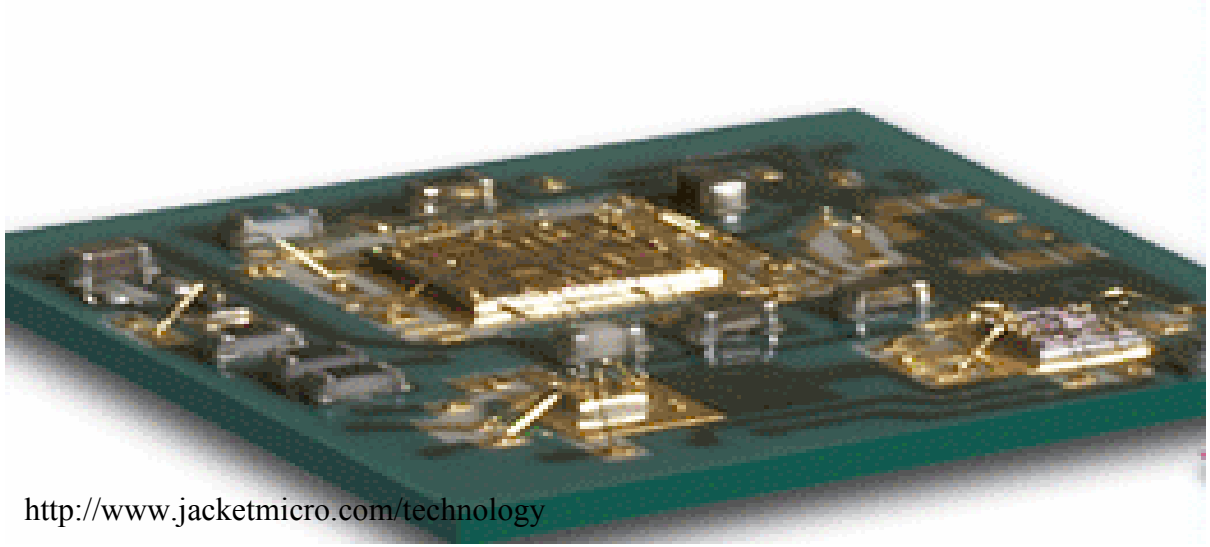
Multilayer Organics System-on-Package Technology for Wireless Applications

Ana Yepes
gth110a
ECE 3080



http://www.jacketmicro.com/technology

Outline

- Commercial RF applications
- Products
- Wireless industry needs
- Current technology
- The RF front end module
- System-on-Package (SOP)
- Multilayer Organics SOP
- Conclusions

Commercial RF Applications (0.1 GHz to 10 GHz)

- WLAN: IEEE 802.11 (a, b, g, n)
  - One of the fastest growing semiconductor markets
  - Chipset market sales: $910 million in 2005
    $2.3 billion in 2009
- WiMax: IEEE 802.16
- Bluetooth (BT)
- GSM
  - Most popular standard for mobile phones
- W-CDMA
- PCN and PCS
- Satellite communications

Products

- Cellular phones, PDAs
- Notebook computers
- Voice-over-WLAN devices
- Digital video broadcast-handheld (DVB_H) TVs
- Entertainment electronics
- DECT (Digital Enhanced Cordless Telecommunications)
- Global positioning systems (GPS)
- Battery power applications

Wireless Industry Needs

- Integration: 5 GHz and 2 GHz WLAN
- High functionality: more passives (L, C, R)
- Better performance: High Q, low signal loss
- Mobility: Small size, light weight
- Low cost: materials, fabrication
- High frequency operation
- Reduced # of components
- Low power Consumption
- Mass Production
- Temperature and reliability

Current Technology

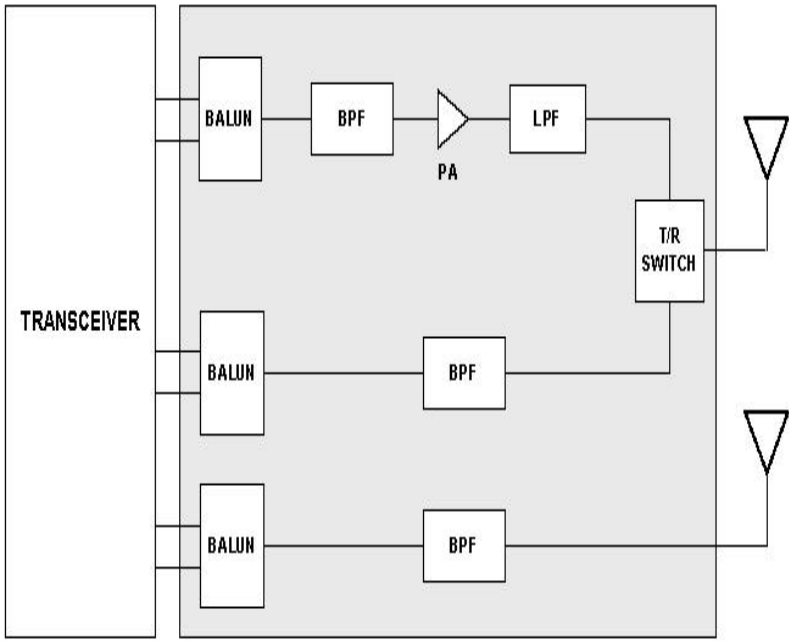
- Typical RF system requires many passives, for filtering, matching, biasing, etc.
- May be hundreds of passives
- Degree of integration of RF modules has mainly depended on dimensions of passives

DRAWBACKS

- Most passives are mounted on PCB or substrate, using surface mounted technology
  → large area of circuit board, high cost, heavy weight
- Large interconnection length
  → low electrical performance
- Solder joints
  → low reliability

The RF Front End Module

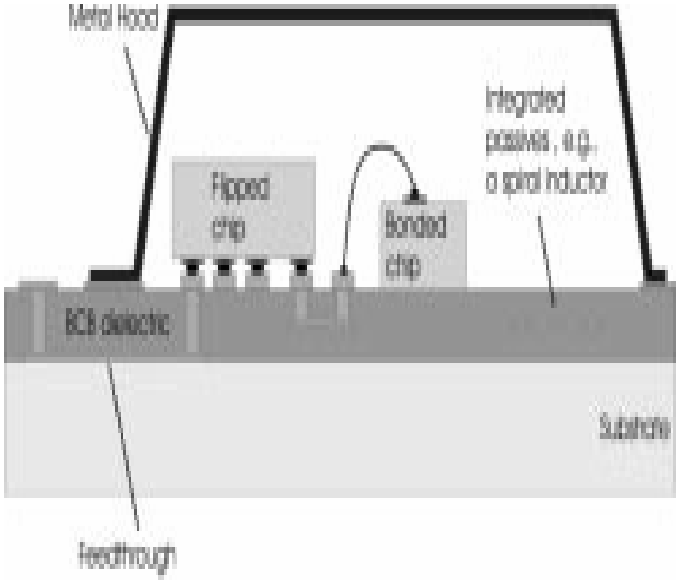
- Integral part of any wireless system
- Integrates all RF functions between transceiver and antenna



R. Wu, "High Performance and Compact Balanced-Filter Design for WiMax Front-End-Modules (FEM) Using LCP-Based Organic Substrates", *IEEE Microwave Symposium,* p.1619-1622, Jun. 2007.

System-on-Package (SOP)

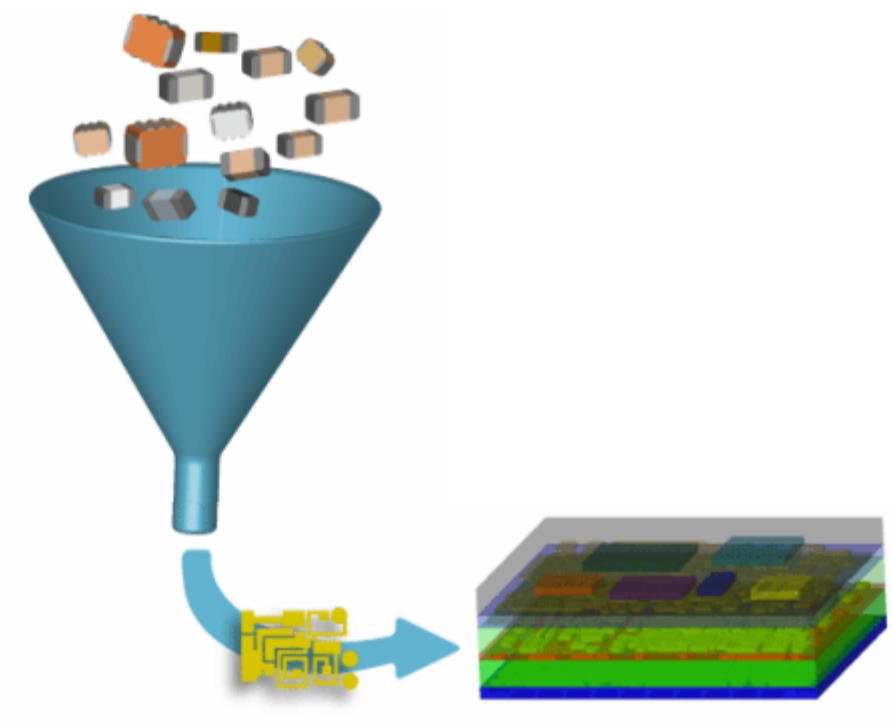
- Passives are as much as possible integrated in low cost substrate
- Metal box on top of circuit protects it from external environment and provides shielding
- Reduced assembly time and cost



G. Carchon, "Multilayer Thin-Film MCM-D for the Integration of High-Performance RF and Microwave Circuits", *IEEE Transactions on Components and Packaging Technologies,* Vol. 24, No. 3, Sep. 2001.

Multilayer Organics SOP

- Dielectric layers composed of advanced RF polymers:
  - Liquid Crystalline Polymer (LCP)
  - Polytetrafluoroethylene (PTFE)
- Low-loss embedded passives
- Components printed into copper layers using laser imaging
- Very thin line-width/line-spacing
- Low temperature process
  - < 2,500° C



http://www.jacketmicro.com/technology/

Dielectric Layers

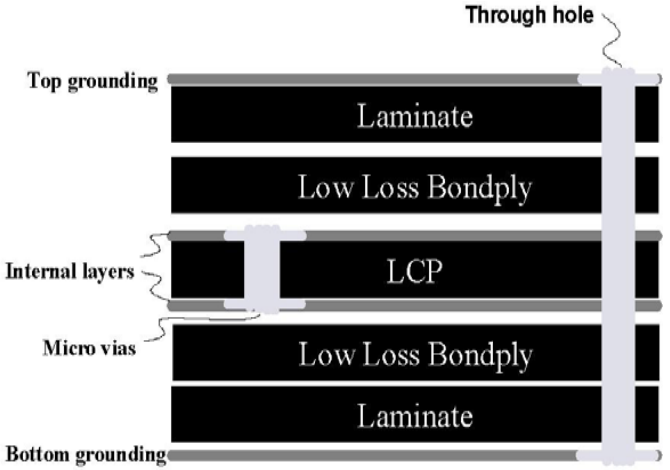
- Very low loss
- High CTEs insure highly reliable interconnects
- Can be produced in large, very thin sheets
  - 2,000 – 10,000 devices
- Compatible with PWB (printing wiring board)

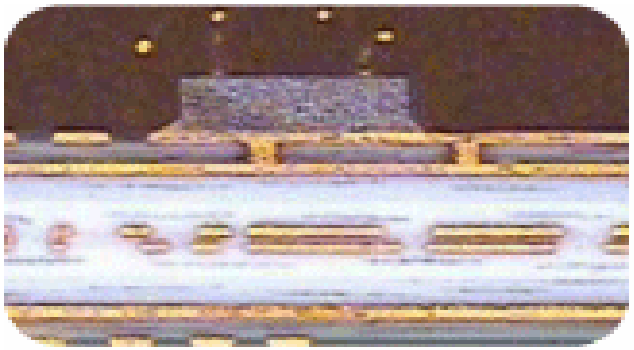
Property	LCP	PTFE	BT	Ceramic
ε_r	2.9	7.6	4	7.8
Tan ξ	0.0025	0.0025	0.035	0.006
Water Absorption	0.04%	<0.2%	<0.8%	<0.01%
Package CTE	14-15	14-15	13-14	5.8
Panel Size	16x20 in	16x20 in	16x20 in	8x8 in
Thickness	25 µm	25 µm	50 µm	50 µm
Conductors	Cu	Cu	Cu	Ag*

http://www.jacketmicro.com/technology/

Substrate Multilayer Stack-Up

- All baluns and filters designed used internal layers
- Top and bottom layers provide complete shielding to inner layers
- Minimal EMI and radiation
- Ability to have micro-vias increases component density

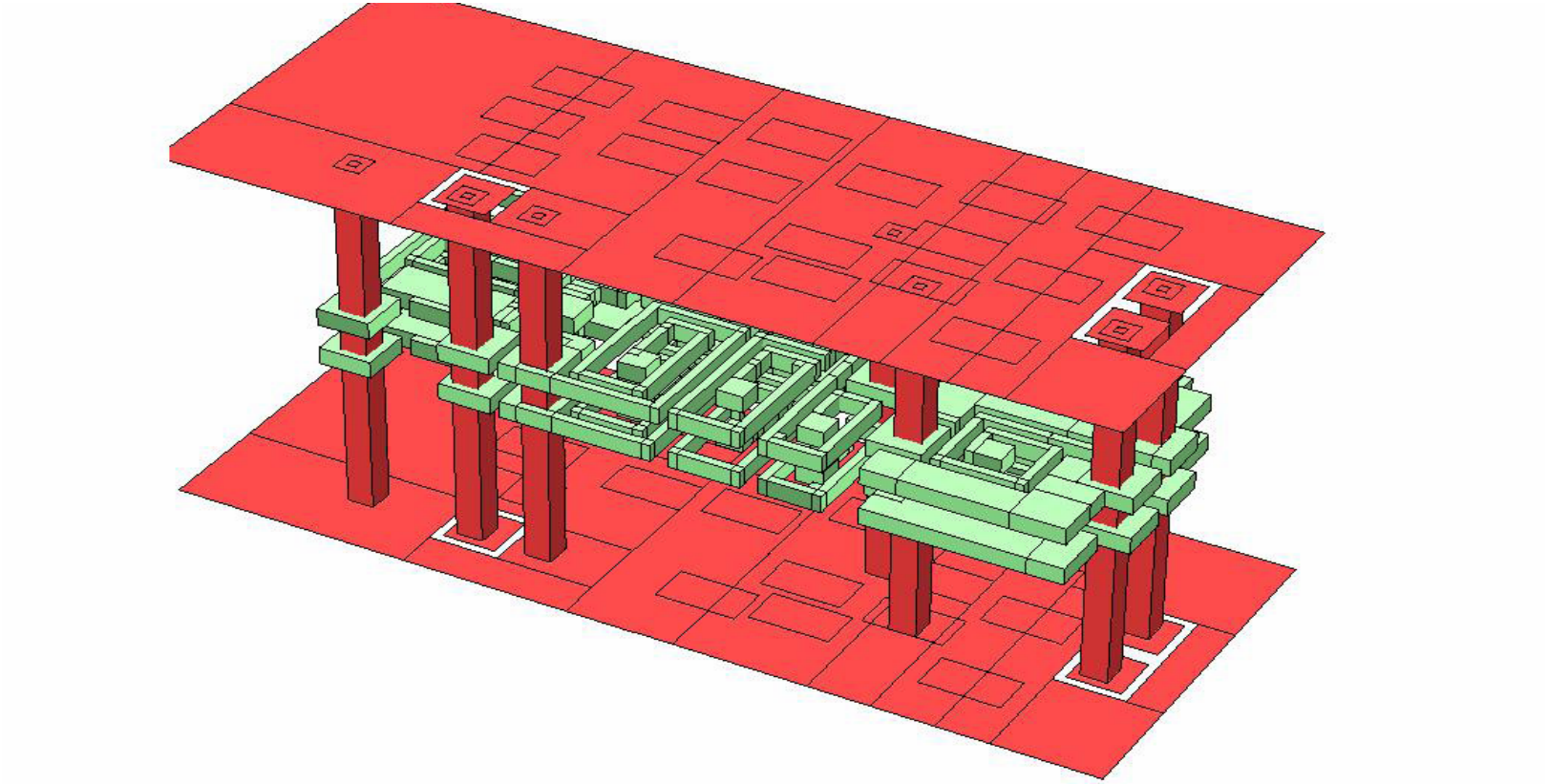




MLO Cross Section

R. Wu, "High Performance and Compact Balanced-Filter Design for WiMax Front-End-Modules (FEM) Using LCP-Based Organic Substrates", *IEEE Microwave Symposium,* p.1619-1622, Jun. 2007.

Embedded Filter Layout



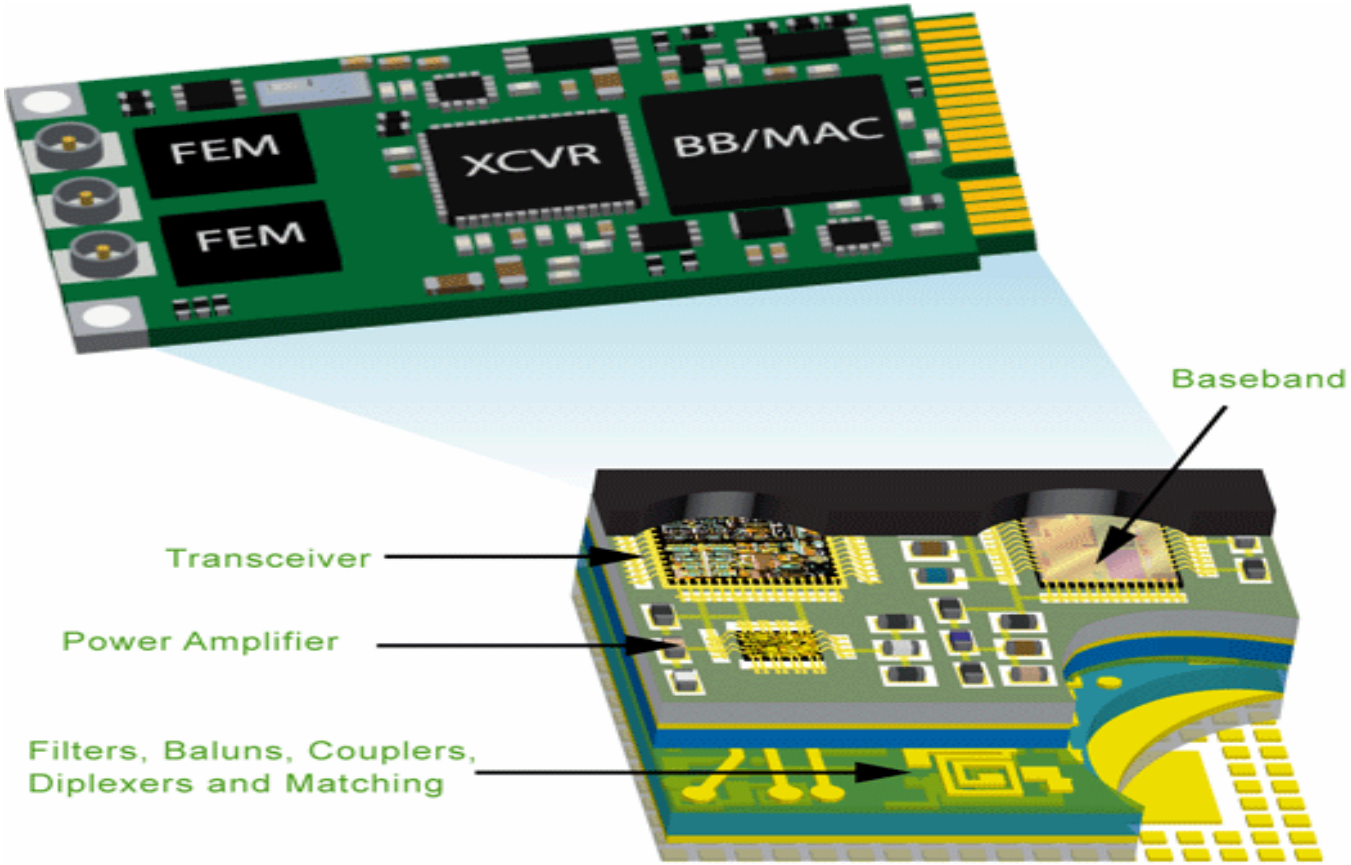
R. Wu, “High Performance and Compact Balanced-Filter Design for WiMax Front-End-Modules (FEM) Using LCP-Based Organic Substrates”, *IEEE Microwave Symposium,* p.1619-1622, Jun. 2007.

Fabrication

After fabrication of embedded passives:

- PSR (photo-imageable solder resist) coated and patterned
- GS or GSG test pads formed and via-interconnected with the I/O ports and ground
- Electroplating (or electro-less plating)
- Copper, nickel, and gold metals
- Active devices are flip-chipped or wire-bonded

Chipset Integration



Module size:

7x7x1.2 mm^3

http://www.jacketmicro.com/technology/

Advantages

- 1 embedded filter = 2 chips
- Organic substrates → low cost, high temperature tolerance
- Multilayer → small size, minimal undesired coupling, design flexibility, optimized integration
- Embedded passives → ease of fabrication, improved reliability
- Reliable assembly process
- Reduction in # and length of interconnections

  → minimal loss and parasitic effects
- Tight tolerances on line-width and line-spacing

  → high Q passives

Performance

COMPARISON OF QUALITY FACTORS OF CONVENTIONAL CHIP AND EMBEDDED CIRCULAR PLANAR INDUCTORS

	3nH			6nH			9nH		
	800MHz	1.8GHz	2.4GHz	800MHz	1.8GHz	2.4GHz	800MHz	1.8GHz	2.4GHz
Chip	28	39	43	26	36	39	26	35	38
Embedded	48.5	63	68	54.5	68	62.5	61	57	47

- Inductors on chip → more precise but more costly
- Inductors on organics → cheaper but have higher tolerances
- Filters using high Q MLO embedded passives:
  - Low insertion losses
  - Good out-of-band rejection characteristics, harmonic suppression
  - No increase on component size

S. Lee, "Fully Embedded High Q Passives and Band Pass Filters for Low Cost Organic RF SOP (System on Package) Applications", *IEEE Electronic Components and Technology Conference*, p.2024-2029, May-Jun. 2007.

MLO vs. LTCC

MLO

- New technology
- Tolerances: 5-10%
- Cost: low
- Process changes: 5-10 μm
- Mass production: yes, batch fabrication
- Frequency range: large, high Qs at high freqs (up to 20 GHz)

LTCC

- More mature technology
- Tolerances: 15-20%
- Cost: high
- Process changes: large
- Mass production: no, due to ceramic shrinkage
- Frequency range: only low RF frequencies

Conclusions

- Wireless products follow the trend of miniaturization with maximum functionality
- Future wireless communication market:

  better performance, better price, smaller devices
- Typical RF system requires many passives:

  surface mounted elements require large space
- MLO SOP technology provides integration of complete RF building blocks
- MLO SOP is a very promising technology that targets the needs of the wireless communication industry including size reduction, greater functionality, better performance and lower cost