Study of the Variation of Power Loss with Frequency along a Rectangular Waveguide for TE $_{10}$ mode due to Conductor Attenuation

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Abstract: **Nowadays microwave communication is an important part in modern telecommunication systems. Microwave travels through waveguides. So loss within a waveguide is a vital matter of concern. In this paper, successfully observed a rectangular waveguide and its powerloss i.e. attenuation variation with the change of microwave frequencies(X-Band) for TE_{10} mode. A simulation is also done using MATLAB platform. For this the b/a ratio of the rectangular waveguide is selected to be 0.5 and also found out the result with other values b/a ratios of 0.2, 0.8.**

Keywords: Rectangular Waveguide, TE_{10} mode, Power Loss variation, X-band Frequency

I. Introduction

Losses in two conductor lines increase with frequency.Hence Microwaves are transmitted through hollow metallic tubes (waveguides) of uniform cross section with minimum loss[1]. If the waveguide walls are not perfectly conducting, there exists a tangential component of electric field and normal component magnetic field at the walls. This results in average power delivered to the waveguide walls and dissipated in it and hence continuous attenuation of propagating electromagnetic waves.[2] Here we will study the variation of conductor attenuation with frequency.

II. Conductor Attenuation In Rectangular Waveguides

If $\vec{H}_t$ and $\vec{E}_t$ are the tangential components of electric and magnetic fields then power loss per unit guide length is given by

$$P_L = \frac{1}{\Delta z}\frac{1}{2}\mathrm{Re}\oiint_{S1}\left(\vec{E}_t \times \vec{H}_t^*\right)d\vec{S}_1 \qquad (1)$$

Δz is the length element

(1)

Since $\vec{E}_t$ results from the flow of current due to $\vec{H}_t$ and the direction of current flow is normal to $\vec{H}_t$,hence $\vec{E}_t$ and $\vec{H}_t$ must be at right angles[8]. The ratio of tangential magnetic field may be defined as high frequency conductor impedance The power loss per unit length of the guide is the space rate of decrease of power flow, or

$$P_L = \alpha_c Z_o \oiint_{S1}\left|H_o\right|^2 e^{-2\alpha_c z}ds \qquad (2)$$

Above equation is the fundamental equation and may be used to evaluate attenuation arising from imperfect conducting walls. However, the problem of evaluating P_L seems to be a difficult one at the outset because the loss depends upon the field configuration within the guide , and the field configuration in turn, depends to some extent ,upon the losses[3][7]. We first write the equations for the electric and magnetic fields as though the guide were loss-less. Since the walls of the guide are assumed to be perfectly conducting, the tangential component of the electric field at the guide walls in zero[5]. However, there will be a tangential component of magnetic intensity which is terminated by a current flowing on the surface of the conductor. If we now assume that the guide walls are imperfectly conducting, the tangential component of magnetic and hence P_L may be evaluated[6].

We find that the attenuation constant arising from guide walls is given by

$$\alpha_c = \frac{R_S \oiint_{S1}\left|H_t\right|^2 ds_1}{2Z_o \oiint_{S1}\left|H_T\right|^2 ds} \qquad (3)$$

The numerator of above equation is evaluated at each conductor surface whereas in the denominator it is over cross-section of the waveguide[4].

We now proceed to find α_c for few waveguide modes.For TM_{mn} Mode since $H_{z=0}$ in this case,

$$\alpha_{c(TM)} = \frac{R_S \lambda_c^{\,2}\left(\frac{n^2 a}{b^2}+\frac{m^2 b}{a^2}\right)}{2\eta ab\sqrt{1-\left(\lambda/\lambda_c\right)^2}} \qquad (4)$$

Or, if we use

$$\lambda_c = \frac{2ab}{\sqrt{n^2a^2+m^2b^2}}$$

$$\alpha_{c(TM)} = \frac{2R_s}{b\eta\sqrt{1-\left(f_c/f\right)^2}}\frac{m^2\left(b/a\right)^3-n^2}{m^2\left(b/a\right)^2+n^2} \qquad (5)$$

Similarly, the expression for $\alpha_{c(TM)}$ may be obtained as

$$\alpha_{c(TE_{mn})} = \frac{2R_s}{b\eta\sqrt{1-\left(f_c/f\right)^2}}\left[\left(1+\frac{b}{a}\right)\left(\frac{f_c}{f}\right)^2+\left\{1-\left(\frac{f_c}{f}\right)^2\right\}\left\{\frac{\frac{b}{a}\left(\frac{b}{a}m^2+n^2\right)}{\left(b^2m^2/a^2\right)+n^2}\right\}\right] \qquad (6)$$

For TE_{10} mode [2],[4] carriers and b/a=2 (substitute m=0 and n=1 in Eq.6)we get,

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$$\alpha_{c(TE_{10})} = \frac{R_S\left[1+\frac{2b}{a}\left(\frac{f_c}{f}\right)^2\right]}{\eta b\sqrt{1-\left(f_c/f\right)^2}} \quad (7)$$

III. SIMULATED RESULTS OF WAVEGUIDE ATTENUATION VARIATION WITH FREQUENCY FOR A PARTICULAR MODE (TE_{10} MODE)

Based on the theoretical discussion I have done a MATLAB program to find out the attenuation of a particular mode(TE_{10})as it flows along the waveguide. For this I have selected a b/a ratio of the rectangular waveguide equals to 0.5 and also found out with other values b/a ratios of 0.2, 0.8. I have varied the frequency from 6.5 GHz to 14 GHz [f_c =6.562GHz].

The simulated graph is shown below:

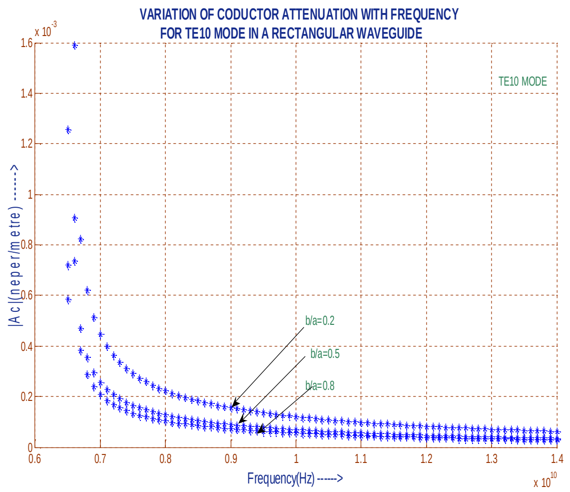

Fig.1 Variation of conductor attenuation with frequency for TE_{10} mode in a rectangular waveguide for different b/a ratios

IV. EXPERIMENTAL ANALYSIS OF WAVEGUIDE POWER LOSSES VARIATION WITH FREQUENCY FOR A PARTICULAR MODE(TE_{10} MODE)

A experimental demonstration was then performed to analyse the conductor attenuation that occurs as an transverse electromagnetic wave propagates within the waveguide. So a experiment in the microwave laboratory was done, the details of which is given below-

A. Apparatus used:

Gunn oscillator, Isolator, Pin modulator, Frequency Meter Variable Attenuator, Rectangular waveguide (Brass Material)Matched Termination, Tunable Detector, Power Meter, CRO,SWR Meter, Coaxial to waveguide adapter

B. Procedure

The main aim was simply to find variation of output power with frequency. For that purpose I chose the Gunn oscillator as a source of microwave power. This microwave power is then fed to the waveguide section as shown in the fig.2 below:

The Gunn bias was set at 8.7mV. In the slotted line section, the probe was tuned for maximum reading in dB on SWR meter. Then I tuned the frequency meter to get a 'dip'(minimum reading) on CRO display and note down the frequency directly from frequency meter. Next I detuned the DRF Meter .We confirm this frequency also by using the slotted line method of measuring frequency from the relation $\lambda_g=2(d_1-d_2)$and thereby from eqn

$$f = \frac{c}{\lambda_0} = c\sqrt{\frac{1}{\lambda_c^2}+\frac{1}{\lambda_g^2}} \quad (8)$$

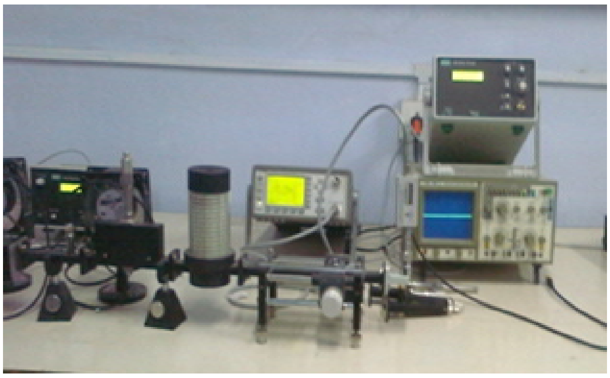

Fig.2 Power Loss measurement setup

A waveguide to coaxial adapter was then substituted in place of matched termination and connected it to the power meter. The power was directly observed from the power meter at that frequency. The steps above are repeated and we observe the power variation for X-band frequency of operation and b/a ratio=0.5. The change of power output to the power input gives the power loss. I plotted the Power loss Vs Frequency graph. The freq and powerloss values I measured is given below-

TABLE I
POWER LOSS VS FREQUENCY VARIATION

Frequency (GHz)	Power Loss (dBm)
11.4	29.67
11.2	26.9
11.02	25.98
10.86	29.07
10.68	30.9
10.59	30.64
10.41	35.4
10.32	35
10.23	35.1
10.08	35.12
9.97	35.21
9.97	35.21
9.7	35.55
9.26	38
9.049	53.53

9.038	57.83
9.026	62.16
9.02	61.9
9.007	61.15
8.94	61.37
8.91	61.37

After placing this readings , the graph obtained is given below:

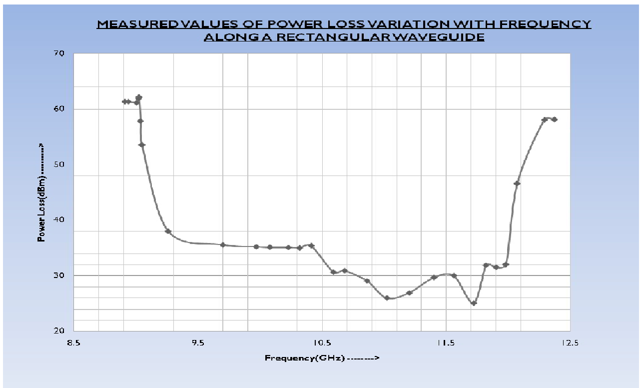

Fig.3 Measured values of Power Loss variation with frequency along a rectangular waveguide

V. CONCLUSIONS

This graph does not have much of deviation from the graph obtained from the MATLAB programming except a little change due to the experimental error of human and also due to those instruments used. Now as we can see from the graph that the power loss within the wave guide is minimum when the frequency ranges from 9.5 to 12 GHz. More precisely we can say at 11.7 GHz frequency it meets minimum losses .The losses encountered accounts for the various attenuation losses that occurs within the waveguide. Here since the dielectric is air ($€_r$=1),we can say this attenuation is primarily the conductor attenuation.

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Biswajit Ghosh, born in India, obtained his M.Tech(ECE) in Microwave Engineering from the University of Burdwan, in 2008.After that he joined Birbhum Institute of Engineering & Technology (Govt. Aided Institution), Suri. He is currently designated as Asst. Professor in the Electronics & Communication Department and in charge of up gradation of the Microwave Laboratory and is also engaged in teaching and research in the areas of Microwaves, Electromagnetics and Antennas. He is a Life Member of the Society of the EMC Engineers (India), The Indian Society for Technical Educations (ISTE), Indian Society of Remote sensing (ISRS), The Indian Science Congress Association (ISCA), International Association of Engineers (IAENG), Indian Society of Electronics & Communication Engineers (ISECE), International Association of Engineers and Scientists (IAEST).