Design of Folded and Slotted Internal Antenna for 3G IMT-2000 Mobile Handsets

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ABSTRACT

A four-sided folded, slotted and shorted rectangular patch antenna for 3G mobile handsets is described. The antenna provides a 17.65% bandwidth at S_{11} < -10 dB from 1885 MHz to 2250 MHz, which completely encompasses the desired UMTS frequency band (1920-2170 MHz). The proposed antenna is minimised to a volume of 30 × 30 × 6 mm, which is about 0.2 wavelengths at the centre frequency 2045MHz, while the height from the antenna to the ground plane is about $\lambda/15$ at the centre frequency (10mm). The experimental and simulated results on a finite ground plane show good agreement. The effect of varying key geometry parameters of the proposed antenna is also discussed.

INTRODUCTION

Evolving mobile communication systems require increasing bandwidth: for 3G UMTS it is 12.2% (1920 to 2170MHz) [1, 2]. However, there is a constant requirement for smaller and lighter internal antennas, which are immune to damage and cause low SAR (specific absorption rate) [3-10]. Due to the limited volume and the influence of the plastic case, the design of internal antennas is challenging. Bandwidth enhancement is a particular problem: the use of thicker substrate with low permittivity, multiple resonances, and modifying and optimizing the geometry of the antenna have been proposed and investigated [2,8,11-13]. Alternatively, by implementing high permittivity substrate, shorting pins and altering the geometry of the internal antennas, the size can be minimized, but bandwidth may fall [3,4,14,15].

In this paper, a new four-side folded, slotted and shorted rectangular patch antenna is introduced for 3G mobile handsets. It provides a bandwidth (return loss ≤ -10 dB) of 17.65% (1885 to 2250 MHz) which completely covers the desired band. By fully utilizing the limited projection area on the top edge of a ground plane of 40×100 mm, the proposed antenna can be minimized to a volume of 30×30×6 mm which is about 0.2 wavelengths of the centre frequency, while the height from the antenna to the ground plane is about 0.07 wavelengths (10mm). All of the analysis of the antenna was conducted using the FEMLAB commercial FEM (finite element method) software package [16].

ANTENNA STRUCTURE

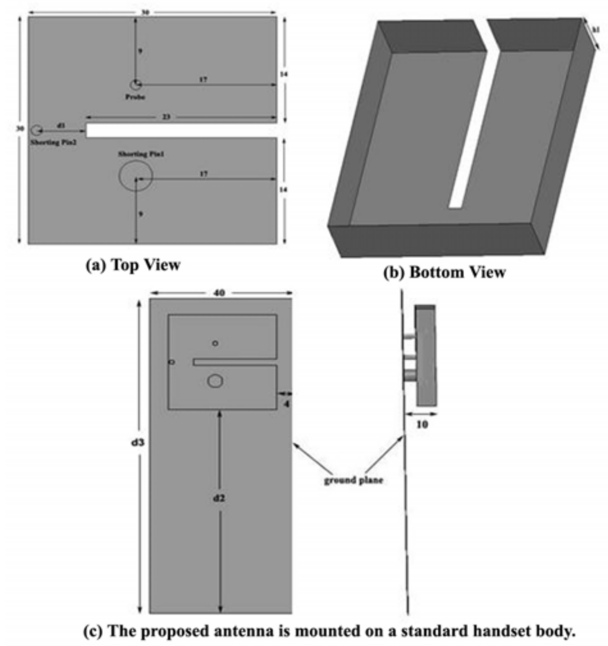
The proposed antenna (Figs.1 & 2) is very similar to that in [7], which was used as the starting point of this work. However, the proposed antenna must operate on a standard mobile handset ground plane, while that in [7] works on an infinite ground. The proposed antenna is a four-folded edge and slotted rectangular antenna with dimensions of 30×30mm, while the slot has variable dimensions 2mm×d1 and the variable height for the four-folded edge is h1. Fig 1c shows the location of the proposed antenna when mounted on a finite ground plane of size (40×d3×2) mm. As can be observed, the proposed antenna is located at (d3-d2-30) mm from the top edge of the finite ground plane in order to prevent the user's hand from causing deterioration of the performance. The distance from the antenna to the ground plane is about 10mm. Since the impedance bandwidth is strongly related to the volume of the radiating patch, four folded edges are implemented in this design in order to broaden the bandwidth. By pin-shorting the proposed antenna, its physical length is halved, for a given operating frequency.

Table 1: List of proposed antenna and finite ground plane parameters and symbols (See Fig.1).

Fixed parameters (mm)		**Variable parameters (mm)**
Antenna length = 30	Antenna width = 30	Position of shorting pin2 = d1 (initial = 25)
Ground length = 100	Ground width = 40	Distance to the top edge of ground =d2 (initial = 65)
Slot width = 2	Slot length = 23	Ground plane length = d3 (initial = 100)
Radius of shorting pin2 = 0.65		folded edge height = h1 (initial= 6)
Height from the antenna to ground = 10		Radius of shorting pin1 = r1 (initial= 2)

PARAMETRIC STUDY RESULTS

The fixed and variable parameters are listed in Table1, where the variable parameters are considered as critical parameters in determining the lowest frequency of the operating bandwidth. In present study, the variable parameters d1, d2, d3, h1 and r1 were initially set to be 25 mm, 65mm, 100mm, 6mm and 2 mm respectively.



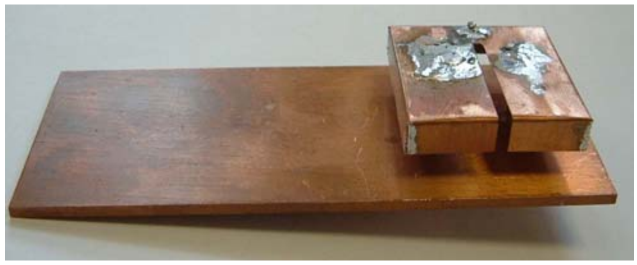


Fig 2 (above): Practical realisation of the proposed antenna

Fig1 (left): Geometry of the proposed antenna:
(a) Top view. (b) Bottom view. (c) Integration into a handset body.

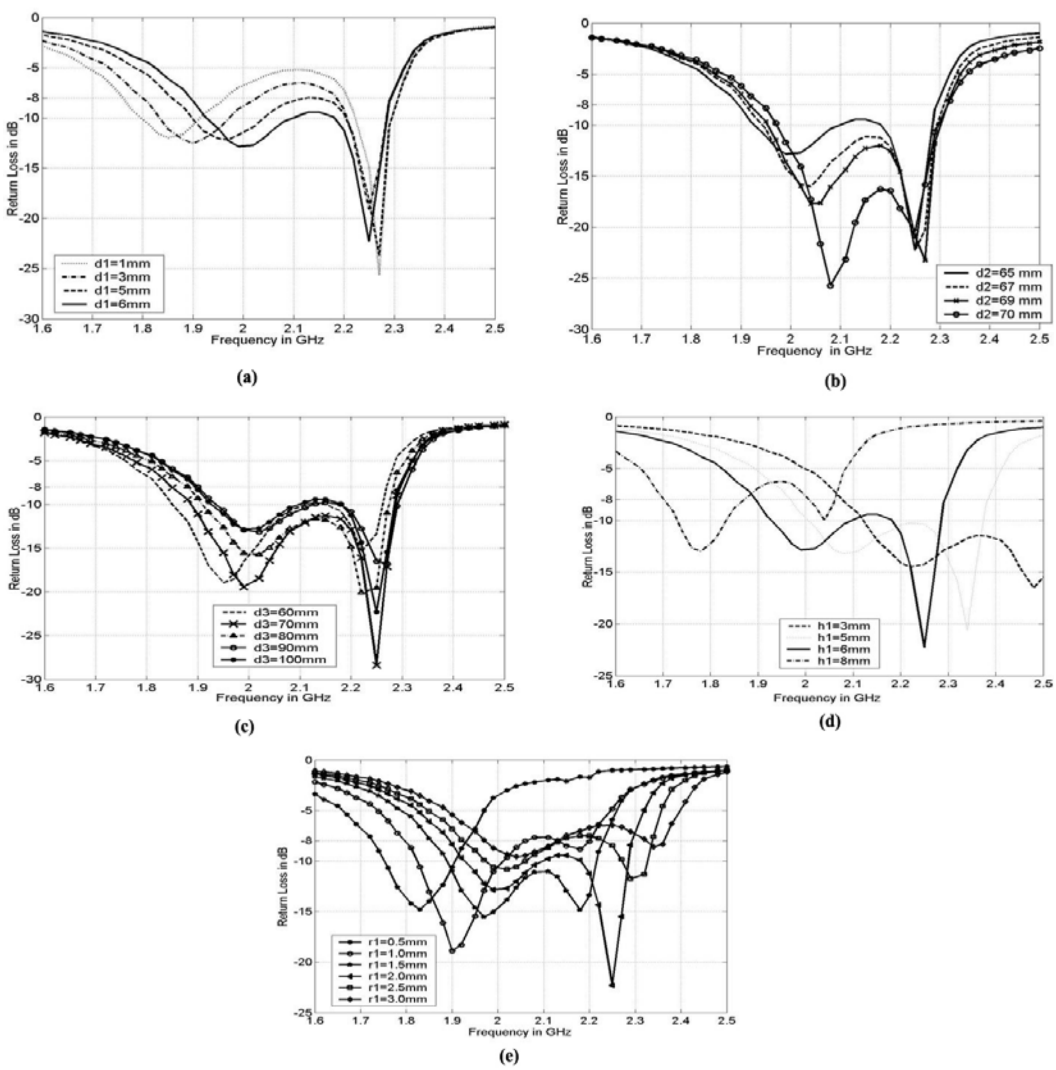


Fig. 3: Simulated return losses with variation of several parameters:
(a) d1. (b) d2.
(c) d3. (d) h1.
(e) r1

The impedance bandwidth will be the main target to be optimized throughout the parametric study (defined at return loss S11 <-8dB). Each simulation is run with only one parameter varied, while other parameters stay invariant. Fig. 3(a) illustrates the effect of the parameter d1 on the bandwidth. As can be seen, with d1 less than 5mm, the desired UMTS band cannot be fully covered. However, with increase of d1 from 5mm to 6mm, the degree of the impedance matching improves and fully covers the UMTS band. Fig. 3(b) shows the influence of the parameter d2 on the bandwidth. When the antenna is mounted closer to the top edge of the ground plane, d2 is increased from 65mm to 70mm, the impedance bandwidth decreases from 19.2% (1.88 to 2.28 GHz) to 16.4% (1.95 to 2.3GHz). The effect of the parameter d3 (which is identical to the length of the ground plane) against the bandwidth is shown in Fig. 3(c). By varying the d3 from 60mm to 100mm, it lowers the resonant frequency band and keeps the UMTS band unchanged.

The tuning effect on the parameter h1, which is the height of the edge, against the bandwidth is depicted in Fig. 3(d). With the increase of h1 from 3mm to 6mm, the frequency band from 2.07 to 2.65 GHz will be shifted to 1.9 to 2.3GHz, which fully covers the UMTS band. Further elongation of h1 to 8mm will impair the impedance matching over the desired UMTS band. The effect of varying the parameter r1 is elaborated in Fig. 3(e). By changing the radius of the shorting pin 1, from 0.5 mm to 2.0 mm, the impedance bandwidth can be increased from 10.93% (1.73 to1.93 GHz) to 20.1% (1.88 to 2.3GHz). A further increase in the radius r1 to 3.0mm will reduce the bandwidth to 18% (1.97 to 2.36 GHz).

COMPUTATIONAL AND EXPERIMENTAL RESULTS

Fig. 4 shows the typical measured and computed antenna performance in term of impedance bandwidth. Two adjacent resonant frequencies in the range of return loss ≤-10 dB are observed, i.e., 1.95GHz and 2.2 GHz. The impedance bandwidth of the proposed antenna, determined from a -10dB return loss, is 0.365 GHz or about 17.65% with respect to the centre frequency at 2.068 GHz (average of measured lower and higher frequencies with a -10dB return loss). The impedance bandwidth (return loss ≤ -10dB) is 17.65% from 1.88 GHz to 2.25 GHz, which fully covers the frequency spectrum of 3G IMT-2000. According to Fig.4, the proposed antenna can be identified as a ground-dependent antenna, due to it having a large variation of the impedance bandwidth when mounted on an infinite ground plane.

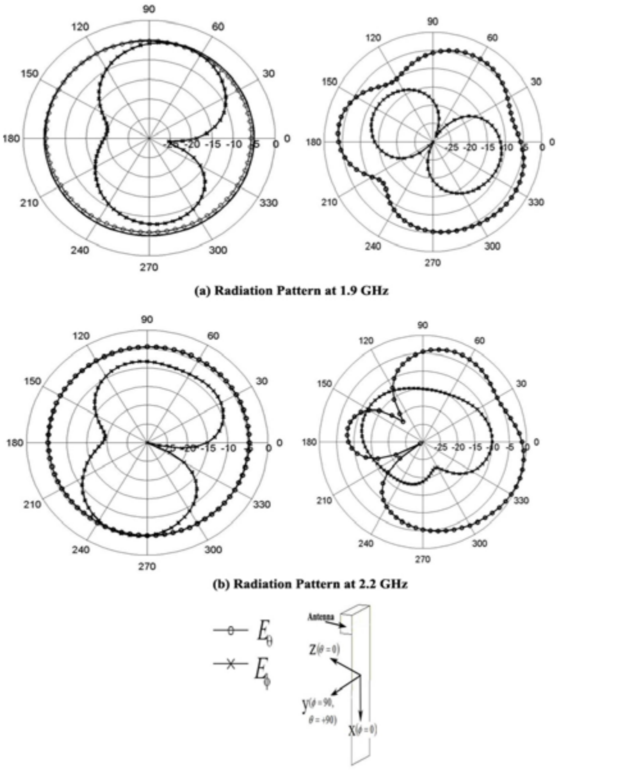


Fig: 5 (left). Computed radiation pattern of the proposed antenna for two planes (left: xy plane, right: xz plane) at (a) 1.9 GHz (b) 2.2 GHz

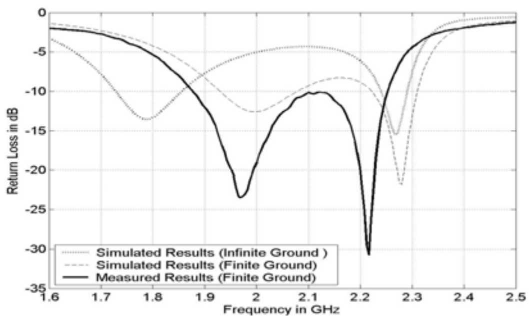


Fig.4: Return loss of the proposed antenna

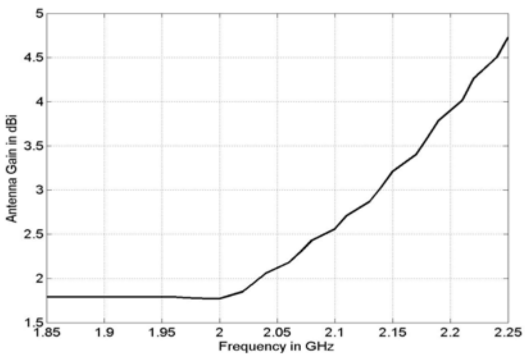


Fig. 6: Calculated antenna gain against frequency across the UMTS band

Fig 2 shows the experimental prototype of the proposed antenna with finite ground plane of 40 ×100 mm, where d1=25 mm, d2 = 67 mm, d3 = 100 mm, h1 = 6 mm and r1 = 2 mm; a thin copper sheet of thickness 0.07 mm was used to prototype this antenna.

The far-field radiation characteristics of the proposed antenna were also investigated. As can be seen in Fig.5, the simulated results show that the radiation patterns (E_ϕ and E_θ) at 1.9 and 2.2 GHz operating frequencies show the same general polarization planes and similar radiation patterns. The calculated antenna gain in the broadside direction of the antenna is also illustrated in Fig.6. From 1.85 to 2 GHz, the antenna gain has a constant value of 1.75dBi, while from 2 to 2.25 the antenna gain increases quasi-linearly up to 4.7dBi.

CONCLUSION

The design and analysis of a low profile folded and slotted microstrip-type antenna for third generation mobile handsets was presented. By careful shaping of a slot and folded edges, it was possible to achieve a very large bandwidth for an antenna of this type (nearly 18%), while maintaining compact size and good pattern behaviour. The proposed antenna was simulated on a finite and infinite ground plane and two different impedance bandwidth behaviours were obtained. When the antenna was mounted on a finite ground, since the finite ground plane resonates at a neighbouring frequency to the antenna, it contributes to the broadening of the bandwidth of the antenna. By contrary, with infinite ground the resultant resonance was eliminated and thus the bandwidth was decreased. This led to the conclusion that it is necessary to utilize the whole metallic structure of the handset to obtain the required bandwidth.

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