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Simulation Of Rectangular Waveguide In Ku Band For Varying Magnetic Field

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Abstract: *Rectangular waveguide is a very promising structure for different applications. It has some unique characteristics that allow for wide range of application including slow and fast light, meta-material, low loss energy transmission, and sensing. The resemblances and differences between this waveguide configuration and metal-insulator-metal (MIM) are discussed in this paper.A Description of the guided modes and their operating band is also given. We also studied the characteristics of the fundamental TM-like mode of this structure for the first time. Its potential application in sensing and low loss energy transporting is also demonstrated. The effect of the design parameters on the performance of the rectangular waveguide is illustrated for different application. Slow light and negative refraction effects using this waveguide design using TE-like mode is also demonstrated. Different designs are proposed using this structure for these different applications. Square shape design allow for polarization insensitive applications which is one of the unique characteristics of the configuration. To observe the EM field characteristics for a rectangular waveguide and observe the interaction efficiency as a function of varying magnetic field. The design of rectangular waveguide operation at Ku band for a high power is done. The effect of input voltage for this purveyance is observed minutely to see transfer of energy from beam to waveguide in EM field. The different pattern of magnetic field lines are applies finally to observe changes in output with same purveyance.*
Keywords: *Rectangular Waveguide, Ku Band, MIM, TE and TM mode, EM field, SWS, BWO.*

I. Introduction

The main aim of the project is to observe the EM field characteristics for a rectangular waveguide and to observe the interaction efficiency.We are using here 2D sheet beam.The design of rectangular waveguide operation at Ku band for a high power is done.The input parameters are input current,inputvoltage,velocity, group velocity, phase velocity and pierce impedence .The output parameters is power.

Overall efficiency of high power microwave generating device depends upon input current in the form of electron beam and currents required for electromagnets. In order to increase the efficiency of device, if electromagnets are replaced by permanent magnets, overall efficiency of device shall increase. So, calculation of exact magnetic field is required. In this paper, the exact relation of magnetic field required in high power microwave generation using Backward Wave Oscillator (BWO) is found. BWO interacts with slow waves and is the most promising device to produce high power microwaves. The interaction involves the beams from high current density and the waveguide mode. An exact relation that specifically relates the various parameters of the waveguide like slow wave structures (SWS) dimensions, input beam voltage and operational frequency with axial magnetic field is derived. The derived equation gives calculation of exact values of magnetic field for focusing of beams. Theoretical and simulated work show good agreement with the previously available experimental data. So, with the derived electromagnetic wave relation exact value of magnetic field is calculated for desired frequency and power regime.

The proper combination of frequency, power and compactness cannot be separated under any circumstances. In reference, an extensive overview for generation of different kinds of electromagnetic waves for various modern and strategic applications is mentioned extensively. In the reference, it was compactness that started to find practical possibility. Clear theories on waveguide modes with dispersion characteristics were made. At the same period, variousother aspects to search every aspect in order to improve efficiency were done. A very fundamental relation, that classifies the arrangements of magnets is mentioned i.e. wiggler or PPM, has experimentally shown that efficiency can be significantly be improved with wigglerarrangements. This is shown through simulation. The calculation of exact value of magnetic field with the derived relation will lead to finite application of magnetic field.

Advanced axial magnetic field equation:

For high current electron beam transport, solenoid magnets are applied conventionally. Most uncommonly, the beam will remain within the magnetic field throughout acceleration and transport processes. More commonly, electron source is outside the magnet. We thus have the electron source outside and for high current electron beam transport, we wish to make use of permanent magnets that require no current to become functional. It is thus essential to understand the motion of electrons in transition region between magnetic field and free space. If a finite length magnetic field is applied then magnetic field will drop over a distance, i.e. beyond the point where force ceases to exist. So, to reduce the transition region, or to decrease the area where the magnetic field effect seen is same, opposite field polarity know as magnetic cusp can be applied. Actually, the opposing current leads to the generation of magnetic field that consequently creates strong radial fields in narrow intervening regions. We must note that total energy of electrons is constant, the force arises from static magnetic field. Deflection results from Vz x Br force. When a particle is into a perpendicular magnetic field, it starts to follow a path of closed circle due to magnetic field effect. There is a sideway force known as Lorentz force.

II. Literature Review

Sr. No.	Year	Name	Article	Significance
01.	2014	Tusharika Sinha Banerjee	Review On Microwave Generation Using Backward Wave Oscillator	High mm conventional magnetic field are used
02.	2015	Tusharika Sinha Banerjee	Numerical Solution Of Exact Axial Magnetic Field For Planar And Cylindrical Beam Driven Backward Wave Oscillator	Waveguide field relation with axial magnetic field
03.	2016	Tusharika Sinha Banerjee	Electromagnetic Wave Theory For Calculation Of Exact Magnetic Field In Case Of BWO	BWO is promising device for generation of power in MW
04.	2016	Tusharika Sinha Banerjee	Understanding The Focussing Of Charged Particle For 2D Sheet Beam In A Cusped Magnetic Field	Here 2D planer sheet beam has lesser space charge effect
05.	2013	Zhanliang Wang, Yubin Gong, Yanyu Wei, ZhaoyunDuan, Yabin Zhang, Linna Yue,Huarong Gong, Hairong Yin, Zhigang Lu, Jin Xu, and Jinjun Feng	High-Power Millimeter-Wave BWO Driven by Sheet Electron Beam	For recatangular waveguide dimensions

III. Indentations And Equations

The axial magnetic field is related to the maximum changed thickness t' of the sheet beam.

It is dependent on space charge length L along the axis of propogation (z here). The requirement of axial magnetic field is infinity if the positioning of magnets are at maximum changed value of t(L=t') or if the beam is allowed to spread as much as possible under given set of operating conditions. The above expression gives a clear understanding on permissible beam spread or allowed change in thickness of sheet beam. It is

evident that at 25% of Lmax, the beam requires thrice axial magnetic field than at 50 % value of Lmax .However, very small change in the value of axial magnetic field is observed at 75% value of Lmax as required at 50% of Lmax .This indicates the positioning of magnets should be somewhere between 50% to 75% value of Lmax.The requirement of axial magnetic field is infinity at 100% value of Lmax.Also,the positioning of magnet should be avoided beyond 90% of Lmax,else large requirements of magnetic field will be there.It is true that the magnets should be placed as far as possible to avoid bulkiness but the beam quality will be compromised with positioning of magnet beyond 50% as evident from the above expression. Since, the reduction

in axial magnetic field by three times is observed at 50% , for optimum outputs, 50% of Lmax can be chosen as the position where magnets should be placed. However the choice of length can go upto 80% if bulkiness is the major criteria.

IV. Software Description

Cst Microwave Studio®(Cst® Mws®) is a specialist tool for the 3D EM simulation of high frequency components. CST MWS' unparalleled performance is making it first choice in technology leading R&D departments.CST MWS enables the fast and accurate analysis of high frequency (HF) devices such as antennas, filters, couplers, planar and multi-layer structures and SI and EMC effects. Exceptionally user friendly, CST MWS quickly gives you an insight into the EM behavior of your high frequency designs.CST promotes Complete Technology for 3D EM. Users of our software are given great flexibility in tackling a wide application range through the variety of available solver technologies.

Beside The Flagship Module, The Broadly Applicable Time Domain Solver And The Frequency Domain Solver, CST MWS Offers Further Solver Modules For Specific Applications. Filters For The Import Of Specific CAD Files And The Extraction Of SPICE Parameters Enhance Design Possibilities And Save Time. In Addition, CST MWS Can Be Embedded In Various Industry Standard Workflows Through The CST STUDIO SUITE® User Interface.CST MICROWAVE STUDIO® Is Seen By An Increasing Number Of Engineers As An Industry Standard Development Tool.

CST Offers Accurate, Efficient Computational Solutions For Electromagnetic Design And Analysis. Our 3D EM Simulation Software Is User-Friendly And Enables You To Choose The Most Appropriate Method For The Design And Optimization Of Devices Operating In A Wide Range Of Frequencies.

CST STUDIO SUITE Is A Software Package Which Can Simulate And Solve All Electromagnetic Problems From Low Frequency To Microwave And Optic As Well As Thermal And Some Mechanical Problems.

It Has Generally 7 Studios:

1- Microwave Studio: for RF and Microwave problems like antenna design
2- EM Studio: for low frequency problems like RFID, electrostatics, magnetostatics, etc.
3- Design Studio: a schematic workflow to design lumed circuits and also join the results of the other studios in order to design a system assembly
4- Particle Studio: for particles and beam simulation like e-Gun, microwave tubes, etc.
5- MPHYSISCS Studio: for some mechanical and thermal simulations
6- Cable Studio: for design and simulation of cables in bundle, harness, etc.
7- PCB Studio: for simulation of PI and SI in multilayered PCBs.

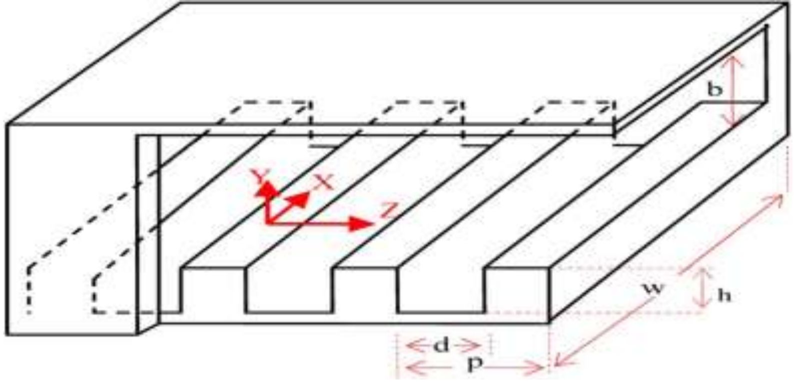
Software Specifications :

We are using CST (Computer Simulation Technology) Software.The version we are using is CST 2014 Student Version using PIC(Particle in Cell) code. We will be using CST 2017 student edition in the next semester.

CST provides accurate 3D simulation of high frequency devices and leader in time domain simulation. Native graphical user interface based on Windows.

- Multiple document Interface
- Dockable tool, parameter, and message windows
- OLE automation server (COM/DCOM)
- VBA programming
- Automatic post processing
- Parameter sweeps
- Automatic optimization
- Animated plot export
- Automatic Power Point slide creation
- Automatic updates
- Project management
- Import of sub-projects
- Copy and paste of 3D objects, inside and between projects

V. Figures and Tables



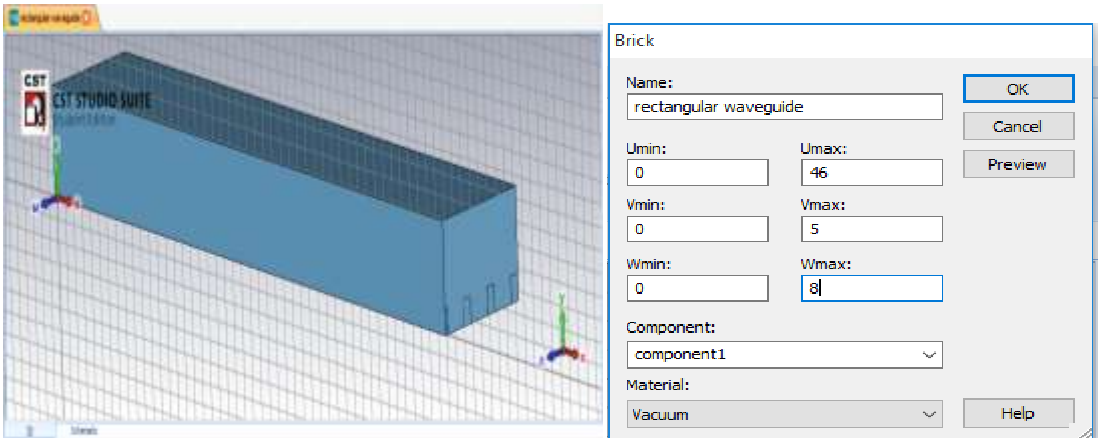


Fig. 1 Rectangular grating SWS.

The dispersion equations of the SWS are:

$$\sum_{n'=\infty}^{+\infty} A_{n'} X_{n,n'} = A_n Y_n \tag{1}$$

$$X_{n,n'} = \frac{2F_{n'}(0)}{s} \sum_{m=0}^{+\infty} \frac{G'_m(0) R(-k^I_{n'}, k^{II}_m d) R(k^I_n, k^{II}_m, d)}{(h^{II})^2 G_m(0)(1+\delta_{m0})} \tag{2}$$

$$Y_n = \frac{F'_n(0)p}{(h^I)^2} \tag{3}$$

$$R\left(k^I_n, k^{II}_m, s\right) = \int_0^d \cos\left(k^{II}_m z\right) \exp\left(jk^I_n z\right) dz \tag{4}$$

$$G'_m(x) = \begin{cases} -k^{II}_x \sin\left[k^{II}_x (x+h)\right] & (k^{II}_x)^2 > 0 \\ t^{II}_x \sinh\left[t^{II}_x (x+h)\right] & (k^{II}_x)^2 < 0 \end{cases} \tag{5}$$

$$G_m(x) = \begin{cases} \cos\left[k^{II}_x (x+h)\right] & (k^{II}_x)^2 > 0 \\ \cosh\left[t^{II}_x (x+h)\right] & (k^{II}_x)^2 < 0 \end{cases} \tag{6}$$

$$F'_m(x) = \begin{cases} k^I_x \sin\left[k^I_x (b-x)\right] & (k^I_x)^2 > 0 \\ -t^I_x \sinh\left[t^I_x (b-x)\right] & (k^I_x)^2 < 0. \end{cases} \tag{7}$$

By solving these equations, we find that the grating depth h and the period p dominate the dispersion relation. The cold bandwidth of the SWS is depressed when h or p increases, as shown in Figs. 2 and 3. The grating width d, the width w, and the waveguide height b have less influence on the dispersion. The Tesla transformer in our laboratory can produce 160-kV pulse. From considerations of the beam voltage, the parameters of the rectangular waveguide grating SWS are chosen: p = 2.6 mm, h = 1.2 mm, w = 46 mm, b = 3.8 mm, and d = 1.82 mm. The dispersion is shown in Fig. 2.

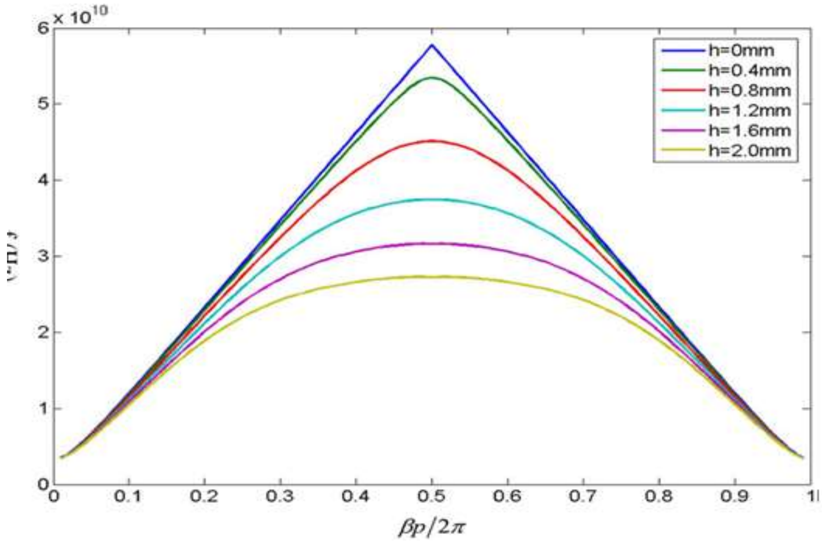


Fig. 2 SWS dispersion for different grating depths *h*'s

VI. Conclusion

We have seen the wave pattern from the dispersion graph.When Input voltage is applied ,then the energy is transferred from beam to waveguide.

The input parameters are :-

- Beam voltage=160KV
- Beam current=1.4KA
- Frequency=12-18GHz

The output parameters are:-

Output Power=MW and beyond

The changes are observed minutely for this,when we vary the magnetic field at different locations.

The main objectives are:

- To study the interaction of electromagnetic field with electrons in the process of electromagnetic wave generation.
- It has three parts:-

1. Study of electromagnetic field or dispersion mode.
2. Study of 2D and 3d electron beam as they along EM fields.
3. Apply different patterns of magnetic field at different locations and observe the changes in output.
4. Apply different dimensions of waveguide and observe the changes in output.

Advantages :

1.Compared with C-band, K_u band is not similarly restricted in power to avoid interference with terrestrial microwave systems, and the power of its uplinks and downlinks can be increased. This higher power also translates into smaller receiving dishes and points out a generalization between a satellite's transmission and a dish's size. As the power increases, the size of an antenna's dish will decrease. This is because the purpose of the dish element of the antenna is to collect the incident waves over an area and focus them all onto the antenna's actual receiving element, mounted in front of the dish (and pointed back towards its face); if the waves are more intense, fewer of them need to be collected to achieve the same intensity at the receiving element.So we can use this Ku band in our simulation of rectangular waveguide which benefits our signal transmission in terms of good output power.

2.Also, as frequencies increase, parabolic reflectors become more efficient at focusing them. The focusing is equivalent given the size of the reflector is the same with respect to the wavelength. At 12 GHz a 1-meter dish is capable of focusing on one satellite while sufficiently rejecting the signal from another satellite only 2 degrees away. This is important because satellites in FSS (Fixed Satellite Service) service (11.7-12.2 GHz in the U.S.) are only 2 degrees apart. At 4 GHz (C-band) a 3-meter dish is required to achieve this narrow of a focus beam. Note the inverse linear correlation between dish size and frequency. For K_u satellites in DBS (Direct Broadcast Satellite) service (12.2-12.7 GHz in the U.S.) dishes much smaller than 1-meter can be used because those satellites are spaced 9 degrees apart. As power levels on both C and K_u band satellites have increased over the years, dish beam-width has become much more critical than gain.As we want a high output powered rectangular waveguide which allows high transmission signal for varying magnetic field Ku band offers high and stable frequencies.

3.The K_u band also offers a user more flexibility. A smaller dish size and a K_u band system's freedom from terrestrial operations simplifies finding a suitable dish site. For the end users K_u band is generally cheaper and enables smaller antennas (both because of the higher frequency and a more focused beam). K_u band is also less vulnerable to rain fade than the K_a band frequency spectrum.Since Ku band has more flexibility than other bands simulation of rectangular waveguides in Ku band becomes more convenient and simple to execute.

4.The satellite operator's Earth Station antenna does require more accurate position control when operating at K_u band due to its much narrower focus beam compared to C band for a dish of a given size. Position feedback accuracies are higher and the antenna may require a closed loop control system to maintain position under wind loading of the dish surface.

Disadvantages :

1.There are, however, some disadvantages of K_u band system. Especially at frequencies higher than 10 GHz in heavy rainfall areas, a noticeable degradation occurs, due to the problems caused by and proportional to the amount of rainfall (commonly known as "rain fade"). This problem can be mitigated, however, by deploying an appropriate link budget strategy when designing the satellite network, and allocating a higher power consumption to compensate rain fade loss. The K_u band is not only used for television transmission, which some sources imply, but also very much for digital data transmission via satellites, and for voice/audio transmissions.

2.The higher frequency spectrum of the K_u band is particularly susceptible to signal degradation, considerably more so than C-band satellite frequency spectrum. A similar phenomenon, called "snow fade" (where snow or ice accumulation significantly alters the focal point of a dish) can also occur during winter precipitation. Also, the K_u band satellites typically require considerably more power to transmit than the C-band satellites. Under both "rain fade" and "snow fade" conditions, K_a and K_u band losses can be marginally reduced using super-hydrophobic Lotus effect coatings. Moreover, snow fade is caused not only by snow accumulation on the antenna, but also by attenuation caused by airborne snow along the RF signal path.

3.Since it's a simulation project its practical implementation is quite difficult.

Applications :

Applications are classified into two types :-

1.Conventional Applications :-

- Broadband Communication
- Satellite Communication
- Fiber optic Communication
- Radar Equipments

2.Modern and Strategic Applications :-

- Jamming
- Directed Energy Weapon Detection
- High Power Transmitters
- Microwave oven
- Low Noise Block Converter(LNB's) which are used in Satellite Communication

Acknowledgements

It gives a great pleasure to present this paper on "SIMULATION OF RECTANGULAR WAVEGUIDE IN KU BAND FOR VARYING MAGNETIC FIELD". While working on this project, we found great opportunity to express our sincere regards, deep sense of gratitude and thanks to our project guide Prof. NileshGode for his valuable suggestions, valuable inputs, able guidance, encouragement, whole-hearted co-operation and constructive criticism, support and timely guidance at every step during course of our project.

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