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The Compact Design of Dual-band and Wideband Planar Inverted F-L-antennas for WLAN and UWB Applications

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Abstract— Two miniature low profile PIFLA antennas with a compact volume size of 30 mm × 15 mm × 8 mm has presented in this paper. By applying the magnetic wall concept a reduced size dual-band and a wideband half PIFLAs for WLAN (2.4 GHz/5.2 GHz) and UWB applications are achieved. The dual-band antenna shows a relative bandwidth of 12% and 10.2% at ISM2400 and IEEE802.11a frequency bands respectively for input return loss less than 10 dB. By carefully tuning the geometry parameters of the dual-band proposed antenna, the two resonant frequencies can be merged to form a wide bandwidth characteristic, to cover 3000 MHz to 5400 MHz bandwidth (57%) for a similar input return loss that is fully covering the lower band UWB (3.1–4.8 GHz) spectrum. The experimental and simulated return losses on a small finite ground plane of size 30 mm × 15 mm show good agreement. The computed and measured radiation patterns are shown to fully characterize the performance of the proposed two antennas.

1. INTRODUCTION

UWB technology is invented for short range and higher data rate communication. The lower and upper UWB spectrums are 3100 MHz to 4000 MHz and 6000 MHz to 10600 MHz respectively. There are three overlapping target segments that could benefit from short-range wireless connections enabled by UWB: PC and peripheral devices, mobile devices, and consumer electronics. By implementing this technology, it is believed capable of delivering 1 Gbit/s data rates over cable and wireless claims to double the exiting most of wireless terminal data-rate. This makes the constant high demand for designing smaller and lighter internal antennas, which immune to damage and low SAR.

There were several antennas size reduction techniques have been proposed over last decades that investigate the use of high permittivity substrate, shorting pins, shorting walls and modifying the geometry of the internal antenna [1–3]. Recently, another size reduction technique is proposed in [4–6] using the magnetic wall concept. It was interestingly found that the performances in terms of return losses, gains, radiation efficiencies, radiation patterns of half size structures of the U-slot, E-shaped [5] and UWB microstrip patch antennas [6] are comparable to their full structures.

2. ANTENNA DESIGN CONCEPT

The PIFLA shown in Fig. 1 is quite similar to the antenna design of the work reported in [7], but the size is reduced to half using the principle of the existing magnetic wall on the antenna surface [5, 6]. The initial geometry parameters of the antenna are stated as follows: $L_1 = 18.6$ mm, $L_2 = 10$ mm, $h_1 = 8$ mm, $h_2 = 4.5$ mm, $d = 3.5$ mm and $w = 0$ mm. It should be noted that these dimensions are the same as in [7], except the width of F-shaped, L-shaped radiator and ground plane have been cropped to half, which are 7.5 mm, 8.5 mm and 15 mm respectively. The copper metal plate thickness of the proposed antenna and the gap distance for the feed are 0.5 mm.

The operation mechanism of this PIFLA is simple. As can be portrayed in Fig. 1, this antenna is a combination of a planar F-shaped antenna with rectangular plate feed and a planar L-shaped antenna. The F-shaped antenna which has a longer electrical length is designed to control the lower resonant mode (2450 MHz), where as the L-shaped antenna is used to provide the higher resonant mode (5200 MHz).

By keeping the same geometry parameters, the return losses of the half size PIFLA are studied. As can be seen in Fig. 2, the bandwidth for lower resonant mode remains, but the bandwidth for higher resonant mode degrades considerably in which 12.2% (5 GHz to 5.65 GHz) to work in [7] and 3.8% (5.15 GHz to 5.35 GHz) to the half structure.

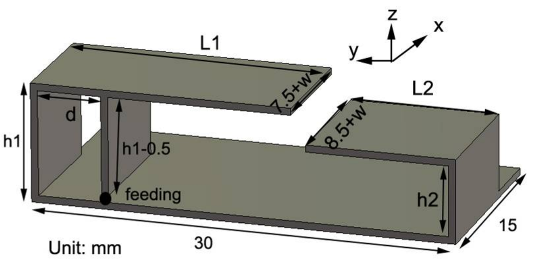


Figure 1: Geometry of the proposed miniature PIFLA.

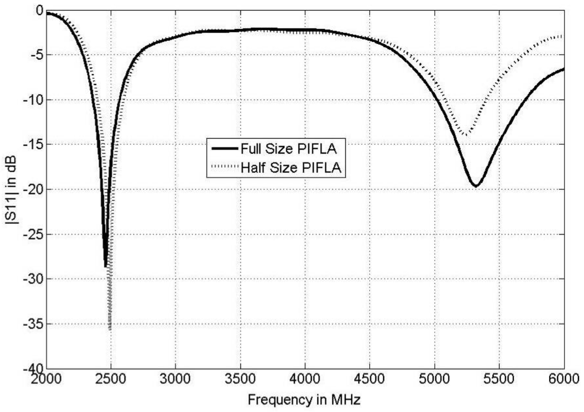


Figure 2: Simulated S_{11} (Full size PIFLA and Half size).

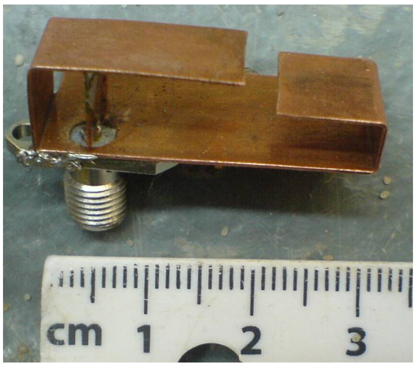


Figure 3: Practical prototype of the proposed dual-bands PIFLA.

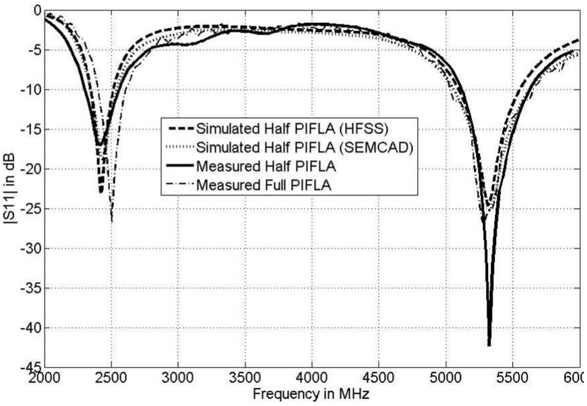


Figure 4: Measured and simulated S_{11}.

3. SIMULATED AND MEASURED RESULT DISCUSSIONS

The prototype antennas were characterised by RF and anechoic chamber measurements. The RF measurements were carried out using an HP-8510C VNA. The radiation patterns were measured as follows. The fixed reference antenna was a broadband horn (EMCO 3115) and the spacing with the antenna under test (AUT) was fixed at 4 m. Two pattern cuts (H-plane and E-plane) were taken for each design frequency covering the target bandwidth.

3.1. Miniature Dual-band PIFLA

By scrutinizing the variations in the geometry against the impedance bandwidth, the optimal parameters can be recognized for dual-band operation. These parameters can be given as follows: $L_1 = 18.6\,\mathrm{mm}$, $L_2 = 10\,\mathrm{mm}$, $h_1 = 8\,\mathrm{mm}$, $h_2 = 5\,\mathrm{mm}$, $d = 4.5\,\mathrm{mm}$ and $w = 1.5\,\mathrm{mm}$.

Figure 3 shows the first miniature dual-band PIFLA prototype. Fig. 4 illustrates the typical measured and computed antenna performance in terms of impedance bandwidth for both full-size and half-size PIFLAs by using two commercial packages (HFSS [8] and SEMCAD X [9]). The return loss is better than $-10\,\mathrm{dB}$, satisfying the desired IEEE802.11b/g frequency band (2400–2485 MHz) and IEEE 802.11a (5.15–5.35 GHz) bands respectively. As can be observed, simulated and measured results for half-size PIFLA were found to be in excellent agreement. The half-size and full-size PIFLA seem to show identical measured impedance bandwidth at two resonant modes.

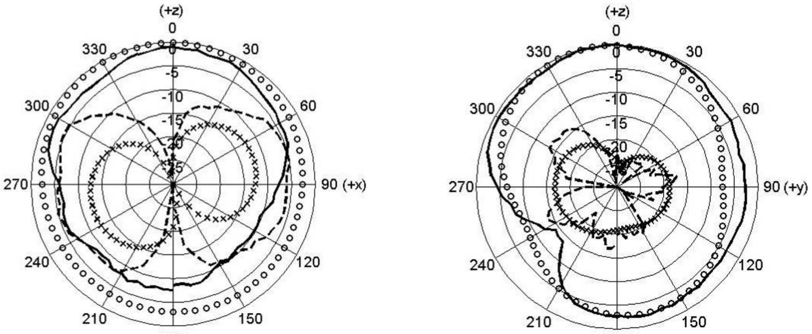
Figures 5(a) and (b) show the simulated and measured co-polar and cross-polar radiation patterns in the x-z and y-z planes at 2400 MHz and 5200 MHz for the miniature PIFLA. The simulated and measured radiation patterns of the fabricated prototype are seen to be quite similar to each other at the two designated centre frequencies.

3.2. Wideband PIFLA

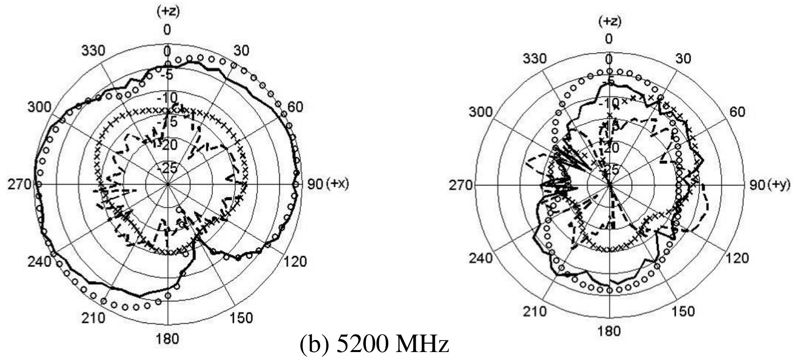
The optimised geometry parameters of the proposed PIFLA for UWB application are given as follows: $L_1 = 18.45\,\mathrm{mm}$, $L_2 = 8.5\,\mathrm{mm}$, $h_1 = 8\,\mathrm{mm}$, $h_2 = 5.5\,\mathrm{mm}$, $d = 14.5\,\mathrm{mm}$ and $w = 4.5\,\mathrm{mm}$.

Fig. 6 describes the experimental prototype of the PIFLA with finite ground plane of 30 × 15 mm, while Fig. 7 shows the typical measured and computed antenna performance in term of impedance bandwidth by using two commercial packages (HFSS [8] and SEMCAD X [9]). As can be seen, the lowest and highest frequency edges, i.e., 3000 MHz and 5400 MHz, of an input return loss ≤ -10 dB are observed. The impedance bandwidth of the proposed antenna, for -10 dB return loss, is 2400 MHz or about 57% with respect to the centre frequency at 3950 MHz (average of measured lower and higher frequencies with a -10 dB return loss), which fully covers the frequency spectrum of uplink UWB (3100 MHz to 4800 MHz). Basic agreement is achieved between the experimental and computed return loss over the desired operating frequency band.

The far-field radiation characteristics of the prototype were also investigated at 3000 MHz, 4000 MHz and 5000 MHz, as shown in Fig. 8. It is observed that the radiation patterns at different frequencies are quite similar, which is expected in a wideband antenna.



(a) 2400 MHz



(b) 5200 MHz

Figure 5: Simulated and measured normalised radiation patterns of the proposed dual-bands PIFLA for two planes (left: x-z plane, right: y-z plane) at (a) 2400 MHz and (b) 5200 MHz. 'xxxx' simulated cross-polarization; 'oooo' simulated co-polarization; '- - -' measured cross-polarization; '—' measured co-polarization.

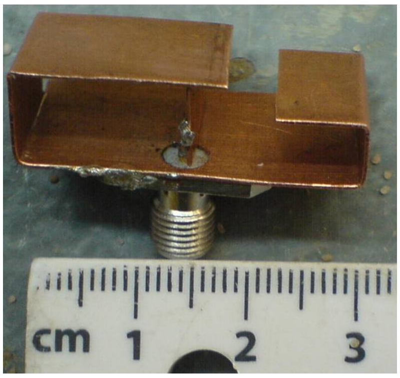


Figure 6: Practical prototype of the proposed wideband PIFLA.

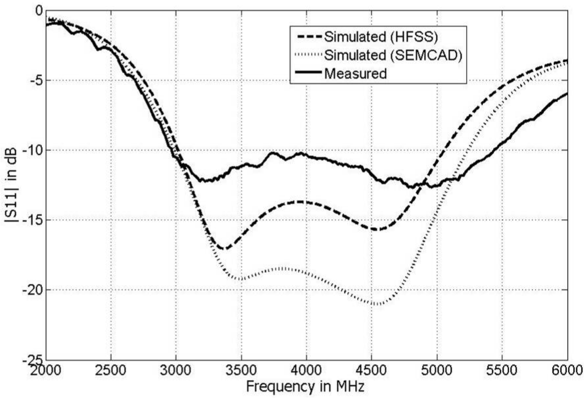
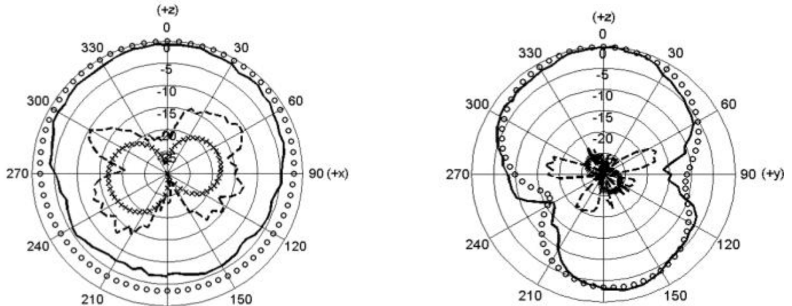
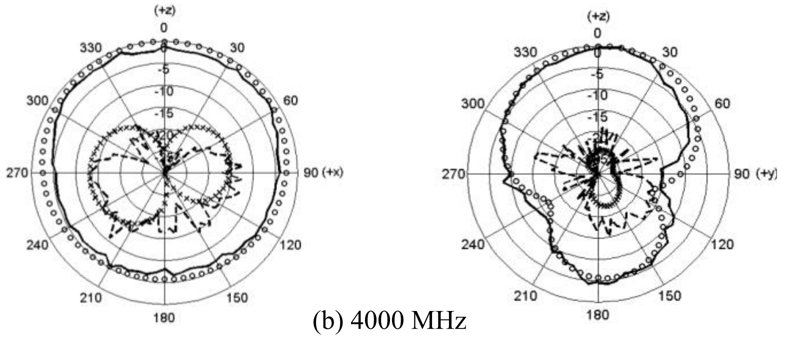


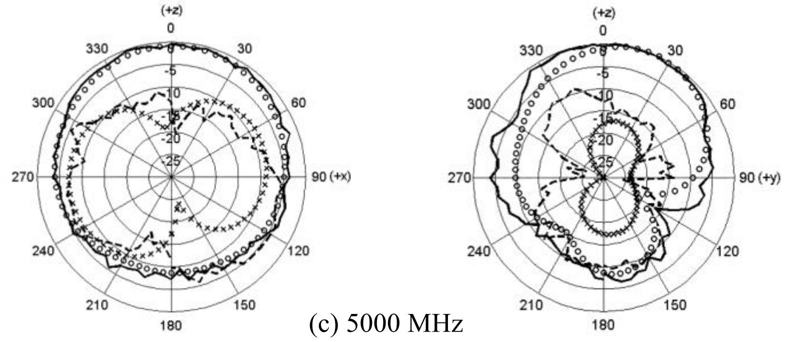
Figure 7: Measured and simulated S_{11}.



(a) 3000 MHz



(b) 4000 MHz



(c) 5000 MHz

Figure 8: Simulated and measured radiation patterns of the proposed wideband PIFLA for two planes (left: x-z plane, right: y-z plane) at (a) 3000 MHz, (b) 4000 MHz and (c) 5000 MHz. 'xxxx' simulated cross-polarization; 'oooo' simulated co-polarization; '- - -' measured cross-polarization; '—' measured co-polarization.

4. CONCLUSION

In this paper a simple geometry of a miniature planar inverted F-L antenna (PIFLA) has been proposed and studied experimentally and theoretically. By carefully selecting different sets of optimal geometry parameters and applying the size reduction techniques to the proposed antenna, two 50% size reduction PIFLAs have been designed and tested. By balancing the size and bandwidth constraints, these proposed antennas have a compact envelope dimension of 30 mm × 15 mm × 8 mm and covers the required operating frequency band for WLAN and UWB applications. These features make the proposed antenna an attractive candidate for application in a range of future mobile terminals.

REFERENCES

1. Skrivervik, A. K., J.-F. Zurcher, O. Staub, and J. R. Mosig, "PCS antenna design: The challenge of miniaturization," *IEEE Antennas and Propagation Magazine*, Vol. 43, 12–27, August 2001.
2. Lee, C. S. and K.-H. Tseng, "Size reduction of microstrip antennas," *Electron. Lett.*, Vol. 37, 1274–1275, 2001.
3. Shackelford, A. K., K. F. Lee, and K. M. Luk, "Design of small-size wideband width microstrip-patch antennas," *IEEE Antennas and Propagation Magazine*, Vol. 45, No. 1, 75–83, February 2003.

4. Deshmukh, A. A. and G. Kumar, "Half U-slot loaded rectangular microstrip antenna," *IEEE AP-S Int. Symp. USNC/CNC/URSI National Radio Science Meeting*, Vol. 2, 876–879, 2003.
5. Chair, R., C.-L. Mak, K.-F. Lee, K.-M. Luk and A. A. Kishk, "Miniature wide-band half U-slot and half E-shaped patch antennas," *IEEE Transactions on AP*, Vol. 53, No. 8, 2645–2651, August 2008.
6. Guo, L., S. Wang, X. Chen, and C. Parini, "Miniaturised antennas for UWB communications," *Proceeding of Eucap*, 3774–3778, Berlin, Germany, March 23–27, 2009.
7. See, C. H., R. A. Abd-Alhameed, D. Zhou, and P. S. Excell, "Dual-frequency Planar Inverted F-L-Antenna (PIFLA) for WLAN and short range communication systems," *IEEE Transactions on AP*, Vol. 56, 3318–3320, October 2008
8. HFSS ver.11, Ansoft. Ltd.
9. SEMCAD X ver.14, Schmid & Partner Engineering AG, Zeughausstrasse 43, 8004, Zurich, Switzerland.