Printed Antenna Structures with Circular Polarisation

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Abstract

An overview of printed antennas with circular polarisation is given in the paper. Several realisations of patch antennas with circukar polarisation and feeding through phase shifters, as well as with single feed point are presented. Feed point on the diagonal of the rectangle patch with circular polarisation is optimised in order to obtain an impedance of (50+j0)Ω. A new concept and design method of printed antenna with circular polarisation consisting of a pair of orthogonal dipoles is also presented. This new antenna has an axial ratio AR less than 3 dB and VSWR less than 1.3 in the frequency range of about 10% (which is 10 times wider than with conventional circularly polarised patch antennas).

Introduction

For more than twenty years there have been intensive activities on research and development of printed antenna structures which are widely applied in radiocommunication, radar, telemetry, navigation and other, especially microwave systems. The main reason for printed antenna structures application is theirhigh reproducibility, as the manufacturing is reduced to a photolitographic process (instead of a complex mechanical treatment), small depth, i.e. the planar structure, low weight and great possibility of integration with other passive and active circuits.

A special class of printed antennas inçludes antennas with circular polarisation which are very often used for the following reasons:

1. Circularly polarised wave, being reflected from surrounding objects changes the direction of polarisation. In this way, receiving of reflected wave is discriminated and receiving of direct wave is favourized.

2. By applying the circular polarisation, rotation symmetry between transmitter and receiver antenna can be arbitrarily changed, while by using linearly polarised antennas the orientations of transmitter and receiver being approximately orthogonal, attenuation is rather high.

Owing to these characteristics, application of circular polarisation in numerous satellite radio systems is practically indispensable.

In this paper, we will present a number of printed antenna structures with circular polarisation, putting a special emphasis on a new type of circularly polarised printed antenna, which has a remarkably wider bandwidth than structures known so far. Investigation of this antenna is still in progress. Methods that can be used in analysis of mentioned antenna structures will also be presented.

Patch antennas with circular polarisation

One of the ways to obtain a microstrip, i.e. patch antenna with circular polarisation is to excite orthogonal modes in a squared patch by feeding adjacent sides of the squared patch with signals in quadrature.

The most simple option of this method is shown in Fig. 1. In this case, the phase shift is accomplished via microstrip line extended for λ/4. Disadvantage of this option, beside relatively high impedance at the feed point, is a phase error even with a small deviation from the central frequency.

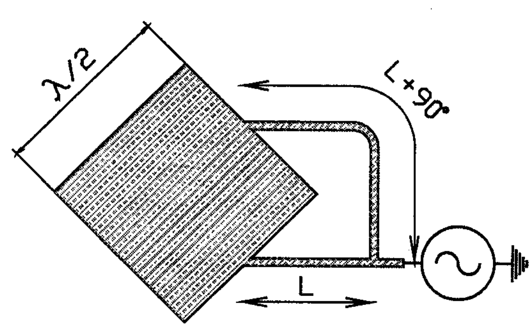


Fig. 1.

Figure 2. shows another option. In this case, adjacent sides of the patch are fed through 90° hybrid coupler. At the ports (3) and (4), there are voltages of the same amplitude and with phase difference of

$\pi/2$. Disadvantage of this option is relatively high impedance at the feed points of squared patch, so that the problem of matching the hybrid coupler (realized in microstrip technology) to the input impedance of the patch occures.

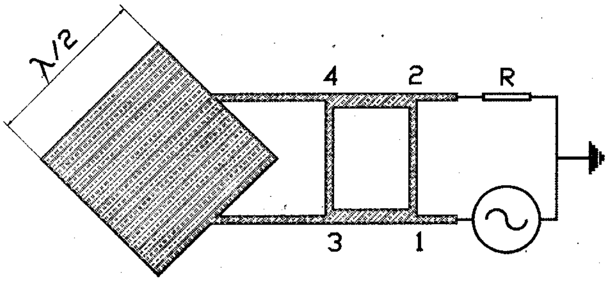


Fig. 2.

Moreover, there are methods for obtaining the circular polarisation in patch antennas fed at single point. The key to obtaining circular polarisation with a single feed point lies in detuning of the two modes by slightly changing the shape of the patch.

There are several types of patches with circular polarisation obtained in this manner. Some of them are presented in figures 3a and 3b. It is also shown that it is possible to accomplish single feed point circular polarisation with a pentagonal patch with suitably chosen sides' lengths and feed point, Fig. 4.

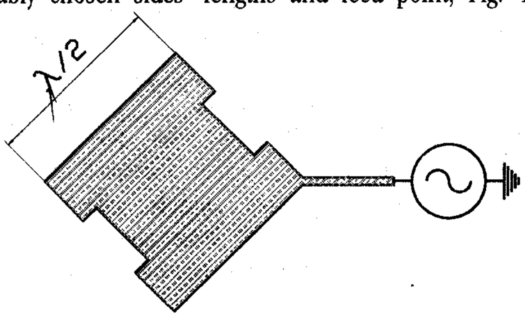


Fig. 3a.

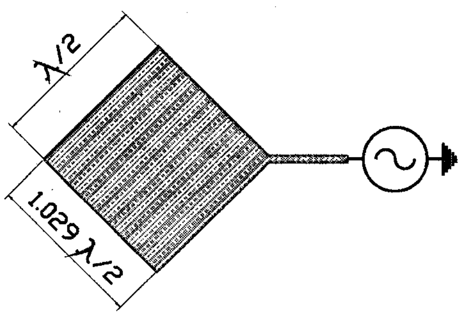


Fig. 3b.

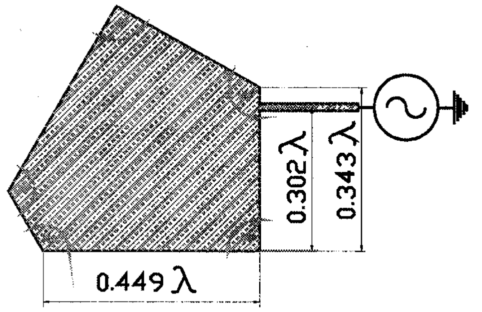


Fig. 4.

However, the essential disadvantage of all presented options is relatively high impedance in the feed point and very narrow bandwidth (about 1%).

Rectangular patch fed at the diagonal point of the rectangle

It can be shown [1] that patch with sides length ratio of about 1.03 (Fig. 3d), fed at the corner of the rectangle, has a circular polarisation. In this case, impedance at the feed point is between 150Ω and 200Ω. We will show that it is possible to change the impedance at the feed point by moving it along the diagonal of the rectangle, still obtaining a circular polarisation. Rectangular patch with feed point on its diagonal is presented in Fig. 5. [2]

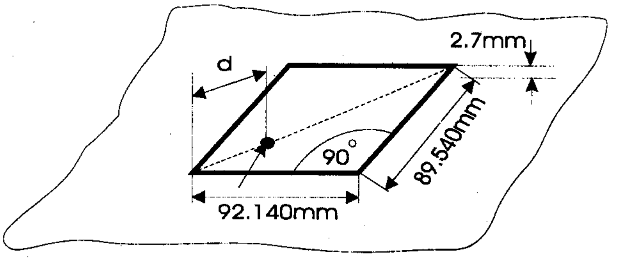


Fig. 5.

Using WIPL software package [3] for electromagnetic analysis of metal and wire structures, rectangular patch with sides ratio 1.029 and fed at several points along the diagonal is analyzed. Impedance, polarisation, i.e. axial ratio in the range around central frequency, for different feed points along its diagonal have been analyzed.

In Table 1, real and imaginary parts of the patch impedance Z for different distances d of the feed point from the rectangle corner, at frequencies where axial ratio is the lowest, are given. If the distance from the rectangle corner is 24.13% of the diagonale length, the impedance of $(51.2+j8.1)\Omega$ is obtained, i.e. VSWR is 1.17.

Table 1.

d [mm]	R	X	f [MHz]
0	162.6	-91.9	1570
20	128.0	-17.5	1571
31	51.2	8.1	1575
35	29.4	10.9	1578

New printed antenna with circular polarisation

Investigations of the new printed antenna structure with circular polarisation are in progress [4]. The basic advantage of this structure over structures used so far, is more than 10 times wider bandwidth and VSWR less than 1.3.

Concept

As it is known, circular polarisation can be achieved if two orthogonal dipoles are fed with currents of the same intensity and in phase in quadrature. Phase difference of $\pi/2$ is conventionally obtained by feeding the dipoles through lines of electrical lengths differing for $\lambda/4$ or by feeding network with reactive elements, providing phase difference of $\pi/2$. However, it can be shown that required phase difference and currents of the same intensity for dipoles feeding can be achieved by parallel feeding, on condition that dipoles' impedances are conjugated, and if real and imaginary parts of them are equal, i.e. $Z_1=R-jX$, $Z_2=R+jX$, $R=X$. In this case, length and width of the first strip dipole are optimised to provide the impedance $Z_1=(50-j50)\Omega$. Of course, the dipole is much shorter than $\lambda/2$. The second strip dipole has the same length and width as the first one, but the feed line enters between two slots along the strip, as is shown in Fig. 6. The length of its entrance between the slots into the strip is optimised so that the dipole's impedance is $Z_2=(50+j50)\Omega$ [4]. In such a manner, when the dipoles are fed in parallel, their currents will be in phase quadrature and total impedance becomes $Z=(50+j0)\Omega$. Dipoles are designed assuming a perfectly conducting reflector plate at a distance $\lambda_0/4$. The analysis and optimisation are realised using the WIPL software package [3].

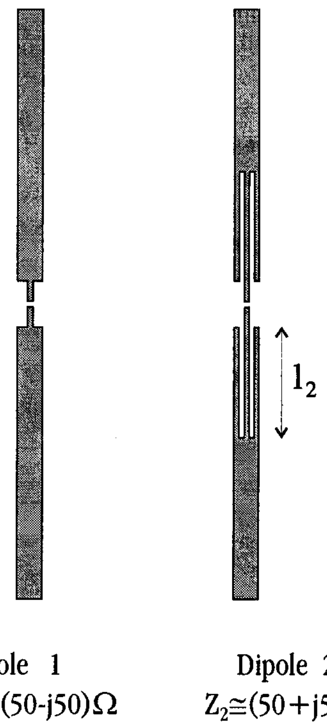


Fig. 6. Pair of dipoles with conjugated impedances

Feeding network

We will present three different methods of parallel feeding of orthogonal printed dipoles with impedances fulfilling the above mentioned conditions.

(1) Half of the first and half of the second dipole are printed on each side of the dielectric substrate and fed by a symmetric (balanced) microstrip. The balanced microstrip is then transformed into a nonsymmetrical, conventional microstrip line, Fig. 7.

(2) Both orthogonal dipoles are printed on the same side of the dielectric substrate. Half of the first and half of the second dipole are connected with one strip of the coplanar strips (CPS), and another halves of the dipoles are connected with another strip of the CPS, Fig. 8. In this case, feeding is performed either through the CPS–rectangular waveguide transition, or through CPS–CPW (coplanar waveguide) transition.

(3) Both orthogonal dipoles are printed on the same side of the dielectric substrate and feeding is performed through the symmetrical (balanced) microstrip line which is placed perpendicularly to the dielectric substrate. Fig. 9. Balanced microstrip line goes through a slit in the reflector plate behind which is a BAL-UN, i.e. transition to a nonsymmetrical microstrip.

Feeding methods (1) and (2) are very suitable for realisation because both the radiating elements and the feeding network are placed in the same plane, so the realisation is reduced to a simple photolithographic process. However, the basic disadvantage of this method is the parasitic coupling between the orthogonal dipoles and the feeding line. As a consequence, a discrepancy from the circular polarisation (higher AR) and change of the impedance

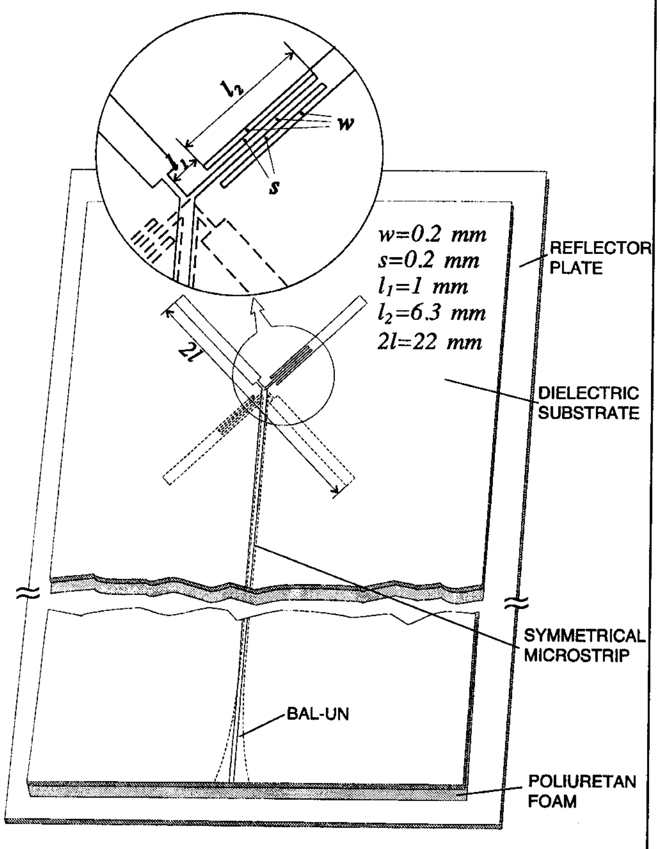


Fig. 7. Two orthogonal dipoles fed by symmetrical microstrip in the plane of dipoles
(1)

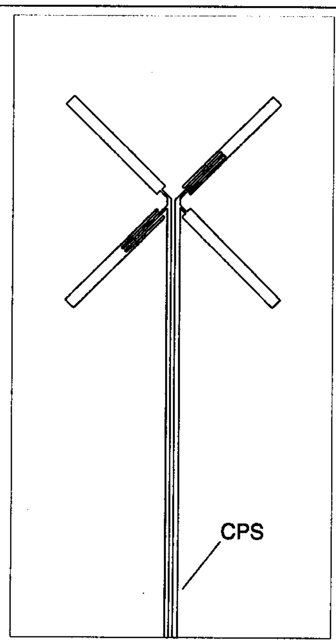


Fig. 8. Two orthogonal dipoles fed by coplanar strips (CPS)
(2)

at the feed point, i.e. increasing of the VSWR occur. These effects are also noticeable on the simulating model. Method (3) requires the connection between the radiating structure with the feeding line realised by bonding or soldering. Still, the parasitic coupling between them practically does not exist, because the feeding line is perpendicular to the radiating structure.

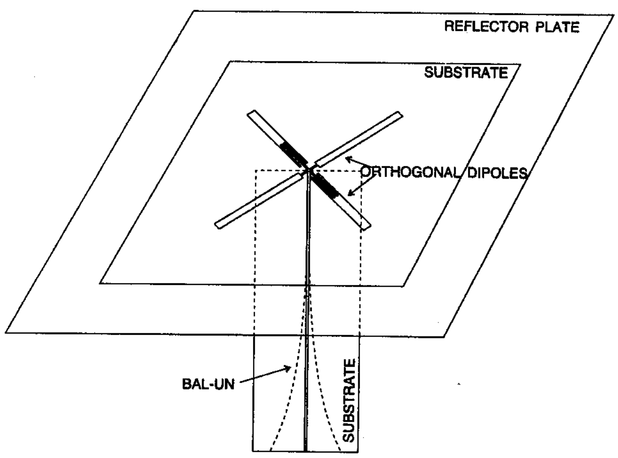


Fig. 9. Two orthogonal dipoles fed by symmetrical microstrip in the plane perpendicular to the plane of dipoles
(3)

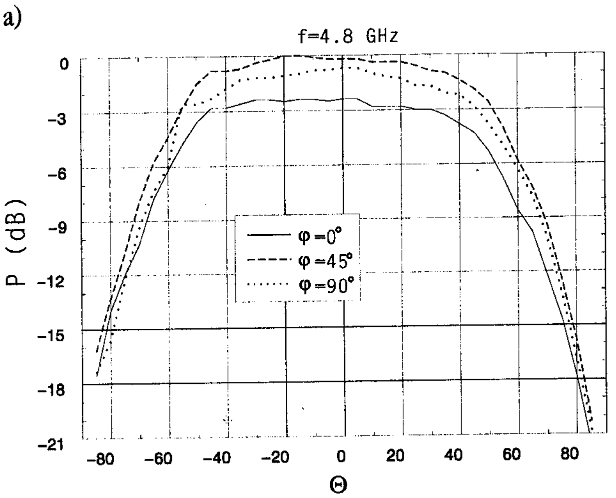
Realisation and obtained results

Two exprimental models of printed orthogonal dipoles with circular polarisation have been realised. The first one is presented in Fig. 7 (feeding method 1), and the other one in Fig. 9 (feeding method 3). In both cases, both the antennas and feeding lines are realised on extremely thin dielectric substrates (h=0.127mm, ε_r=2.17). Dimensions of the orthogonal dipoles are optimised at central frequency f=5.1 GHz while neglecting the influence of the dielectric substrate. Radiation patterns are measured using a linearly polarised standard gain horn (Scientific Atlanta) as a reference antenna. E_θ and E_φ radiation patterns for $-90° \le \theta \le 90°$, as well as VSWR for both models are measured in the frequency range from 4.5GHz to 5.5GHz (20% of the bandwidth).

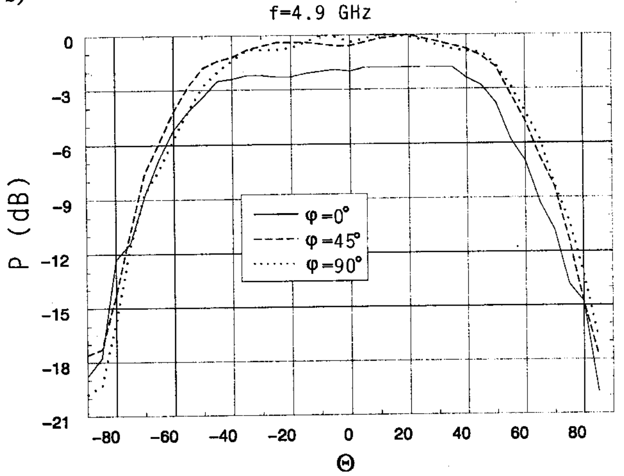
On model (1), an AR<3dB and VSWR<1.6 in the frequency range from 4.7GHz to 5.0GHz have been obtained. On model (3), we have obtained an AR<3dB in 7% of the bandwidth and AR<6dB in 20% of the bandwidth. VSWR (Fig. 11) is less than 1.5 in the whole frequency range (4.5–5.5) GHz.

E_θ and E_φ versus θ, relating to model (3) for frequencies 4.8GHz, 4.9GHz and 5.0GHz, are shown in Fig. 10a, 10b and 10c.

a)



b)



c)

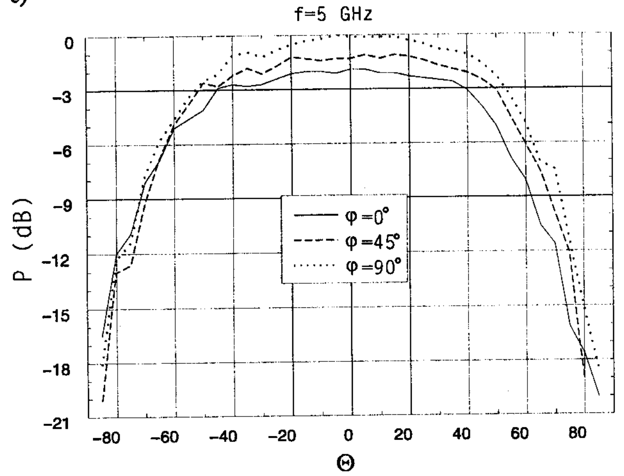


Fig. 10. a), b), c) E_θ and E_φ measured for $-90° \le \theta \le 90°$ (model 3)

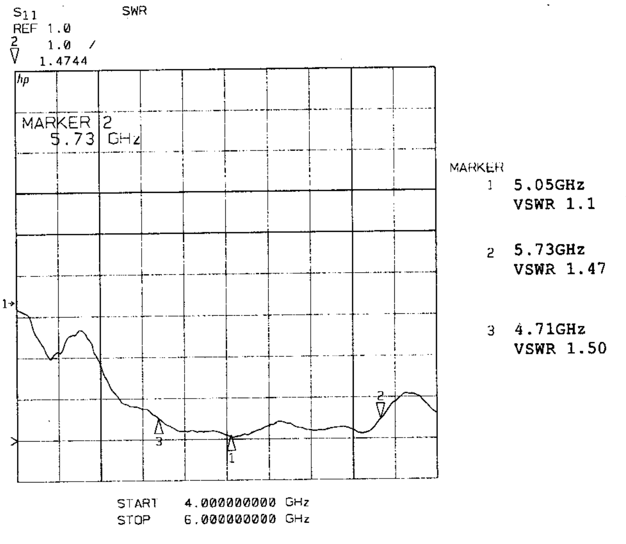


Fig. 11. Measured VSWR for model (3)

Conclusion

An overview of printed antennas with circular polarisation is given. In the first part of the paper, microstrip, i.e. patch antennas with circular polarisation, fed at two points through networks that provide phase shift are presented. Also, we have shown some of the types of patch antennas with single feed point in which orthogonal modes in quadrature can be excited by slightly changing the shape of the patch. The change of the impedance of the circularly polarised rectangular patch versus change of the feed point position along the patch diagonale is presented.

Concept, methods of analysis, realisation and experimental results of printed antennas with circular polarisation consisting of two orthogonal dipoles with conjugated impedances of equal real and imaginary parts are presented in the second part of the paper. Three ways of feeding of these antennas are given. Bandwidths for axial ratio AR<3 dB and AR<6 dB and VSWR<1.3 are about 10 times wider than those of known circularly polarised antennas.

References

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