Characteristics of a New Circularly-Polarised Conical-Beam Microstrip Patch Antenna Arrays

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Abstract

This paper demonstrates the characteristics of a new microstrip antenna arrays radiating circularly polarized conical beam. The proposed antenna is realised as an array of a number of stripline fed slot patches whose diagonal corners are cut off and feed lines meet a central feed point. Designs of practical prototypes of such an antenna array with three patches are studied and tested. Both simulated and measured results meet satisfactory agreement for the Wireless Sensor Network (WSN) and Wireless LAN applications.

1. INTRODUCTION AND METHOD

Due to the huge use of wireless LANs, the majority of computer sold to consumers today come pre-equipped with all necessary wireless LAN technology. As a result, the growth of this technology increases the demand of research and development activities. In order to provide better Quality of Service (QoS) to a number of users, the design of the antenna for the wireless access point becomes one of the challenging topics in this research area. However, the natural choice of polarisation WLAN is not obvious, and the IEEE 802.11x standards at present contain no recommendation. It was suggested that horizontal polarisation [1] may reflect more strongly from ceilings, while there is also the possibility of using switched - polarisation diversity to improve reliability. Likewise it may be possible to improve frequency re-use by using orthogonal polarisations to increase isolation or using dual-polarized form of ring array by exciting square patches in two orthogonal modes [2]. This given uncertainties about the propagation conditions, it would be useful to have a free choice of polarisation, and a polarisation diversity scheme might also be considered. An interesting problem for such wireless networks is the use of conical beam radiators that consider the peak radiation could be made to occur at higher values of θ, i.e. lower elevations. This also explains the type of mounting of these antennas on ceilings and ground surface.

A method of realising circularly-polarised conical beam antennas, using an array of patches [2-4], for short-range low power WSN applications, such as Bluetooth, WiFi and ZigBee, are studied and discussed. This work represents an extension of the research work in [2] that used of horizontal or vertical polarised conical beams antenna arrays, however, the operating frequency considered in this work is at ISM 2400 band.

2. THE MULTIPATCH DESIGN CONCEPT AND ANTENNA GEOMETRY

The design of an antenna for broadband performance implies using a moderate substrate thickness with dielectric constant as low as possible [4]. Although the requirements for avoiding feed line radiation contradict these criteria, the section of the feed networks which performs power splitting can have the same symmetry as the group of patches, and its spurious radiation can therefore also approximate to a conical beam. Taking account of the above arguments and practical considerations, all the antennas were fabricated using air filled substrate.

By extending the previous works from [2, 6], a new conical beam circular polarized antenna is proposed. The designed antenna, as shown in Fig. 1, was made by three of 4.5 x 4.6 cm rectangular patch antenna which is 120 degree apart from each other around the circumferential ring. By inserting a square slot of unequal size (1cm x 1.1cm) into the rectangular patch and diagonally truncating two corners of the rectangular patch, these will cause excitement of two orthogonal modes of equal magnitudes and 90 degree out of phase [6], to achieve the required

circular polarisation. In order to prove the required matching of the input impedance at the desired frequency band, a feed network is designed which will permit equal feeding of all the patches from a central point fed by a SMA connector from the rear of the ground plane. It should be noted that the proposed antenna is mounted 1cm above a 30cm x 30 cm ground plane.

However, once the basic patch geometry has been optimized and fixed, to complete a testable design it is only necessary to devise a feed network which will permit equal feeding of all the patches from a central point fed by a pin from the rear of the substrate. This network should if possible also provide the necessary matched input impedance. Design of the feed line networks is an essentially separate issue from the pattern design. The feeds are not expected to affect the pattern very significantly and they can be realised in many different ways. In a narrow band system there is little reason to choose between any two reasonable designs. The condition was imposed, however, that the prototypes would use microstrip line feeds attached at the centre of the radiating edges of the patches. It was expected that this would help to maintain low cross-polarisation, for individual patches.

3. SIMULATION AND RESULTS

The computed and measured return loss of the proposed antenna shown in Figs. 1 and 2, is presented in Fig. 3. The predicted return loss of the proposed antenna is simulated using the commercial software package CST [6], where as the measured return loss was obtained using an HP8510A network analyser. The measured and simulated impedances were referenced to the point where the central feed pin crosses the ground plane.

As can be observed, the proposed antenna operates over the frequency band from 2400 MHz to 2485 MHz at $S_{11} < -10$ dB which is fully covered the ISM2400 band. The best match of the proposed antenna occurs at 2.44 GHz in which the input impedance is $Z_{in} = 44.56 + j\ 12.4\ \Omega$ at the input return loss of 18.3 dB. Both simulated and measured return losses of the proposed antenna are in well agreement.

Measurements of the far field radiation patterns of the prototype, was carried out in a far-field anechoic chamber using an elevation over-azimuth-positioner with the elevation axis coincident with the polar axis ($\theta = 0$) of the antenna's co-ordinate system. The elevation drive thus generates cuts at constant θ (is not presented in this work), and the azimuth drive cuts at constant ϕ. The fixed antenna was a broadband horn (EMCO type 3115) and the spacing between the test antenna and the horn was 4 m. The azimuth elevation positioner was rotated from $\phi = -90°$ to 90° for E - plane measurement with an increment of 5°. The antenna pattern was measured at two individual frequencies. Four patterns cuts at constant ϕ were shown in Figs. 4 and 5.

Fig. 4 illustrates the axial ratio of the proposed antenna against the elevation angle θ at 2400 MHz and 2450MHz for four vertical planes i.e., $\phi = 0°$, $\phi = 30°$, $\phi = 45°$ and $\phi = 90°$. As can be observed, the proposed antenna maintains a good axial ratio of less than 4 dBs over ± 50° elevation angle. Fig. 5 shows the radiation patterns of the proposed antenna at 2450MHz for four planes, similar to those considered in axial ratio. As can be examined, the symmetrical and identical variations were obtained for all the radiation patterns. The maximum gain of the antenna is found to be around 5 dBi at 2450MHz. The results confirm the superior circular polarized conical beam shape for the proposed antenna.

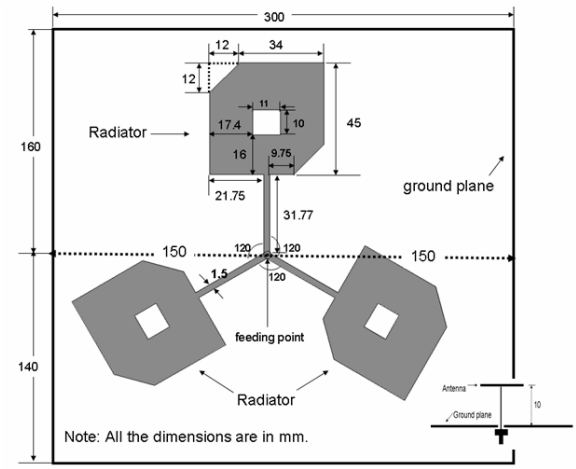

Fig.1: Geometry of the proposed three elements antenna array.

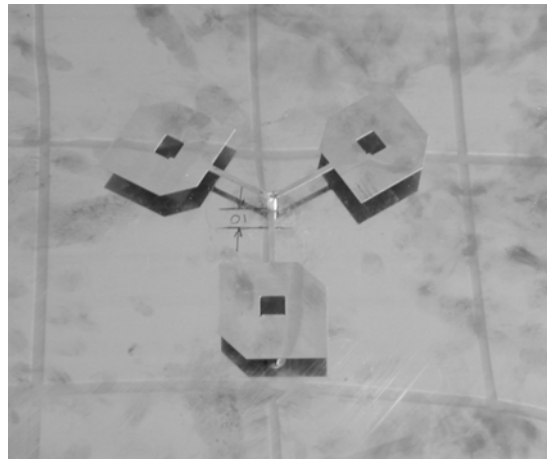

Fig.2: Prototype of the proposed antenna

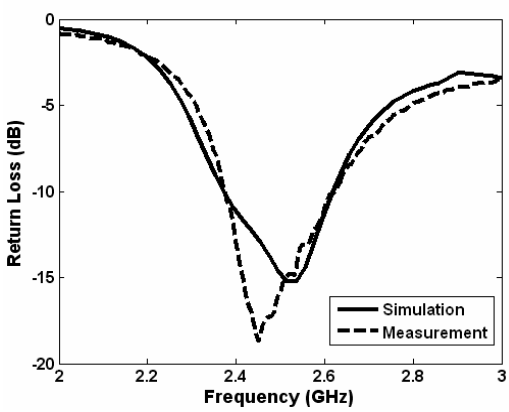

Fig. 3: Simulated and measured return loss of the proposed antenna shown in Figs. 1 and 2.

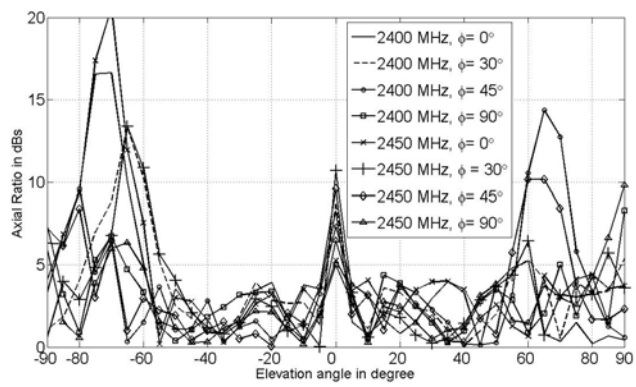

Fig. 4: Measured axial ratios against the elevation angle of the proposed antenna for two operating frequencies, at four vertical cuts; $\phi = 0°$, $\phi = 30°$, $\phi = 45°$ and $\phi = 90°$

4. CONCLUSION

It has been shown that a conical beam antenna suitable for WLAN application, but working in circularly polarization, can be very similar to those realized for vertical or horizontal polarization in the already reported disc antenna forms, so it may be claimed that the target of producing an circularly polarization has been met. The characteristics of the proposed antenna (impedance bandwidth and far field radiation patterns) have been discussed theoretically and experimentally. The experimental results verified the simulated ones.

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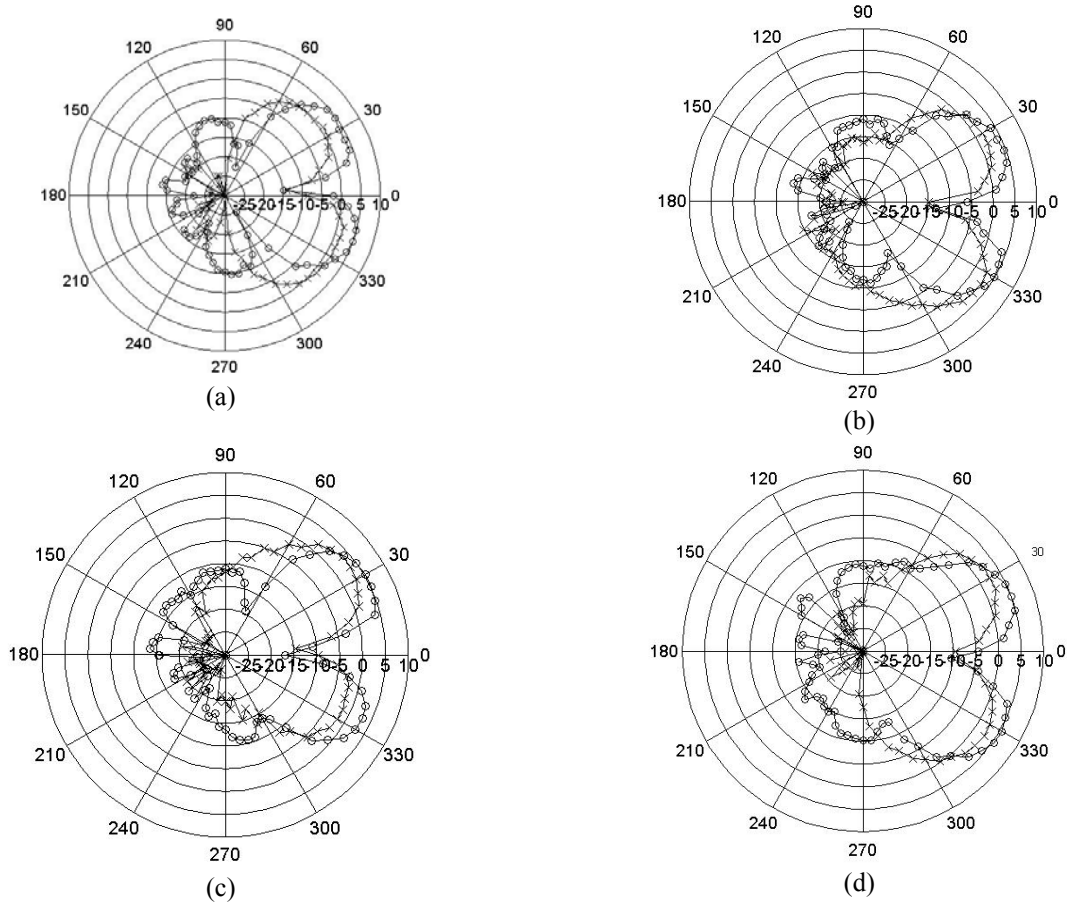

Fig. 5: Measured radiation patterns of the proposed antenna at 2450MHz for four vertical planes (a) $\phi = 0°$, (b) $\phi = 30°$ and (c) $\phi = 45°$ (d) $\phi = 90°$ where 'x-x-x' measured cross-polar pattern component and 'o-o-o' measured co-polar pattern component.