Variations of the Axial Ratio of Microstrip Antenna for Circular Polarization with the Electrical Parameters of the Substrate

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Abstract – **Microstrip patch antenna with truncated corners is described. It is designed for 2GHz central frequency with different electrical substrate parameters – thickness and relative dielectric permittivity. It is shown that the Axial Ratio and the bandwidth are strongly dependent on the substrate parameters. The most proper combination between the parameters to achieve the best performance of the antenna is also discussed**

Keywords – **microstrip patch antenna, truncated corners, axial ratio, bandwidth.**

I. Introduction

Microstrip patch antennas are increasing in popularity for use in wireless applications due to their low-profile structure. Therefore they are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers, GPS receivers etc. Some of their principal advantages are: light weight and low volume, low profile planar configuration, low fabrication cost, hence can be manufactured in large quantities, supports both, linear as well as circular polarization, can be easily integrated with microwave integrated circuits, capable of dual and triple frequency operations, mechanically robust when mounted on rigid surfaces. Microstrip patch antennas suffer from a number of disadvantages as compared to conventional antennas: narrow bandwidth, low efficiency, low Gain, extraneous radiation from feeds and junctions, low power handling capacity, surface wave excitation [1].

In many cases a circularly polarized antenna is desirable. For example, it may be difficult to know beforehand the required orientation of the antenna when linear polarization is used. Satellite-to-mobile ground-based or airborne links are a good example of this problem. In other situations, a circularly polarized antenna may make a system more user-friendly by avoiding the need lo line-up the antenna with the signal polarization. Right- and left-hand circular polarizations are orthogonal to each other. This can he employed to double the channel capacity on a link by having one signal use right-hand and the other left circular polarization [2].

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For example the GPS antenna in actuality needs to be a circularly polarized antenna. This not only eliminates the need to orient the antenna but also maximizes the received signal and can reduce the effects of multipath.

A circularly polarized wave has two orthogonal field components that are in phase quadrature. Microstrip antennas can be designed to radiate circular polarization with one feed. It is possible to excite the two modes with one feed by introducing a small perturbation in the patch shape [3]. Many types of perturbations are used. One of the most common used is a squire patch with two diagonally opposite truncated corners. The patch is fed at the center of one of its sides. The antenna is fed along a center line as with a linearly polarized patch.

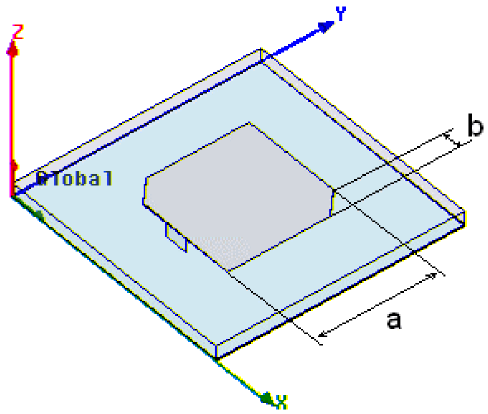

Fig.1. Circularly polarized microstrip antenna with truncated corners

The feed excites fields under the patch just as with a linearly polarized antenna. The signal injected by the feed tends to propagate in one direction, guided by the transmission line formed by the patch. In very approximate terms, the perturbation segment "scatters" [3] the feed fields into a mode that is spatially orthogonal. Because of the different patch geometry this scattered mode has a resonant frequency shifted slightly from that of the squire patch. To achieve circular polarization, these two modes must be made equal in amplitude and must differ in phase by 90 degrees. The equal amplitude is obtained by proper positioning of the feed. The creation of a 90-degree phase shift is due to two factors. One is again the feed position, but this time it involves the orientation of the feed with respect to the perturbation. Shifting from one side to the adjacent side changes the sense of the polarization for the truncated patch. The other factor is the size of the perturbation. For the singly-fed patch, only one mode is excited by the feed. The perturbation scatters some of this into a mode similar to the first one. In actuality, the perturbation also modifies the original mode, creating two new modes [4].

In the field of the circular polarized microstrip antennas two bandwidths are defined [5]: impedance bandwidth and axial ratio bandwidth. These two bandwidths are connected but corners-truncated patch antennas are very narrowband. In the most cases the impedance bandwidth is wider then the axial ratio bandwidth when the impedance matching between the antenna and the feed line is performed.

II. Corners-truncated patch design

Dimensions design of a corners-truncated patch antenna includes calculation of the resonant length, input resistance at resonance, radiation efficiency, overall efficiency, and bandwidth for a rectangular patch. The basis for the calculations is a series of closed form expressions which were generated by curve fitting to full wave solutions. The closed form expressions calculate the patch resonant dimension and quality factor (Q). Formulas derived from patch cavity models determine Q's for conductor and dielectric losses. From all the Q values, the overall efficiency can be found. The overall Q also determines the bandwidth. The input resistance at resonance also follows from results derived from cavity models. Even though the solution is based upon full wave results, there are some limitations on certain parameters. The relative dielectric constant should be between 1 and 10. It is used a simulation software that iterates the element dimension until the correct resonant frequency is found. It stops iterating when the resonant frequency is within 0.001 GHz of the input value. The accuracy of the results is a few percent (2% to 3%). Unfortunately the bandwidth for good circular polarization may be 1% or less [4]. It may be necessary to use the model to establish initial dimensions. A combination of more model runs and some experiment may be needed to reach a final design.

As it was mentioned above there are not simple analytical expressions for synthesis and analysis of the corners-truncated microstrip antenna because of the complex character of the field in the antenna. That's why numerical methods for analysis as Moments Method, Finite Difference Method etc. have to be used. In the current analysis a model of a microstrip antenna with truncated corners by the medium of a software package, working with Finite Elements Method has been designed.

The feeding of the corners-truncated patch antenna can be realized by several methods: by microstrip line, by coaxial probe, by proximity coupling etc. In this analysis the antenna is fed by a microstrip line but similar results can be achieved with using of a coaxial probe.

III. Results from the analysis

On the basis of models of corners-truncated microstrip antennas designed for operation at central frequency of 2 GHz are obtained the variations of the axial ratio with the parameters of the substrate.

Fig. 2, 3 and 4 show the variations of the axial ratio with the frequency for different values of the substrate thickness h. On these plots the axial ratio bandwidth can be determined as the difference between the frequencies for which the axial ratio has value of 3dB. With the increasing of the thickness the bandwidth becomes wider. That is due to the variations of the geometrical dimensions of the patch. As it can be seen from Table I the nominal patch size (a) decreases but the size of perturbation (b) increases.

The curve of the axial ratio on the plots has two minimums, which improve approximately 0dB but there is a maximum between the minimums. This maximum shows that at the central frequency the axial ratio has a value grater than 0dB. The two minimums are obtained for the resonance frequencies of the modes. For these frequencies the polarization is almost circular. The effects of increasing the axial ratio due to the resonance character of the field from the two excited modes and to the feeding of the antenna. As it was mentioned above one of the requirements to achieve circular polarization is the two excited modes to be equal in amplitude. This is difficult to realize and as a result of the difference in the amplitudes the axial ratio increases at the central frequency. This disadvantage can be avoided by some changes of the dimensions of the patch but that leads to reduction of the bandwidth. To operate the antenna with wider bandwidth the increasing of the axial ratio can be neglected but only when the maximal value is less than 3dB.

TABLE I
Numerical results

h, mm	ε_r	a, mm	b, mm	BW, MHz
1.1	2.2	49.450	4.057	37
1.5	2.2	49.120	4.577	43
2	2.2	48.782	5.178	65
1.4	2.2	49.245	4.453	41
1.4	5	32.813	2.344	31
1.4	7.5	26.838	1.779	26

The impedance bandwidth of a microstrip antenna increases with larger substrate thickness. That is attended by some disadvantages – presence of higher level surface waves that degrade the radiation pattern, polarization characteristics and leads to poor radiation efficiency; higher antenna profile and higher level of the maximum in the axial ratio within the operating bandwidth.

Fig. 5, 6 and 7 illustrate the variations of the axial ratio with the frequency for different values of the relative permittivity of the substrate. It can be seen that the bandwidth decreases for higher ε_r but the patch dimensions are reduced. The maximum level of the axial ratio also decreases. The impedance bandwidth decreases because more energy is stored within the dielectrics with high ε_r. The energy of the surface waves is also increased. As a result the radiation losses are reduced and radiation quality factor increases. On the other hand when ε_r increases, the patch dimensions decreases (see Table I). That is an advantage because microstrip antennas are commonly used in antenna arrays and rarely as single radiators. Then the patch size is important.

Microstrip antennas are printed antennas. When they are fed by a microstrip line the dielectric of the antenna and transmission line is common. Microstrip line must guide the energy and it should not radiate but this can be achieved with higher values of ε_r. In the same time the antenna must radiate and wide bandwidth is the most important purpose. Therefore the optimal value of ε_r, which partially satisfies all requirements, should be accepted.

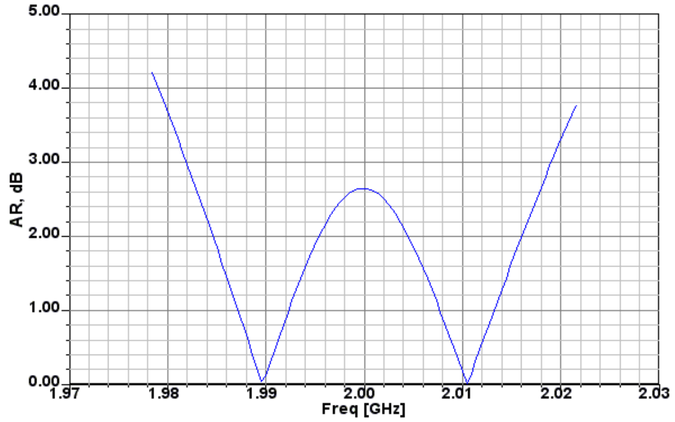

Fig.2. Axial Ratio versus frequency, ε_r =2.2, h=1.1 mm

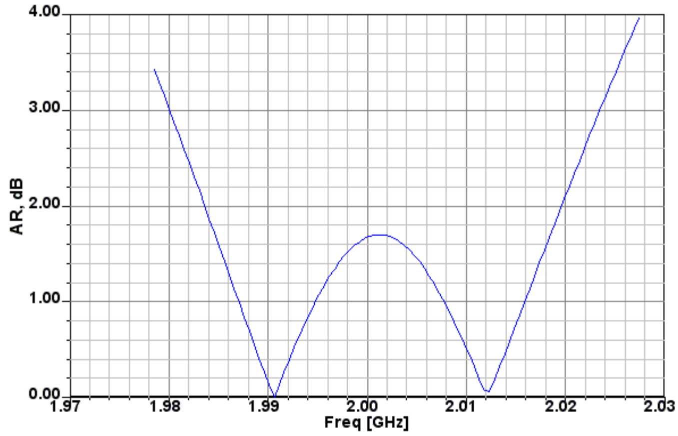

Fig.3. Axial Ratio versus frequency, ε_r =2.2, h=1.5 mm

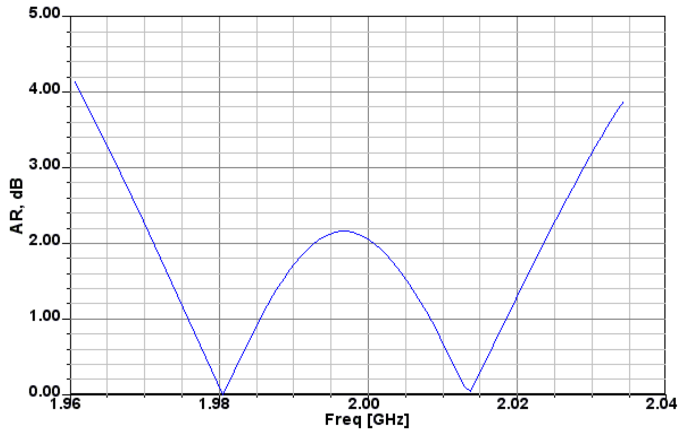

Fig.4. Axial Ratio versus frequency, ε_r =2.2, h=2 mm

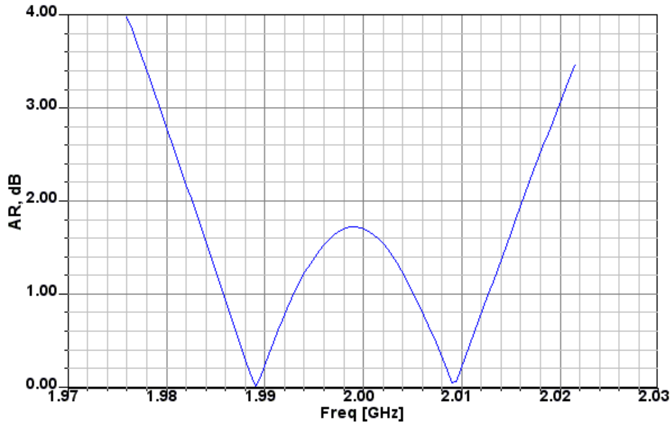

Fig.5. Axial Ratio versus frequency, ε_r =2.2, h=1.4 mm

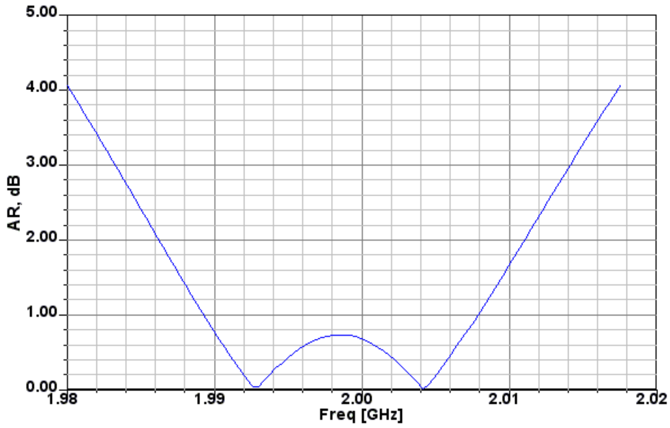

Fig.6. Axial Ratio versus frequency, ε_r =5, h=1.4 mm

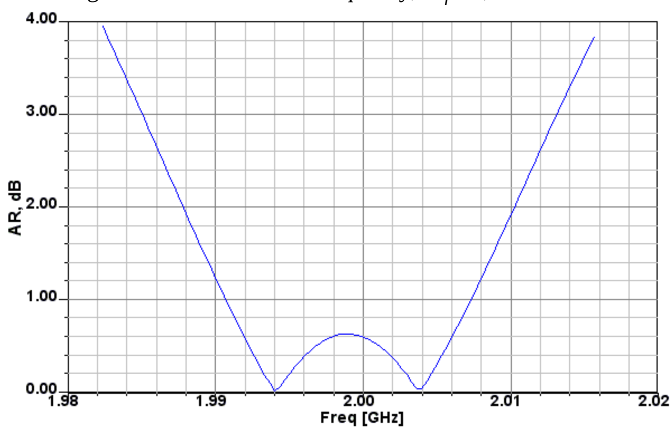

Fig.7. Axial Ratio versus frequency, ε_r =7.5, h=1.4 mm

IV. Conclusion

In this paper a circularly polarized antenna with truncated corners has been analyzed from the view point of the polarization characteristic – Axial Ratio and respectively Axial Ratio Bandwidth. The widest bandwidth is obtained with larger thickness and lower relative permittivity of the substrate.

That is attended by several undesired effects – high level of the axial ratio for the central frequency, transformation of more energy to surface waves, larger antenna dimensions and surface profile. Some of these disadvantages can be reduced by different modifications of the geometry and feeding system.

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