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Design of a mm-wave 1 : 3 waveguide power divider using E-plane bifurcated waveguide

Yogesh K Verma*, Arvind Agarwal and B K Sarkar
SAMEER, IIT Campus, Powai, Mumbai-400 076, India
E-mail yogesh@sameer.ernet in

Abstract A new design of mm-wave waveguide power divider is presented here The waveguide used is WR28 rectangular waveguide The concept of bifurcated waveguide is used to divide the input waveguide into three standard height waveguide outputs In general, an E-plane bifurcated waveguide consists of a rectangular waveguide and a thin metal plate that effectively converts the guide into two reduced height waveguides Since the plate is perpendicular to the TE_{10} electric field, the field and current patterns are unchanged and hence no reflections are created This assumes that the metal plate is negligibly thin compared to the guide height The electric field is same in all the guides and the voltage in the output guide is proportional to the height of the guide The currents in all the waveguides remain same, which means that the E-plane bifurcation represents a series connection On the same concept of the bifurcated waveguide, the waveguide is divided into three reduced height guides of equal height by putting two thin metal plates Since the voltage in the guide is proportional to the height of the guide, E-field bifurcated is same in all the three branches resulting into equal power division in all the three outputs Chebyshev waveguide impedance transformers are designed to step up the reduced height guide impedance to the standard WR28 waveguide impedance The structure is simulated using Ansoft's High frequency Structure Simulator The results are presented graphically The amplitude imbalance among the three outputs centered at 34 25 GHz is less than ±0.4 dB and the input return loss is better than 30 dB with 20% bandwidth

Keywords Rectangular waveguide, power divider

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1. Introduction

Power divider is a very major element used to split the power among the arms of a branched microwave transmission system. In general, a N-way power divider has a main branch as input port *i.e.* port 1 and N output ports as port 2, port 3 and so on. A 1 : 3 power divider has three output ports as port 2, port 3 and port 4 and input as port 1. A power divider is required to satisfy the match condition at the input port *i e.* S11 = 0, and conditions for the power transfer from the input port to output ports in such a way that S21, S31 and S41 have specified magnitudes [1].

2. Bifurcated waveguide theory

A bifurcated waveguide consists of a rectangular guide and a thin metal plate that effectively converts the guide into two reduced height waveguides. This bifurcation is the E-plane bifurcation [2]. Since the plate is perpendicular to the TE_{10} electric field, the field and current patterns are unchanged and hence no reflections are created. This assumes that the metal plate is negligibly thin compared to the guide height. Input SWR is unity when outputs are matched terminated (*i.e.* $Z_{L1} = Z_{01}$ and $Z_{L2} = Z_{02}$). Also, since the electric field is the same in all three guides and the voltage is proportional to the height of the guide, $V = Eb$ and $V_1 = Eb_1$, $V_2 = Eb_2$, and therefore, $V = V_1 + V_2$ (1 and 2 are used to indicate the bifurcated guide 1 and 2 respectively). The currents in all three waveguides are same, which means that the E-plane bifurcation represents a series connection.

The power division between output ports when they are matched terminated is given by

$$\frac{P_1}{P_2} = \frac{Z_{01}}{Z_{02}} = \frac{b_1}{b_2},$$

* Corresponding Author

since $P_1 = I^2 Z_{01}$ and $P_2 = I^2 Z_{02}$ and characteristic impedance is proportional to the guide height. Also, $P_1 + P_2$ equals the input power, assuming lossless guides. The output lines are connected to the standard size waveguide by using the waveguide impedance transformers. The input SWR and the power division remain unaffected if the transformers are well matched

3. Power divider design

On the same concept of the bifurcated waveguide, the waveguide is divided into three reduced height guides of equal height by putting two thin metal plates. Since the voltage in the guide is proportional to the height of the guide, E-field bifurcated is same in all the three branches resulting into equal power division in all the three outputs. Chebyshev waveguide impedance transformers are designed to step up the reduced height guide impedance to the standard WR28 waveguide impedance.

Impedance transformers are designed for 34.25 GHz with 20% bandwidth. The design uses two sections for each transformer. Since impedance transformation ratio is much less than $(2/\omega_q)^{n/2}$ ($\omega_q = 0.2$, $n = 2$), first order theory has been used for the transformer design. Complete details of Chebyshev transformer design can be found in [3]. Junction susceptances are calculated for small corrections in the lengths of each section of the transformers. The normalized junction susceptance for E-plane step in waveguide is given by [4,5].

4. Simulation

The structure is simulated using Finite Element Method based Electromagnetic simulator Ansoft's HFSS ver. 5.0 before fabrication. The results are obtained for 0.1 mm thickness of the metal plates. This result shows input return loss better than 30 dB and amplitude imbalance within ± 0.3 dB. The power division at the design frequency is about 4.7 dB. The results are graphically presented in Figures 1 and 2.

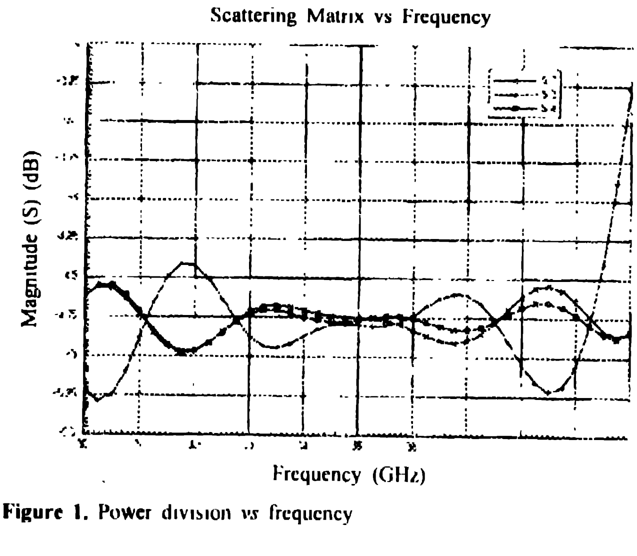

Figure 1. Power division vs frequency

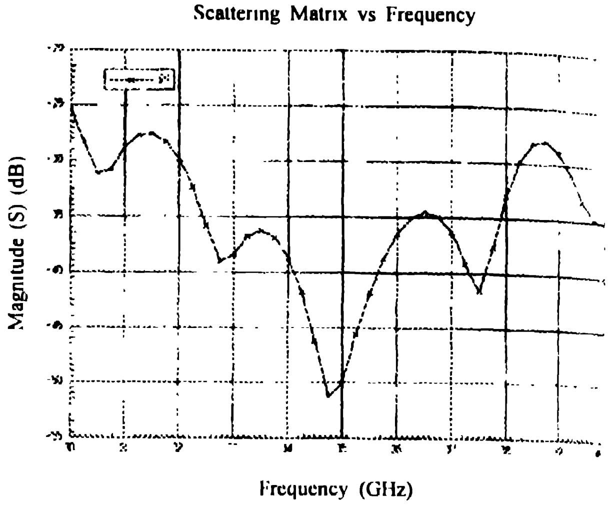

Figure 2. Return loss vs frequency

5. Fabrication

Fabrication of this device is difficult task because of the mechanical limitations. The metal sheet thickness was taken as 0.1 mm, but due the mechanical limitations, this was changed to 0.28 mm, thus leaving 1.0 mm for each guide It is not possible to take all the outputs on the same side, therefore, two outputs are taken on either side of the input guide. The device was under fabrication at the time of writing this paper.

6. Conclusions

A mm-wave 1 : 3 waveguide power divider has been designed at design frequency of 34.25 GHz with a bandwidth of 20% using E-plane bifurcation. Input waveguide is divided into three output ports using two metal sheets of 0.1 mm thickness. The device structure is simulated using FEM based commercial electromagnetic simulator Ansoft's HFSS ver. 5.0. Simulated results show that the input return loss is better than 30 dB and the power division is 4.7 dB at the three outputs with an amplitude imbalance of ± 0.3 dB at the design frequency. This device is being used to distribute LO power to three channels of monopulse receiver.

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