Design of an multiband resonance antenna with a complementary split-ring based on EMSIW

Huaiqiang Wang[1],Ping Li[2]&Xiangjin Quan[1]

[1]Department of graduate management, Engineering University of CAPFXi'an, 710086, China

[2]Department of IT engineering, Engineering University of CAPFXi'an, 710086, China

Keywords:EMSIW ; complementary split-ring ; antenna design ; computer simulation ;

Abstract. This paper designs an antenna with resonance frequency in 17.1 GHz , 27.6 GHz and 30 GHz. The antenna loads on one eighth-mode substrate integrated waveguide (EMSIW), metallic silver vias have been punched via the EMSIW ,and etched on the surface of metal sheet a complementary split-ring. The size of the antenna only takes up 12.5% of the traditional substrate integrated waveguide(SIW).Using computer simulation software HFSS to simulate, I get its return loss, VSWR and three-dimensional gain plot and so on. The simulation results show that at the resonance frequency of 17.1 GHz, the bandwidth with return loss less than -10 dB reaches 1.9%, the largest gain reaches 4.4 dB; At the resonant frequency of 27.6 GHz and 30 GHz, the two useful bandwidths with return loss less than -10 dB appear to be united perfectly , making the total bandwidth reach 15.2%, it biggest gain reaches 7.68 dB.

Introduction

Due to the rapid development of modorn wireless communication systems, design of high performance, small size and low cost antennas caused great concern around the world, and with a variety of services and increasing demand of frequency,design of high-performance multi-band antennas is a more economical and practical solution. SIW has manyadvantages of not only lightweight, compact, low-cost, but also small loss of ennergy, high Q value , and is widely used in the field of antenna design. In the past few decades, people mainly researchon SIW, half SIW or folded SIW[1-3], especially when the antenna ofright hand and left hand hybrid materials based on SIW and half SIW has been designed, it greatly reduce the size of the antennas[4-6]. In addition, these antennas also have advantages ofrelatively high radiation efficiency and gain . Similarly, the antennawith a complementary split-ringloaded on SIW has been designed, this its area is only about about 42 percent of a smallsquare strip .

Antenna Design Theory

substrate integrated waveguide

Substrate integrated waveguide (SIW) is a new form of microwave transmission lines, the technology isproposedby a Japanese scholar H. Furuyamain the nineties of the last century[7]. In high frequency applications, since the wavelength is very short, too high tolerance requirements often make microstrip line useless. The waveguide is commonly used in high frequency, but its volume is too large to integrate. It has created a new point of view: By metal vias through periodic waveguide structure to achieve the advantages of both conventional waveguide and microstrip transmission lines[8-10], the structure shown in Figure 1:

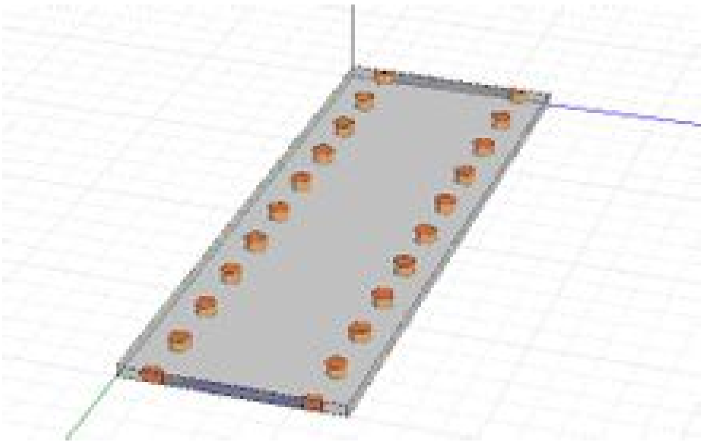

Fig 1: structure of SIW

It uses PCB, LTCC or diaphragmtechnologyto achieve two rows of vias, electromagnetic wave is limited inrectangle cavity of two rows of holes and upper and downer metal boundary. Due to the vias on the edge ,transverse, magnetic wave (TM) does not exist, transverse electric waveTE10 is the main mode.

Radiationtheory

Since SIW has the propagation characteristics of the waveguide, so SIW rectangular cavity propagatetransverse wave TE10 mode, FIG. 2 is a rectangular waveguide structure.

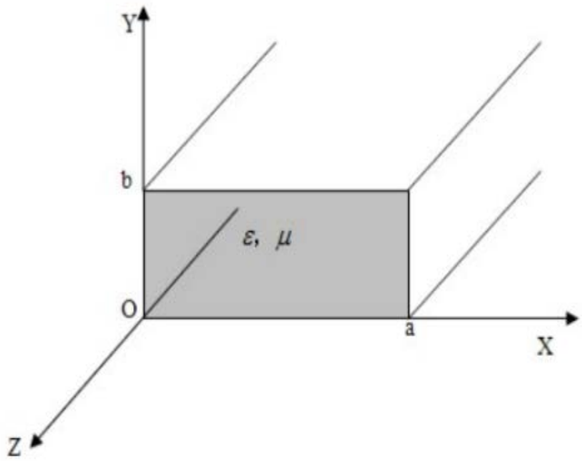

Fig. 2: a rectangular waveguide structure.

For TE10 mode, EZ=0, the equation of HZ is:

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+k_c^2\right)h_z(x,y)=0\ (1)$$

In addition ,$H_Z(x,y,z)=h_z(x,y)e^{-j\beta z}$, the deadline wave $k_c^2=k^2-\beta^2$, and

$$h_z(x,y)=X(x)Y(y)(2)$$

Substitute all into (2) , we get :

$$\frac{1}{X}\frac{d^2X}{dx^2}+\frac{1}{Y}\frac{d^2Y}{dy^2}+k_c^2=0(3)$$

According to the theory of PDE , erery item of (3) is a constant , so we get :

$$\frac{d^2X}{dx^2}+\ k_x^2X=0(4)$$

$$\frac{d^2Y}{dy^2}+\ k_y^2Y\ =0(5)$$

$$k_x^2+k_y^2\ =\ 0(6)$$

According to Fig. 2, when the boundary condition y=0 and y=b ,

$$e_x(x,y)=0(7)$$

When x=0 and x=b ,

$$e_y(x,y)=0(8)$$

So the crosswise component of TE_{mn} can be simplified to :

$$E_x = \frac{j\omega\mu n\pi}{k_c^2 b} A_{mn} \cos\frac{m\pi x}{a} \sin\frac{n\pi y}{b} e^{-j\beta z} (9)$$

$$E_y = \frac{-j\omega\mu n\pi}{k_c^2 a} A_{mn} \sin\frac{m\pi x}{a} \cos\frac{n\pi y}{b} e^{-j\beta z} (10)$$

$$H_X = \frac{j\beta m\pi}{k_c^2 a} A_{mn} \sin\frac{m\pi x}{a} \cos\frac{n\pi y}{b} e^{-j\beta z} (11)$$

$$H_y = \frac{j\beta n\pi}{k_c^2 b} A_{mn} \cos\frac{m\pi x}{a} \sin\frac{n\pi y}{b} e^{-j\beta z} (12)$$

$$\beta = \sqrt{k^2 - k_c^2} = \sqrt{k^2 - \left(\frac{m\pi}{a}\right)^2 - (\frac{n\pi}{b})^2} (13)$$

Therefore, by the basic transfer characteristics of rectangular waveguide TE mode , we get the transfer characteristics of SIW, and it provides a theoretical basis for the next step of antenna simulation analysis .

technology of slottedsurface of antenna

Through etching slots in the surface of the antenna, we can increase the equivalent size 'L' of antennas without increasing the real size of antennas ,and thus reduce the real size of antennato achieve the purpose of miniaturization.

$$f = \frac{c}{2L\sqrt{\varepsilon_r}} (14)$$

Simulation design of antennas

The selection of antenna simulation in this paper is an EMSIW.It is based on an isoscelesright-angletriangle of Rogers RT/Duroid 5880 with ε = 2.24, h = 1.575 mm. As shown in Fig.3:

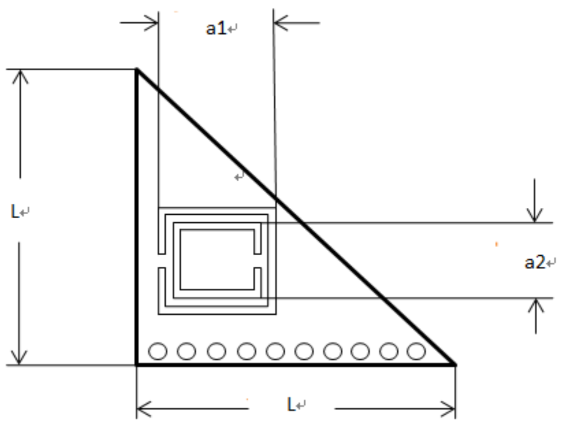

Fig.3:structure of the antenna

Cyclical holeat a right-angleboundary of this substrate.A complementary square split-ringis Etched on the upper surface, and it links the metal surface of the radiating patch and the substrate metal at the bottom by another right-angle side.The area of the antenna is （11*11）/2mm2 . Compared to the half-wave antenna , the size reduces about 14%.The antenna use feed-side method to signal from shorting incentives. There are 10 silver holes on the EMSIW, the diameter ofeach silver hole is 0.7 mm, the center distance of adjacent silver holes is 1.15 mm. The right-angle edge of the antenna L=11mm, the outer edge of the outer square complementary split-ring a1=4mm, the outer edge of the inner square complementary split-ring a2=2.6mm, the width of the grooveof the square b1 and the width between the groove b2 are 0.35mm. The width between the square and the edge of the EMSIW t1=0.35mm, the width between the top of the silver holes and the square t2=0.42mm, as is shown in Fig.3.I Use software HFSS to establish the model of antenna ,as shown in Fig.4:

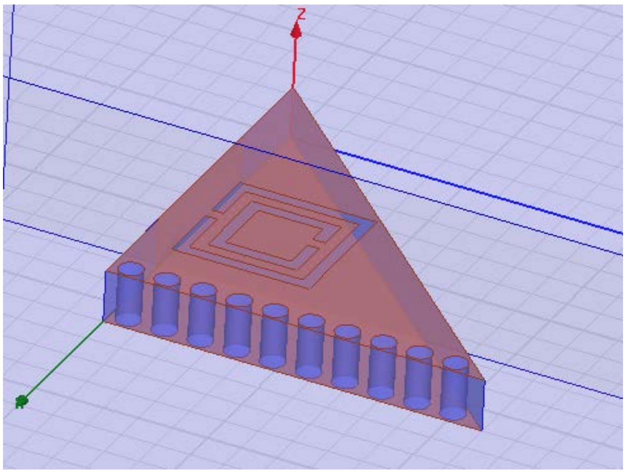

Fig.4:the model of the antenna

The simulation results

Center frequency f = 17.1 GHz

Center frequency f=17.1GHz, the frequence sweep is between 15GHz and 20GHz. The return loss S11 reaches -30.55dB, and the bandwidth with S11<-10dB reaches 1.5%, thebiggest gain reaches 4.44dB, as is shown in Fig.5:

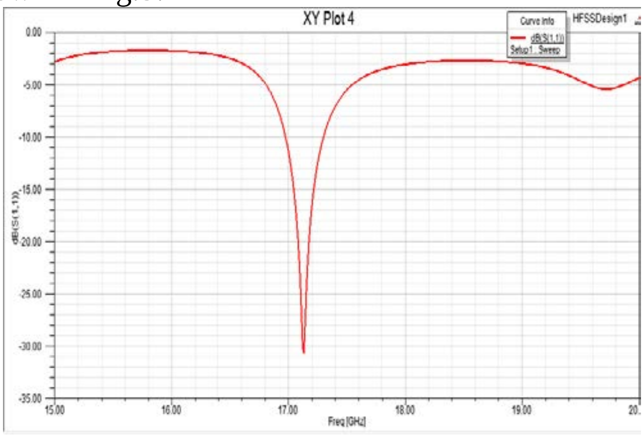

Fig.5(a):the S_{11} of the antenna at 17.1GHz

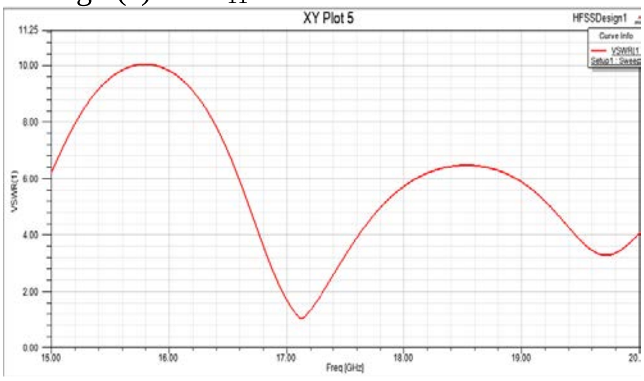

Fig.5(b):the VSWR of the antenna at 17.1GHz

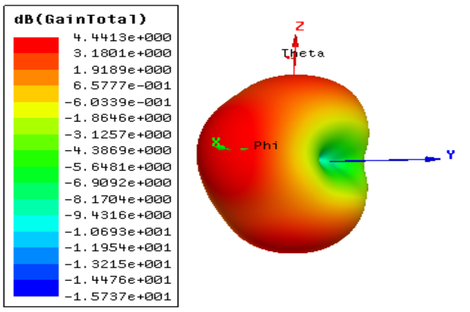

Fig.5(c):the gain of the antenna at 17.1GHz

Center frequency f = 27.6 GHz

Center frequency f=27.6GHz, the frequency sweep is between 25GHz and 32GHz. As a result, At the resonant frequency of 27.6 GHz and 30 GHz, the two useful bandwidths with return loss less than -10 dB appear to be united perfectly , making the total bandwidth reach 15.2%, it biggest gain reaches 7.68 dB, as is shown in Fig. 6:

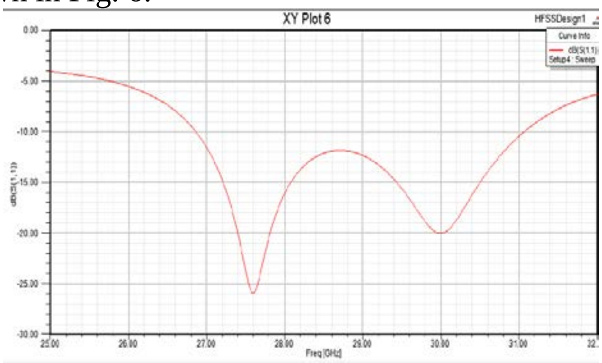

Fig.6(a): the S_{11} of the antenna at27.1GHz and 30GHz

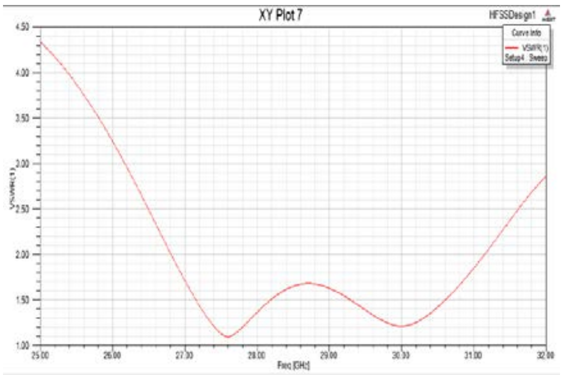

Fig.6(b):the VSWR of the antenna at 27.1GHz and 30GHz

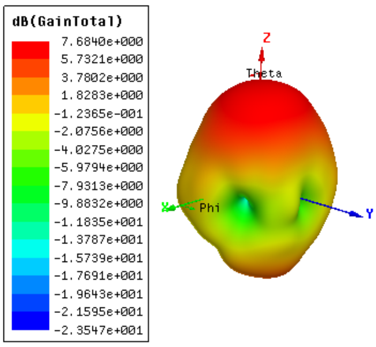

Fig.6(c):the gain of the antenna at 27.1GHz and 30GHz

Conclusions

In this article, based on the electromagnetic properties of SIW we have carried on the theoretical research, and design an antenna based on EMSIW, then use HFSS to simulate the antenna. By etching an complementary split-ring on the EMSIW, the area of the antenna is only （11*11）cm2. At the resonance frequency of 17.1 GHz, the bandwidth with return loss less than -10 dB reaches 1.9%, the largest gain reaches 4.4 dB.At the resonant frequency of 27.6 GHz and 30 GHz, the two useful bandwidths with return loss less than -10 dB appear to be united perfectly , making the total bandwidth reach 15.2%, it biggest gain reaches 7.68 dB.

References

[1] Deslandes.D and Wu Ke. Single-substrate intergration technique of plannar circuits and waveguide filters[J].IEEE Trans. Microw . Theory Tech， 2003，51(2):pp. 593-596.

[2] Cheng Y. J ，Hong W， and Wu K. Millimeter-wave half mode substrate intergrated wave frequency scanning antenna with quadri-polarization[J] IEEE Trans. Antennas Propag，2010，58 (6)：pp.1848-1855.

[3] Grigoropoulos. N ， Sanz-Izquierdo .B ， and Young P.R. Substrate integrated folded waveguides (SIFW) and filter[J].IEEE Microw . Wirel .Compon .Lett，2005，15(12):pp.829-831 .

[4] Dong Y.D and Itoh. T. Miniaturized substrate integrated waveguide slot antennas based on negative order resonance[J].IEEE Trans. Antennas Propag，2010，58(12):pp.3856-3864.

[5] Dong Y.D and Itoh. T. Composite right/left-handed substrate integrated waveguide leaky-wave structures[J].IEEE Trans. Antennas Propag，2011，59(3):pp.767-775.

[6] Choi. J and Lim. S. Complementary split ring resonater (CSRR)-loaded substrate integrated waveguide(SIW) metamaterial antenna [J].IEICE Trans. Commun，2012，E95b(1)：pp.304-307

[7] Deslandes. D and Wu Ke. Integrated microstrip and rectangular wave-guide in planar form[J].IEEE Microw．Wireless Compon．Letters，2001，1 1(2):pp.68-70．

[8] Zhang Yulin , Hong Wei，Wu Ke，et a1．Novel substrate integrated waveguide cavity filter with defected ground structure[J]． IEEE Trans， Microw， Theory Tech， 2005，53(4):pp.1280-1287．

[9] Deslandes. D，Wu Ke． Substrate integrated waveguide dual-mode filters for broadband wireless Systems[C].Proc． IEEE Radio Wireless Conf． (RAWCON)，Boston:2003:pp.385-388．

[10] Tsung-hui Huang，Chin-Sheng Chang Hart-Jan Chen，et a1.Simple Method for AK-Band SIW Filter with Dual-Mode Quasi-Elliptic Function Response[J].Microwave and optical Technology. Letters，2007，49(6):pp.1246-1248．