Design of Broadband Transition Based on Substrate Integrated Waveguide

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Abstract—**A broadband transition device based on substrate integrated waveguide structureis proposed in this letter. With the novel guide wave structure, electromagnetic waves could be limited in the rectangular cavity formed by two rows of metal hole and the upper and lower metal border to achieve low losseffect. Combined with the advantages of that multiple impedance transformer, it can broaden the bandwidth of microwave circuits. A broadband transition is designed to cover the 33GHz-50GHz band showing a return loss of 10dB and insertion loss of 0.68dB. The measurement error is within an allowable range and consistents with the simulation results. The proposed transition meets the design requirements for broadband and low-loss.**

Keywords—SIW; multiple impedance transformer; broadband

I. Introduction

Guided wave structures is the basis of microwave circuit, its transmission characteristics and stable properties has a direct impact on the performance of the microwave circuit.From the beginning the study of metal waveguide structure to the development of the microstrip circuit[1].People summarized the integration problem between circuit and analyzed the future development trend, this paper proposes a waveguide structure based on dielectric substrate-Substrate Integrated Waveguide[2],(SIW).SIW in addition to comprehensive metal waveguide structure and advantages of microstrip circuit, it also has a high quality factor and high integration ability, at the same time can reduce the manufacturing cost. It widely used in military communication, ground radar, and other fields, and yet in many special fields as the preferred parts, it has become one of the important research direction of microwave circuit in recent years.Due to the need of impedance matching[3-4], impedance transformation is necessary, but at higher in RF and microwave band, it is difficult to achieve broadband for larger impedance transformation.Through the reflection and discontinuity theory to design of device, by increasing the impedance converter session can be made on wide band to obtain the ideal matching features.

This article through to the study of substrate integrated waveguide and the theory and structure of the impedance converter. A broadband transition is designed.the transition device has the advantages of wide band, low loss.

II. Basic Knowledge and Design Waveguide Transition

A. Substrate Integrated Waveguide Theory and Design

The basic structure of the substrate integrated waveguide is in double sided PCB dielectric plate coated copper perpendicular to insert two rows of parallel with periodic metal hole clearance, and the upper and lower sides of the metal surface of PCB board.Because each row metal hole hole spacing is far smaller than the wavelength, therefore Small aperture leakage of energy, equivalent to the rectangular waveguide filled the medium. the most parts of the electromagnetic energy is limited within the space between the metal wall.

To achieve good loss within the wide band, two transitions.wide-band rectangular waveguide converter and SIW with microstripline.wide-band converter in high frequencies, its high order modes of the coaxial connector joint converter work bandwidth will be seriously affected.

A microstrip part of SIW and microstrip line transformation form will have higher radiation loss.SIW waveguide section of this article is the relative dielectric constant is 2.65 FR4.its medium plate thickness is 0.5mm. Small to large is 5mm×5.7 mm.In the medium plate have two rows of cylindrical hole, six in each row hole, a total of 12 hole.The distance between two rows of hole is 4.5 mm, the diameter of the hole is 0.3 mm, the distance between the hole and the hole is 0.4 mm.

B. Section Impedance Converter Theory and Design

Because of the single section 1/4 impedance bandwidth for narrow-band converter work, so this paper uses the combination of multiple class impedance converter cascade to broadening the working frequency band.Insection impedance stepped impedance converter, if each impedance ladder produced by the reflected wave offset each other, its can make the matching band broadening[5].

For an ideal section rheostat, after a variable resistance, on the transmission line $Z_0 = 1$, the reflection coefficient should be 0.

Insert the transmission properties of two port with attenuation L said:

$$L = \frac{1}{|S_{12}|^2} = 1 + \frac{1-|S_{12}|^2}{|S_{12}|^2} = 1 + \xi \tag{1}$$

Type(1) ξ known as the excess attenuation,It represents and the difference between the state of ideal two-port network.As a matter of fact in a certain frequency range, excess attenuation ξ can't all is 0.As long as meet at the specified frequency band is less than a certain value.

The excess attenuation of section impedance converter:

$$\xi = \frac{(R-1)^2}{4R} COS^{2n}\theta \tag{2}$$

Type (2) R for the variable resistance ratio, n for the rheostat session, θ for the transmission line segment length.

Analysis (1), (2) .In the center frequency $\omega = \omega_0$, $\theta = 90^o$, $\cos\theta = 0$ .at this time $\xi = 0$ Section for more ideal rheostat.When $\theta = \pi$, for the greatest excess attenuation.Which can determine the Q band, the size of section impedance transformer:

L_1=3.67mm,L_2=1.287mm,L_3=2.1mm,L_4=2.166mm$a$=8.7mm,a_1=5.7mm,a_2=7.8mm,a_3=7.7mm$b$=2.85mm ， b_1=2.7mm, b_2=1.99mm, b_3=1mmb_4=0.5mm.
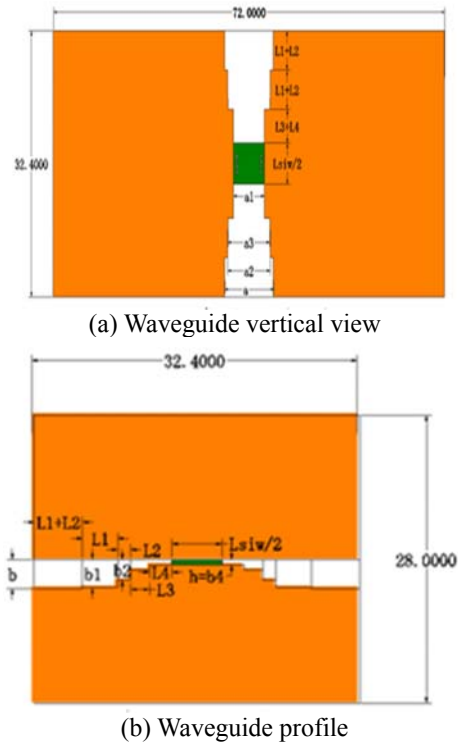
III. TRANSITION DESIGN

This article uses is SIW and conversion of the rectangular waveguide.Used to ensure that when the design within the required working frequency band characteristic impedance of the microstrip line and SIW equivalent impedance matching, reduce the reflection.Thus the bandwidth of the extension.

This structure as shown in figure 2.1, the waveguide model is made in two copper (orange) between designing a broad band of transition.The size of the copper is 72mm*32.4mm*28mm.Air rectangular(white) waveguide which is on the copper block dug a four step of waveguide.Figure 2.1, the green part is made of FR4 SIW waveguide. $\varepsilon_r = 2.65$,the size is 5.7mm*5mm*0.5mm.Design of waveguide transition model is shown in figure 2.1.

Using Ansoft HFSS15.0 for the simulation analysis, main parameters and the optimization analysis, it is concluded that the optimized data for:

L_1=3.67mm, L_2=1.287mm, L_3=2.1mm,L_4=2.166mm ， a=8.7mm, a_1=5.7mm, a_2=7.8mm, a_3=7.7mm$b$=2.85mm ， b_1=2.7mm, b_2=1.99mm, b_3=1mmb_4=0.5mm, L_{siw}=10mm, W_{siw}=4.5mm, L_h=1.5mm, d=0.3mm, s=0.4mm.

(a) Waveguide vertical view

(b) Waveguide profile

FIGURE I. TRANSITION MODEL

Due to the effect of medium uniformity, actual length and the ideal optimization length will vary slightly, the transition of the final design is given priority to with the actual length optimization.

IV. SIMULATION OPTIMIZATION AND THE RESULT ANALYSIS

Using Ansoft HFSS15.0 for the simulation analysis, The simulation results are shown in Figure 2, 3 and 4.

Figure 2 for the transition model with substrate integrated waveguide and without substrate integrated waveguide when the return loss of contrast.

For the presence of substrate integrated waveguide transition frequency almost does not have any effect, just an irregular impact on return loss.When without substrate integrated waveguide in the entire model, the return loss in most frequency are above -10 dB.when with substrate integrated in the entire model,Because the electromagnetic wave are limited to two rows of metal hole, this makes transverse magnetic wave does not exist.See in the figure 3 in the whole 30 GHZ - 55 GHZ range return loss are below - 10 dB,So comprehensive consideration to insert substrate integrated waveguide can realize the design of wideband low-loss.
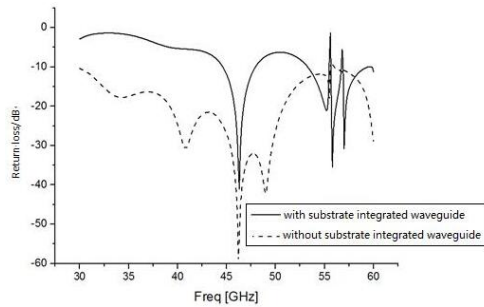
FIGURE II. PRESENCE OF SUBSTRATE INTEGRATED WAVEGUIDE RETURN LOSS

Figure 3 for the substrate integrated waveguide between hole and the hole is different spacing on the transition, the influence of the return loss. Different hole spacing of the transition had a greater influence on the return loss.therefor when S = 0.4 mm, ensure the high frequency return loss is small.
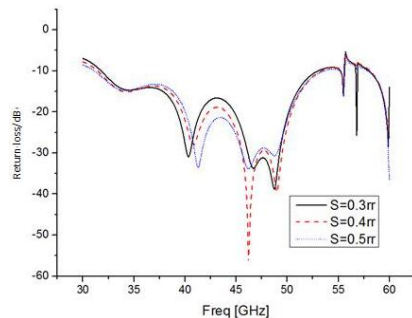

FIGURE III. DIFFERENT S VALUE RETURN LOSS

Figure 4 for the hole diameter of different substrate integrated waveguide transition, the influence of the return loss.

Ander different value of d, within the required band, S11 can below - 10 dB.the d value, the greater the S11 value is smaller, indicates that the metallized hole radius, the greater the return loss.at the same time, with the increase of d value frequency also increases gradually, and the curve of the population distribution is relatively ideal, choose d value of 0.4 mm.
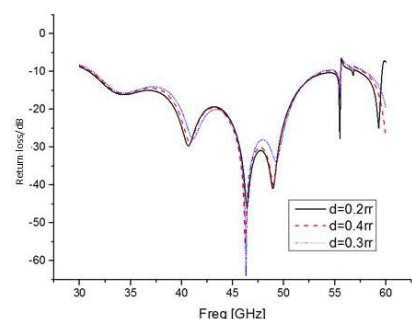

FIGURE IV. DIFFERENT D VALUE RETURN LOSS

Waveguide physical is shown in figure 5.

FIGURE V. TRANSITIONPHYSICAL

V. THE MEASURED RESULTS AND ANALYSIS

Physical transition by coaxial BJ400 conversion interface is connected to the vector network instrument for testing.The test results are shown in figure 6.
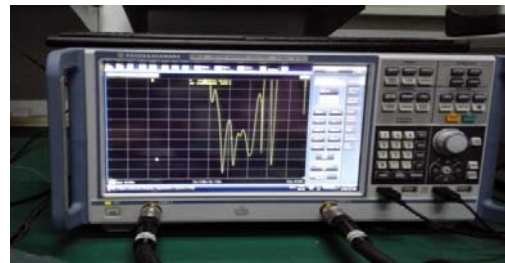

FIGURE VI. AGILENT TECHNOLOGIESN5230C 30GHZ-50GHZ

Figure 6 testing result compared with the results of simulation and comparison results as shown in figure 7 and figure 8.

Figure 7 for transition simulation results with the measured results figure return loss.

Waveguide simulation return loss in 30-50 GHZ are below - 10 db,Compared with the simulation results.Waveguide spectrum test results in 30 GHZ - 36 GHZ, 53 GHZ - 55 GHZ return loss upward migration, in 36 GHZ - 53 GHZ in the whole band return loss are below - 10 db.Due to the material and production process, error in the range of allowable error, the measured results and simulation results.
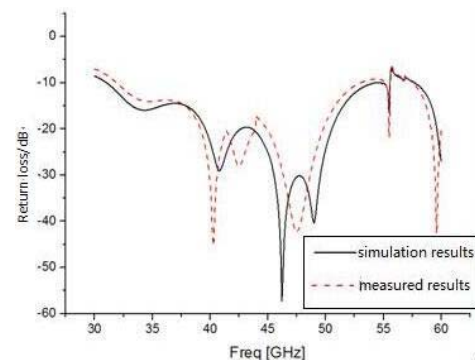

FIGURE VII. TRANSITION RETURN LOSS

Figure 8 for the transition simulation results compared with the measured results of insertion loss.

Waveguide simulation insertion loss in the whole 30 GHZ - 55 GHZ within 0.68 dB,Compared with the simulation results.Waveguide spectrum test results in 30 GHZ - 40 GHZ insertion loss downward shift.This is because the waveguide in the simulation itself as the ideal wall thickness, and in the actual production of waveguide is itself has certain thickness, is it going to affect insertion loss.in the simulation, the four step Angle as rectangular waveguide.in the actual process, because of the limitation of process precision made physical radian Angle,Cause certain influence to the insertion loss.
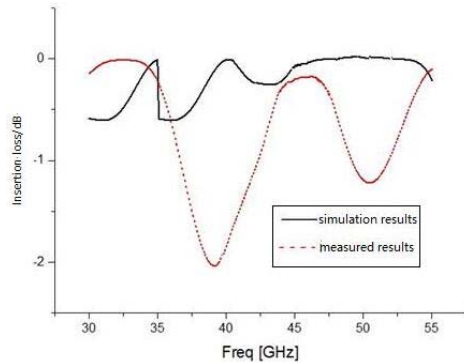

FIGURE VIII. TRANSITION INSERTION LOSS

VI. CONCLUSION

Section impedance converter can be used to broaden the microwave circuit bandwidth realized the transition of the advantages of wide band design.At the same time in the middle to insert substrate integrated waveguide to realize transition of the low loss design.UsingAnsoft HFSS15.0 for the simulation analysis,Simulation and test of transition return loss under - 10 db, basic covers 30 GHZ - 55 GHZ frequency band,Overall the transition and realize the microwave circuit design of wide band, low loss.

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