Wideband single-ridge waveguide-coaxial converter design

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ABSTRACT

In order to meet the conversion requirements between various types of transmission lines in microwave systems, an ultra-broadband single-ridge waveguide-coaxial converter spanning X and Ku bands is designed in this paper by using a single-ridge waveguide plus a stepped impedance converter. The operating bandwidth is 7.31Ghz-15GHz, and the return loss is better than -20dB. The design uses coaxial probe back-feeding, which is conducive to the cascading of the system, and also sets the tuning screw to facilitate the subsequent adjustment.The design provides a new idea for an ultra-broadband waveguide coaxial line converter across frequency bands.

Keywords: Single-ridge waveguide; Waveguide Coaxial Conversion; Broadband

1. INTRODUCTION

Waveguide-coaxial converters are extremely important passive connection devices in radar systems, precision guidance systems, and microwave test systems [1], and broadband waveguide coaxial converters have been extensively designed and studied to meet the application requirements of broadband systems [2]. A ridge waveguide is a rectangular waveguide protruding inward at the center of its wide edge, which is actually a deformed structure of a rectangular waveguide, which has a wide operating band, low equivalent characteristic impedance, and small size compared to a rectangular waveguide [3].

The coaxial waveguide converter inserts a coaxial inner conductor into the waveguide cavity, and the coaxial inner conductor is equivalent to a probe in the waveguide, which will radiate the energy transmitted by the coaxial line through the probe head, and the electromagnetic field excited in the waveguide will complete the energy exchange between the probe and the waveguide [4]. In the waveguide, the insertion of the probe will cause discontinuity, which in turn generates an infinite number of higher modes, and only the primary mode can be transmitted in the waveguide, and the higher modes that cannot be transmitted will gather around the probe to generate reactance effects, and the introduction of the step matching structure through the double ridge structure and the adjustment of the probe insertion can largely offset the reactance introduced by the higher modes [5].

At present, there are two types of insertion methods for coaxial-waveguide converter connector probes, one is the inline structure and the other is the back-fed structure. The analysis method of inline is mainly pattern matching idea, and the input port and output port of this inline structure are not on a horizontal line, which is not compact enough and is not conducive to the cascade between systems. The coaxial waveguide converter designed in this paper adopts the back-fed structure, where the input port of the coaxial line and the output port of the waveguide are on the same horizontal line, which is conducive to the cascade between systems [6].

Coaxial-waveguide conversion is mainly mode conversion and impedance matching. The coaxial line transmits TEM waves, the main mode of the ridge waveguide is T E10 mode, and the coaxial waveguide converter is to realize the conversion from coaxial line TEM to TE10 mode of the waveguide, while the characteristic impedance of the standard coaxial is 50 Ω and the characteristic impedance of the waveguide is greater than 120 Ω. The impedance matching of the coaxial waveguide is to match between the 50 Ω of the coaxial line to the high impedance of the waveguide [7].

In this paper, the idea of designing a ridge waveguide-coaxial converter is to use a back-fed type to connect the probe of SMA connector to a rectangular waveguide of the same size as the ridge waveguide, and to direct the electromagnetic waves transmitted by the coaxial line to the ridge waveguide by coupling the coaxial probe to excite the electromagnetic field in the waveguide and introducing a section of square coaxial transmission line for transition. However, direct introduction will produce large reflections due to mismatch and affect the electromagnetic wave transmission, so a step

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impedance converter is used to achieve good matching by setting up a step impedance converter and changing the characteristic impedance size in a graded manner to achieve good transmission effect.

2. BROADBAND SINGLE-RIDGE WAVEGUIDE-TO-COAXIAL CONVERTER DESIGN AND SIMULATION

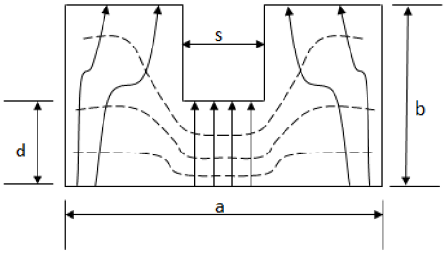

Figure 1 Schematic diagram of ridge waveguide EMF force line distribution

The ridge waveguide propagation modes are TM and TE modes, and Figure 1 shows the distribution of the main mode TE10 mode electromagnetic field force lines for a single ridge waveguide, along with the physical dimensions of the single ridge waveguide such as the wide edge a, narrow edge b, ridge height d, and ridge width s. The loading of the ridges inside the waveguide makes the impedance of the ridge waveguide lower relative to that of the rectangular waveguide [8] making it easier to match the impedance to the coaxial line. The dimensions of the ridge waveguide selected for this paper are wide edge a = 16.42 mm, narrow edge b = 5 mm, ridge height d = 1.75 mm and ridge width s = 5.3 mm.

In order to verify the above design scheme, a simulation model was created in HFSS. It can be concluded from the research literature that the input impedance of the probe of the SMA connector is related to the diameter of the probe, the length of the probe inserted into the cavity [5]. The matching effect can be adjusted by adjusting the depth of the probe into the cavity, so this parameter becomes a key influencing factor for the ridge waveguide-coaxial converter. In this paper, an SMA connector, model KFD-21, with a probe diameter of 1.3 mm is used. the cavity is chamfered to facilitate processing.

After the above analysis, the final specific HFSS modeling is shown in Figure 2. From left to right: single ridge waveguide - stepped impedance transform - square coaxial structure - coaxial probe back-feed structure - coaxial line.

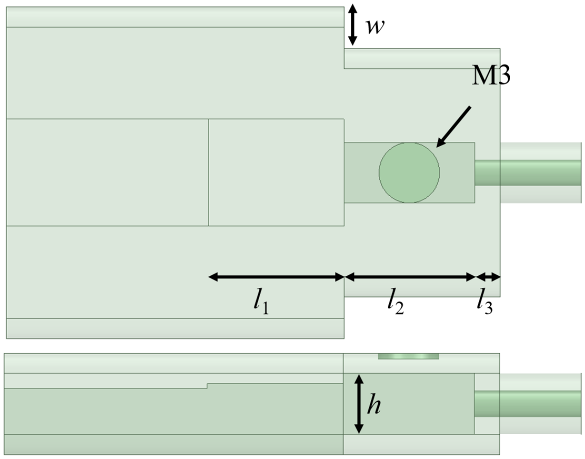

Figure 2 Ridge waveguide coaxial conversion structure

Table 1 Dimensions of the ridge waveguide coaxial line converter

Name	l_1	l_2	l_3	h	w
Size/mm	6.69	6.47	2.42	3	2.07

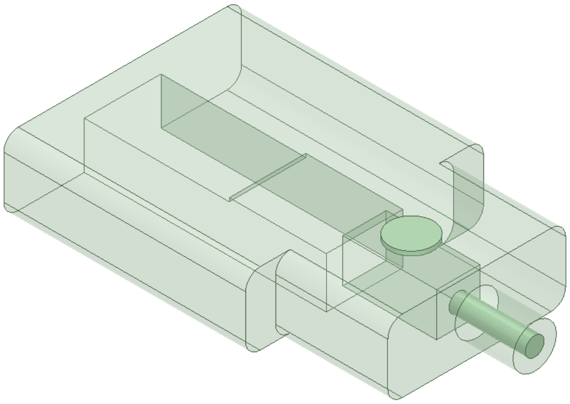

Figure 3 ridge waveguide coaxial conversion overall structure

In order to facilitate the subsequent processing and debugging, a tuning screw of size M3 is set directly above the square coaxial connected to the coaxial line probe, and the size of the tuning screw into the cavity is used as one of the optimization parameters for co-optimization simulation, and finally, after optimization and adjustment, the physical size is obtained as shown in Table 1, and the simulation results are shown in Fig. 4. From the results, it can be seen that S11 is better than 20 dB in the range of 7.31 GHz-15 GHz. The field distribution of the ridge waveguide coaxial converter is shown in Fig. 5.

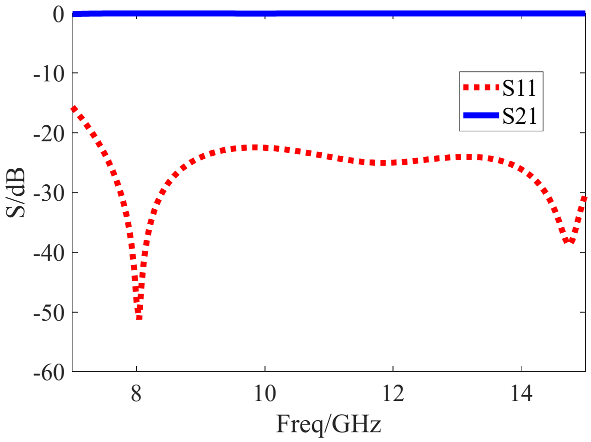

Figure 4. Simulation results of ridge waveguide coaxial line converter

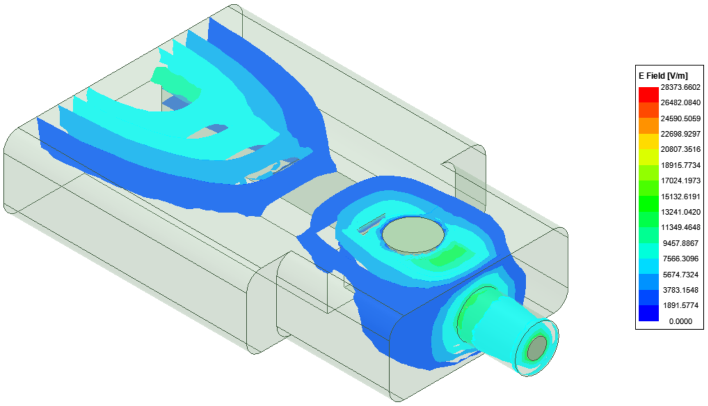

Figure 5 Ridge waveguide coaxial line converter field distribution

3. WAVEGUIDE COAXIAL LINE CONVERTER PHYSICAL TEST

To verify the correctness of the wave-to-simulation results, the ridge waveguide coaxial converter was applied to the common common terminal output of a duplexer across the X and Ku bands and machined for physical testing.

Due to the special structure of this duplexer, the precise machining of the common end is a difficult task, and for the sake of accuracy of the machining assembly, the wave-to-converter is machined separately. As shown in the figure, the marked part is the structure of the wave-to-switching converter, the ridge of the wave-to-switching converter is machined directly with the two channels as one, and finally the common end of the wave-to-switching converter is fixed by screws; in order to better weld the SMA connector, a hole slightly thicker than the probe is machined in the centre of the protruding ridge, and the final assembly result is shown in Figure 7, the marked part is the M3 screw of the simulation design. After actual testing, the test results of the duplexer match the simulation results, which indirectly verifies the correctness of the ridge waveguide coaxial converter.

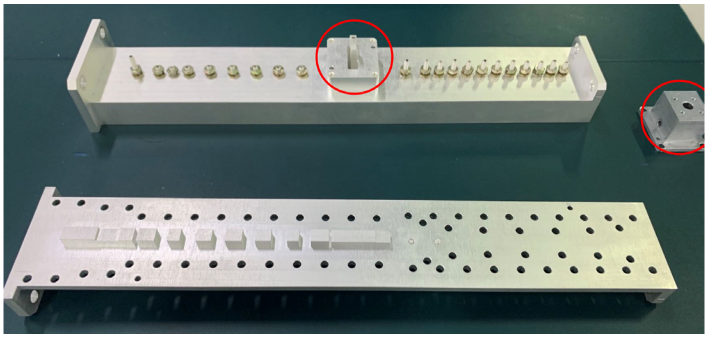

Figure 6 Physical Waveguide Coaxial Cable Converter

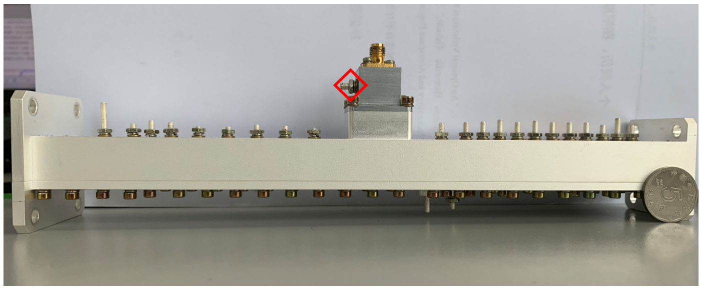

Figure 7 Overall structure of the waveguide coaxial line converter

4. CONCLUSION

In this paper, the working principle of the ridge-waveguide coaxial converter and the matching method are analyzed, and the dual-ridge coaxial-waveguide converter is studied. A good match is finally achieved by building a realistic simulation in HFSS and optimizing the height of the step and the depth of probe insertion, and this converter is verified by simulation.The ridge waveguide coaxial converter uses a new form of stepped impedance combined with a square coaxial line, providing a new idea for the design of ultra-wideband wave-to-side converters across frequency bands.

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