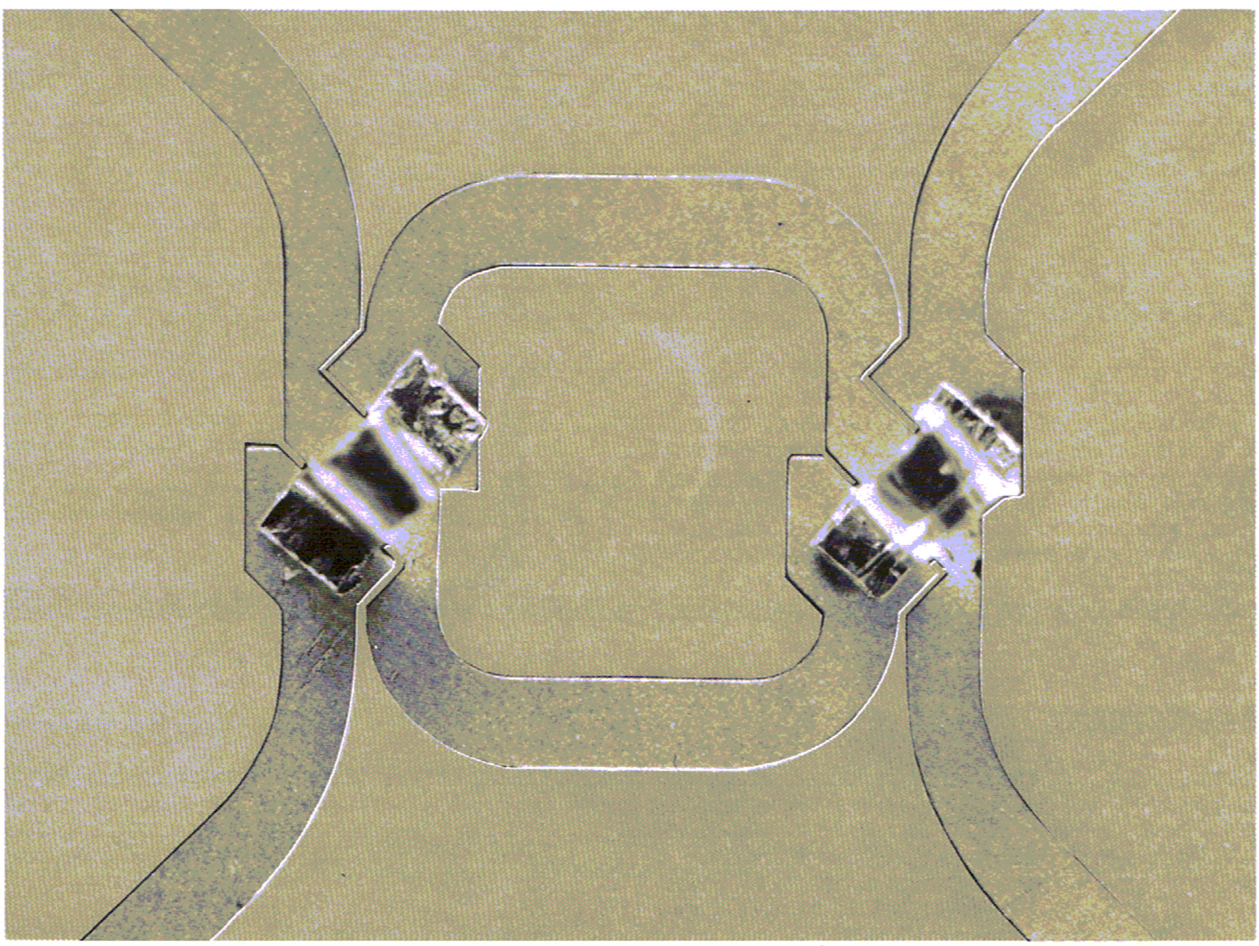
# MICROWAVE AND MILLIMETER WAVE INTEGRATED COMPONENTS AND SUBSYSTEMS

PLAMIC

*PLANAR MICROWAVE INTERNATIONAL CORPORATION*



PLAMIC

## FACILITY

PLAMIC's facility has a working area that is specifically designed for the fabrication of Microwave Integrated Circuits and subsystems. The new facility is capable of handling typically a volume of 800 MIC circuit assemblies a month and is designed to meet better than class 100,000 cleanroom standards. The clean area is divided into two discrete sections—a chemical fabrication area and an assembly area. Each area functions independently of the other. Positive air pressure is maintained in both areas and the temperature is controlled to ±2°F over a temperature range of 66° to 74°F in both areas, even though the ambient temperature may have large variations. The chemical fabrication area is a safe-light area (yellow light) that is utilized for photo-imaging, photoresist application, mask aligning, photoresist development and chemical milling of circuits. The personnel in the circuit assembly area perform the task of final manufacturing after the circuits have been etched. The types of circuits that are produced range from passive components, such as 3dB hybrids, to active circuits, such as single and multi-stage FET or bipolar amplifiers. Additionally, subsystems such as receiver front ends and transponders utilizing modular construction techniques are also produced in the same facility using the individual components.

**1.** *All RFQs and RFPs are reviewed by the staff for an optimum in design, cost and scheduling.*

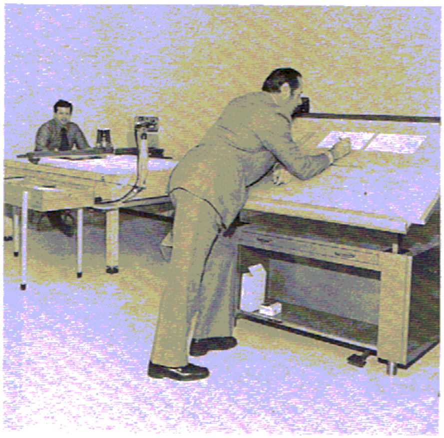
## PLANAR TECHNOLOGY

The main emphasis at PLAMIC is the use of proprietary *planar* technology techniques to fabricate Microwave Integrated Circuits (MICs) over wide frequency ranges. The circuits and subsystems manufactured use packaged and chip devices. Emphasis is on smaller compact circuits using chip devices and wire or ribbon bonding techniques. These circuits and subsystems can be manufactured to meet the requirements of MIL-STD-38510A and MIL-STD-883 or other ruggedized quality and reliability standards.

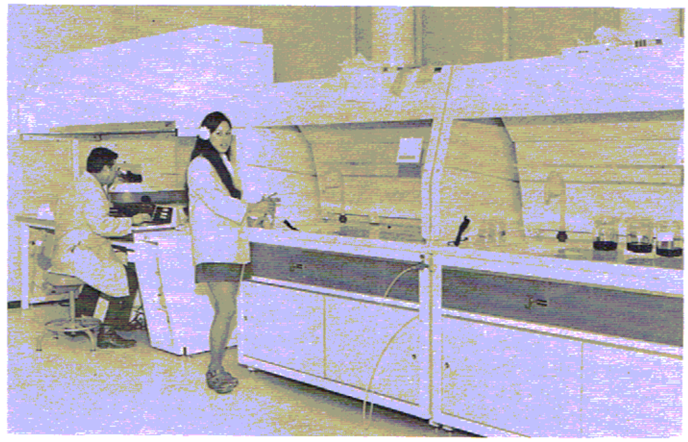
**4.** *MIC fabrication can involve several bonding techniques, such as ultrasonic, thermocompression and wedge bonding of the chip and packaged devices.*

## PERSONNEL

The MIC facility is staffed with experienced personnel at all levels. MIC fabrication personnel have many years of experience in all aspects of MIC and subsystem production. This includes circuit layout, art work preparation, fabrication, assembly, and thorough familiarity with the production of bipolar and FET amplifiers utilizing small and complex geometry devices. At the Manager/Engineer level, the individuals have extensive experience in the design and processing of MICs and subsystems. This team has actively pursued the design, production and testing of Microwave Integrated Circuits for the past ten years. Some of the key members are responsible for applying unique MIC techniques for multioctave bandwidth circuits up to 18 GHz and have also successfully applied these techniques to 60 GHz and above. Many of the millimeter wave components developed by members of the technical staff at PLAMIC are innovative and the first of their kind.



**2.** *Typical design of an MIC involves computer analysis optimization, rubylith cutting of the art work, final mechanical layout and approval.*



**3.** *PLAMIC offers modern environmentally controlled clean rooms for photoresist processing and chemical etching.*

**5.** *At millimeter wavelengths, assembly of the MIC substrates into the final package requires close attention to mechanical tolerances.*

**6.** *Test and measurement of MIC assemblies involves use of modern broadband test equipment.*

## CHIEF CAPABILITIES

- A quick reaction capability—six hours from mask to circuit.
- Multi-talented personnel.
- Modern equipment especially installed and designed for MIC fabrication.
- Facilities for etching linewidths as small as 0.001 inches typically.
- Facilities for etching and up-plating gapwidths as small as 0.0004 inches typically.
- Design and production of broadband passive circuits for frequency ranges up to 100 GHz.
- Design and production of broadband active circuits up to 100 GHz.
- Meet MIL-Q-9858A, MIL-I-45208A, MIL-STD-38510A.

## PLAMIC MEANS MIC

**PLAMIC** (Planar Microwave International Corporation) is located approximately 40 miles south of the San Francisco airport. PLAMIC's expertise in design and development of MICs provides it with a unique capability to meet many demanding *electronic warfare* and *communication* requirements. At PLAMIC *planar* technology is considered the key ingredient for meeting many of the stringent size, weight and performance requirements of both military and civilian applications. PLAMIC is capable of providing MIC components and subsystems for airborne, submarine, shipbound, ground-level, and satellite requirements, over a frequency range of 1 to 100 GHz.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REPRESENTED BY

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# TEST RESULTS

# AND

# DATA ON KEY

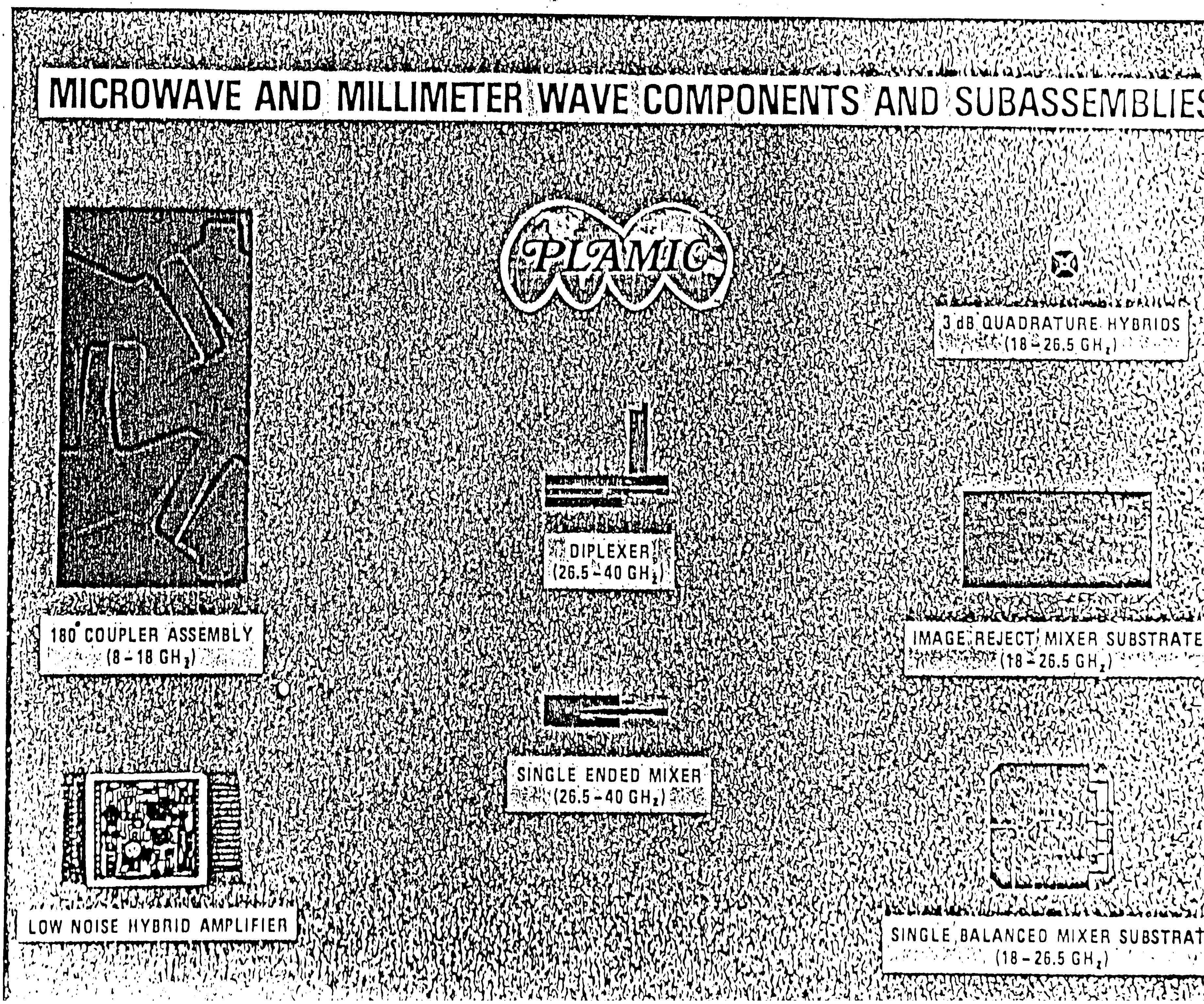
# PLAMIC PRODUCTS

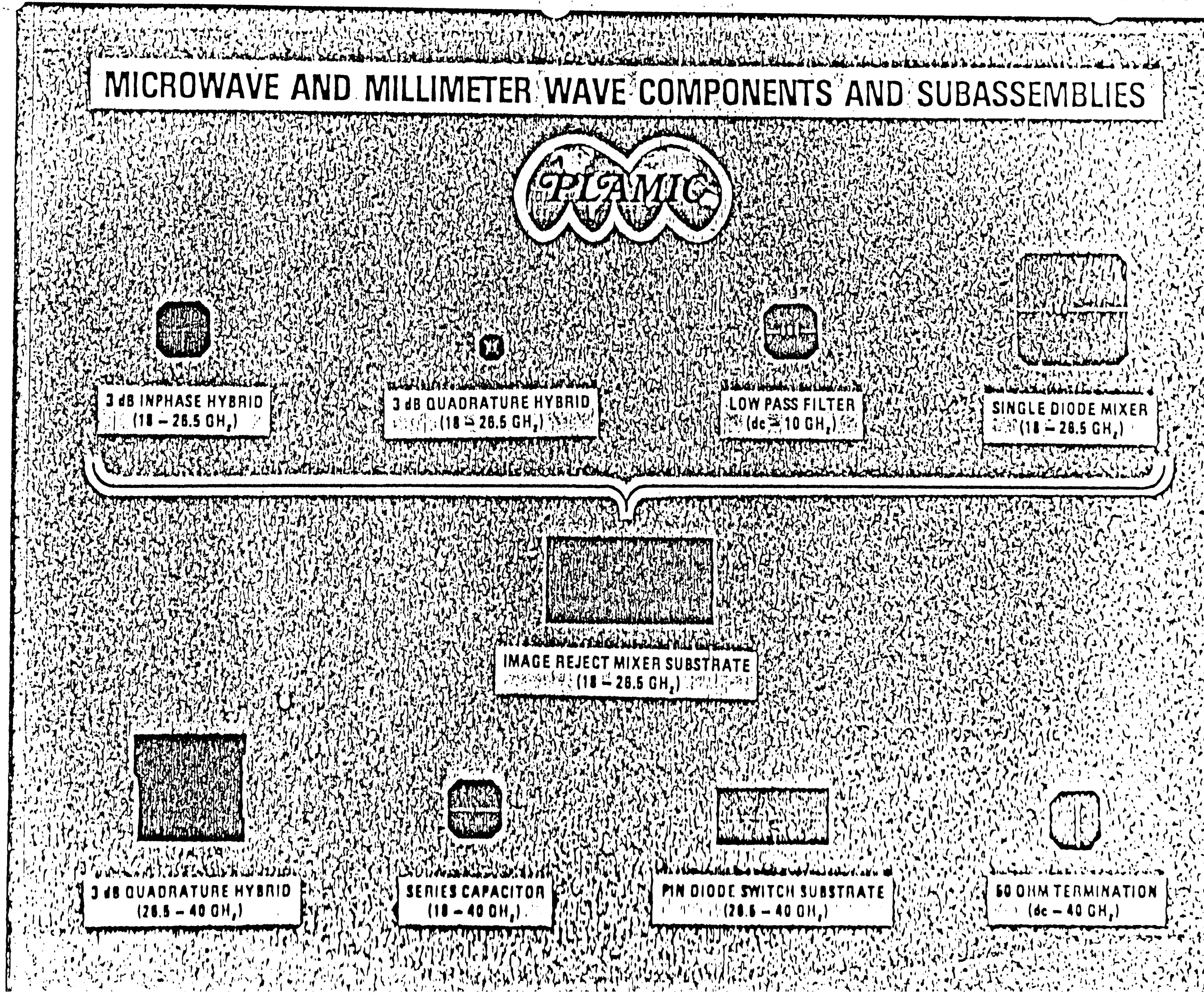
CABLE ADDRESS: PLAMIC

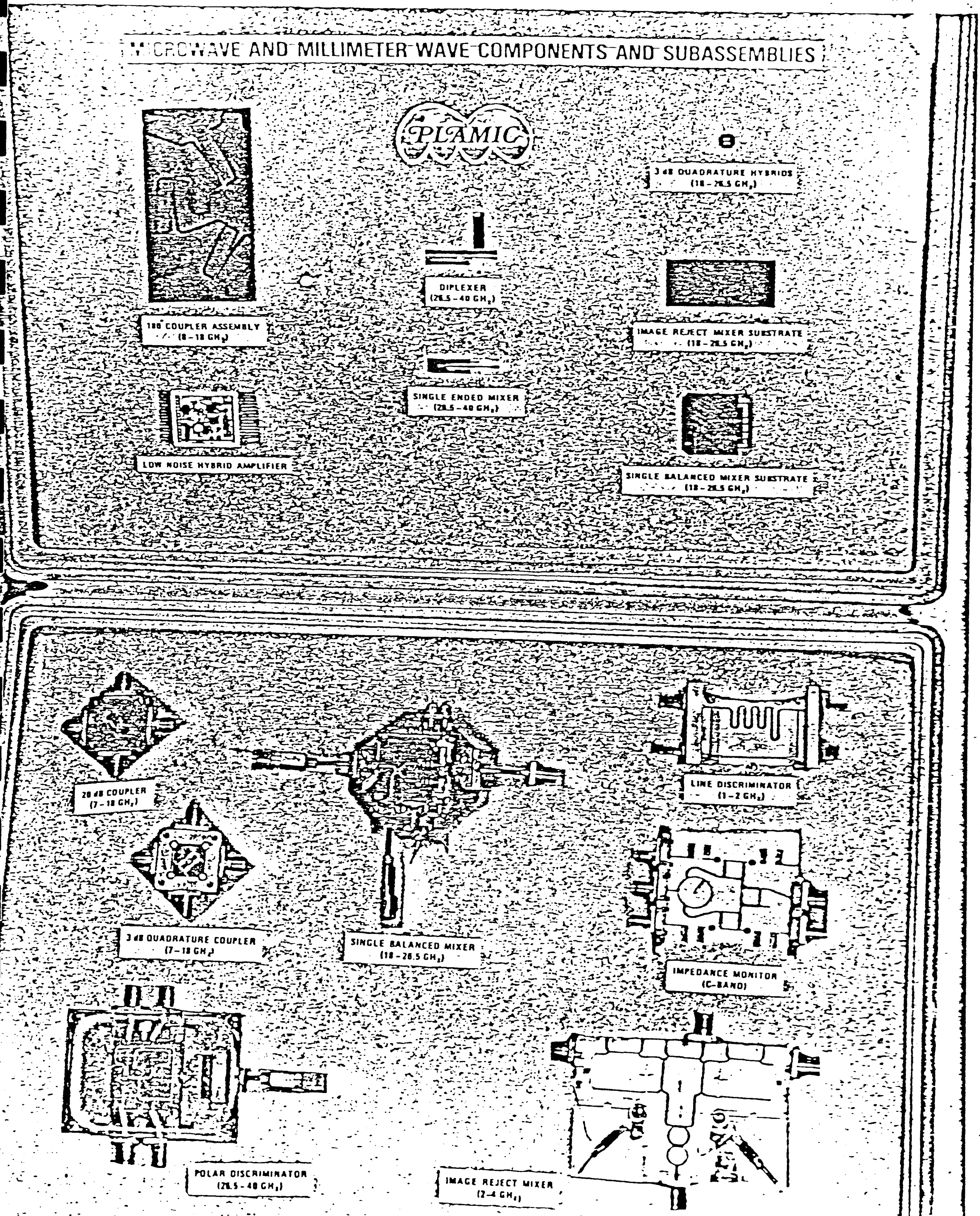
# INDEX



* PREVIOUSLY DEVELOPED PRODUCTS BY PLAMIC STAFF MEMBERS ALSO INCLUDED.


MICROWAVE AND MILLIMETER WAVE COMPONENTS AND SUBASSEMBLIES
PLAMIC
180° COUPLER ASSEMBLY (8 - 18 GH$_z$)
DIPLEXER (26.5 - 40 GH$_z$)
3 dB QUADRATURE HYBRIDS (18 - 26.5 GH$_z$)
IMAGE REJECT MIXER SUBSTRATE (18 - 26.5 GH$_z$)
SINGLE ENDED MIXER (26.5 - 40 GH$_z$)
LOW NOISE HYBRID AMPLIFIER
SINGLE BALANCED MIXER SUBSTRAT (18 - 26.5 GH$_z$)


MICROWAVE AND MILLIMETER WAVE COMPONENTS AND SUBASSEMBLIES
PLAMIC
3 dB INPHASE HYBRID (18 – 26.5 GHz)
3 dB QUADRATURE HYBRID (18 – 26.5 GHz)
LOW PASS FILTER (dc – 10 GHz)
SINGLE DIODE MIXER (18 – 26.5 GHz)
IMAGE REJECT MIXER SUBSTRATE (18 – 26.5 GHz)
3 dB QUADRATURE HYBRID (26.5 – 40 GHz)
SERIES CAPACITOR (18 – 40 GHz)
PIN DIODE SWITCH SUBSTRATE (26.5 – 40 GHz)
50 OHM TERMINATION (dc – 40 GHz)


MICROWAVE AND MILLIMETER WAVE COMPONENTS AND SUBASSEMBLIES
PLAMIC
3 dB QUADRATURE HYBRIDS
(18 – 26.5 GHz)
DIPLEXER
(26.5 – 40 GHz)
180° COUPLER ASSEMBLY
(8 – 18 GHz)
IMAGE REJECT MIXER SUBSTRATE
(18 – 26.5 GHz)
SINGLE ENDED MIXER
(26.5 – 40 GHz)
LOW NOISE HYBRID AMPLIFIER
SINGLE BALANCED MIXER SUBSTRATE
(18 – 26.5 GHz)
20 dB COUPLER
(7 – 18 GHz)
LINE DISCRIMINATOR
(1 – 2 GHz)
3 dB QUADRATURE COUPLER
(7 – 18 GHz)
SINGLE BALANCED MIXER
(18 – 26.5 GHz)
IMPEDANCE MONITOR
(C-BAND)
POLAR DISCRIMINATOR
(26.5 – 40 GHz)
IMAGE REJECT MIXER
(2–4 GHz)

| Test Parameter | MIXER TYPE: 18 to 26 GHz Balanced Mixer | MIXER TYPE: 18 to 26 GHz Image Reject Mixer | MIXER TYPE: 26 to 40 GHz Balanced Mixer |
|---|---|---|---|
| Conversion loss at +6 dBm LO power | 7.5 dB ±0.6 dB | 8.7 dB ±0.8 dB | 7.3 dB ±0.6 dB |
| Noise figure at +6 dBm LO power (60 MHz IF amplifier with 1.5 dB NF) | 9.8 dB at 26 GHz | 9.5 dB at 26 GHz | 8.8 dB at 39 GHz |
| LO to RF isolation | 9 dB min | 11 dB min | 20 dB min |
| Image rejection | N/A | 19 dB min | N/A |

## Novel Microstrip Hybrids

o 6 GHz to 18 GHz hybrids

A packaged 3 dB quadrature hybrid of microstrip construction using gold plated sapphire substrate is shown in Figure 1. The measured performance is shown in Figure 2. The measured bandwidth of the hybrid is slightly greater than 3:1 as expected, and derived from the use of three section couplers in the hybrid. The following table summarizes the characteristics:

| | Design Goal | Model | Final Test Unit |
|---|---|---|---|
| Maximum amplitude imbalance (dB) | 0.5 | 0.8 | 0.7 |
| Minimum isolation (dB) | 20.0 | 20.0 | 17.0 |
| Maximum VSWR | 1.3 | <1.25* | 1.48** |
| Maximum insertion loss (dB) | 0.7 | 0.4 | 0.5 |

*Maximum return loss measured was >20 dB.
**Includes connector VSWR.

It should be noted that the isolation of the final unit is greater than 20 dB over most of the band and increases to the maximum only at the upper frequency limit. Also, the VSWR is 1.3 or lsss except over a small range just above midband.

o 2 GHz to 4 GHz hybrid

Figure 3 shows a modified Lange' coupler for the 2 to 4 GHz band using microstrip techniques. The performance of this hybrid is as follows:

| | |
|---|---|
| Insertion Loss | 0.5 dB |
| Maximum VSWR | 1.3:1 |
| Directivity | 20 dB |
| Isolation | 24 dB |

In the above paragraphs we have demonstrated the edge that our team has in successful fabrication of microstrip 3 dB quadrature hybrid over any competitors.

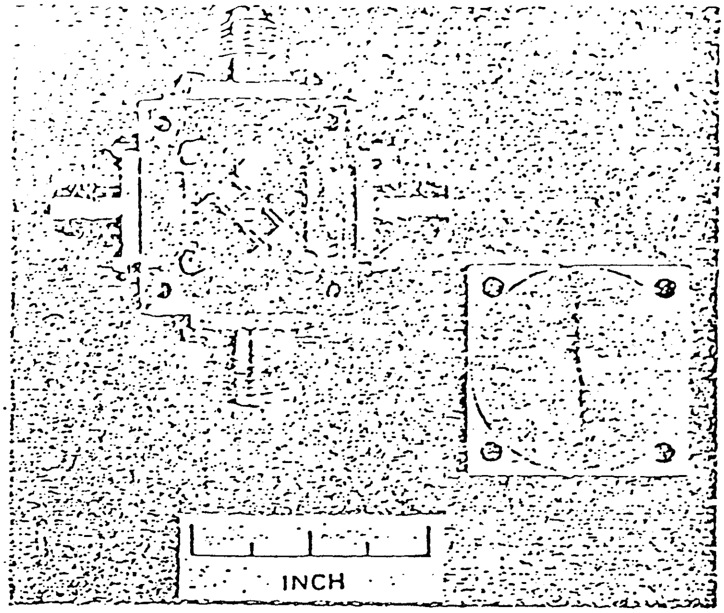



Figure 3-16 Three-Section, Wideband, Microstrip, 3-dB Quadrature Hybrid Packaged for Military Applications (U)

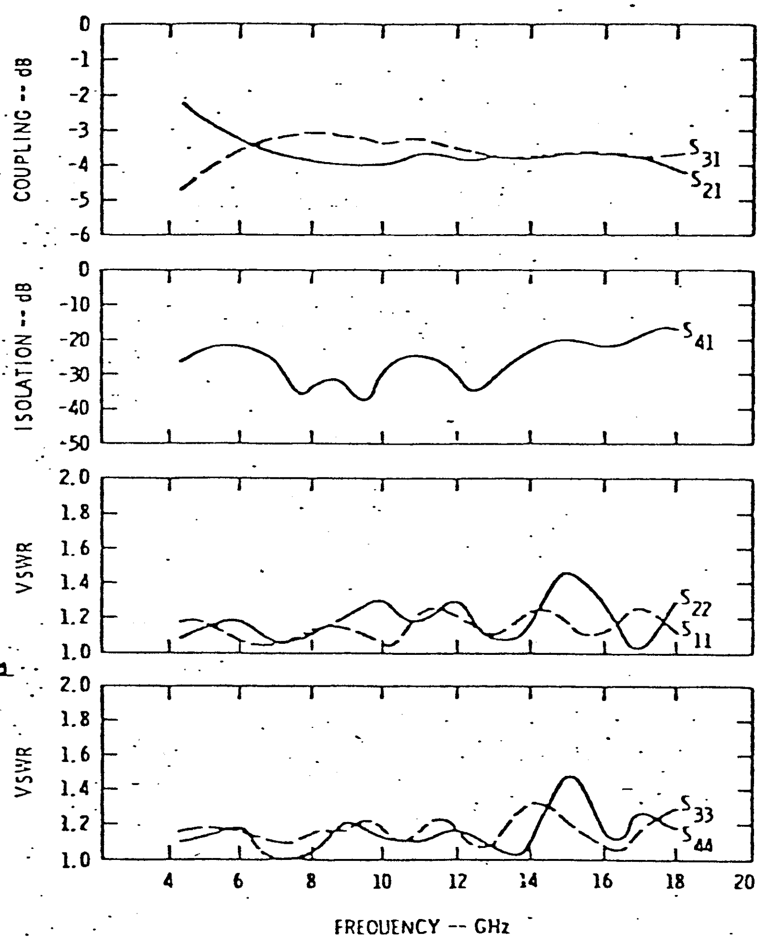





Figure 3-17 Measured Performance of Wideband, Three-Section, 3-dB Microstrip Coupler for Quadrature-Fed High-Dynamic-Range Mixer (U)

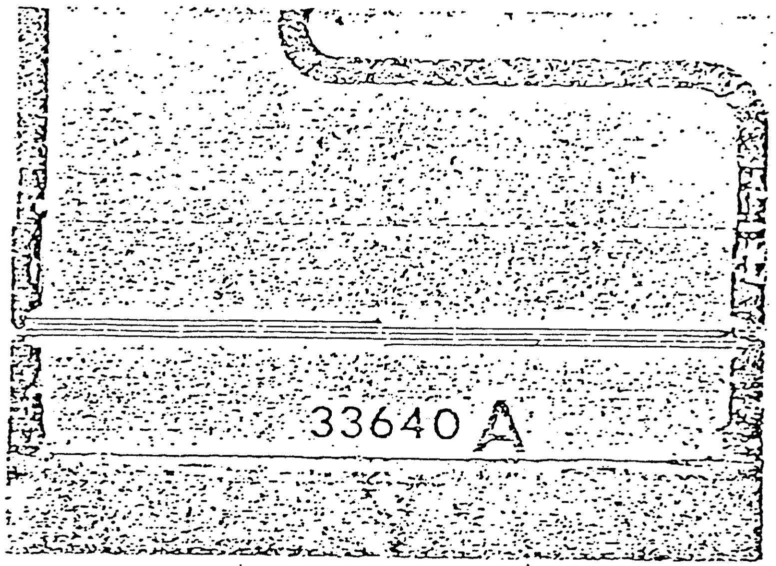



Figure 3-18 Modified Lange Coupler Constructed on 0.025-Inch Alumina for the 2- to 4-GHz Band (The wire jumpers were bonded with a thermal compression bonder similar to that used in the semiconductor industry.) (U)

13.1 Broadband INTEGRATED MIC RECEIVER FRONT END. (Designs which are representative of the complexity in MIC design proposed for this procurement)

Figure 13.2 shows a completed receiver front end packaged for airborne application (cover removed) that was designed by a our team member. Also shown is the circuit schematics combination of microstrip and stripline techniques in one package. The microstrip circuits are visible. The stripline circuits are mounted under the ground planes between the microstrip circuits.

Performance of the X-band mixer portion of the receiver shown in Figure 13.2 is as follows:

| | |
|---|---|
| RF frequency range | 4 to 8 GHz / 8 to 13 GHZ } Two channels in one package |
| IF frequency | 400 MHz |
| IF bandwidth | 400 MHz |
| Conversion loss | 9.3 dB, maximum |
| Noise figure (if amplifer noise is 2.2 dB) | 11 dB, maximum |
| Rejection ratio | |
| Real channel | 20 dB, minimum |
| Image channel | 16 dB, minimum |
| 2x2 spurious | 54 dB, minimum |
| LO to RF isolation | 16 dB, minimum |

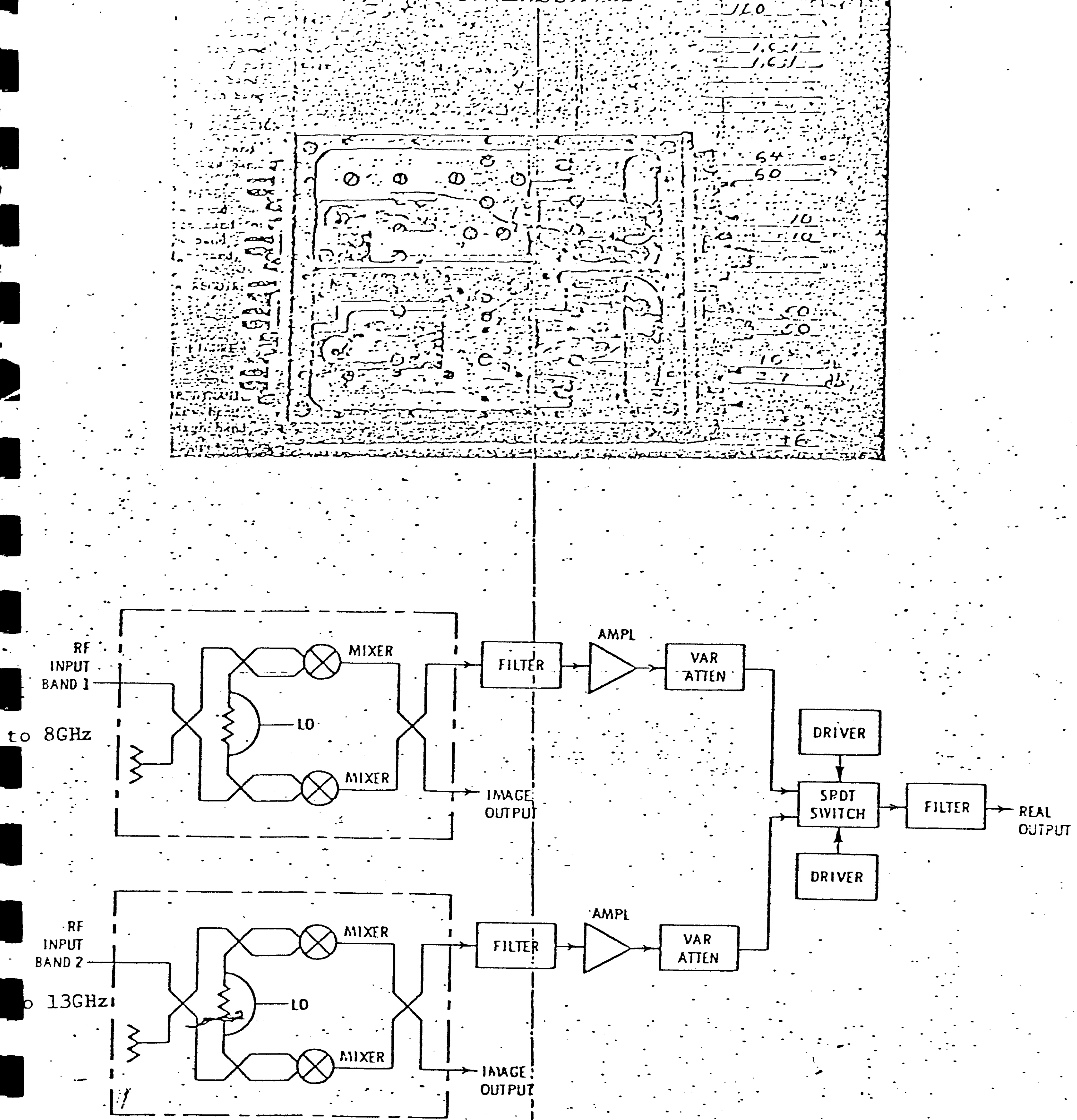



Figure 13.2 Integrated Receiver Front End Combining Microstrip and Stripline Circuits (Cover is removed from flight qualified package.) (U)

13.2. 2 to 4 GHz Image Reject Mixer (Representative of the complexity in MIC designs used in most integrated assemblies)

An all microstrip image reject mixer for the frequency range of 2 to 4 GHz is shown in Figure 13.3. This shows the complexity of integration that has been achieved by the team in constructing mixers, quadrature hybrids, and IF filter circuits. Performance is as follows:

| | |
|---|---|
| Conversion loss | 6 to 7 dB |
| Noise figure | 7.5 to 8.6 dB (1.5 dB IF amplitude noise figure) |
| Image rejection | 30 dB at 2GHz |
| | 44 dB at 3 GHz |
| | 22 dB at 4 GHz |

2 X 2 distortion products are 40 dB down and are balanced to within 3-dB at the real and image IF ports.

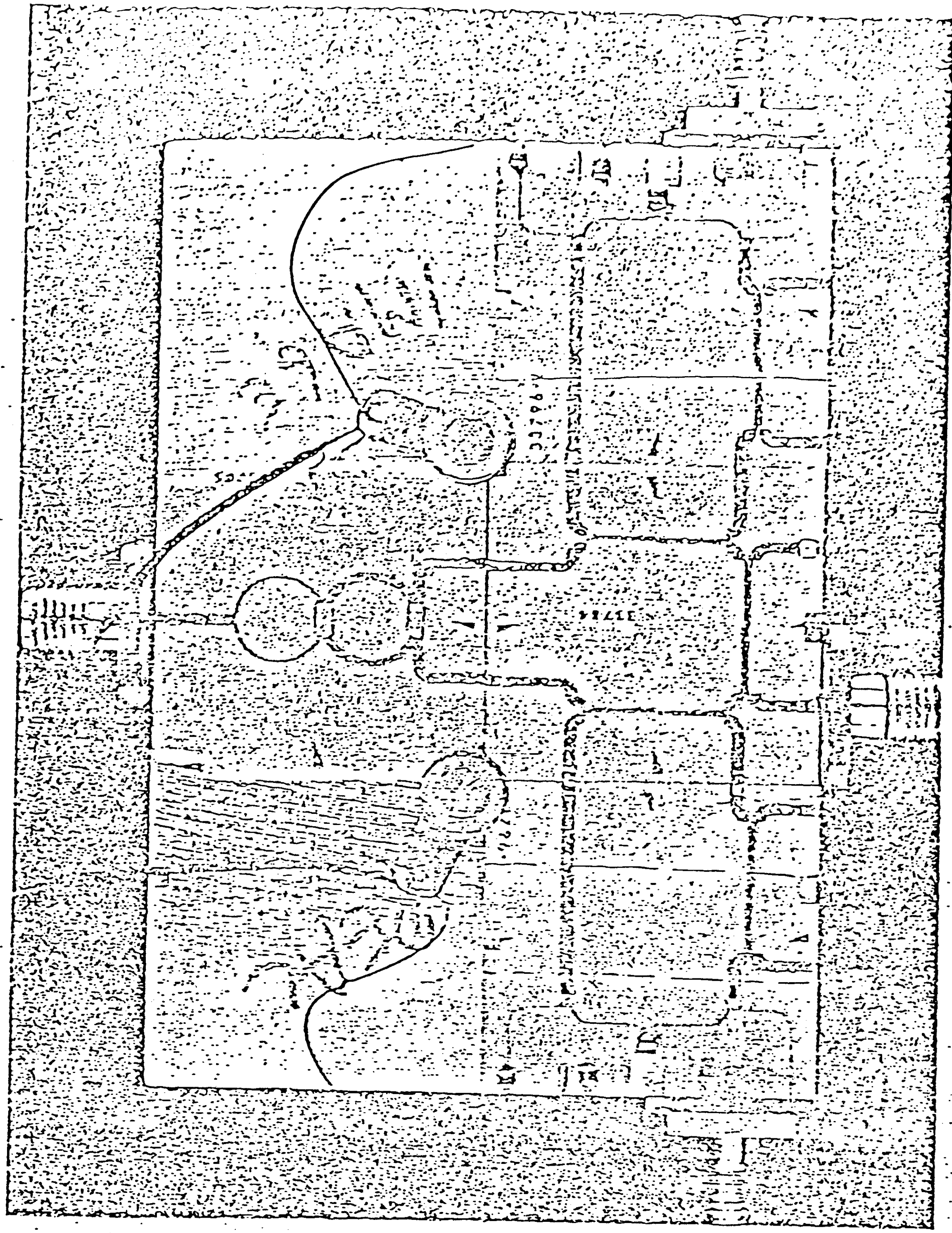


FIGURE 13.3 TYPICAL OCTAVE BANDWIDTH MIC IMAGE REJECT MIXER (VIEW OF SUBSTRATE ONLY) (U)

(2 to 4GHz)

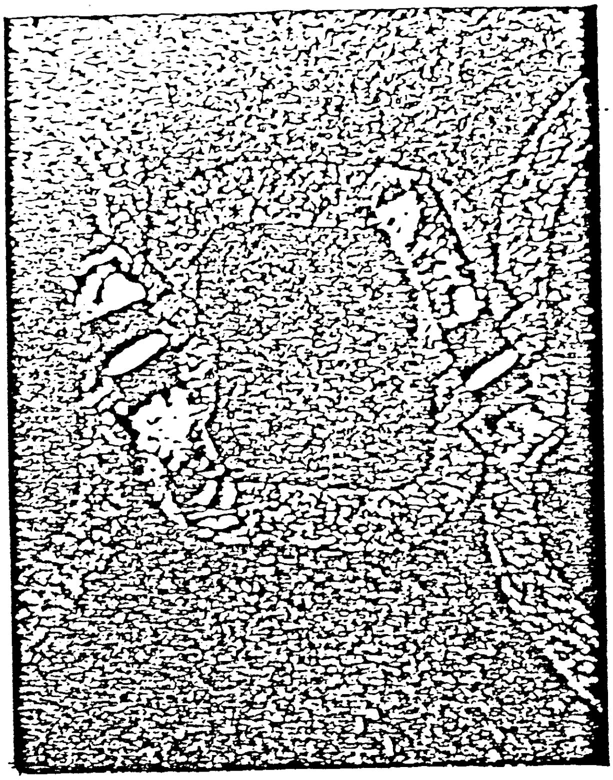
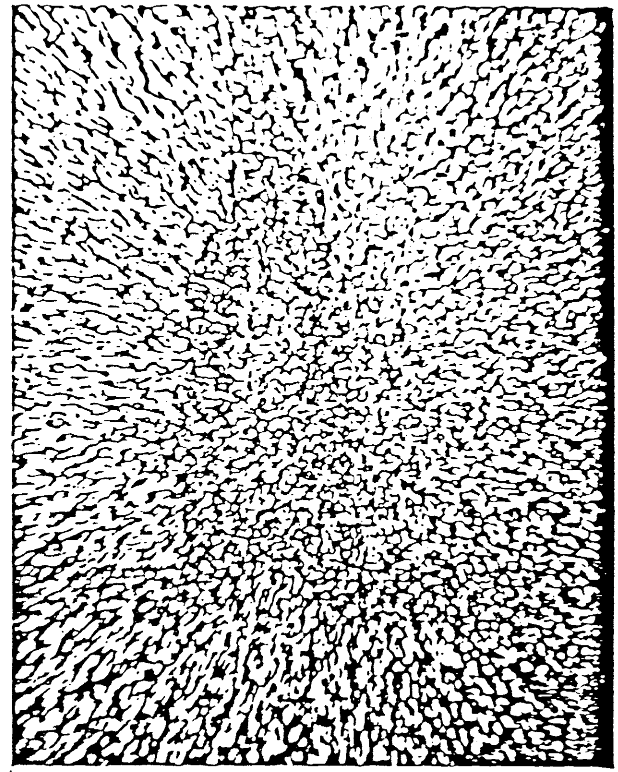
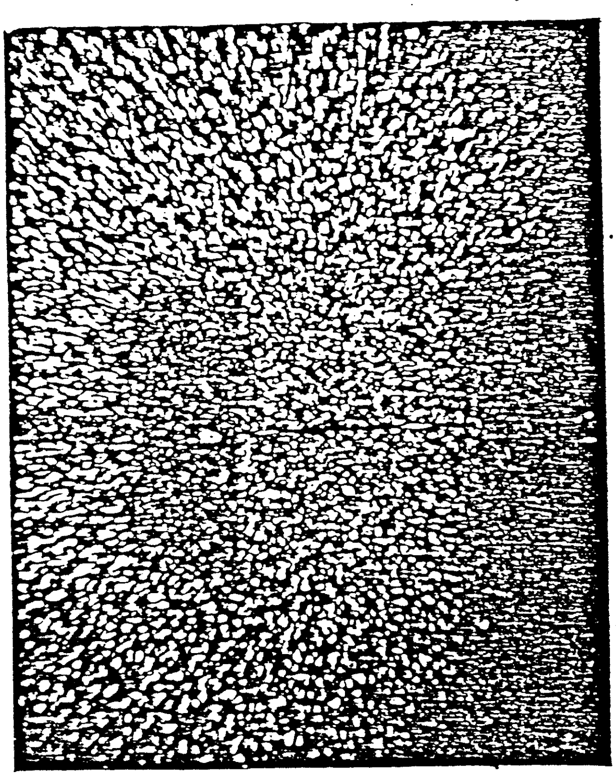
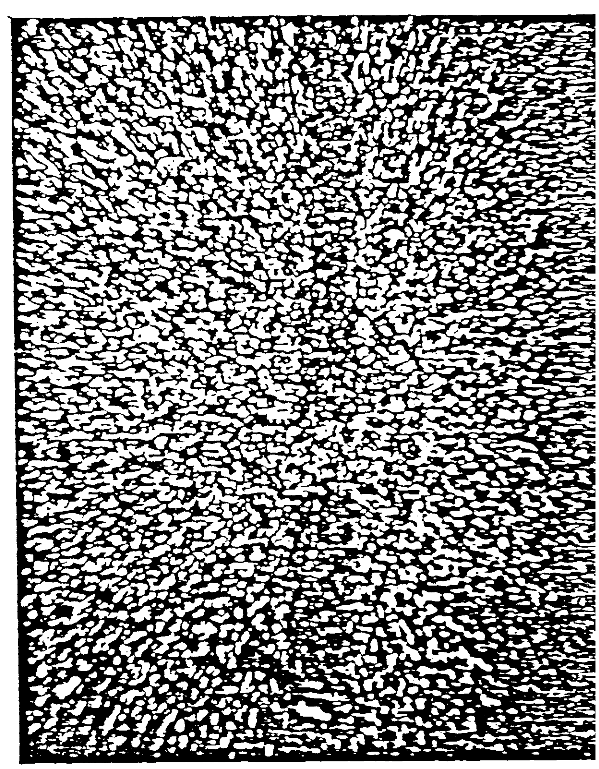
## INTRODUCTION

Some results of the first circuits etched can be seen in Table 1. These results indicate that undercutting has been held to a nominal minimum using our techniques. This is as was expected theoretically. Our line width and gapwidth control shall be held to tighter tolerance by using up-plating techniques for the millimeter components.

TABLE 1

CIRCUIT FABRICATION

| ITEM | MASK SIZE MILS | ETCHED SUBSTRATE SIZE MILS |
|---|---|---|
| GAPWIDTH | 0.8 | 1.2 |
| LINEWIDTH | 10.4 | 10 |
| LINEWIDTH | 6.4 | 6 |

# PERFORMANCE RESULTS ON PLANAR 26.5 TO 40 GHz BALANCED MIXER

PREPARED

BY

ASHOK K. GORWARA

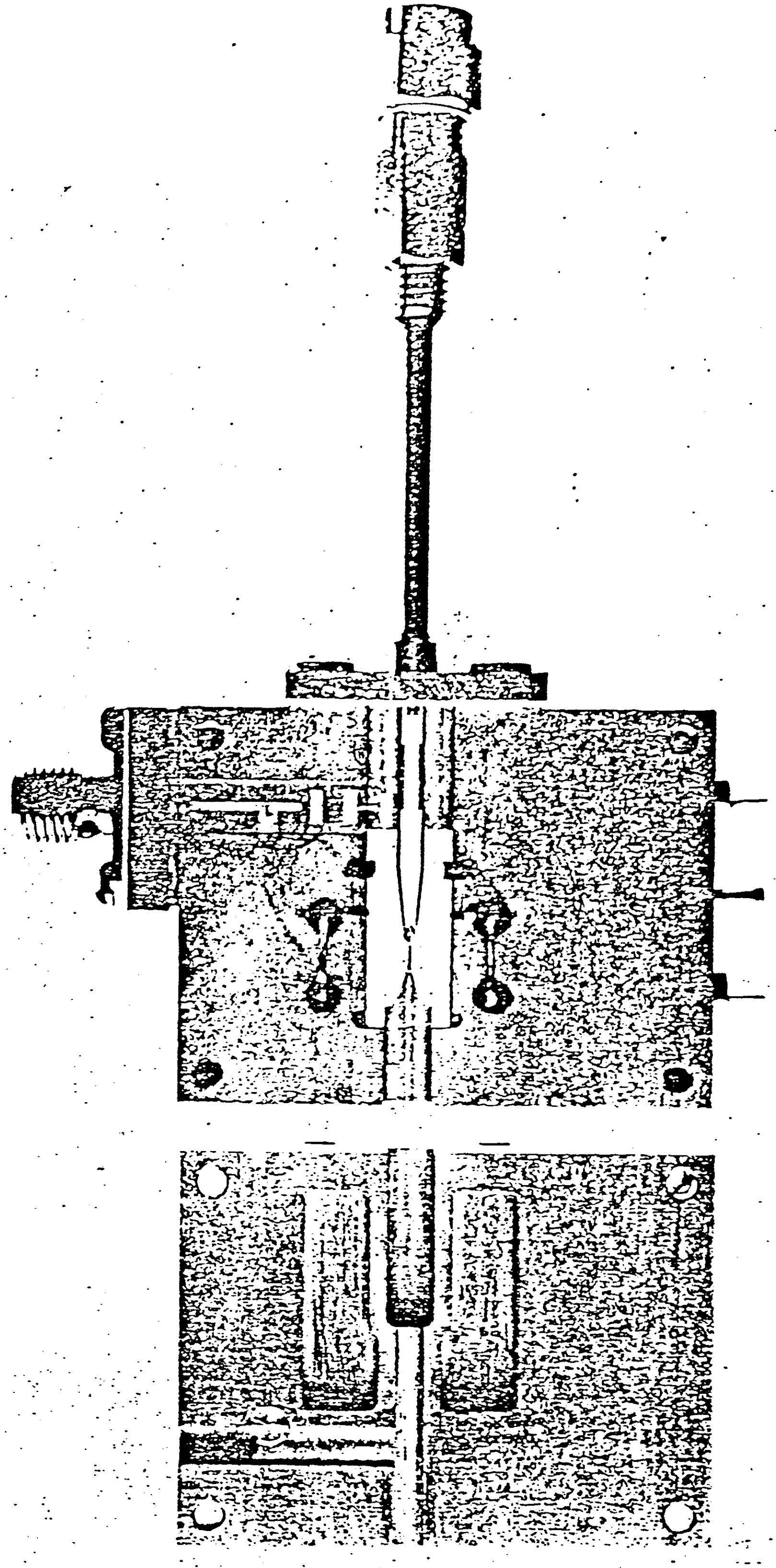


FIGURE 2 PHOTOGRAPH OF BALANCED MIXER FROM 26.5 TO 40 GHz SHOWING THE TWO HALVES OF THE HOUSING AND THE TWO QUARTZ SUBSTRATES

## 3. Test Results

A final version of the 26.5- to 40-GHz mixer was subjected to numerous tests. A summary of the test results is presented in Table 1.

Table 1

TEST RESULTS OF 26.5- TO 40-GHz BALANCED MIXER, S/N RBM-1
(At Nominal Bias Current of 1.5 mA per Diode)

| Parameter | Test Conditions | Value |
|---|---|---|
| Conversion loss | $P_{LO}$ = +3 dBm | 8 dB typ<br>9.5 dB max |
| | $P_{LO}$ = +6 dBM | 7.6 dB typ<br>8.2 dB max |
| Noise figure | 1.3 dB IF Amp. NF<br>$P_{LO}$ = +6 dBm | 9.1 dB |
| RF port VSWR | $P_{LO}$ = +3 dBm | ≤1.9 |
| LO port VSWR | $P_{LO}$ = +3 dBm | ≤3.0 |
| IF port VSWR | $P_{LO}$ = +3 dBm<br>0.1 to 2 GHz | ≤1.33 |
| LO to RF isolation | $P_{LO}$ = +3 dBm | 25 dB typ<br>≥17 dB |
| 2 x 2 spurious suppression | $P_{LO}$ = +3 dBm<br>$P_{RF}$ = -20 dBm | ≥39 dB |
| LO AM suppression | $P_{LO}$ = +3 dBm | ≥30 dB |

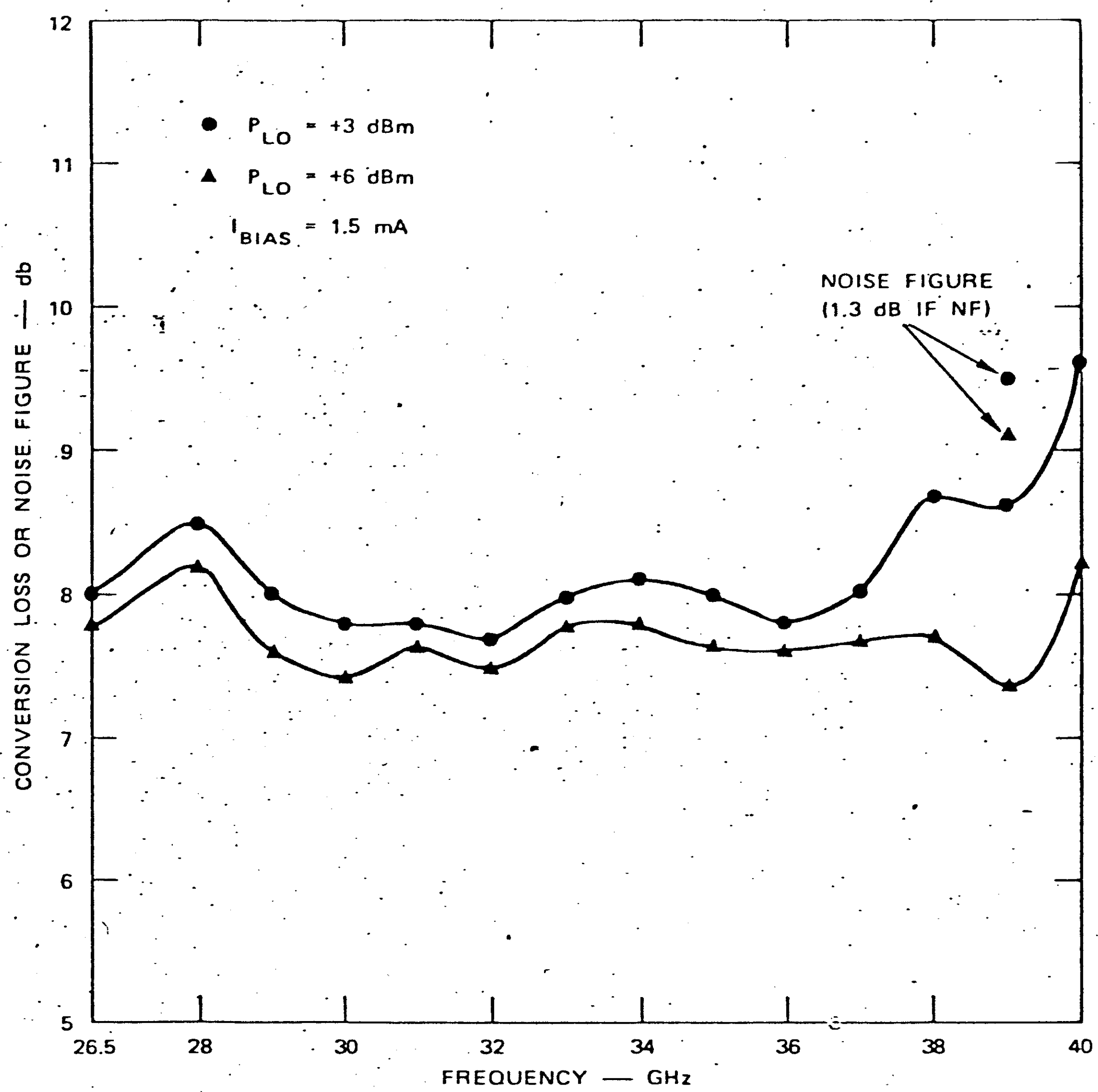



FIGURE 4 CONVERSION LOSS AND NOISE FIGURE OF R-BAND BALANCED MIXER, S/N RBM-1

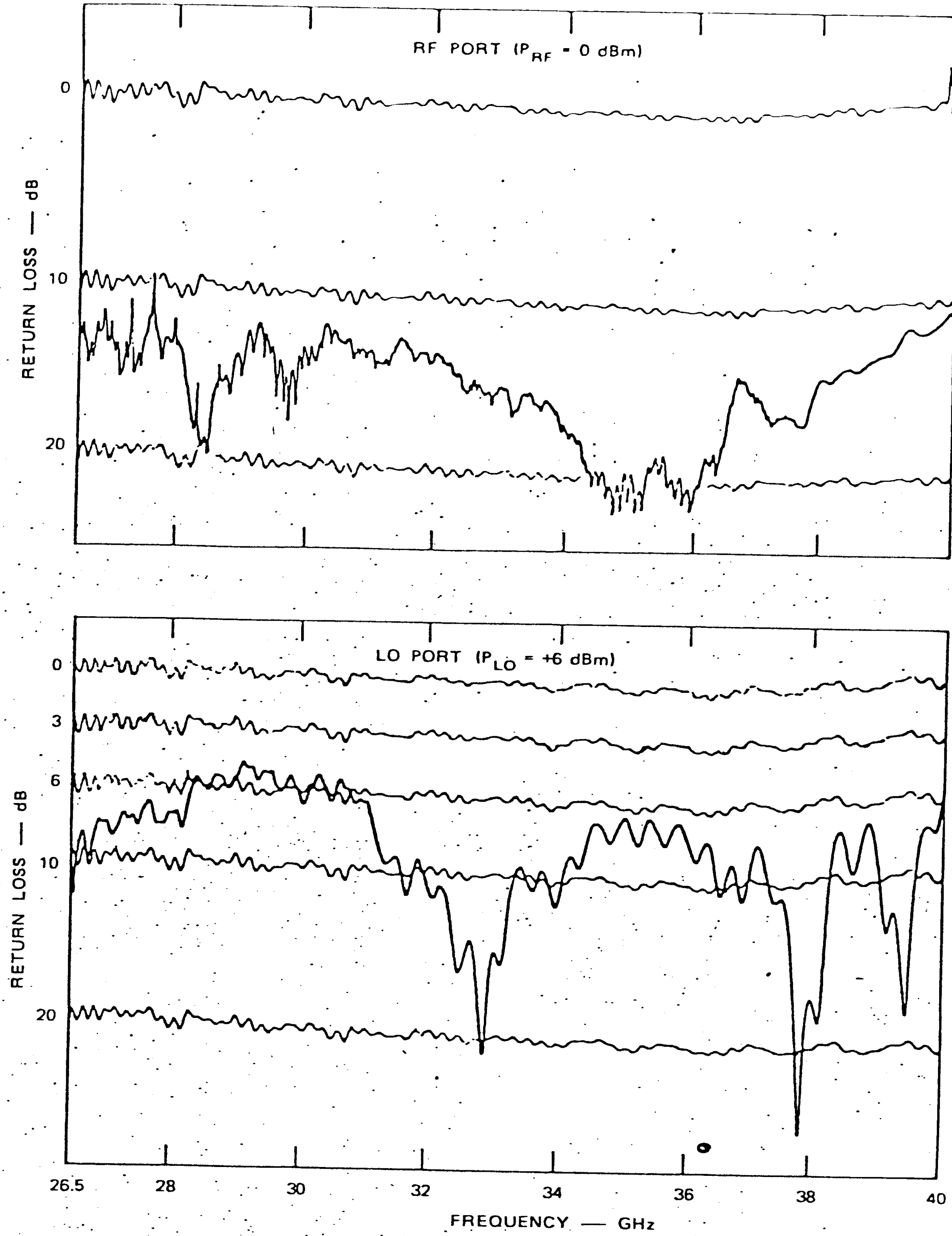



FIGURE 5 RETURN LOSS OF RF AND LO PORT OF R-BAND BALANCED MIXER, S/N RBM-1

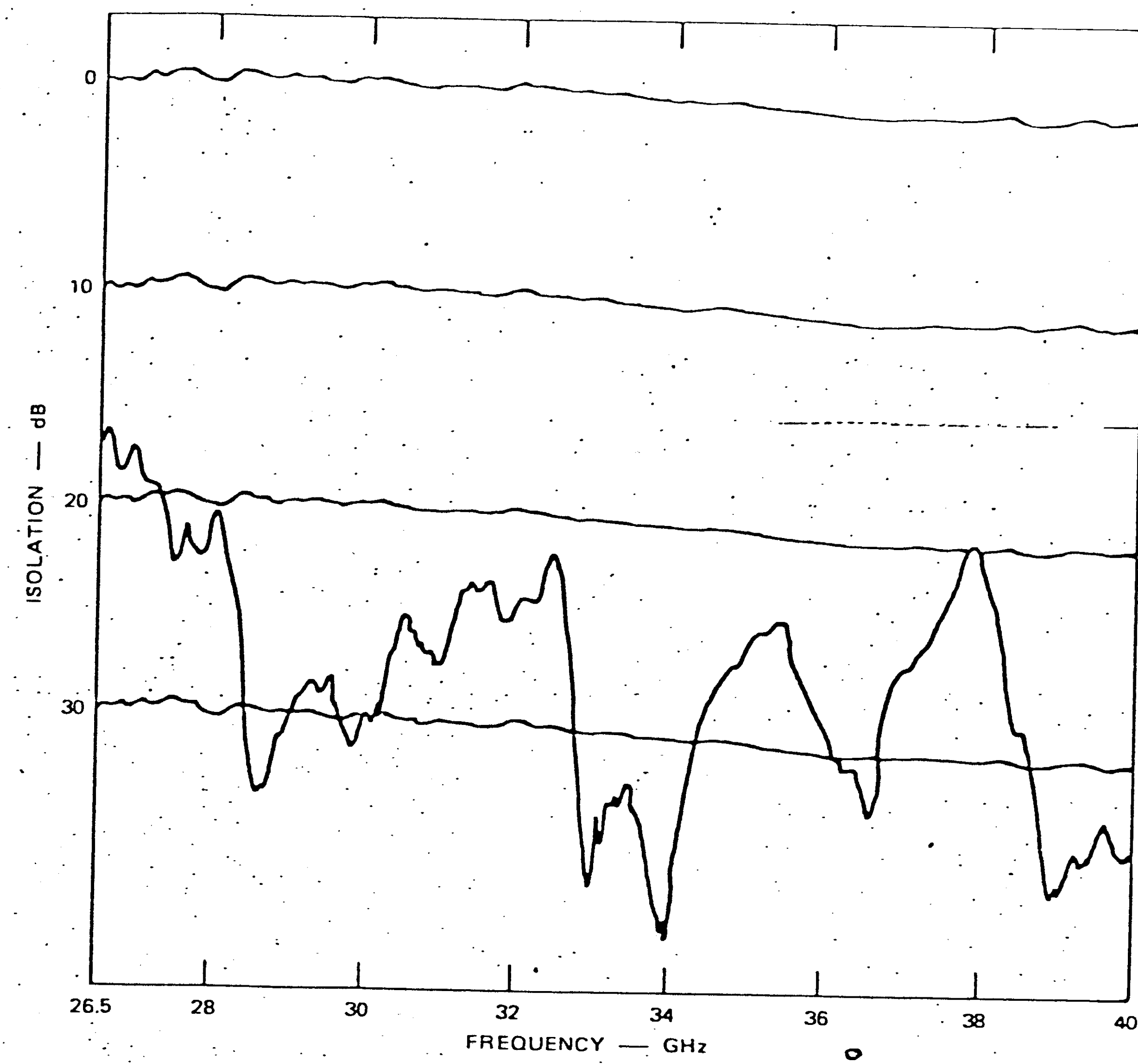



FIGURE 6 LO-TO-RF ISOLATION FOR R-BAND BALANCED MIXER, S/N RBM-1 ($P_{LO}$ = +6 dBm)

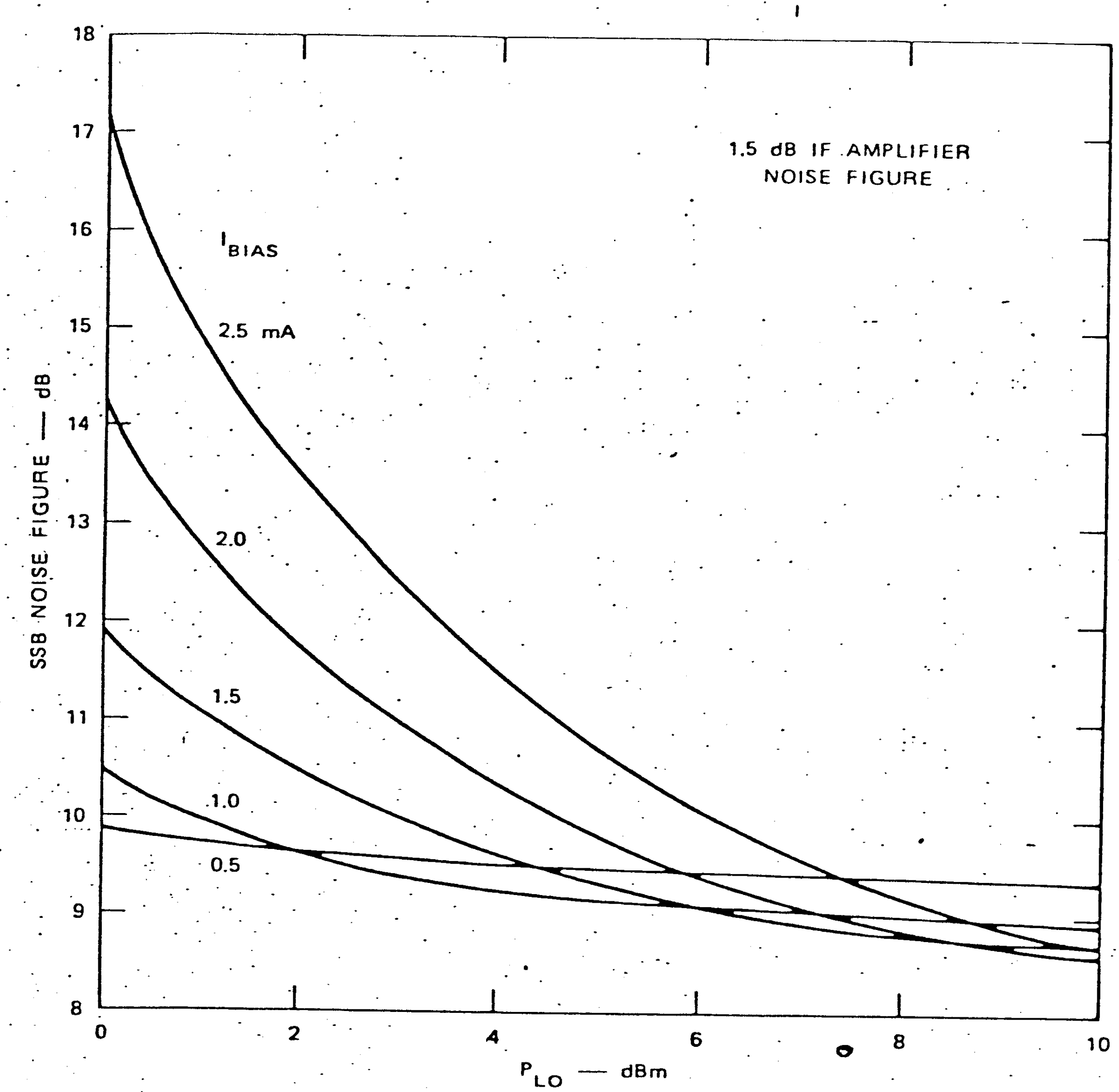



FIGURE 7 NOISE FIGURE VERSUS LO POWER FOR R-BAND BALANCED MIXER, S/N RBM-1

# DESIGN AND PERFORMANCE OF A BROADBAND LOW-NOISE K-BAND MICROSTRIP SINGLE BALANCED MIXER

by

Ashok K. Gorwara

## ABSTRACT

The design and experimental performance of a broadband (18-26.5 GHz) single balanced mixer fabricated in microstrip on sapphire is described. Typical conversion loss is 7.5 dB with a maximum of 8.5 dB at the top end of the band. RF and LO input VSWR are less than 2:1 over the band.

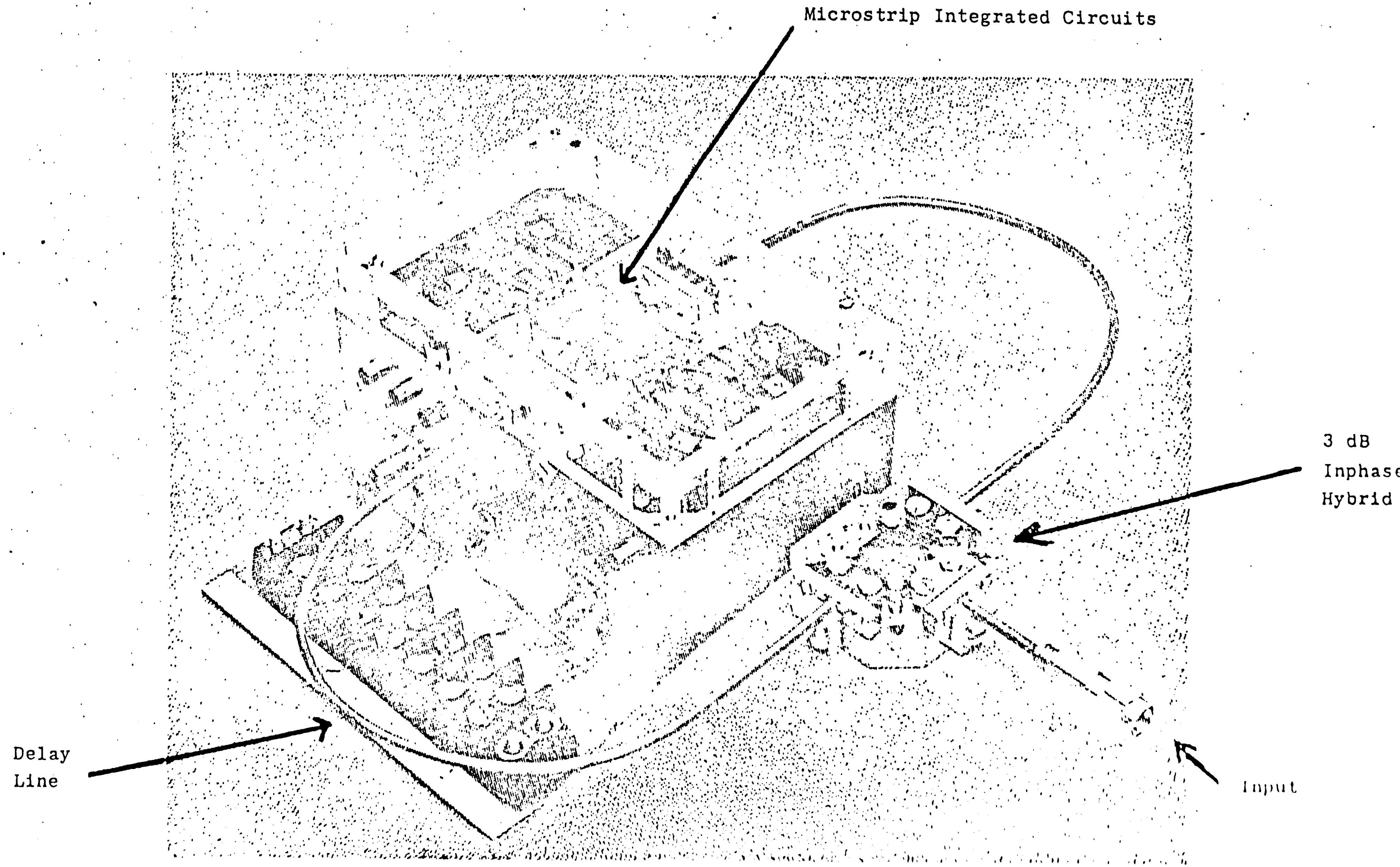



Figure 3 Photograph of the Exploratory Model of MIC K-Band Polar Discriminator

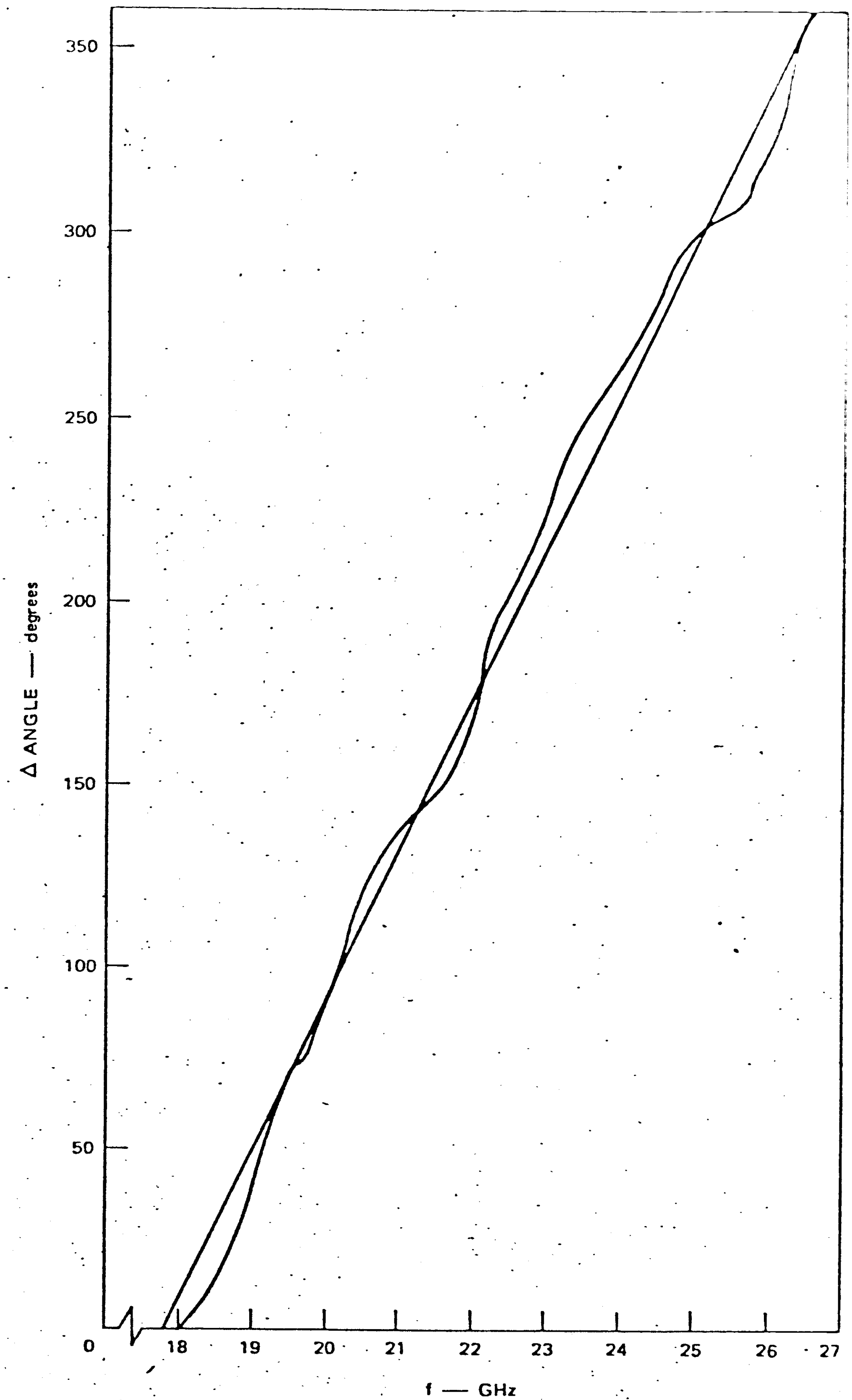



Figure 4 Phase Angle as a Function of Frequency for the Experimental Model of 18-26.5 GHz MIC Polar Discriminator

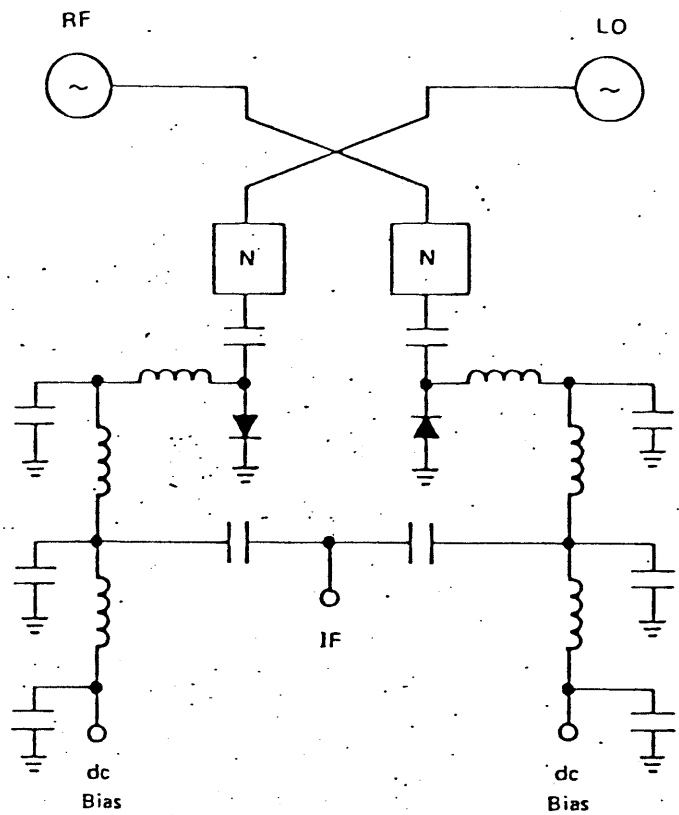



Figure 1 Circuit Diagram of Single Balanced Mixer

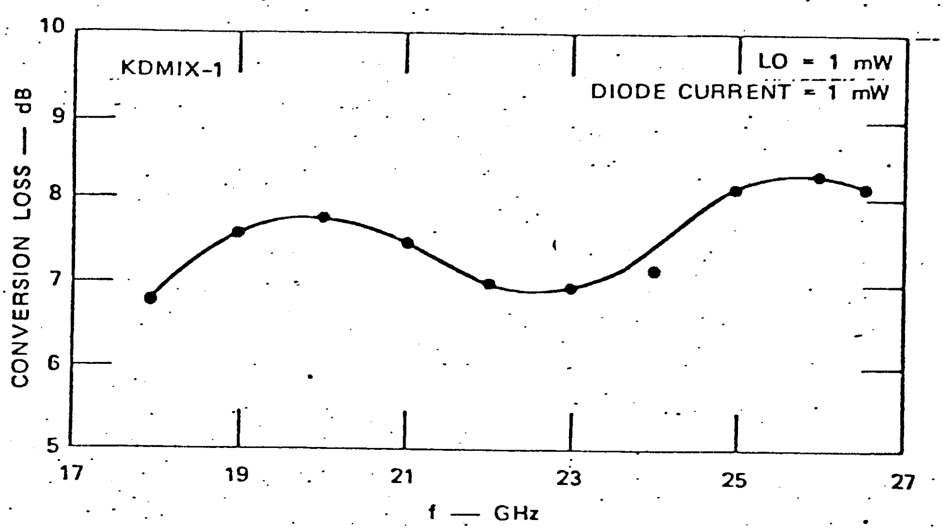



Figure 3 Conversion Loss as a Function of Frequency for the Single Balanced Mixer

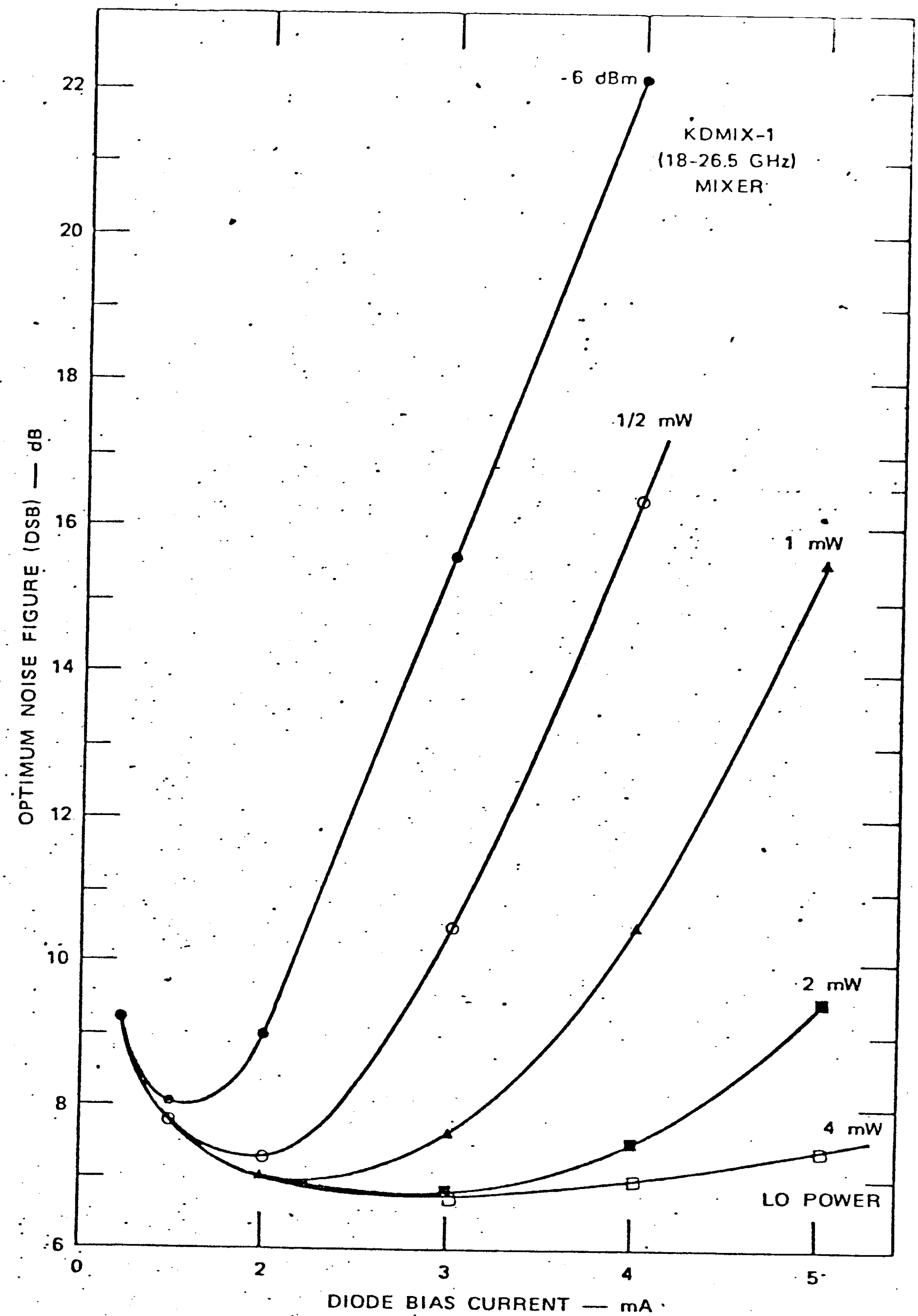



Figure 4 Double Sideband Noise Figure of the Single Balanced Mixer as a Function of Diode Bias Current for Various LO Drive Powers

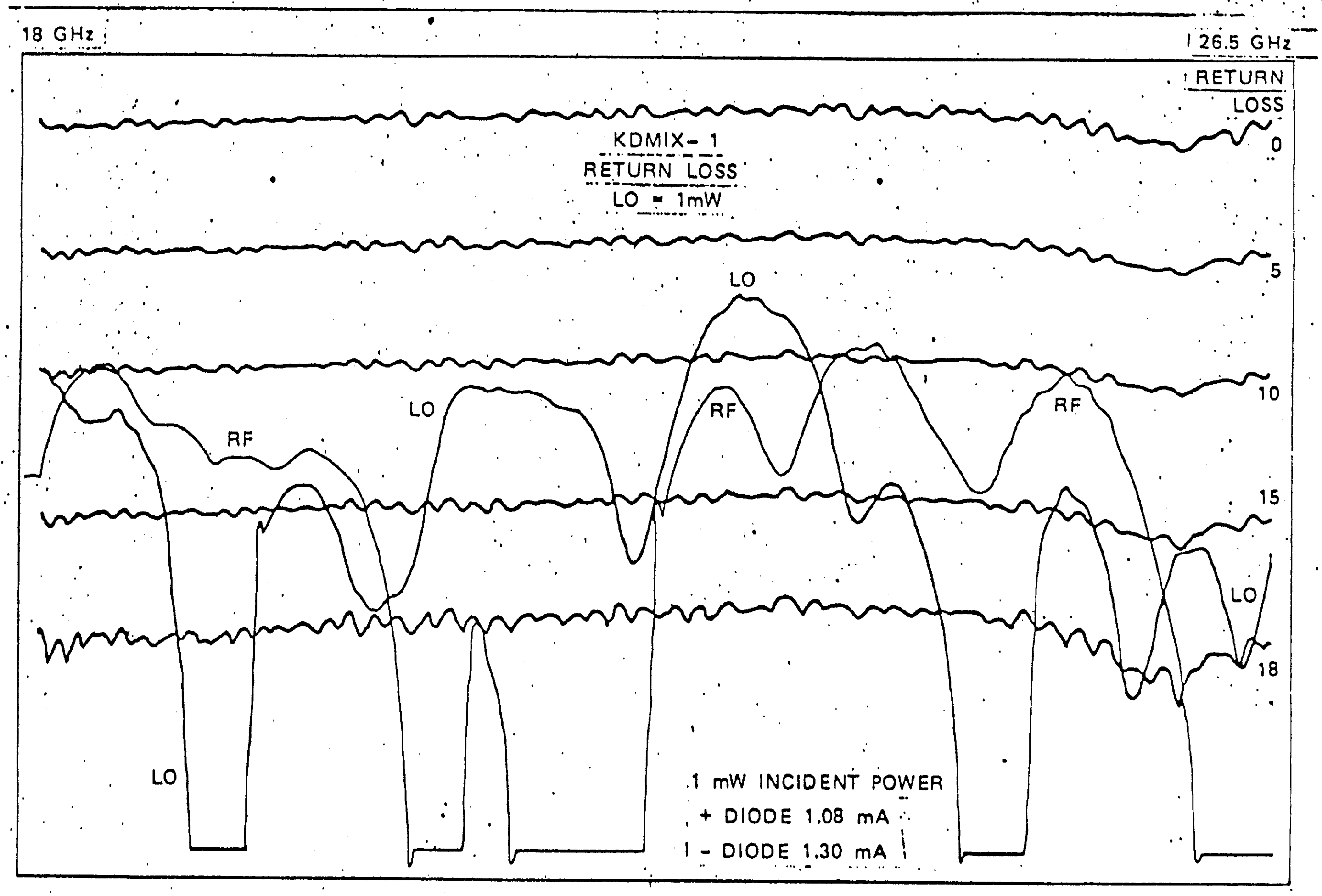



Figure 5 Return Loss of RF and LO Ports as a Function of Frequency

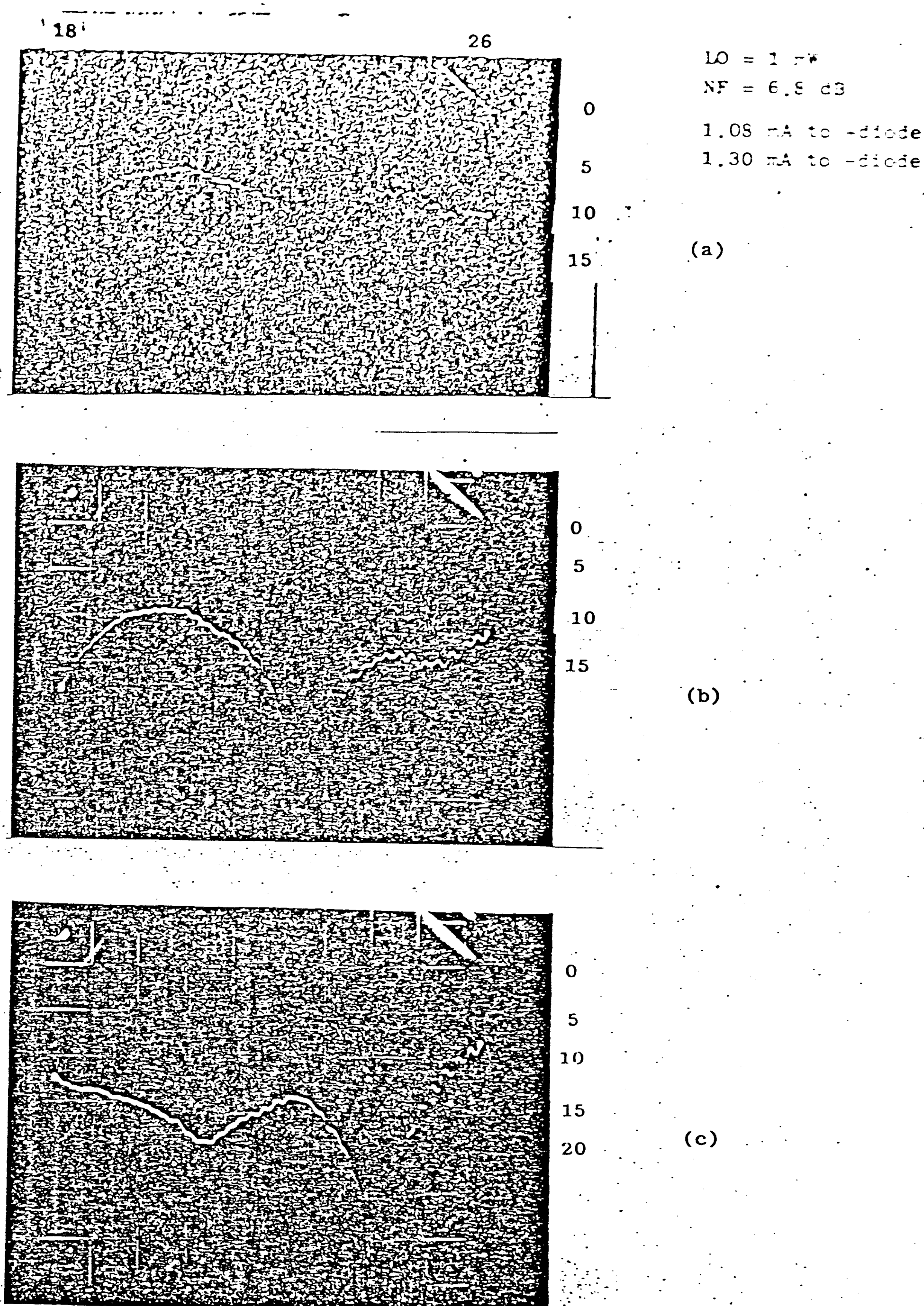



Figure 6 LO to RF Isolation as a Function of Frequency. (a) Diode Bias Current Adjusted for Optimum Noise Figure. (b) Bias Current Equals 2 milamps. (c) Bias Current Equals 3 milamps.

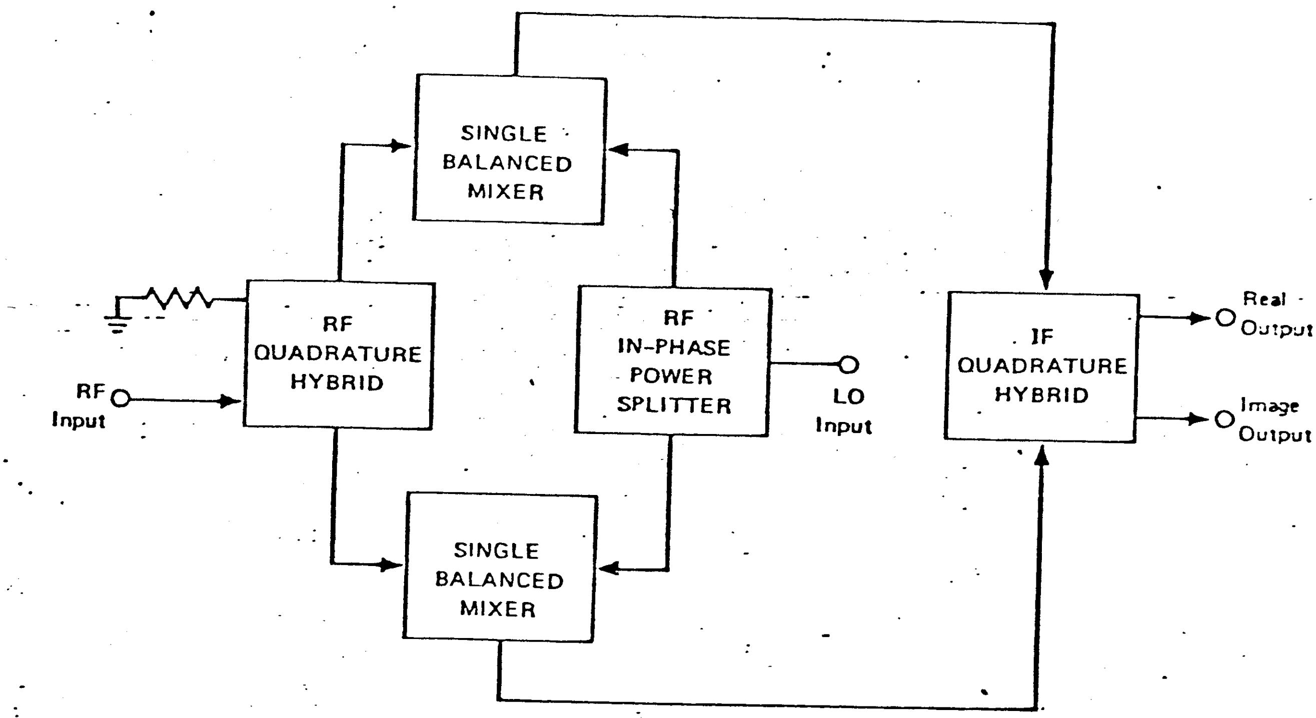
# DESIGN AND PERFORMANCE OF A BROADBAND LOW-NOISE K-BAND MICROSTRIP IMAGE REJECT MIXER

by

Ashok K. Gorwara

## ABSTRACT

The design and experimental performance of a broadband, low-noise (18-26.5 GHz) image reject mixer (IRM) fabricated in microstrip on 0.010-inch thick gold plated sapphire substrate is described. Typical conversion loss of 8.6 dB with a maximum of 9.6 dB at the top end of the band was achieved at LO power level of +6 dBm. Image rejection of 20 dB was achieved across most of the band. RF, LO and IF input VSWR are less than 2:1 over the band. The common mode rejection measured was 35 dB and the 2 x 2 suppression for RF level of -20 dBm was 45 dB minimum.




UNCLASSIFIED

FIGURE 1     MIC IMAGE REJECT MIXER BLOCK DIAGRAM

Table 1

PERFORMANCE OF K-BAND, MIC, IMAGE REJECT MIXER

Summary

| | |
|---|---|
| Frequency: | 18.0 to 26.5 GHz |
| Size: | 4" × 2.5 " × 2.1 " excluding connectors |
| Weight: | 1 pound |
| Power Requirements: | + 15 VDC at 2 mA<br>– 15 VDC at 2 mA |
| LO Drive Range: | +3 to +6 dBm |

Test Results

| Notes | Parameter | Max or Min Data +3 dBm | Max or Min Data +6 dBm | Typical Data |
|---|---|---|---|---|
| | Conversion loss | 10.0 dB | 9.6 dB | 8.7 dB |
| | Image rejection | 18 dB | 17 dB | 22 dB |
| | LO to RF isolation | 12 dB | 9 dB | 15 dB |
| | LO to IF isolation | 36 dB | 36 dB | 41 dB |
| | RF VSWR | 2.4:1 | 2.6:1 | 1.5:1 |
| | LO VSWR | 2.0:1 | 2.4:1 | 1.4:1 |
| | IF VSWR (168 MHz) | 1.4:1 | 1.4:1 | 1.25:1 |
| | 1 dB Compression point | 0 dBm | +1 dBm | +1.5 dBm |
| 1 | Common mode rejection | 26 dB | 26 dB | 35 dB |
| 2 | 2 × 2 suppression | 44 dB | 45 dB | 53 dB |
| 2 | 4 × 3 suppression | >60 dB | >60 dB | > 60 dB |
| 2 | 3 × 4 suppression | >60 dB | >60 dB | > 60 dB |
| 3 | 2 tone 2nd order intermod | -40 dB | -42 dB | N/A |
| 3 | 2 tone 3rd order intermod | -52 dB | <-60 dB | N/A |

Notes: (1) Injected RF level = -20 dBm
IF output level measured relative to RF level

(2) RF level = -20 dBm
IF output level measured relative to primary IF output

(3) RF1 = RF2 = -20 dBm
Data taken at 25 GHz

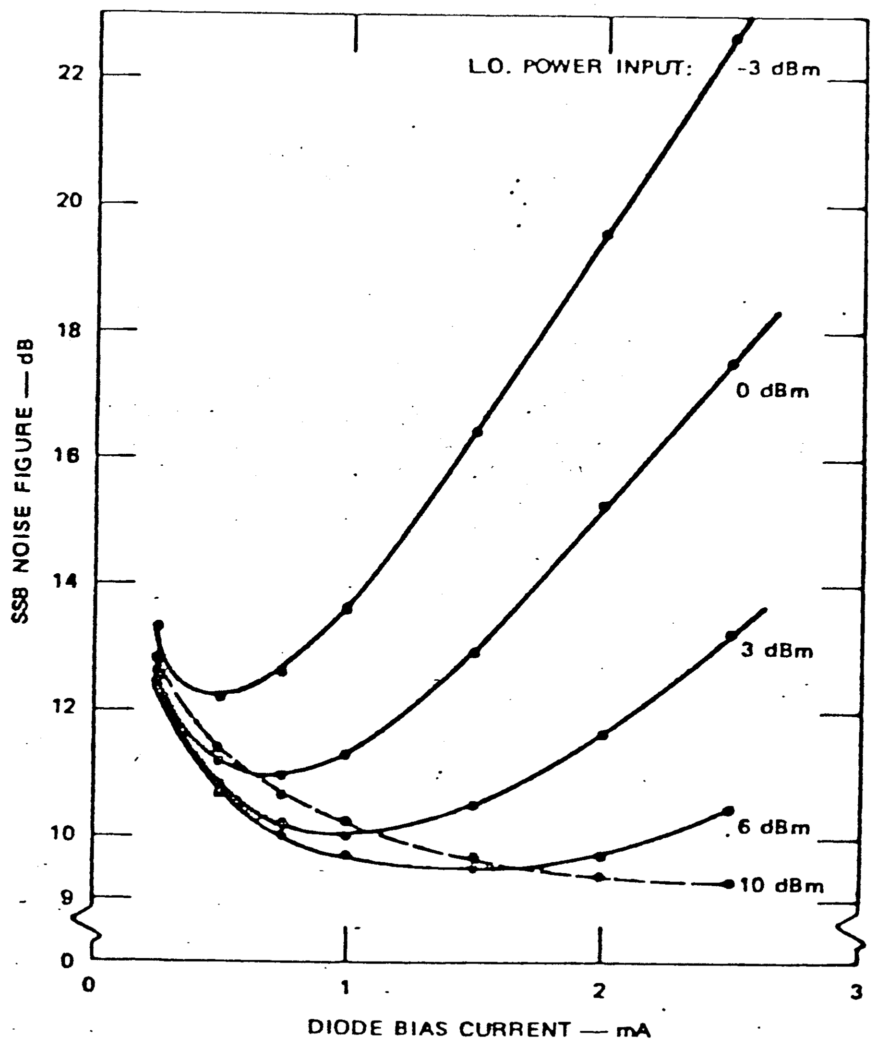



FIGURE 4 NOISE-FIGURE CHARACTERISTICS AT 26 GHz FOR THE K-BAND (18.0 to 26.5 GHz), MIC, IMAGE-REJECT MIXER, MODEL KIRM-2(2)

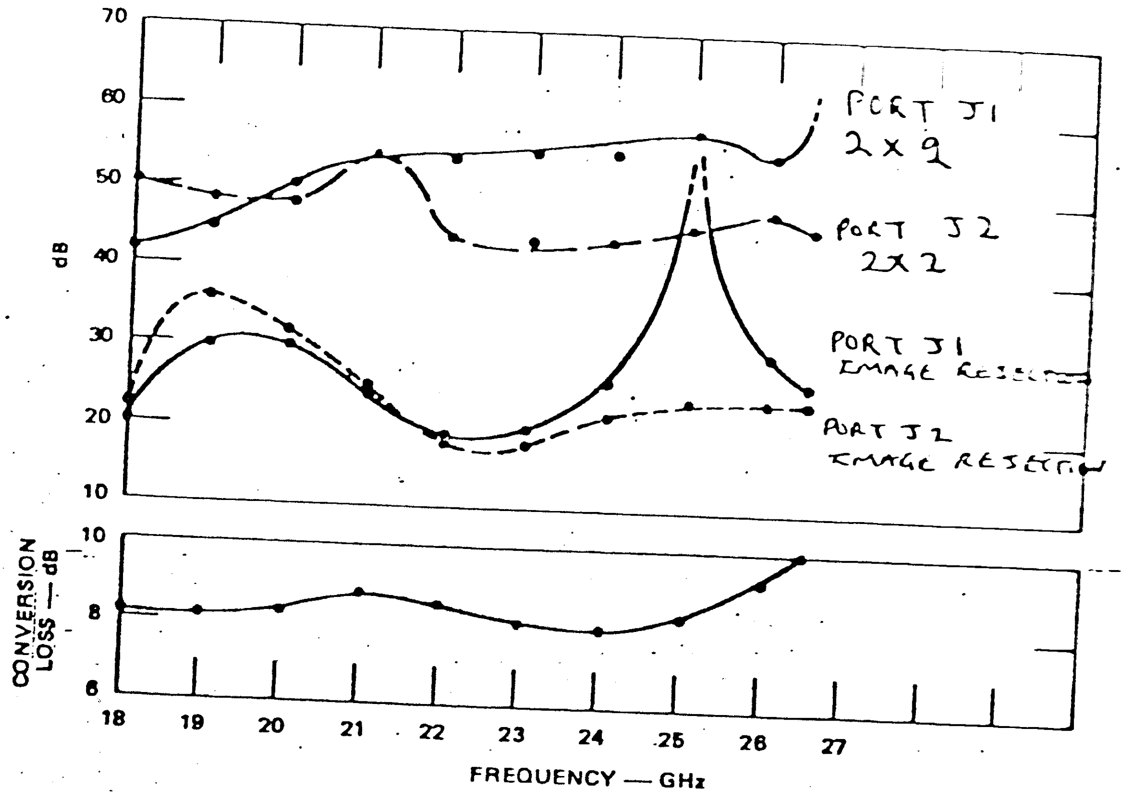



FIGURE . 5 CONVERSION LOSS, IMAGE REJECTION, AND 2 X 2 INTERMODULATION PRODUCTS FOR THE K-BAND (18.0 to 26.5 GHz), MIC, IMAGE-REJECT MIXER, MODEL KIRM-2(2). IF frequency = 168 MHz, diode bias currents = 1.0 mA, LO power input = 3.0 dBm.

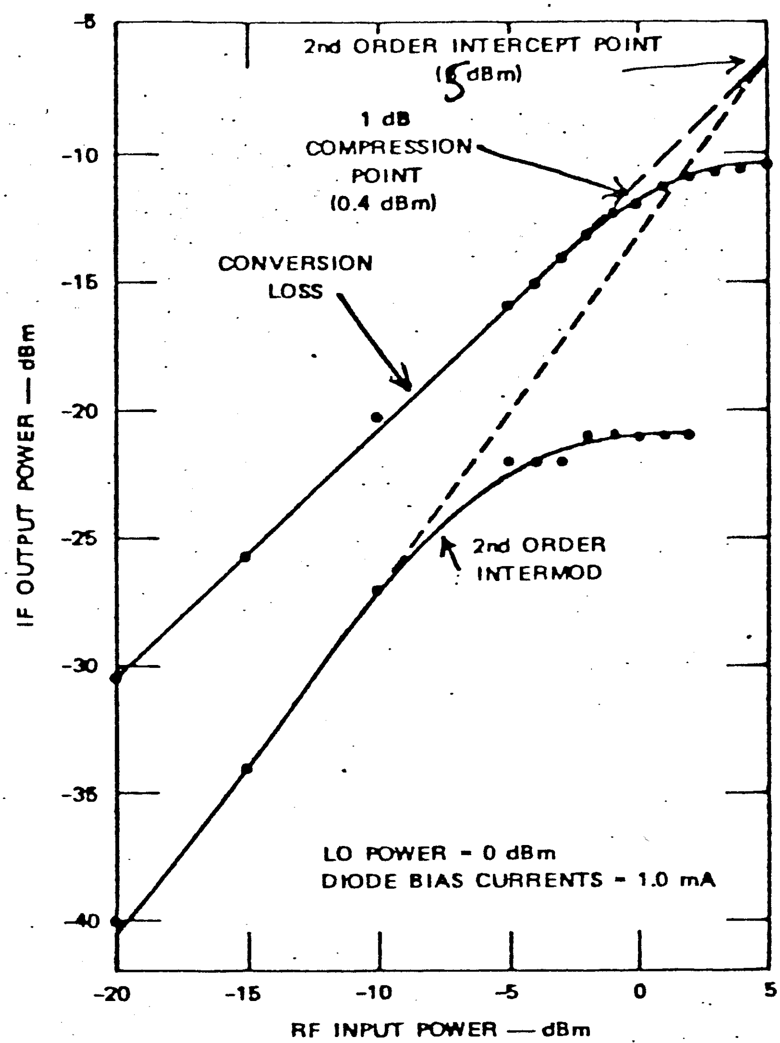



FIGURE 6 TRANSFER CHARACTERISTICS FOR THE K-BAND (18.0 to 26.5 GHz), MIC, IMAGE-REJECT MIXER, MODEL KIRM-2(2). Diode bias currents = 1.0 mA, LO power input = 0 dBm.

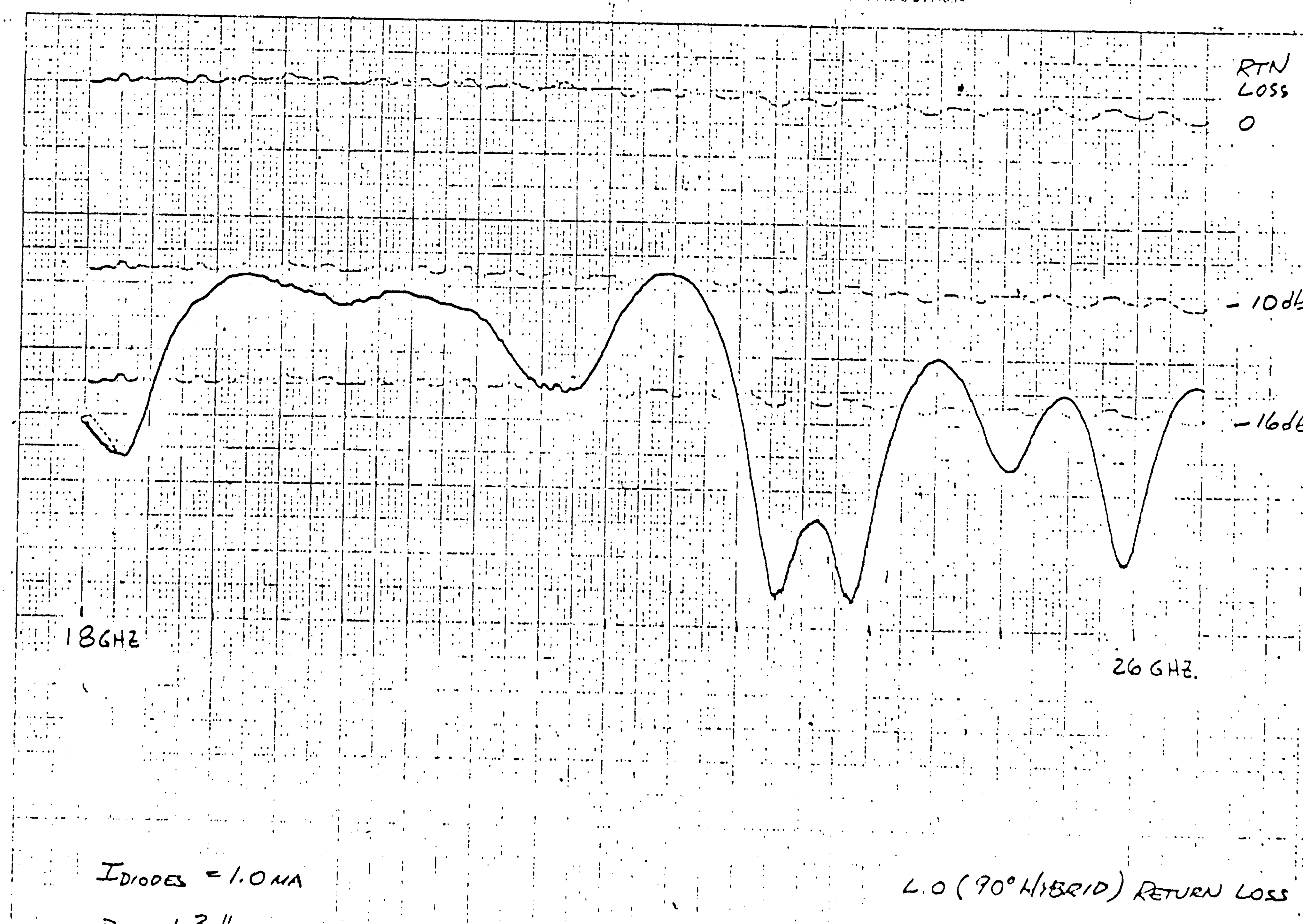



FIGURE 7(a) RETURN LOSS CHARACTERISTIC FOR K-BAND MIC IMAGE REJECT MIXER

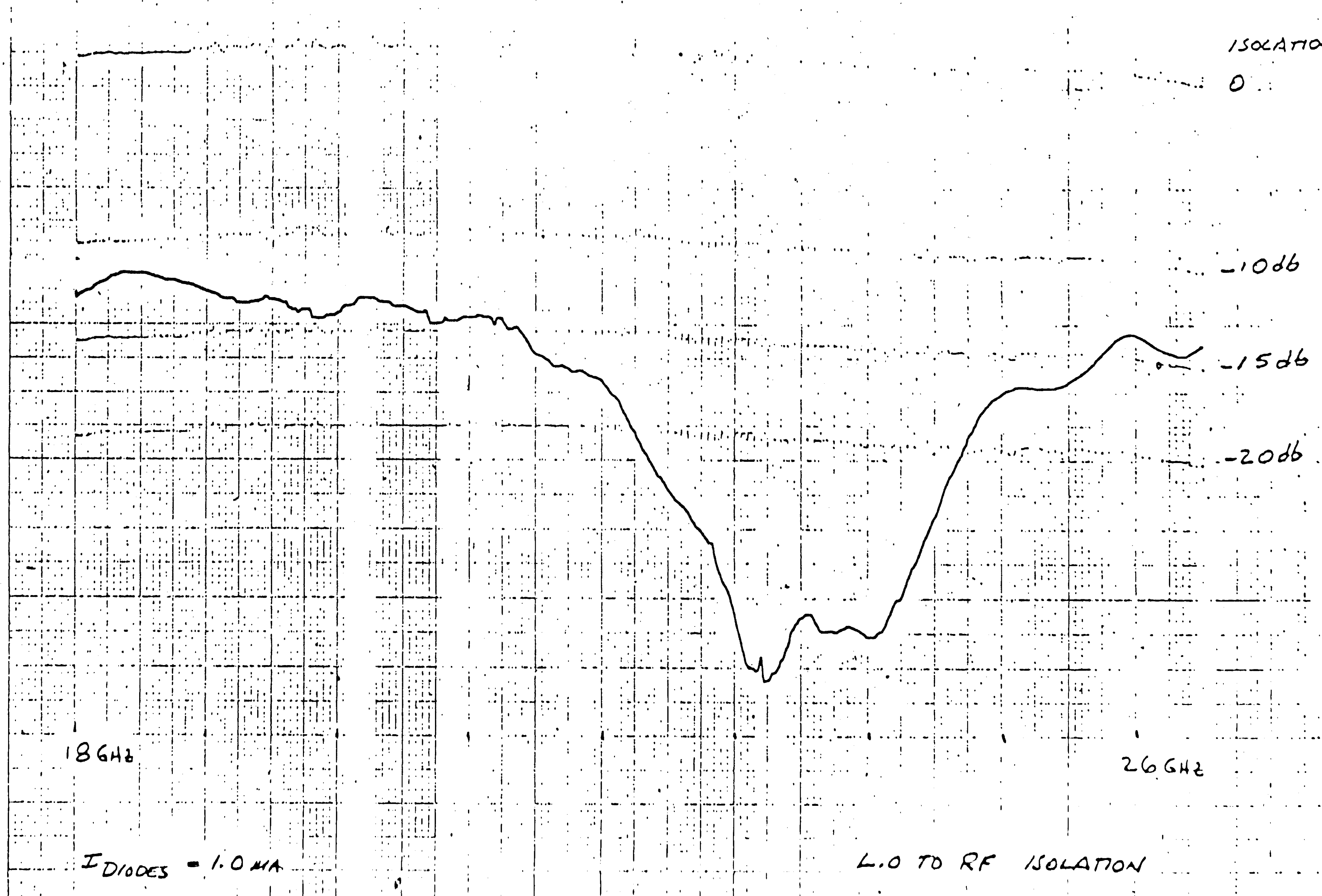
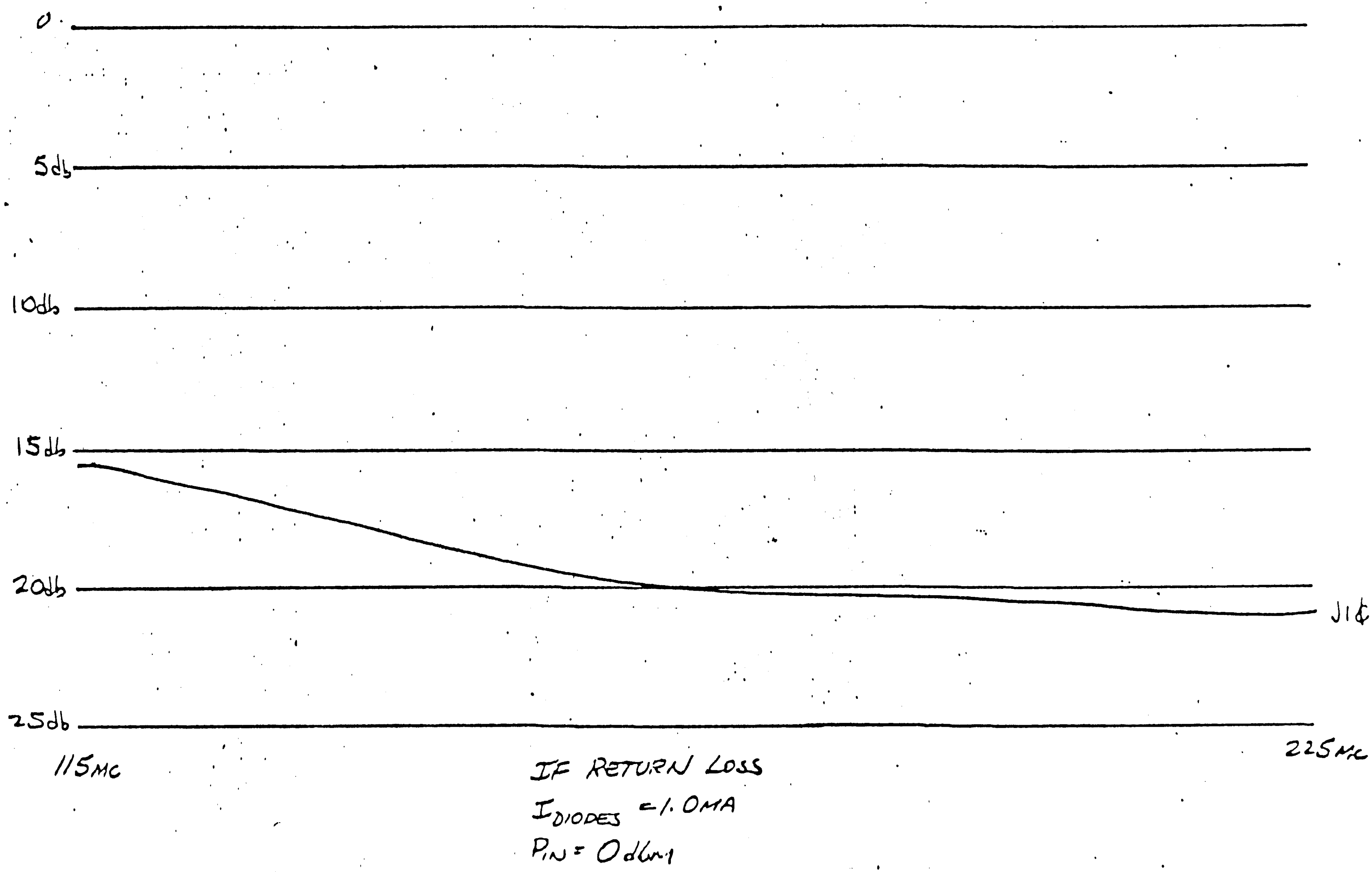
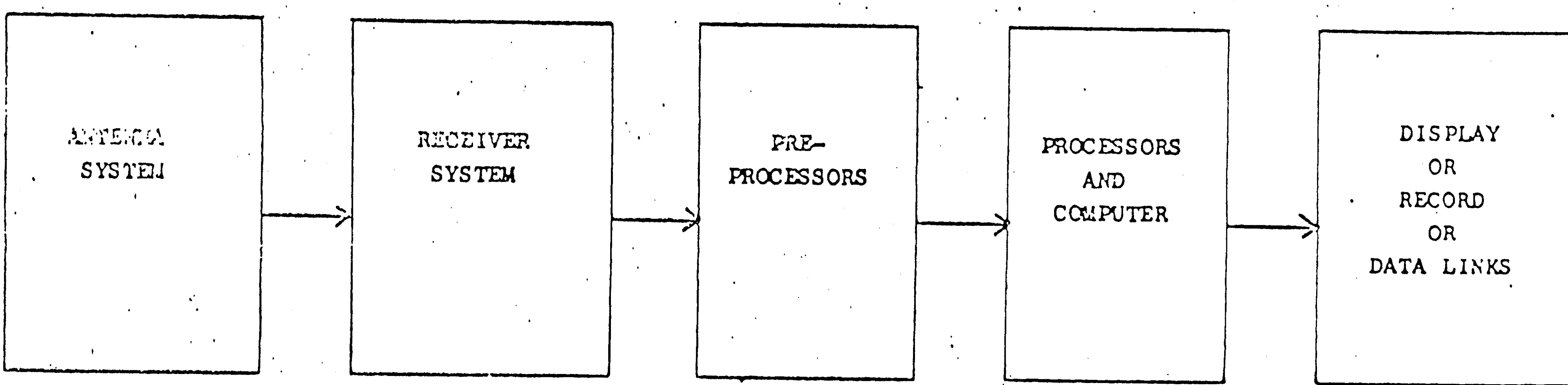



FIGURE 7(b) LO-RF ISOLATION CHARACTERISTICS FOR K-BAND MIC IMAGE REJECT MIXER




1/15/75JW

FIGURE 8 REAL AND IMAGE IF RETURN LOSS CHARACTERISTICS FOR K-BAND




- ETL'S CONTRIBUTIONS ARE APPLICABLE TO
  - ANTENNA SYSTEM
  - RECEIVER SYSTEM
  - PRE-PROCESSORS AND DATA LINKS (SECONDARY

TYPICAL ESM SYSTEM CONCEPT

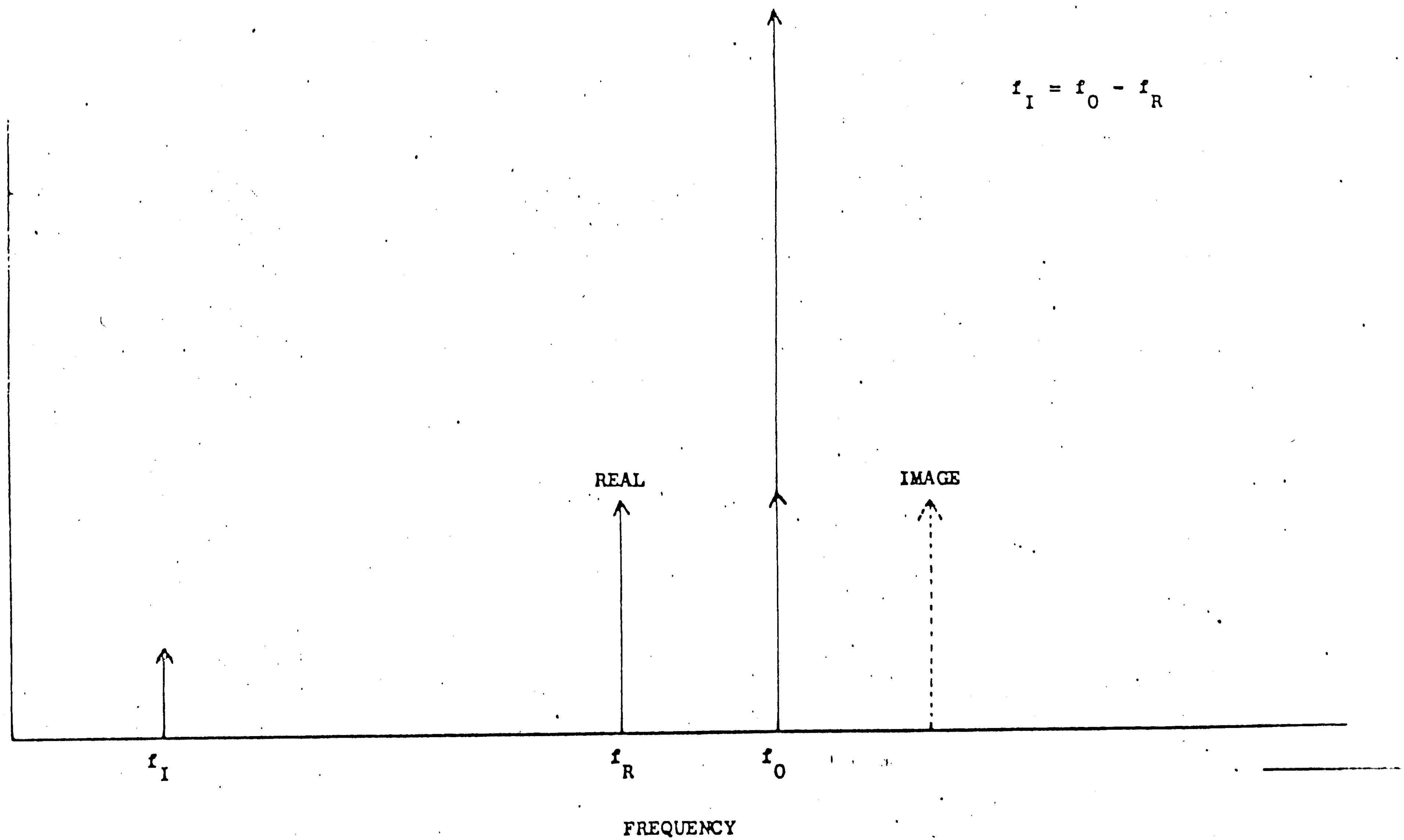
# PURPOSE OF A RECEIVER FRONT END

- IT IS BASICALLY A DOWN CONVERTER

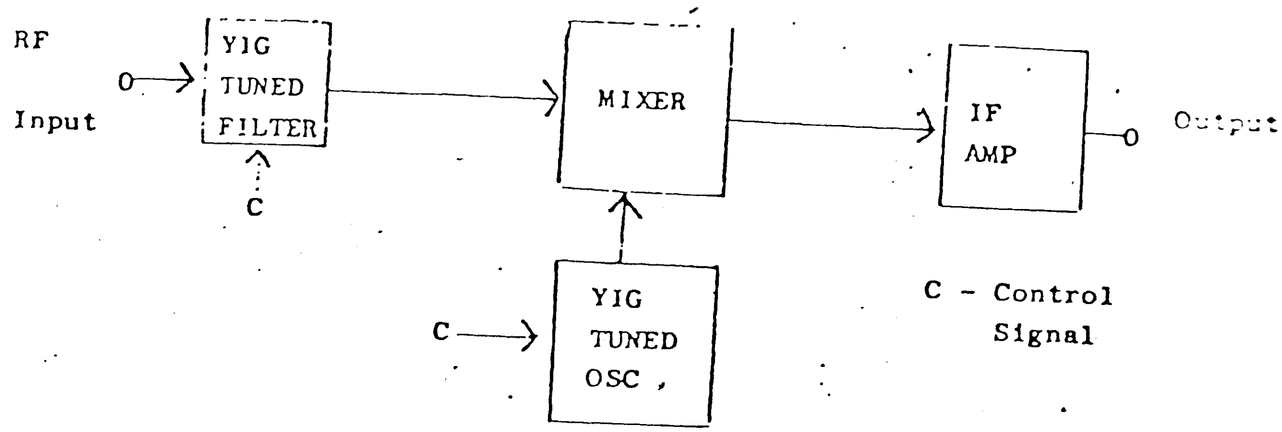
- WHAT IS DOWN CONVERSION?

  THE CONVERSION OF A HIGH FREQUENCY SIGNAL TO A LOW FREQUENCY SIGNAL WITHOUT LOSS OR DISTORTION OF INFORMATION TO ALLOW A PROCESSING SYSTEM TO CHARACTERIZE THE UNKNOWN SIGNAL

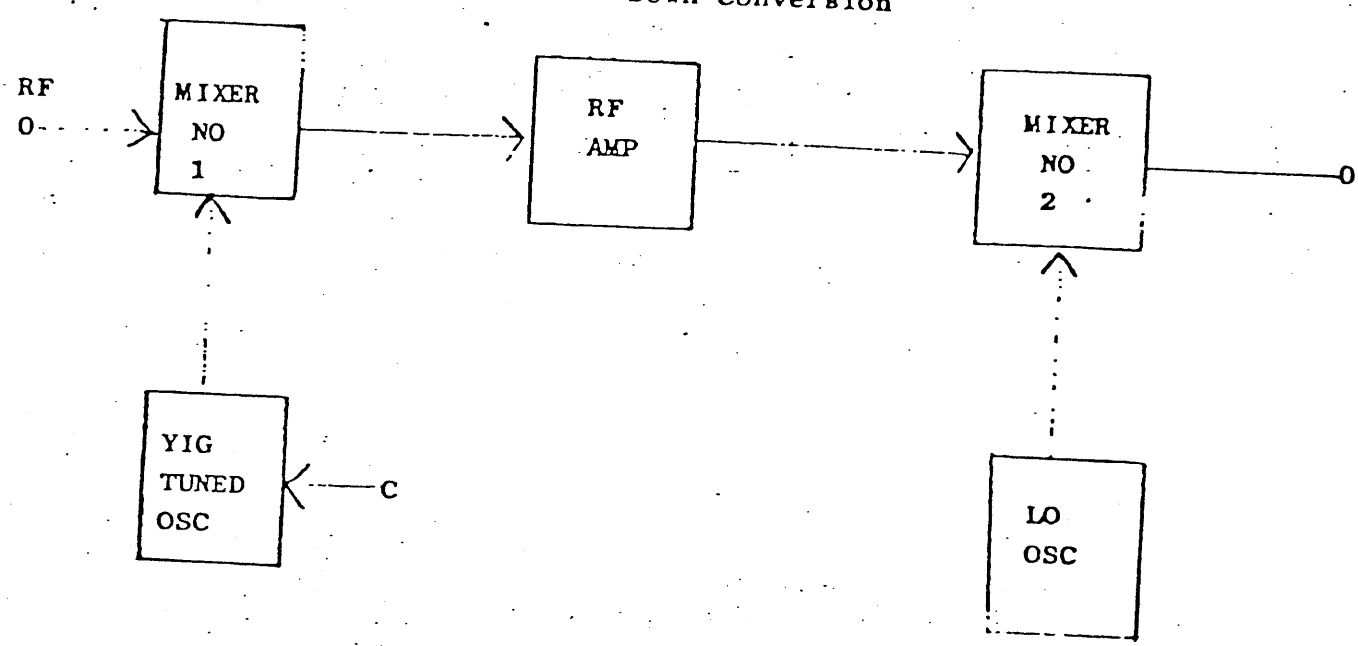
FREQUENCY SPECTRUM



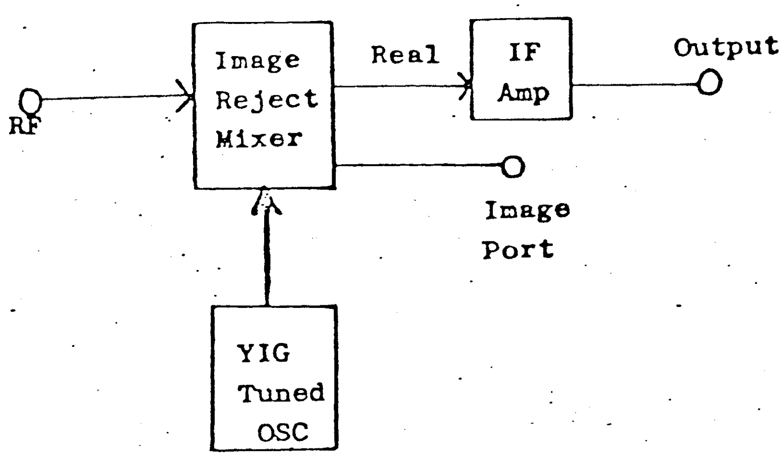
## Single Down Conversion




## Double Down Conversion



SINGLE DOWN CONVERSION WITH IMAGE REJECTION



# PRINCIPLE FACTORS THAT DETERMINE THE SELECTION OF A PARTICULAR MIXER KIND ARE:

- FREQUENCY RANGE AT ALL PORTS
- NOISE FIGURE
- LO-RF ISOLATION
- VSWR
- DYNAMIC RANGE
- INTERMODULATION PRODUCTS
  $(mf_s \pm nf_{LO})$
  - SINGLE BALANCED
    ODD AND EVEN OF LO ONLY
    ODD OF SIGNAL ONLY
  - DOUBLE BALANCED
    ODD OF LO AND RF ONLY
- LO NOISE SUPPRESSION
- IMAGE REJECTION REQUIREMENTS
- STARVED LO OPERATION

## BACKGROUND ON MIXER DESIGNS AND CONCEPTS

- THERE ARE BASICALLY FIVE TYPES OF MIXERS

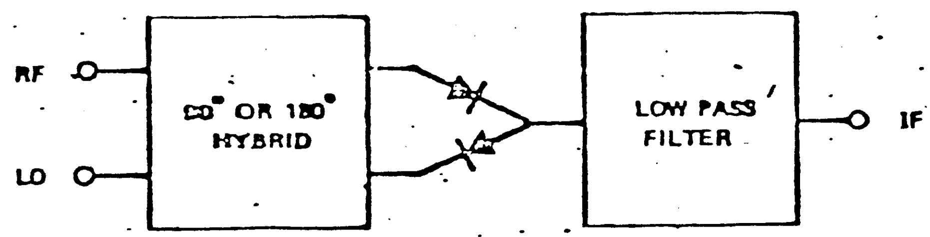
  -- SINGLE-ENDED MIXER

  -- SINGLE-BALANCED MIXER

  -- DOUBLE-BALANCED MIXER

  -- IMAGE REJECT MIXER

  -- IMAGE ENHANCED MIXER




BASIC SCHEMATIC OF BALANCED MIXER

## SELECTION OF PARTICULAR CIRCUIT MEDIA

- FOUR MAIN TYPES ARE

  -- WAVEGUIDE

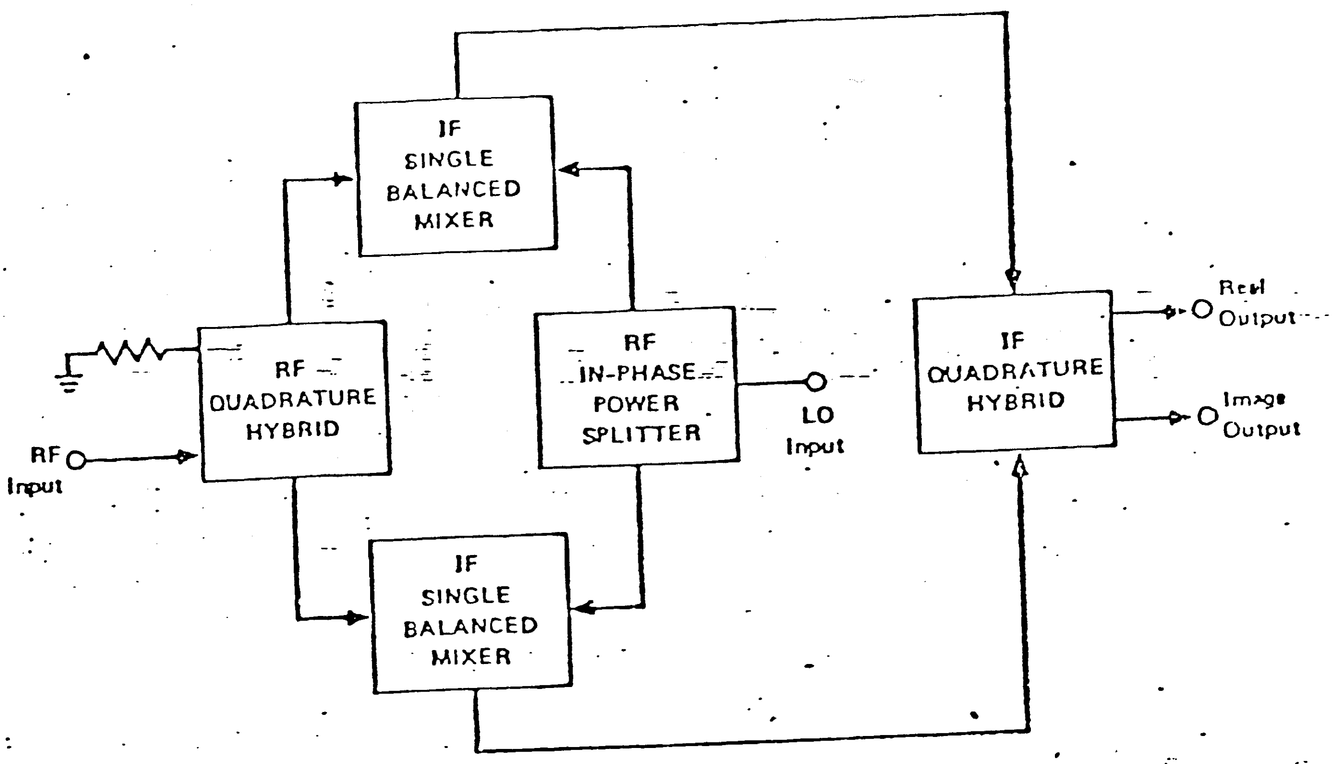
  -- COAXIAL

  -- STRIPLINE (air or dielectric)

  -- MICROSTRIP

  -- IMAGE LINE

  -- MICROGUIDE




UNCLASSIFIED

FIGURE 2 MIC IMAGE REJECT MIXER BLOCK DIAGRAM

## KEY REASONS FOR USING MICROSTRIP MEDIA AT MICROWAVE- AND MILLIMETER-WAVE FREQUENCIES

- LOW RECURRING COSTS
- LARGE SCALE PLANAR INTEGRATION
- CAPABILITY FOR INTEGRATING OPTIMIZED DISCRETE COMPONENTS
- BROAD BANDWIDTH CAPABILITY
  - -- LOW PARASITICS
- EXCELLENT MANUFACTURABILITY
  - -- STABLE WITH TIME AND TEMPERATURE
  - -- OPTIMIZED PERFORMANCE IN PRODUCTION
- MEDIA IS WELL UNDERSTOOD AND DEFINED
  - -- STANDARD DISCRETE CIRCUITS CAN BE CONVERTED TO MICROSTRIP BY USING KEY EQUIVALENT CIRCUITS
  - -- MAIN MODE CAN BE LAUNCHED FROM COAXIAL OR WAVEGUIDE PORTS
- RELATIVELY LOW LOSS

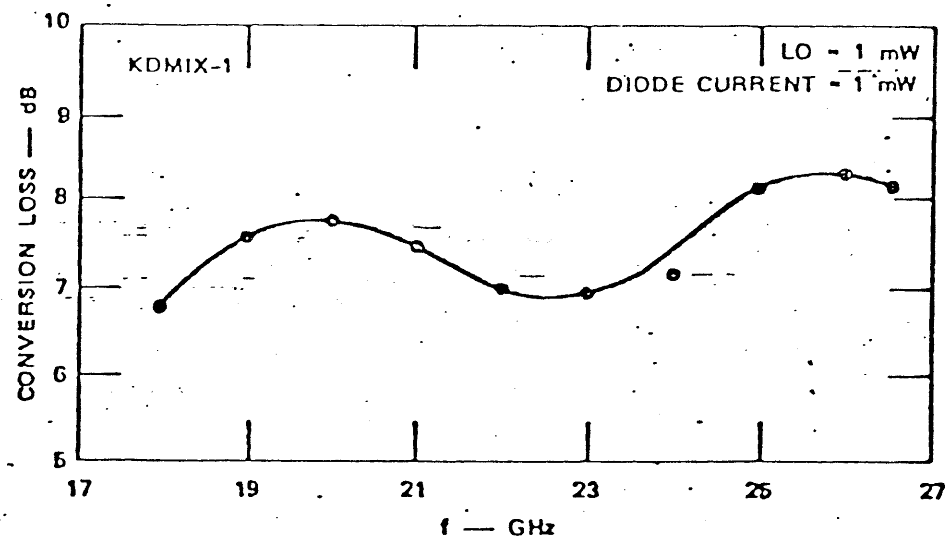



Figure 3 Conversion Loss as a Function of Frequency for the Single Balanced Mixer

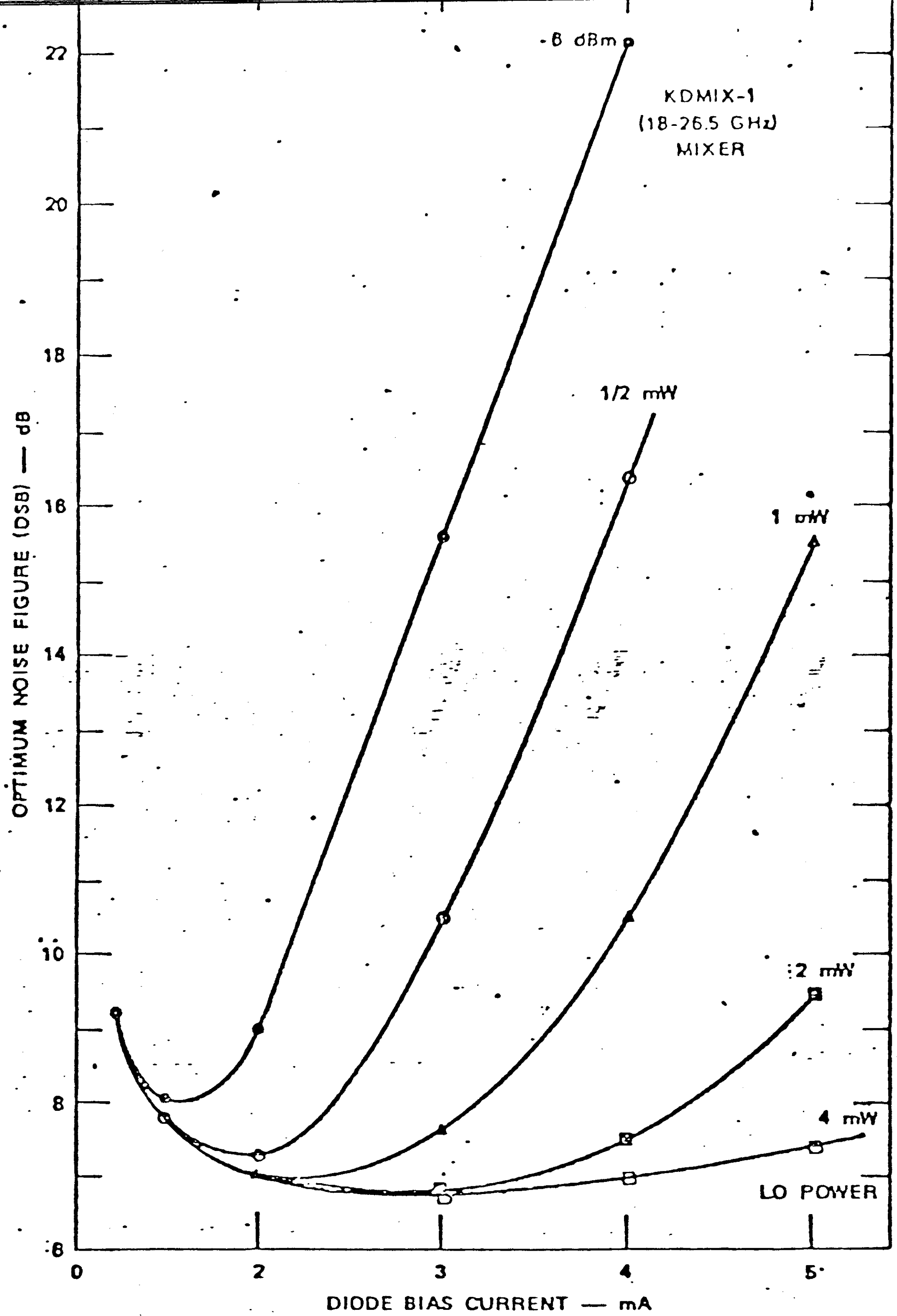
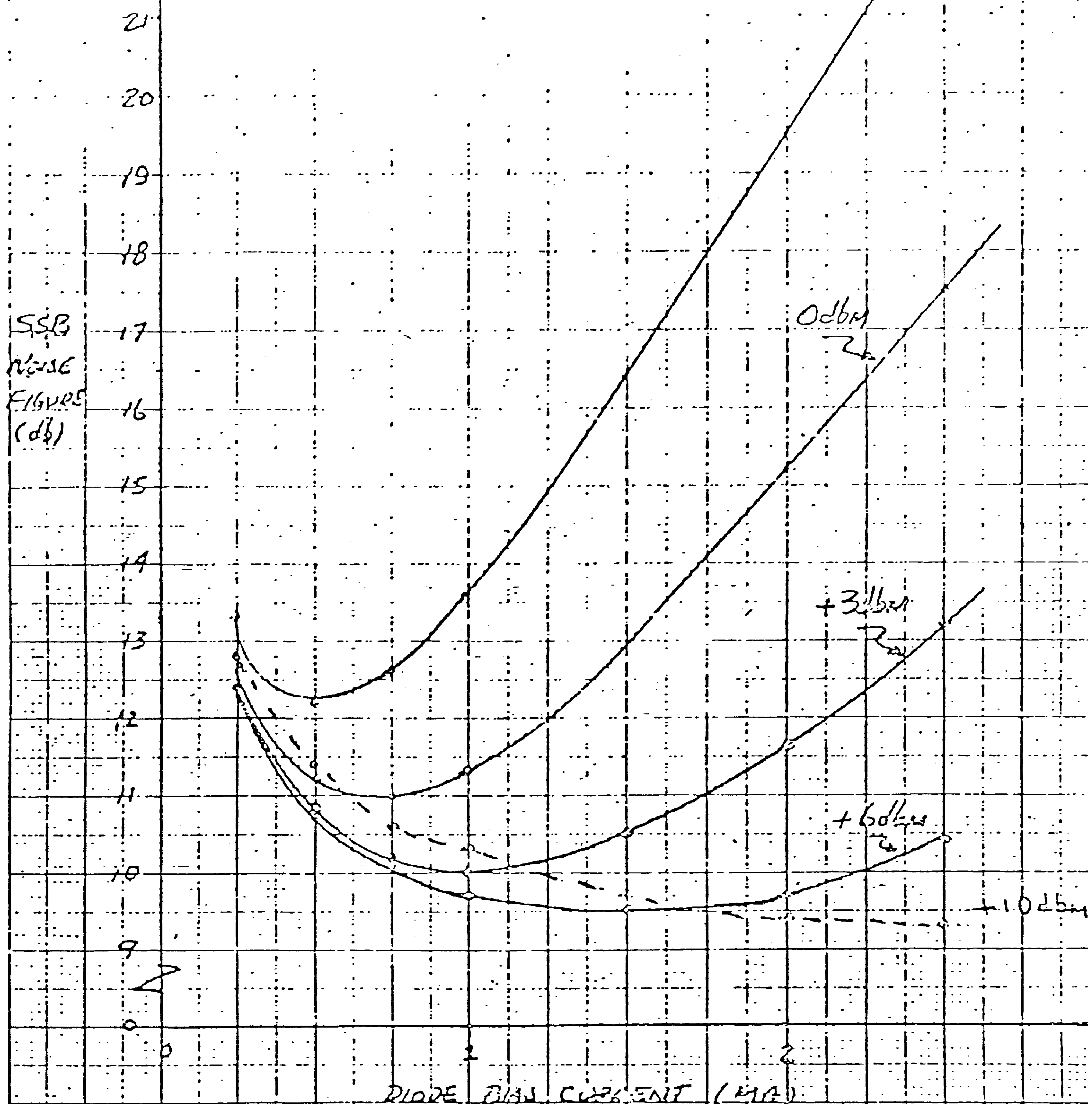



Figure 4 Double Sideband Noise Figure of the Single Balanced Mixer as a Function of Diode Bias Current for Various LO Drive Powers




NOISE FIGURE CHARACTERISTICS
OF A PLANAR MICROSTRIP
1/7/75 IMAGE REJECT MIXER AT 26GHz

## Summary

| | |
|---|---|
| Frequency: | 18 to 26 GHz |
| Size: | 4" × 2.5 " × 2.1 " excluding connectors |
| Weight: | 1 pound |
| Power Requirements: | + 15 VDC at 2 mA<br>– 15 VDC at 2 mA |
| LO Drive Range: | +3 to +6 dBm |

### Test Results

| Notes | Parameter | Max or Min Data +3 dBm | +6 dBm | Typical Data |
|---|---|---|---|---|
| | Conversion loss | 10.0 dB | 9.6 dB | 8.7 dB |
| | Image rejection | 18 dB | 17 dB | 22 dB |
| | LO to RF isolation | 12 dB | 9 dB | 16 dB |
| | LO to IF isolation | 36 dB | 36 dB | 41 dB |
| | RF VSWR | 2.4:1 | 2.6:1 | 1.5:1 |
| | LO VSWR | 2.0:1 | 2.4:1 | 1.4:1 |
| | IF VSWR (50-70 MHz) | 1.5:1 | 1.5:1 | 1.25:1 |
| | 1 dB Compression point | 0 dBm | +1 dBm | +1.5 dBm |
| 1 | Common mode rejection | 26 dB | 26 dB | 35 dB |
| 2 | 2 × 2 suppression | 44 dB | 45 dB | 53 dB |
| 2 | 4 × 3 suppression | >60 dB | >60 dB | > 60 dB |
| 2 | 3 × 4 suppression | >60 dB | >60 dB | > 60 dB |
| 3 | 2 tone 2nd order intermod | -40 dB | -42 dB | N/A |
| 3 | 2 tone 3rd order intermod | -52 dB | <-60 dB | N/A |

Notes: (1) Injected RF level = -20 dBm
IF output level measured relative to RF level

(2) RF level = -20 dBm
IF output level measured relative to primary IF output

(3) RF1 = RF2 = -20 dBm
Data taken at 25 GHz

# SUMMARY OF TEST RESULTS FOR WIDEBAND 26.5 to 40 GHz BALANCED MIXER

Test Results at +6 dBm LO Power Level
and 1.5 mA Bias Current (Both Diodes)

| | |
|---|---|
| Conversion Loss | 7.3 dB ± 0.6 dB |
| RF Port VSWR | 3.0 max |
| LO Port VSWR | 3.0 max |
| IF Port VSWR | 1.2 |
| Noise Figure at 39 GHz<br>Incl. 1.3 dB IF Noise Figure | 8.8 dB |
| LO to RF Isolation | 24 dB typ<br>18 dB min |
| 2 X 2 Spurious Response<br>at -20 dBm RF Level | -45 dB min |

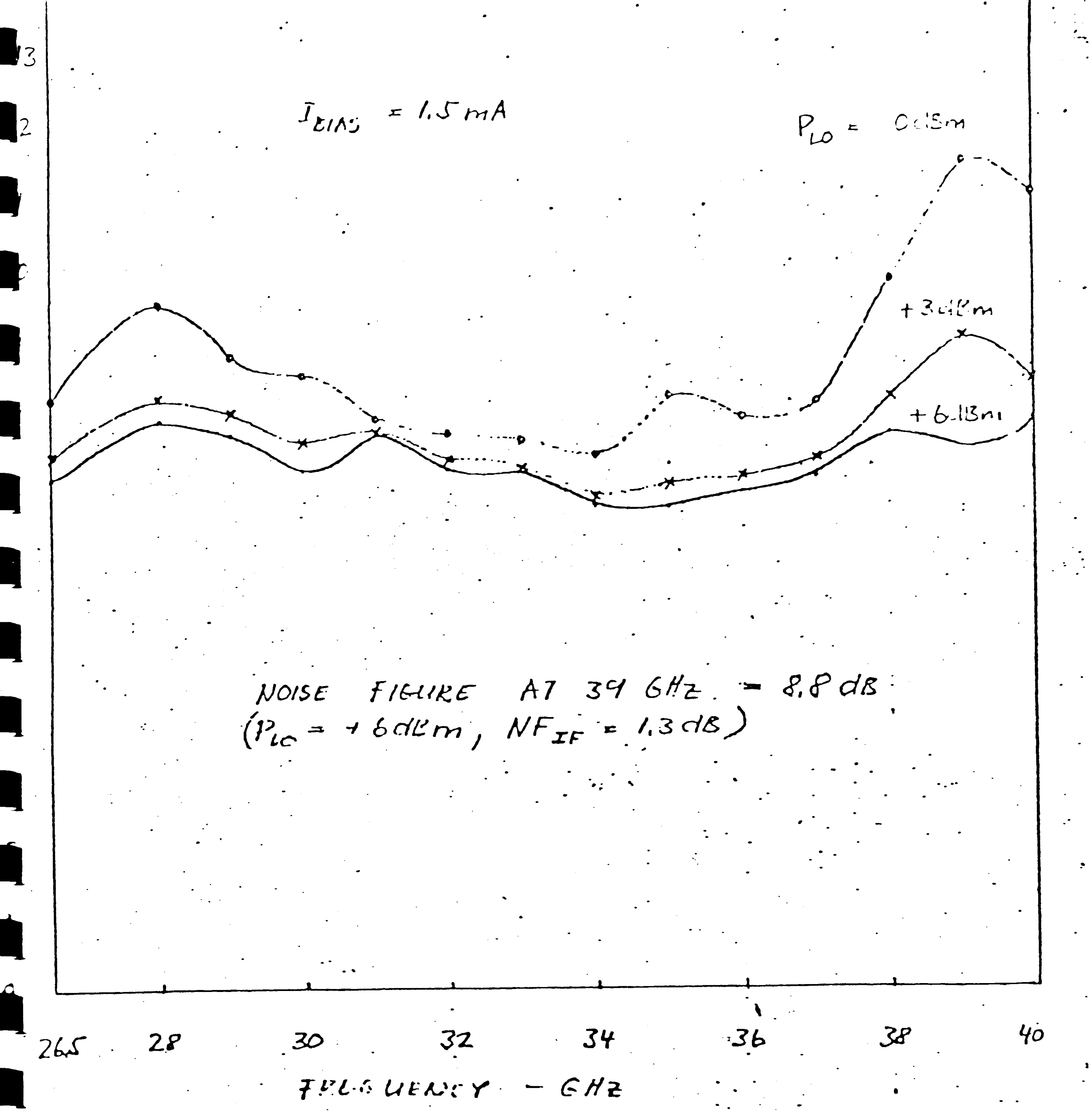



FIGURE 2 CONVERSION LOSS OF WIDEBAND 26.5 TO 40 GHz BALANCED MIXER

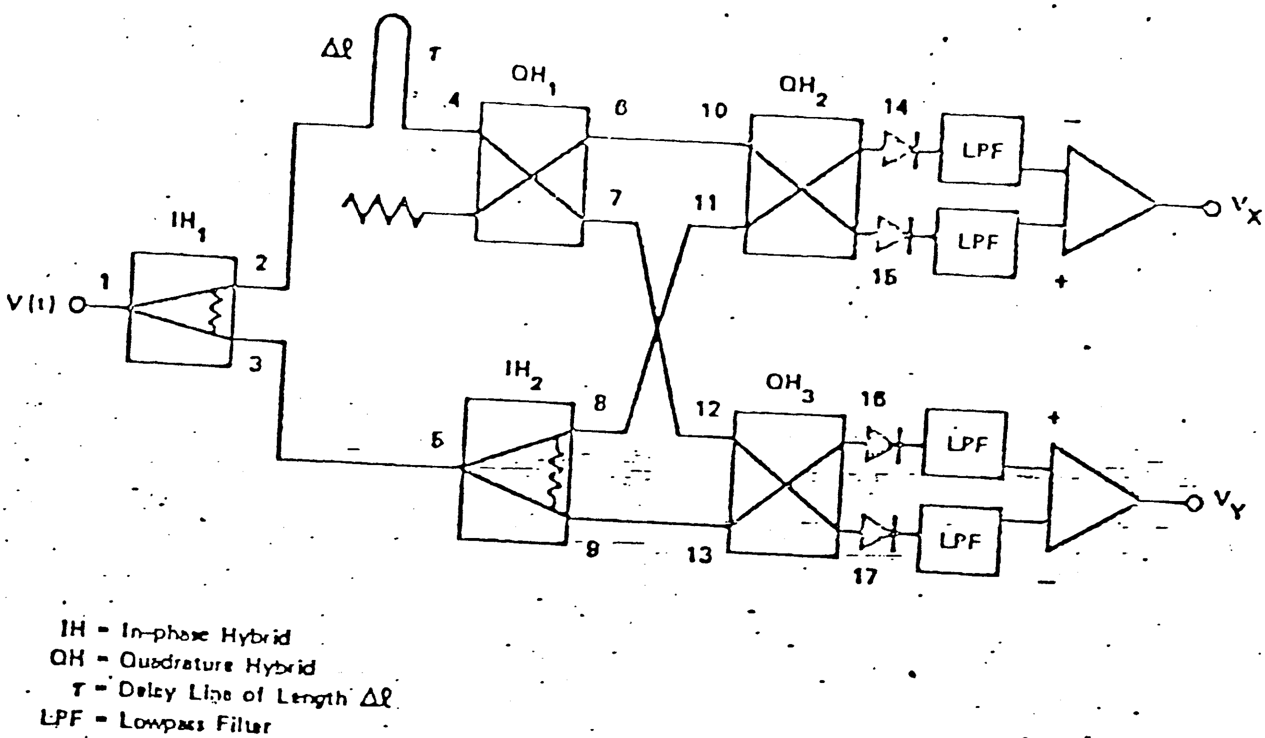



Figure 1 Block Diagram of Polar Discriminator

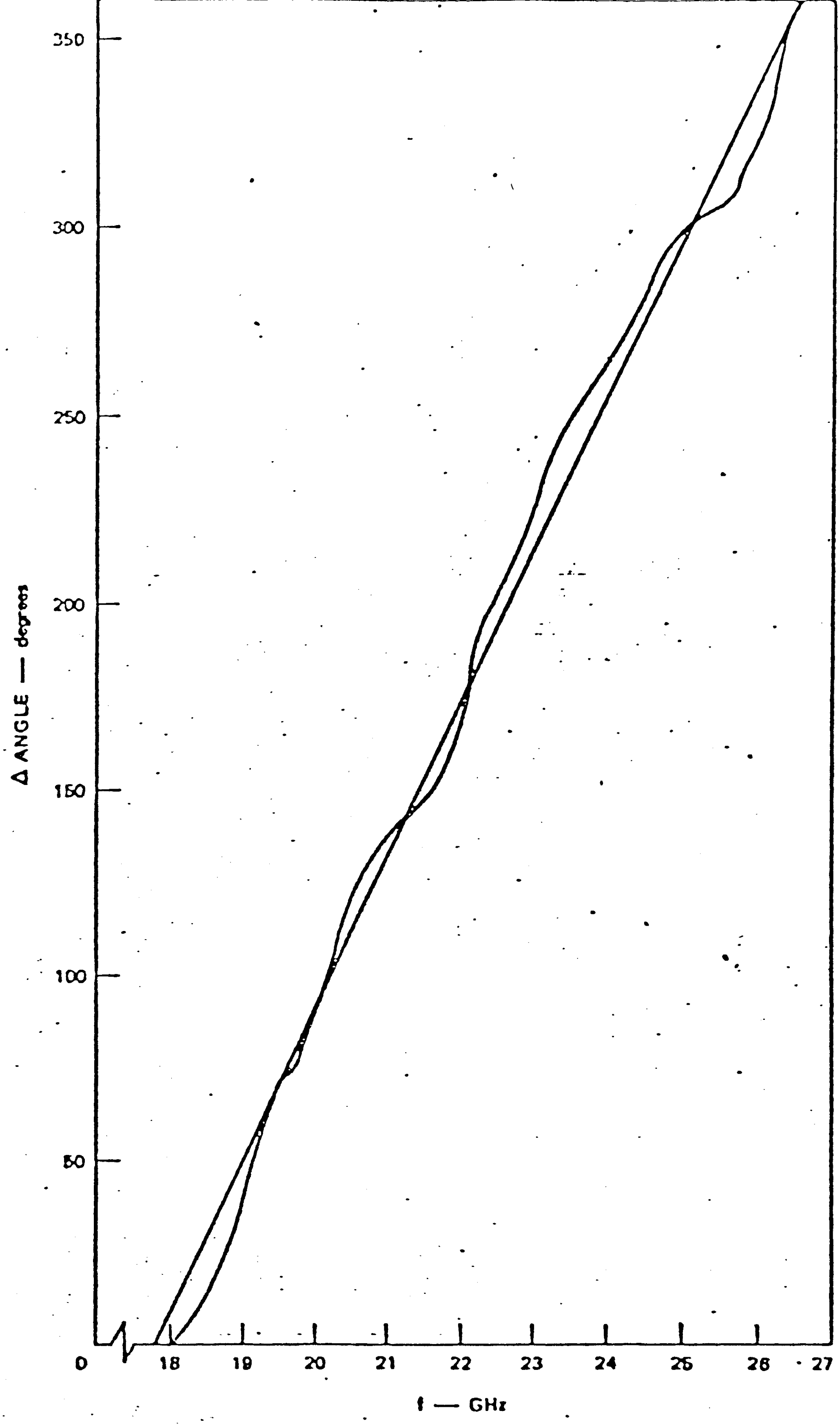



Figure 4 Phase Angle as a Function of Frequency for the Experimental Model of 18-26.5 GHz MIC Polar Discriminator

## 10.2 Line Discriminators

A line discriminator as shown in figure 10-2 has one output proportional to cosine of a phase angle proportional to the input frequency. This discriminator is generally used only over the linear portion of the cosine curve where output voltage is directly proportional to the input frequency.

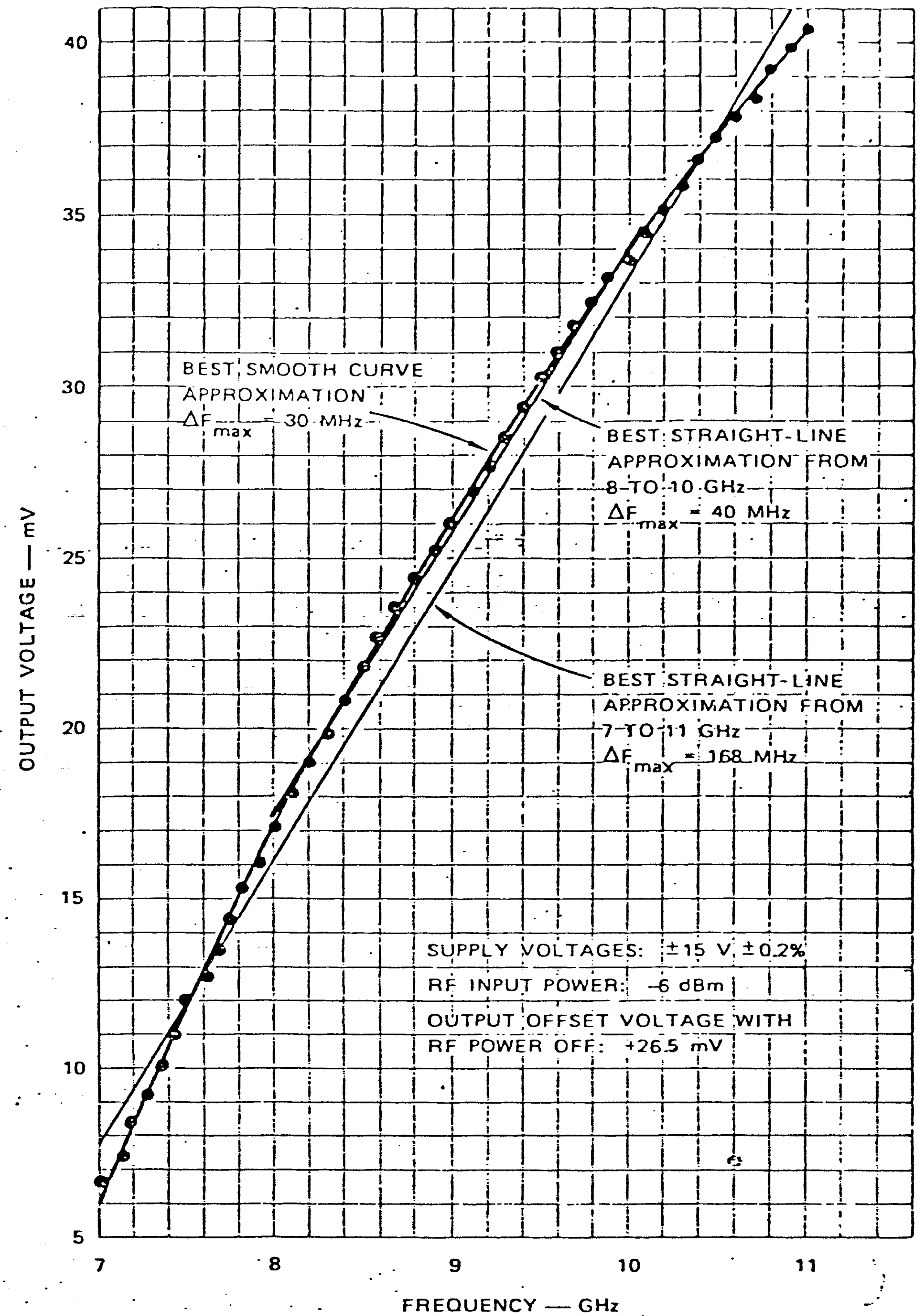
The team has designed, developed and manufactured linear line discriminators using planar MIC-technology, in the frequency range of 1 GHZ to 12 GHz. Higher frequency models can easily be fabricated by extending our designs to 40 GHz.

The advantages of our line discriminators for a system designer are as follows:

- o Low cost
- o High linearity $\pm$ 50 MHz (typical) to $\pm$ 100 MHz (max) in the frequency range of 7 to 11 GHz or 11 to 18 GHz
- o High sensitivity
- o Broad bandwidths and operation at higher frequencies 7 to 11, 11 to 18 GHz, 18 to 26 GHz, 26 to 40 GHz
- o Fast response. If input RF is pulsed, output will be pulsed. --High video bandwidth.
- o Small size, weight, volume and compact
- o High reliability and ruggedized
- o Coaxial RF inputs up to 40 GHz are available if required by customers for integration in a system without bulky waveguide interface

A line discriminator consists of two in phase quadrature hybrids that are connected by a delay line which is generally quarter wavelength or three times quarter wavelength depending on the sensitivity required.

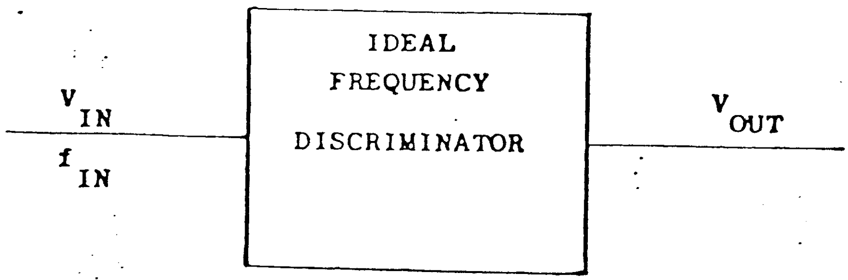
The team has fabricated linear line discriminator at the following frequencies: ~~1.5 GHz (basewidth $\pm$ 200 MHz), 1.7 GHz (± 400 MHz bandwidth),~~ 3.4 GHz ($\pm$ 400 MHz bandwidth), 7 GHz ($\pm$ 2 GHz bandwidth). The response of the MIC line discriminator for application at band is shown in figure 10-3. The key item in the discriminator is the design and fabrication of quadrature 3 dB hybrid. The team has fabricated such hybrids up to 40 GHz.



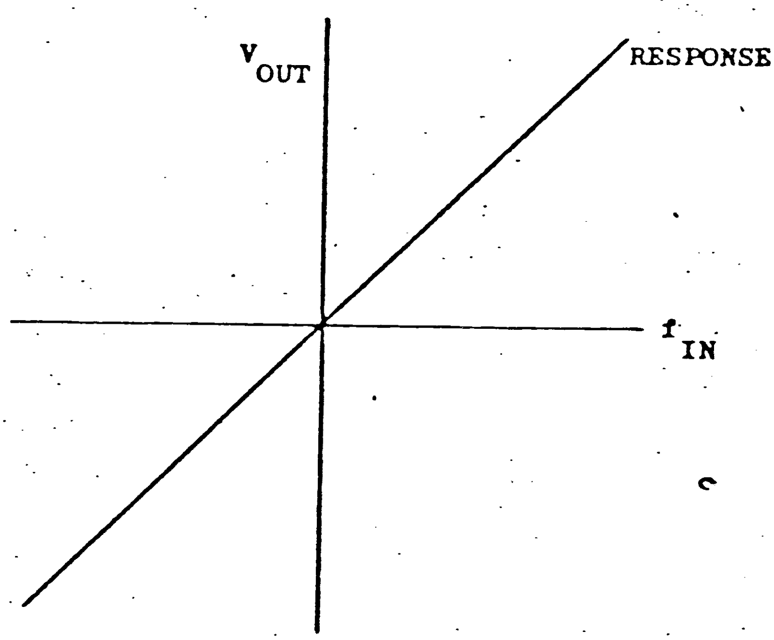
BEST SMOOTH CURVE APPROXIMATION
ΔF max = 30 MHz
BEST STRAIGHT-LINE APPROXIMATION FROM 8 TO 10 GHz
ΔF max = 40 MHz
BEST STRAIGHT-LINE APPROXIMATION FROM 7 TO 11 GHz
ΔF max = 168 MHz
SUPPLY VOLTAGES: ±15 V, ±0.2%
RF INPUT POWER: -6 dBm
OUTPUT OFFSET VOLTAGE WITH RF POWER OFF: +26.5 mV
OUTPUT VOLTAGE — mV
FREQUENCY — GHz
5
10
15
20
25
30
35
40
7
8
9
10
11


CLASSIFIED

- WHAT IS A FREQUENCY DISCRIMINATOR?




$V_{OUT} \propto f_{IN}$ FOR ANY $V_{IN}$.



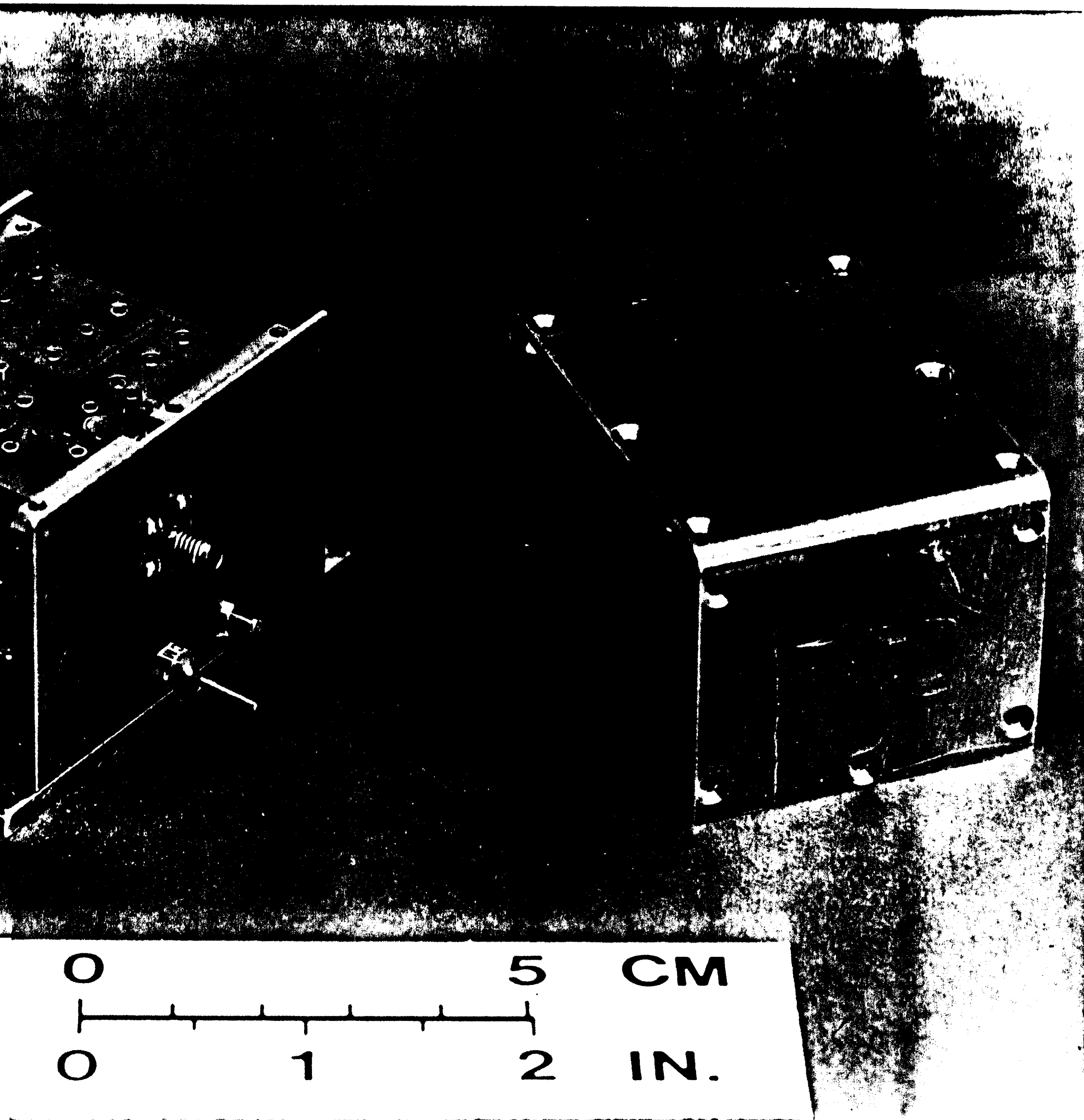

- RESPONSE IS INDEPENDENT OF INPUT SIGNAL

# MILLIMETER WAVE AMPLIFIERS

18-45 GHz

## ABSTRACT

The design and performance of fullband, low noise solid state Gunn effect amplifier modules for the K and Ka waveguide bands is described. These low noise modules are to be used in the design of long life, high gain multi-stage TWT replacement amplifiers. The K-band amplifier utilizes a thin film dual diode approach and provides 16.0 ± 2.0 dB gain with noise figures in the 16.8 to 18.1 dB range. A staggered gain configuration is utilized in Ka-band yielding 19 ± 2.4 dB gain and noise figures of 15.6 to 16.5 dB. Fullband amplifiers with 40 dB gain and slightly improved gain variation performance are the next logical step. Use of InP devices in the input stages will be shown to significantly reduce noise figures.




K-BAND, TWO STAGE, DUAL DIODE CIRCUIT, LOW NOISE AMPLIFIER WITH COVER REMOVED. CENTER JUNCTION IS AN ISOLATOR. D.C. ELECTRONICS ARE MOUNTED IN BASEPLATE.

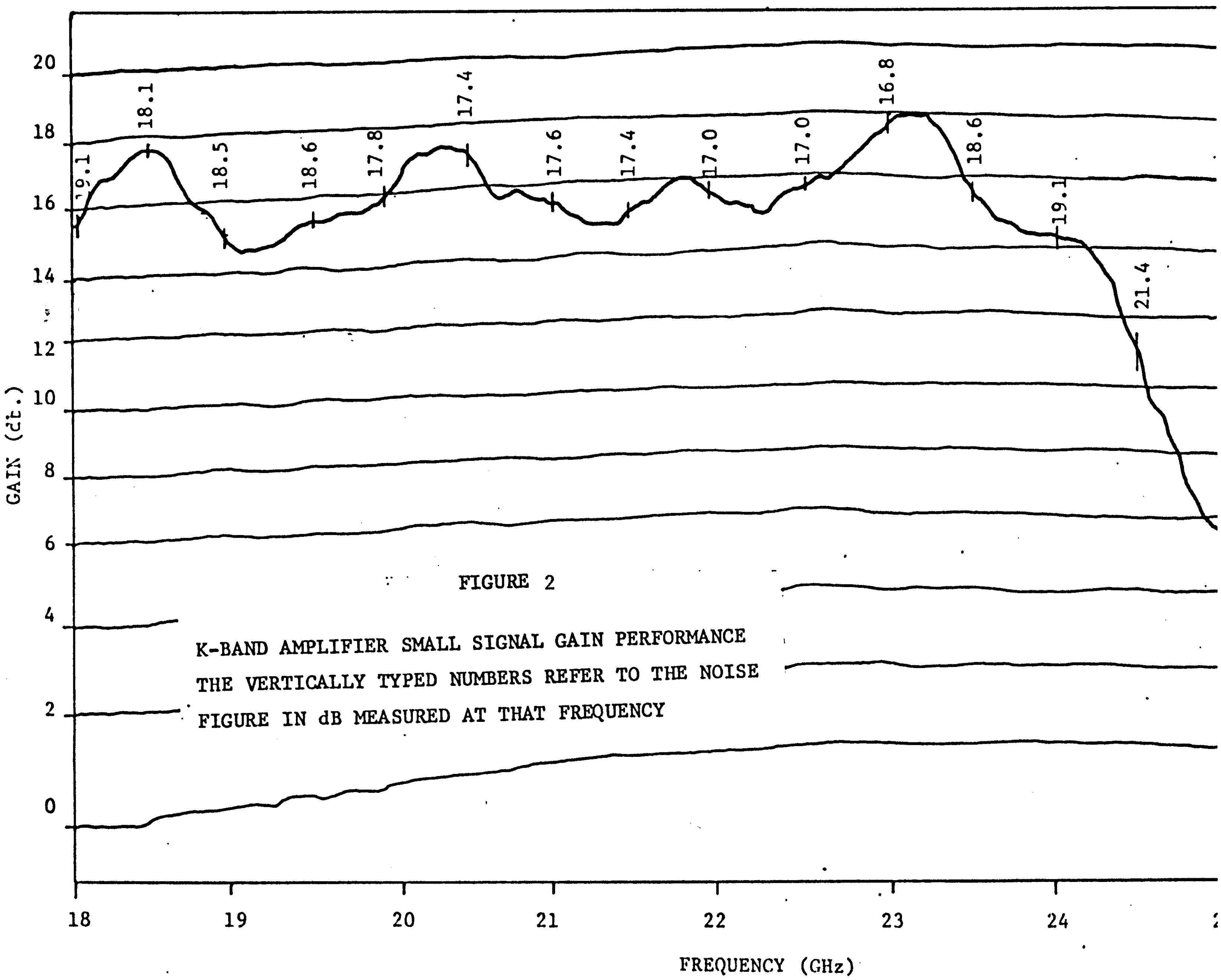
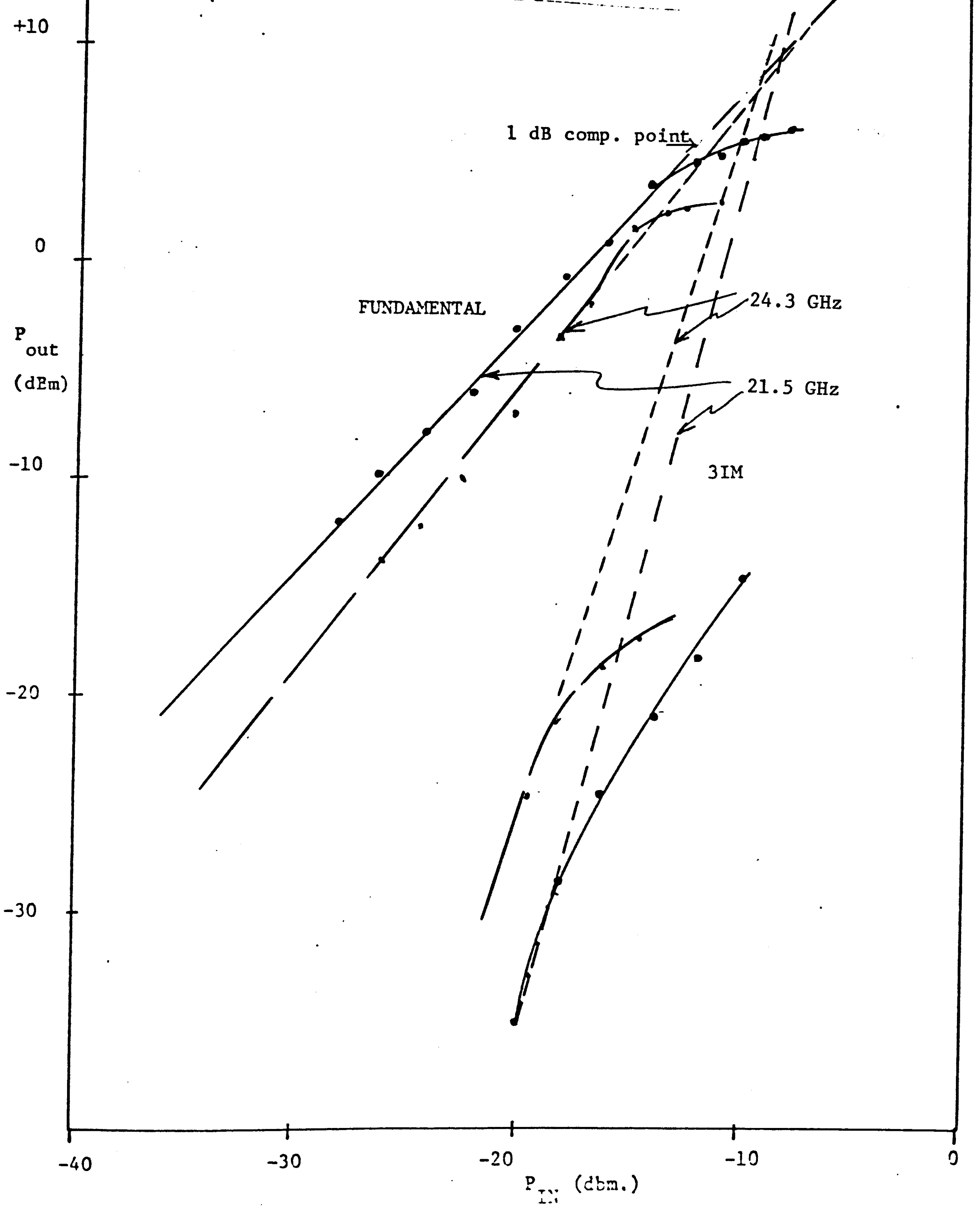


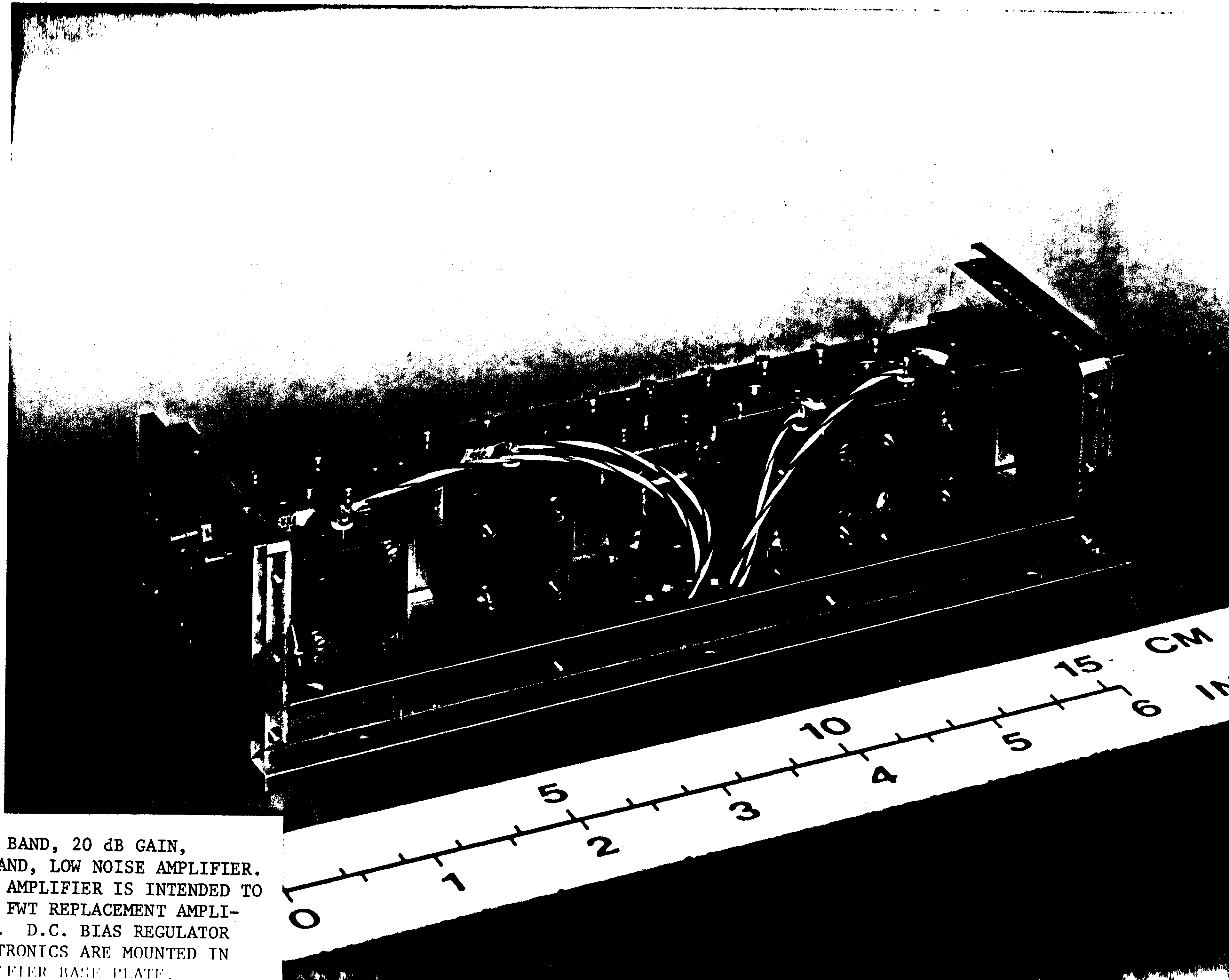

FIGURE 2

K-BAND AMPLIFIER SMALL SIGNAL GAIN PERFORMANCE
THE VERTICALLY TYPED NUMBERS REFER TO THE NOISE
FIGURE IN dB MEASURED AT THAT FREQUENCY

FIGURE 3

K-BAND AMPLIFIER GAIN COMPRESSION CHARACTERISTICS AND 3 IM PERFORMANCE AT 21.5 GHz and 24.3 GHz






FULL BAND, 20 dB GAIN, KA-BAND, LOW NOISE AMPLIFIER. THIS AMPLIFIER IS INTENDED TO BE A FWT REPLACEMENT AMPLIFIER. D.C. BIAS REGULATOR ELECTRONICS ARE MOUNTED IN AMPLIFIER BASE PLATE.

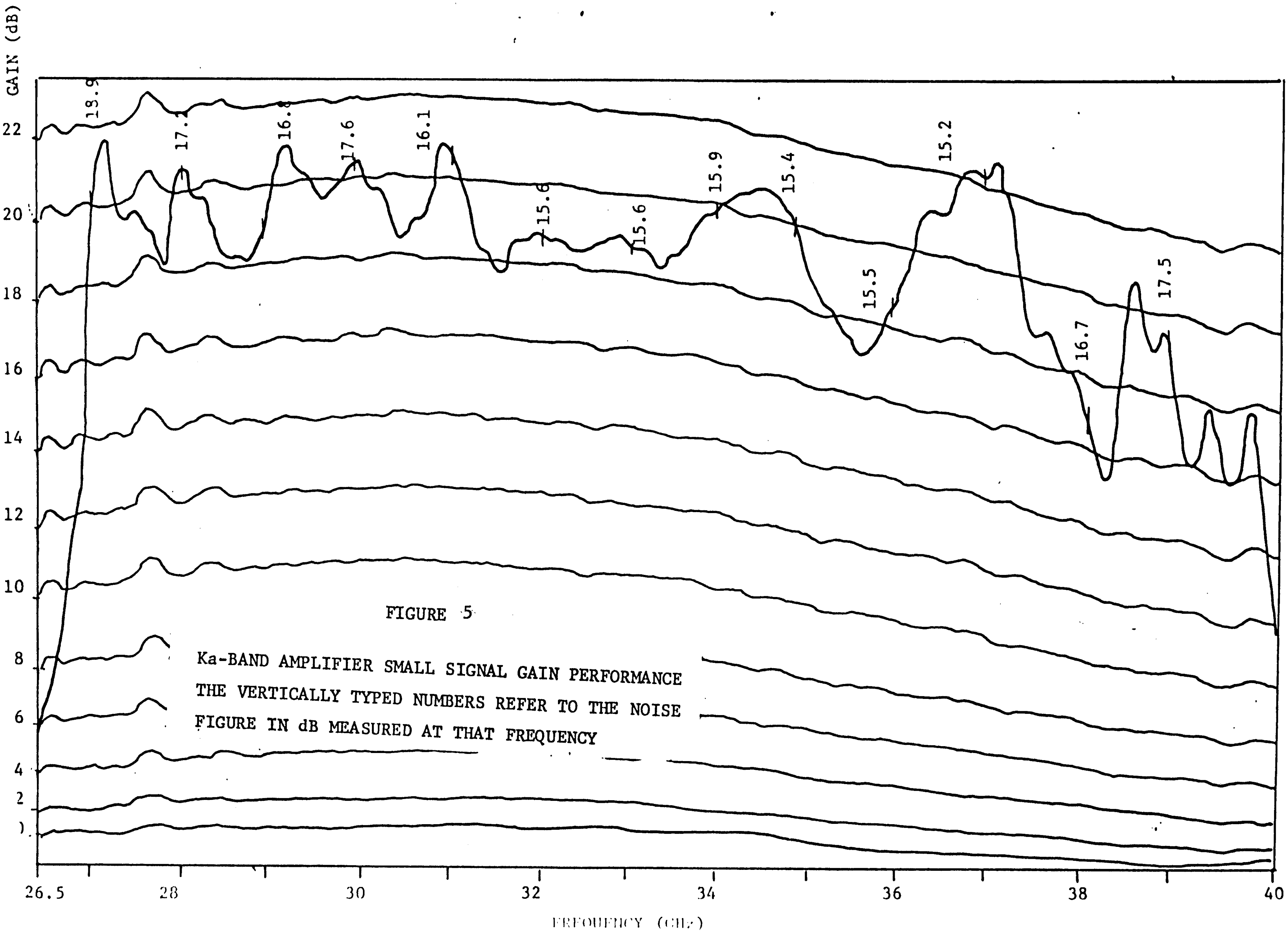



FIGURE 5

Ka-BAND AMPLIFIER SMALL SIGNAL GAIN PERFORMANCE
THE VERTICALLY TYPED NUMBERS REFER TO THE NOISE
FIGURE IN dB MEASURED AT THAT FREQUENCY

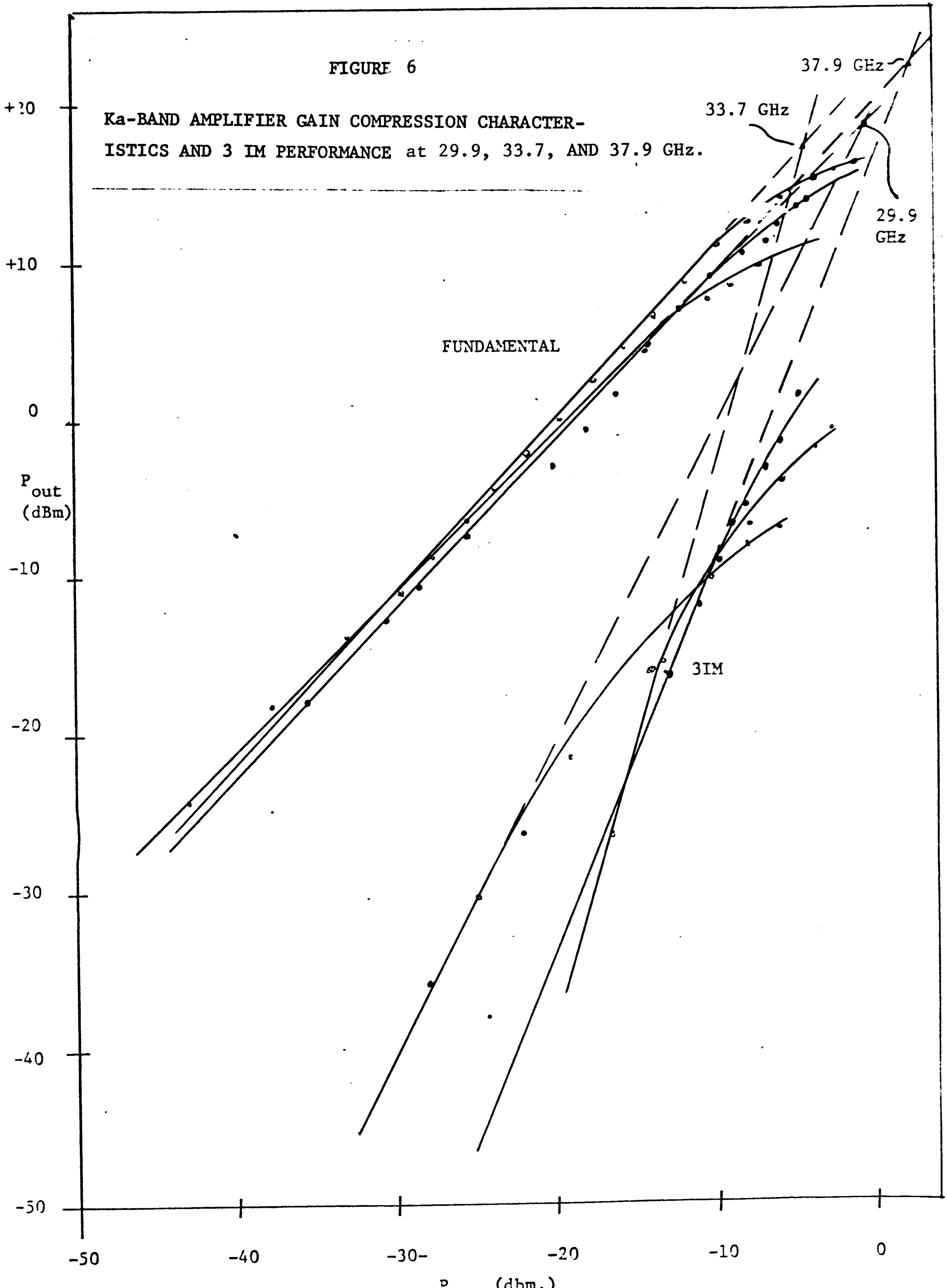


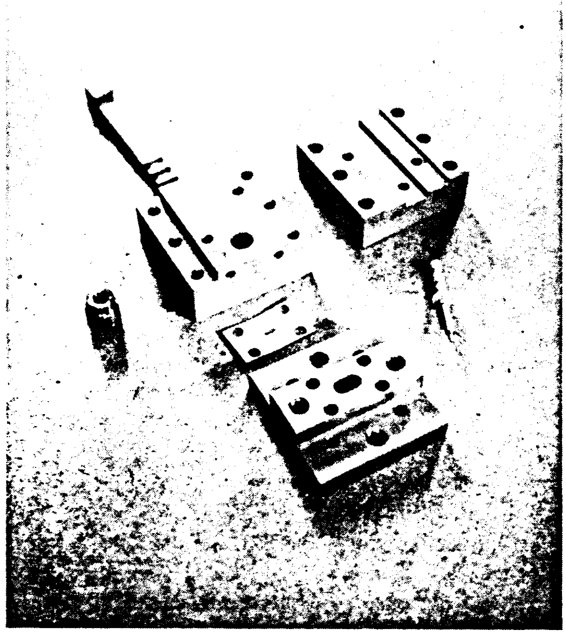

FIGURE 6

Ka-BAND AMPLIFIER GAIN COMPRESSION CHARACTERISTICS AND 3 IM PERFORMANCE at 29.9, 33.7, AND 37.9 GHz.

# MILLIMETER WAVE OSCILLATORS

## 50-75 GHz

Oscillators at a wide range of millimeter wave frequencies have been developed and in several transmission mediums. Shown on the following pages are photographs of waveguide and radial line oscillators in the 60 GHz frequency region. Also presented is a table with performance summarized for several oscillator types.



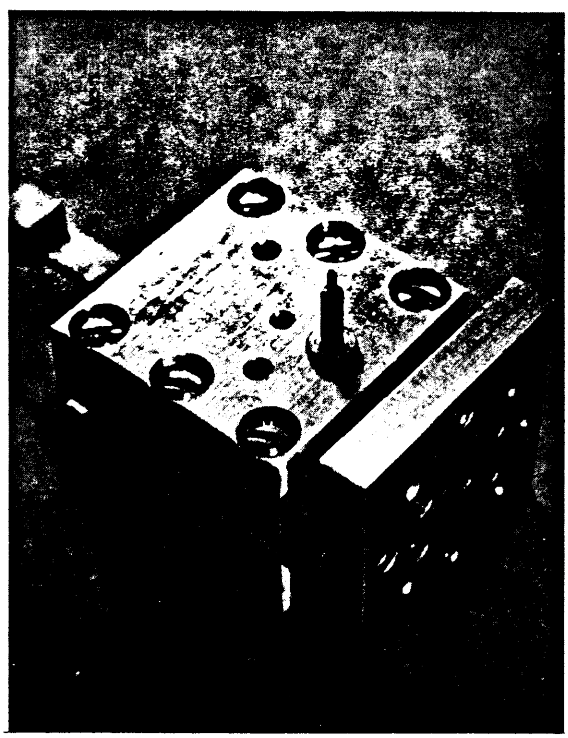


Figure 5.2. Iris Coupled Reduced Height Waveguide 60 GHz Oscillator Circuit

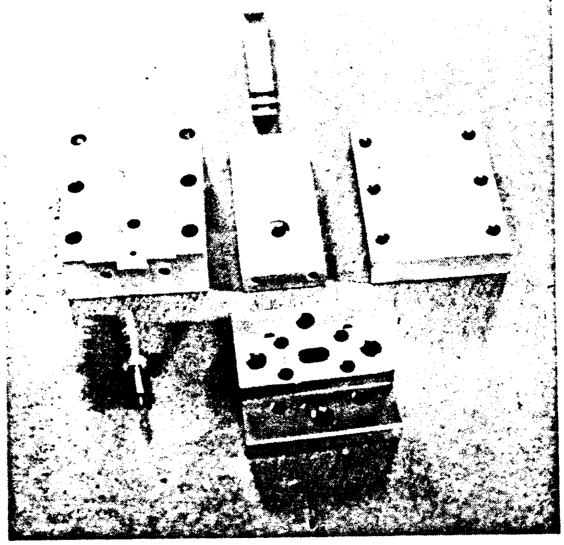


Figure 5.3. Radial Line Waveguide 60 GHz Oscillator Circuit

CIRCUIT TYPICAL PERFORMANCE SUMMARY

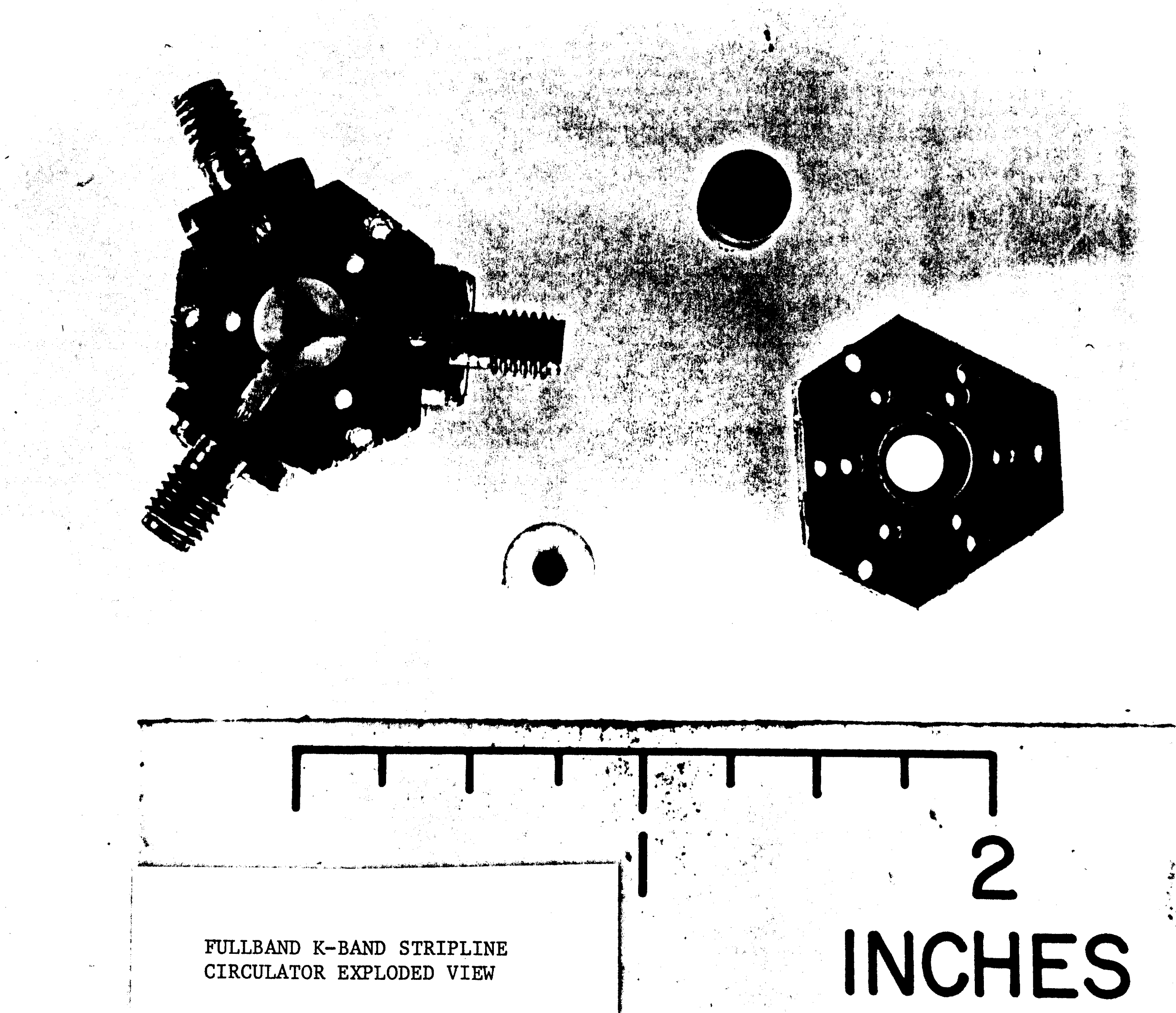
| Gunn Device Material | Circuit Type | | |
|---|---|---|---|
| | Radial Line | Iris Coupled | Coaxling |
| GaAs | 42 mw<br>48 GHz | 60 mw<br>64 GHz | 25 mw<br>51 GHz |
| InP | 95 mw<br>58 GHz | 27 mw<br>53 GHz | 170 mw<br>64 GHz |

# MILLIMETER WAVE CIRCULATORS

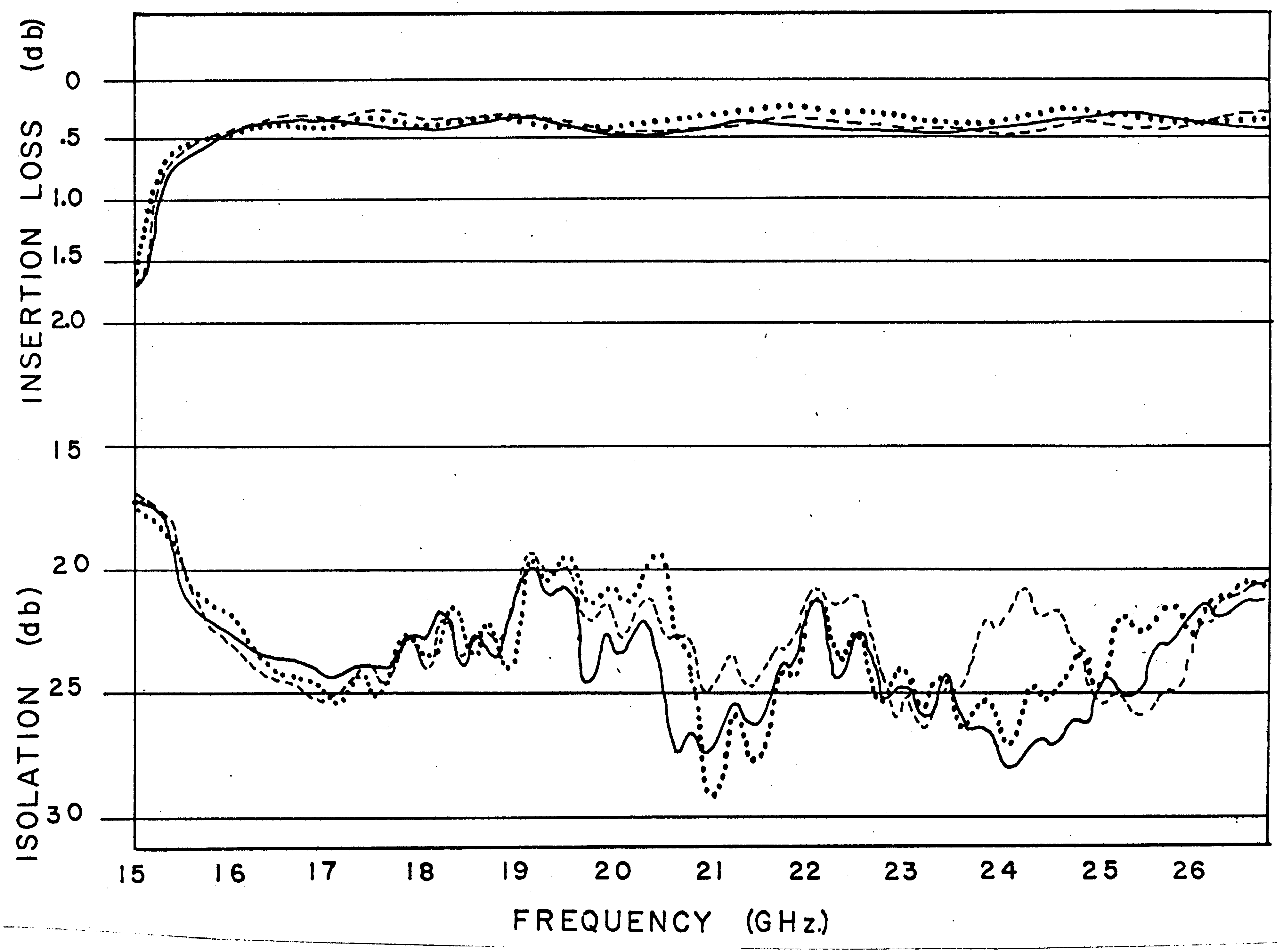
## 18-40 GHz

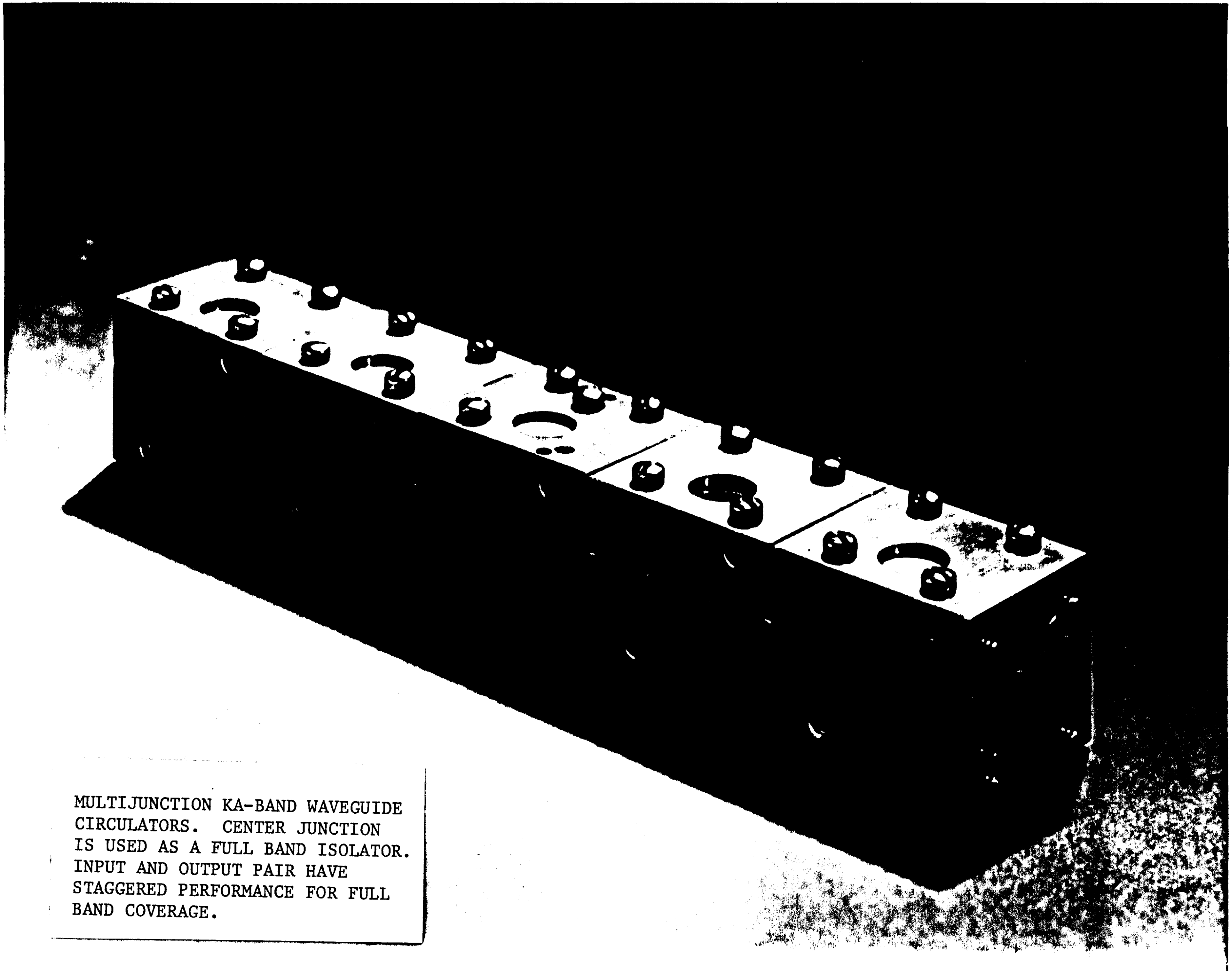
The continuous tracking principle was applied to the design of a wideband, Y-junction stripline circulator for the 18 to 26.5 GHz frequency band. Near octave low loss and high isolation performance was demonstrated without the need for repeated design cycles. Mode-free miniature SMA convertors are utilized.

A waveguide approach was utilized in Ka-band utilizing a triangular ferrite design. Due to the ferrite material's limited saturization magnetization, two circulators are required to adequately cover the entire band with high isolation and low return loss. This staggered approach with each circulator having low loss over the entire band was highly satisfactory in a reflection amplifier application. A single full band isolator based on the same design has been demonstrated also.




FULLBAND K-BAND STRIPLINE
CIRCULATOR EXPLODED VIEW


INSERTION LOSS (db)
0
.5
1.0
1.5
2.0
ISOLATION (db)
15
20
25
30
15
16
17
18
19
20
21
22
23
24
25
26
FREQUENCY (GHz.)



MULTIJUNCTION KA-BAND WAVEGUIDE CIRCULATORS. CENTER JUNCTION IS USED AS A FULL BAND ISOLATOR. INPUT AND OUTPUT PAIR HAVE STAGGERED PERFORMANCE FOR FULL BAND COVERAGE.

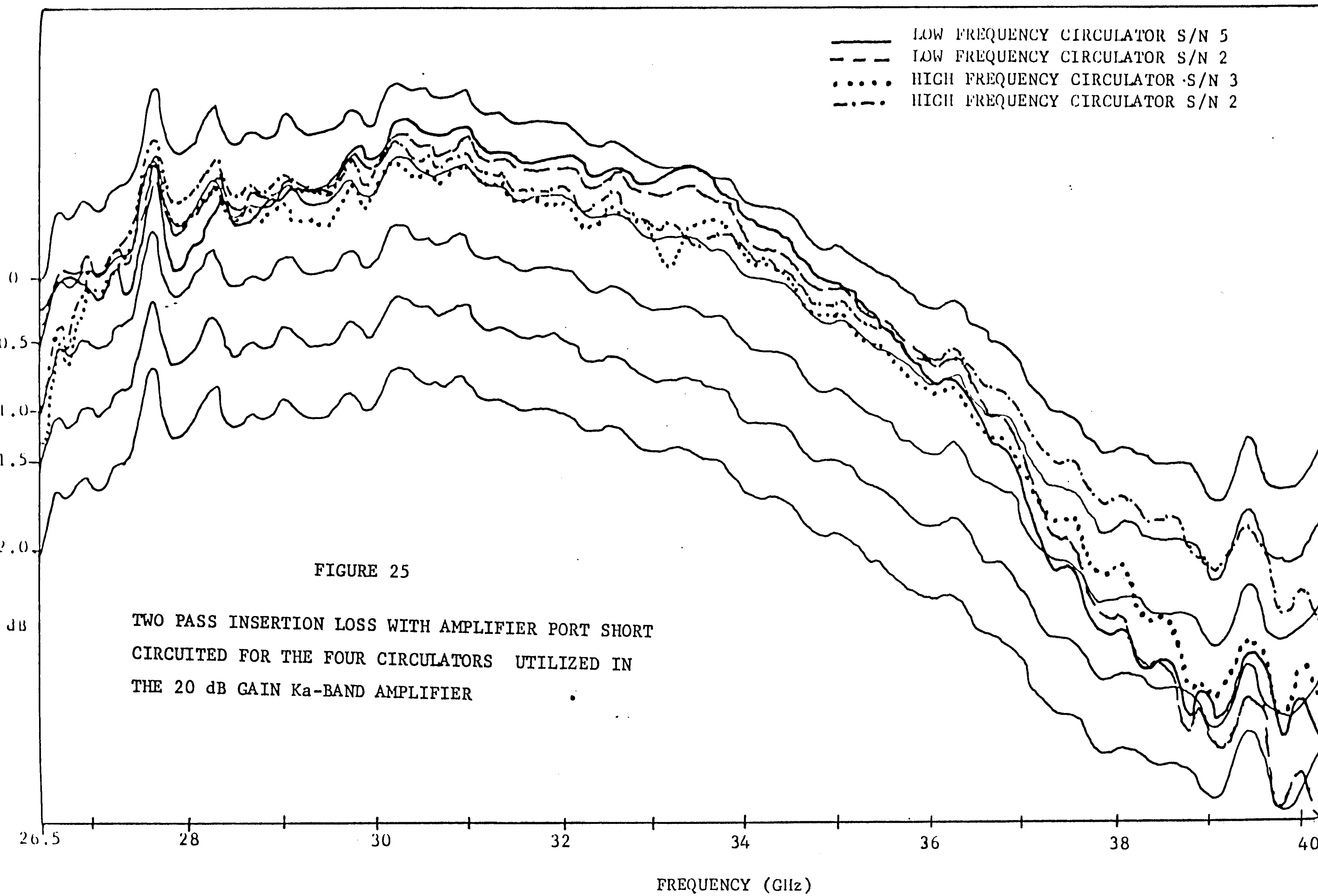



FIGURE 25

TWO PASS INSERTION LOSS WITH AMPLIFIER PORT SHORT CIRCUITED FOR THE FOUR CIRCULATORS UTILIZED IN THE 20 dB GAIN Ka-BAND AMPLIFIER

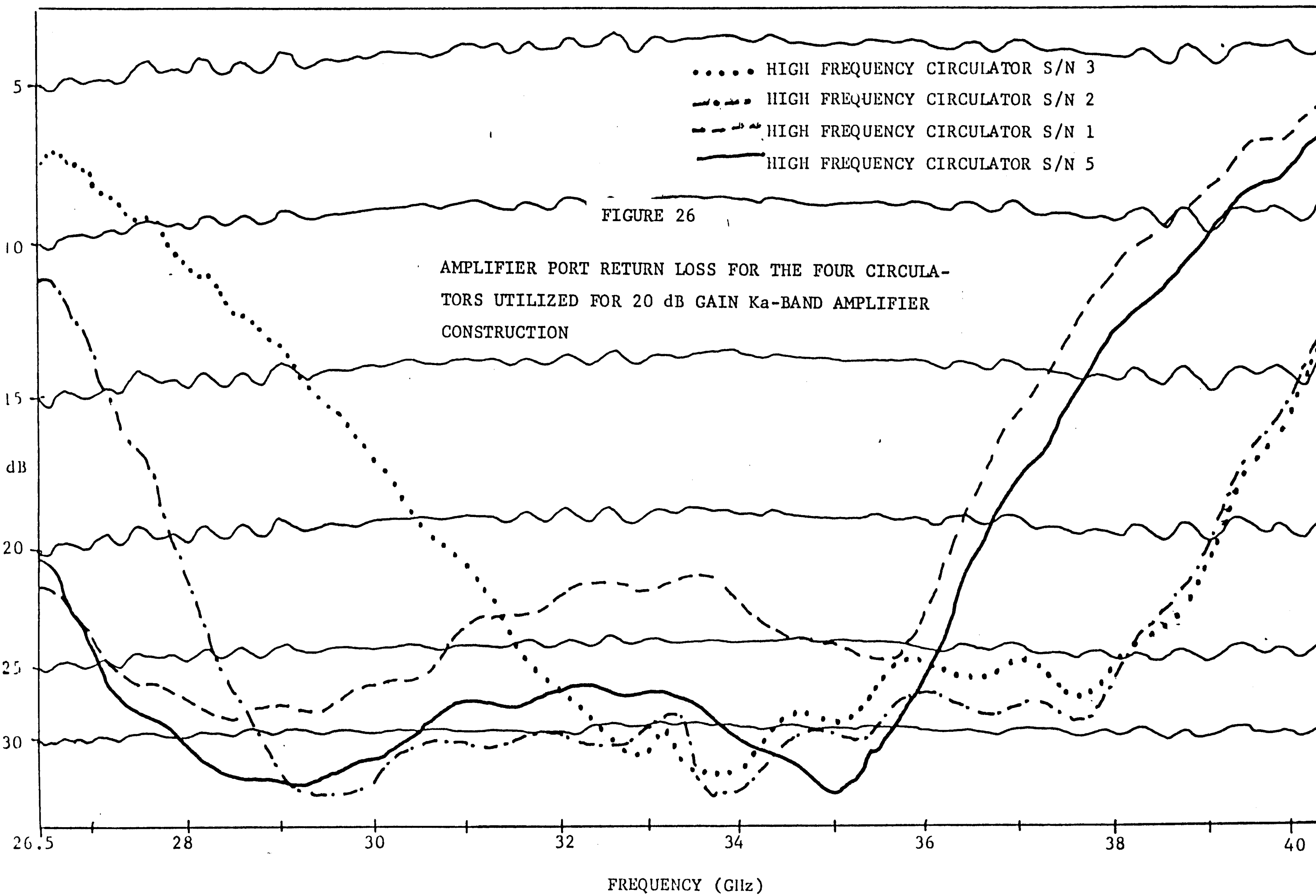



FIGURE 26

AMPLIFIER PORT RETURN LOSS FOR THE FOUR CIRCULATORS UTILIZED FOR 20 dB GAIN Ka-BAND AMPLIFIER CONSTRUCTION

# COMPONENTS AND SUBSYSTEMS
# IN
# E S M AND E C M AREA

- DIRECT COUPLED CRYSTAL VIDEO COMPONENTS
- A.C. OR QUASI DC COUPLED DLVA'S
- MULTIFUNCTION CRYSTAL VIDEO RECEIVERS
- IFM SUBSYSTEMS

DIRECT COUPLED CRYSTAL VIDEO COMPONENTS

Detector Log Amplifiers

- Frequency Range from 0.5 to 40 GHz in octave and multioctave bands
- Dynamic Range from -75 dBm to 0 dBm
- DC coupled
- C.W. or pulsed operation
- Rise Time of 30 Nano Secs. Max.
- Recovery Time of <1.0 microsecond @ +10 dBm input
- Tracking between a quad of 2.0 dB in 2-4 GHz and 3.0 dB at X-band. This includes frequency, temperature and a dynamic range of 70 plus dB.
- Analog or digital output.

Inhouse capability of GaAs FET amplifiers, MIC power dividers, couplers, etc. greatly helps to reduce size and increase performance of 70 dB plus type DLVA's.

## A.C. OR QUASI DC COUPLED DLVA'S

- Dynamic Range up to 45 dB with a single detector
- Dynamic Range up to 75 dB with RF preamplifier and MIC power divider/ coupler
- Rise Time of 11.0 nano seconds max. for 30 to 50 nano second wide pulse measurements
- Linearity of ±0.5 dB max. at a single frequency
- Frequency Range for 0.5 to 40 GHz in octave and multioctave bands

## MULTIFUNCTION CRYSTAL VIDEO RECEIVERS

- Units with one RF input and multiple outputs
  1. Pulse Width
  2. Amplitude (Analog & Digital Output)
  3. C.W. Flag
  4. Time of Arrival Information

     Response time down to 18 nano seconds
     (50% RF to 90% logic)

# I F M SUBSYSTEMS

- Sensitivity down to 75 dBm
- Video Bandwidth up to 30 MHz to allow pulse processing for 30 nano seconds wide pulses
- D.C. or A.C. Coupled Video
- Units with either multiple polar discriminators or digital correlators based on requirements
- Linear Discriminators with appropriate analog circuitry suitable for jammer applications
- Units with either analog output or digital output