Use of 3D Reflector Plates for Measuring Microstrip Dipole of the Symmetrical Antenna

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ABSTRACT: *In the current work we have investigated the symmetrical microstrip antennas and their bandwidth using 3D reflector plates. We have deployed the WIPL-D software and measured the microstrip dipole. The new models which we presented have new symmetrical microstrip dipoles of varied shapes and have pentagonal dipole.*

Keywords: Bandwidth, Symmetrical Microstrip Dipole, Reflector Plate

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1. Introduction

Printed antennas feature advantages that make them suitable for many modern wireless communication services. They have low profile and low weight, simple and inexpensive production using standard photolithographic technique, great reproducibility and the possibility of integration with other microwave circuits [1]. Their major disadvantages are spurious feed radiation, tolerances in fabrication, very narrow frequency bandwidth and surface wave effect [2]. The mentioned limitations can be overcome using symmetrical microstrip dipole which operates on the second resonance (antiresonance) enabling both much slower impedance variation with frequency and useful wide bandwidth than in case of operation on the first resonance [3- 8]. Consequently, it has lower sensitivity to fabrication's tolerances enabling the use of low-cost photolithography printing process for its manufacture. Further, the feeding symmetrical microstrip line causes the reduction of unwanted radiation, parasitic coupling and surface wave effect [3-8].

There are many published research results of symmetrical microstrip dipole of pentagonal shape and its arrays [3-8] that demonstrate their advantages over classical printed antennas. This paper presents examination of symmetrical microstrip dipoles of different shapes with different 3D reflector plates. Special attention is given to the bandwidth of proposed symmetrical microstrip dipoles as well as to the bandwidth of their arrays.

2. Symmetrical Microstrip Dipoles

The symmetrical microstrip dipole is presented in Figure 1. One its half is on one side and another half, contrariwise turned, is on the opposite side of the substrate.

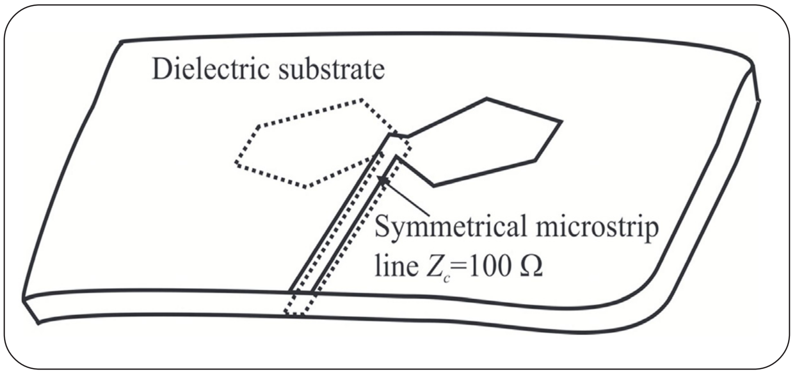


Figure 1. The symmetrical microstrip dipole

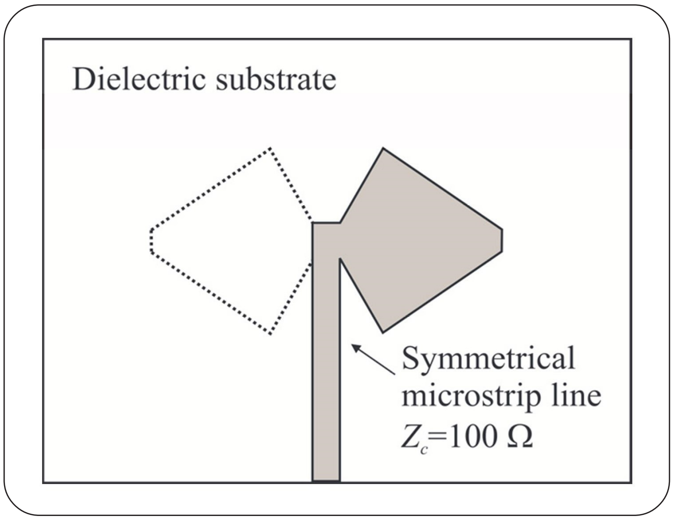
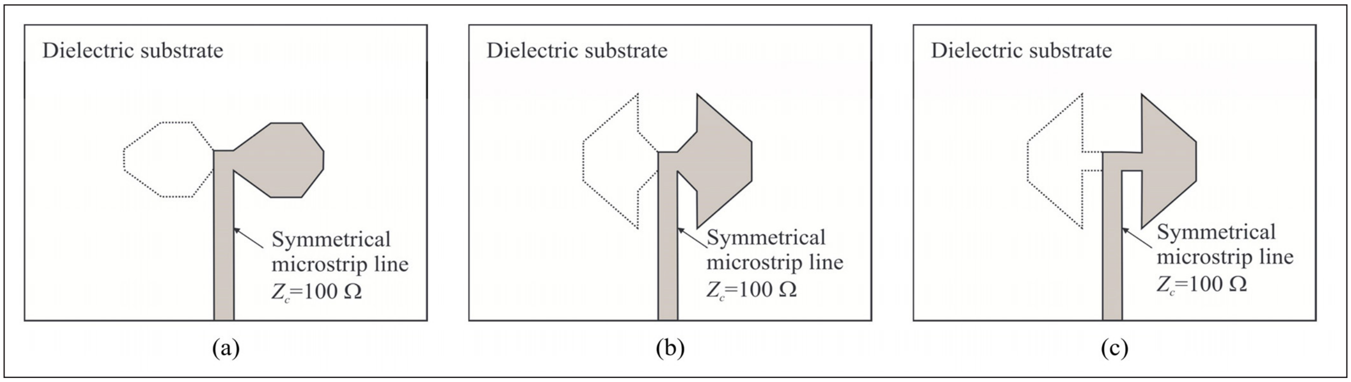


Figure 2. The symmetrical microstrip dipole of pentagonal shape

The previous research [3-8] showed all advantages of both symmetrical pentagonal dipole (Figure 2) and its arrays. The single pentagonal dipole with different 3D reflector plates has satisfactory large bandwidth [8]. However, its gain and sidelobe suppression are usually with unappropriated values for modern communication systems. Therefore, symmetrical pentagonal dipoles are organized in arrays that can have sufficient many antenna parameters (bandwidth, gain, sidelobe, etc.) [3-7].

In order to improve bandwidth of symmetrical microstrip antenna, whatever single dipole or its arrays, the different shapes of dipole are investigated. Half-dozen different shaped symmetrical microstrip dipoles have been modelled and simulated using WIPL-D software [9]. Also, different reflector plates have been used: plane, parallel or normal to dipole, and corner with 90° and 60° angle. All considered dipoles are printed on the dielectric substrate of 0.508 mm thickness end dielectric constant ε_r=2.17. The central frequency of all examined symmetrical dipoles is f_c = 30 GHz. The dimensions of all considered shaped dipoles are optimized to achieve dipole's impedance Z_d = 100Ω at the centre frequency f_c. Three shapes of symmetrical microstrip dipole, that have bandwidth noticeably better then classic pentagonal dipole, are shown in Figure 3. Their simulated bandwidth results [9] are presented in Figures 4-7 and Table 1-4 for parallel reflector, perpendicular reflector, 90° corner reflector and 60° corner reflector, respectively.



(a) (b) (c)

Figure 3. The symmetrical microstrip dipole of (a) Shape 1, (b) Shape 2, and (c) Shape 3

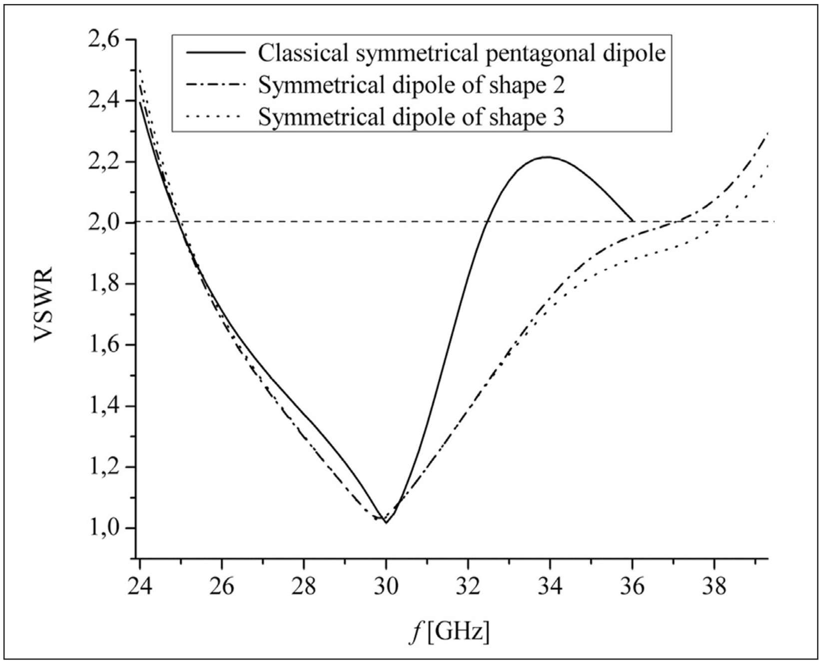


Figure 4. VSWR parameter of symmetrical dipoles with parallel reflector

Shape	***f*[GHz]**	***f* [%]**
Classical pentagonal	25-32.4	24.6
Shape 2	25-36.9	39.66
Shape 3	25.1-38.1	43.33

Table 1. Frequency range of symmetrical dipoles with parallel reflector where VSWR < 2

For every considered reflector only three best simulation results are presented. Firstly, VSWR parameters of symmetrical dipoles with parallel reflector at distance $\lambda_0/4 = 2.5$ mm (λ_0 is wavelength in vacuum at $f_c = 30$ GHz) are presented in Figure 4 and in Table 1. It can be noticed that symmetrical microstrip dipoles of shape 2 and shape 3 have significantly greater bandwidth where their VSWR<2 then classical symmetrical pentagonal dipole. Furthermore, Figure 5 and Table 2 show the simulation results of symmetrical dipoles with perpendicular reflector at distance $\lambda_0 = 2.5$ mm from dipole. There are only simulation results for bandwidth of symmetrical dipoles of shape 1-3 that are all better than simulation results for bandwidth of symmetrical pentagonal dipole (27.33 % of central frequency).

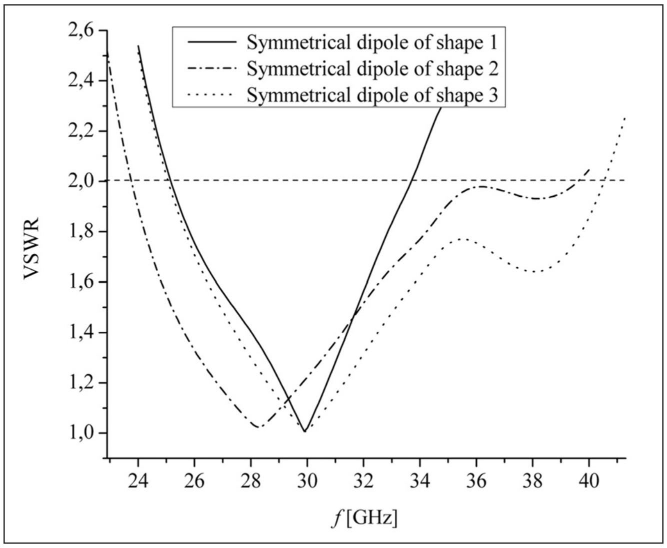


Figure 5. VSWR parameter of symmetrical dipoles with perpendicular reflector

Shape	***f*[GHz]**	***f* [%]**
Shape 1	25.2 - 33.6	28
Shape 2	23.8 - 39.6	52.67
Shape 3	25.1 - 40.5	51.33

Table 2. Frequency range of symmetrical dipoles with perpendicular reflector where VSWR < 2

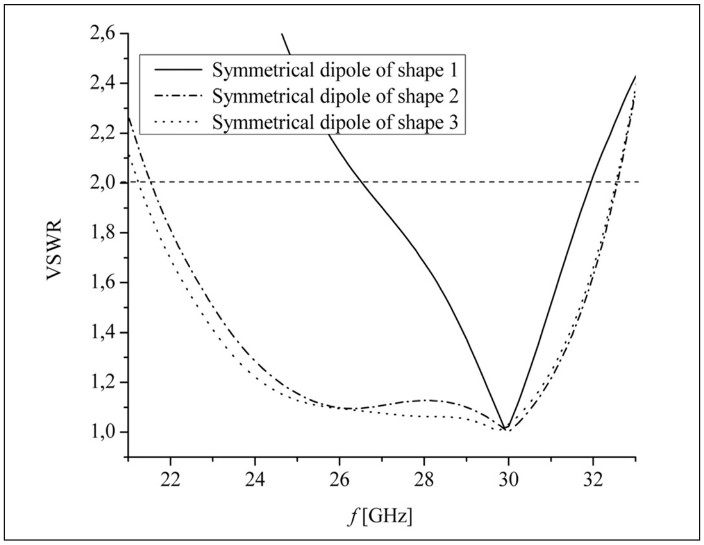


Figure 6. VSWR parameter of symmetrical dipoles in corner reflector with 90° angle

Moreover, Figure 6-7 and Table 3-4 present the simulated VSWR parameters of symmetrical dipoles in corner reflectors whose apex is at distance $\lambda_0/2 = 5$ mm from dipole. Feeding lines for dipoles penetrate the junction of two reflector plates through holes with diameter of 2.3 mm so the influence of the metallic plates on the microstrip lines is minimized. Obviously, the dipoles in corner reflectors have smaller frequency range where their VSWR<2 then dipoles with plane reflector plate (parallel or normal to dipole). Although, the symmetrical dipoles of shape 1-3 have better wideband characteristics then symmetrical pentagonal dipole in case of reflector with 90° angle. Symmetrical pentagonal dipole's bandwidth is 13% of central frequency. When dipoles are examined in corner reflector with 60° angle, only symmetrical dipoles of shape 2-3 have greater bandwidth then classical symmetrical pentagonal dipole. The gain of all considered dipoles is 6-7 dBi.

Shape	***f*[GHz]**	***f* [%]**
Shape 1	26.6 - 31.9	17.67
Shape 2	21.6 - 32.5	36.33
Shape 3	21.3 - 32.5	37.33

Table 3. frequency range of symmetrical dipoles in corner reflector with 90° angle where VSWR < 2

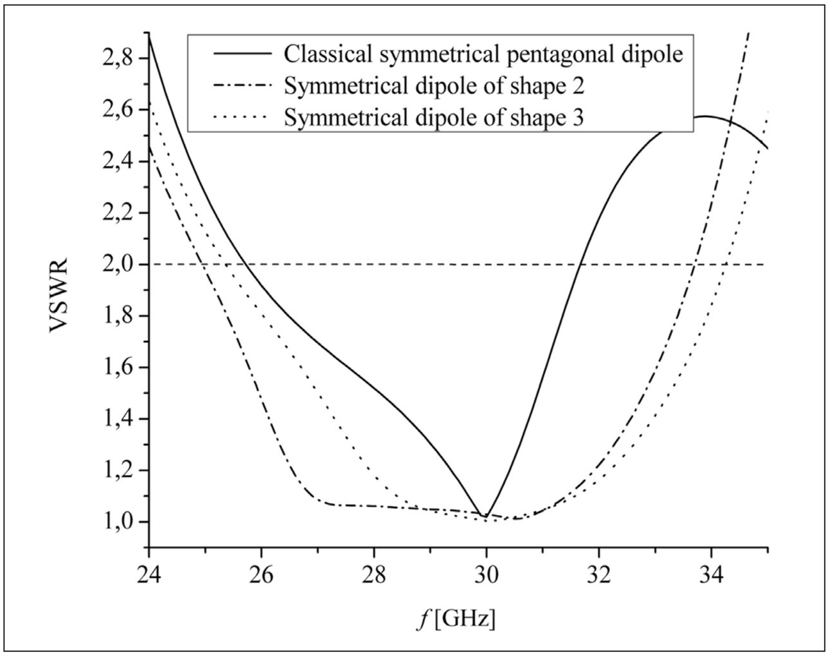


Figure 7. VSWR parameter of symmetrical dipoles in corner reflector with 60° angle

Shape	***f*[GHz]**	***f* [%]**
Classical pentagonal	25.8 - 31.6	19.33
Shape 2	25 - 33.7	29
Shape 3	25.4 - 34.2	29.33

Table 4. Frequency range of symmetrical dipoles in corner reflector with 60° angle where VSWR < 2

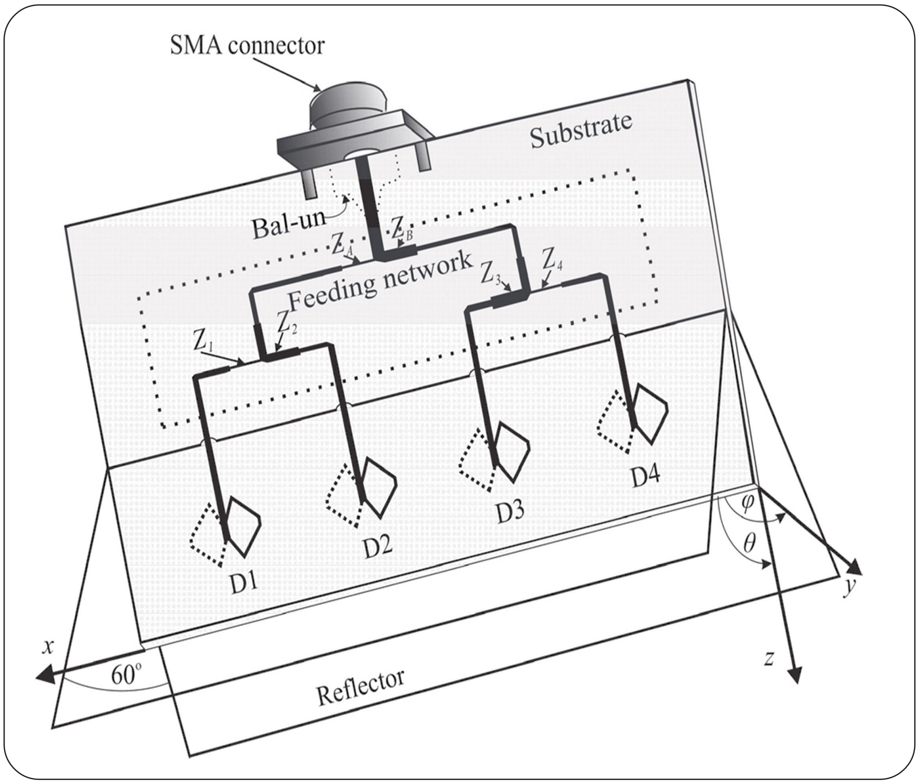


Figure 8. Antenna array with cosecant squared-shaped radiation pattern

3. Antenna Array with Cosecant Square Shaped Radiation Beam

The antenna array of four radiating elements, feeding network and bal-un are printed on the same dielectric substrate with dielectric constant $\varepsilon_r = 2.17$ and thickness of 0.508 mm. The array is positioned in corner reflector with angle of 60° and with apex at distance $\lambda_0 / 2$ (at the centre frequency $f_c = 30$ GHz) from centres of radiating elements (Figure 8). Three antenna arrays have been modelled whose radiating elements are symmetrical printed dipoles of pentagonal shape, shape 2 and shape 3 (Figure 2 and Figure 3). The dipoles are axially placed, decreasing their mutual impedance, at the distance $d = 0.8\ \lambda_0 = 8$ mm (at $f_c = 30$ GHz). Orchard Elliot's and genetic algorithm methods have been applied for synthesizing the antenna array. The normalized amplitude for dipoles $i = 1, 4$ are $u_1 = 0.4038$, $u_2 = 0.567$, $u_3 = 1$ and $u_4 = 0.725$ while phase shifts are $\varphi_1 = 0°$, $\varphi_2 = 14°$, $\varphi_3 = 0°$ and $\varphi_4 = -36°$ [10].

The feeding network is also the symmetrical microstrip structure (Figure 8). After the coaxial connector there is a beginning part of feeding network BAL-UN for transition from conventional microstrip to symmetrical microstrip structure (Figure 8). Characteristics and dimensions of the $\lambda/4$ transformers in symmetrical microstrip technique have been calculated using TEM analysis. Using values u_1, u_2, u_3 and u_4 for dielectric substrate of 0.508 mm thickness, 2.17 relative dielectric permittivity, 41 MS/m conductivity of metal, insignificantly small values of loss tangent and conductor thickness, the width W_k, $k = 1, 2, 3, 4$, A, B (Figure 8) of $\lambda / 4$ impedance transformers have been obtained ($W_1 = 0.49$ mm, $W_2 = 1$ mm, $W_3 = 1.02$ mm, $W_4 = 0.53$ mm, $W_A = 1.29$ mm, $W_B = 1.89$ mm). The phase shifts are adjusted by setting the lengths of dipoles' feeding microstrip lines of 100&!. The feeding line for the second dipole, whose phase shift is 14°, is 0.4 mm shorter than feeding line for the first dipole with phase shift of 0°. Similarly, the feeding line associated with the fourth dipole with phase shift of -36° is 1.04 mm longer than feeding line of the third dipole with phase shift of 0°. Lastly, the feeding network was developed and verified using WIPL-D Microwave Pro software [9].

The Figure 9 shows the simulated radiation pattern of antenna arrays with symmetrical microstrip dipoles of classic pentagonal shape, shape 2 and shape 3. Antenna gain is about 15 dBi and side lobe suppression (SLS) is higher than 15 dB at the centre frequency $f_c = 30$ GHz. In can be noticed that the simulated cosecant squared shaped beam in the elevation plane has coverage beyond 15°. Further, the Figure 10 shows simulated VSWR parameter of three proposed antenna arrays for frequency from 22

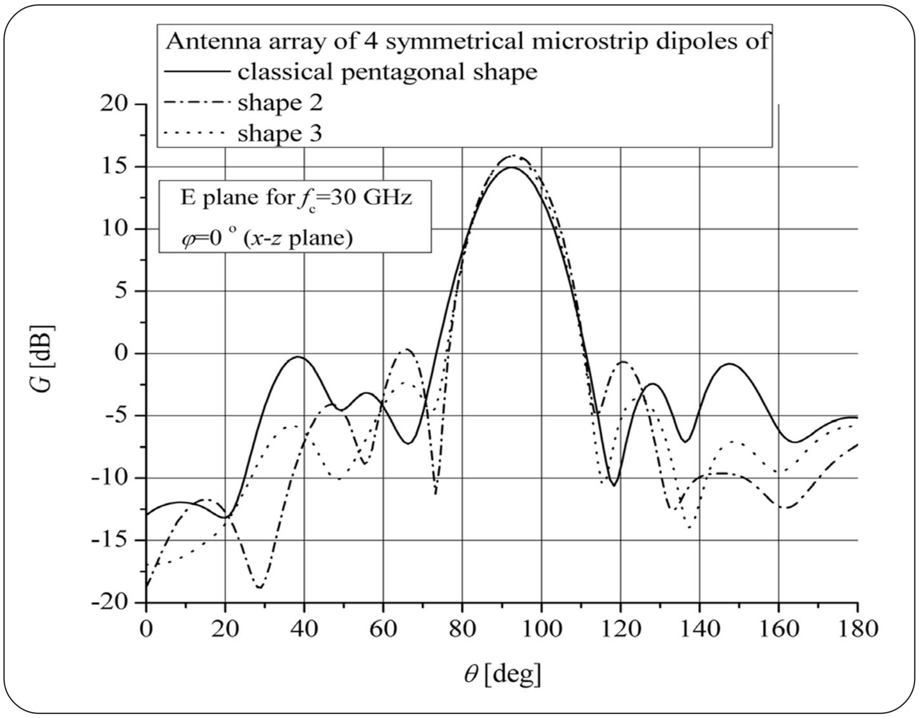


Figure 9. The simulated radiation pattern of antenna array of 4 symmetrical microstrip dipoles in corner reflector with 60° angle

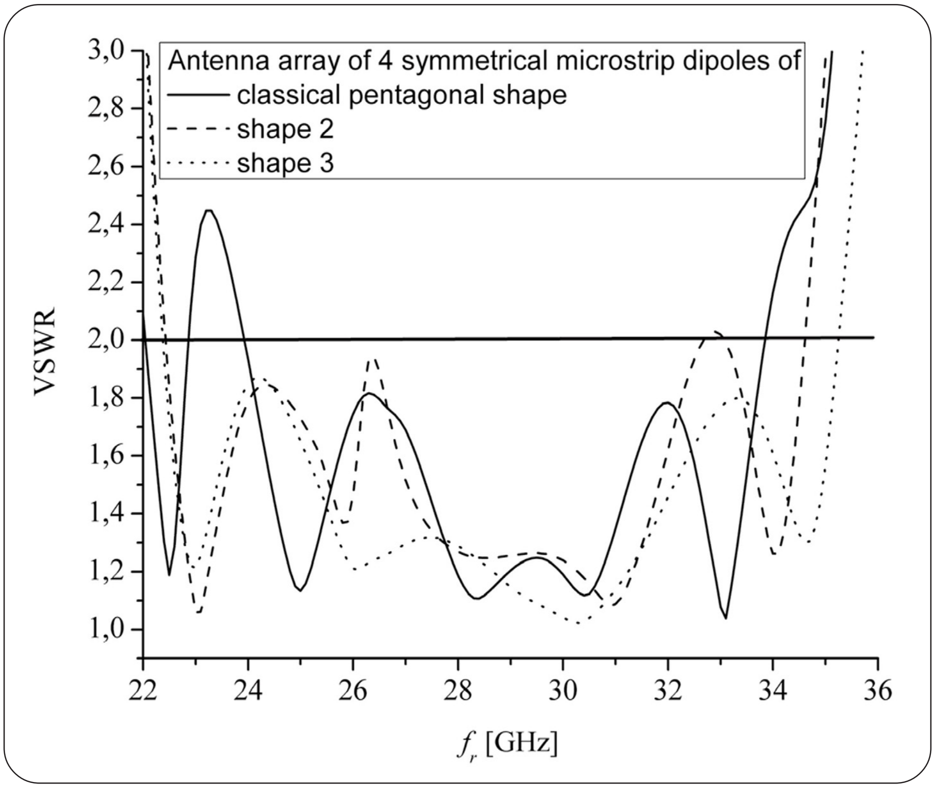


Figure 10. The simulated VSWR parameter of antenna array of 4 symmetrical microstrip dipoles in corner reflector with 60° angle

GHz to 36 GHz. It can be seen that antenna array of symmetrical dipoles of shape 3 has the widest bandwidth where VSWR < 2 (22.4-35.2 GHz – 42.67% of f_c). It is better than bandwidth of antenna array of symmetrical dipoles of shape 2 (22.5-32.6 GHz – 33.67% of f_c) and bandwidth of antenna array of symmetrical pentagonal dipoles (24-33.8 GHz – 32.67% of f_c).

4. Conclusion

Symmetrical printed antennas have a few advantages over standard printed antenna. They have wide bandwidth that can be useful for their usage in many modern wireless services. Therefore, symmetrical printed antennas have less sensibility to fabrication tolerances and they can be produced using cheap photolithographic process not demanding expensive equipment and reducing their manufacturing price.

This paper presents symmetrical printed antennas that have different shapes of classical symmetrical pentagonal dipole. Considering their VSWR parameter, it can be concluded that proposed symmetrical dipoles have bandwidth in range or better than bandwidth of symmetrical pentagonal dipole, especially when they are place in corner reflector with 180° and 90° angle. Similarly, their arrays with cosecant square shaped radiation pattern placed in corner reflector of 60° angle have VSWR parameter greater than 2 in wider frequency range then antenna array of symmetrical pentagonal dipoles fed by the same network of impedance transformers and with corner reflector of 60° angle.

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