# SAR SENSOR ELECTRONICS

# T/R MODULES

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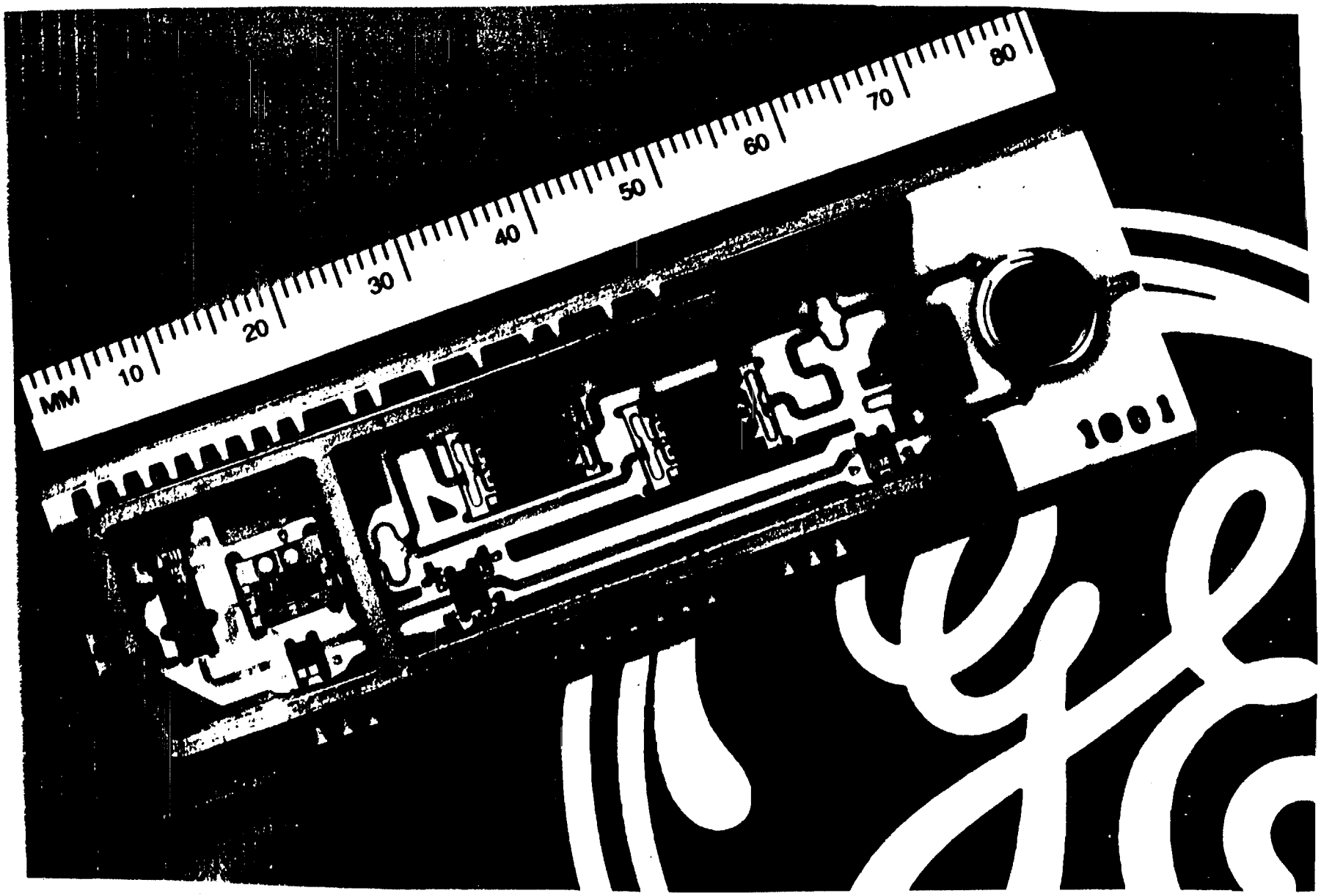
# Outline



- INTRODUCTION
  - Opening Remarks
  - Module Architecture
  - T/R Module in SAR System
- MODULE REQUIREMENTS
  - Requirements Traceability
  - Antenna Configuration
  - Typical Module Specifications/Requirements
- MODULE TECHNOLOGY DEVELOPMENT
  - L-Band
  - C-Band
  - X-Band
- CONCLUDING REMARKS

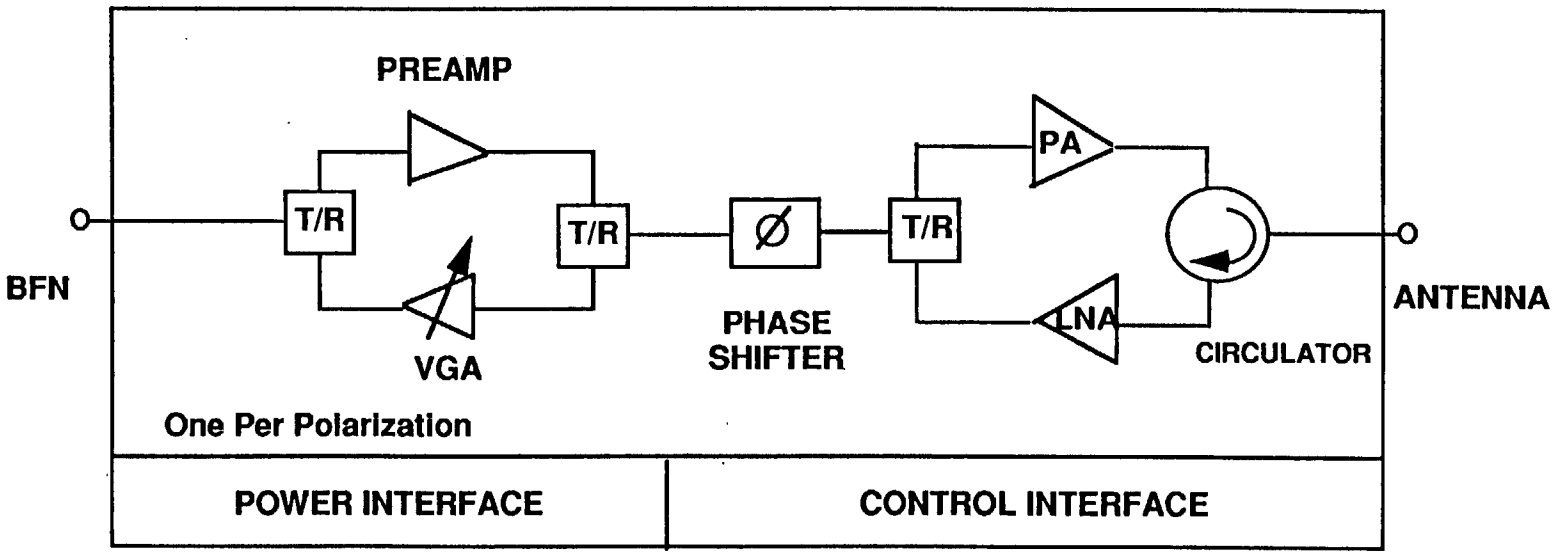
# T/R Module Photo





# SAR T/R Module Architecture

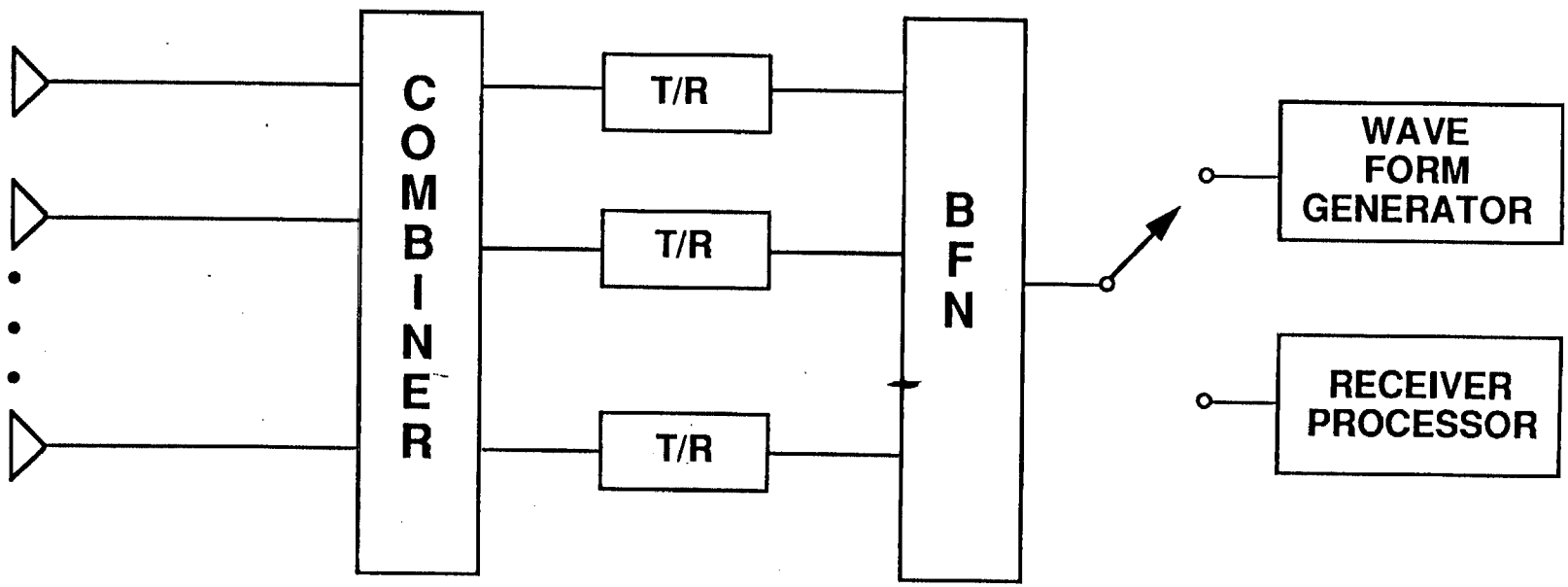





T/R Module is a Unique Assembly of the SAR Functional RF Components

# Simplified Block Diagram of SAR System






Antenna Elements

Element Combiner

Transmit/Receive (T/R) Modules

Beam Forming Network

Wave Form Gen/ Receiver Processor

**T/R Module is a Key Element in the Overall SAR system**

# Requirements Traceability



- SCIENCE MISSION
  - Biomass Assessment
  - Soil and Snow Moisture Measurements
  - Ice Type and Ice/Water Boundary Identification
  - ...

- SAR CAPABILITIES
  - Spectral Coverage
  - Polarimetric Coverage
  - Global Coverage and Nested High Resolution
  - ...

- SAR PERFORMANCE REQUIREMENTS
  - Sensitivity, Resolution
  - Dynamic Range, Data Rate
  - System ISLR, Ambiguities
  - Life
  - ...

# Requirements Traceability (cont'd)

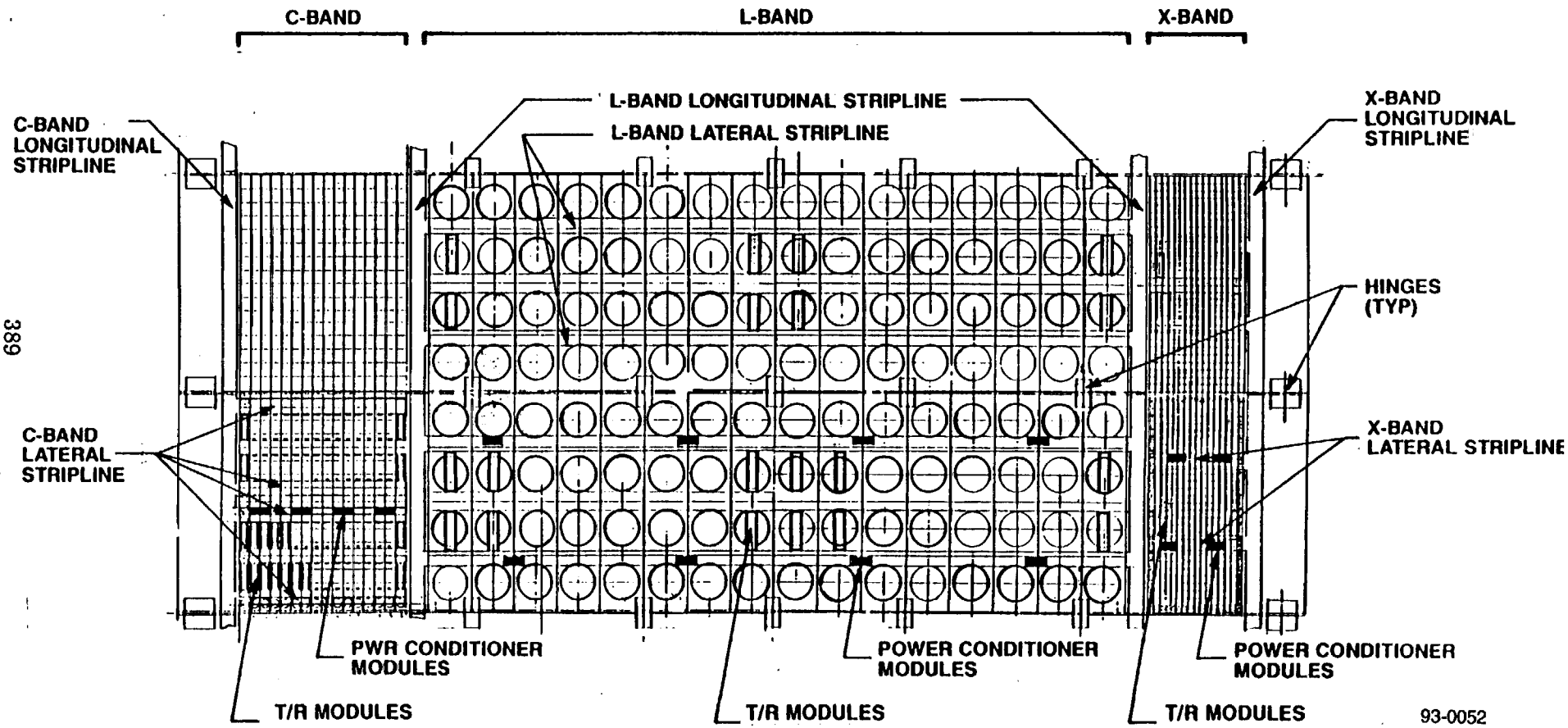


## SAR ANTENNA SUBSYSTEM

- RF
  - Frequency/Bandwidth/Polarization
  - Input/Output Power
  - Beam Steering/Boresight Accuracy/Beamwidth Control
  - Gain(Aperture, Directivity, Receive)/ Sidelobes
  - Receive Noise Temperature
- ELECTRICAL
  - Dwell Time/ Beam Switching/ Waveform
  - DC Input Power
- THERMAL, MECHANICAL AND STRUCTURAL
  - Antenna Flatness and Stiffness
  - Antenna Size and Weight
  - Deployment and Stowage

# Typical SAR Antenna Configuration

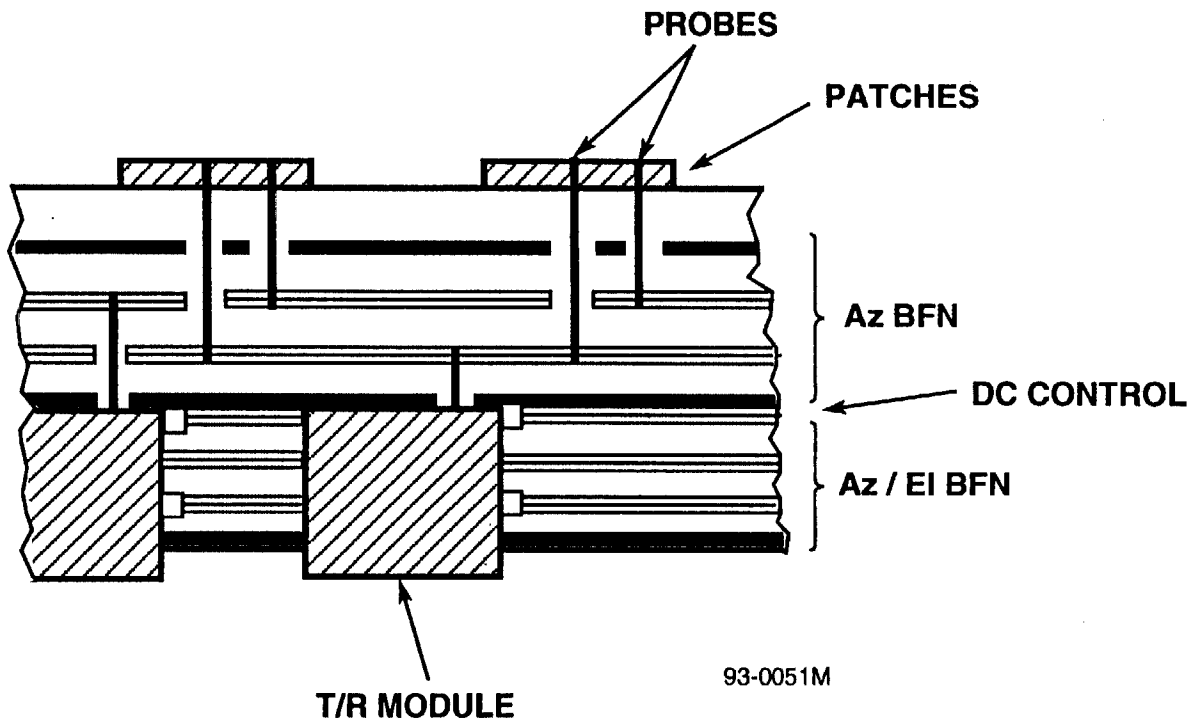
*Astro Space Division*




**T/R Module is an Integral Part of Antenna Design**

# Typical SAR Antenna Panel Cross Section






**T/R Module Characteristics Are Key Drivers of Electrical, Mechanical and Thermal Designs of Antenna and SAR System**

# Desired Module Characteristics



- Electrical
  - High Power Added Efficiency
  - Low Losses
  - Low Receiver Noise Figure
- Mechanical
  - Small Size
  - Low Weight
- Thermal
  - Low Power Dissipation
  - Good Thermal Conduction

**The Better the Module, the Better the Antenna and Overall SAR System**

# Typical T/R Module Specifications/Requirements



| Parameter | L-Band | C-Band | X-Band |
|---|---|---|---|
| Frequency (GHz) | 1.25 | 5.3 | 9.6 |
| Bandwidth (MHz) | 30 | 30 | 30 |
| Phase Control (bits) | 6 | 6 | 6 |
| Gain (dB) | | | |
| Receive | ≥25 | ≥27 | ≥32 |
| Transmit | ≥35 | ≥34 | ≥34 |
| Amplitude Tracking (dB) | <0.5 | <0.5 | <0.5 |
| Phase Tracking (deg) | <3 | <3 | < 3 |
| Noise Figure (dB) | ≤2.5 | ≤3.0 | ≤3.5 |
| Peak Power (W) | ≥4.5 | ≥3.5 | ≥2.5 |
| Efficiency (%) | | >25 | >15 |
| Size (inches) | 5x1.4x.25 | 3.3x1x.25 | 2x1x.25 |
| Weight (grams) | <50 | <40 | <30 |

* Application: EOS SAR

T/R Module Specifications are a Combination of Derived, Self-Imposed, and Direct Flow Down Requirements

# L- Band T/R Module Development



## SEASAT

- Solid State Power Amplifier

## SHUTTLE IMAGING RADAR - C

- T/R Module With Less Emphasis on Size and Weight

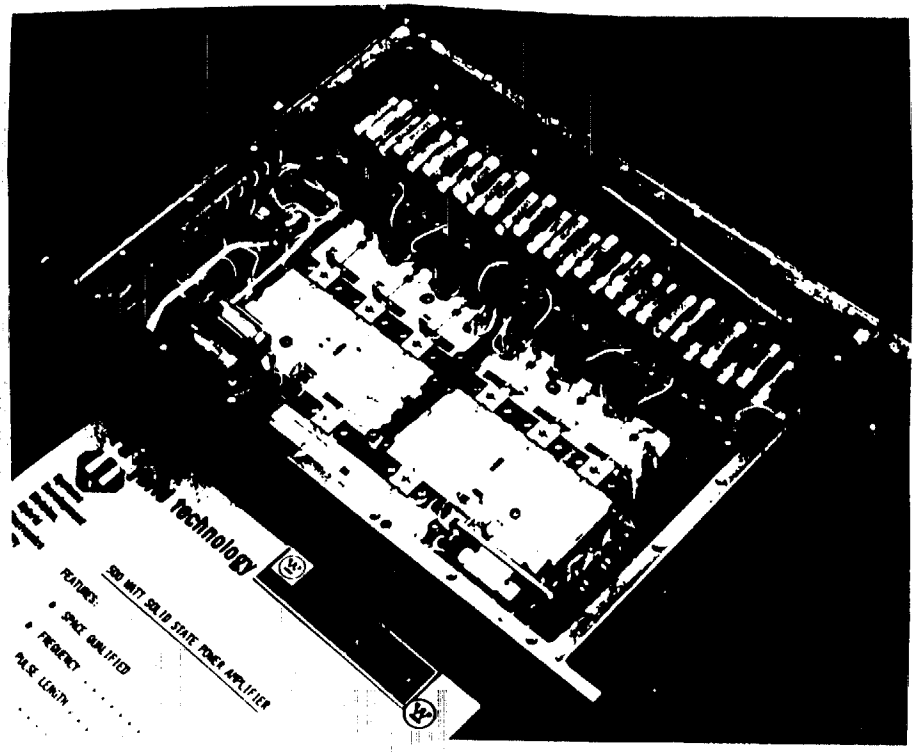
## SPACE BASED RADAR

- Industry Built High Performance, Advanced Light Weight Modules
- Primarily DoD Sponsored Development
- Technical Data is Export Restricted by the Arms Export Control Act

**L-Band T/R Module is Ready For Insertion into SAR Applications With Little or no Modifications**

# SEASAT L-Band 500 W SSPA

*Astro Space Division*




## Solid State Power Amplifier Features :

| | |
|---|---|
| - Frequency | 1.225-1.325 GHz |
| - Pulse Length | 34 usec |
| - Duty | 6% |
| - Efficiency | 31 % |
| - Size | 2x7x9 in |

## 3 Combined :

| | |
|---|---|
| - Power | 1200 W |
| - Size | 9x16x31 in |
| - Weight | 90 lbs |

# SIR-C L-Band T/R Module



## Module Specifications

- **Transmit**
  - Output Power 28 W
  - Duty Cycle 4-7 %
- **Receive**
  - Noise Figure 2.5 dB
  - Gain 25.5 dB
- **Mechanical**
  - Size 5.5x4x in
  - Weight 454 grams

# SBR L- Band T/R Module



| Parameter | Phase A | Phase B | Phase C |
|---|---|---|---|
| Bandwidth (MHz) | 100 | 200 | >200 |
| Noise Figure (dB) | X | X-0.5 | X-1.0 |
| Peak Power (W) | X | X | X(var.) |
| Efficiency (%) | X | X+5 | X+10 |
| Size (inches) | 5x1.4x.5 | smaller | smaller |
| Weight (grams) | 227 | 142 | 56-112* |



* Radar System Configuration Dependent

D. Temme, Space Radar Technology Program Review, MIT Lincoln Laboratory, June 1987.

**Current SBR T/R Module Performance Meets or Exceeds SAR Requirements and Improvements are Possible**

# GBR C-Band T/R Module

*Astro Space Division*

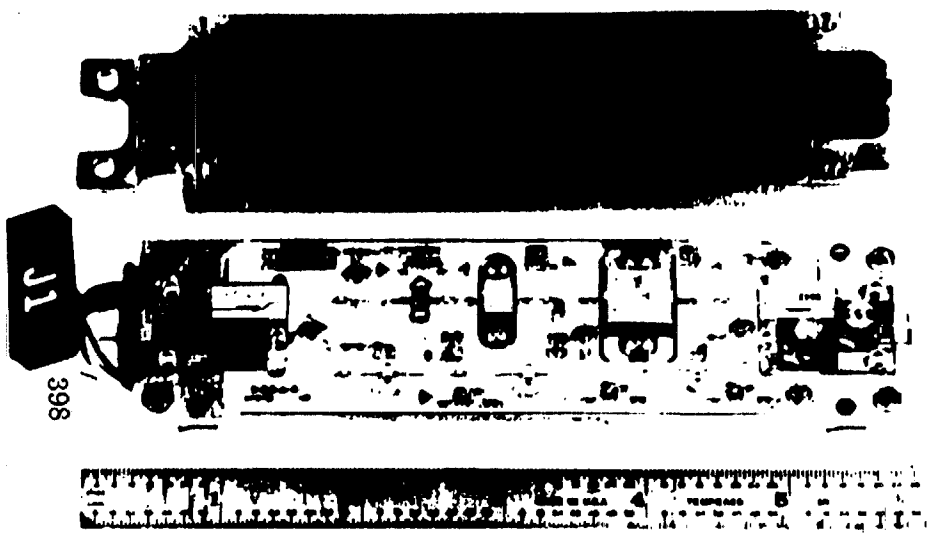
| Parameter | 1987 Tech | MMIC - Phase I |
|---|---|---|
| Bandwidth (MHz) | 700 | 700 |
| Noise Figure (dB) | 3.0 | 2.5 |
| Peak Power (W) | 10 | 10 |
| Efficiency (%) | 20 | 25 |
| Size (inches) | 1.08x.87x.11 | 1.08x.87x.11 |
| Weight (grams) | 4.22 | 4.22 |

Hughes/GE - Ground Based Radar
F. Brand, IEEE MTT-S Int'l Microwave Symp Keynote Address, IEEE Trans MTT,Vol 36, No 12, Dec 1988

**C-Band Module Can Be Made Even Lighter and Space Qualified**

# SIR-C C-Band T/R Module

*Astro Space Division*




## Module Specifications

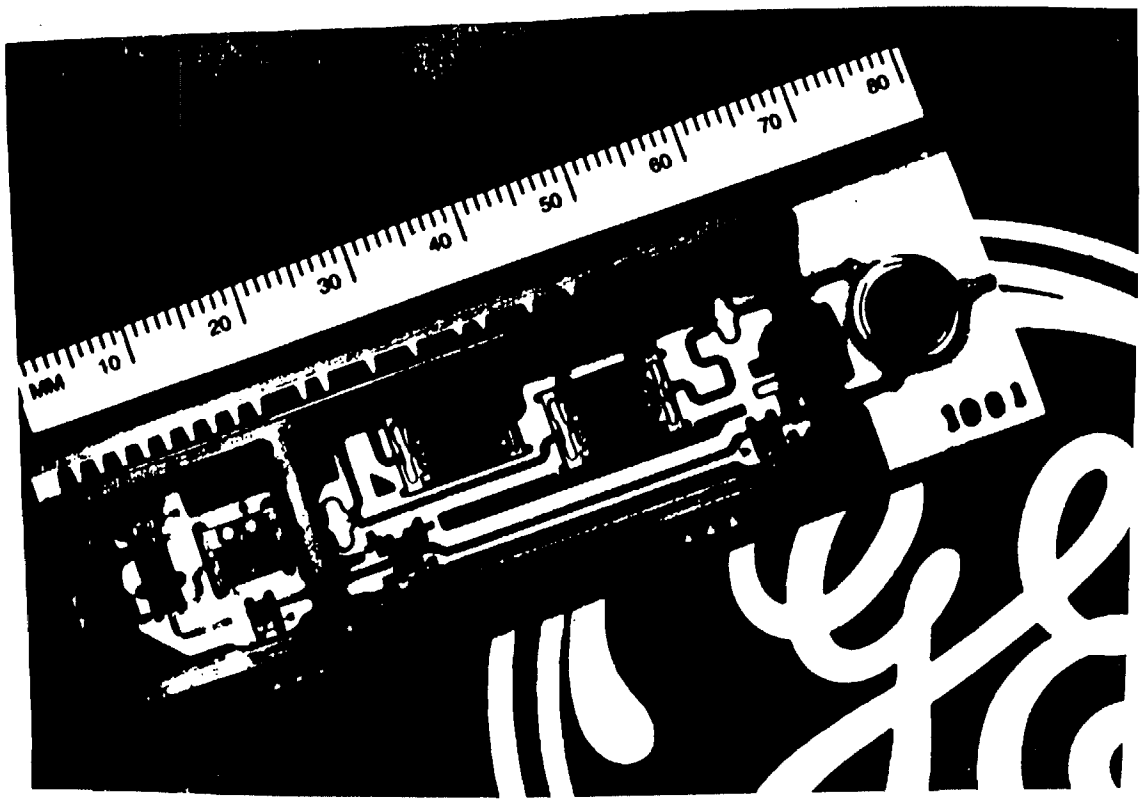
- **Transmit**
  - Output Power 7.8 W
  - Duty Cycle 4-7 %
- **Receive**
  - Noise Figure 2.8 dB
  - Gain 32.5 dB
- **Mechanical**
  - Size 5.5x1.5x0.56 in
  - Weight 159 grams

# COBRA C-Band T/R Module



**Module Characteristics :**

- Output Power <10 W
- Noise Figure <4.0 dB



# Airborne X-Band T/R Module



| Parameter | 1987 Tech | MMIC - Phase I |
|---|---|---|
| Bandwidth (MHz) | 2000 | 2000 |
| Noise Figure (dB) | 3.0 | 2.0 |
| Peak Power (W) | 2 | 2.5 |
| Efficiency (%) | 15 | 25 |
| Size (inches) | 1.34x.48x.11 | 1.34x.3x.11 |
| Weight (grams) | 2.57 | 1.8 |

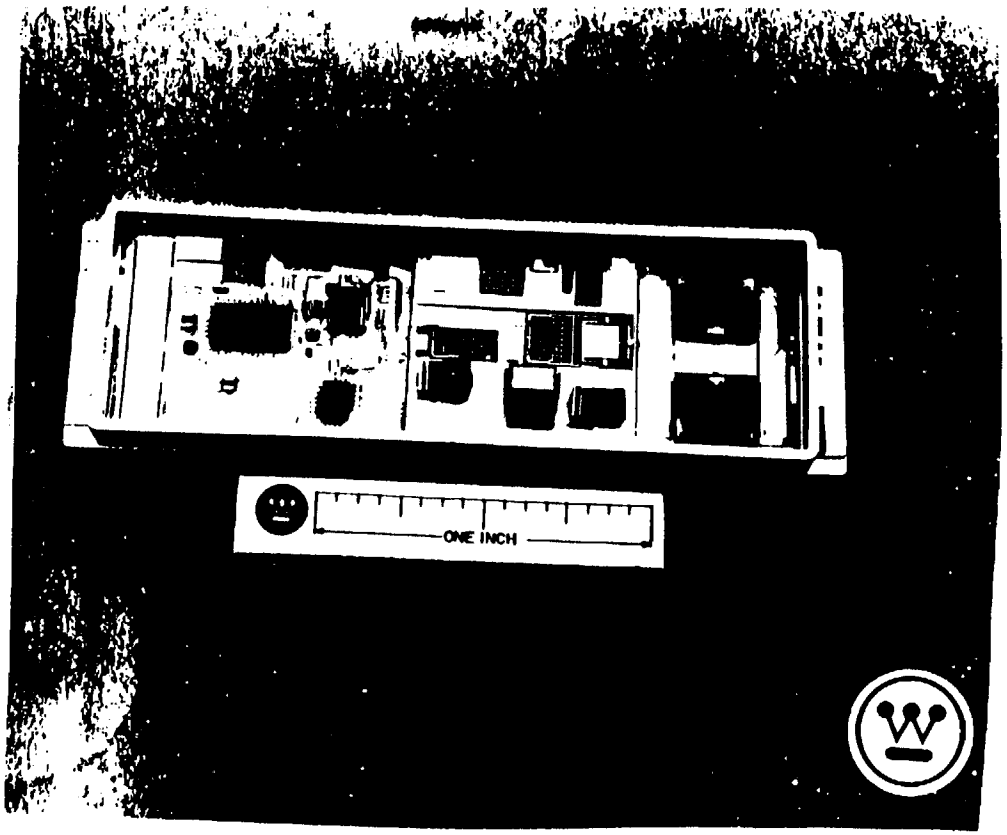


Hughes/GE - Airborne Radar
F. Brand, IEEE MTT-S Int'l Microwave Symposium Keynote Address, IEEE Trans. MTT, Vol 36, No 12, Dec 1988

**X-Band Module is Ready and Can Be Made Space Qualified**

# X-Band T/R Module






## Functional Module :

**Transmit :**

| | |
|---|---|
| Freq/Bandwidth | X-Band/20% |
| Power/Duty | 5-10 W/>30% |
| Efficiency | 25-30% |

**Receive :**

| | |
|---|---|
| Noise Figure | 3 dB |

| | |
|---|---|
| Size | 2.5x0.6x0.2 in |
| Weight | 30 gm |

# Concluding Remarks



- GaAs MMIC Technology Has Been Demonstrated and Complete T/R Modules have been Developed in L, C, and X Frequency Bands

- Technology is at Hand to Produce Light, Small, Efficient T/R Modules that Meet the Spaceborne Imaging Radar Requirements

- SAR is an Opportunity to Leverage the Huge DoD and Industry Investment in MMIC and T/R Module Development