Overview of Corrugated Wave guides- recent Advancement

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***Abstract*— Corrugated waveguide is used to transmit high power microwave from the microwave devices like Gyrotron. HE11 mode has the lowest loss and is a fundamental mode of corrugated waveguide. Corrugated waveguides have proved to be the most efficient waveguides for transmitting high power GHz & THz radiation compared to smooth wall circular waveguide at the operational frequency of the transmission line. High power, high frequency microwave radiation can be transmitted with very low loss in oversized corrugated metallic waveguide. We derive a linearly polarized (LPmn) mode basis set for these waveguides for the special case of quarter wavelength depth corrugations. The loss in a gap or equivalent miter bend in the waveguide is calculated for single mode and multi-mode propagation on the line. In the latter case, it is shown that modes of the same symmetry interfere with one another, causing enhanced or reduced loss, depending on the relative phase of the modes. If two modes with azimuthal (m) indeces that differ by one propagate in the waveguide, the resultant centroid and the tilt angle of radiation at the guide end are shown to be related through a constant of the motion. Nowadays, an increasing number of applications need stable radiation patterns with low sidelobes and low crosspolar levels in a very wide bandwidth. Gaussian Profiled Horn Antennas (GPHA's) have demonstrated its feasibility as one of the best solutions. A corrugated gaussian horn antenna design with more than 40% bandwidth is proposed in this paper.**

Keywords—Corrugated waveguide; RF; hardware; I/O; instrument

I. INTRODUCTION

An important problem in research with high power, high frequency coherent microwave radiation is the transmission of the radiation from the source to the application. In recent years, rapid advances in the development of gyrotrons have made available sources of continuous power at levels in the megawatt range at frequencies of up to 170 GHz. The radiation from gyrotrons is often transported long distances, many tens of meters, before being launched for plasma heating. The transmission lines ordinarily used in these applications are over-sized corrugated metallic waveguides. These waveguides provide low loss and low mode conversion. The metallic wall helps to prevent accidental loss of radiation. Other major uses of these corrugated waveguides include transmission lines for plasma diagnostics, radar, materials heating and spectroscopy. The theory for modes of corrugated metallic waveguides has been previously developed [1], [2], [3], [4]. The original application of corrugated waveguides was in the development of horn antennas, but recent applications of straight corrugated waveguide have led to a large literature devoted to that specific topic. A set of eigenmodes has been derived for corrugated metallic waveguide, consisting of hybrid modes, both HE mn and EHmn modes, plus the TE0n and TM0n modes [5], [6], [7]. The fundamental mode of corrugated waveguide, the HE 11 mode is linearly polarized. However, the hybrid modes are, in general, not linearly polarized. The purpose of this paper is to develop a set of linearly polarized eigenmodes (LPmn) for corrugated metallic waveguide. Since gyrotron beams are linearly polarized, the LPmn mode set has advantages for describing this radiation. We also develop a number of useful results for the propagation of LPmn modes in corrugated metallic waveguide. The corrugated waveguides consist of hollow metallic cylinders where the inner wall has periodic wavelength-scaled grooves, as depicted in Figure 1. Figure 1 also shows the parameters of the waveguide and the coordinates used in describing the modes. The fundamental mode of the corrugated waveguide, the HE11 mode, has less attenuation than the fundamental modes for equivalent smooth-wall cylindrical and rectangular waveguides. This effect is reviewed for frequencies from 1-10 GHz in [1] and for the 100 GHz range in [3]. Overmoded corrugated waveguides have extremely low losses at high frequencies, even for higher order modes [8], [9]. The attenuation for a corrugated guide scales inversely with the cube of the radius to wavelength ratio, a/λ. The loss in straight waveguide sections is so low that we will omit discussion of that loss in this paper; the loss is discussed at length in [5]. However, if the guide size (a/λ) is too large for the application at hand, power will be lost due to misalignment and fabrication errors.

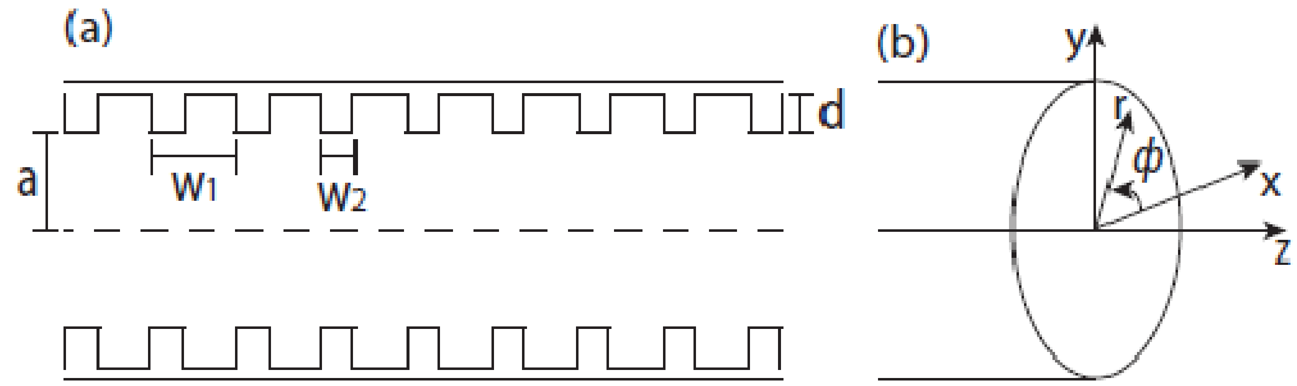

Fig.1 (a) A cylindrical corrugated waveguide with a radius of a. The corrugations are defined by w1, w2, and d. For low loss characteristics the corrugation depth is d = λ/4. (b) An illustration of the variables in the cylindrical geometry.

2. DESIGN OF HIGH POWER LOW LOSS CIRCULAR CORRUGATED WAVEGUIDE

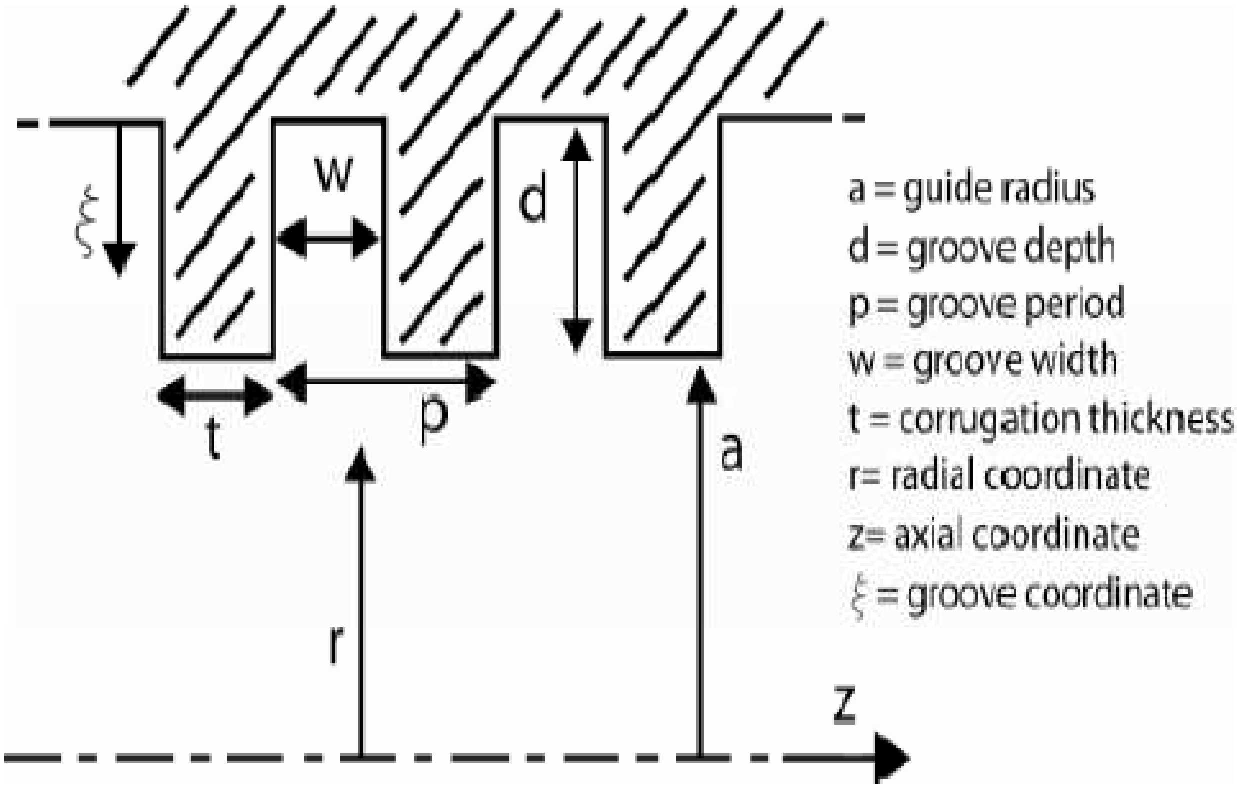

Fig -2: Illustration of circular corrugated waveguide [1]

To design corrugated waveguide for low losses, the radius a should be much larger than a , the corrugations are optimized when theλwavelength / 3 and groove width λ ≈/ 4, period p λ≈groove depth d p / 2. The corrugation tooth thickness is denoted by <w t = p-w [1]. Using above criteria we have calculated the design parameters for the circular corrugated waveguide and are given in Table 1. Table 1: Calculated Design parameters of circular corrugated waveguide Sr. No. Parameter Value 1 Operating frequency (f) 42 GHz 2 Wavelength (λ) 7.14 mm 3 Radius (a) 31.75 mm 4 Corrugation depth (d) 1.785 mm 5 Corrugation periodicity (p) 2.37 mm 6 Corrugation thickness (t) 1.37 mm 7 Groove width (w) 1 mm 8 Waveguide material Aluminum , copper , stainless steel

II. SUMMARY

This work has presented the design and simulation of high power low loss circular corrugated metallic waveguide for 42 GHz Gyrotron. And also presented the simulation comparison between smooth wall circular metallic waveguide and corrugated circular metallic waveguide. Simulation results shows that the corrugated waveguide have low insertion and return loss compared to smooth wall circular waveguide. Insertion loss is affected by varying the corrugation depth (d), whereas return loss is not that much dependent on corrugation depth (d). For microwave transmission, material choice is also important for design. Corrugated waveguides have proved to be a reliable technique with regards to their low loss nature and ability to handle high powers with low losses.

References

[1] P. J. Clarricoats and A. D. Olver, "Low attenuation in corrugated circular waveguides," *Electronics Lett.*, vol. 9, no. 16, pp. 376–377, 1973.
[2] A. D. Olver, P. J. Clarricoats, and S. L. Chong, "Experimental determination of attenuation in corrugated circular waveguides," *Electronics Lett.*, vol. 9, no. 18, pp. 424–426, 1973.
[3] A. Cavallo, J. Doane, and R. Cutler, "Low-loss broadband multimode corrugated waveguide performance," *Rev. Sci. Instr.*, vol. 81, no. 9, pp. 2396–2400, 1990.
[4] M. K. Thumm and W. Kasparek, "Passive high-power microwave components," *IEEE Trans. Plasma Sci.*, vol. 30, no. 3, pp. 755–786, June 2002.
[5] J. L. Doane, "Propagation and Mode Coupling in Corrugated and Smooth-Wall Circular Waveguides," in *Infrared and Millimeter Waves, Vol. 13, Millimeter Components and Techniques Part IV*, K. J. Button Ed. Academic Press, 1985, pp. 123–170.
[6] C. Dragone, "Attenuation and radiation characteristics of the HE11- mode," *IEEE Trans. Microwave Theory and Techniques*, vol. 28, no. 7, pp. 704–710, 1980.9
[7] J. P. Crenn and C. Charollais, "Propagation and Radiation Characteristics of the Circular Electric, Circular Magnetic, and Hybrid Waveguide Modes," *Int. J. Infrared and Millimeter Waves*, vol. 17, no. 9, pp. 1475–1506, 1996.
[8] E. Marcatili, "Hollow metallic and dielectric waveguides for long distance optical transmission and lasers," *Bell System Tech. J.*, vol. 43, pp. 1783–1809, 1964.
[9] P. J. Clarricoats and R. D. Elliot, "Multimode corrugated waveguide feed for monopulse radar," *IEEE Proc.*, vol. 128, no. 2, pp. 102–110, 1981.