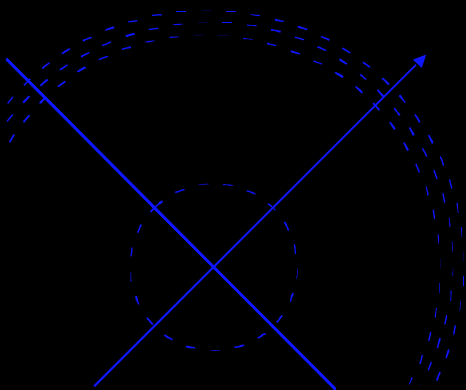




# **RF TECHNOLOGY FOR BROADBAND Ka-BAND COMMUNICATION SYSTEMS**

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**Communications Research Centre**



6/27/98

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# OUTLINE

- **Introduction**
- **Requirements**
- **Semiconductor Device Types & Capabilities**
- **Integration Technologies**
- **Examples**
- **Conclusions**

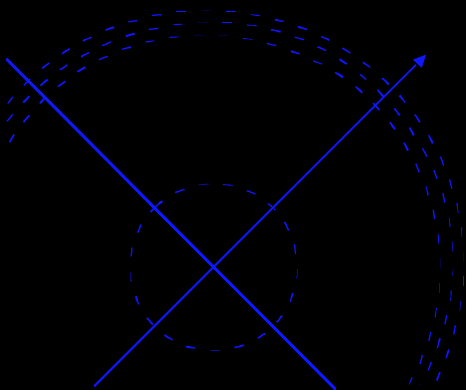
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# INTRODUCTION

- This presentation will focus on LMCS and Ka-Band Satcom Terminals
- System architectures are variable so the specifics of the RF technology are difficult to generalize





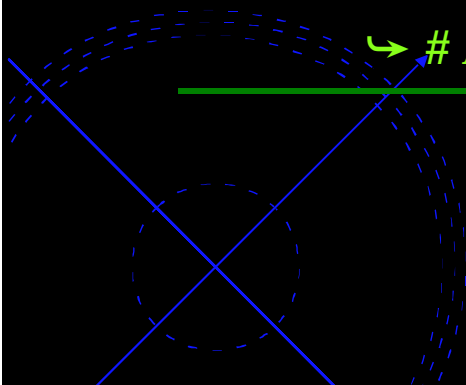
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# TYPICAL LMCS RF REQUIREMENTS

	HUB(Sector)	CPE
<b>• Transmit</b>		
↳ EIRP	-9 dBW/MHz	+15 dBW/MHz
↳ Power/Channel	1 Watt	100 mW
↳ Total Hub Tx Power	4-15 Watts/sector	100 mw to 1 Watt
<b>• Receive</b>		
↳ LNA Noise Figure	< 4 dB	< 4 dB
<b>• Other</b>		
↳ Resistive Losses	Tower Cable?	Low
↳ Cost		Very Low
↳ # Amplifiers	Single or Multiple	Single





# Representative Ka-band LEO and GEO Satcom Terminal Requirements

	<b>GEO-Ka</b>	<b>LEO-Ka</b>
<b>Frequency Bands</b>		
↳ <b>Transmit</b>	28.35-28.6 & 29.35-30	28.6-29.1 GHz
↳ <b>Receive</b>	17.7-18.8 & 19.7-20.2	18.8-19.3 GHz
<b>Transmit</b>		
↳ <b>EIRP</b>	43-67.2 dBW	35-60 dBW
↳ <b>Power</b>	1-10 Watts	1-2 Watts?
↳ <b>Transmission Bandwidth</b>	1-250 MHz	1-155 MHz
<b>Receive</b>		
↳ <b>LNA Noise Figure</b>	<3 dB	<3 dB
<b>Filtering</b>		
↳ <b>Tx/Out of Band Rejection</b>	>30 dB	Same?
<b>Other</b>		
↳ <b>Phase Shifters or Switches</b>	No	Yes
↳ <b>Resistive Losses</b>	Low	Low
↳ <b>Cost</b>	Very Low	Very Low

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# OUTLINE

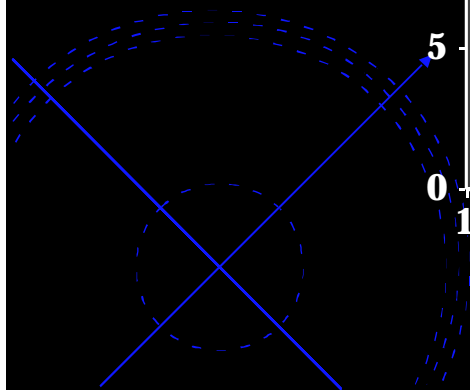
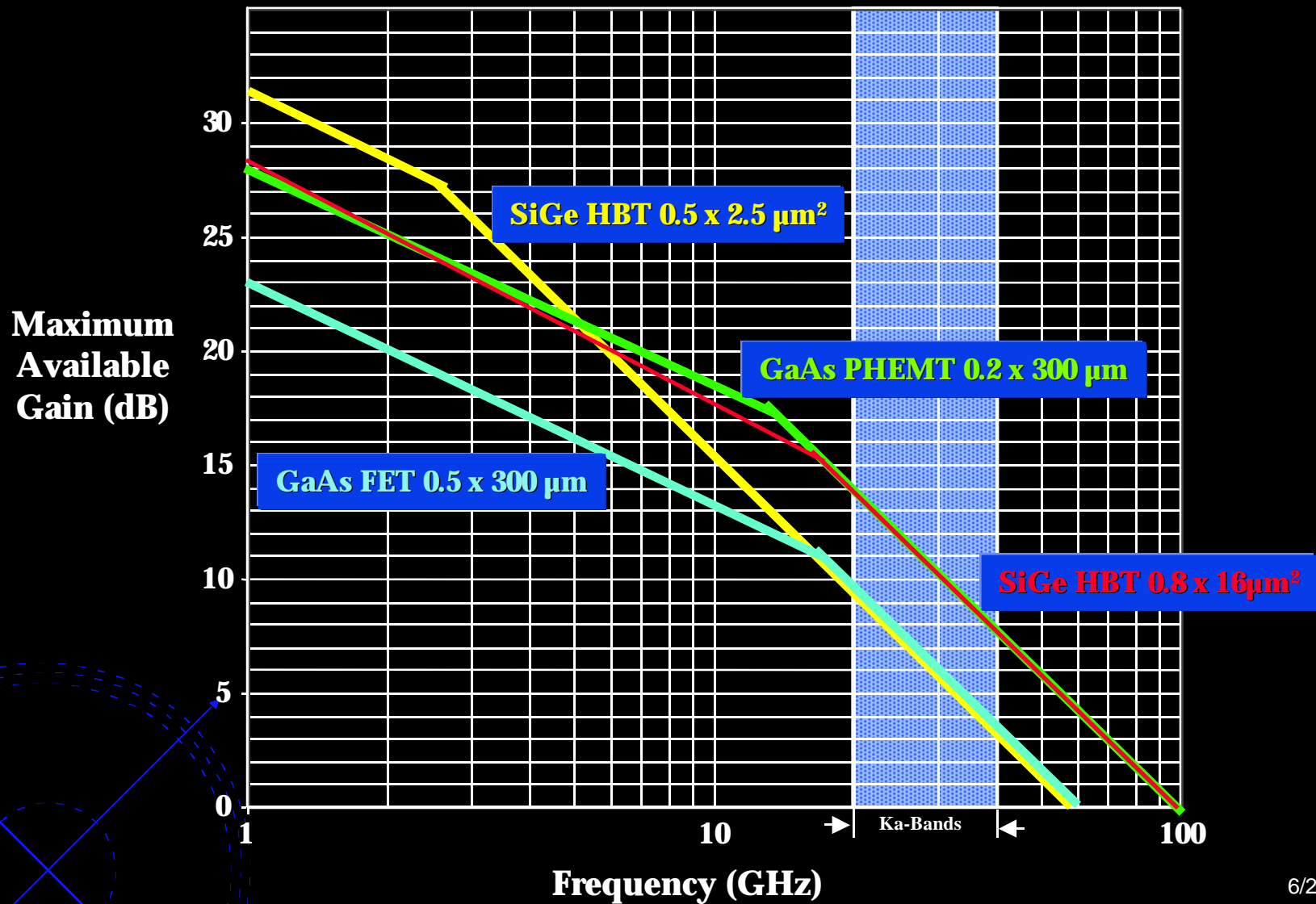
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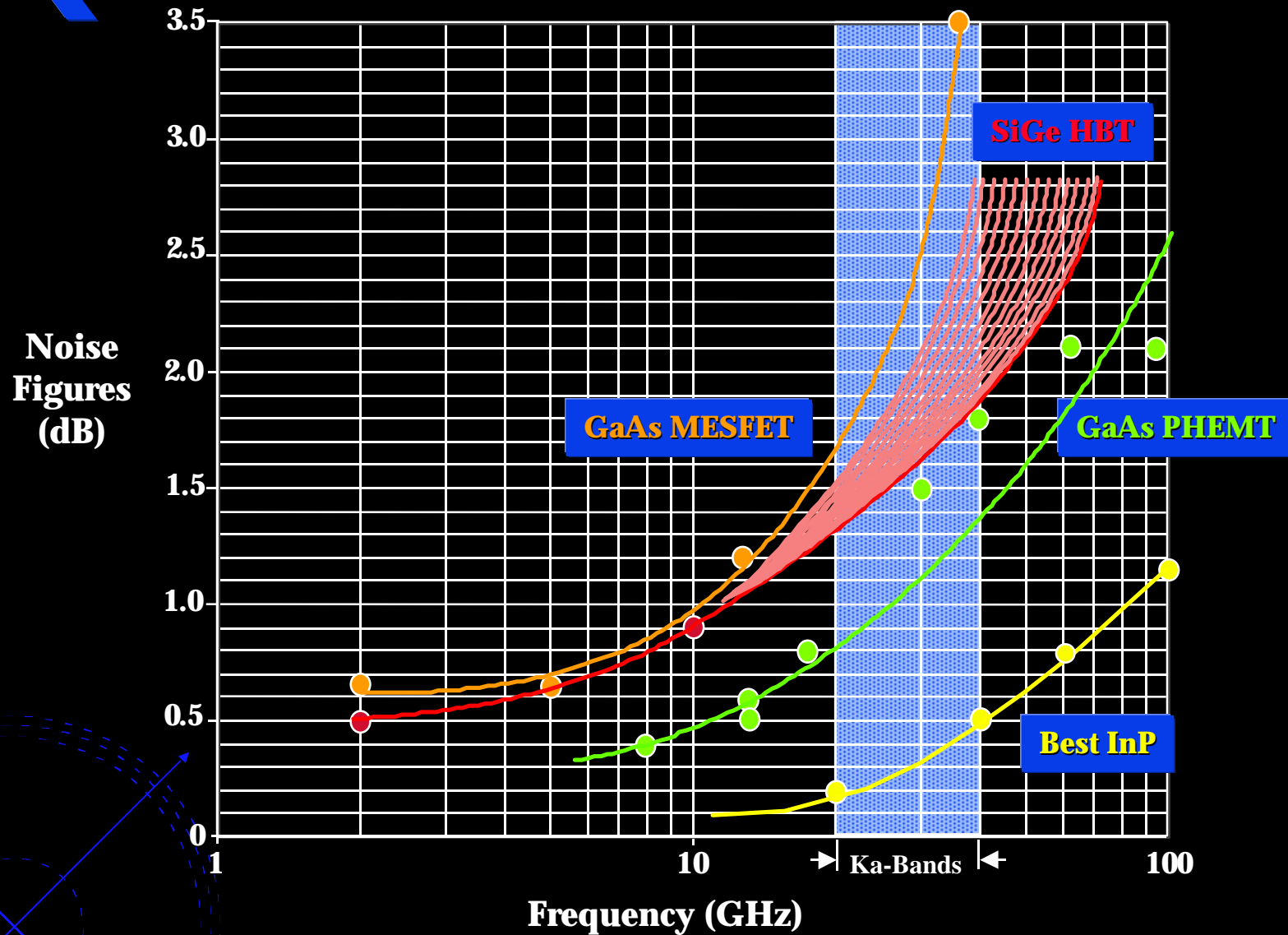
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# SEMICONDUCTOR DEVICE GAINS



# SEMICONDUCTOR DEVICE NOISE FIGURES

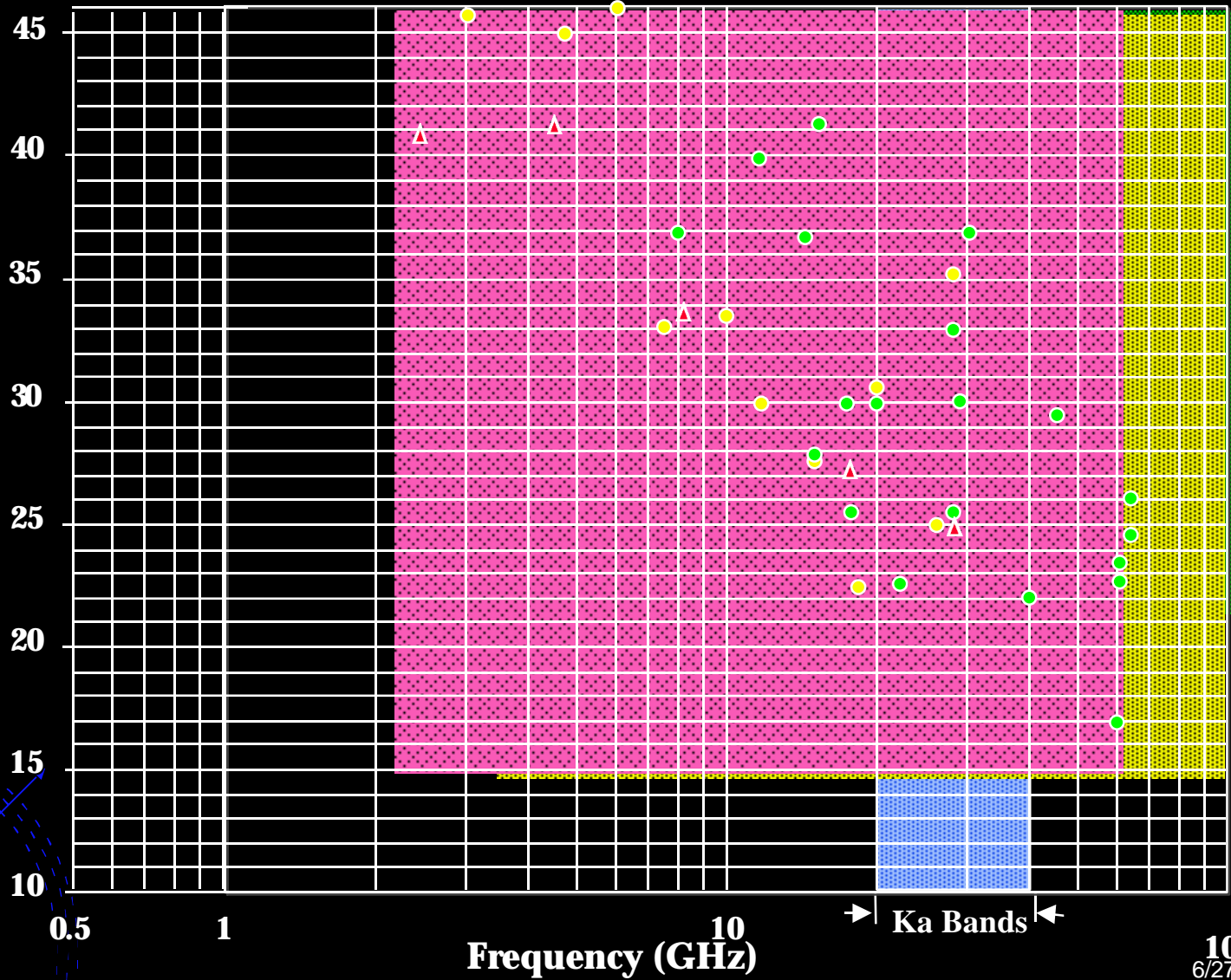


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# SEMICONDUCTOR DEVICE POWERS

- GaAs HBT
- PHEMT
- ▲ MESFET

Power(dBm)



100  
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# DEVICE PERFORMANCE COMPARISONS

	<b>InP HEMT</b>	<b>GaAs MESFET</b>	<b>GaAs PHEMT</b>	<b>GaAs HBT</b>	<b>SiGe HBT Low <math>\rho</math></b>
<b>NF(dB)</b>	0.4	1.6	0.8	3.5	1.5
<b>MAG(dB)</b>	12-15	-8	11	10	6
<b>Power(W)</b>	<2	-2	2+	0.2	?
<b><math>f_T</math></b>	>250	30	>125	>60	50
<b><math>f_{max}</math></b>	>250	76	>200	>200	95
<b>Osc. Perf.</b>	?	Med	Good	V.Good	V.Good
<b>Cost</b>	V.Hi	Med	Med/Hi	High	Low



# OUTLINE

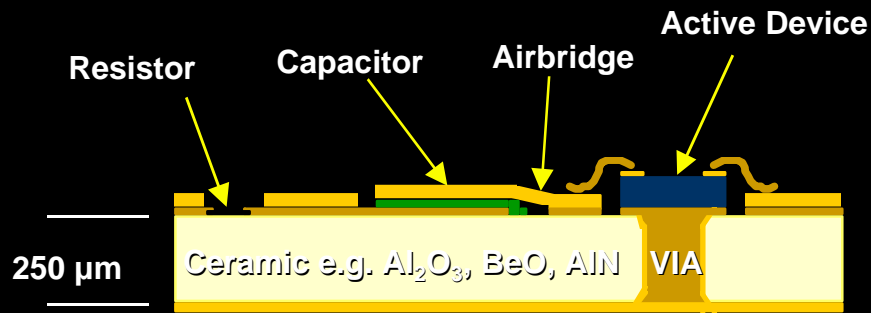
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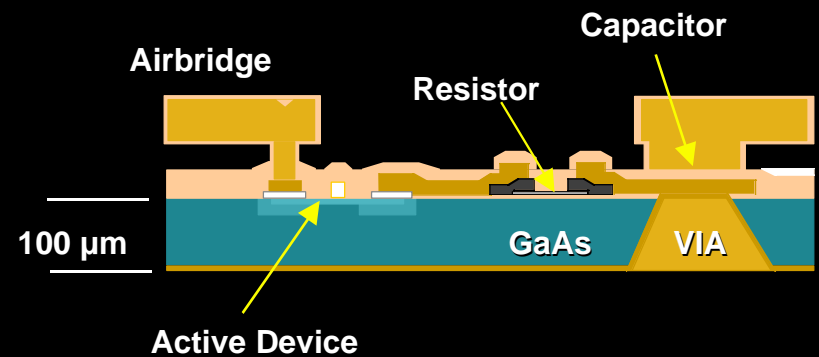
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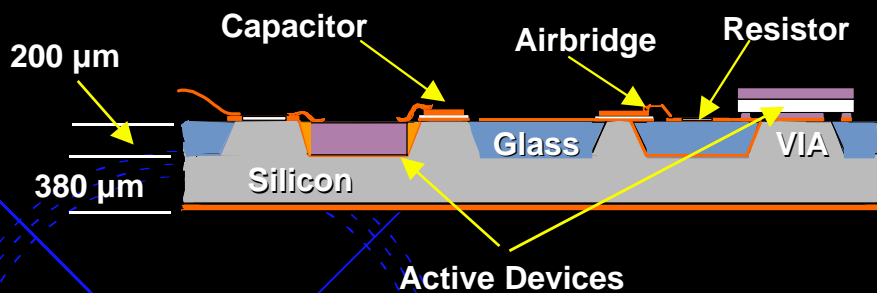
# CROSS-SECTIONS OF INTEGRATION TECHNOLOGIES



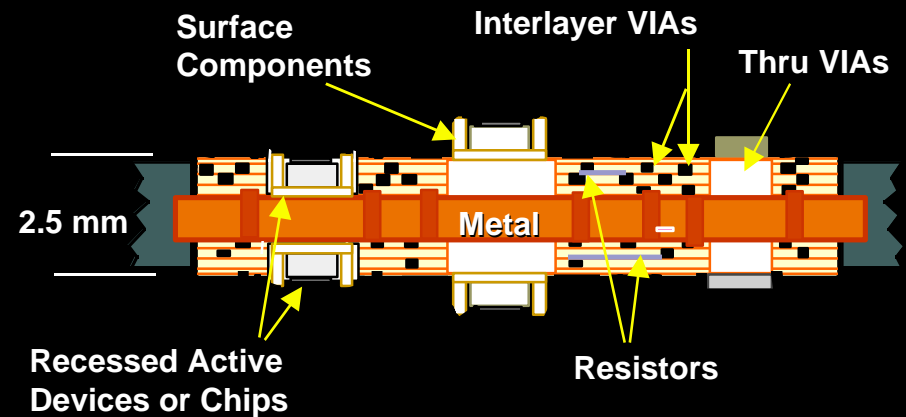
**Miniature Hybrid MIC**



**Monolithic MIC**



**Glass MIC**



**Low Temperature Cofired Ceramic**

# CRCC LMCS INTEGRATION TECHNOLOGIES

Technique	MMIC <sup>1</sup>	MHMIC	GMIC	Multilayer Soft Substrate	LTCC
<b>Ka Band Performance</b>	Compromised	Good	Moderate	Good	Mod-Good
<b>Flexibility</b>	Poor	Moderate	Mod-Good	Moderate	Good
<b>Reliability</b>	Highest	Good	Good	Lowest	Good
<b>Heatsinking</b>	Poor	Moderate <sup>2</sup>	Mod-Good	Mod-Poor	Mod-Good
<b>Size</b>	Minimum	Moderate	Moderate	High	Moderate
<b>Mechanical Assembly</b>	Minimum	Moderate	Moderate	Most	Moderate
<b>Yield</b>	Poor	Moderate	Moderate	Good	Good
<b>Cost in Large Volume</b>	High <sup>3</sup>	Moderate	Mod-Low	Mod-Low <sup>4</sup>	TBD
<b>Maturity</b>	Advanced	Advanced	Proprietary	Emerging @Ka	Emerging @Ka
<b>Accessibility</b>	Limited	Moderate	None	Widely	Limited

<sup>1</sup> MMIC here refers to its use to integrate most or all functions onto one or two MMIC chips.

<sup>2</sup> Can be better if Aluminum Nitride or diamond used.

<sup>3</sup> High integration level reduces yields and drives cost up. Until process yields substantially improved, cost high.

<sup>4</sup> Depends on ability to package devices cheaply or use chips

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# Range of Parameters for Three Processes

PARAMETER	MMIC	MHMIC	GMIC
<b>MIM Capacitors</b>			
• Capacitance Range	80 pF	0.2 to 50 pF	0.2 to 80 pF
• Breakdown Voltage	15 V	50 V	150 V
<b>Resistors</b>			
• Value $\Omega/\square$	50 $\Omega/\square \pm 5\%$ (TaN)	25 to 100 $\Omega / \square \pm 5\%$ (TaN) 1000 $\Omega / \square$ (Semi)	100 $\Omega / \square \pm 5\%$
• Range of R	5 to 10 k $\Omega$	5 to 2 k $\Omega$	5 to 10 k $\Omega$
<b>Inductors</b>	0.2 to 15 nH	0.1 to 20 nH	1 to 15 nH
<b>Critical Dimensions</b>			
• Plate-up Layer Width	0.2 $\mu\text{m}$	15 $\pm$ 2 $\mu\text{m}$	10 $\pm$ 1.2 $\mu\text{m}$
• Airbridge Layer Width	4 $\mu\text{m}$	20 $\pm$ 2 $\mu\text{m}$	20 $\pm$ 4 $\mu\text{m}$
• Plate-up thickness	3 $\mu\text{m}$	4 $\mu\text{m}$	3 $\mu\text{m}$
<b>Substrate Properties</b>			
• Epsilon	12	4-10	4 (Glass)
• Thickness	200 $\mu\text{m}$	250-625 $\mu\text{m}$	90 $\mu\text{m}$
<b>Microstrip Properties</b>			
• 50 $\Omega$ linewidth	70 $\mu\text{m}$	250 $\mu\text{m}$ (250 thk & $\epsilon=10$ )	400 $\mu\text{m}$
• $\lambda$ @ 28 GHz	3.75 mm	4.0 mm	6 mm
• Losses @ 28 GHz	0.7 dB/cm	0.3 dB/cm	0.3 dB/cm
<b>Number of Process Steps</b>	10-14	6	8

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# OUTLINE

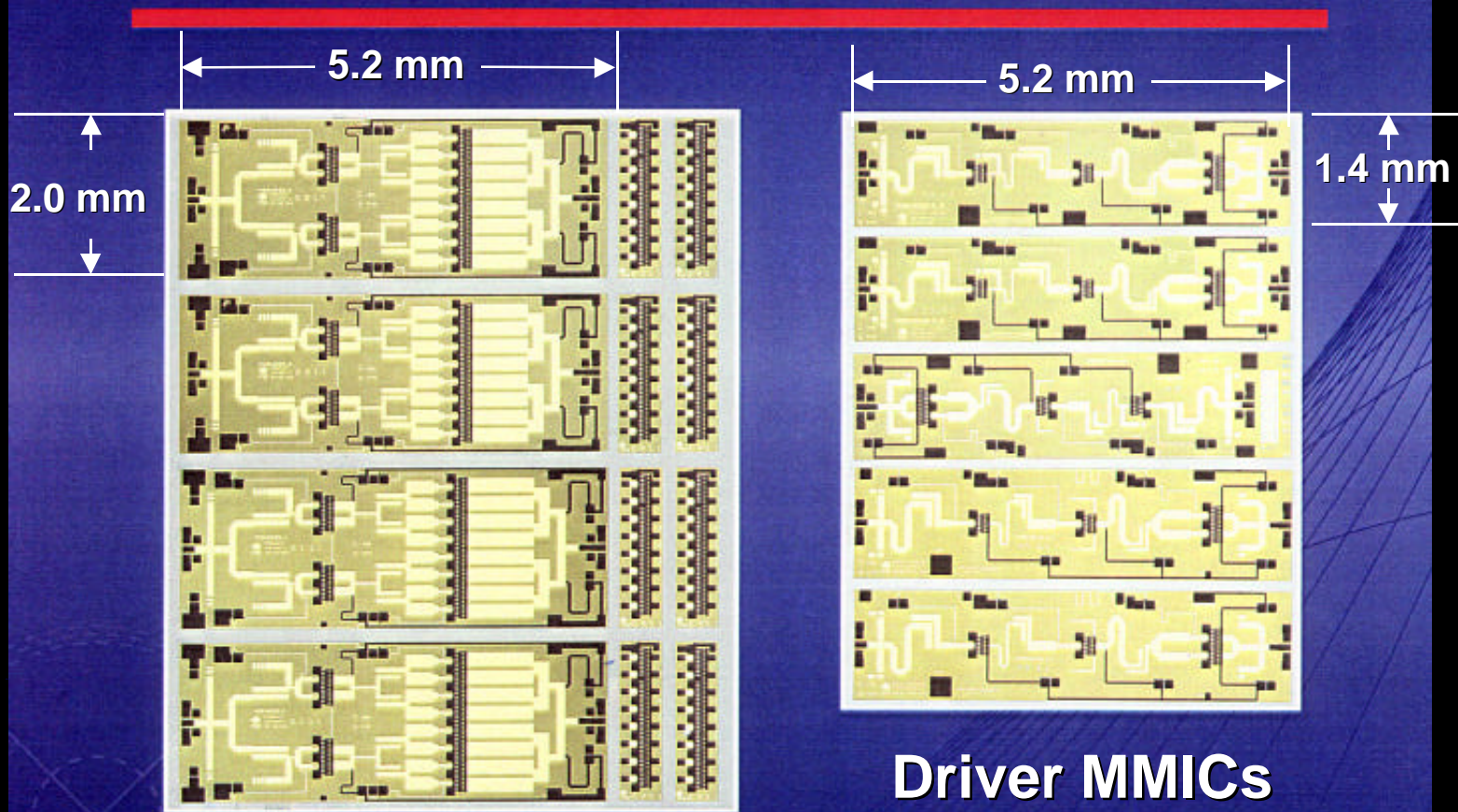
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# 25 - 30 GHz Power Amplifier and Driver MMICs

## M961NG MMIC RETICLE 1996



97-2136

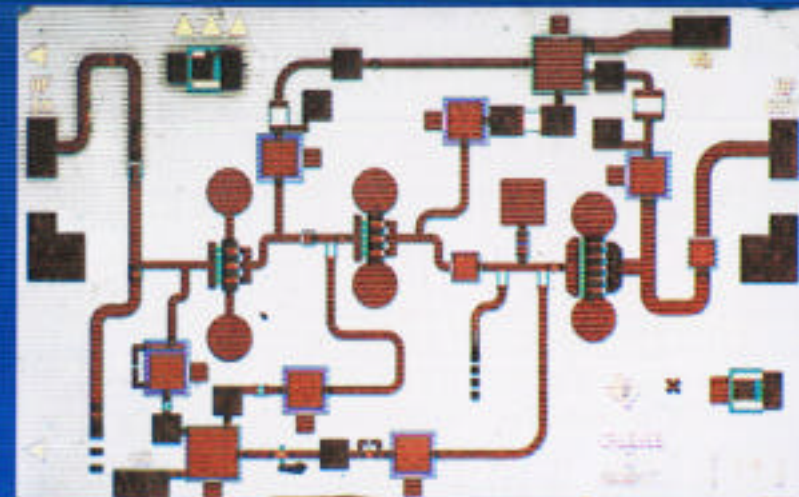
1 Watt MMICs



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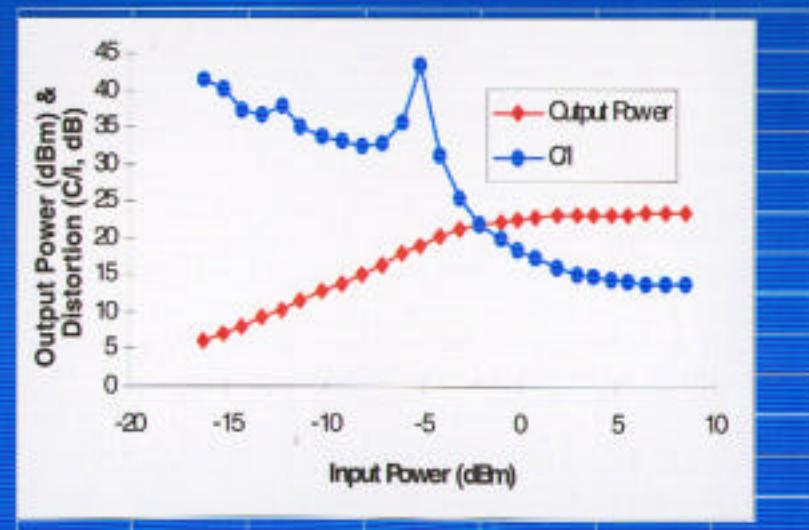
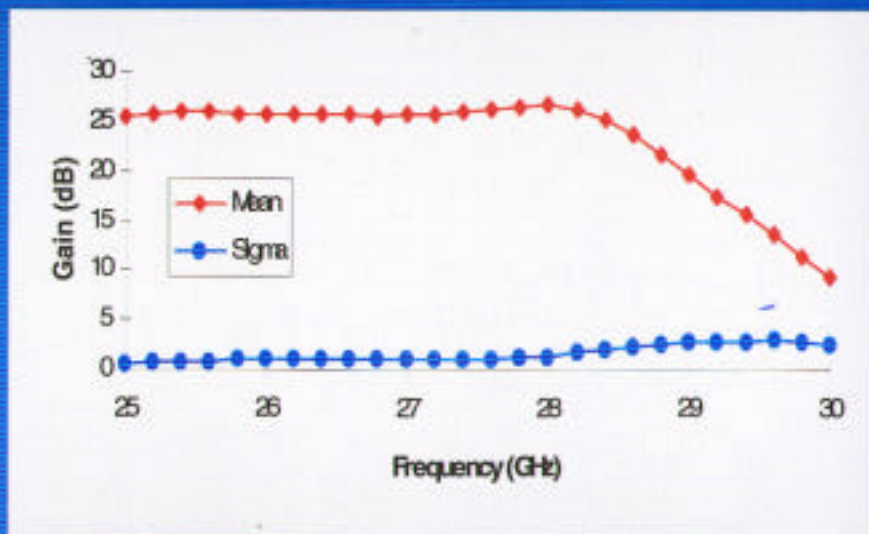
## Electrical Characteristics

- Operating Frequency: 27.5 - 28.5 GHz
- Gain: 25 dB Mean
- Output Power: 23 dBm
- Single Supply Voltage
- Linearity: 31 dB C/I @ 20 dBm Pout



Gain

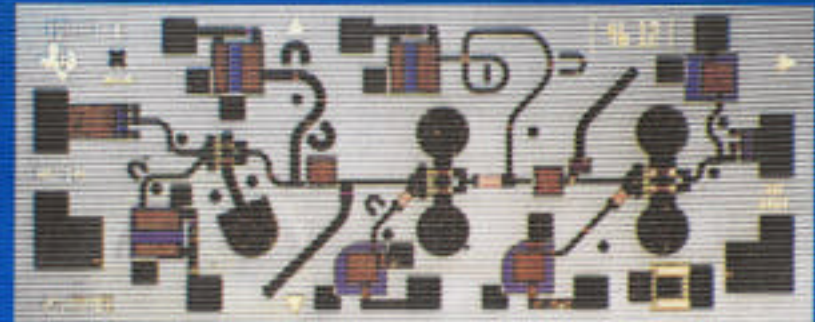
Output Power



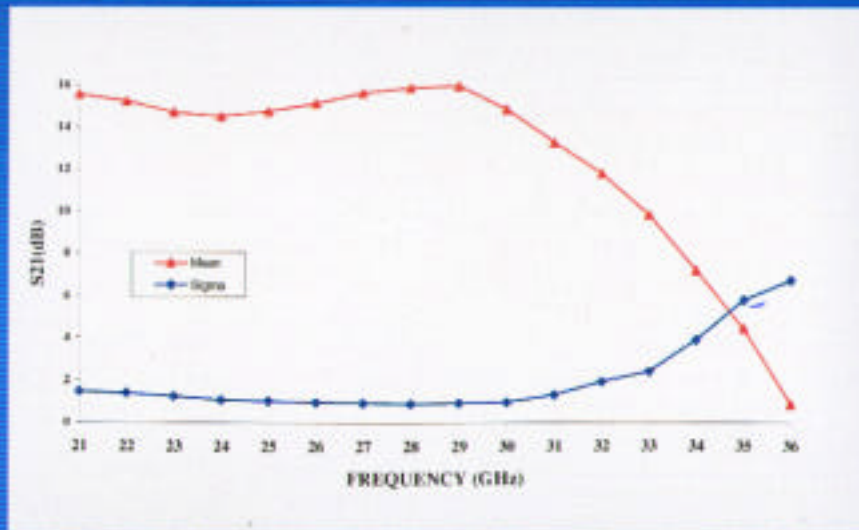
# Low-Noise Amplifier MMIC

## Electrical Characteristics

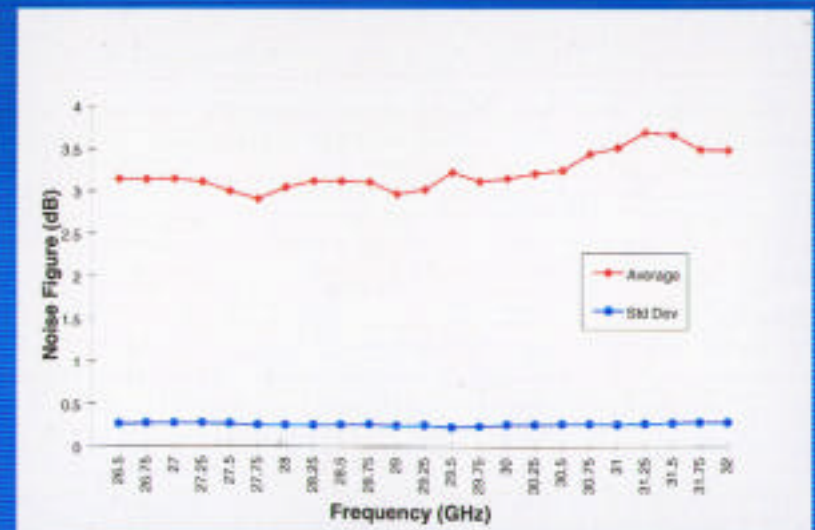
- Operating Frequency: 27.5 - 28.5 GHz
- Noise Figure: 3.1 dB Mean
- Gain: 16 dB Mean
- Single Supply Voltage



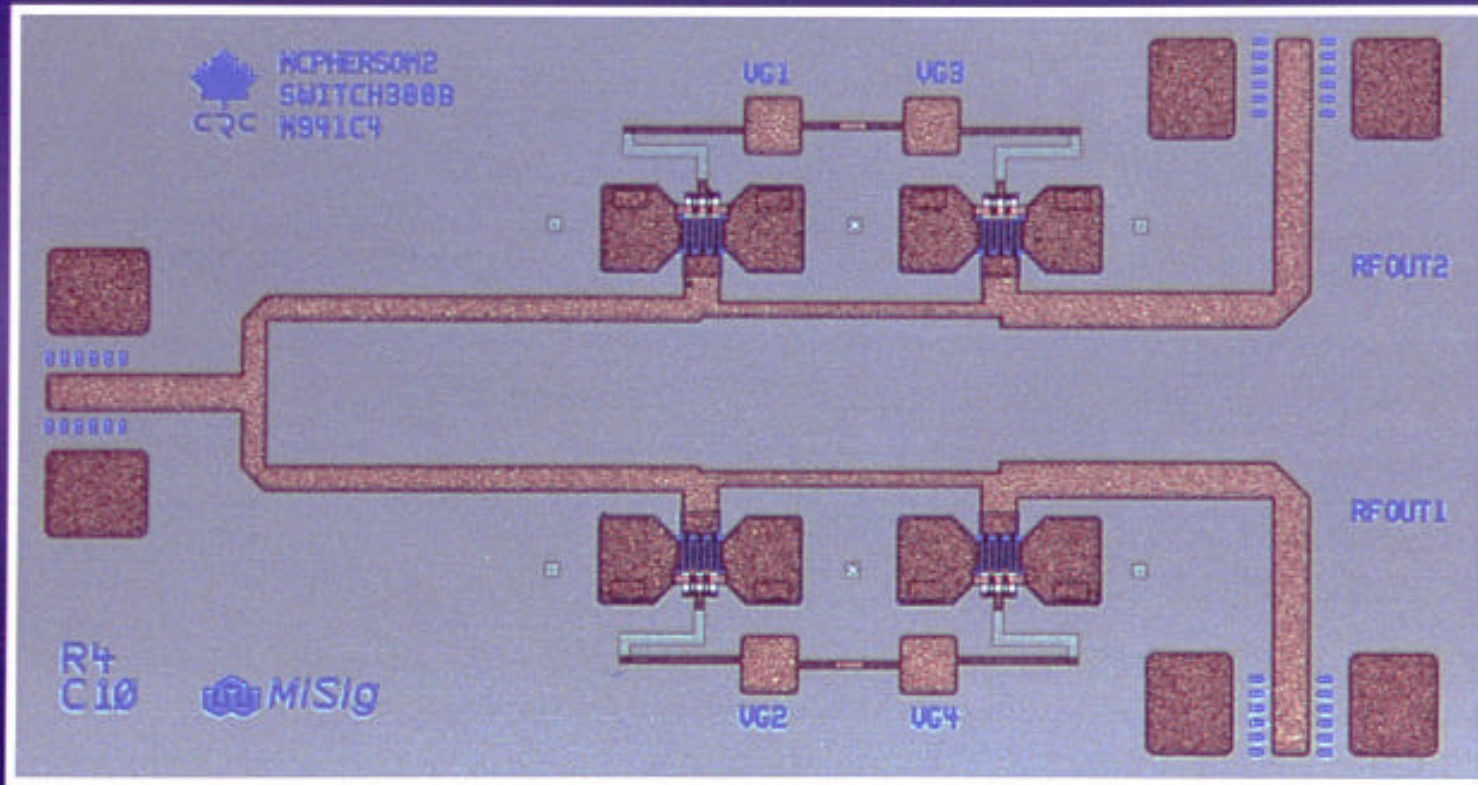
Gain



Noise Figure

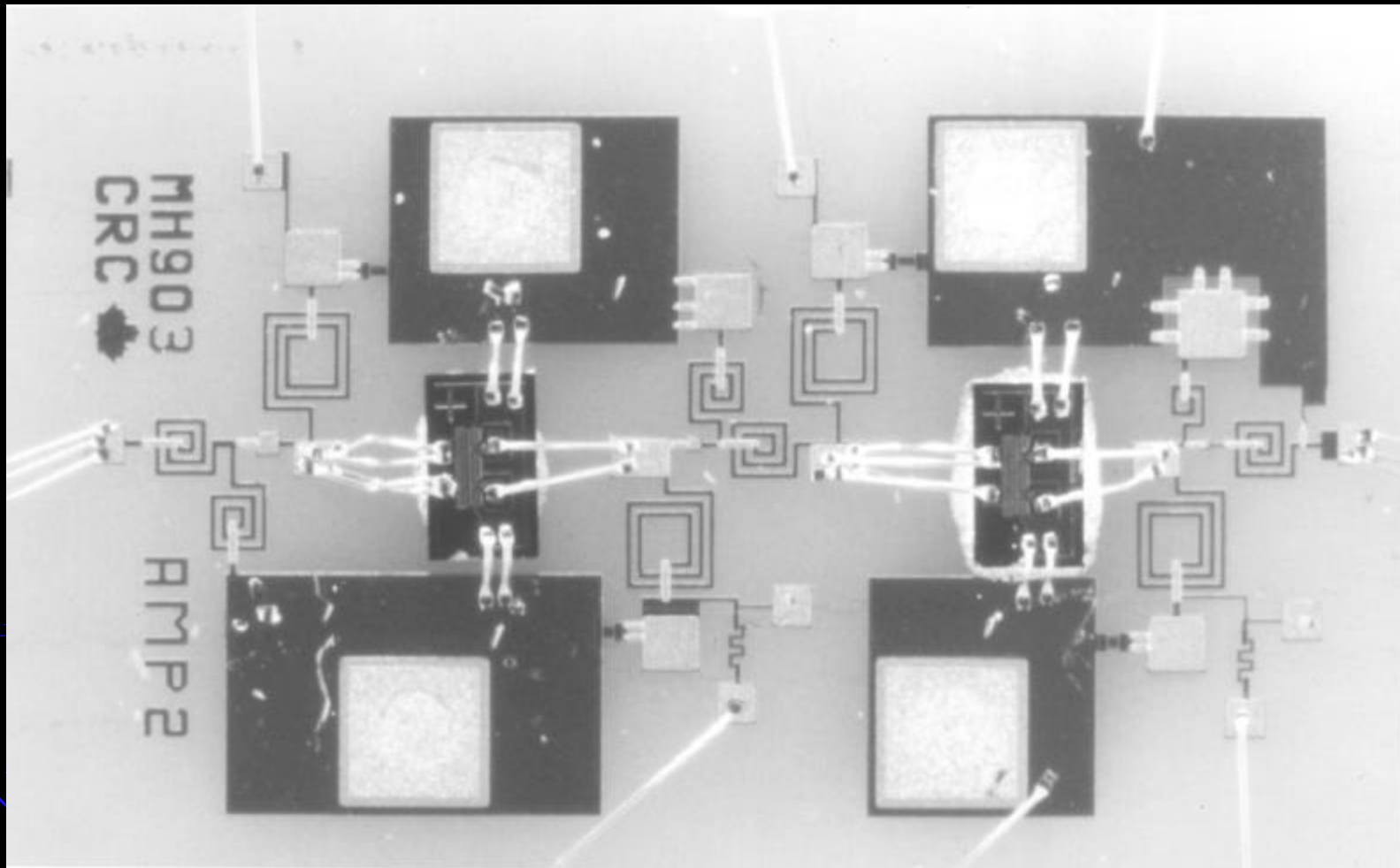


# LOW LOSS HIGH ISOLATION BROADBAND EHF SWITCH



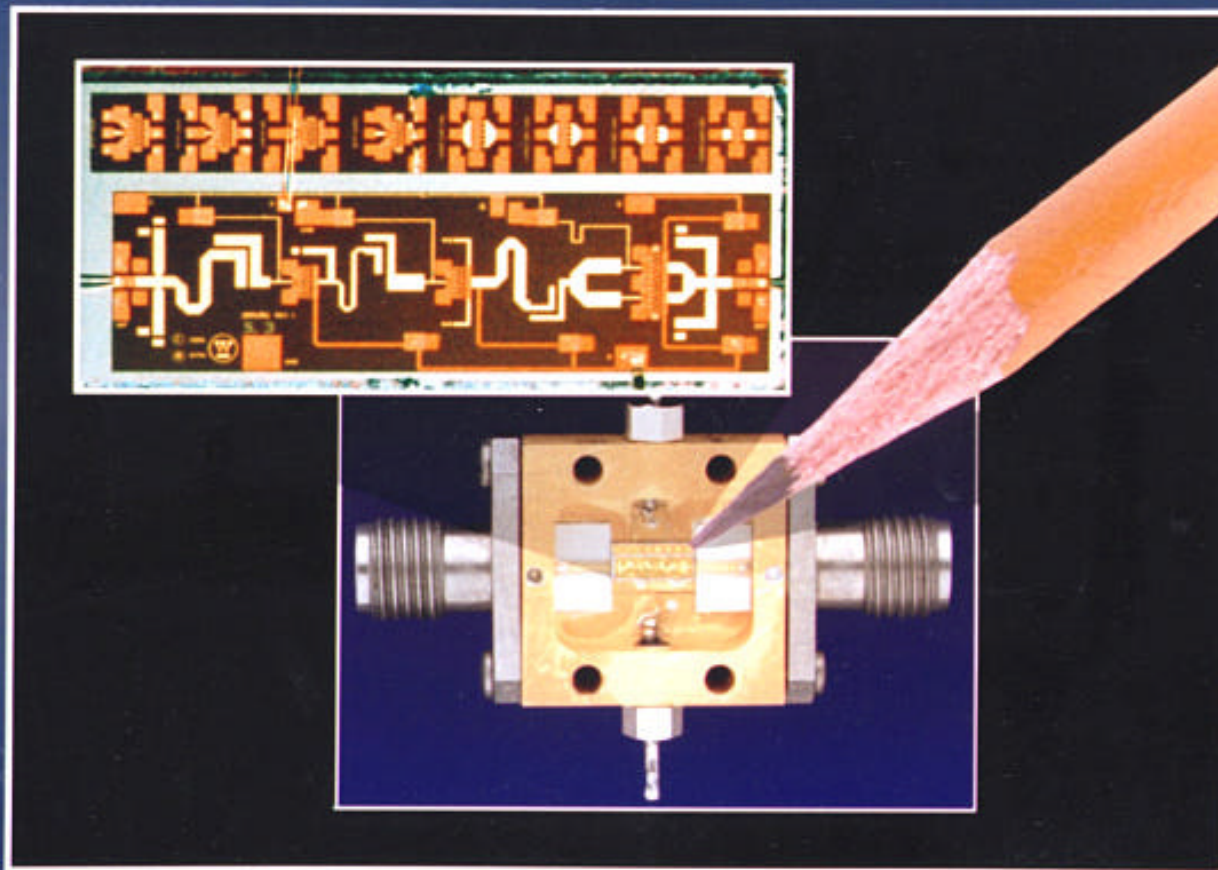


# 28 GHz Amplifier in Miniature Hybrid MIC Technology



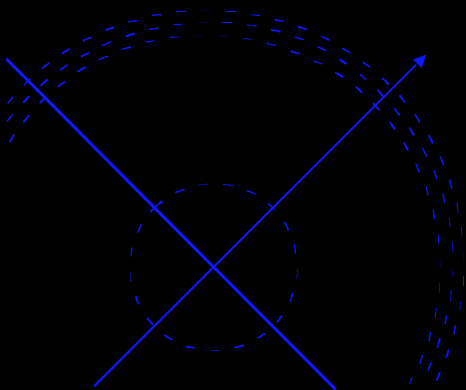
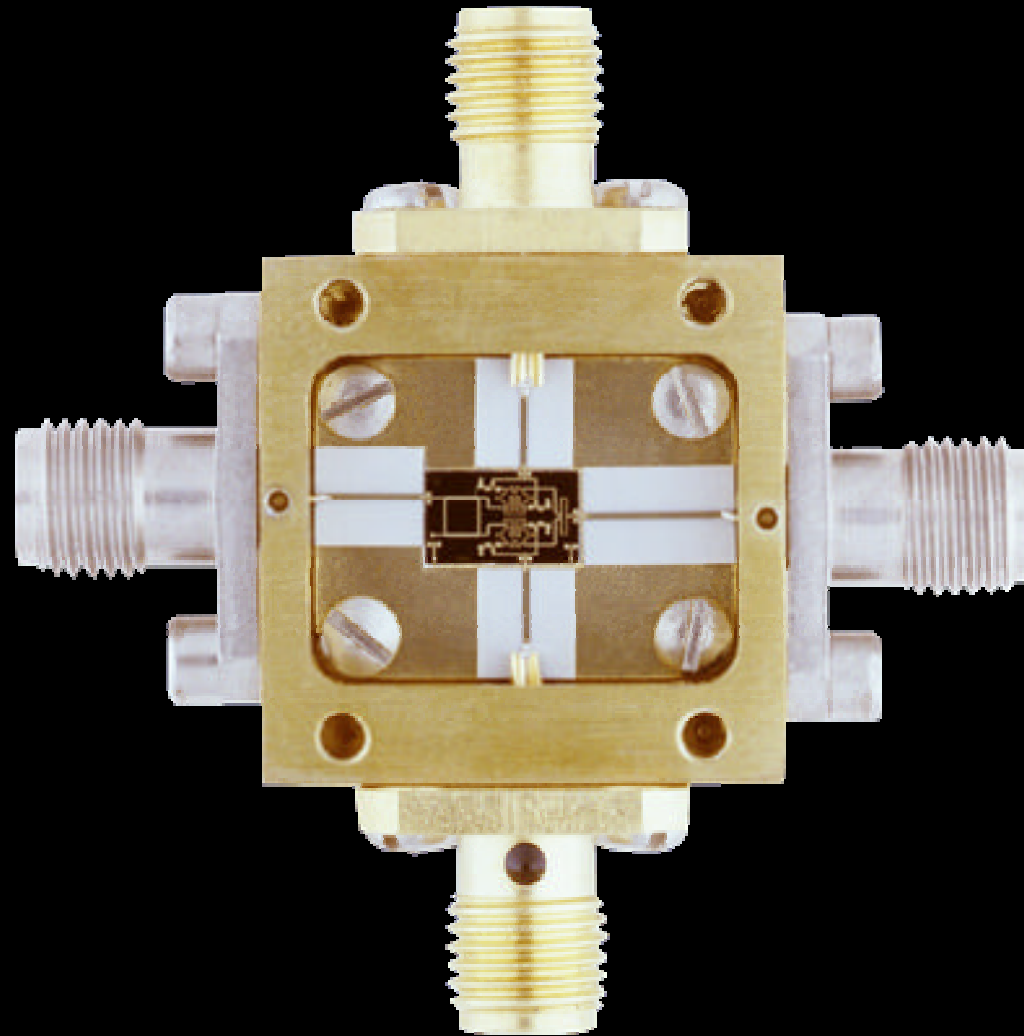
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# 30 GHz 1/2 Watt Amplifier





# K-Band Direct I/Q Demodulator

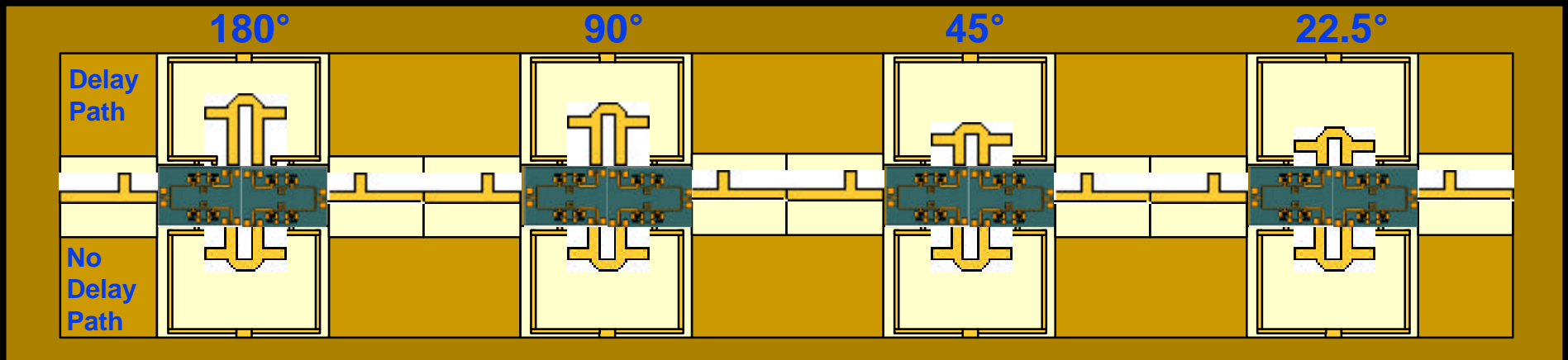


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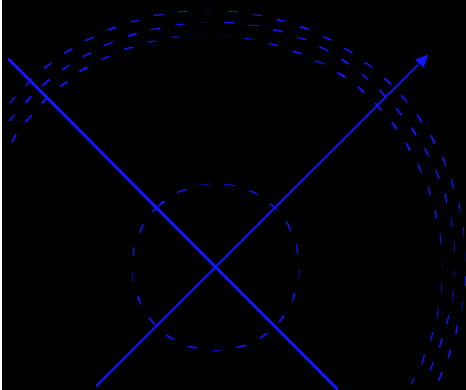
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# Phase Shifter Configuration and MHMIC Assembly

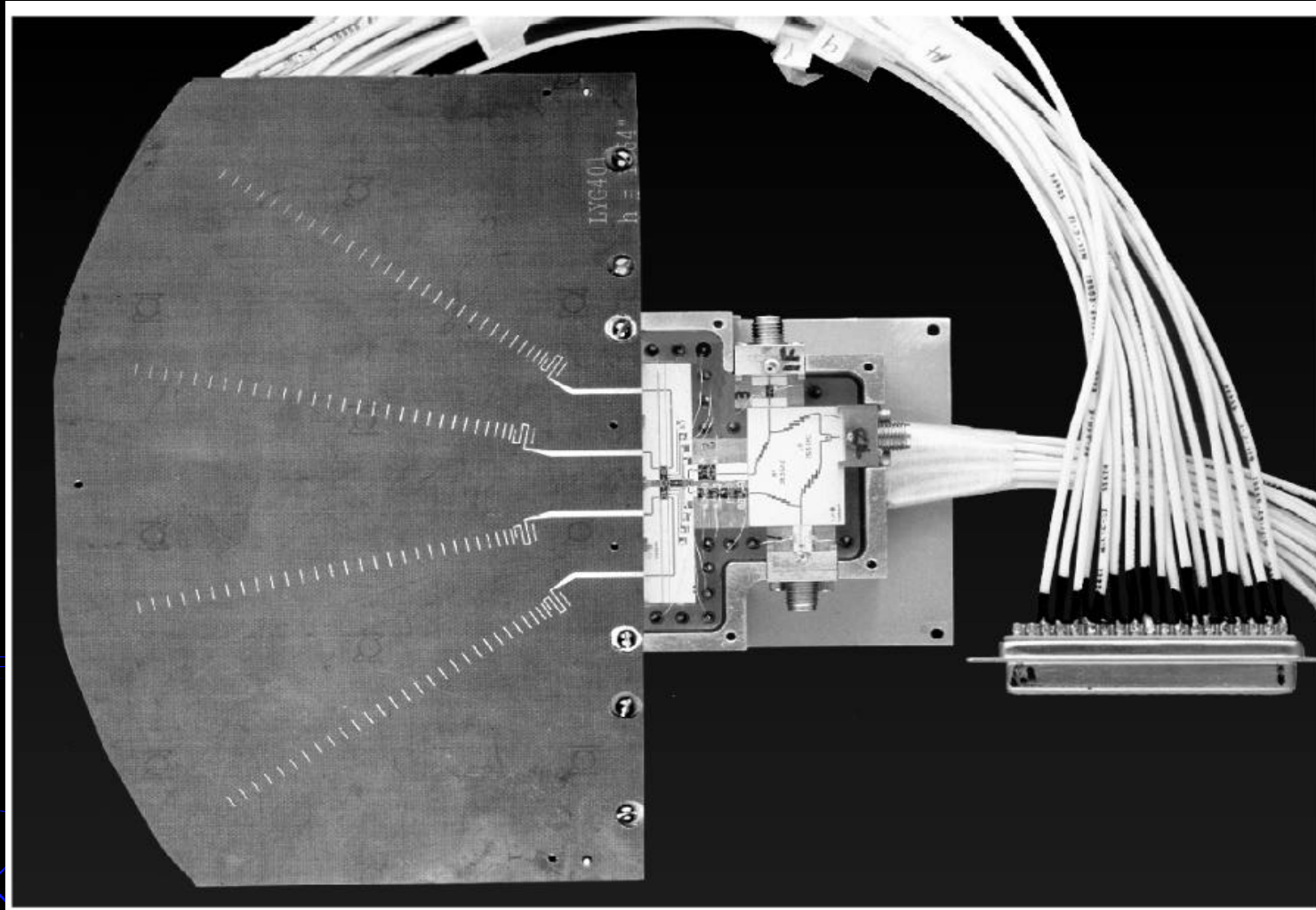


4 Bit Phase Shifter Assembly





# 28 GHz Switched Beam Receiver/Transmitter



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# OUTLINE

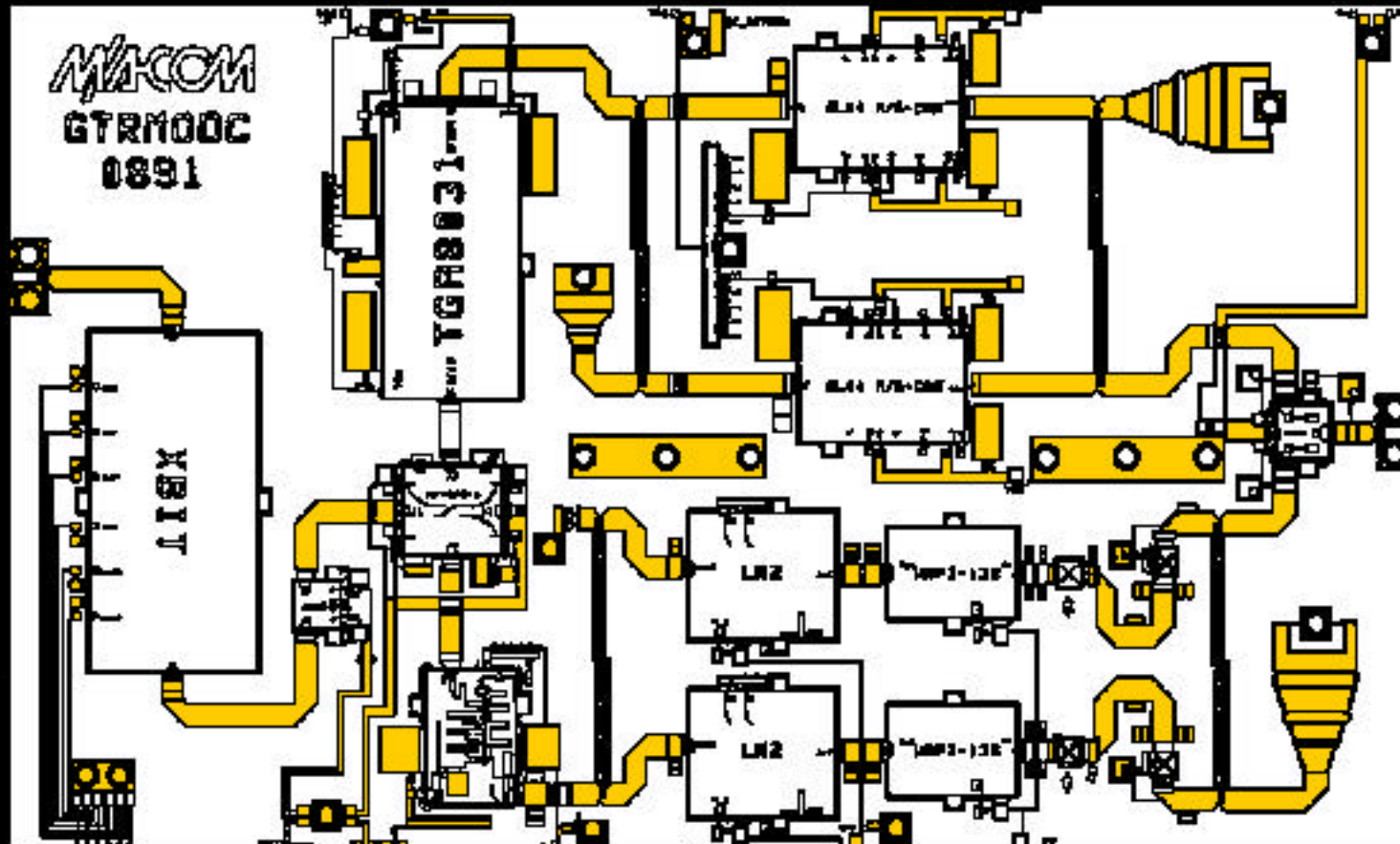
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# MACOM GMIC Technology (Low Frequency)



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# INTEGRATION CONSIDERATIONS

<b>CHARACTERISTIC</b>	<b>HMIC</b>	<b>MHMIC/GMIC</b>	<b>MMIC</b>
<b>NUMBER OF FABRICATION STEPS</b>	<b>1-2 PER SECTION</b>	<b>5-8</b>	<b>10-14</b>
<b>MASK EXPENSES</b>	<b>LOW</b>	<b>MODERATE</b>	<b>HIGH</b>
<b>DESIGN ITERATION TIME</b>	<b>1 MONTH</b>	<b>&lt;2 MOS</b>	<b>3-6 MOS</b>
<b>MANUAL MECHANICAL INVOLVEMENT</b>	<b>ALL ACTIVE &amp; PASSIVE CHIPS &amp; I/O's</b>	<b>ACTIVE CHIPS &amp; I/O's</b>	<b>I/O's ONLY</b>
<b>NUMBER OF CIRCUITS PER CYCLE</b>	<b>1</b>	<b>10's -100's</b>	<b>100's - 1000's</b>