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Wideband power divider design based on miniaturized ridge waveguides

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***Abstract*—Beam forming networks (BFNs) are of paramount importance in communication satellite systems, subject to stringent mechanical, thermal and RF requirements. One of the fundamental constituents of these BFN are power dividers, enabling the distribution of the signal from a centralized input port to a larger array of output ports. In this work, we present a design of a wideband compact power divider transition connecting a conventional waveguide ridge (WRD180) to two smaller symmetric ridge waveguides within the same cross section envelope and along the longitudinal main direction of the waveguide. This strategy allows to save space by combining in a single element the functionalities of waveguide transition and power divider, minimizing its impact on the in-plane dimensions of the feeding network. The design follows a semi-analytical method for optimizing a smooth profile variation along the transition that is compatible with the tolerances of conventional milling techniques, and state-of-the-art metal 3D printing technologies. The developed design operates from 17.2 GHz to 33.9 GHz with return losses better than 20 dB in simulation, covering the uplink and downlink frequency bands dedicated to satellite communications in K/Ka-band.**

***Index Terms*— Satellite communications, K/Ka-band, Ridge Waveguide Transition, Wideband Power Divider**

I. Introduction

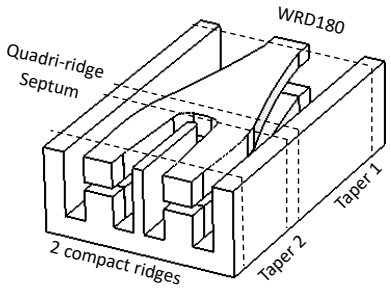
The K/Ka band satellite communications are emerging as a viable solution to provide broadband access, avoiding the already congested C- and Ku-bands. The space segment is adapting to this new reality where commercial interest in small satellites is flourishing. These systems rely on cost-effective broadband RF devices for stringent space requirements [1]. Fully metallic RF components are usually employed in RF satellite systems, e.g., orthomode transducers [2], turnstiles [3] and antennas [4]. These designs tend be more efficient and stable against the harsh space environment and avoid outgassing issues. Waveguide solutions are also being considered for the ground segment to produce power-efficient user-terminals [5], [6].

Beam forming networks (BFNs) are composed of power dividers spreading the energy from the input port(s) to a larger array of output ports [7]. Usually, a large division ratio is required between the input and output ports increasing the overall size and complexity of the structure. Broadband power dividers in magic-tee like configurations are a mature solution [8]. The presence of the loaded port enables to absorb possible mismatch coming from the radiating elements. But it has been demonstrated that with adequate design, a reactive tee-junction is sufficient in most cases [6].

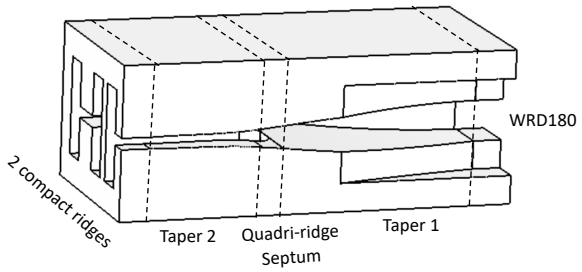
The goal of this work is to present a more compact alternative. The proposed power divider works as an adapter from a conventional ridge waveguide (WRD180) to two compact ridge waveguides with balanced power transfer. The differentiating feature of this device is that the cross-section of the transition has always the same size, producing two separate electromagnetic paths within a constant envelop. When integrated in a BFN, this configuration allows having closer feeding points which can decrease the overall size of the structure while avoiding grating lobes at array level. This miniaturization is obtained by controlling the ridge spacing, which requires a specific transition. Based on equivalent circuit model theory [9], we optimize the smooth profile variation along the transition while keeping it compatible with typical fabrication tolerances of conventional milling techniques, and state-of-the-art metal 3D printing technologies. The operating bandwidth of the power divider preserves the operating bandwidth of the standard input double-ridged waveguide. The simulated return loss of the proposed waveguide power divider is better than 15 dB from 16.8 to 40 GHz. From 17.2 GHz to 33.9 GHz, the return loss is better than 20 dB, covering the uplink and downlink frequency bands dedicated for satellite communications in K/Ka-band.

II. Design Procedure

As represented in Fig 1, the proposed waveguide power divider comprises the cascading of an input standard WRD180 Ka-band double ridged waveguide (corresponding to the device input port), a tapered double ridged waveguide, a quadri-ridged tapered septum and two adjacent double ridged waveguides with smaller cross sections, corresponding to the two device output ports. As mentioned above, the cross-section of the component remains unchanged throughout the transition, resulting in the two output ports having the same in-plane dimensions as a single standard SRD180.



a)



b)

Fig. 1 Power divider schematics: (a) top isometric cut view; (b) lateral isometric cut view.

The design procedure starts by defining the output ports geometry. The restrictions that the two output ports occupy the same cross-section as the standard double-ridge waveguide WRD180 and are symmetric (for a balance power division), implies that the only degree of freedom is the ridge spacing. It is well characterized that when the ridge gap in a double-ridge configuration is reduced, the bandwidth of the waveguide increases. The cut-off frequency of the waveguide is obtained based on the Transversal Resonant method [9] using the equivalent circuit shown in Fig. 2. The validity of this approached was confirmed by full-wave simulations showing a relative error below 1%. The ridge spacing obtained for a cut-off frequency of 16.5 GHz is 0.4 mm (see Fig.3).

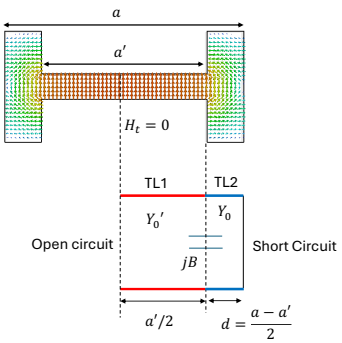


Fig. 2 Equivalent circuit model of a general double ridge waveguide [9].

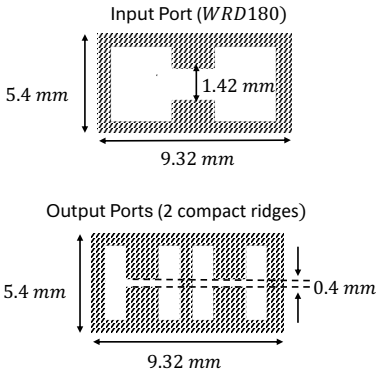


Fig. 3 Transversal section of the input and output ports. .

The next step is to design the transitions between the quadri-ridge septum and the input and output ridged waveguides. This septum has multimode operation. To avoid exciting higher-order modes, the geometry of these transitions needs to be carefully crafted, avoiding impedance discontinuities. The classical approach is to perform a multi-step transition, herein we adopted a continuous taper which do not adds fabrication complexity, assuming 3D metal printing as a baseline. Simulations show that better return loss can be obtained in these cases. Applying the transversal resonant method for the other types of cross sections along the device (Fig. 4) we can find the possible locus for these required tapers in both dimensions (i.e. ridge gap and in-plane cross section). The final profile is represented in Fig. 1. The return loss of the power divider (Fig 5.) is shown to be better than 20 dB between 17.2 GHz to 33.9 GHz, which covers the uplink and downlink frequency bands allocated to satellite communications in K/Ka-band.

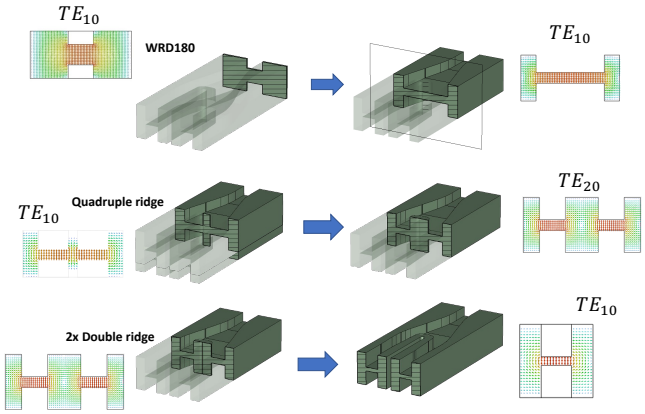


Fig. 4. Cross sections along the power divider and corresponding propagating modes.

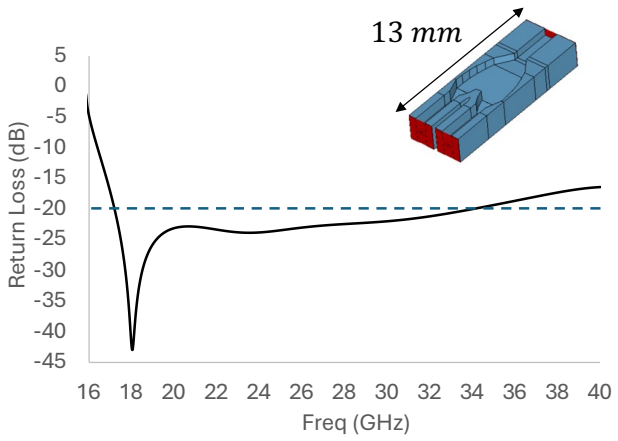


Fig. 5. Simulated power divider return loss.

III. Conclusions

We presented a wideband compact waveguide power divider for integration into BFNs of satellite communication devices that can provide power division from a standard ridge waveguide (WRD180) to two balanced compact double-ridged ports. The device has the particularity of having a constant cross-section, corresponding to that of the standard waveguide, facilitating the integration of this device in the corresponding BFN. Experimental validation of a back-to-back configuration is ongoing using full-metal 3D printing.

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