Novel broadband Antenna Configuration for Wireless Communications Applications

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Abstract:- New configuration of multiband / broadband Planar inverted F- Antenna (PIFA) is investigated. The antenna is a V-shaped patch with unequal arms coupled electromagnetically to single feed triangular PIFA thorough two unequal slots' dimensions. The six multiband operations are achieved due to the different lengths and widths of the V-shaped patch as well as the two coupling slots. Two more modes can be added by loading the triangular PIFA with V-shaped slot. Wide bandwidth of 27% is achieved by simply adjusting the feeding point position, thus generating staggered resonating modes. UWB operation can be achieved by folding the shorting wall of the triangular PIFA. 55% bandwidth is achieved from 3.8GHz to 6.4 GHz.

Key words: V-shaped patch, triangular PIFA, multiband, broadband, ultrawideband.

1 Introduction

As mobile communication grows rapidly, the demands of multiple frequency bands are raised. It is desirable for a single handset to access several different services such as voice, data and video, at same time in any place [1-2].

Due to the attractive merits of wide frequency bandwidth, Ultrawideband communication systems have recently received great attention in wireless world. UWB system is defined as any radio system that has a 10dB bandwidth larger than 25%perecent of the center frequency [3]. Microstrip patch antenna as well as PIFA is successful candidates for most wireless communication applications due to their low profile, light weight and ease of fabrication and integration with other system components [4]. In the triangular PIFA, the dual frequency operation is with extended frequency ratio ranges 1-3.5. The resonating modes are TM10 and TM20 compared to ratio of 1.6-2 in the conventional rectangular PIFA which are due to TM01 and TM03 modes [5-8].

Although microstrip PIFA with multiband operation offers a number of attractive advantages, it has the disadvantage of narrow bandwidth around 4%. Some methods to enhance the bandwidth were investigated in literature as using probe feed with L-shaped [9], or adding parasitic elements [10]. Wide and multiband characteristics in this paper are achieved by electromagnetically coupled the V-shaped patch with the triangular PIFA. Controlling the coupling mechanisms by adjusting the feeding point position, one can choose between the multiband and Ultrawideband operations [11, 12]. At certain distance d_f between the feeding point and the shorting wall, multiband operation can be achieved with resonating modes at 2.88GHz, 3.64GHz, 3.95GHz, 4.38GHz, 4.81GHz and 5.6 GHz, respectively. The bandwidths for all the six resonating modes are around 4%. Two more modes can be added by inserting V-shaped slot on the radiating surface of the triangular PIFA. Moving the feeding point far from the shorting wall, hence increasing the distance d_f, the resonating modes become staggered close to each other, hence wide bandwidth operation at 2.95GHz and 4.7GHz with respective bandwidths of 3.5% and 27% are achieved. With folding the shorting wall with distance (δx, δy) as shown in figure 1(d), ultawideband operation of about 55% bandwidth is achieved.

2 Antennas Configurations

The geometry of the proposed antennas is as shown in figure 1. V-shaped patch with unequal arms of dimensions are (L_1, W_1) = (41mm, 5.4mm), (L_2, W_2) = (38mm, 3.85mm) is investigated. The isosceles triangular antenna is with dimensions (L_p, W_p) = (25.5mm, 22mm) and the shorting wall width is equal to W_p. The ground plane is with rectangular shape of dimensions (L_g, W_g) = (70mm, 50mm). The two parts of the structure, V-shaped patch and triangular PIFA, are coupled through V-shaped slot with unequal arms with dimensions (L_{s1}, W_{s1}) = (36mm, 10.5mm) and (L_{s2}, W_{s2}) = (33mm, 3.76mm). To add two more resonating modes, equal arms V-shaped slot is loaded on the triangular patch radiation surface with dimensions (L_{slot}, W_{slot})= (17mm, 8mm). The slot air gap width is 1mm. The substrate is foam with dielectric constant 1.07 and substrate height h=6mm.

The Triangular PIFA part is excited by coaxial probe feed. The probe is positioned in the centerline of the shorted patch at distance d_f from shorting wall. The photo of the fabricated proposed antennas is shown in figure 2. The value of the d_f controls the characteristics of the antenna. For multiband operation the distance d_f is 16.75mm while for ultrawideband operation, the distance d_f is increased to be 18.5mm.

3 Results and Discussion

The triangular PIFA geometry, as shown in figure 1, has a patch separated from the ground plane by foam substrate with ε_r =1.07 and h=6mm. The triangular PIFA is loaded with V-shaped patch with two unequal arms. The antenna is fed electromagnetically by coaxial cable on the same layer. To widen the bandwidth, the two following techniques are used. First, the lengths of the two arms of the V-shaped patch are different in order to achieve staggered resonant modes. Second, two different spacings between the triangular shorted patch and the V-shaped patch are used for different coupling levels.

The antenna structures are fabricated with thin film photolithographic technique while Simulation was done using HFSS. The main characteristics are measured with 8719EB vector network analyzer. There are small differences between measured and simulated results in some cases. This could be attributed due to using duroid RT/5880 with thickness 0.25 mm instead of cupper clad on the foam substrate. Also the adhesion material used between the two layers is an error source.

3.1 Multi band antenna

First antenna shape is as shown in figure 1 (a) and 1(b). By adjusting the position of the coaxial feed at d_f = 16.75mm, resonating frequencies of multi-band operation is achieved at 2.88GHz, 3.64GHz, 3.95GHz, 4.38GHz, 4.81GHz and 5.6GHz, with reflection coefficient -21.5dB, -20.7dB, -26.5dB, -24.5dB -19dB and -22.5dB, respectively and with acceptable impedance bandwidths of 3.5%, 4%, 4.25%, 6%, 4% and 7.7%, respectively (refection coefficient is considered at S_{11}<-10dB). The frequency selection is in the S-bad and C-band to be applicable for wireless communication applications. The antenna results are as shown in figure 3. The simulated radiation pattern at both E-plane and H-plane of the antenna at the lowest resonant frequency is shown in figure 4. The triangular PIFA resonant frequencies i can be roughly determined from following equation [12].

$$F_i \approx \frac{C}{4 L_{sloti}} \qquad (1)$$

Where

F_i is the resonant frequencies in GHz

C is the velocity of light $= 3 \times 10^8$ m/s

L_{sloti} is the length of the radiating surface and slots at operating band;

Moving coaxial feeding towards open end of triangular PIFA antenna at d_f = 18.5mm, the resonant frequencies of the antenna become staggered to each other so achieving wider bandwidths at 3% and 27% for resonating frequencies 2.95GHz and 4.721GHz, respectively and with reflection coefficients –21dB and –20.7dB, respectively as shown in figure 5.

3.2 improvement of multiband operation

As shown in figure 1(a), to increase the number of resonating modes, V shaped slot is embedded in the triangular PIFA plate with dimensions (L_{solt}, W_{slot}) = (17mm, 8mm). The number of resonant frequencies is increased to eight as shown in figure 6. The resonant frequencies are at 2.6GHz, 2.7GHz, 3.4GHz, 3.6GHz, 3.8GHz, 4.3GHz, 5GHz and 5.8GHz with reflection coefficients –22.3dB, -24.5dB, -24dB, -18.2dB, -18dB, -32.4dB, -32dB and –14.6dB, respectively. The antenna have acceptable impedance bandwidths of 4.5%, 4%, 3.5%, 3.2%, 3%, 5,5%, 4% and 5.2%, respectively.

3.3 bandwidth enhancement

For more increase in the antenna bandwidth, The triangular PIFA shorting wall is folded by distances (δx, δy) =(2mm,2mm) as shown in figure

1(d)[13]. The antenna has two resonating frequencies at 2.9GHz and 4.7GHz. The simulated and measured bandwidth for the upper resonance is from 3.8GHz to 6.4 GHz with corresponding impedance bandwidth of 55% and with reflection coefficient –30dB as shown in figure 7. The gain of the antenna is stable across the bandwidth with average value of 10.5dBi. The simulated radiation pattern at the lower resonant frequency 2.9GHz is shown in figure 8.

4 Conclusions

An ultrawideband and multiband triangular PIFA are investigated in this paper by loading V shaped patch with unequal arms and adjusting the feeding point location. Another technique is used to increase the number of resonant frequencies from six resonant frequencies to eight resonant frequencies by embedding V shaped slot on the surface of the triangular PIFA.

A novel technique is used to enhance the bandwidth of the structure by folded the shorting wall. The impedance bandwidth increased from 27% to 55%. Stable radiation patterns at both E and H-planes are reached with average gain of 11.5dBi.

Rigid structure was fabricated on a foam substrate. Simulation was done using HFSS and fabrication with photolithographic technique. Measurement shows very good agreement between simulated and measured results.

REFERENCES

[1] P.Salonen, M. Keskilamni, and > Kivikoski, “Single-feed dual0band planar inverted-F antenna with U-shaped slot,” IEEE Trans. Antennas Propagation, vol.48, PP:1262-1264, Aug. 2000.

[2] P.Salonen, M. Keskilamni, and Kivikoski, “Dual-band and wide-band PIFA with U and meanerline-shaped slots,” in IEEE Tran. Antenna and Propagation Symp., Dig., vol.2, Jul.2001, PP: 8-13

[3] D.Pengcheng Li, Jianxin Liang, “Study of Printed Elliptical/Circular Slot Antenna for Ultraeideband Application” IEEE Antennas and Propagation Trans, vol. 54, No 6, pp: 1670-1675, June 2006.

[4] D.Nashaat, H. A.Elsadek and H. Ghali, “Dual band reduced size PIFA antenna with U-slot for Bluetooth and WLAN applications” in IEEE Trans. Antenna Propagat. Symp., Dig., vol. 2, Jun. 2003.

[5] S.Maci, G.Biffi Gentili, P. Piazzesi, “Dual-Band slot-Loaded Patch Antenna,” IEE Proc.-Microw. Antennas Propag., vol. 142, PP: 225-232, 1995.

[6] K. l. Virga and Y. Rahmat-Sami, “Low profile enhanced-bandwidth PIFA antennas for wireless communication packaging.” IEEE Trans. Microwave Theory Tech, vol. 45, pp: 1879-1888, Oct. 1997.

[7] Y. X. Guo, C. L. Mak, K. M. luk, and K. F. Lee, “Analysis and design of L-probe proximity fed patch antennas,” IEEE Trans. Antennas Propagation, vol.49, pp: 145-149, Feb. 2001.

[8] Shoichiro Nakamura “Applied Numerical Methods With Software.” Prentice hall International Inc.,1991.

[9] C. L. Mak and K. M. Luk "Microstrip line-fed L-strip patch antenna," in Proc. Inst. Elect. Eng. Microwave, Antenna, and Propagation, Vol. 146, Aug.1999, PP: 282-284.

[10] Yong-Xin Guo, kwai-Man Luk, Kai-Fong Lee, and Ricky Chair “A Quarter-wave U-shaped patch antenna with two unequal arms for wide band and dual-frequency operation,” IEEE Antennas and Propagation Trans, vol. 50, no.8, pp: 1082-1087, Aug. 2002.

[11] Ki-Hak Kim and Seong-Ook Park, "Analysis of the Small Band-Rejected Antenna with the parasitic strip for UWB", IEEE trans. Antenna and Propagate., Vol. 54, No 6, PP: 1688-1692, June 2006.

[12] Jeen-Sheen Row "Dual-Frequency Triangular Planar Inverted-F antenna," IEEE Antennas and Propagation Trans, vol. 53, no.2, pp: 874-876, February 2005.

[13] Yuan Li, R. Chair and K. F. Lee "Broadband Triangular Patch Antenna With a Folded Shorting Wall," IEEE Antennas and Wireless Propagation Letters, Vol.3, pp: 189-192, February2004.

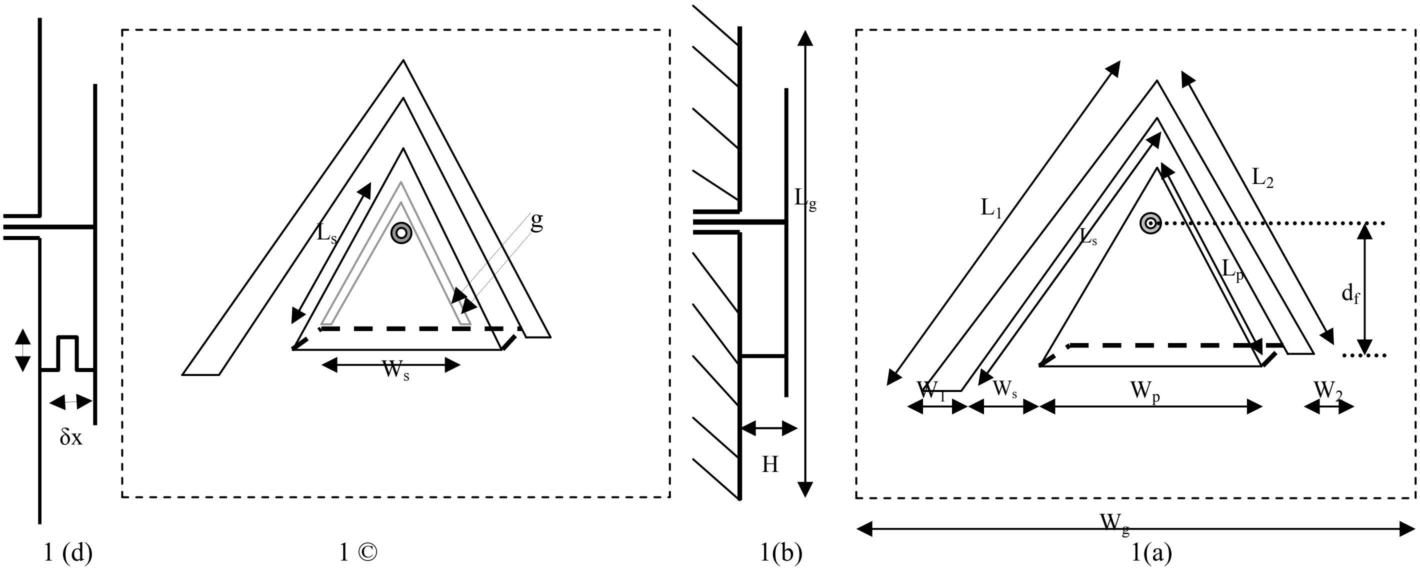

Fig. 1: 1(a), 1(b) the configurations of the proposed antennas PIFA with V-shaped patch with unequal arms, elevation and side view, respectively, 1(C) antenna with V shaped slot and 1(d) antenna with folded shorting wall

Fig.2: Photo of the fabricated proposed antenna for six multi-band operations

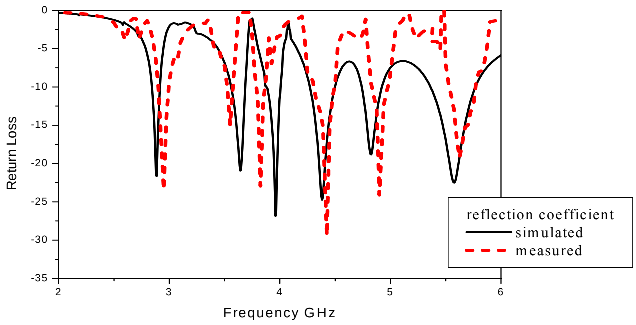

Fig. 3: The reflection coefficient comparison between simulated and measured multi-band PIFA antennas with V-shaped patch with unequal arms

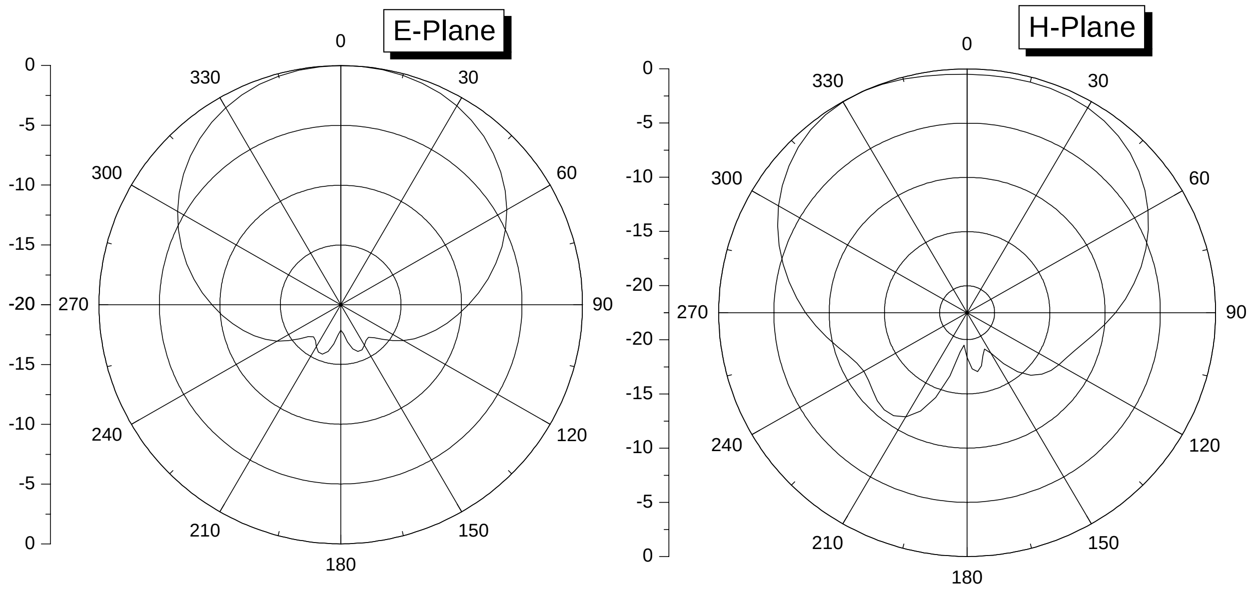

Fig. 4: The simulated radiation pattern E-plane and H-plane for multi-band PIFA antennas with V-shaped unequal arms

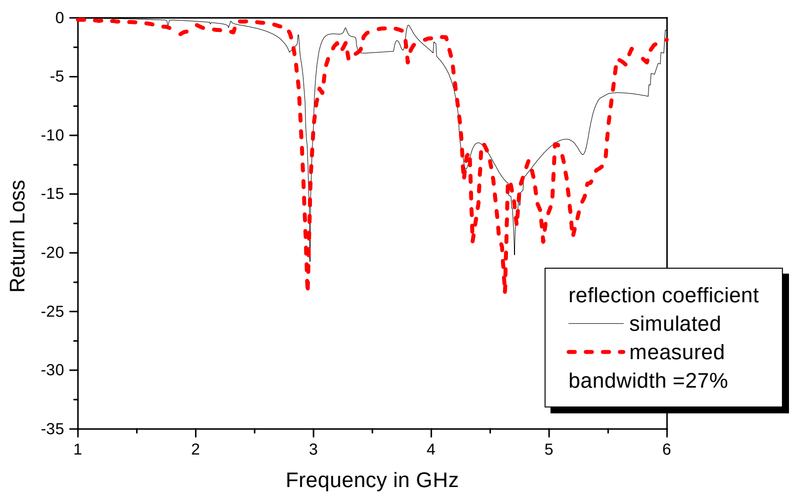

Fig. 5: The reflection coefficient comparison between simulated and measured broadband PIFA antennas with V-shaped slot with unequal arms

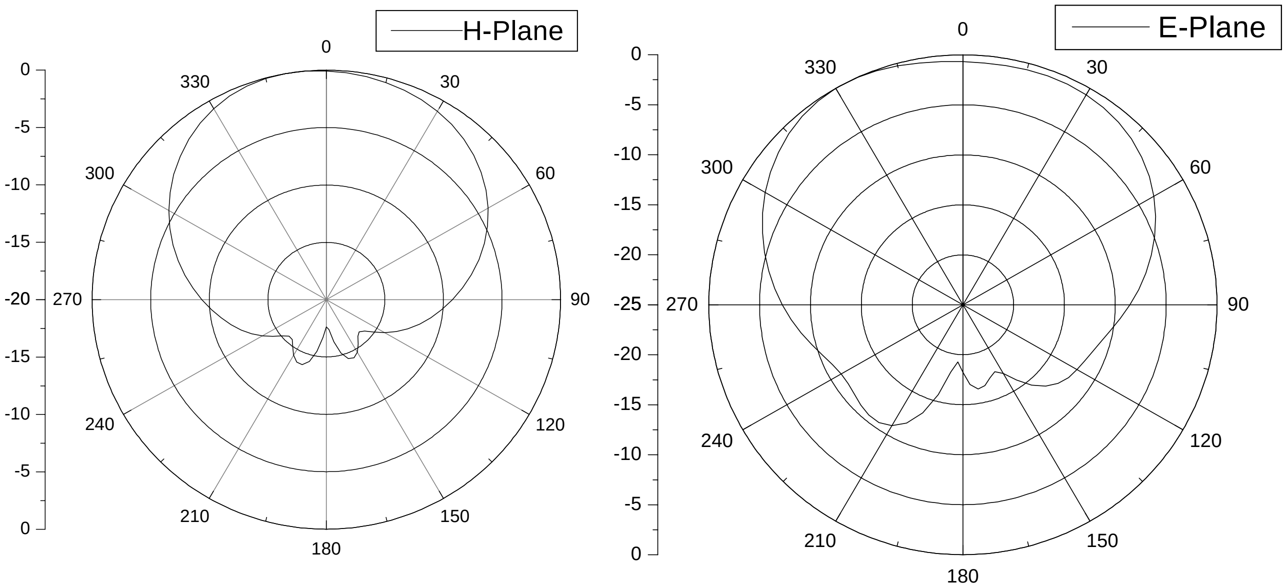

Fig. 6: The simulated radiation pattern H-plane and E-plane for broadband PIFA antennas with V-shaped slot with unequal arms

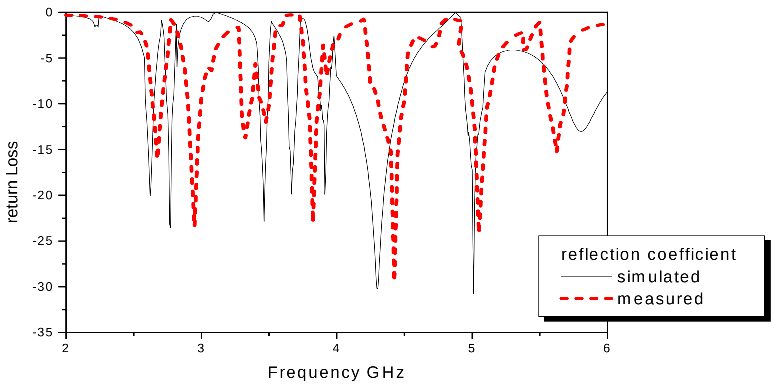

Fig. 7: The reflection coefficient comparison between simulated and measured results of multi-band PIFA antennas with embedded V-shaped slot

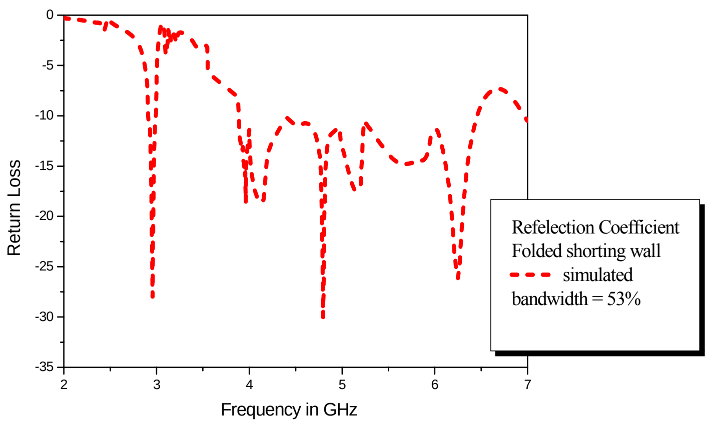

Fig. 8: The simulated reflection coefficient for ultrawideband PIFA antenna with V-shaped slot of unequal arms and with folded shorting wall