



## DESIGNING AND SIMULATING WAVEGUIDE COMBINER 16:1 FOR HIGH POWER APPLICATIONS IN FREQUENCY RANGE OF 8-12 GHZ WITH WAVE TRANSDUCER

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### Abstract

*In this paper, a new design of the combiner and mode transducer in X-band is proposed. A two-step structure is applied within the combiner structure to improve isolation between ports. High isolation and wide bandwidth are the major features of the proposed combiner. The results of this paper, simulated by CST, clearly show that the return loss is within an acceptable range. The model converter structure in this paper, as compared to similar structures, is configured in a way that it has less resonance. In this regard, the resonation of the proposed design has successfully been reduced up to one third of similar structures.*

**Keywords:** combiner, wave transducer.

### 1. Introduction

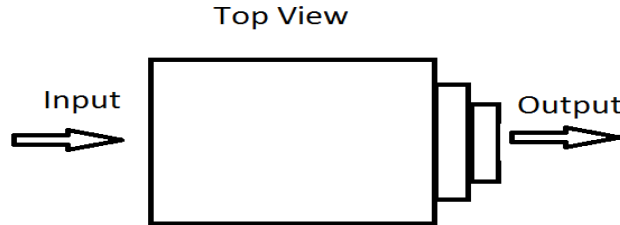
The output power is a very important factor of system efficiency in the millimeter wave, advanced microwave radars and telecommunication systems. The high output power means a wider operational area, stronger interference ability as well as higher efficiency of communications. Some power generators are not able to supply the needed power by themselves [1]. In this regard, combiner technique is applied to provide the needed power [2, 3]. Usually the waveguides are used for combiner design due to their low power loss. One of the major features of this work is designed using the rectangular WR90 waveguide. Applying this standard waveguide contributes in its simple fabrication process. In addition, to minimize waveguide structure, width of the circular waveguide input part was gradually decreased.

In this research, a new design of combiner with 16 input ports was designed. As many applications require rectangular transmitted wave and regarding that the combiner's output is circular, a waveguide transducer was used in this work. At first, waveguide, combiner and mode transducer are optimized separately by CST, and then the general structure of waveguide combiner is modeled by the optimized parts.

### 2. Combiner design

The basic structure of the combiner is extracted from [4, 8-10]. The first step in designing combiner is to select the standard waveguide appropriate to the frequency band. Therefore, the standard WR90 waveguide is used for X-band frequency. As mentioned in the introduction section, the research ultimate goal is to design a combiner with 16 input ports. In the final arrangement of the 16

rectangular waveguides, all waveguides enter into another cylindrical waveguide; so that, all 16 rectangular waveguides are placed around a cylindrical periphery. Therefore, for direct use of WR90, the cylinder radius must be selected large enough to avoid waveguides interferences. The radius size would be a critical factor when increasing the number of input ports, as excessive size of the structure prevents its practical implementation. Hence, the gradual structure is used to deal with this issue (Fig. 1). As shown in Fig. 1, by creating two steps, it is possible to reduce rectangular waveguide width in the cylindrical waveguide input part and prevent structure enlargement.

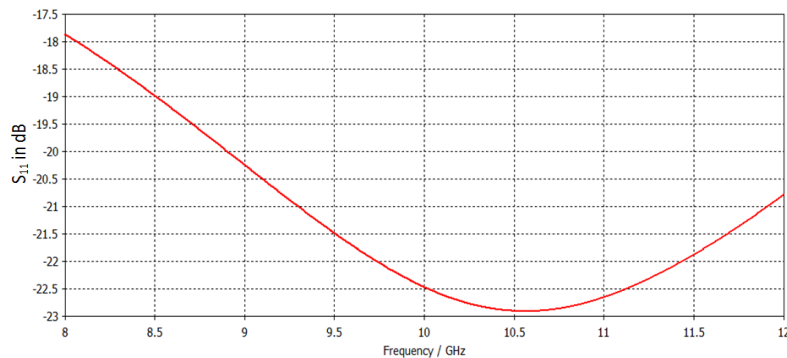


**Figure 1:** Side view of the rectangular gradual waveguide.

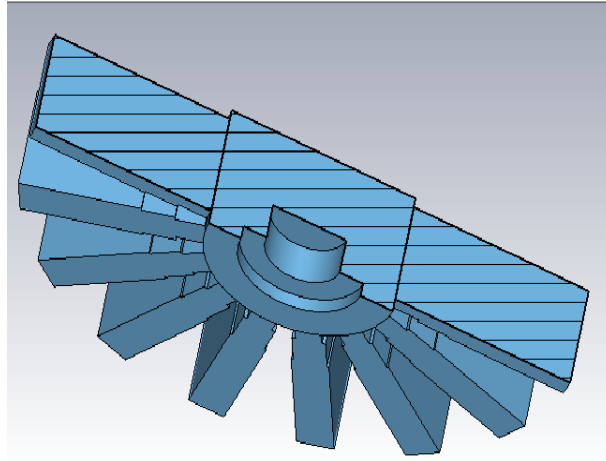
Fig. 2 represents the simulated reflection coefficient of waveguide structure shown in Fig. 1. All the simulations of this paper are done by CST software [11]. As shown in this figure, the reflection coefficient throughout the frequency range of X-band is less than -17.8 dB, so that this structure can be used in the entire following simulation steps.

Fig. 3 presents the simulated structure of combiner in CST software. This structure was selected based on the work conducted by [1]. The main cause of the circular shape of the combiner output is forming a symmetric geometry [1]. As the asymmetry of structure results in insertion loss, the isolation would externally be added to the system, if needed.

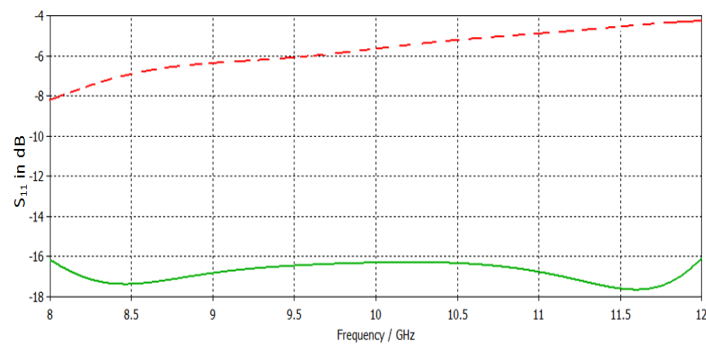
In previous studies conducted on millimeter wave band [4], a cylindrical stage was installed in the combiner cylinder. As shown in Fig. 3, in this paper, two metallic cylinders are installed in the combiner cylinder to improve isolating of the combiner system. Since the structure symmetric geometry, reflection coefficients are equal for all inputs. Fig. 4 illustrates combiner reflection coefficient with one and two cylindrical stages. As shown in Fig. 4, extra cylindrical stage improves the reflection coefficient of the combiner. As shown in the simulated reflection coefficient diagram, the reflection coefficient of two cylindrical stages is generally less than -16.2 dB throughout the frequency range. Fig. 5 presents the coupling between one input port of the combiner and its output port. As shown in this figure, the entire curve is below -12.31 dB, which is proper for 24 ports combiner, so that the structure can be considered as an optimum structure.



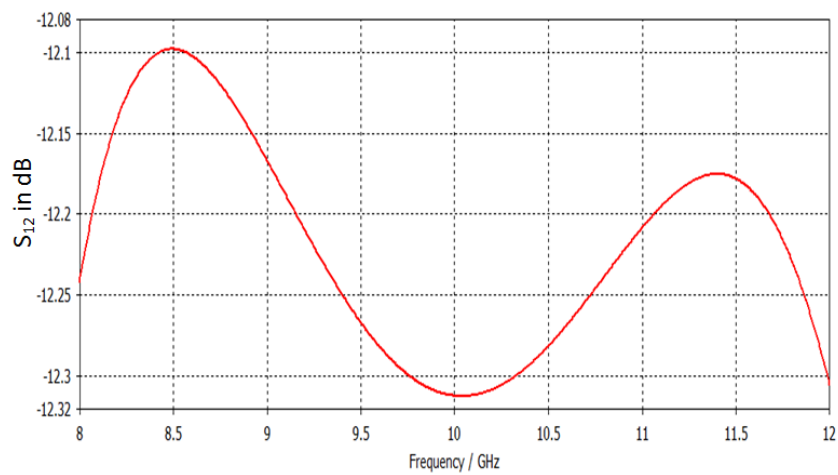
**Figure 2:** reflection coefficient diagram of the gradual rectangular waveguide.



**Figure 3:** Combiner structure in CST.



**Figure 4:** reflection coefficient of combiner with one (dashed line) and two (solid line) cylindrical stages.



**Figure 5:** The coupling between one input port of the combiner and its output port.

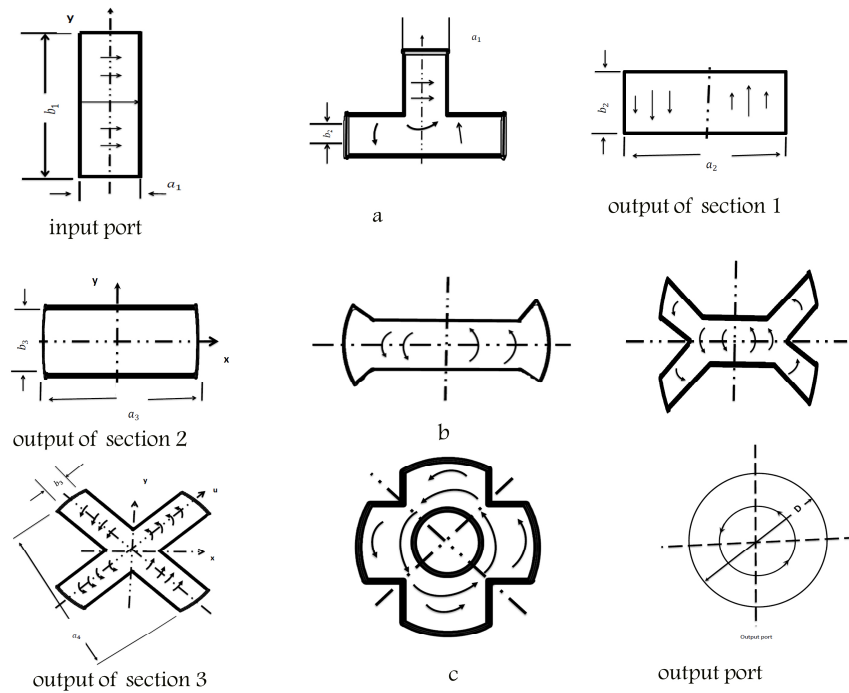
### 3. Analysis and design of mode transducer

In this section, a structure is proposed to convert rectangular TE<sub>10</sub> mode to circular TE<sub>01</sub> and vice versa.

As it was mentioned in previous sections, the ultimate output of the combiner is circular; however, it is required to transmit the wave in rectangular mode. Therefore, mode transducer (described in the following lines) was utilized.

There are different types of transducers to convert the rectangular mode to circular mode. The most common type of these transducers is “flower-petal” transducer [5], which its main drawback is its extremely narrow bandwidth [4]. The design proposed by Marie [6] has optimum efficiency of information bandwidth, so that it was also applied in this work.

The main structure of this transducer, in turn, consists of three separate transducers (Fig. 6), through which the desired structure is obtained.



**Figure 6:** 2D shape and field pattern of mode transducer different sections [7].

Fig. 6 illustrates 2D shape and field pattern of different sections along the transducer length. The transducer prototype was designed by [7]. Based on the computations, the input size in the first stage is calculated as follows:

Based on the study performed by [7], the first step for designing this system is to determine the input and output dimensions of rectangular waveguide using  $a_1$ ,  $b_1$ ,  $a_2$ , and  $b_2$  (Fig. 6). Since the first part of the rectangular system converts TE<sub>10</sub> into TE<sub>20</sub>,  $b_1$  and  $a_2$  are determined using the following equations:

$$b_1 = \frac{\lambda_{cr}}{2} \quad \text{and} \quad a_2 = 2b_1$$

where,  $\lambda_{cr}$  is cut-off wavelength in TE<sub>10</sub> mode.

However, simulating the system other parts is different from the process mentioned in Ref. [7], where the stages of transducer are not equal. This difference offers two problems in designing transducer in X-band:

- 1- Creating intense resonances; and
- 2- Uncovered bandwidth at the beginning of X-band

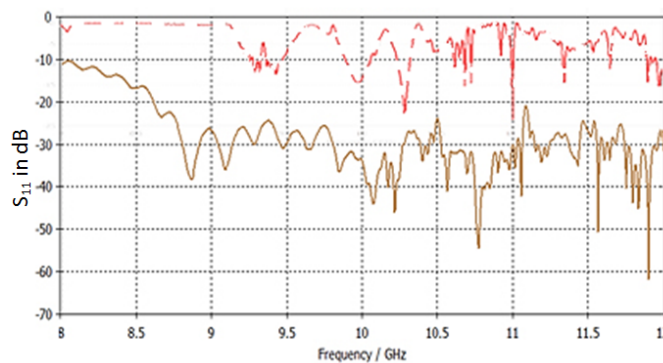
Fig. 7 illustrates the reflection coefficients of the proposed transducer and the transducer which is presented in [7]. As shown in the figure, the structure of [7] has severe resonances and does not cover the frequencies below 9.2 GHz.

To deal with these issues, in designing the transducer, the joint dimensions in different stages of transducer were considered equal so that the resonance problem is solved and the entire bandwidth is covered.

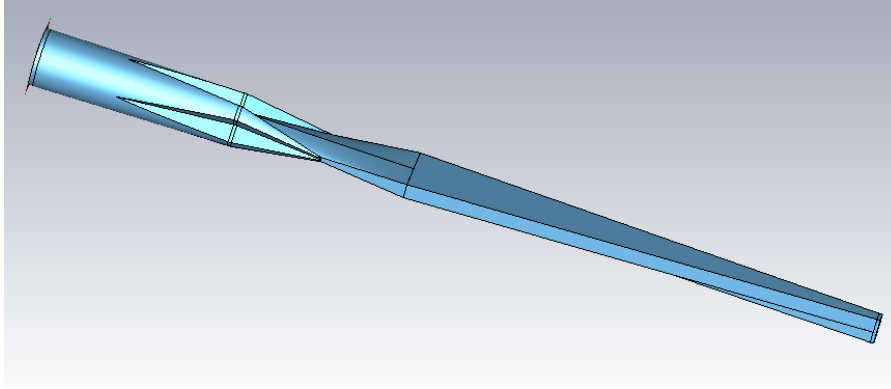
Fig. 8 presents the overall structure of the mode transducer plotted in CST. The transducer overall height is 45.8 cm. To deal with the two abovementioned problems, the proposed structure was optimized through using optimization algorithm. In this way, the transducer length will be shortened in addition to removing the severe resonances. Finally, the obtained values of the design parameters are optimized by CST software and are as follow:

$$a_1 = 11, a_2 = 59, b_1 = 24.5 \text{ and } b_2 = 13.8.$$

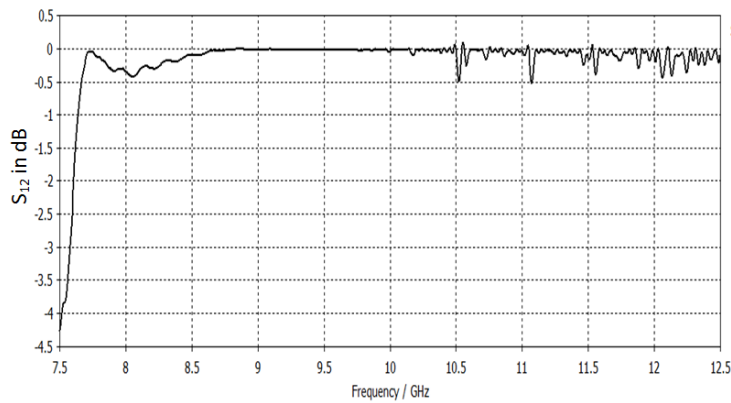
As shown in Fig. 7, the return loss of the proposed transducer is improved greatly and its structural resonance is slight. Fig. 9 is illustrations of the transducer coupling. As shown in the figure, the coupling of the structure in the given frequency is near 0dB which is appropriate. Thus, this transducer is efficient for the purpose of present study.



**Figure 7:** reflection coefficients of proposed transducer (solid line) and the transducer of [7] (dashed line).



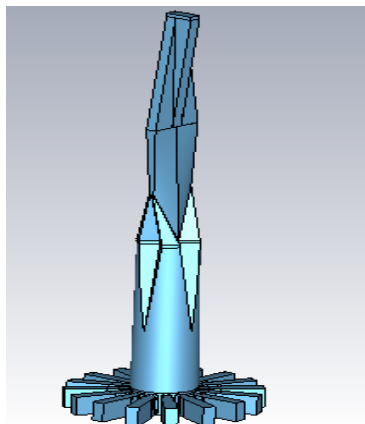
**Figure 8:** The transducer Final structure.



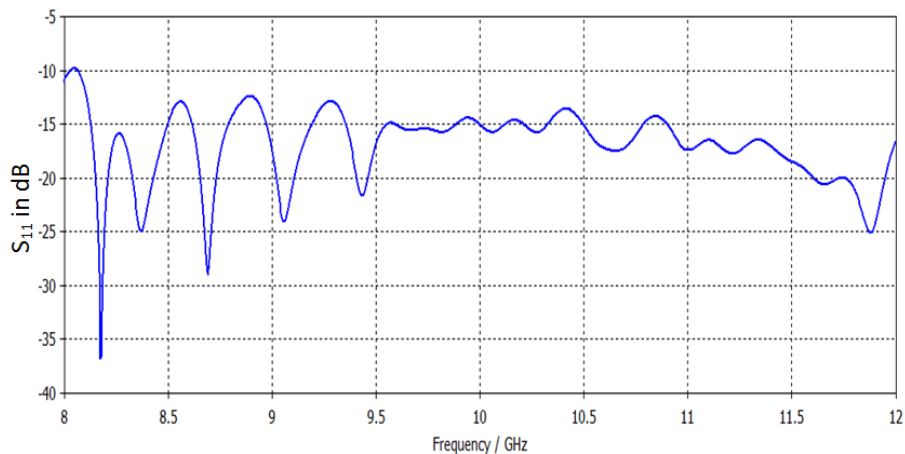
**Figure 9:** The coupling between transducer input and output ports.

#### 4. Final structure

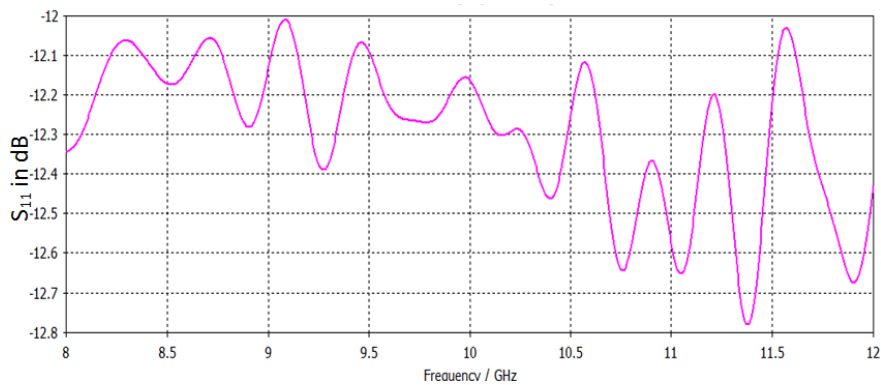
In this section, the research final results are presented. Fig. 10 illustrates the final structure of the combiner with mode transducer. Fig. 11 shows its reflection coefficient. As shown in this curve, the reflection coefficient in the entire bandwidth is less than -10 dB. Fig. 12 demonstrates coupling between one input port of the final structure and its output port. As expected the coupling value is about -12dB which is the right value of 24 ports combiner.



**Figure 10:** final structure of the combiner with mode transducer.



**Figure 11:** reflection coefficient of the proposed structure.



**Figure 12:** coupling between one input port of the proposed structure and its output port.

## 5. Conclusion

In this paper, a different design of the combiner and mode transducer was presented. The simulation results indicated the structure efficiency. Based on the obtained results, it can be observed that the structure is efficient in X-band. The small dimensions and lack of resonances are among the proposed design other advantages. This paper proposed a new approach to design combiner and mode transducer in X-band.

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