Analysis, Design and Implementation of a Broadband Coaxial-to-microstrip Transition for UWB Radars

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Abstract— In this paper a useful, simplex and broadband coaxial-to-microstrip transitions using GCPW, simple pre-transition, are designed and implemented. The GCPW, pre-transition section is utilized to provide a smooth transition from coaxial to microstrip. In this transition the effects of the field and impedance matching with considering possible fabrication errors in total performance are completely analyzed. Experimental results are very close with simulation results. The results of 50 mm length of Microstrip line with back-to-back transitions show that a ultra wideband transition with return loss better than −10 dB and in the worth case, total insertion loss is less than 1 dB up to 30 GHz. These good performances and its simplicity, easy fabrication and good performances make this proposed transition very useful in many applications such as UWB short range Radars up to 30 GHz and make it a very good candidate for higher frequencies.

1. INTRODUCTION

Microstrip lines are the most widely used planar transmission lines for microwave circuit applications due to their low cost and ease in circuit layouts [1]. Also in near mm-wave frequency band, some functional modules are realized by plane structure of hybrid integration, and again microstrip is the most common transmission line [2]. On the other hand, for most equipment used for microwave circuit measurements, coaxial structures are normally employed for signal inputs and outputs. Thus, coaxial-to-microstrip transitions are required [1]. Despite the impedance matching between the coaxial connectors and the microstrip lines, a discontinuity exists due to the different electromagnetic (EM) field distributions of these two transmission lines and so signal reflection and radiation are expected. These problems become worse when the operating frequencies are higher and having the same characteristic impedance does not always guarantee a good transition between two transmission lines at higher frequencies [3]. For the past few decades, many techniques have been proposed to improve the high-frequency performance of coaxial-to microstrip transitions by modifying the structures of coaxial connectors or microstrip lines for better matching of the EM field distributions at the transitions [3, 4–7]. However in some of these transitions, only the impedance is match in a narrow frequency bands and in some others, complicated structure, high cost and large size make them undesirable. Furthermore it is important to have simplex, low-cost and wideband coaxial-to-microstrip transition.

In this paper a useful, simplex and broadband transitions between Air-Coaxial SMA connector and microstrip line is designed and implemented. This transition is designed by the use of a simple and small size ground coplanar waveguide (GCPW) as a pre transition. The CPW and its various configurations such as GCPW have several attractive features in comparison with microstrip line. For example these lines have low wave propagation dispersion up to very high frequency [8]. There have been intensive studies on transition from CPW to other planner transmission lines [9–11]. However, in the conventional method that connects the coaxial inner conductor and CPW center conductor on the same plane, higher-order modes arise at the connection section. This results in the insertion of unnecessary reactance in the line at discontinuous sections in a serial or parallel manner thereby generating a large mismatch [11].

The GCPW, pre-transition section is utilized to provide a smooth transition from coaxial to microstrip. The signal and ground current paths through a transition are also critical and these paths must often be continuous and as close as possible together, to suppress radiation [4]. In this transition the effects of the field and impedance matching on the bandwidth are discussed. To study the effects of GCPW section on the transitions, electromagnetic fields of transition structure in different cut are completely analyzed with CST. Moreover the influence of the possible fabrication and assembly errors such as slightly gap, height of laminate, misalignment between microstrip and center of SMA connector, excitation of higher order modes of SMA in connections and uncertainty of measurement instruments in total performance are completely analyzed and considered. The simulation results using CST and ADS softwares indicate that the bandwidth is increased to maximum operating frequency of SMA connector and The experimental results are in good agreement with simulation results. Insertion loss less than 1 dB and return loss better than −10 dB are obtained from 6 to 30 GHz.

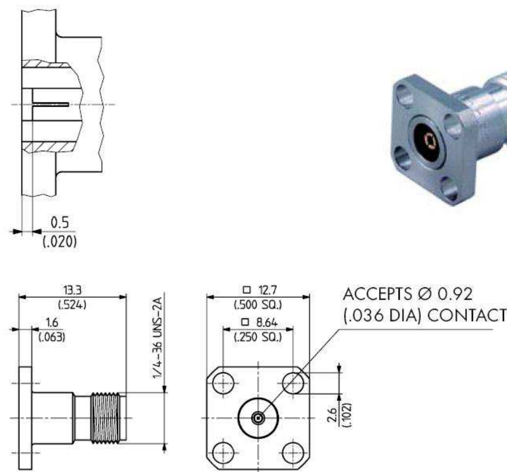

Figure 1: SMA connector [12].

2. PROPOSED TRANSITION

It is important to design a broadband coaxial-to-microstrip transition since the transition bandwidth determines the bandwidth over which the effects of the transition can properly be de-embedded from measurement results [1]. The goal of this work is to develop a coaxial-to-microstrip transition that works up to 30 GHz. The material used in the design are Rogers RT Duroid 5880 with $\varepsilon_r = 2.2$ and $\tan\delta = 0.0009$, the metal thickness is 0.017 mm and the substrate thickness is 10 mil and 20 mil. There are many coaxial connectors employed to implement coaxial-to-microstrip transitions. In this work the SMA coaxial connector which is used in the design is 23_PC35-50-0-53/199_UE from Huber-Suhner Company. This connector works in a single mode up to 33 GHz [12]. As it is shown in Fig. 1, SMA conductor has inner and outer diameter of 1.52 mm and 3.5 mm consequently which should be considered in simulation structure. The width of the microstrip line is chosen 1.59 mm (20 mil) and .77 mm (10 mil) to yield characteristics impedance of 50 ohm within the desired frequency band. The length of microstrip line is 50 mm.

As it is shown in Fig. 2, return loss in the Rogers 5880 laminate with the 10 mil of height is better than of the 20 mil. After adding the SMA connectors to the 10 and 20 mil microstrip lines with direct soldering the SMA connector to the microstrip lines of back to back transition which are shown in Fig. 3 and running the full wave analysis with CST software, S-parameters are obtained

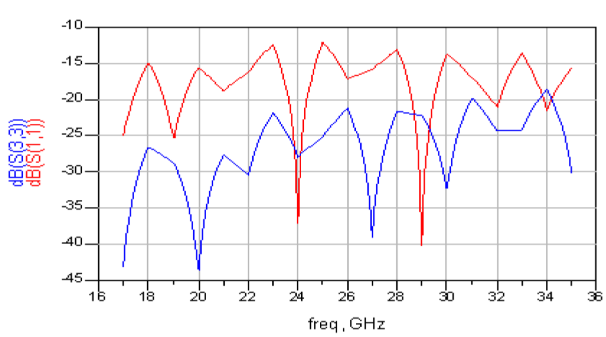

Figure 2: S-parameters of an 50 mm length Mline with ADS software, S_{11} is the return loss of the Rogers 20 mil laminate and S_{33} is for 10 mil.

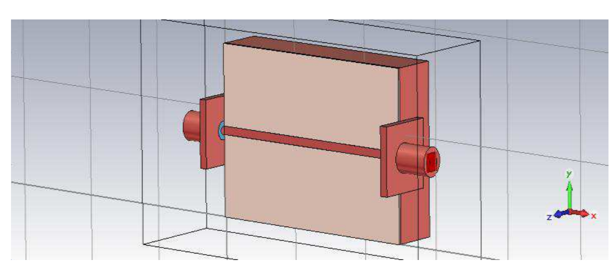

Figure 3: Proposed transition overall view.

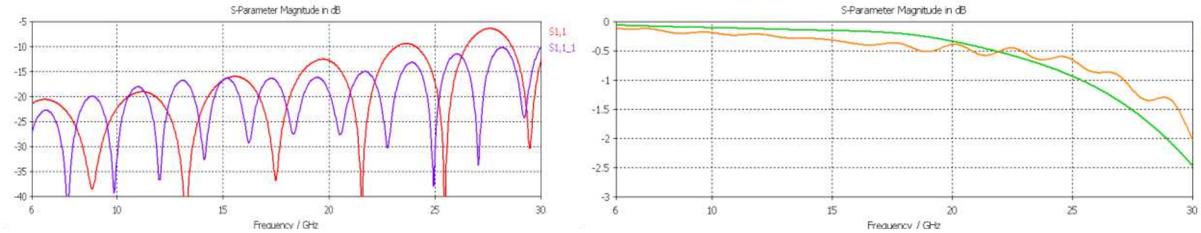

Figure 4: Scattering parameter of the 10 mil and 20 mil laminates using CST software.

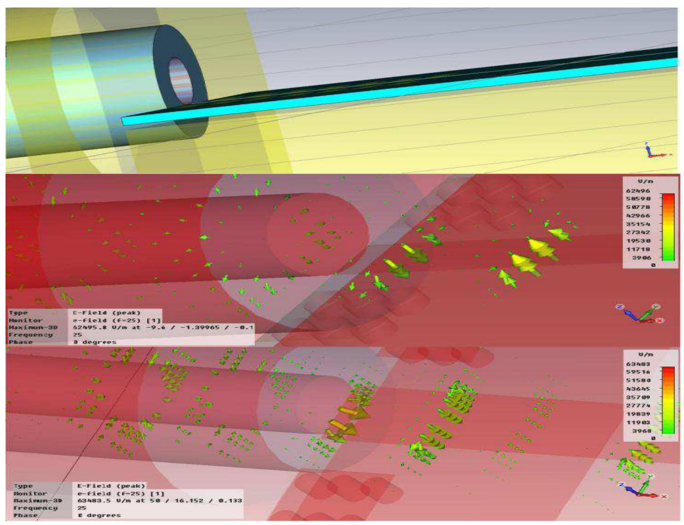

Figure 5: Electrical field in 10 and 20 mil laminate, (a) non coincidence between laminate and coaxial SMA coneector in height, (b) electrical field mismatch in 10 mil laminate, (c) electrical field mismatch in 20 mil laminate.

from CST simulation.

Unlike the ADS results; CST results show that the reflection and transmission of the 20 mil height is better than 10 mil, as it is shown in Fig. 4, which S_{11}, S_{21} are the S-parameters of the 10 mil and the $S_{11}-1$, $S_{21}-1$ are of the 20 mil. For investigation of this confliction between CST and ADS results, Electrical field simulation with CST is run.

As could be seen in Figs. 5(b), (c), electrical fields in 10 mil laminate have more mismatches against 20 mil in contact point with the coaxial connector. This is because that there is more gap in the point contact of the 10 mil laminate with the proposed SMA coaxial connector against 20 mil laminate, because the distance between inner and outer diameters of the coaxial connector is about 1 mm. As a result the electrical fields has more mismatch in 10 mil laminate, as it is shown in Fig. 5(a). Field matching as discussed before is very important in all transitions and so for the transition design in this paper, rogers5880 laminate with 20 mil height is considered.

2.1. Transition Design

The microstrip to coaxial transition that is proposed in this work is shown in Fig. 6. The structure includes GCPW pre-transition section that ensures proper field match between coaxial and microstrip lines. The center conductor of GCPW section should has the near same width as the SMA tab contact (1.51 mm) in center conductor in order to reach good impedance matching and robust solder connection.

The length of microstrip line is 50 mm. The parameters of the transition are $W_1 = 1.57$, $W_2 = 2$ $D_1 = 3.6$, $D_2 = 1.1$, $G_1 = 0.54$, $L_1 = 2$ and $d_x = 0.54$ (all in millimeter). In the GCPW section the value of W_1 and the value of G_1 are chosen in order to yield a characteristic impedance of 50 ohm along the transition within the desired frequency band. The value of W_1 is chosen near equal to the width of microstrip line to avoid abrupt discontinuity and to minimize the reflection along the transition. In this transition also the number of via and placement of them are optimized to suppress parallel plate mode and radiation loss and to obtain maximum band width.

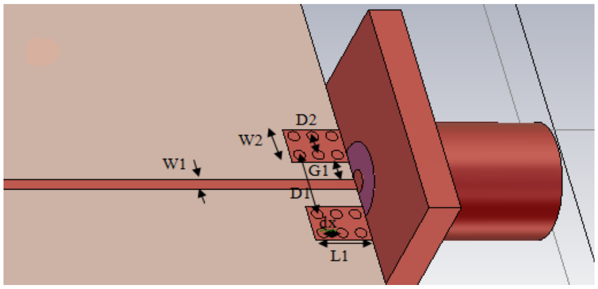

Figure 6: Proposed transition configuration.

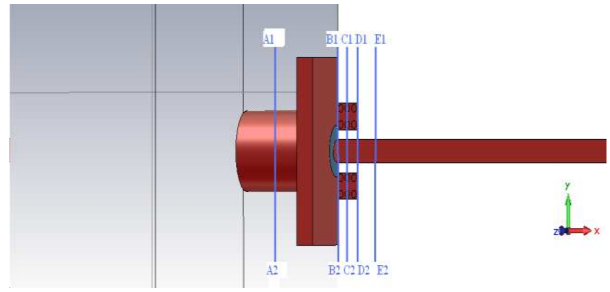

Figure 7: Proposed structure and cut plane for electrical field study.

2.2. Electromagnetic Field Matching Study

Having the same characteristic impedance does not always guarantee a good transition between two transmission line at higher frequencies and the field distributions of the transmission line must also be matched. Therefore the GCPW section used as an interface to match the electromagnetic field distributions at the coaxial-to-microstrip transition. To study the effects of GCPW section on the transitions, electromagnetic fields of transition structure which is shown in the Fig. 7 are analyzed with CST.

Figure 8 shows the magnitude and direction of the electric fields at A1-A2, B1-B2, C1-C2, D1-D2, E1-E2 cross-sections. This figure indicates that in the presence of GCPW section, the electric field distributions, step by step, from top (coaxial connector) to down (Microstrip line) figures are concentrated along the center conductor providing a good matching to the field distribution of the coaxial connector to Microstrip line.

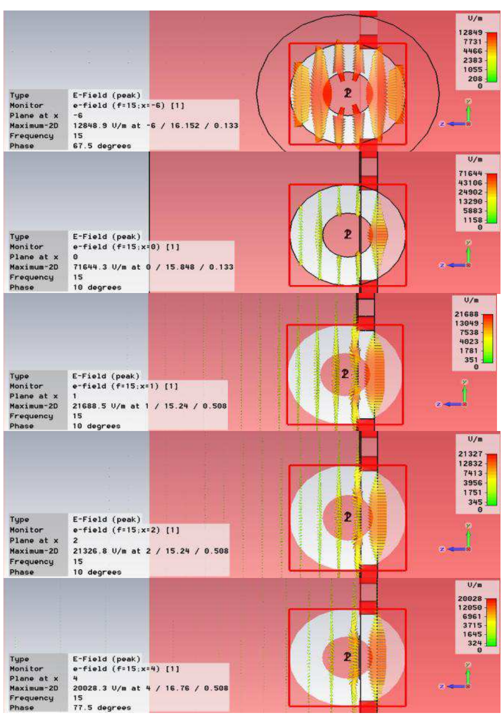

Figure 8: Magnitude and direction of the electric field at 15 GHz from top to down: A1A2: center of the coaxial connector, B1B2: coaxial to GCPW contact, C1C2: center of the GCPW, D1D2: GCPW to microstrip contact and E1E2: along microstrip transition structure shown in Fig. 7.

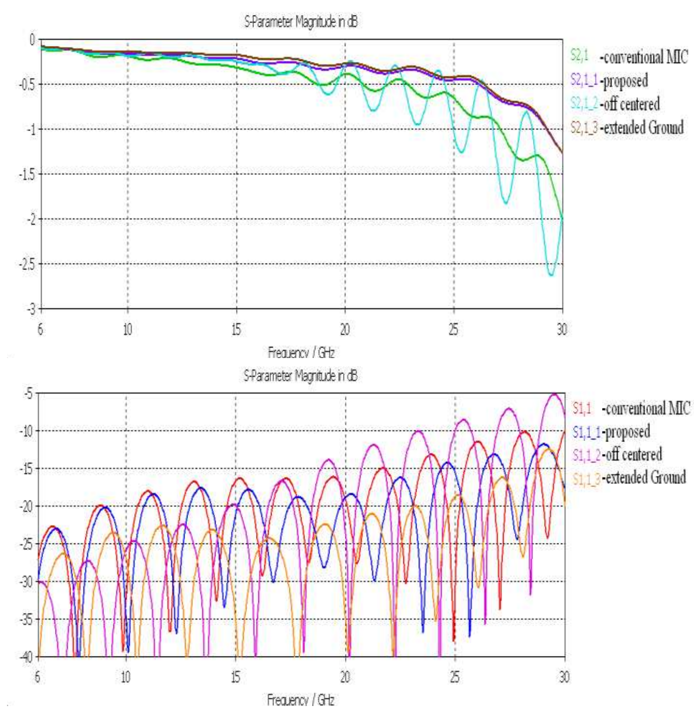

Figure 9: Scattering parameters of the proposed transition combined with a microstrip line with the length of 50 mm, against conventional coaxial to microstrip line transition, extended ground in GCPW and misalignment of the center conductor.

3. SIMULATION AND MEASUREMENT RESULTS

Figure 9 compares the S-parameters of the back to back transition structures with and without GCPW. Adding GCPW section affects the overall bandwidth of transition such that the bandwidth is wider in the presence of GCPW section. Also for better study of the proposed transition; simulation results of the transition with the extended ground in GCPW (twice in height and length) and a slightly gap (.1 mm) and misalignment between microstrip and center of SMA connector (.1 mm) in the In/Out connections are presented in Fig. 9.

As it is shown in Fig. 9, using extended ground in GCPW pre transition more than the proposed transition in the main design has no valuable effects in the performance, but the misalignment has destroying effects on the S-parameters.

The proposed transition has insertion loss less than 1.2 dB and reflection better than −12 dB up to 30 GHz. By the way it is clear that the insertion loss of the 50 mm Microstrip line in the frequency of 30 GHz is more than .6 dB (using Rogers Microwave Impedance Calculator 2014 or other software) so by removing this insertion loss from the total insertion loss, the proposed transition has less than .6 dB insertion loss up to 30 GHz.

Experimental results of the proposed transition with considering 50 mm Microstrip line is presented in Fig. 10. As can be seen from Figs. 9, 10 the measurement results are in very close with simulation results and some differences between simulation and experimental results are due to the reasons that were discussed before. In the worth case and in the worth case, total insertion loss; by removing the insertion loss of the 50 mm Microstrip line and connectors; the proposed transition has insertion loss less than 1.2 dB that can be improve to .6 dB by doing better assembly, and so can be used in many applications. Fig. 11 shows the photos of the fabricated transition with the 50 mm Microstrip line. As it is seen in Figs. 11(a), (b) there is some gap, and some misalignment respectively in the assembly. And as discussed before due to these reasons the insertion loss and resonances are increased.

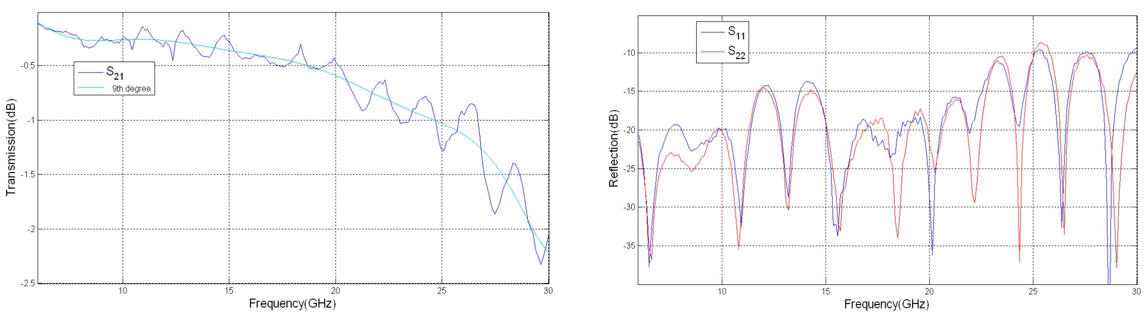

Figure 10: Experimental transmission and reflection results of the proposed transition considering 50 mm microstrip line.

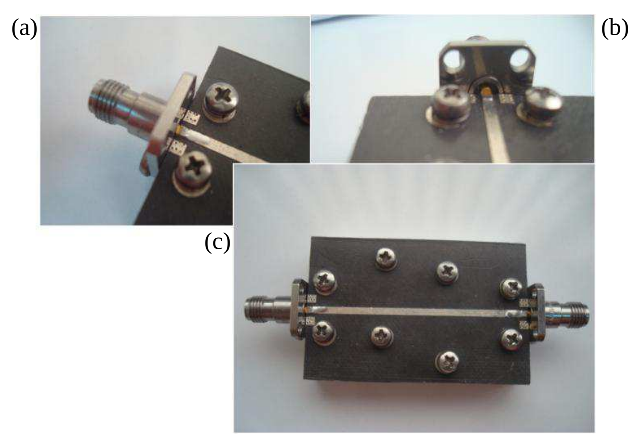

Figure 11: Photos of the proposed transition and the 50 mm microstrip line. (a) Gap view, (b) misalignment view and (c) overall top view.

4. CONCLUSION

In this paper, a very simple, low-cost, low complexity, useful and wideband coaxial-to-microstrip transition up to 30 GHz were presented. The good effects of GCPW pre transition on the overall bandwidth were discussed. In this transition the effects of the field and impedance matching with considering other practical effects in total performance were completely analyzed. The measured and simulated results of back-to-back transition were showed very good agreement. The simulation and measurement results verified that the fabricated back-to-back coaxial-to-microstrip transition can achieve a 0.6 dB insertion loss and a return loss better than −10 dB up to 30 GHZ that can be improve easily by this simple structure. This low complexity low cost and easy fabrication is very useful in many application such as UWB short range Radars which work in 22–29 GHz, collision avoidance Radars in vehicular systems and UWB communications. Other transitions to improve bandwidth and other performances in UWB microwave circuits are under investigation and will be presented in the future works.

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