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FEASIBILITY OF A TRIPLE MODE, LOW-SAR MATERIAL COATED ANTENNA FOR MOBILE HANDSETS

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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 Microstripes 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 ($\varepsilon_r = 41, \sigma = 1.65$ 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**


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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