A SIW based Leaky-Wave Antenna for 5 GHz Narrowbeam Applications

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***Abstract*—A substrate integrated waveguide (SIW) based leaky wave antenna (LWA) with narrow beamwidth, low side lobe levels and high directivity is proposed. The desired radiation characteristics are attained by periodic arrangement of a group of slots whose lengths follow the binomial distribution. Without the need for any complex feeding structure, the antenna exhibits a beamwidth of 11.3° and sidelobe level (SLL) < -10 dB at 5.6 GHz. Designed on an Rogers Duroid 5880 substrate, the antenna's size is 250×45 mm^2. Achieving a good match between simulated and measured results, the proposed antenna can be used in applications requiring narrowbeam patterns in the 5 GHz band.**

I. Introduction

Narrow beam antennas, also known as directive antennas, are popular because of their use in long range communication, jamming, precise targeting of the object, interference cancellation, estimation of angle of arrival, and their ability of multipath fading mitigation. Narrowbeam is mostly achieved using antenna arrays. Many array designs exist in literature with narrowbeam. In [1], an antenna array based on the Long Slot Antenna (LSA) array technology consisting of 4×15 slot array is proposed. Operating from 4 GHz to 6 GHz, the antenna has a beamwidth of less than 12°. The antenna has a size of 396×121 mm^2 and required complex excitation mechanism with 139 feeding ports. In [2], a four element antenna array is proposed in which each element is composed of two pairs of stepped-impedance slots. The feeding circuit consists of cascaded microstrip T-junctions.

In general, antenna arrays require complex feeding structure to excite each element. Nevertheless, this type of antennas has remain a foremost choice to obtain narrowbeam.

Leaky wave antennas (LWA) are a class of traveling wave antenna. They are like a transmission-line from which energy leaks into the free space as the wave propagates through it. A narrowbeam can be achieved in LWA without the need of any complex feeding network. The direction of the beam of LWA is function of the propagation constant of the transmission-line. In recent years, Substrate integrated waveguide (SIW) based LWA have become popular because of its low-profile, characteristics being similar to that of a rectangular waveguide and compatibility with printed circuit technology. Several designs can be found in literature on SIW based LWA. In [3], SIW based LWA antenna is proposed with low side lobe levels and good port matching. The features are achieved through changes in the length of slots etched periodically on the SIW. The antenna operates from 10-12 GHz. This paper presents the design of a simple SIW based LWA operating in the 5 GHz band. The antenna has a narrowbeam with low sidelobe levels (SLL). With comparable size to an array and extremely simple feeding mechanism, the proposed antenna can be used in applications requiring narrow beam in the 5 GHz band.

II. Antenna Design

A simple SIW operating at the dominant TE$_{10}$ mode is designed. The dimensions of the SIW are computed using [4] such that its cutoff frequency is 5 GHz. Designed on a Rogers Duroid 5880 substrate, the width of the waveguide W_1 for the given conditions are calculated as;

$$w_1 = a/\sqrt{\epsilon_\mathrm{r}} + d^2/0.95p \tag{1}$$

where a is the longer dimension of the equivalent rectangular waveguide.

To minimize the leakage losses, the distance *'p'* between adjacent vias of the waveguide is kept at minimum. Using condition given in [4], it is selected to be $p = 2d$, where *'d'* is the diameter of the via. A microstrip-to-SIW transition based on taper is chosen due to its simplicity and ease of fabrication. The ports are designed at both ends of the waveguide. The tapering improves the impedance matching and results in enhanced bandwidth of antenna. Its width is selected to get a 50Ω characteristic impedance and the tapered parameters are optimized to improve the return loss.

Finally, the slots are etched periodically in the top wall of the SIW for radiation. To get the desired narrowbeam radiation patterns with low SLL, a new pattern of the slots is proposed. Assuming a maximum length of slot to beλ_g*/4* at the center, the length of adjacent slots are binomially distributed symmetrically. A group of 8 slots is chosen so that the smallest length of slot is easy to fabricate. The binomially distributed slot group is periodically repeated 5 times to cover the entire length of the waveguide. The width of the slot is selected so that w_s/l_s is small and distance between the adjacent slots p_s is chosen to be λ_g*/10* to avoid multibeam operation [3]. The total size of the antenna is 250×45 mm^2. The proposed antenna with all the dimensions is shown in Fig. 1.

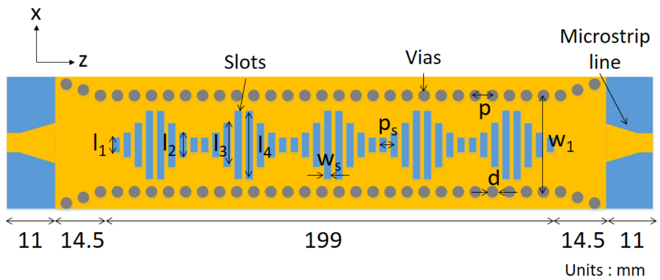

Fig. 1: Geometry of the proposed SIW based LWA. l_1 = *0.51 mm*, l_2 = *3.39 mm*, l_3 = *11.65 mm*, l_4 = *16.12 mm*, w_s = *0.88 mm*, p_s = *4.97 mm*, *d = 2 mm*, *p = 4 mm*, w_1 = *24.39 mm*. Length of the SIW taper is 14.5 mm and width is varying from 24.39 mm to 26.39 mm. Length of microstrip feed is 6 mm and width varies from 4.85 mm to 5.29 mm.

III. Results & Discussions

The proposed design is fabricated as shown in Fig. 2. S-parameters of the antenna are measured using VNA. Fig. 3 shows the S-parameters of the antenna obtained from measurement and from simulation. A close agreement is found between the two results. The antenna operates from 5.15 GHz to 6.19 GHz which shows that microstrip feed is well designed.

The radiation gain patterns of the antenna are measured in far-field anechoic chamber. One port of the antenna is excited while the other is terminated with a 50Ω load. Simulation result and measured far-field radiation patterns of the antenna in yz-plane at 5.6 GHz when port 1 is excited are shown in Fig. 4. The antenna radiates towards the broadside. When the antenna is excited from one port, the main lobe occurs at 95° while for the other port, the main lobe is oriented at 85°. The half power beam-width (HPBW) of the antenna is 11.3° and SLL is -11 dB. The antenna has a measured peak gain of 2.5 dBi. As the operating frequency of the antenna increases, its main lobe tilts towards end-fire. However, for a wide operating band, the antenna maintains its beam-width. At 6 GHz, the antenna's main lobe occurs at 79° with a HPBW of 11.4° and a peak gain of 3 dBi.

IV. Conclusion

A SIW based LWA with novel distribution of slot length on the waveguide is proposed which results in narrow beam-width and low SLL. The length of slots follow binomial distribution. Design for 5 GHz band, the proposed LWA has a narrow beam-width of 11.3° and SLL is -11 dB. With simple design, comparable size with array and no complex feed, the proposed design is useful in applications requiring narrowbeam antennas. The same design procedure can be followed to model a similar antenna at higher frequencies.

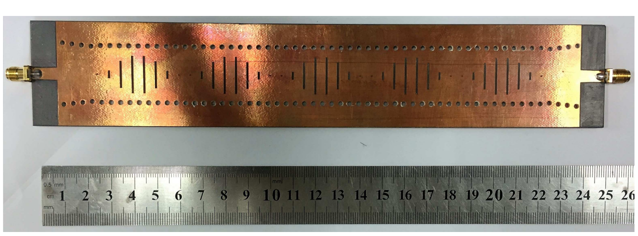

Fig. 2: Fabricated SIW based LWA

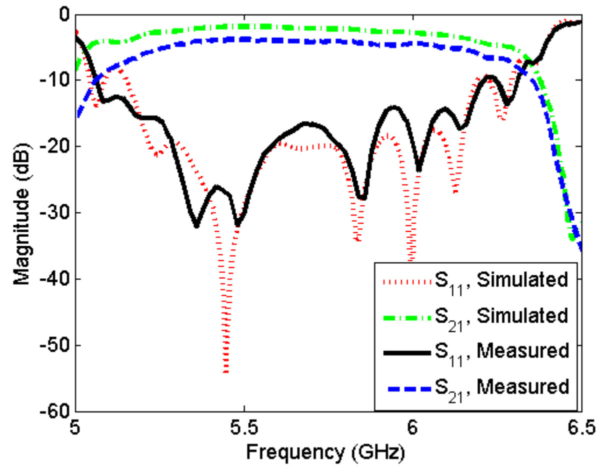

Fig. 3: Simulated and measured S-parameters of the proposed SIW based LWA

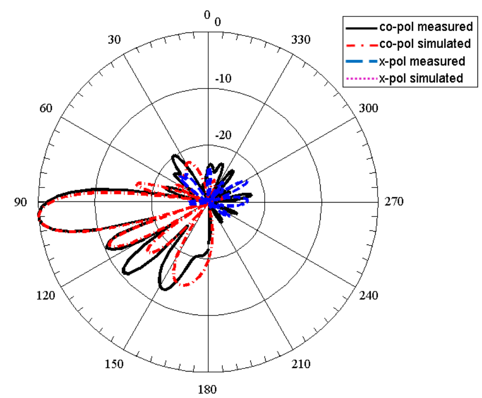

Fig. 4: Far-field radiation pattern of the SIW based LWA at 5.6 GHz

References

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