Feasibility of a triple mode, low SAR material coated antenna for mobile handsets

This item was submitted to Loughborough University’s Institutional Repository by the/ an author.

Citation: KITRA, M.I. ... et al (2005). Feasibility of a triple mode, low SAR material coated antenna for mobile handsets. IN: Proceedings of Loughborough Antennas and Propagation Conference, Loughborough University, Loughborough, April

Additional Information:

- This is a conference paper

Metadata Record: https://dspace.lboro.ac.uk/2134/2964

Publisher: © Loughborough University

Please cite the published version.
This item was submitted to Loughborough’s Institutional Repository by the author and is made available under the following Creative Commons Licence conditions.

For the full text of this licence, please go to:
http://creativecommons.org/licenses/by-nc-nd/2.5/
FEASIBILITY OF A TRIPLE MODE, LOW-SAR MATERIAL COATED ANTENNA FOR MOBILE HANDSETS

CMCR, Electronic & Electrical Engineering, Loughborough University, UK

Abstract
It has been previously established that material loaded monopoles having equal
permittivity and permeability values, give increased bandwidth and radiation
efficiency for a given size reduction. Very low Specific Absorption Rates (SAR) have
been obtained by orthogonally positioning the antenna towards the head. Recent
results obtained from a TLM simulator indicate the antenna’s capability to operate in
dual mode. In this present paper various designs are researched, in order to preserve
and translate the antenna features into a more compact embedded version. A final
design solution is presented with the addition of metal strips, confirming the
realisation of a small, triple-band, low-SAR handset antenna.

1. Introduction
The rapid development of wireless communications has resulted in the escalating need
of handset manufacturers to cover several operational bands with a single antenna. At
the same time, there is continued interest in further reducing the size of the antenna
and its Specific Absorption Rate (SAR) whilst maintaining a good efficiency.
The use of ceramic materials provides a useful means of compacting the antenna but
the bandwidth and efficiency can be significantly reduced. It has recently been
demonstrated [1] that the inclusion of ferrite material can overcome some of the
aforementioned constraints. Broad band versions of material loaded antennas have
been investigated [4] and the effect of the aspect ratio has been determined. In
addition, very low SAR values have been achieved [2] by orienting the antenna
orthogonal to the head.
In this present paper, an attempt is made to incorporate the above design
methodologies into a mobile handset and at the same time create a multi-band
antenna, covering the GSM1800, GSM1900 and Bluetooth bands. The antenna height
is constrained to 1 cm and the various design options involving coupled metal strips
are examined. In conclusion, an optimum design is identified and the implementation
is discussed.

2. Efficiency and bandwidth optimisation
An analytical model based on a ceramic spherical resonator excited by a small wire
probe or loop [1] has initially established the performance benefits of introducing
permeability into dielectric resonator antennas. The generality of the benefits [2, 3]
has been confirmed by extensive simulation of rectangular and other irregular shapes
using Flomerics Microstrips TLM. The efficiency and bandwidth are maximised for
any particular mode when the permeability and permittivity are of comparable values.
The additional design freedom introduced with \( \mu_r \) provides more control over the
frequency separation between adjacent modes and hence allows wideband dual mode
operation by coupling together two adjacent modes. The antenna SAR is mainly
dependent on the positioning of the antenna and reduces by an order when the axis of symmetry of the antenna is orthogonal to the head.

The above findings are shown in Figures 1 and 2, which display the efficiency, bandwidth and SAR variations for a cube antenna (side=30mm) sourced by a wire-fed dipole. For each permittivity value, \( \mu_r \) and the monopole length were adjusted to achieve resonance at 1.8GHz. The permeability for maximum efficiency is 3.3. Realistic permeability loss tangents are included which are seen to reduce the efficiency.

Apart from the introduction of permeability, another factor that was found to significantly influence mode coupling was the width to height ratio of the antenna [4]. A rectangular antenna with dimensions 40x20x20mm and a width to height ratio of 0.5 was modelled and compared to the previously simulated 30x30x30mm cube antenna (width to height ratio of 1). As the aspect ratio decreases, the -10dB bandwidth increases by 5%. The efficiency and 10gSAR values are also affected, with the rectangular antenna exhibiting 3.7% increase in efficiency and 12% decrease in 10gSAR. It is concluded that a reduction in the width to height ratio enhances the wideband dual operation and general performance of the antenna but this situation is constrained by the height constraint imposed by the handset space available.

### 3. Handset size constraints

The next step involved the integration of the antenna into the handset, trying to preserve its attributes of high efficiency, broad bandwidth and low-SAR. The necessary dimension reductions presented a lot of constraints, regarding efficiency and the application of broad-banding techniques such as the width to height ratio.

As a starting point to the investigation, it was decided to model a 20x20x10mm rectangular antenna, mounted on a 40x40mm ground plane and fed by a 4.5mm monopole. The antenna was simulated for various ratios of permittivity and permeability and its efficiency and bandwidth response resembled the one of the cube resonator (shown in Figure 1) however their maxima had dropped by 74% and 60% respectively due to the size reduction.

In order to determine the effect of the length of the block, two more rectangular antennas were modelled with dimensions 15x20x10mm and 25x20x10mm. The results for all three resonators are shown in Figure 3. It was concluded that increasing the length resulted in increased efficiency and a slightly decreased bandwidth. Also, for a higher length to height ratio, the minimum \( Q \) shifted to lower \( \varepsilon_r \), \( \mu_r \) values, favouring antenna realisation.

A similar investigation was made for the width of the block and a similar conclusion as above was reached.

Having determined the effect of altering two of the block dimensions, a second mode had to be introduced to get closer to the ultimate aim, of achieving a multi-band handset antenna.

Keeping the height and width of the antenna constant at 10mm and 20mm respectively, a set of simulations was run, with 2mm steps from 15mm to 40mm, to find the length of the antenna that would introduce a second mode near 2.4GHz. It was decided to optimise an antenna with dimensions 32x20x10mm.
4. Triple band antenna

The initial target frequency bands for the handset antenna were the GSM1800 and Bluetooth. The 32x20x10mm block antenna was re-modelled with varying ratios of $\varepsilon_r$ and $\mu_r$, to determine values of permittivity and permeability that would maintain resonance at 1.8GHz and 2.45GHz and also maximum bandwidth at –10dB. Those values were found to be $\varepsilon_r = 6$ and $\mu_r = 8.05$ for $\tan \delta_{\varepsilon\mu} = 0.03$. This resulted in the modes being at the required frequency, however neither of them covered the necessary bandwidth.

In order to achieve that, several design variations were attempted. It was concluded that the addition of wrap-around metallic strips was the most advantageous. Altering the thickness and distance separating the two rings, the resonance of a new mode could be controlled and added a new band. The final antenna design is shown in Figure 4. By tuning $\varepsilon_r$, $\mu_r$ and the monopole length, the antenna covered the GSM1800, GSM1900 and Bluetooth frequency bands at –6dB. The S11 and radiation pattern are shown in Figure 5 and Figure 6 respectively.

5. Specific Absorption Rate

The radiation pattern of the antenna at 1800MHz in Figure 6 is dipole like, as expected. The pattern null is directed towards the head and previous research has indicated that this is the main cause behind minimum radiation absorption by the head.

When the antenna was modelled against a 75mm spherical phantom ($\varepsilon_r = 41, \sigma = 1.65 \text{ Ohm/m}$), the bandwidth remained unchanged, the installed efficiency was 13.9% and the 1g and 10gSAR values were 0.025W/Kg and 0.0176W/Kg respectively. Compared to the SAR values obtained from the cube resonator (Figure 2), they had further reduced. This is mainly attributed to the decreased efficiency of the antenna (12.19%) compared to the efficiency of the cube resonator (50%).

6. Conclusions

* Design methodologies based on previously investigated broad band versions of material loaded antennas, revealed the optimum dimensions for a compact embedded version of the antenna.

* The addition of metal strips and tuning of the antenna parameters led to the realisation of a triple band antenna, covering the GSM1800, GSM1900 and Bluetooth bands. The SAR remains at very low values, due to the preservation of the antenna null towards the head.

* Installation is likely to require some small design parameter adjustments compatible with a given handset ground plane environment.

7. References


The authors acknowledge the contribution of Flomerics and the use of their MicroStripes TLM modelling tool. This work was supported by the UK EPSRC, Grant number GR/R94596/01.

Figure 1 – Efficiency and BW for cube resonator

Figure 2 – 10gSAR variation for cube resonator

Figure 3 – Efficiency and BW for diff. lengths

Figure 4 – Tri-band Antenna design

Figure 5 – S11 graph of tri-band antenna

Figure 6 – Pattern cuts of tri-band antenna