RAYSPAN® Metamaterial Antenna Benefits for Cell Phone Manufacturers

Improving OEM and ODM Profitability

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Abstract

Metamaterial (MTM) antennas offer multiple benefits for cellular handset Original Equipment Manufacturers (OEMs) and Original Design Manufacturers (ODMs). Improved Over the Air (OTA) performance, reduced Specific Absorption Rate (SAR) values, and reduced Bill of Materials (BOM) costs are only a few of the advantages to be gained through the use of MTM antennas. The following paper outlines the advantages of using *RAYSPAN*® MTM antenna technology for cellular handset designs. Specific examples of cost and time benefits for OEMs and ODMs are provided.

1 – Introduction: Key Benefits of *RAYSPAN*® MTM Antennas

Metamaterials (MTM) 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. MTMs enable physically small but electrically large air interface components, with minimal coupling among closely spaced devices.

MTM antenna structures are made of copper printed directly on the dielectric substrate and can be fabricated on a conventional FR-4 substrate or a Flexible Printed Circuit (FPC) board.

For cellular handset applications, MTM antennas offer several benefits over conventional antennas. They are ultra-compact in size and as thin as paper. In fact, MTM 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, an MTM 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.

MTM antennas can be made very broadband to support today's multiband wireless application requirements. A single MTM antenna can support all cellular frequency bands (from 700MHz to 2.7GHz), using single or multiple feed designs, which eliminates the need for antenna switches. Multi-band MTM functionality provides global cellular connectivity that 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 injecting any undesirable coupling, eliminating the need for multiple large external and internal antennas and associated decoupling and matching circuitry.

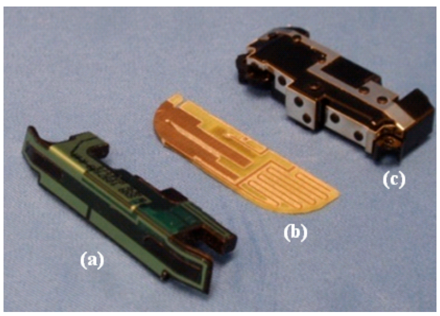

Figure 1-1 (a) F-PC flexible printed circuit, (b) MTM antenna printed on FR4, (c) Sheet metal on plastic carrier.

2 – TRP, TIS and SAR Concerns with Traditional Antennas Decreasing Handset Profitability

Cellular phone designers face several common challenges when integrating traditional 3D antennas. Cell phones need to pass carrier requirements for total radiated power (TRP), total isotropic sensitivity (TIS), as well as governmental regulations regarding specific absorption rate (SAR) before they can be deployed.

TRP is a measure of the antenna's efficiency: how much power is transferred from conducted power to radiated power. TIS is a measure of the power that reaches the receiver through the antenna averaged over all directions. This measurement is effected by the sensitivity of the receiver and other sources of noise as well as the antenna efficiency. Objects in the vicinity of the phone including the human head and hand affect both TIS and TRP. Interaction between the handset antenna and the human body influences the antenna's voltage standing wave ratio (VSWR), gain, radiation patterns and current distribution.

This interaction between the human body and the cell phone is also regulated as a matter of public health. 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. 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.[i]

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 TRP requirements, 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.

3 – Resolving TRP, TIS and SAR Concerns with RAYSPAN® MTM Antennas

RAYSPAN® MTM Antennas offer advantages to handset designers in terms of significant SAR reduction and improved TRP and TIS in actual configurations of use. 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 MTM antennas achieving better TIS and TRP measurements and reducing the current distribution on the board 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, MTM 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. The figures below depict such a comparison. Figures 3-1 and 3-2 show the current distribution of conventional and MTM 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 3-1 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 3-2 shows that almost no currents are induced on the PCB with the MTM antenna. Hence, current distribution of the MTM 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, thereby preserving handset manufacturer's program cost estimates.

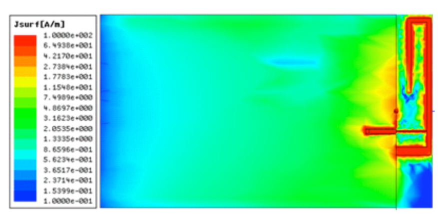

Figure 3-1 Current distribution of an Inverted F Antenna (conventional) at 875 MHz

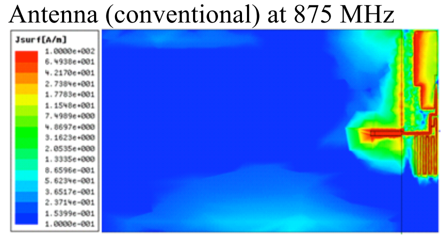

Figure 3-2 Current distribution of a penta-band MTM Antenna at 875 MHz

4 – Cost of Product Delays With Traditional Antenna Designs Impact ROI

The consequences of the traditional antenna design issues outlined above are detrimental to handset manufacturers' project return on investment (ROI) and their overall profitability. Delayed certification from regulatory bodies can mean delayed product launch, increased costs from product retesting and additional use of engineering resources. Product teams end up putting in extra hours redesigning and retesting. Carrier acceptance can be delayed, or the handset's slot in the carrier line-up may be given to a different handset manufacturer. At a minimum, the life of the product is reduced, potentially costing the manufacturer millions of dollars in ROI.

For example, at a starting unit sales price of $100 per handset with a 1M unit product run, a one month delay can mean nearly $15M in reduced revenue and a $2M profit reduction.[ii] This is a 20% loss in margin per product, or **more than $1.15/unit,** and a 30% reduction in overall product profit.[iii]

A $1.15/handset cost penalty is three to six times the price of the antenna. Further, a one quarter delay brings the per handset profit margin down by $2.58. The antenna is not the only possible reason for delays, but it is always the last component to be optimized and carries a great deal of late-stage risk for manufacturers. At that stage, delays are the most costly and can even cause project cancellation.

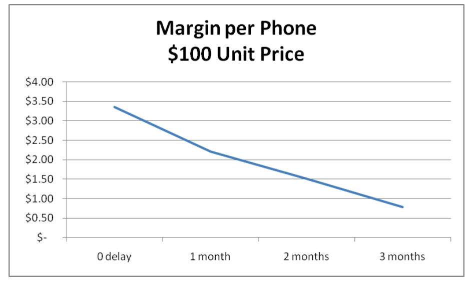

Figure 4-1 Drop in handset margin due to delays measured in months.

With higher end handsets and new smartphone technologies where first mover advantage is critical, delays can be even more costly. For a device with a $200 sales price and a 1 million unit run, a one-quarter delay results in an estimated $10.8 million in lost profits.

5 – Conclusion: *RAYSPAN*® MTM™ Technology Advantages for ODMs and OEMs

Designing handsets using Rayspan MTM technology achieves project savings for both ODMs and OEMs. For the ODM, teams spend less time on design and redesign, manufacturing equipment needs are reduced and fewer projects are cancelled because of regulatory and OTA testing delays. This results in the ODM being able to complete more projects and become more competitive when bidding for new handset programs – all driven by the greater reliability of MTM™ antenna solutions.

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For the OEM, MTM technology ensures that new handset designs hit the market when they need to. This provides the

OEM a better chance at being first-to-market with newest technologies that can extract a higher sales price, higher margins and a longer product life cycle. What's more, with more reliable product launches and successful OTA testing, OEMs are more often selected by mobile operators to launch new technologies.

Reduced overall BOM and manufacturing cost, enhanced performance, faster time to market and more reliable regulatory and carrier acceptance make Rayspan MTM antenna technology beneficial, not only for OEMs and ODMs, but for the entire mobile handset value chain.

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

[ii] Source: Rayspan study of multiple tier 1 OEM and ODM handset program costs.

[iii] Assumptions: $5M development costs. 12 month sales horizon. Handset price at launch = $100 with a 5% quarterly drop in price. Overall product BOM = $90 with a 3% quarterly drop in cost. Total sales volume is 1M units, ramping to 150K units/month in month 3, ramp down begins in month 11.

