Trends in RF/Wireless Packaging
An Overview, 2004

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Outline

- Thank You for your slides
- About IWPC
- Conclusions
- Wireless Industry Overview
- Portable and Mobile Wireless
- Infrastructure & Broadband Equipment
- MMwave
- Automotive
- Antennas
- Shielding
- Materials
- Environmental Issues (RoHS)
- Other Advanced Packaging Technology Options
- Collaboration

Thank You for your Slides

- Agere
- AMKOR
- Arlon
- ASCOM
- BWA
- Cambridge Silicon Radio (CSR)
- Celestica
- Chip Pak
- Continental Temec
- CTIA
- Daimler Chrysler
- Dr. Robert Heile
- Emerson & Cuming
- Endwave
- IBM
- Imbera
- Infineon
- Intel
- Kyocera
- Laird Technologies
- M/A-COM
- Merrimax
- Microsoft
- Motorola
- Motorola
- Nortel
- Ogier Electronics
- Park Nelco
- Perlos
- Philips Semiconductors
- Polyphaser
- Raytheon
- RFM
- Road Eye
- Rogers
- Rosenberger
- Samsung
- Saratel
- Skyworks
- Texas Instruments
- WL Gore
- Xytrans

About IWPC

IWPC Mission

Founded 1998

The International Wireless Packaging Consortium, IWPC, is a pro-active organization of 115+ WIRELESS and RF PRODUCT OEM's and their SUPPLIERS.

Our mission is to facilitate communication up and down the entire wireless industry supply chain, to:

- **Identify/Clarify New/Existing Markets and Product/Service Opportunities**
- **Reduce Costs**
- **Improve performance and**
- **Decrease time to market**

... with an emphasis on packaging and interconnect technologies.

Our Definition of Packaging

- From sand to systems

IWPC Members (as of May 2004)

3M
Aeroflex
Agere
Agilent
Alcatel
Amkor
ANADIGICS
Analog Devices
Andrew Corp.
Arlon Inc.
BridgeWave Comm.
Brush Engineered Materials
Cambridge Silicon Radio
Celestica Inc.
ChipPac
CommScope
Conexant
CoorsTek
CSIRO
Dielectric Laboratories
Dow Corning
DragonWave
DuPont
E2V Technology
EADS Deutschland GmbH
Elcoteq
EMS
Emerson & Cuming
Emerson & Cuming Microwave
Endwave
EPCOS
Fairchild RF
Farran Technology
Filtronic
Flarion Technologies
Flextronics
Fujitsu Quantum Devices
Harris Corp.
HEI Inc.
Hitachi Chemical
Hittite Microwave
Huber + Suhner
Hughes
Hypres
IBM
Infineon Technologies AG
Intel
Interconnect Devices
Jabil Circuit
Johanson Technology
Kaneka High-Tech
Kathrein Inc.
Kyocera America Inc.
L3Comm., Narda
Laird Technologies
Lucent Technologies
Mark IV
Merix Corp.
Merrimac Industries
Microwave Photonics
Milmega Ltd.
Millisys
Mimix Broadband
Motorola
Nera Networks
Nortel Networks
Northrop Grumman
Paratek Microwave
Park Electrochemical
PCH International
Perlos Corp.
Philips
PMC-Sierra
Polyphaser
Powerwave Tech.
Radio Frequency Systems
Raytheon
Renaissance Electronics
Research In Motion (RIM)
RF Monolithics
RJR Polymers
Rogers Corp.
Rosenberger
Sarantel Ltd.
Siemens
SiGe Semiconductor
Skyworks
Sonion Kirk A/S
Sony Ericsson
Symmorphix
Taconic
Terabeam
Tessera
Texas Instruments
Thales Microelectronics
TLC Precision Wafer Processing
TRAK Communications
TriQuint Semiconductor
Tyco, M/A-COM Division
Tyco Germany
United Monolithic Semiconductors
WL Gore
Xilinx
Xytrans

IWPC Thrusts

- **Mobile and Portable Products**
  - Cellular, Wireless PDAs, PCS, GPS, short range radios, (Bluetooth, WPANs, WLANs, automotive telematics, etc)
- **Cellular Infrastructure Products**
  - Base Stations, WLAN Distribution Networks, Smart Antennas, Repeaters, In-building coverage extension, etc.
- **Broadband and Millimeterwave Products**
  - MMDS, LMDS, MVDS, PTP, PMP, MMWave Unlicensed, Satellite, Stratospheric
  - Last Mile Access Solutions (wireless and optoelectronic)
  - Automotive ACC, side radar, sensors
- **Cross-thrust workshops** (technologies, financial or markets)
  - Wall Street Sessions
  - Outsourcing Trends
  - Environmental Issues
  - other
- **Technology Exchange Forums and Telecons** (within each thrust)

IWPC Workshops 2004 (planned)

- **Implementing Environmental Compliance in the Wireless Industry Supply Chain**
  Hosted by: **Celestica, Lucent**
  August 10-13, 2004, Toronto, Canada

- **High Efficiency, High Linearity Power Amplifiers for 3G+ Basestations**
  Hosted by: **Filtronic, Powerwave, Andrew**
  Sept 20-21, 2004, U.K.

- **Lowering Basestation Equipment OPEX**
  Hosted by: **T-Mobile**
  Sept 21-24, 2004, U.K.

- **Millimeterwave Automotive and Communication Markets and Technologies**
  Hosted by: **Daimler Chrysler, Siemens, Alcatel**
  October 18-21, 2004, Germany

- **802.16x vs 802.20x vs 3G vs 4G**
  Hosted by: **France Telecom**
  Dec. 2004, San Francisco, CA

- **Other topics to be announced (Suggestions welcomed)**

IWPC Workshops Held - 2004

- **Emerging 60 and 70-90 GHz "GigaBit Wireless" Communications**
  January 18-21, 2004
  San Jose, CA
  Hosts: **Cisco Systems, IBM, Infineon, Endwave, Velocium**

- **Short Range Radio Equipment, Technologies & Markets**
  Co-Hosted by: **EPCOS, Fairchild RF (*), Infineon, Intel (*), Philips Semiconductor (*), RF Monolithics, Skyworks (*), Texas Instruments**
  April 2004

- **A Day with Ford Motor Company**
  Hosted by: **Ford Motor Company**
  April 2004

- **Future SmartPhone Power Management**
  Hosted by: **Microsoft**
  May 10-13, 2004

- **Wall Street Meets the Wireless Industry Supply Chain**
  Hosted by: **CIBC World Markets**
  May 19-20 2004

NEW
IWPC WEB Based Discussion Centers

IWPC Discussion Center links Available

- The IWPC has formed a number of new WEB based discussion centers.
- Please forward this list to your colleagues and invite any of them to opt-into any group(s) by simply sending an email to the link(s) provided.
  - **General IWPC Member Discussion Center**
    IWPC_Members-subscribe@yahoogroups.com
  - **Environmental issues of electronics design, manufacturing, process and recycling**
    IWPC_Environmental_DiscussionGP-subscribe@yahoogroups.com
  - **Power Amplifier Packaging**
    IWPC-PA-Pkg-subscribe@yahoogroups.com
  - **Software Defined Radio (SDR) and the issues related to RF Front End development**
    IWPC_SDR-subscribe@yahoogroups.com
  - **IWPC China Wireless Industry Research – issues, comments, questions**
    IWPC_Asia_Research-subscribe@yahoogroups.com
  - **IWPC Broadband Roadmap Development**
    IWPC_Broadband_Roadmap-subscribe@yahoogroups.com
  - **IWPC_Environmental_DiscussionGP**
    IWPC_Enviornmental_DiscussionGP-subscribe@yahoogroups.com

IWPC Workshops Held - 2003

- **Wall Street Meets Wireless Industry Supply Chain**
  January 14
  San Francisco, CA
  Host: **Merrill Lynch**

- **Emerging In-Building & Short Range Wireless Equipment**
  January 15,16
  San Francisco, CA
  Hosts: **EMS and Intersil**

- **Basestation Coverage Enhancement Equipment**
  March 4-7
  Kansas City, Missouri
  Host: **Sprint PCS**

- **Mmwave Markets, Applications and Technologies from 20-100 GHz : An Overview**
  May 5-8 -- Stuttgart, Germany
  Hosts: **DaimlerChrysler, Endwave, Stratex, IBM, UMS, Velocium, Raytheon**

- **Outsourcing Trends in Wireless Industry**
  June 17-20
  Toronto Canada
  Host: **Celestica**

- **Last Mile Broadband Access**
  September 30/October 1-2
  United Kingdom
  Host: **British Telecom**

- **Upgradeable BaseStations and 2G/3G Transition**
  November 4-7
  United Kingdom
  Host: **O2**

- **A Day with Elcoteq**
  2D --> 3D --> SiP Migration & Electro-Mechanical Integration
  November 9-10, 2003
  Espoo, Finland
  Host: **Elcoteq**

- **Next Generation "Ecological" Handset Design & Manufacturing**
  December 9-12
  Plantation, Florida
  Hosted by: **Motorola and Amkor and Nextel**

IWPC Workshops Held -- 2002

- **Unlicensed Band Short Range Radios, WLAN, Bluetooth**
  January 29-31
  Austin, TX
  Hosts: **Wayport, Philips, Intersil**
- **Ka-Band Satcom Terminals**
  February 26-28
  Rome, Italy
  Host: **Alenia Spazio**
- **Frequency Agile, Adaptive Base Stations**
  April 9-12
  Stuttgart, Germany
  Host: **Alcatel**
- **Millimeterwave Backhaul and 60 GHz Unlicensed Band Radios Plus – WALL STREET SESSION**
  June 17-20
  San Jose, CA
  Host: **Harris Corp.**
- **Last-Mile Broadband Solutions**
  Trends, Tradeoffs and Requirements of Consumer Priced Wireless, Optoelectronic, Copper Equipment
  July 22-25
  Montreal, Canada
  Hosts: **Bell Canada, Telcordia & Lucent Technologies**
- **Handset Packaging Workshop III**
  Towards 40% Integration at NO Additional Cost
  Sept 10-13
  Aalborg, Denmark
  Host: **Flextronics**
- **Automotive Telematics & Wall Street Session**
  Dec 3-6
  Dearborn, MI
  Host: **Ford Motor Company and Solectron**

Workshops Held, 2000/01

- **2001**
  - **GigaBits to the Desktop, Convergence of MMWave Radio and OptoElectronics at 10's of GB/S (hosts Endwave and Lucent)**
  - **Wireless Internet -- Impact on Next Generation Handheld Packaging (Host France Telecom)**
  - **Millimeterwave Supply Chain Summit II (Host Winstar)**
  - **Future Bluetooth and Bluetooth-Like Applications & Packaging (Host Philips)**
  - **High Capacity Power Efficient 2.5G/3G Basestations & Systems (Host Nortel Networks)**
  - **Multi-GigaBit OptoElectronics -- Breakthrough Packaging and Assembly (Host JDS Uniphase)**
  - **Next Generation Handset Integrated Packaging Roundtable (Host Sony/Ericsson)**
- **2000**
  - **Millimeterwave Design and Manufacturing Supply Chain Initiative (Host Raytheon)**
  - **Next Generation Handset Packaging (Host Sprint PCS)**
  - **Future… Bluetooth, Home RF, WLAN, Automotive Wireless Packaging (Intel and ITSA)**
  - **EPDeS 4 Working Groups Workshop**
  - **Broadband MMWave Service Providers & Supply Chain Summit (Hosts WCA, Morgan Keegan)**
  - **Reliable Tower Top Electronics Packaging and Smart Antennas (Host Ericsson)**
  - **Future Broadband User Terminal Packaging (Host Alcatel)**
  - **Automotive Wireless Packaging (Host Ford)**

Workshops Held, 1998/99

- **1999**
  - **Electronic Product Design System 1 (EPDeS) (hosted by Nokia Corp.)**
  - **Consumer Priced Millimeter Wave/Microwave Antenna Subsystem for Ground Based LEO Satellite Systems (hosted by Motorola/Teledesic**
  - **EPDeS 2 (hosted by Qualcomm Corp.)**
  - **Fanless Basestations (Co-hosted by Nortel Networks and Harris)**
  - **Breakthrough Packaging for LMDS (hosted by Raytheon Systems)**
  - **First EPDeS DEMO (hosted by Lucent)**
- **1998**
  - **Handset Packaging**
  - **Base Station Packaging**
  - **Satellite Packaging**
  - **RF ID Tag Packaging**
  - **Point to Point and Point to Multi-Point Radio Packaging**
  - **Roof Top Subscriber Antenna System Packaging for LEO Satellites**

Conclusions (1 of 4)

- **All RF/wireless packaging is "application specific" (there are NO magic technologies which addresses ALL packaging requirements)**
  - Cost
  - Frequency
  - Data rate
  - Power
  - Size
  - Weight
  - Time to market
  - Volumes
  - Cost
  - Cost

Conclusions (2 of 4)

- **Radio standards are application specific (and in some cases, country specific)**
  - 802.11 a, b, g, p, n, ??
  - WAPI (Chinese WiFi Standard)
  - UWB
  - Bluetooth with 20+ profiles
  - Zigbee
  - 60 GHz PAN
  - Low power radio technology (LPR)
  - DSRC
  - 802.16 a, e, ??
  - 802.20 x
  - GSM
  - CDMA
  - UMTS
  - WCDMA
  - TD-SCDMA (Chinese standard)
  - Radar of all types
  - GPS
  - HD Radio
  - Satellite radio
  - Ka, Ku, L, etc bands
  - Proprietary solutions for all of the above
  - Etc., etc., etc…
  - And many more to come…

Conclusions (3 of 4)

- **Packaging designs are based on the experience and legacy of suppliers and customers**

- **Who is the customer? Who sets the specs?**
  - OEMs
  - EMSs
  - ODMs

- **Avoid spec creep**
  - Clearly understand what the ULTIMATE customer wants

- **Avoid margin stacking**
  - Be careful to minimize margins on top of margins

- **Custom vs commodity packaging choices**
  - Discrete component packaging, vs
  - Integrated packaging, vs
  - Integration at the semiconductor level
    - Based on customer requirements

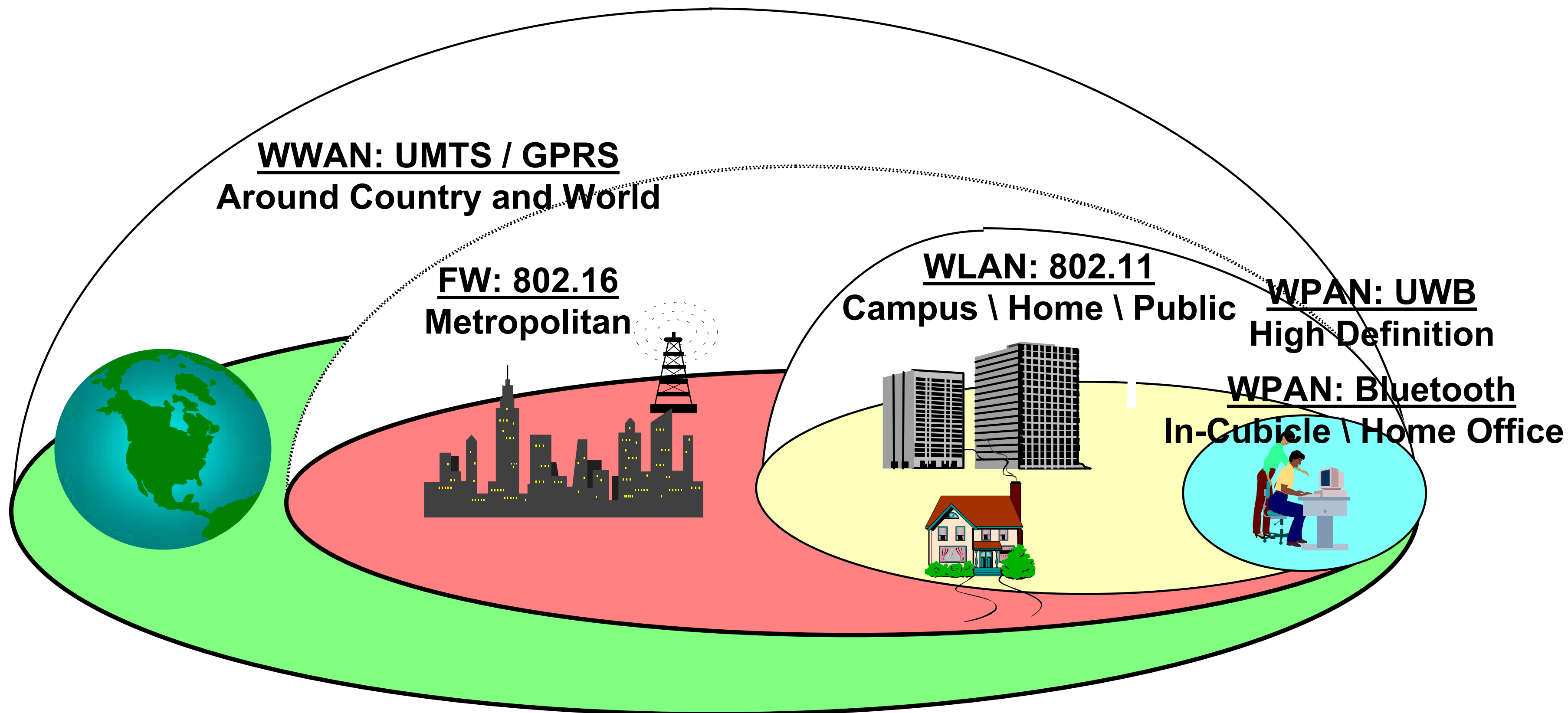
Conclusions (4 of 4)

- **The electronics industry IS REQUIRED support environmental regulations developed for Europe, North America, Asia and elsewhere.**
  - Choices of materials, manufacturing technologies and logistics are undergoing epoch changes in the next few years

- **To achieve best overall solution, packaging technology is an global collaborative effort between ALL layers in the supply chain.**
  - Ultimate customer
  - System house
  - Sub-system house
  - Active component suppliers
  - Passive component suppliers
  - Materials suppliers
  - Raw materials supplies
  - Package and/or module Designer
    - OEM, EMS, ODM, IPD
  - Package and/or module manufacturing

Wireless Industry Overview

Bridging Wireless Domains

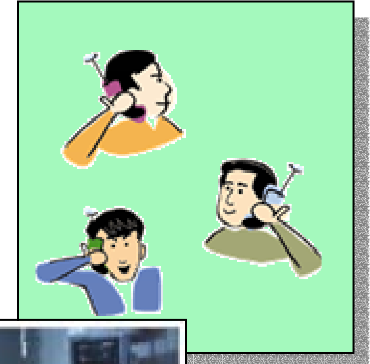


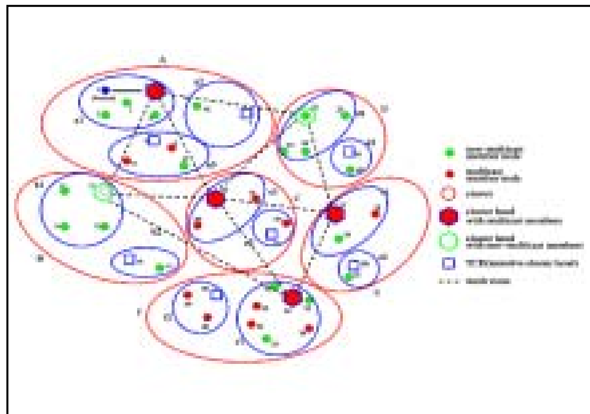
- Multi-mode radios & modems will be needed
- Integration makes it feasible & affordable

The wireless landscape is changing

- People to People 10^8
- People to Things
- Things to People
- Things to Things 10^{14}

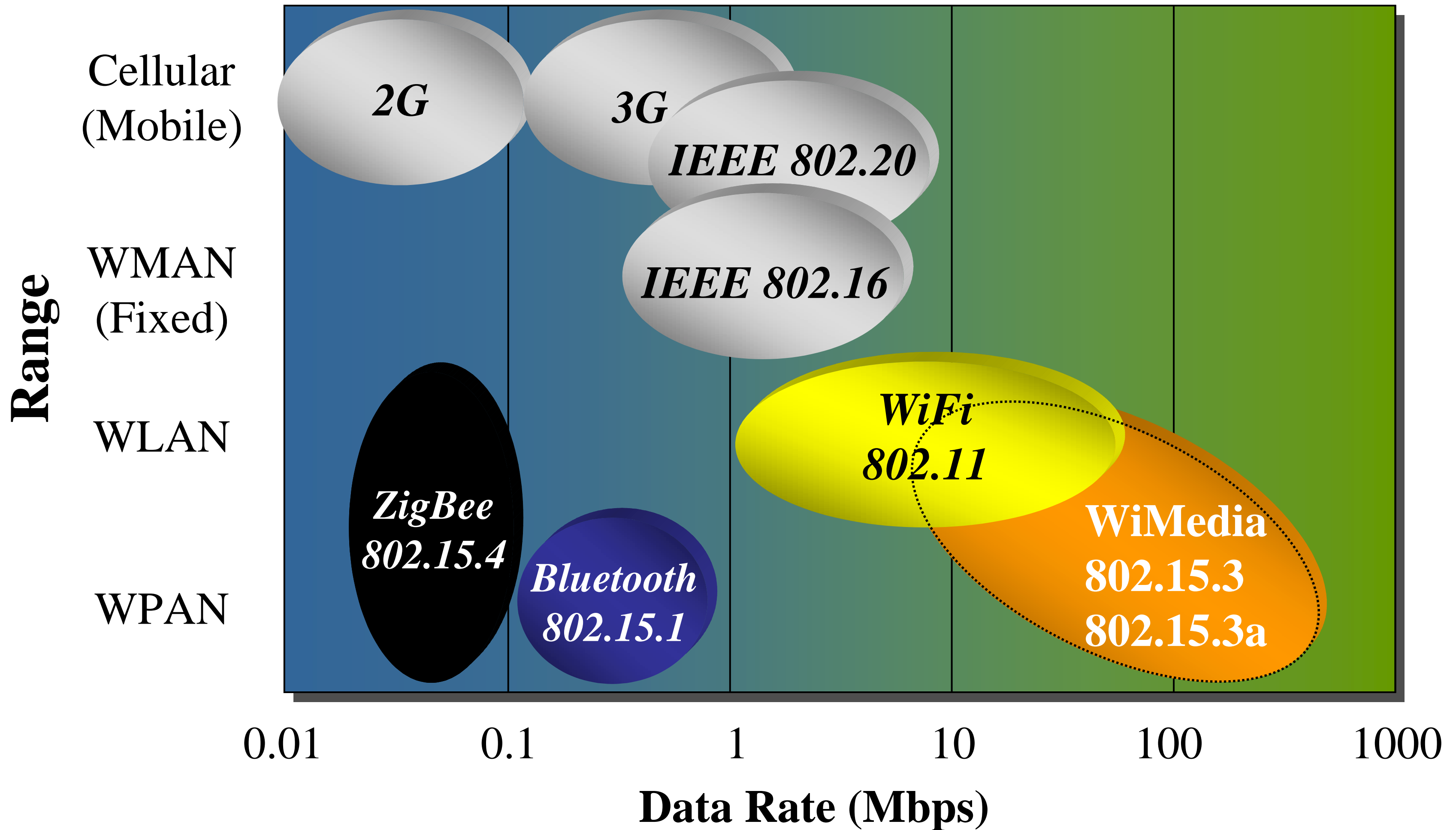
Ed Zander CTIA





Motorola

Data Rates in the Wireless Space



Dr. Robert Heile

Portable and Mobile

Hardware Confusion

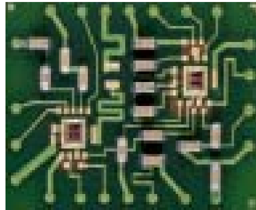
Microsoft

Bluetooth Products In The Market – **Headset Products**

CSR

Handset Interconnect Technology Solutions

- CABGA (LFBGA)
  - Saw singulation Innovation
  - Production volume
- System in Package
  - RF Module Leader
  - Industrialization of hybrid technology (CSP equation)
  - Laminate substrates
    - Worlds largest buyer
- MLF (QFN)
  - Strong IP Position
  - Dominant market share
- Memory and IO Cards
  - Low cost leadframe based



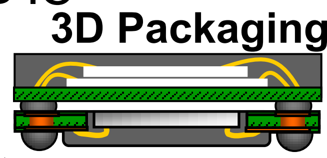
MMC

AMKOR

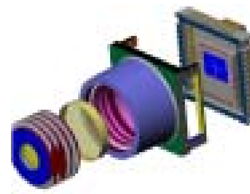
- Stacked die Packaging
  - Leader in 3 and greater die stacks
  - Suppplier to all major BB IC suppliers
- Stacked Packaging
  - Aggressive development activity
- Camera Modules
  - Aggressive development on low cost structures
- Touch Chips
  - Volume production with IDM Partner
- MEMS
  - 3D Accelerometers
  - RF MEMS devices

Die Stack

3D Packaging



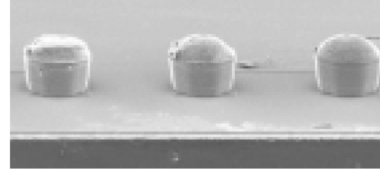
Vision

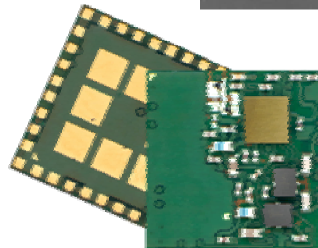


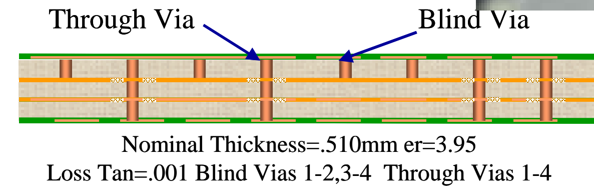
TouchChip™

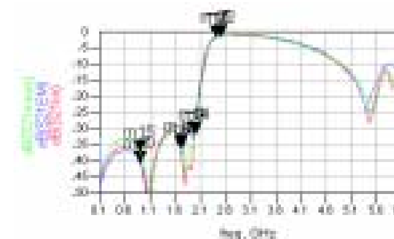
RF Integration Technologies

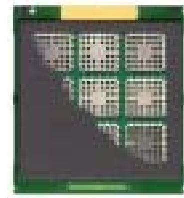
- Flip Chip SiP SiGe, GaAs
- RF Substrates
- SMT in MLF (QFN)
- Embedded Filters/BALUNs
- LTCC Processing
  - Overmolded Ceramics
- Integrated Shielding
  - With or without Overmolding
- SD Radio Cards
- Antenna Integration



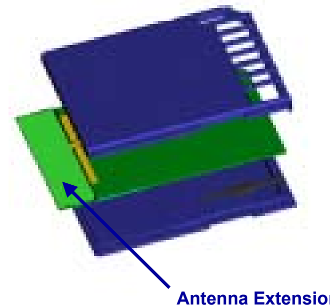


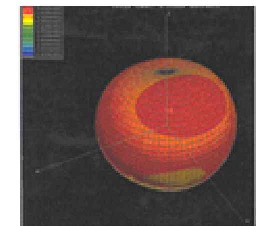






Skyworks





Omni-Directional Pattern

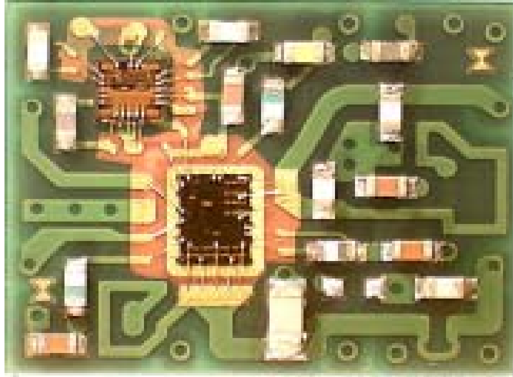
RF-Module Package Roadmap for Mobile Phone

YEAR	2002	2003	2004	2005
Mobile phone system – Japan	cdmaOne PDC	cdmaOne(1X) PDC & W-CDMA	cdmaOne/cdma2000 1X W-CDMA	
Mobile phone system – Europe Asia	GSM/DCS/PCS		GSM/DCS/PCS/ W-CDMA	
Mobile phone system – US	D-AMPS/PCS cdmaOne	cdmaOne/PCS	cdmaOne/cdma2000 1X PCS/EDGE	
RF block diagram on Package – GSM	FEM (ANT, SW, DIP, LPF) Triple PA	TX Module (FEM+PA) (ANT, SW, BPF, DIP, LPF)	TX Module + VCO (SW, BPF, DIP, LPF, VCO)	
RF block diagram on Package – W-CDMA	Single PA (ANT, DUP, LPF, ISO)	FEM (ANT, DUP, LPF, GSM/DCS/PCS/W-CDMA)	PA	TX Module (ANT, GSM/DCS/PCS/W-CDMA FEM, PA)
Built-in Function	Low pass filter (900M) Diplexer (900M/1.8G) Switch circuit L,C, λ/4 (900M/1.8G)	Duplexer (2G) Low pass filter (2G)	Choke with Ferrite De-coupling C	

Kyocera

Module Evolution

Year → 1999 2000 2001 2002 ← → 2003 → 2004

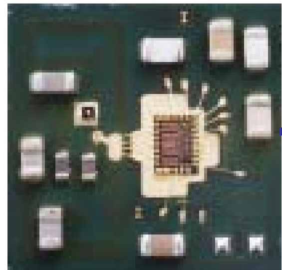


> Functionality

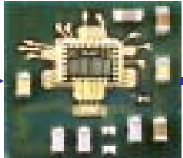
- **RM009 GSM/DCS PA - 11.6 x 9.1 MCM, 4 layer, PTH, MSL3/225°C**
- 2 die (1 GaAs PA, Si)
- 16 passive components (0402 – 0603)

Skyworks

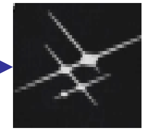
> Miniaturization



6 x 6 mm CDMA PA



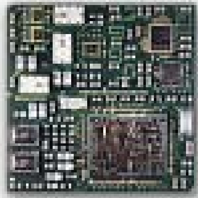
4 x 4 mm CDMA PA



3 x 3 mm CDMA PA

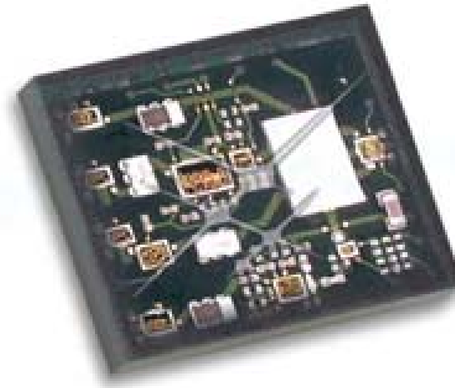
- **SKY74073 SPR- 13 X 13 MCM, 4 layer, PTH & μVia, MSL3/250°C, Aggressive/optimized Design Rules, material/process improvements**
- 6 die (1 PA, 2 GaAs Switch, 1 Detector, 1 PA Controller, 1 DCR)
- 75 Passive Components (0201-0603 Size)
- 2 Filters, 2 SAWs and 1 Diplexer

Packaging Development Roadmap



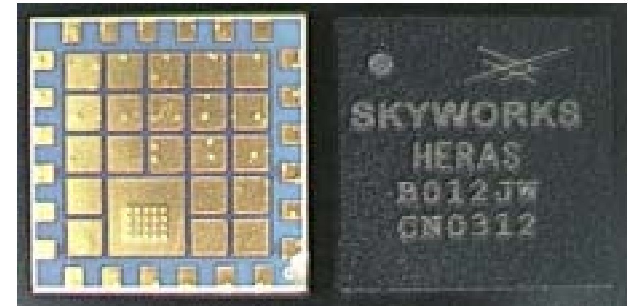
Demonstrated

- **> 275 Million cellular PAMs shipped**
- **Flexible factory**
- **World class cycle times**



Today

- **3 x 3 mm CDMA PAMs**
- **RF LGA and FP BGA**
- **Integrated Modules Wireless LAN**

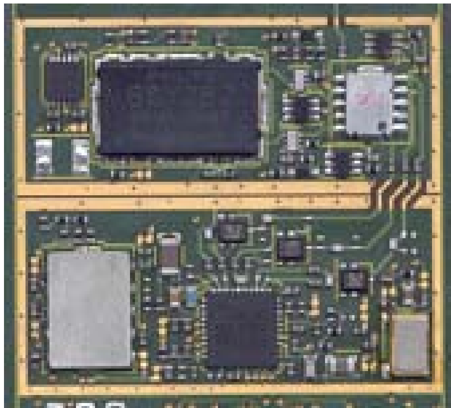


2nd Half 2004

- **Smaller form factors**
- **Stacked IC & Flip Chip**
- **Further integration**
- **Integrated shielding**
- **Alternative materials**

Leading Packaging Integration Capability

The Radio Integration Battlefield



Base-band IC

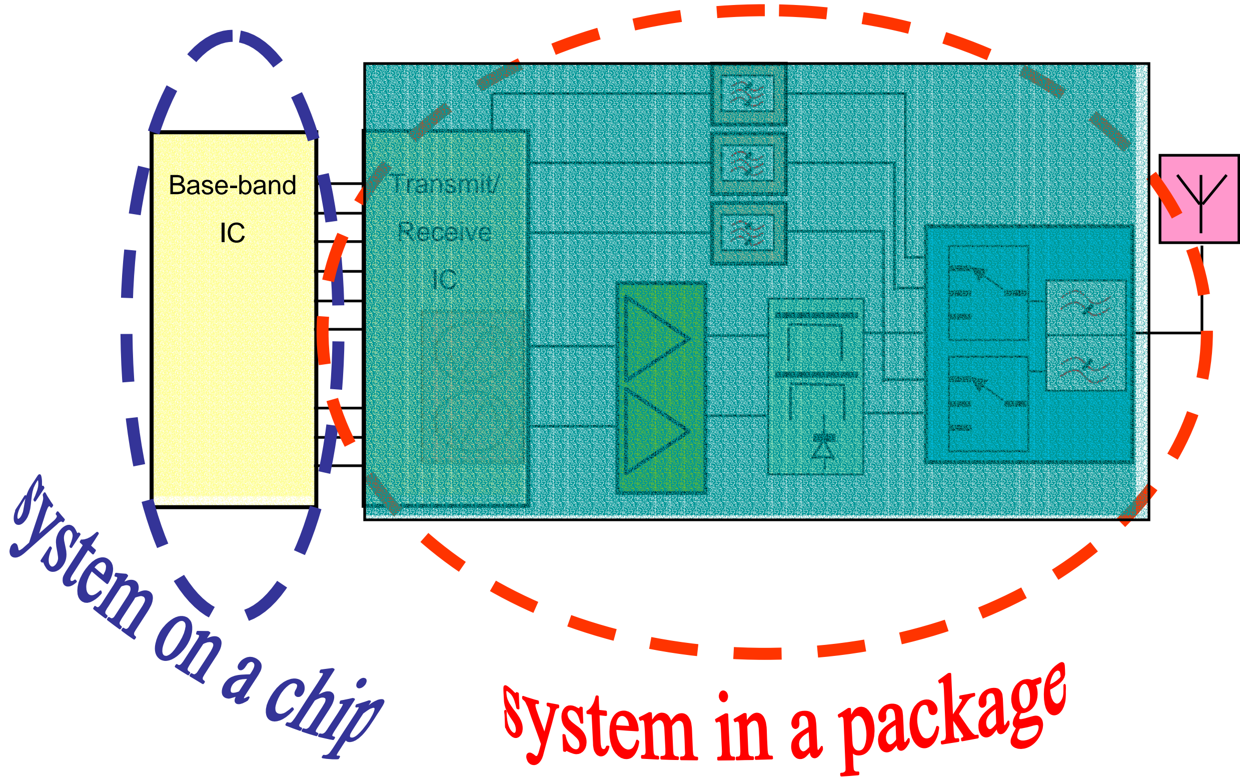
Transmit/ Receive IC

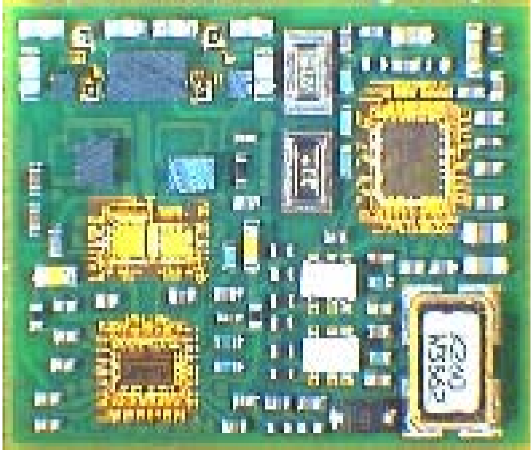
system on a chip

system in a package

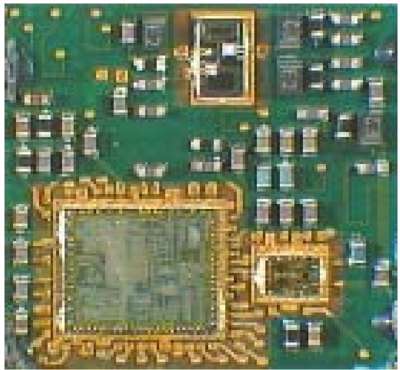
Philips Semiconductors

System in a Package; single package, multi technology "plug & play radios

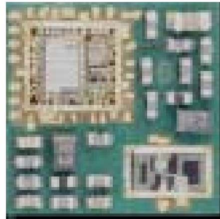




Dual band GSM radio module 160 mm^2



802.11B radio module 100mm^2



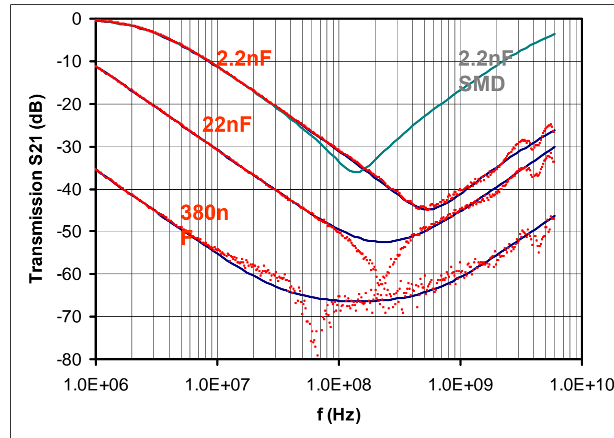
BT radio module 36mm^2

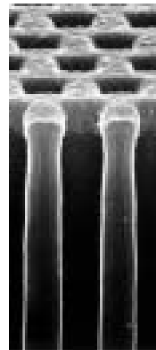
Latest update from the Radio Integration "battlefield"

Philips Semiconductors

High density decoupling capacitors

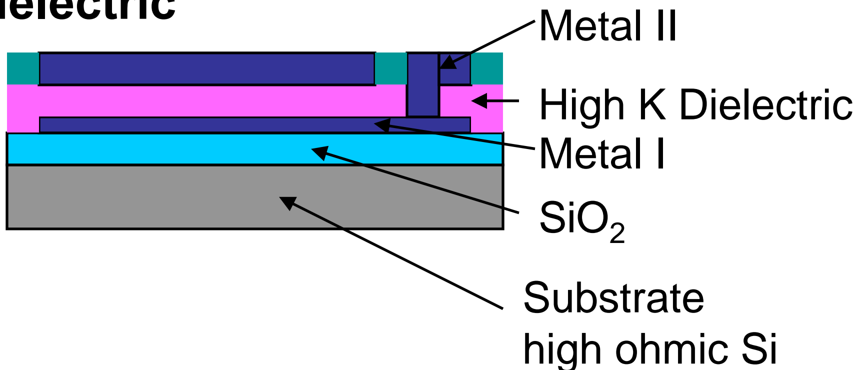
Excellent RF behavior (ESL < 50 pH, ESR < 200 mΩ)

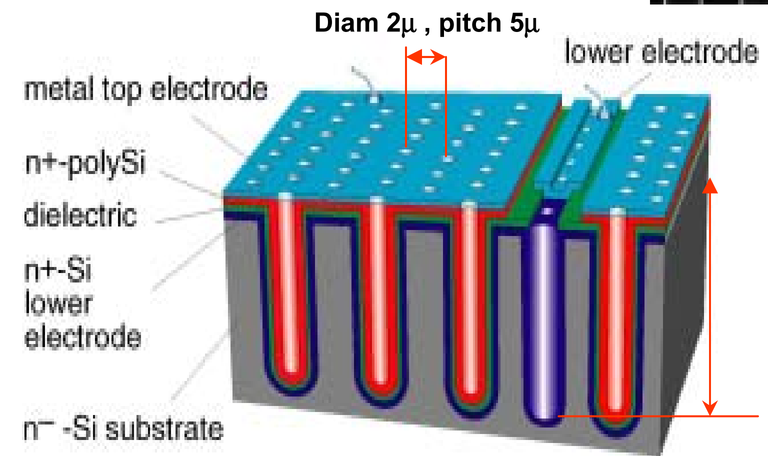




MOS Capacitor on macro-porous Si

MIM Capacitors with High K Dielectric





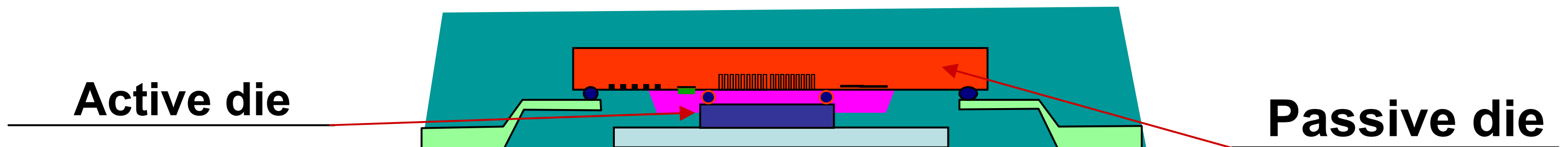
Integrated High Density Capacitors (> 20nF/mm^2; > 20 Volt breakdown), which can be combined with the basic L/C Passive Integration process

Philips Semiconductors

“Actives on Passive”

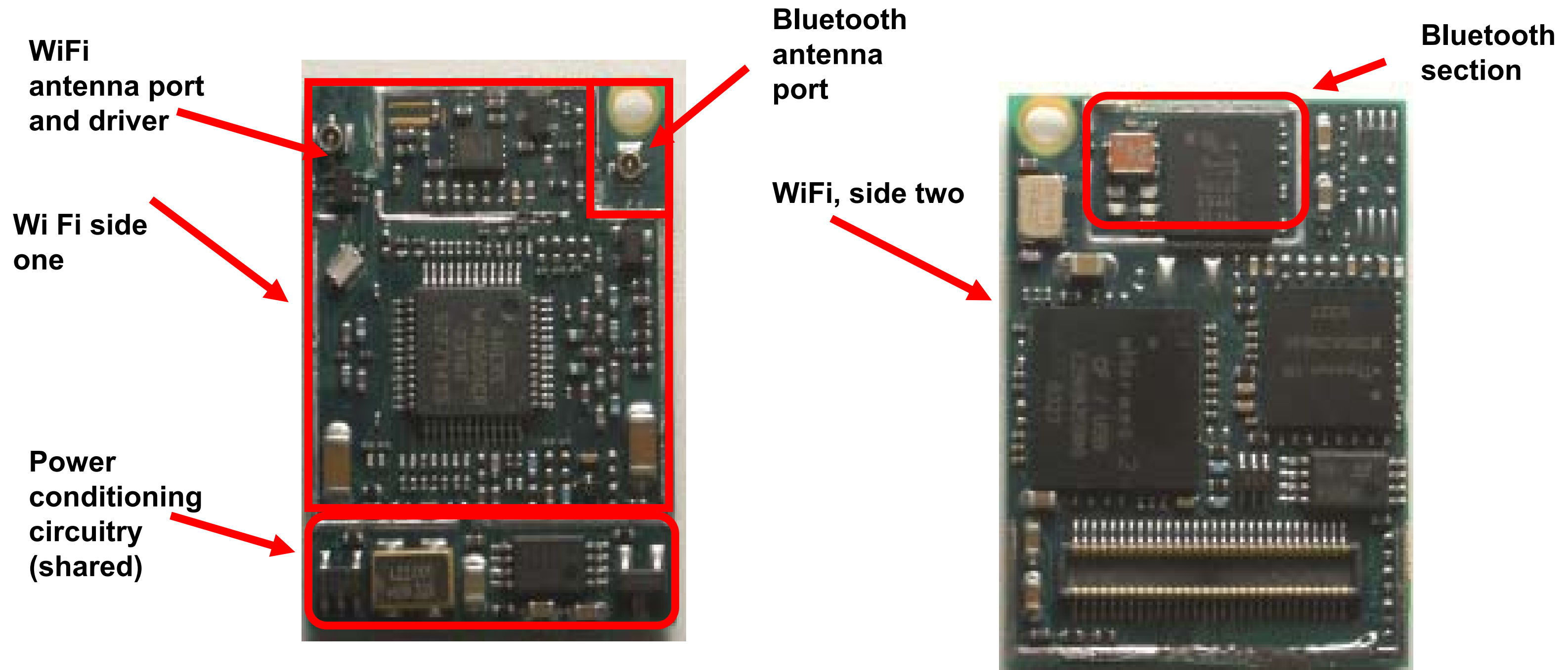
Underfill material

UAA3559 die, bottom up



Philips Semiconductors

WiFi / Bluetooth combo card



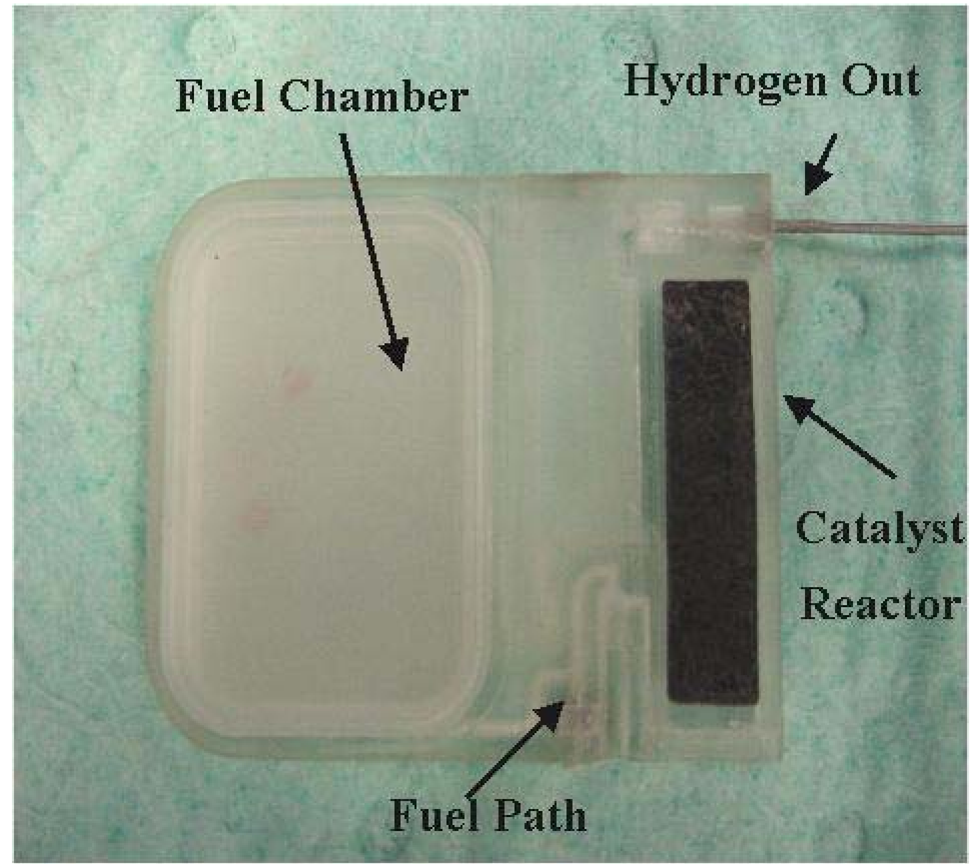
CSR

Examples of Low Power Radio Products

RFM

Demonstrated size and operation fuel cell concept for handheld devices

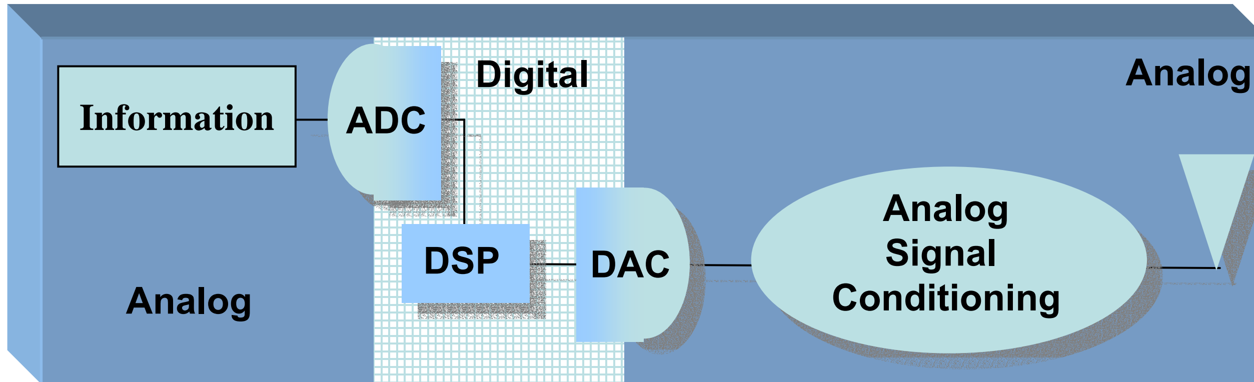
- **Dimensions**
  6 cm x 4 cm x 0.3 cm
- **Reactor volume**
  0.2 cc
- **Output Power**
  2 Watts
- **Hydrogen Flow Rate**
  >24 sccm



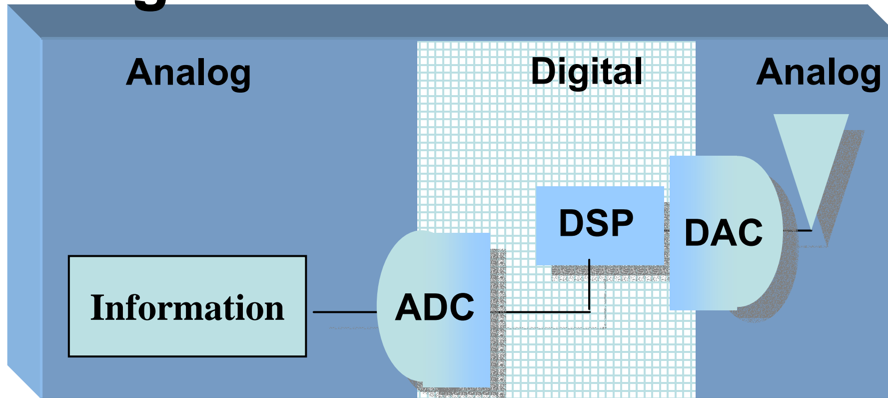
Samsung

Move Digital Processing to the Antenna

Conventional Transmitter Architectures



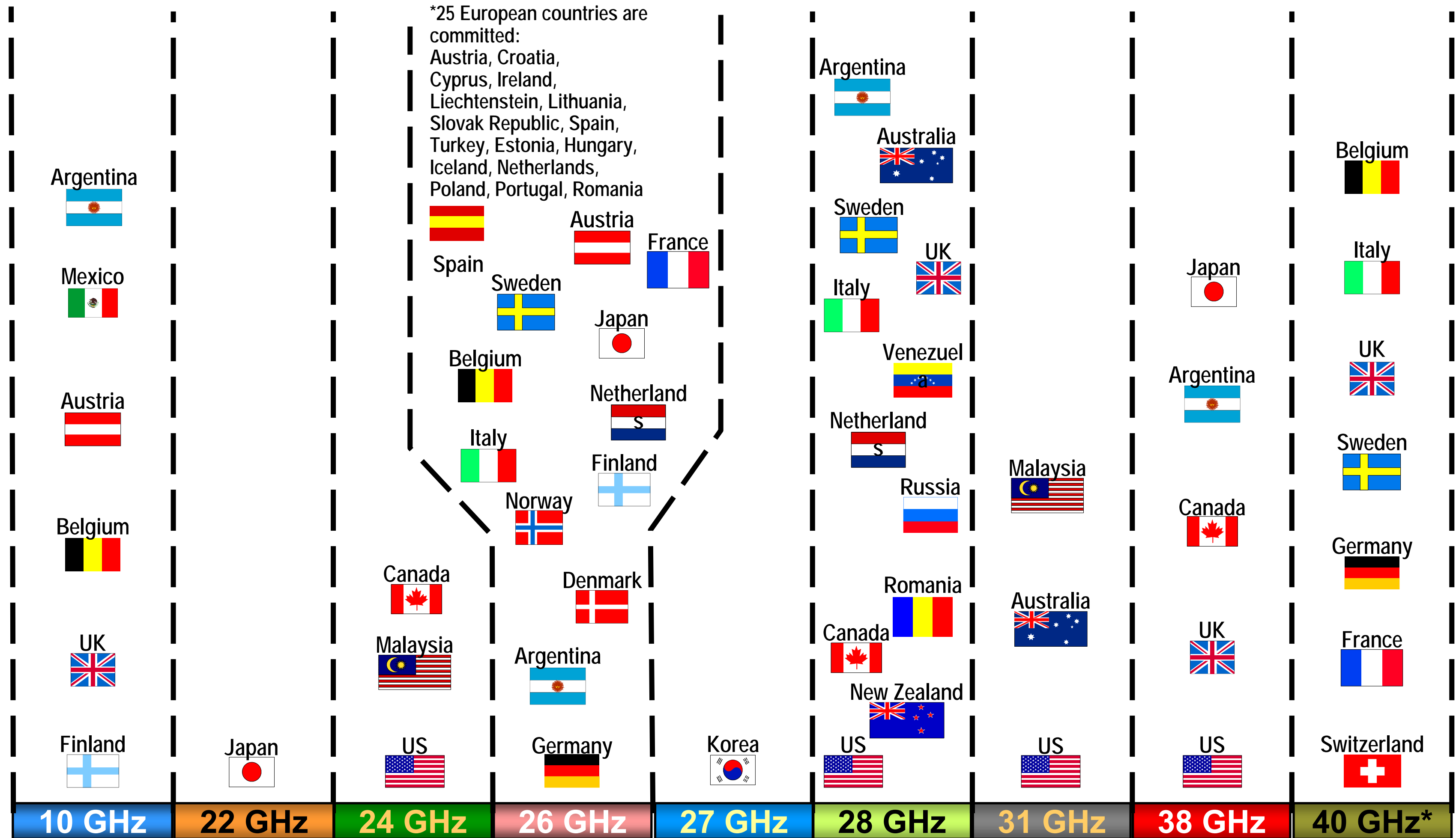
Digital Transmitter Architecture



M/A-COM

Infrastructure & Broadband Equipment

Global BFWA Spectrum Allocations



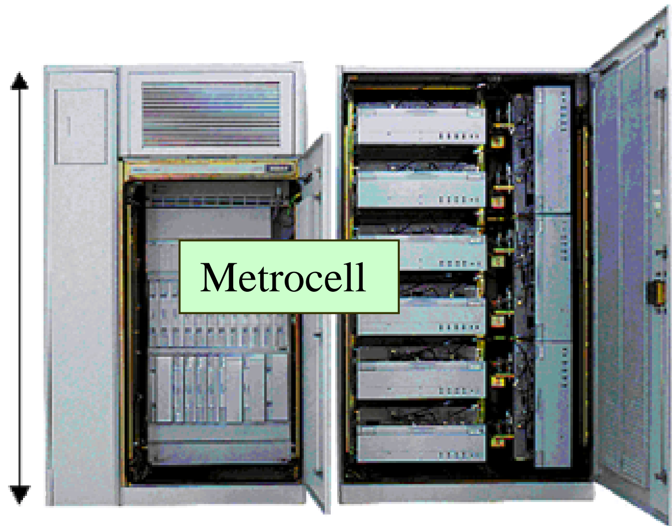
BWA

802.16 Overview and Comparison

	802.11	802.16	802.16a	802.16e	802.20
Status	Complete	Dec 2001	Jan. 2003	ETA Nov. 2003	ETA ’05-06
Target App.	LAN	MAN	MAN	MAN	WAN
Range	Up to 100 meters optimized for indoor LAN	Up to 8 kilometers Average Cell Radius 1-5 kilometers	Up to 40 kilometers Average Cell Radius 6-10 kilometers	Average Cell Radius 1-4 kilometers	
Channel Conditions	LOS when outdoors	LOS	nLOS	nLOS	nLOS
Spectrum	2.4 GHz & 5 GHz – Unlicensed	10-66 GHz Licensed	2-11 GHz Licensed and Unlicensed	2-6 GHz Licensed and Unlicensed	<3.5 GHz Licensed
Mobility Support	Portable – Local Roaming	Fixed	Fixed	Pedestrian Mobility – Regional Roaming	Vehicular Mobility – Global Roaming
Channelization	20 MHz	Scalable 1.5-20 MHz	Scalable 1.5-20 MHz	Scalable 1.5-5 MHz w/ sub-channels	1.25 or 5 MHz
Spectral Efficiency (data rate)	< 2.7 bps/Hz	< 4.8 bps/Hz	< 3.75 bps/Hz	< 3 bps/Hz	< 1.25 bps/Hz
Bit Rate	54 Mbps (20 MHz Channel)	< 134 Mbps (20 MHz Channel)	< 75 Mbps (20 MHz Channel)	15 Mbps (5 MHz Channel)	< 6 Mbps (5 MHz Channel)

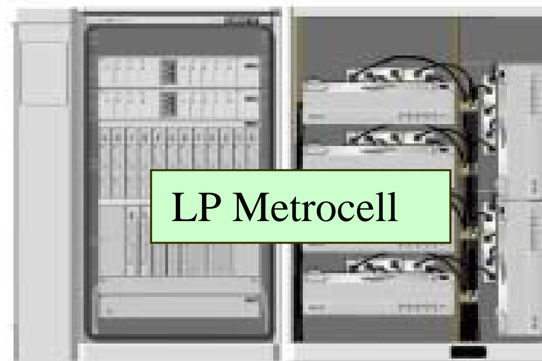
Intel

Urban/Suburban Coverage Enhancement Solutions



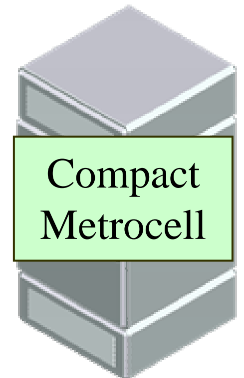
Footprint Reduction for A fixed amount of Carrier/Sector support

20% reduction in Height for equivalent capacity



SMALL

73% reduction in volume for equivalent capacity

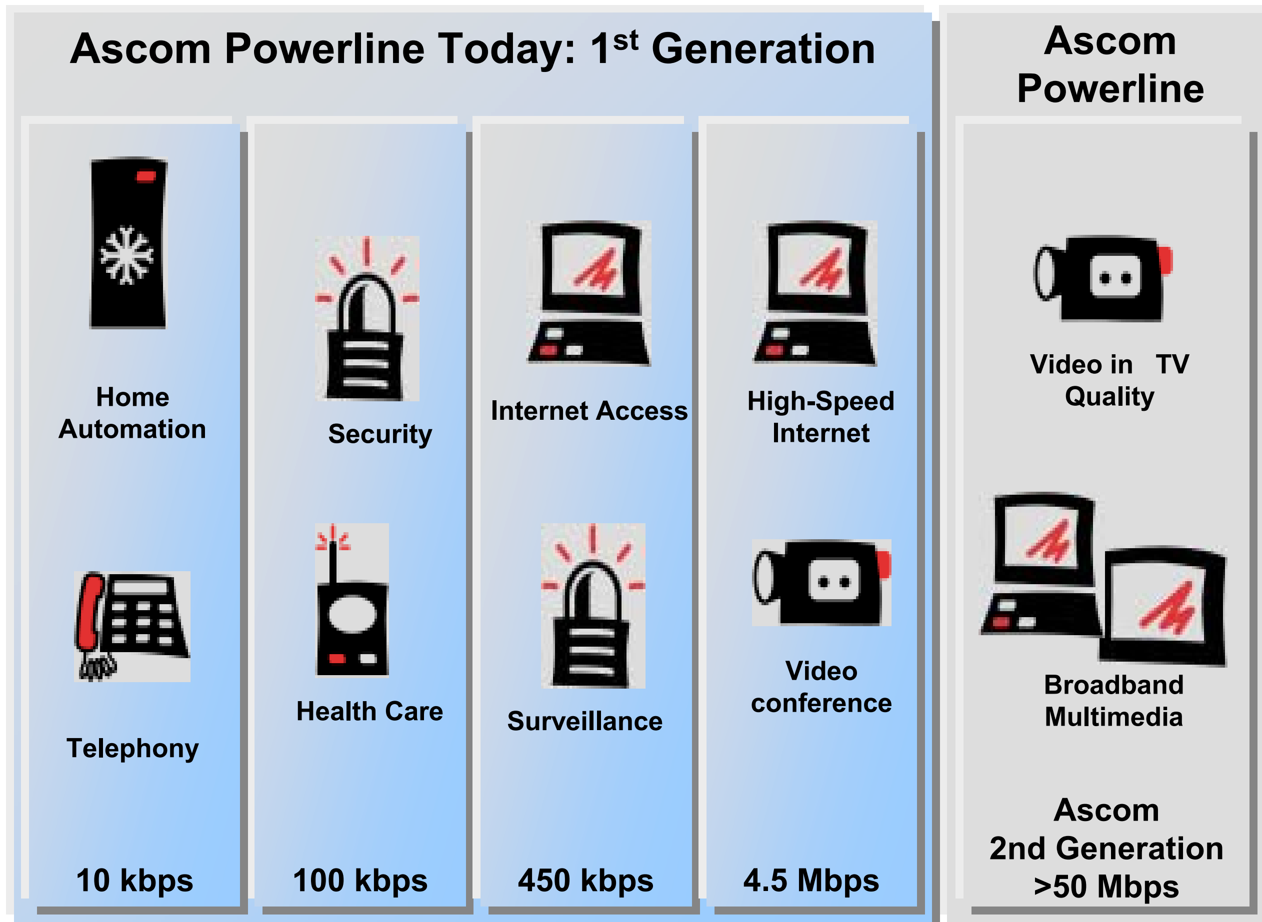


SMALLER

- Ideal for cell splits, network expansions
- Small outdoor footprint allows for curb side deployments, eases zoning approval.

Nortel

Powerline Today and Tomorrow



Ascom

A (really) brief
Introduction
to
Lightning Protection

Rule #1
Lightning doesn't
always follow
the rules

Rule #2
All rules are
conditional

Photo Courtesy NASA

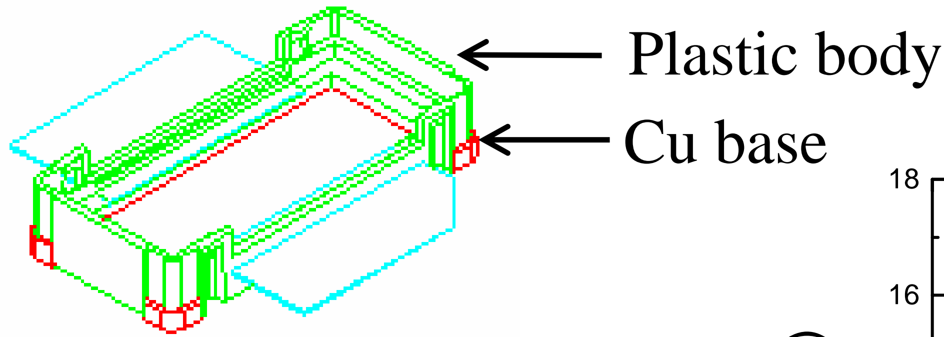
Note lightning rod
on top of gantry

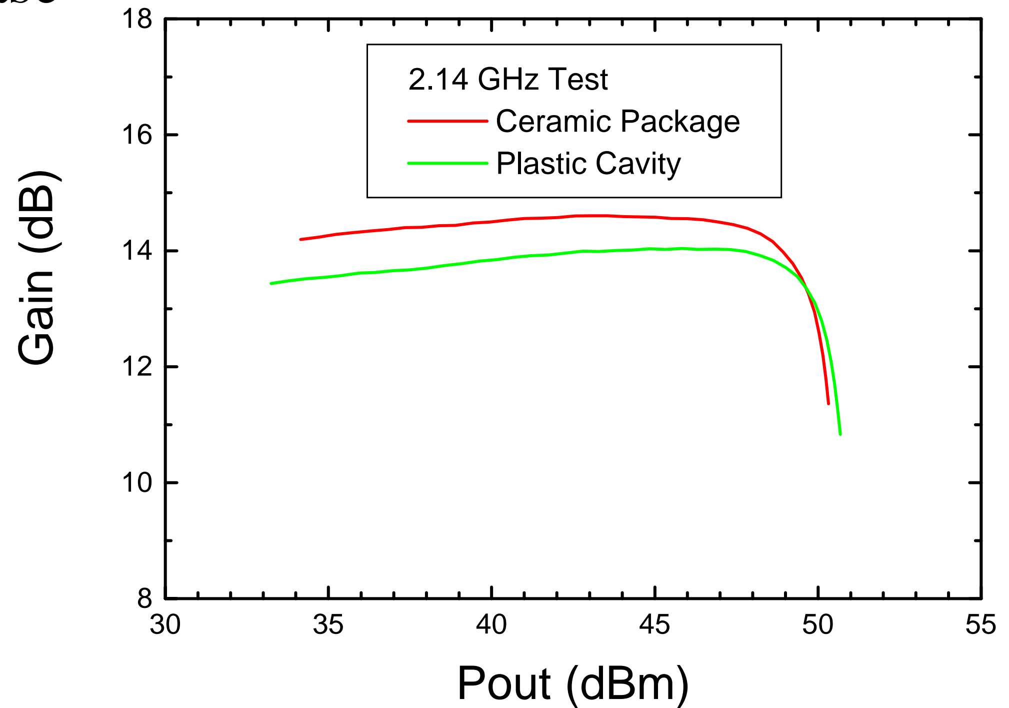
See where the
lightning went!

There is no
lightning system
yet designed
that can
guarantee protection

Polyphaser

Plastic Cavity Packages for higher power, higher performance RF power devices





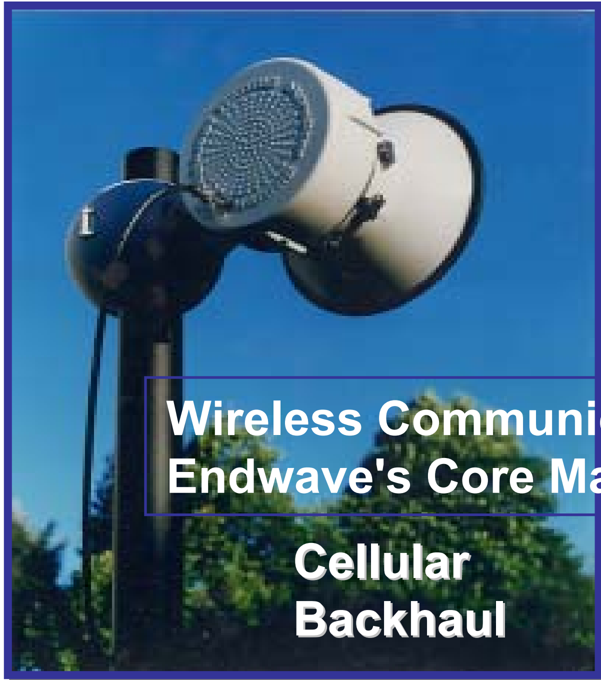
- Same dimensions as current ceramic packages
- Thermally superior Cu base
- High temperature plastic compatible with lead-free reflow temperatures
- Cavity design for reduced performance degradation (vs. overmold)

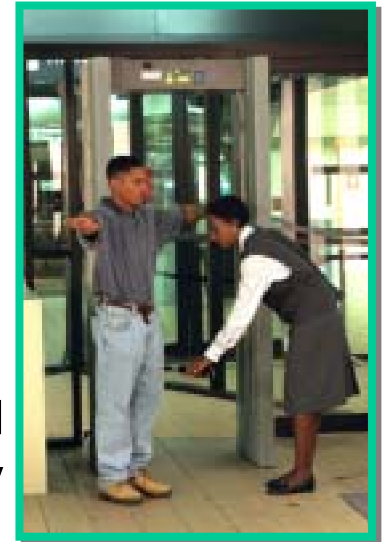
Agere

Millimeterwave Equipment

Multiple Broadband Markets

RF performance is critical to all broadband applications





Homeland Security

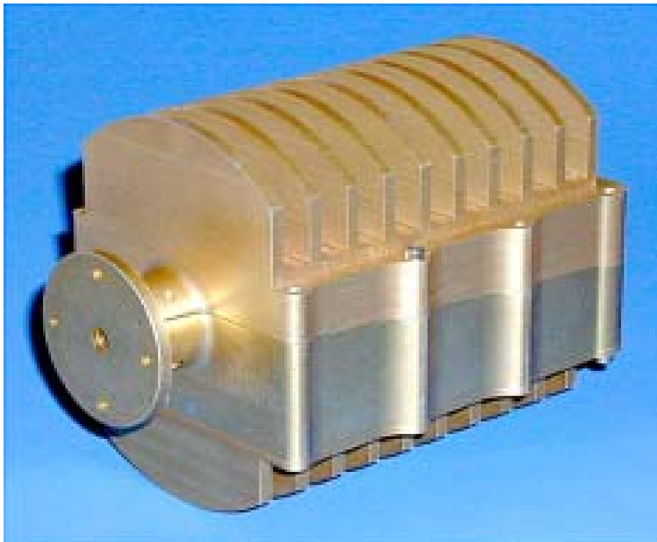
Military and Defense

Test Equipment

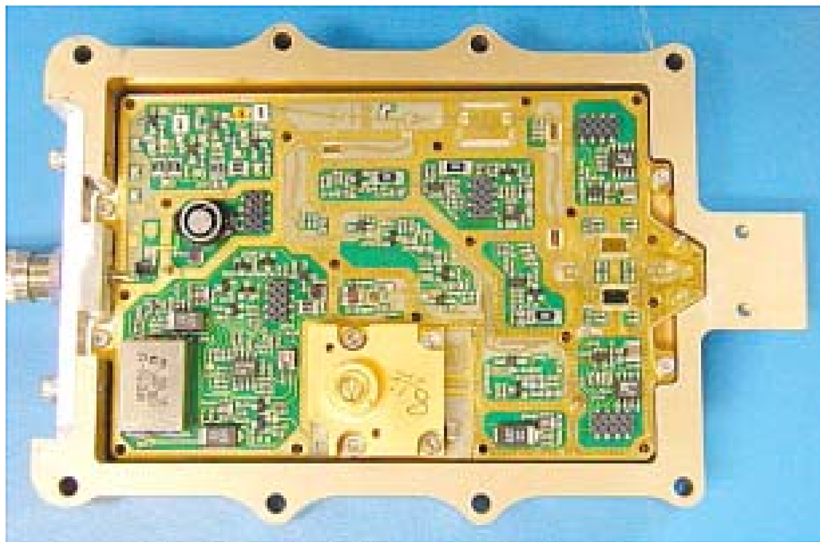
Free Space Optical FSO

BWA

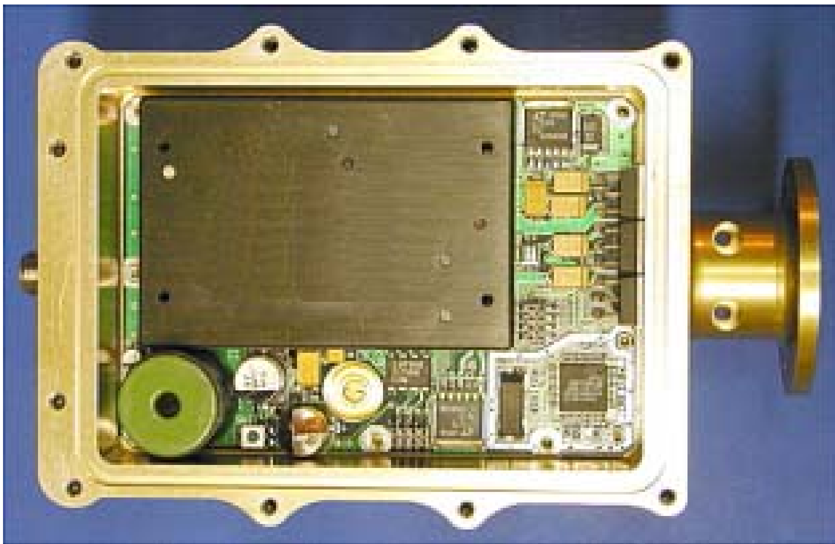
Ka-Band Up-Converter Module Configuration



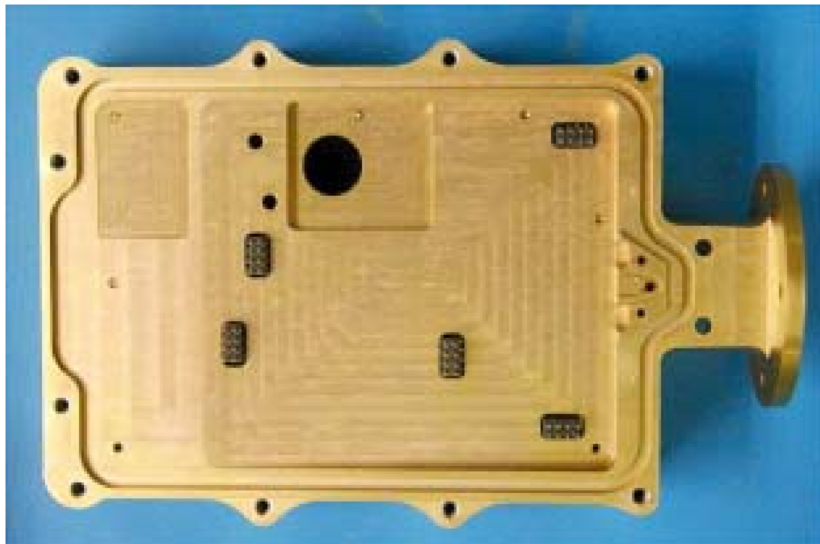
Assembled Module



RF Board on Baseplate and In Module



DC Power Supply & Control Board



Housing with Connections to DC Board

Raytheon

40 GHz Equipment examples

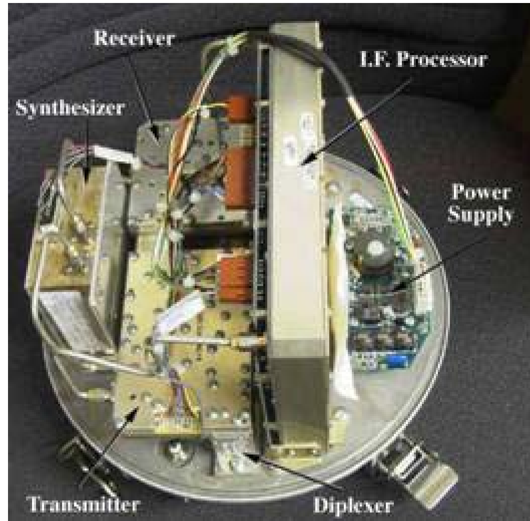
Subscriber Unit

Transmitter Unit

Ogier Electronics

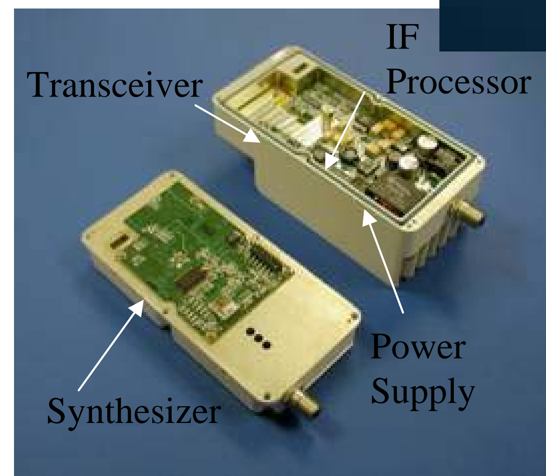
MMwave Radios with Reduced Parts and Cost

Existing Bulky Radios and ODUs



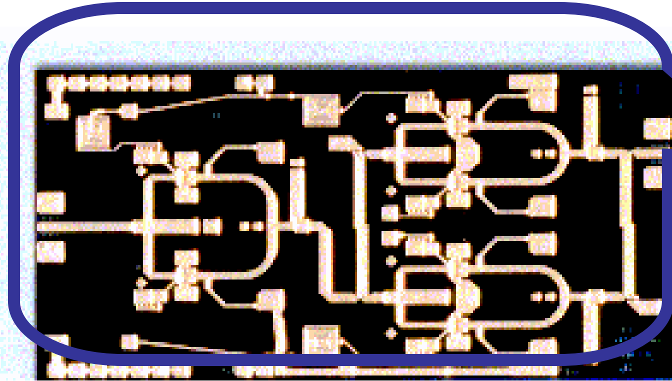
Xytrans Offers Significant Reductions

- Size, weight: 10:1
- Manufacturing assets: 10:1
- Direct labor: 20:1
- Parts count: 5:1
- Total cost: 3:1

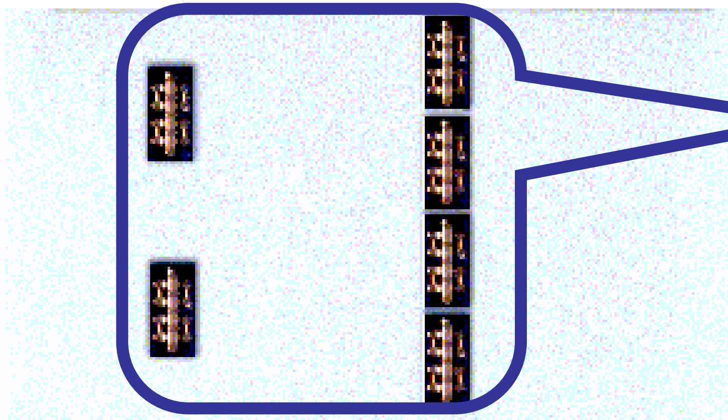


Xxtrans

"Flip" Has Size Advantages



Traditional Monolithic Millimeterwave Integrated Circuit, MMIC

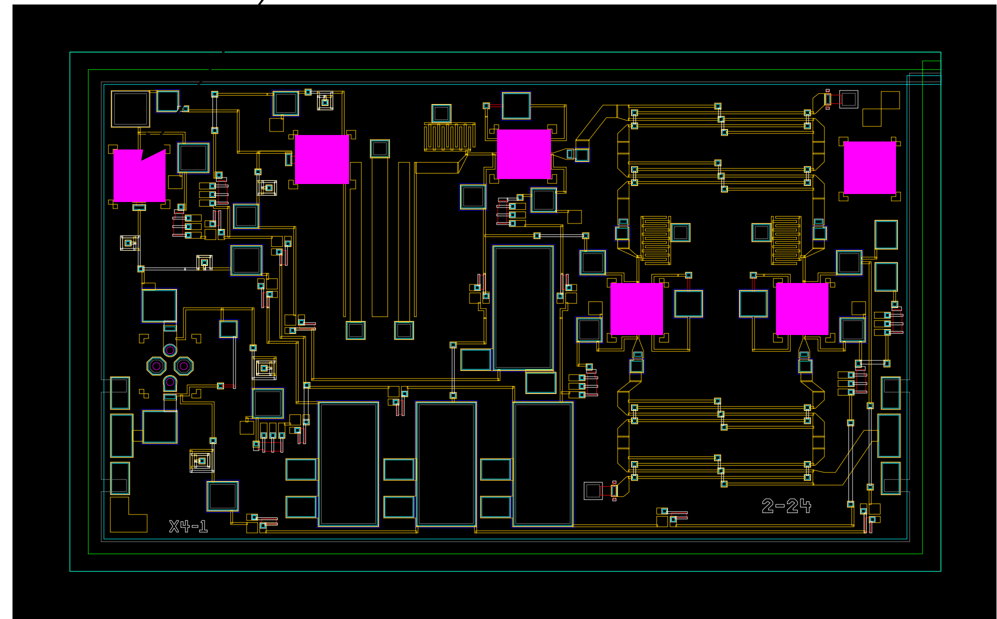


EndWave "Flip - Chip" MCICs, 90% GaAs saving

MLMS: The Flip Chip Example

- Expensive semiconductor area reduced—typical MMIC is *MOSTLY PASSIVE*
- Low parasitic interconnects yield MMIC performance
- Heat path through “bumps” better than 4 mil GaAs MMIC
- Estimated cost is 30 - 40% less than traditional MMIC solutions

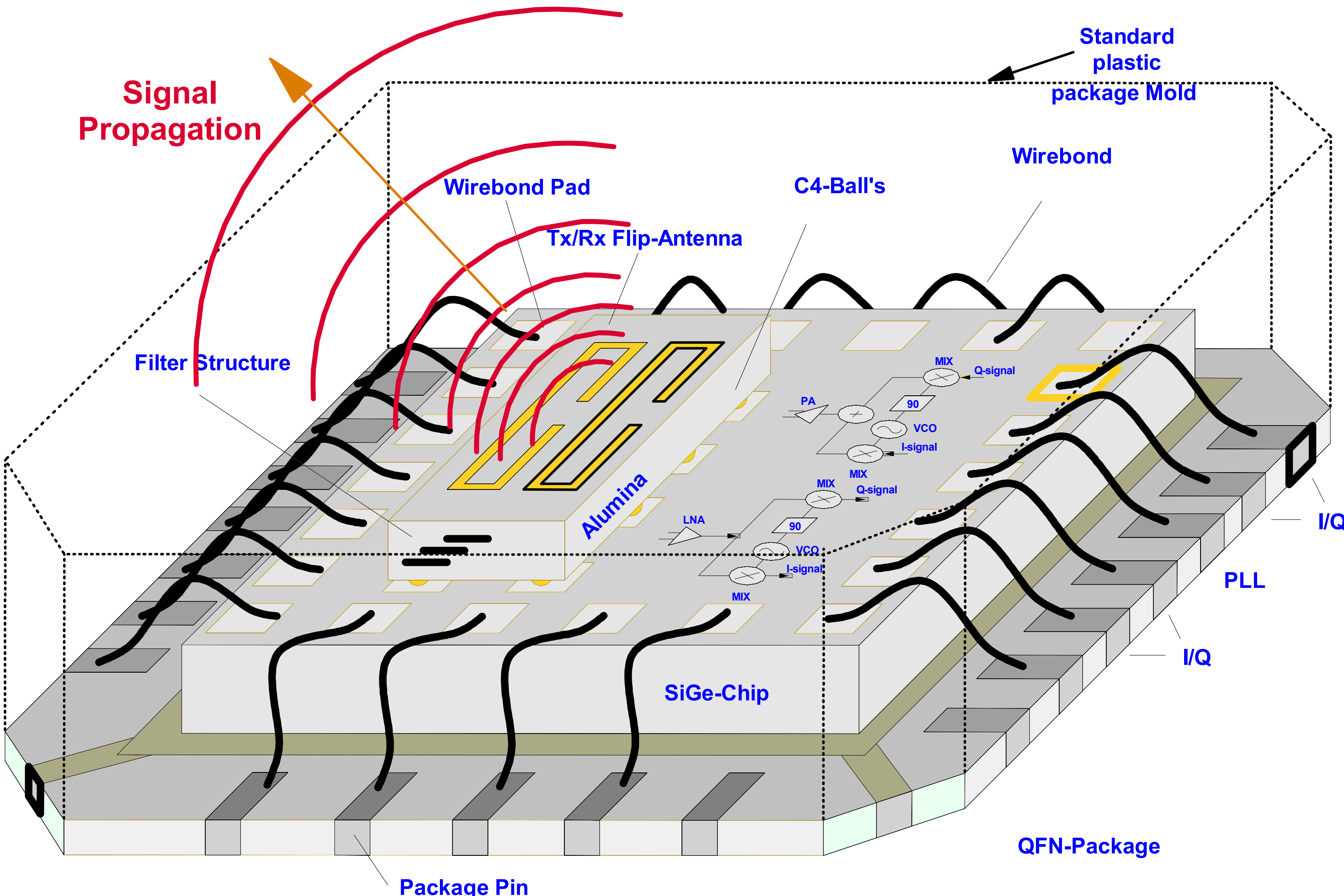
GaAs PHEMT Devices



38 GHz Multiplier Example: This MLMS circuit integrates the functions of a traditional 38 GHz MMIC quadrupler and its off chip filter and capacitors. It utilizes 7 flipped PHEMT devices for an 12X GaAs area reduction. The circuit measures 4.5x2.8 mm

Endwave

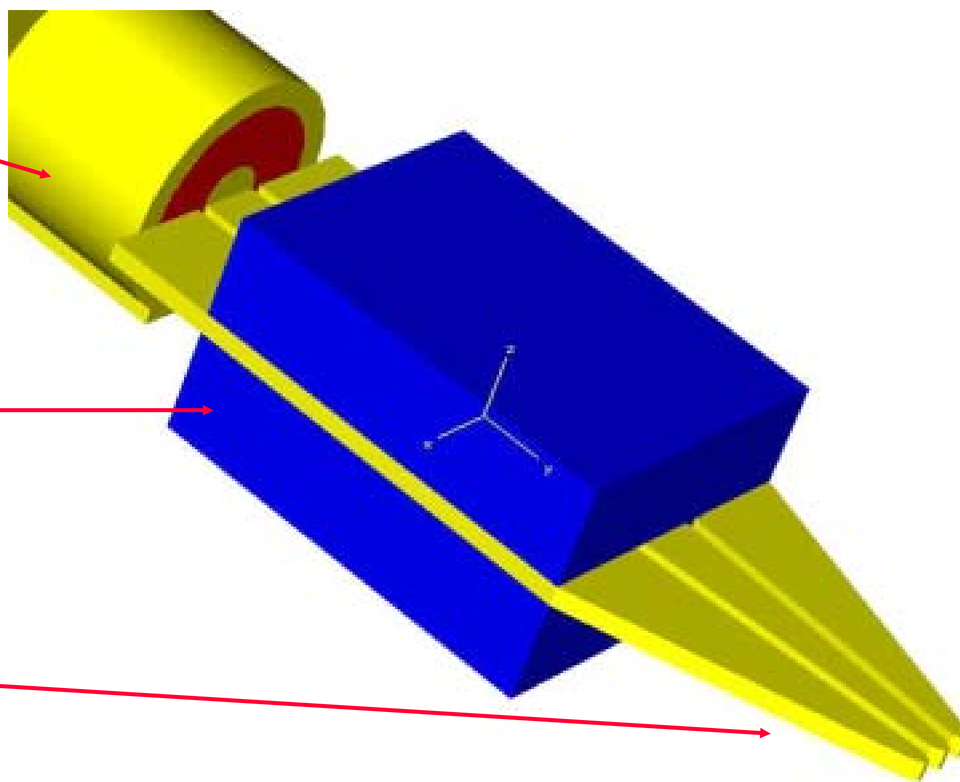
Concept for a packaged 60GHz transceiver



IBM

Contactelement for Controlled Impedance Transitions from Coaxial to planar for MMIC

Coaxial Line



MMIC -Housing

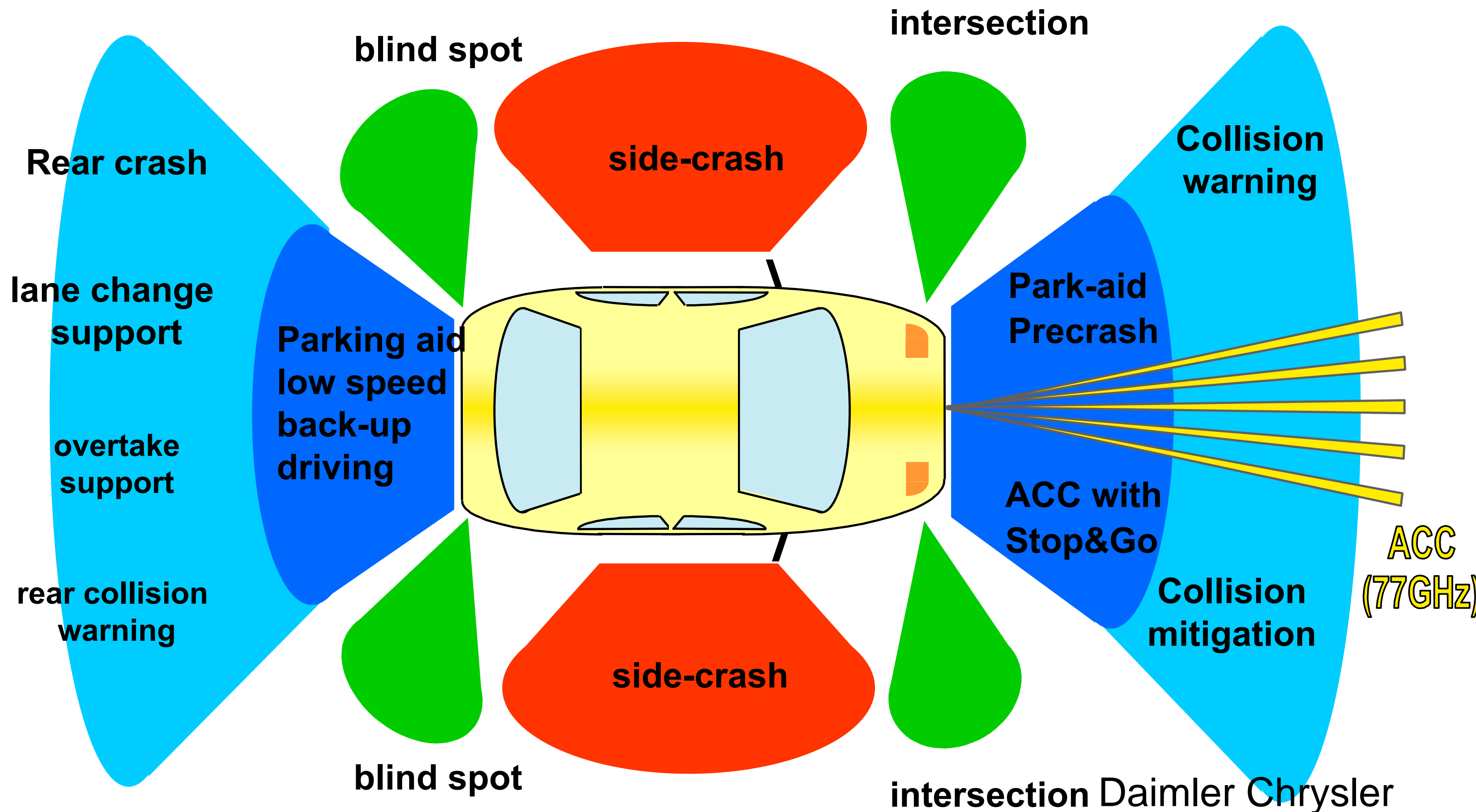
Coplanar Controlled Impance Transition

CICE

Rosenberger

Automotive Applications

Applications based on Short Range Radar



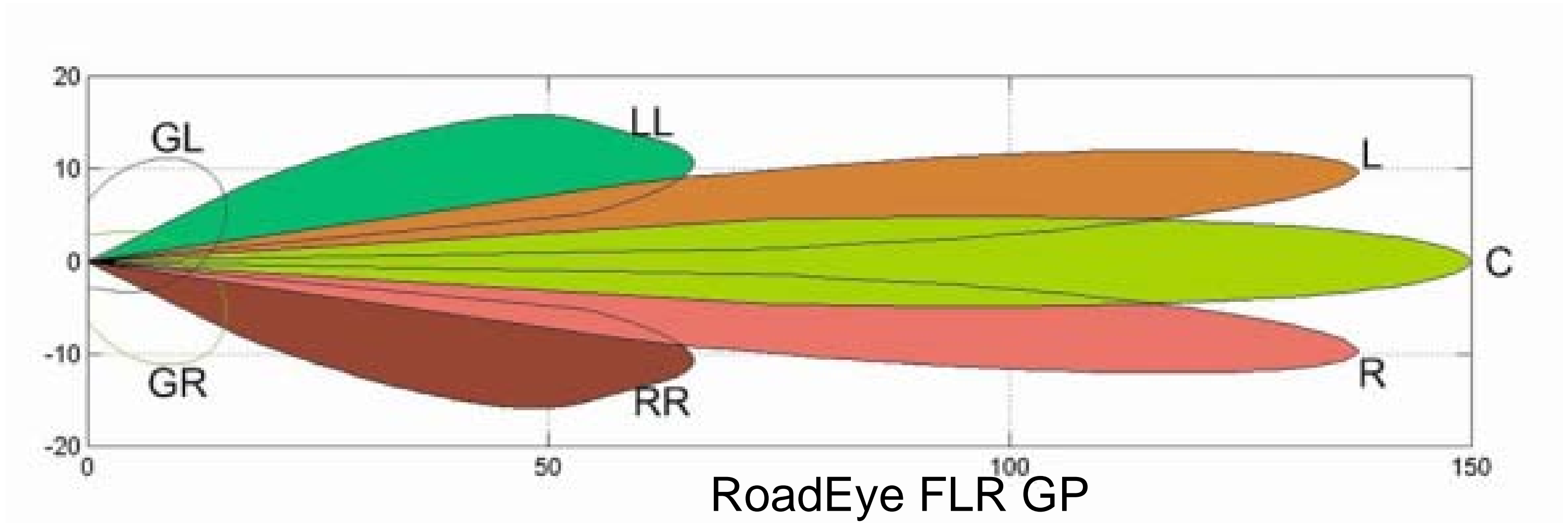
Daimler Chrysler

Distronic

Control unit

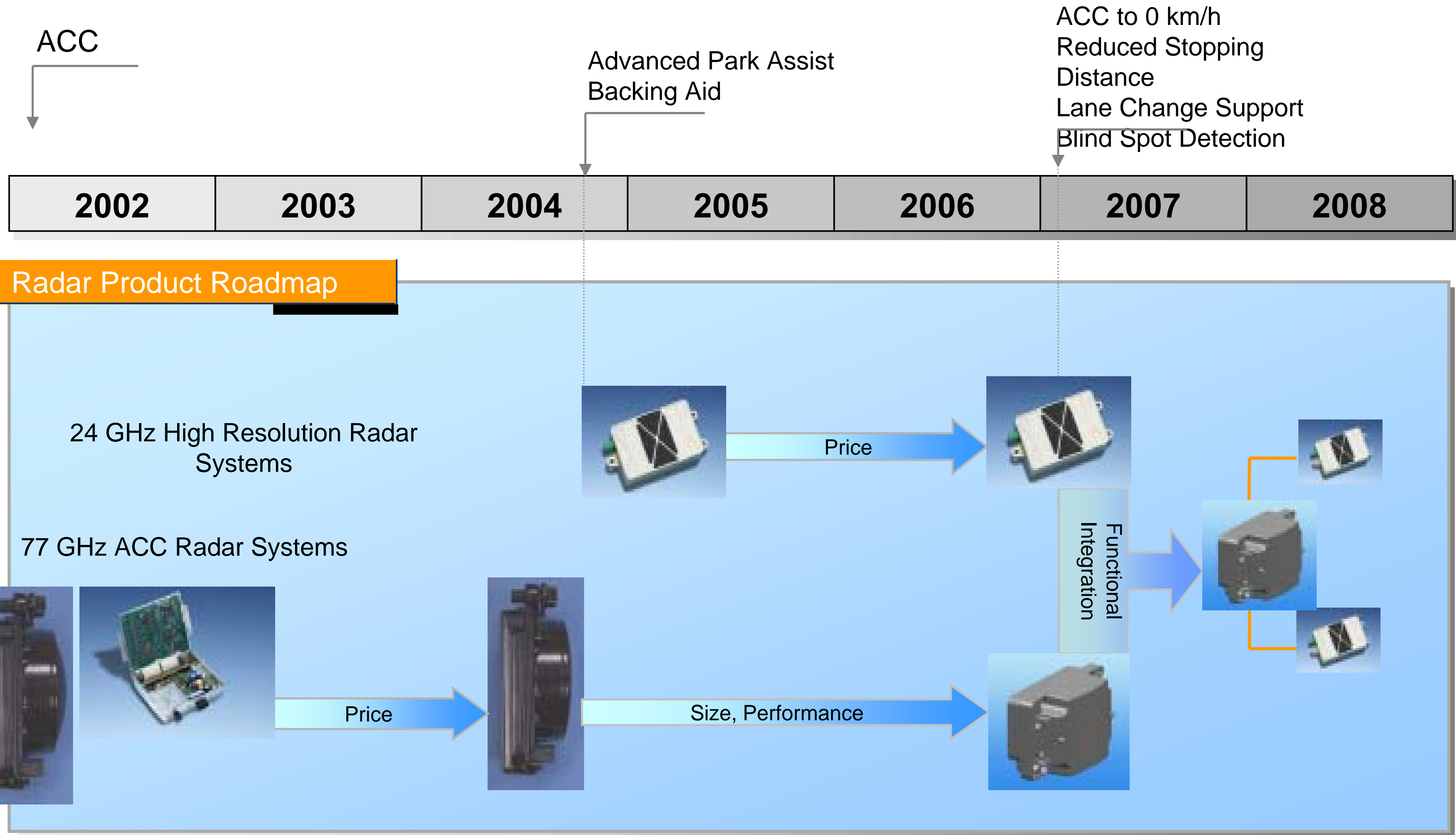
Proximity sensor (radar aerial)

Antenna



RoadEye FLR GP

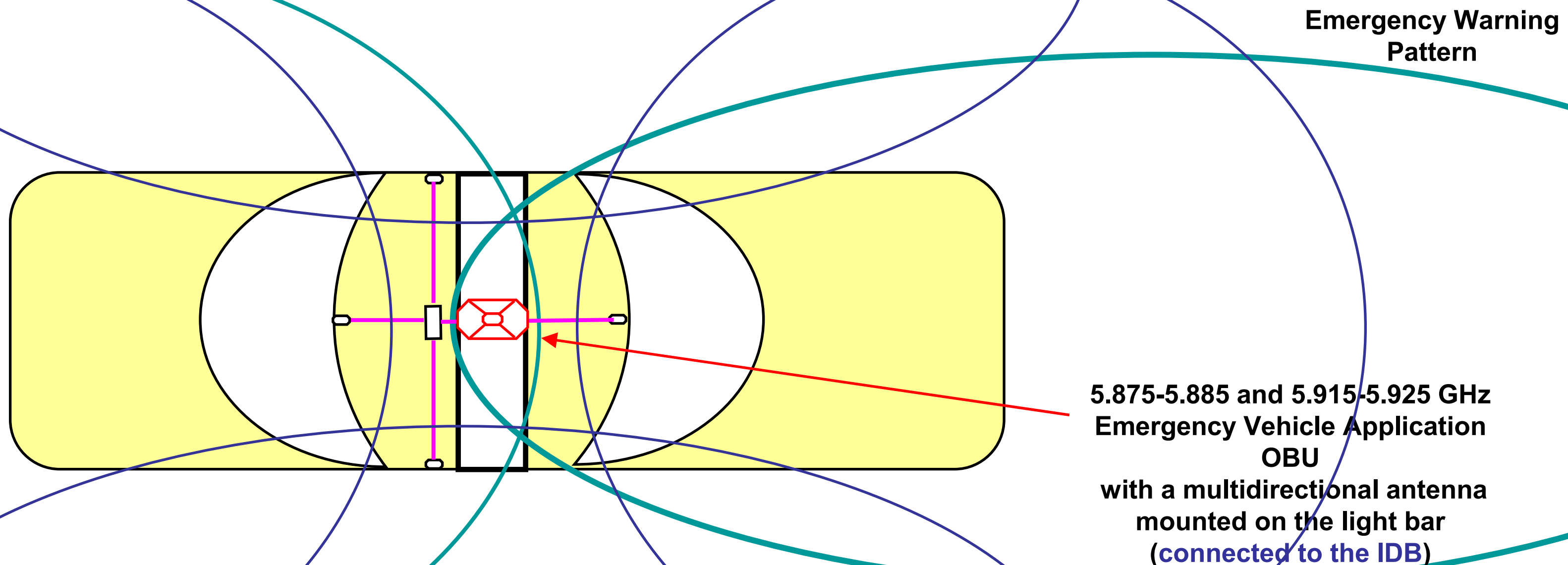
Radar Technology Roadmap



Continental Temec

Common Vehicle On-Board Equipment (Emergency Vehicle Pattern Example)

The emergency vehicle will select the emergency warning forward pattern, the rearward pattern, or the 360 degree multiple antenna pattern depending on the requirements of the application being implemented.



Not to scale

M/A-COM

Interoperability Needs to be Addressed

Why not find a good location and
integrate all the antennas into a single structure ?

M/A-COM

HD Radio Products Planned

KENWOOD

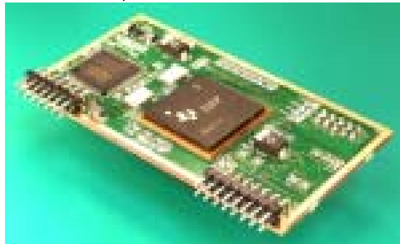
Trunk mounted HDRadio at retail today

Factory installed HD Radio in 2005

Panasonic

Head unit at retail today

TOKO, TBK Modules



Head unit in early ‘04

YAMAHA

High end AV in ‘04

SANYO

Head unit in 2H04

Many more’04 and ‘05 products unannounced …

Texas Instruments

Antennas

High Dielectric Ceramic Antennas

Sarantel uses high dielectric ceramic to create balanced, surface mount & connectorized antennas for hand-held & body-worn RF applications

- Reduced size
- Constrained near-field
- Predictable performance
- Filter-like frequency response

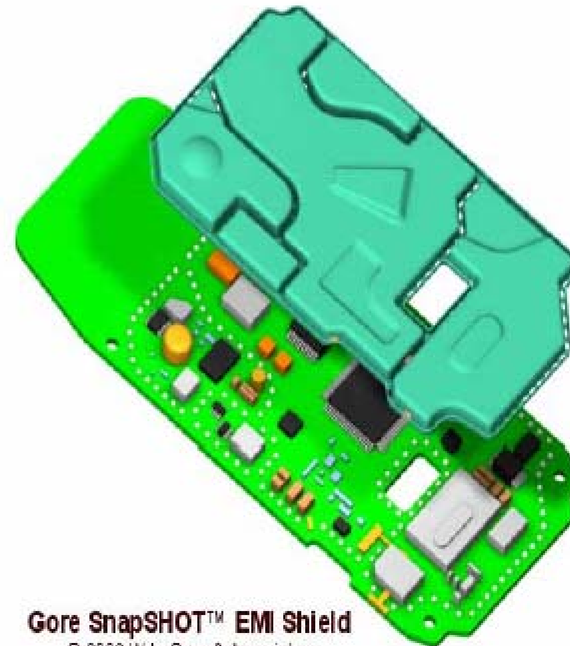
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Sarantel

Shielding Technologies

What is the snapSHOT™ Shield?

- Multi Cavity thermoformed plastic EMI shield
- Metallized on the outside for EMI shielding
- Insulating on the inside for low profile



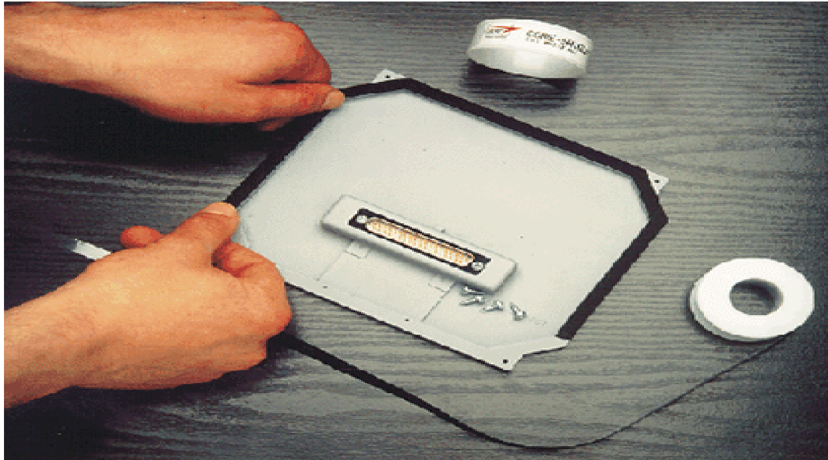
© W. L. GORE & ASSOCIATES, INC.

GORE-SHIELD® EMI Gaskets

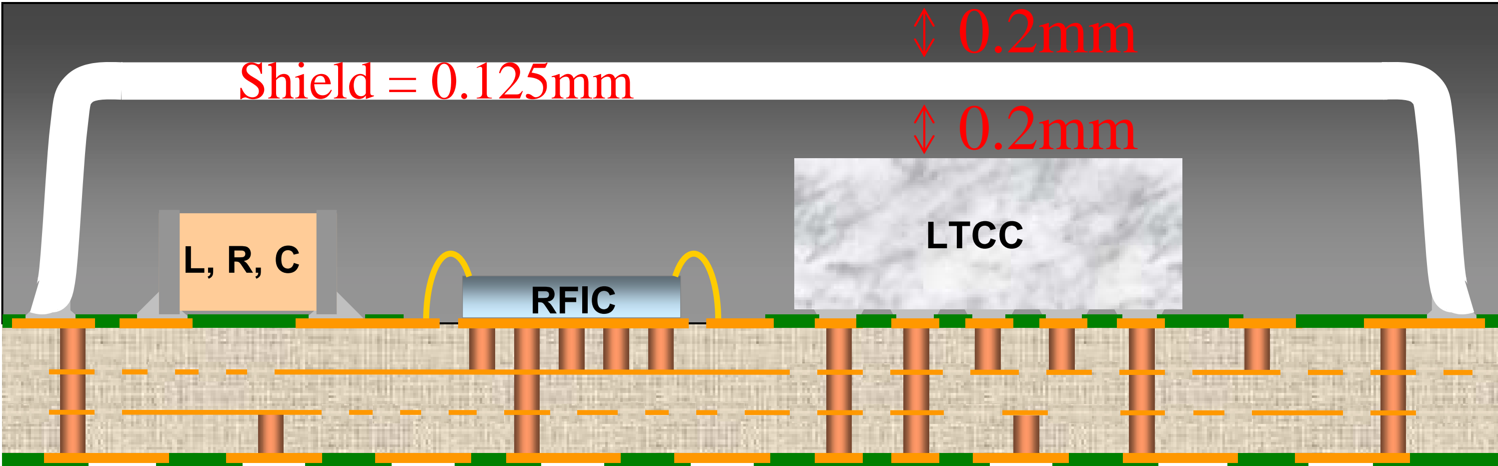
GS5200 & GS8000

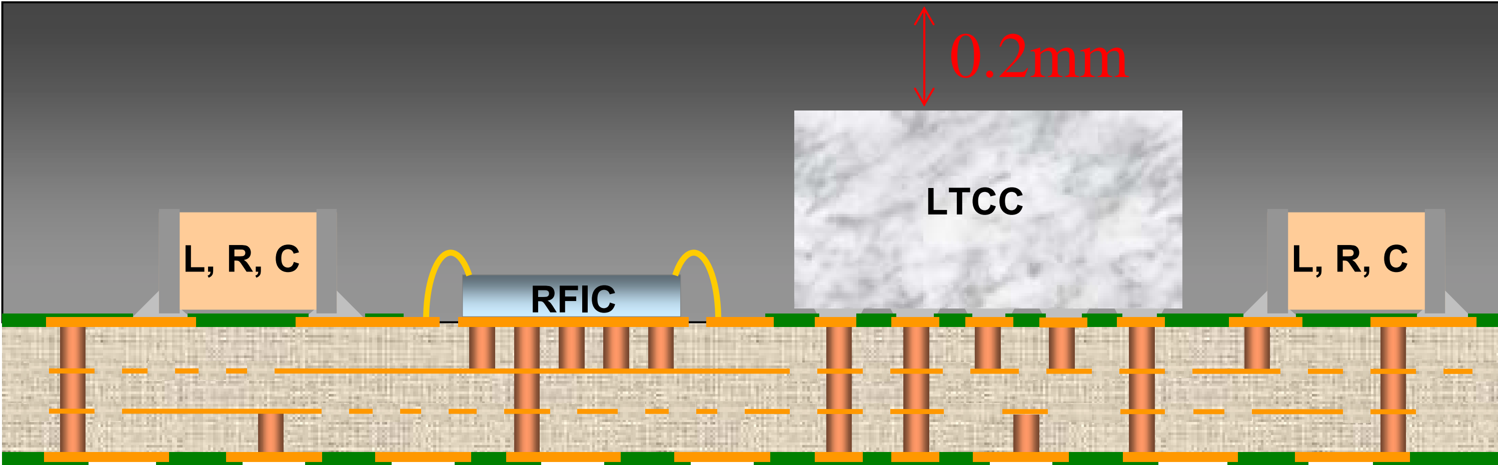
Properties

- High Shielding Effectiveness
- Automated Installation Processes
- Simple And Easy To Prototype
- Conformal Material



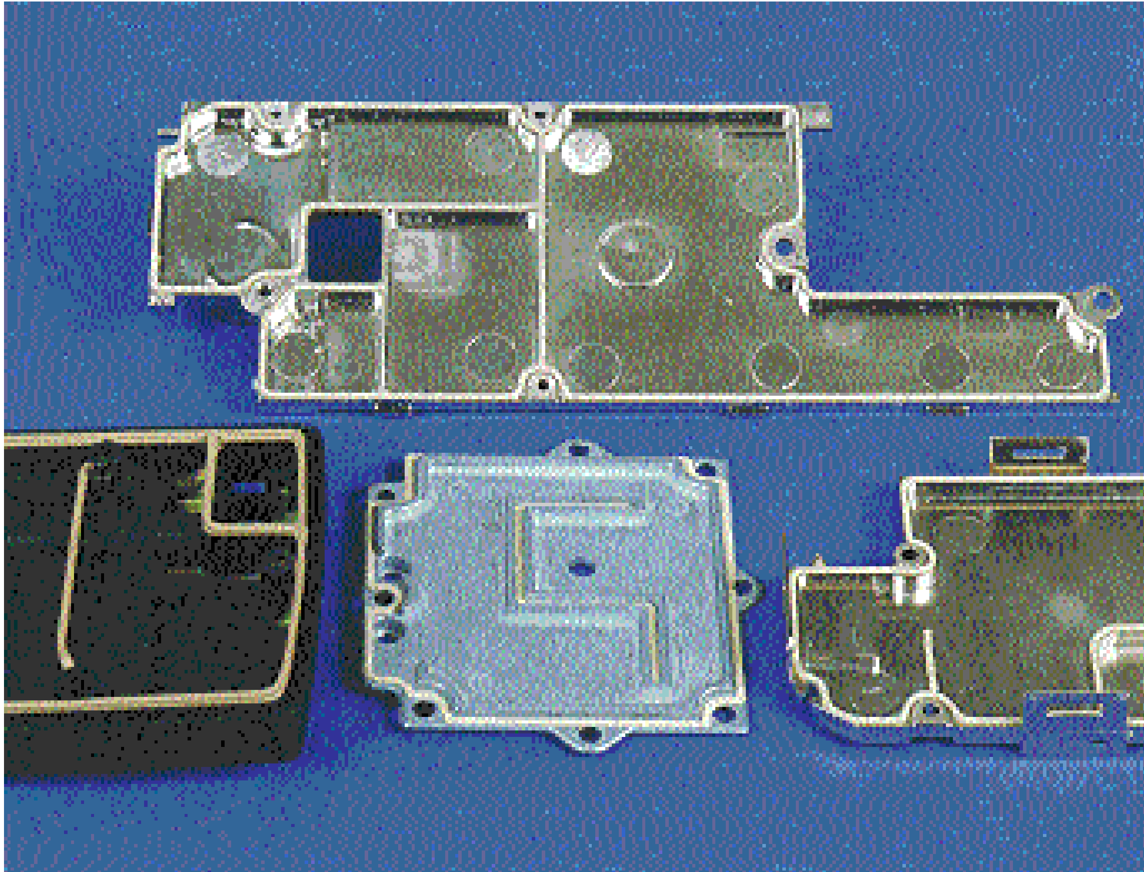
Shield Under the Moldcap





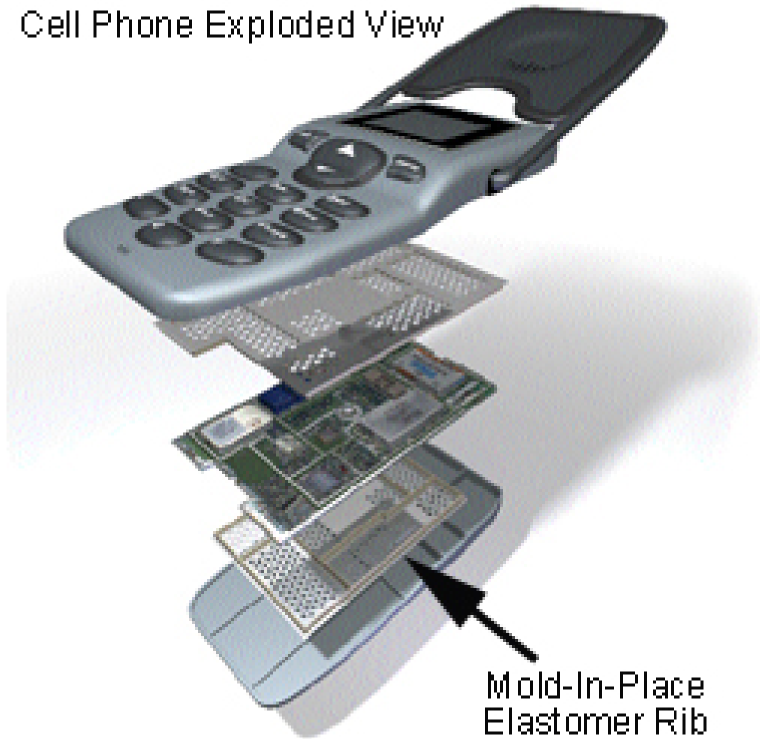
AMKOR

Form-In-Place Elastomer Gaskets

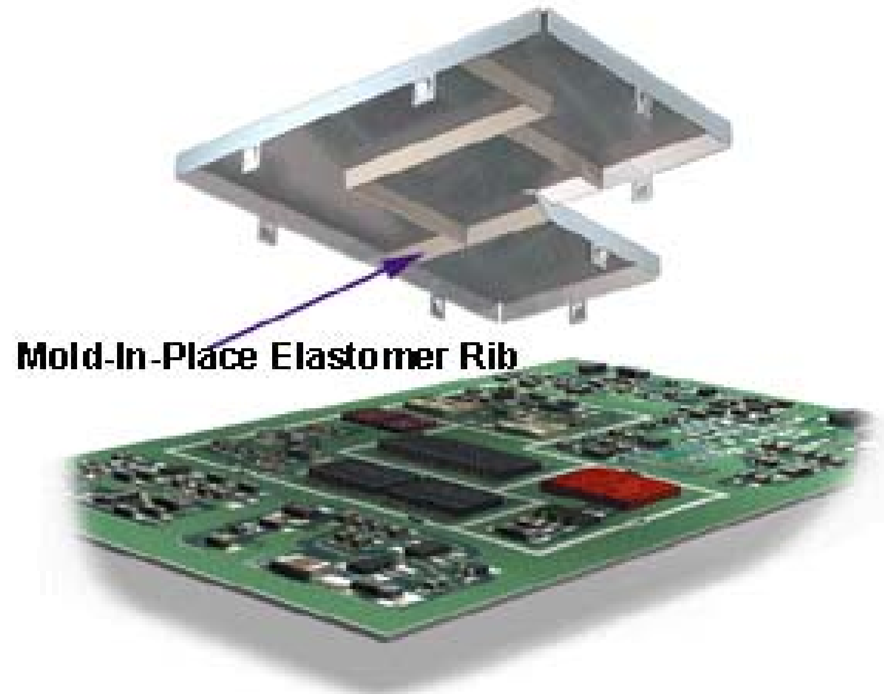


- Applied to die-cast metal or metalized plastic parts.
- Can be applied to non-planar surfaces.
- Can be applied with standard application machinery

Mold-In-Place PCB Shield



-Replaces multiple soldered printed circuit board shield cans with a single piece approach
-Ideal for hand held devices where space is at a premium
-The metal substrate acts as a shielded enclosure allowing the use of a non-conductive housing



-Metal component can be custom designed in various shapes, mounting tabs, and heights

- Elastomer mold-in-place ribs can be provided with a tapered design to lower compression force

Laird Technologies

New Materials

Microwave Substrates

- *PTFE/glass (woven) Dk=2.08 to 3.20*
- PTFE/glass (non-woven) Dk=2.17 to 2.33
- *PTFE/glass/ceramic (woven) Dk=2.94 to 4.50*
- PTFE/ceramic (non-woven) Dk=2.94 to 10.5
- Hydrocarbon/glass/ceramic (woven) Dk=3.20 to 3.58
- Hydrocarbon/ceramic (non-woven) Dk=3.27 to 9.8
- *PTFE/glass/epoxy (woven) Dk=3.00 to 3.48*
- *Epoxy/glass (woven) Dk=3.80*
- LCP (non-woven) Dk=2.90

Park / Nelco materials available in categories marked in ***blue***

• **Arlon's FoamCore$^{R/F}$*™**

"Taking Foam to the Power of R/F"

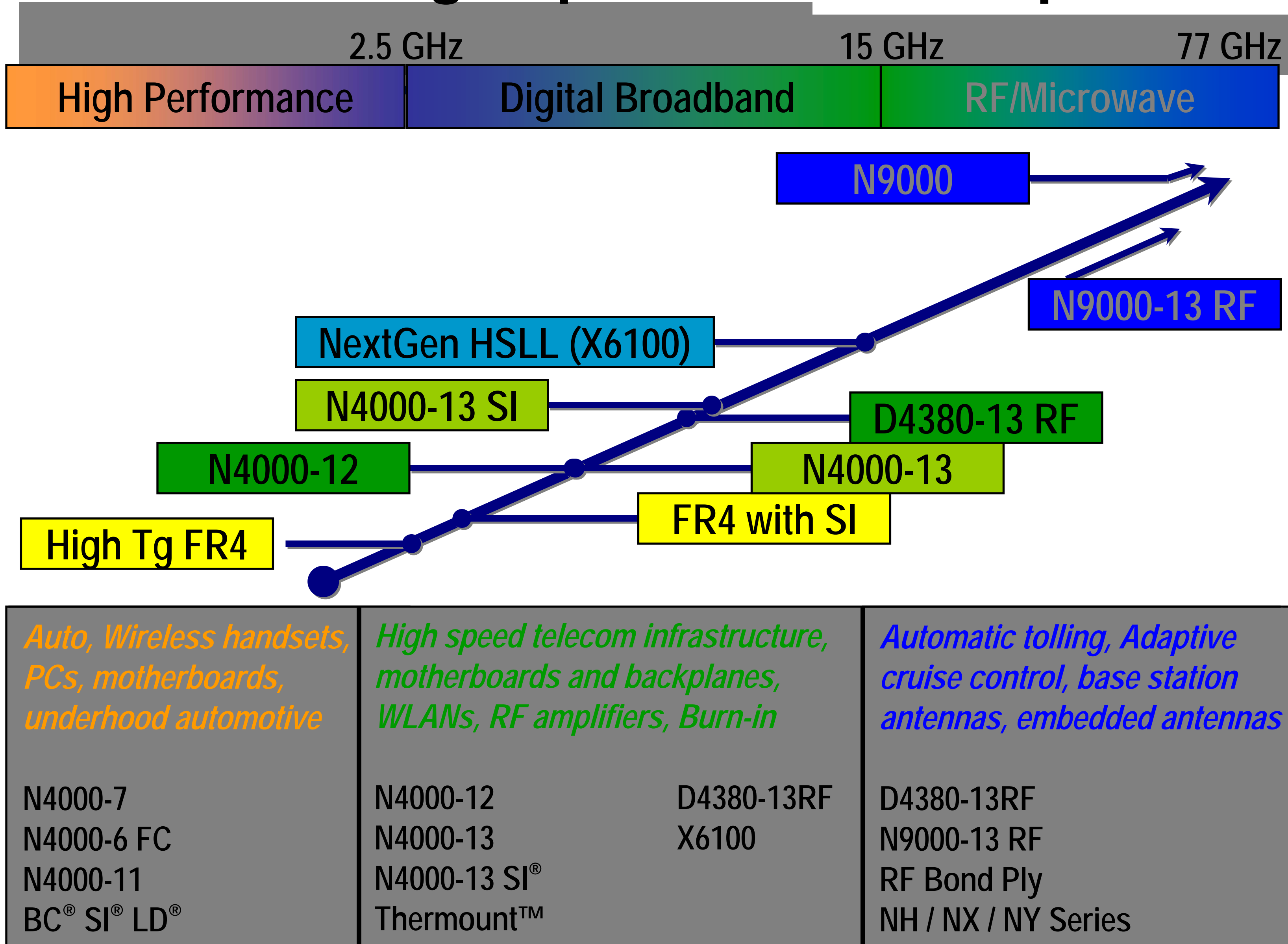
• **Electrodeposited Copper Foil Surface(s), bonded to**

• **An Impervious Polymeric Membrane, bonded to**

• **Low Density (6 lb/ft^3)Closed Cell Foam**

* Patent Pending

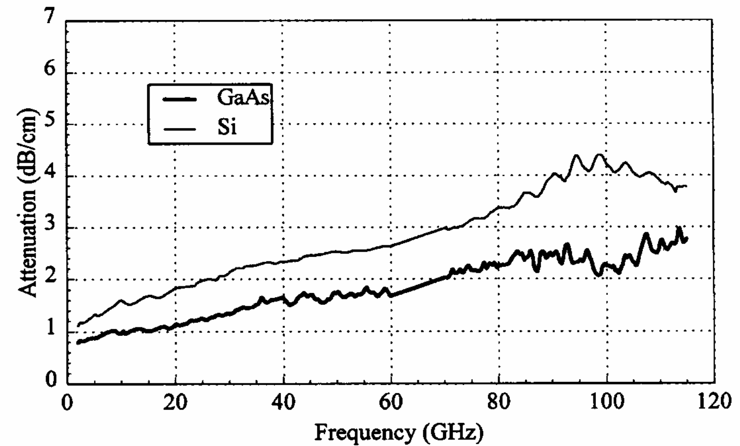
Park / Nelco High Speed Low Loss Spectrum



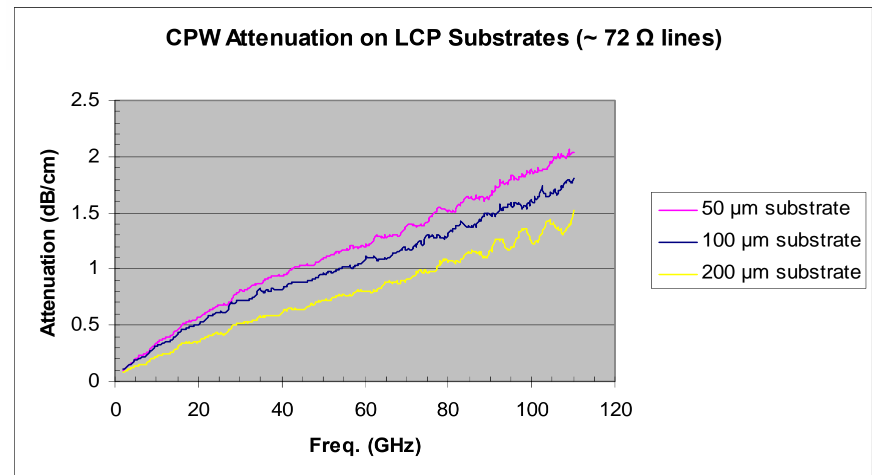
LCP Performance Results

United States LCP Georgia Tech

Liquid Crystal Polymer (LCP) measurements on coplanar waveguides (CPWs) of different substrate thicknesses show attenuation characteristics similar to GaAs



Flexibility demonstration of 14 GHz 1x2 antenna array on 425 micron LCP substrate



Rogers

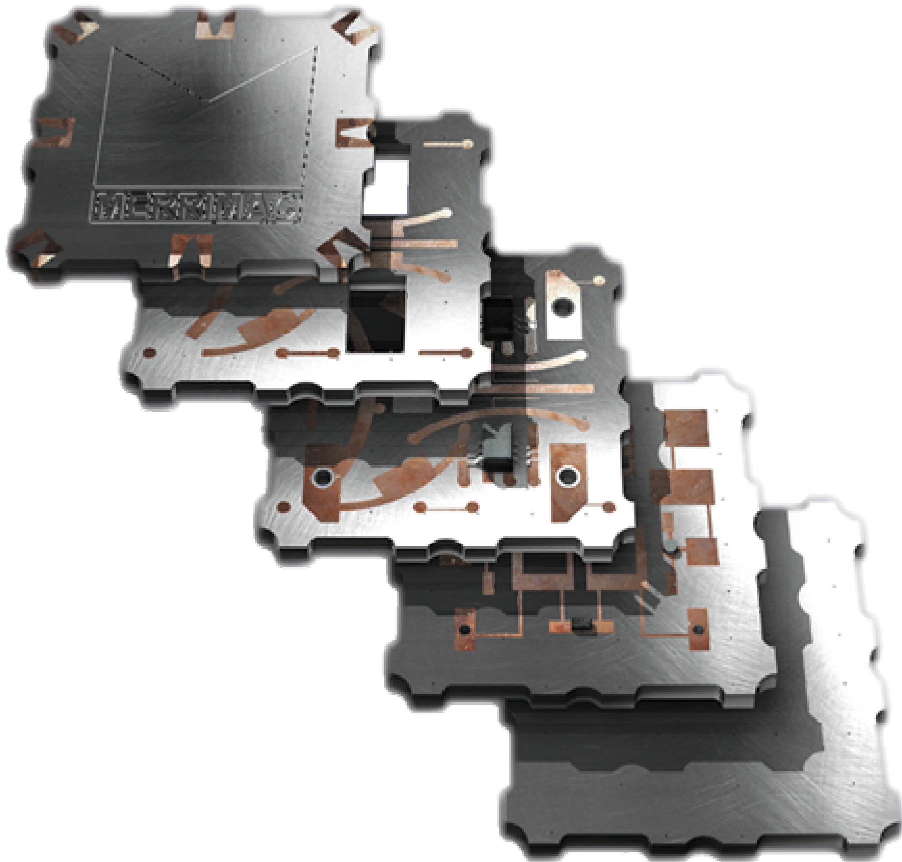
Low-Loss Materials Comparison

	Material	Tg (TMA)	Tg (DMA)	Z-CTE [%]	Dk at 10 GHz	Df at 10GHz
X5300	Halogen Free	175	241	3.2	3.5	0.013
X5300 SI	Halogen Free	175	241	3.2	3.2	0.012
N4000-13	Modified Epoxy	200	250	3.5	3.5	0.008
N4000-13 SI®	Modified epoxy / SI®	200	250	3.5	3.2	0.006

- X5300 and X5300 SI®
  - ✓ Electricals are similar to brominated high speed/low loss materials
  - ✓ Fully thermosetting for lowest CTE

PARK nelco

Multi-Mix® Technology

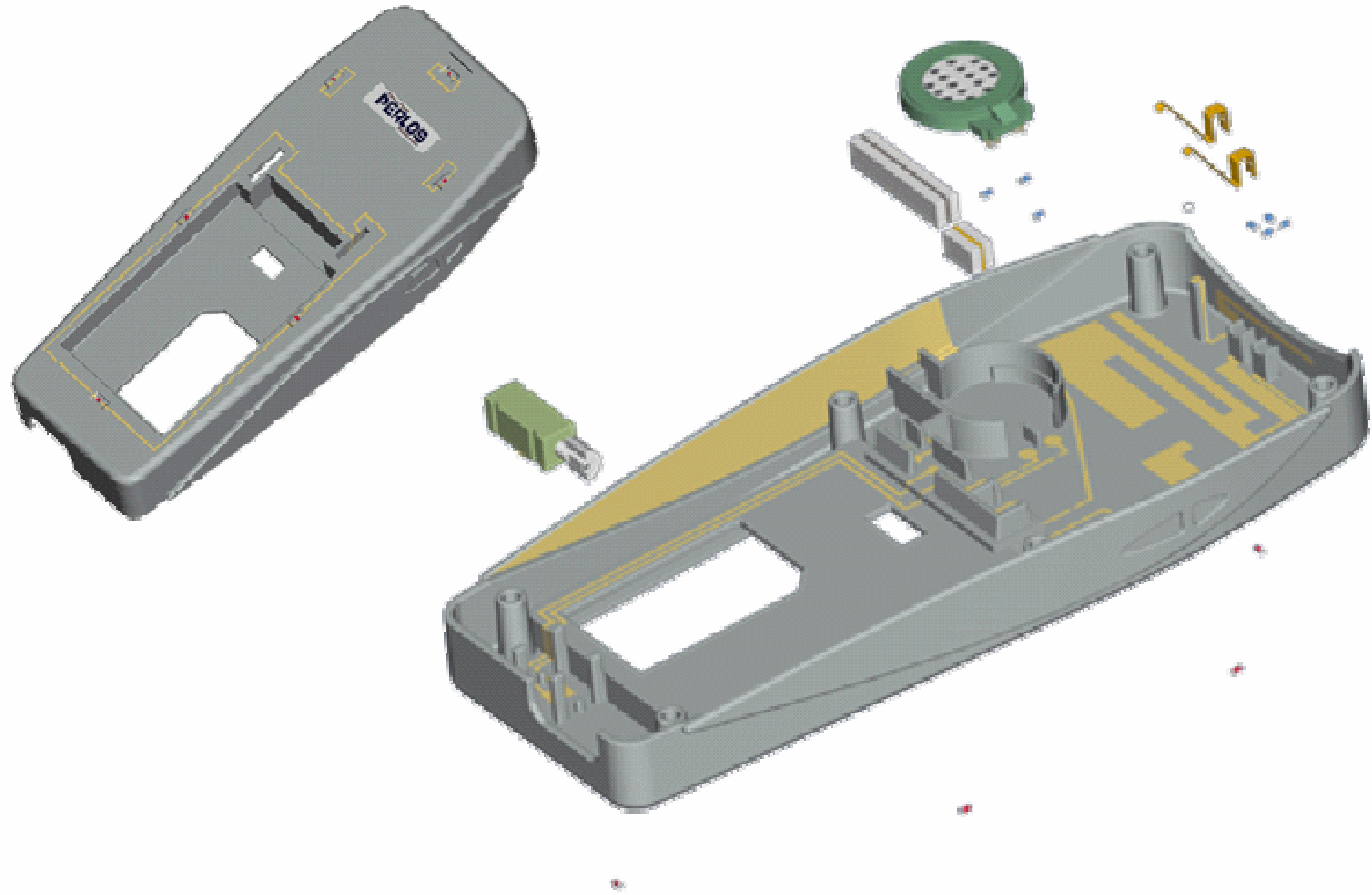


Antenna
Quad Hybrids
Couplers
Power Dividers
Baluns
Filters/Duplexers
Delay Lines
MMICs
Mixers
Phase Shifters
Attenuators

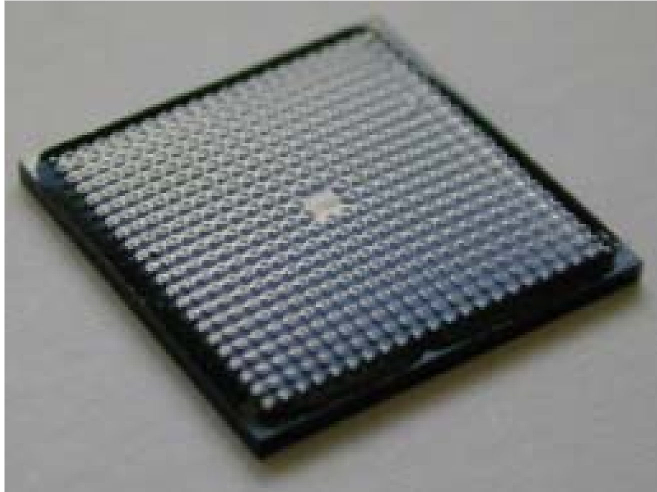
Merrimax

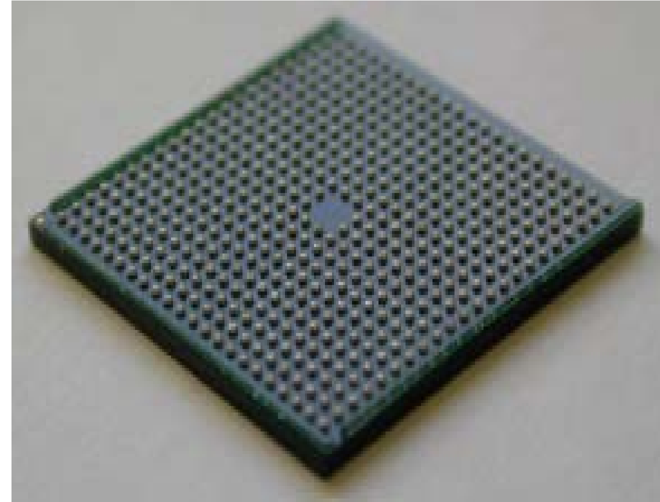
Smart Plastics...What's on offer ?

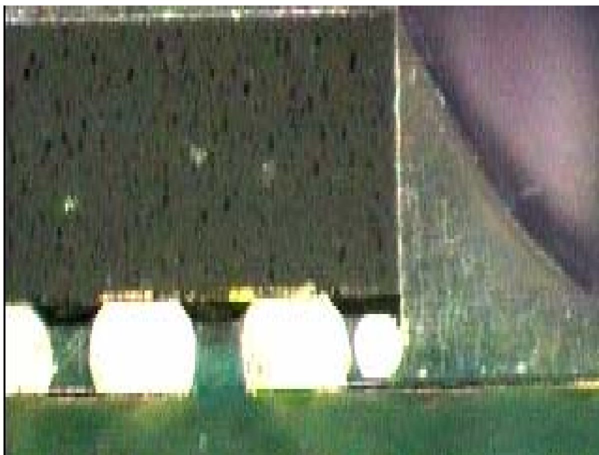
PERLOS
Solutions to challenges



Pre-Applied Underfill







Emerson & Cuming

Environmental Issues (RoHS)

CTIA

Europe

- **RoHs Directive:** Electrical and electronic equipment restrictions to remove certain potentially hazardous materials from equipment by July 1, 2006.

- **WEEE Directive:** Producers responsible for financing collection, treatment and recovery of electrical and electronic equipment waste (WEEE). Product design requirements; ambitious recovery, re-use and recycling rates.

- **Basel Convention Mobile Phone Partnership Initiative (MPPI):** Guidelines on refurbishing&recycling, best practices for transboundary movement of used phones. Membership comprised of manufacturers, NGOs, GSMA, CTIA.

Motorola

EU Regulatory Timeline for Producers

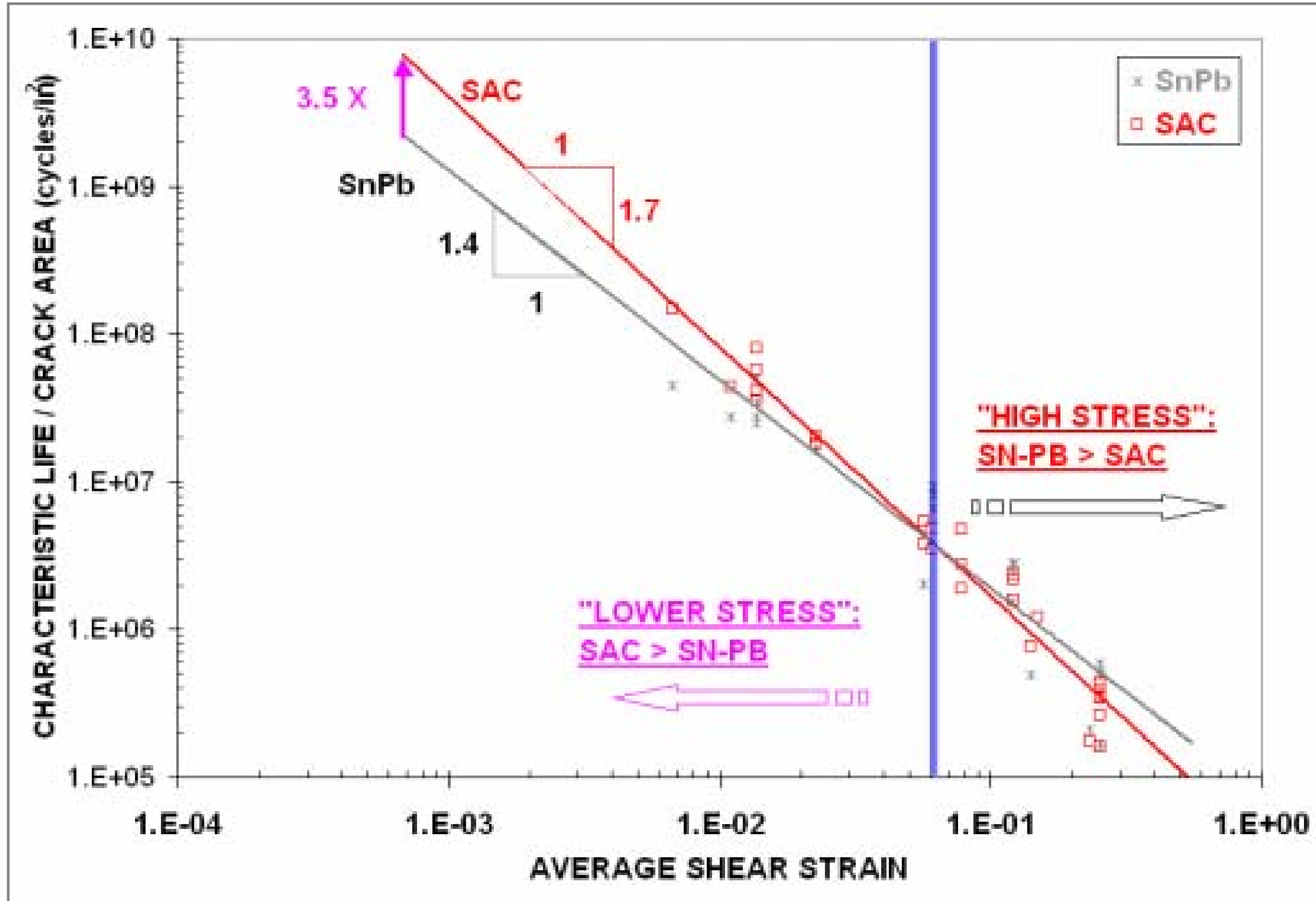
Aug 04	Aug 05	July 06	Dec 06
Directives adopted in member states	Take - back systems and funding established Information recyclers / customers	Lead (Pb), Mercury (Hg), Cadmium (Cd), Hexavalent Chromium (Cr VI), Polybrominated Biphenyl (PBB), Polybrominated Diphenyl Ether (PBDE) banned	Recycling rates requirements (75%/ 65%)

- **EU Directives Adopted, March 2003**
- **California Prop 65 settlement effective, September 3, 2003**
- **China adopting EU-like Environmental Legislation (January 2006)**
- **Korea adopting EU-like Environmental Legislation**

Motorola

Reliability Modeling

SnAgCu(SAC) vs. SnPb Test Data Correlation



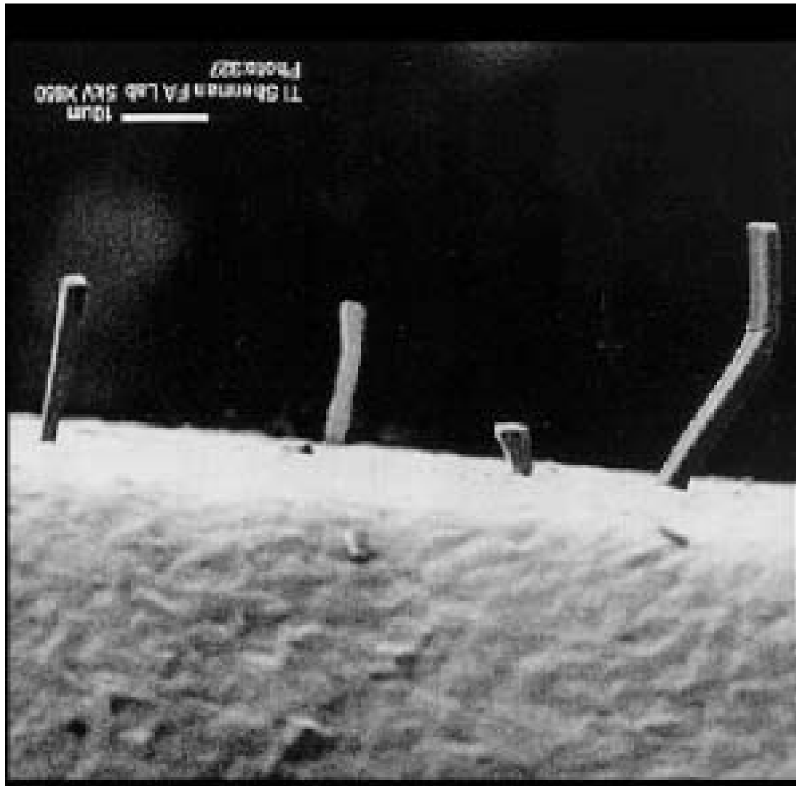
Difference in slopes suggests opposite reliability rank-ordering under low and high stress conditions

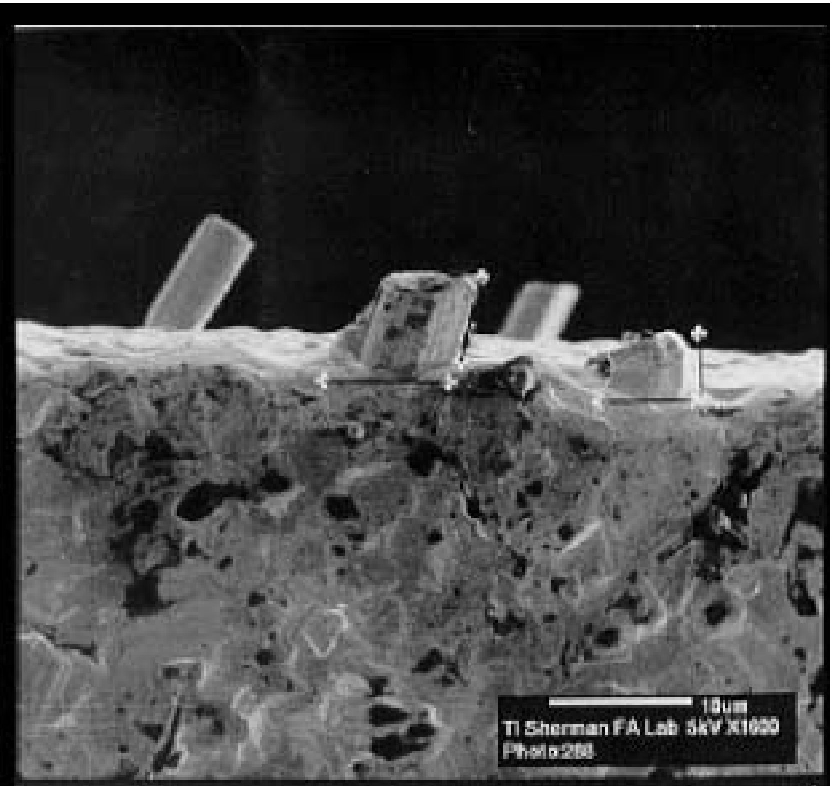
Slide Data Courtesy EPSI Inc.

Celestica

Tin Whisker Issue

- ***Examples of tin whisker growth***:





Example of tin whisker growth: Tin finished unit at 950X, 3624 hours exposure to precondition + 51C/85RH, unbiased. Length = 6.1 to 32 microns.

Example of tin whisker growth: Tin finished unit at 1600X, 3624 hours exposure to 51C/85RH, no precon, unbiased. Length = 6.1 to 32 microns.

Other Advanced Packaging Technology Options

Packaging Technology Convergence to SiP

Chip Pak

3-D Packaging
Test Yield and Complexity

Stacked-Die Module | Die+Package Module | Stacked-Package Module

100%
FinalTest Yield
Probed Good Die Yield
90%
Yield

Final Test Complexity

Flash+SRAM+PSRAM
RF MODULE
LFCSP Hybrid
DSP+Memory
DSP+Memory
RF/Analog/Digital
GPU+Memory(4)
GPU+Memory(8)
RF/Analog/Digital
ASIC+ASIC

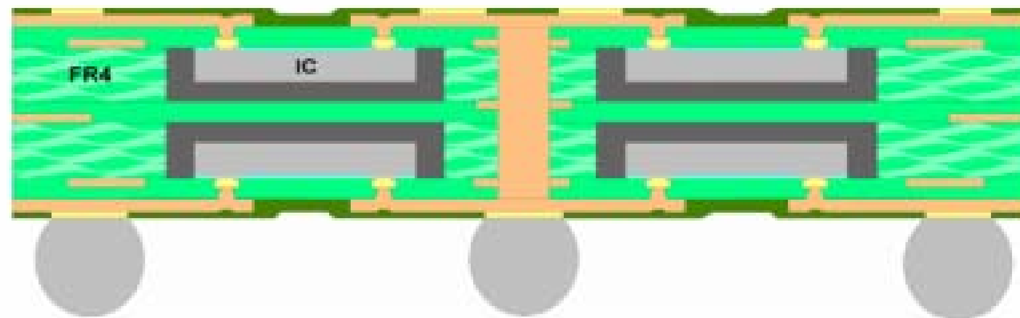
Die/Pkg Cost: Low → High
Pkg Cost: Low → High

Stacked-die for high yielding die
Stacked-package for low yielding high cost die

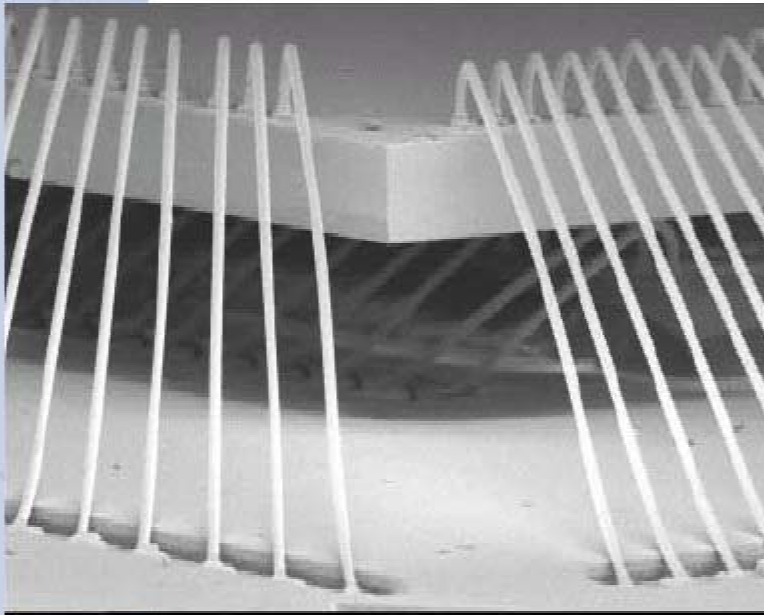
SHAPING SOLUTIONS™

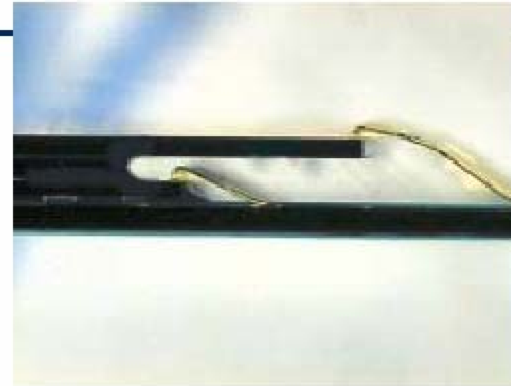
Chip Pak

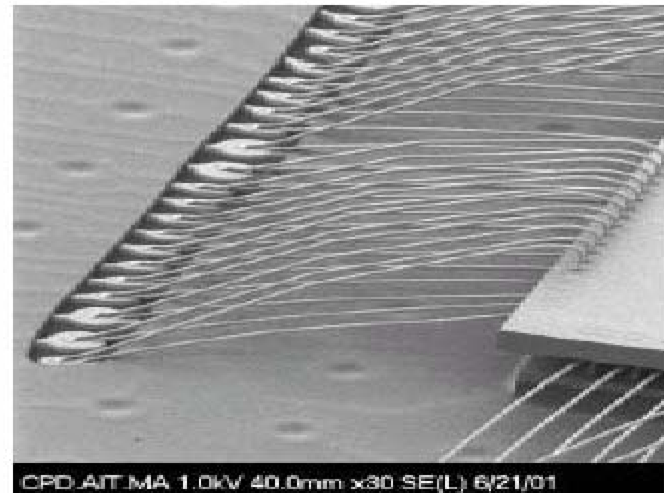
3D IMB Module



Infineon's SysBiz Enablers (5): SiP

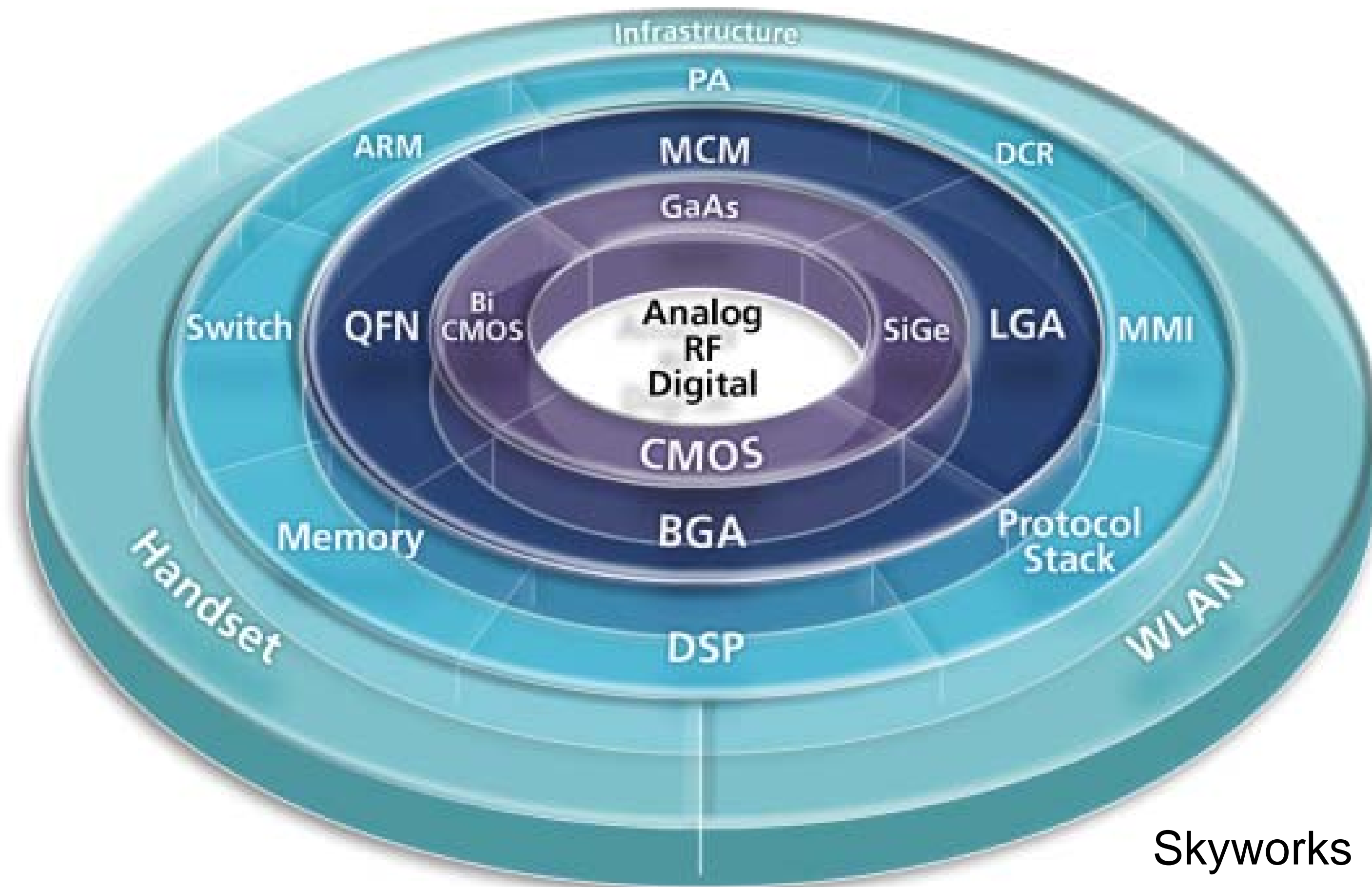






Collaboration

Systems-level Expertise



Skyworks

Addressing All Key Wireless Markets

Competitive Environment

RF- IC Vendors

Infineon, Philips, TI, Skyworks, SiLabs, RFMD, ST

- Customers and/or Competitors
- Joint Ventures and Partnerships
- Vertical Integration
- Go it alone (margin stacking)

What Business Model will win?

RF Module Suppliers

Switch Vendors

NEC, M/A-COM, Skyworks

PA Vendors

RFMD, Skyworks, Hitachi, Triquint

LTCC Vendors

Epcos, Murata, TDK, NTK, Kyocera

IPN Vendors
EMS
IDM's
ODM's

Skyworks

Filter Vendors

Epcos, Murata, Fujitsu, Triquint, Agilent

Subcontract Assembly Services Provider:
Amkor, ASE, IDM, etc
PLUS Internal IDM

Vertically Integrate for Competitive Differentiation…

…Partnerships and Alliances for Key Processes

Skyworks

It Takes Team Work!

Thank you for your time

Questions?

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