

Novel waveguide components based on complementary electrically small resonators

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Abstract

In this paper, we present a new class of waveguide components based on the use of complementary electrically small resonators etched on metallic sheets. We first show a rectangular-to-circular waveguide transition that allows to effectively match waveguides with different cross-sections and to transform the linearly polarized TE₁₀-mode of a rectangular waveguide into a circularly polarized TE₁₁-mode of a circular waveguide. Then, using similar structures, we present the design and the numerical results of two power dividers and of an orthomode transducer. All these components, employing only thin metallic sheets with properly shaped slits, can be integrated in waveguide transmission systems without increasing their space occupancy. A proper set of full-wave numerical simulations proves the validity of the proposed approach.

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1. Introduction

Since metamaterials were proposed and experimentally realized, there has been an increasing interest in using their unique properties to improve the performances of standard microwave components. A large number of antennas and microstrip components have been already realized by using volumetric and transmission line metamaterials [1–6], or by properly loading conventional structures with metamaterial-inspired resonators [7–9]. In particular, several new microstrip components (filters, phase shifters, couplers,

duplexer, etc.) have been introduced [10] that, thanks to the use of metamaterial concepts, exhibit unique properties, such as compactness, multi-functionality, multi-band behavior, etc.

While these results have been extensively obtained in microstrip technology, little efforts have been devoted to the implementation of similar concepts in the context of metallic waveguides, where only recently some interesting applications have been proposed. For instance, in [11], a possible solution to design a compact waveguide filter based on a complementary split-ring resonator drilled in a metallic sheet has been presented. Moreover, exploiting the frequency selective power transmission of bi-omega particles placed at the junction sections of different waveguides, our group has recently proposed a waveguide diplexer [12] and a

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balanced and an unbalanced waveguide power splitter [13].

In this paper, replacing the bi-omega particles with complementary electrically small resonators, we generalize this approach to the use of circular waveguides working in circular polarization. In particular, we first introduce a rectangular-to-circular waveguide transition and, then, we use a similar structure to design a power divider that equally splits the input power into two circularly polarized (CP) modes at the output ports. Finally, we also propose the design of a novel orthomode transducer that can be useful in dual-polarized antennas or in diplexing systems based on the use of orthogonal polarization.

The structure of the paper is as follows. In Section 2, we present the design and the simulated results of the rectangular-to-circular waveguide transition that allows transforming the linearly polarized TE_{10} -mode of the rectangular waveguide into a CP TE_{11} -mode in the circular waveguide. In Section 3, we use a similar structure to design a waveguide power divider that equally splits power from a rectangular waveguide input port to two output ports. In particular, two different configurations characterized by either linear or CP fields at the output ports will be presented. Then, in Section 4, we present the design of an orthomode transducer based on the same concepts. Finally, in Section 5, we draw the conclusions.

2. Design of the rectangular-to-circular waveguide transition

In [14], we have presented a CP filtering horn antenna based on the use of a complementary electrically small resonator. This radiator consists of a standard horn antenna in which we have inserted a metamaterial-inspired resonator drilled in a metallic sheet. This structure, exploiting its geometrical features and the inherent narrow bandwidth of metamaterial-inspired components [15], allows radiating only in a narrow frequency band and transforming the linear polarization of a rectangular waveguide into a CP radiated field.

Using a similar structure, we propose here to design a waveguide transition that allows connecting waveguide ports with different cross-sections. This kind of structure can be useful in satellite systems where horn and reflector antennas are typically fed by circular waveguides, while rectangular waveguides are preferred for connecting the radiating elements to the remaining receiving/transmitting circuitry.

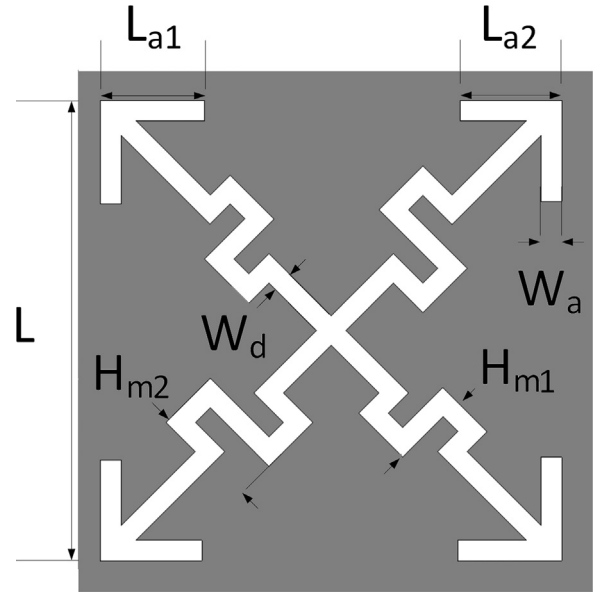


Fig. 1. Geometrical sketch of the proposed complementary resonator with dimensions: $L = 8.2$ mm, $L_{a1} = 2$ mm, $L_{a2} = 1.9$ mm, $H_{m1} = 1.8$ mm, $H_{m2} = 1.5$ mm, $W_d = 0.4$ mm, $W_a = 0.4$ mm. The resonator is drilled in a metallic sheet.

In particular, we have placed the complementary resonator reported in Fig. 1 between a WR-90 waveguide and a standard circular waveguide, as shown in Fig. 2. The used complementary resonator consists of two mutually orthogonal meander-line slot dipoles, which are terminated with arrows that have slightly different dimensions. As experimentally demonstrated in [16], this kind of structure effectively acts as a linear-to-circular polarization transformer. In fact, the two meander-line slot dipoles can be excited by a vertical or horizontal linearly polarized electromagnetic field impinging on one side of the screen. Moreover, due to their slightly different dimensions, the two dipoles radiate on the other side of the screen with a $\pi/2$ phase shift between them. In this way, we expect that the two meandered dipoles of the complementary resonator convert the TE_{10} -mode of the rectangular waveguide into a CP TE_{11} -mode of the circular waveguide. Moreover, this setup is greatly independent from the surrounding environment; therefore, the operation is not affected by the different cross-sections of the connected waveguides.

In order to validate this idea, we have numerically simulated the behavior of the overall structure reported in Fig. 2, consisting of a rectangular and a circular waveguide connected together through the proposed complementary resonator.

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