Investigation of a Printed Coaxial-to-Waveguide Transition

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Abstract — an S/C-band printed circuit coaxial to rectangular waveguide transition component, containing one tuning piston at the waveguide’s back wall is investigated. Both simulation and measurement show a good matching level in a bandwidth of more than 87%. Very good agreement between simulation and measurement was achieved. The performance of the transition element can be matched to user’s demands.

Index Terms— Printed transition component, coaxial, rectangular waveguide.

I. INTRODUCTION

The usage of coaxial-to-waveguide transition components to transfer information is very common for low and medium power systems. Some radar systems and horn antennas require transitions between coaxial cables and rectangular waveguides. The main challenge is obtaining good impedance matching at most of the bandwidth of the rectangular waveguide (Theoretical f=2f). Such components have existed for a long time, and their design methods are varied. Generally the electrical volume of the high quality components is not negligible. The common transitions are horn transitions, ridge transition [1], steps transitions [2], adjusting screws [3] and many other transitions based on very complicated geometrical shapes without extensive machining work on the coaxial probe [4], or on the waveguide. Therefore, there are different transitions, some being geometrically complicated and most being good only for the specific needs of the companies who order them. Generally the prices of these components are high, and they are suitable to standard waveguides.

The present research describes a compact printed-circuit component which is easy to use and easy to change according to a systematic algorithm which we have developed.

The structure of the paper is as follows: Section II describes the geometry of the component. The main results of computer simulations are presented in section III. The experimental validation of the simulation results are provided in section IV. A parameter study is presented in section V. The paper is concluded with a general discussion and some conclusions in section VI.

II. GEOMETRY OF THE TRANSITION COMPONENT

Fig 1 shows the dimensions of the printed-circuit transition component, and its disposition within the cross-section of the waveguide (a=60mm, b=30mm). The conductor of the SMA connector (diameter 1.25mm) protrudes 1.5mm above the waveguide lower surface, and is integrated into a 4mm diameter Teflon holder. In addition, moving piston at the back wall of the waveguide is set at 16.9mm from the printed circuit conductor transmission, and is used for tuning the matching level as function of frequency. A side view of the printed transition element is shown in fig.2

Figure 1. The printed- circuit transition component.
III. SIMULATION

CST-Microwave Studio software was the software used during the design stage. The software calculates Maxwell’s equations in the finite time domain [5]. Figure 3 shows the plane of the simulated transition component. Fig. 4 shows the return loss of the transition component.

It is seen in the figure that the bandwidth is more than 2.84 - 5GHz for SWR = 2, which is 87% of the theoretical bandwidth (f/2f). The level of the minimum points of the return loss, in this case at 3.8GHz and 4.28GHz is between 45dB to 50dB. The frequencies of the minimum points can be controlled as it’s shown in section V.
IV. MEASUREMENT

A box-shape waveguide is 15cm length and assembled from four components. One component is the waveguide bottom surface with two sidewalls. On each sidewall there is a vertical small sized tunnel of 1.5mm wide and a depth of 1mm. The tunnel stabilizes the second element, which is the printed circuit’s transition component and allows quick and easy switching. The third component is the piston back of the waveguide’s wall, which connects to a handle. This part of the waveguide allows tuning which fixes the bandwidth and frequency range (see Fig. 5). The waveguide’s back wall functions as an energy barrier, which reflects the incoming waves at 90 degrees phase.

The last component is the upper wall, which is connected with screws and allowed the opening and closing of the printed circuit’s switching. The waveguide is soldered to SMA connector of a standard coaxial cable. Measurements were performed using a Network Analyzer that was connected to the device via a coaxial cable. A highly absorbent material was set at the end of the waveguide to prevent reflectance, serving as an ideal port. The back wall was set as listed in chapter II, which after much research proved to serve the average user most efficiently. The measurements of the returned loss wave are presented in figure 6. The minor changes between the simulated and the measured return loss is presented in table 1, is due to construction deficiencies.

V. PARAMETER STUDY

The high quality of the matching level of the transition element was achieved due to extensive work of simulations and optimizations. In this section we describe a parameter study, which allows the user to match the performance of the element to its own needs. The research was simplified for two actions of two different parameters, to make the conversion simpler for the average user demands. Every parameter of the

<table>
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<td>Bandwidth under SWR=2</td>
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<td>2.16GHz</td>
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<td>Centers of minimal frequencies</td>
<td>-32dB, -37dB</td>
<td>-51.79dB, -46.16dB</td>
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<td>Bandwidth under SWR=1.2</td>
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<td>1.55GHz</td>
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<td>Frequencies for the minimal points</td>
<td>3.4GHz, 3.9GHz</td>
<td>3.8GHz, 4.28GHz</td>
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Table 1. Comparison between simulated and measured return loss.
original design went through graduated change for the creation of accurate results. In the research it could be observed that the frequency for minimal value of the $S_{11}$ can be controlled. The two parameters that presented here had the biggest impact on the passed energy progression. Those two parameters are: the distance from transition element to the back wall of the waveguide $v$, and the elevation of the transition element above the waveguide surface $d$. Those parameters were analyzed by few central values: bandwidths for RL = 10dB, 20dB, 30dB, the value of reduction and the location of each main reduction frequency. When the bandwidths were analyzed and compared with the returned loss wave reductions (figures 7, 8) we could see in the graphs, that those parameters splits for two different main frequencies in the relevant range. The next stage was to define the location of the two main frequencies and characterize them in equations (figures 9, 10). For example, if a wider bandwidth is desired (Figure. 12), or a wider distance between those two main frequencies reductions (Figure. 13), both can be achieved in simple actions, as many others. Figure 12 was achieved as a result of moving the back wall of the waveguide to a distance of $v = 21$mm from the transition element, figure 13 was achieved with lowering the transition element 0.05mm relative to the original position, for achieving wider distance between the frequencies of the maximal attenuation points. It was set to $D = 0.8$mm above the bottom of the waveguide's surface.

Figure 12. Return loss of about 98% bandwidth relative to the theoretical value for SWR = 2 ($v = 21$mm).

Figure 13. Return loss with wider distance between the frequencies of the maximal attenuation points.

Figure 7. Bandwidth and S11 RL minima's in a function to parameter ‘D’.
Figure 8. Bandwidth and S11 RL minima's in a function to parameter 'v' 

![Bandwidth and RL minima's in a function to 'v'](image)

Figure 9. The RL minima’s locations compared to the elevation of the transition element.

![RL Minima location in a function to parameter 'D'](image)

\[ y = -2 \times 10^{-5}x^3 + 0.0004x^2 - 0.0052x + 4.8492 \]

\[ y = -0.0034x + 4.181 \]

Figure 10. The RL minima’s location compare to the elevation of the transition element

![RL Minima's locations in a function to 'v'](image)
As a result of the characterization of all the values in graphs and equations, it was possible to develop an algorithm for a computer, to define what the changes needed to be done to the transition (figure 11). The algorithm lets the user choose the bandwidth, the reduction, one or two main frequencies and the location of the main frequency in the relevant range. The algorithm works with the default that it will try to solve the demands first with the adjustable back wall of the waveguide, only if necessary the program will indicate the change of parameter \( d \) in the printed circuit. The transition element shape and the algorithm allow one to design the transition element according to the technical requirements. We could see as a result of the algorithm, that when setting \( S = 2, A = 2, B = 1.5, C = 1 \) gives matching results by changing parameter \( d = 0.8 \text{mm} \) (Figure.13). Setting \( S = 1, D = 3, A = 2.4, B = 0.5, C = 0 \) gives matching results by changing parameter \( v = 21 \text{mm} \) (Figure.12).

**Figure 11. The flow diagram of the algorithm.**

**VI. CONCLUSIONS**

A novel low-cost, broadband coaxial-to-waveguide transition element having an excellent matching level has been presented. The agreement between simulation and measurement was very good. The device has a compact design, which allows a big improvement in the costs of manufacturing using a low cost printed circuit without the need for machined components in the waveguide. This makes it inexpensive to manufacture. The parameter study allows the user changing the transition device is easy because of the simple removal of the printed circuit and the systematic method of making the changes.

Future studies will involve an optimization process and a combined the algorithm to and the designing software.

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