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Defense & Space

Reducing Cost, Size, & Mass of Radar Components

Presentation to:

MPAR Symposium

Presenters: Steve Nelson, Chris Ison

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REMEC gratefully acknowledges the guidance and support of AFRL – WPAFB, & historical perspective from retired meteorologist Ray Nelson

COBHAM Defense Electronic Systems

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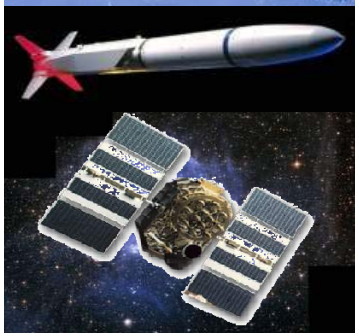
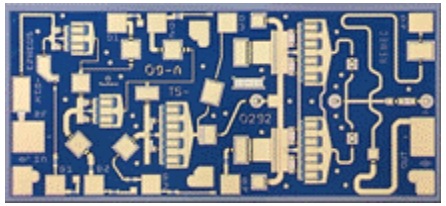


- REMEC is part of Cobham Defense Electronics Systems (CDES)
- Microwave Engineering design and manufacturing solutions:
  - Components to Multi-Function Assemblies
- Product focused toward **M**ultifunction **P**hased **A**rray **R**adars
  - Highly Integrated T/R MMICs
  - Multi-Channel T/R Modules
  - Analog Combiner Circuits
  - Time Domain Units
  - Antenna Elements
  - Low Phase Noise Synthesizers
  - Broadband Up Down Converters
  - D / A and A / D Converter Modules



- REMEC integrates these technologies into Phased Array and Digital Receiver Exciter subsystems

Weather – 1800's – Mark Twain

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"A great, great deal has been said about the weather, but very little has ever been done."

"Weather is a literary specialty, and no untrained hand can turn out a good article of it."

Weather Surveillance Radars - *Progress*

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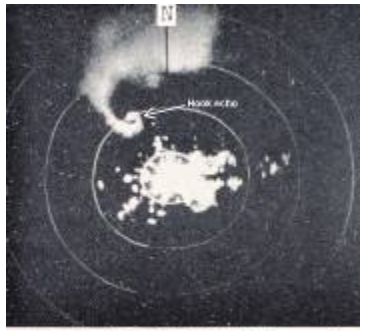
Radar	Minimum Detectable Return	Angular Beam Width
WSR-3 (1950's) (Navy 3 cm)	"large" storms	
WSR-57 (10.3 cm) (late 50s – 80s) WSR-74S	18 dBZ light precipitation	2.0 deg
WSR-88D (11.1 cm) (1990s --)	-28 dBZ very light precipitation, snow, clear air boundaries	0.96 deg (2.7 GHz) 0.88 deg (3.0 GHz)

Phased Array Radar
Solid State

concept -
AFAL "molecular electronics"
IC Concept – UK Royal Radar Establishment 1952
G.A.W. Dummer; Kilby
MERA S-Band PAR - silicon – **1964** (AFAL, TI)

"Brick" T/R Modules - 1970s – 90s

Surface Mount
Plastic / LCP Package
T/R Modules
2005 --



(g) 1831 CST, RBM 5 n.mi.

WSR-3 Topeka office tornado hook echo 5/9/60 (NOAA)

WSR-57 Antenna (NOAA)

Reducing Cost, Size, and Mass

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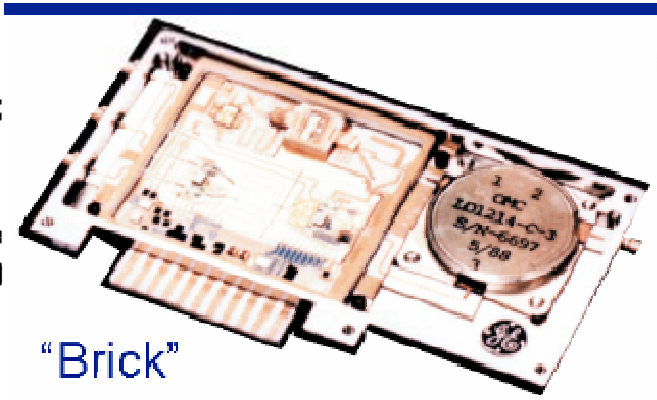


"Brick"

L-band T/R module, early 90s;
Lincoln Lab Journal, Vol 12, No. 2, 2000

T/R Modules

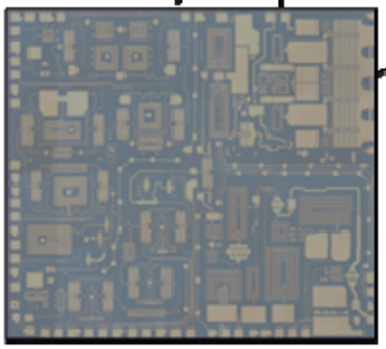
Reduction in
size mass cost
75x 200x 50x
(comparison for similar ckt functions)

5x 5x 5x

Transition from Brick to Tile / Panel

Cost, Size, & Mass Decrease

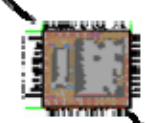
T/R MMIC, 15 sq. mm



< 1 sq. inch
7 g

T/R Module & MMICs

5x 20x 5x



1 sq. cm;
0.25 g

3x 2x 2x

T/R MMIC & ASIC in QFN Plastic Package or LCP Package

30 sq. mm;
0.1 g

Transition from 2D Panel to 3D Panel / ICs

3-D IC

1990 2003 2007 2008

Transmit/Receive MMICs – 1985 - 2005

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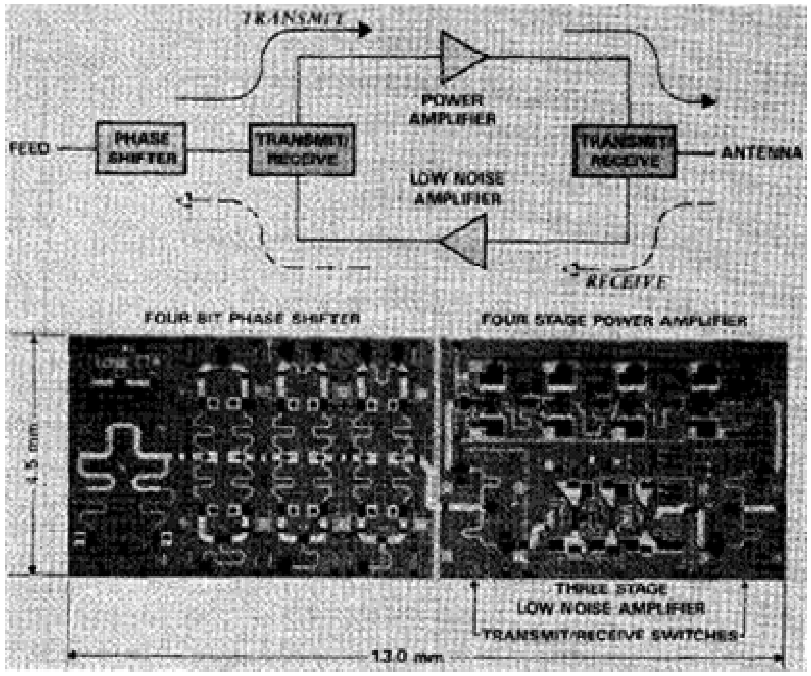
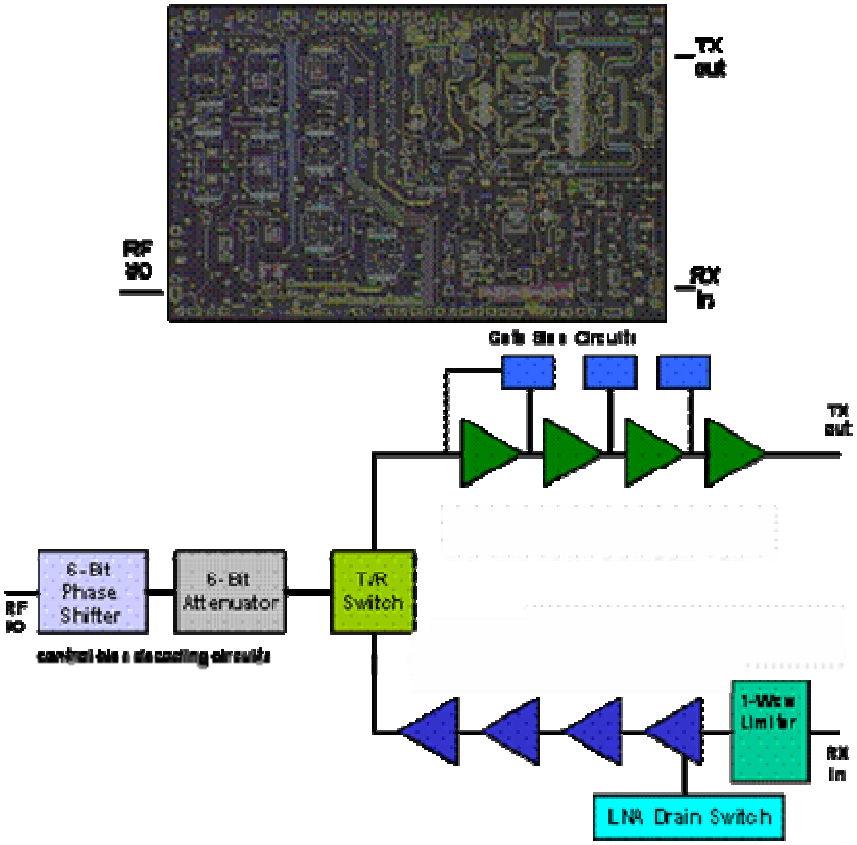


First T/R MMIC, 1985, Texas Instruments CRL
DARPA 1979-85; 0.5-um II MESFET
20-mm on-chip gate width; 377-pF capacitance;
0.45-W PA, 12% p.a.e.;
approx. 80 sq. mm area
14% yield; 50-mm diameter wafers
McQuiddy, et al, Proceedings IEEE, Vol. 79, No. 3, March 1991



REMEC D&S T/R MMIC
21 sq. mm area, 100-mm diameter wafers
HPA, 40% p.a.e.; 60% yield

1979 – 1985 *Higher integration; >4x size reduction; >> 16x cost reduction* **2005**

More Integration – Less T/R Module Complexity

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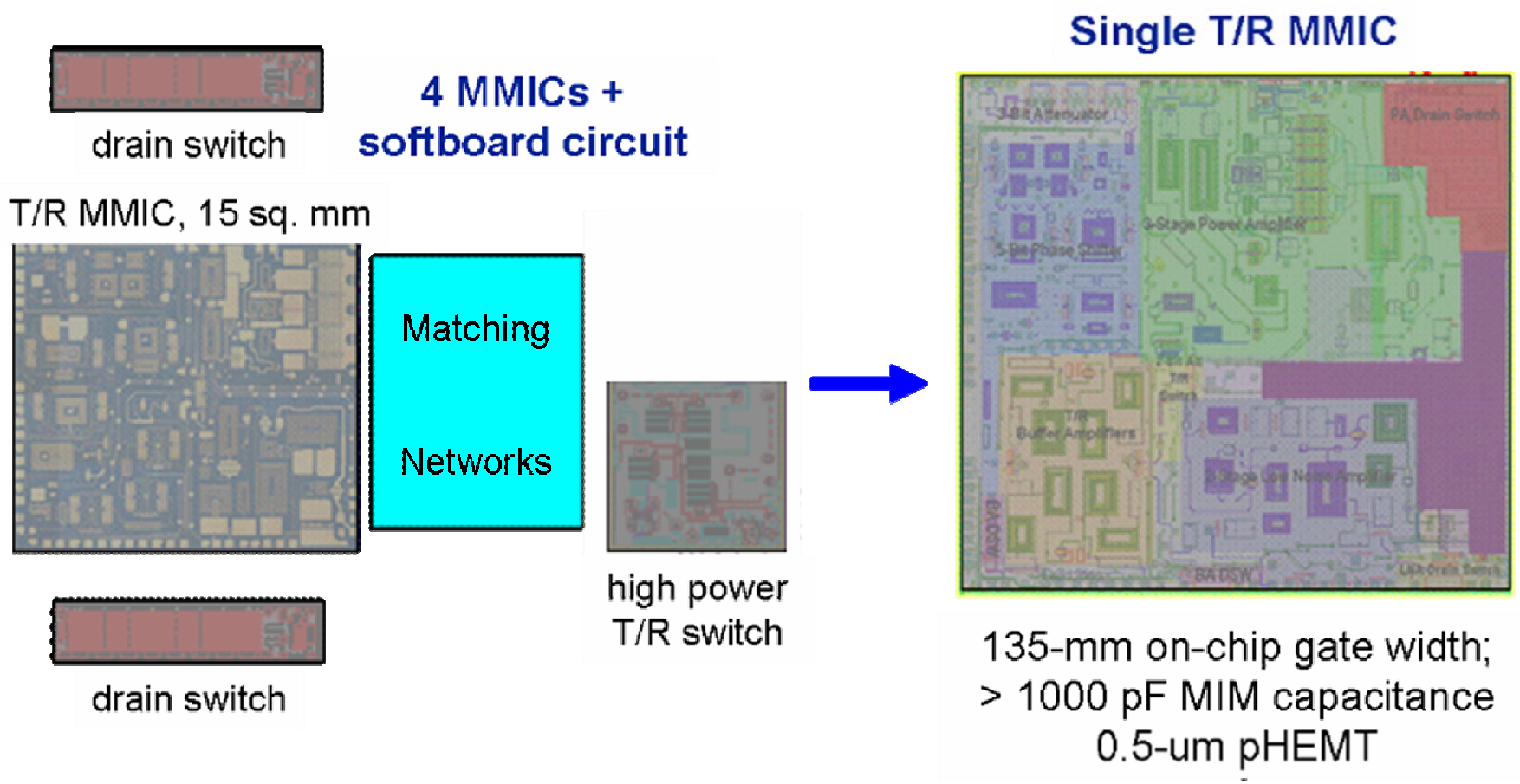
Low Wafer Cost, High Yield Commercial Foundry Processes



T/R MMICs Contain:

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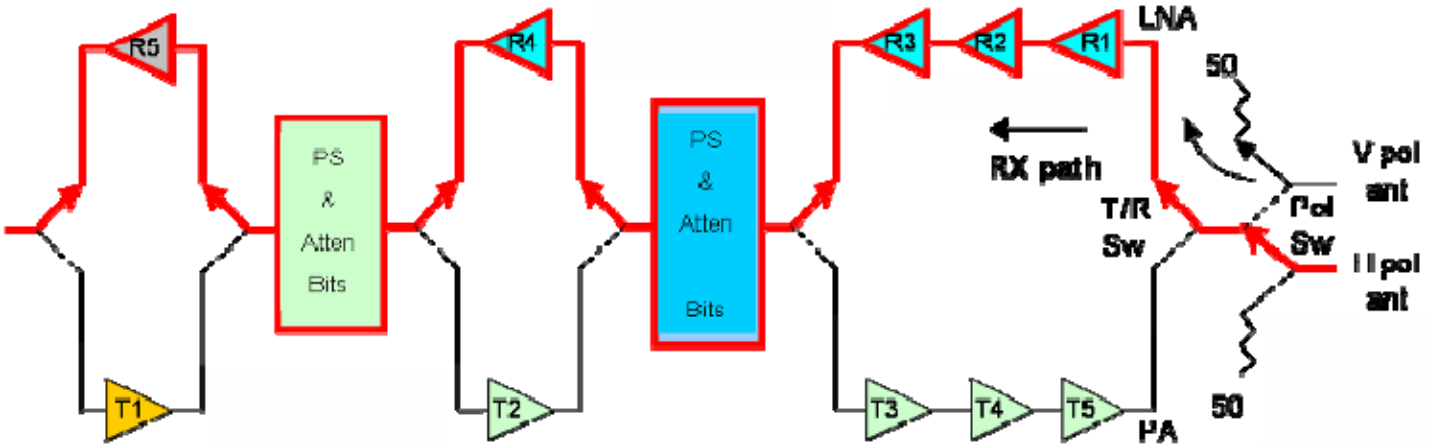
RF Circuits:

Power Amplifier — Low Noise Amplifier
n-Bit Phase Shifter or Time-Delay Circuit
n-Bit Attenuator — T/R Switches
Limiters — Buffer Amplifiers



DC Circuits:

Decoders — Bias Noise Reduction
Drain Switches * — ESD Protection

** remove external MOSFET pulse on/off components*

T/R MMIC Features

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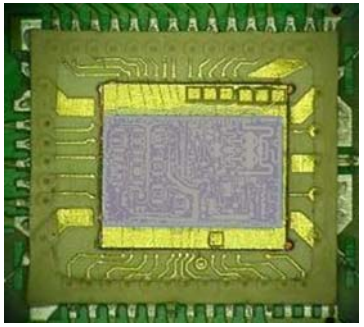
Small area, low aspect ratio MMICs

< 30 sq. mm typ. area -- high level of integration

< 2:1 aspect ratios of T/R MMICs improve strength

Increase package options, reduce package size



LCP
Package
& T/R MMIC

BCB dielectric overcoat

Enables molded, low cost plastic/LCP – surface mount packages

Reduce handling damage, improve strength

Component Count & Assembly

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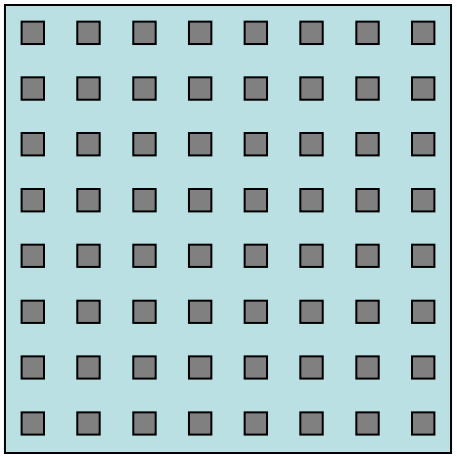
- **Surface mount, small area T/R modules greatly *reduce component count - & simplify assembly of* - phased array radar panels.**



- **Surface mount assembly allows 16-, 64-, or more T/R modules to be assembled at one time**

Cooling Drives Cost & Reliability

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Array packaging is critical for thermal performance

*REMEC **air cooling** solutions to **40 W Tx power per element** - for MPAR applications*

***Very low thermal impedance,** high efficiency power transistors*

< 2.5 C/W for **12-W** PAs
< 1.0 C/W for 30-W PAs

Transistor Tchannel **< 125 C** w/ 90 C MMIC base *

Enables low cost, surface-mount packaging (plastic, LCP)

**Transistor Channel Temperature vs. Median Life*
125 C: 10^7 hours (> 1000 years median life)
150 C: 10^6 hours (> 100 years)
175 C: 10^5 hours (> 10 years)

Digital Receiver Exciters (DREX)

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- ***Digital*** Array Radars require ***multiple DREX*** subsystems

  Ideally - 1 per element -- ***Reality*** (cost, size) - **1 per many elements**

- *Recent technology investments* are *beginning to drive DREX down a similar cost - size – mass reduction roadmap* as T/R modules

- *DREX solutions – simple low cost chipsets, to complex integrated microwave assemblies – are driven by these requirements:*

  Phase Noise **Spurious Signals** **Instantaneous Bandwidth**

- ***MPAR cost goals are highly dependent on these requirements***

Summary

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- T/R module technologies have advanced significantly in the past five years

  T/R MMIC integration & packaging - are key to these advancements

- Antenna array packaging significantly influences cost

- DREX content per array will grow as cost and size decrease, with new technology insertions

- **T/R module technology exists today *to meet MPAR cost goals***