Power Splitting Transition for Circularly Polarized Feed Networks

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***Abstract*—A new power splitting transition is introduced that is based on a step transformer approach for interfacing two square waveguides with a mutual alignment of the cross sections of 45°. It is shown to provide high-performance matching properties while maintaining easy and low-cost fabrication. A well-suited mode matching CAD has been used for study and hardware design. Verification is provided by experimental results of transitions realized for the 27 GHz band.**

***Index Terms*—Boundary contour method, dual circular polarization, matching transformer, mode matching, power splitting transition, square waveguides with spatial 45° alignment.**

I. Introduction

DUAL circular polarization is still used in modern radar and satellite communications systems even at millimeter-wave frequencies. There are several different methods for the generation of the dual circular polarizations (left hand -LHCP- and right hand circular polarizations -RHCP-) [1]. Fig. 1 shows a block diagram of the most general approach that is based on a differential phase shifter-called polarizer-providing 90° phase difference between two linear orthogonal polarized semi signal portions propagating within a common waveguide [1]–[4]. A prerequisite for these methods is the accurate 3 dB power splitting into orthogonal polarized signal portions within the operating frequency band with low VSWR. Concerning polarizer applications within circular waveguides, power splitting is easily obtained by feeding the incident polarized signals with a spatial 45° offset regarding to the differential phase shifting region, this is, the proper alignment of the feeding orthomode transducer (OMT) for the separation of the dedicated LHCP and RHCP signals [1]. However, polarizers with square waveguide interfaces need particular means for converting the feeding signals of an OMT into 3 dB portions with orthogonal alignment. For this purpose a special power splitting transition based on a smooth taper between a rectangular waveguide and a square waveguide with 45° alignment of the cross section wrt. the incident linear polarization has been introduced by Simmons [2]. Since this transition is only capable for serving a single polarization, a structure allowing dual polarized operation has been shown in [1, p. 423]. The principle electrical fields at the input and output ports are shown in Fig. 1. Such smooth tapers can be realized with good wide band performance, however, the design requires high manufacturing expense due to special processes as e.g., electroforming. In addition the design can only be supported by finite element CAD tools that suffer from high computation time.

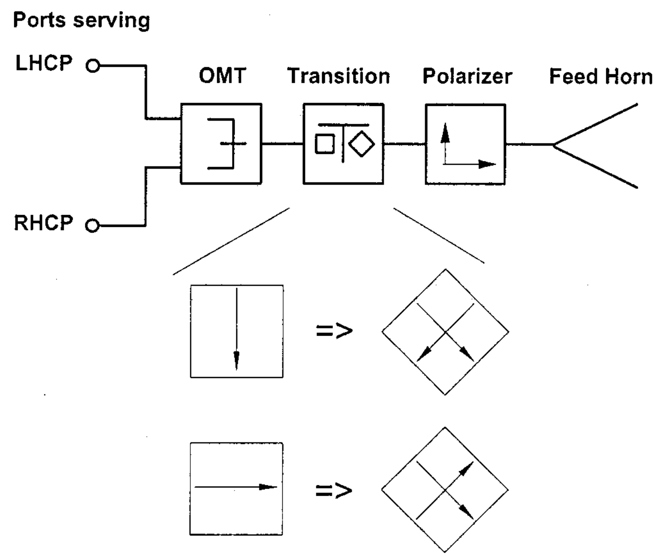

Fig. 1. Principle block diagram of circularly polarized feed network (top) and principle electrical field at input and output ports of power splitting waveguide transition (bottom)

A novel 3 dB power splitting transition, based on quarter wave transformer steps with curved cross sections is introduced in this letter. The design is shown to cope with high performance demands while maintaining low cost fabrication aspects even for mm-wave applications. A useful CAD tool—based on a boundary contour mode matching method—yields accurate dimensioning and performance prediction as presented results for a transition at 27 GHz demonstrate.

II. Basic Considerations

The complete circularly polarized feeding network comprises an OMT with a common square waveguide port, a corrugated waveguide polarizer exhibiting square waveguide interface ports and the power splitting transition for the high performance interconnection of the polarizer and the common OMT port with 45° alignment. OMT and polarizer designs can be accurately computed with the aid of standard mode matching methods [1] and their realization in two halves by CNC milling techniques is favorably suited for millimeter-wave applications. To cope with low-cost manufacturing and high-performance demands a special power splitting transition has been established that is based on a quarter wave transformer principle with curved cross sec-

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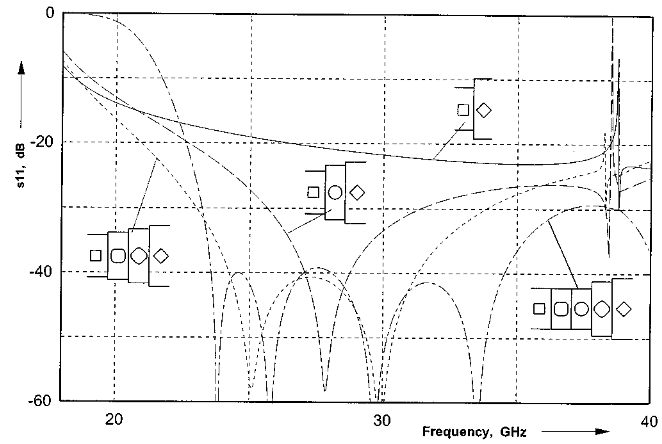

Fig. 2. Computed return loss of two interconnected square waveguides with 45° alignment—solid line for direct interconnection and dashed curves for transformer transitions with one, two, and three sections, respectively

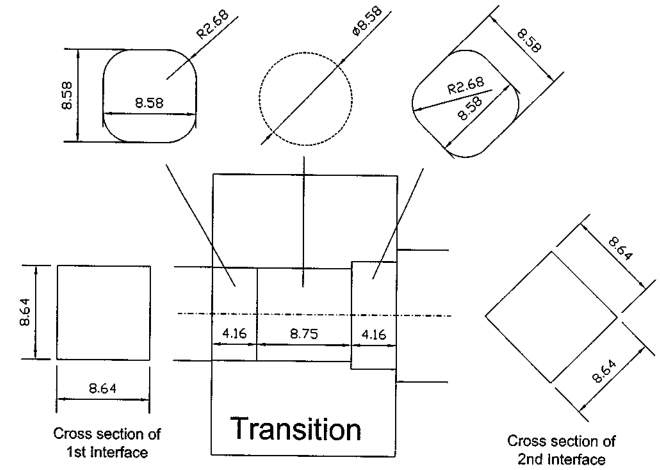

Fig. 3. Optimized structure of the three-section transtion

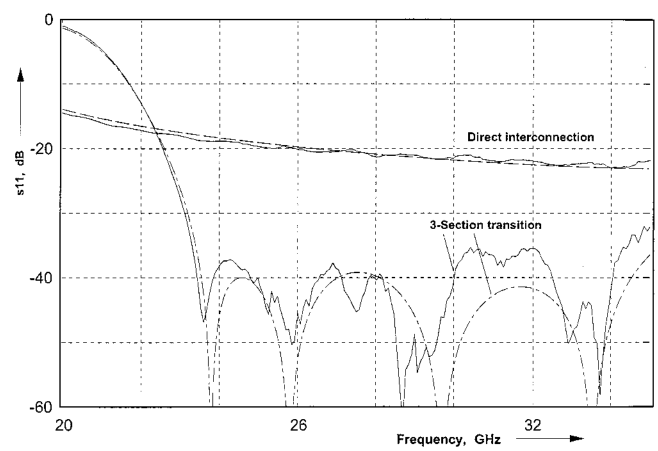

Fig. 4. Comparison of computed (dashed lines) and measured (solid lines) results of direct interconnected square waveguides and the application of the three-section transition

tions. Recently, the boundary contour mode matching method (MMM) has been introduced for the computation of the eigenmodes of curved cross sections [5]–[7]. This approach has been used to form a proper CAD tool for the prior study and the final design task of the complete transition.

The investigations have been exemplified for the 27 GHz band considering square waveguide interfaces with a width of 8.64 mm. First, the direct interconnection of the two interface square waveguides with 45° alignment has been studied. This configuration yields the typical return loss response shown in Fig. 2. Although the return loss exceeds 20 dB within the upper useful band, such values are generally not acceptable for such a "transition" since the overall return loss of the complete circularly feeding network may become very poor, due to the contributions of all components (OMT, polarizer). Consequently, quarter wave transformers with one, two, and three quarter wave sections have been investigated for the matching task of the 45° aligned square waveguides. The application of a single quarter wave step with circular cross section already improves the matching properties of the interconnection, as shown in Fig. 2. Considering a return loss goal of more than 35 dB this solution can be used for applications with up to 5% useful bandwidth. The computation of the two and three step transformers yields the expected high performance within enhanced bandwidths as the responses in Fig. 2 demonstrate, namely up to 25% and 36% useful bandwidth for the two and three section type, respectively. The two section type comprises identical transformer sections exhibiting a square cross section with rounded corners with a mutual 45° alignment. The structure of the three step design is principally the same extended with a circular transformer section in the center as the schematics in Fig. 2 depict. It should be noted, that the diameter of this section must not exceed the cross sections of the interconnecting transformer steps to facilitate manufacturing of the unit in one part by CNC milling techniques (see Fig. 3).

III. Experimental Results

The above computed power splitting transitions have been realized and measured for the verification of the applied CAD and to demonstrate the feasibility of the unique design. All the structures have been manufactured in one part from the flanges by state-of-the-art CNC milling techniques. Due to the limitation of length, this letter only provides two results, namely, the direct interconnection of two square waveguides and the three section transition design with the dimensions given in Fig. 3. Due to the desired extreme low VSWR of the transitions high measurement accuracy was necessary. This has been achieved with square waveguide standards allowing direct calibration of the HP8510 at the square interface cross sections. The measurements have been performed over 54% bandwidth, which is wider than the conventional bandwidth of standard rectangular waveguides (e.g., WR34). The comparison of the measured and computed responses shown in Fig. 4 exhibits almost exact coincidence up to more than 35 dB return loss demonstrating high accuracy of the CAD and the feasibility of the unique power splitting transition approach.

IV. Conclusions

Since the above introduced power splitting transition provides high performance properties while maintaining easy

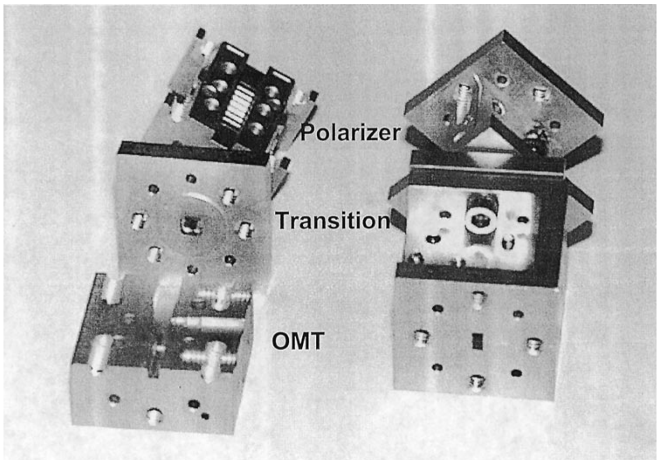

Fig. 5. Breadboard of circularly polarized feed network for 77 GHz—all components are manufactured with state-of-the-art CNC milling techniques

and low cost production it is a favorable alternative to the state-of-the-art designs especially for millimeter-wave applications. As an example Fig. 5 depicts the application of the new transition design in a 77 GHz dual circularly polarized feed network, this is, the interconnection of an OMT and a corrugated polarizer.

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