MTO Technology Programs Progress

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BAE SYSTEMS

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **06 MAR 2007**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **MTO Technology Programs Progress**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **BAE Systems**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
DARPA Microsystems Technology Symposium held in San Jose, California on March 5-7, 2007. Presentations, The original document contains color images.

14. ABSTRACT

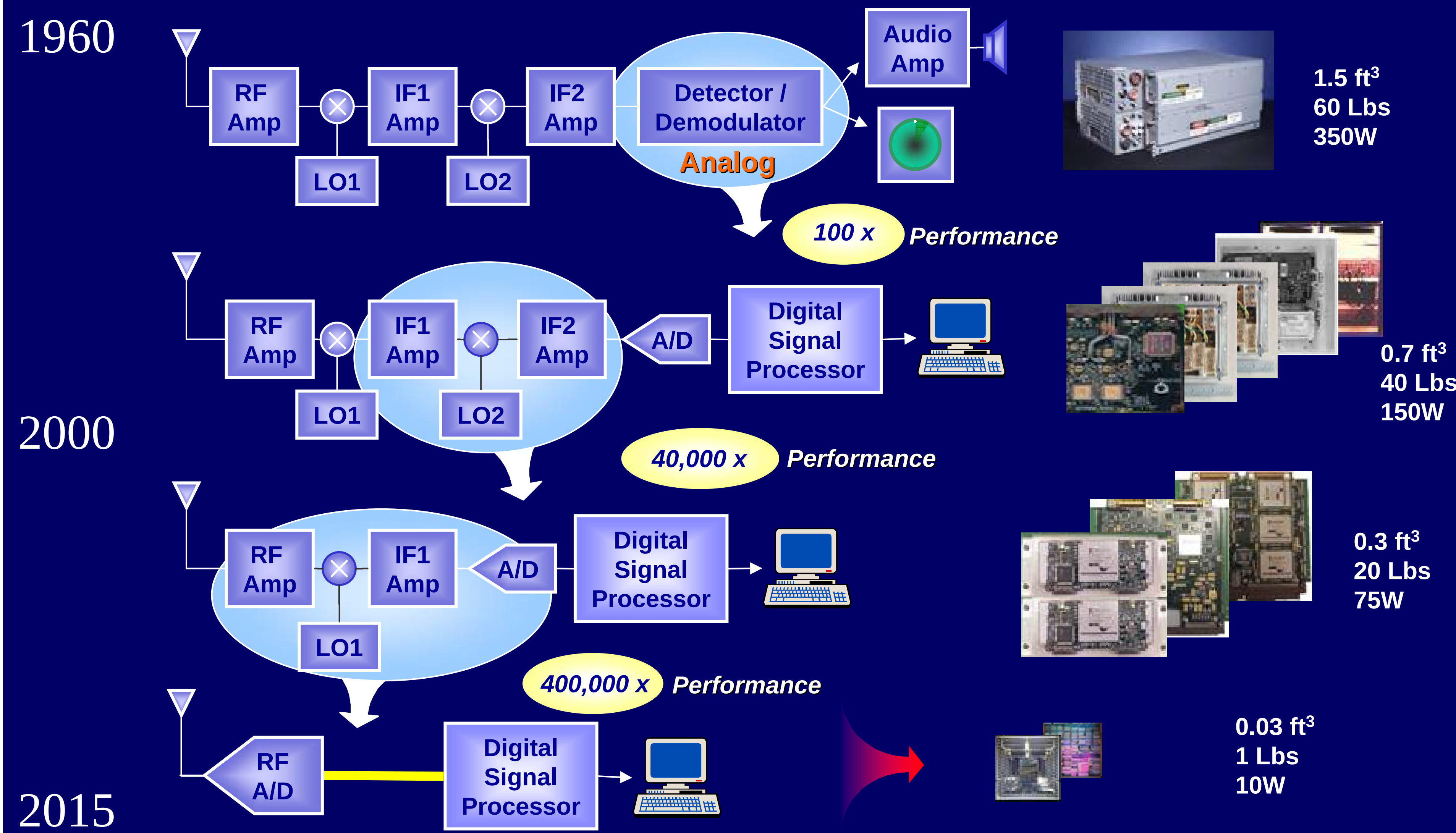
15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**13**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

BAE SYSTEMS

RF Systems Evolution

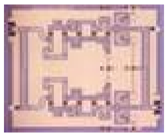


Key Technologies: RF ICs, Filters, A/D Converter, SoCs, DSP, Packaging

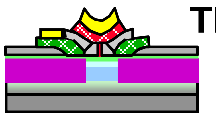
DARPA MTO Technology Impact

Devices

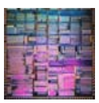
WBGS-RF



Circuits

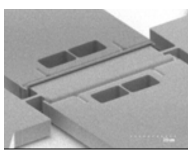


TFAST



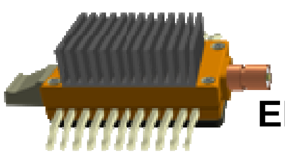
TEAM

μ-Systems

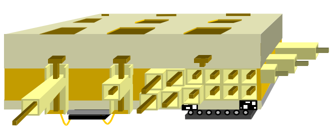


ASP

Packaging / Integration



EPIC



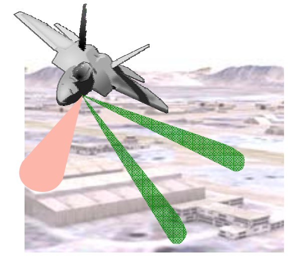
3DMRFS

- MTO Programs -
Revolutionary Technology

High Payoff Military Capabilities

Next Generation
RF Systems

Compact, Intelligent RF Microsystems enabling new architectures where mission flexibility and response time are critical



Digital Beamforming

Soldier Systems

Next Generation Multifunction Platforms

Low Cost Expendables

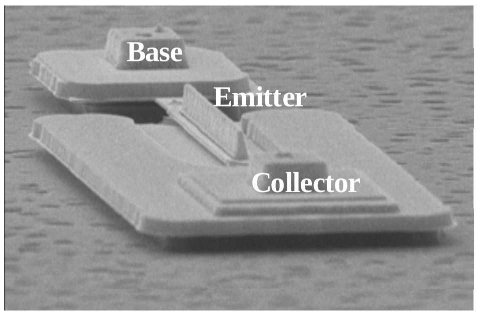
TFAST Accomplishments

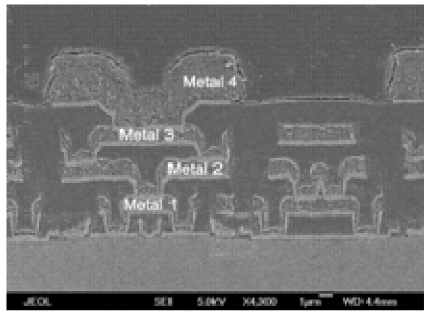
Phase 1

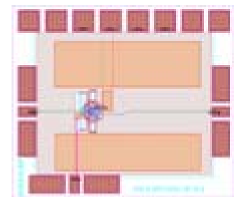
> 330GHz Ft → ***150GHz Digital Circuit Demonstrated***

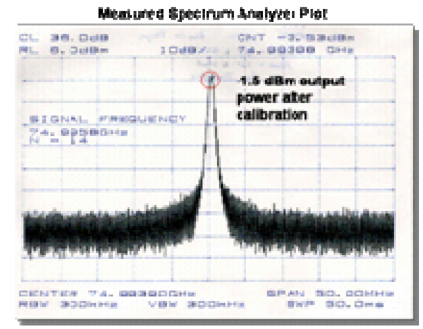
0.25μ InP HBT

4 levels of interconnect for high density



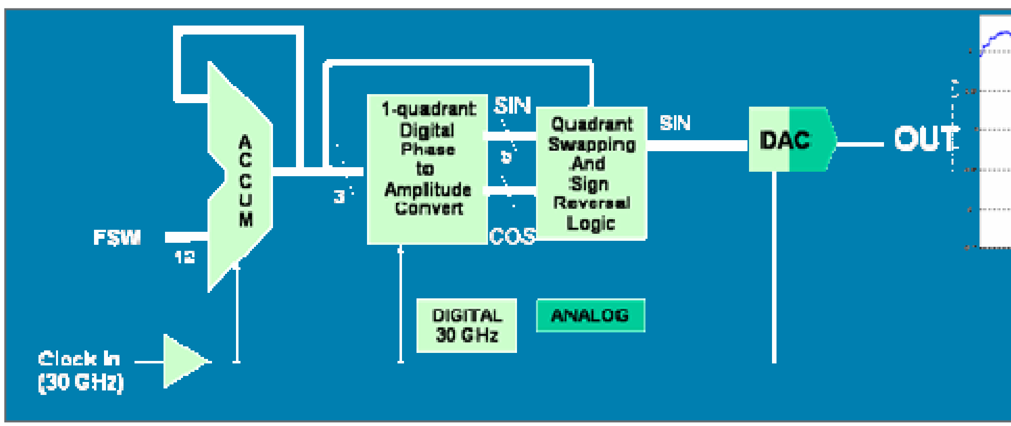


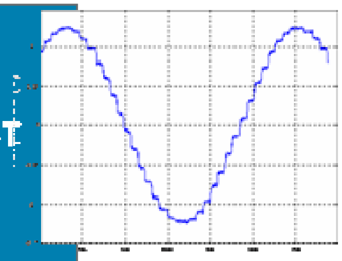


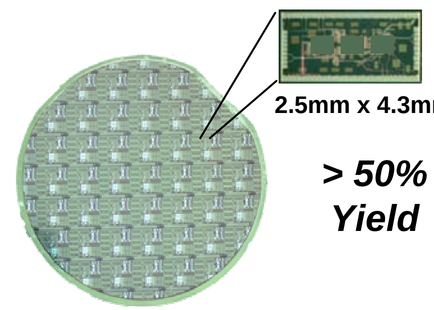


Phase 2

> 400GHz Ft → ***DDS Demonstrated - 30 GHz with 40dB SFDR***



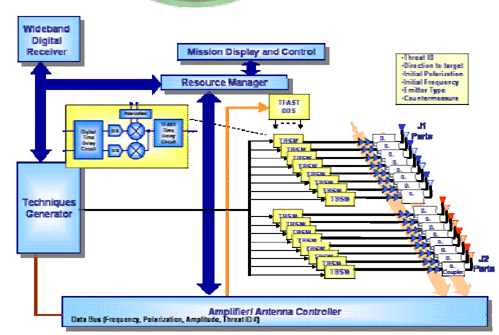




> 50% Yield

Phase 3

> 500GHz Ft → ***Transition Digital E/A***



BAE SYSTEMS

TEAM - SiGe Technology for DoD Systems

SiGe BiCMOS Provides the Optimal Mix of RF and Digital Technology

- **HBT devices** are optimal for circuits requiring precision threshold control, Wide Bandwidth, and high dynamic range (ie, ultra-wideband ADC& DAC)
- **CMOS devices** are best suited to high density digital processing (ie, Digital Control, DSP, memory)
- **High-Quality on-chip passives** for on-chip filters, oscillators, and other RF functions
- Advanced **Copper Interconnects** provide Low latency and High-Throughput
- Highly **manufacturable** process with **open access** to DoD customers via trusted foundry access

Challenges to Mature this Technology:

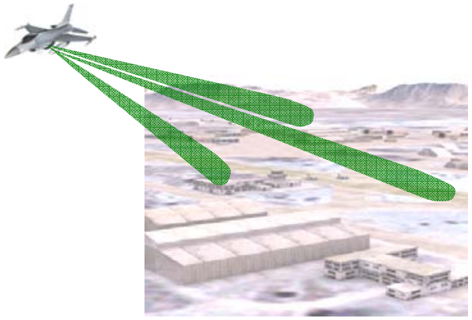
- **>80 dB of broadband isolation** between sensitive analog circuits and high speed digital switching
- Methodologies for design of ultra large-scale circuits operating at **mm-wave frequencies**
- Maintaining **linear performance** while using fast devices with **low breakdown voltages**
- New circuit structures that leverage **the level of analog and digital integration**

DoD System Impact Enabled By DARPA Development of SiGe SoC

System-on-a-Chip (SoC) implementation permits installation of Digital EW receivers at the Antenna

- **Dramatic reductions in size, weight & recurring cost**
- **Improved Performance**

SiGe SoC is a critical enabler for Multi-Beam, Multi-Function Element-level Digital Beamformer Arrays



Maximum Flexibility for Multifunction Operation

SiGe SoCs enable Intelligent, High-Performance RF Low Cost Sensors

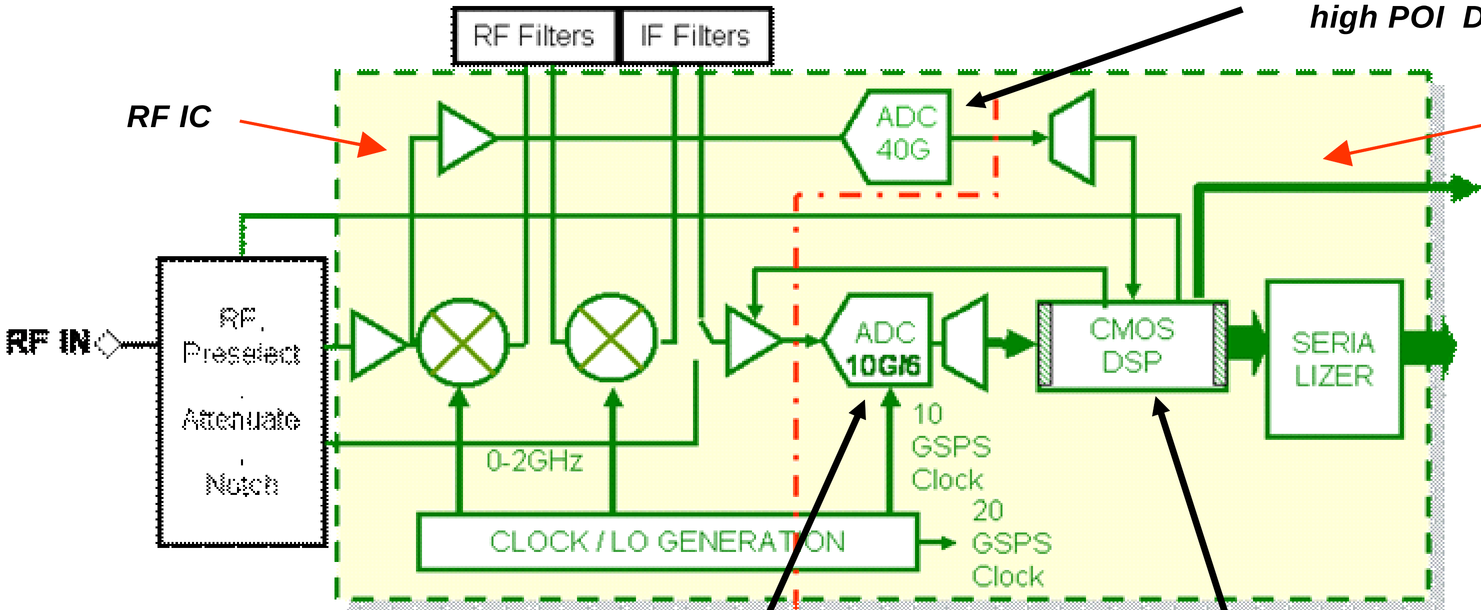
Small, Affordable Sensors including: Situational Awareness, Comms Relay & Electronic Attack

TEAM Receiver-on-a-Chip Architecture

IFM Monitors full spectrum for high POI Detection

RF IC

ADC IC

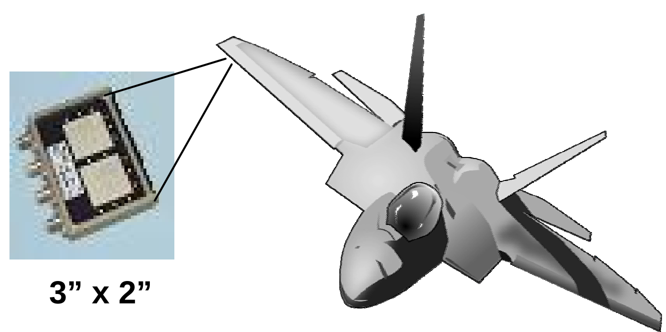


Dual Interface formats provide remote or local receiver processing

- *A/D provides 5GHz bandwidth*
- *On-chip dither improves SFDR*

- *Custom CMOS DSP for Receiver Applications*
- *Migrate to on-chip FPGA core*

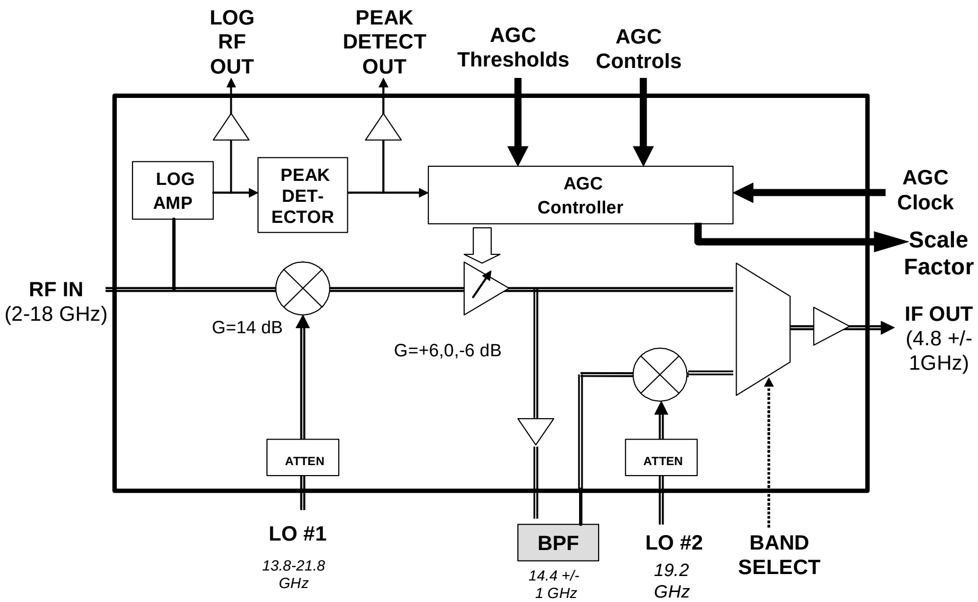
Architecture Features
- **On Chip Clock Generation**
- **Automatic on chip AGC control extends A/D dynamic range by 18dB**
- **Serial I/F for remote sensing**

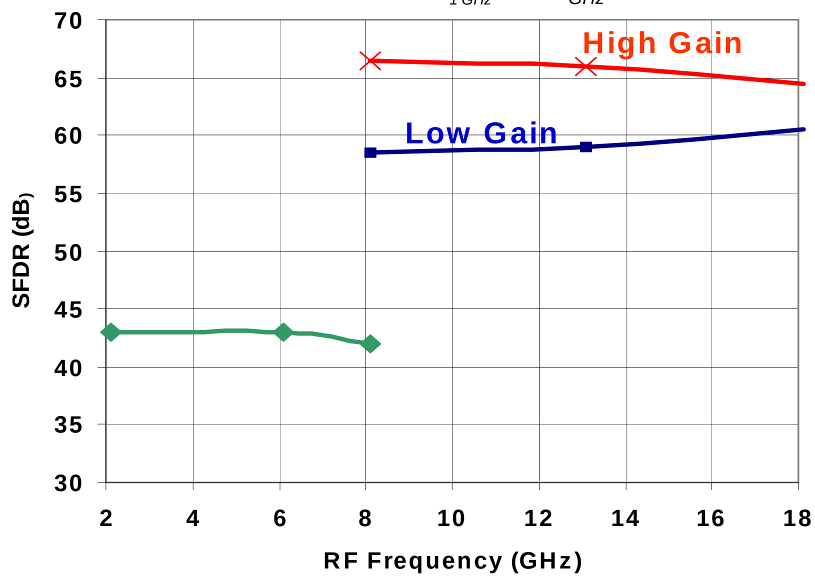


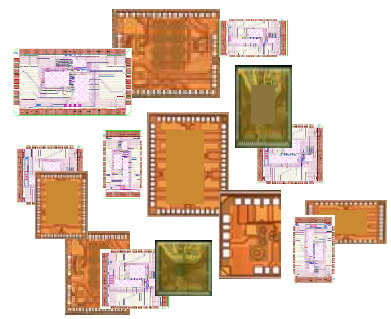
3” x 2”

Enables new “Receiver at the Antenna” Architecture

TEAM SiGe RF IC



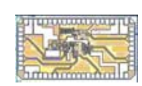




15 Discrete COTS Components

Power: 6 W

TEAM



One Component

Chip Size = 3.1 mm X 1.6mm

IBM SiGe 8HP

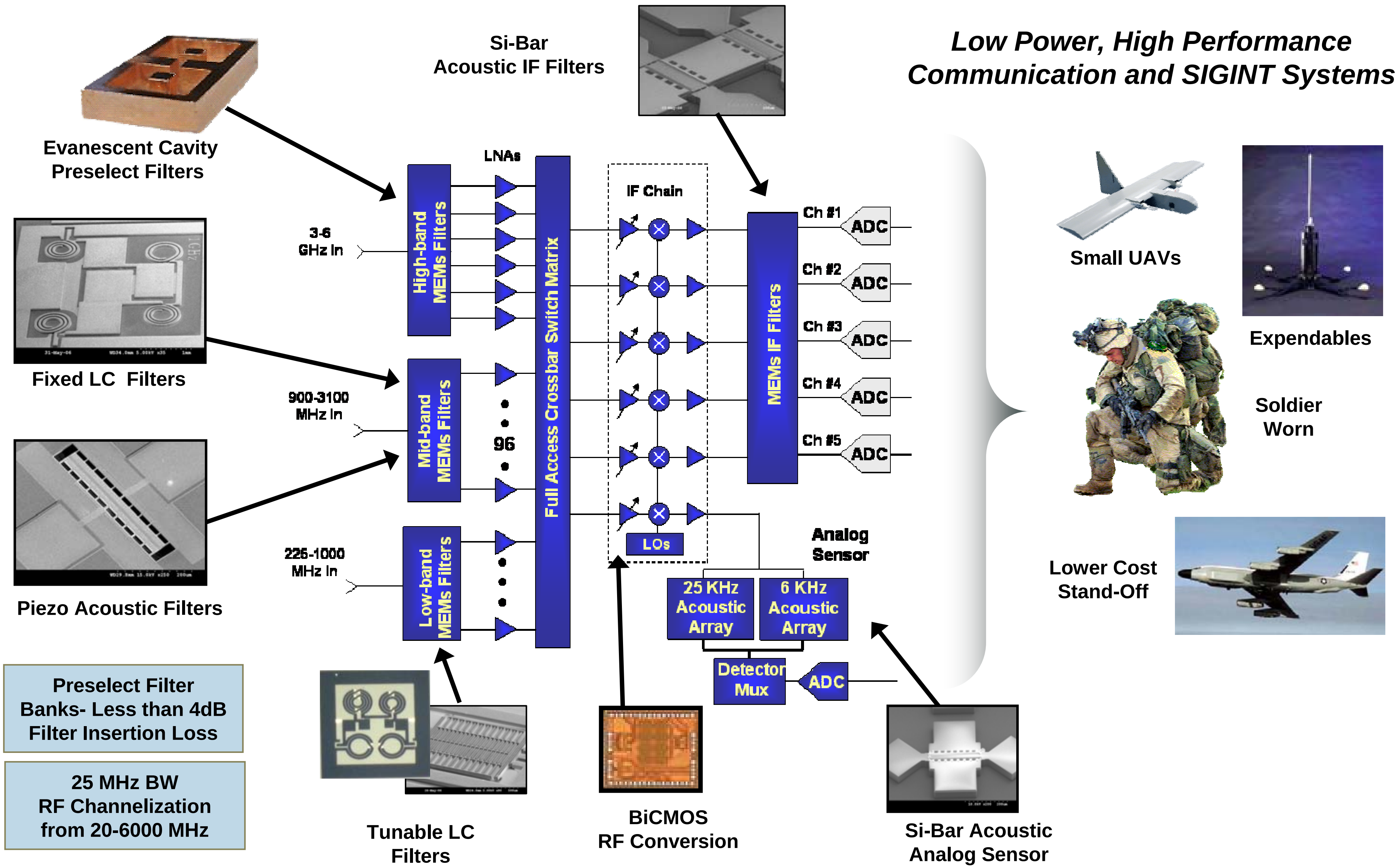
Transistor Count: 313 npn, 162 cmos

Power: 2.5 W

BAE SYSTEMS

Analog Spectral Processor
MEMS Based RF Filters

Dr. John Evans, DARPA MTO



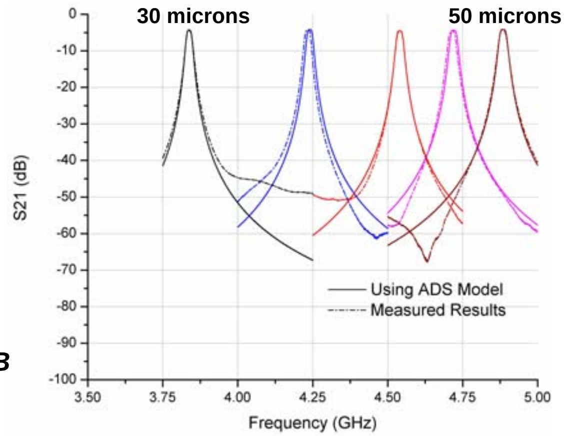
BAE SYSTEMS

MTO DARPA Microsystems Technology Office

ASP Progress
First Iteration Results (12/06)

DARPA

Evanescent Cavity Filters

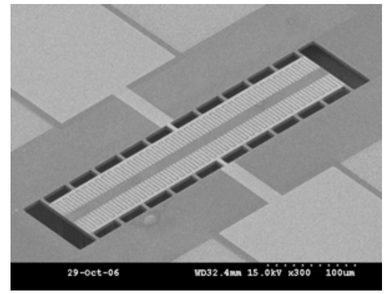


- **3.75 to 5 GHz**
- **BW = 21MHz to 27MHz**
- **Insertion loss *4.2 to 3.7 dB***

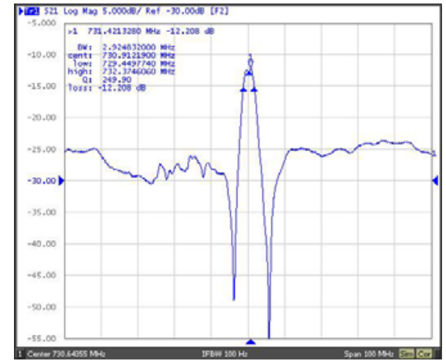
PURDUE UNIVERSITY

Simulated Vs. Measured Results

Piezo Acoustic Filters



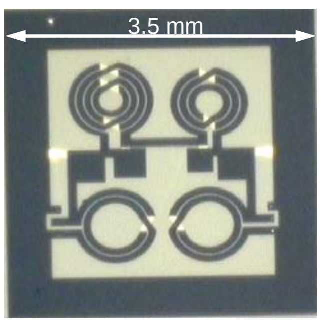
(405µmx70µm)

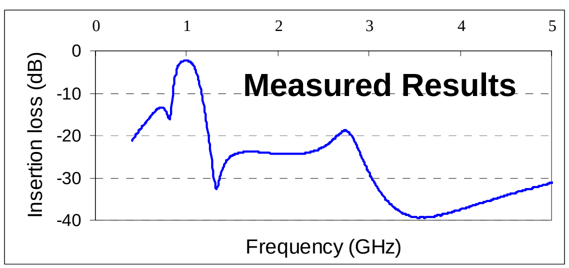


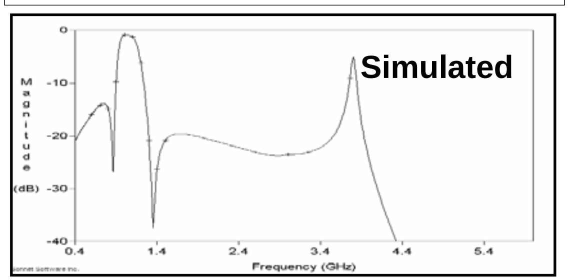
- **BW = 2.9 MHz at 730 MHz**
- **Insertion loss *12 dB***

Georgia Tech

Fixed LC Filter





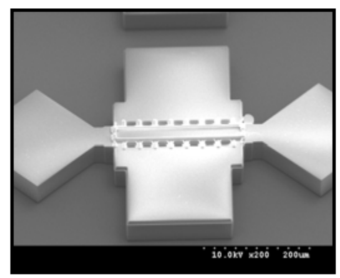


- **BW = 300 MHz at 1.05 GHz**
- **Insertion loss *2 dB***

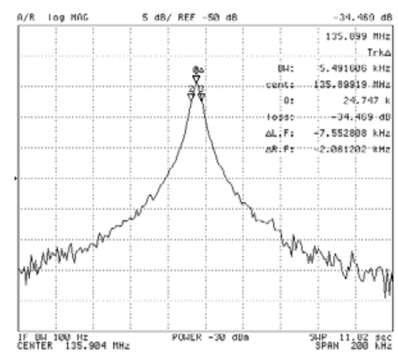
Georgia Tech

BAE SYSTEMS

Si-BAR IF Filters



(120µmx30µm)



135MHz SiBAR resonator

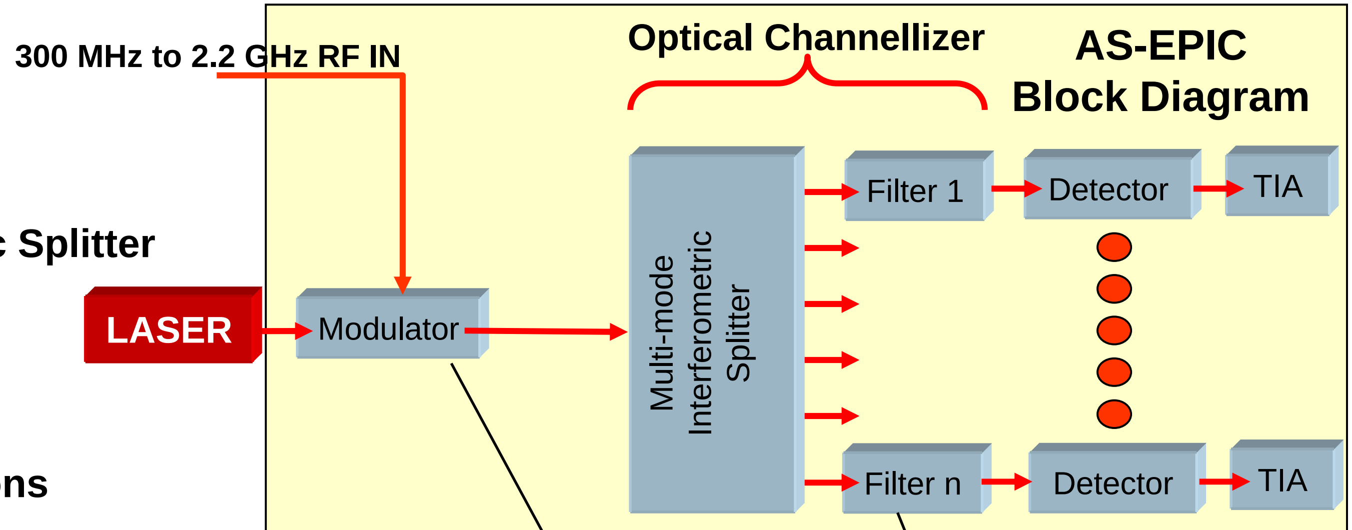
- **Measured Q= 24700**
- **Insertion loss 34.5dB**

Georgia Tech

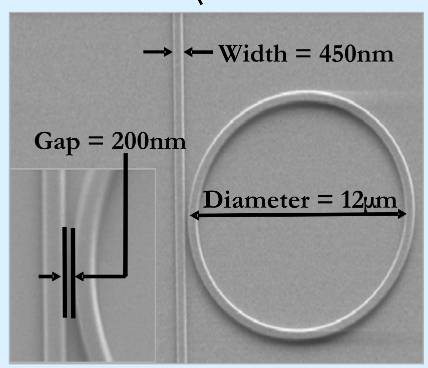
EPIC – RF Photonics on CMOS

Dr. Jagdeep Shah

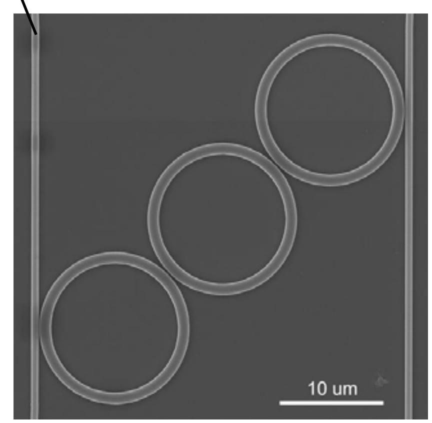
- 20 X 20 mm Chip
- 100 Photonic Devices
- 1000 Electrical Devices
- Modulator
- Multimode Interferometric Splitter
- Filter Bank
- Detector
- TIA
- Optical Filter Elements
- Optical Bends & Transitions



- Lowest power consumption reported to date.
  - Less than 0.3V and μA current needed for complete modulation in DC.
  - In AC, 3.3Vpp and 1mA current were used.
- Expected theoretical bandwidth limit >10Gb/s



Optical Modulator

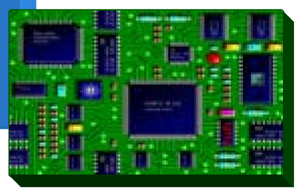


Optical Filter

Dr. John Evans, DARPA MTO

3D MERFS

Notion of a Printed Circuit Board



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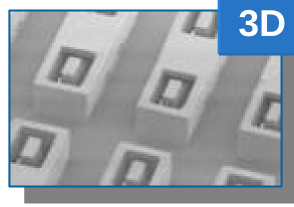
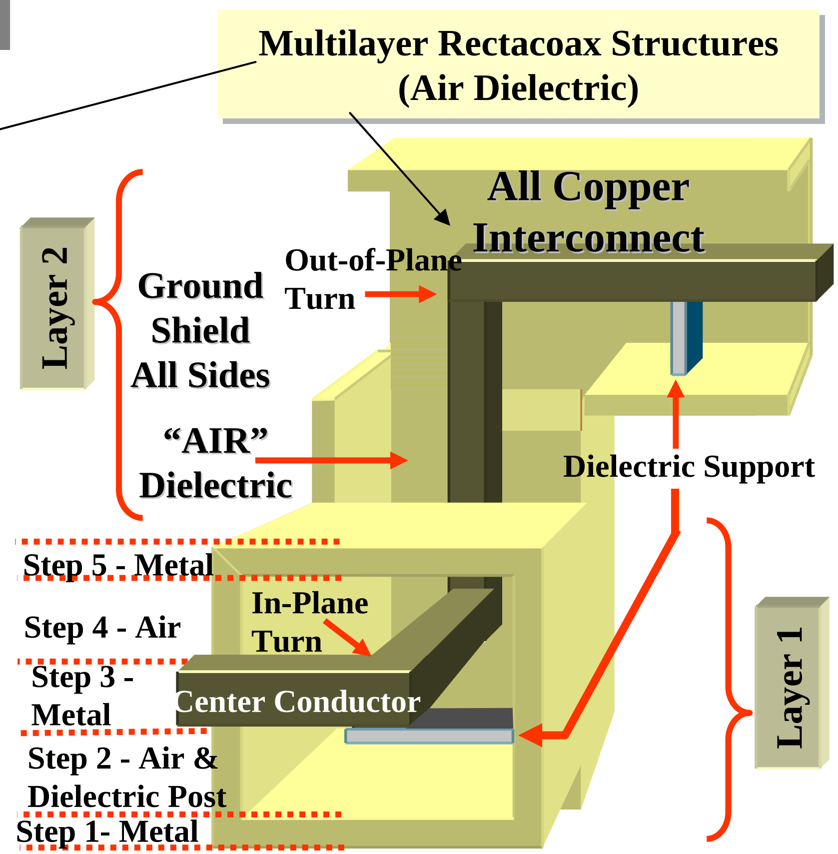


3D MicroFab Processing

=

3-D MERFS



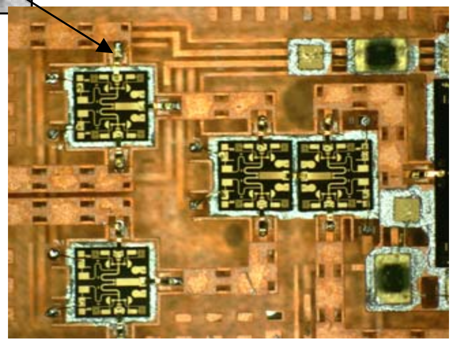
- 3D Substrate Architecture
- PWB Like Sequential Build
- Photolithography based batch process
- Monolithic Integration of passive RF components

3D MERFS Implementation

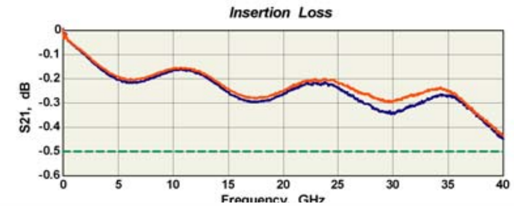
Close-up of 3D MERFS to RF Switch Interface

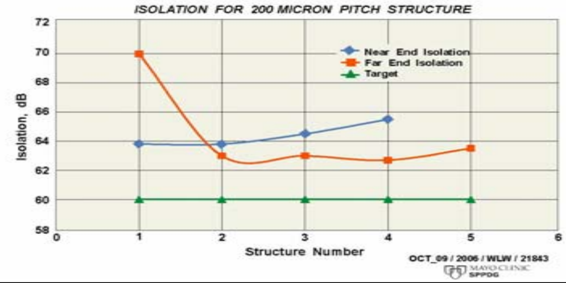
Eleven strata geometry provides full functionality for GNG & Subsystem Demos.

Embedded RF Devices in MERFS 3D Interconnect Substrate



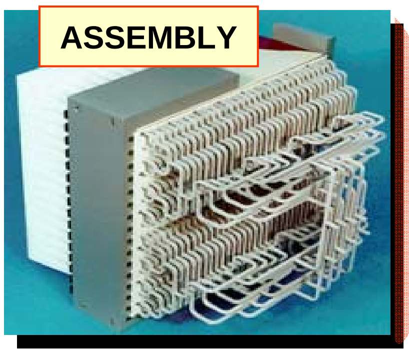
MERFS PHASE 2 BUILD 2 TRANSMISSION LINE INSERTION LOSS (S21) AND RETURN LOSS (S11) MEASURED RESULTS THAT MEET PHASE 2 PERFORMANCE TARGET OF 0.5 dB/cm
(Wafer B2-6, 200 Micron Pitch, 1 cm Length Structures)





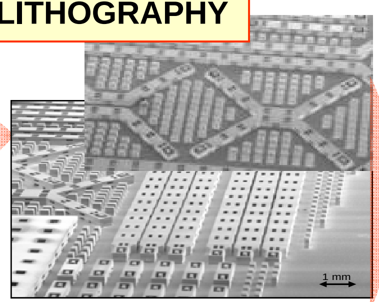
PWB like fabrication processing allows for the integration of RF distribution networks, waveguide manifold and embedded T/R circuits in a single monolithically integrated subsystem.

ASSEMBLY



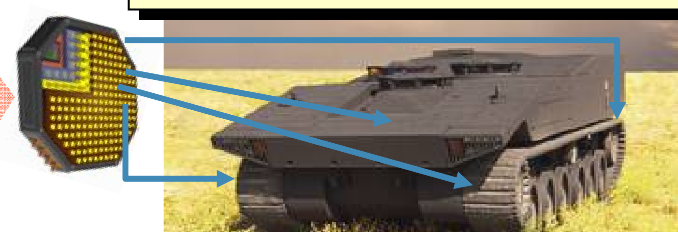
2.5 λ spacing
λ/2 NOT DOABLE

LITHOGRAPHY



Low loss , high isolation transmission lines, couplers and resonators have been fabricated using 3D MERFS Technology.

3D-MERFS Suitable For High Volume “PCB-Type” Manufacturing > 10K Qtys.



Proliferation of systems - low cost, high volume manufacturing

BAE SYSTEMS

Future Directions and Challenges

- DARPA investments are successfully developing technologies which can enable new wideband military system capabilities.
  - Electronic Support/Attack Systems migrating from large platforms to small UAVs, vehicles and soldiers
  - Improved “Kill Chain” response time due to higher persistence and high POI
  - Improved self protection with increased sensitivity
  - Concurrent Multi-functionality

….but the picture is getting more and more complex. Threats are getting smarter and the spectrum more cluttered

- What’s needed is higher dynamic range mixed signal electronics *without sacrificing speed or circuit density*
  - Can dramatically reduce the amount of hardware and number of platforms needed to achieve full spectrum dominance
  - Can revolutionize handhelds by enabling low cost, assured communications in high interference environments (e.g. Communicating while IED jamming)
  - Can enable ultra high capacity SATCOM