Multiband and UWB V-Shaped Antenna Configuration for Wireless Communications Applications

Hala Elsadek, *Member, IEEE*, and Dalia M. Nashaat

***Abstract*—A new configuration of multiband/ultra-wide-band (UWB) antenna is investigated. The antenna is a V-shaped patch with unequal arms coupled electromagnetically to single feed isosceles triangular PIFA thorough two unequal slots. 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 planar inverted F-antenna (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 with 53% bandwidth can be achieved by folding the shorting wall of the triangular PIFA.**

***Index Terms*—Multiband, triangular planar inverted F-antenna (PIFA), ultra-wide-band (UWB), V-shaped patch.**

I. 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 the same time in any place [1], [2].

Due to the attractive merits of wide frequency bandwidth, ultra-wide-band (UWB) communication systems have recently received great attention in the wireless world. A UWB system is defined as any radio system that has a 10 dB bandwidth larger than 25% percent of the center frequency [3]. Microstrip patch antenna as well as planar inverted F-antenna (PIFA) is a successful candidate for most wireless communication applications due to their low profile, light weight, and ease of fabrication and integration with other system components [4].

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 the literature using probe feed with L-shape [5] or adding parasitic elements [6]. Wide bandwidth and multiband characteristics in this letter are achieved by electromagnetically couple 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 wide-band operations [7], [8]. At certain distance d_f between the feeding point and the shorting wall, multiband operation can be achieved with six resonating modes. Eight modes of operation can be achieved by inserting V-shaped slot on the radiating surface of the triangular PIFA. Moving the feeding point far from the shorting wall, hence increasing d_f, the resonating modes become staggered close to each other; hence wide bandwidth operation at 2.95 and 4.65 GHz with respective bandwidths of 3.5% and 27% is achieved. Folding the PIFA shorting wall with appropriate dimensions increases the bandwidth to 53% [9].

II. Antennas Configurations

The geometry of the proposed antennas is as shown in Fig. 1. The dimensions of the V-shaped patch with V-unequal arms are $(\mathrm{L}_1, \mathrm{W}_1) = (41\ \mathrm{mm}, 54\ \mathrm{mm})$, $(\mathrm{L}_2, \mathrm{W}_2) = (38\ \mathrm{mm}, 3.85\ \mathrm{mm})$. The isosceles triangular antenna is with dimensions $(\mathrm{L}_\mathrm{T}, \mathrm{W}_\mathrm{T}) = (25.5\ \mathrm{mm}, 22\ \mathrm{mm})$. The shorting wall width is equal to W_T for maximum size reduction [8]. The ground plane is with rectangular shape of dimensions $(\mathrm{L}_\mathrm{g}, \mathrm{W}_\mathrm{g}) = (70\ \mathrm{mm}, 50\ \mathrm{mm})$. The two parts of the structure, V-shaped patch and triangular PIFA, are coupled through V-shaped slot with unequal arms with dimensions $(\mathrm{L}_\mathrm{s1}, \mathrm{W}_\mathrm{s1}) = (36\ \mathrm{mm}, 10.5\ \mathrm{mm})$ and $(\mathrm{L}_\mathrm{s2}, \mathrm{W}_\mathrm{s2}) = (33\ \mathrm{mm}, 3.76\ \mathrm{mm})$. To add two more resonating modes, an equal arms V-shaped slot is loaded on the triangular patch radiation surface. The substrate is foam with dielectric constant $\varepsilon_r = 1.07$ and substrate height $\mathrm{h} = 6$ mm. It is worth it to mention that as the ground plane size is reduced, the antenna behavior is changed. The operating frequencies are changed. For example, at ground plane size reduced to be $45 \times 55\ \mathrm{mm}^2$, the antenna behavior changes to be a wide-bandwidth antenna rather than a multiband antenna.

The resonating frequencies can be approximately determined from the following equation [1], [4]:

$$f_i = \frac{c}{4L_i} \tag{1}$$

where

f_i is the resonant frequency at band i;

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

Manuscript received December 15, 2006; revised May 14, 2007.

The authors are with the Microstrip Department, Electronics Research Institute, Cairo 12622, Egypt (e-mail: helsadek@mcit.gov.eg).

Color versions of one or more of the figures in this letter are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/LAWP.2007.900953

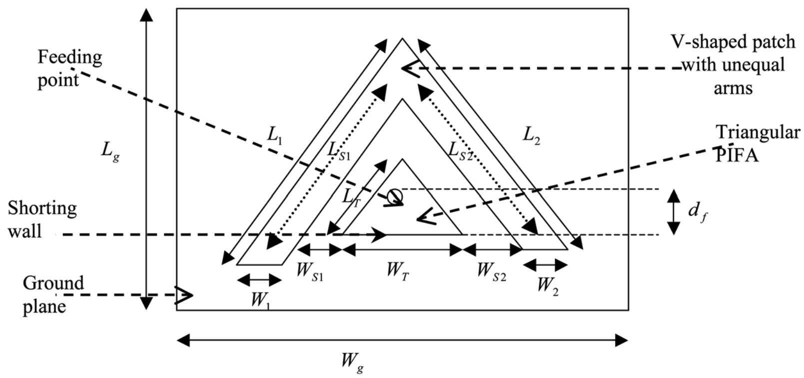

Fig. 1. Configuration of the proposed antenna of V-shaped patch with unequal arms coupled to isosceles triangular PIFA through V-shaped slot of unequal arms.

Fig. 2. Photograph of the fabricated proposed antenna for six multiband operations.

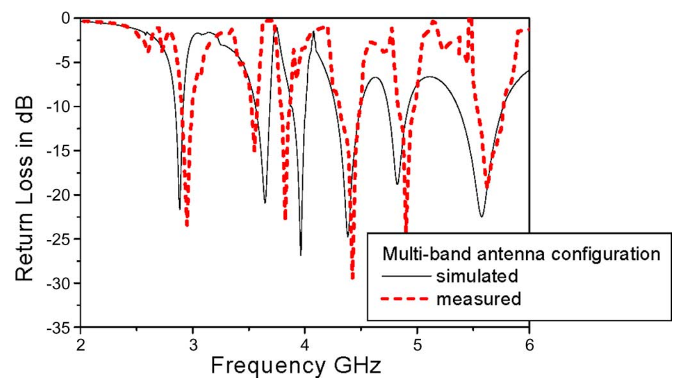

Fig. 3. Comparison between simulated and measured results of the multiband proposed antenna configuration.

L_i is the half-length of the radiating surface or length of the slot at the corresponding operating band i. 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 photograph of the fabricated proposed antenna for multiband operation is shown in Fig. 2. The d_f value controls the antenna characteristics. For multiband operation, the distance d_f is 16.75 mm while for broadband operation, the distance d_f increased to be 18.5 mm.

III. Results and Discussion

The two arms of the V-shaped patch excite TM_{01} mode. The length of the two arms of the V-shaped patch is different in order to excite two different staggered resonant modes. The unequal spacing widths between the coaxially fed triangular shorted patch and the V-shaped patch are for different values of coupling and thus excite two more different modes.

The antenna structures are fabricated with thin-film photolithographic technique. The main characteristics are measured with 8719 EB vector network analyzer. There are small differences between measured and simulated results due to some tolerated fabrication errors as using Duroid RT/5880 with thickness 0.508 mm instead of copper clad for covering the foam substrate.

Adjusting the position of the coaxial feed point at $d_f = 16.75$ mm, multiband operation is achieved with resonating frequencies at 2.88, 3.64, 3.95, 4.38, 4.81, and 5.6 GHz, with reflection coefficients -21.5, -20.7, -26.5, -24.5, -19, and -22.5 dB, respectively, and with impedance bandwidths of 3.5%, 4%, 4.25%, 6%, 4%, and 7.7%, respectively (the bandwidth is at reflection coefficient $S_{11} < -10$ dB). Fig. 3 illustrates a comparison between the simulated and measured results for this multiband structure. The radiation pattern of the antenna is approximately omnidirectional in both E-plane and H-plane with back-to-front ratio of less than -15 dB and 3 dB beamwidth of about 60°. The deformation in the radiation pattern at higher frequencies is acceptable as shown in Fig. 4. Inserting a V-shaped slot on the triangular PIFA radiating plate adds two more resonating frequencies.

Moving coaxial feeding towards open end of triangular PIFA antenna at $d_f = 18.5$ mm, the resonant frequencies of the antenna become staggered close to each other, so achieving wideband operation. The bandwidth is 3% at the fundamental mode 2.95 GHz, hence the fundamental resonating frequency will approximately not be affected by changing the feed position. The higher resonance bandwidth is 27% at 4.721 GHz. The reflection coefficients are -21 and -20.7 dB for the two resonating bands, respectively. Fig. 5 presents the comparison between the simulated and measured results of the wide-band antenna structure. Folding the shorting wall of the triangular PIFA increases

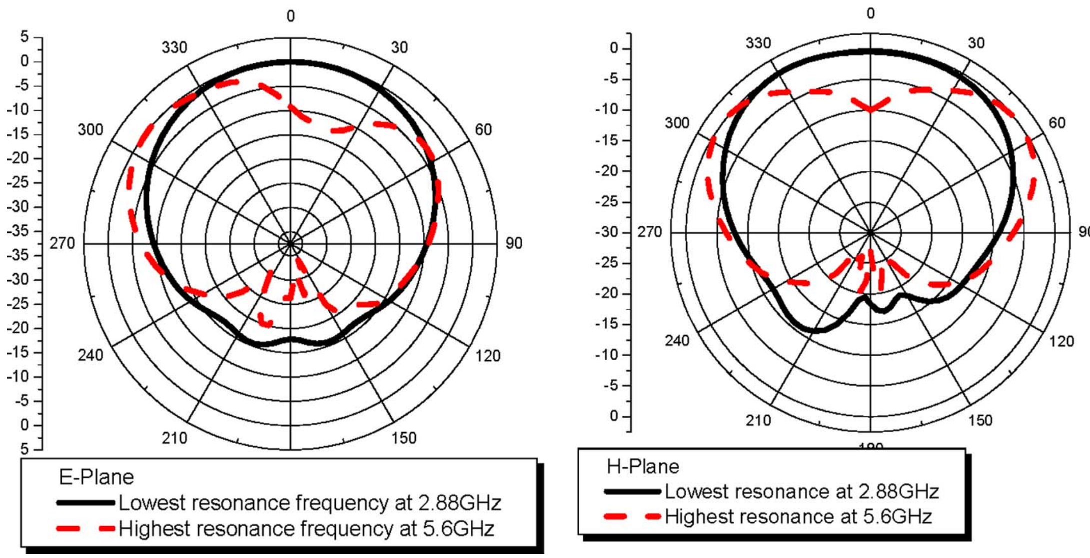

Fig. 4. The simulated radiation pattern at (a) E-plane and (b) H-plane for multiband proposed antenna configuration with six bands of operation at the lowest and highest resonating frequencies.

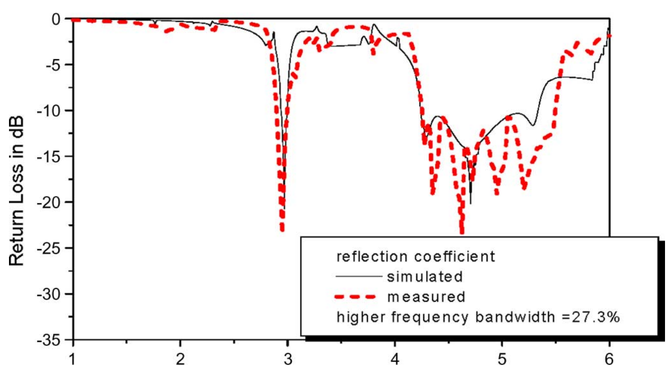

Fig. 5. Comparison between simulated and measured results of the proposed wide bandwidth antenna configuration.

the bandwidth to reach 53% at the same resonating frequency 4.65 GHz. The antenna gain is 10.5 dBi.

IV. Conclusion

A multiband/UWB microstrip antenna configuration is investigated. The antenna is a V-shaped patch with unequal arms coupled to triangular PIFA through a V-shaped slot with unequal arms. The isosceles triangular PIFA is fed by coaxial cable. The antenna is six bands of operation. Two more bands can be added by inserting a V-shaped slot on the triangular PIFA radiating surface. The bandwidths of resonating frequencies are about 4% in average. Simply by moving the feeding point towards the shorting wall, the excited modes are staggered to be near each other, creating a 27% bandwidth. More bandwidth enhancement can be added by folding the shorting wall. UWB behavior is achieved with 53% at same resonating frequency. The antenna gain and radiation pattern are acceptable at almost all bands of operation. Simulations and measurements comparison shows good agreement.

References

[1] P. Salonen, M. Keskilamni, and Kivikoski, "Single-feed dual band planar inverted-F antenna with U-shaped slot," *IEEE Trans. Antennas Propag.*, 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 *Proc. IEEE Int. Symp. Antennas Propag. Dig.*, Jul. 2001, vol. 2, pp. 8–13.

[3] D. P. Li and J. Liang, "Study of printed elliptical/circular slot antenna for ultrawide band application," *IEEE Trans. Antennas Propag.*, vol. 54, pp. 1670–1675, Jun. 2006.

[4] D. Nashaat, H. Elsadek, and H. Ghali, "Dual band reduced size PIFA antenna with U-slot for Bluetooth and WLAN applications," in *IEEE Int. Symp. Antennas Propag. Dig.*, Jun. 2003, vol. 2.

[5] 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 Propag.*, vol. 49, pp. 144–149, Feb. 2001.

[6] Y.-X. Guo, K.-M. Luk, K.-F. Lee, and R. Chair, "A quarter-wave U-shaped patch antenna with two unequal arms for wide band and dual-frequency operation," *IEEE Trans. Antennas Propag.*, vol. 50, pp. 1082–1087, Aug. 2002.

[7] K.-H. Kim and S.-O. Park, "Analysis of the small band-rejected antenna with the parasitic strip for UWB," *IEEE Trans. Antennas Propag.*, vol. 54, pp. 1688–1692, Jun. 2006.

[8] J.-S. Row, "Dual-frequency triangular planar inverted-F antenna," *IEEE Trans. Antennas Propag.*, vol. 53, pp. 874–876, Feb. 2005.

[9] Y. Li, R. Chair, and K. F. Lee, "Broadband triangular patch antenna with a folded shorting wall," *IEEE Antennas Wireless Propag. Lett.*, vol. 3, pp. 189–192, Feb. 2004.