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Design of Slotted Waveguide Antenna for Radar Applications at X-Band

S. Murugaveni[1]
[1]Assistant Professor,
Department of Telecommunication Engineering,
SRM University, Kattankulathur – 603203,
Chennai, India.

T. Karthick[2]
M.Tech,[2]
Department of Telecommunication Engineering,
SRM University, Kattankulathur – 603203,
Chennai,India.

***Abstract* --A slotted waveguide antenna has been designed for radar applications at X-band, 9.47 GHz. Slotted waveguide antennas are mostly employed in Radar applications. This paper analysis the structure and design procedures of slotted antenna in the broad wall. This design specifications are chosen for high gain and mechanical robustness. The slotted waveguide antenna designed is a directional type antenna with gain of 16db. We first obtain the physical size of each slot by using parameter sweep function Ansoft High Frequency Structured Simulation (HFSS) software. Then we created a complete model. Finally we perform the simulation and compare against the design requirement. There is a good agreement between simulation and design requirement.**

INTRODUCTION

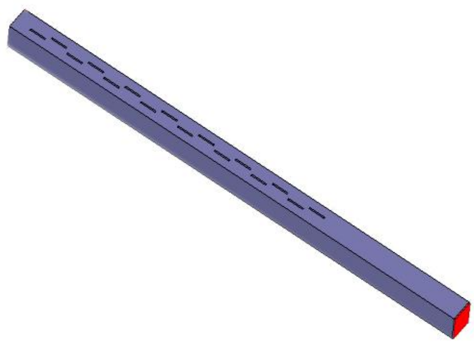
As the name suggest, Slotted waveguide antennas consist of waveguide with multi number of slots. Slotted waveguide antenna has no reflectors, but it emits directly through the slots. The spacing of the slots is critical and is a multiple of wavelength used for transmission and reception. The dominant mode in a rectangular waveguide with dimension a > b is the TE10 mode.

Depending upon the desired field polarization, the slots can be placed in either narrow wall or in broad wall of the waveguide. At the fundamental TE10 mode, longitudinal slots on the broad wall will produce a field with vertical polarization, while transverse slots on the narrow wall will produce horizontal field polarization [1]. For each design, the polarization depends upon the specific antenna use.

The HFSS is a software package analysis modeling and analysis of 3 dimensional structures. HFSS utilizes a 3D full wave finite element method to compute the electrical behaviours of high frequency and high speed components. The HFSS is more accurately characterizes the electrical performance of components and effectively evaluates various parameters. It helps the user to observe and analyze various performance of electromagnetic properties of structures such as propagation constant, characteristic port impedance, generalized S parameters are normalized to specific port impedance. The HFSS software is designed for extracting model parameters by simulating passive devices.

I MATHEMATICAL MODELING

The dominant mode in a rectangular waveguide with dimension a > b is the TE10 mode. Dominant mode is always a low loss, distortion less transmission and higher modes result in significant loss of power and also undesirable harmonic distortion. The standard length of the wave guide is shown in the figure where the slot length is around half of the wavelength over the air, $\lambda/2$. The slots are milled onto a standard waveguide wr90 with inner waveguide dimension of 22.86 × 10.16 mm arranged in two vertical columns offset from the centre which acts as an array of slots[3,0]. The slots are placed at the centre of the waveguide to the right and left sides alternately. Width of the slots is around $\lambda_g/20$ and slots offset from the centre are around 3.6 mm. In this case, 16 slots were cut on this waveguide.



The cut-off frequency of TE10 mode is given by

$$f_c = \frac{1}{2\sqrt{\mu\epsilon}} * \sqrt{\frac{m^2}{a^2} + \frac{n^2}{b^2}}$$

m,n =0,1,2… m=n ≠ 0 (1)

The guided wavelength λ_g in the waveguide is given by

$$\lambda_g = \frac{\lambda}{\sqrt{1-(\frac{f_c}{f})^2}} \quad (2)$$

For $f>f_c$

Where λ is the wavelength (unbounded dielectrics).

The range of greatest use in the design of slot array is 0.95< l/lr< 1.05 where l is the slot length and lr is the slot resonant length given by $\lambda_g/2$. Initially a slot of width is considered as 1.6mm and the obtained curve results in the following equation

l = 0.2032*x + 9.816.

The above equation is an important relation which gives the relationship between the slot resonant length and slot offset.

In this design, we use the following formulations to predict the values of slot resonant conductance, which were normalized to the waveguide impedance, and were obtained based on transmission line theory and waveguide model green theory. The conductance of the longitude shunt slot can be expressed as.

$$g=g_1 \sin^2\left({}^{d\pi}/_{a}\right) ; \quad (3)$$

$$g_1=\left(2.09\ a\ \lambda_g/b\lambda\right)\cos^2\left({}^{\lambda\pi}/_{2\lambda_g}\right) \quad (4)$$

In (3), d is the slot displacement from the waveguide center-line, and a and b are the width and height of the waveguide.

II NUMERICAL RESULTS

Numerical results of return loss, gain and radiation patterns are shown in this section. In particular, Figure 2 shows the return loss of the slotted antenna and Figure 3 shows the gain of the slotted antenna.

Table 1. Antenna parameters

Parameters	Simulated
Frequency range	9.4 to 9.5 GHz
Return loss	>10
Gain	16 db
Polarization	Horizontal

Without Reflector

The return loss achieved for slotted waveguide antenna is shown in the figure 2. This return loss shows that SWA almost achieve the required specification of more than 10 db.

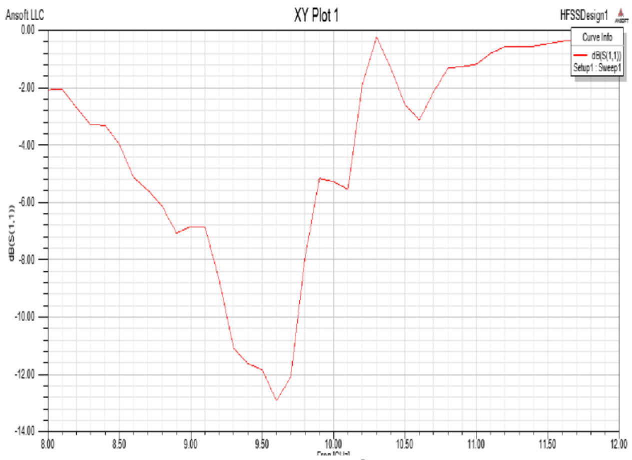


Fig.2 Return loss

Radiation pattern of the slotted waveguide antenna is shown in the figure 3. The max gain obtained here is 16 db.

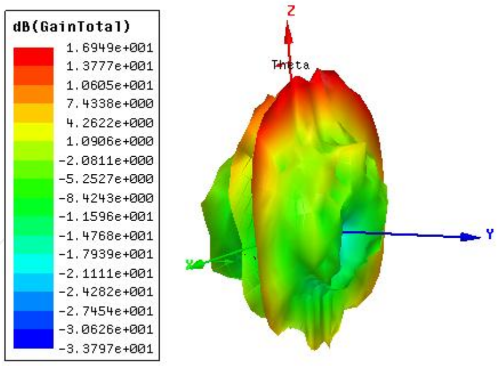


Fig.3 3D radiation pattern

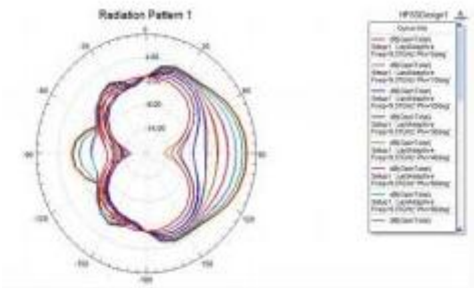


Fig.4 Radiation Pattern

With Reflectors

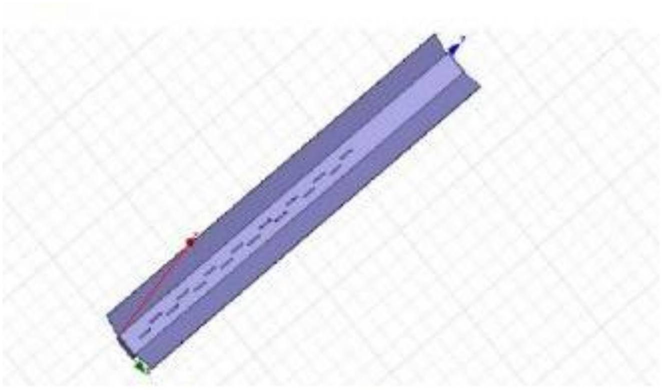


Fig.5 SWA with reflectors

The return loss achieved for slotted waveguide antenna is shown in the figure 2. This return loss shows that SWA with
reflectors are almost achieved the required specification of more than 22.5db.

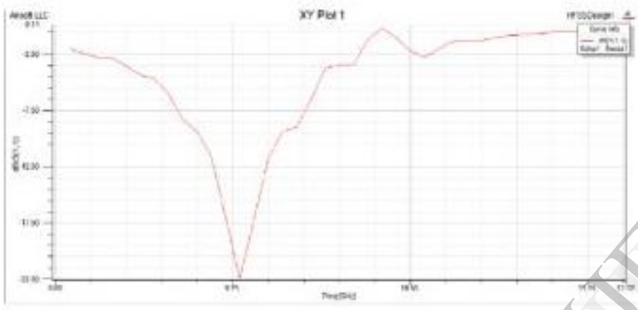


Fig.6 Return loss with reflector.

Thus when comparing to without reflector, the Return loss and
gain obtained by reflector design will be good in comparison.

Fig.7 3D Radaition Pattern.

III CONCLUSION

This paper presents the design and simulation of slotted waveguide antenna of 9.47 GHz used for radar applications. Characteristics of return loss and gain of the SWA for X Band are presented, such that it will be useful for practical implementations. In overall, the simulated results correlate with the required results. It shows that HFSS software helps up to predict the performance of SWA in less time without any physical equipment.

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