Design of a Planar Inverted F Compact Dual Frequency Antenna for Mobile, Wireless and Automotive Applications

A compact (Planar Inverted F Antenna) for wireless, mobile, and automotive applications was designed with full wave simulation software.

By Pasquale Dottorato

Abstract

A compact PIFA (Planar Inverted F Antenna) for wireless, mobile and automotive applications was designed with full wave simulation software. Size reduction of the antenna was achieved through an increase in the path length of the currents for a fixed frequency. Finally, a comparison was made between a non-compact PIFA with a compacted PIFA.

The development of wireless technologies and mobile communications has included considerable research on the production of small, easily adaptable, low cost antennas. One such device, the PIFA (Planar Inverted F Antenna), is widely used in mobile, automotive and wireless communications. The advantage of using this type of antenna in wireless communications is its small size, low profile, and avoidance of additional matching networks.

Thanks to its compact design, the PIFA has recently been developed for multiband applications. For the model investigated, shown in Figure 1, there were two main objectives: one that uses two electromagnetic paths to generate two separate resonant modes; the other offers the two first resonant frequencies of a single electromagnetic path. In the first a slot of variable shape (L or U, in the figure) or two inductive or capacitive resonators is employed. In the second we add just the resonance frequencies of the first two modes in a manner such that their relationship is about 2. In this case appropriately dimensioned gaps are implemented.

II. Design of the Antenna

II.1 Layout of the PIFA

Figure 1 shows a patch with a slot to the U shaped antenna. There is a central patch of the original size, $L_1 \times W_1$, and a smaller patch of size $L_2 \times W_2$ operating in the 1800 MHz band from lower frequency f_1, to the highest, f_2. For this type of PIFA we can be determine d approximately by:

$$f_1 \cong \frac{c}{4(L_1 + W_1)}$$

$$f_2 \cong \frac{c}{4(L_2 + W_2)}$$

where c is the speed light in free space: $c = 3 \times 10^8$ m/s. These two equations make it simple to achieve the requirements of the dual-frequency PIFA.

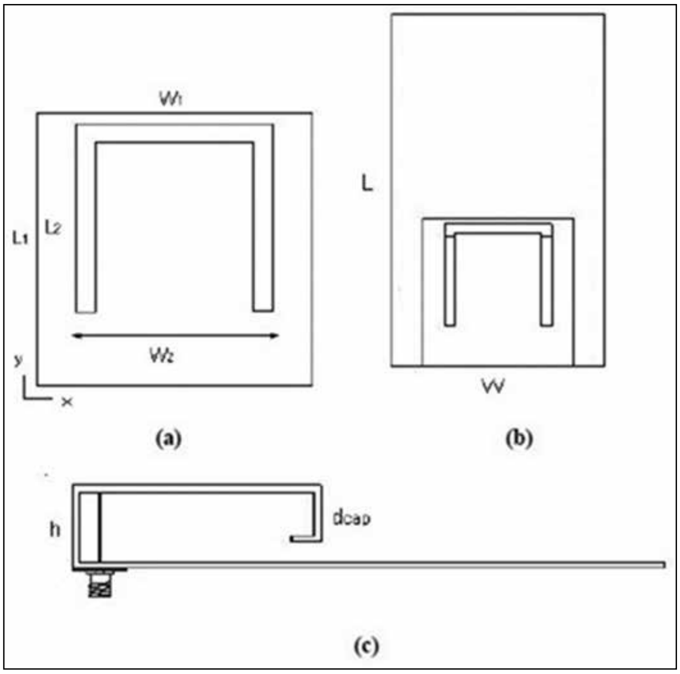

Figure 1 • (a) Patch Top Layer of the PIFA, (b) Top View of the PIFA, (c) Side Profile of the PIFA.

Figure 1 shows the geometry of the antenna. As you can see in Figure 2 (a), the upper radiating patch is inserted into a slot in the U for the purpose of obtaining a dual-frequency operation that uses two resonant paths for the currents induced from the feed, in order to generate two separate operating modes. Specifically, the resonant frequency for the lowest band is dictated substantially by the size of the patch and is only partly affected by the slot, while the resonance frequency for the higher band is dictated mainly the size of the slot to U. The dimensions of the patch are higher (W_1, L_1) = (42, 42) mm, while the dimensions of the U-shaped slot are (W_2, L_2) = (30.28,7.00) mm, the ground plane has dimensions (W, L) = (60,100) mm. The antenna is fed to the base of the line as shown in Figure 1(c), at a distance (30, 2) mm from the origin of the axes. The antenna height is h = 12.90 mm. The capacitive load is formed by bending the upper patch to the ground plane for a DCAP distance = 9.4mm and adding to this a line (5mm long), parallel to the ground plane. The shorting wall is 12.90mm wide and 42mm high. The antenna is inserted at the center of the ground plane at a distance (9.0) mm from the origin of axes. The entire structure was fabricated using a thickness of 1 mm for both ground planes, both for patch and the shorting wall. The slot in the shorting wall (shown in Figure 2) consists of two parts: one, with U-shape, has a height h_1 = 8.4 mm and a width w_1 = 28 mm; the other part, however, is formed by two smaller slots (of height h_2 = 1mm and width w2 = 14.5mm), which are merged with the larger slot in order to form a single opening (as shown in figure 2).

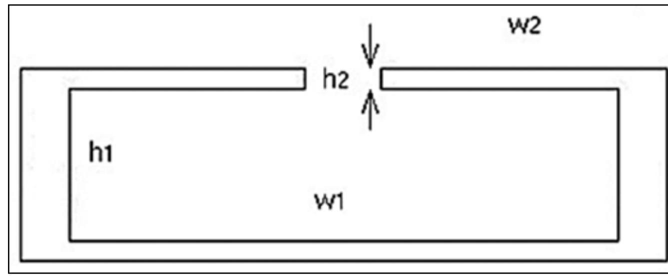

Figure 2 • Slot Inside the Shorting Wall with h1 = 8.4mm, w1 = 28mm, 1mm and h2 = w2 = 14.5mm.

II.2 Design Features

The antenna proposed in the previous section was simulated with commercial full wave simulation software. It is designed to work at frequencies 900/1800 MHz bands, respectively, for GSM / DCS. Figure 3 shows the reflection coefficient of the antenna. The antenna resonates very well at the frequencies of interest, in fact for f_1 = 0.9 GHz has that S_{11} = 29. 21 dB, while for f_2 = 1.8 GHz is obtained by a coefficient of reflection of S_{11} = 29. 8 dB. Figure 4(a) and Figure 4(b) shows the impedance input in its real part and imaginary part. Matching the antenna to an input impedance of 50Ω is obtained by controlling the distance between the shorting wall and the feed point. For f_1 = 0.9 GHz has an impedance of (51.96 + j2.97) Ω, while for the second frequency resonance has an impedance of (52.99 + j0.89) Ω. The bandwidth, calculated for a 2:1 VSWR, is 3.7% with a range of frequencies of 34 MHz, from 880 MHz to 914 MHz for f_1 = 900 MHz, whereas for f_2 = 1800 MHz, has a bandwidth of 3% with a range of frequencies of 55 MHz, from 1774 MHz to 1829 MHz. The size reduction antenna is obtained at the expense of bandwidth, which is quite close to that actually required for systems cellular communication GSM/DCS, respectively 70 MHz (890-960 MHz) and 170 MHz (1710-1880 MHz) for GSM and DCS. A disadvantage of the PIFA, in fact, is the bandwidth reduction evident due to the presence of capacitive load. Figure 5 shows the current distributions for both the working frequencies. It should be noted that in order to adapt the antenna to an impedance of 50Ω it is necessary to bring the RF feed wire to the shorting wall, where the currents are concentrated. Indeed, the presence of the slot in the shorting wall causes a concentration of currents in that direction, especially at a frequency of 0.9 GHz. In Figure 5 it can be noted that the frequency resonance for the lowest band is dictated by the size of the slot inside the wall the shorting patch square, while the resonance frequency for the higher band is dictated mainly from the smaller size (those of the U-shaped slot). In Figure 6 the radiation patterns of three-dimensional components of θ and φ for the two frequencies of interest are shown (cases 1 ab for f_1 = 0.9 GHz, cd cases for f_2 = 1.8 GHz). A directivity of 4.514 dB is obtained for the first frequency (f_1), while for

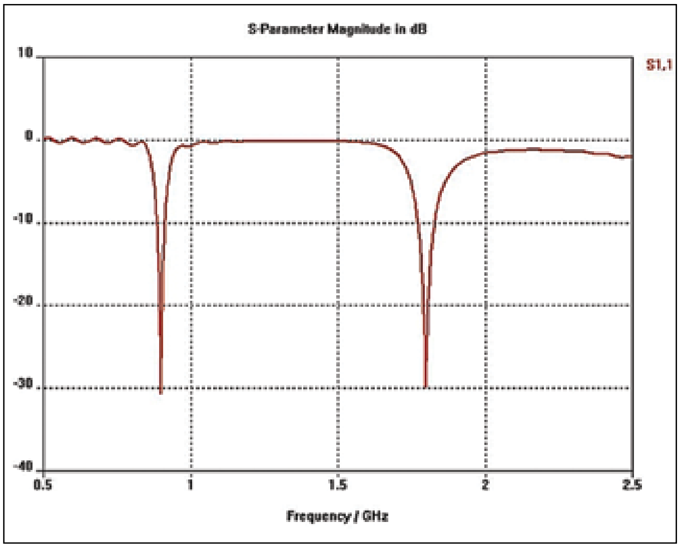

Figure 3 • Simulated Reflection Coefficient of the PIFA.

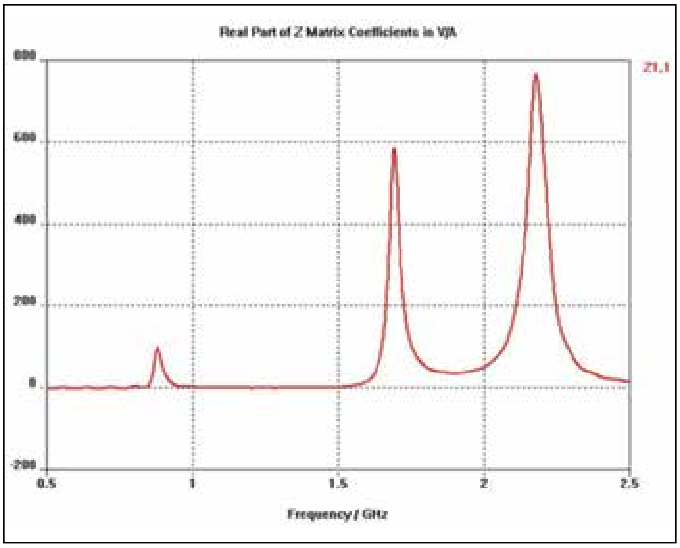

Figure 4(a) • Simulated Real Part of the PIFA's Impedance.

the second frequency of interest (f_2), the directivity is 5.271 dB.

II.3 Comparison with the Non-Compacted PIFA

Since the purpose of this work has been the realization of compact dual frequency planar antenna for mobile applications, it is interesting to compare between the two devices, compact vs. non-compacted. Starting with an antenna that occupies a volume of 40×67×12.90 mm^3, we arrived at an antenna with a volume of 42×42×12.90 mm^3, thus obtaining a reduction of the size of 34.17%, maintaining the same antenna height h (h = 12.90 mm) and the same plane mass (60×100 mm^2). Naturally the PIFA is compacted principally as a result of the slot in the wall and shorting the capacitive load, but because the antenna is designed entirely in free space, it is easily realized with the addition of these two changes. Compared to the initial case, the feed point shifted to the shorting wall in order to adapt the input impedance to 50Ω, since it has a greater intensity of current due to the insertion of the slot. The reduction of antenna size also causes a decrease of the width of band compared to the case of non-compacted PIFA. For the lower frequency (f = 900 MHz) it has gone from a bandwidth of 4.6% to a bandwidth of 3.7%, while for the higher frequency band (f = 1800 MHz), reduction is from 3.3% to 3%. This bandwidth reduction is probably due to the presence of the capacitive load. Figure 8 shows the two antennas viewed from above. Size reduction of the second antenna compared to the first is clearly visible.

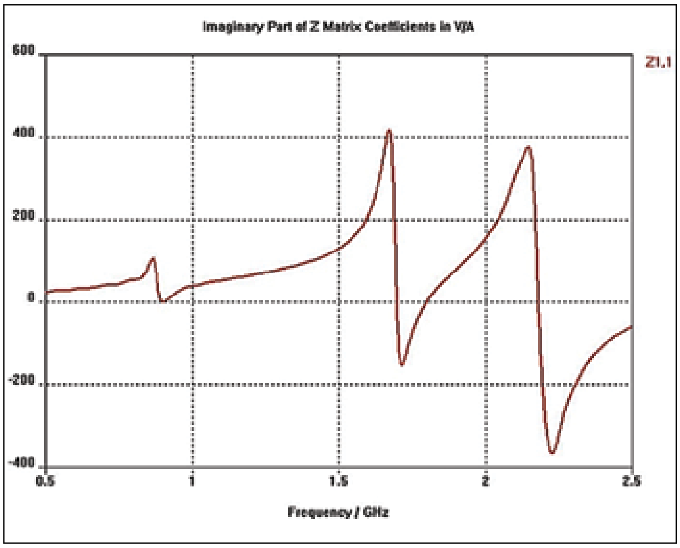

Figure 4(b) • Simulated Imaginary Part of the PIFA's Impedance.

PIFA in Automotive Applications

The growing demand for compact and multi-band antennas has been seen in the automotive sector. Indeed functionality and aesthetics play a very important role in this market. Modern automobiles are designed to have every kind of comfort and technology, such as for example; GPS, internal telephone, television, radio, and bluetooth. That is why there is a necessity to have antennas that are multifunctional, not visible and very small to meet aesthetic requirements. The antenna described in this paper has also been designed for automotive applications. Car roofs are often the ideal location for antennas. In fact, since the roof is very large compared to the compact PIFA, it can be considered as infinite ground plane for the antenna. Inserting the PIFA in the center of a ground plane of dimensions 5λ × 5λ, was simulated. The behavior is the same as if it were on the roof of an automobile.

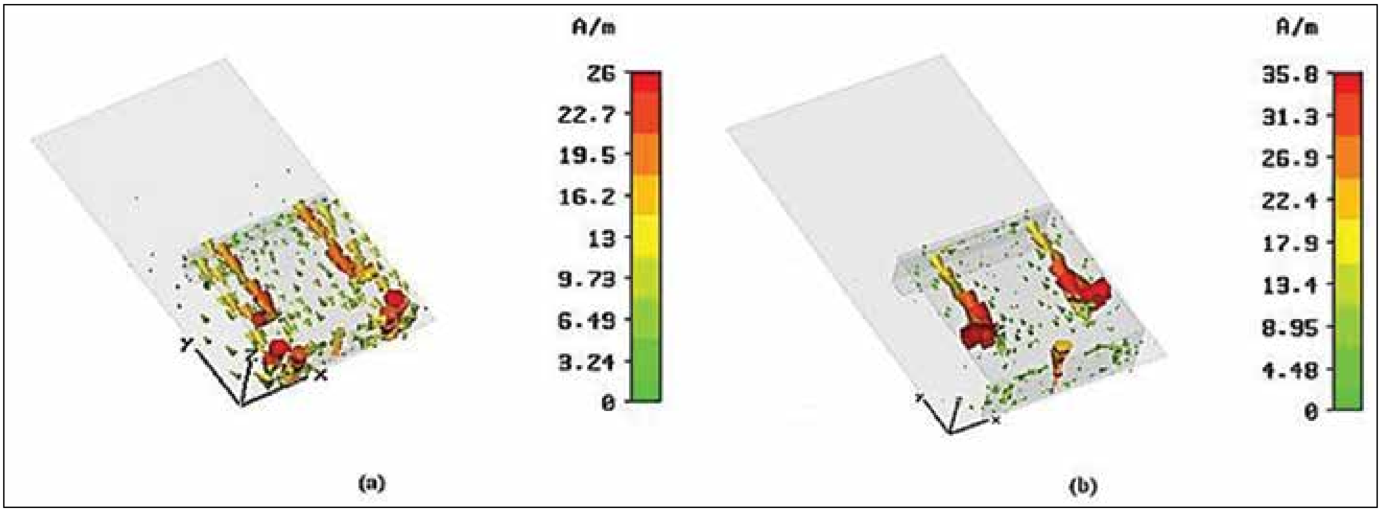

Figure 5 • Current Distribution for (a) F = 900 MHz (b) F = 1800 MHz.

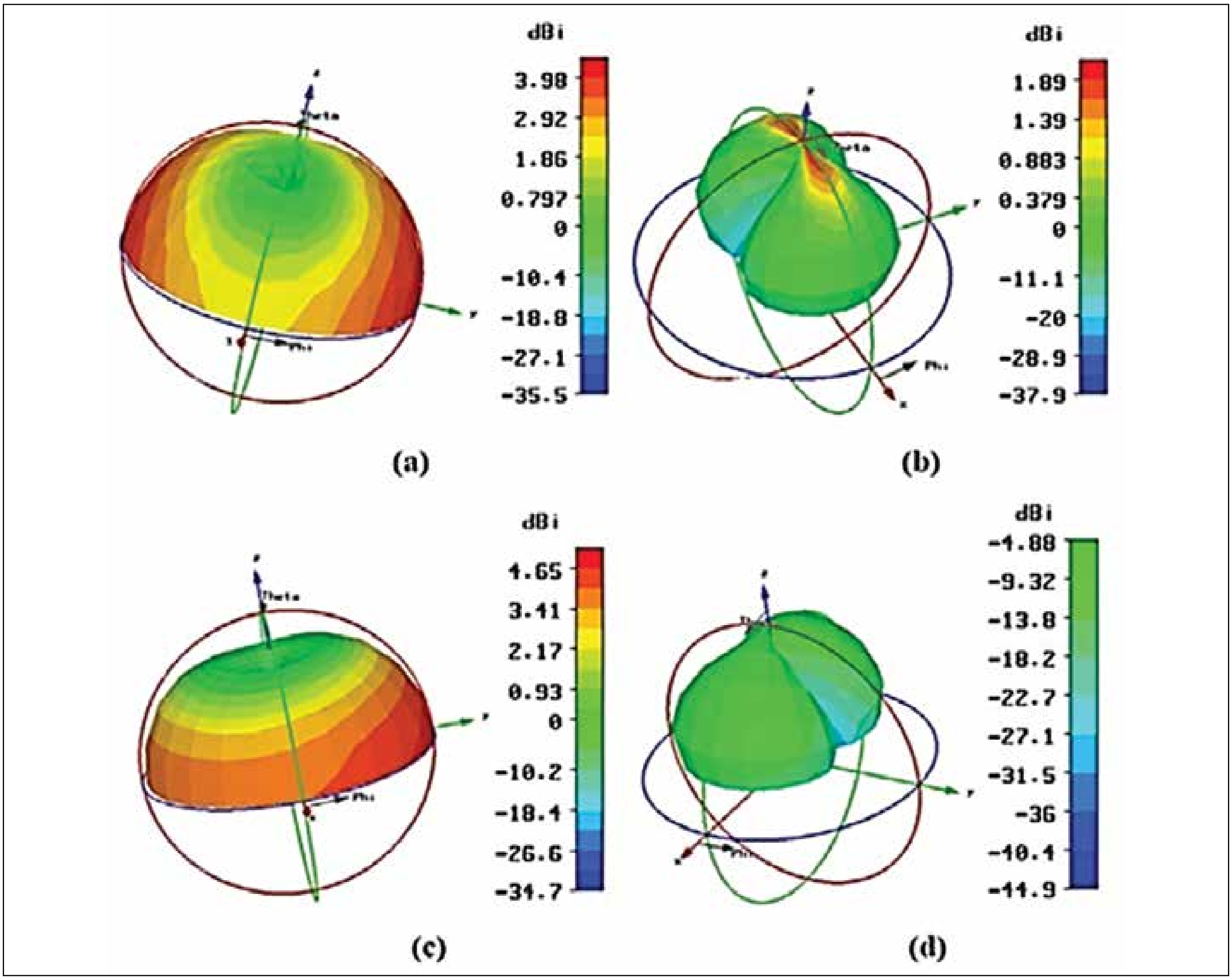

Figure 6 • Radiation Pattern (a) component θ for F = 900 MHz, (b) φ component for F = 900 MHz, (c) component θ for F = 1800 MHz, (d) φ component for F = 1800 MHz.

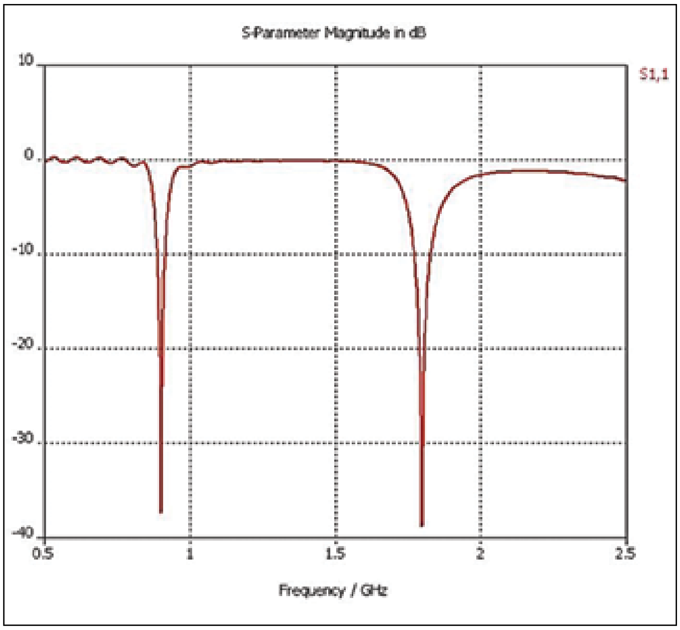

Figure 7 • Reflection Coefficient for the Compact Dual-Frequency PIFA with Infinite Ground Plane.

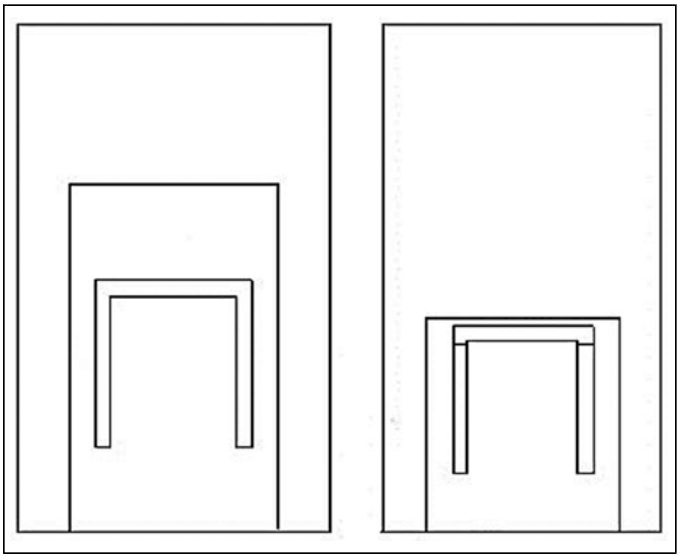

Figure 8 • The Two Antennas Viewed from Above: On the Right the Compact PIFA, On the Left Non Compact PIFA.

Figure 9 shows the reflection coefficient of the antenna. An excellent reflection coefficient of 37.3 dB is achieved for f = 0.904 GHz, while for f = 1.8 GHz it has S_{11} = 38.72 dB. The bandwidth hardly decreases. It has a bandwidth of 24.8 MHz at f = 904 MHz, while for f =1.8 GHz a bandwidth of 52 MHz is achieved. The radiation patterns are very similar to those shown in Figure 7.

IV. Conclusion

The purpose of this article was to design a compact antenna dual frequency for mobile applications. The antenna used for the project is Planar Inverted-F Antenna (PIFA). It has characteristics that correspond to those required by the market today, that is: simplicity of realization, low cost and small size. The techniques used to compacting the dual-frequency PIFA are the inclusion of a capacitive load and the insertion of a slot within the shorting wall. The two techniques together allow lowering of the resonant frequency with a consequent decrease in the size of the antenna. The compacted PIFA was sacrificed a small percentage bandwidth on the two working frequencies (900 MHz and 1800 MHz). The future development of this project could be to modify the geometry of the PIFA to regain bandwidth, such as increasing the height h antenna, or studying alternative profiles to the slot provided on the shorting wall.

About the Author:

Pasquale Dottorato received his BSEE and PhD degrees from University of Naples, Italy, with a dissertation on measuring the electromagnetic characteristics of anisotropic material and information retrieval due to dispersion and non-linear media. Dr. Dottorato followed that with experience at IRECE and the electronics and telecommunication departments at the university level, continuing in the design of microwave equipment for defense electronics in Rome. Since July 2005 Pasquale has worked in the R&D department of an electronics company in Bologna, Italy. His interests include inverse electromagnetic problems, the design of antennas, phased array antennas and microwave devices; the design of passive RFID transponders; and numerical modeling and simulations of signal and system electromagnetics.

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