Suppressed back-lobe substrate-integrated waveguide slot array antenna for X-band

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Utilising an array that is constructed by combining short-ended stubs and microstrip lines, a planar-choke structure is presented. By locating the proposed chock structure on the bottom of the substrate-integrated waveguide slot array antenna, undesired spillover current and edge diffractions are removed. Measurement result show that in the operational bandwidth the backward radiation is reduced by more than 20 dB and the side-lobe level is improved by 5 dB without degrading of the antenna's electrical performance.

Introduction: Owing to the attractive features of slot array antennas such as high gain, high efficiency and mechanical strength, they are widely used in radar and communication systems [1]. The longitudinal shunt slot array is the most common structure in many applications owing to its low cross-polarised levels [2]. With this antenna, the defined gain and the side-lobe level (SLL) can be achieved using Elliott's design method [3, 4]. However, this method is not considered for the back-lobe radiation level. Substrate-integrated waveguide (SIW) technology has the advantages of low profile, small size, ease of fabrication and low cost [5]. To improve the front-to-back ratio (FTBR), previous studies have reported methods such as placing a reflector or an absorber in the antenna downside [6, 7], adding metal sidewalls [8] and using an electromagnetic bandgap [9]. The main disadvantages of these methods are increasing the SLL and the size of the antenna.

In this Letter, a planar-choke structure is proposed for improving the FTBR and the SLL of the SIW-fed slot array antenna. The proposed structure creates a very high impedance surface at the ground plane of the conventional antenna that eliminates the edge diffractions related to the undesired surface current.

Planar-choke element: To suppress the unwanted surface wave/current on the ground plane of the SIW slot array antenna, the structures of the folded corrugated SIW (FCSIW) [10] (see Fig. 1*a*) and the comb-shaped choke [11] (see Fig. 1*b*) are presented. Both structures are designed based on the quarter-wave impedance transformer method. In [11], the strip length of the choke element is equal to $\lambda_g/4$, while in [10] the total delay of the via and the strip must be equal to a quarter-wave (90°) delay. Both the comb-shaped choke element and the folded corrugated element can be modelled by a shunt inductance.

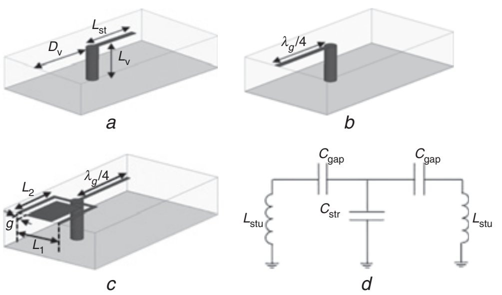

Fig. 1 *Reported and proposed choke elements*

a Perspective view of FCSIW [10]
b Perspective view of comb-shape choke [11]
c Perspective view of proposed planar choke
d Equivalent circuit of proposed planar choke

As can be seen from Fig. 1*c*, by combining the short-ended stubs and microstrip lines, this Letter presents a planar-choke element to provide significant attenuation on back-lobe radiation. The equivalent circuit of the proposed choke element shown in Fig. 1*d* consists of the shunt inductances and capacitance to model the short-ended stubs and a microstrip line, respectively. Moreover, the coupling between the short-ended stubs and the microstrip line is represented by series capacitances. So the proposed planar-choke element has the same characteristics as the five-order bandpass filter, which results in suppression of the surface current/wave better than that in [10, 11].

Antenna configuration: As shown in Fig. 2, to validate the proposed edge diffraction suppression technique, a 1 × 4 SIW-fed slot array antenna is designed and simulated by the full-wave ANSYS HFSS simulator for X-band application. Both the SIW and choke substrates are RO4003C substrate with a thickness of 0.78 mm and a relative permittivity of 3.55. The SIW substrate is bonded to the choke substrate by a bonding sheet with a relative dielectric constant of 3.5 and height of 0.25 mm. By placing an array of the proposed choke elements under the conventional SIW-fed slot array antenna, the unwanted surface current/wave at the ground is significantly attenuated. Therefore, this current/wave cannot disrupt the surface wave at the plane of the antenna that slots are etched on it and cause the FTBR and SLL of the antenna to be improved. The proposed antenna dimensions are listed in Table 1.

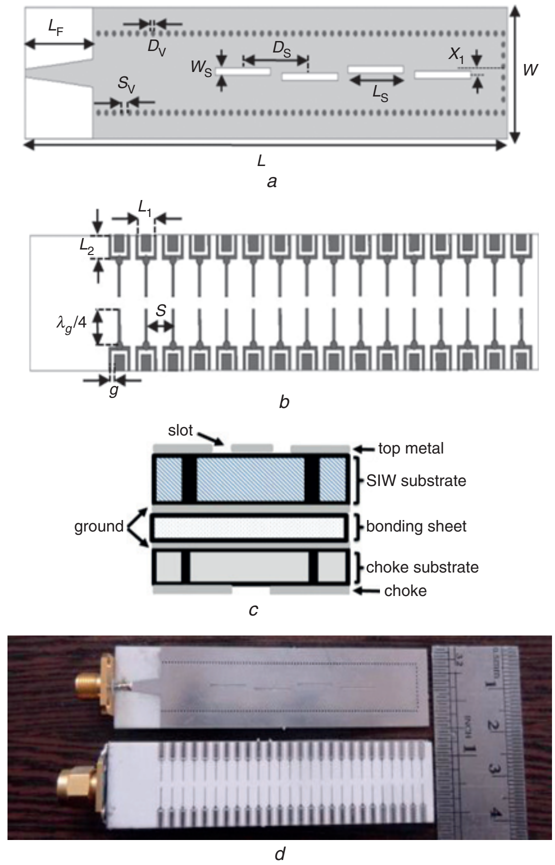

Fig. 2 *1 × 4 SIW-fed slot array antenna*

a Top view
b Bottom view
c Side view
d Photograph of fabricated antenna

Table 1: Dimensions of proposed antenna (millimetres)

Slots	SIW	Proposed choke array
$w_s = 0.4$	$D_v = 0.6$	$L_1 = 1.5$
$L_s = 10.8$	$S_v = 1.1$	$L_2 = 3.8$
$D_s = 13.45$		$g = 0.2$
		$S = 3$

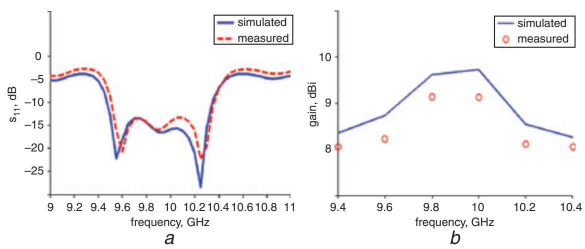

Fig. 3 *Characteristics of 1 × 4 SIW-fed slot array antenna with proposed choke*

a Return loss of proposed antenna
b Gain of proposed antenna

The simulated and measured return losses of the proposed antenna are compared in Fig. 3*a*. The antenna has an impedance bandwidth of about 850 MHz around the 9.9 GHz centre frequency with the reflection coefficient under −10 dB. The differences between the results may have been due to fabrication errors and connection/bonding losses.

Fig. 3*b* depicts the simulated and measured gains of the proposed antenna for different frequencies. These results are in good agreement, the slight differences being accorded to measurement errors. Over the −10 dB impedance bandwidth, the gain of the proposed antenna is more than 8 dB.

The radiation patterns of a 1 × 4 SIW-fed slot array antenna with and without the proposed planar choke at 10 GHz are compared in Fig. 4. Utilising the proposed choke structure on the antenna configuration eliminates the surface wave/current at the antenna's ground edges. Therefore, in both *E*-plane and *H*-plane radiation patterns, the FTBRs and the SLLs of the proposed antenna are improved by 20 and 5 dB, respectively.

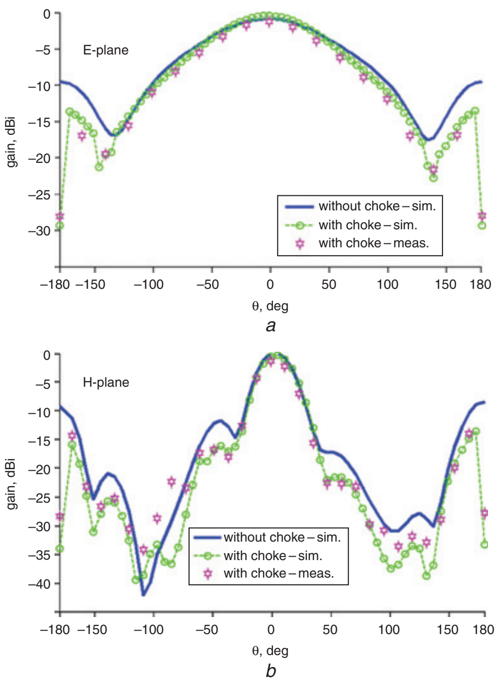

Fig. 4 *Comparison of radiation patterns at 10 GHz of 1 × 4 SIW-fed slot array antennas with and without proposed choke*

a E-plane pattern
b H-plane pattern

Table 2: Electrical performance comparison at 10 GHz

1 × 4 SIW-fed slot array with	Impedance bandwidth (MHz)	Gain (dBi)	FTBR (dB)	SLL (dB)	3 dB Beamwidth (deg)
Planar choke	850	9.1	29	17	30
FCSIW [10]	800	8.7	23	13	31
Comb-shaped choke [11]	730	8.5	20	12.5	29.5

In further studies, in the presented 1 × 4 slot array antenna, the proposed planar-choke structure is replaced by the arrays of FCSIW [10] and comb-shaped choke [11], independently. A comparison of the electrical performances of the proposed antenna and the two replaced choke antennas at 10 GHz is given in Table 2. These results show the proposed planar-choke structure improves the FTBRs and SLLs better than the configuration of the two previous works in [10, 11].

Conclusion: A planar-choke element involving a combination of short-ended stubs and a microstrip line for suppression of the back-lobe radiation patterns of the SIW-fed slot array antenna is proposed. The resonance of the presented choke elements creates an infinite impedance on the edges which eliminates the surface wave/current on the ground plane of the antenna. So, undesired edge diffractions are significantly attenuated. The measurement results indicate that the FTBRs and the SLLs in both the *E*-plane and the *H*-plane radiation patterns of the proposed antenna are improved by more than 20 and 5 dB, respectively. Compared with previous structures for back-lobe suppression in [10, 11], the proposed choke has better electrical performance.

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One or more of the Figures in this Letter are available in colour online.

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