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PATTERN DIVERSITY ANTENNAS FOR FUTURE MOBILE COMMUNICATION SYSTEMS

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Abstract: In the past, pattern diversity in a conformal antenna system has usually been achieved through the use of an antenna array and a complicated feeding network. However due to the size constraints, the number of antenna elements that could be mounted onto a mobile device (e.g. laptop) are limited. In this paper, It will be shown how a simple microstrip patch antenna could be used to design a conformal pattern diversity antenna. These antenna elements are capable of pattern diversity performance. Using these antennas, the diversity performance of the devices should be greatly enhanced. In additions, these antennas could also be used in an array configuration to enhance performance. In this paper, three pattern diversity microstrip patch antenna configurations are presented.

Introduction: In a mobile communication environment, the rapid signal fluctuations inherent in a multi-path environment can severely degraded the performance of any communication system. Due to these effects, diversity scheme employing techniques such as space, polarisation, pattern, frequency and time have been used in one form or another to combat this effect[1][2]. One of the most common techniques used in mobile devices is space diversity. For example, two antennas placed about 0.3λ apart could provide good de-correlation between the received signals and thereby increase the probability of the signal reception in the mobile device[3].

However, due to limited space constraints, the number of antennas that could be realistically employed in the mobile is very small. One possible scenario is to develop an antenna element capable of multi-mode operations. To put it simply, the antenna must be capable of performing more than one operation[4][5]. In the paper, we considered the possibility of designing a conformal antenna element capable of pattern diversity performance. For example, the advantages of using two of these elements will not only provide pattern but space diversity as well. In additions, these antenna elements could also be used in an array to improved the signal reception. In the following sections, it will be demonstrated how the current of the patch antenna is controlled to generate the different radiation patterns.

Antenna Design and Experimental results: Consider a simple square microstrip patch antenna, through careful positioning of the shorting pins, the radiation pattern of a shorted microstrip patch antenna could be controlled by modifying the current flow on the patch[6][7]. However, to make this design feasible, both antenna modes (e.g. patch and the monopolar mode) must be able to resonate at the same frequency. This is achieved by raising the frequency of the patch mode by increasing the inductance as seen by the patch mode's antenna. The final antenna configuration is shown in figure 1a. In this design, eighteen PIN diodes have been used.

In figure 3a, the measured S_{11} of the pattern diversity square patch in both the forward and reverse bias are illustrated. From the graph, it is clearly seen that it is possible to operate and match both antennas at the same frequency. In the forward bias condition, PIN diodes at both end of the antenna are turned on. This caused the current to flow in a radial direction from the centre of the patch causing the antenna to radiate in a monopolar-like pattern. In the reverse condition, all the pin diodes along one edge of the patch are turned on. This has the effect of forcing the shorted patch to work like a quarter-wave patch antenna producing a patch like pattern. Figure 4.1.a and 4.1.b shown the radiation patterns of the switchable square antenna in the forward and reverse bias conditions respectively.

Another switchable pattern diversity antenna using the monopolar and the TM_{01} mode is also demonstrated in figure 1b. In this design, the frequency of the TM_{01} mode of the antenna is reduced by increasing the electrical length of the patch antenna through the introduction of notch placed in the position of the current maximum. The notch has little effect on the current distribution of the monopolar antenna. Due to this property, the antennas could be forced to operated at the same frequency. In total, 6 PIN diodes are used.

The measured S_{11} of the switchable H-patch antenna when it switched on and off is shown in figure 3.b.It can be seen that both the TM_{01} and monopolar mode could be operated and matched at the same frequency. In this design, the radiation pattern of the fundamental mode(PIN diodes are switches off), TM_{01}, of the H patch antenna is clearly demonstrated in figure 4.2.b. When the PIN diodes is turned on, the fundamental mode, TM_{01}, is shifted up in frequency due to the inductance present in the diodes resulting in an additional mode. This mode (monopolar) is capable of generating the dipole-like pattern shown in figure 4.2.a.

In certain applications, both radiation pattern might be required simultaneously (e.g. diversity system employing maximal ratio combining or selection diversity). In order to meet this requirement, a two port stack microstrip antenna configuration is devised as shown in figure 2. In this particular design, the properties of the patch antenna is fully utilised to provide the isolation required between the two port. The top antenna and the bottom antenna is used to generate the monopolar and TM_{01} mode respectively. For brevity, the operation of this antenna will be described in more details during the conference

The measured S_{11}, S_{22} and S_{21} of the stacked patch antenna configuration are shown in figure 3.a. From the results obtained, good matching and isolation between the two antenna ports have been achieved. In addition, the pattern diversity performance of this antenna configuration as shown in figure 4.3.a and 4.3.b are comparable to the above two antennas shown earlier.

Conclusions: Due to the size constraints inherent in mobile devices, there is a need to integrated more functionality into an antenna. This has lead us to the following pattern diversity antenna designs. When two or more of this antenna elements are used, pattern as well as space diversity could be achieved. The simplicity and compactness of the above design would make it very attractive for use in mobile communication devices. These antennas might also proved useful in enhancing the signal reception capability of an antenna array.

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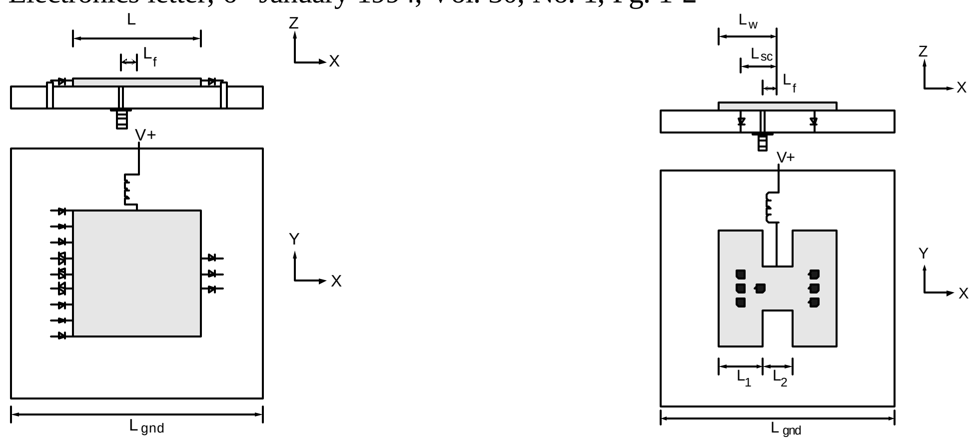
REFERENCES

[1] Vaughan R, “Switched Parasitic Elements for Antenna Diversity”, IEEE Transactions on Antennas and Propagation, Vol. 47, No. 2, February 1999, Pg. 399 - 405

[2] Lee T.S., Chen C.T. and Lin T.T., "Design of Pattern Diversity Antenna for Mobile Communications", Antennas and Propagation Society International Symposium, 1996. AP-S. Digest Volume: 1 , 1996 , Page(s): 518 -521 vol.1
[3] Ebine Y.; Yamada, Y,, "Vehicular-Mounted Diversity Antennas for Land Mobile Radios", Vehicular Technology Conference, 1988, IEEE 38th , 1988 , Page(s): 326 -333
[4] Liu Z, P.S. Hall and Wake D, "Dual frequency Planar Inverted F-antenna", IEEE Transactions on Antennas and Propagation, Vol. 45, No. 10, February 1997, Pg. 1451 - 1458
[5] Lee E, P.S. Hall and P. Gardner, "Compact dual-band dual-polarization microstrip patch antenna", Electronics Letters, vol 35, no 13, (**1999**), Pg. 1034-1036
[6]Wong K.L, Chen W.S, "Compact microstrip antenna with dual-frequency operation" Electronics Letters, vol 33, no 8, (**1997**), Pg. 646-647
[7] Ch. Delaveuad, Ph. Leveque and B. Jecko, "New Kind of Microstrip antenna: Monopolar wire-patch antenna", Electronics letter, 6th January 1994, Vol. 30, No. 1, Pg. 1-2



(a) (b)

Figure 1: Geometry of a switchable a) square pattern diversity antenna (ε_r = 4.5, h =1.6, L = 40 mm, L_f = 7 mm and L_{gnd} = 140 mm) and b) H-patch pattern diversity antenna (ε_r = 4.5, h =1.6, L_1 = 15 mm, L_2 = 10 mm, L_{gnd} = 140 mm, L_w = 20 mm and L_{sc} = 10 mm and L_f = 5 mm.)

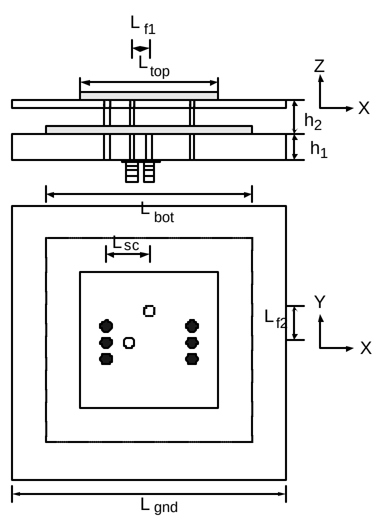
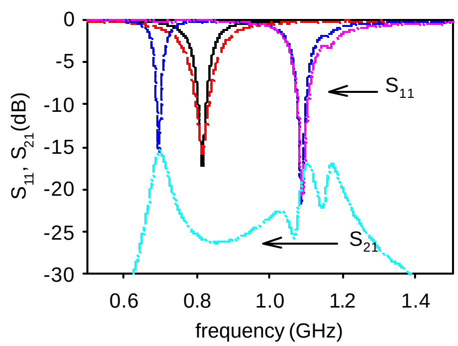
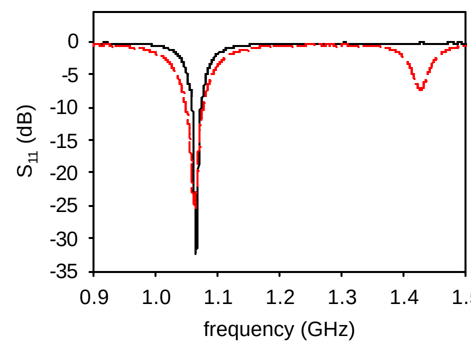


Figure 2: Geometry of a stacked patch antenna configuration for pattern diversity applications (ε_r = 4.5, h_1 =1.6 mm, h_2 = 8 mm , L_{top} = 60 mm, L_{bot} = 65 mm, L_{sc} = 5 mm, L_{f1} = 10 mm and L_{f2} = 20 mm.)

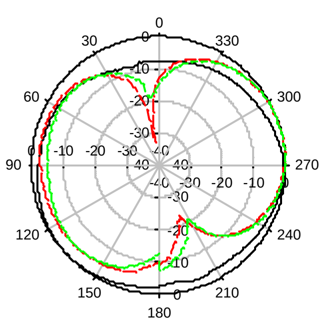


(a)

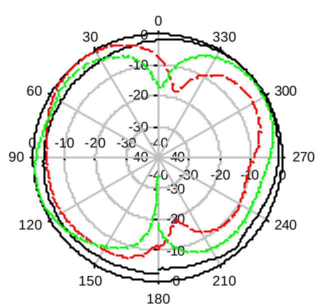


(b)

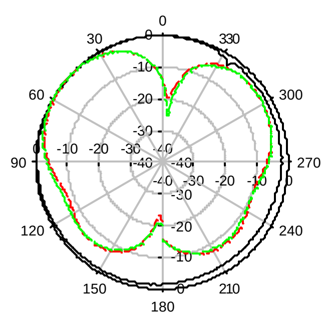
Figure 3: a) Measured S_{11} of the switchable pattern microstrip square patch (—— Sq patch (Patch mode), — — — Sq patch (Monopolar mode), – – – Stacked patch (Patch mode), —•— Stacked patch(Monopolar mode) and —• •— Stacked patch (Measured S_{21})) and b) Measured S_{11} of the switchable pattern H-microstrip patch antenna (—— H patch (Patch mode), — — — H patch (Monopolar mode))



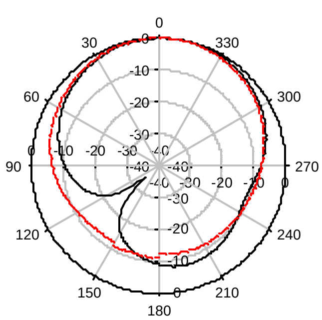
(1a)



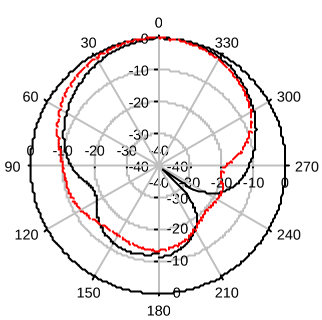
(2a)



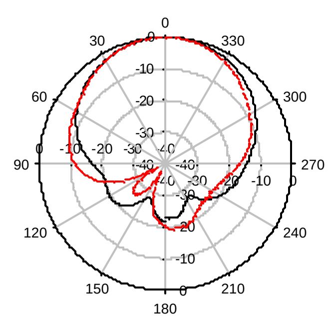
(3a)



(1b)



(2b)



(3b)

Figure 4: Measured radiation pattern of (1) switchable pattern microstrip square patch, (2) switchable pattern H-microstrip patch and (3) Measured radiation pattern of a stacked microstrip patch antenna configuration ((a) —— E_θ (XY Plane), — — — E_θ (XZ Plane), – – – E_θ (YZ Plane) and (b) —— E plane Co-Polarisation and — — — H plane Co-Polarisation)