# $TE_{20}$ Mode SIW based Bi-directional Leaky-wave Antenna


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*Abstract*—**In this paper, a bi-directional frequency beam-scanning leaky-wave antenna (LWA) using $TE_{20}$ mode substrate integrated waveguide (SIW) is proposed. 45° tilted radiating slots are etched (based on E-field maxima) on the top wall of $TE_{20}$ mode SIW power divider. Using a novel microstrip to SIW transition is used to feed the proposed design. The proposed antenna shows a frequency beam scanning range of 54° in each quadrant having the maximum gain of 10.8 dBi within the operating range of 10-11.5 GHz. Full-wave simulations are performed in HFSS.**



***Keywords-$TE_{20}$ mode SIW, leaky-wave antenna; frequency beam-scanning***


## I. INTRODUCTION

The significant benefits of substrate integrated waveguide (SIW) open a new avenue in the design of various microwave and millimeter wave circuits. Moreover, its use in designing various leaky-wave antennas for frequency beam-scanning applications is explored by extensive research [1]-[4]. In recent years, various leaky wave antennas have already been proposed. For the purpose of enhancement of gain and miniaturization, the use of $TE_{20}$ mode SIW in designing LWA is also proposed in [5].

In this paper, a compact $TE_{20}$ mode SIW based LWA is proposed which is capable to scan in two quadrants simultaneously. A SIW based power divider with novel feeding mechanism is designed and later is incorporated in designing LWA. The proposed antenna eliminates the parallel array concept for gain. The proposed geometry shows a maximum radiated peak gain of 10.8 dBi within the operating bandwidth of 13.95% having the beam scanning range of 54° in each of the two quadrants.

## II. DESIGN OF $TE_{20}$ MODE POWER DIVIDER

A novel $TE_{20}$ mode SIW power divider is designed. The power divider consists of a microstrip line to slotline (etched

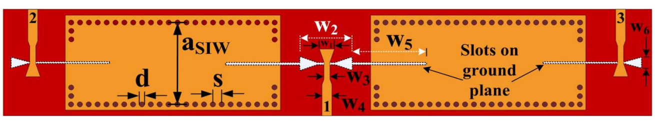
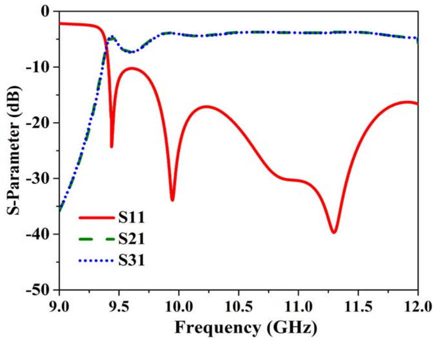
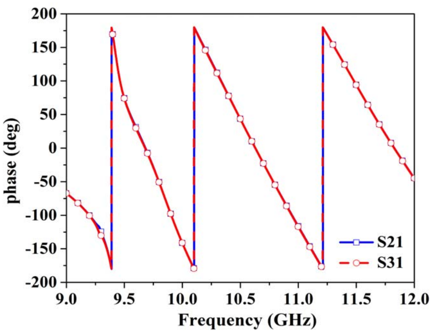



Fig. 1. $TE_{20}$ mode SIW power divider (not to scale).




(a)




(b)

Fig. 2. (a) Magnitude of S-parameter response of the power divider. (b) phase of S-parameter responses.

on ground plane) transition and slotline to SIW transition. By using slotlines, 180° out of phase but equal in magnitude electric fields are formed automatically on both sides of the symmetric plane of slot line (electric wall). The magnitude of electric field distribution and electric field vector distribution are shown in [5].The width of the $TE_{20}$ SIW can be determined from [6]. The layout of the power divider is shown in Fig. 1. The magnitude and phase responses of the power divider are shown in Fig. 2(a) and (b) where it is working from 10-11.5 GHz (<-20 dB). At a fixed spatial position of $TE_{20}$ mode of SIW, two E-field maxima exists simultaneously (one in top plane and one in ground). Thus the array dimensions get reduced. The dimensions of the Fig. 1 are $a_{SIW}$ =22, $w_1$=3.5, $w_2$=7.6, $w_3$=1.6, $w_4$=2.32, $w_5$=19.84, $w_6$=1, d=0.8, s=1.6 (all dimensions are in mm.).

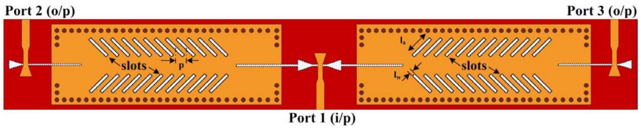



Fig. 3. Layout of the proposed leaky-wave antenna (not to scale).

## III. Leaky-wave Antenna Design and Analysis

To design the LWA, rectangular radiating slots are etched periodically with periodicity p= 3mm. on the top plane of the SIW depending on the E-field distribution where on either side of the symmetric plane of slot line (electric wall), slots are orthogonally oriented (+45° and -45°). The working range of the antenna is from 10-11.5 GHz where $n$=-1 spatial harmonic is fast wave in nature and responsible for radiation. The layout of the proposed antenna is shown in Fig. 3. The antenna is designed on Rogers RT/duroid 5880 substrate with $\mathcal{E}_r$= 2.2, tan$\delta$= 0.0009 and height of 0.787mm. To make the slots non-resonant, dimensions of the slots are chosen as 1/4$^{th}$ of the guided wavelength $\lambda_g$ and to maintain the homogeneity condition, the periodicity of the slots are kept p<<$\lambda_0$/4. The scanning angle of the proposed antenna depends upon $n^{th}$ spatial harmonic $\beta_n$ and free space wave number $k_0$. The antenna is working in fast wave region where $\beta_n$<$k_0$. The direction of maximum radiation from z-axis can be determined from [7]. The dimensions mentioned in Fig. 3 are $l_a$= 4.44mm, $l_w$= 0.5mm. The overall dimension of the antenna is 260 x 28.7 x 0.787 mm$^3$.

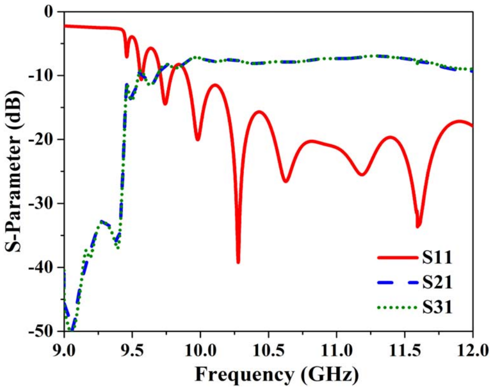



Fig. 4. The variation of reflection co-efficient with frequency.

Magnitude of S-parameter responses is shown in Fig. 4 where the antenna is working within the frequency range of 10-11.5 GHz. The normalized radiation patterns with variation of frequency are shown in Fig 5 where bi-directional beam-scanning is observed in visible space by radiated fan-beam. The maximum peak gain is achieved is 10.8 dBi. The scanning range of the antenna is 54° in each of the two quadrants.

## IV. Conclusion

In this paper, a bi-directional beam scanning LWA is designed at X-band by using a $TE_{20}$ mode T-shape SIW power divider. The use of higher order mode of SIW miniaturizes the whole antenna array geometry. The radiated main beam is simultaneously scanning in two quadrants with a scanning range of 54° in each within the frequency range of 10-11.5 GHz. The maximum peak-gain is achieved is 10.8 dBi. The proposed antenna can be a potential candidate for several wireless applications such as X-band applications, radar and navigational purpose etc.

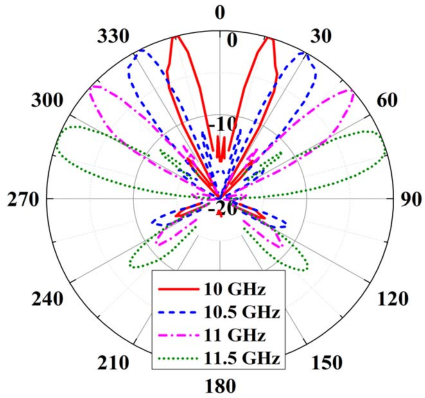



Fig. 5. Normalized radiation patten of the proposed antenna at different frequencies.

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