Double-Ridge Five Port Power Splitter Using Gap-Waveguide

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***Abstract*—In microwave engineering, waveguides are a key component when transmitting high frequency waves with low losses. However, these are inherently bulky in size and difficult to integrate with other microwave components. Gap-Waveguides are a good solution for mm-wave frequencies since they are easier to integrate with other components and easier to fabricate since there is no need for a complete physical shield. This work uses gap-waveguide technology to develop a 4:1 power splitter network that can operate from 20 GHz to 40 GHz with very low losses and less than 2:1 VSWR.**

I. Introduction

One of the early milestones in microwave engineering was the development of waveguides and other transmission lines for the low-loss transmission of power at high frequencies [1]. Conventional metallic waveguides have the drawback of being bulky in size and hard to integrate with integrated circuits, and require high resolution for their fabrication at mm-wave frequencies. In addition to conventional waveguides, substrate integrated waveguide (SIW) and Gap-Waveguides can be used as alternatives. Normal waveguides have the drawback of being bulky in size and hard to integrate with other waveguides whereas substrate integrated waveguides introduce high dielectric losses at the higher frequencies. On the other hand, gap-waveguides eliminate dielectric losses and are easy to implement at higher frequencies. This makes them suitable for high frequency applications, especially applications at extreme environmental conditions where substrates could be structurally and mechanically compromised. Gap-waveguide can provide large bandwidths which, in addition to their flexibility in integration, makes them very suitable for feed networks for antenna arrays.

In this work a five-port corporate feed network is designed, using a double ridge-gap waveguide. So far, all the works reviewed [2-4] studied feed networks with a maximum bandwidth of 50% using single ridge gap waveguide technology. Adding a second ridge will help to move the second mode up in frequency and makes it possible to operate over a 2:1 frequency bandwidth.

II. Double-Ridge Gap Waveguide Design

The very first step in this design is the design of the so-called bed of nails. The bed of nails will substitute the waveguide walls acting as an artificial perfect magnetic conductor which produces a stop-band filter effect. For this work the bed of nails should have a stop band effect from a bandwidth wider than 20-40 GHz which is the intended operational bandwidth. The design was completed using eigenmode analysis in the Ansys High Frequency Structure Simulator (HFSS). With the eigenmode analysis completed a dispersion diagram was then generated to corroborate the frequency bandwidth of the stop-band effect. Fig. 1 shows the dispersion diagram and the key design parameters of the nails. From the dispersion diagram it can be observed that the stop band effect of the bed of nails operates at the desired operational bandwidth of 18-45 GHz.

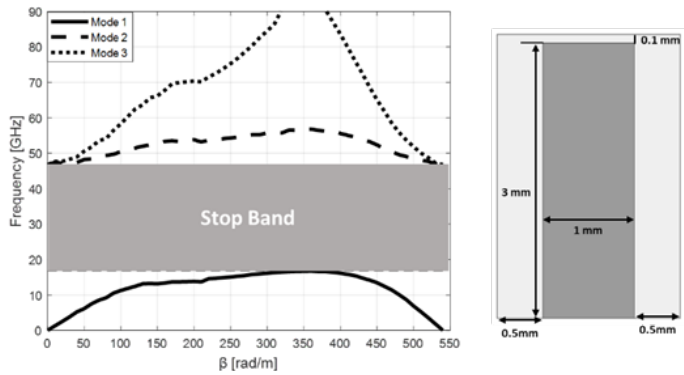

Figure 1. Bed of Nails Dispersion Diagram (left) and Design Parameters (right)

Once the design of the bed of nails was completed, a baseline Double-Ridge Gap Waveguide (DRGW) was then defined, as shown in Fig.2. The DRGW structure consists of two identical ridges at the center of the waveguide separated by a gap of 0.2 mm between the two ridges. The ridges are separated from the bed of nails by 2.55 mm on each side. The baseline DRGW was simulated in Ansys HFSS and the results of the propagation constant are shown in Fig 2. From Fig 2. it can be observed that the fundamental mode of the waveguide starts to propagate well below 10 GHz. As mentioned before, adding a second ridge would help to push up the cut-off frequency of the second and third mode. As shown in Fig 2., the cut-off frequency of the second propagating mode in the waveguide was pushed to approximately 47 GHz and the third mode with the same behavior as mode 2. Note that the first mode started to propagate well below 10 GHz, therefore, it is good to say that the waveguide will easily achieve the desired 2:1 frequency bandwidth.

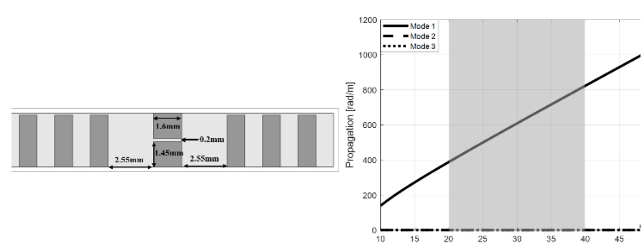

Figure 2. Double Ridge Gap Waveguide Configuration (left) and Propagation Results (right)

III. CORPORATE FEED NETWORK DESIGN AND RESULTS

The main purpose of this work is to design a five-port power divider. The network consists of three power dividers made out a double ridge topology. Inherent impedance mismatches are created at each of the power dividers used as shown in Fig. 3. Based on the analysis an impedance transition from 40 to 70 ohms is needed to properly reduce mismatch losses at each of these power dividers. The transitions were implemented by changing the spacing between the ridges given that a larger gap produces a larger impedance. Such transitions were implemented with linear tapers to eliminate the frequency dependence of the impedance behavior hence producing a wider frequency bandwidth.

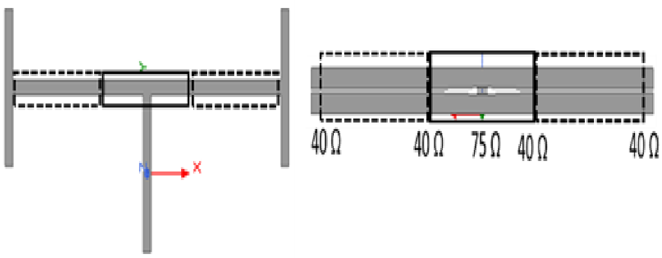

Figure 3. Impedance Mismatched in the power divider (left) and impedance transition implemented (right)

With all the components needed for the network properly designed, the power divider was defined as described in Fig. 4. Three rows of the bed of nails were used and a portion of two pins were used in the intersection of the power divider to further improve guiding and avoid interaction between each branch of the power divider. This was implemented in all three of the dividers in used.

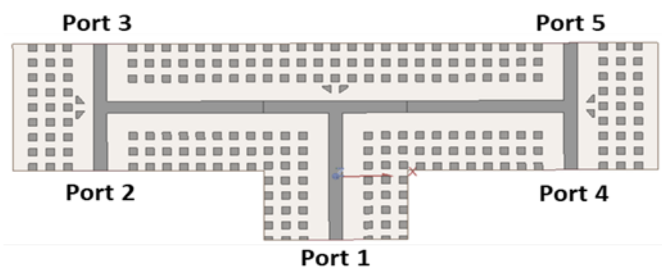

Figure 4. Five Port Double Ridge Corporate Feed Network

As shown in Fig. 5, the VSWR is maintained below 2 through the entire bandwidth (20-40 GHz). Coupling terms, also depicted in figure 5, show minimal transmission losses through the entire 20-40 GHz bandwidth. Functionality of the bed of nails can be observed in Fig. 6, which clearly show the E field contain withing the waveguide only at the frequencies where it operates.

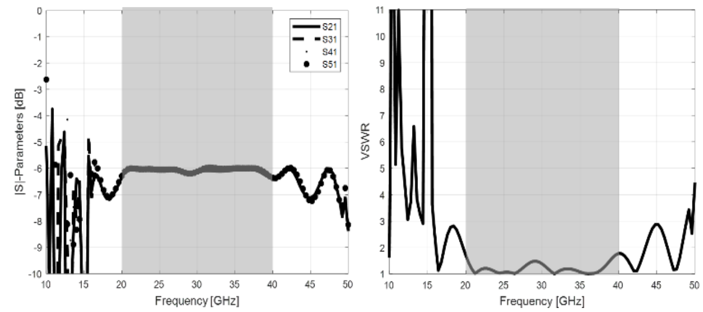

Figure 5 Transmission Coefficients (left) and VSWR (right) for the feed network.

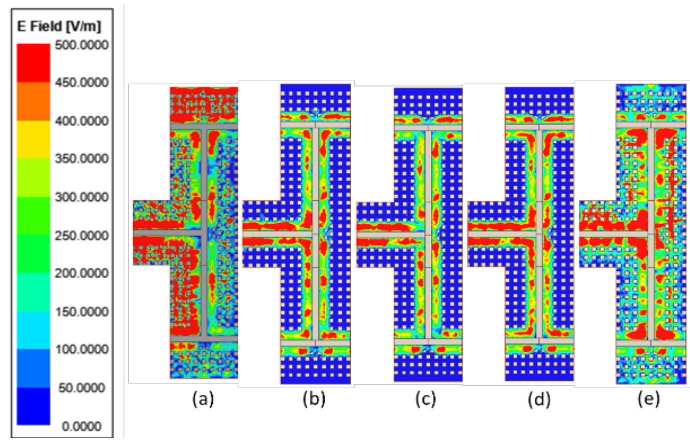

Figure 6. Electric field for 10 GHz (a), 20 GHz (b), 30 GHz (c), 40 GHz (d), 50 GHz (e)

IV. CONCLUSION

A five-port double ridge corporate feed network was designed. As desired the network works over a 2:1 frequency bandwidth (20-40 GHz) with the possibility to expand such bandwidth. The was implemented using the so-called bed of nails to act as the waveguide walls. Due to the inherent impedance mismatched at the power dividers in the network, taper impedance transitions were implemented to further improve the performance. VSWR and transmission coefficients showed minimal losses in the network.

ACKNOWLEDGMENT

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