E-Band Microstrip-to-Waveguide 90 Degree Transition

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***Abstract*— A new Microstrip-to-Waveguide 90 degree Transition (MWT) is proposed in this report. This MWT is carried out as a single component placed in the waveguide opening of the PCB and soldered on the PCB and, at the same time, incorporates a transformer and a 90 degree waveguide bend able to match the quasi-TEM mode of the microstrip line with the fundamental TE_{10} mode of the 90 degree bended rectangular waveguide with 15 dB RL in the entire E-Band (from 71 to 86 GHz). The work focuses on simulations in order to optimize the design as well as tolerance analysis for production aspects.**

***Index Terms*—microstrip, rectangular waveguide, transition.**

I. Introduction

Ericsson is the largest supplier of short haul microwave radio systems with about 40% of the world market. MINI-LINK cost-efficiently connects base stations and switch nodes, forming either single radio connections or complete microwave networks. Nowaday the MINI-LINK product portfolio is using a wide range of frequencies, from 7GHz up to 38GHz but the need to focus on the development of a new generation of MINI-LINK shifts the focus on higher frequencies.

Microwave/millimeter wave radios for wireless point-to-point Gbit transmission is a growing market and has potential of becoming a large volume application. One condition for reaching high volumes is low cost. Cheap and robust package design for frequencies in the range from 71 to 86 GHz will significantly contribute to the cost of the overall product. Transition from the active circuits to a waveguide is an important area to address to achieve low cost.

This work consists of the analyses and design with a full-wave simulator of a innovative transition from microstrip to waveguide; the transition has to be low loss and have wide bandwidth. It can be used for example to transfer the signal from the active circuits placed above the PCB to the antenna placed below it. In all approaches the configuration of the structure consist of a "custom waveguide" and a standard WR12 waveguide whose standard dimensions are 3.099mm x 1.55mm. Standard WR12 waveguide was chosen considering its cutoff frequency of 48.4 GHz and because it is typically used in the band from 60 to 90 GHz. No experimental verifications have been done nor are reported here, since these required too much time compared to the extent of the master thesis work period.

The entire project has been carried out at Ericsson MINI-LINK Department in Molndal (Goteborg, Sweden) with Ing. Per Ligander and Ing. Ove Persson as supervisors and under the advice of Prof. Roberto Sorrentino (University of Perugia) between September 2011 and March 2012.

II. Design procedures and results

The basic concept of the Microstrip-to-Waveguide Transition is to realize a launcher as a component placed in a waveguide opening of a PCB. The innovation respect to what has been done in [5]-[7] is that in this case we have a single component both to match the quasi-TEM mode of the microstrip line with the fundamental TE_{10} mode of the rectangular waveguide and both for 90 degree bend the E-Band. Actually one requirement for the MWT, as shown in Fig.1, is that the occupied area on the PCB should be as small as possible. Three different solutions for the MWT have been studied. All solutions were designed and optimized to reach 15 dB RL (target is 20 dB RL) in the frequency range from 71 to 86 GHz.

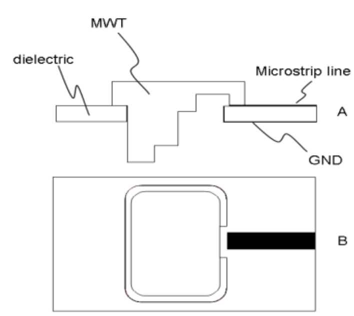

Fig. 1. A, side view of the MWT; B, PCB with waveguide opening.

Fig.2 shows the first solution, constituted by two different components: the microstrip-to-transformer junction inserted in the custom waveguide and a 2-step ridge Chebyshev transformer, designed starting from the theory described in [1]-[4], inserted inside the WR 12 waveguide. The complete transition does not ensure the goal of 20 dB RL due to manufacturing constraints. Indeed the transition does not performs very well: in the bandwidth from 71 to 86 GHz the return loss is only partially less than 20 dB and the IL is around 0.9 dB. The target of 20 dB is not entirely satisfied; the RL however is always below 17dB. The problem occurs at low frequency; future study will be done to investigate and solve this problem.

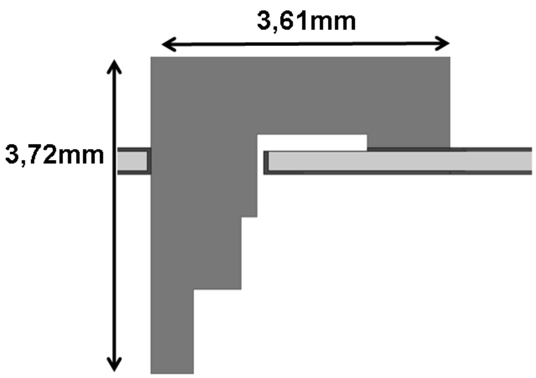

Fig. 2. MWT first solution, side view.

The second solution (Fig. 3) is a complete different design. In this case we combine a first transformer to match the quasi-TEM mode of the microstrip with the fundamental TE10 mode of the rectangular waveguide. A second transformer is used, placed in the waveguide opening to rotate the E-Field by 90 degree and also to match the impedance levels. This solution shows better performance compared to the previous one; actually in the bandwidth from 71 up to 86 GHz the return loss is around 24 dB and the IL is around 0.24 dB.

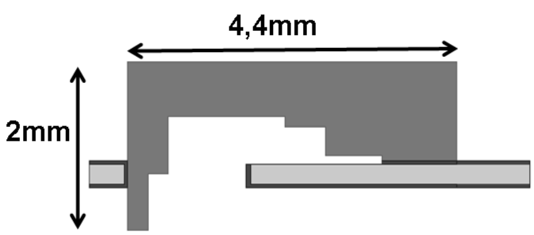

Fig. 3. MWT second solution, side view.

The tolerance analyses of the first and the second solution show that the sensitivities are roughly the same. The tolerance analysis of each complete MWT showed a good robustness of the structure; only the height of the gap below the first ridge step seems to be critical. Nevertheless, the performance remains within the specification of 20 dB RL under variations of +/- 20 µm. The transition is quite insensitive to all other milling variations, even including possible systematic errors in the milling process. Such errors may make all the steps longer or shorter and the heights higher or lower. Referring to Fig. 4. regarding the position of the MWT in the x-direction, both positive and negative misplacements have to be taken into account. In the y-direction, the only misalignment allowed is in the negative direction because along the positive direction the MWT is bounded by the PCB. Misalignments of the MWT with respect to the PCB along the x-axis do not show critical sensitivity. On the contrary a misalignment along the negative direction of the y-axis can destroy the entire performance. Actually a 50 µm variation in the positioning of the MWT destroys both the level of S_{11} and the bandwidth; even a 6 µm variation is damaging. This problem was carefully analysed and in order to overcome it a third solution was designed.

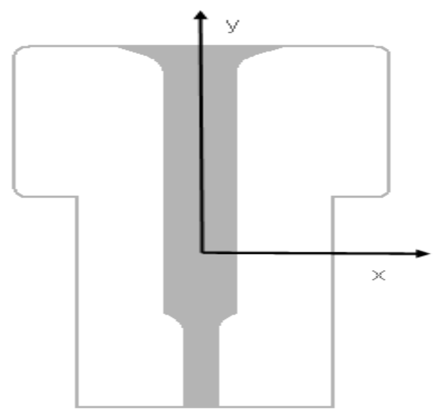

Fig. 4. Reference axis for the position of the MWT.

Fig.5 shows the third solution, that consists of the combination of a transformer and a bend. Both such components are placed on the PCB and not in the waveguide opening in the PCB. The first component is a transformer placed in the custom waveguide used to connect the microstrip line with the WR12 waveguide. This component is a three-step ridge-to-rectangular waveguide Chebyshev transformer with 1mm step widths. A fixed step width is required to connect the microstrip line and the transformer; it extends to the top of the microstrip and has the same width as the microstrip (0.5mm). The second component is a 90˚ waveguide E-plane bend placed in the WR12 waveguide. It is constituted by a cascade of discrete steps dimensioned so as to obtain the best behavior and matching in the frequency band of interest. The bend is directly connected to the transformer and it is dimensioned in order to avoid to go through the waveguide opening in the PCB.

As is shown in Fig. 6 the complete transition performs very well: in the bandwidth from 71 up to 86 GHz the return loss is less than 24 dB and the IL is around 0.4 dB.

The tolerance analysis for the third solution was completed showing a good robustness of the structure; the performance is maintained within the specification of 15 dB RL under variations of +/- 20 µm. Misalignments of the MWT with respect to the PCB along the x- and y-axes were considered showing no critical sensitivity. The specification of 15 dB RL is still satisfied under a 50 µm misplacement.

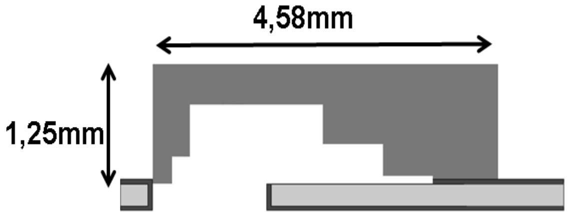

Fig. 5. MWT third solution, side view.

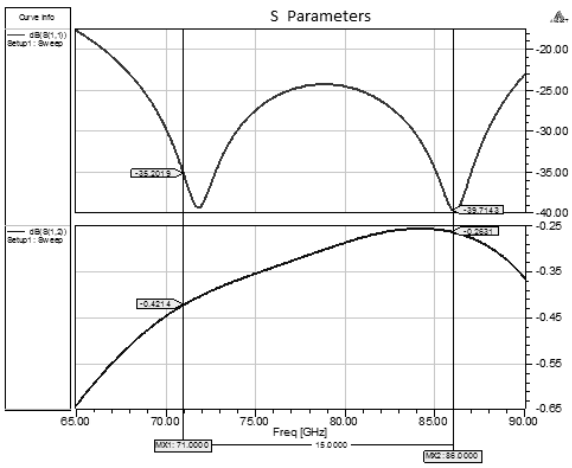

Fig. 6. MWT third solution, HFSS results.

III. Conclusion

Three approaches have been used in order to achieve the results and match the quasi-TEM mode of the microstrip with the fundamental TE_{10} mode of the rectangular waveguide with 15 dB RL in the entire E-Band.

The first approach was to realize a MWT as a connection between a microstrip-to-transformer junction and a transformer and to place the transformer completely inside the hole in the PEC and to design a microstrip-to-transformer junction, to solder on the microstrip line on the PCB, as shorter as possible.

The second design combines a first transformer, able to match the quasi-TEM mode of the microstrip with the fundamental TE10 mode of the rectangular waveguide, and a second transformer used both for rotate the E-Field, since the second waveguide is bended 90 degree with respect to the first one, and for match the levels of impedance.

The third design is similar to the second solution, i.e. consists of the combination of a transformer with a bend. Both these components are placed on the PCB and not in the waveguide opening in the PCB in order to overcome the problems described above.

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