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Ultra Wideband Three-Channel Rotary Joint Design Using Curved Double-Ridged Waveguide

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***Abstract* — In this paper design and simulation of an ultra wideband three-channel rotary joint is presented. To do so, the double-ridged waveguide is exploited to increase the bandwidth of the operation. Due to use of the concentric coaxial lines and curved form of the waveguides, the rotary joint has a small size. Simulated results demonstrate the VSWR of less than 2 and the insertion loss of less than 0.5 dB for three channels over the frequency bandwidth of 8 to 18 GHz.**

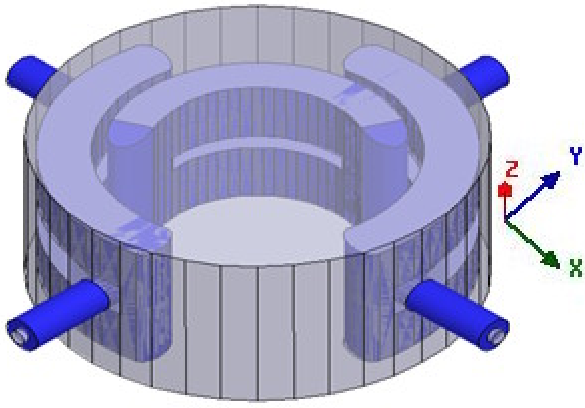
***Index Terms* — Concentric coaxial line, double-ridged waveguide, rotary joint.**

I. INTRODUCTION

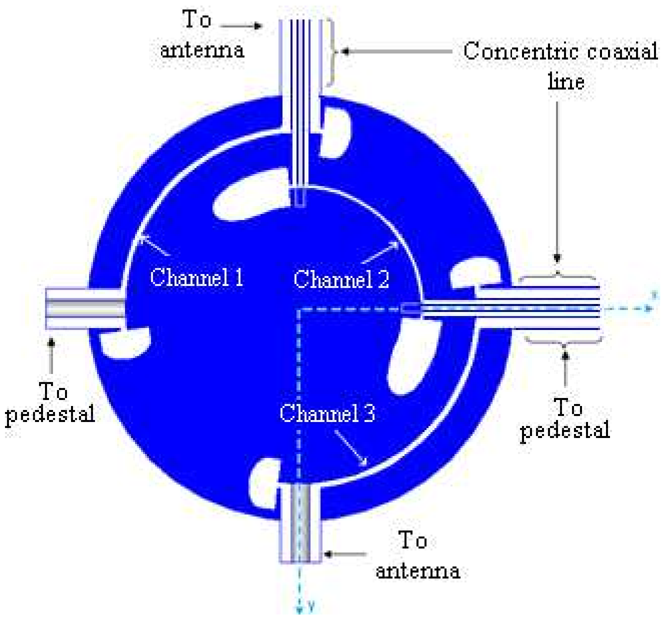
The rotary joint is an integral part of any rotational microwave communication systems, such as spacecraft [1] and tracking radar systems [2]. It is an electromechanical device that provides a critical interface between the stationary and rotating section of system, allowing signals to be transmitted back and forth between the antenna and the pedestal with little reflection and low insertion loss. Characteristics of rotary joint should not be sensitive to mechanical rotations. Conventional rotary joints are narrow in bandwidth so they should have several channels to cover a wide frequency bandwidth. In this paper a wideband characteristic for the rotary joint is achieved through utilizing double-ridged waveguide. Propagation characteristics of a double-ridged waveguide have been investigated with various methods [3]-[7]. Double-ridged waveguides have preferential features for using in wideband applications such as the low cutoff frequency and wide bandwidth. Double-ridged waveguides satisfy requirements of applications that need to have a transmission line with a single mode of propagation over extensive bandwidth. An additional advantage follows from the fact that the low insertion loss of double-ridged waveguides make them suitable candidates for use in the design of rotary joints.

II. ROTARY JOINT CONFIGURATION

Fig. 1(a) shows 3D view of the configuration of the rotary joint. The structure is a cylinder with four arms, which three waveguide channels are subtracted from it. The cross section of rotary joint in x-y plane is depicted in Fig. 1(b). The configuration is symmetric with respect to x-y plane. Each c-



(a)



(b)

Fig. 1. (a) 3D configuration of rotary joint, (b) cross section in x-y plane.

hannel is a curved double-ridged waveguide which is connected to two coaxial lines. Geometries of Channels 1 and 3 are identical to each other therefore in the following sections characteristics of channels 1 and 2 are presented.

Due to rotation in both directions of azimuth and elevation, waveguides are bent so that the angle between axes of coaxial lines is 90 degrees and it makes the mounting of rotary joint on pedestal possible. Curved form of waveguides causes waveguides to fit into small space and a compact structure is achieved. To avoid misalignment of axes of coaxial lines of channel 2, from x or y axes, it should be passed through the inner conductor of ports of channels 1 and 3, making concentric coaxial line.

The proposed wideband rotary joint design follows the following steps: (1) design of curved double-ridged waveguides for channels 1 and 2 (2) design of coax to waveguide transition, (3) shape the cavity with the purpose of decreasing VSWR.

A. Design of double-ridged waveguide

The configuration of curved double-ridged waveguide is depicted in Fig. 2. Parameter R is the mean radius of curvature of the waveguide. The length and width of the cross section of the waveguide are determined by parameters a and b. The parameter s is the width of each ridge and d is the size of the gap between ridges. These two parameters perform the most significant role in frequency dependent behaviors of the waveguide and determine the cutoff frequency, wave number, waveguide impedance and attenuation of propagating modes. In ridged waveguides, operating bandwidth is the frequency range in which there is just one propagating mode but it is common to adjust the first cutoff frequency smaller than the low end of the desired bandwidth. Design of double-ridged waveguide for specified bandwidth is straightforward, but use of concentric coaxial lines, imposes a limitation on selecting values of ridges width. This implies that the ridge width of waveguide of channel 1 must be larger than the waveguide of channel 2 to allow inner line of concentric coaxial lines to pass through it and feeds channel 2. Owing to the previously mentioned reason, two waveguides for channel 1 and 2, with different sizes of ridges width and only one propagating mode over the frequency range 8 to 18 GHz are needed and this c-omplicates the design procedure. Different dimensions of ridges result in difference in waveguides impedances and this may be problematic when a matching to the 50 ohms coaxial line is required. A way to overcome this issue is to change width of waveguides cross section b, to make value of the waveguides impedance of both channels waveguides nearly equal. The Waveguide Impedance increases with the spacing between ridges and inversely with the ridges width and is real value for propagating modes [8]. Considering the value of waveguide impedance close to 50 ohms and operating frequency between 8 to 18 GHz, two different waveguides are designed and their accurate values of dimensions are presented in table 1. These parameters are chosen so that cutoff frequencies of dominant mode, i.e. TE_{10}, are 3.7 GHz and 4.5 GHz for waveguides of channel 1 and 2, respectively. Values of real part of waveguides impedance are in the range 40 to 50 ohm in operating bandwidth as depicted in Fig. 3.

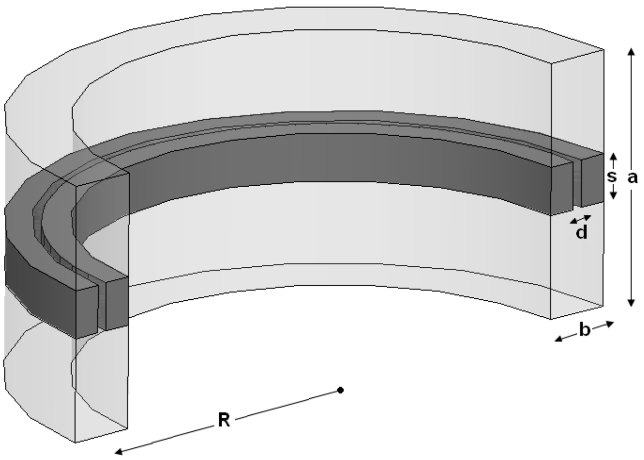


Fig. 2. Configuration of curved double-ridged waveguide.

TABLE 1
DIMENSIONS OF WAVEGUIDES FOR CHANNELS 1 AND 2. DIMENSIONS ARE IN MILLIMETERS.

	Channel1	Channel2
a	16.5	16
b	5.4	3.5
s	3.9	1.55
d	0.55	0.3
R	18.3	14.25

B. Design of coax to waveguide transition

In proposed rotary joint, the design of coax to waveguide transition is a critical issue. Duo to use of concentric coaxial lines and the curvature of waveguides, the matching technique is a bit different from method which is presented in [9]. Fig. 4 shows the curved double-ridged waveguide which is connected to two coaxial lines. Angles Θ_1 and Θ_2 are two

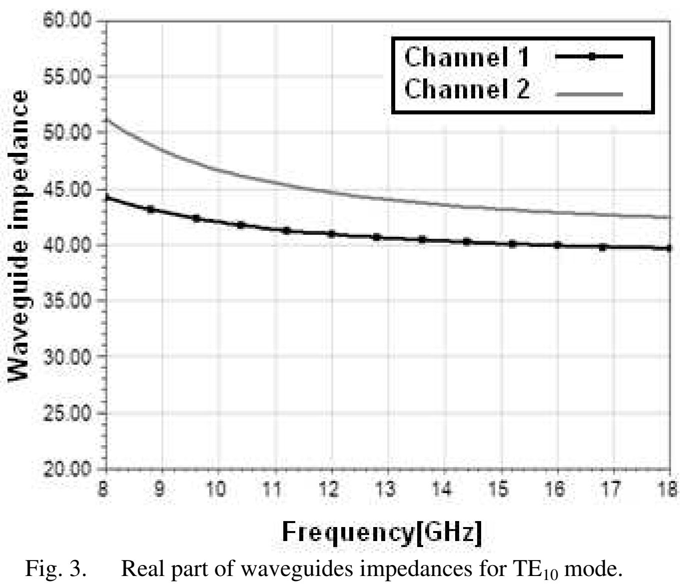


Fig. 3. Real part of waveguides impedances for TE_{10} mode.

parameters for adjusting the length of curves of inner and outer ridges, respectively. The outer ridge is a ridge which has larger radius than another ridge (inner ridge). To achieve a low VSWR in operating bandwidth, the shield of coaxial line should enters close to the edge of the outer ridge [9]. This can be done by choosing proper value of Θ_2. The inner conductor should also passes through the outer ridges and is connected to inner ridges. We found that to improve the VSWR, the junction of the inner conductor and the inner ridge must be very close to the edge of the inner ridge and it can be done by adjusting Angle Θ_1.

B. Design of cavity

In order to realize improvement in VSWR over the frequency band, existence of a cavity back is critical. To avoid discontinuity in curvature of waveguide the cavity follows the curved form of the waveguide. Fig. 5 demonstrates shape of the designed cavity back. The cavity is divided into two parts. The first part is the extension of the waveguide without ridges. The angle Θ_3 (Fig. 4) specifies the required length of waveguide for this part. Values of angles Θ_i are presented in table 2. Second part is an elliptical shaped cavity. It is half of a cylinder that is united to waveguide. Its cross section is half of an elliptic whose large diameter is equal to the width of the waveguide cross section, b. Dimensions of cavity are optimized to obtain the best possible VSWR. Results of optimization for value of small diameters of elliptical cavities are 3 and 4 mm for waveguides of channels 1 and 2, respectively.

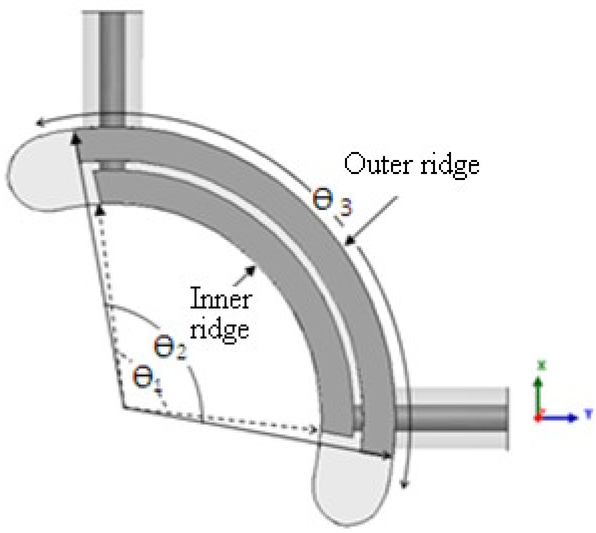


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Fig. 4. Transition of coaxial lines to the curved double-ridged waveguide.

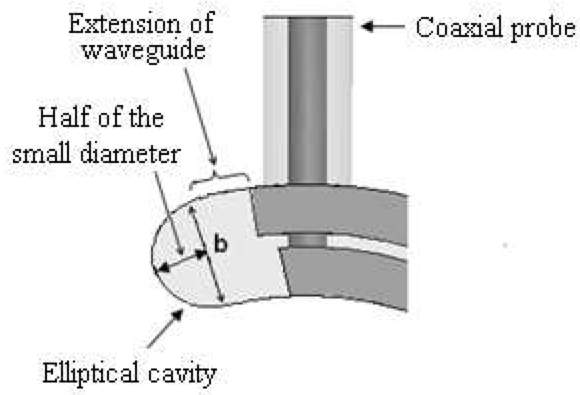

Fig. 5. Side view of the elliptical cavity.

TABLE 2

VALUES OF Θi FOR WAVEGUIDES OF CHANNELS 1 AND 2.

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	Channel1	Channel2
Θ_1(deg)	103.0	96
Θ_2(deg)	105.3	98
Θ_3(deg)	111.7	138

III. RESULTS

Fig. 6 shows the VSWR versus frequency for the channel 1 and channel 2 obtained by HFSS [10]. The figure demonstrates the maximum peak of the VSWR reaches to 1.92 for the channel 1, and 1.55 for channel 2. Simulations show the excellent results for insertion loss of rotary joint (Fig. 7). The insertion loss is less than 0.5 dB for channels 1 and 3 and is less than 0.3 dB for channel 2 over the frequency bandwidth.

IV. CONCLUSION

In this paper design and simulation of an ultra wideband three-channel rotary joint is presented. By utilizing curved double-ridged waveguide a wideband characteristics, ranging from 8 to 18 GHz with VSWR<2 and excellent insertion loss, is achieved. This frequency range along with compact size of rotary joint is very useful for wideband applications such as seeker antennas.

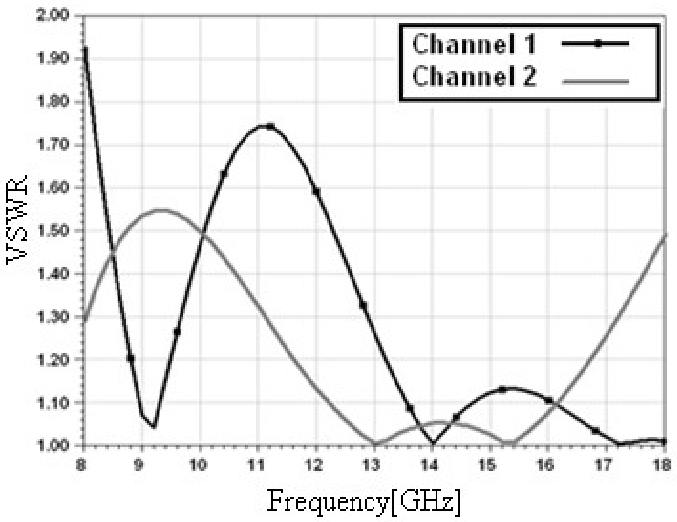

Fig. 6. VSWR versus frequency for channels 1 and 2.

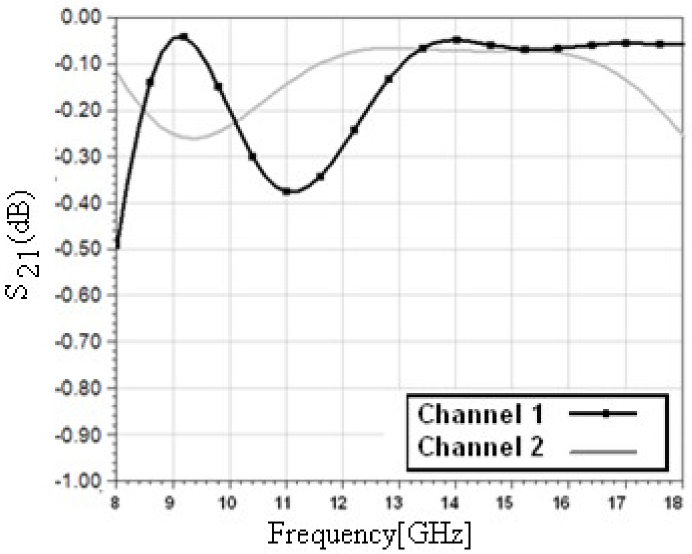

Fig. 7. Insertion loss versus frequency for channels 1 and 2.

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