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SAR SENSOR ELECTRONICS

T/R MODULES

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Acknowledgement

Astro Space Division

- JPL
 - Mr. Mike Sander
 - Dr. Bob Ferber
- Texas Instruments
 - Mr. Gene Harrell
- Westinghouse
 - Mr. Charles Corson
 - Mr. Michael Doty
- GE
 - Dr. Leonard Yorinks
 - Mr. Joe Tedeschi
 - Dr. Doug Reep



Outline

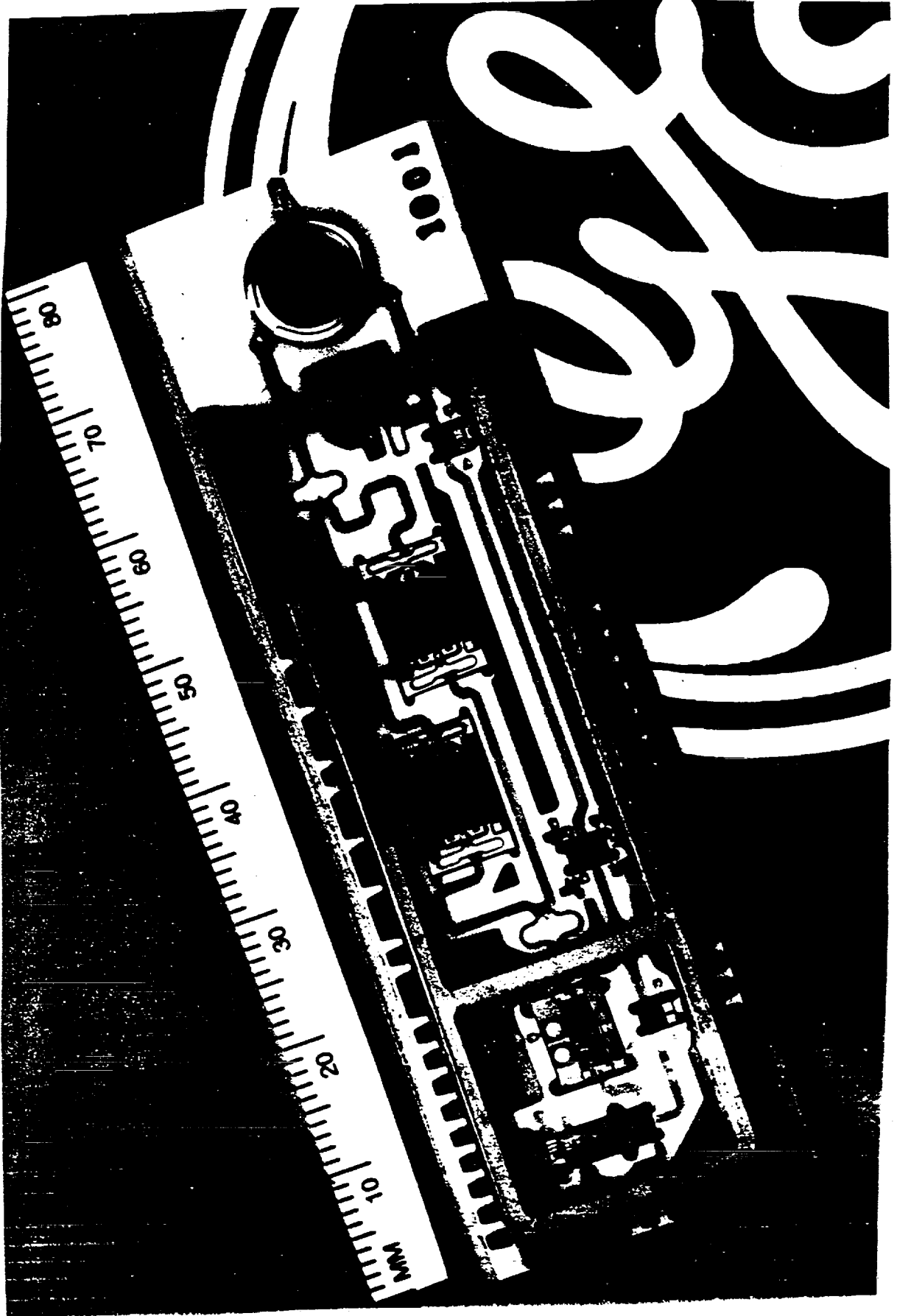
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- **INTRODUCTION**
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 - Module Architecture
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T/R Module Photo

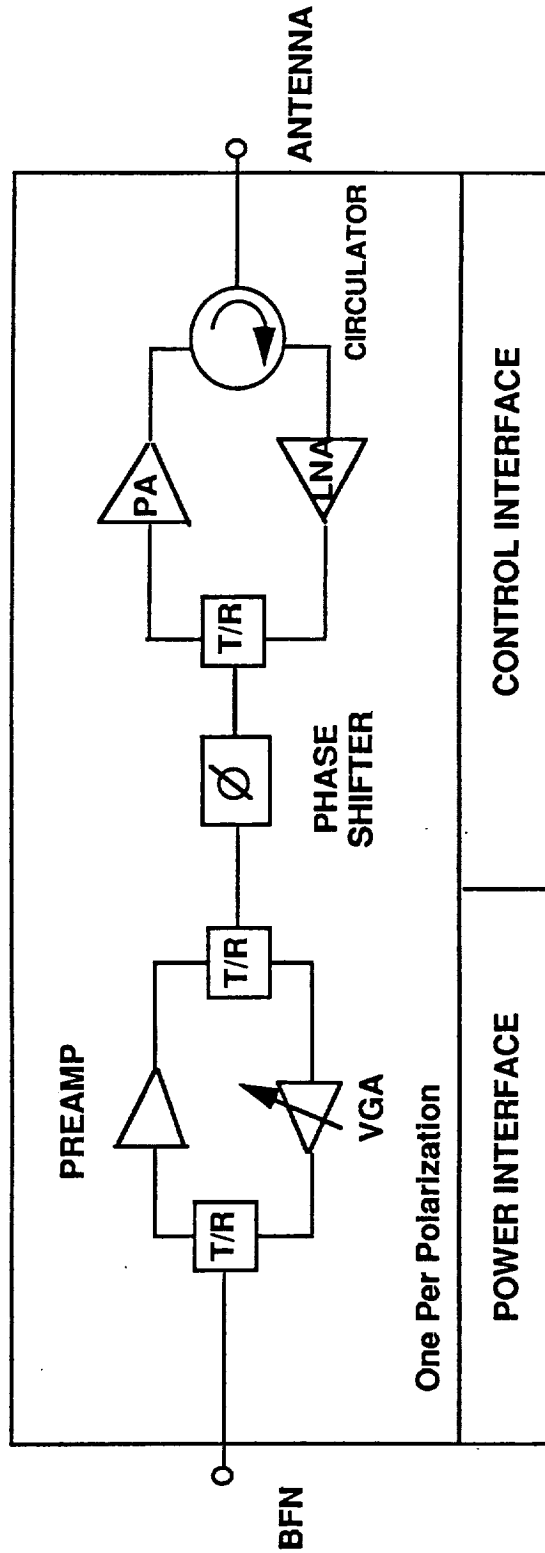
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SAR T/R Module Architecture

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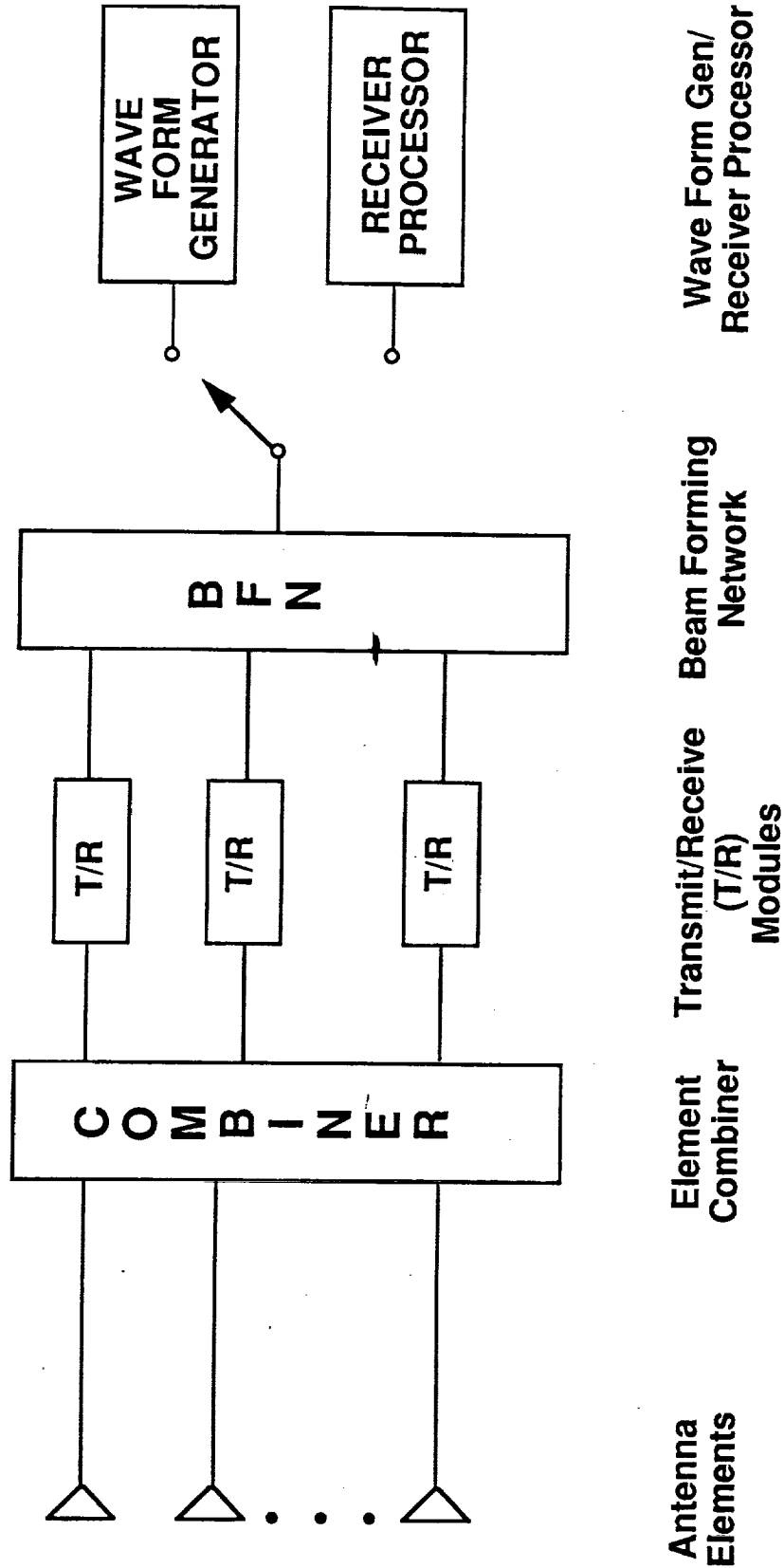


T/R Module is a Unique Assembly of the SAR Functional RF Components



Simplified Block Diagram of SAR System

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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

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- **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)

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SAR ANTENNA SUBSYSTEM

- **RF**
 - Frequency/Bandwidth/Polarization
 - Input/Output Power
 - Beam Steering/Boresight Accuracy/Beamwidth Control
 - Gain(Aperture, Directivity, Receive)/ Sidelobes
 - Receive Noise Temperature

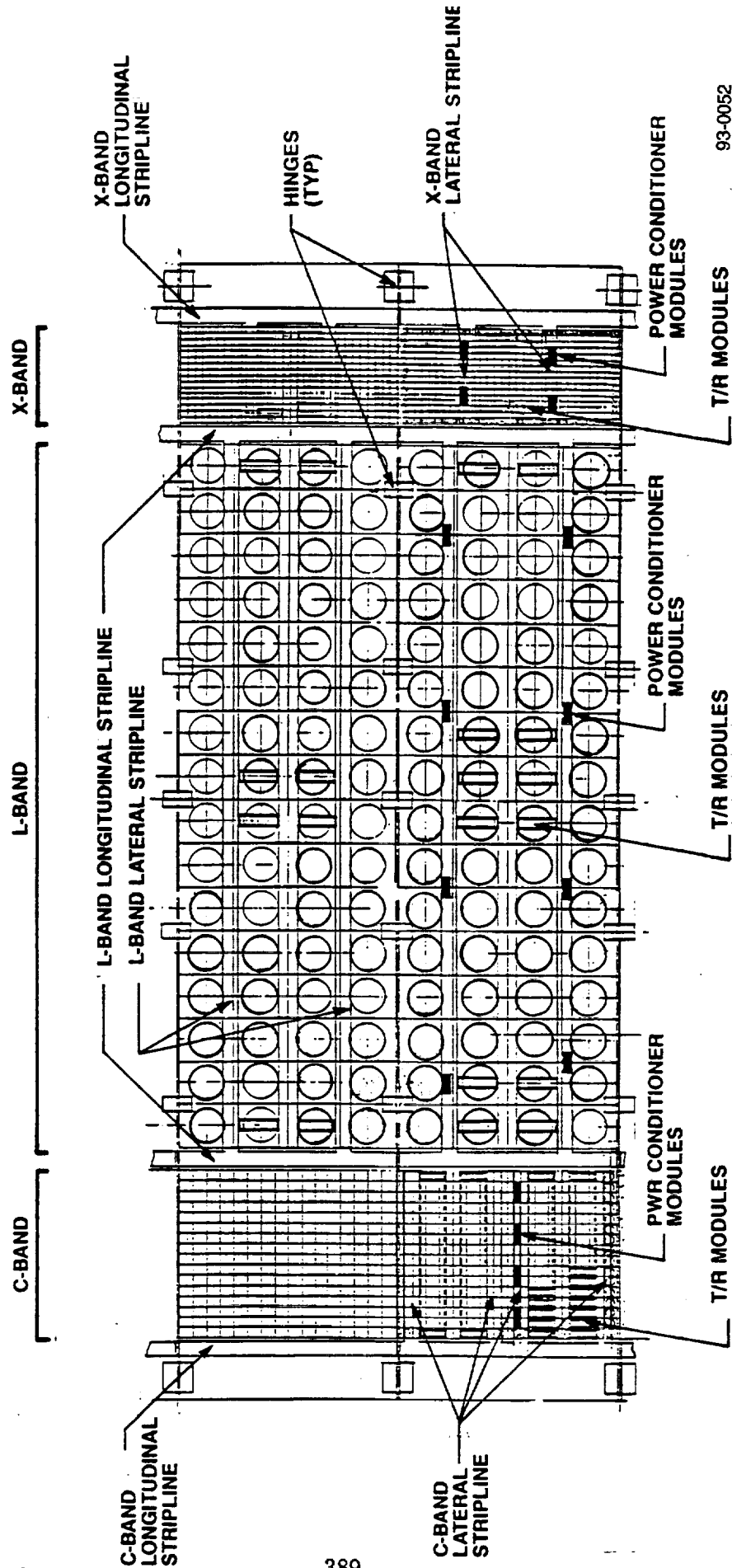
- **ELECTRICAL**
 - Dwell Time/ Beam Switching/ Waveform
 - DC Input Power

- **THERMAL, MECHANICAL AND STRUCTURAL**
 - Antenna Flatness and Stiffness
 - Antenna Size and Weight
 - Deployment and Stowage



Typical SAR Antenna Configuration

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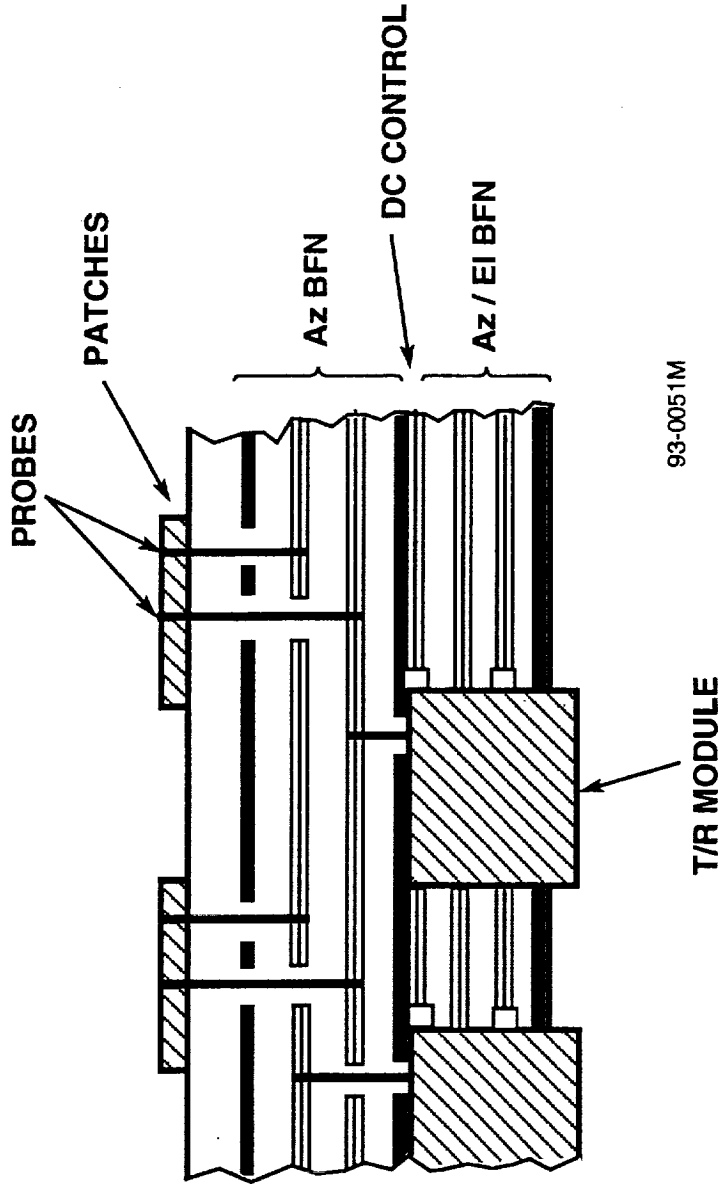
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T/R Module is an Integral Part of Antenna Design



Typical SAR Antenna Panel Cross Section

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93-0051M

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



Desired Module Characteristics

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- **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

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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

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SEASAT

- Solid State Power Amplifier

SHUTTLE IMAGING RADAR - C

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

SPACE BASED RADAR

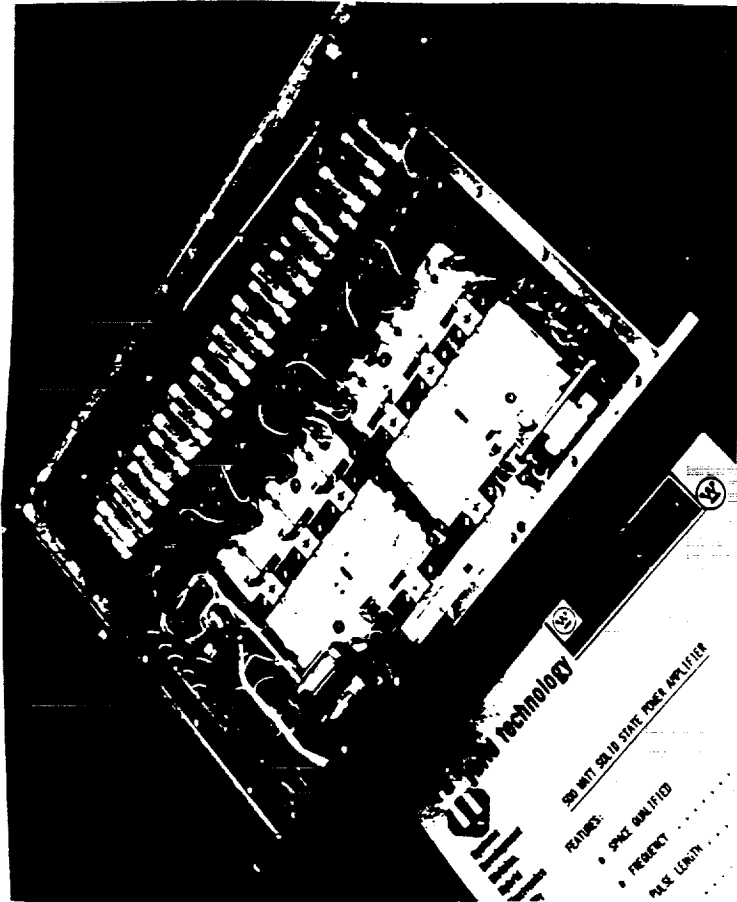
- Industry Built High Performance, Advanced Light Weight Modules
- Primarily DoD Sponsored Development
- Technical Data is Export Restricted by the Arms Export Control Act

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



SEASAT L-Band 500 W SSPA

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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

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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

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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

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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

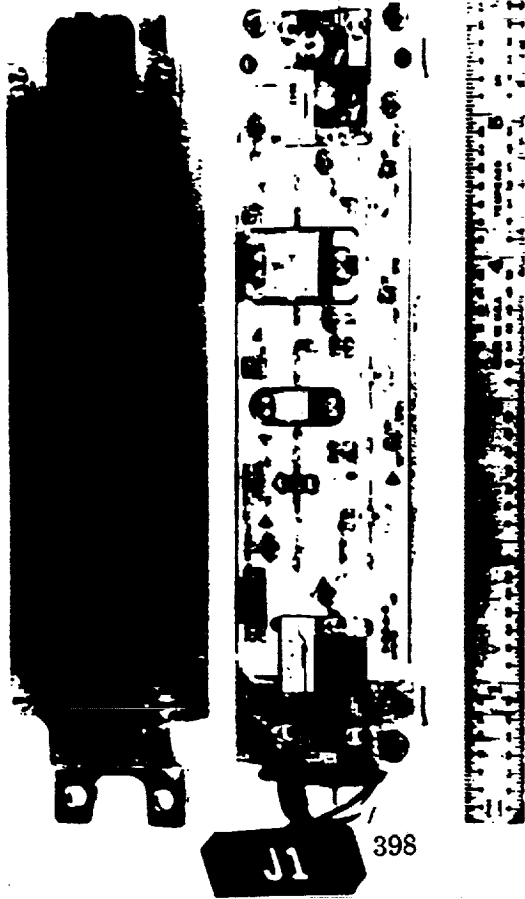
Hughes/GE - Ground Based Radar
 F. Brand, IEEE MTT-S Int'l Microwave Symp Keynote Address, IEEE Trans MTT, Vol 36, No 12,
 Dec 1988

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



SIR-C C-Band T/R Module

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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

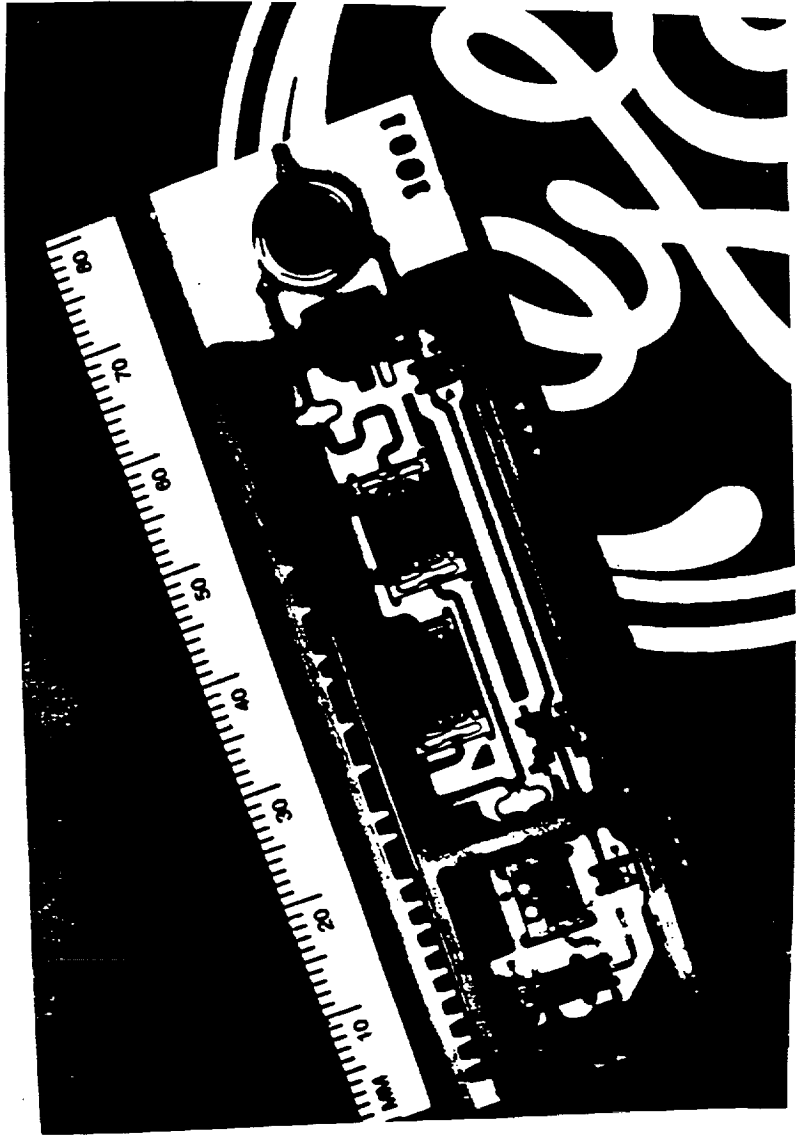


COBRA C-Band T/R Module

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Module Characteristics :

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





Airborne X-Band T/R Module

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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

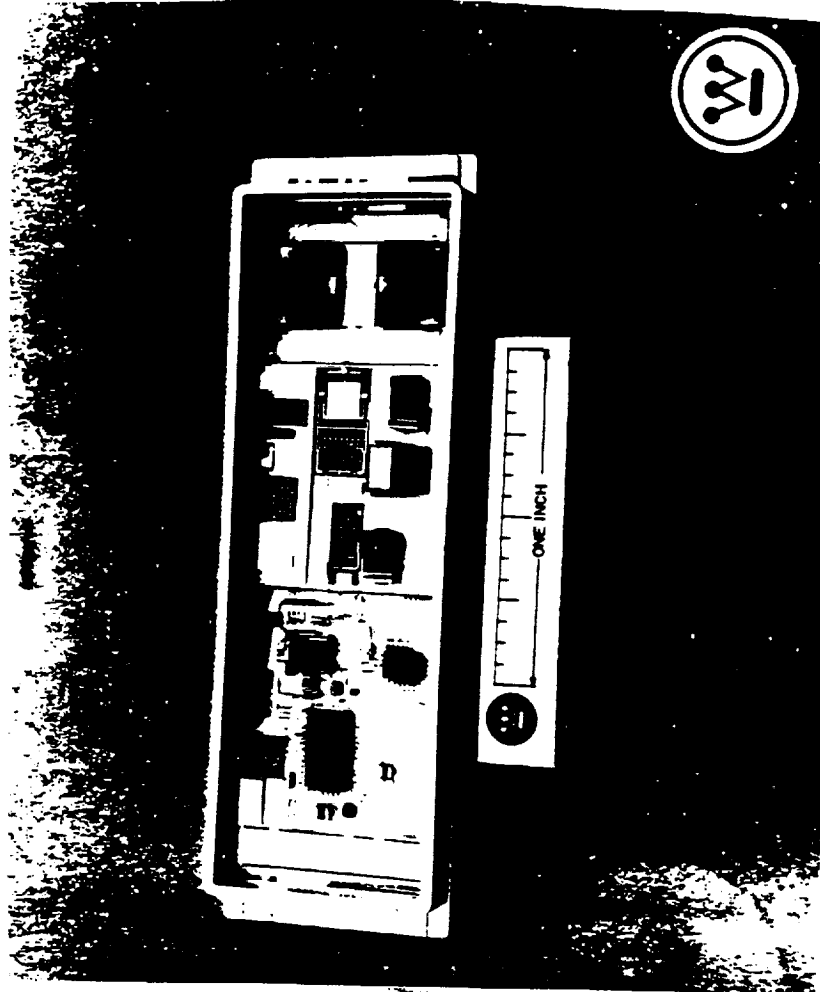
Hughes/GE - Airborne Radar
F. Brand, IEEE MTT-S Int'l Microwave Symposium Keynote Address, IEEE Trans. MTT, Vol 36, No 12, Dec 1988

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



X-Band T/R Module

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Functional Module :

<u>Transmit :</u>	X-Band/20%
<u>Freq/Bandwidth</u>	5-10 W/>30%
<u>Power/Duty</u>	25-30%
<u>Efficiency</u>	
<u>Receive :</u>	
<u>Noise Figure</u>	3 dB
<u>Size</u>	2.5x0.6x0.2 in
<u>Weight</u>	30 gm



Concluding Remarks

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- **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**