Dual Band Half-Mode Substrate Integrated Waveguide Leaky Wave Antenna with Wide Backward Scanning

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***Abstract*— A novel half-mode substrate integrated waveguide (HMSIW) leaky wave antenna is presented. The HMSIW loaded with periodic horizontal T shaped slots produces dual-band characteristics with backward scanning capability in each band. The obtained return loss bandwidths are 1.65 GHz in the upper band (10.95 GHz to 12.6 GHz) and 0.9 GHz in the lower band (9 GHz to 9.9 GHz). The achieved scanning ranges are 27° in the upper band (from -8° to -35°) and 30° in the lower band (from -38° to -68°). The simulated gain is 13.2 dBi and 16.5 dBi in the lower and upper band respectively. The proposed structure has inherent band rejection filtering capability from frequency 10 GHz to 10.9 GHz.**

Keywords- Periodic leaky wave antenna(PLWA); Half-mode substrate integrated waveguide(HMSIW);

I. INTRODUCTION

The increasing demand for beam steering antennas in modern communication applications brings leaky wave antenna (LWA) as a prominent candidate with respect to the cost and complexity. LWA was first proposed by A. A. Oliner [1]. Based on the structure, they are classified into two categories i.e. uniform and periodic leaky wave antenna. The advantage of periodic leaky wave antenna (PLWA) is no need of impedance matching element in the structure because of each unit cell can be properly matched individually. The periodic repetitions of unit cell generate multiple pass band-stop band characteristics. Therefore, multi-band characteristics can be easily obtained in PLWA than of the uniform leaky wave structure. The leaky wave antenna using substrate integrated waveguide (SIW) has attracted much attention as low cost and ease of integration. A SIW loaded with periodic H shaped transverse slots achieved 16 dBi gain with 30 unit cells [2]. A half-mode SIW (HMSIW) was used as leaky wave antenna in [3]. The magnetic wall in HMSIW works as a line source for radiation and enhance radiation efficiency than of SIW LWA. A similar dual-band half width microstrip antenna with periodic U-shaped slots has been reported with a maximum gain of 15 dBi using 15 unit cells [4].

In this paper, a HMSIW leaky wave antenna with periodically loaded horizontal T shaped slots is proposed for dual-band operation. The gain and directivity are improved as compared to the proposed structure in [4]. The continuous scanning is achieved by the lower band to upper band as frequency increases. The proposed antenna has inherent band rejection filtering capability out of operating bands. Thus the proposed antenna can be applied where the suppression of particular frequency band is needed in desired angular scanning range.

II. ANTENNA STRUCTURE

Fig. 1 depicts a top view of antenna configuration consists T shaped slots periodically loaded on the HMSIW structure with 15 unit cells. The Perfect Electric Conductor (PEC) wall of the HMSIW is designed by using septum of 0.8 mm width in place of via array for ease of simulation. The 50Ω transition from the microstrip line to HMSIW is done at both ports by using half tapered line as shown in Fig. 2. The prototype is designed on Rogers RT/duriod 5880 substrate (dielectric constant = 2.2, loss tangent = 0.0009) with thickness of 1.575 mm.

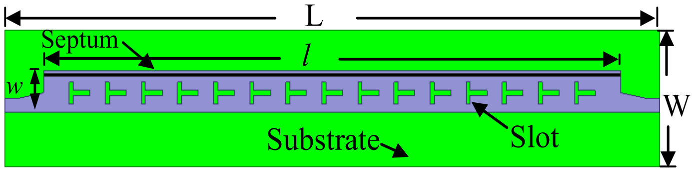


Fig. 1. Configuration of T shaped loaded HM-SIW with parameters: L = 254 mm, W = 50 mm, l = 224 mm, w = 15 mm.

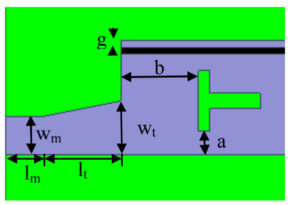
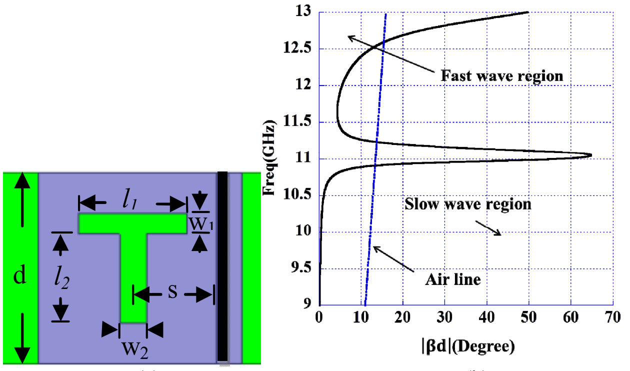


Fig. 2. Transition from microstrip line to HMSIW with parameters: w_m = 5 mm, l_m = 5 mm, w_t = 7 mm, l_t = 10 mm, b = 10 mm, g = 1 mm, a = 3 mm.

The proposed prototype is designed and simulated using EM solver HFSS v17. A unit cell structure of proposed antenna and its dispersion diagram are shown in Fig. 3 (a) and (b) respectively. As we know that air-line ($\beta = k_o$) divides fast and slow wave region. It can be clearly seen that the two operating bands are present in the fast wave region. A sharp transition from fast wave region to slow wave region is observed near 11 GHz. It clearly shows that the energy remains bound to surface of the structure and does not radiates near 11 GHz. However, the band rejection bandwidth is improved in HMSIW loaded with 15 unit cells due to mutual coupling between the unit cells. Therefore, T Shaped slots loaded HMSIW structure can be used as a band reject filter in the frequency span of 10 GHz to 10.9 GHz. [5].

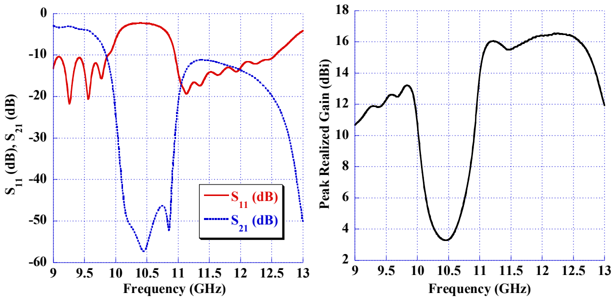


(a) (b)

Fig. 3. (a) A unit cell structure with parameters d =14 mm, l_1 = 8 mm, l_2 = 6.5mm, w_1 =1.5 mm, w_2= 2 mm, s = 6 mm.(b) The dispersion diagram of the single unit cell.

III. Result and Discussion

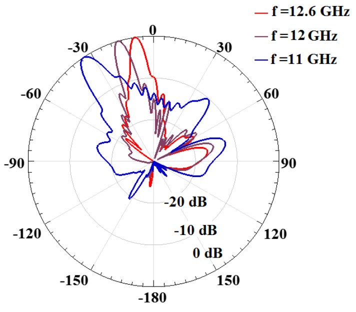
The simulated S-parameters and peak realized gain of proposed antenna are shown in Fig. 4 (a) and (b) respectively. The -10dB impedance bandwidth is 14 % in the upper band and 9.5 % in the lower band. The transmission coefficient is below -10 dB throughout upper band shows proposed antenna is an efficient radiator in the upper band. The gain at lower cutoff frequency (10.95 GHz) of the upper band is 12 dBi. In the lower band, the gain is 10.67 dBi and 13.2 dBi at 9 GHz and upper cutoff frequency (9.9 GHz) respectively. It can be observed that the realized gain increases from 9 GHz to 9.9 GHz in the lower band as transmission coefficient decreases from -3 dB (at 9 GHz) to -10 dB (at 9.9 GHz) with increase in frequency.



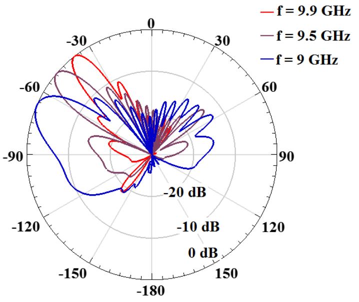
(a) (b)

Fig. 4. (a) The simulated S-parameters (b) The Peak realized gain of proposed LWA

The return loss is 2 dB at center frequency of the stopband shows that some radiation through surface due to present discontinuities at the transition from the microstrip line to HMSIW. It can also be noticed that the gain is about 3 dBi at the center frequency of the stop band in Fig. 4 (b) probably due to radiation by feed. The simulated normalized radiation patterns of both bands are shown in Fig. 5. The minimum half power beamwidth is 6.5° in the upper band. The sidelobe level(SLL) in both bands is below -10 dB. It can be noticed that radiation patterns are affected at lower cutoff frequencies due to transition between the leaky mode region to bound mode region.



(a)



(b)

Fig. 5. Simulated normalized radiated patterns of the proposed LWA in H-plane (a) in upper and (b) in lower band

IV. Conclusion

A periodic LWA has been designed to achieve dual-band operation with beam scanning capability. Total 57° scanning range is achieved with -10 dB return loss bandwidth. The horizontal T shaped slot is effective to excite the leaky mode as well as the bound mode in HMSIW for antenna and filter applications.

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