A Miniature Dielectric Loaded Antenna with Low SAR

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Abstract

This paper introduces a novel antenna type suitable for mobile telephones. The simulation and measured results are presented. Also a Specific Absorption Rate evaluation for this type of antennas is included.

I. Introduction

In the frequency range of mobile communications, safety levels are formulated in terms of the rate of energy absorbed per unit body mass, this quantity is known as the specific absorption rate (SAR). Thus antennas have to be designed to comply with the standards for peak SAR values to prevent localised heating.

In use, the conventional personal telephone handset is placed close to the face of the user; within the near-field zone of the antenna where most of the electromagnetic energy is stored rather than radiated. Consequently the dominant cause of high SAR with personal telephone handsets is the potential for high coupling into the absorbent tissue of the face of the near field (the reactance and electrostatic fields).

Reactance and electrostatic fields can be managed both by means of the topological design of the antenna (such as the loop antenna as opposed to the monopole) as well as by the use of materials of high dielectric constant or high magnetic permeability to load the antenna. These materials concentrate the electric and magnetic stored fields respectively into the volumes that they occupy. Dielectric and magnetic loading of antennas also reduces their size so that the electric and magnetic dipoles are formed over a shorter distance thereby further concentrating the fields into a region that is close to the antenna. The reduction in size that is brought about by dielectric or magnetic loading gives the antenna more flexibility to orientate the electric or magnetic field into directions which minimise the field that is incident on the user's face[1].

In this paper, the twisted loop antenna is analysed using electromagnetic modelling. Simulation results are compared with experimental measurements for a dielectric loaded twisted loop antenna in free space. However the SAR results given for our antenna are measured with a phantom head and a generic handset.

II. Dielectric Loaded Twisted Loop Antenna

A geometrical representation of the twisted loop antenna is shown in Figure 1.

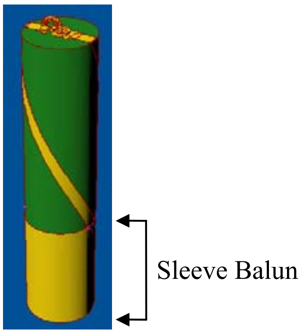

Figure 1: Geometric representation of the Dielectric Loaded Twisted Loop Antenna.

The dielectric loaded twisted loop antenna, realised using Zirconium Tin Titanate ceramic, ε_r of 36, is a backfire fed bifilar antenna that is optimised to minimise the SAR whilst maintaining high efficiency. It is basically a loop antenna which is balance-fed at the top by a co-axial feed which passes axially through the centre. The lower portion of the antenna is a sleeve balun which creates a transition between the single-ended and balanced drive so that the loop antenna can be fed with balanced currents. Currents at the centre conductor feed point of the antenna pass round a 360° path including the rim of the sleeve balun and then back to the outer conductor of the co-axial cable feed.

Current distributions shown in Figure 2a, illustrates that the twisted loop antenna creates a voltage maximum half-way up each helix for the balance mode with the net effect that an equivalent voltage dipole is resolved across the diameter of the antenna in a direction which meets the two helices at their voltage maxima. For optimum SAR performance the antenna should be orientated such that this dipole is placed normal to the surface of the face. In this direction the antenna projects an electrostatic minimum into the user's face and also the far-field radiation pattern in this direction is also minimum.

The 180° twist in the twisted loop topology provides the characteristic that the axis of electrostatic field minimum and also far-field radiation pattern minimum are the same direction whereas for the conventional planar loop these two axes are orthogonal. Also the twisted loop antenna orientates the magnetic fields in such a way that half-way up each helix, there are no induced eddy currents in the adjacent absorbent surface, which are present in a conventional 360° planar loop. The antenna thus provides magnetic field minimisation in the direction of the users head.

III. Simulated Results

The design was analysed by means of electromagnetic modelling. A time domain Transmission Line Modelling (TLM) approach was used. This was implemented in package called Micro-Stripes™ [3] produced by Kimberley Communications Consultants.

The code allows a graded mesh scheme for greater accuracy and to reduce simulation time. Absorbing boundaries are defined close to model to limit the simulation domain. All the field components and currents are solved in a specified region surrounding the model.

As can seen in Figure 2, the quarter wavelength balun transforms the impedance at the base to an infinite impedance at the rim, such that the currents can only flow at the rim, with no currents in the rest of the balun. This has an advantage in that the handset is effectively 'cold', unlike the monopole were currents flow in the (ground) handset. In our case the user's hand will have virtually no effect on antenna performance.

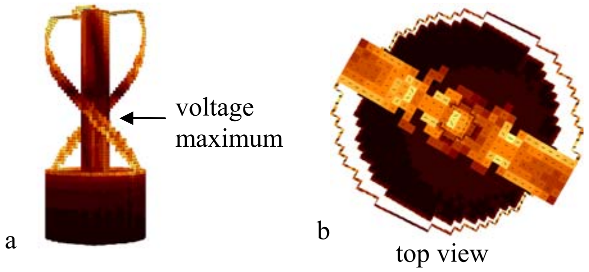

Figure 2. Simulated current distribution

Near-to-Far field transformation is used to obtain the far field radiation patterns. The simulated predictions for azimuthal pattern are shown in Figures 3 and 4.

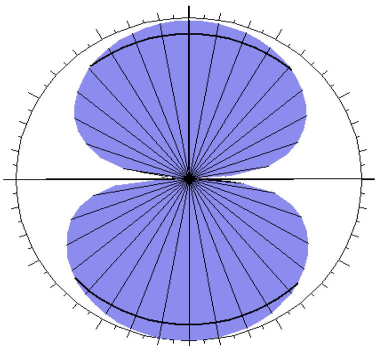

Figure 3: Simulated (Vertical Polarisation)

From the results it can be seen that the antenna adopts a near-perfect figure-of-eight radiation pattern. This will result in a minimum radiation exposure of the human head when is placed where the nulls are.

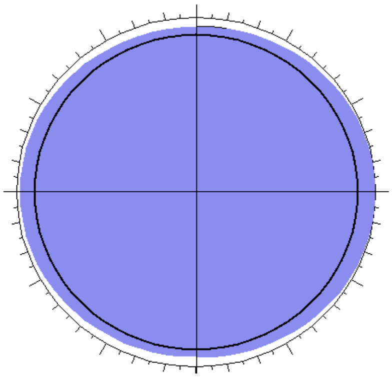

Figure 4: Simulated (Horizontal Polarisation)

IV. Measured Results

A number of prototypes were built and tested using Navstar's facilities which includes a 10mx4mx5m anaechoic chamber. The relevant results are shown below in Figures 5 and 6.

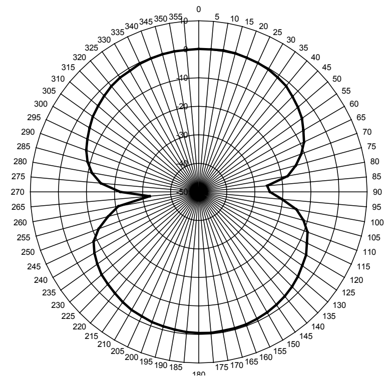

Figure 5: Measured Azimuth (Vertical Polarisation)

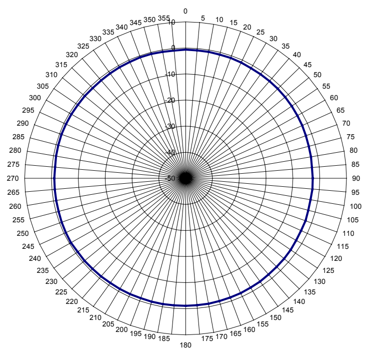

Figure 6: Measured Azimuth (Horizontal Polarisation)

The simulations accurately predict the measured antenna patterns. The measured figure-of-eight radiation pattern is formed with the two nulls close to 30dB.

V. Specific Absorption Rate (SAR) Evaluation

The SAR evaluation of the prototype twisted-loop antenna was carried out to determine its suitability for use in handheld mobile communications equipment with respect to radiation exposure of the user.

All measurements were performed at the ETH[2] Zurich with DASY3 dosimetric assessment system and near-field scanner. Measurements of the near-field magnetic field in the presence of a generic phone were performed. SAR measurements were also carried out with the addition of a flat and head phantom with brain simulating fluid.

The dielectric loading and low impedance of the antenna results in high currents and thus high H-fields in the immediate vicinity of the antenna. At 10mm distance from the antenna axis, the H-field is about 2-3 times higher than that from a typical dipole measured under similar conditions. Further away from the antenna, the H-field decays very quickly due to the compensation from both helix arms. At 20mm away, the H-field corresponds to that from a dipole and at 50mm away the H-field is about 3-6 times lower (depending on the direction).

For SAR measurements, the antenna was connected to a generic phone with the dimensions: length 140mm, width 40mm, thickness 16mm.

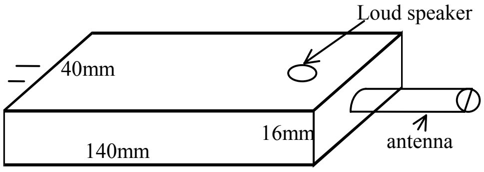

Figure 7 Generic phone with antenna

The measurements were performed with different antenna rotation angles.

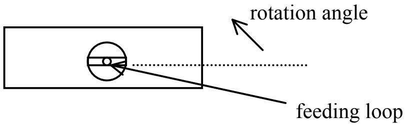

Figure 8 Top view of generic phone and antenna

In near-field situations, SAR is dominantly produced by induced currents from electromagnetic coupling into the lossy medium. Measurements of both the H-field and SAR indicates that the H-field component parallel to the surface produce a stronger coupling than components normal to the surface[2]. Thus minimum SAR values will be obtained when the orientation of the voltage dipole across the helices is normal to the head. The SAR distribution and spatial peak values are shown in Figure 9. The measurements were performed in the flat phantom. A measurement distance from the surface of 4.6mm was used.

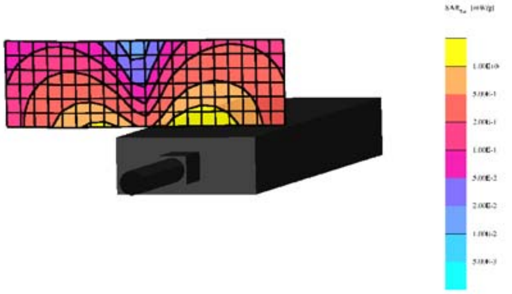

Figure 9: SAR distribution in flat phantom

In all SAR measurements with the phantom, a homogenous lossy dielectric medium is assumed with $\varepsilon_r = 41.5$, $\mu = 1$, $\sigma = 0.84$ at 900MHz. An input power of 250mW was used.

The SAR measurements for our antenna with a resonant frequency of 908GHz are tabulated in Table 1. Measurements were taken for various hand-set positions including the CENELEC intended use position (80°).

d indicates the shortest distance between the active part of the antenna and the outer phantom shell and the location column indicates the shortest distance on the antenna. 0% indicates the lower end of the helices and 100% the top end of the helices.

Position	d / mm	location	SAR 1g (mW/g)	SAR 10g (mW/g)
intended	13	0%	0.24	0.14
100°	1.5	70%	3.29	1.70
30° tilted	4	40%	1.51	0.75

Table 1a: SAR results with antenna rotated at 0° [2].

Position	d / mm	location	SAR 1g (mW/g)	SAR 10g (mW/g)
intended	13	0%	0.36	0.20
100°	1.5	70%	5.34	2.14
30° tilted	4	40%	2.05	0.86

Table 1b: SAR results with antenna rotated at 90° [2].

The antenna orientation affects the evaluated SAR by a factor of about 1.5 for the 1g cube and about 1.3 for the 10g cube. The orientation with the lowest SAR values occurs when the helix feed is parallel to the absorbing surface.

In all the above SAR measurements, a +25% uncertainty has been added to the actual measurements, which is a very pessimistic estimate. With a 10% uncertainty, the SAR values will be much lower then recommended standards in all cases.

Thus given the measured SAR, the FCC limits (1.6mW/g over 1g in the standard position) can be met if the antenna is mounted so that it's minimum distance to the head is above 6.5mm in the standard position.

The CENELEC limits (2mW/g over 10g) can be met if the antenna is mounted so that it's minimum distance to the head is above 4mm in the worst case position.

VI. Conclusions

The twisted loop antenna is a novel antenna design concept for personal telephones. It is small, light-weight, and has demonstrated low SAR values much less than the peak recommended standards. We believe this antenna not only meets the need for safer personal telephones but also the continuing desire for miniaturisation of mobile handsets.

Acknowledgement

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References

[1]. O.P.Leisten, G.Ffoulkes-Jones, "Performance of a Miniature Dielectrically Loaded Antenna," ION (Institute of Navigation) 95, pp 869-877.
[2]. T.Schmid "SAR Test Report for Navstar's Dielectric-Loaded Twisted-Loop Antennas," Nov. 1997, ETH (Eidgenossische Technische Hochschule) Zurich.
[3]. Micro-Stripes^{TM} User Manual ,Kimberley Communications Consultants Limited, Nottingham, England.