RADIATION CHARACTERISTICS of 4 ELEMENT SLOTTED WAVEGUIDE ARRAY

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Abstract:

This paper gives an insight on Rectangular SWA.To achieve enhanced performance of the waveguide, slots are introduced in the proposed model. It is designed to operate in the frequency range of 2GHz to 4GHz which falls under S-Band, while the operating frequency is chosen to be 3GHz. A radio wire has been implanted on the WR284 substrate with a dimension of 72.136mm*34.036mm.Design and analysis procedure is performed through the commercially available CST, which is in good agreement with experimental results. Simulated results show the far field radiation and directivity at the operating frequency.

Keywords:*Rectangular slotted waveguide antenna, S-Band,WR284 substrate,far field radiation.*

1. INTRODUCTION

Microwaves are typically a form of EM waves with the wavelengths of the order one meter to as short as one millimeter or equivalently frequency between 300MHz to 300 GHz. A waveguide is a hollow conducting tube like structure used to propagate EM waves from one place to other. In fact, any group of conductors and insulators for transporting electromagnetic waves could be called a waveguide, but it is customary that specially constructed hollow metallic pipes are usually referred to as waveguide. Copper, aluminium and brass or any metal with low restivity are best suited for a waveguide. It is also feasible to utilize metals with poor conductivity characteristics as the interior walls of waveguide. It is also possible to design a dielectric waveguide. Waveguides replaces transmission lines in microwave frequency range because they are relatively less lossy. Due to their power handling capacity and ease of integration with highly directive horn antennas, hollow (air filled) waveguides are extensively appreciable to use.[1]

Mode means electromagnetic wave inside the waveguide which have infinite number of patterns. In H or TE mode, E-Field is transverse or perpendicular to the axis of the guide at every location inside the waveguide. In E or TM mode, H-Field is transverse or perpendicular to the guide axis.Rectangular waveguides are the one of the types of the waveguide, with a wide range of applications. Several microwave components like isolators, detectors, attenuators, couplers and slotted lines are available for various standard waveguide bands between the spectrum range of 1 GHz to above 220 GHz.A rectangular waveguide supports E and H modes but not TEM waves because of no possibility to define a unique voltage since there is only one conductor in a rectangular waveguide.

2. SLOTTED WAVEGUIDE

SWA arrays are predominantly used with waveguides are very fesiable structures in navigation, Radar and high frequency systems.These are well known for their ease of fabrication, high antenna efficiencyand radiate linear polarization with low cross-polarization [2]. These antennas are often used in aircraft applications because they can be made to conform to the surface on which they are mounted. The slots are typically thin, usually less than 0.1⅄ and 0.5 ⅄ long[2]. Radiation characteristics of rectangular SWA are highly dependent on theposition, shape and orientation of the slots will determine how they radiate. In addition, the shape of the waveguide and frequency of operation will play a major role.

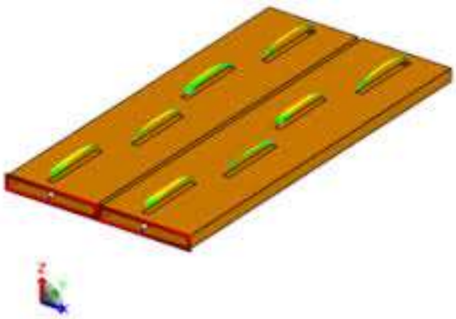

Fig. 1: Slotted Rectangular waveguide

Slotted waveguide antenna offers valuable advantages in terms of their design, weight, volume, power handling, directivity and efficiency [3].The inherent disadvantage of that technology is the lowimpedance data transfer capability, which limits its own use to support high resolutions SAR frameworks for general military applications. When focusing on SWA space applications, a decrease in the thickness is appreciable. SWA'sresonate depending on the mechanism of propagation within the waveguide.

3. DESIGN CALCULATIONS

In this design, WR284 substrate is used within S band with a center frequency of 3GHz. All the calculations are done with respect to the center frequency. In order to design a rectangular slotted waveguide antenna there are certain parameter to be calculated with the help of some standard mathematical equations. The dimensions of the rectangular waveguide are as follows a = 72.136mm and b= 34.036mm. Distance between two equal phase planes along the waveguide is known as guide wavelength. It is a function of the operating wavelength (or frequency) and the lower cut off wavelength, and iscalculated according to the following formula [3-4]

$$\lambda g = \frac{c}{f}\frac{1}{\sqrt{1-\frac{c}{2af}}} \qquad (1)$$

$$\lambda g = \frac{3*10^8*10^3}{3*10^9}\frac{1}{\sqrt{1-\frac{3*10^8*10^3}{2*72.136*3*10^9}}}$$

$$\lambda g = 180mm$$

Slot lenth is designated as 'L' and width of the slot is designated with the letter 'W'. The center of slot 1 is at a distance of 0.5 times of guide wavelength from the feeding side of waveguidei.e., λg⁄2. The center of slot 4 is implanted at a distance of 0.25 times of guide wavelength from the short-circuited side of the waveguide i.e., λg⁄4. By taking several references regarding slot width into consideration, it is calculated as below:

$$\text{Slot width} = a * \frac{0.625}{0.9} \qquad (2)$$

=72.136 *(0.625/0.9)
= 5mm

Here in this design, typically four slots are introduced in the substrate. All the four slots are at equidistant with respective to their mid locations i.e., the separation distance between each slot is λg⁄2.

For given number of slots (N), the slot displacement is mathematically given by [5-7]

$$du = \frac{a}{\pi}\sqrt{arc \sin\frac{1}{NG}} \qquad (3)$$

$$G = 2.09 * \frac{a}{b} * \frac{\lambda g}{\lambda_0} * [\cos(0.464\pi * \frac{\lambda_0}{\lambda g}) - \cos(0.464\pi)] * 0.0003^2$$

In the above formula, λ_0 is known as free space wavelength. The values of $\frac{\lambda g}{\lambda_0}$ and $\frac{\lambda_0}{\lambda g}$ are 1.18 and 0.555 respectively. Hence from the calculations the value of G is obtained as $4.206*10^{-6}$and by substituting this value in equation 3, the value of slot displacement can be determined. It is 25.45mm in this case. Figure 2 shows the proposed model of the 4 slotted rectangular waveguide antennas.

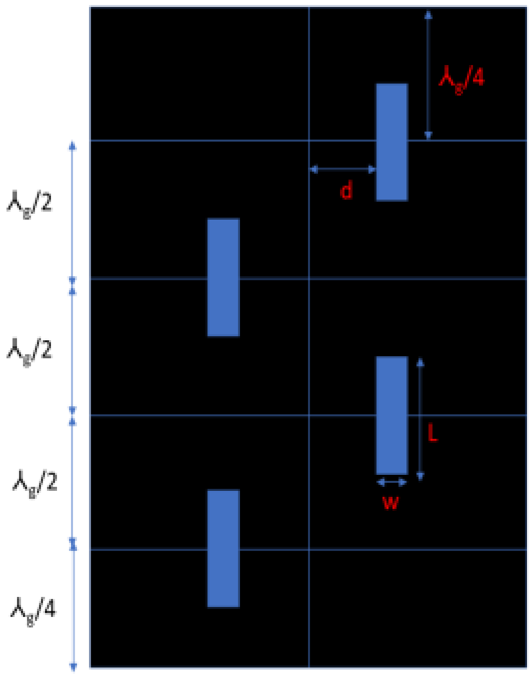

Fig. 2: Slotted Waveguide Antenna with 4 slots

4. RESULTS AND DISCUSSIONS

The proposed model is designed and simulated using a commercially available CST software. As the major concentration of this design revolves around the far field radiation and directivity, all the other parameter such as impedance bandwidth, standing wave ratio etc were given a less preference.

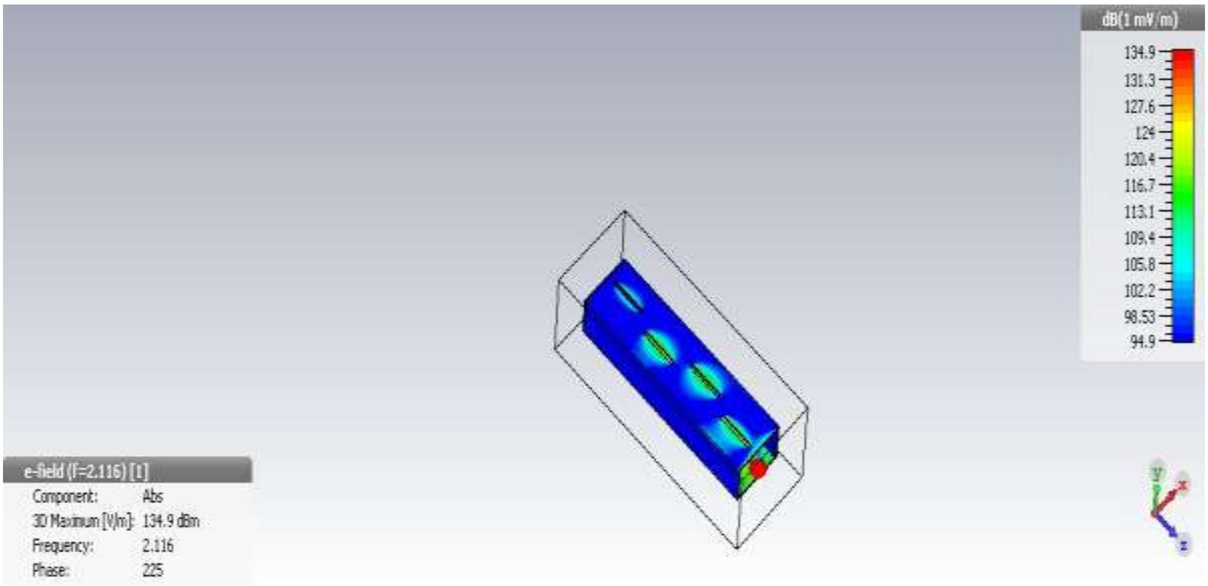

Fig.3:Rectangular Slotted Waveguide Antenna

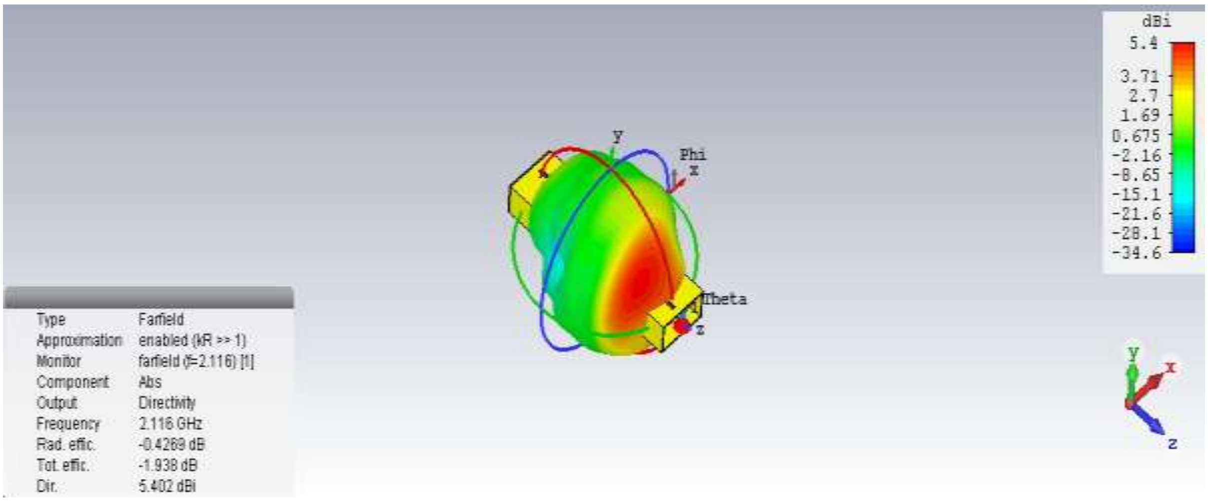

Fig.4:Directivity of a Rectangular Slotted Waveguide Antenna

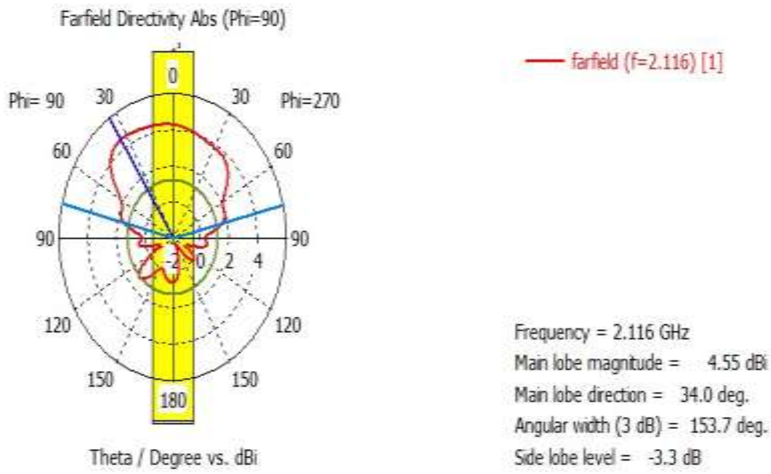

Fig.5:Radiation pattern of a Rectangular Slotted Waveguide Antenna

The below tabular data gives and glimpse regarding the results of the rectangular slotted waveguide antenna.

Parameter	Value
Radiating Frequency	2.116GHz
Main Lobe Magnitude	4.55dBi
Main Lobe Direction	34^0
3 dB Beamwidth	153.7^0
Side Lobe Level (SLL)	-3.3dB

Table 1: Results

From the table, it is clearly evident that the directivity of the proposed model is about 4.55dB with reference to an isotropic antenna. It is also displaying an appreciably good 3dB Beamwidth. Side lobe level can be further improved by using some advanced optimization techniques.

5. CONCLUSION

Hence in the endeavour, an attempt has been made to design a slotted waveguide antenna with minimal number of slots. The proposed model can find its applications in S band range like aircraft applications. Still there is lot of scope to improve the side lobe level and directivity by increasing the number of slots with appropriate optimization techniques. A good agreement should be maintained with respect to return loss, directivity, 3dB Beamwidth in order to expand its wings several other fields of applications.

6. REFERENCES

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