UWB PIFA for simplified transceivers

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Abstract- A planar inverted-F antenna (PIFA) with an input match designed to offer the capability of a front-end bandpass filter in mobile communication transceivers is presented. The proposed antenna is low cost, easily fabricated, and operates in the unlicensed lower band (3.168– 4.752 GHz) of the ultra-wideband (UWB) communication standard with a 3.57:1 VSWR. It is demonstrated that the antenna possesses a radiation pattern with good front-to-back ratio and shows acceptable impedance matching in proximity to large ground planes making it suitable for applications such as in-vehicle communications.

Introduction: Planar inverted-F antennas (PIFAs) are well suited for integration with portable wireless equipment and hidden in-car wireless systems. Ultra-wideband (UWB) technology is of global interest in modern communication systems owing to its potential to deliver high data rates with multipath immunity at low power and low cost [1]. The deployment of UWB inside vehicles can provide mobility and connectivity to a host of passenger devices while significantly reducing the costs associated with wiring. Vehicle chasses typically contain large steel plates and antennas over ground planes are favoured for ceiling mounts [2].

A novel UWB PIFA incorporating two shorting posts with coupling gaps is presented in this Letter. The antenna operates at the lower UWB band (3.168–4.752 GHz) with a 3.57:1 VSWR and has a tailored impedance bandwidth and roll-off comparable to a standard front-end bandpass filter (BPF). To bring down unit cost, there has been a drive to simplify the hardware of UWB systems [3], and hardware could be further reduced by the adoption of the UWB PIFA proposed here, because the commonly deployed front-end BPFs would not be required. Additionally, the elimination of the BPF with its associated insertion loss could offer power savings from the battery.

Antenna design structure: Fig. 1 depicts the geometry of the UWB PIFA antenna. It consists of two planes, an etched upper layer (A) and a bottom ground (B) separated by an air substrate (ε_r ~1). The A and B planes are capacitively coupled via the two pairs of pins (a and a’ and b and b’) as shown in Fig. 1. The dimensions of both posts a and b are $2.9 \times 2.9 \times 2.9$ mm^3 while posts a’ and b’ are $2.9 \times 2.9 \times 1.45$ mm^3. Coupling between planes A and B is achieved across the gaps in the posts. The antenna is fed at the upper plane A using the inner core (0.51 mm) of a 50 V rigid coax cable with a total diameter of 2.16 mm and 62 mm length. The outer shield of the cable is attached to a grounding strip, D, electrically connected to B. The total volume of the antenna is $19.58 \times 15.75 \times 5.53$ mm^3. The maximum dimension is smaller than 0.21l at the lowest frequency of operation.

UWB PIFA operation: The concept of etching slots in monopole UWB antennas to produce band notches has previously been reported, e.g. [4]. This Letter reports a similar technique applied to a PIFA to obtain a bandpass filter characteristic. To illustrate the effect of the design modifications made here, comparison is made between the newly proposed antenna and a similar reference PIFA not containing the capacitively coupled posts (a and b). In a simulated parametric variation study using Zeland IE3D, the capacitive gap size d was varied in steps of 0.2 mm. The results are given in Table 1. Decreasing d tended to improve the band-notch depth and impedance roll-off. An optimum length value of a = b = 2.9 mm and, a' = b' = 1.45 mm was found to give a band-notch at 5.5 GHz, a return loss (RL) of 25 dB, roll-off of 0.18 and 0.03 dB/MHz and a 25 dB S_{11} fractional bandwidth of 40%. The optimal value of d corresponds to 1.18 mm. The reflection coefficient of the proposed antenna is shown in Fig. 2 compared to a standard front-end BPF [5]. The commercially available BPF has a passband rejection of 2441 MHz with an S_{21} of approximately 2 dB. The proposed antenna shows a 3.168– 4.860 GHz bandwidth and a frequency roll-off of 0.024 and 0.030 dB/MHz for the lower and upper bands, respectively. Compared to the commercially available BPF, the proposed antenna has a lower 1108 MHz passband rejection and improves the roll-offs to 0.024 and 0.030 dB/ MHz as opposed to 0.050 and 0.031 dB/MHz which were measured for the BPF. If the bandpass filter and its associated mismatch loss of 2 dB were removed, then the return loss of the antenna can be relaxed from 10 to 5 dB and there will still be an overall reduction in loss of 0.8 dB. The measured 5 dB return loss bandwidth of the proposed PIFA is 42.15% for the 3.168–4.860 GHz FCC ultra-wideband (UWB).

Table 1: Results

Frequency (GHz)	Bandwidth (%)	Lower roll-off (dB/MHz)	Upper roll-offs (dB/MHz)
Reference PIFA	29.88	0.068	0.027
Reference PIFA with single post (a)	28.75	0.068	0.028
Reference PIFA with double post (a + b)	40.17	0.178	0.028
Parametric 1 (d = 5.28 mm)	56.31	0.054	0.022
Parametric 2 (d = 4.08 mm)	55.48	0.062	0.021
Parametric 3 (d = 3.08 mm)	56.25	0.058	0.021
Parametric 4 (d = 2.28 mm)	54.99	0.061	0.023
Parametric 5 (d = 1.68 mm)	52.80	0.015	0.028
Parametric 6 (d = 1.28 mm)	51.23	0.068	0.029
Parametric 7 (d = 1.18 mm)	40.17	0.178	0.028

Compared to the reference PIFA, Table 1, the new antenna has similar roll-offs and an improved BW of 951 MHz for RELSP 25 dB return loss bandwidth. The final band-notch is improved by 4.48 dB at 5.5 GHz. Therefore, adjusting the gap capacitance of the electrically unconnected shorting posts allows a BPF-like characteristic to be defined.

To investigate the effect of attaching the antenna to a large conducting plate in a car chassis, a larger ground plane (E) of dimensions 510 × 800 × 0.75 mm^3 was placed a quarter wavelength below the PIFA. Fig. 2 shows the S11 curve for the proposed PIFA over the large plane E and little effect can be seen compared to the UWB PIFA without the extra ground. This makes the antenna suitable for in-vehicle applications where large ground planes may be present. Selected measured far-field radiation patterns in polar form are depicted in Fig. 3 for the PIFA and for the PIFA mounted on the large ground plane, E. The patterns are essentially directional, presenting a 1208 half power beam-width and 1.33/1 front-to-back ratio in the H-azimuth plane and similar value for the E-elevation. When the large plane E was added, the beam-width and the front-to-back ratio are, respectively, 1208 and 1.53/1. The measured gains of 7.11 and 2.35 dBi were obtained with and without the E plane present. Antenna efficiency including input match and radiation efficiency were simulated to be 80 and 95%, respectively.

Conclusion: A novel compact, efficient, directional UWB PIFA with a bandpass filter characteristic is presented. The antenna potentially eliminates the need for the front-end filter devices within transceivers leading to a more compact system.
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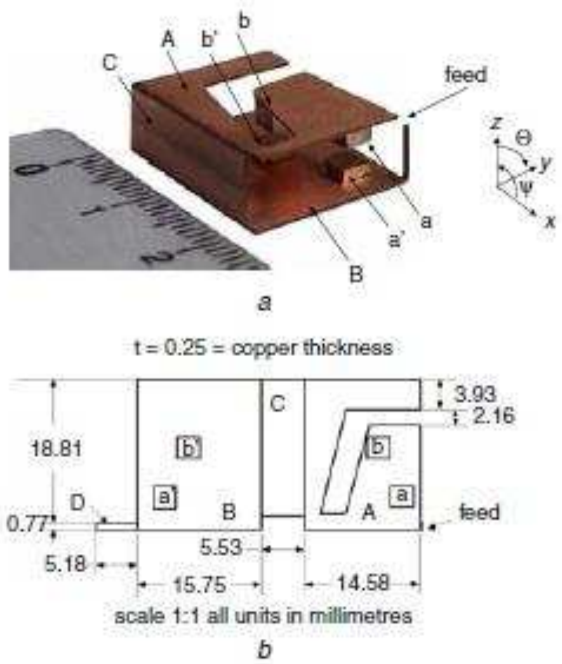

Fig. 1 *Geometry of proposed PIFA*

a Isometrical view
b Unfolded planar view of conductors

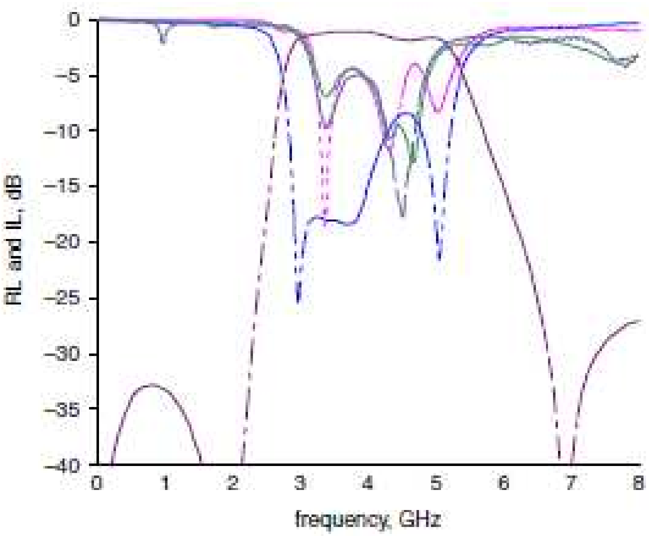

Fig. 2 *PIFA and BPF comparison*

- - - - simulated reflection coefficient (S11) PIFA
—— measured reflection coefficient (S11) PIFA
– – – measured reflection coefficient (S11) PIFA with E plane
– ·· – measured reflection coefficient (S11) BPF
– · – measured insertion coefficient (S21) BPF

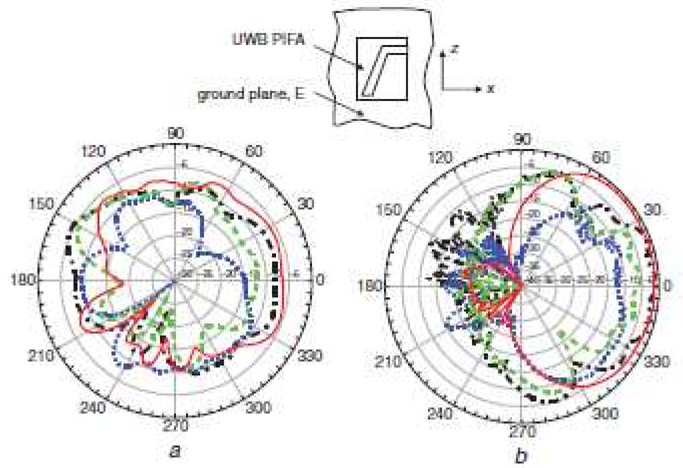

Fig. 3 *Radiation patterns*

a Proposed PIFA
b PIFA with large ground plane E
—— co-polarisation, azimuth, *y-z* plane 4.752 GHz
- - - - co-polarisation, elevation, *x-z* plane 4.752 GHz
...... cross-polarisation, azimuth, *y-z* plane 4.752 GHz
– · – cross-polarisation, elevation, *x-z* plane 4.752 GHz