Substrate Integrated Waveguide Cavity-Backed Ku-Band Slot Antennas With Shorting Vias

Dr. S. Anand[1], R.Palanichamy[2], Fx.Joshua Paul Ebenezer [3]
[1,2,3]Dept of Electronics & Communication Engineering
[1,2,3]Mepco Schlenk Engineering College, Sivakasi

Abstract- *A substrate integrated waveguide (SIW) cavity-backed slot Ku-band antennas using shorting vias is presented in this paper. The antenna has wide bandwidth and low profiles. By loading the SIW cavity with shorting vias and substrate value and material is changed. So as a result, a wide bandwidth with cavity-backed slot antenna is achieved. Based on the similar principle, a cavity-backed slot antenna having an even wider bandwidth is also developed. Prototypes of the antenna is measured. With a low profile of 0.03λ (wavelength in free space), the cavity-backed slot antenna design has a bandwidth efficiency of 21.04% and a peak gain of 6.884dBi.*

Keywords- Cavity-backed slot antenna, shorting vias, substrate integrated waveguide (SIW), wideband.

I. INTRODUCTION

SUBSTRATE integrated waveguide (SIW) cavity-backed slot antenna shows outstanding advantages (such as light weight, low profile, and easy integration with planar circuits) in microwave systems. However, due to the high-quality factor and quad-resonance response, conventional SIW cavity-backed slot antennas, limiting their applications in wideband communication systems.

Recently, works have been presented in the literature [1] for enhancing the bandwidths of SIW cavity backed slot antenna. In [2] the bandwidth was increased up to 2.18% by partial removal of the substrate. However, the bandwidth enhancement was limited because the design only utilized a single slot mode. Using additional resonant patch, some wideband multimode mode SIW cavity backed slot antenna were developed. In, a wideband SIW cavity-backed patch antenna was proposed, in which an additional patch mode was existed. In [3], a dual-resonance slot-patch structure composed of a half-wavelength slot and a parasitic patch was employed for bandwidth enhancement. In [4], a wideband dual mode design using triangular complimentary split ring slot (TCSRS)achieved bandwidth of 21.04%. Several dual-band SIW cavity backed slot antenna were also realized with specific slot shapes (e.g., dumbbell-shaped slot [5], dual rectangular slot [6]). In, by dividing an SIW cavity into two half parts with a non-resonant rectangular slot, two hybrid cavity modes were excited, and the fractional bandwidth could be improved up to6.3%. Based on the similar principle, the SIW cavity antenna in achieved a wider bandwidth of 9.4% using a bowtie shaped slot. In, a SIW cavity-backed 3 × 3 slot array antenna was studied. Three high-order cavity modes along with the slot mode were utilized in this design, leading to a bandwidth over 26%. Previously, shorting vias were introduced in SIW based feeding networks for improving the impedance matching of the cavity-backed slot antenna. In, a dual-resonance SIW cavity-backed slot antenna was realized using a via hole above the slot. Nevertheless, the bandwidth of the antenna in was comparatively narrow (3.3%). Shorting vias were also used in SIW filters, SIW frequency selective surface, and patch antenna for bandwidth enhancement.

In [5] this paper, we propose single wideband SIW cavity-backed slot antenna using shorting vias. The antenna has cavity backed slot in their operation bands, respectively. With the shorting vias loading, the lowest mode in the SIW cavity is shifted upward and coupled with two higher order modes. Therefore, a wide bandwidth with cavity backed slot is realized. The cavity backed slot antenna has a very low profile of 0.03λand a measured bandwidth of 21.04%. The antenna has stable radiation patterns and flat gains in their operation bands.

II. CAVITY-BACKED SLOTANTENNA

A. *Geometry*

Fig. 1 shows the geometry of the proposed cavity-backed Ku-band slot antenna. The antenna is constructed on a single-layer substrate with a thickness of *h* and a relative permittivity of εr. Arrays of grounded vias are uniformly distributed along the edges of the antenna to build an SIW cavity. In order to avoid the energy leakage from the via gaps, the diameter *d* and the spacing of the sidewall shorting vias are chosen to be d = 1mmand s = 1.5 mm, respectively, which satisfy the conditions of $s/\varepsilon d$= 2andd/λ= 0.1. Another two shorting vias with the same diameter *d* and a spacing $s0$are inserted near the center of the SIW cavity. A rectangular slot is etched on the ground plane for radiation. Here, the slot has a length of more than λ0/2, and therefore it is a non-resonant slot.A50Ω microstrip line is used to feed the antenna.

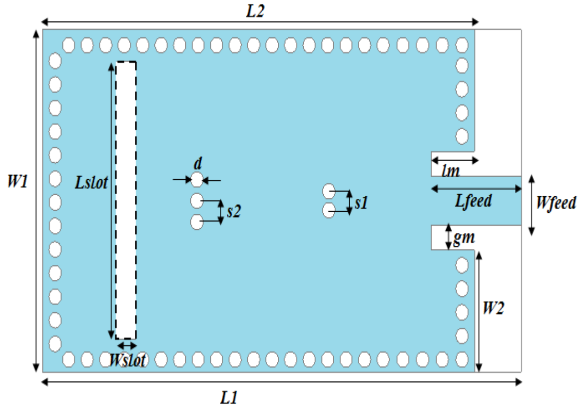

Fig. 1. Configuration of the proposed cavity-backed slot antenna.

Table I Dimensional Parameters For The Proposed Antennas

Size Parameter	Via-loaded quad-resonance antenna
W1	21.8mm
W2	7.75mm
Wslot	1.5mm
Lslot	17.7mm
L1	38.8mm
L2	35mm
Wfeed	3.1mm
Lfeed	7.3mm
S1	1.2mm
S2	1.35mm
d	1.0mm
gm	1.6mm
lm	3.5mm
h	2.4mm
εr	4.4

In addition, two rows of shorting vias are made. The numbers and via spacings of the two rows of shorting vias have been chosen properly for an optimal bandwidth.

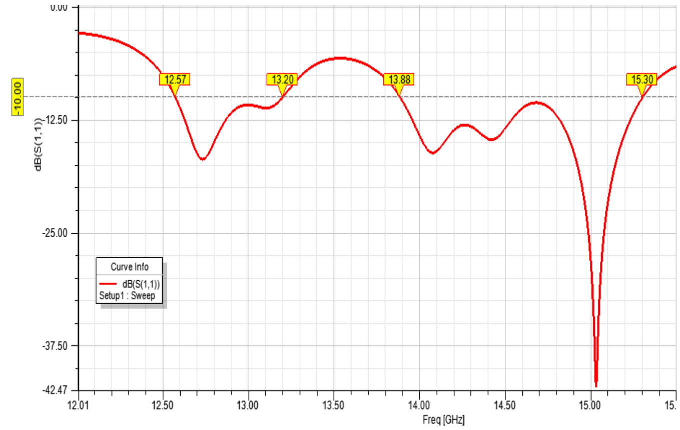

Fig. 2. Simulated and measured reflection coefficients of the proposed cavity backed slot antenna

III. EXPERIMENT FOR QUAD-RESONANCE ANTENNA

A prototype of the cavity-backed slot antenna has been designed on a FR4 epoxy substrate with a thickness of *h* = 2.4 mm, a relative permittivity of *εr* = 4.4, and a loss tangent of tanδ = 0.02. Detailed dimensional parameters for the fabricated antenna are listed in Table I. The measured reflection coefficient (|*S11*|) of the design antenna is shown in Fig. 2. It is seen that the measured result agrees well with the simulated one from HFSS. The measured result shows that the antenna has a 10-dB impedance bandwidth of 21.04%, ranging from 12.80 to 15.81 GHz.

Similar to the working mechanism of the triple resonance antenna, the shoring vias here also have an upward shifting effect on the lower three modes. Therefore, the four resonance modes of the quad- resonance antenna can be merged to generate a wider bandwidth. Detailed dimensional parameters of the antenna are listed in Table I.

Fig.2. shows the simulated and measured reflection coefficients of the cavity slot antenna. It is obviously seen that four resonance modes are excited. The measured result shows that the antenna has a reflection coefficient below -10 dB from 12.7 to 15.83 GHz, with a wide fractional bandwidth of 21.04%.The efficiency and gain of the antenna. The simulated efficiency reaches a peak value of 56.79% at12.8 GHz. The measured gain is stable, with a peak gain of 6.88 dBi and a gain variation within 1.5 dB from 12.8 to 15.81 GHz mode is a non-radiating mode, since it is an even mode with respect to the slot. Fortunately, the non-radiating mode does not exactly resonate in the operation band, and therefore the antenna gain can maintain stable in the operation band. Compared with the triple-resonance design, an about 2.5 dB gain increment is obtained, due to an electrically larger SIW cavity adopted in the cavity backed slot design

IV. CONCLUSION

A substrate integrated waveguide (SIW) cavity-backed slot Ku-band antennas using shorting vias is presented in this paper. The antenna has wide bandwidth and low profiles. By loading the SIW cavity with shorting vias and substrate value and material is changed. So as a result, a wide bandwidth with cavity-backed slot is achieved. Based on the similar principle, a cavity-backed slot antenna having an even wider bandwidth is also developed. Prototypes of the antenna is measured. With a low profile of 0.03λ (wavelength in free space), the cavity-backed slot antenna design has a bandwidth efficiency of 21.04% and a peak gain of 6.884dBi. This antenna can also be used in Ku band applications such as RADAR, SONAR etc...

REFERENCES

[1] T. Y. Yang, W. Hong, and Y. Zhang, "Wideband millimeter-wave substrate integrated waveguide cavity-backed rectangular patch antenna," IEEE Antennas Wireless Propag. Lett., vol. 13, pp. 205–208, 2014.

[2] S. Yun, D. Y. Kim, and S. Nam, "Bandwidth and efficiency enhancement of cavity-backed slot antenna using a substrate removal," *IEEE AntennasWireless Propag. Lett.*, vol. 11, pp. 1458–1461, 2012.

[3] K.-S. Chin, W. Jiang, W. Che, C.-C. Chang, and H. Jin, "Wideband LTCC 60-GHz antenna array with a dual-resonant slot and patch structure," IEEE Trans. Antennas Propag., vol. 62, no. 1, pp. 174 182, Jan. 2014.

[4] P. Chou bey, W. Hong, Z.-C. Hao, P. Chen, T.-V. Duong, and M. Jiang, "A wideband dual-mode SIW cavity-backed triangular complimentary split-ring-slot(TCSRS) antenna," IEEE Trans. Antennas Propag., vol. 64, no. 6, pp. 2541–2545, 2016.

[5] S. Mukherjee, A. Biswas, and K. V. Srivastava, "Substrate integrated waveguide cavity-backed dumbbell-shaped slot antenna for dual frequency applications," IEEE Antennas Wireless Propag. Lett., vol. 14, pp. 1314–1317, 2015.

[6] S. Mukherjee, A. Biswas, and K. V. Srivastava, "Substrate integrated waveguide cavity backed slot antenna with parasitic slots for dualfrequency and Broadband Application," in *Proc. 9th Eur. Conf. AntennasPropag. (EUCAP)*, 2015, pp. 7–11.

[7] W. Han, F. Yang, J. Ouyang, and P. Yang, "Low-cost wideband and high-gain slotted cavity antenna using high-order modes for millimeter wave application," IEEE Trans. Antennas Propag., vol. 63, no. 11, pp.