SLOT ARRAY ANTENNA USING FOLDED WAVEGUIDES

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Abstract:

A highly compact slot array antenna using substrate integrated folded waveguides (SIFW) is proposed in this paper. The device has three key components: a non radiating SMA to standard waveguide transition, a power divider from standard waveguide to folded waveguides, and slot arrays on the folded waveguide. The antenna is built using two substrates aligned with conducting vias which makes the device, low profile, small size, low cost and easy to manufacture.

1. Introduction

In recent years, there has been a growing research interest in the development of rectangular waveguides filled with dielectric materials. As a result, novel techniques have shrunk the size of devices using dielectric filled rectangular waveguides, which are called substrate integrated guides. Multilayer low temperature co-fired ceramic (LTCC) [1], single [2] and multi- [3] layer microwave laminate and photoimageable thick film [4] are good candidates to integrate such devices. Plated holes and metallic vias have been successfully employed to create the side walls in RWGs [1],[5] and the integration with planar circuitry has also been reported. In [6], the so-called SIW have been further compressed by folding the bottom metal layer of a dielectric filled waveguide.

Waveguide longitudinal slot array antennas are widely used for microwave engineering in applications where narrow band, high gain, low cross-polarization and narrow radiation beams are desirable. Waveguide slot antennas have been produced for many years on conventional air filled waveguides and, more recently, on substrate integrated guides [7]. The feasibility of producing more advanced slot waveguide arrays integrated with standard MMIC passive transitions and power dividers have been shown in [8].

In this letter, a SIFW slot array antenna and transition to standard SIW is presented. The device produced is made up of two dielectric layers and consists of a non radiating SMA to SIW transition, a power divider-transition SIW-SIFW and the slot array antenna. The result is a slot array antenna where slots placed on the adjacent waveguides are closer, making a more compact antenna than the one on a SIW.

2.1 Design procedure

A cross-sectional view of a folded waveguide and a conventional waveguide is shown in Fig.1. Looking at the TE10 mode, the SIFW in (b) resembles that on a conventional SIW in (a) with the advantage of having half of the width of the conventional SIW. The height doubles, but as with conventional RWG the height has little effect on the propagation characteristics, and can be set as small as required [9].

(a) (b)

Fig. 1. Cross-sectional view of a standard waveguide (a) and folded waveguide (b)

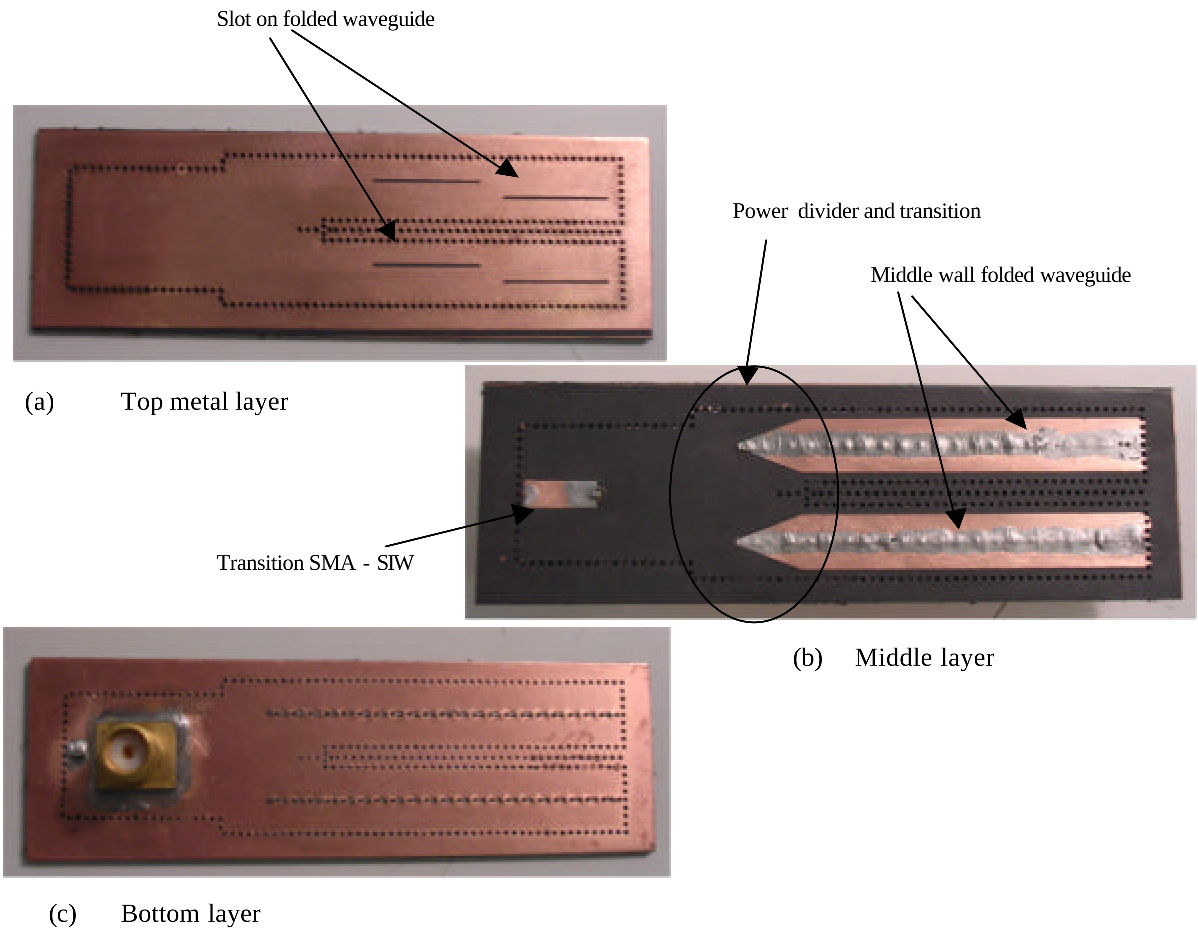
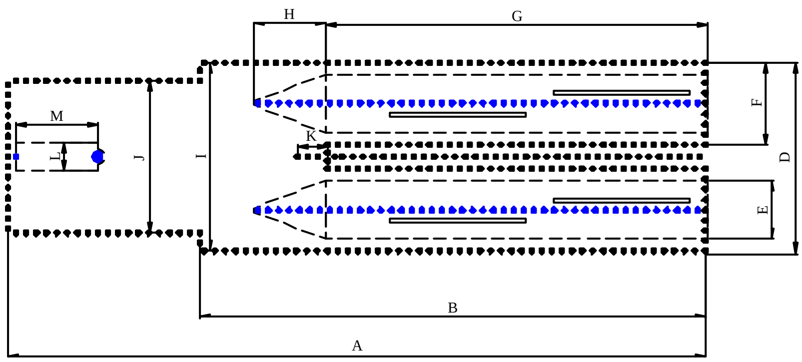


Figure 2. Photograph of the substrate integrated waveguide array antenna

Figure 2 shows a photograph of the slot waveguide array antenna showing the top metal layer on the top substrate and the middle conducting layer and the bottom layer on the two sides of the bottom substrate. As can be seen in (a) the slot array is printed in the two parallel folded waveguides (right hand side of the picture) and on the top metal layer. The metal clad on other side of this dielectric layer is removed, leaving the raw dielectric material with the holes. Conducting metal vias have been used to fill these holes and create the side walls of the device. In (b) the middle plates of the SIFWs and transitions to a SIW, and the transition from SMA connector to SIW are etched on the side of the bottom waveguide that joins the top dielectric material.

Figure 3 shows the dimensions of the device which have a total size of 75mm x 25mm including the extra substrate around the vias. The antenna was fabricated using a dielectric constant of er = 2.33 and the structure consists of two dielectric layers of 1.575mm thickness making a total thickness of 3.15mm. The metal conducting vias have a diameter of 0.35mm and pitch of 0.5mm. The slots were optimized for a resonant frequency of 9.5GHz using the finite element method. The resulted slot length and width were 13.2mm × 0.5 mm for an offset of 1.2mm. As for conventional waveguide the outer slots were placed ?g/4 from the ends of the waveguide with ?g/2 between the slot centres (?g=30mm). The antenna was fed by a SMA connector and a non-radiating transition to SIW consisted of a metal stripline of ?g/4 in the middle metal plate which connects on one side the inner part of the SMA connector and on the other side the bottom plate of the waveguide through a shorti[illegible]



A	B
68.2	49.5

L	M
2.8	8

Fig. 3. Dimensions of the folded waveguide array antenna

The device was fabricated manually, by passing the metal wire through the holes and soldering the formed vias.

2.2 Results

CST Microwave studio was used to simulate the antenna. The simulation of the non-radiating transition SMA – SIW gave an S11 of -40 dB and S12 of -0.0029 for the operating frequency and S11<-30dB and S12>-0.031 along the antenna frequency band.

The simulation and measured reflection coefficient of the complete antenna device is shown in figure 4. The measured reflection coefficient (S11) achieved its minimum at 9.53 GHz with S11= -24.4dB; the bandwidth was 255 MHz.

The simulated gain for the 2x2 array was 9.8dB, compared to 8dB for two slots and 6.5dB for one slot. A similar gain relationship between one, two and the 2x2 slot array was found in the measurements.

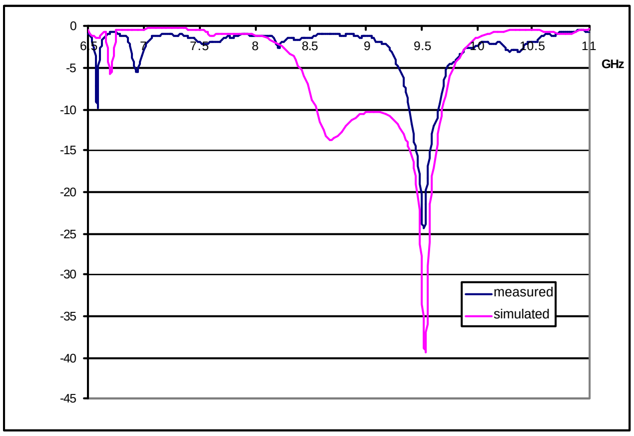


Fig.4 Simulated and Measured S11

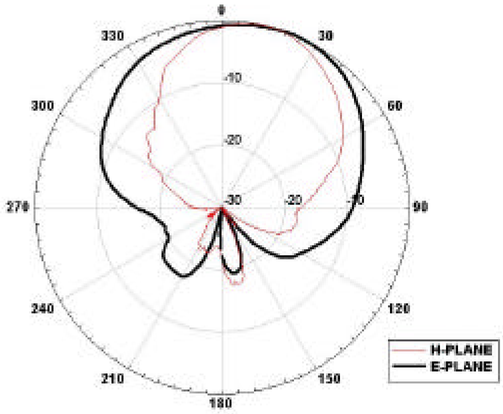


Fig.5. Radiation pattern

3. Conclusions

A novel slot array antenna on substrate integrated folded waveguide has been presented. The device uses the folded waveguide develop in [7] to produce a dense slot array antenna. The result is a more compact antenna implemented with the SIW technology, making it low cost and small size. The transitions between the SMA connector, the SIW and the power divider SIW-SIFW employed allow the device to be integrated with other low-cost integrated circuits.

References:

[1] W. Menzal and J. Kassner, .Millimeter-wave 3D integration techniques using LTCC and related multilayer circuits,. 30th European Microwave conference proceedings, pp. 33-53, Paris 2000.

[2] U. Hiroshi, T. Takeshi and M. Fujii, "Development of a 'laminated waveguide'," IEEE Trans. Microwave Theory Tech., vol. 46, no. 12, pp. 2438-2443, December 1998.

[3] D. Deslandes and K. Wu, "Integrated microstrip and rectangular waveguide in planar form," IEEE Microwave Wireless Compon. Lett., vol. 11, No. 2 February 2001.

[4] M. S. Aftanasar, P. R. Young, I. D. Robertson, J. Minalgiene and S. Lucyszyn, "Photoimageable thick-film millimetre-wave metal-pipe rectangular waveguides," Electron. Lett., vol. 37, No. 18, August 2001, pp. 1122-1123.

[5] C. Y. Chang and W. C. Hsu, .Photonic bandgap dielectric waveguide filter,. IEEE Microwave wireless Compon. Lett., Vol. 12, no. 4, pp. 137-139, April 2002.

[6] N. Grigoropoulos and P. R. Young, "Compact folded waveguides," 34th European Microwave conference, Amsterdam 2004.

[7] A. J. Farrall and P. R. Young, "Integrated waveguide slot antennas," Electron. Lett., vol. 40, No. 16, 5th August 2004, pp. 974-975.

[8] Li Yan, Wei Hong, Guan Hua, Jixin Chen, Ke Wu and Tie Jun Cui, "Simulation and experiment on SIW Slot Array Antennas" IEEE Microwave wireless Compon. Lett., Vol. 14, no. 9, pp. 137-139, September 2004.

[9] N. Grigoropoulos and P. R. Young, "Compact substrate integrated folded waveguides," unpublished.