



Principles and applications of the Folded Inverted Conformal Antenna (FICA) technology

Carlo Di Nallo, Antonio Faraone

Motorola Labs, Corporate EME Research Lab, Fort Lauderdale, FL, USA

Marco Maddaleno, Timoteo Galia

Motorola Electronics SpA, Mobile Devices Turin Design Center, Turin, Italy

CONVERGE 2005 – Milan, Italy, November 2005

Overview

Motivation

Background on mobile phone antennas

Planar Inverted-F Antenna (PIFA) technology

FICA technology

Volume reuse concept

FICA operation theory (excitation mechanism and modes)

FICA Applications

Benchmark of FICA vs PIFA

Integration in mobile phones

Conclusions and future directions



Background of mobile phone antennas

Cellular frequency bands

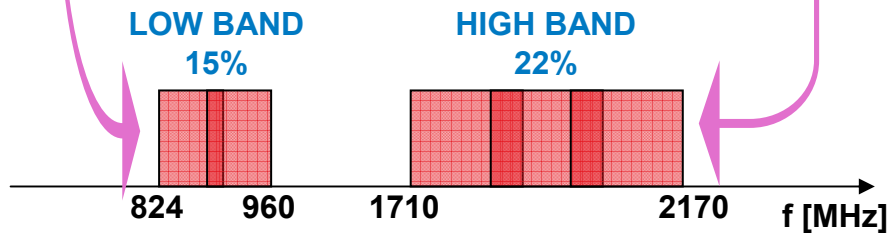
824-894 MHz (CDMA/TDMA/GSM)

880-960 MHz (EGSM)

1710-1880 MHz (DCS)

1850-1990 MHz (PCS)

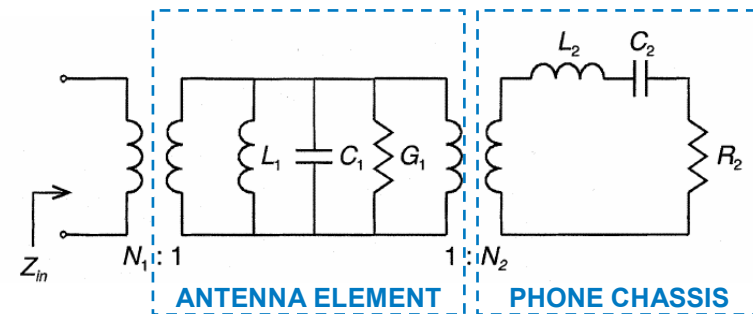
1920-2170 MHz (UMTS)



“Antenna element” = PCB exciter

Particularly in the low band, the “antenna element” mainly serves to excite radiating currents on the device chassis

Vainikainen, et al., IEEE Trans. AP, Oct. 2002



Particularly for internal antennas, bandwidth limitations are due to the narrow bandwidth of the “antenna element”, i.e., exciter

Planar Inverted-F Antenna (PIFA) technology

Multi-band PIFAs are by far the most used internal antennas

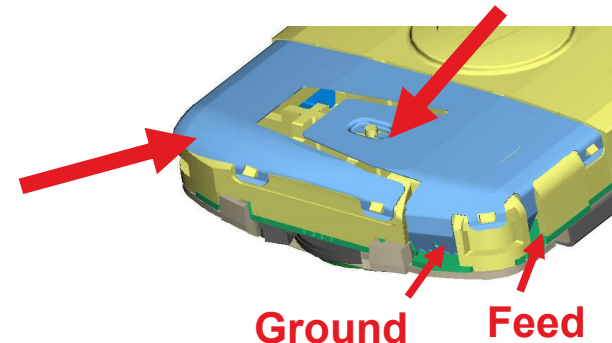
Straightforward operational principle

Liu, et al., IEEE Trans. AP, Oct 1997

“volume sharing” principle

Longer arm resonates at low band

Shorter arm resonates at high band



Example

Ericsson T68i



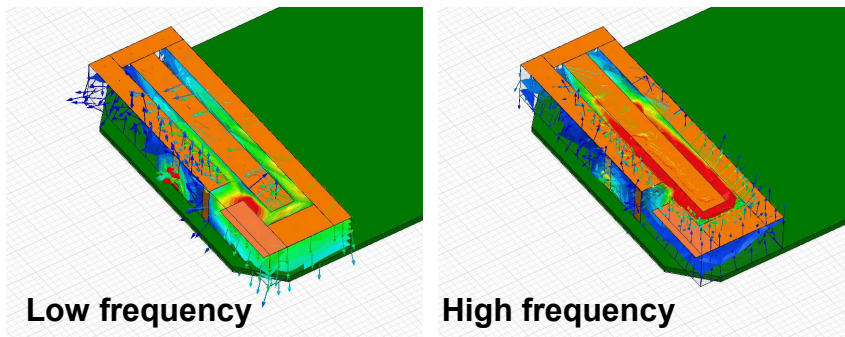
PIFA characteristics and limitations

Advantages:

- proven technology
- available from vendors
- easy to design for dual band

Drawbacks

- difficult to design for tri-band
- different resonances “compete” for space in a given volume
- hard to integrate with other components (speaker, mic,...)



Antenna volume allocated selectively to each resonance

Each resonance uses a different part of the antenna volume

Reactive energy concentrated mainly around and underneath one PIFA arm at a time

Multi-banding implies narrowing each individual band

Q of each “antenna element” resonance is narrow, thus the Q of the device is narrow

PIFA should be considered a sub-optimal solution

Motivation, i.e., why still researching?

Particularly for internal antennas, bandwidth limitations of the device are due to the narrow bandwidth of the “antenna element”, i.e., the exciter

PIFA is a sub-optimal solution because it implements an operation principle based on “volume sharing”

Need to provide tri-, quad-, penta-band solutions



Folded Inverted Conformal Antenna (FICA)

FICA implements a “volume reuse” principle

Each resonant mode uses the whole antenna volume

Structure

**Elongated conductor mostly symmetrical
with respect to PCB center line**

U shape mostly used

Slot conforming to elongated conductor

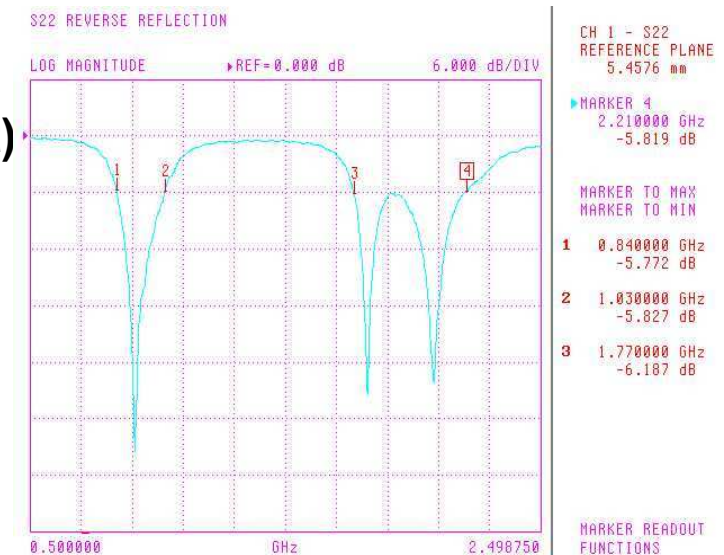
Folding the slot provides extra length
to enable proper tuning

**Unbalanced feeding structure (feed,short)
in mostly symmetrical location**

Three resonant modes are synthesized

One resonance in the low band
common mode

Two resonances in the high band
differential and slot modes



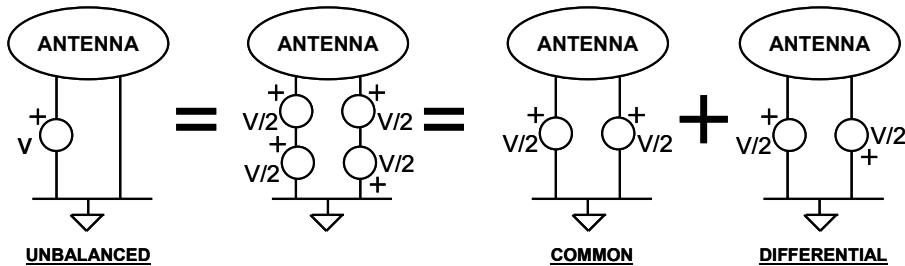
FICA excitation mechanism and resonant modes

Unbalanced feeding structure capable of exciting even and odd current configurations

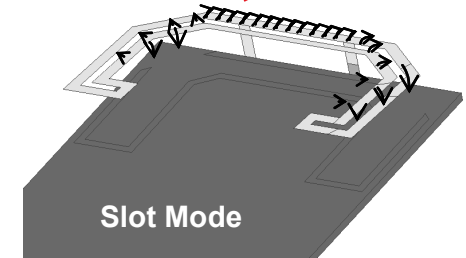
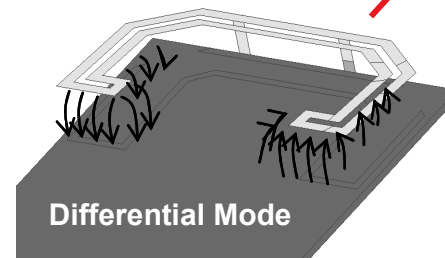
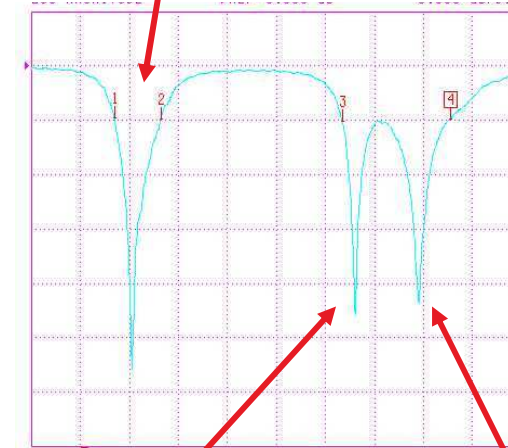
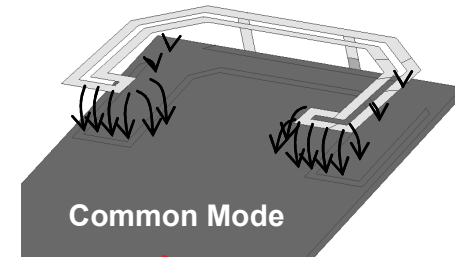
Mode nomenclature

Multi-mode excitation explained by superposition principle

Even and odd current modes maximally excited at their respective resonance frequencies



Feed and short placed on the same side, roughly symmetrical



Benchmark FICA vs. PIFA

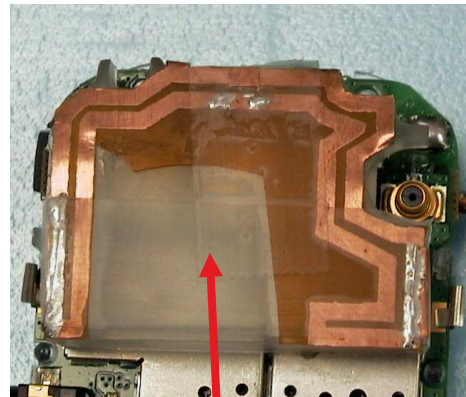
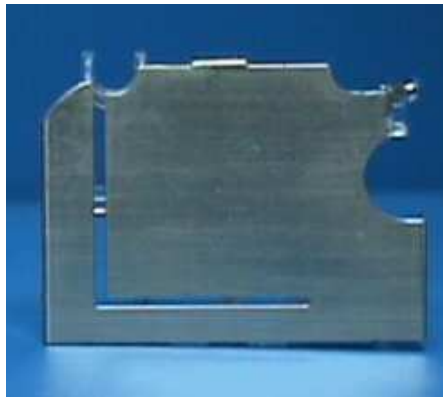
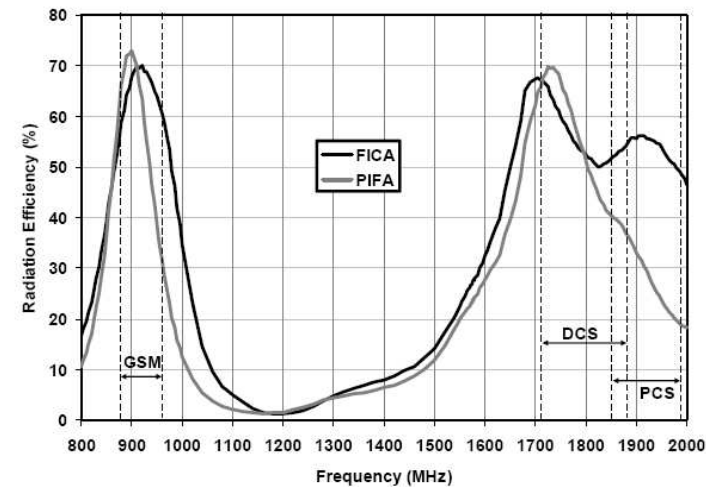
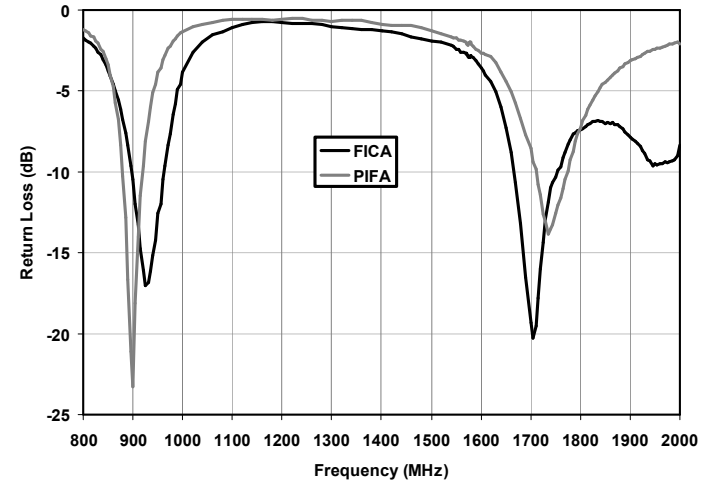
Motorola T192

Dual band GSM

PIFA footprint:
38 X 24 mm²

Height: 6.5 mm avg

FICA etched on Kapton



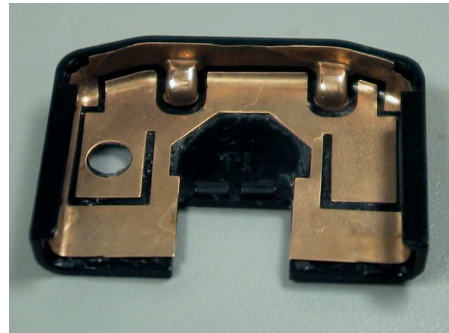
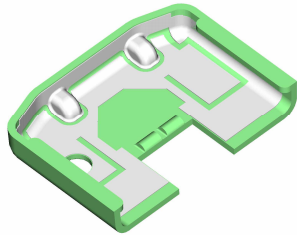
Space available for component placement

FICA yields tri-band coverage in less than half dual-band PIFA volume !

Examples of FICA Applications

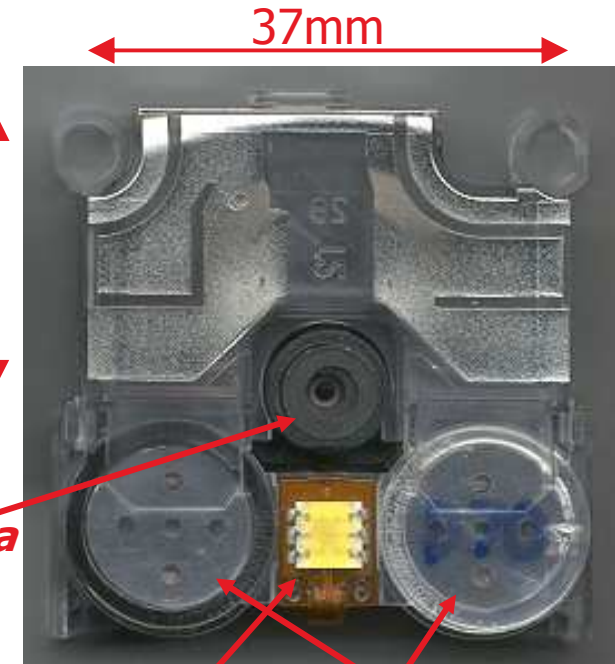
E398/E399 tri-band GSM phone (ROKR)

INITIAL CONCEPT



24mm

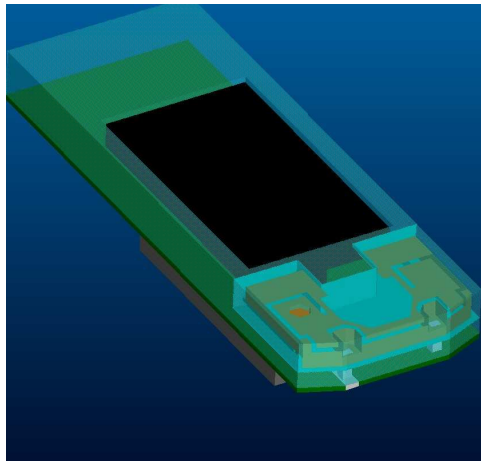
FINAL DESIGN



Camera

Flash memory

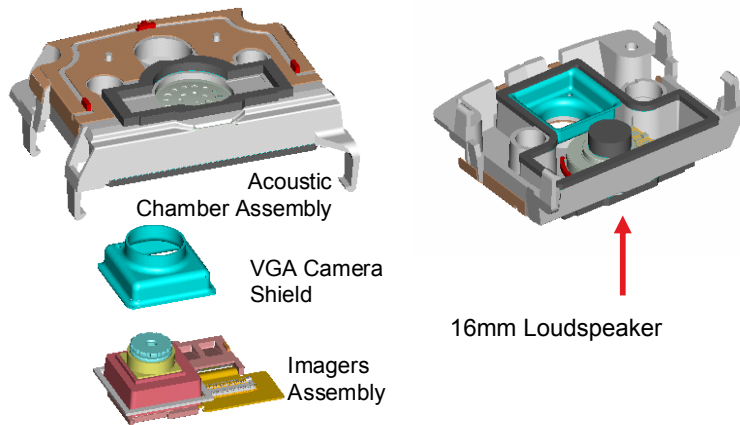
MFTs (3mm from antenna)



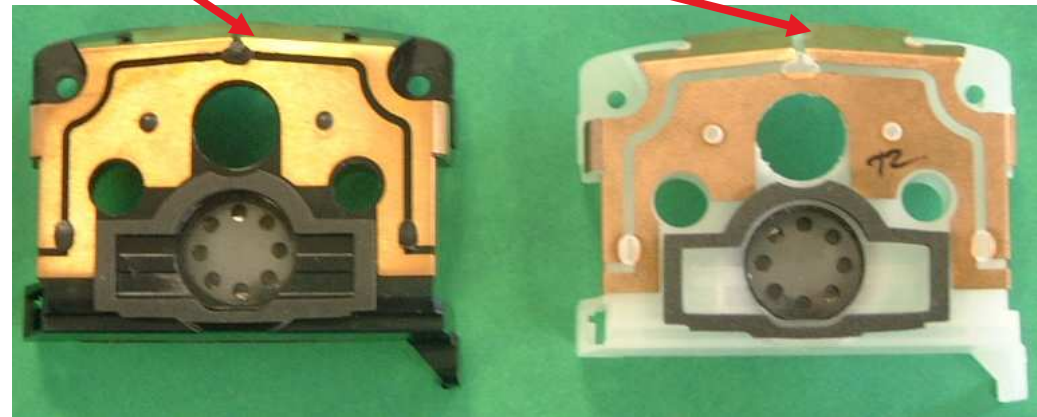
SIMULATION MODEL

Examples of FICA Applications

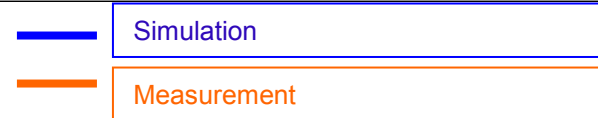
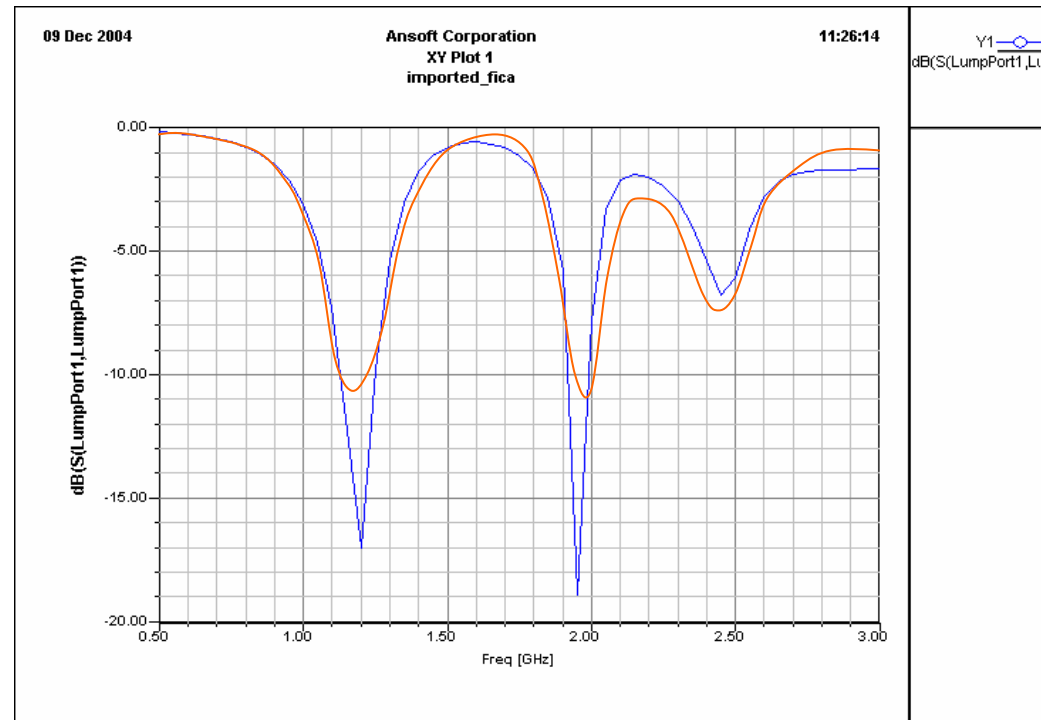
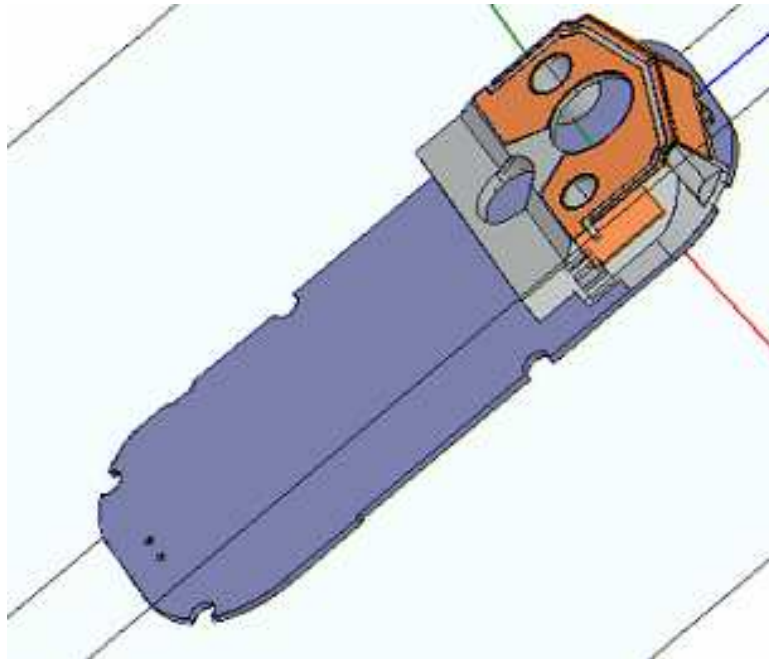
C975/C980 quad-band (GSM/UMTS)



From CAD model to Prototyping



HFSS EM simulation from CAD model

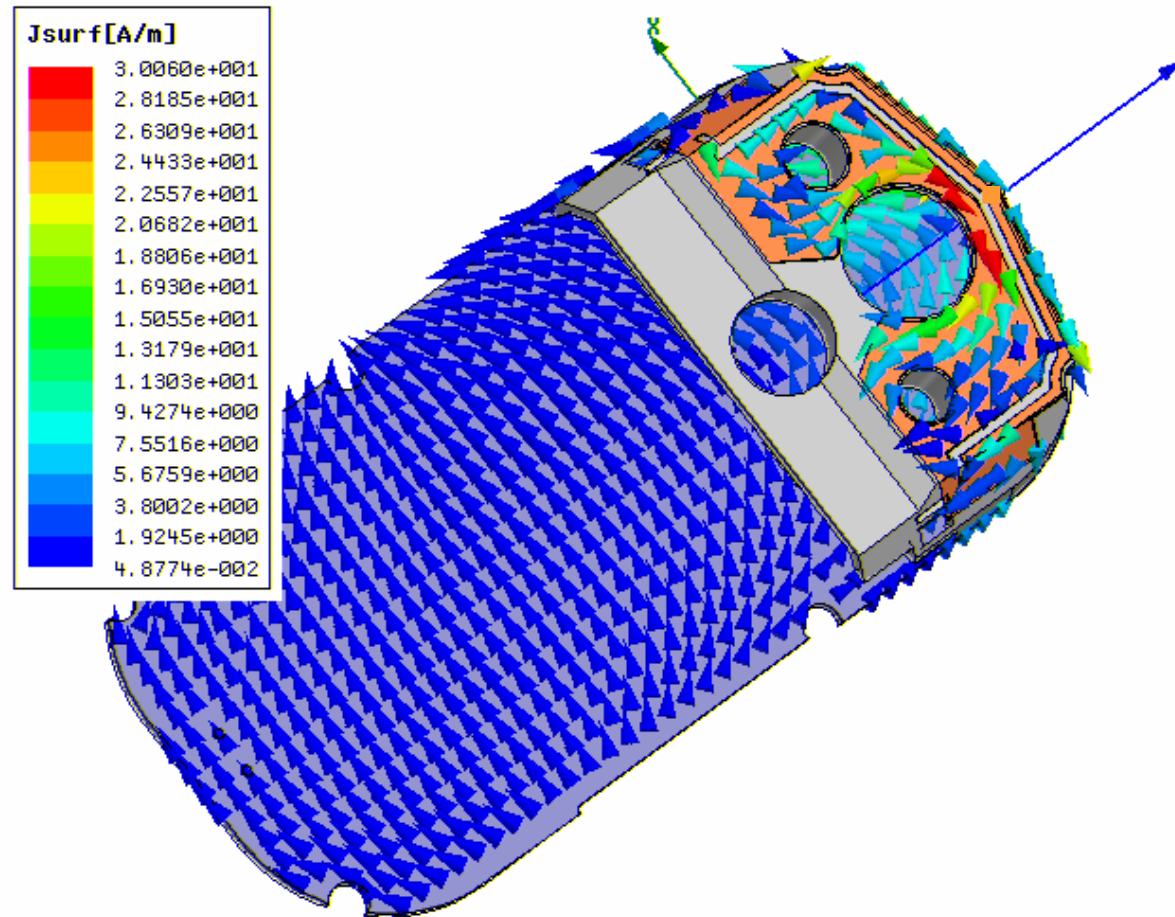


HFSS in the design process

- Design concept
- EM model - simulation– optimization (Optimetrics)
- CAD model – details – simulation - verification
- Prototyping - measurements



HFSS post processing to help RF insight



Conclusions and future directions

FICA technology provides a significant improvement in the state-of-the-art for multi-band integrated antennas

FICA outperforms PIFA in:

multi-banding

volume vs bandwidth

conformability and integration

FICA design is more challenging and takes advantages from EM simulation/ optimization

FICA technology has been successfully implemented on several Motorola handsets

Future work

Extend bands beyond cellular

Reduce thickness

