Design of a Periodic Substrate-Integrated-Waveguide Leaky-Wave Antenna

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Abstract— **This paper presents the design and implementation of a periodic SIW leaky wave antenna. The design employs transverse slots along the length of the structure. The resulting SIW leaky wave antenna has a 8.9º narrow beam with side lobe level of -11.9dB down. The antenna is fabricated on Roger 5880, measured using the network analyzer, and simulated using CST microwave studio. Experimental measurements are in good agreements with simulation results.**

I. INTRODUCTION

The development of modern microwave and millimeter wave communication systems requires high quality and high density circuit integration and packaging. Size and cost are two of the most critical requirements of these systems. Recently, Substrate- Integrated-Waveguide (SIW) design has been proposed for high-density integration of microwave and millimeter-wave systems [1]. In this technique, wither image guides, non-radiated dielectric waveguides, slab waveguides, or rectangular waveguides are synthesized inside a dielectric substrate using rows of dielectric or metal holes. This approach is cost effective given the fact that waveguides and planar circuits are manufactured on the same substrate at the same time [2, 3]. Hence, a SIW design consists of a top and bottom of conducting material and a dielectric substrate layer between them. The top and bottom layers are connected to each other by columns of via holes in both sides as described in [4].

II. SURFACE-INTEGRATED-WAVEGUIDE

The cutoff frequency of the regular rectangular wave guide is defined as [5, 6]:

$$f_c = \frac{c}{2\pi}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2} \tag{1}$$

where c is the speed of light in free space (3×10^8m/sec), m and n are mode indices, a and b are dimensions of the wave guide. For TE_{10} the cutoff frequency will be,

$$f_c = \frac{c}{\lambda c} = \frac{c}{2a\sqrt{\varepsilon r}} \tag{2}$$

For dielectric filled wave guide, the relation between the waveguide as SIW and the rectangular waveguide (figure 1) can be written as [21]-[22].

$$\lambda_c = 2*a_{RWG}\sqrt{\varepsilon r} \tag{3}$$

$$\lambda_g = \frac{\lambda 0}{\sqrt{\varepsilon r - \left(\frac{\lambda o}{\lambda c}\right)^2}} \tag{4}$$

$$a_{RWG} = a_{SIW} - d^2/0.95P \tag{5}$$

to prevent the leakage between vias, the relation between the diameter of the vias and the separation between vias should satisfay the following condition,

$$\frac{p}{d} < 2.5 \tag{6}$$

On the other hand to prevent the band gap, the following equation should hold,

$$0.05 < \frac{p}{\lambda c} < 0.25 \tag{7}$$

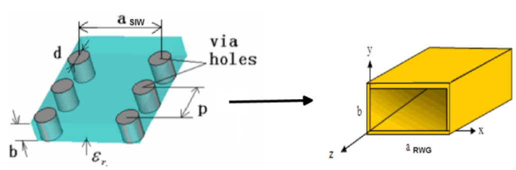

Figure 1:SIW and the equivilant waveguide

III. TRANSVERSE SLOTTED SIW LEAKY-WAVE ANTENNA

The leaky-wave antenna has been widely used in areospace applications for many years. This type of antenna radiates continuously along its length. It has a low profile and is easy to fabricate. Moroever, its output beam can be usually frequency scanned, with little beam shape deterioration, over relatively large sweep angles. Additionally, the possibility to control the phase and the amplitude of the field on the aperture on the leaky-wave antenna gives the possibility to shape the pattern within a certain degree of freedom [7]-[10].

In this paper, we adopt the design, analysis and fabrication of a transverse slotted periodic SIW leaky-wave antenna (TSIWLWA). The antenna is printed on roger RT5880 of relative permittivity 2.2, thickness 1.57mm, loss tangent of 0.0009 and overall dimensions of 2cm×15.4cm as shown in Figs. 2 and 3. The design is based on specifying the required frequency band for operation based on eqs. (1), (3), and (4). where the cut off frequency and the guided wavelength are calculated. Using eq. (5), the width of the SIW waveguide is calculated. The periodicity and the diameter of the vias are then determining using equations eqs. (6)and (7), to prevent the leakage and band gap. Table I depicted all the dimensions of the structure. The resulting TSIWLWA conducts a band from 11.9GHz to 14.5GHz as shown in Fig. 4. It has beam steering with frequency from 120º to 102º, also the antenna conducts a narrow beam of 8.7^0 and gain of average 11.2dB as shown in Figs. 5 and 6. It is also found that the proposed antenna conducts a SLL of -11.7dB at s_w= 8mm.

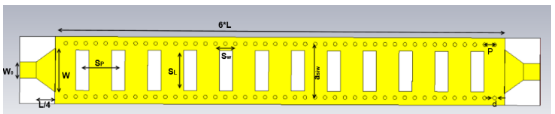

Figure 2. TSIWLWA structure.


(a)


(b)

Figure 3 : Fabricated TSIWLWA (a) top view (b) bottom view

Table I : Dimensions of TSIWLWA

Dimensions	Length in mm
a_{SIW}	158.4
d	1.1
L	22.54
p	3
S_W	2
S_L	7
S_P	8
W	13
W_0	4.88

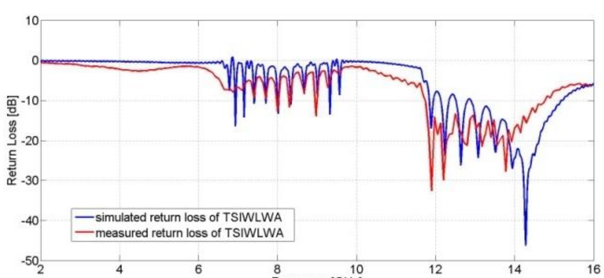

Figure 4: Measured and simulated return loss of TSIWLWA

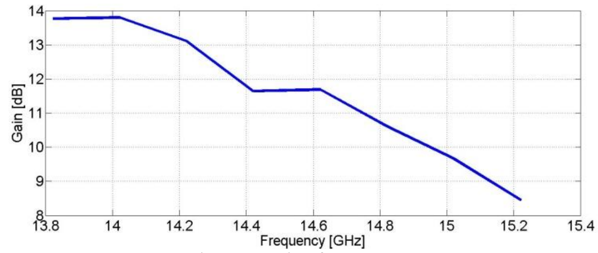

Figure 6: Gain of TSIWLWA

CONCLUSION

This paper presented the design and implementation of a periodic transverse-slotted SIW leaky wave antenna. The designed antenna has a 8.9º narrow beam with a side lobe level of -11.9dB down. The antenna is fabricated on Roger 5880, measured using the network analyzer, and simulated using CST microwave studio. Experimental measurements and simulation results are in good agreement.

REFRENCES

[1] K.sond,Y.Fan and X.Zhou, " X-band broadband substrate integrated rectangular waveguide power divider", Electronic letters, Vol 44, no. 3, January 2008.

[2] D. Deslandes, Ke.Wu, "Analysis and design of curent of probe transition from groundde coplanar to substrate integrated rectangular waveguide", IEEE Trans. Tech., vol.53, (8), Aug. 2005.

[3] K. Wu, “Integration and interconnect techniques of planar and non planar structures for microwave and millimeter-wave circuits—Current status and future trend,” in *Asia–Pacific Microwave Conf.*, Taipei, Taiwan, R.O.C., Dec. 2001, pp. 411–415.

[4] D. Deslandes and K. Wu, “Design consideration and performance analysis of saubstrate Integrated Waveguide Components,” European Microwave Conference, Oct. 2002, pp.1-4.

[5] Carr, J., "Practical Antenna Handbook", Tab Books, Blue Ridge Summit, PA, 1989, ISBN: 0-8306-9270-3.

[6] Edminister,"Electromagnetics (Schaum’s Outline)", McGraw-Hill, New York, NY,1993, ISBN: 0-07-018993-5.

[7] K. Wu, D. Deslandes and Y. Cassivi, "The Substrate integrated circuits a new concept for high-frequency electronics and optoelectronics," TELSKIS 2003, Nis, Serbia and Montenegro, Oct. 2003.

[8] J. E. Rayas-Sanchez and V. Gutierrez-Ayala, "A General EM-based design procedure for single-layer substrate integrated waveguide interconnects with microstrip transitions", IEEE MTT-S Int. Microwave Symp. Dig., Atlanta, GA, Jun. 2008, pp. 983-986.

[9] A.A.Oliner and D.R.Jackson, "Leaky wave antennas", chapter 11, "Antenna Engineering Handbook", J.L.Volakis, editor McGrawhall, 2007.

[10] J.liu, D.R.Jackson and y. Long," Model analysis of dieclectric-filled rectangular waveguide with transverse slots", IEEE transactions on antennas and propagation ,vol.59, (9),2011.

[11] S. Doucha and M.abri," New design of leaky wave antenna based on SIW technology for beam steering", IJCNC ,vol.5, September 2013.