# A NOVEL DUAL-FREQUENCY MICROSTIP PATCH ANTENNA FOR IMT2000 MOBILE HANDSETS

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A compact and novel dual-frequency microstrip patch antenna for IMT2000 mobile handsets is described. Two shorted semi-discs couple together to give a wide impedance bandwidth with a small size. Impedance behavior, radiation pattern, and frequency agility of the proposed antenna are introduced.

**Introduction**:
The International Telecommunication Union (ITU) has been in the process of developing family-standard for the future third generation (3G) mobile cellular system, namely IMT2000 (International Mobile Telecommunications 2000), which will support voice, data, and multimedia services. A common air interface as well as frequency spectrum allocation globally will continue to remain an issue. As the third generation cellular is moving from development into trials and implementation, some countries of interest have allocated radio spectrum for the IMT2000. [1].

For example, Japan and Europe have allocated radio spectrum for 3G mobile services as follows:
Japan Downlink 2110-2200MHz, Uplink 1920-2025MHz
Europe Downlink 2110-2200MHz, Uplink 1900-2025MHz
In North America, service providers are intending to provide 3G mobile services in the PCS1900 band:
Downlink 1930-1990MHz, Uplink 1850-1910MHz
Generally, 3G handset antennas will be required to satisfy the frequency bandwidth in the range of uplink 1885-2025MHz and downlink 2110-2200MHz, with the impedance bandwidths of 7.2% and 4.2%, respectively.

The mobile handset requirements of small size, thin profile, light weight, low cost and low SAR (specific absorption ratio) can be achieved using a microstrip patch antenna (MPA), particularly when dual-frequency operation is needed.

In this paper, a novel design of double-semi-disc patch antenna with a wide SWR bandwidth is presented. It consists of two semi-discs of different radii, with a shorting-pin in each element and parasitically coupled each other along the diameter edges. Only one single probe-feed is incorporated to the semi-disc of the larger radius. This new structure shows frequency-agility and a wide impedance bandwidth, which will be suitable for the future IMT2000 mobile handsets.

**Antenna and Theory**:
Short-circuited microstrip patch antennas (MPAs), say PIFAs [2], have been widely used as internal mobile handset antennas. They provide some advantages over conventional external whip and helical antennas in terms of increased efficiency, decreased SAR towards the operator, and increased robustness. However, the main disadvantage is their narrow impedance bandwidth, which limits their applications. It is demanding to design a compact, low profile and integrated mobile handset antenna with high radiation efficiency and wide bandwidth.

Normally, there are two main kinds of bandwidth enhancement techniques, namely the bandwidth enhancement technique for antenna elements and arrays, and the frequency-agility improvement technique for antennas operating over several adjacent resonant frequencies [3], or multi-frequency operation.

There have been numerous antenna element designs and variations proposed for bandwidth enhancement [3]. Typically, they can be categorized into three main methods: by impedance matching method, using multiple resonance method, and by reducing the effective permittivity of substrates.

A substantial amount of effort has also been devoted to increase the frequency-agility of MPAs. One potion is to make the antennas operate at two adjacent resonant frequencies, or, dual-frequency operation [4]. The typical techniques for dual-frequency operation can be subdivided into three categories, i.e., 1) orthogonal-mode dual-frequency MPAs, 2) using multiple resonance method, and 3) reactively-loaded dual-frequency MPAs.

Here, both dual-frequency technique by the use of multiple resonance and size-reducing method by the aid of shorting-pins [5 – 8] are incorporated to one double-semi-disc probe-fed MPA to achieve wide bandwidth dual-frequency operation with a compact overall size.

**Design and Results**:

The antenna consists of a driven semi-disc of radius $R_1$ with a single shorting-pin, a parasitically coupled semi-disc of smaller radius $R_2$ with a shorting-pin, and one probe-feed in the larger semi-disc. The two co-planar semi-discs are placed above the common ground plane with several spacers and are electrically coupled along the respective diameter edge, with airgap thickness of t, as depicted in Fig.1. The shorting-pin of each semi-disc is located on the centerline of each semi-disc, while the probe-feed point is selected between the two shorting-pins. Our design simulation suggested that the coupling-gap between the diameter edges of each semi-disc should be large enough to reduce the influence of the input impedance at the two resonant frequencies. In addition, the input impedance at the two resonances is dependent on the relative position of the two shorting-pins and probe-feed.

In our design, the following parameters were chosen to achieve the dual-frequency operation.

Airgap thickness: t10mm; radii of the semi-discs: $R_1$ 19.8mm and $R_2$ 17mm; coupling-gap: $\Delta$ 8.0mm; shorting-pins positions: ( $x_{s1}$ -16mm, 0) and ( $x_{s2}$ 20mm, 0); radii of shorting-pins: $r_{s1}$ 1.2mm and $r_{s2}$ 0.7mm; probe-feed position: ( $x_p$ -5.6mm, 0); radius of the probe-feed: $r_p$ 1.6mm.

Initially, it is essential to control the coupling gap between the two semi-discs, and relative positions between the probe-feed point and shorting-pins, for the input impedance optimizing. The coupling depends on the distance away from the radiating diameter edge of the driven element, while the shorting-pin position will affect the input impedance. A parasitic semi-disc of smaller radius is incorporated to resonate at a lower frequency near the main resonant frequency, which is excited by the larger semi-disc. The lower resonant frequency may be excited by both the semi-discs.

The antenna operates at two discrete resonant frequencies, that is, 1.76GHz and 2.16GHz, with SWR (<2:1) bandwidths of 6.5% and 22.2%, respectively, as shown in Fig.2 (a). The input impedance and far-field radiation pattern are plotted in Fig.2 (b & c).

It is noted that the return losses of the frequencies between the two resonances are slightly larger than –10dB in Fig.2 (a), It may be possible to make these two resonant frequencies closer to each other so as to achieve broader impedance bandwidth. This can be fulfilled by adjusting some parameters above. As a result, a wider overall bandwidth of 27.6% are observed, as shown in Fig.3, where dual-frequency operation still exist. In this case, the resonant frequencies are shifted to 1.83GHz and 2.14GHz, respectively, and the return losses of the frequencies between the two resonant frequencies are lower than –10dB. The modified parameters are listed below,

Airgap thickness: t10mm; radii of the semi-discs: $R_1$ 19.8mm and $R_2$ 16mm; coupling-gap: $\Delta$ 8.0mm; shorting-pins positions: ( $x_{s1}$ -15mm, 0) and ( $x_{s2}$ 20mm, 0); radii of shorting-pins: $r_{s1}$ 1.2mm and $r_{s2}$ 0.7mm; probe-feed position: ( $x_p$ -5.6mm, 0); radius of the probe-feed: $r_p$ 1.6mm.

Moreover, it is interesting to modify the parameters further and we can see the lower resonance will decline gradually to give wider bandwidth of 24.9% for the higher resonant frequency. The radius of the smaller semi-disc has been reduced to 15mm, whereas the other parameters remain unchanged as in the above case. This is a typical example of obtaining broader bandwidth by use of a parasitic radiating element. The corresponding return loss, input impedance, and radiation pattern are plotted in Fig.4.

The described antenna is the simplest example of a double-semi-disc shorted MPA. It shall be noted that it will be possible to achieve more compact internal antennas by reducing the airgap thickness at the expense of impedance bandwidth.

**Conclusions**:

A novel and compact dual-frequency double-semi-disc MPA with shorting-pins has been presented. The antenna has a small size, novel radiating shape, and wide impedance bandwidth. The radiation pattern and impedance bandwidth are acceptable for internal antennas. The proposed double-semi-disc MPA will be suitable for the IMT2000 mobile handset antennas.

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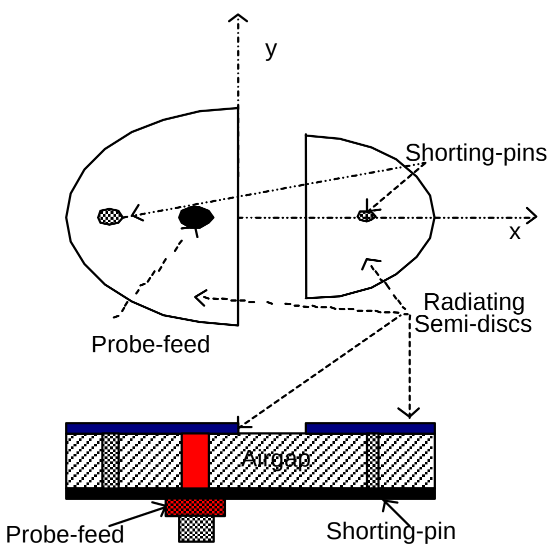
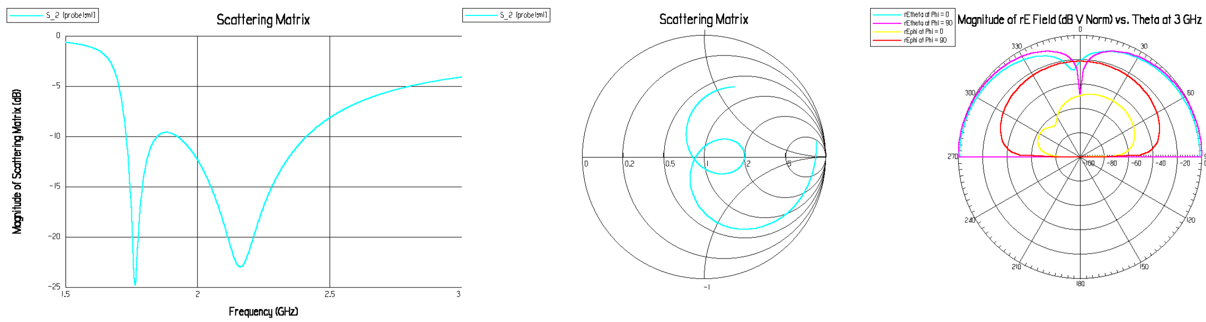



**(a),** Top-view

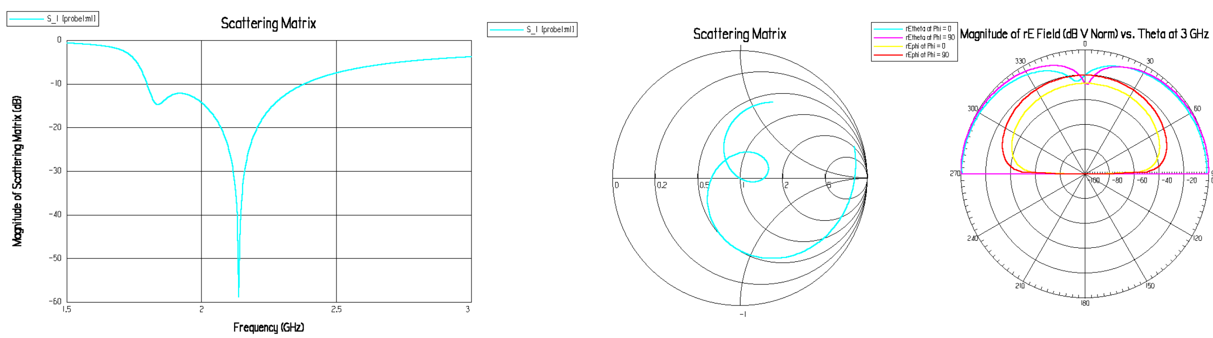
**(b),** Side-view

**Fig.1,** Geometry of the Double-semi-disc Shorted MPA



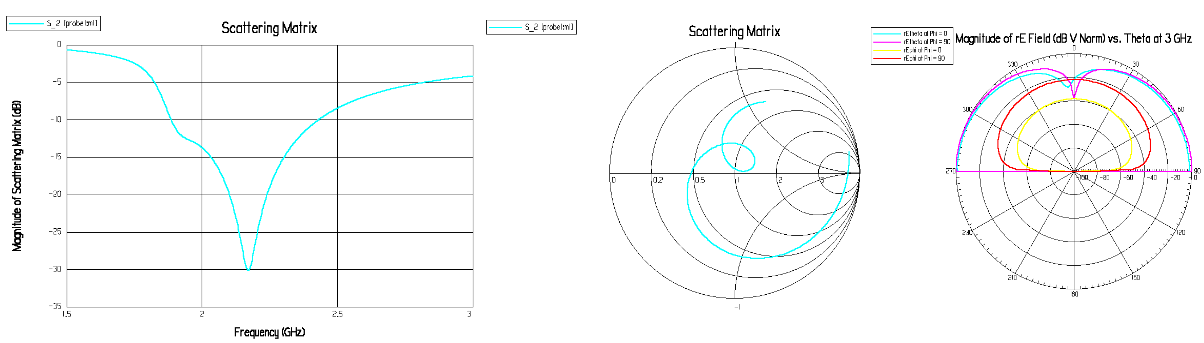

**a.** Return Loss **b.** Input Impedance **c.** Radiation Pattern

**Fig.2**. Return Loss, Input Impedance, and Radiation Pattern of the MPA operating at dual-frequency




**a.** Return Loss **b.** Input Impedance **c.** Radiation Pattern

**Fig.3**. Return Loss, Input Impedance, and Radiation Pattern of the MPA for IMT2000 Handsets




**a.** Return Loss **b.** Input Impedance **c.** Radiation Pattern

**Fig.4**. Return Loss, Input Impedance, and Radiation Pattern of the MPA Degrading into a Single-frequency