MTO Technology Programs Progress

Frank Stroili
Technical Director, RF/Mixed signal
603-885-7487
frank.stroili@baesystems.com

BAE SYSTEMS

Report Documentation Page

Form Approved
OMB No. 0704-0188

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

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
MTO Technology Programs Progress	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

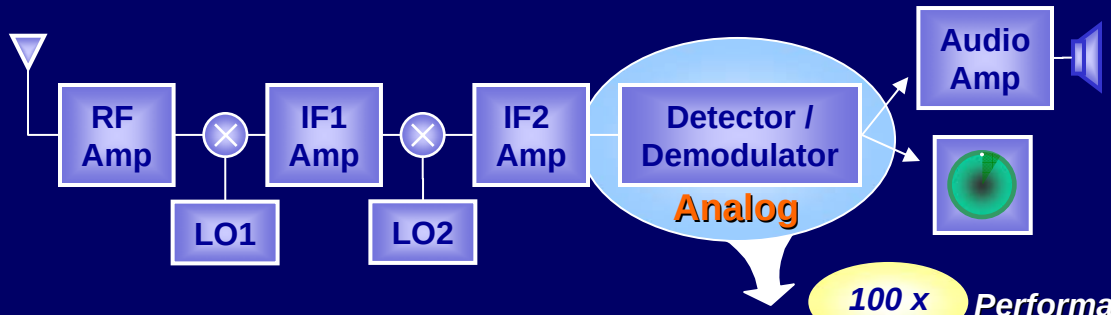
15. SUBJECT TERMS

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**	

RF Systems Evolution

BAE SYSTEMS

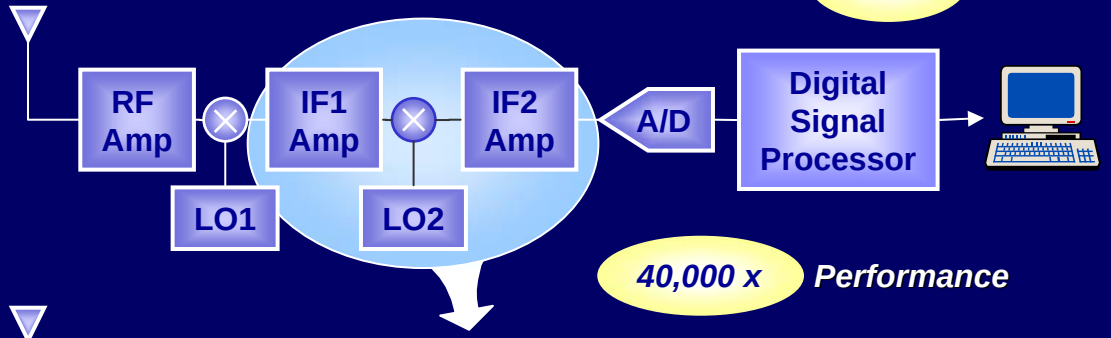
1960

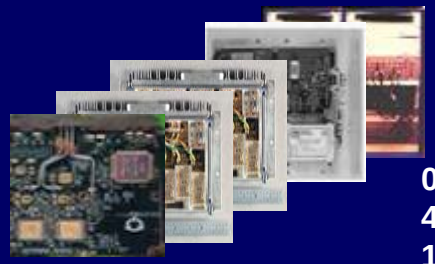


1.5 ft³
60 Lbs
350W

100 x Performance

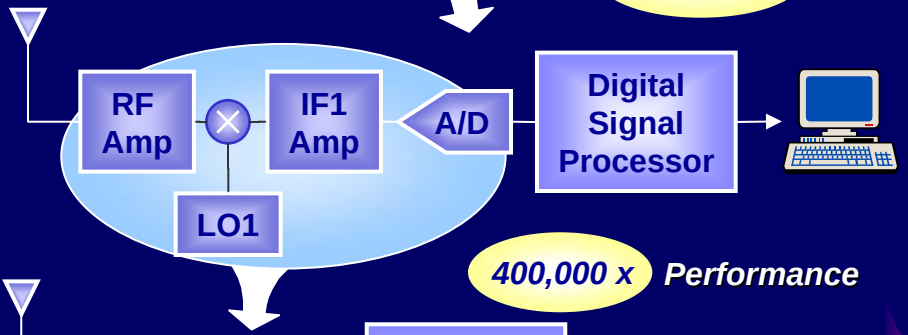
2000





0.7 ft³
40 Lbs
150W

40,000 x Performance



0.3 ft³
20 Lbs
75W

400,000 x Performance

2015

0.03 ft³
1 Lbs
10W

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

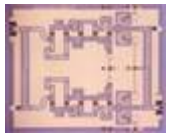
DARPA MTO Technology Impact

- MTO Programs -
Revolutionary Technology

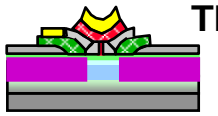
High Payoff Military Capabilities

Devices
Circuits
μ-Systems
Packaging / Integration

WBGS-RF

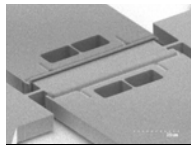


TFAST

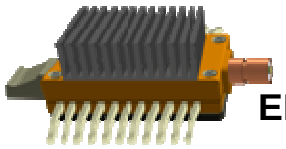


TEAM

ASP

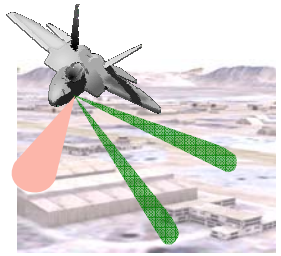


EPIC



3DMRFS

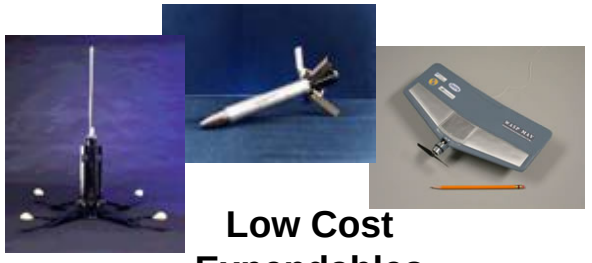
Next Generation
RF Systems



Digital Beamforming

Soldier Systems

Next Generation
Multifunction Platforms



Low Cost
Expendables

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

BAE SYSTEMS

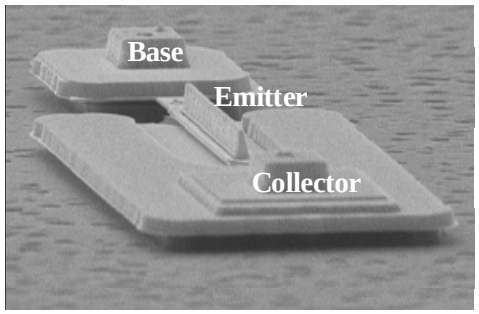
TFAST Accomplishments

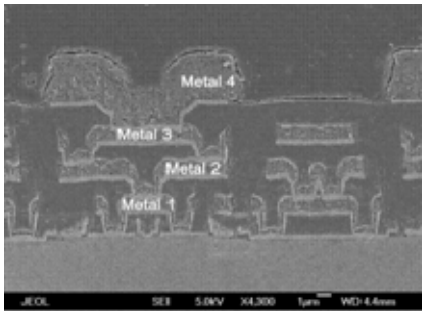
Dr. Steve Pappert, DARPA MTO

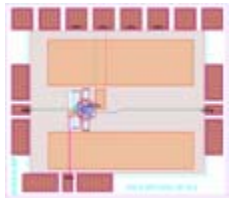
Phase 1 *> 330GHz Ft* → *150GHz Digital Circuit Demonstrated*

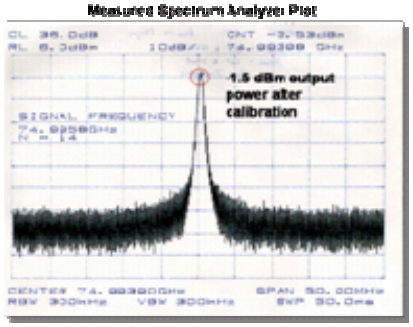
0.25μ InP HBT

4 levels of interconnect for high density

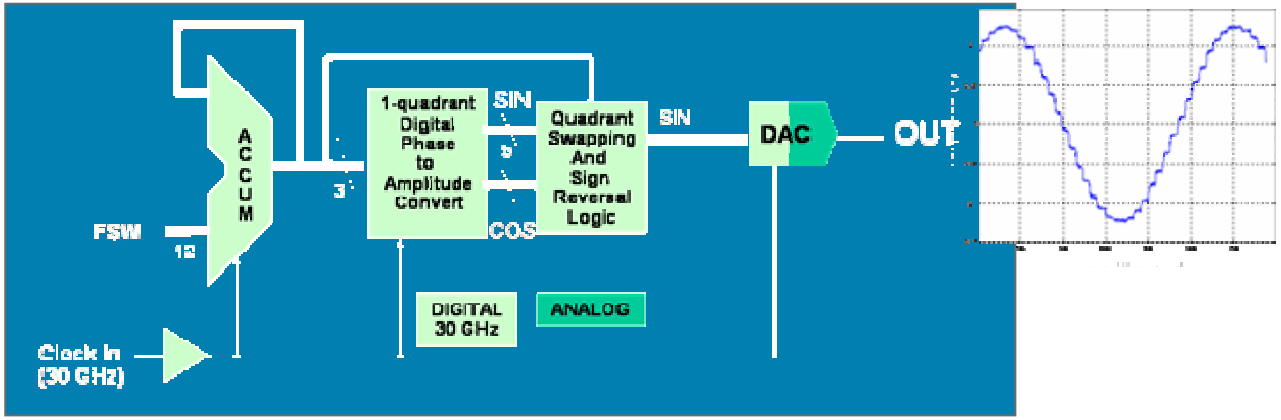


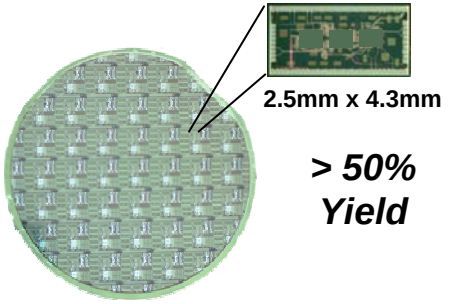






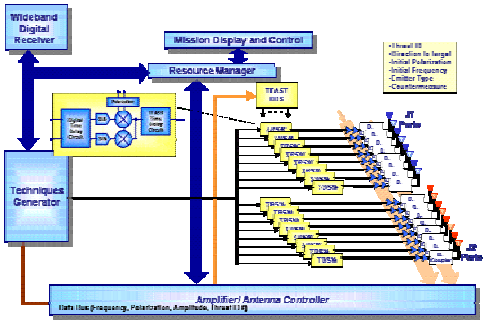
Phase 2 *> 400GHz Ft* → *DDS Demonstrated - 30 GHz with 40dB SFDR*





> 50% Yield

Phase 3 *> 500GHz Ft* → *Transition Digital E/A*



BAE SYSTEMS

TEAM - SiGe Technology for DoD Systems

Dr. Michael Fritze, DARPA MTO

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:

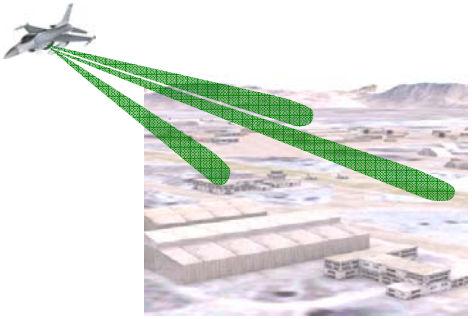
- **>80 dB of broadband isolation** between sensitive analog circuits and high speed digital switching
- Methodologies for design of ultra large-scale circuits operating at **mm-wave frequencies**
- Maintaining **linear performance** while using fast devices with **low breakdown voltages**
- New circuit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



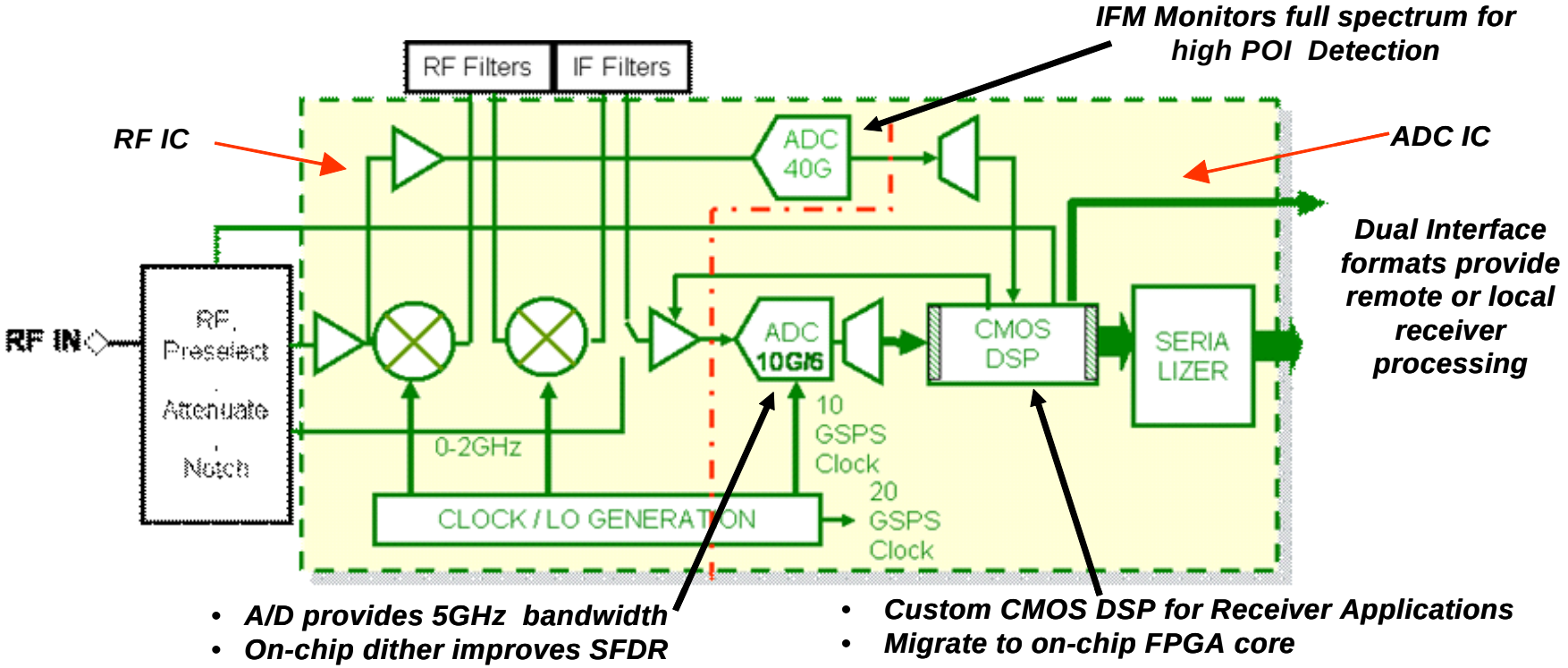
Maximum Flexibility for Multifunction Operation

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

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

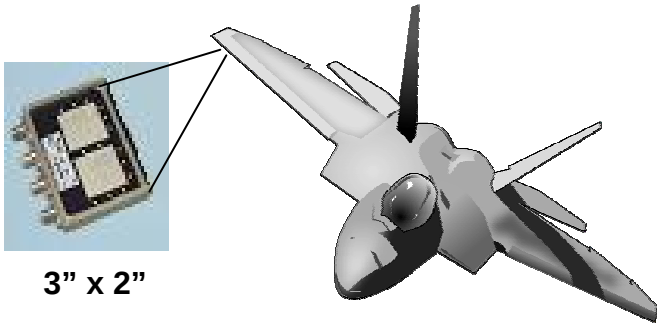
BAE SYSTEMS

TEAM Receiver-on-a-Chip Architecture



Architecture Features

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

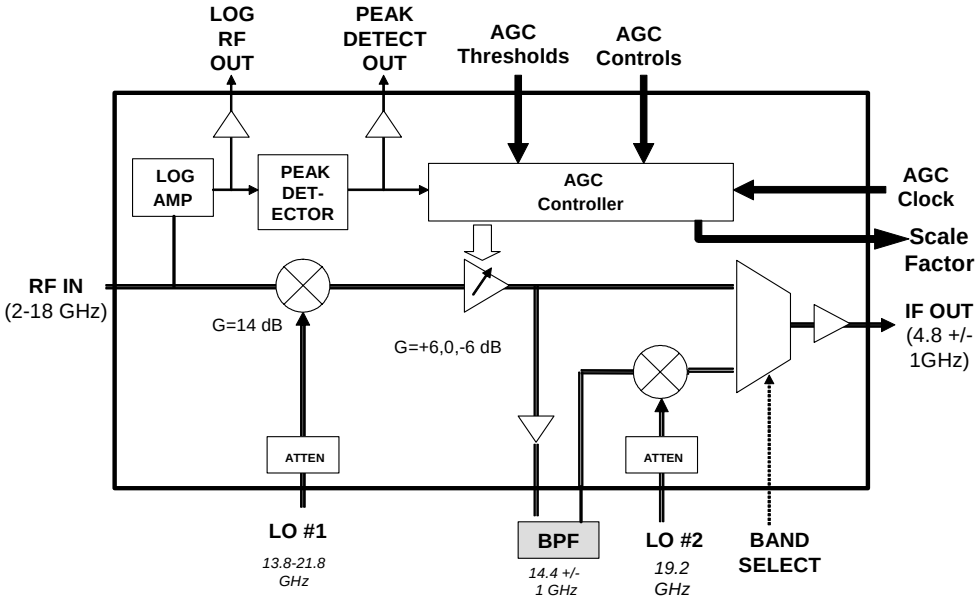


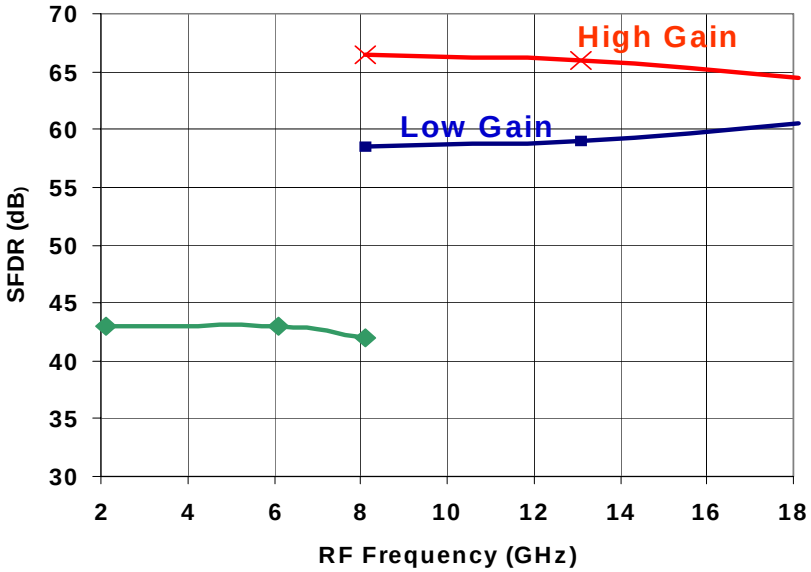
3" x 2"

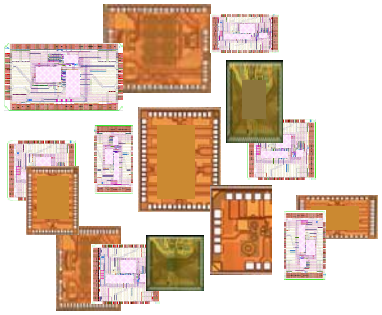
Enables new "Receiver at the Antenna" Architecture

BAE SYSTEMS

TEAM SiGe RF IC

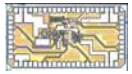






15 Discrete COTS Components
Power: 6 W

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

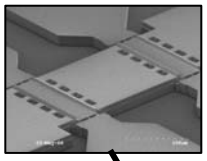
Analog Spectral Processor
MEMS Based RF Filters

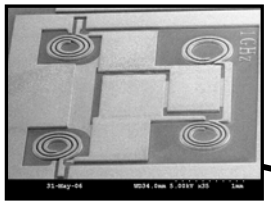
Dr. John Evans, DARPA MTO

Low Power, High Performance Communication and SIGINT Systems

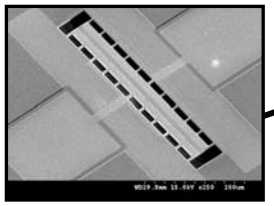
Evanescent Cavity Preselect Filters

Si-Bar Acoustic IF Filters





Fixed LC Filters



Piezo Acoustic Filters

3-6 GHz In

900-3100 MHz In

225-1000 MHz In

High-band MEMs Filters

Mid-band MEMs Filters

Low-band MEMs Filters

96

LNAs

Full Access Crossbar Switch Matrix

IF Chain

LOs

MEMs IF Filters

Ch #1 ADC

Ch #2 ADC

Ch #3 ADC

Ch #4 ADC

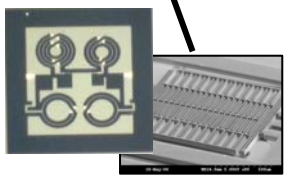
Ch #5 ADC

Analog Sensor

25 KHz Acoustic Array

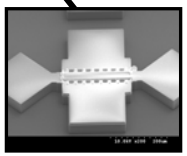
6 KHz Acoustic Array

Detector Mux ADC



Tunable LC Filters

BiCMOS RF Conversion



Si-Bar Acoustic Analog Sensor

Small UAVs

Expendables

Soldier Worn

Lower Cost Stand-Off

Preselect Filter Banks- Less than 4dB Filter Insertion Loss

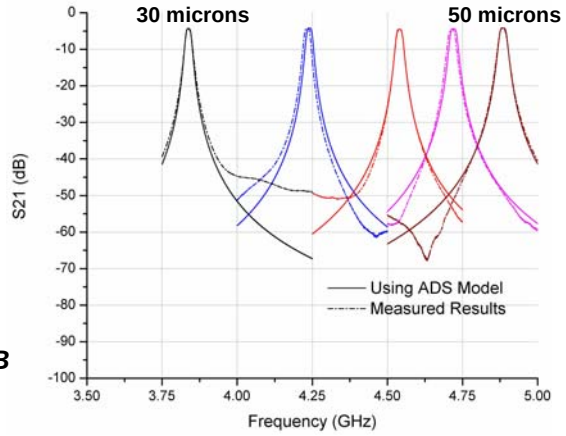
25 MHz BW RF Channelization from 20-6000 MHz

BAE SYSTEMS

ASP Progress
First Iteration Results (12/06)

Evanescent Cavity Filters

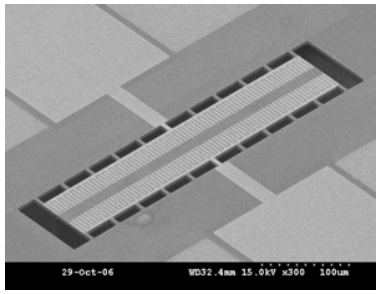
- 3.75 to 5 GHz
- BW = 21MHz to 27MHz
- Insertion loss *4.2 to 3.7 dB*



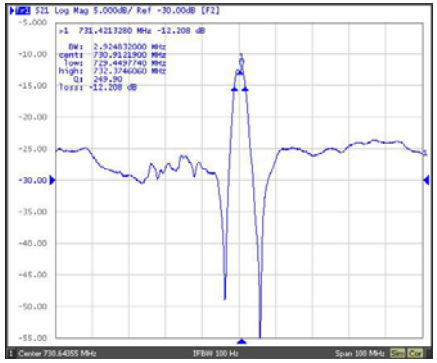
Simulated Vs. Measured Results

PURDUE UNIVERSITY

Piezo Acoustic Filters



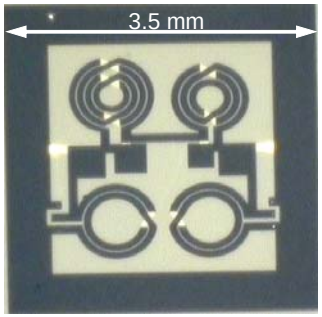
(405µmx70µm)

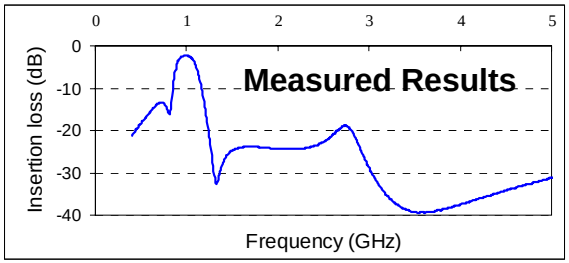


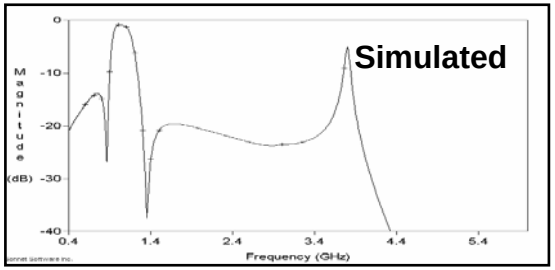
- BW = 2.9 MHz at 730 MHz
- Insertion loss *12 dB*

Georgia Tech

Fixed LC Filter





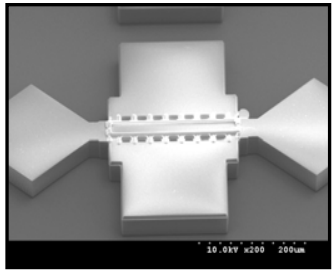


- BW = 300 MHz at 1.05 GHz
- Insertion loss *2 dB*

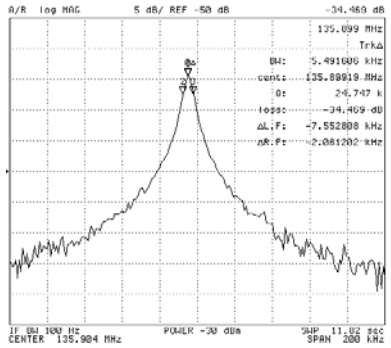
Georgia Tech

BAE SYSTEMS

Si-BAR IF Filters



(120µmx30µm)



135MHz SiBAR resonator

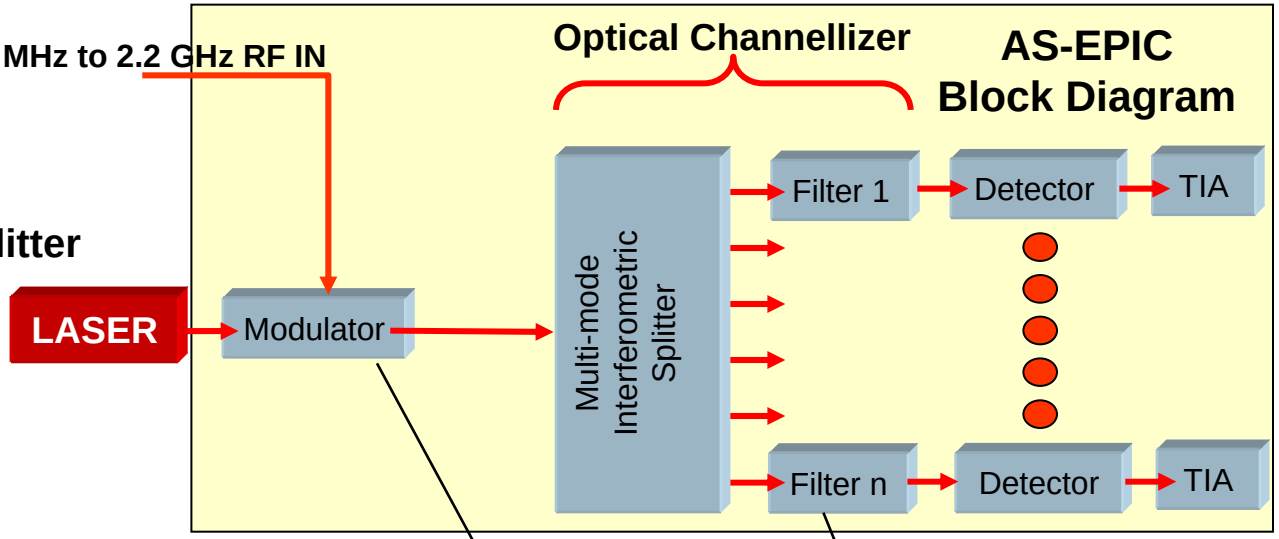
- Measured Q= 24700
- Insertion loss 34.5dB

Georgia Tech

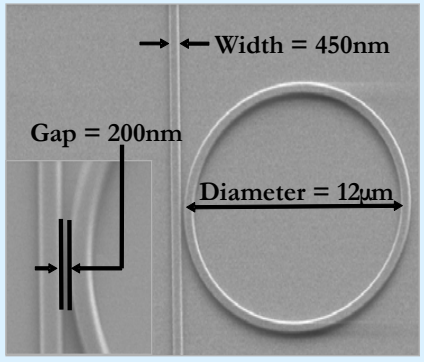
EPIC – RF Photonics on CMOS

Dr. Jagdeep Shah

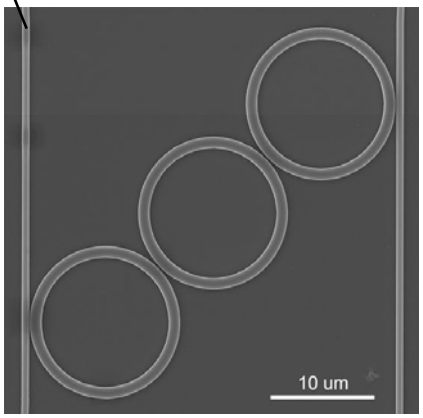
- 20 X 20 mm Chip
- 100 Photonic Devices
- 1000 Electrical Devices
- Modulator
- Multimode Interferometric Splitter
- Filter Bank
- Detector
- TIA
- Optical Filter Elements
- Optical Bends & Transitions



- 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

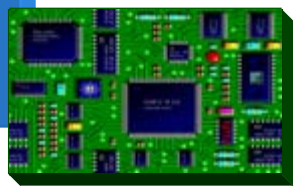


Optical Filter

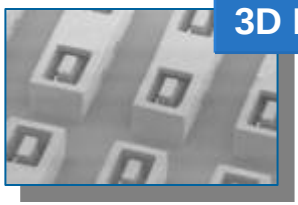
BAE SYSTEMS

3D MERFS

Notion of a Printed Circuit Board

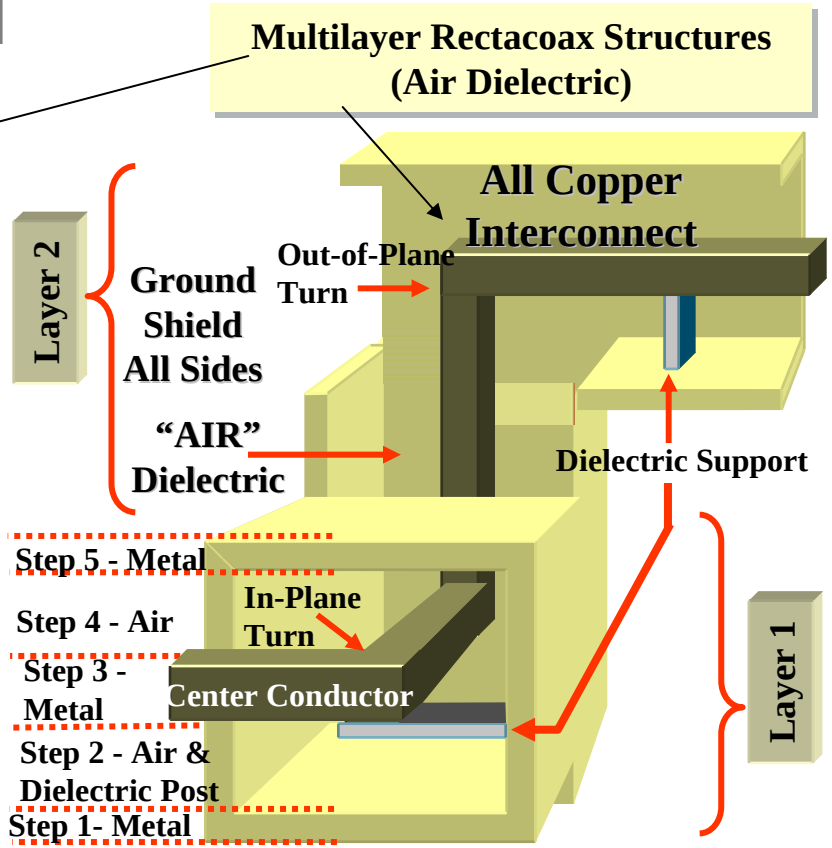


3D MicroFab Processing



3-D MERFS

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

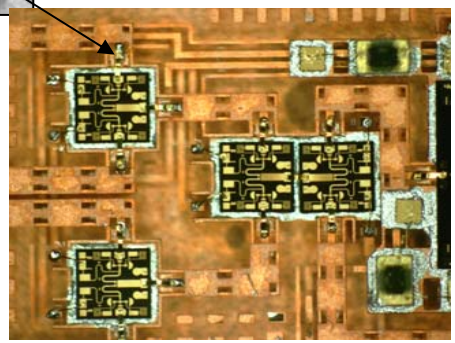


3D MERFS Implementation

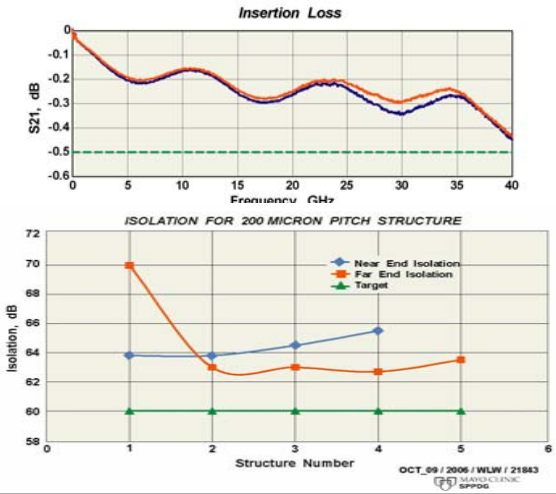
Close-up of 3D MERFS to RF Switch Interface

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

Embedded RF Devices in MERFS 3D Interconnect Substrate

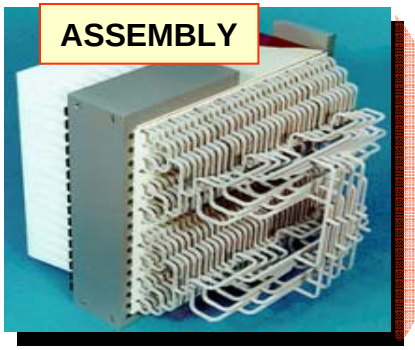


MERFS PHASE 2 BUILD 2 TRANSMISSION LINE INSERTION LOSS (S21) AND RETURN LOSS (S11) MEASURED RESULTS THAT MEET PHASE 2 PERFORMANCE TARGET OF 0.5 dB/cm
(Wafer B2-6, 200 Micron Pitch, 1 cm Length Structures)



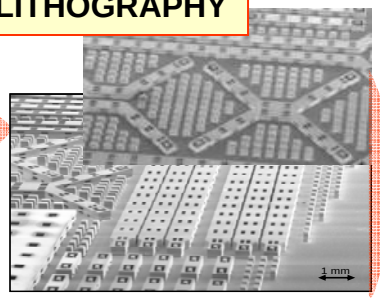
PWB like fabrication processing allows for the integration of RF distribution networks, waveguide manifold and embedded T/R circuits in a single monolithically integrated subsystem.

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