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Enabling Antenna Technologies for the Software Defined Radio

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Motorola Corporate EME Research Lab

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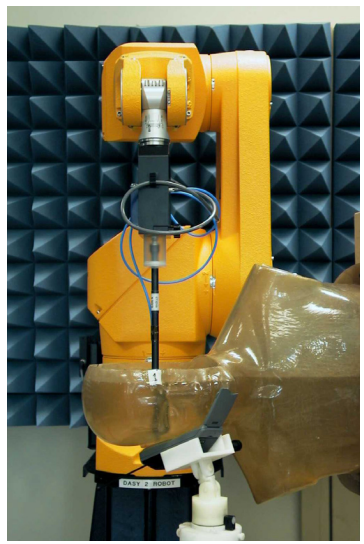
EME research program founded in 1974

- *Program started by Dr. Quirino Balzano*
- Biological effects of electromagnetic energy (EME) exposure
- Radiofrequency dosimetry for product safety and compliance
- Antenna R & D
- EMC/EMI compliance



2004

- *Dr. Mays Swicord – Head of the EME programs*
- *Dr. C-K Chou – Motorola Chief EME Scientist*
- *12 research staff (6 Ph.D., 4 MSEE)*
- *Leading EME program in the wireless industry*
- *Significant involvement in safety and compliance standards*
  - *IEEE, IEC, CENELEC*
- *Significant involvement in government relations worldwide*

EME @ Motorola *(continued)*

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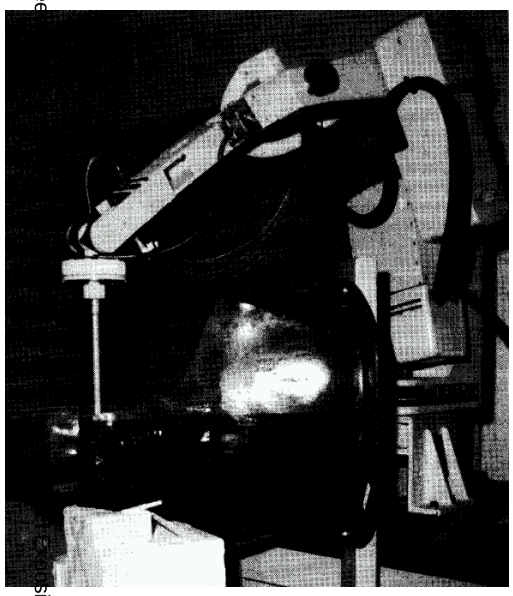
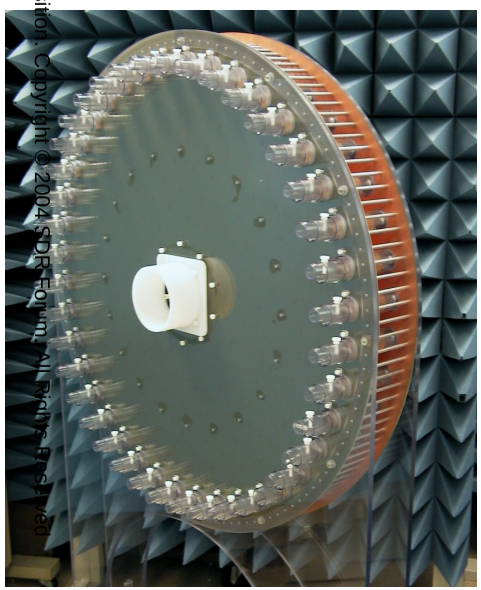
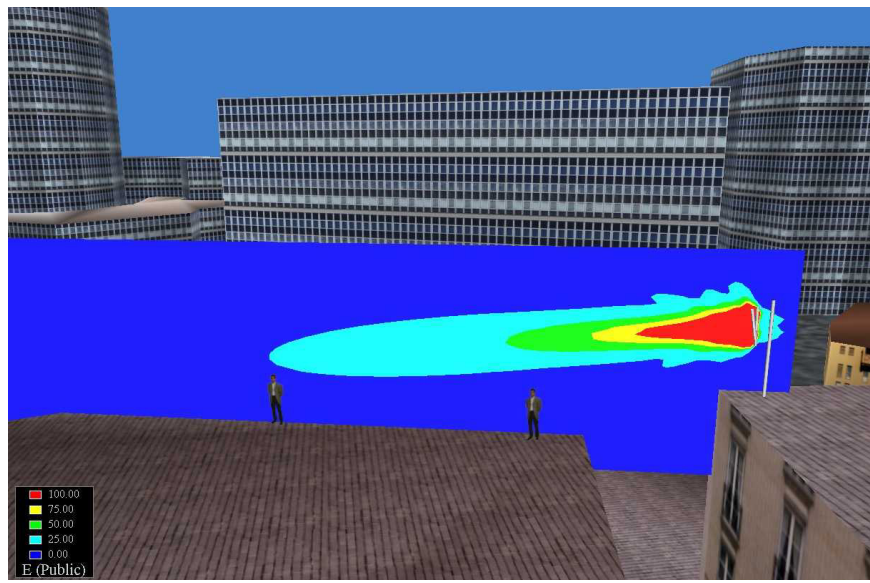


First SAR measurement system for handheld transceivers [1]

EME compliance for mobile radio equipment [2]



"Ferris Wheel" Exposure system for in-vivo bioassays [3]



EME compliance for wireless infrastructure equipment [4-5]

Antenna R&D Program

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Goal

- Pursue reach out technologies while also producing short/medium term impact on products
- Attain and maintain industry leadership in antenna technologies that are relevant to Motorola businesses

Focus

- Software Defined Radio (SDR) enabling technologies

  The SDR framework establishes perhaps the utmost challenge for multi-band portable radios that enable the "seamless mobility" vision

- Technologies
  - Multi-band antennas
  - Tunable antennas
  - Wideband antennas
  - Active antenna systems
- Performance
  - Efficiency, bandwidth, size, complexity, cost, reliability, etc.

Seamless Mobility and SDR/CR

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SDR

- … the result of an evolutionary process from purely hardware-based equipment to fully software-based equipment… (FCC NPRM)
  - All waveforms are software definable
  - SDR is reprogrammable via the air-interface
  - Upgradeable in the field

Cognitive radio

- "smart and alert"
  - Location awareness
  - Spectrum availability and selection
  - Usage pattern awareness and prediction
  - Air-interface selection (cost/performance)

SDR/CR requirements on antenna systems

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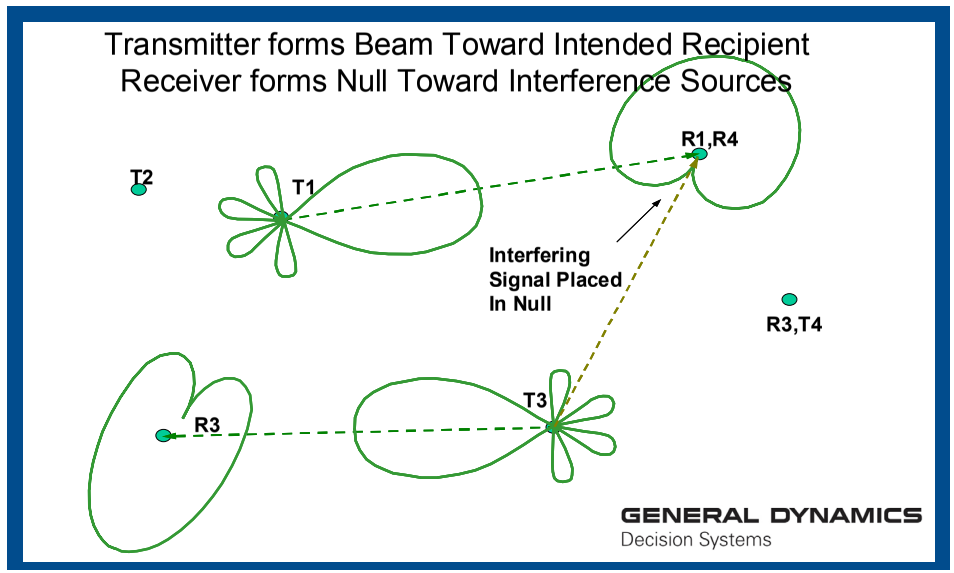
- **Simultaneous or selective spectrum coverage**
  - **E.g., 800 MHz-2.5 GHz**
  - **100 MHz – 6 GHz (PS radio)**
  - **Ability to operate in multiple bands simultaneously**
  - **Ability to increase system capacity**
    - **MIMO**
    - **Diversity**
  - **Ability to beam-steer**
  - **Ability to operate across terrestrial and satellite networks**
    - **IRIDIUM, etc.**
    - **GPS, Galileo**

Spatial - Beam Steering and Null Steering



Antenna Technologies

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- **Multi-band (integrated) antennas**
  - PIFA
  - FICA
  - DRA
  - MP-H
- **Reconfigurable Antennas**
  - TuNA
- **Wideband antennas**
  - Teardrop on handset form factors
- **Active antennas**
  - Compact antenna structures with multi-octave bandwidth
- **Multi-antenna systems**
  - MIMO
  - Diversity

Multi-band technology: PIFA

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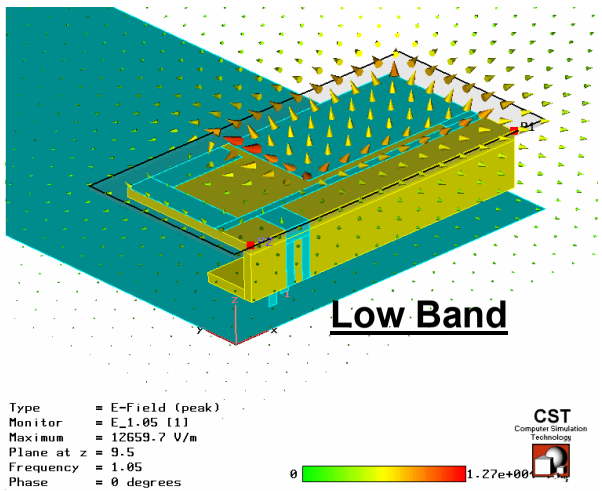
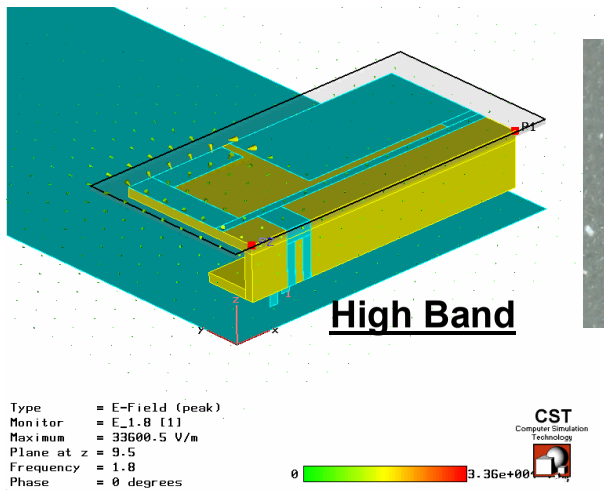
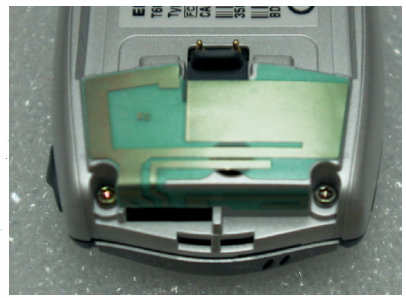
PIFA (Planar Inverted-F Antenna) is the most widely adopted technology in multi-band cellular phones

- Nokia pioneered PIFA integration in mobile phones
- Employed today by most cellphone manufacturers
- Compatible with aesthetic form factors
- Allows flexible choice of antenna location and volume shape
- Multi-band operation based on a “volume-sharing” principle







EricssonT68i

- Sub-optimal use of the antenna volume due to high-Q of each resonance

Multi-band technology: FICA

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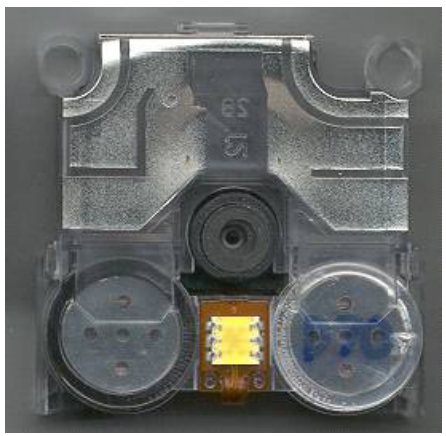
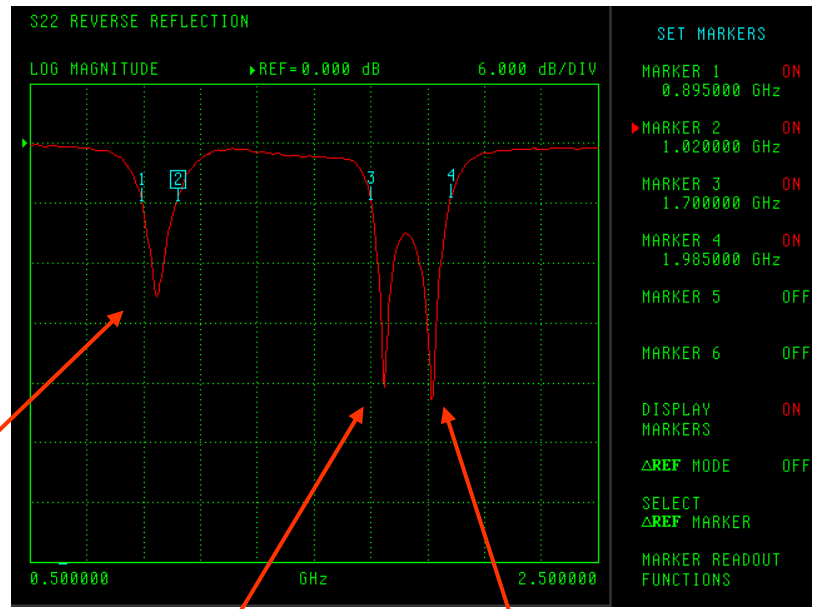
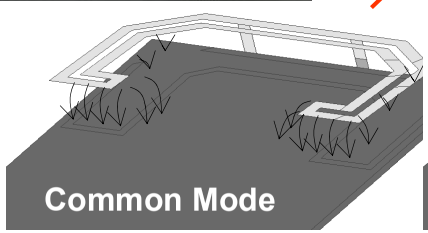
FICA (Folded Inverted Conformal Antenna) advances the current state-of-the-art for multi-band integrated cellphone antennas

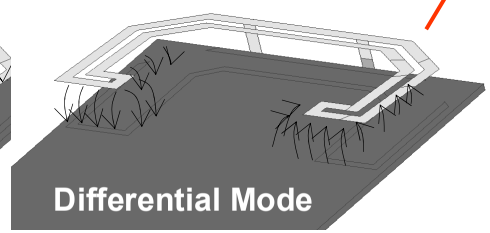
- Implements a “volume-reuse” principle yielding three resonances
- Resonances exhibit lower Q than for PIFAs having the same volume
- Motorola IPR

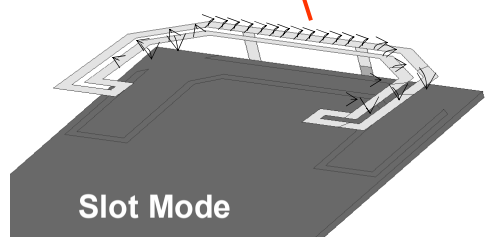


Motorola E398









FICA Resonances

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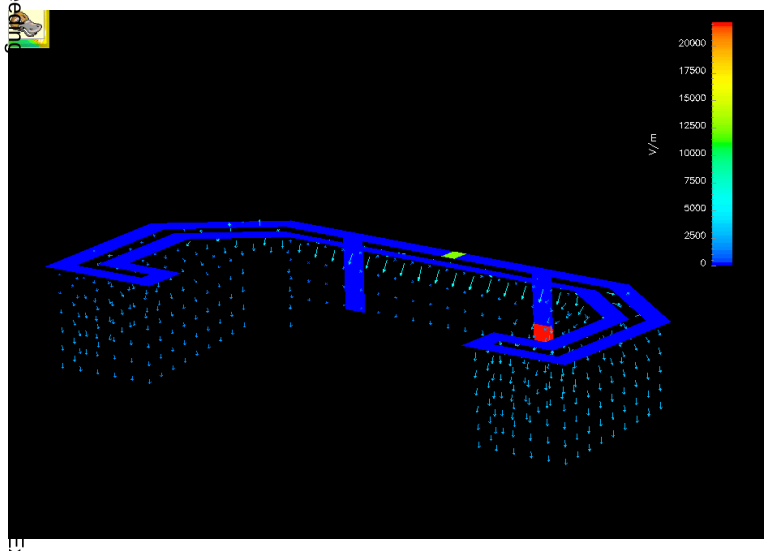
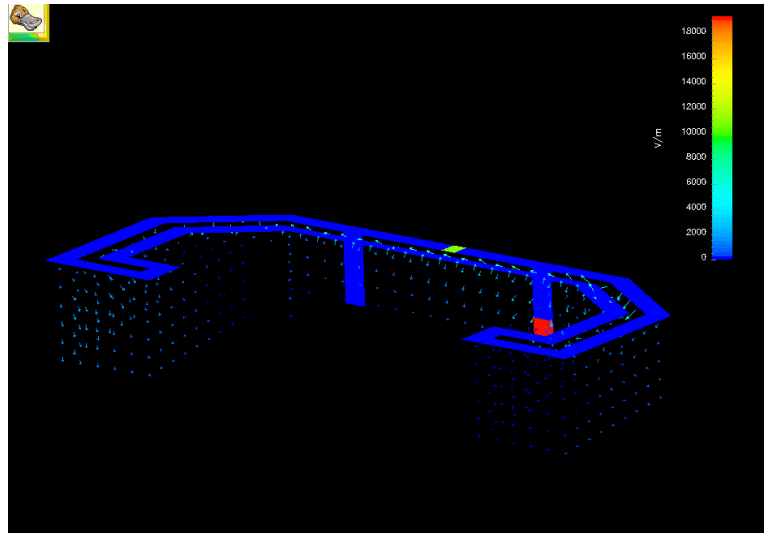
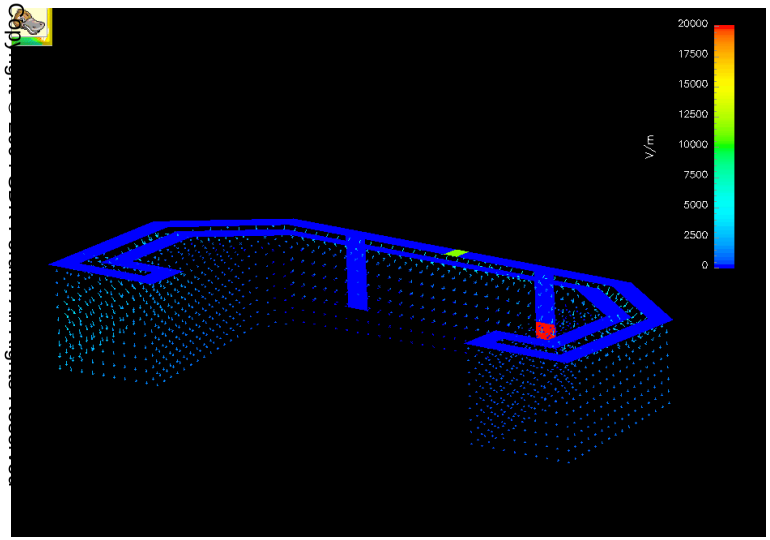


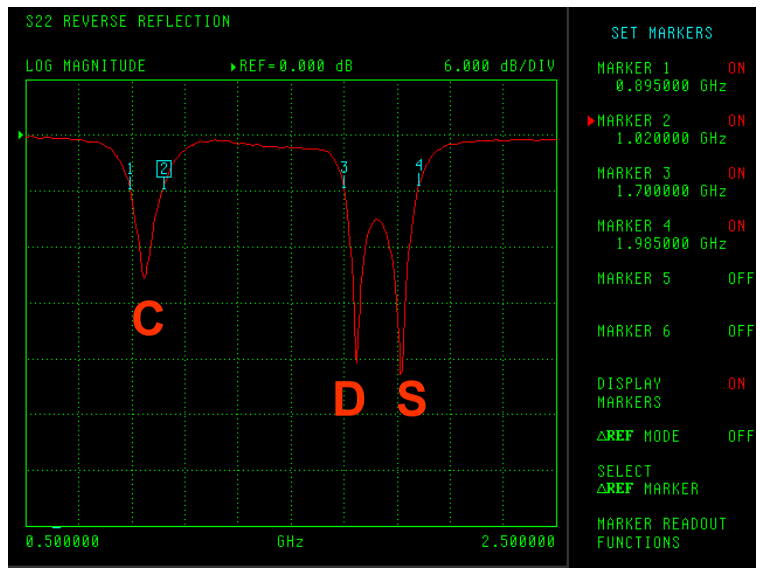
COMMON MODE



DIFFERENTIAL MODE

SLOT MODE





FICA vs PIFA

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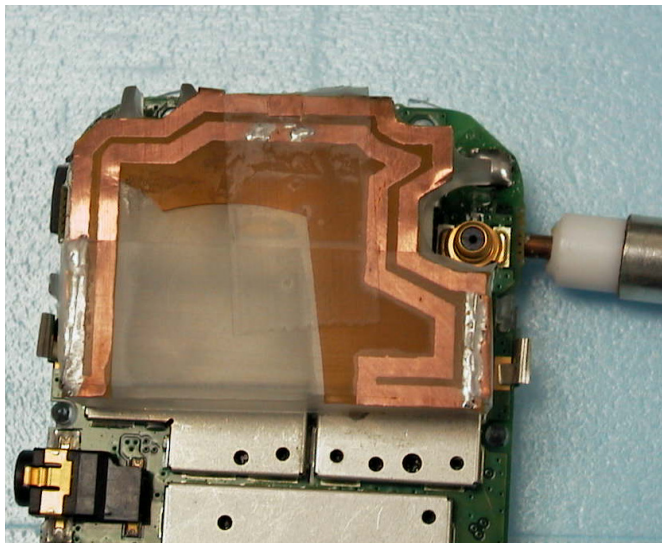
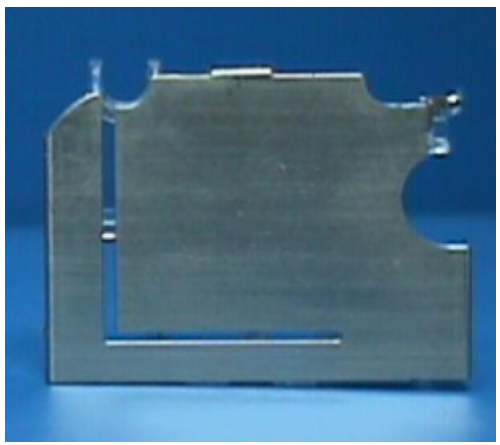
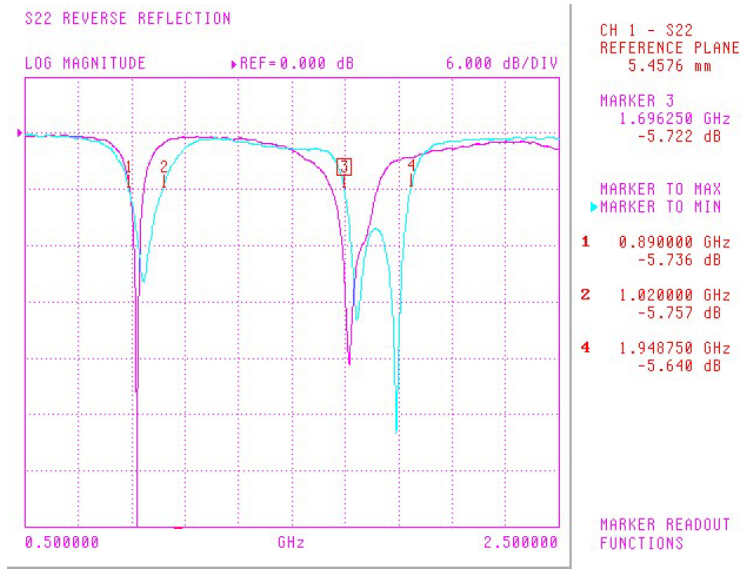
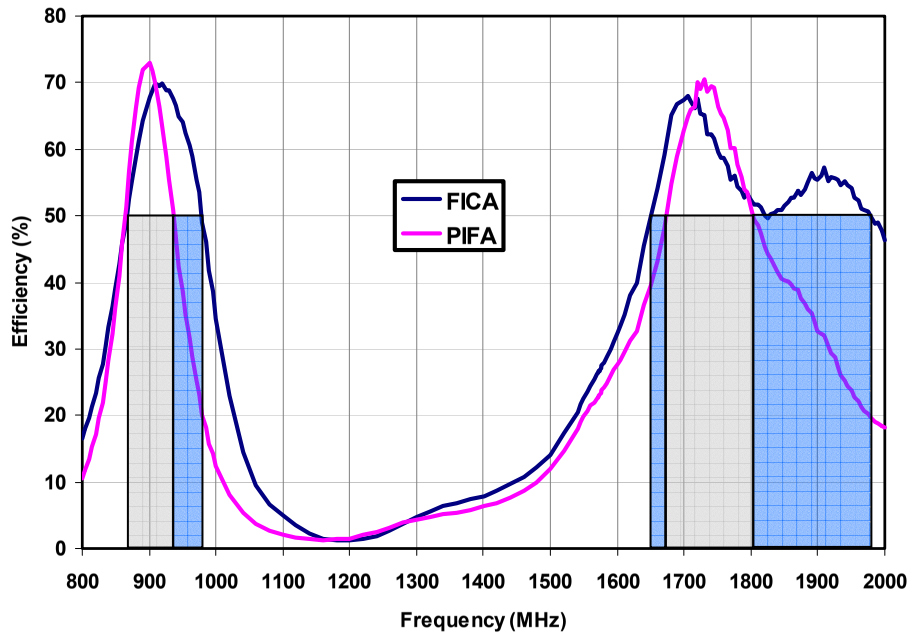
Motorola T192 (dual band GSM)









Multi-band technology: DRA

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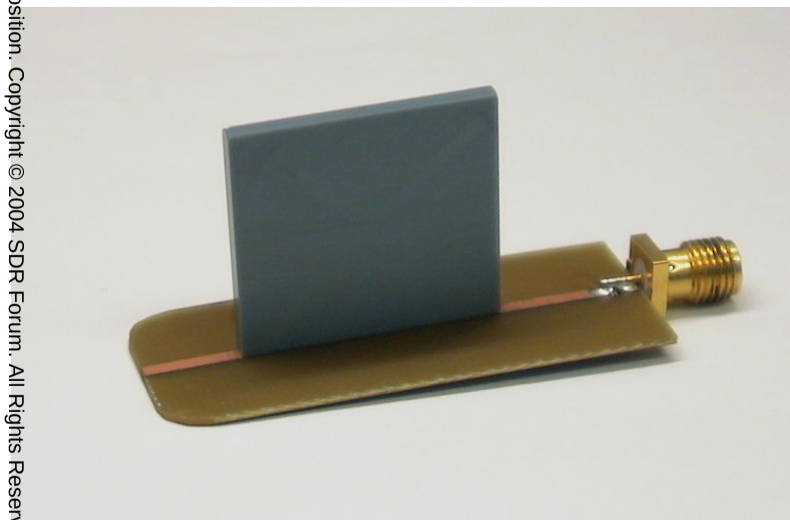
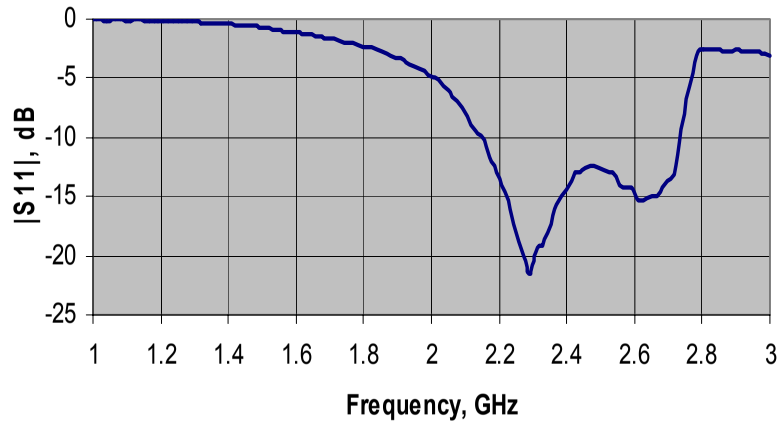
Multi-mode DRAs (Dielectric Resonator Antennas)

- DRA made of low-loss, high-K dielectric material
- Partially confined volume resonance yields high efficiency
- Compact, self-consistent antenna when high-K (>80) is used
- Manufacturing issues
- Motorola IPR





Dimensions of dielectric resonator are: 25 x 23 x 2 mm ; ε_r=80; 50-Ohm feeding microstrip on 31 mil FR-4

DRA Field Configurations

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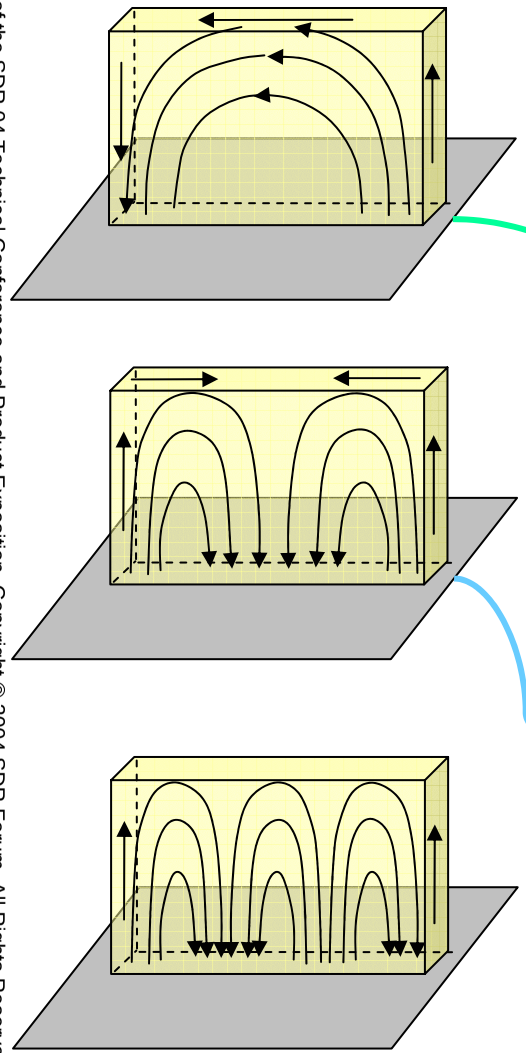
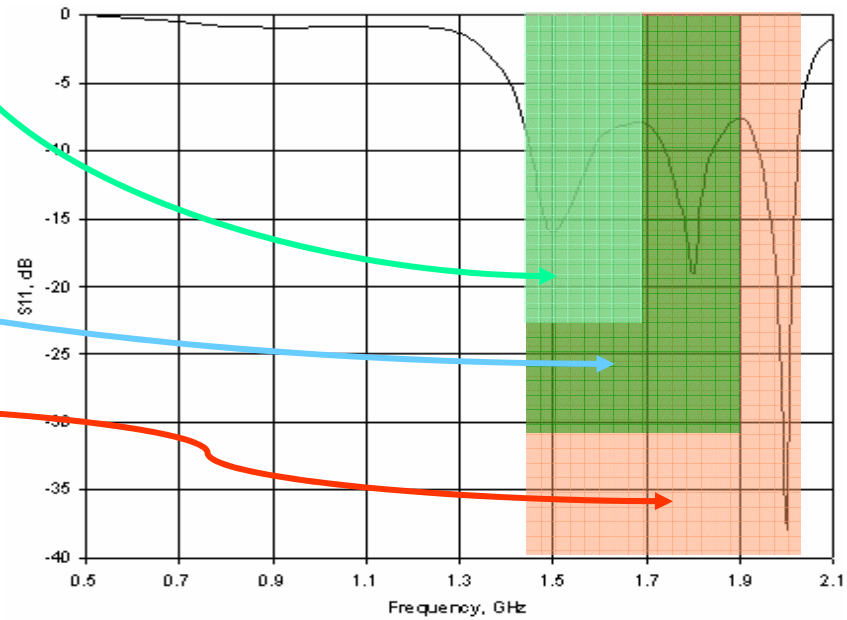


- **Resonant modes**
  - Resonance frequencies NOT in harmonic relation
  - Ground plane or grounded substrate can be used to reduce the height of the resonator
  - Ground plane introduces a significant back-to-front ratio



Multi-band technology: MP-H

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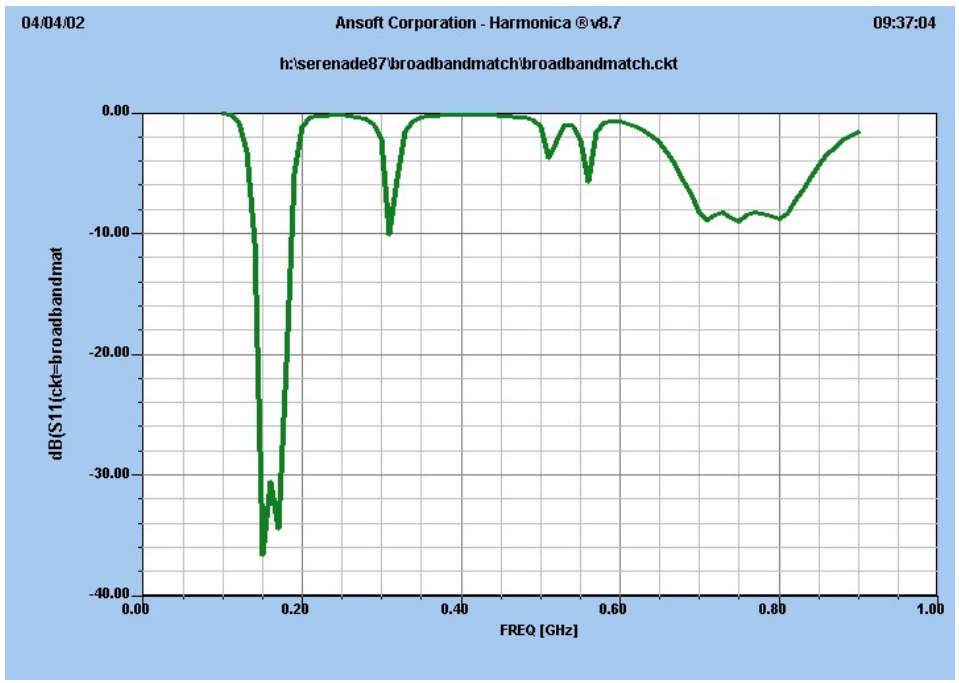
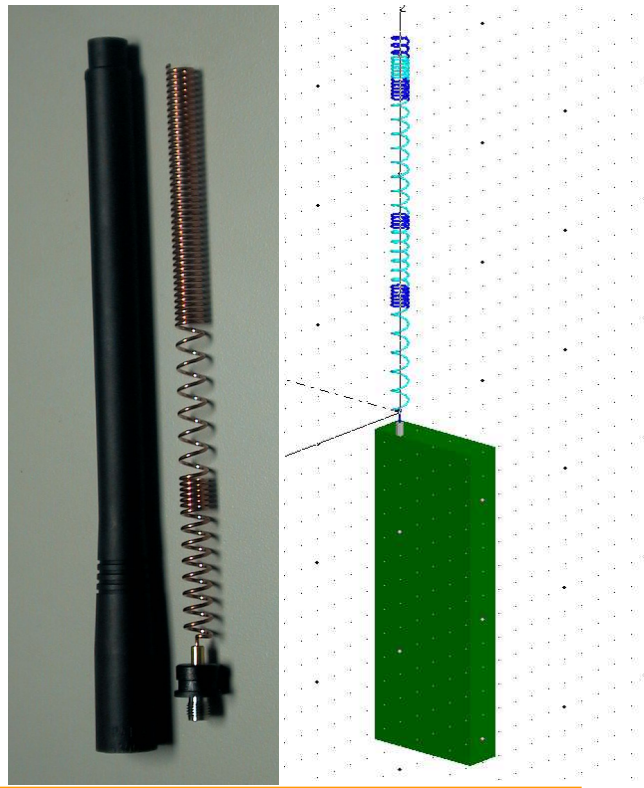
MP-H (Multi-Pitch Helical) technology enables multi-band public safety radios (VHF/700/800)

- Reliable, cost-effective technology for professional SDR
- Pattern characteristics are controllable in order to enhance the communication range
- Terrestrial and satellite coverage





Reconfigurable technology: TuNA

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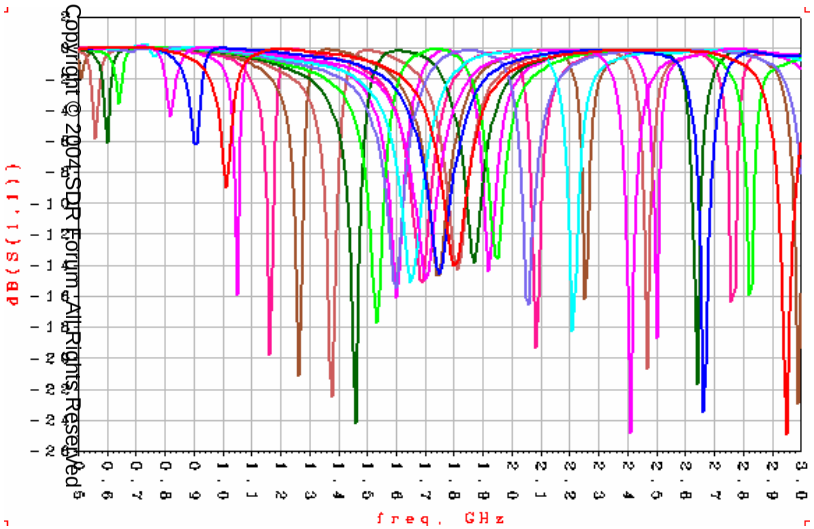
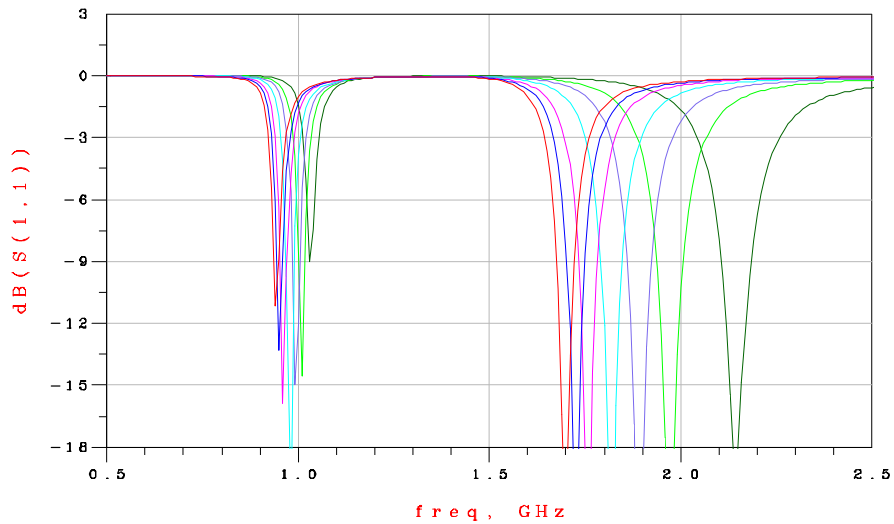
TuNA (Tunable Narrowband Antenna) technology provides extremely compact size and multi-octave tuning range

- Selective coverage of broad spectrum
- Continuous or discontinuous tuning range
- 50-ohm match maintained across tuning range "MATCHED TUNABILITY"
- Conventional switch technology employed to realize tuning states
  - Switches operate in a conducted current environment
- High efficiency (~70%) demonstrated
- High dependency of switch technology evolution
- *Motorola IPR pending*





TuNA Demo

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MEMS switch (Magfusion)

- Bistable
- 3V driving voltage

Tuning network

- 2 switches
- 3 tuning states

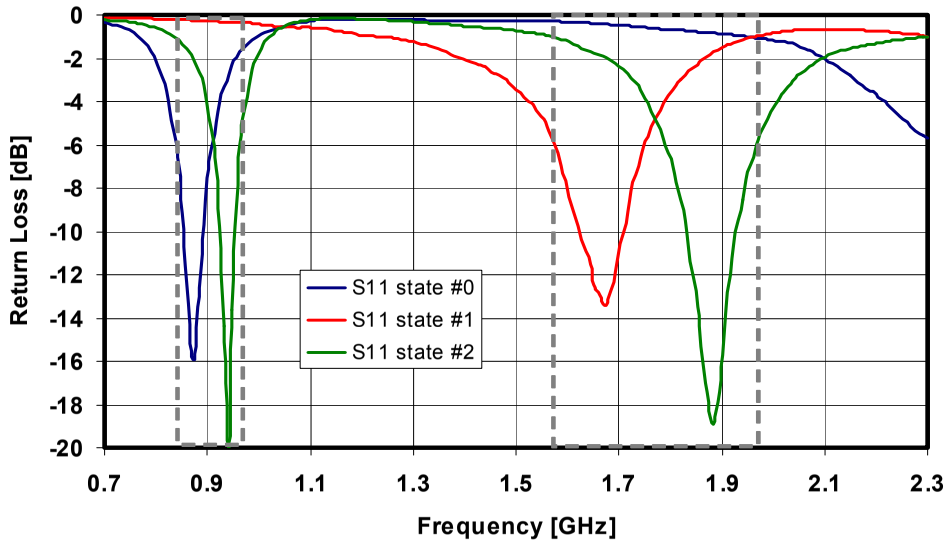
Antenna element

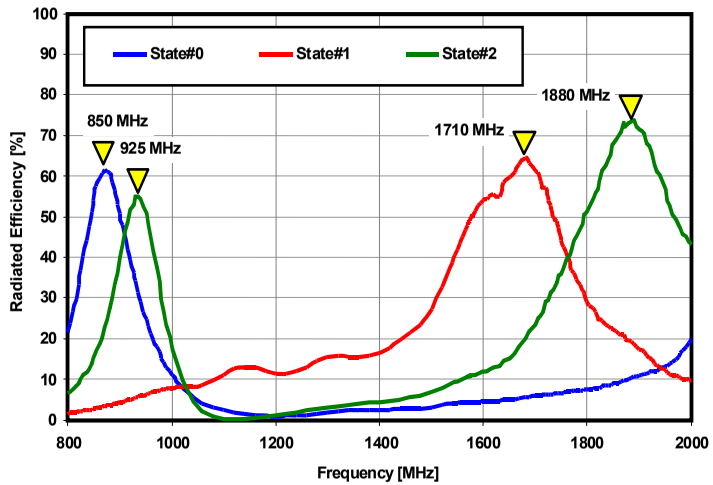
- 3.6 cm^3 antenna element
- 40 x 90 cm^2 PCB

Quadband GSM

- Efficiency > 50%
- Fractional BW covers RX/TX

More states needed





Wideband antennas: Teardrop

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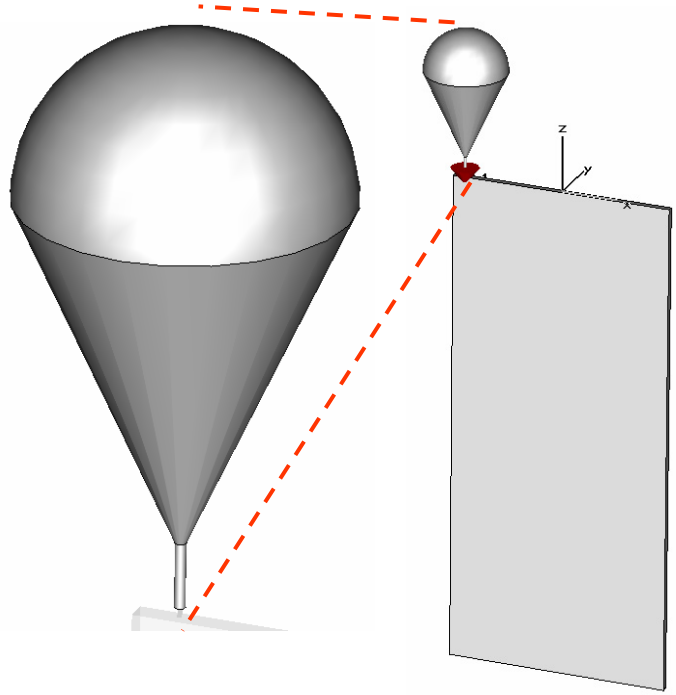
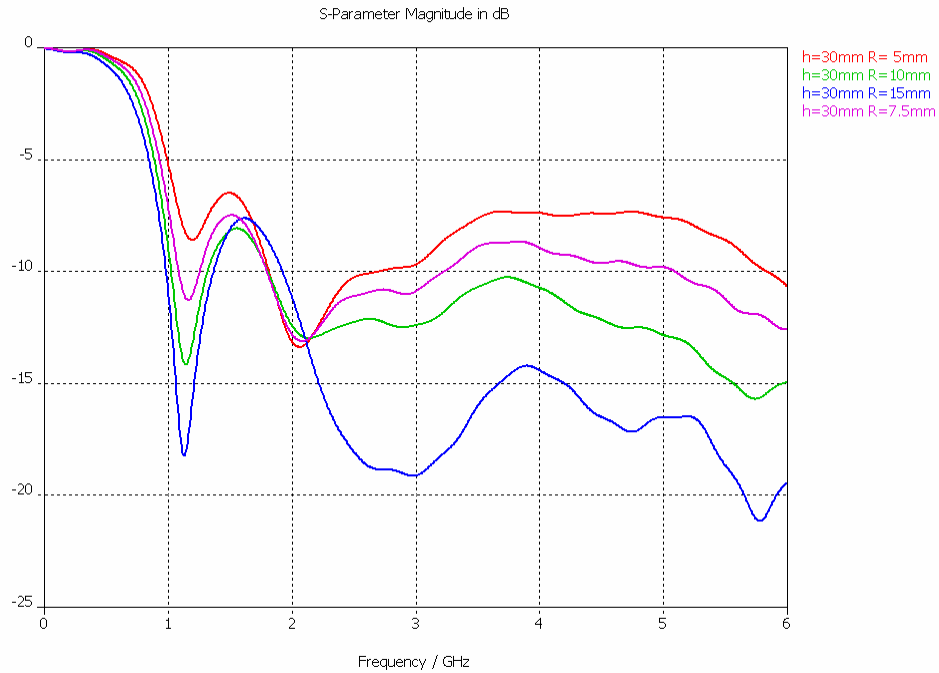
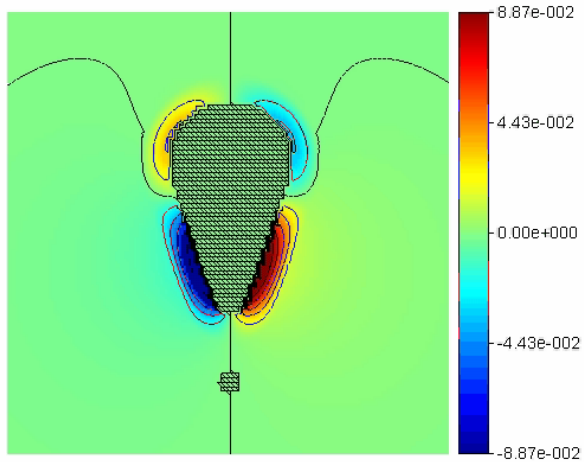
- **External, voluminous antenna**
  - **Instantaneous wide band**
  - **Antenna height determines lower frequency bound**







Teardrop vs Helix

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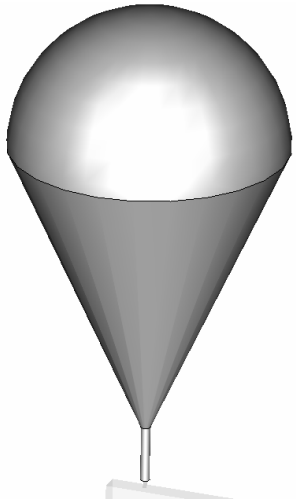

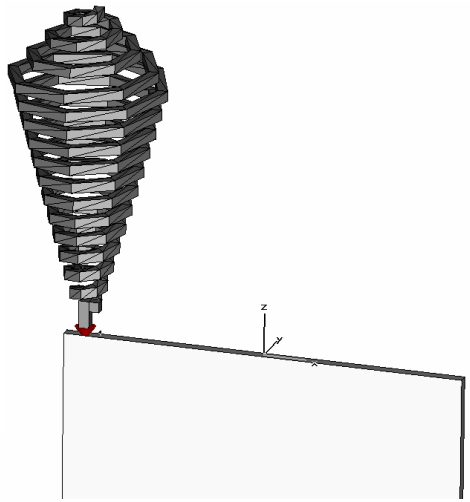

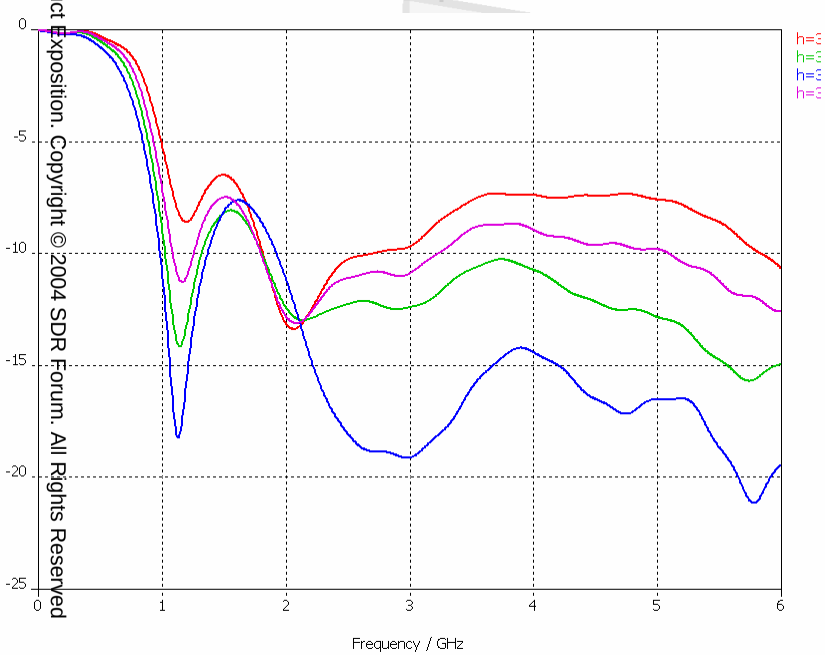

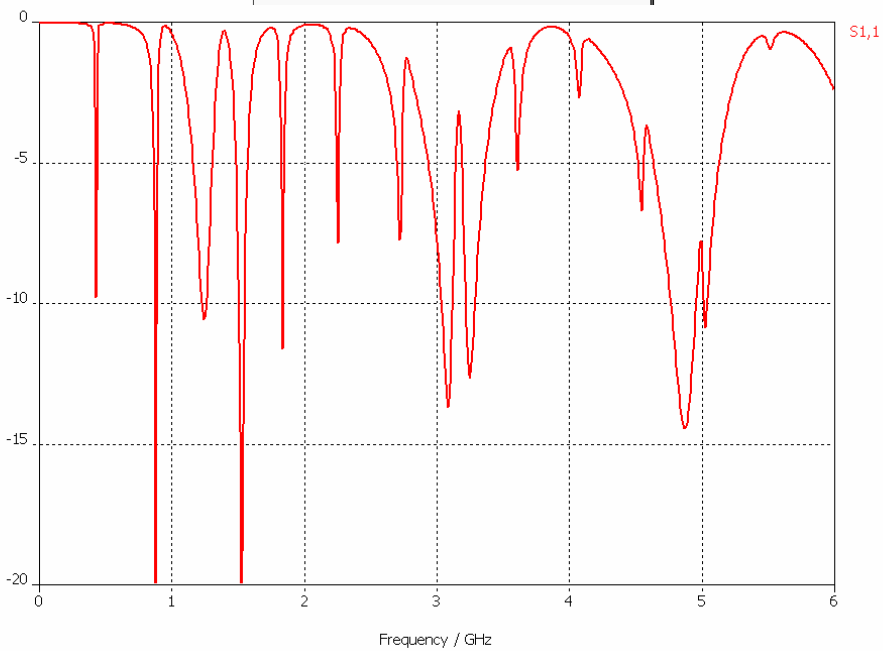

Active antenna systems

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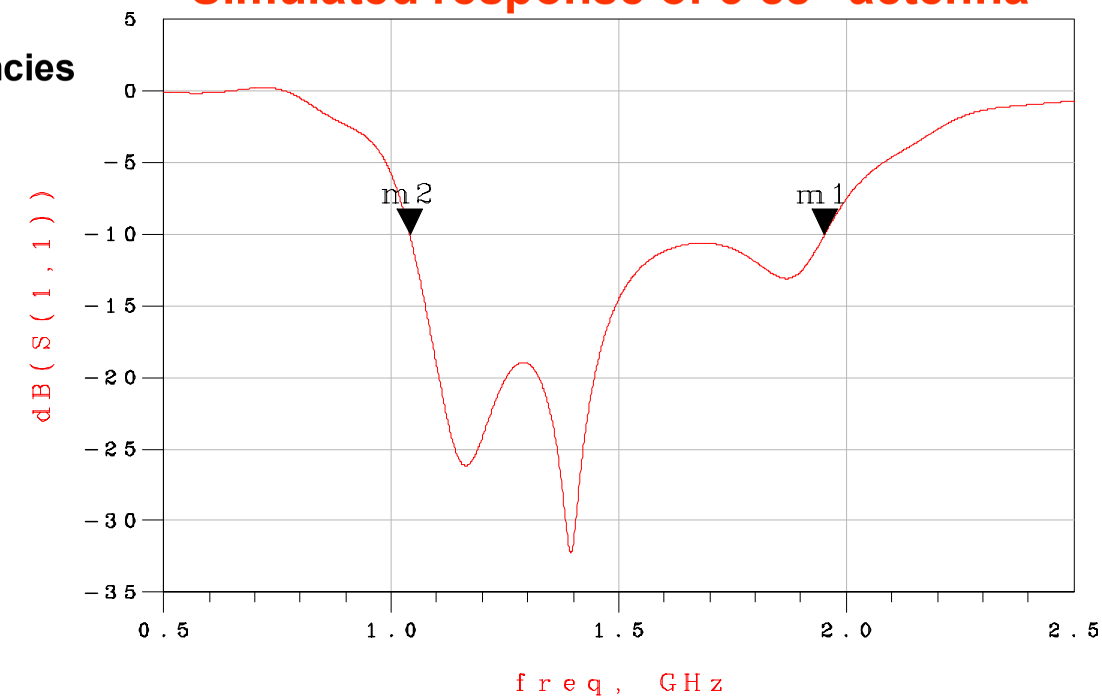
- **Antenna system comprising active circuitry to synthesize desired functions**
  - **Wideband tuning or matching**
  - **Compact size**
  - ***Challenges***
    - **Linearity (dynamic range)**
      - ***Receive only?***
    - **Parasitics at high frequencies**
    - **Cost and complexity**
    - **Reliability**
  - ***Motorola IPR pending***

Simulated response of 3 cc "actenna"



Multi-antenna Systems

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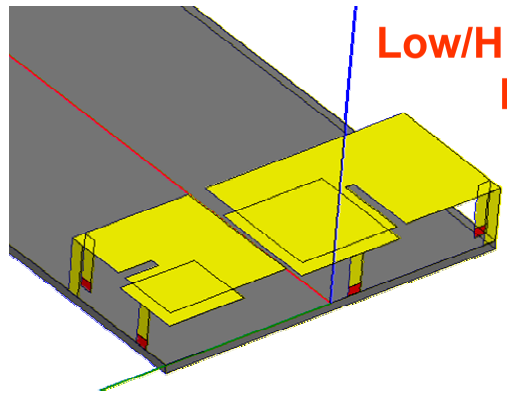
- **Implementing MIMO (Multiple-Input Multiple Output) on portable radios will require multiple antennas, possibly featuring**
  - Low pattern correlation
  - High isolation
  - Compact dimensions
  - Comparable efficiency
  - *Challenges*
    - Size vs BW and efficiency
    - Integration



  - Alternative: single antenna exhibiting multiple radiating modes
    - Less expensive
    - More compact
  - Antenna systems suitable for MIMO can also be employed to implement diversity schemes

References

[1] Balzano et al., "Electromagnetic energy exposure of simulated users of portable cellular telephones," IEEE Transactions on Vehicular Technology, Aug. 1995.

[2] McCoy et al., "Field strengths and specific absorption rates in automotive environments," IEEE Transactions on Vehicular Technology, July 1999.

[3] Balzano et al., "An efficient RF exposure system with precise whole-body average SAR determination for in vivo animal studies at 900 MHz," IEEE Transactions on Microwave Theory and Techniques, Nov. 2000.

[4] Faraone et al., "Estimation of the average power density in the vicinity of cellular base-station collinear array antennas," IEEE Transactions on Vehicular Technology, May 2000.

[5] Cicchetti and Faraone, "Estimation of the peak power density in the vicinity of cellular and radio base station antennas," IEEE Transactions on Electromagnetic Compatibility, May 2004.