A Wideband Orthogonal-Mode Junction Using a Junction of a Quad-Ridged Coaxial Waveguide and Four Ridged Sectoral Waveguides

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***Abstract*—A wideband orthogonal-mode junction (OMJ) using a quad-ridged circular coaxial waveguide and four single-ridged sectoral waveguides is described. The new structure is used for extracting a wide lower band signal from a coaxial dual-band feed. Theoretical results show that the broadband incoming signal in the quad-ridged coaxial waveguide can be coupled to four single-ridged sectoral waveguides with low reflection. The new structure transforms a complex system to a simple single-ridged sectoral waveguide where multi-band separation can be accomplished by a number of means. The transformation eliminates the interference among the excitation sources and enables the accurate mathematical modeling of the complete system possible.**

***Index Terms*—Coaxial quad-ridged waveguide, dielectric loaded horn, OMJ, orthogonal-mode junction, sectoral ridged waveguide.**

I. INTRODUCTION

A dielectric-cone-loaded feed horn has been developed for broadband applications [1]. The dual-band polarized signals can be coupled to a coaxial waveguide by using a proper matching section. There are at least two methods proposed for extracting the polarized lower band propagating in the coaxial waveguide, one being a quad-ridged circular coaxial waveguide diplexer [2] and the other a circular coaxial orthogonal-mode-junction coupler (OMJ) [3]. The quad-ridged coaxial waveguide design has some problems in the interference among the excitation probes, especially for dual-polarization operation. Moreover, this structure has been found difficulty in extracting multiple bands, and current designs rely largely on empirical methods. In contrast, the circular coaxial OMJ can be used for multiband operations. However, it has limited bandwidth. To date, the maximum achieved bandwidth is less than 10% for these structures [3], thereby limiting the full bandwidth potential of the dielectric-cone-loaded horn.

To overcome the problems in the previous designs, we propose a wideband orthogonal-mode junction (OMJ) [4] based on a junction of a quad-ridged circular coaxial waveguide and four single-ridged sectoral waveguides. Details of this OMJ are presented in the following sections with some theoretical results obtained by using a commercially available finite-element method software package [5] and partially validated using the mode-matching method [2].

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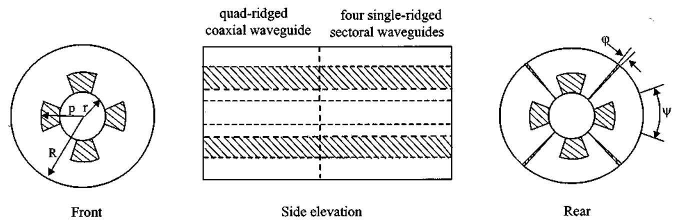

Fig. 1. Wideband OMJ using a junction of a quad-ridged circular coaxial waveguide and four single-ridged sectoral waveguides.

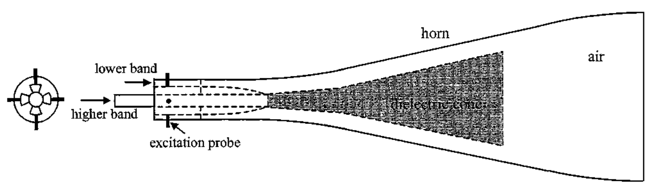

Fig. 2. Wideband OMJ connecting with a dielectric-cone-loaded horn.

II. THE NEW STRUCTURE

The wideband OMJ structure and together with a dielectric-cone-loaded horn described here are shown in Figs. 1 and 2, respectively. A quad-ridged circular coaxial waveguide is converted to four single-ridged sectoral waveguides by the insertion of four metal fins as shown in Fig. 1. Dual-polarized signals in the quad-ridged coaxial waveguide then separate into the four single-ridged sectoral waveguides. Thus, the hybrid TE_{11} mode in the quad-ridged region is transformed to a hybrid TE_{10} mode in each of the sectoral waveguides. Opposite pairs of these sectoral ridged waveguides can then be recombined in various ways, including use of a circular OMJ as presented in [3], to extract the signal.

The main advantage of this structure is transformation of hybrid TE_{11} mode in the quad-ridged coaxial waveguide to hybrid TE_{10} mode in four identical single-ridged sectoral waveguides, where analysis and design procedures become much simpler. The TE_{10} mode in each of these waveguides can be launched by using a probe or waveguide excitation as shown in Fig. 3(a) and (b). Furthermore, the isolation between orthogonal modes in the coaxial waveguide region is greatly improved with this structure as there is no direct cross-coupling among the sources.

To simplify the design further, the single-ridged sectoral waveguide can be transformed to a standard single-ridged rectangular waveguide by using a quarter-wave transformer or a slowly tapered section [4]. Following this transformation, off-the-shelf components can then be used directly for launching the required hybrid TE_{10} mode.

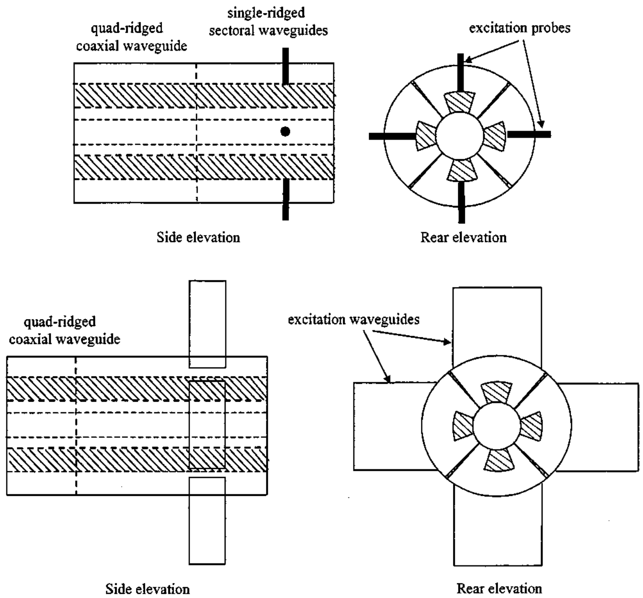

Fig. 3. Methods to excite the required TE_{11} mode using the proposed wideband OMJ.

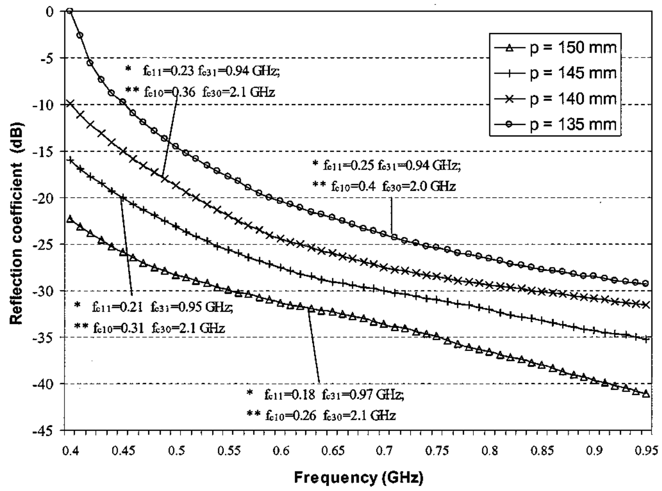

Fig. 4. Reflection coefficient of the junction of quad-ridged coaxial waveguide and four single-ridged sectoral waveguides with height of the ridge (p) as a parameter. $R = 160$ mm, $r = 60.8, \varphi = 2°$, and $\psi = 45°$. * cutoff frequency for TE_{11} and TE_{31} mode in quad-ridged coaxial waveguide; ** cutoff frequency for TE_{10} and TE_{30} mode in single-ridged sectoral waveguide.

III. Performance Analysis

Coaxial quad-ridged waveguide and sectoral ridged waveguide are well known as wide bandwidth structures. The proposed OMJ is a transformer that couples these two types of waveguides and the bandwidth of the OMJ is determined by the reflection/transmission parameters of the junction. Usually, the structure needs to be operated in the fundamental mode only and, therefore, the bandwidth is determined by the common bandwidth of the quad-ridged and single ridged waveguides.

A preliminary study on the reflection coefficients of the junction was conducted using the finite-element method [5]. For simplification in the mathematical modeling, a sectoral metal fin as shown in Fig. 1 is used to separate the quad-ridged waveguides. Fig. 4 shows the reflection coefficient in the quad-ridged coaxial waveguide end as a function of frequency with the height of the ridges as a parameter. To evaluate the bandwidth, the cutoff frequencies for the given quad-ridged coaxial waveguide (TE_{11} and TE_{31}) and single-ridged sectoral waveguide (TE_{10} and TE_{30}) are also given in the same figure. These cutoff frequencies have been verified using the mode-matching method [2].

Fig. 4 shows that the reflection coefficient reduces with increasing frequency. The figure also indicates that the reflection coefficient reduces with increase in the height of the ridges. This is because the field intensity in the metal fin region decreases with the increase in the height of the ridges, the reflection created by the wall (metal fin) of the sectoral waveguide reduces with increase in the height of the ridges. If a 20 dB return loss is regarded as the minimum performance and each structure is required to operate in the fundamental mode, the figure shows that the structure retains more than 40% of the bandwidth offered by the coaxial quad-ridged waveguide. For example, the bandwidth of the structure with ridge height $p = 150$ mm has a bandwidth greater than 1:2.5 (retaining 45% of 1:5.5 bandwidth offered by the quad-ridged waveguide). As the bandwidth of the ridged coaxial and sectoral waveguides increase with the height of the ridges, the bandwidth of the proposed OMJ can be broadened by increasing the height of the ridges.

IV. Conclusion

A broadband orthogonal-mode junction (OMJ) using a junction of a quad-ridged circular coaxial waveguide and four single-ridged sectoral waveguides is described and analyzed. The result shows that the bandwidth of this structure is broad and can be obtained without complicated analysis and optimization. The transformation from a dual-polarized quad-ridged coaxial waveguide to four identical single-ridged sectoral waveguides significantly increases the isolation among the excitation sources and provides increased flexibility for the antenna designer to configure the OMJ for single and multi- band applications. In addition, the single-ridged sectoral waveguide can be readily transformed to a standard single-ridged rectangular waveguide if desired and thereby utilize standard off-the-shelf components.

The current design and that presented in [6] use similar ridged waveguide structure. However, there are some distinctions between them. The new structure is designed for dual-band applications. Its sectoral and circular waveguide based structure offers smooth transition from the dielectric-cone-loaded horn to quad-ridged coaxial waveguide and OMJ. Moreover, the inner-ridged structure offers more flexibility for fabrication. The new structure has been implemented in the design of a dual-band feed system for the Parkes radio telescope with lower band operateing at 640 to 710 MHz [7] and higher band above 2 GHz. The performance of the entire system will be reported when the system completed.

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