ANALYSIS OF THE TRANSITION BETWEEN TWO COPLANAR WAVEGUIDE TRANSMISSION LINES

Abdelnasser A. Eldek, Atef Z. Elsherbeni and Charles E. Smith
Center of Applied Electromagnetic Systems Research (CAESR), Department of Electrical Engineering
The University of Mississippi
University, MS 38677

ABSTRACT: *Different approaches for the transition between two coplanar waveguides of different characteristic impedances have been investigated to improve the efficiency of both feeding network and the antenna element of an antenna system operating in the X-band. Return loss, effect of feed line shaping and parametric study are presented with each approach. The outcomes of this study leads to efficient transition between the antenna element and its feeding network.*

Key words: Transition, Coplanar Waveguide, X-Band

1. INTRODUCTION

Transitions between different configurations of planar transmission line become very important in many recent applications. As a result, researchers have tried to introduce the proper transitions in terms of low reflections and insertion loss. The transitions and mode conversion at the transitions from coplanar waveguide (CPW) to 50 Ω grounded CPW (GCPW), and 50 Ω microstrip line are recently studied in [1] and [2] respectively. CPW to CPW transition is introduced through GCPW and microstrip line in [3]. Another study for vertical transition between two CPW is introduced in [4]. However, all these research applications are addressing the transition between two 50 Ω feed lines. In this paper, the transitions between a 50 Ω and non-50 Ω CPW are introduced.

In the design process of antennas, designer usually use the feed line parameters as tuning parameters for controlling both reflection level and bandwidth (BW). The coplanar patch antennas presented in [5], named designs 1 through 4, operating in wireless communication frequency bands, have coplanar waveguides (CPW) of characteristic impedances equal to 70.4, 86.4, 96.4 and 117.17 Ω, respectively, and the BW of these designs reach up to 22.2%. Similarly, The antennas presented in [6], operating in the X-band, do not have 50 Ω feeding line, however, they are designed to cover the 8-12 GHz band. These antennas are usually fed by existing 50 Ω lines, therefore, efficient transition between a non-50 Ω CPW and a 50 Ω CPW is required to maintain the antenna characteristics.

The starting point of this study began with a bow-tie slot antenna which covers the entire X-band from 8 to 12 GHz, with 40% BW. The antenna is simulated using the commercial computer software package, Momentum of Agilent Technologies, Advanced Design System (ADS), which is based on the method of moment (MoM) technique for layered media. Momentum solves mixed potential integral equations (MPIE) using full wave Green's functions [7]. The antenna is also simulated using the finite difference time domain (FDTD) technique, and good agreement between both results is obtained. The antenna is fed by a CPW of (W, G) = (3, 0.25) mm, where W is the feed line width and G is the gap or slot width. The substrate is RT/duriod 5880 of height equals 1.57 mm and dielectric constant equals 2.2. The characteristic impedance of the CPW of these dimensions is found to be 60.87 Ω, using LineCalc software of ADS. Since the antenna is required to be fed by a 50 Ω line, a transition between the 60.87 Ω and 50 Ω CPWs is required to be studied for minimum reflections and maximum bandwidth throughout the X-band. Three approaches have been investigated for this application, namely the direct connection to the antenna without any transitions and the connection of the antenna feed line to a wider CPW through both an angled and perpendicular slot line. All dimensions shown in the figures are in mm.

2. RESULTS AND ANALYSIS

First Approach

The first approach is to connect the feed line of the antenna directly to a 50 Ω CPW. In this approach, W is kept the same; 3 mm, and G is adjusted for 50 Ω characteristic impedance. Using LineCalc, a CPW of (W, G) = (3, 0.1044) mm, and the same type of substrate is considered. Figure 1 shows the combination of the antenna and the 50 Ω CPW feed line of length L. The return loss of the combination while varying L is shown in Fig. 2, compared with the return loss of the original antenna. This approach gives excellent results as shown in Fig. 2. The return loss of the feeding CPW is studied separately for different L values, as shown in Fig. 3. The return loss is almost less than 40 dB in the X-band. To examine the effect of deforming the CPW feed lines, often required for the feeding network, a simple configuration is shown in Fig. 4, with different horizontal extension length, L. With different values of L, the BW still covers the entire X-band.

Second Approach

The second approach is to connect the feed line of the antenna to a wider 50 Ω CPW through angled slot line. This combination is shown in Fig. 5, where d is the vertical length between the two CPWs. The 50 Ω CPW has (W, G) = (11, 0.3) mm and the same type of substrate, as determined by LineCalc. The return loss of the combination while varying d is shown in Fig. 6, compared with the return loss of the original antenna. As d equals to multiples of $\lambda g/2$, the BW is nearly the same as that of the original antenna. When d = 0, good return loss is obtained, thus, further investigation for this condition is performed as part of the third approach. The return loss of the CPW feedline together with the angled slot line is studied separately for different d values, as shown in Fig. 7. The return loss is almost less than 16 dB in the X-band range.

Third Approach

The third approach is a special case of the second one, where d = 0 and (W, G) equal (11, 4) mm, and the thickness of the perpendicular slot, t, is tapered for matching between the two CPWs. Figure 8 shows this combination of the antenna, the perpendicular slot of thickness t and a 50 Ω CPW feed line. When t is decreased from 0.35 to 0.20 mm in 0.05 mm steps, the BW increases as shown in Fig. 9, and becomes almost constant when t is in the range 0.18 to 0.15 mm, then starts to decrease as shown in Fig. 10 for t = 0.1 and 0.06 mm. By using non-uniform horizontal slot thickness, where t is larger at the 50 Ω CPW and smaller at the 60.87 Ω, better results are obtained, as shown in Fig. 11, where t varies from 0.1 to 0.25, 0.3 and 0.35 mm. The return loss of the feeding CPW connected with a horizontal slot is studied separately for t = 0.15, 0.18 and 0.2 mm and for a non-uniform t that varies from 0.1 to 0.3 and 0.35 mm. As shown in Fig. 12, the maximum return loss for t = 0.2 and 0.18 mm is 22 dB, while Fig. 13 shows that the non-uniform cases give return loss smaller than 25 dB. The effect of the length of the 50 Ω CPW is also studied as shown in Fig. 14, where the BW remains almost constant. To examine the possibility of an offset or redirection of the CPW feedline, a simple offset to the CPW, as shown in Fig. 15, is studied for different horizontal extension length, L with thickness = 0.3 mm. With different values of L, the BW still covers the entire X-band. By varying the thickness of the horizontal slot from 0.1 to 0.3 as shown in Fig. 16, the return loss showed noticeable improvement throughout the X-band frequency range.

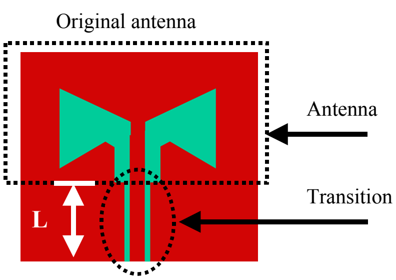

Fig. 1. First type of transition with direction connection.

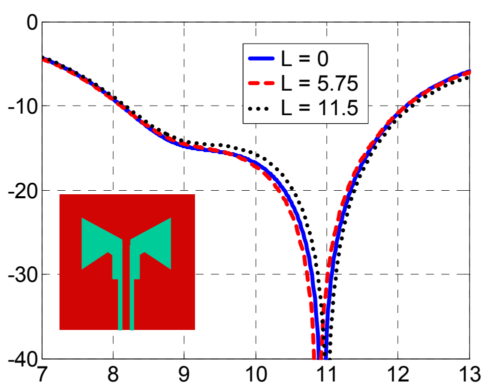

Fig. 2. S11 of the antenna with direct connection to a CPW transition for different L values.

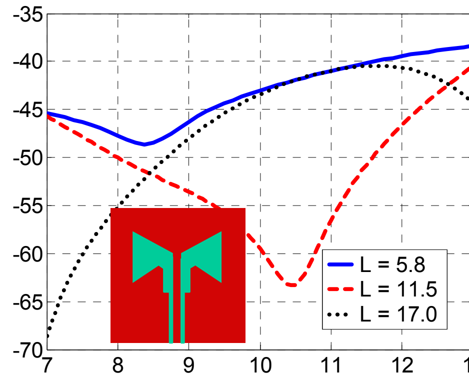

Fig. 3. S11 of the transition with in direct connection.

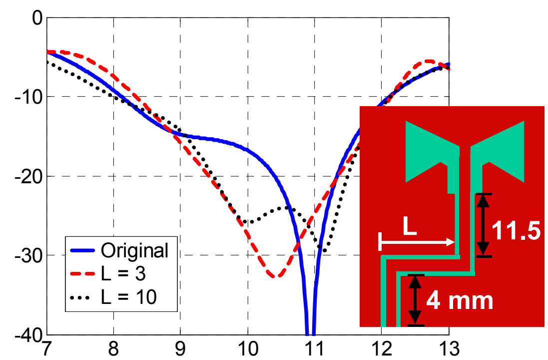

Fig.4. S11 of the antenna with direct connection to deformed CPW line.

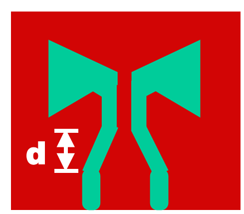

Fig. 5. Antenna connected to the second type of CPW transition.

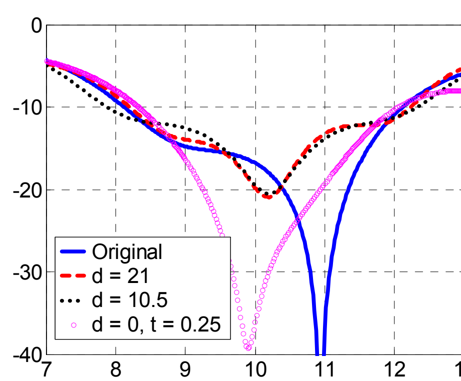

Fig. 6. S11 of the antenna connected to the second type transition with different d values.

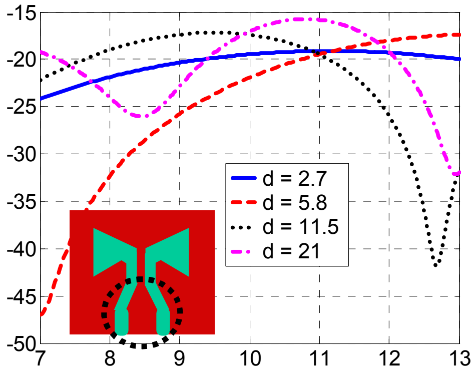

Fig. 7. S11 of the second type transition with the 50 Ω CPW of length 5.8 mm.

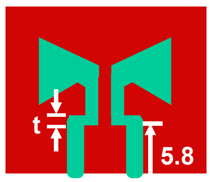

Fig. 8. Antenna connection by the third type approach.

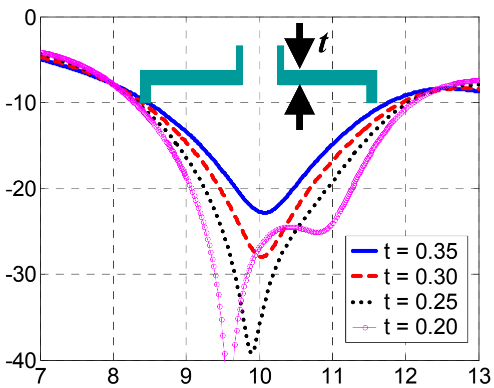

Fig. 9. S11 of the antenna connected to the third type transition with uniform slot thickness changing from 0.35 to 0.2 mm.

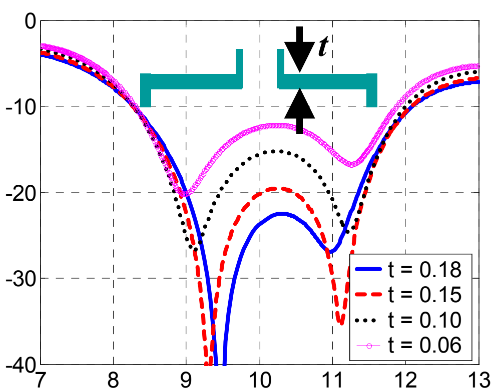

Fig. 10. S11 of the antenna connected to the third type transition with uniform slot thickness changing from 0.18 to 0.06 mm.

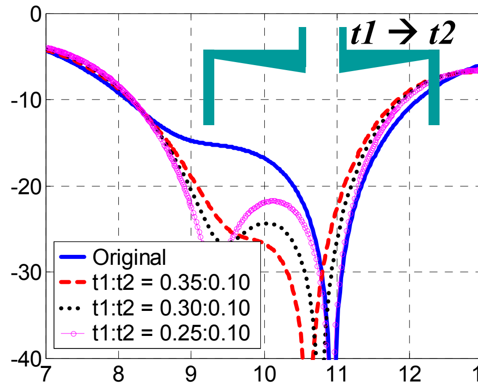

Fig. 11. S11 of the antenna connected to the third type transition with non-uniform slot thickness.

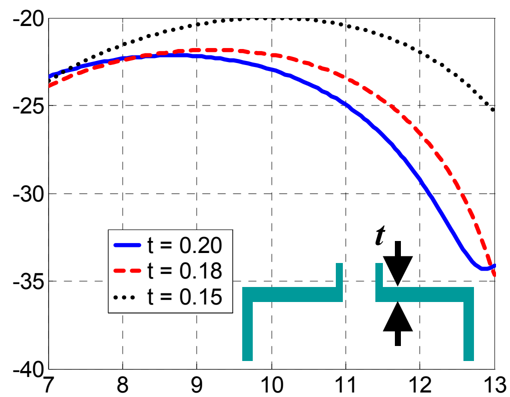

Fig. 12. S11 of the perpendicular slot transition with uniform thickness and the 50 Ω CPW of length 5.8 mm.

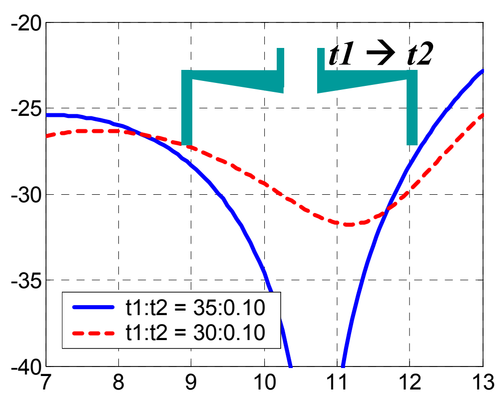

Fig. 13. S11 of the perpendicular slot transition with non-uniform thickness and the 50 Ω CPW of length 5.8 mm.

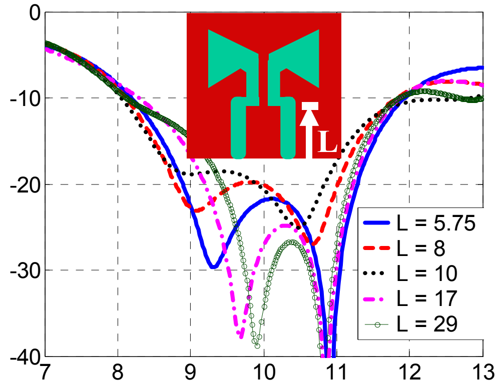

Fig. 14. Effect of changing in L on the return loss of the antenna while connected to the third type transition. The parameter t changes from 0.25 to 0.1 mm.

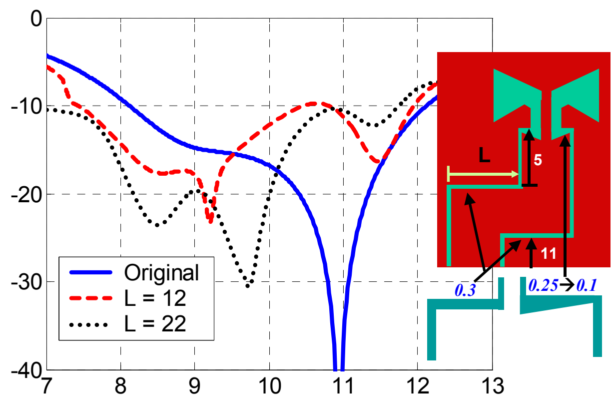

Fig. 15. S11 of the antenna connected to the third type transition with deformed line. The lower perpendicular slot has uniform thickness.

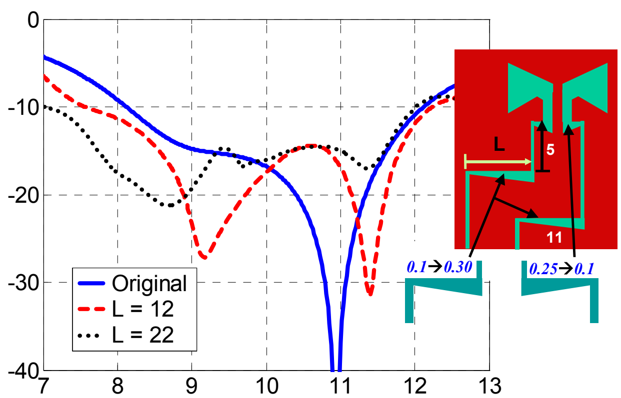

Fig. 16. S11 of the antenna connected to the third type transition with deformed line. The lower perpendicular slot has non-uniform thickness.

3. CONCLUSION

Three approaches for the transition between two coplanar waveguides, one of 60.87 Ω and the other of 50 Ω, have been investigated to reduce the reflection resulting from the transition and to improve the overall efficiency of an antenna system operating in X-band. The direct connection of two CPWs of the same feed line width, yielded excellent performance regardless of the length of the CPW. For unequal feed lines, the connection through angled slot line of length equal to multiples of $\lambda g/2$, the bandwidth changes are insignificant. However, for the connection between two unequal feed lines through a horizontally tapered slot line, excellent performance is observed.

REFERENCES

[1] Jean-Pierre Raskin, Gildes Gauthier, Linda P. Katehi, and Gabriel M. Rebeiz, "Mode conversion at GCPW-to-microstrip-line transmissions," *IEEE Antenna Trans. Microwave Theory and Techniques,* Vol. 48, No. 1, pp. 158-161, January 2000**.**

[2] Amr M. E. Safwat, Kawthar A. Zaki, William Johnson and Chi H. Lee, "Novel transition between different configurations of planar transmission lines*," IEEE Microwave and Wireless Components Letters*, Vol. 12, No. 4, pp. 128-131, April 2002.

[3] Gildes P. Gauthier, Linda P. Katehi, and Gabriel M. Rebeiz, "W-band finite ground coplanar waveguide (FGCPW) to microstrip line transition," *MTT-S Int. Microwave Symp. Dig.*, pp. 107-109, 1998.

[4] Jean-Pierre Raskin, Gildes Gauthier, Linda P. Katehi, and Gabriel M. Rebeiz, "W-band single-layer vertical transitions," *IEEE Antenna Trans. Microwave Theory and Techniques*, Vol. 48, No. 1, pp. 161-164, January 2000**.**

[5] Abdelnasser A. Eldek, Atef Z. Elsherbeni, Charles E. Smith and Kai-Fong Lee, "Wideband rectangular slot antenna for personal wireless communication systems," *IEEE Antennas and Prob. Magazine,* Vol. 44, No. 5, pp. 146-155, October 2002.

[6] Abdelnasser A. Eldek, Brad N. Baker, Atef Z. Elsherbeni, Charles E. Smith and Kai-Fong Lee, "Wideband coplanar patch-slot antennas for radar applications," *IEEE International Symb. Antennas and Prob. And URSI National Radio Science meeting,* San Antonio, Texas, Vol. 2, pp. 436-439, July 2002.

[7] Agilent Technologies, Advance Design Systems 1.5 Momentum, Appendix A, December 2000.