ethertronics

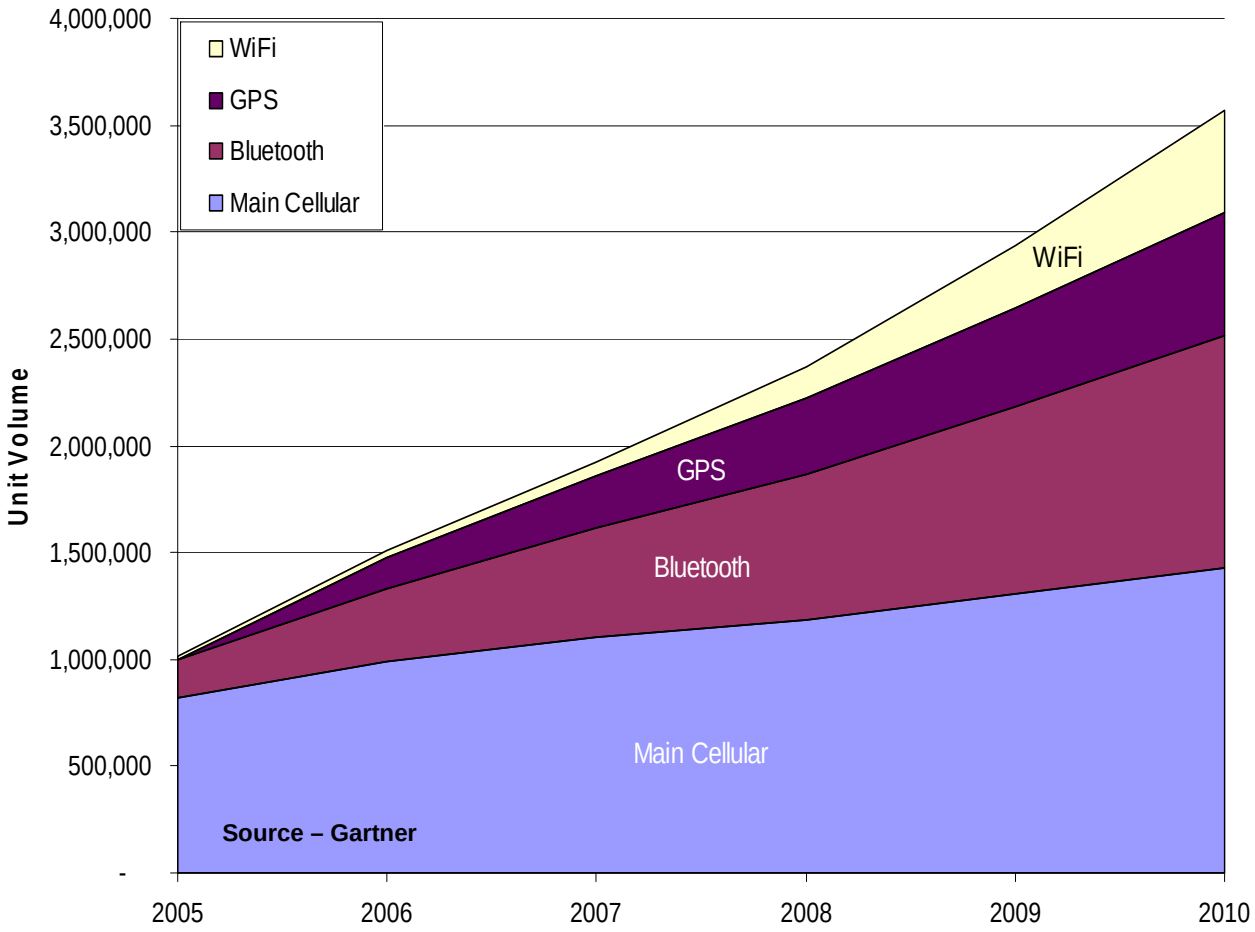
shaping antenna technology™

Advances in High-Performance Ceramic Antennas for Small-Form-Factor, Multi-Technology Devices

Presentation outline

- Market Requirements Driving Multiple Antenna Integration & Thinner Packages
- Antenna Design Requirements
- Advantages of Ethertronics IMD Technology
- GPS Antenna Comparison Testing
- Dual frequency products

Trend: Multiple Antennas per Phone



- Common to have 2-4 antennas per phone
- Most popular features with highest attach rates
  - Bluetooth - 50%
  - GPS - 25%

Trend: Smaller Handsets – Less Volume

71 cubic cm

75 cubic cm

56 cubic cm

55 cubic cm

- Thin phone trend is accelerating
  - Volumes decreasing ~10% per year
  - Ultra Thin handsets are challenging
    - Utilize ~50% of the average volume

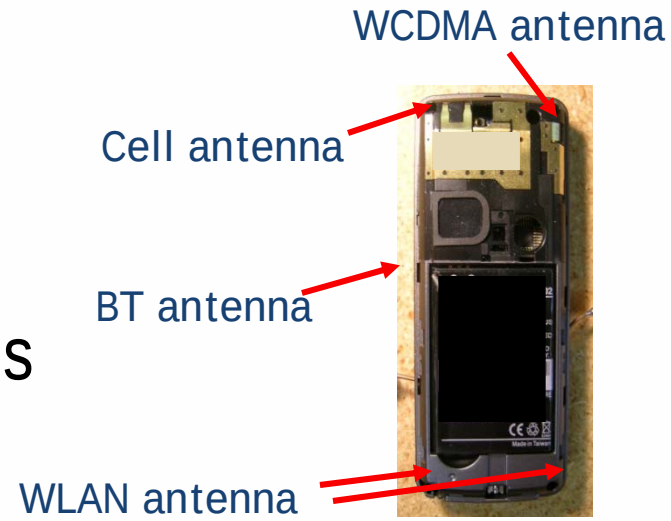
Industry Trendline
Cell Phone Volumes

	Avg Phone Volume
2004	131 cu.cm
2005	122 cu.cm
2006	106 cu.cm
Ultra Thin	55 cu.cm

Source: Current Analysis

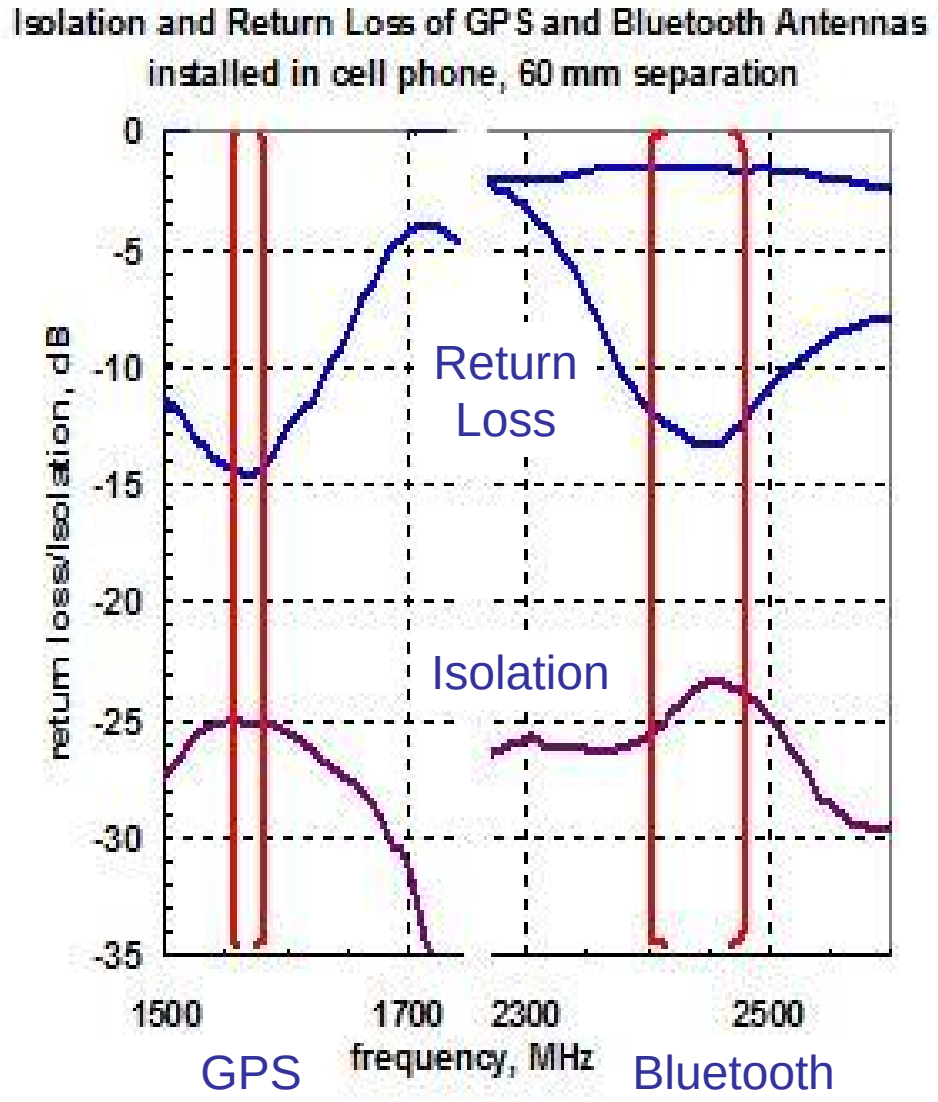
Design Challenges

- Overall device size shrinking
  - More antennas in less space
  - Maximum component height under 2.5mm for Ultra models
- More parasitic elements
  - Speakers, cameras, flex…
- Less quality real estate
  - More I/O connectors on side of the board
- Antenna collocation
  - Diversity or different applications
  - Example: Bluetooth and WiFi integration



Antenna Requirements

Benchmark Dual Band Performance



- Typical antenna specifications:
  - Better than 10 dB Return Loss
  - Better than 20 dB Isolation
- Benchmark phone required 25 dB of isolation to meet OEM performance specifications

Antenna Volume Theory

- Wheeler & Mc Lean provided the basic insights for identifying the real effective volume of embedded antennas
- Wheeler's Formula

$$\frac{\Delta f}{f} = K \times \frac{\text{antenna mode volume}}{(\text{radio wavelength})^3}$$

- Given constraints on design space, how should one compare two antennas when their "antenna mode volume" will become altered as part of the mechanical design?
  - How close is the nearest metal object?
  - Should coupling effects and consequences be considered?

Antenna Requirements

- Smaller antennas in close proximity
  - With high efficiency – above 40% threshold
  - Well-controlled radiation – resist performance changes (good for customer as well as designer)
  - Immunity to other frequencies or diversity antennas
    - GPS separation from UMTS-1700, sharing of 2.4 GHz
- How to achieve ideal performance:
  - Decrease interaction between antennas
  - Decrease interaction between phone elements
  - Minimize antenna ground dependence

Key Factors

Isolation

Selectivity

Isolation Drives Overall Performance

Isolation describes how an antenna interacts with its surrounding.

How can isolation be improved ?

By shaping the antenna's near field away from the perturbations and the absorbers.

ET antenna isolation: 2mm
for 0.3% frequency shift

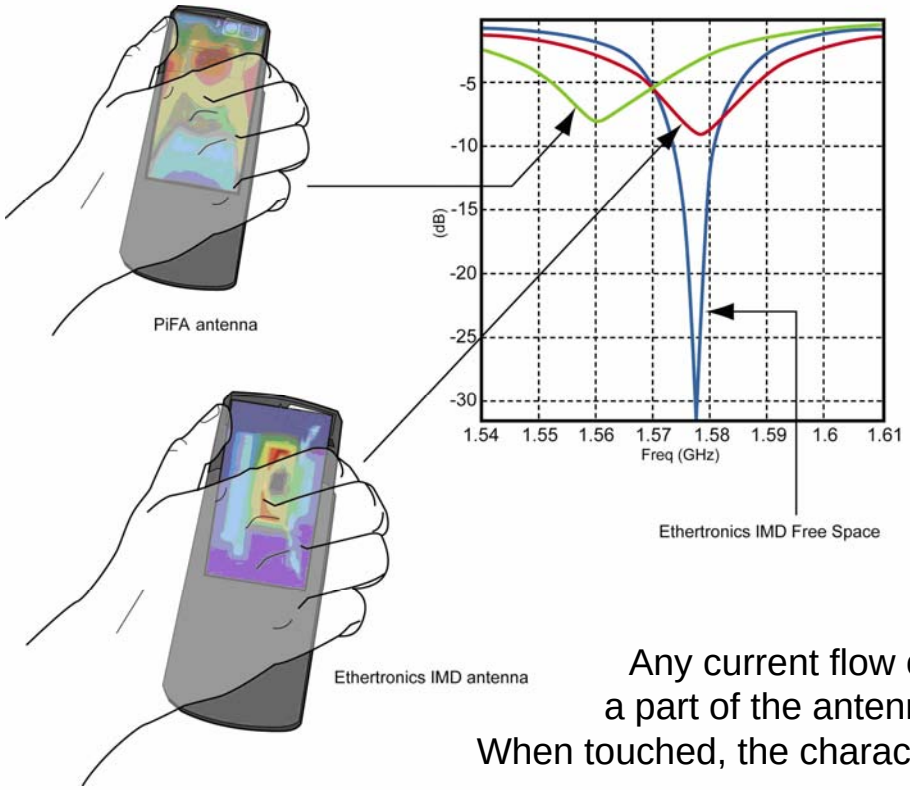
Superior isolation allows:
- better efficiency
- easier integration
- semi-standardized products

IMD Provides Superior Isolation

- ET IMD antennas are more tolerant of interfering objects
  - Hand placement and head significantly impact performance
- GPS signal strength improved by staying on frequency

Return-Loss Chart

Before / After Hand Placement



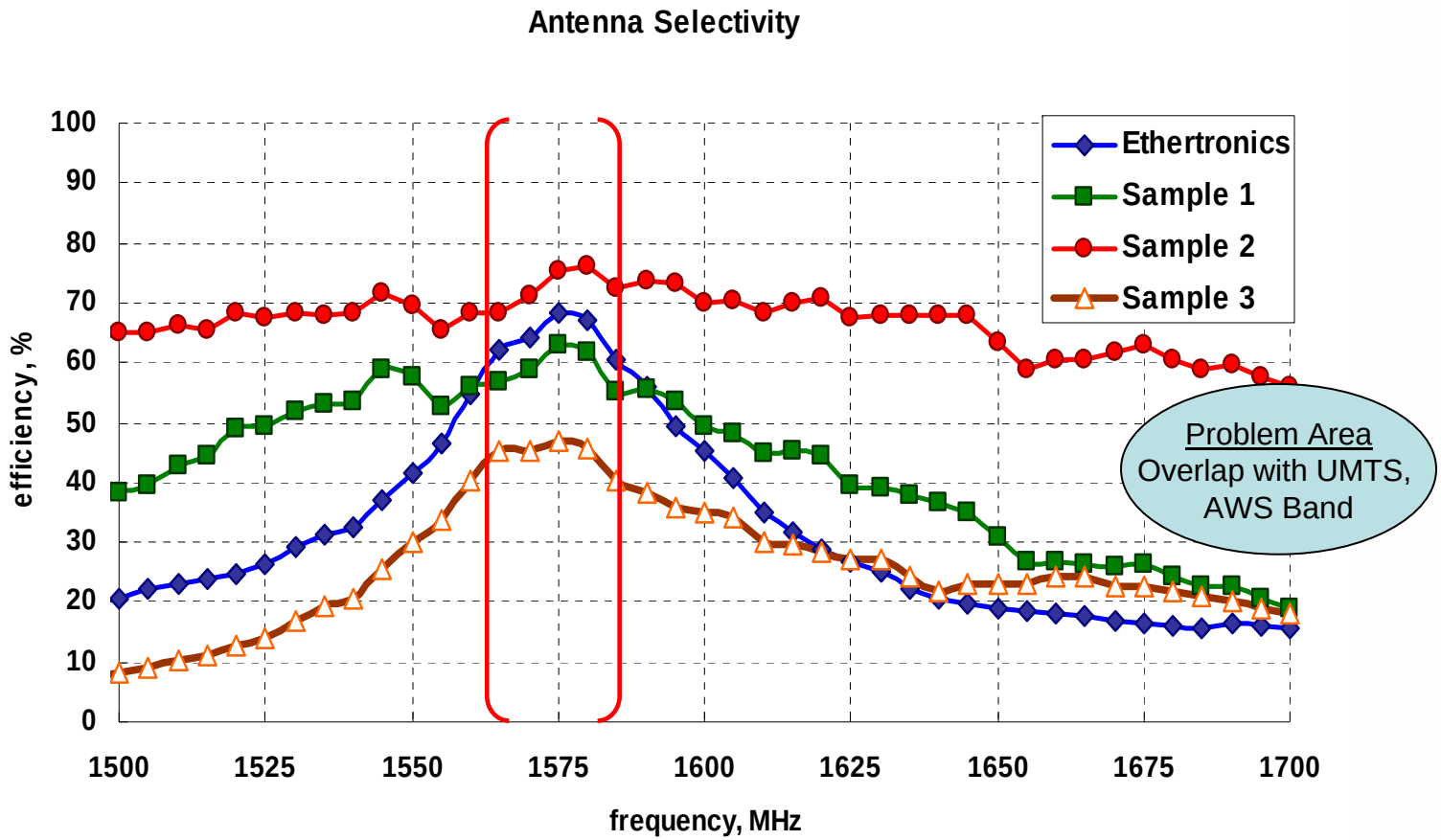
Isolation Test Results

- **GPS Internal antenna example**
  -very sensitive to freq. shift
- **IMD antennas stay on frequency even with interference from other objects – e.g., hand**

Any current flow on the board becomes
a part of the antenna radiating mechanism.
When touched, the characteristics of the antenna change.

GPS Antenna Comparisons

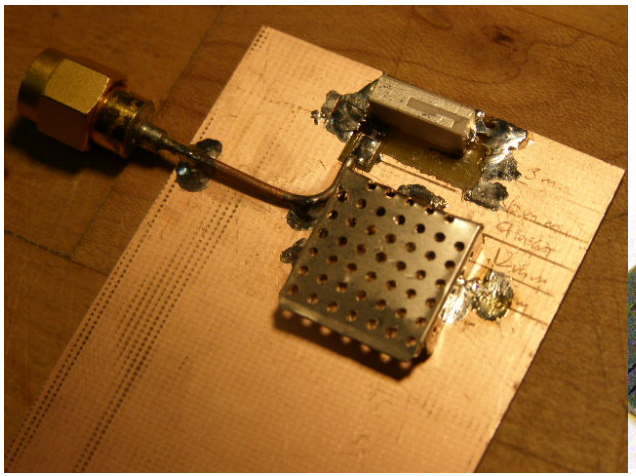
(following vendors recommendations)

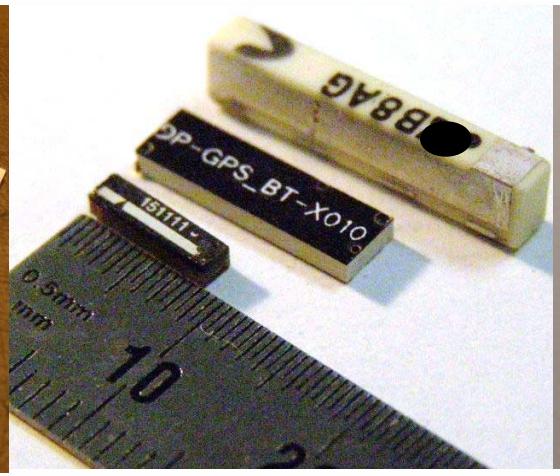


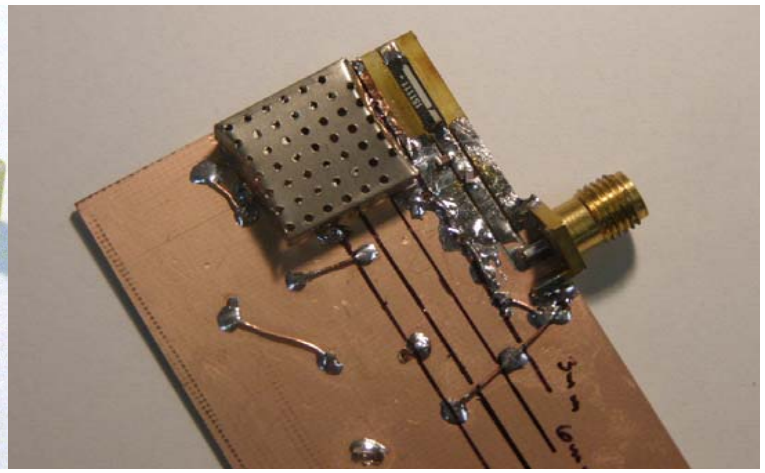
- Highest efficiency does not tell entire story
  - Important to also study the frequency component of antenna's efficiency
- Selectivity – ability to reject the frequencies outside its range

Ceramic GPS Antenna Test Bed

Several Variables to Consider



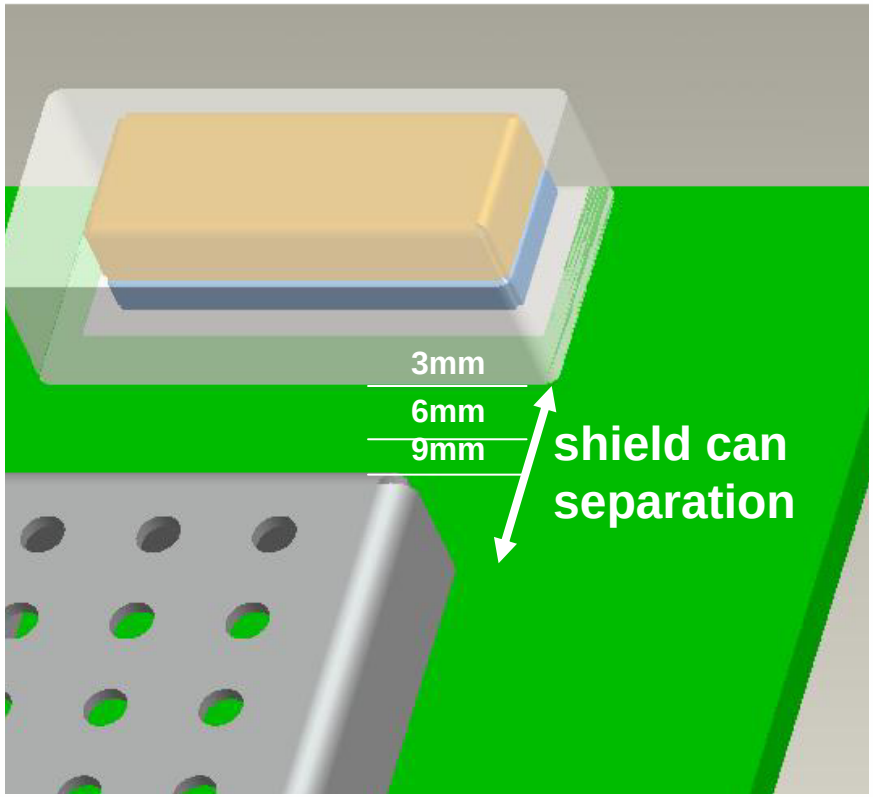




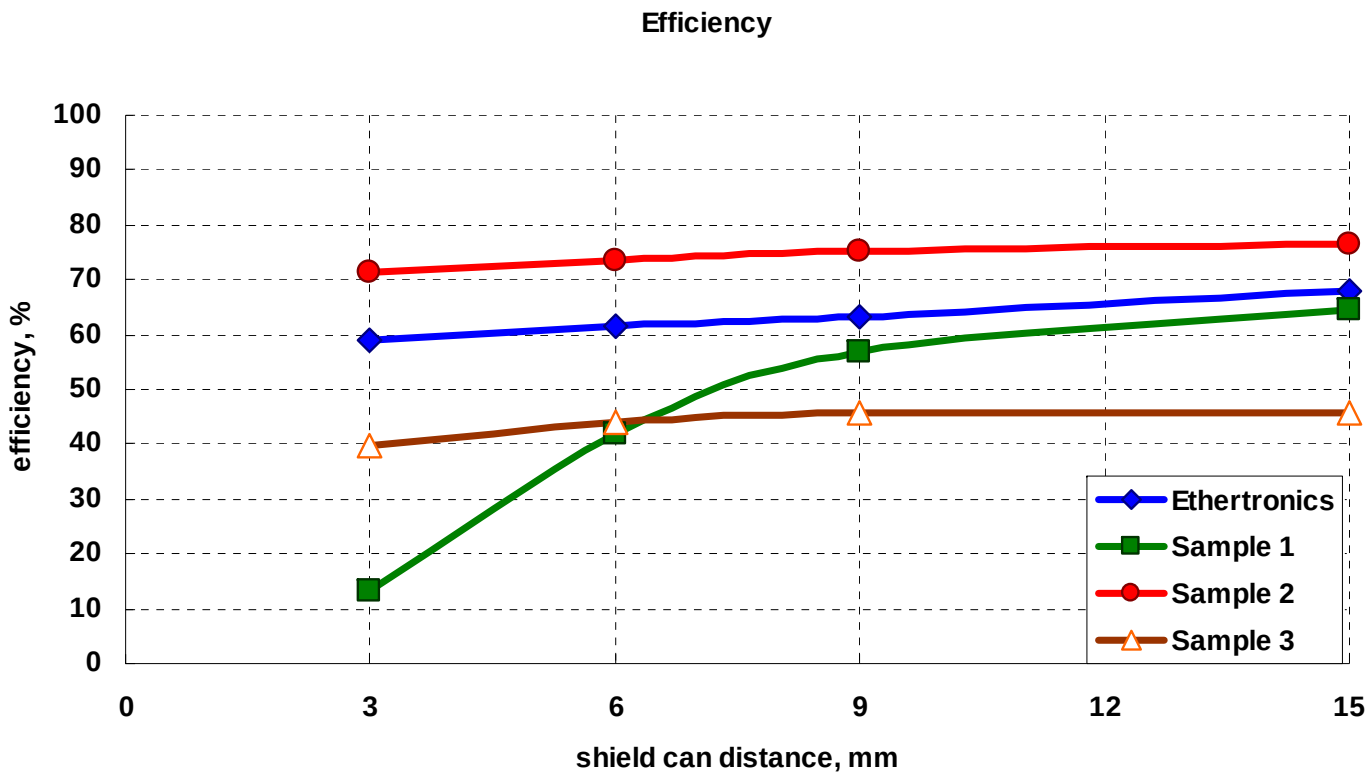
- The antenna may require ground plane removal
- It will excite some of the board, but how much?
  - the board itself could become the antenna
- What about board placement, and distance to nearest interferers, eg a shield can, or a battery
- We developed a test bed, focusing on the isolation, selectivity, efficiency and position of the antenna

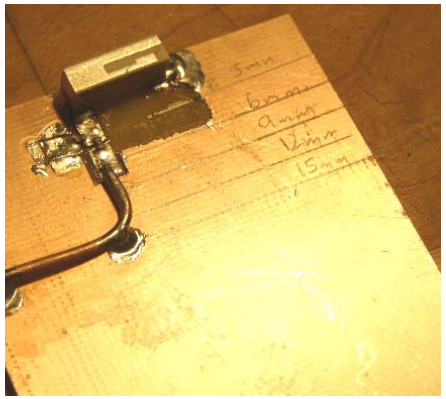
Shield Can Separation Test

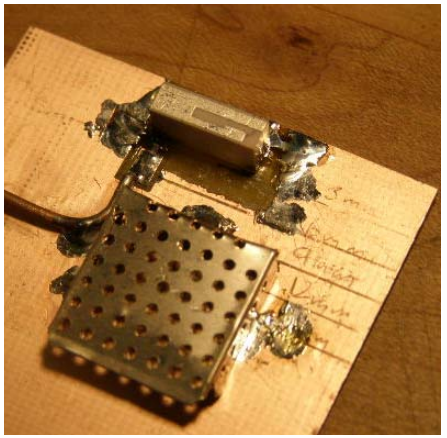
- Several Tests utilizing metal can as interferer
  - Measure changes in:
    - Efficiency
    - Center frequency
  - At 3 distances
    - 3, 6 and 9mm apart
- Calculate Volume/Area
  - Device size
    - Footprint & placement
  - Real antenna volume
    - Interaction with can
- Keep-out zone is 3D



Efficiency Lowered by Shield Can

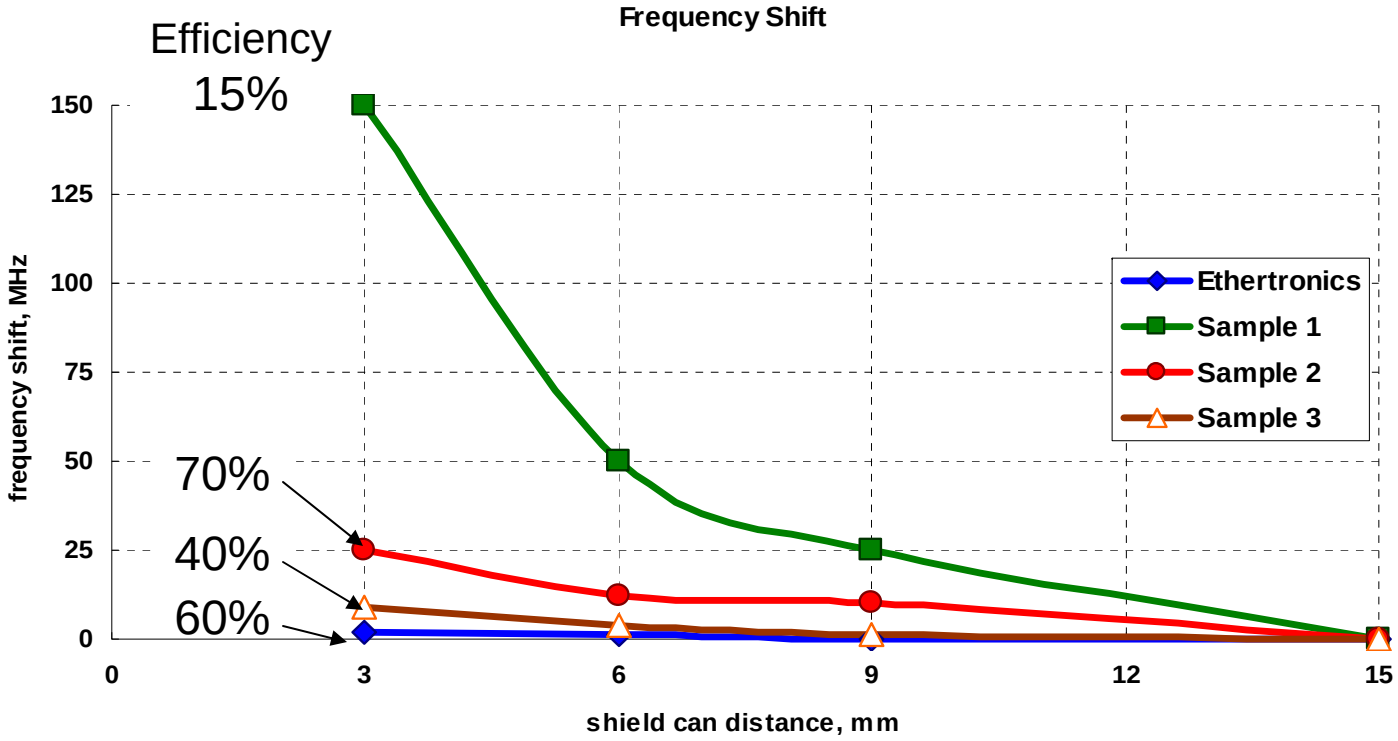


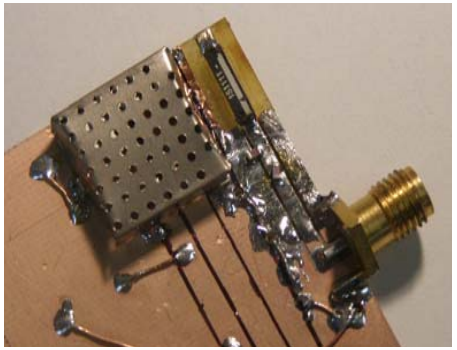


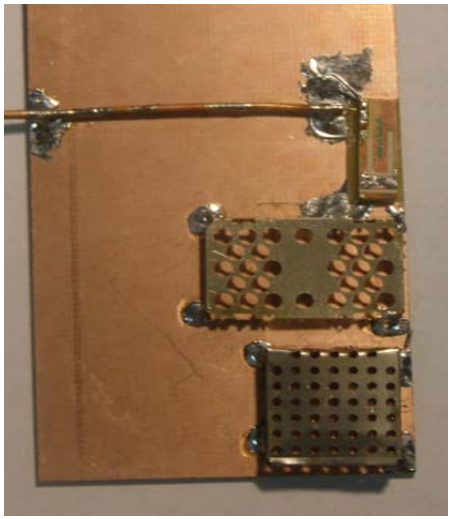


- Sample 1, significantly impacted
- Broadband antenna has best performance
- All samples above 40% efficiency threshold in free space

Frequency Shifted by Shield Can





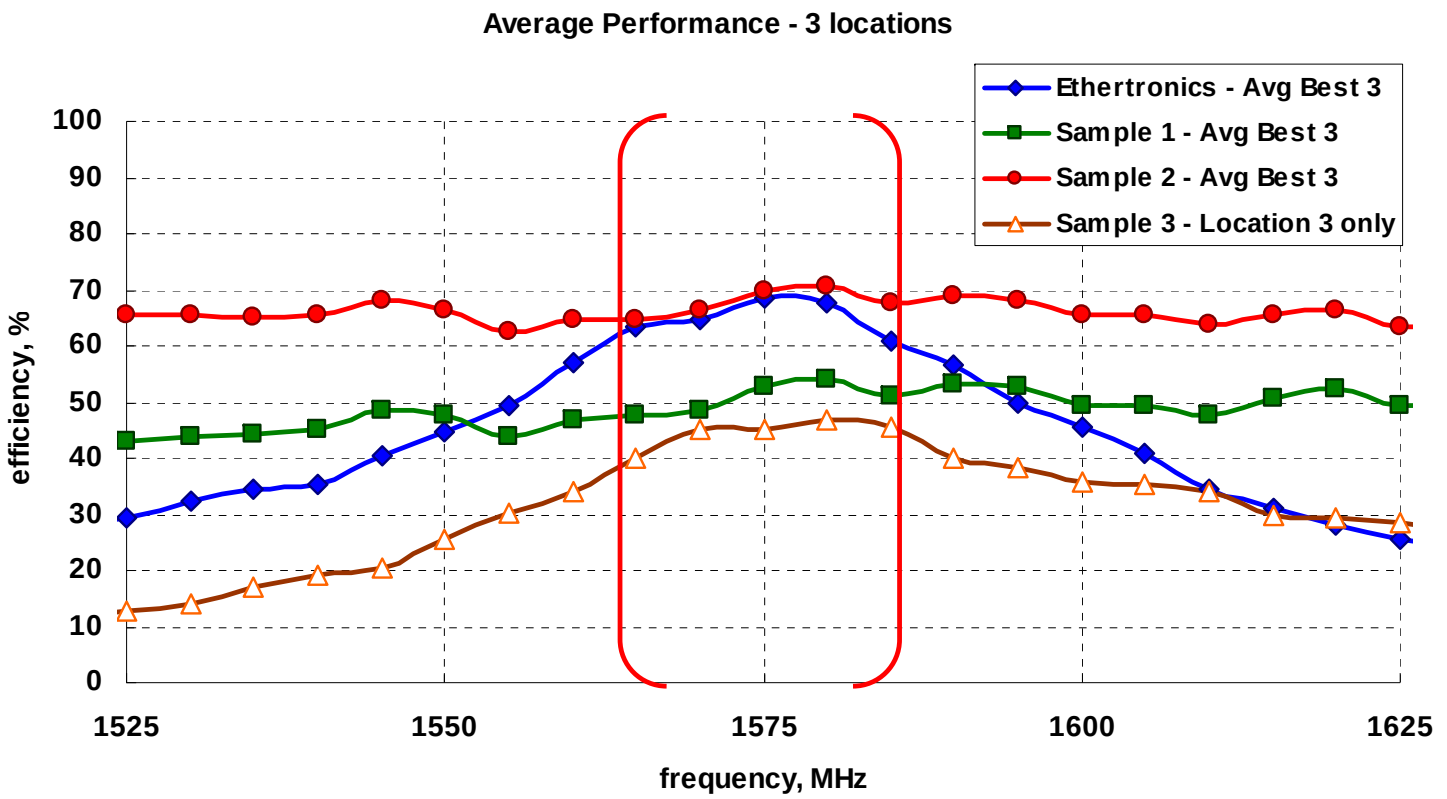


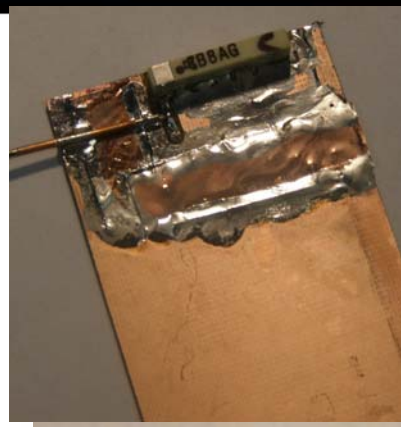
- Sample 1 significantly impacted
- High-efficiency, broadband sample 2 survives shift's impact
- IMD antenna stays rock solid on frequency

Board Position Test Set up

- How often is the best antenna location where one has space to place it?
- Determine how much normal performance can vary from the specified best case…

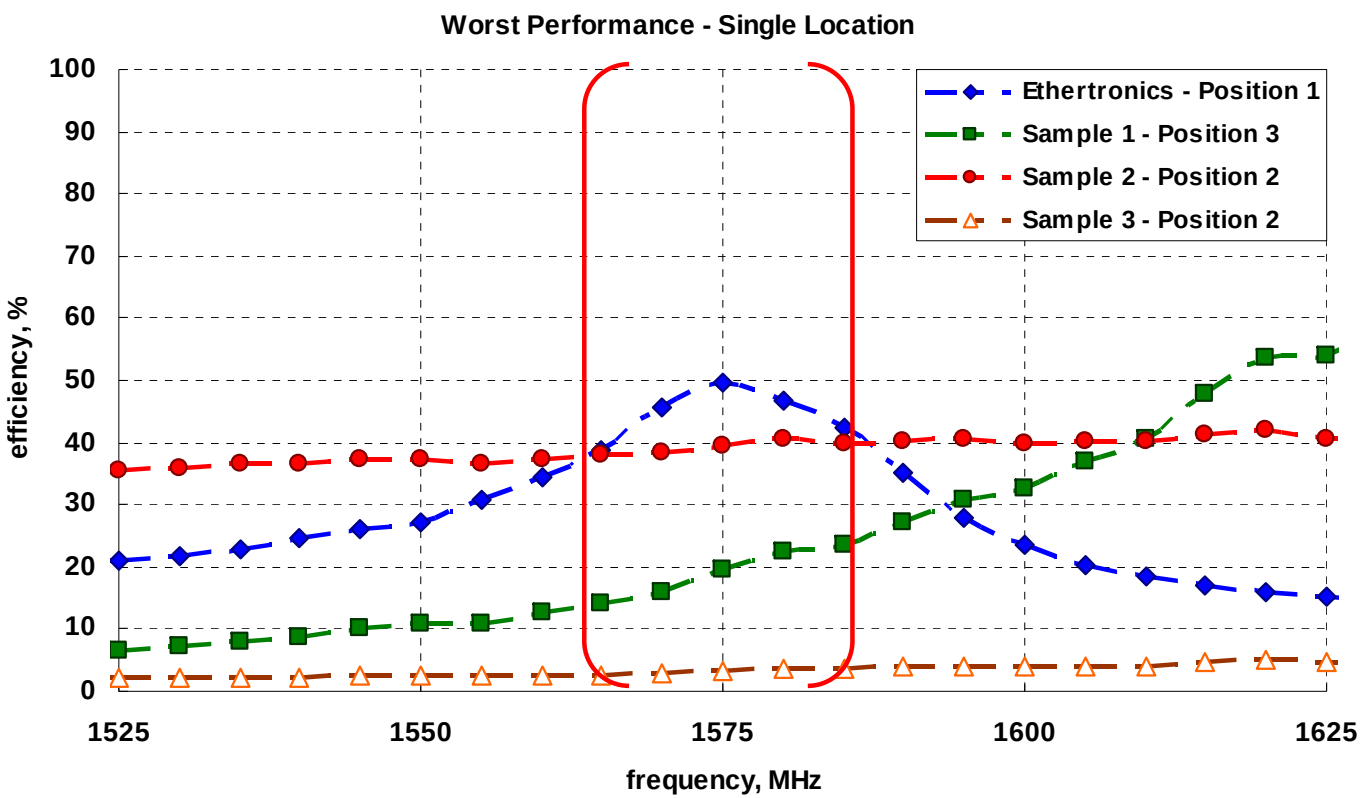
Typical GPS Antenna Performance

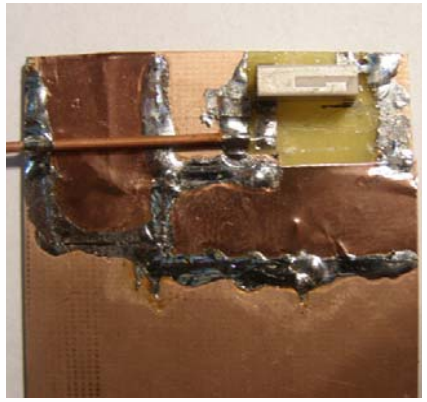




- Average from 3 best positions out of 4 tested
- Samples 1 & 2 show a 5~10% drop from peak efficiency
- IMD stayed consistent across all three locations

“Worst Case” Performance





- Two antennas still above 40% threshold
  - Broadband antenna Sample 2 vs IMD Dual Band, Dual Feed
    - IMD antenna decreased efficiency by 25% vs >50%+ by all others

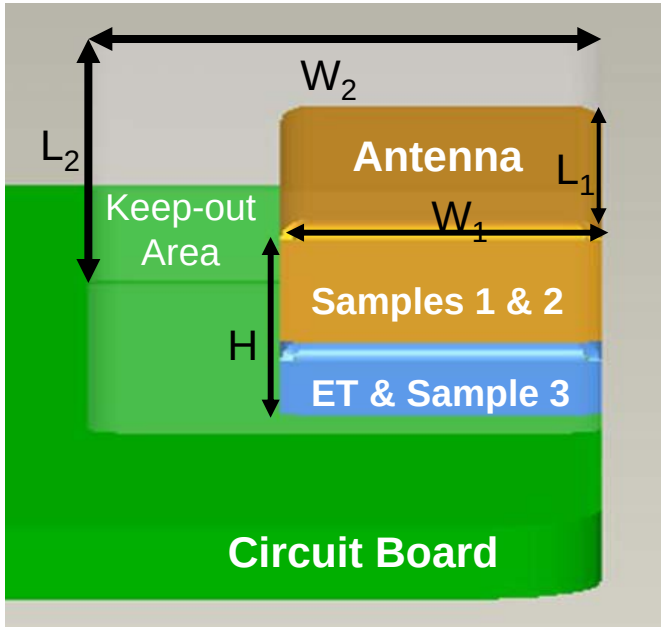
Summary of Test Results

	L_1	W_1	H	Ground Clearance (GC)	Total PCB Area	Shield Can Offset	Real PCB Area	Antenna's Volume	Measured Efficiency	Observations
Sample 1	10	3	4	3	96	9	**336**	**1,344**	65%	Limited Isolation from its environment; significant perf changes
Sample 2	20	3	4	0	60	3	**156**	**624**	77%	High Gain, but poor GPS band selectivity; need BPF
Sample 3	8	2	1.5	2	48	3	**70**	**105**	46%	Low Efficiency, stable performance, single location usage
ET BT & GPS	14	4	1.3	1	80	3	**140**	**182**	68%	Steady performance under all conditions; thinnest package
ET GPS only	10	4	1.3	1	60	3	**112**	**146**	68%	Best efficiency to volume ratio

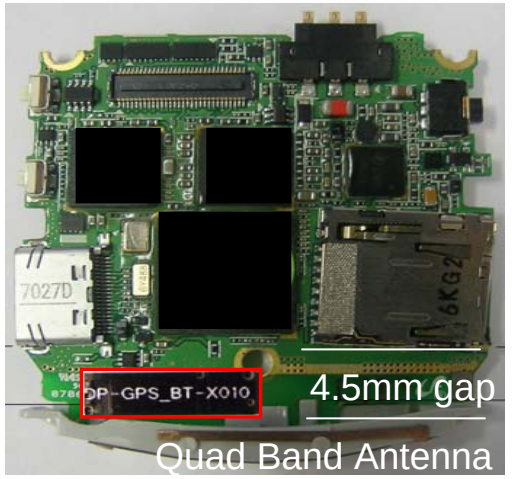
all measurements in mm, sq mm, or cu mm

Area = (L_1 + 2x GC) x (W_1 + GC) Use L_2 and W_2

- Simple Volume test provided valuable insights on efficiency and freq shifts
- Two antennas excelled throughout
  - Ethertronics and Broadband Sample #2
- Design Tradeoffs include:
  - Keep Out and Ground restrictions
  - Cost & Space needed for Filters



New Antenna Up To Market Challenges



- Phone real estate as pricey as Paris
  - So combining functions is mandatory
  - Yet antennas prefer separation for isolation
- Perform a Best of Performance Criteria Review
  - Compact Size, Great Isolation & Freq Stability
  - Flexible implementation without sacrificing gain
- ET's IMD dual band, dual feed antenna products
  - GPS and Bluetooth sampling now
  - PCS Diversity, WiFi, WiMAX and others in testing

Next Generation of Ceramic Antennas

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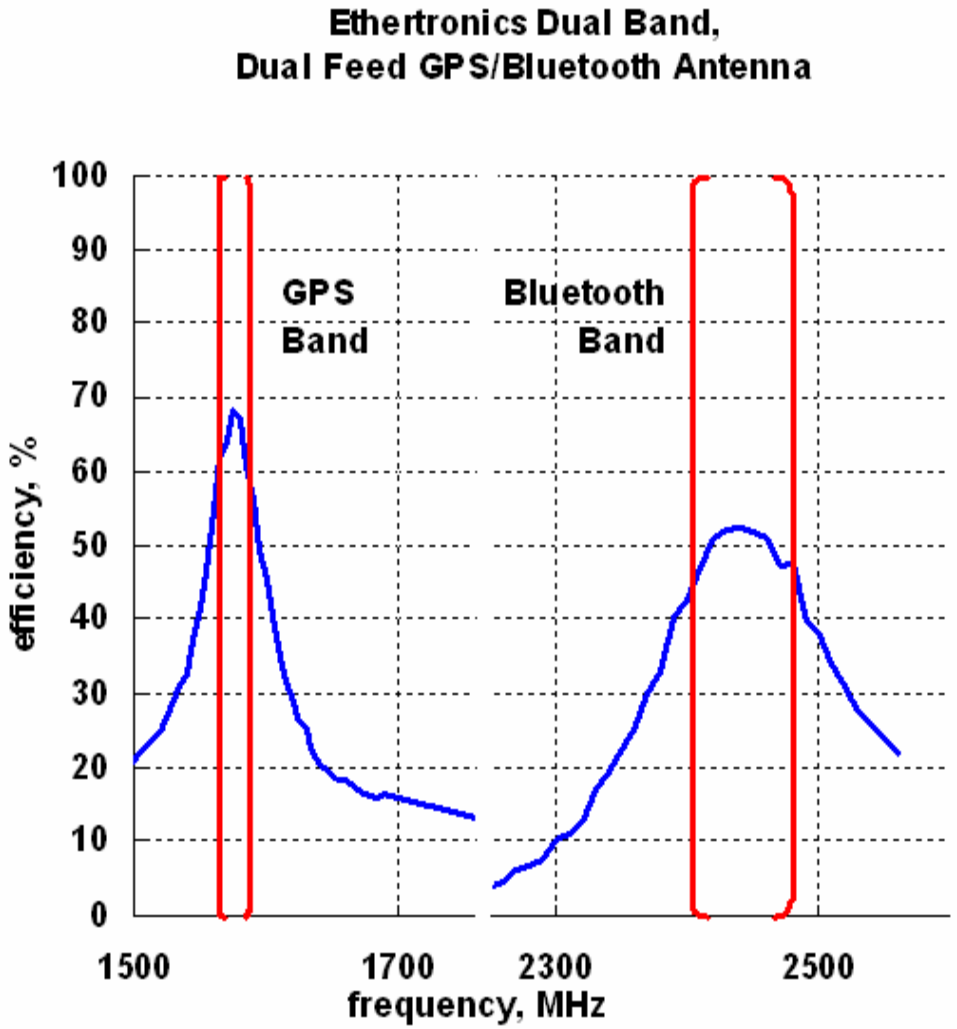
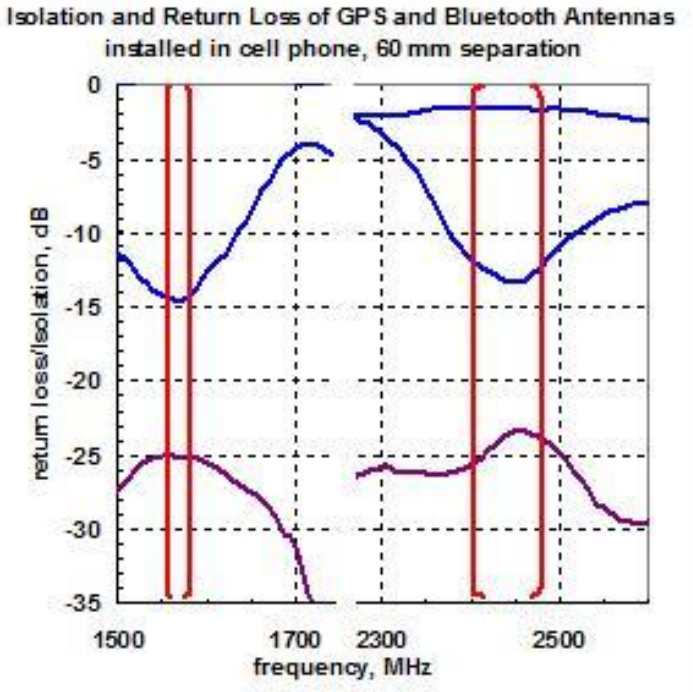
shaping antenna technology

- Leverages underlying IMD technology
- Dual Band, Dual Feed
  - Ideal implementation

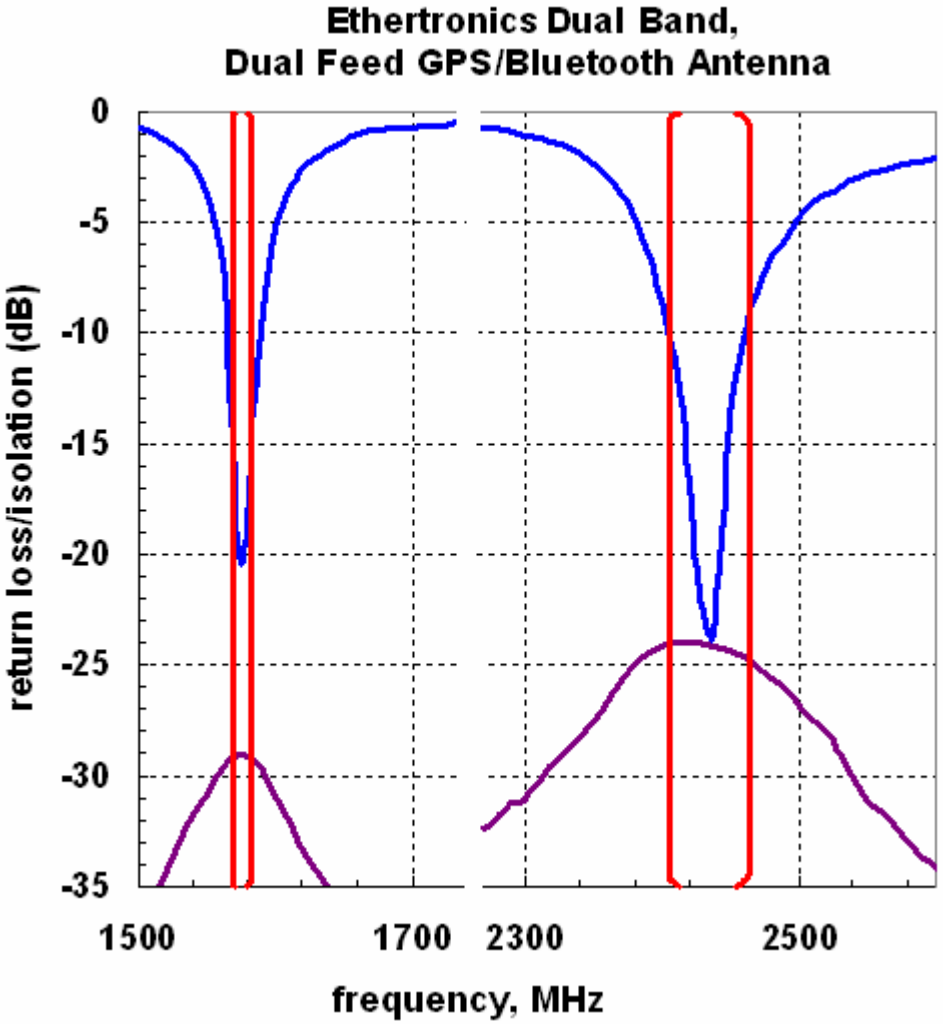
- Peak Efficiency
  - GPS over 68%
  - Bluetooth over 50%



One Antenna Outperforms Two…



- Ceramic version improves key results by approx 4 dB
  - GPS isolation



Conclusion

- Smaller and more complex phone designs make antenna design more challenging.
- IMD technology allows smaller designs and better performance in densely populated volumes.
- IMD's isolation and selectivity allow integration of multiple antennas in a single ceramic block.
- Ceramic IMD antennas demonstrate ideal characteristics for next-generation products.

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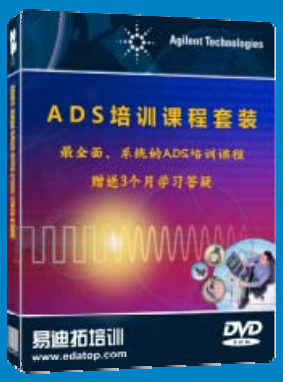

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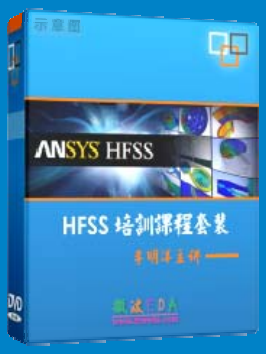

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