TriQuint SEMICONDUCTOR

MPAR Symposium
Norman, OK

Gailon Brehm

11 October 2007

Component Technology: What the Future Holds in Cost and Performance

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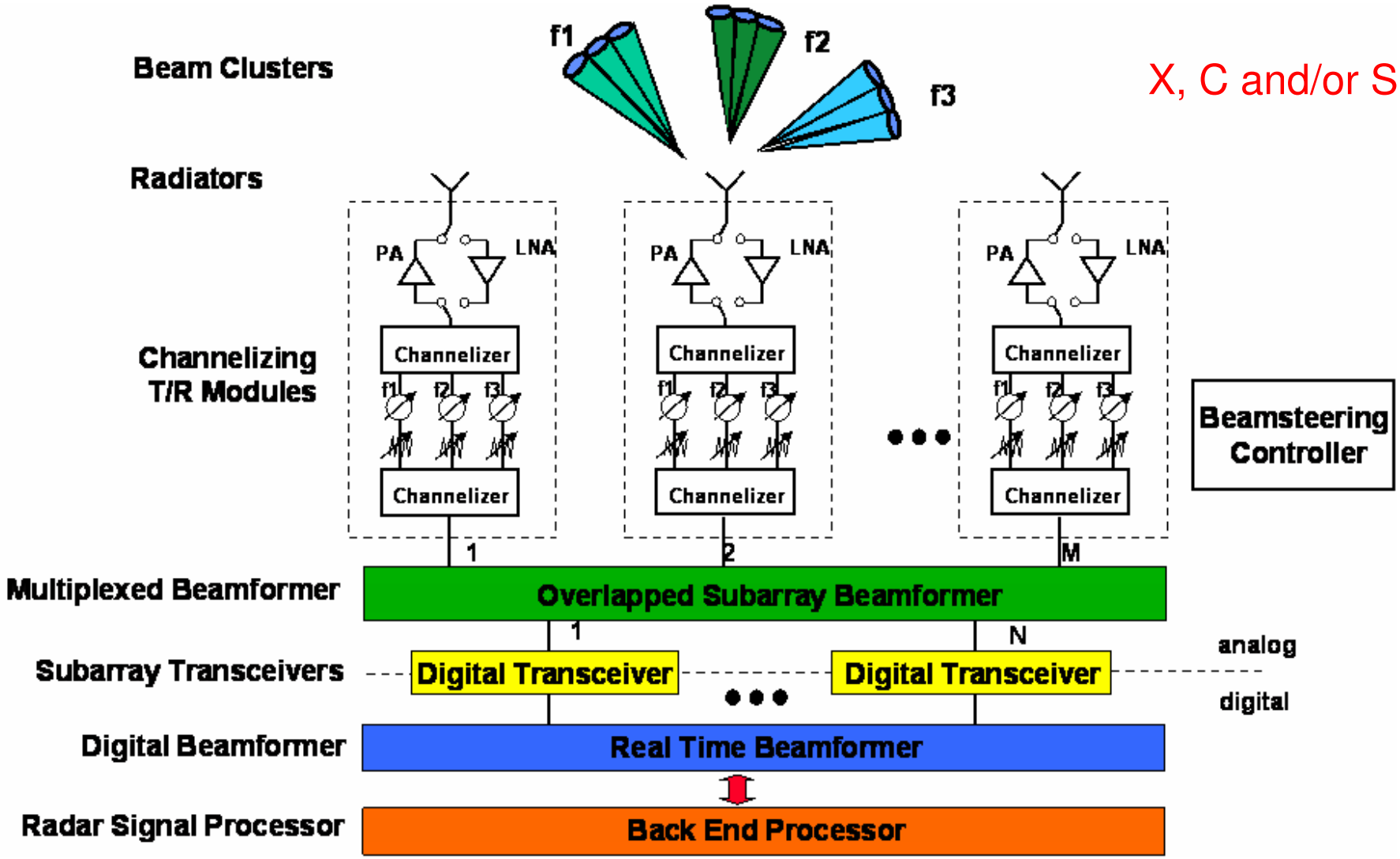
Multi-Function Phased Array Radar (MPAR)



*M. Weber, MIT, Lexington, MA: and J. Cho and J. Herd "Multifunction Phased Array Radar: Technical Synopsis, Cost Implications and Operational Capabilities", 23rd IIPS Conference., San Antonio, TX, January 2007

Multi-function phased array radar (MPAR) provides terminal-area and long-range aircraft surveillance and weather measurement

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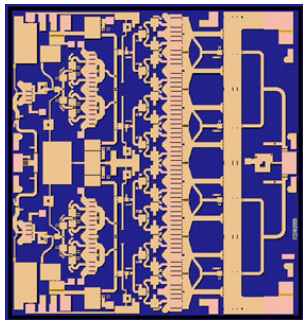
The MPAR Components Challenge

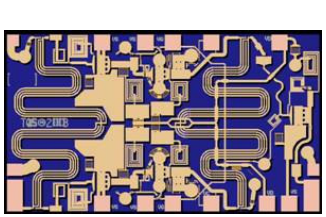
- MPAR requires large numbers of transmit and receive components at very low price per function
- Must minimize cost by designing for modest transmit power per element and a narrow frequency band to facilitate chip design, technology, and packaging
- Highly integrated chips/modules and reduced power consumption to simplify system boards
- Adopt technologies and approaches used for volume commercial applications at adjacent frequencies

TriQuint Phased-Array Background – chips and packages

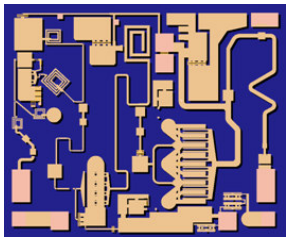
X-Band PAR Components



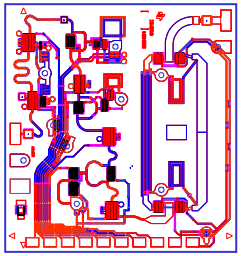
TGA2517 Power Amplifier



TGA2512 LNA



TGA2700 Driver

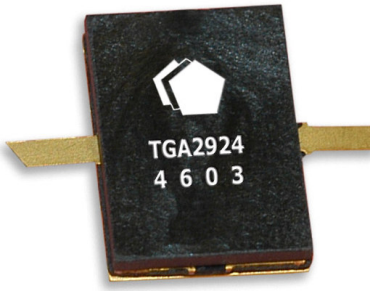


TGP2103 Phase Shifter

Commercial Components

TGA8652 Optical Driver MCM

TGA2703 3.5 GHz Gain Block



10-W Discrete PA

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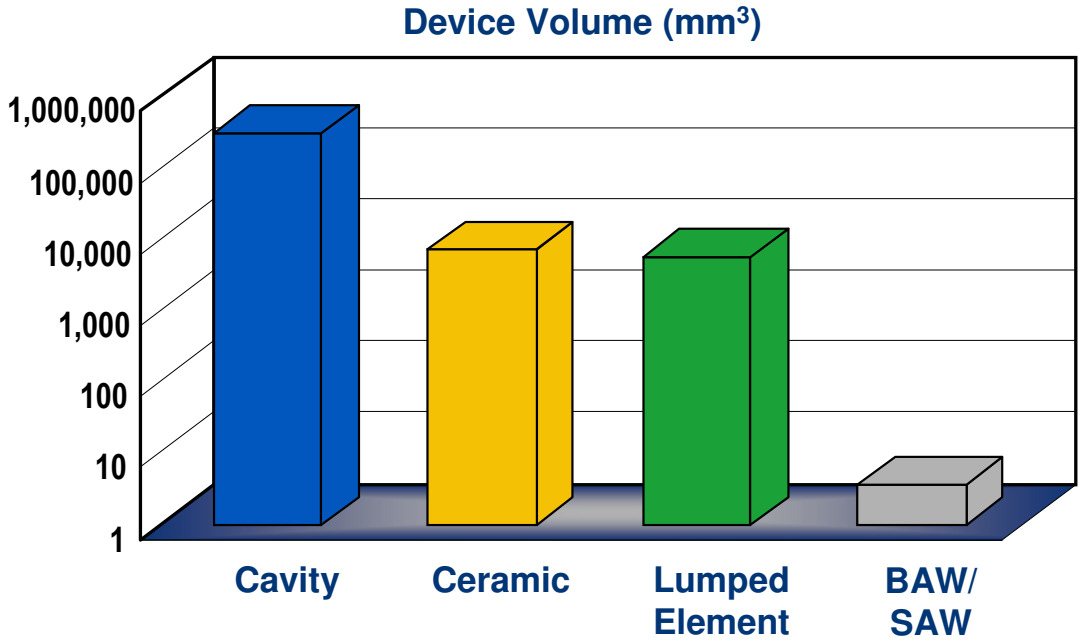
TriQuint Compact Filter Background

TriQuint SAW or BAW Filter

1.5mm × 0.75 mm × 0.5mm



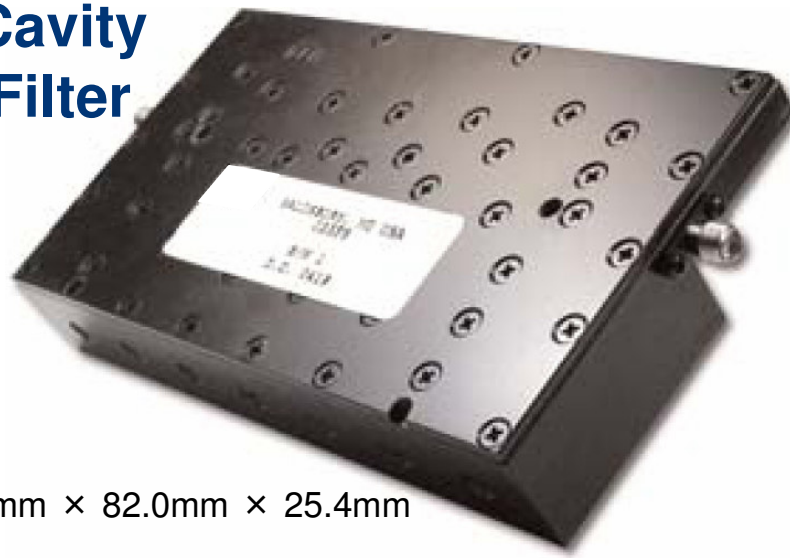
Ceramic Filter

33.02mm × 22.35mm × 10.16mm

Lumped Element Filter

44.45mm × 12.7mm × 10.16mm

Cavity Filter



148.6mm × 82.0mm × 25.4mm

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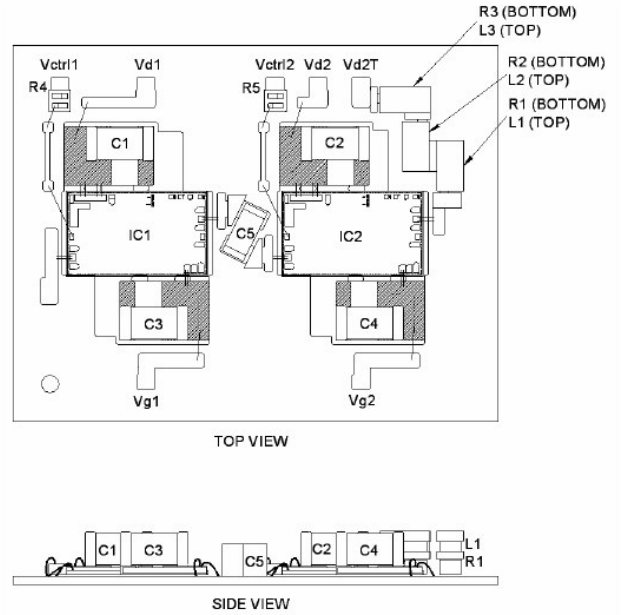
MCM Fiberoptic Driver in Laminate Package

- Air cavity module package for production optical driver products: TGA8652, TGA4918, TGA4953, TGA4954
- 3-layer sandwich: Rogers 4003 substrate, wall, and lid



Product	Description	Frequency Range, GHz	RF Pout, dBm	DC dissipation, W
TGA4954	OC192 Optical Modulator Driver	0.00001 - 12	25	0.9
TGA4819	OC192 Linear Modulator Driver	0.00003 - 8	25	2.5

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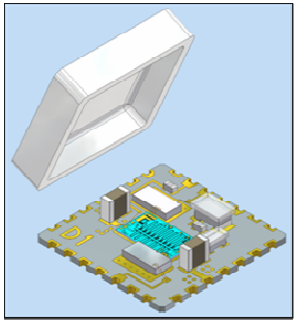
Packaged Power Amplifiers

- S-band power amplifiers for WiMAX
- Packaged HPAs with output power levels to 10W in plastic, laminate and ceramic packages
  - 2 to 30 GHz

Air-cavity LCP QFN
1.5-W Ka-band PA



Ceramic 8x8 QFN

Carrier Plate Rogers Laminate
4-W Ka-band PA

LCP package
10-W MMDS PA

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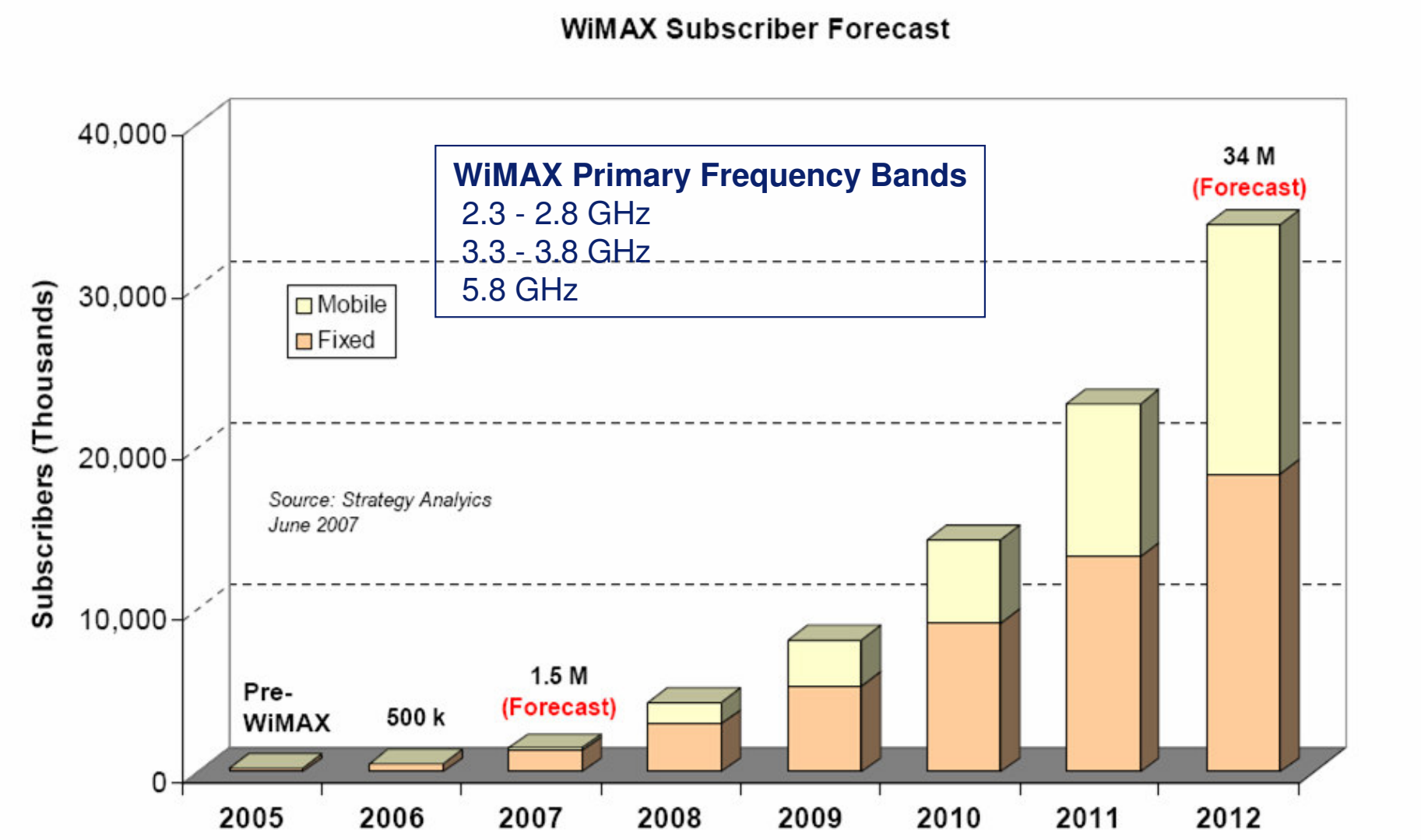
Broadband Wireless (WiMAX) Market Outlook

Mass market, based on planned deployments, realistic investments, build-out rates and consumer adoption scenarios, benefits MPAR



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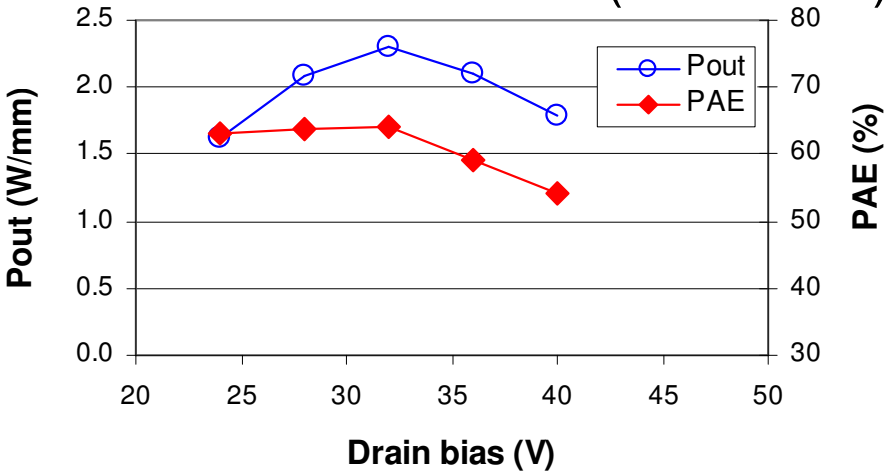
MPAR HPA Performance and Cost Reduction

- Critical factors affecting HPA performance and cost
  - **Transistor RF-power density (W/mm)** – chip size/cost
  - **Power-Added-Efficiency** – system power/cost (est. 10% increase in MMIC PAE gives 16.6% decrease in prime power).
    - Employ switch-mode circuits to maximize efficiency
  - **Integration** – maximum functionality on-chip or in the package
    - HPA drain switch and other control functions
- Emerging HV technologies to maximize chip power density while reducing voltage regulator loss
  - **HV PHEMT:** > 28V operation, 2 – 3 W/mm
  - **GaN:** > 40V operation, >5 W/mm; highest Ft facilitates switch-mode class of operation

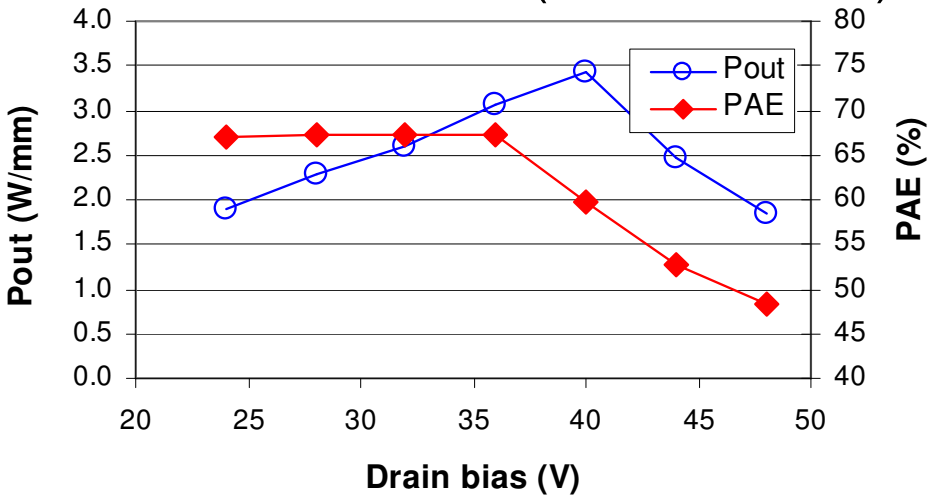
TriQuint HV PHEMT and GaN Processes

28V HV PHEMT (Released)



3.5 GHz load pull performance
2 W/mm and **65% PAE at 28 V**

40V HV PHEMT (Under Devel)



3.5 GHz load pull performance
3W/mm and **65% PAE at 40V**

40V GaN (Under Devel)

- **Pout > 5 W/mm; PAE ~ 65%; gain > 11 dB @ 10 GHz**
- **Fmin ~1 dB; Ga ~13 dB @ 10 GHz**
- ft = 49 GHz; fmax = 102 GHz based on 10V s-parameters

With harmonic tuning >80% has been demonstrated for each of these technologies, showing the potential for high-efficiency designs

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MPAR LNA Performance and Cost Reduction

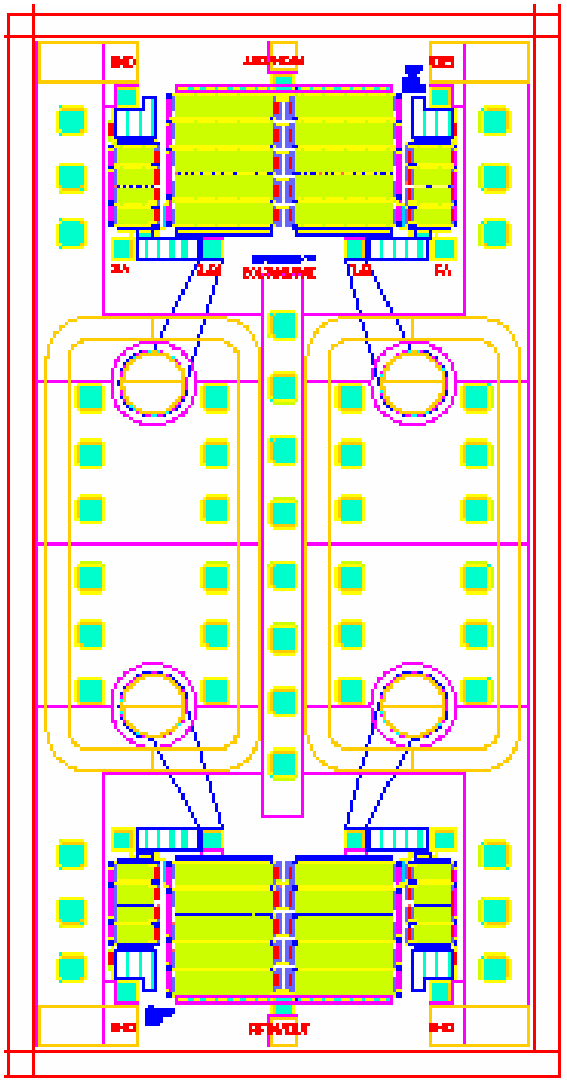
- Alternatives to integration LNA, PA, T/R switches, and phase shifter (if needed)
  - Single MMIC chip
  - Low-cost commercial multichip module
- GaN LNA eliminates the need for a limiter - decreasing overall system NF by 0.2 - 0.3 dB

MPAR – GaAs or GaN?

HV PHEMT	GaN
Lowest chip cost	Higher cost for several years
Integrated HPA/drain switch/RF switch/phase shifter	Integrated HPA/LNA/drain switch/RF switch/phase shifter
Separate LNA	Highest Ft

MPAR BAW Switched Filter Bank Approach

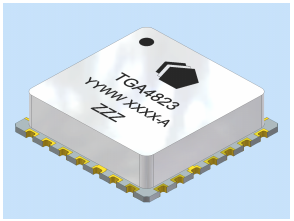
3.23 x 1.6 mm



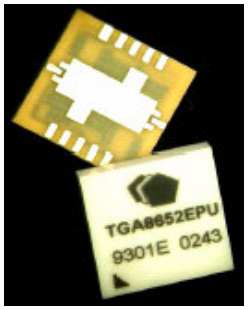
- Compact BAW filters coupled with GaAs switches provide low-cost multi-channel filters in surface-mount package

Low-Cost Packaging Options

- SMT Ceramic



- SMT Laminate



- Plastic QFN
  - Air cavity
  - Over-molded

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Die Cost Reduction Roadmap

- Migration to 150-mm wafers
  - GaAs factories continue to be driven by commercial applications
  - Volume commercial applications for GaN may take off in MPAR time frame
- WiMAX will be a production volume driver over the next four years
- TriQuint is developing 3.5-GHz WiMAX PAs on 6” E/D PHEMT

Packaging, Assembly and Test Cost Reduction

- Surface-mount package follows commercial approach and minimizes next-level interconnect cost
- Commercial volumes drive down package material and assembly costs
- Test cost for highly integrated modules will be initially challenging
  - Increased commercial and military market for packaged parts above 2 GHz should drive cost down

Conclusion

- GaAs or GaN MMIC Technology
  - High efficiency HPA with integrated drain switch
  - Integrated T/R functions
- Packaging and Interconnects
  - Commercial surface mount packages on low-cost boards
- Cost
  - Integration
  - Commercial packaging and test approaches
  - Commercial market drives volume