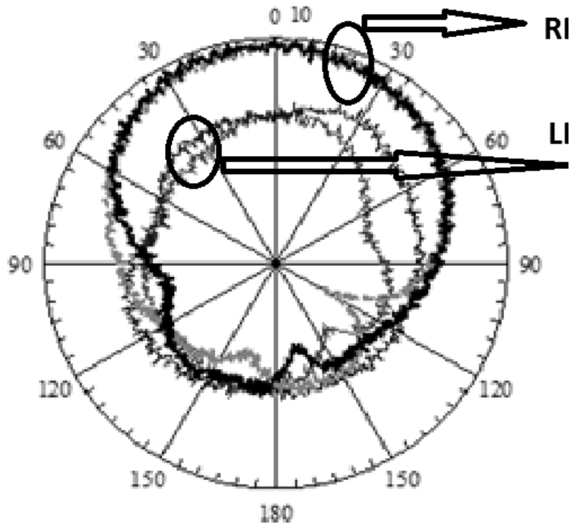


Fig. 5. RHCP- and LHCP radiated patterns at 12 GHz

3- Conclusion

A novel two-layered SIW-fed slot antenna embedded in a cavity-backed resonator, is proposed that has a unified impedance matching network inside the SIW feeding structure. Additionally, the RHCP characteristic has been easily accomplished by employing a cover layer on cavity back resonator. It is expected that the proposed structure can be applied to the phased array antenna for high-speed data communication in satellite systems.

References

[1] H. Uchimura, T. Takenoshita, and M. Fujii (1998). Development of a ‘laminated waveguide. IEEE Trans.Microw. Theory Tech., vol. 46, no. 12, pp. 2438–2443.

[2] J. Hirokawa and M. Ando (2000). Efficiency of 76-GHz post-wall waveguide- fed parallel-plate slot arrays. IEEE Trans. Antennas Propag., vol. 48, no. 11, pp. 1742–1745.

[3] D. Deslandes and K. Wu (2006). Accurate modeling, wave mechanisms, and design considerations of a substrate integrated waveguide. IEEE Trans. Microw. Theory Tech., vol. 54, no. 6, pp. 2516–2526.

[4] G. Q. Luo, Z. F. Hu, L. X. Dong, and L. L. Sun (2008). Planar slot antenna backed by substrate integrated waveguide cavity. IEEE Antennas Wireless Propag. Lett.IEEE, Vol. 7, pp. 236–239.

[5] J. Liu, D. R. Jackson, and Y. Long (2012). Substrate integrated waveguide (SIW) leaky-wave antenna with transverse slots. IEEE Trans. Antennas Propag., vol. 60, no. 1, pp. 20–29.

[6] O. Kramer, T. Djerafi, and K. Wu (2011). Very small footprint 60 GHz stacked Yagi antenna array. IEEE Trans. Antennas Propag., vol. 59, no. 9, pp. 3204–3210.

[7] G.Q. Luo, Z. F.Hu, Y. Liang, L. Y.Yu, and L. L. Sun (2009). Development of low profile cavity backed crossed slot antennas for planar integration. IEEE Trans. Antennas Propag., vol. 57, no. 10, pp. 2972–2979.

[8] S. Razavi and M. Neshati (2013). Development of a low profile circularly polarized cavity backed antenna using HMSIW technique.

[9] C. Jin, R. Li, A. Alphones, and X. Bao (2013). Quarter-mode substrate integrated waveguide and its application to antennas design. IEEE Trans. Antennas Propag., vol. 61, no. 6, pp. 2921–2928.

[10] S. Sam and S. Lim (2013). Electrically small eighth-mode substrate-integrated waveguide antenna with different resonant frequencies depending on rotation of complementary split ring resonator. IEEE Trans. Antennas Propag., vol. 61, no. 10, pp. 4933–4939.

[11] J. Xu, W. Hong, H. Tang, Z. Kuai, and K. Wu (2008). Half-mode substrate integrated waveguide (HMSIW) leaky-wave antenna for millimeter wave applications. IEEE Antennas Wireless Propag. Lett., vol. 7, pp. 85–88.

[12] B. Liu, W. Hong, Y.-Q.Wang, Q.-H. Lai, and K.Wu (2005). Half mode substrate integrated waveguide (HMSIW) 3-dB coupler. IEEE Microw. Wireless Compon. Lett., vol. 17, no. 1, pp. 22–24.

[13] N. Grigoropoulos, B. Sanz-Izquierdo, and P. R. Young (2005). Substrate integratedfolded

waveguides (SIFW) and filters. IEEE Microw. Wireless Compon. Lett., vol. 15, no. 12, pp. 829–831.

[14] S. Zhang, T.-J. Bian, Y. Zhai,W. Liu, G. Yang, and F.-L. Liu (2012). Quarter substrate integrated waveguide resonator applied to fractal-shaped BPFs," Microw. J., vol. 55, pp. 200–208.

[15] Q. Lai, C. Fumeaux, W. Hong, and R. Vahldieck (2009). Characterization of the propagation properties of the half-mode substrate integrated waveguide. IEEE Trans. Microw. Theory Tech., vol. 57, no. 8, pp. 1996–2004.