The design of the one-eighth mold SIW (EMSIW) omnidirectional antennas

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Abstract. Since the size of the early antenna is big and not easy to carry, the one-eighth mold SIW Omni-directional antenna is described. The overall performance has been improved. Compared with a quarter mode antenna which is already existed, the relative area has reduced by 50%.

Introduction

With the rapid development of modern information technology, the global communication service has increased dramatically. The need for antenna miniaturization is becoming more and more urgent. In this situation, SIW becomes a new type of waveguide structures. It not only has the advantages of the waveguide and microstrip line but also overcomes the disadvantages of the traditional transmission line when working in the high frequency, such as coupling faults. However, the large volume makes the passive components big. Therefore, SIW resonator miniaturization research is imminent.

Theoretical analysis

The method of SIW resonator miniaturized, starting from QMSIW [1]. When resonator works in TE101 mould, cavity field distribution is symmetrical. A quarter model is obtained by secondary segmentation, but the quality factor is lower than the SIW cavity [2, 3], its reason is:

The equivalent width of HMSIW is formula (1)

$$W_{eff}^{HMSIW} = W_{eff}^{SIW}/2 + \Delta W \tag{1}$$

The type of the corresponding original SIW equivalent width (△W) is the width of the attached. It can use the nonlinear least squares estimate. Formula follows (2):

$$\Delta W = h\cdot\left(0.05+\frac{0.30}{\varepsilon_r}\right)\times In\left(0.79\frac{W_{eff}^{SIW}}{4h^3}+\frac{52W_{eff}^{SIW}-261}{h^2}+\frac{38}{h}+2.77\right) \tag{2}$$

Therefore, the resonance frequency of the resonator mode TE_{MOP} can be like the SIW structure estimated by the following formula [4]: formula (3)

$$f_{mnp}^{QMSIW} = \frac{1}{2\pi\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m\pi}{2L_{eff}^{QMSIW}}\right)^2+\left(\frac{p\pi}{2W_{eff}^{QMSIW}}\right)^2} \tag{3}$$

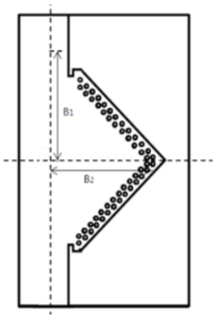
Type m = p = 1, 2, ... , the equivalent width and length of QMSIW can be used in formula(4)

$$\begin{aligned} W_{eff}^{QMSIW} &= W_{eff}^{HMSIW} \\ L_{eff}^{QMSIW} &= L_{eff}^{HMSIW} \end{aligned} \tag{4}$$

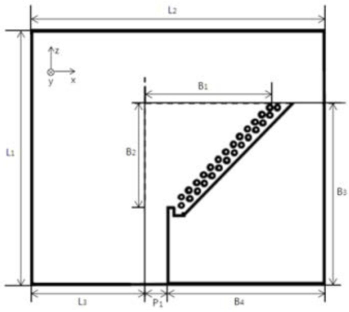
In practical application, the width and length of QMSIW will be slightly bigger than the estimate size. This is because in the process of making, in order to prevent the reduce of the field, the edge of the substrate has been made appropriate extension.

Antenna design

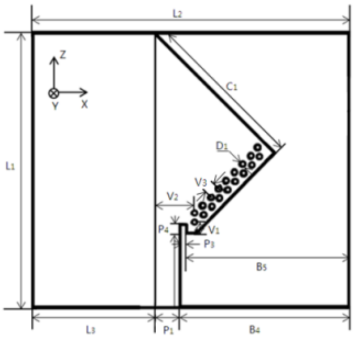
In order to facilitate further research, a traditional single diamond SIW cavity has been designed. Its structure as shown in figure 1, simulation model is shown in figure 2. In the input and output ports adopt 50 microstrip line directly connected to the cavity. The line width is 6.8 mm, cavity structure parameters as shown in table 1. The cavity use PCB process and choose Roger 5880, which relative dielectric constant is 2.2. The thickness of the substrate is 1.57 mm. The size of the square base board is 48 mm x 48 mm. Through the HFSS simulation analysis, the resonant frequency is 6.0 GHz.



(a)HMSIW



(b) QMSIW



(c) EMSIW

Fig.1: SIW cavity structure

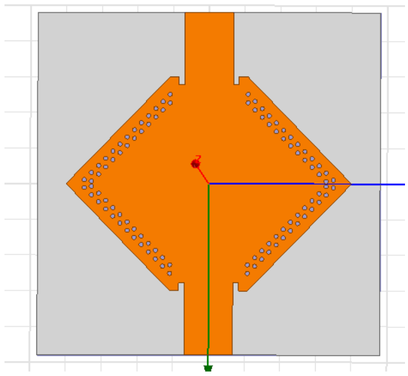


Fig.2: SIW cavity simulation model

Table 1: Cavity structure parameter

Lc	Wc	B1	B2	V1	V2	V3	D1	h	C1
22.6	22.6	16	16	2.45	5.45	1.5	0.6	1.57	11.3
L1	L2	L3	P1	P2	P3	P4	B3	B4	B5
35	40	20	3.4	9	0.8	1.1	24	16.6	15.8

Then the SIW cavity mode TE_{mnp} resonance frequency is listed in table 2.

Resonance frequency and the simulation results is almost the same.

Table 2: SIW cavity mode TE_{mnp} resonance frequency

M/p	1	2	3	4	5
1	5.9212	9.3622	13.2401	17.2630	21.3491
2		11.8423	15.0916	18.7244	22.5471
3			17.7635	20.9345	24.4136
4				23.6847	26.8092
5					29.6085

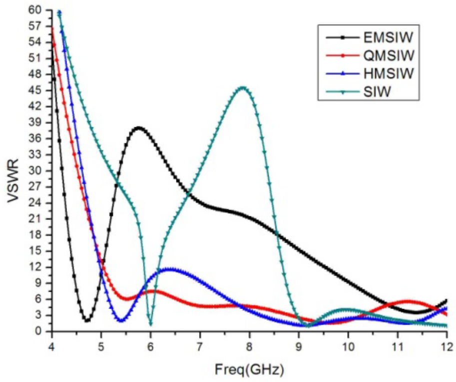
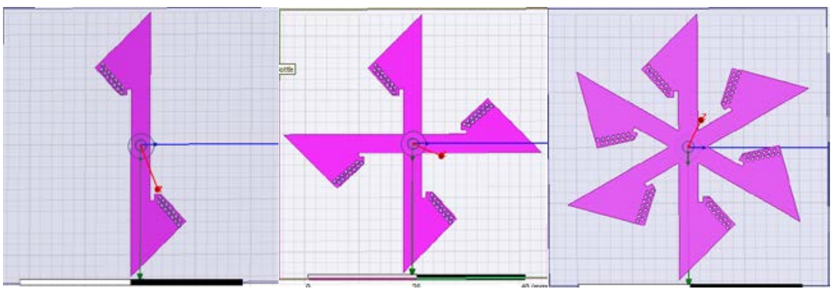


Fig.3: Voltage Standing Wave Ratio (VSWR) curve comparison chart

In figure 3, the green line is the VSWR of the figure 2 model. The resonance frequency of the mode TE_{101}, TE_{102} and TE_{202} is 6, 9. 2, 11. 34 and 11.93 GHz. Because cavity causes feeder structure of the two boundaries are not identical, resonant patch of symmetry is broken, the resonance frequency of the mold in the structure of the symmetry is separated into a pair of frequency. Due to the asymmetric factors of interference, two poles appear in 11.34GHZ and 11.93 GHZ.

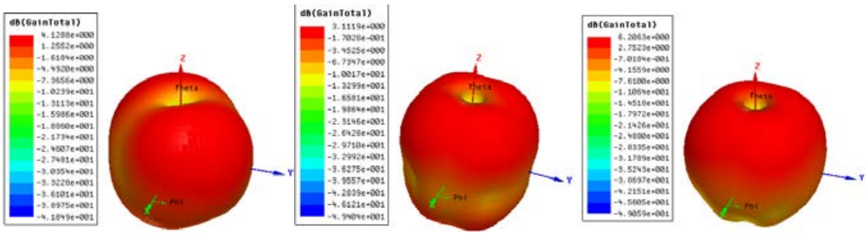
Because a single array element can only provide lateral direction, therefore, in order to generate all the polarization direction of conical lobe figure, multiple unit cells are arranged in windmill shape, to make the lateral direction becomes zero. Considering the symmetry, Omni-directional of the antenna, 2 units, 4 units and 6 units antenna array model is built in figure 4



(a) 2 unit (b) 4 unit (c) 6 unit

Fig.4: The structure of EMSIW antenna

In Figure 5 also shows the gain of each antenna. [7]Through lots of simulation and operation, six units antenna array model in the reflection coefficient and gain performance is much better than the other two, so six single array elements combined into an Omni-directional antenna array through a simple network integration has become the best choice of the antenna design.



(a)2 unit (b)4 unit (c)6 unit

Fig.5: 2, 4, 6 units gain antenna array

The production and the measured results

Figure 6, Figure 7 and Figure 8 show the production of EMSIW antenna. Figure 9 shows that the antenna performance is good. Its return loss curve is basically in conformity with the simulation results. The resonance frequency has a tiny deviation, because of the inevitable assembly test environment and the differences caused by the antenna itself. In conclusion, the one-eighth model of Omni-directional antenna design has achieved the expected effect.

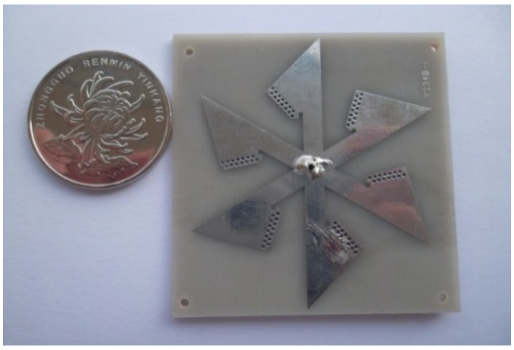


Fig.6: The production of EMSIW antenna

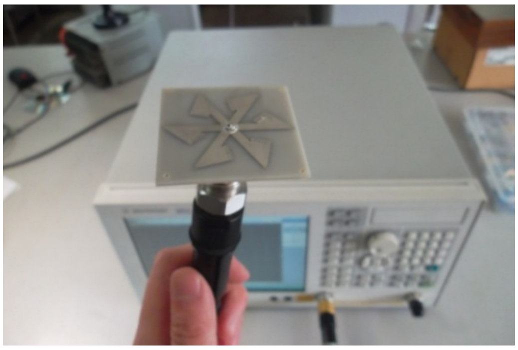


Fig.7: EMSIW antenna test pattern

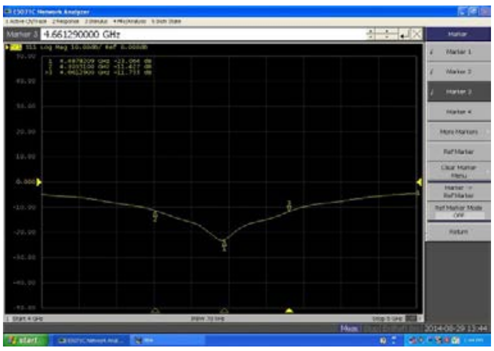


Fig.8: vector network analyzer

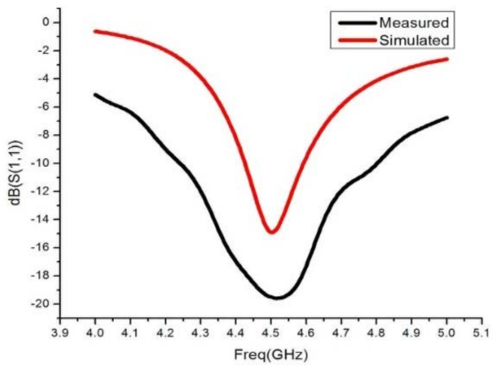


Fig.9: contrast of the return loss

Conclusions

Considering the design of a quarter of the SIW antenna, after the simulation of Omni-directional antenna measurement, we can clear decide the rationality and operability of the one-eighth SIW antenna. Compared with the quarter SIW antenna, the relative area of the one-eighth model of Omni-directional antenna has reduced about 50%.It realizes the miniaturization of the antenna.

Acknowledgements

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