Mode Conversion from TE11 to TM11 in Circular Waveguide using Step Discontinuity Method for Ku-Band Applications

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Abstract— This paper discusses about the Mode Conversion from TE11 to TM11 mode in circular waveguide using step discontinuity is investigated. We use this method for Ku band (12GHz – 18GHz) application and our designed frequency is 15 GHz. We get the amount of power converted from TE11 to TM11 is 10 to 20 %. In this paper we have designed the light weight, compact size and high directivity Circularly Polarized waveguide with high Directivity, high Gain, low return losses and good VSWR. It is found that an abrupt change in guide radius (step) will produce a wide range of mode conversion which can be used in most dual – mode feed horn applications. The step discontinuity is found to produce relatively constant mode conversion over a wide band of frequencies. In this we have varied the length, flare angle, aperture diameter of the conical antenna These dimensions will explain the required features such as impedance matching, radiation pattern of the conical antenna. The electromagnetic accuracy of the antenna is measured with the help of High Frequency structure simulator (HFSS) Software. The measured results of the conical antenna confirmed the simulation results and satisfied the design requirement. In view of this paper, the measured results show that this antenna has gain of 10.80 to 13.20 dB, bandwidth of 300 %, return losses level of -25dB. Simulation for horn antenna has been done on Ansoft HFSSv11.

Key words: Mode Conversion, HFFS, Ku Band, Step Continuity, Aperture radius.

I. INTRODUCTION

Horn antennas have been widely used for space applications from the very beginning due to their capability of being best operation from Megahertz to Gigahertz to Terra hertz range. The goal of the system is to maximize the power transfer from the source to the radiating system while keeping the system as compact as possible. A compact conical horn antenna has been designed that operates in the Ku band that produces a forward directed radiation beam with maximum directivity. Horn antenna typically consists of a rectangular or cylindrical metal tube, closed at one end and flaring into open end or pyramidal shape on other end. They can be easily flush mounted on the satellite structure body. It affords a gradual transition structure to match the impedance of a tube to the impedance of free space, enabling the waves from the tube to radiate efficiently into space. Horn antenna is used to transmit radio waves or collect radio waves into a waveguide. The radio waves are introduced into the waveguide by a coaxial cable attached to the side. The waves then radiate out the horn end in a narrow beam. However in some equipment the radio waves are conducted between the transmitter or receiver and the antenna by a waveguide, and in this case the horn is just attached to the end of the waveguide. To be generally useful, the mode conversion configuration must provide controlled mode conversion over a useful band of frequencies without introducing significant reflection of the input TE11 mode. It is further required that the converter discontinuity be circularly symmetric, both to prevent excitation of unwanted modes and to permit operation of the device for signals of arbitrary polarization. The radiation characteristics of a conical horn are disposed by its dimensions in wavelengths, it has been convenient to normalize all dimensional data in terms of wavelength. Advantages of horn antenna over other types of antenna are: (a)Complexity involve in the design of horn antenna is less as compared to phased array antennas & corrugated cousins. (b) Feeding a horn antenna is less complex as compared to other antennas which require complex feeding techniques.(c)High data rate systems needs to be operated at a higher frequency range in order to carry out higher bandwidth. This can be easily carry out using a horn antenna.(d)Power handling capability of horn antenna is superior to other antennas as it is waveguide fed antenna, especially in the of TWTs used in satellites, radars and many other applications making it an ideal choice for space Applications. If horn antenna is properly designed & optimized than side lobes can be suppressed to very low levels. Various space programs in which horn antennas are used by NASA, ESA.

II. DESCRIPTION OF STEP DISCONTINUITY

Mode conversion from TE11 to TM_{11}, in circular waveguide is achieved by an abrupt change in waveguide shown in Fig.(1). The discontinuity is suitable for mode conversion because it perturb the incident TE wave in such way as it produce a component of field in direction of propagation. At discontinuity the conducting surface is transverse to direction of proportion therefore as per boundary condition electric field produce in propagation direction. The radius a must be large enough for support the TE11 mode but small enough to ensure that the TM_{11} is cut-off(i.e., l.84 $<ka<$ 3.83).The amount of TM_{11} generated in this way increases with the ratio b/a, but b should not be so large as to permit the TE12mode to propagate (3.8 $<kb<$ 5.33).The step discontinuity boundary condition zero tangential electric field on the step surface will be largely satisfied by the TE11 and TM_{11} modes. The two diameters are chosen to satisfy the following four conditions:

1) Only TE_{11} (and possibly TM_{01} and TE_{21}) can propagate to the left of the step.
2) Only TE_{11}, TM_{01}, TE_{21}, TE_{01} and TM_{11} can propagate to the right of the step.
3) TM_{11} is generated in the correct power ratio relative to TE_{11}.

In the Figure the radius a and b shown can be given by following expression

The amount of power transfer to TM_{11} from TE_{11} is dependent on difference of diameter of circular waveguide. Here amount of power of TE_{11} mode approximately 10% to 20% is converted into the higher order TM_{11} mode which is required to make surface current approximately zero at the aperture and get symmetry in all planes

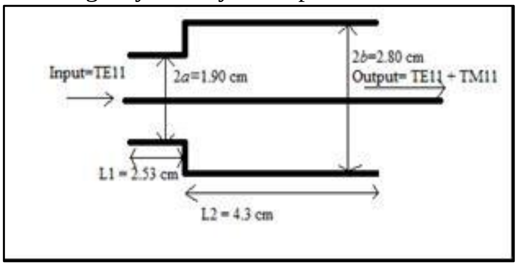

Fig. 1: Design of Step Discontinuity

III. SIMULATION AND RESULT

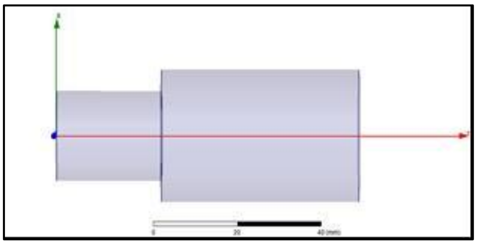

Fig. 2: Design of step discontinuity (a) Side view of design

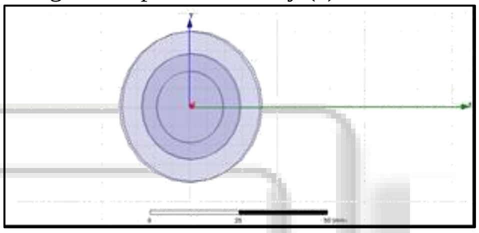

Fig. 3: Design of step discontinuity (a)Front view of design

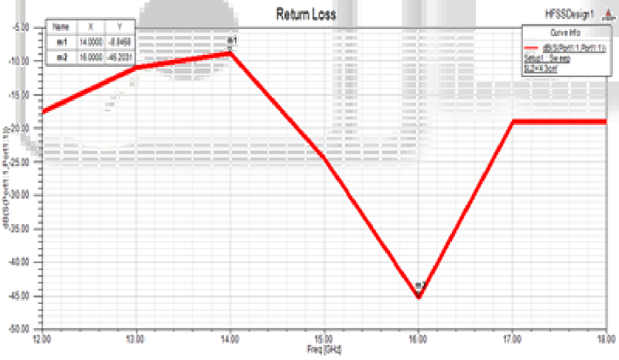

Fig. 4: Return Power Loss

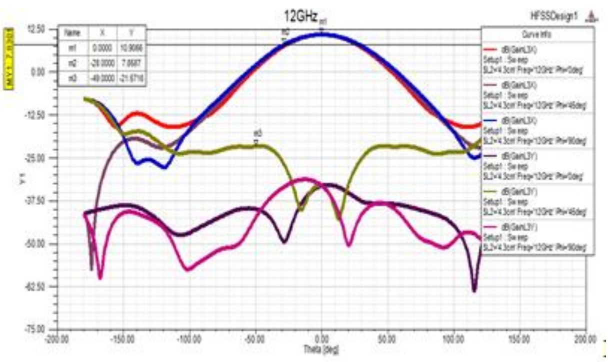

Fig. 5: Radiation pattern at 12 GHz

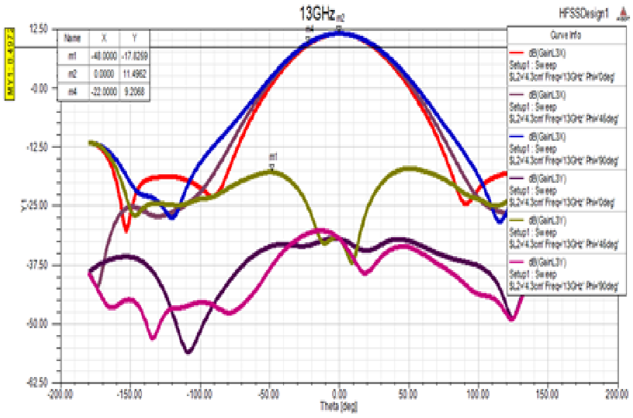

Fig. 6: Radiation pattern at 13 GHz

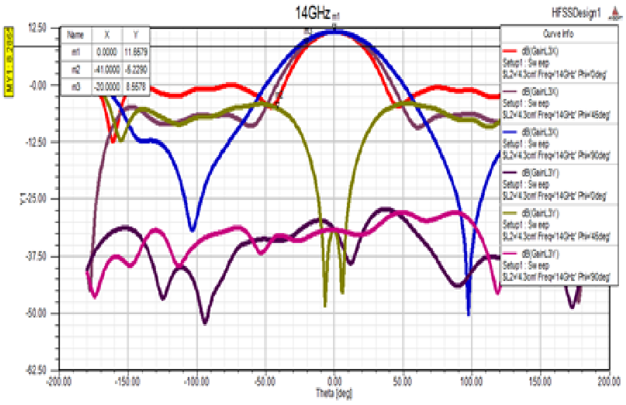

Fig. 7: Radiation pattern at 14 GHz

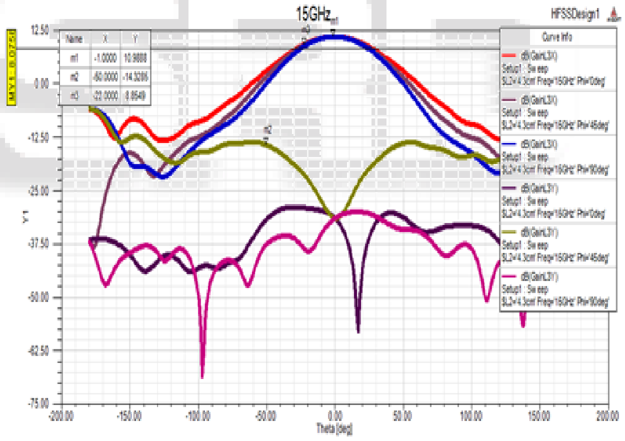

Fig. 8: Radiation pattern at 15 GHz

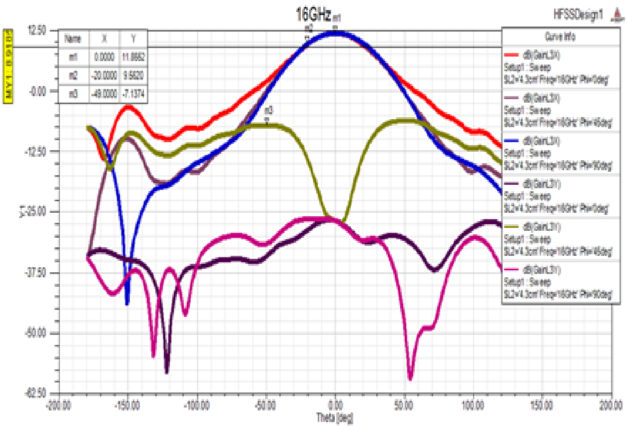

Fig. 9: Radiation pattern at 16 GHz

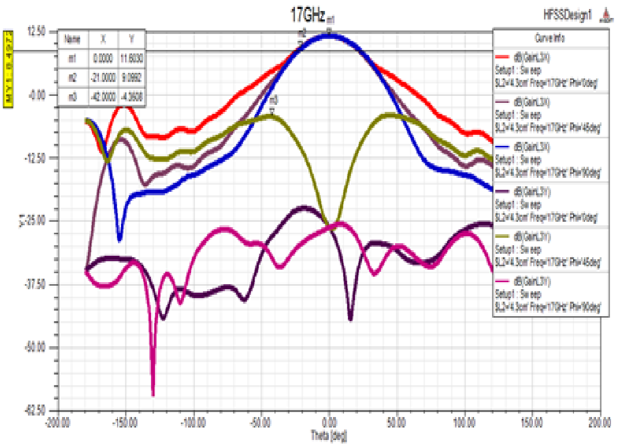

Fig. 10: Radiation pattern at 17 GHz

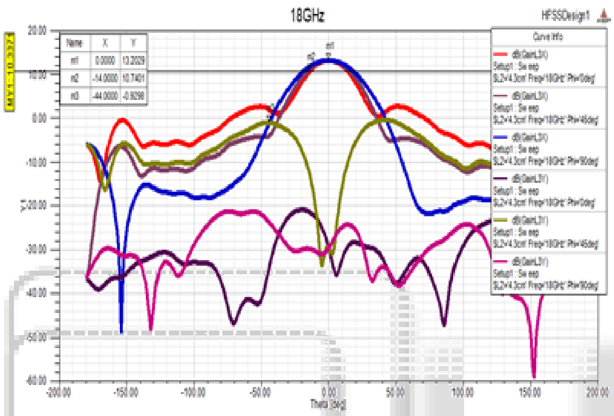

Fig. 11: Radiation pattern at 18 GHz

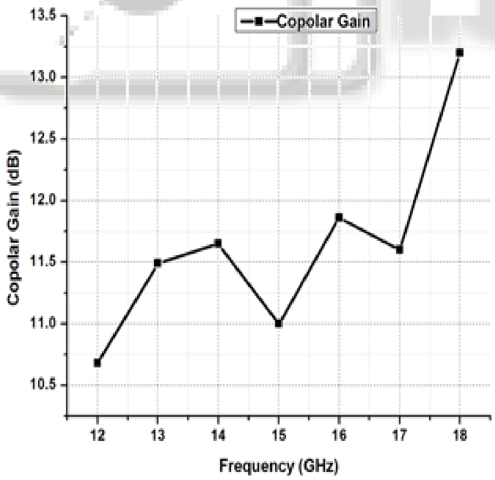

Fig. 12: Frequency vs. Gain graph. It represents the value of gain at different frequency. With the increase in frequency, the value of gain increases.

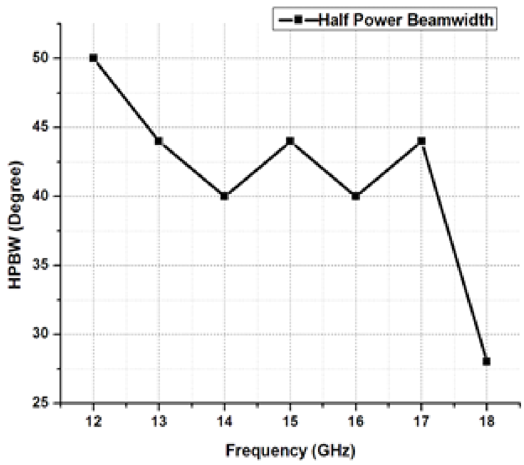

Fig. 13: Frequency vs. HPBW graph. It represents the value of HPBW at different frequency. With the increase in frequency, the value of HPBW decreases.

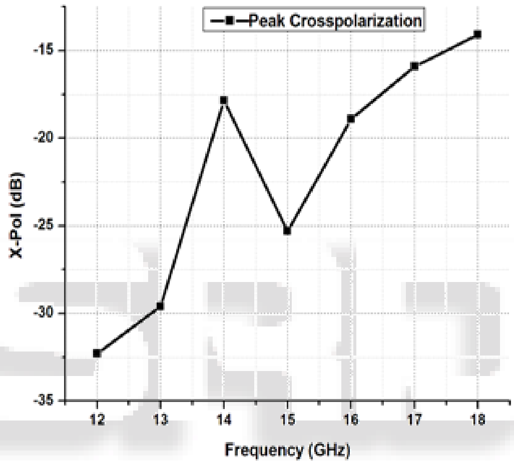

Fig. 14: Frequency vs. Cross polarization graph. It represents the value of cross polarization at different frequency. With the increase in frequency, the value of cross polarization increases.

IV. CONCLUSION

This paper discusses the Mode conversion from TE_{11} to TM_{11} in circular waveguide for Ku-Band Applications of 12-18GHz. It is done using step discontinuity method and conical horn antenna with high gain, suppressed side lobes, good VSWR. The amount of power transfer to TM_{11} from TE_{11} is dependent on difference of diameter of circular waveguide. In our method the amount of power of TE11 mode approximately 10% to 20% is converted into the higher order TM_{11} mode. All requirements for space application have been tried to meet according to international space standards. This can be used in space applications. The procedure is straightforward, and determines the physical dimensions of a conical horn that determine the performance of the antenna. To examine the accuracy of this design procedure, antenna was designed over 12 to 18GHz with specific electromagnetic features. The measurement results showed that the antenna's gain of 10.80dB to 13.20dB, bandwidth of 300%, return losses level of -25db. These measurement results confirmed the results of the simulations and satisfied the design requirements.

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REFERENCES

Research papers

[1] E.R.NAGELBERG and J.SHIFFER, 1965, 'Mode conversion in circular waveguides' Bell Labs Technical Journal(Volume 7, No.44).
[2] HANS-GEORG UNGER, 1958, 'Circular waveguide taper of Improved Design', bell labs technical journal (Volume 37, No.4).
[3] D. MARCUSE and R.DEIOSIER, 1969, 'Mode conversion caused by diameter changes of a circular waveguide', Bell System Technical Journal (Volume 48, No.10).
[4] H.WOLF and E.SOMMER, 1988, 'An Advanced Compact Radiator for Multifeed Antennas', Microwave Conference (18th European).
[5] D.T.YOUNG, 1963,'Model for Relating Coupled Power Equations to Coupled Amplitude Equations', Bell System Technical Journal (Volume 62, No.6).

Books

[6] Advance Engineering Electromagnetics, C.A.BALANIS, John Wiley and Sons Inc. Second edition
[7] Antenna Engineering Handbook, RICHARD JOHNSON, McGrow Hill Publications, Third Edition.
[8] Microwave devices and circuit components, SAMUEL LIYO, Eastern Economy Edition, Third Edition.

