Design of an UWB power splitter of arbitrary split ratio using asymmetrical double ridge waveguide

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Abstract

An asymmetrical double ridge waveguide is used to develop power splitter/combiner with arbitrary power division ratio. The power splitter is inherently wide band covering the whole band of the waveguides. The splitter can have a very short length and needs the same width as the input waveguide. It has a highly constant coupling value with return loss better than 25 dB. Results of a 10-dB power splitter are presented as an example.

1. Introduction

Ridge waveguide technology has great importance in different microwave and antenna system since its invention in 1944 [1]. Its bandwidth is wider than conventional rectangular waveguides and it has a higher power handling capability, compared to planar and coaxial transmission lines. In addition, its ability to work at high frequencies makes it vital for many applications like radio astronomy and satellite communications. Lots of studies are performed to get the cutoff space and the field distribution inside the double and single ridge waveguides. A summary of these studies is available in [2]. Most of the studies on double ridge waveguides concentrate on the symmetric double ridge waveguides. To the best of our knowledge, the analysis of the asymmetric double ridge waveguide can be found only in [3], which presents its design curves.

Here, the asymmetric double ridge waveguide is used to develop an arbitrary-ratio power splitter/combiner that achieves wideband operation. Such splitter may be used either to divide the power equally between two ports or to sample the power propagating in the guide for measurement purposes. The paper is organized as follows: Section 2 introduces the geometry and design concept of power splitter that uses asymmetric double ridge waveguide. Section 3 shows the results of a 10-dB power splitter. Section 4 concludes the paper and states future work.

2. Design Concept and Geometry

Figure 1 shows an asymmetric double ridge waveguide with unequal ridge heights. The inner overall dimensions of the guide are a and b. s is the lower and upper ridge widths. Lower and upper ridge heights are denoted by h_1 and h_2, respectively, with an air gap between ridges d where $d = b - h_1 - h_2$. If $h_1 = h_2$, then the double ridge waveguide

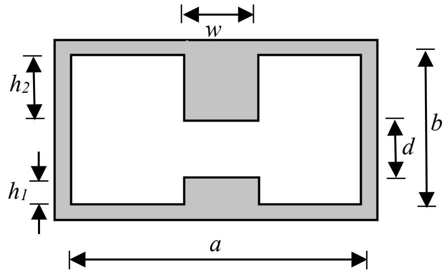

Figure 1: Asymmetrical double ridge waveguide.

is said to be symmetric. In this case, the double ridge waveguide cutoff space is determined by the transverse resonance method where the jump in the ridge waveguide on both sides of the ridge is represented by a capacitive susceptance calculated as in [2]. To calculate the cutoff space of the single ridge waveguide, same formulas are used such that the cutoff space of the single ridge waveguide formed by halving a symmetric double ridge waveguide is the same as the double ridge cutoff space. The reason behind this can be understood from the field distribution inside a symmetric double ridge waveguide. At the horizontal plane passing through the half of the structure, the electric field lines are found to be all perpendicular to the plane. It means that dividing the double ridge waveguide into two equal single ridge waveguide using a Perfect Electric Conductor (PEC) sheet at the position of the horizontal plane shall change nothing of the double ridge characteristics. This consequently means that the generated single ridge waveguides have the same cutoff space of double ridge waveguides and same field distribution found in a half of the double ridge waveguide.

In case of asymmetrical double ridge waveguide, the horizontal sheet of zero tangential electric field still exists; however, it is not in the middle of the guide anymore. Since the only asymmetric part of the guide now is the ridge heights then we can consider that height of new symmetry plane b_1 is determined by the ratio of ridge heights such that:

$$\frac{h_2}{b - b_1} = \frac{h_1}{b_1} \quad . \tag{1}$$

This means the appropriate position in symmetry plane is:

$$b_1 = \frac{b\, h_1}{h_2 + h_1} \tag{2}$$

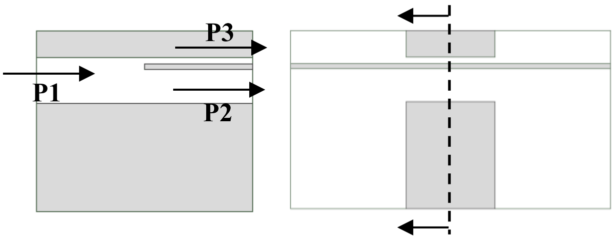

Figure 2: Power splitter side and front view.

Equation (2) specifies the location of the symmetry plane. However, the power split ratio cannot be determined this way. In order to determine the power split ratio, we consider two single ridge waveguides G_1 and G_2 of the same width and whose ridges have the same width are placed on top of each other with the rule in equation (1) has been considered. If a part of the common wall is removed from one side of the guide, this in fact will not perturb the field distribution in the guide and in this case, we have double ridge to a single ridge power splitter/combiner. It is supposed that the amount of power carried by each guide can be computed at $f = \infty$ using the formula in [2]:

$$P_{SR} = \left(\frac{E_o{}^2 d\, \lambda_c}{2\pi\eta_o}\right) \left\{ \left(\frac{4d}{\lambda_c}\right) \ln\left(cosec\left(\frac{\pi d}{2b}\right)\right) (\cos\theta_2)^2 + 0.5\,\theta_2 + 0.25\sin(2\theta_2) + \left(\frac{d}{b}\right)\left(\frac{\cos\theta_2}{\sin\theta_1}\right)^2 [0.5\,\theta_1 - 0.25\sin(2\theta_1)] \right\} \qquad (3)$$

where E_o is the peak electric field at the center of the guide, $\theta_1 = \pi(a - s)/\lambda_c$ and $\theta_2 = \pi s/\lambda_c$.

Now, since we can obtain the two guides' cutoff frequencies [2], then their relative power ratios can be determined as P_{G1}/P_{G2}, which is actually the power splitting ratio. During synthesis, if h_1 *and* b_1 are in hand, a value of h_2, and consequently *b,* generating a certain power ratio may be obtained, which is the typical synthesis problem for a power splitter designed to measure the power flowing in a single ridge waveguide.

Design geometry is shown in Figure 2 as it appears in HFSS software. The structure has 3 ports: Port 1 is an asymmetrical double ridge waveguide, Ports 2 and 3 are the single ridge waveguides. For power splitting, power is supposed to enter the guide through Port 1 and exit through Ports 2 and 3. The structure has been made long for illustration only.

Later, a 3 dB, 6 dB and 15 dB power splitting ratio will be presented. For splitters of high splitting ratio, a correction factor needs to be used with the equations in order to be able to design the required power split ratio accurately. Also, a study of the dominant mode, bandwidth on each port of the device is carried out to prove that the intersection bandwidth of the dominant mode reaches 3 to 1 even for 15 dB coupling ratio. In addition, analyses of the effect of sheet thickness of the device are carried out.

3. Results

The proposed ridge waveguide power splitter/combiner is tested using the following set of parameters: b=9.14 mm, h_1=6 mm, h_2=0.86 mm, a=18 mm and s=5 mm. Splitting sheet has thickness 0.2 mm. The design shown in Figure 2 is simulated on ANSYS HFSS v.17 [4]. If we used this set of parameters with a splitting sheet of thickness 0.2 mm, the S-parameters of the structure are obtained as shown in Figure 3. The structure is shown to have S_{11} < -25 dB with a constant coupling level of -10 dB at Port 2.

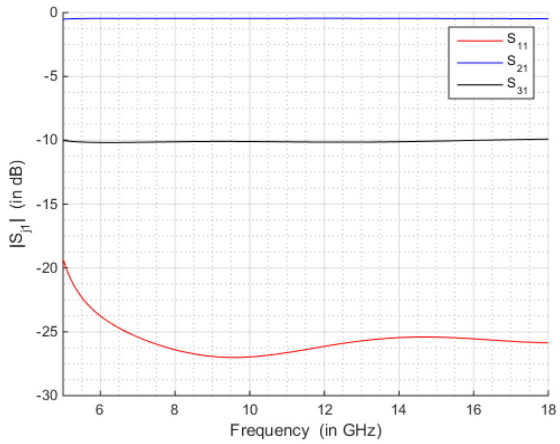

Figure 3: S-parameters for 10 dB power splitter.

It is worth noting that the CST Eigenmode solver is used to determine the dominant mode band for each of the device ports. Port 1 (asymmetrical double ridge waveguide) has dominant mode 4.5 GHz - 15.3 GHz, port 2 of lower power has 5.1 GHz – 19.77 GHz while Port 3 has 4.4GHz- 15.65 GHz. This means the intersection bandwidth for dominant mode operation for whole device is 5.1 GHz to 15.3 GHz i.e. 3 to 1.

4. Conclusions

A 3-port power splitter/combiner has been designed to work on a very wideband with arbitrary power division ratio. The input port of the splitter is a double ridge waveguide whose symmetry depends on the desired power split ratio while output ports are single ridge waveguides. A design procedure has been outlined for such splitter to have different splitting ratios beyond 10 dB. The results of a 10-dB splitter have shown that the splitter has a very low return loss. Such power divider may be used as a coupler for measurement purposes.

5. References

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