RAYSPAN® Proprietary Metamaterial Antennas

A Proven SAR Reduction Solution

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Abstract

Rapid advances in the personal communications industry and the ubiquitous use of cellular phones throughout much of the world have increased concern about the effects of radio frequency radiation from these devices on public health. Regulatory bodies in the United States and Europe have defined the allowable Specific Absorption Rate or SAR in order to ensure that radiation emitted by personal communications devices is safe for the public. Mobile phone manufacturers have used various methods to control or lower the SAR in order to meet these regulations. In a recent article in the British Telegraph, the BL-40 handset from LG, the first ever to utilize a metamaterial antenna based on a proprietary *RAYSPAN*® solution, was declared the phone with the lowest SAR value when compared with some of the most popular handsets currently sold in Europe. *RAYSPAN*® engineering team has also observed SAR improvement of up to 50%, when conventional antennas in production handsets are replaced with *RAYSPAN*® metamaterial antennas.

1 – Defining SAR

Mobile communication uses radio waves for transmission. When we call someone or receive a call, the mobile phone sends and receives radio waves. Most of the radio waves transmitted by mobile phones do not interact with the human body; but the body does absorb some of the energy from the radio waves.

The Specific Absorption Rate or SAR is a measure of the energy absorbed by the human body due to the exposure to radio waves. Factors that affect the amount of energy absorbed into the human body include the size and shape of the device, the distance of the device from the human body, the transmit power level and the electric current distribution on the device.

SAR is calculated using the following formula:

$$SAR = \sigma E^2/\rho \text{ (Watts/Kg)}$$

Where σ is the electrical conductivity, ρ is the mass density and E is the measured internal electric field strength.[i]

2 – SAR Regulation and Implications for Handset OEMs

Since 1996, the FCC has defined allowable SAR levels as well as guidelines for evaluating the effects of radio frequency radiation in order to protect the public and workers from potentially hazardous RF emissions from cellular phones.[ii] In the United States, the FCC requires that the SAR produced by a mobile phone must be less than 1.6W/Kg averaged over one gram of tissue. In Europe, the allowable SAR is 2W/Kg in 10 grams of tissue. The American National Standards Institute (ANSI) has published standards for measuring localized SAR.[iii]

Until recently, methods for reducing SAR for devices using conventional antennas were limited to device transmit power reduction, the use of metal brackets to change current distributions and/or correct antenna mismatch. Each of these methods negatively impacts cost, performance, industrial design and time to market for the handset manufacturer. Reducing the power can cause handsets to fail carrier over-the-air (OTA) performance criteria, significantly delaying launch and adding to the development cost of new handsets. In the worst-case scenario, original equipment manufacturers (OEMs) may be prevented from launching new handsets all together on some carrier networks. The use of brackets, EMI tape or metallic paint to reduce SAR adds to the handset bill of materials (BOM) and adds complexity to the assembly process, reducing OEM profitability.

The results of the SAR measurements published in the British Telegraph bring to light a new solution for reducing SAR while maintaining or improving performance, cost and time to market for new handset designs. *RAYSPAN®* proprietary metamaterial antennas are enabling unmatched SAR while at the same time improving performance and offering design and manufacturing benefits in production handsets today.

3 – *RAYSPAN®* Proprietary Metamaterial Antenna

Metamaterials are manmade composite materials engineered to produce desired electromagnetic propagation behavior not found in natural media. They make possible unprecedented improvements in air interface integration, OTA performance and miniaturization while simultaneously reducing BOM costs and SAR values. Metamaterials enable physically small but electrically large air interface components, with minimal coupling among closely spaced devices.

When designed for cellular handsets, metamaterial antennas offer several benefits over conventional antennas. They are ultra-compact in size; smaller than 10mm by 50mm in area and as thin as paper. In fact, metamaterial antennas are typically at least five times smaller than conventional antennas, or 1/10th of the signal's wavelength, while offering equal or better performance. Furthermore, unlike conventional three dimensional (3D) antennas, which must be designed, tooled and fabricated as a complex metal-and-plastic assembly, a metamaterial antenna is a simple two dimensional (2D) design in which copper artwork is printed directly on a handset's printed circuit board (PCB) using standard PCB manufacturing techniques. This offers manufacturers faster time to market and reduced BOM due to the simplified design and greatly reduced need for fabrication and assembly of antenna components.

Metamaterial antennas can be made very broadband to support today's multiband wireless application requirements. A single metamaterial antenna can support all cellular frequency bands (from 700MHz to 2.7GHz), using single or multiple feed designs, which can eliminate the need for antenna switches. Multi-band metamaterial functionality for global cellular connectivity covers both low-band frequencies including GSM/WCDMA/HSPA/LTE (700/800/900 MHz) and high-band frequencies including DCS/PCS/WCDMA/HSPA/LTE (1700/ 1800/1900/2100 MHz). Integration of GPS, Bluetooth, WiFi, and WiMax is also possible within the same antenna array without undesirable coupling, eliminating the need for multiple large external and internal antennas and associated decoupling circuitry.

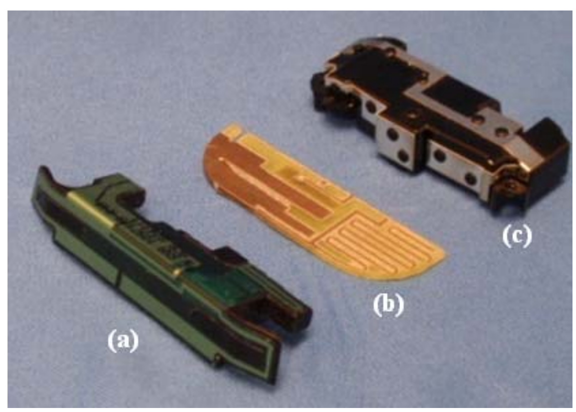

Figure 3-1 (a) F-PC flexible printed circuit, (b) Metamaterial antenna printed on FR4, (c) Sheet metal on plastic carrier.

4 - Improving SAR using Metamaterial Antennas

In addition to size and performance improvements, metamaterial antennas offer advantages to handset designers in terms of significant SAR reduction and increased performance in actual configurations of use. Interaction between the handset antenna and the human body is an important consideration in cellular handset antenna design. The user's body, especially the head and hand, influence the antenna's voltage standing wave ratio (VSWR), gain, radiation patterns and current distribution. Since conventional antennas use the entire device ground plane as a radiating element, head and hand more negatively impact them. By contrast, metamaterials' ability to concentrate electromagnetic fields and currents near the antenna structures results in metamaterial antennas achieving better performance while exposing the user to less radiation regardless of typical head and hand positioning.

In conventional antennas, such as Planar Inverted-F Antennas (PIFAs), currents can flow throughout the PCB. For example, to enable radiation in the low-frequency bands, PIFA relies strongly on the ground plane. This results in strong currents being concentrated at the end opposite the antenna structure, which is typically found on the bottom, near the chin. Hence, with current concentrated on the head side of the PCB, the head absorbs more RF energy.

In addition, metamaterial antennas operate more efficiently in constrained spaces, with most of the radiation originating from the antenna itself instead of currents induced by the antenna on the PCB. Figures below depict such a comparison. Figures (a) and (b) show the current distribution of conventional and metamaterial antennas, respectively, on a PCB board of handset size, where the red, green, blue colors reflect peak, high and low intensity of current in logarithmic-scale. Figure (a) shows that the PIFA relies heavily on the PCB ground plane to radiate (hence the green color covering most of the PCB ground plane). By contrast, Figure (b) shows that almost no currents are induced on the PCB with the metamaterial antenna. Hence, current distribution of the metamaterial antenna solution is more easily confined enabling isolation of radiation to one small area of the handset, in most cases at the chin, farthest from the head. Dependency on ground planes, which distribute radiation across a larger area of the handset, is reduced or eliminated, thereby reducing the SAR. This effectively minimizes the tradeoff between OTA performance and SAR, ensuring successful carrier field trials and regulatory approval. .

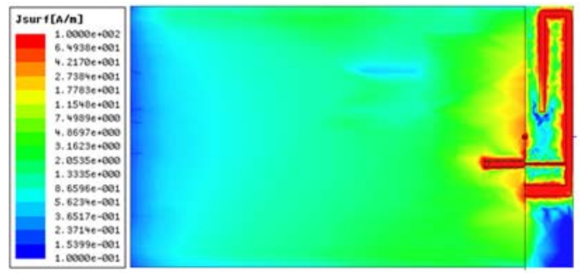

Figure 4-1 Current distribution of an Inverted F Antenna (conventional) at 875 MHz

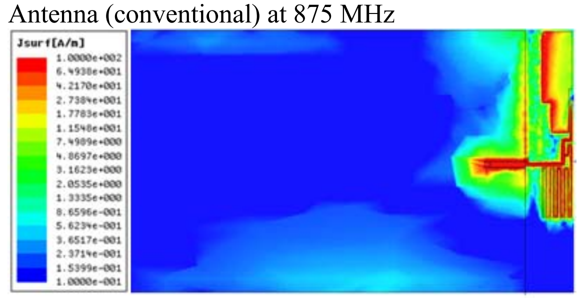

Figure 4-2 Current distribution of a penta-band Metamaterial Antenna at 875 MHz

5 – Measured SAR Values in Cellular Handsets Using *RAYSPAN®* Metamaterial Antennas

On October 24, 2009, the British Telegraph published SAR values for 10 of the most popular handsets in the Europe. Of the 10, the LG BL40 Chocolate achieved the lowest SAR value at 0.21W/Kg which was approximately 1/3 the value of the next lowest SAR value.[iv] In a Hankyung News article from November 18, 2009, LG Senior Engineer Ahn-Sun Hyun attributes this low SAR to the use of the *RAYSPAN®* metamaterial antenna. Hyun states that along with reducing SAR, the metamaterial antenna improves efficiency and receiver sensitivity while maintaining a small footprint.[v]

Figure 5-1 Typical SAR measurement equipment

In an internal study, *RAYSPAN®* engineering team has also observed SAR improvement of up to 50%, when conventional antennas on production handsets are replaced with *RAYSPAN®* metamaterial antennas. Comparative tests have been performed on various styles of cellular handsets including candy bar phones and slider phones.

SAR(in W/Kg)	Bar-type Phone		Slider Phone	
	low band	high band	low band	high band
OEM	1.27	0.94	1.06	1.06
RS	1.15	0.78	0.96	0.64
% Improvement	10	21	10	66

Figure 5-2 *RAYSPAN®* internal SAR study results

6 – Conclusion: Low SAR Solution Benefits for OEMs and ODMs

Cellular handset OEMs and ODMs (original design manufacturers) can greatly benefit from the use of metamaterial antennas for new handset designs.

Metamaterial antennas allow for unprecedented flexibility in PCB layout and handset design, as the need to separate the antenna from mechanical components such as the keypad, microphone and speakers and the need to make last minute mechanical changes due to SAR related issues is virtually eliminated. Additionally, the thin profile of metamaterial antennas allows for sleek handset designs. Design-in for metamaterial antennas is straightforward and fast, usually requiring no more than two weeks to a month.

RF performance improvements due to metamaterials' ability to concentrate electromagnetic fields close to the antenna minimize the SAR vs. OTA performance trade-off, guaranteeing successful carrier field trials and regulatory approval. Metamaterial antennas can achieve best in class carrier OTA performance while achieving superior SAR values, all within in a very short development cycle.

Finally, the shorter design cycle and more reliable time to market offered by *RAYSPAN®* metamaterial antennas are especially important to OEM/ODM profitability – the greatest margins are always achieved by the first handsets to bring to market the latest capabilities and highest levels of performance.

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[i] Bajwa, Asher Ali. "Mobile Phone Radiations & Health" ADC, MicNordic AB 2009

[ii] FCC ET Docket 93-62 6 August 1996

[iii] "Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz" IEEE/ANSI C95 January 2005

[iv] "Mobile phones: SAR ratings of popular handsets" British Telegraph 24 October 2009 <http://www.telegraph.co.uk/news/uknews/6416338/Mobile-phones-SAR-ratings-of-popular-handsets.html>

[v] "The Secret for the Lowest SAR with the New Chocolate Phone" Hankyung Newspaper 18 November 2009