Analysis and Design of TE11-to-HE11 Corrugated Cylindrical Waveguide with Variable Depth Slot Mode Converter

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Abstract—The paper presents the parametric study of profiled corrugated horn. Variable Depth -slot-mode converter sections are used to convert dominant mode, TE_{11} in to hybrid HE_{11} mode to achieve wider bandwidth. is shown that a mode converter consisting of only five slots achieves a return loss better than 30 dB over the band 2.7 <ka< 3.8 (where a is the internal radius of the waveguide) with the HE11 mode in the balanced condition at ka = 2.9.

I. INTRODUCTION

In 1966 the idea of corrugated horn was first considered by Kay and Simons [1], Minnett and Thomas [2] described propagation and radiation behaviour of corrugated feeds. The profiled horn was first described by Watson et al. [3]. Since then there have been relatively few papers giving details of the design of these horns. Simple design information is given by Clarricoats and Olver [4], and some information on mode conversion is presented in Mahmoud [5]. James [6] showed that compact horns can operate over a wide band.

To achieve better mode conversion a corrugated transition section can be used where, by gradual variation of the slot depth, the longitudinal surface reactance x, is made to change smoothly from zero at the smooth-walled input guide to the high value required in the corrugated output waveguide [20]. Our purpose here is to optimize the design of such a converter to achieve maximum mode conversion (i.e., minimum reflection of the TE11 mode) over as wide a band as possible. The purpose of the mode converter is to provide a smooth change in x, from zero at the input waveguide supporting the TE11 mode, to a large value to match the corrugated output waveguide designed to support the HE11 mode, This mode is balanced at a frequency f_0, chosen to be near the centre of the waveguide band (where typically ka, = 2.9). Using a corrugated structure the surface impedance can be altered by changing the slot depth (starting either from zero or a half-guide wavelength at a given design frequency *fi* at the input to the converter), varying the ratio of slot width to pitch, or a combination of both.

II. DESIGN PARAMETER

An ideal feed for a reflector antenna is one which has a symmetric radiation pattern and this also ensure a very low cross-polarization. The symmetry of the radiation pattern requires that, if E_θ and E_Φ are the spherical polar components of the radiation field, where θ and Φ are the elevation and azimuth angles respectively.

In which the walls of the horn should be such that the same boundary condition is applicable to E and H. This condition can be achieved by a circular waveguide with transverse circumferential grooves of appropriate depth, called corrugated horn.

The corrugated horn consists of an input taper between the input waveguide and the mode converter, a corrugated transition section between the mode converter and the output flare.

The corrugated horn must radiate near frequency-independent pattern to achieve wide bandwidth performance. The mode converter is ring-loaded-slot-mode converter in order to achieve wide bandwidth. Further it is essential to optimize the parameter of the mode converter independently of the input waveguide diameter and the horn output flare also for enhanced bandwidth.

A. Input cylinder

This section provides an increase in radius from the input waveguide to that required for the mode converter. The radius of the input cylinder is $1.841(\lambda i/2\pi)$.

B. Mode converter

To achieve better mode conversion a corrugated transition section can be used where, by gradual variation of the slot depth, the longitudinal surface reactance x, is made to change smoothly from zero at the smooth-walled input guide to the high value required in the corrugated output waveguide. The bandwidth provided by this mode converter is 1.8:1.

A common method of achieving this is to use a corrugated waveguide transition section in which the depth of the slots gradually decreases from an initial value of λ/2 (so that the input slot appears as a short circuit) to a final slot-depth of approximately λ/4 as given by the corrugated output-waveguide.

Such converters, however, have a limited high-frequency performance owing to the excitation of unwanted modes.

Parameter	Name
f_0	Design frequency
λ_0	Wavelength (c/ f_0)
p_0	Pitch ($p_0 = 0.1\ \lambda_0$)
k_0	Wave number($2\pi/\lambda_0$)
a_i	Input radius ($k_0\ a_i > 1.84$)
δ	Pitch-to-slot Width Ratio
b_n	Slot depth($\delta\ p_0$)
d_n	Ridge width($d_n = p_0 - b_n$)

Table. 1: Design parameter of variable slot mode converter

The performance is limited by the deterioration in return loss, while at high frequency the generation of a small amount of unwanted EH_{12} mode is the restriction. The parameters of the variable depth- slot-mode converter are given in the Table I.

In any type of corrugated horn we can identify four parts of the horn for design purpose.

They are,

1) The aperture diameter and flare angle which principally determine the co-polar beam width.
2) The corrugations, which determine the pattern symmetry and the cross-polar characteristics.
3) The flare section between the throat and the aperture which determines the position of the phase centre and the generation of the higher order modes along the horn.

The throat regions which determine both impedance match into the section of waveguide behind the horn and mode conversion level at the throat.

III. THEORETICAL PERFORMANCE

We have assumed ka=2.9 at the nominal waveguide-band center frequency & with this value, the corrugated output waveguide outer radius

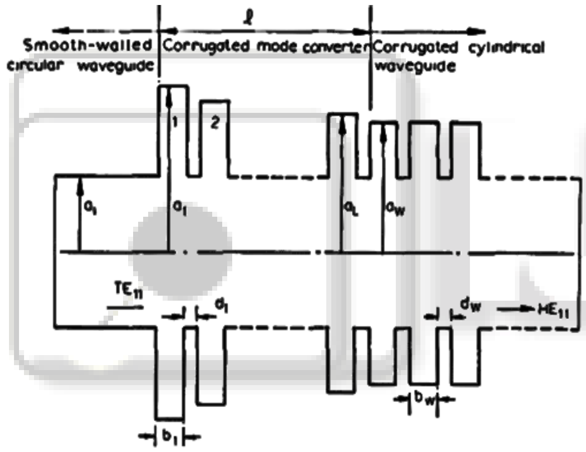

Fig. 1:Cross-sectional view of circular waveguides. Corrugated mode converter section at the junction between a smooth-watled and corrugated waveguide.

n	Slot radius(ka_n) Case i & ii	Slot radius(kb_n) Case i & ii	Flange width(kd_n) Case i & ii
0	2.90		
1	5.50	0.47 0.94	0.32 0.64
2	5.34	0.47 0.94	0.26 0.52
3	5.18	0.47 0.94	0.22 0.44
4	5.02	0.47 0.94	0.19 0.38
5	4.86	0.47 0.94	0.16 0.32

Table. 2 :Computed Parameters For Two Optimized Five Slot TE11–TO–HE11MODE CONVERT-ERS, EXPRESSED IN TERMS OF THE DESIGN FRE-QUENCY F_0 WHERE Ka_i, Is 2.9 (THE CORRUGATED-OUTPUT WAVEGUIDE HAS A PITCH OF $0.1\lambda_0$ IN CASE(I)AND 0.2 Λ_0 IN CASE (Ii))

ka was 4.7 at f., while § was fixed at 0.75. Two values of pitch p for the output waveguide were considered: p= $0.l\lambda_0$ and 0.2 λ_0 (cases (i) and (ii)). Optimum results were obtained when the depth of the first slot of the converter was λi /2 at a frequency j corresponding to ka, =3.48. The converter length kl was found to be 3.5 at f =fo for case (i) and 7.0 at f =fo for case (ii). The details of the five-slot optimum mode converter for these two cases are given in Table 2. To facilitate manufacture, all of the slots in the converter have the same width as the slots in the corrugated output waveguide. Consequently, to optimize the length 1 the flange width was varied linearly, corresponding to a variation of § from 0.6 to 0.75 along the converter.

IV. SIMULATED RESULTS

The simulation has been carried out for asymmetrical sine squared profiled corrugated horn by using variable depth-slot-mode converter. Ansoft HFSS has been used as simulation software. Ansoft H F S S employs the Finite Element Method (FEM), to give high quality performance. The simulation frequencies are from 3 GHz to 4 GHz.

V. CONCLUSION

The simulated results of asymmetric sine squared profiled corrugated horn with above mentioned variable depth slot -mode converter are given. The bandwidth of 1.18:1 is achieved for cross-polarization less than 23 dB and return loss better than 39 dB. The radiation pattern symmetry is achieved over the 3 GHz to 4GHz band.

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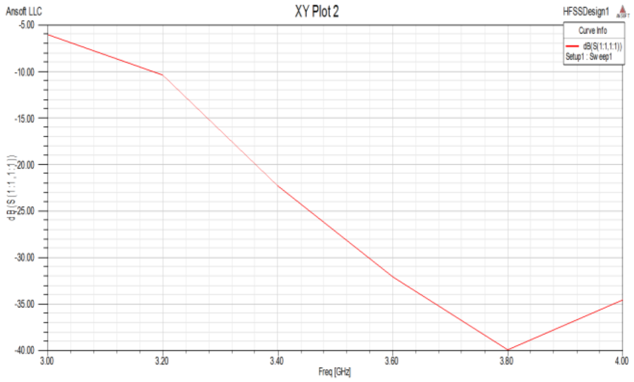
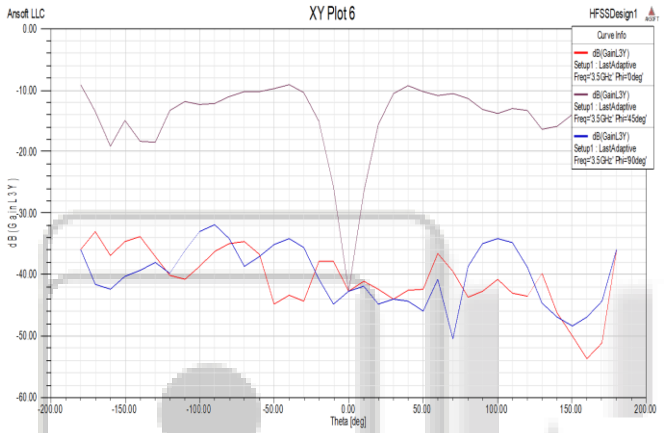
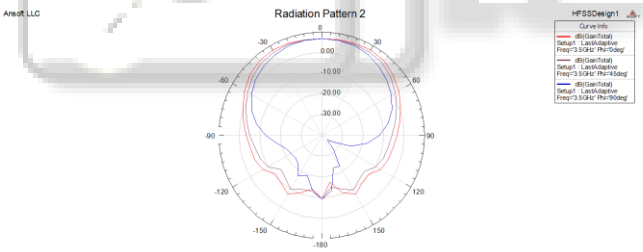


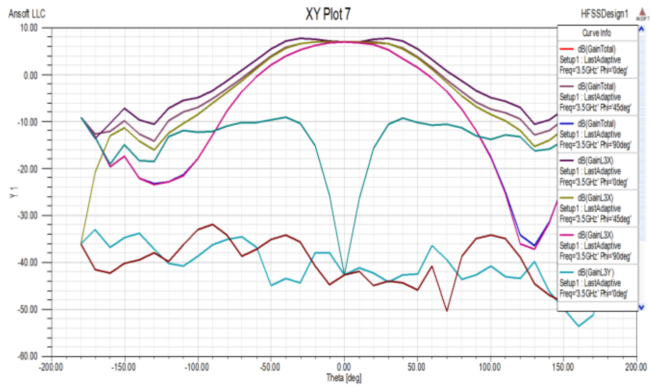
RETURN LOSS IN XYPLOT USING HFSS



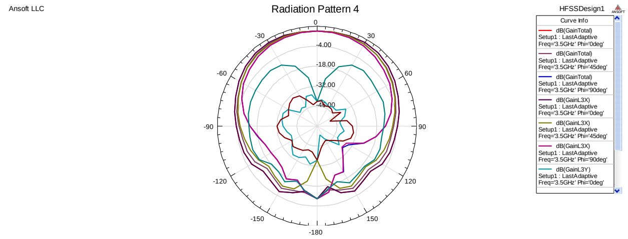
CROSSPOLARIZATION IN XY PLOT USING HFSS



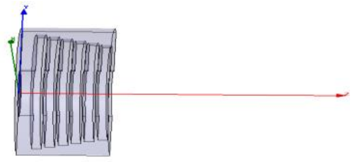
CROSSPOLARIZATION IN POLAR PLOT USING HFSS



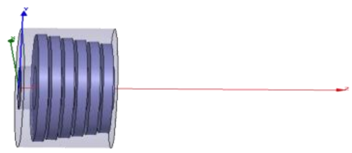
RADIATION PATTERN OF CORRUGATED HORN WITH VARIABLE DEPTH SLOT -MODE CONVERTER.3.5GHZ USING HFSS IN XY PLOT



RADIATION PATTERN OF CORRUGATED HORN WITH VARIABLE DEPTH SLOT -MODE CONVERTER.3.5GHZ USING HFSS IN POLAR PLOT



CROSS-SECTION OF VARIABLE DEPTH SLOT MODE CONVERTER



VARIABLE DEPTH SLOT MODE CONVERTER WITH 5 SLOT IN HFSS

	Freq [GHz]	dB(S(1:1,1:1)) Setup1 : Sweep1
1	3.000000	-6.083515
2	3.200000	-10.388547
3	3.400000	-22.292350
4	3.600000	-32.067666
5	3.800000	-39.847220
6	4.000000	-34.486975

