Design of Octave-Band Magic-T Using Stepped Ridges and Posts

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***Abstract*— In this paper, the design of a wideband ridged waveguide magic-T is presented. The magic-T has three branches of single-ridged waveguide which is connected to a standard double ridged waveguide at the output. Utilizing an L-shaped septum and posts aid in achieving a return loss (RL) better than 20 dB over a frequency range of 20 GHz to 40 GHz. Additionally, the proposed Magic-T exhibits high E-H port isolation (>60 dB). This innovative design is well-suited for utilization in applications related to radio astronomy.**

***Keywords*— Magic-T, matching structure, rectangular waveguide, octave- band, ridged waveguide, radio astronomy.**

I. Introduction

THE magic-T is a passive microwave device that features four ports. Due to the limitation of regular three-port networks, which cannot be lossless, reciprocal, and perfectly matched across all ports simultaneously, the four-port magic-T addresses this challenge by integrating a combination of E-plane and H-plane T-junctions [1]. Upon introducing a signal to any of the ports, it divides equally between two output ports in terms of amplitude. Additionally, if the signal is applied to the H-plane (sum arm) port, the outputs will be in phase, while they will be 180 degrees out of phase if the signal originates from the E-plane (difference arm) port. The remaining port stays isolated and the level of isolation in a magic-T is significantly influenced by the matching structures employed in the junction. Usually, this configuration includes capacitively placed posts within the H-plane and inductively positioned irises near the E-plane [2]. Also, the symmetry in structure, particularly at the junctions, is a crucial factor that needs careful consideration during the design [3].

The primary benefit of the magic-T, distinguishing it from other T junctions, is that it ensures isolation among all ports regardless of the port which power is introduced. This characteristic makes the magic-T particularly well-suited for various applications like duplexers, mixers, isolators, and power combiners [4]. It can also improve the performance of an orthomode transducer and decrease the possibility of higher order mode excitation [5], [6], [7]. This design aims to create an octave band magic-T with excellent isolation, minimal loss, compatible with standard double-ridge waveguide.

II. Magic-T Design

The advancement of millimeter-wave instrumentation has created a high demand for magic-Ts that have wide bandwidth and can be integrated with other RF components specially in the field of radio astronomy [6], [8]. Nevertheless, it has been observed when designing a magic T, to achieve full 2:1 frequency bandwidth operation while also simplifying the

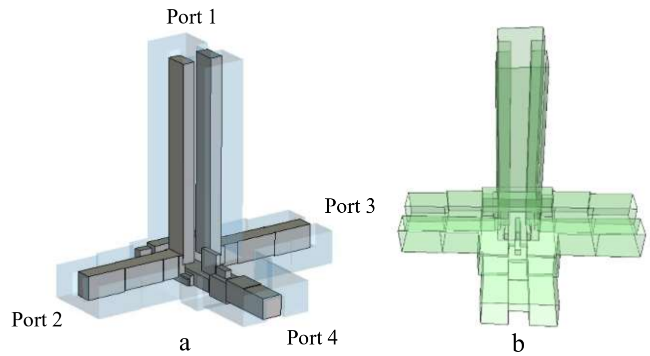

Fig. 1. Prototype of the proposed magic-T (a) CST, (b) µWaveWizard

fabrication and assembly process remain a challenging task. Adding ridges to waveguides is a way to lower the cutoff frequency and increase the total bandwidth [9]. The matching structures are crucial to address the inherent mismatches in Magic-Ts. Various types of matching structures have been proposed in earlier studies to fulfill this requirement. For example, in [3], metallic cones at the junction's center, a septum in the first port, and conducting posts in the second, third, and fourth ports enable a 36% bandwidth with RL < 20 dB. However, this design is tailored for lower frequencies, and challenges arise in machining the sharp cone edge at higher frequencies. The presented design in [10] incorporates stepped waveguides and a ridge at the sum port to achieve the desired performance within the frequency range of 28 to 36 GHz. In [11], a magic T is created with two rectangular posts, an L-shaped septum, and a cylindrical platform, operating in the 24 to 28 GHz frequency range for satellite communication. In [12], two designs utilizing Double-Ridged Waveguide (DRWG) and Pyramidal Ridged Waveguide (PRWG) are presented. The DRWG magic-T operates within a bandwidth of 27% (12.2 to 16 GHz) but requires assembly after separate processing. In contrast, the PRWG magic T, with a narrower bandwidth of 8.6%, meets printing requirements without overhang concerns, allowing for direct printing as a single piece. In [2], a magic-T operates from 7.5 to 18 GHz, utilizing a double ridged waveguide and two cylindrical posts. While achieving desired results for ports 1,2 and 3, there is no reported information on the return loss of port 4 and the isolation between the sum and differential ports.

Fig. 1 illustrates the design of the suggested wideband magic T, featuring four ports arranged in two planes: E-plane (first, second, and third ports) and H-plane (second, third, and forth port). The second, third, and forth ports each adopt a single ridged waveguide configuration, while the first port utilizes a double ridged WRD180 waveguide for the convenience of a standard interface. As previously indicated, the effectiveness of the magic-T relies heavily on achieving substantial isolation between port 1 and port 4, also between port 2 and port 3. On

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the other side, minimizing insertion loss between port 2 (port3), and ports 1 and 4 is crucial so different impedance matching components, such as L-shaped metal elements, steps, and metallic segments, must be employed collectively to function as inductive and capacitive elements in arms and junctions. While modal analysis has been conducted for a basic magic-T structure [13], there are currently no explicit solutions available for designing a wideband symmetric magic-T [14]. In this design, it has been noted that the rectangular step located at the midpoint of the junction near the E-arm output significantly influences the achievement of the desired outcomes for port 1. Additionally, the inclusion of an L-shaped septum in the sum arm is crucial, serving to separate the RF waves and achieve the desired isolation between the ports.

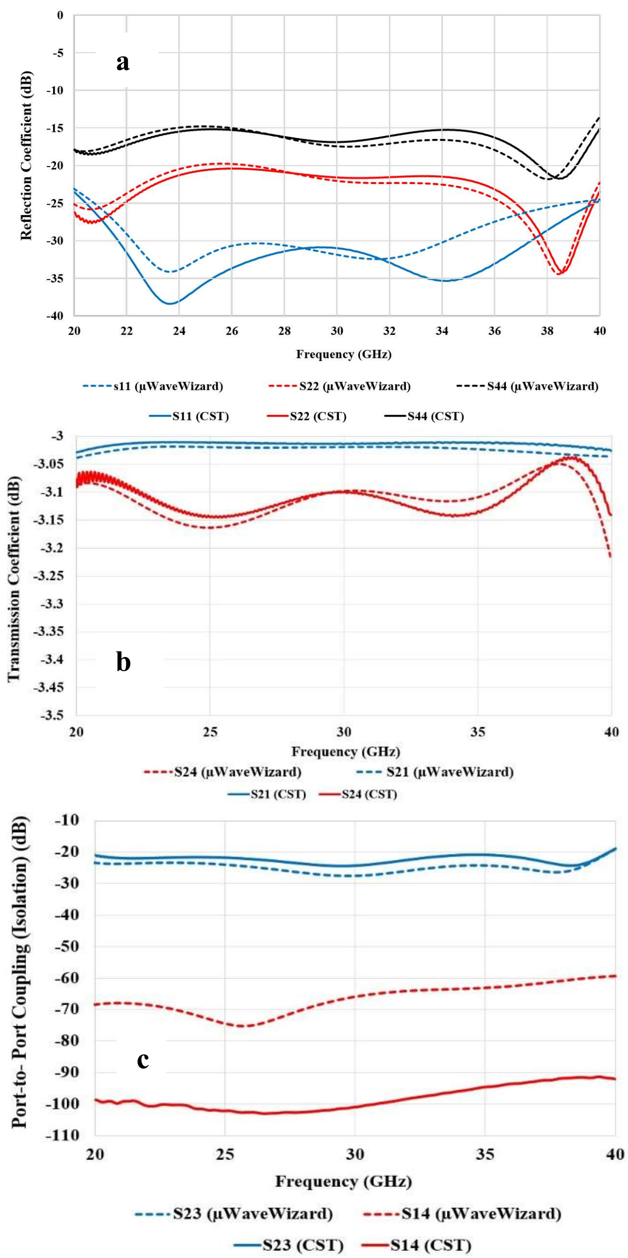

Fig. 2. Simulation results of the magic-T (a) Reflection coefficients at Ports 1, 2 and 4. (b) Transmission coefficients (Insertion loss) from Port 1 to 2 and from Port 4 to 2. (c) Isolation between port 2 and 3and between port 1 and 4.

III. Simulation Result

The proposed magic-T was designed and simulated using both µWave Wizard and CST Microwave Studio to confirm its functionality. Dashed lines represent simulation results from µWaveWizard, while solid lines depict simulation results from CST. The results of the simulated S parameters, shown in Fig. 2, demonstrate consistent and satisfactory agreement between the two software tools throughout the entire frequency range of the octave band. Because of structural symmetry, the results for both port 2 and port 3 are identical. Hence, only the results for one of them are showcased in Fig. 2.

IV. Conclusion

This paper explores a waveguide magic-T designed to attain one octave bandwidth, effective isolation, machinable, and a compact size. Two high-frequency software tools were employed to analyze the design. The use of stepped ridged waveguide and posts has enhanced the bandwidth in comparison to prior designs. Simulation results indicate that the suggested magic-T exhibits promising potential for integrated front-end receiver designs.

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