Electromagnetic Interference Shielding For New Communication Products

Presented to: IEEE Oakland East Bay Local Chapter

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EVP/CEO, WaveZero, Inc.

Corporate Background

A Public Company:
Listed in the UK under BLS.L

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Electronic Shielding

- **Major Operations:**
  - **HQ, California USA**
  - **North American Manufacturing Center, IL, USA**
  - **Asia – Pacific Manufacturing Centers, TW & China (2005)**
- **Business Sector**
  - **Engineered Components for EMI Suppression**
- **Business Applications**
  - **EMI shielding**
  - **Radio Frequency Identification (RFID)**
  - **Microwave components**
- **Core Competency**
  - **Metal coating of polymers by vacuum deposition**
  - **Design & manufacture products for EMC**
- **Intellectual Property**
  - **8 Patents Granted (U.S.)**
  - **24 Patent Applications Filed (U.S. and International)**

WAVEZERO PIONEERED THE CONCEPT OF INSERTIBLE SHIELDING™

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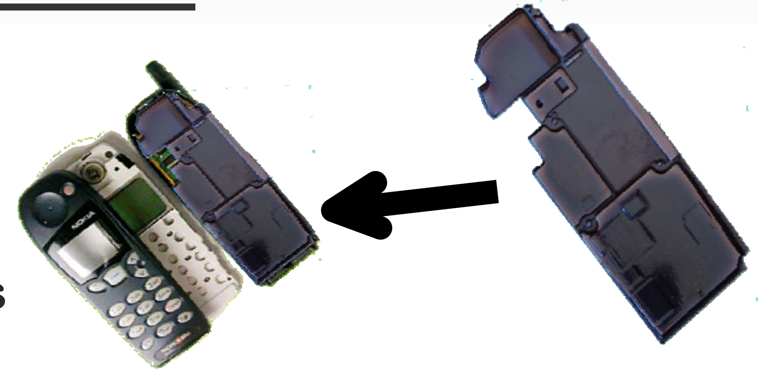
- Form/Met® -- The Insertible EMI Shield
  - Delivered to CM for final assembly
  - Minimizes physical logistics
  - Satisfies EU WEEE & RoHS Directives
  - Minimizes EOL issues (recycling)



- Wavezero products provide OEMs and CMs with great flexibility
  - Enclosure level shielding
  - Board level shielding
  - Component level shielding

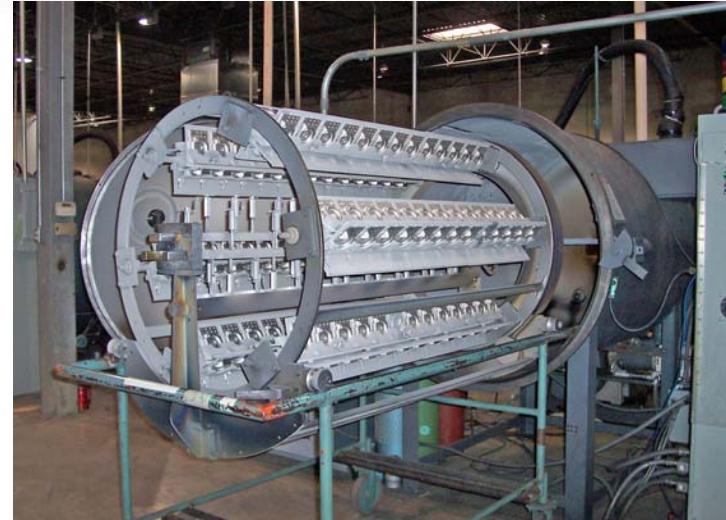
Customer Base

- Consumer
  - Bose, AXSYS, Motorola, Kyocera
- Computer
  - Rockwell, LXE, Sun, Maxtor, Seagate
- Data
  - Apple, Sun, Watkins-Johnson
- Industrial/Military
  - National Instruments, Thales, Insight
- Medical
  - B-Braun, Siemens, Zoll Medical, Aspect Medical, Orasure
- Telecom
  - Alcatel, Motorola, Rotani, Symbol, Harmonic, Juniper

- Contract Manufacturers (CM)
  - Plexus
  - Celestica

WAVEZERO MANUFACTURING

Production Lines for Industrial Vacuum Deposition Products



Facilities

- USA Manufacturing Center
  - 30,000 sq. ft.
- Volume USA Capacity
  - 12 million sq. ft.
- ISO 9001: 2000 Compliant

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Environmental Compliance (EVC)

Trends in Electronic Products

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- Continued growth in the overall number electronics products

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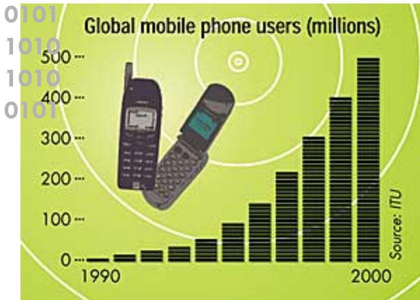
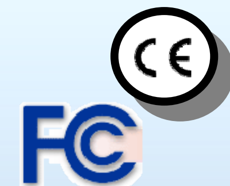
- Advent of digital technology
- Miniaturization trends



- Change in materials choice (to plastics)
- Wireless explosion
- Increasing performance of ICs

- OEM outsourcing of manufacturing
- OEM/CEM focus on reduced logistical costs

- Increased EMC and environmental regulation



Environmental Compliance (EVC)

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- **European Union (EU) regulations under discussion for years have been approved**
  - **Waste Electrical and Electronic Equipment (WEEE) Directive**
    - Full implementation/enforcement August 13, 2005
    - Requires "Producers" (not consumers) recover/recycle their electronic products and certify compliance or face penalties
    - Makes EVC an economic/competitive factor for OEMs
    - Impacts NPI teams: To remain competitive, OEMs must minimize/optimize EOL regulatory and cost burdens
  - **Restriction on the Use of Hazardous Substances (RoHS) Directive**
    - Full implementation/enforcement July 1, 2006
    - Restricts 6 chemicals including lead using in solder
    - Impacts components and products using pure-tin materials (the "tin whiskers" problem)

Products Subject to WEEE

1. Large household appliances	Refrigerators, microwaves, etc.
2. Small household appliances	Vacuum cleaners, toasters
3. IT and telecom equipment	Central data processing, mainframes, minicomputers, printer units, personal computing, personal computers, lap-top computers, printers, copying equipment, telephones
4. Consumer equipment	Radio, television, musical instruments
5. Lighting equipment	
6. Electrical and electronic equip.	Drills, saws, sewing machines
7. Toys, leisure, and sports equip.	Electric cars, trains, etc., video games
8. Medical devices	
9. Monitoring & control instrum.	Smoke detectors, heating regulators
10. Automatic dispensers	

RoHS Directive

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- Six banned substances
  - Lead
  - Mercury
  - Cadmium
  - Hexavalent chromium
  - PBB (polybrominated biphenyl)
  - PBDE (polybrominated diphenyl ether)
- No “de minimus” exemption today but amendments addressing this issue are anticipated
- Impact on soldered components is certain

Environmental Compliance Costs

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Activity	WEEE: Return to Manufacturer	WEEE: Distinct Parts /Materials		WEEE: Painted/Coated Integrated Parts		RoHS: Parts & Materials
	Parts	Metal	Plastic	Metal	Plastic	

Transport to final process location

Sorting & Mechanical Disaggregation

Chemical Dissolution & Separation

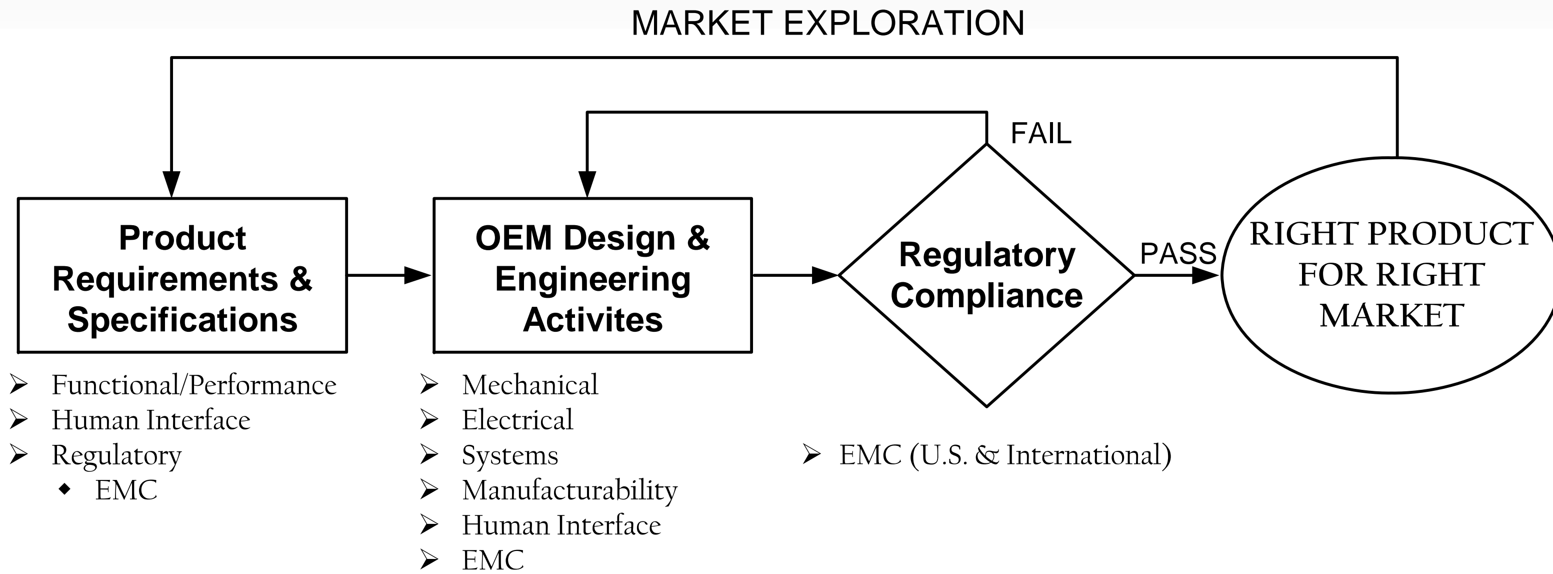
Solid waste (sludge) processing (recycle/ disposal)

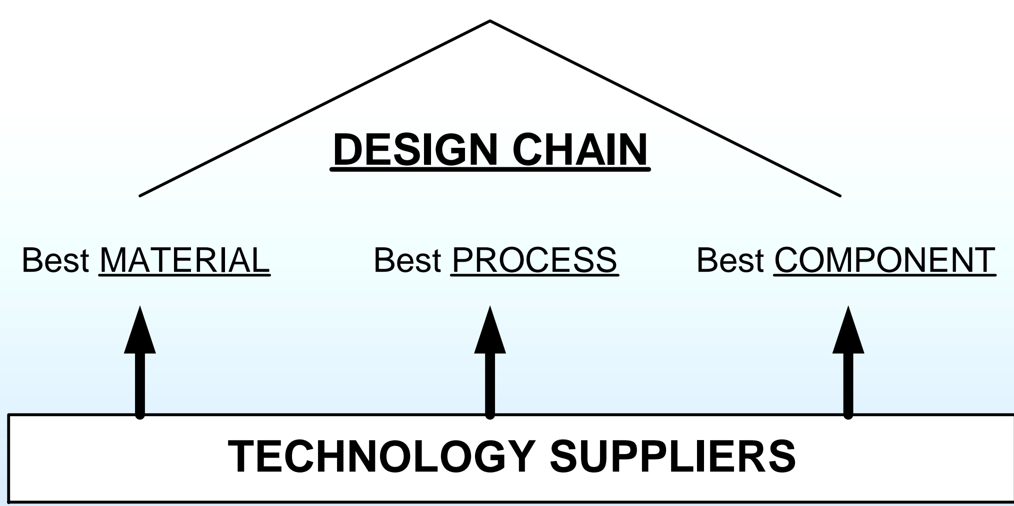
Liquid waste processing & disposal

Hazardous waste processing & disposal

Increasing cost

Design Chain Environment Prior to 2004





Design Chain Environment After 8/2005

MARKET EXPLORATION

Product Requirements & Specifications

- Functional/Performance
- Human Interface
- Regulatory
  - EMC
  - Environmental (WEEE)
  - RoHS

OEM Design & Engineering Activites

- Mechanical
- Electrical
- Systems
- Materials (RoHS)
- Manufacturability
- Human Interface
- EMC
- Environmental (WEEE)

Regulatory Compliance

FAIL

PASS

- EMC (U.S. & International)
- Environmental Compliance
  - WEEE
  - RoHS
  - Country-specific

RIGHT PRODUCT FOR RIGHT MARKET

End of Life Considerations

- Reuse or recycling
- WEEE compliance costs
- 3rd parties for recycling
- Impact on competitive position

DESIGN CHAIN

Right MATERIAL for Right Product

Right PROCESS for Right Product

Right COMPONENT for Right Product

TECHNOLOGY SUPPLIERS

Design Chain Optimization for EVC

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- **Minimize EOL costs by up-front "DESIGN-IN"**
  - **Think "reuse" first followed by "recycling"**
  - **Avoid materials listed in RoHS**
  - **Avoid paint on plastic -- removal is very costly!**
  - **Provide for economic disaggregation**
  - **Develop plan for recycling – vendors can help**
  - **Work with vendors who offer environmentally compliant materials and components**

- **Goals for increased competitiveness**
  - **Minimize life cycle cost (not just initial cost)**
  - **Pass EMC compliance testing first time**
  - **Design for EVC**
  - **Get to market faster than competitors**

EVC Issues with Legacy EMI Shielding Choices

Historic EMI Shielding Approaches -- Conductive Coating on Molded Plastic

- **Materials**
  - **Copper, silver, nickel, tin often in combination**
  - **Organic base solvents**
- **Processes**
  - **Spray painting (VOC emissions)**
  - **Electroplating (liquid chemical waste)**
  - **Masks and tools must be cleaned with solvents and liquid/solid waste safely disposed**
  - **Yield losses result in hard-to-reprocess plastic housings**
- **End of Life consequences**
  - **65% of electronic product (by weight) must be recycled**
  - **Metals must be chemically removed from plastic creating more liquid and solid waste**
  - **Few opportunities for recycling and reuse of plastic**
  - **Significant environmental compliance issues and costs**
  - **Major impact on competitive position vis-à-vis competitors**

Historic EMI Shielding Approaches -- Metal Soldered Cans

- **Materials**
  - Steel, electroplated tin on steel
  - Lead based solders
    - Prohibited by RoHS after July 1, 2006
  - "No-lead" new solders require higher processing temperatures
    - Potential issues with PCB/can warpage and residual stresses
    - Mechanical reliability problematic until history established
- **Processes**
  - Electroplating tin involves toxic chemicals and liquid waste
  - Soldering traps high value ICs under metal cans
- **End of Life consequences**
  - Demanufacturing/desoldering are costly IF recovery of the underlying (an expensive) IC is a requirement/goal
  - Mechanical disaggregation of plastic and metal is possible
  - Further separation of metals complex but possible
  - Compliance costs add to Producer's total life cycle costs

- **NPI teams should choose EMI shielding solutions that:**
  - Can be designed-in and thus
    - Minimize end of design cycle risk (assure compliance)
    - Maximize (guarantee) EMC; pass tests 1st time
  - Minimize EOL costs by avoiding
    - Conductive paint on plastic
    - Use of lead-based solders
    - Disaggregation activities that are costly
  - Enable high Design for Manufacturability (DfM)
    - Eliminate extraneous assembly operations
    - Minimize effects of yield on final product costs

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New Technology for EMC and EVC

A Better Way …

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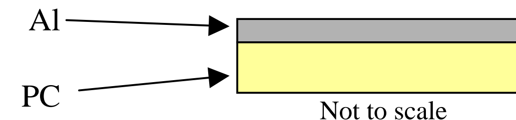
- **Vacuum metalized thermoformed structure (VMTS)**
  - **Trade name: Form/Met®**
  - **Patented in the U.S. & Internationally**
  - **Five years of research and development**
- **Core technology:**
  - **Vacuum metalized thermoformed plastic substrates**
    - **A thin film of aluminum is vaporized and deposited on a pre-formed polymer film part**
    - **US patents granted and International applications pending**
    - **“Green” processes and products -- Satisfies requirements of EU WEEE & RoHS Directives**

- **Form/Met®, an EMI shield component**
  - **Substrates from PC, PBT, PETG, or PVC**
    - 10 mil standard for most uses
    - Thermoformed prior to metalization
    - Die cutting before metalization



  - **Single or double sided metalization ("shielding")**
    - 0.5 μm - 3 μm aluminum
    - Double sided adds 5-30 dB of additional SE
  - **Multiple attachment methods**
    - Compress (capture) between plastic housing and PCB
    - Mechanical attachment
    - Conductive pressure sensitive adhesives (PSA)
    - Dispensed electrically conductive adhesives (DECA)
    - Innovative, customer-specific approaches
  - **Highly adaptable and scalable**
    - Enclosure, PCB, and component level EMI shields

ADVANTAGES OVER LEGACY SOLUTIONS

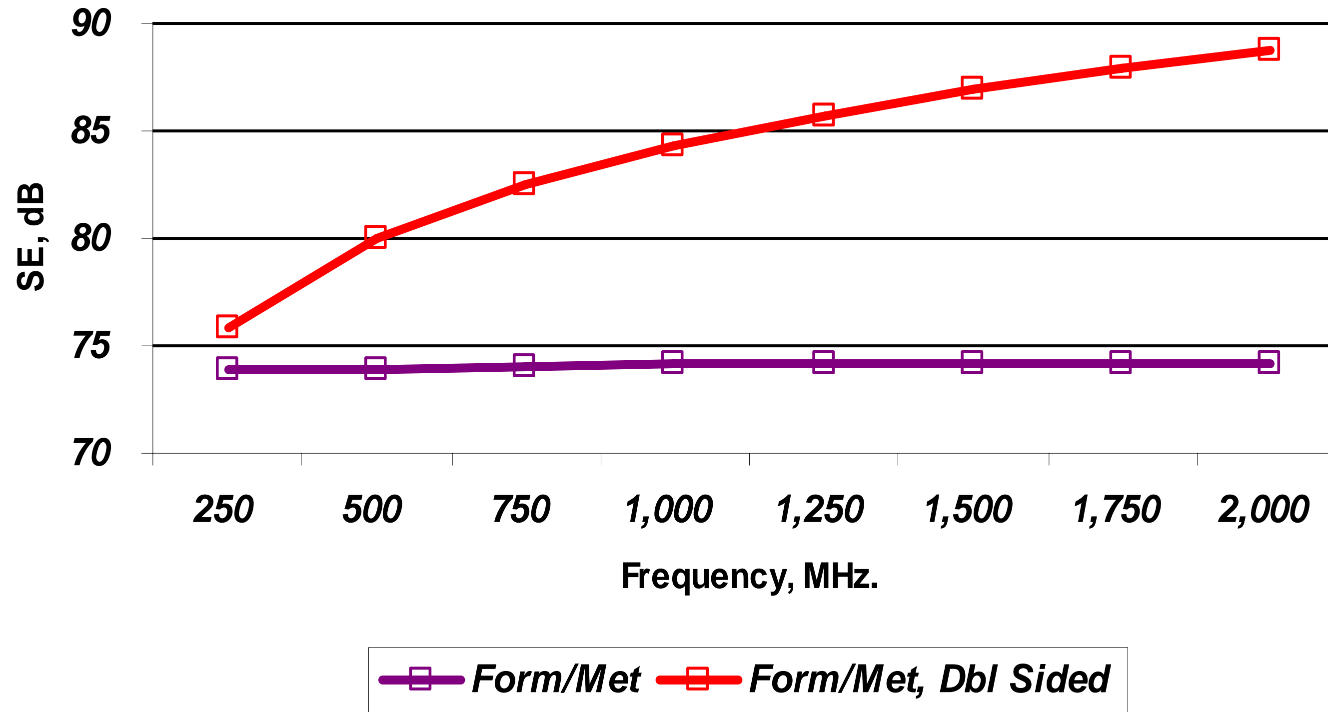
- **Aluminum coating is not toxic to the environment or to humans**
- **Vapor deposition is a "green" process well suited for the modern age of environmental regulation**
  - **Electroplating and painting are not regarded as "green"**
    - **They are highly regulated and require special controls and handling processes for toxics**
- **Vapor deposited aluminum creates a virtually stress-free high quality coating**
  - **Electroplating processes create high compressive stresses**
    - **Tin coatings may lead to "tin whiskering"**
- **Metal coating is put on <u>after</u> the part is formed**
  - **Metal coatings put on <u>before</u> forming create shields that:**
    - **Have thinned areas (from the thermoforming process)**
    - **Are not stress-free at room/operating temperatures**

EVC with Form/Met® EMI Shielding

- **Materials**
  - **Aluminum – not toxic to humans or environment**
  - **Film – compliant with all EU regulations**
- **Processes**
  - **Vacuum metalization (no VOC emissions, no toxic chemicals)**
  - **Masks and tools mechanically cleaned without solvents**
- **End of Life consequences**
  - **Impact to injection molded plastic housings**
    - **Eliminates coating thus no chemical process to remove coating**
    - **Housing plastic easily recycled by sorting plastic type**
    - **Plastic can be sold to third parties for reuse (no contamination)**
  - **EMI shield easily removed from PCB or electronic product thus allowing recovery of valuable ICs**
  - **Recycling of shield by various means**
    - **Return to WaveZero for processing (reuse in new shields)**
    - **Ground up. Sold to extruders who can tolerate 1% aluminum**
    - **Placed in approved dump or burned for energy**

Customers
Applications & Performance

Shielding Effectiveness*



- 75 dB of shielding effectiveness (SE)
- Double sided Form/Met provides additional 5-30 dB of SE

*Before “material” is made into an EMI shield.
Based on theoretical analysis.

Weight Comparisons

Type	Grams per sq. inch
8 mil steel	1.01
Form/Met, 10 mil	0.21

Grams/part

3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

10 15 20 25 30 35 40 45 50

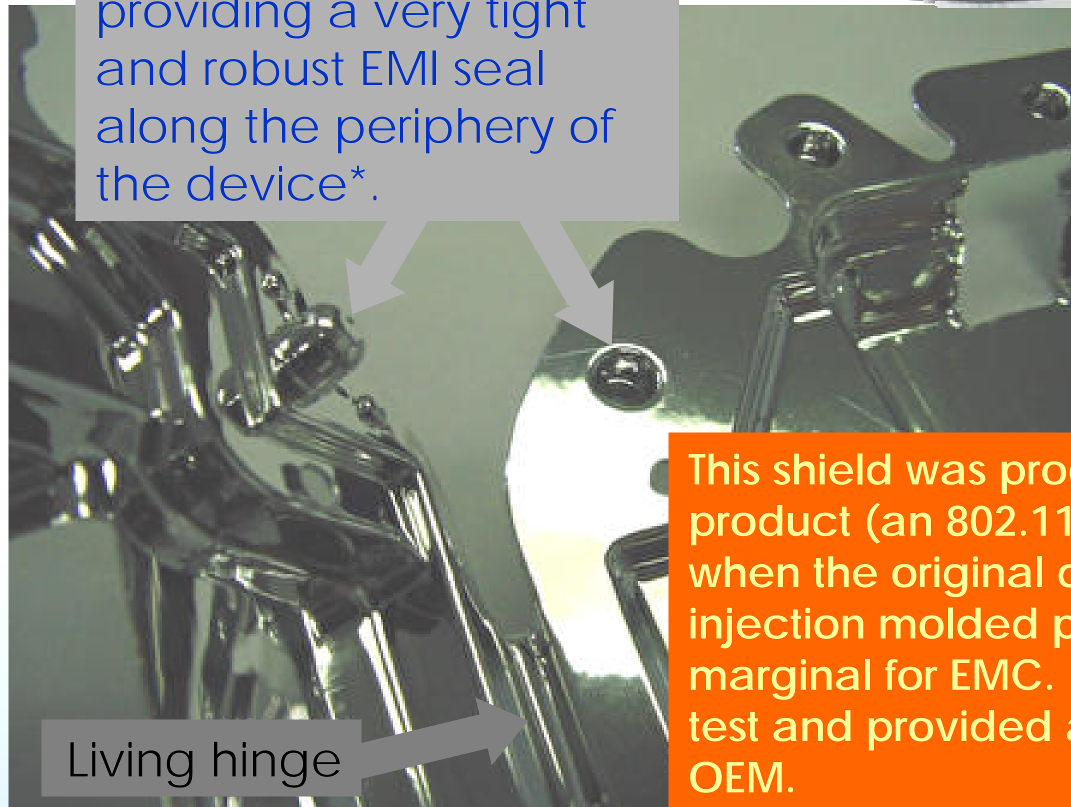
Parts/sq. ft.

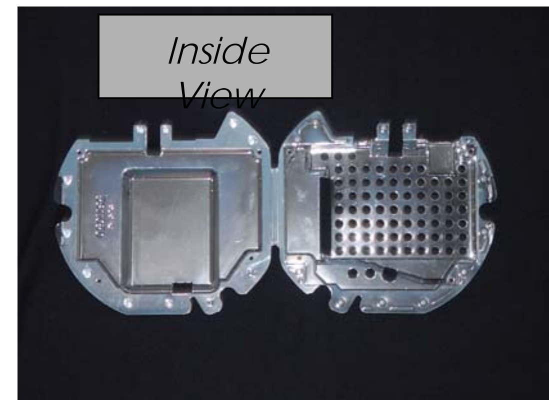
10 mil Form/Met

NOTE: 20 square inches of paper (20#) weighs 1 gram.

Enclosure (Clamshell) Design

In this design, pins are designed to "snap" into their adjacent hole thus providing a very tight and robust EMI seal along the periphery of the device*.





This shield was produced for a major OEM's product (an 802.11b wireless LAN) as a retrofit when the original design (electroplated injection molded plastic) was found too marginal for EMC. Form/Met passed EMC first test and provided a 30% cost reduction for the OEM.

ENCLOSURE LEVEL EMI SHIELD

*Design concept covered by patent.

Design Flexibility

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The other half of this two-part shield (not shown) has designed-in features along the edges that allow the two halves to nest and provide a tight EMI shield.

Ventilation holes

Connector access

This shield was produced for the leading U.S. industrial design firm and its OEM partner. The electronic product is an office connectivity device. Sheet metal was found to be too heavy and the tooling costs too great. Form/Met was an ideal solution for the design house and its OEM partner.

ENCLOSURE LEVEL EMI SHIELD

EMI Shields for a PCB – Compression Bumps

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"Bumps" can be used to provide a compression force between ground traces and shield when stack tolerance is an issue*.

This shield was produced for one of the world's largest contract electronic manufacturers. The electronic device was a PDA. The shield was used to evaluate new shielding technologies – Form/Met was equal to the best conductive paint and superior to other technologies evaluated.

PCB LEVEL EMI SHIELD

*Design concept covered by patent application.

PDA Shield Validation*

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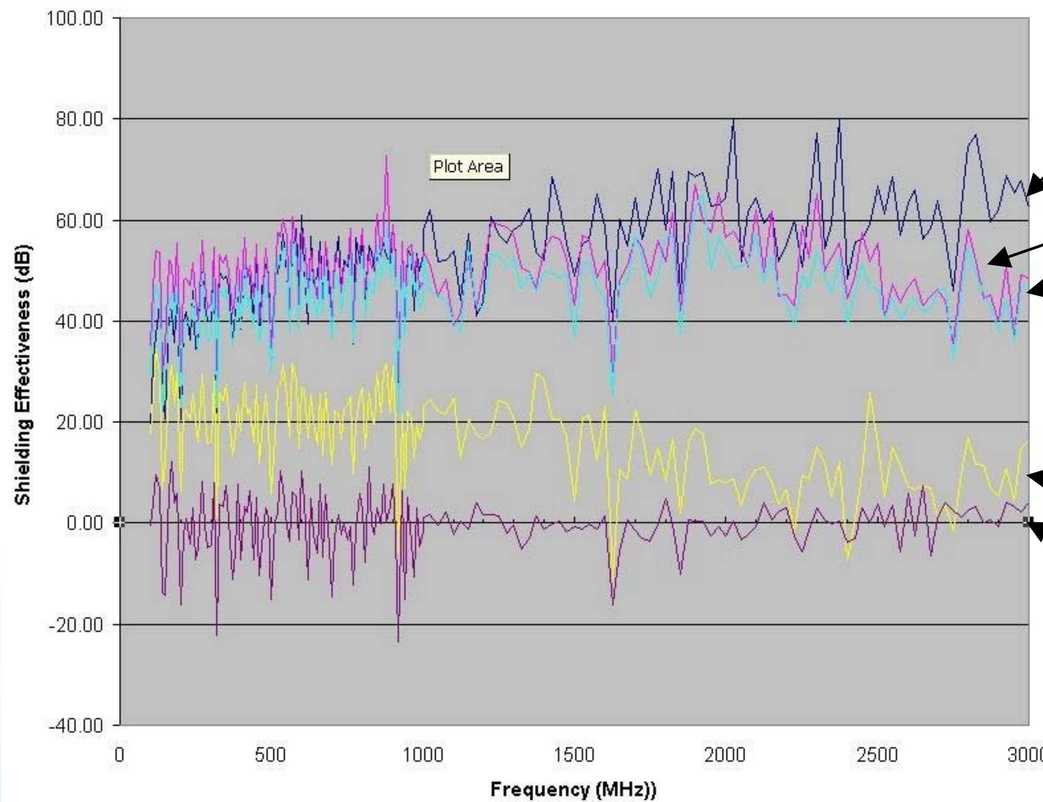
PDA Product



Closed aperture (Maximum shielding effectiveness)

Form/Met®

High quality paint

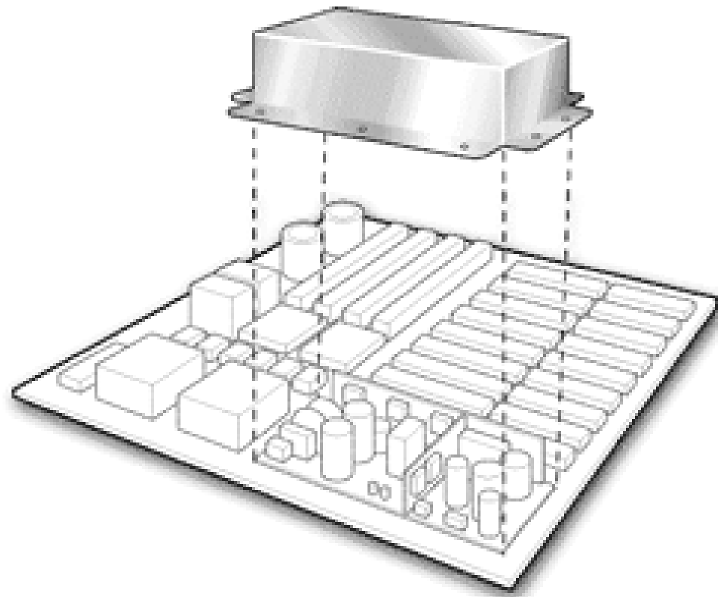
A variety of Form/Met designs were tested.

Cu/Ni Paint

Film only (no shielding effectiveness)

* Major CEM.

WAVEZERO SHIELDING CONCEPT



PCB LEVEL EMI SHIELD

This shield was produced for a leading OEM in the telecommunications segment and is currently in seven different products. Form/Met replaced conductive paint.

PSA & Component Level Shielding

The conductive PSA allows for easy assembly and rapid disassembly for repair without damaging sensitive circuits and chips.

Removable protective film

Pressure sensitive adhesive between shield and ground trace

This shield was produced for a leading OEM in the telecommunications segment and is currently in seven different products. Form/Met replaced conductive paint.

PCB LEVEL EMI SHIELD

PCB Level (Compartmentalized) Shielding

The design flexibility of Form/Met enables precise mechanical fits and provides increased suppression of radiating emissions, immunity from external radiation sources, and component isolation.

Compartmentalization* isolates interfering circuits and components

The ridge design provides essentially two shields between adjacent components.

Ridge width to match trace width

These prototypes passed testing from a major cell phone manufacturer.

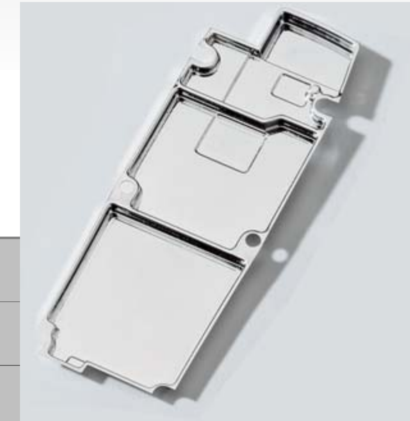
Vacuum metalization

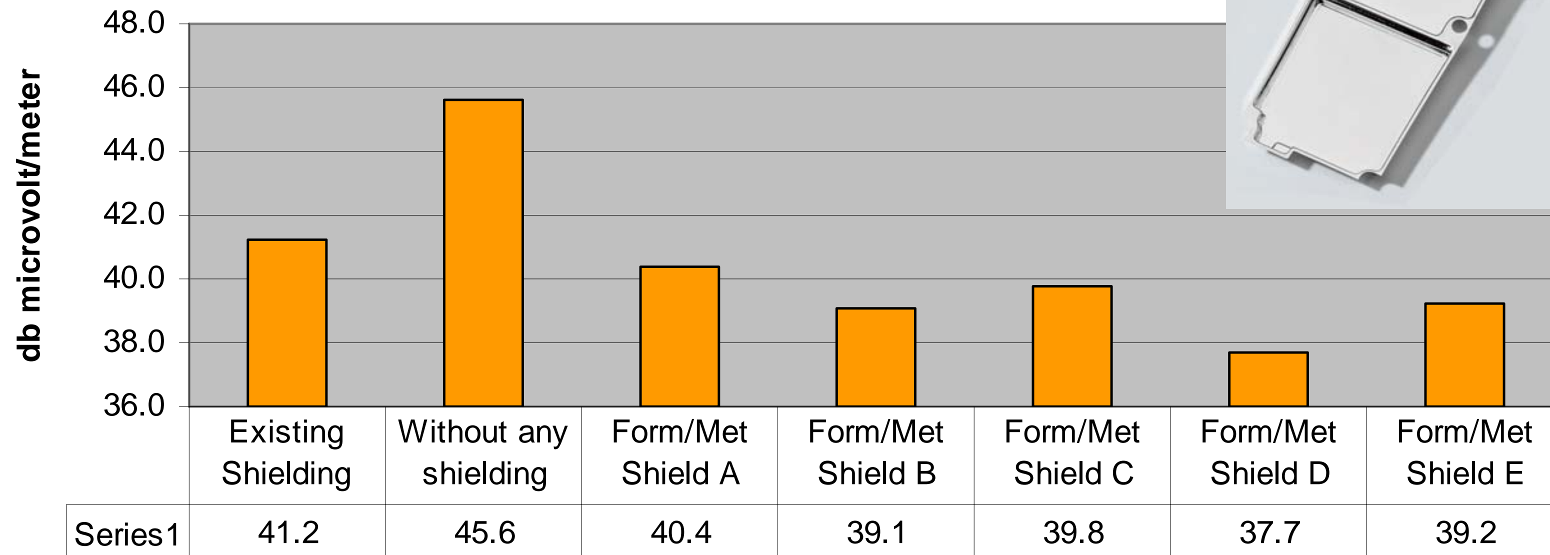
See next slide

PCB LEVEL EMI SHIELD

*Design concept covered by patent.

Cell Phone Shield Validation*





	Existing Shielding	Without any shielding	Form/Met Shield A	Form/Met Shield B	Form/Met Shield C	Form/Met Shield D	Form/Met Shield E
Series1	41.2	45.6	40.4	39.1	39.8	37.7	39.2

Five designs and mechanical attachments methods were evaluated.

4.2 dBµV/meter to 7.9 dBµV/meter improvement over <u>no</u> shield
0.8 dBµV/meter to 3.5 dBµV/meter improvement over <u>current</u> shielding

*Elliot Laboratories, Sunnyvale, CA

Summary

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- **WaveZero**
  - Complete capabilities to design and manufacture, in volume, EMI suppression products for CMs
  - Validated new technology product with broad acceptance by major OEMs to replace legacy shielding solutions
  - Valuable CM partner for NPI
- **Form/Met® meets the demands of today's OEMs and their CM partners**
  - High technical performance
  - Environmentally sound processes and recyclability
  - Readily adaptable technology to new applications
  - High scalability -- across a wide range of sizes and volumes
  - Reduced tooling and NRE costs
  - **Impact: EMC and EVC accomplished with high DfM**
- **Mature manufacturing capabilities**
  - North American and Asia-Pacific capabilities

Electromagnetic Interference Shielding For New Communication Products

Q&A

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Shield Attachment to Board Using ECA

NEW MULTI-CAVITY SHIELDING

Legacy Solution	*WAVEZERO Solution*

PCB LEVEL COMPARTMENTALIZED EMI SHIELD

Shielding Effectiveness

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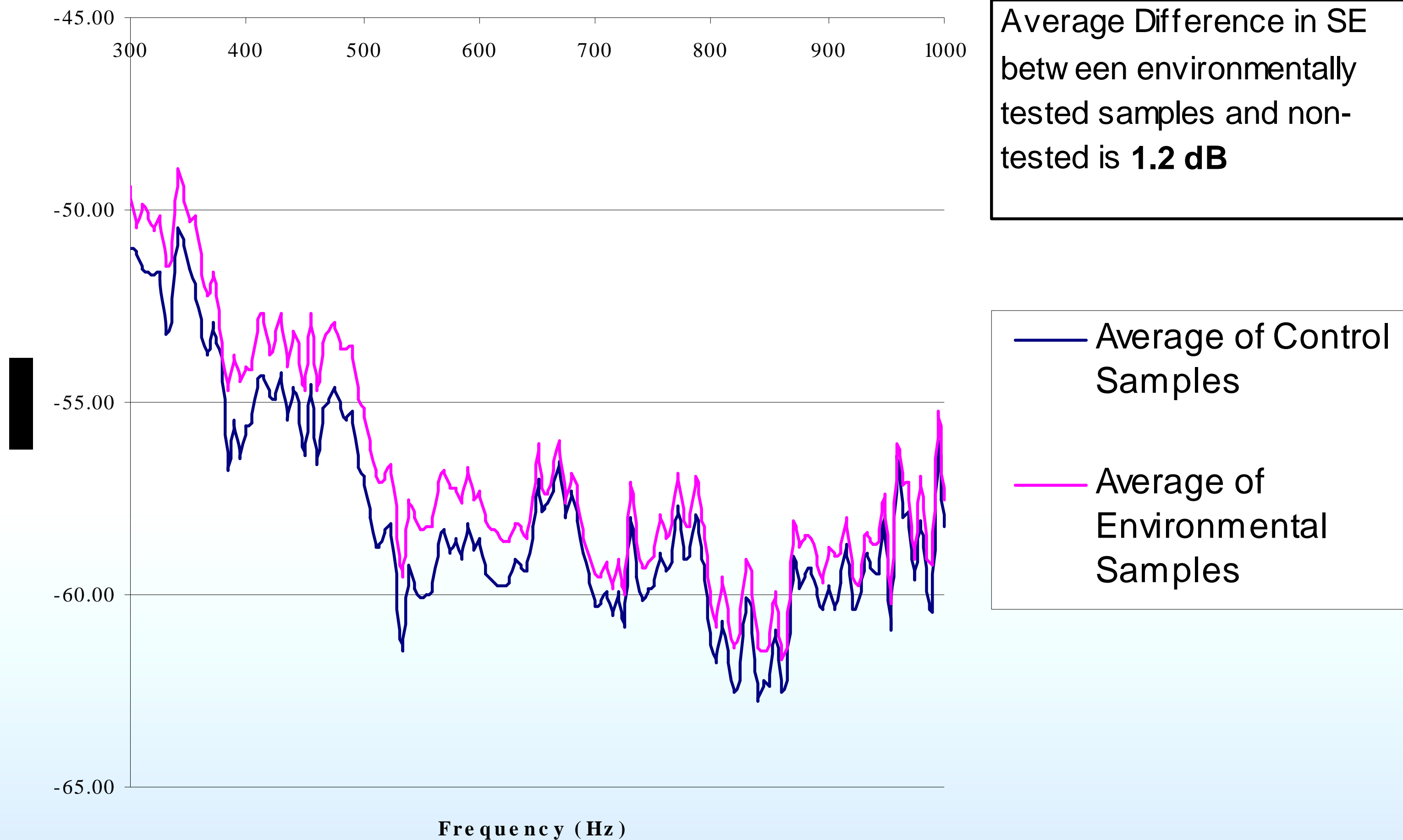
- **Minimal changes in shielding effectiveness after environmental exposure**



Mechanical Strength

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Mechanical considerations

- Form/Met® weigh 0.0004 lbs per square inch for 10 mil film (15% of steel).
- Normal bond-line stress at 2000 g's is 0.8 psi.
- Shield is designed for ease of removability.

Test results

- Mechanical pull-test
- Bond-line strength@ failure significantly below requirement for both original and post-ALT conditions

SN#	ECA	Bond-Load at Failure	Calculated Bond-Line Strength
		lbs	psi
1	Epoxy	53	154
2	Epoxy	40	118
3	Epoxy	55	162
4	Epoxy	83	243
5	B-stage	85	250
6	B-stage	68	199
11	Silicon	40	118
12	Thermoplastic	15	44

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- Example test sample
  - Compartmentalized shield (ala 2G/3G cell phones)
    - ~ 0.12” by 1.5” by 2.5”
    - 1.0 mil flange
    - Smooth or ribbed flanges
  - 2 layer PCB (FR4)
  - 500 MHz. free running oscillator
  - One transmitting antenna
  - Two receiving antennae
- ISA computed from comparing with and w/o shield, before/after ALT

ISA Test Results

- Summary results below show best/worst data providing a range for comparison
- Performance index (PI) = post-ALT/pre-ALT ISA
- Conclusions
  - Thermoplastic best, PI > 110%
  - B-stage OK, PI > 70%
  - Epoxy marginal, one sample had PI < 70%

Adhesive	Original ISA, dB	Post-ALT ISA, dB	Performance Index Post-ALT ISA/Original ISA
Epoxy	29	29	1.0
Epoxy	33	12	0.4
B-Stage	34	31	0.9
B-Stage	30	21	0.7
Thermoplastic	**30**	**32**	**1.1**
Thermoplastic	**27**	**31**	**1.1**

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