APERTURE COUPLED PERTURBED ANTENNA WITH A PARASITIC ELEMENT FOR RAPIDLY DEPLOYABLE WIRELESS ATM NETWORK

Mazlina Esa, Noor Arjunadi Mohd Noor, Mohd Rijal Hamid,
Suhaila Subahir, Norsheila Fisal and Sharifah Kamilah Yusof
Fakulti Kejuruteraan Elektrik
Universiti Teknologi Malaysia
81310 UTM Skudai, Johor DT, Malaysia
e-mail: mazlina@suria.fke.utm.my

Abstract: A circular perturbed patch antenna with an aperture coupling feed and has a parasitic element of the same patch shape is presented. The antenna is proposed for the receiver of a rapidly deployable wireless ATM (asynchronous transfer mode) network, operating at 1.57542 GHz. The receiver is able to receive the signal beamed by the Global Positioning System (GPS) satellite which carries navigation message. The basis of the antenna is a circular patch which is then perturbed to achieve circular polarisation which matches the GPS signal. The aperture coupling feed has the advantage of avoiding physical connection to the antenna radiating structure. A shunt quarter-wavelength open-circuited stub was employed with the microstrip feed to reduce unneeded back radiation. This enhances the relative gain of the broad beamwidth broadside radiating antenna. The antenna was experimentally found to be well matched at the frequency of operation and exhibit a sufficient 3 % reflection bandwidth.

Keywords:
Aperture coupled, perturbed, parasitic, wireless ATM.

I. INTRODUCTION

The Global Positioning System (GPS) satellite operates at the particular frequency of 1.57542 GHz to send navigation message for civillian communities [1]. The GPS signal is circularly polarised. The receiver of a rapidly deployable wireless ATM (asynchronous transfer mode) network may make use of this signal in remote areas such as in islands or remote military bases during operatios, or in areas where communication network has been destroyed. An example of a rapidly deployable radio network operating at 5.3 GHz of the Industrial, Scientific and Medical (ISM) band is being developed at ITTC, University of Kansas.

This paper proposes a structure which is able to operate for such environment. The proposed structure is based on a circular microstrip patch which was given two perturbation sections. It has an aperture coupling feed in the form of a 50 ohm microstrip line in parallel with a quarter-wavelength open stub. A similar radiating structure which acts as a parasitic element is placed on the topmost layer. The structure (ACP) is compared with three corresponding structures; aperture-coupled fed perturbed circular patch antenna (AC), coaxially fed perturbed circular patch antenna (CF) and coaxially fed perturbed circular patch antenna with circular parasitic element (CFP). All antennas have the same feeding position, initially obtained for the CF from theoretical formulations and numerical simulation using an electromagnetic software. The four antennas have been built and experimentally tested.

II. DESIGN CONSIDERATIONS

The basic structure of the antenna is the microstrip circular patch [2] operating at 1.575 GHz as shown in Fig. 1(a). The microstrip structure was chosen due to the advantages of being light, flat, low-profile and easily integrated with other components [2]-[4] such as the electronic circuitry. The chosen microwave laminate is the TLE material from Taconics with the following specifications: relative permittivity $\varepsilon_r = 2.95$, thickness of substrate $h = 1.57$ mm, loss tangent $\tan\delta = 0.0028$, thickness of copper $t = 35$ μm, surface roughness = 0.0024 and conductivity of copper $\sigma = 5.882 \times 10^7$ S/m. The designed patch of 33 mm radius [3] was introduced with perturbation segments arranged such that the right hand circular polarisation (RHCP) property will be achieved. An unloaded Q factor of 100 satifies the condition [5]. The location of the feeding point was determined using the Micropatch 2.0 electromagnetic simulation software [6]. This was found to be at a radius of 8.2 mm. The exact location depends on the chosen polarisation as depicted in Fig. 1(b) of the plan view of the CF and AC antennas. The added parasitic layer consists of the radiating structure over a dielectric layer. The structure shares the same ground plane as the bottom radiating patch. For the AC and ACP, there is only a single ground plane being shared by the radiating patches and the feeding network. The aperture is constructed in the ground plane.

Cross-sectional views of the four antennas are illustrated in Fig. 2.

The coaxial feed is directly connected from underneath the dielectric through a via. The via is just sufficient to allow the center pin of the connector at the input to pass through. For the aperture coupling feed, the antenna is fed from a 50 ohm microstrip line with a shunt quarter-wavelength open circuit stub through an aperture having the same width as the feed line. The width of the line can be determined using the Micropatch 2.0 software. This was found to be 3.96 mm, exactly the same as that obtained from mathematical formulations available in the literature [7]. The board size was chosen to be of square shape, having the dimension of almost half-wavelength. Larger dimensions is expected to degrade the performance of the antenna. However, performance of the antennas in terms of board size has not been investigated in this work.

The rectangular aperture constructed in the ground plane offers the advantage of reducing any back radiation, in addition to the benefit of having the open stub [8]. The width of the aperture is the same as that of the feed line. The length of the aperture increases with the amount of coupling, however, longer lengths will increase unneeded back radiation [8], [9].

III. HARDWARE IMPLEMENTATION AND MEASUREMENTS

The antennas were implemented on TLE microwave laminate using the standard photolithography and wet etching techniques for printed circuit boards. The inputs of the antennas are 50 ohm SMB connectors. Such connectors were chosen to directly match with the connectors of the measurement set-up. A low permittivity double sided tape was used to carefully attach both structures together, ensuring minimal amount of air gap between them. Two identical antennas have been fabricated for each type of antenna. This serves the purpose of having identical transmitting and receiving antenna. Hence, the calculation of antenna gain is simplified as proposed in [2].

Single and two port measurements were performed with the Feedback Antennalab measurement set-up. The antennas were tested in the co-polarisation E-plane, co-polarisation H-plane, cross-polarisation E-plane and cross-polarisation H-plane alignments. These are sufficient in testing the circular polarisation property [10]. The distance between the transmitting and receiving antennas are in the Fraunhofer far-field region [2]. The Fraunhofer distance is 14.37 cm. The separation chosen was 1.5 m.

IV. RESULTS AND DISCUSSION

Numerical simulation of the basic circular patch is performed using Micropatch 2.0 CPDESIGN command. The optimised size was found to be of 32 mm radius. This agrees quite well with the designed dimension discussed earlier in Section II. The command CPANALYZE was then used to simulate the single and two-port performances of the antennas. A very low return loss of -50 dB at the operating frequency of 1.57542 GHz was obtained, indicating an almost perfectly matched antenna at the input. This corresponds to an almost perfect voltage standing wave ratio (VSWR) of 1.0061 and an input impedance of 50.0986 ohm. The -10 dB reflection bandwidth was found to be 17.33 MHz or 1.1 %. Such narrow bandwidth is one of the disadvantages of microstrip antennas in applications where wide bandwidth is required. However, a higher 3 % reflection bandwidth is needed for a good GPS receiving antenna and this is achievable with the addition of parasitic elements. In the hardware implementation, only one parasitic element is considered. Nevertheless, the basic patch possesses a high efficiency of 68 % and 6.7 dBi directivity. This corresponds to a gain of about 5 dBi [2].

Measured results of all antennas showed that they are well matched at their corresponding 1.57 GHz frequency of operations, indicating low return losses. A very slight difference of less than 4 MHz in the measured frequency of operation is well within the designed -10 dB reflection bandwidth. AC and ACP antennas are better matched by 20 dB. CF and CFP antennas posses narrow reflection bandwidths of 1%, with CFP antenna having the larger value. The AC and ACP antennas have wider narrow reflection bandwidths of 3 % that suit the GPS requirement. That of the ACP antenna is almost 15 % larger. The co-polarisation E-plane far-field radiation pattern of all antennas are unidirectional and normal to the antenna plane, as depicted in Fig. 3. The shunt quarter-wavelength open stub of the feeding line helped reduce the back radiation of the AC and ACP antennas. The half-power beamwidth (HPBW) of all antennas were over 90^0 indicating broad beamwidths, with the exception of the CF antenna. That of the AC and ACP are over 100^0. The aperture coupling feed enhanced the reflection bandwidth whilst reducing the return loss. The presence of the parasitic element has also increased the reflection bandwidth. All the antennas exhibit low gains. However, the AC and ACP antennas have higher low relative gain with respect to the CF antenna, with the ACP antenna having the highest at 1 dBi.

V. CONCLUSION AND FUTURE WORK

The basic circular microstrip patch antenna has been successfully optimised using the Micropatch 2.0 simulation software. The size of the structure agrees well with the theoretical values. All the tested antennas are well matched at their corresponding 1.575 GHz frequency of operations which indicate low return losses. The aperture coupling feed produces better impedance matched performance at the input and wider narrow reflection bandwidth with the ACP antenna exhibiting about 3 % which suits the GPS requirement. Unidirectional broad HPBW co-polarisation

E-plane radiation patterns which are normal to the antenna plane have been observed on all antennas, with the ACP having the broadest HPBW of 107^0. Table 1 summarises the important measured results for all the antennas. The feed line with the open stub decreases the presence of back radiation, thus increasing the antenna relative gain. The parasitic element has also increased the reflection bandwidth. All the antennas exhibit low gains with the ACP antenna having the highest. Circular polarisation has been achieved with the introduction of perturbation structures. It is anticipated that higher gain is achievable if the double sided tape is replaced with plastic screws as this will minimise the presence of any air gap layer. Millitary applications may opt the proposed structure but redesign to operate at its allocated frequency. Work is currently under way to integrate the structure with the ATM wireless network by developing the beamforming circuitry with software radio capabilities. Other possible antenna candidates are also being considered.

VI. REFERENCES

[1] B. Hofmann-Wellenhof, H. Lichtenegger and J. Collins, GPS Theory and Practice, New York: Springer, 1997.

[2] C. A. Balanis, Antenna Theory: Analysis & Design, 2nd edition, New York: Wiley, 1997.

[3] J. R. James and P. S. Hall, Handbook of Microstrip Antennas, London: Peter Peregrinus, 1989.

[4] I. J. Bahl and P. Bhartia, Microstrip Antennas, Deedham: Artech, 1986.

[5] K. Hirasawa and M. Hanaeishi, Analysis, Design and Measurement of Small and Low-Profile Antenna, London: Artech, 1992.

[6] A. Benalla, C. H. Thang and K. C. Gupta, Computer Aided Design and Analysis of Microstrip Patch Antenna, User's Manual, Boulder: Microstrip Designs, 1993.

[7] I. J. Bahl and P. Bhartia , Microwave Solid State Circuit Design, New York: 1988.

[8] D. M. Pozar and S. M. Duffy, "A Dual-Band Circularly Polarised Aperture-Coupled Stacked Microstrip Antenna for GPS", IEEE Trans Antennas and Propagat., Vol. 45, No. 11, Nov. 1997.

[9] D. M. Pozar and D. H. Schaubert, Microstrip Antennas, The Analysis and Design of Microstrip Antennas and Array, New York: IEEE Press, 1995.

[10] W. L. Stutzman, Polarization in Electromagnetic Systems, Boston: Artech, 1993.

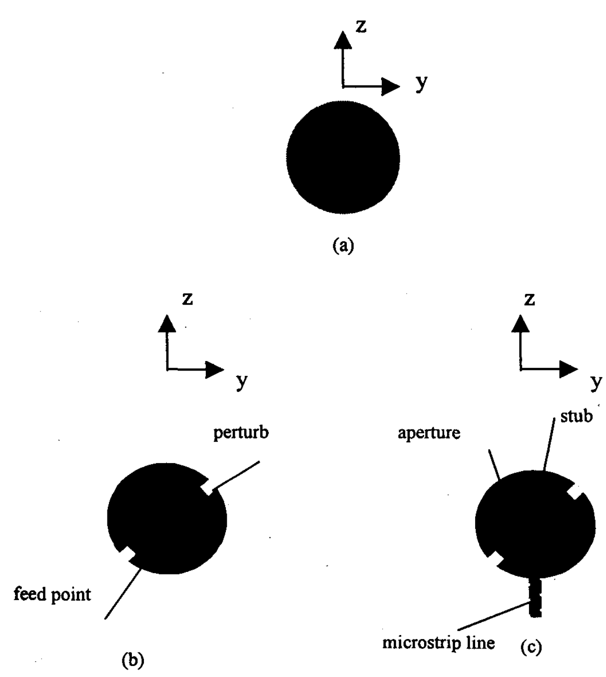


Fig. 1 (a) Circular patch (b) CF antenna (c) AC antenna.

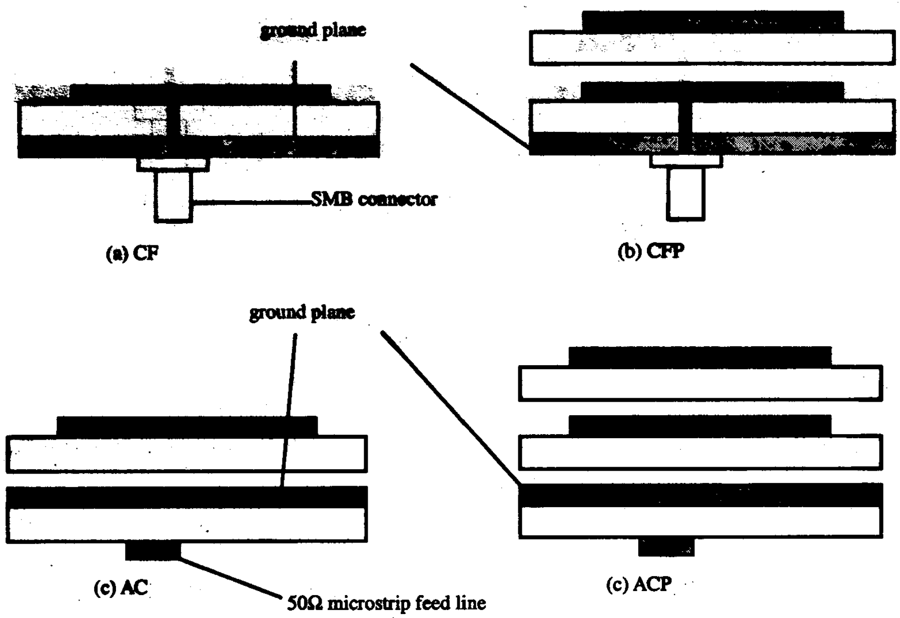
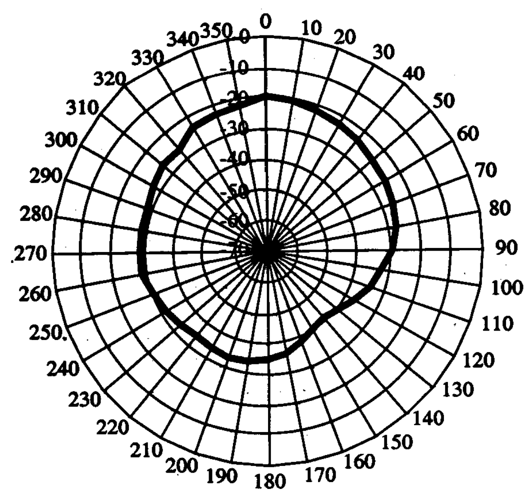
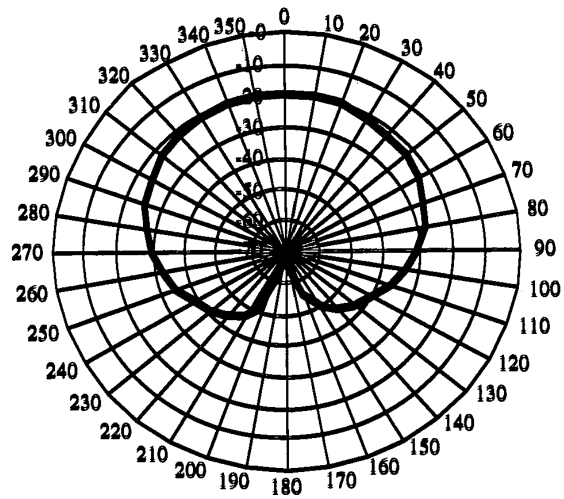


Fig. 2. Cross-sectional view of antenna configurations.

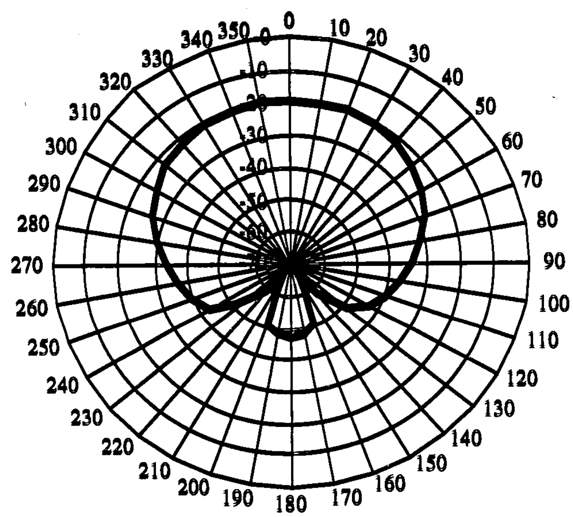


(a) CF

Fig. 3. Co-polarisation E-plane far-field radiation pattern for all the antennas.

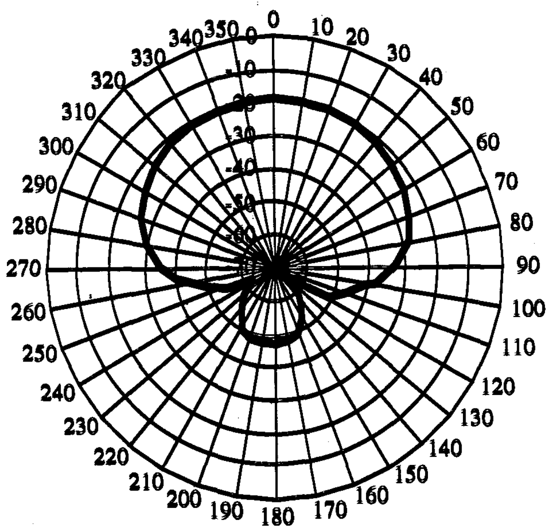


(b) CFP



(c) AC

Fig. 3. Co-polarisation E-plane far-field radiation pattern for all the antennas (contd.).



(d) ACP

Fig. 3. Co-polarisation E-plane far-field radiation pattern for all the antennas (contd.).

Table 1 Overall performance of measured results.

Measured results	CF antena	CFP antena	AC antena	ACP antenna
Return loss, dB	-15.0	-13.5	-31.5	-35
Reflection bandwidth, %	1.02	1.72	3.0	3.56
VSWR	1.14	1.16	1.07	1.06
Frequency response, dB	-19.58	-19.20	-19.01	-18.58
HPBW, °	80	100	104	107
Relative gain, dB	0	0.39	0.57	1.0