A 2.4GHz Omni-directional Horizontally Polarized Planar Printed Antenna for WLAN Applications

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Abstract - This paper presents the design simulation, implement, and measurement of a 2.4GHz omni-directional horizontally polarized planar printed antenna for WLAN application. The HFSS 3-D EM simulator is used for design simulation. The antenna is fabricated on a double-sided FR-4 printed circuit board. The antenna pattern measurements are performed for the antenna is alone in free space, printed on a PCMCIA card, and that inserted inside a notebook PC. In addition to be used alone for a horizontally polarized antenna, it can be also a part of a diversity antenna.

1. INTRODUCTION

In the urban or indoor wireless environment, after complicated multiple reflection or scattering, the polarization of the propagating radio wave may change significantly. As reported in [1][2] that, although many current wireless system are vertically polarized, it has been predicted that using horizontally polarized antenna at both the transmitter and receiver will result in 10dB more power (in the median), as compared to the power received using vertically polarized antennas at both end of the link. A printed IFA (inverted-F antenna) is a popular choice to be used in a WLAN card [2]. The dominant polarization of an IFA printed on a PCMCIA card and placed horizontally (to be inserted inside a notebook PC) is basically horizontal (and has a certain degree of omnidirectional H-plane pattern). In this paper a horizontally polarized planar antenna which uses the Alford-loop-structure [3][4] to achieve an omni-directional pattern is designed for 2.4 GHz WLAN applications.

2. ANTENNA DESIGN

In order to achieve horizontally polarized radiation, a loop antenna is a suitable choice. A loop antenna with a uniform current distribution will have an omnidirectional pattern. However, a small loop antenna will have a very small radiation resistance and a high reactance. This will cause difficult impedance matching problem. A larger loop antenna will have a reasonable radiation resistance. But the antenna current distribution along the loop becomes nonunifrom and hence could not yield a desired omnidirectional pattern. To design a loop antenna with an omnidirectional pattern and an acceptable input impedance matching becomes a design challenge. In [3] the Alford loop structure [4] is adopted to design a 900 MHz planar printed omni-directional horizontally polarized antenna. Here the same structure is used for 2.4 GHz design. As shown in the Fig. 1 (left), a printed "Z" strip is on the top plane and the other one is on the bottom plane. The "Z" strip on the bottom plane is arranged in such a manner that, the "arm" is mapped to that of the "Z" strip on the top plane through the substrate. And the "wings" of two "Z" strip form a "loop"-type structure (though separated by the substrate). The "wing" length of the Alford loop is of the order of a quarter of wavelength. A connector linked the top and bottom strip is located at the center of the "arm".

Due to structure symmetry, the antenna current distribution on two strips will have the same magnitude and 180-degree phase difference. This is illustrated in Fig.2 (left). Since the (substrate) distance between the top and bottom strip is very small, the radiation of the antenna current along the "arm" will cancel by each other. The currents on two "wings" of each "Z" strip establish a rectangular "loop"-type current distribution. This "loop"-type current distribution will radiate a horizontally polarized wave and is expected to have an omnidirectional pattern, as illustrated in 2 (right).

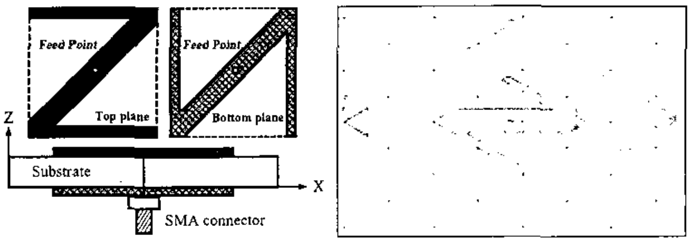

Fig. 1. Illustration and HFSS schematics of a planar printed Alford-loop antenna.

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The required dimension of the "Z" strip, such as, the length and width of the "arm" and the "wing", should be carefully designed for good antenna impedance match at the desired frequency band. The length of the "wing" is approximately a quarter-wavelength long. However, the exact length and width are remained to be fine tuned. The Ansoft HFSS 3D-FEM simulator is used for the design simulation. Fig. 1 (right) shows the HFSS schematics of a planar printed Alford-loop antenna. The antenna current distribution, input impedance, and polarization/radiation patterns can be computed.

3. SIMULATED AND MEASURED RESULTS

Fig. 3 (right) shows a photograph of the designed antenna fabricated on a FR-4 PCB substrate with a 1mm-thickness. A SMA connector is used to connect the central feed point of the top and bottom "Z" strips. This is for design verification. For practical WLAN card with a PCB thickness of 6 mil, the designed printed antenna can be much smaller. The measured VSWR is 1.31 at 2.545 GHz. Fig. 3 (left) shows the simulated antenna current distribution at 2.45 GHz. Fig. 4 shows the simulated and measured radiation patterns of E_ϕ field (horizontal polarization) at 2.45 GHz. As expected, the H-plane pattern has an omni-directional horizontal polarization (E_ϕ) field. The measured average antenna gain of the E_ϕ field in H-plane is –3.92dBi at 2.545GHz and is 15dB greater than the E_θ field. Fig. 5 shows the HFSS simulated antenna current distribution of a 2.4 GHz printed Alford loop antenna on a simulated WLAN (PCMCIA) card. The Alford loop antenna is printed on a FR-4 PCB board (120mm×54mm), which has the same dimension as a PCMCIA card, with the ground plane on the bottom to share with other circuit components on the card. The simulated and measured patterns of E_ϕ field (horizontal polarization) are shown in the Fig. 6. The measured average antenna gain of the E_ϕ field in H-plane is –8.24dBi, which is about 4 dB less than that (–3.92dBi) of a printed Alford loop antenna. The effect of the large ground plane of the PCMCIA card should be taken into consideration for the design of this horizontally polarized planar printed antenna for WLAN application. Fig. 7 shows the measured H-plane patterns of a printed Alford loop antenna, which is stand-alone, on a simulated PCMCIA card, or on a simulated PCMCIA card and inserted inside a notebook PC. It can be observed that there is about more than 15 dB attenuation of the gain pattern in the opposite direction (-x direction) of the PCMCIA slot on the notebook PC when the antenna card is inserted inside the notebook PC. The measured average H-plane antenna gain of the E_ϕ field is –12.13 dBi. To reduce the attenuation effect of the notebook PC housing on the antenna performance is needed for further study.

Table 1 Measured H-plane antenna gains of a 2.4 GHz printed Alford loop antenna at various conditions.

2.4 GHz Planar-printed Alford loop antenna	E_θ (vertical pol.) gain (dBi)			E_ϕ (horizontal pol.) gain (dBi)		
	Max.	*Min.*	*Average*	*Max.*	*Min.*	*Average*
Alone	-10.67	-24.50	-16.43	-1.68	-5.24	–3.92
On PCMCIA card	-13.45	-19.67	-16.36	-3.25	-15.37	–8.24
On PCMCIA card Inserted inside notebook	-10.55	-34.77	-17.24	-1.49	-25.98	-12.13

4. CONCLUSION

The design simulation, fabrication, and measurement of a 2.4GHz omni-directional horizontally polarized planar-printed antenna are presented for WLAN application. It has been predicted that using horizontally polarized antenna at both the transmitter and receiver will result in 10dB more power (in the median), as compared to the power received using vertically polarized antennas at both end of the link. The antenna is fabricated on a double-sided FR-4 printed circuit board for design verification. To simulate the antenna on a WLAN (PCMCIA) card, the same antenna is printed on a FR-4 PCB board (120mm×54mm), which has the same dimension as the PCMCIA card with the ground plane on the bottom to share with other circuit components on the card. The measured average antenna gains of the E_ϕ field in H-plane for a printed Alford loop antenna which is alone in free space, printed on a PCMCIA card, and that inserted inside a notebook PC, are –3.92, –8.24, and -12.13 dBi, respectively. Also, when a printed Alford loop antenna on a simulated PCMCIA is inserted inside a notebook PC, there is about more than 15 dB attenuation of the gain pattern in the opposite direction of the PCMCIA slot on the notebook PC. The effect of the large ground plane of the PCMCIA card and the attenuation effect of the notebook PC housing should be taken into consideration for the antenna design for WLAN applications.

REFERENCE

[1] Dmitry Chizhik, Jonathan Ling, and Reinaldo A. Valenzuela, "The Effect of Electric Field Polarization on Indoor Propagation," IEEE ICUPC, Florence Italy, 1998.

[2] C. Soras, M. Karaboikis, G. Tsachtsiris, and V. Makios, "Analysis and Design of an Inverted-F Antenna Printed on a PCMCIA Card for the 2.4GHz ISM Band," *IEEE Antenna's and Propagation Magazine*, vol. 44, no. 1, pp. 37-44, Feb. 2002.

[3] H.-R. Chuang, et al., "Omni-Directional Horizontally Polarized Alford Loop Strip Antenna", US patent 5,767,809, June 1998.

[4] A. Alford and A. G. Canadian, "Ultra-high frequency loop antenna," *Trans. AIEE*, vol. 59, pp. 8443-8448, 1940.

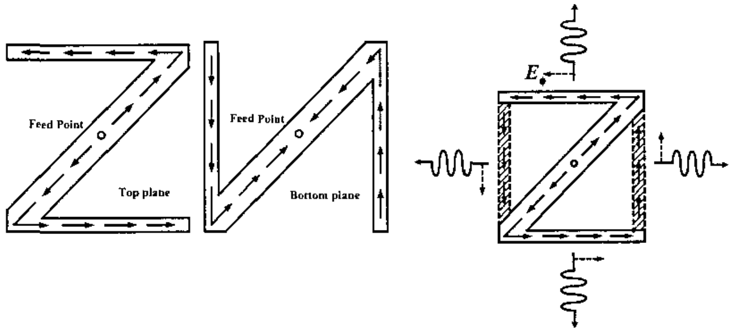

Fig. 2 Illustrations of the current distributions and horizontally polarized omni-directional patterns of a planar printed Alford loop antenna.

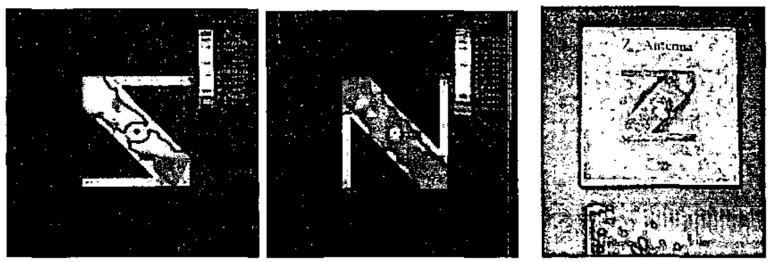

Fig. 3. Simulated current distribution and photographs of a fabricated planar printed Alford-loop antenna.

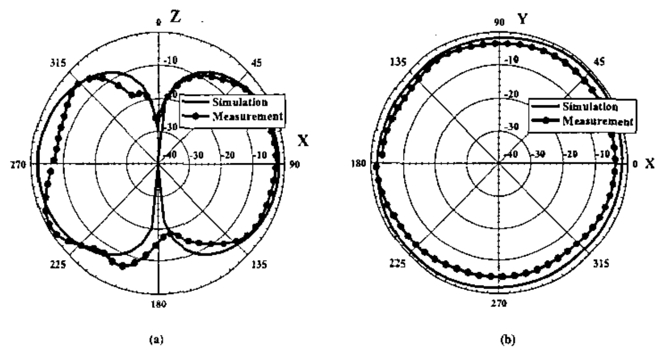

Fig. 4. Simulated and measured radiation patterns of E_ϕ field (horizontal polarization) at 2.45 GHz:
(a) E-plane. (b) H-plane.

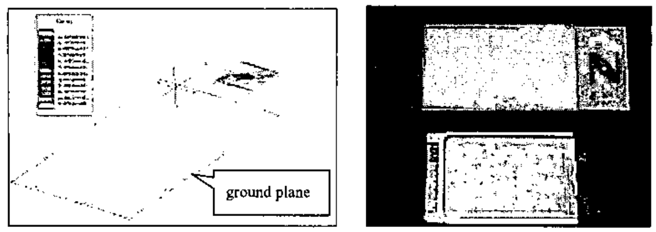

Fig. 5. HFSS simulated antenna current distribution (left) of a 2.4 GHz printed Alford loop antenna on a PCB board to simulate a WLAN (PCMCIA) card and a photograph of a realized antenna (right).

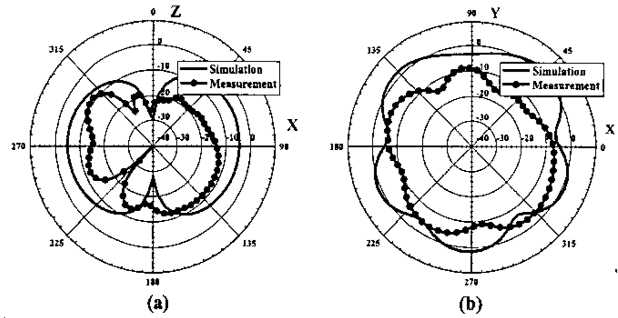

Fig. 6. Simulated and measured patterns of E_ϕ field (horizontal polarization) of a printed Alford loop antenna on a simulated PCMCIA card at 2.45 GHz: (a) E-plane. (b) H-plane.

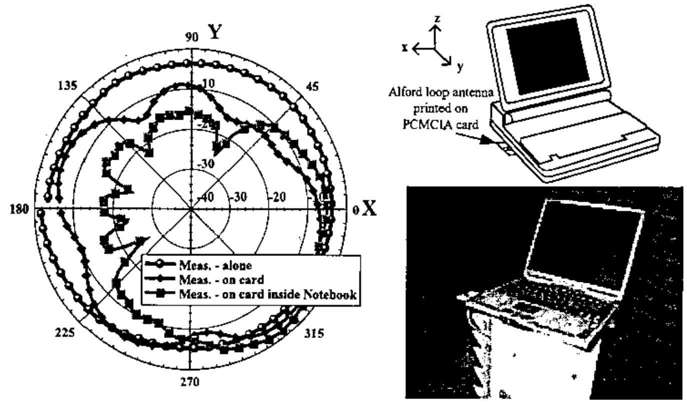

Fig. 7. Measured H-plane patterns of E_ϕ field (horizontal polarization) of a printed Alford loop antenna, which is alone, on a simulated PCMCIA card, or on a simulated PCMCIA card and inserted inside a notebook PC, at 2.45 GHz.

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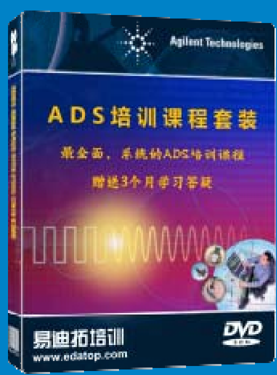

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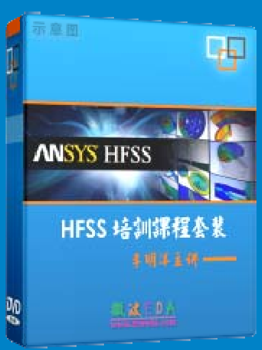

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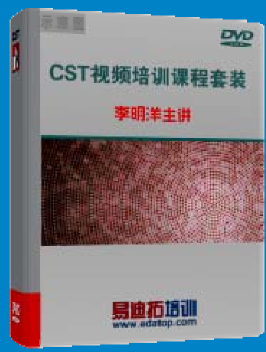

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