Circularly Polarized Aperture Coupled Microstrip Antenna with a Screen and Impedance Transformer: Part 2. Final Results

G. S. Kirov[1] and D. P. Mihaylova[2]

Abstract – **A circularly polarized aperture coupled microstrip antenna with a screen and impedance transformer is studied in this paper. A comparison between antennas with an impedance transformer and without transformer is accomplished.**

Keywords – **Aperture coupled microstrip antenna, Circularly polarized microstrip antenna, Microstrip antenna with an impedance transformer.**

I. Introduction

The effect of the antenna dimensions on the electrical characteristics of the circularly polarized aperture coupled microstrip antenna (ACMSA) with a screen and impedance transformer is investigated in part 1 of this article [1]. In this part the effect of the impedance transformer dimensions on the electrical characteristics of the antenna is studied. Also a comparison between antennas with an impedance transformer and without transformer is carried out.

II. Effect of the Impedance Transformer Dimensions on the Antenna Characteristics

The simulation results presented hereby fulfill the parameter study of the circularly polarized ACMSA with a screen and provide a deeper insight into the benefits and problems associated with this structure. In this respect, it should be mentioned that thanks to the screening effect the back radiation of the antenna improves almost two times compared with the design without a screen. This solution of the problem with spurious radiation, however, is accompanied with two main drawbacks. First, the effective CP bandwidth seems to restrict up to 2 % while the optimum value of the same parameter of the antenna without a screen is around 3.2 %. Second, the input matching of the unit aggravates, which in fact yields to another modification of the structure. A common solution of the matching problem makes use of an impedance transformer. This arrangement actually allows independent optimization of the feeding system due to the loading effect of the transformer.

The geometry of the aperture coupling and the impedance transformer is illustrated in Fig. 1.

In order to improve impedance matching, the additional quarter-wavelength microstrip section has to comply with certain rules. It must be placed at a distance *Lb* away from the load at point z*=0, where the input impedance toward the load at z*=*Lb* is real. Referring to the existing theory, the distance *Lb* should satisfy the equation:

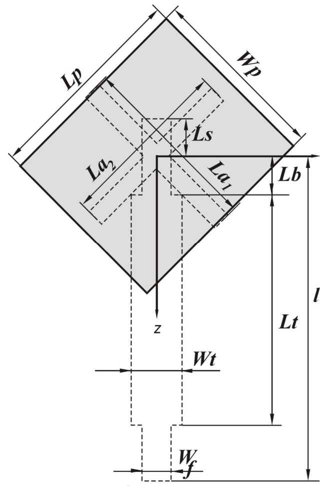

Fig. 1. Geometry of the aperture coupling and the impedance transformer

$$x(Lb) = 0 \qquad (1)$$

The latter is the reactive part of the normalized input impedance of the line at z*=*l*, derived as follows:

$$x = \frac{[x_L.M + \sin(2\beta l)]Q - [r_L.M + \sinh(2\alpha l)]U}{Q^2 + U^2} \qquad (2)$$

where

$$z_L(f) = r_L(f) + jx_L(f) \text{ at point z*= 0} \qquad (3)$$

$$\gamma = \alpha + j\beta \text{ is the complex propagation constant} \qquad (4)$$

$$M = \cosh(2\alpha l) + \cos(2\beta l) \qquad (5)$$

$$Q = M + r_L \sinh(2\alpha l) - x_L \sin(2\beta l) \qquad (6)$$

$$U = r_L \sin(2\beta l) + x_L \sinh(2\alpha l) \qquad (7)$$

The effect of the distance *Lb*=0.0 – 2.0 mm on the electrical characteristics of the antenna is shown in Fig. 2. One may see that in case of a symmetrical disposition of the load and the transformer (*Ls*=*Lb*) best impedance matching is ensured. Consequently, the curve of the axial ratio becomes symmetrical, which usually comes with a broader CP bandwidth.

The impact of the transformer length *Lt* and width *Wt* on the antenna electrical characteristics is exhibited in Figs. 3 and 4. Care should be taken when choosing the step of parameter deviation. Note that variation of *Lt* with 1 mm and *Wt* with 0.4 mm may change the matching characteristic with approximately 3 dB.

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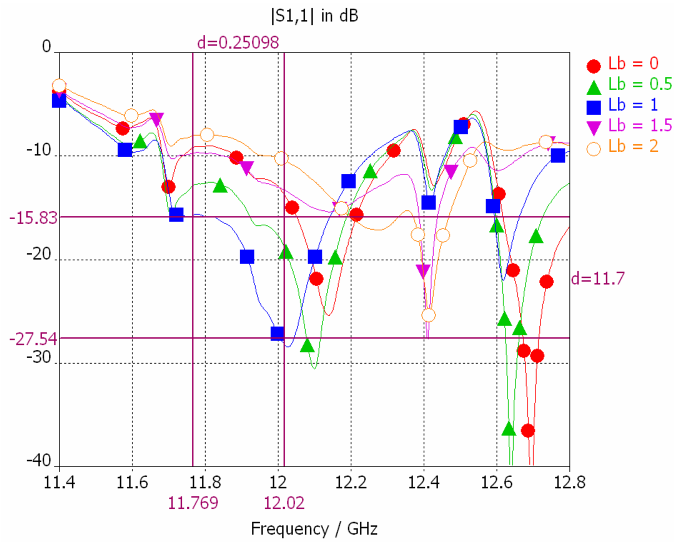
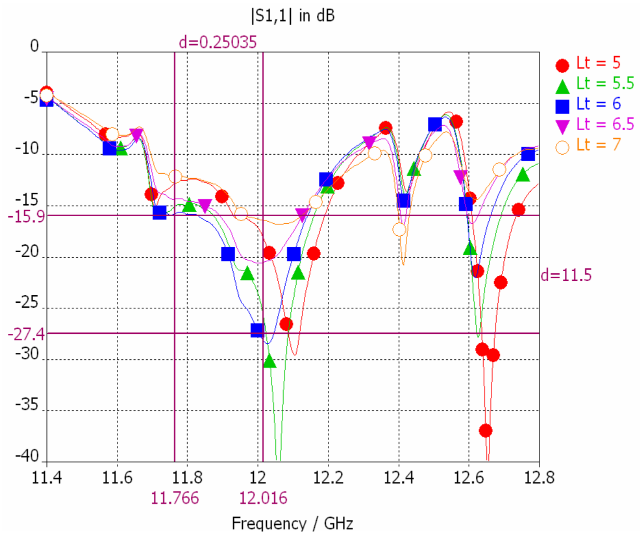
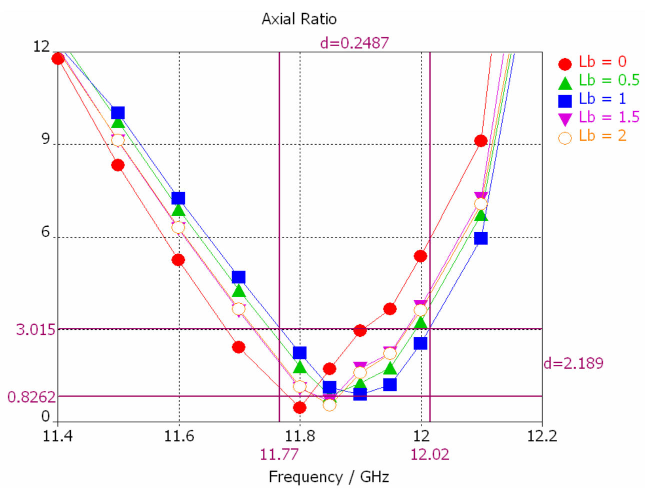


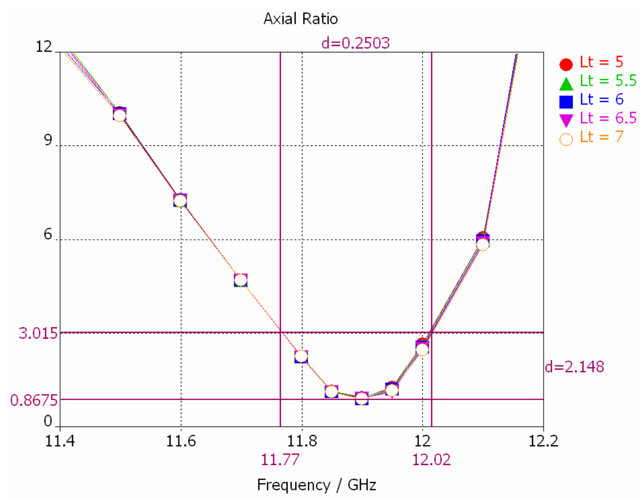
a) Return loss S_{11} [dB].



a) Return loss S_{11} [dB].



b) Axial ratio [dB].



b)

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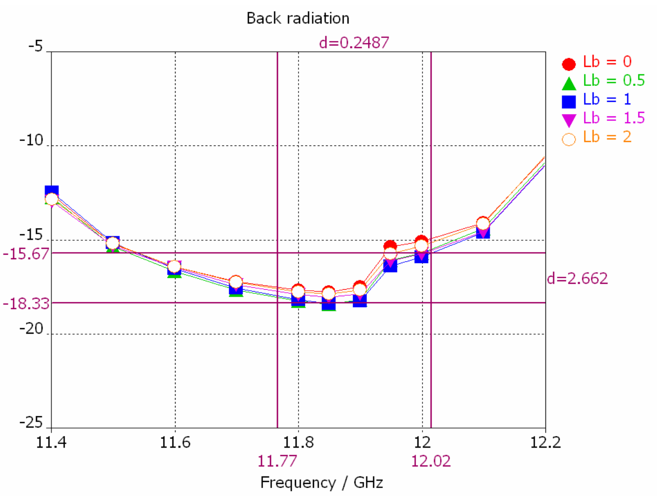
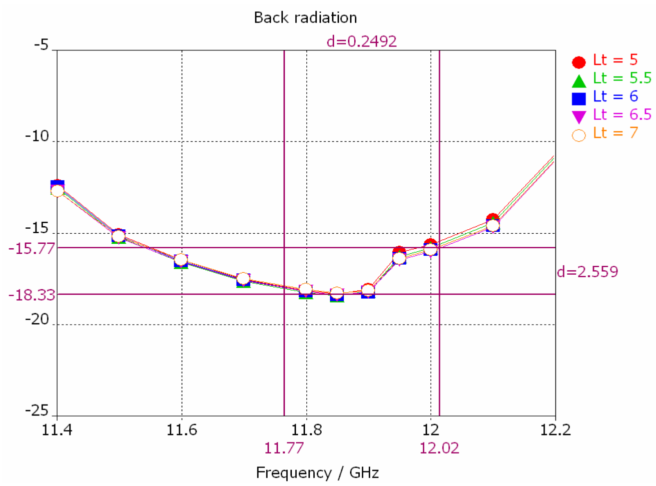


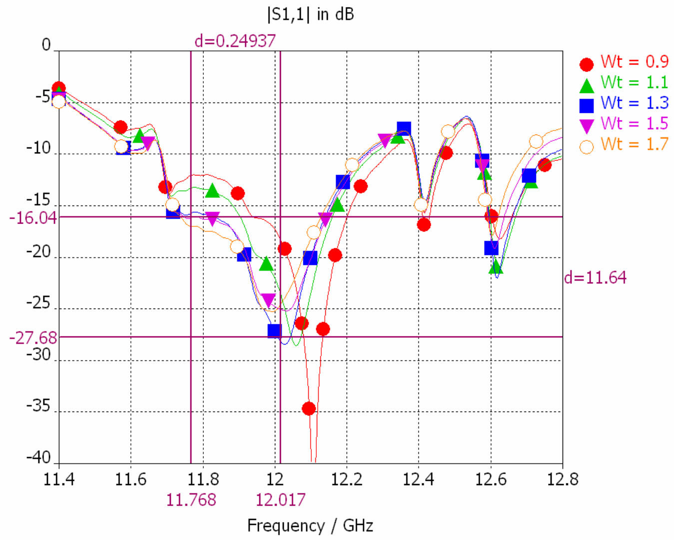
c) Back radiation [dB].



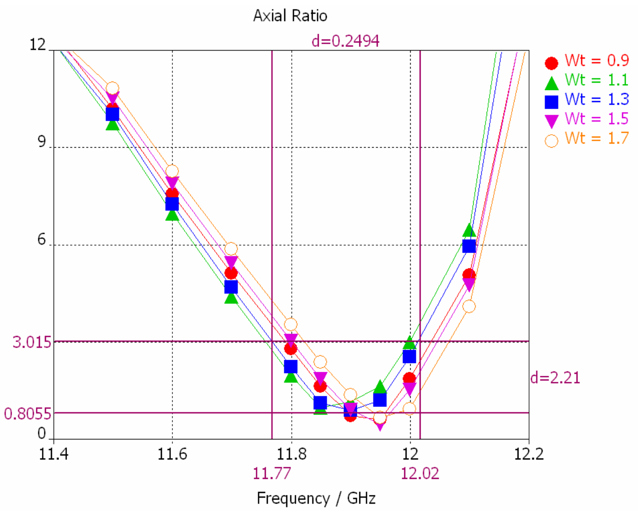
c) Back radiation [dB].

Fig. 2. Effect of the distance between the antenna centre and impedance transformer *Lb*=0.0 – 2.0 mm on the electrical characteristics of the antenna: a) Return loss *S*11; b) Axial ratio (*AR*); c) Back radiation.

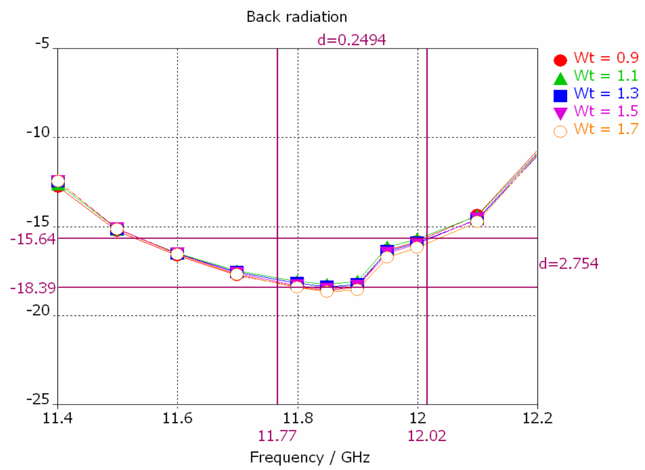
Fig. 3. Effect of transformer length *Lt*=5.0 – 7.0 mm on the electrical characteristics of the antenna with a screen and impedance transformer: a) Return loss *S*11; b) Axial ratio (*AR*); c) Back radiation.



a) Return loss S_{11} [dB].



b) Axial ratio [dB].



c) Back radiation [dB].

Fig. 4. Effect of transformer width *Wt*=0.9 – 1.7 mm on the electrical characteristics of the antenna with a screen and impedance transformer: a) Return loss *S*11; b) Axial ratio (*AR*); c) Back radiation.

III. Final Results and Data for Comparison

Data for comparison of the characteristics of antennas with and without an impedance transformer are listed in Table I.

TABLE I
ELECTRICAL CHARACTERISTICS OF ANTENNAS WITH AND WITHOUT AN IMPEDANCE TRANSFORMER

ANTENNA CHARACTERISTICS	
WITHOUT AN IMPEDANCE TRANSFORMER	WITH AN IMPEDANCE TRANSFORMER
Impedance Bandwidth	
f_{min}=11.7 GHz	f_{min}=11.68 GHz
f_{max}=12.5 GHz	f_{max}=12.25 GHz
f_o=12.1 GHz	f_o=11.965 GHz
λ_o=24.79 mm	λ_o=25.07 mm
bw=6.61 %	bw=4.76 %
Bandwidth acc. to AR	
f_{minAR}=11.82 GHz	f_{minAR}=11.77 GHz
f_{maxAR}=12.07 GHz	f_{maxAR}=12.02 GHz
f_{oAR}=11.95 GHz	f_{oAR}=11.9 GHz
λ_{oAR}=25.105 mm	λ_{oAR}=25.21 mm
AR_o=0.7 dB	AR_o=0.88 dB
bw_{AR}=2.09 %	bw_{AR}=2.1 %
Directivity, Gain and Back Radiation within CP bandwidth	
D=(6.82; 7.54) dB	*D*=(6.78; 7.46) dB
G=(6.1 ; 6.8) dB	*G*=(6.00 ; 6.67) dB
BR=(-19.0; -15.6) dB	*BR*=(-18.33; -15.73) dB

As seen from table I, the improvement of input matching is on the expense of impedance bandwidth, which is not critical until the CP operation is uninterrupted. One may gain a better impression of this dependency from fig.5.

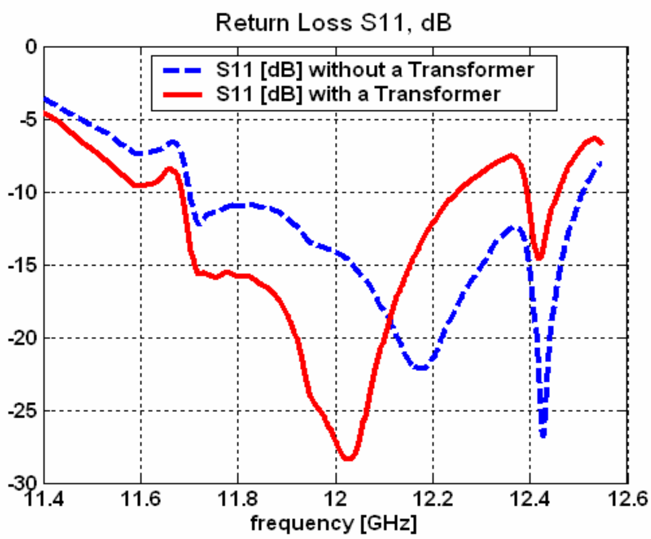


Fig. 5. Return loss *S*11 [dB] versus frequency of the antenna with and without an impedance transformer.

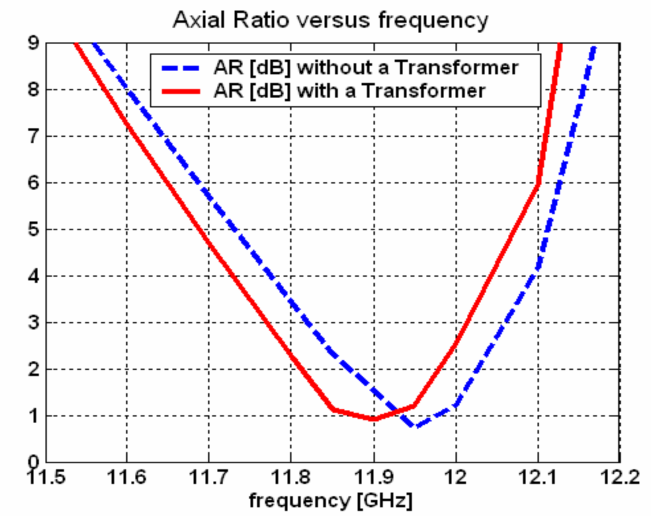


Fig. 6. Axial ratio [dB] versus frequency of the antenna with and without an impedance transformer.

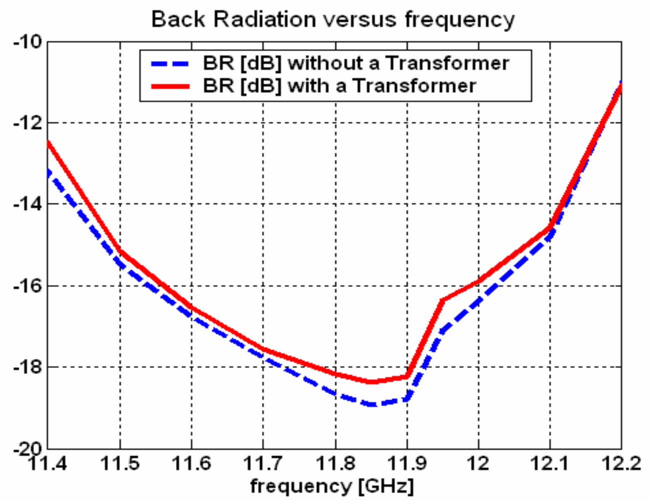


Fig. 7. Back radiation [dB] versus frequency of the antenna with and without an impedance transformer.

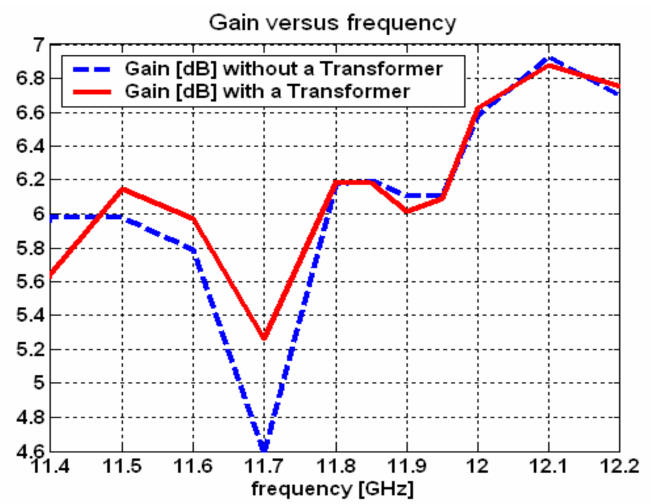


Fig. 8. Gain [dB] versus frequency of the antenna with and without an impedance transformer.

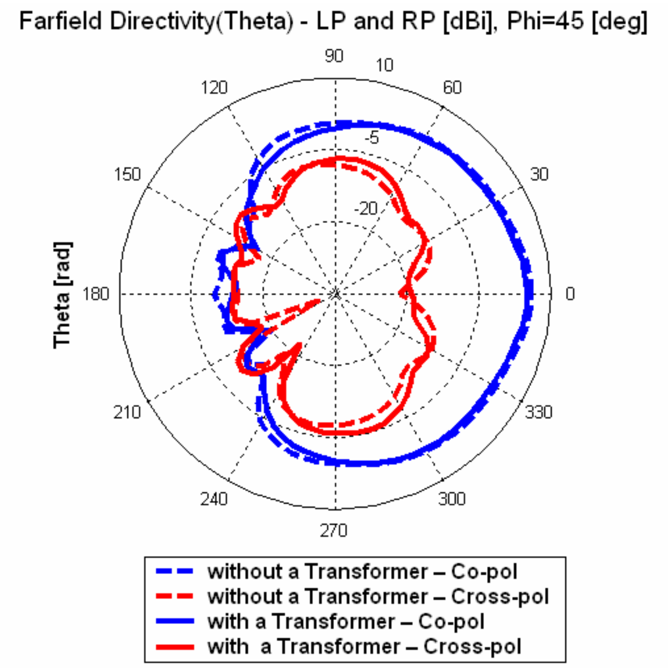


Fig. 9. Radiation Patterns of the antenna with an impedance transformer (*f*o= 11.9 GHz, φ=45°) and without a transformer (*f*o= 11.95 GHz, φ=45°).

Referring Fig. 6, another detail about the design with transformer is the slightly decreased operation frequency of circular polarization. The other characteristics, such as back radiation, Gain and radiation patterns displayed in Figs. 7, 8 and 9 are not influenced significantly.

IV. Conclusion

A study of the effect of the impedance transformer dimensions on the electrical characteristics of a circularly polarized aperture coupled microstrip antenna with a screen and impedance transformer has been accomplished. The results obtained can be used for design of circularly polarized broadband microstrip antennas.

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References

[1] D. P. Mihaylova and G. S. Kirov, “Circularly Polarized Aperture Coupled Microstrip Antenna with a Screen and Impedance Transformer: Part 1. Effect of the Antenna Dimensions on the Electrical Characteristics of the Antenna”, ICEST2009, 25-27 June, 2009, Veliko Tarnovo, Bulgaria.

[2] CST Computer Simulation Technology, www.cst.com