A REVIEW ON SUBSTRATE INTEGRATED WAVEGUIDE AND ITS NATURE OF SUPPORTING MULTIBAND FREQUENCIES

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Abstract: A substrate Integrated Waveguide with substrate being the dielectric material Rogers RT/duroid 5880 (tm) having relative permittivity 2.2 is designed and simulated. Shifting of operating frequency band from X-band to Ku- band with the changes in design parameters is analyzed. Substrate Integrated waveguide supporting operation at multiband frequencies is analyzed in contrary to normal rectangular waveguide which support only single frequency band operation.

Keywords: Substrate Integrated waveguide (SIW), Return loss (RL), vias

INTRODUCTION

In the course of time the usage of electromagnetic radiations has tremendously increased in vast fields. Thus, it is important to study medium guiding this energy. Transmission lines, and strip-lines are the very initial medium of study in this field. Both transmit energy at MHz range frequency. And not higher frequencies are possible to guide using transmission lines as there are many disadvantages of using transmission lines at higher frequencies. These transmission lines result in lot of radiation loss, copper loss, skin effect and dielectric loss. Moreover, they are non-planar in nature, so their integration with planar circuit and its components is complex. To work on higher frequencies waveguides where then introduced. Waveguide can work on GHz frequency. But, even waveguide have many disadvantages. They are bulky and non-planar in nature. Substrate Integrated Waveguide (SIW) acts as alternative option to metallic waveguides. SIW are planar structures fabricated using two periodic rows of metallic vias (holes) or slots connecting top and bottom metallic ground planes of dielectric substrate. Using SIW Technology a non-planar metallic waveguide can be modeled into a Substrate Integrated Waveguide, which will be planar in nature and can be fabricated on, as well as integrated to, planar circuits with ease. SIW offers low cost, high Q factor and low insertion loss at high frequencies and are very appropriate to feed millimeter wave integrated antennas and beamforming networks (BFN). As SIW exhibits propagation characteristics such as of the rectangular metallic waveguides, SIW modes have same modes as of the latter i.e. TE_{n0} modes. SIW doesn't support TM waves because of gaps between the metallic vias, which means TM fields determine longitudinal surface currents which are subject to a strong radiation due to presence of the gaps. Therefore, TE10 mode is the fundamental mode.

1. Design of Substrate Integrated Waveguide

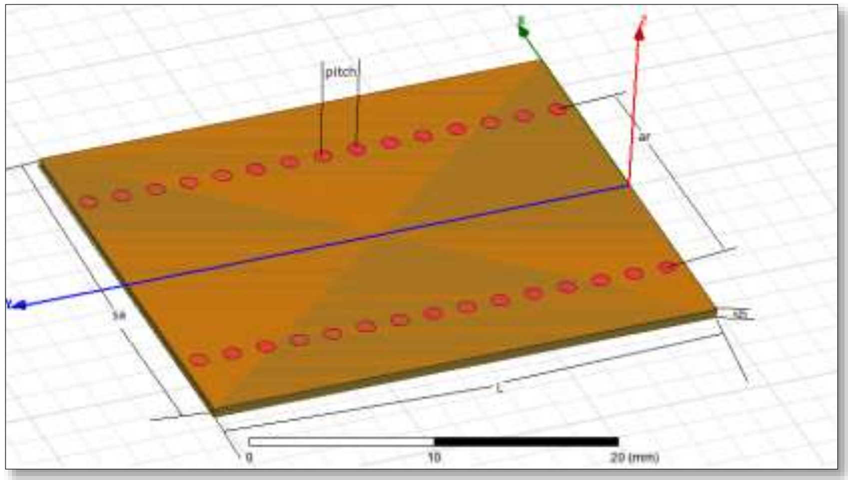

Figure 1: Substrate Integrated Waveguide

SIW has a substrate which may be a dielectric material or air filled sandwiched between two metallic plates at the top and bottom. Two periodic rows of Vias (holes) or hollow metallic cylinders connect top and bottom metallic plates as shown in above fig1. In a rectangular waveguide, length(a) and height(b) are important factors of design as the cutoff frequency depends on these two parameters. In case of SIW also the cutoff frequency is calculated using the same formula.

In the fig1, **pitch (p)** is the distance between the center of two via holes. '**sa**' is the width of the substrate. '**L**' is the length of the SIW. '**sb**' is the height of SIW. '$\boldsymbol{a_r}$' is the center to center via separation. '**d**' is the diameter of the via.

The cutoff frequency 'fc' is calculated using formula mentioned below.

$$f_c = \frac{c}{2\pi\sqrt{\epsilon_r}}\sqrt{\frac{m^2}{a^2}+\frac{n^2}{b^2}} \qquad (1)$$

Where a and b are the dimensions of the rectangular waveguide.

Formula to calculate other parameters of SIW are specified as under:

$$a_{r=}a + \frac{d^2}{0.95p} \qquad (2)$$

For minimum radiation loss or leakage, the diameter of the via should be less the one fifth of the guide wavelength. And the pitch should be greater than twice the diameter of via.

$$D < \frac{\lambda_g}{5} \qquad (3)$$

$$p < 2d \qquad (4)$$

$$\lambda_g = \frac{2\pi}{\sqrt{\frac{\epsilon_R(2\pi f)^2}{c^2} - \frac{(\pi)^2}{a^2}}} \qquad (5)$$

λ_g- guide wavelength

c- Speed of light

2. Simulation results and discussion

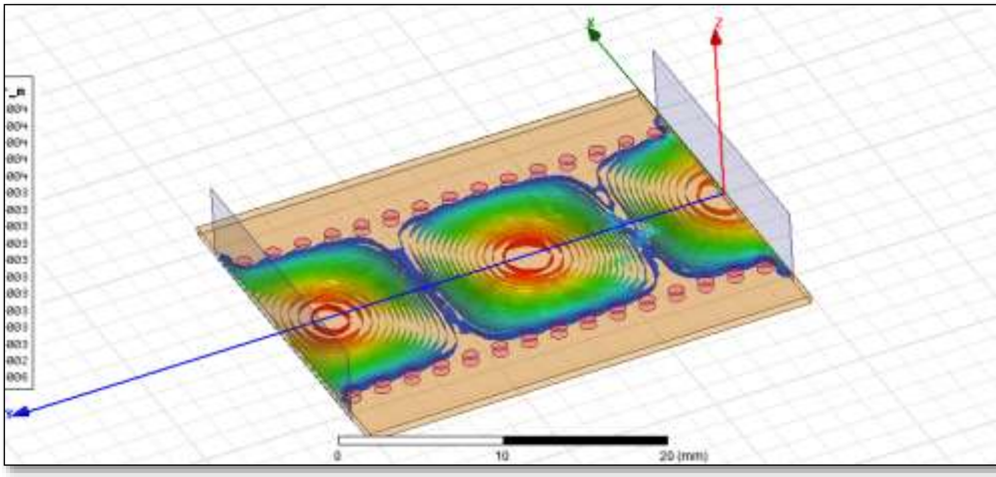

Figure 2: E field magnitude representation of TE10 mode

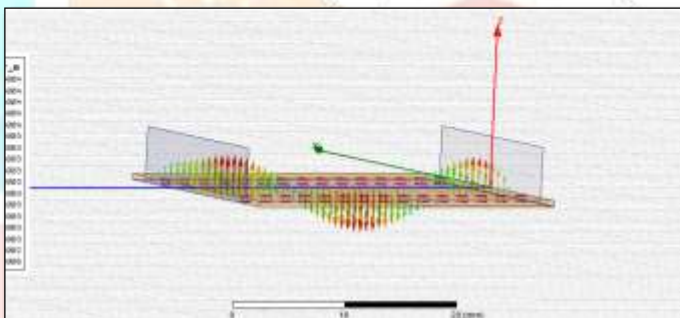

Figure 3: E field vector representation of TE10 mode

Physical Parameter name	Value
sa	25mm
L	30mm
sb	0.508mm
ar	15.77mm
d	1mm
pitch	2mm

Table1: representing value of physical parameters taken for the design of SIW.

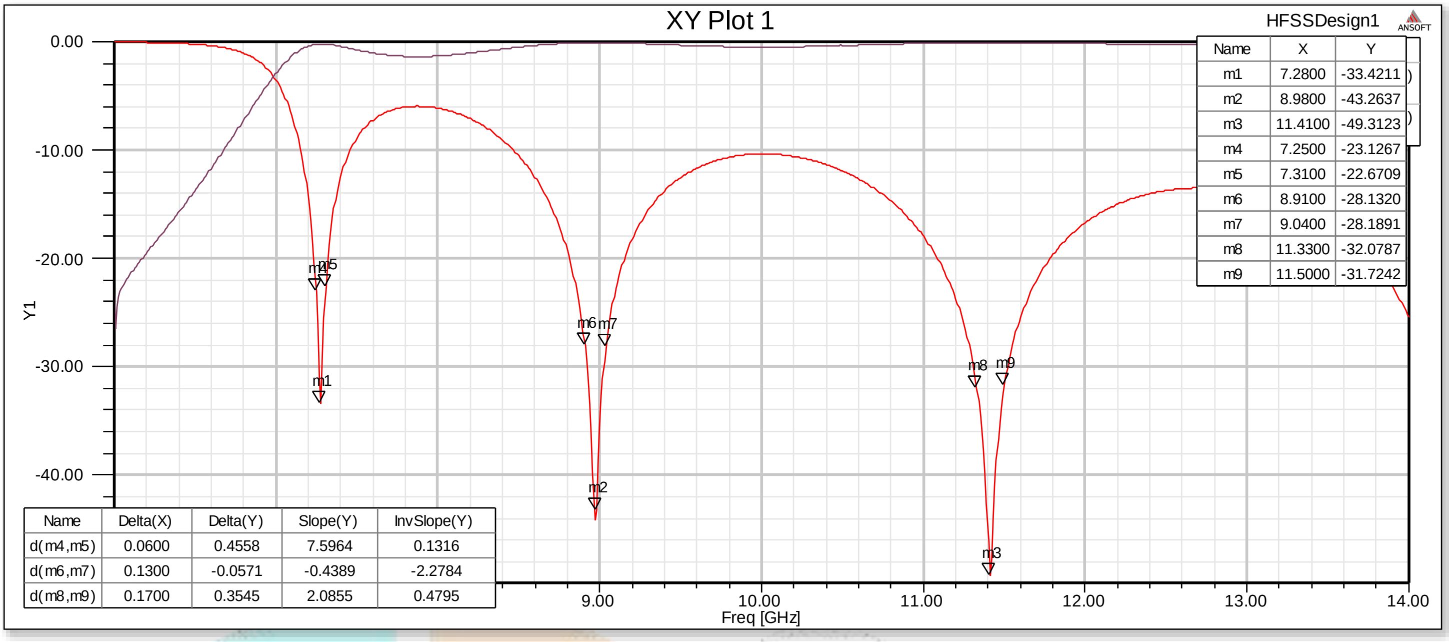

Fig4: Plot of Frequency v/s Return Loss(RL)

Result analysis: From the figure 4 it is observed that the return loss is below -20dB for three sets of frequency band and all lie in X-band (8 to 12 GHz).First band of frequency is from 7.25 GHz to 7.31 GHz, second band of frequency is from 8.91 GHz to 9.04 GHz and third band of frequency is from 11.33 GHz to 11.5 GHz. Meaning the designed SIW with specific parameters transmits these three bandwidth of frequencies without any return loss. And insertion loss is 0 dB in the operating frequency band. Thus, SIW acts as perfect transmitting medium.

3. Analysis after variation of design parameters

Parameter name	Value1	Value2	Value3
sa	25mm	25mm	25mm
L	30mm	30mm	30mm
sb	0.508mm	0.508mm	0.508mm
ar	15.77mm	10.77mm	10.77mm
d	1mm	1mm	1.3mm
pitch	2mm	2mm	2mm

Table 2: comparison of values of parameters for designing SIW

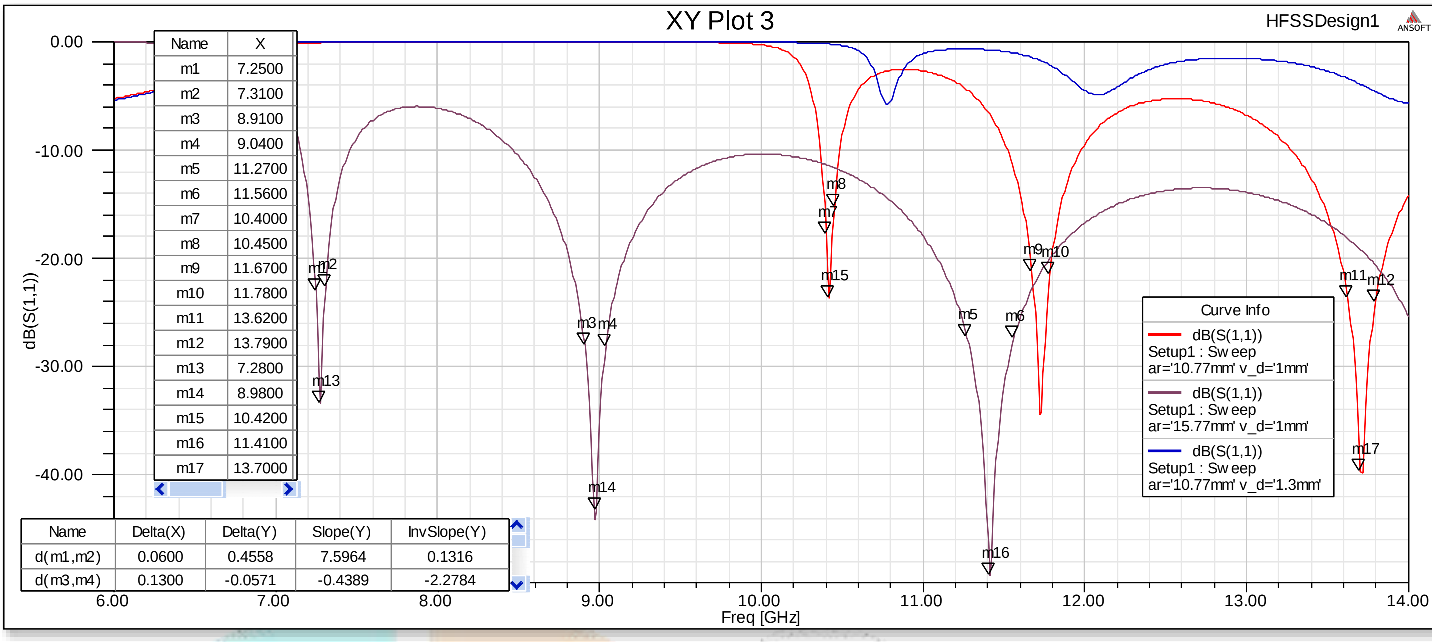

Figure 5: Plot of Frequency v/s Return Loss(RL) for different parameters

Result analysis: In the above figure 5, the black colored plot is traced for the value1 in table 2. Red color plot is traced for the value 2 in table 2. And blue color plot is traced for value 3 in table2. In the blue colored plot, the RL loss is above -20 dB at every frequency. Thus, on increasing the diameter of the via does not give optimal result and no frequency gets transmitted.

Results	band	f1(GHz)	f1(GHz)	Return Loss(RL)	Return loss Bandwidth (MHz)
Value1	Band1	7.25	7.31	-22 dB	60
	Band2	8.91	9.04	-28 dB	130
	Band3	11.27	11.56	-27 dB	290
Value2	Band1	10.4	10.45	-24 dB	50
	Band2	11.67	11.78	-34 dB	110
	Band3	13.62	13.79	-40 dB	170

Table3: Results of Return Loss and Bandwidth

Result analysis: From table 3 it can be observed that, with the decrease in the center to center via separation from 15.77mm to 10.77mm the frequency band shifts from X-band (8GHz to 12 GHz) to Ku-band (12GHz to 18GHz). Thus, by appropriate variation in different parameters increasing range of frequencies can be obtained moving to operation in higher bands.

4. Benefits of Using SIW over Waveguide

According to the observation SIW can be utilized for multiband frequency operation while a waveguide works on single operating frequency. Apart from this SIW has benefits of higher power density, low radiation losses, high density integration, low cost of fabrication and because if its planar nature it is easy to implement and fabricate on PCB.

5. Conclusion and Future Work

A Review on Substrate Integrated Waveguide and Its Nature of supporting Multiband frequencies shows that using suitable techniques a nonplanar dielectric filled waveguide can be converted to planar SIW. From simulation results of demonstrated example of SIW, it can be concluded that, SIW works in X-band frequency and by certain modifications it can be made work on higher frequency range with multiband operation. It can be seen that the E-field is within the SIW (figure 2) indicating no leakage of radiation. For low loss performance, excellent power handling capacity and millimeter technology the future work on Air Filled Substrate Integrated Waveguide is preferred.

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