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# A Compact PIFA Suitable for Dual Frequency 900/1800MHz Operation †

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*Abstract*

Planar Inverted F Antennas (PIFA) have been proposed as possible candidates for mobile telephone handsets. In this letter we describe the design of a compact PIFA suitable for operation at 900MHz. In addition we provide modifications to this design that allow it to operate in dual frequency bands at 900MHz and 1800MHz. FDTD and experimental results are provided.

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## I. Introduction

Mobile telephone antennas that can be integrated into the handset offer several advantages compared to conventional external antennas such as monopoles or helix [1], [2], [3], [4]. They are less easily broken off, reduce power absorption by the head and are less sensitive to the geometry of the handset. A suitable candidate for an integrated antenna is the planar inverted-F antenna (PIFA) but it is still considered too large for applications at 900 MHz. Additionally in many parts of the world mobile telephone systems have been allocated spectrum centered around both 900MHz (cellular systems) and 1800MHz (Personal communication systems) with the corresponding demand that mobile telephones operate in both bands.

Here we investigate the design of an integrated compact antenna suitable for mobile telephones operating at 900MHz. We also describe a modification to this design that allows it to be used at dual frequencies in the 900MHz and 1800MHz mobile telephone bands.

## II. The Antenna Structure

The geometry we utilize is illustrated in figure 1. Features of the design include a slot, capacitive load, capacitive feed and also an offset short post as illustrated. A dielectric layer with low permittivity ($\epsilon = 2.1$) is also utilized between the top and ground plates. The resonant frequency is controlled by the size of the capacitive load ($d_{cap}, w_{cap}$), the slot length and width ($l_s, w_s$), and the overall dimensions of the antenna ($l_{pifa}, w_{pifa}$).

To include the effect of the mobile telephone circuit components we mount the PIFA onto the end of a printed circuit board with dimensions of $(128, 35)mm$. The plastic handset casing has not been considered but the effect of this is generally to reduce the resonant frequency by approximately 5% [1].

## III. Analysis and Results

To understand the operation of our design we begin with a conventional PIFA (the capacitive load, capacitive feed and slot structures are removed), using air dielectric, with dimensions of $(l_{pifa}, w_{pifa}) = (25, 26)mm$, height, $h_{pifa} = 4mm$ in which the short post is located at $d_{short} = 13mm$ and the coax feed is connected directly to the top plate. The resultant resonant frequency from finite–difference time–domain (FDTD) simulations is 2.2GHz. To this conventional PIFA design we add, in turn, the offset feed, capacitive load, capacitive feed, slot and dielectric to determine their effect.

By offsetting the short post to $d_{short} = 5mm$ the resonant frequency is decreased to 1.95 GHz. By adding a capacitive load to the design we can reduce the resonant frequency by any desired amount at the expense of operating bandwidth [4]. Here we add an equivalent capacitance equal to $C = \frac{A}{d}\epsilon = 0.5pF$ to the end of the conventional PIFA, using plates $w_{cap} = 4mm$ with separation $d_{cap} = 2mm$, and insert a capacitive feed $l_{cf} = 13mm$ (its width is the same as $w_{pifa}$) with separation $d_{cf} = 2mm$ to provide a good match at 50Ω. The resulting resonant frequency is 1.64 GHz.

To further decrease the resonant frequency, a slot is cut into the antenna, so the top plate current flows around the slot, creating an electrically longer antenna. For every 5mm increase in slot length the resonant frequency approximately decreases by 3%. If a slot of dimensions, $(l_s, w_s) = (24, 1)mm$, is placed along the center of the antenna ($d_s = 12mm$), the resonant frequency is reduced to 1.4 GHz. Finally, to allow easier construction, a low–loss dielectric material ($\epsilon = 2.1$) is placed between the top and ground planes resulting in a resonant frequency of 940 MHz.

Experimental results are provided in figure 2, where a bandwidth ($VSWR < 2.0$) of 7% can be observed. Comparison with FDTD simulations reveal that the simulations accurately predict the resonant frequency and degree of match but underestimates the bandwidth.

## IV. Dual Frequency Antenna Design

By modifying the PIFA design described in sections II and III it is possible to produce a dual frequency PIFA operating at both 900 and 1800 MHz with the same overall dimensions. The dual frequency modification utilizes a dual feed on the assumption that receivers with dual front ends will become popular and readily available [5].

The geometry for the dual frequency PIFA is provided in figure 3. In the modification we have confined the feed plate so that it does not cross the slot, so that the length and width of the feed plate are $13mm$ and $10mm$ respectively. The effect of this is to decrease the input impedance, as demonstrated in [4], [6], so that the bandwidth for which we can achieve a good impedance match is reduced. No change in resonant frequency occurs. By then removing a section of top plate from the end of the antenna, $l_d > 0$ (see figure 3) we find that we can make space for another PIFA operating at 1800MHz in a similar manner as described in [3]. For every $5mm$ of top plate removed (i.e. $l_d$ increases by $5mm$) the resonant frequency of the original PIFA increases by approximately 2%. By removing enough top plate we can then insert another PIFA, fed separately, with top plate dimensions $l_d = 23mm$ that is resonant at 1800MHz. A capacitive feed plate is also employed for matching the second PIFA and its length and width are $20mm$ and $13mm$ respectively.

In general the resonant frequency for the lower band is controlled by the capacitive load, the slot, and the physical dimensions of the antenna; whereas, the resonant frequency of the upper band is controlled by only the physical dimensions of the inserted antenna.

Experimental and FDTD results have been obtained. The resonant frequencies of the dual band antenna are 910 MHz and 1790 MHz. The upper band has better performance characteristics with a bandwidth of 8% as illustrated in figure 4. The bandwidth of the lower frequency element is 5% with a frequency range of 40 MHz from 890 to 930 MHz.

## V. Conclusions

A PIFA with a slot and a capacitive load is introduced. Using overall antenna dimensions of $(25, 26)mm$ with a height of 4mm a compact antenna with a bandwidth of 7% operating at 940MHz results. By removing part of the top plate and inserting another PIFA, a dual–fed dual–band antenna is also constructed. This antenna resonates in the 900 MHz and 1800 MHz bands, potentially suitable for both cellular and PCS operation.

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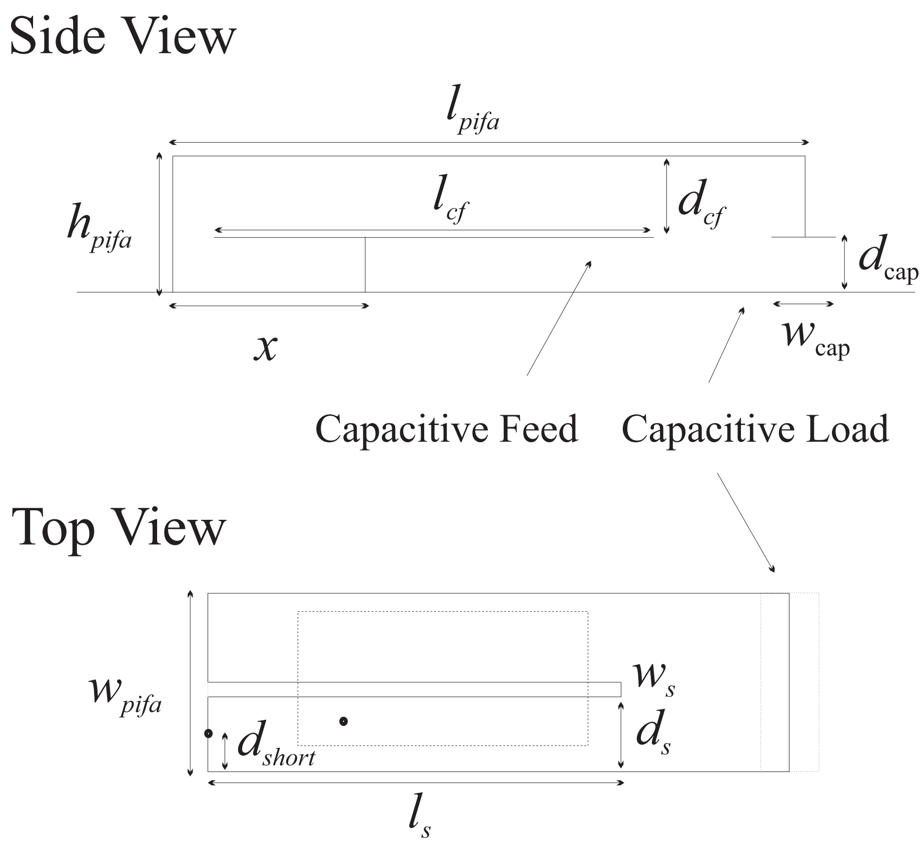


Fig. 1. Top and side views of the single frequency antenna structure. In our design $(l_{pifa}, w_{pifa}) = (25, 26)mm$, $h_{pifa} = 4mm$, $w_{cap} = 4mm$, $d_{cap} = 2mm$, $l_{cf} = 13mm$, $d_{cf} = 2mm$, $d_{short} = 5mm$, $(l_s, w_s) = (24, 1)mm$ and $d_s = 12mm$.

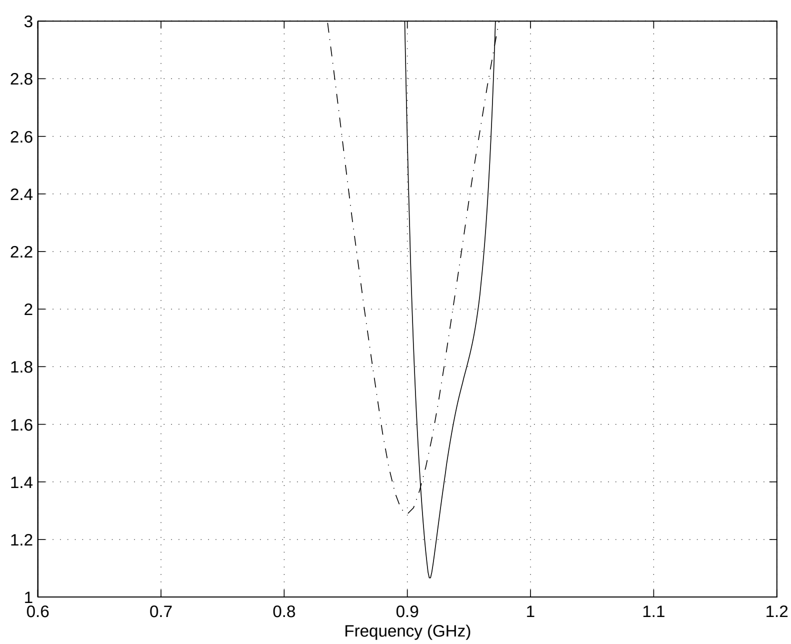


Fig. 2. VSWR Curves for single band antenna. The solid line is the FDTD simulation results and the dashed line represents the experimental results.

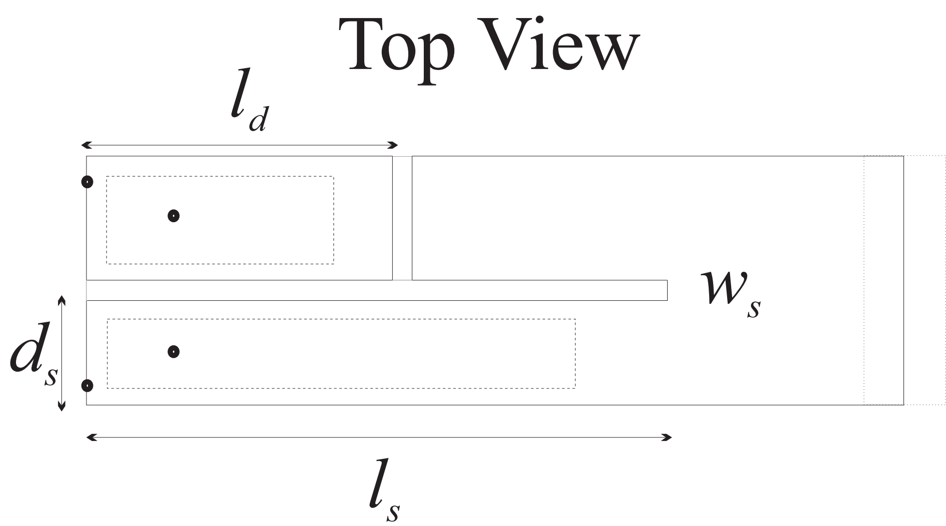


Fig. 3. The top view of the dual-feed dual-frequency antenna. In our design $l_d = 23mm$, $(l_s, w_s) = (24, 1)mm$ and $d_s = 12mm$. Otherwise the overall dimensions and side view are the same as illustrated in figure 1.

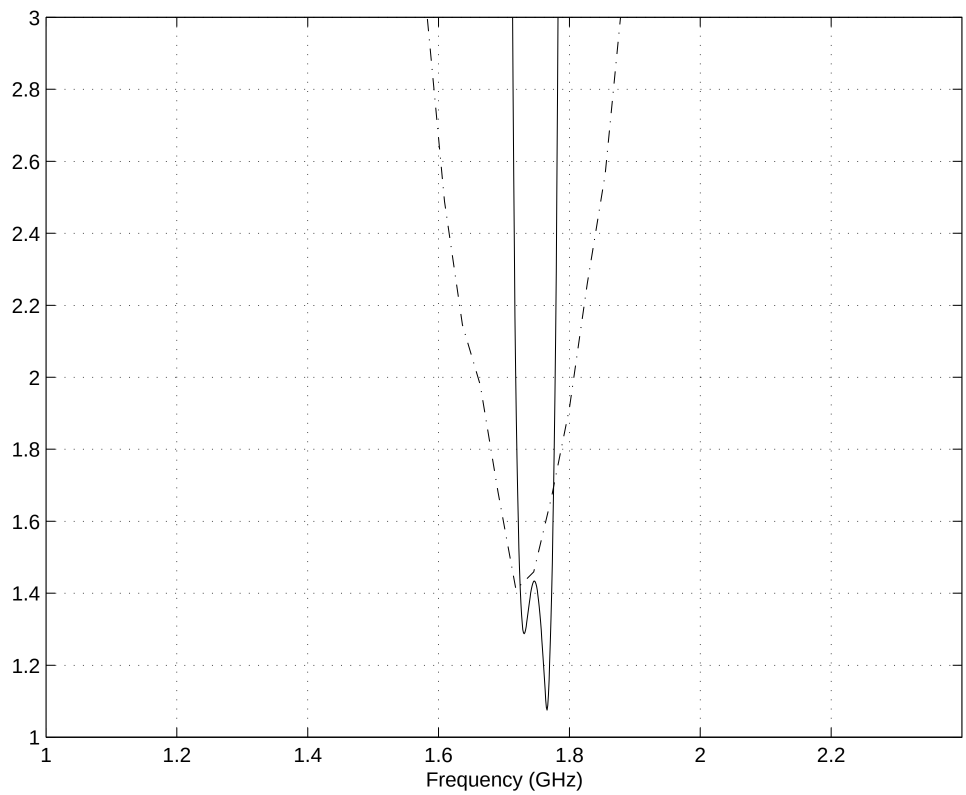


Fig. 4. VSWR Curves for dual band antenna. The solid line is the FDTD simulation results and the dashed line represents the experimental results.