GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: November 16, 1979

Project Title: Specifications for Adaptive Milimeter Imaging System

Project No: A-2488

Project Director: Mr. ~~J.M. Schuchardt~~ R.E FORSYTHE

Sponsor: Naval Research Laboratory; Washington, D.C. 20375

Agreement Period: From 9/28/79 Until 3/27~~/81~~ 3-27-84 (contract period)

Type Agreement: Contract No. N00173-79-C-0389

Amount: $300,207

Reports Required: Monthly Progress Reports; Final Report

Sponsor Contact Person (s):

Technical Matters

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Code 7110
Naval Research Laboratory
Washington, D.C. 20375
(202) 767-3443

Contractual Matters

(thru OCA)
Mr. Thomas A. Bryant
ONR Resident Representative
Georgia Institute of Technology
325 Hinman Research Building
Atlanta, Ga. 30332

Defense Priority Rating: DO-C9 under DMS Reg. 1

Assigned to: EML/RSD (School/Laboratory)

COPIES TO:

- Project Director
- Division Chief (EES)
- School/Laboratory Director
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)RGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 7/12/84

ct No. A-2488 School/Lab EML

des Subproject No.(s)

ct Director(s) R. E. Forsythe GTRI /~~GIT~~

sor Naval Research Laboratory; Washington, D.C.

"Specifications for Adaptive Millimeter Imaging System"

ctive Completion Date: 3/27/84 (Performance) 3/27/84 (Reports)

t/Contract Closeout Actions Remaining:

- [ ] None
- [X] Final Invoice or Final Fiscal Report
- [X] Closing Documents
- [X] Final Report of Inventions
- [X] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

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A-2488

Monthly Progress Report No. 1

Report Period

1 October through 31 October 1979

Report Prepared

9 November 1979

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

J. M. Schuchardt
J. A. Gagliano

Contract N00173-79-C-0389
(A-2488)

Prepared For

Naval Research Laboratory
Washington, D.C. 20375

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

Efforts are underway on defining the system requirements and operating parameters of the Advanced Airborne Millimeter Wave Imaging System (AAMWIS). System requirements under study include transmitter specifications, receiver requirements, antenna configuration, and data processing requirements. Changes to the conceptual block diagram proposed in the Georgia Tech proposal EM-RSD-1001 Figure 11, page 26, are under investigation. One change suggested is to replace the IF amplifier between the subharmonic mixer and the power splitter with a low noise pre-amplifier followed by a lower gain IF amplifier in order to reduce the overall system noise figure. At the same time the IF bandwidth would be increased from (2.0 to 3.0 GHz) to (2.0 to 4.0 GHz) to improve the sensitivity of the passive receiver channel. Another change involves adding an image reject filter, of the lower sideband, between the transmit/receive (T/R) switch and the subharmonic mixer to improve the signal-to-noise ratio of the active receiver channel. These changes would be relatively easy to implement in the system and would have negligible effects on the overall hardware costs.

During this period several vendors have been contacted regarding price quotations and delivery schedules on critical components, particularly long lead items. One such item is the pulsed EIO transmitter with designated performance goals of 1 kilowatt peak power output at a 10 kHz pulse repetition frequency with a pulse width of 10 ns. The latest written quote from Varian Associates of Canada on the EIO transmitter Model VKB2443S1 was $23,408 with delivery time of 180-210 days from receipt of order. Other vendor quotes received on items with delivery schedules of 90 to 180 days include TRG subharmonic mixers, Narda and RHG IF amplifiers, and TRG waveguide and assembly components.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems to report at this time.

WORK TO BE PERFORMED NEXT PERIOD

The EIO transmitter procurement will be initiated, that is, bids will be sent out to pertinent vendors. A summary of written quotes on all hardware defined to date will be prepared and forwarded to NRL.

Work will continue on establishing the signal processing and operational mode details of the AAMWIS. In order to determine capability of the hardware design approach with the environment of the P3 aircraft, plans will be coordinated with NRL to visit a chosen site at which the P3 aircraft would be available for inspection. Such a visit is recommended before a final design review of the AAMWIS between Georgia Tech and NRL personnel is conducted.

Cost Information

The following charges have been incurred against the contract during period 1 October through 31 October 1979.

	Expended	Encumbered
Personal Services (PS)	$2,949.46	-0-
Materials and Supplies	-0-	-0-
Travel	-0-	-0-
Overhead (@ 76% of PS)	2,241.59	-0-
Retirement (@ 10.51% of PS)	309.90	-0-
TOTAL	$5,501.04	-0-

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ 933.82	44
Senior Research Scientists/Engineers	-0-	-0-
Research Scientists II/Engineers II	1,308.82	98
Research Scientists I/Engineers I	655.37	60
Technicians/Draftsmen	-0-	-0-
Students	-0-	-0-
Secretarial/Clerical/Other	51.45	9
TOTAL	$2,949.46	211

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 76,614.00	$2,949.46	$ 73,664.54
Materials and Supplies	156,000.00	-0-	156,000.00
Travel and Shipping	2,500.00	-0-	2,500.00
Computer	-0-	-0-	-0-
Overhead	57,041.00	2,241.59	54,799.41
Retirement	8,052.00	309.99	7,742.01
Encumbered	---	---	---
FUNDING	$300,207.00	$5,501.04	$294,705.96

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 2% of the proposed task has been completed.

A-2488

Monthly Progress Report No. 2

Report Period

1 November through 30 November 1979

Report Prepared

13 December 1979

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

J. M. Schuchardt
J. A. Gagliano

Contract N00173-79-C-0389
(A-2488)

Prepared For

Naval Research Laboratory
Washington, D.C. 20375

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

Requests for quotation on a pulsed EIO transmitter with 95 GHz center frequency, peak power output of 1 kW, and 10 nsec pulse width using external modulation techniques were received during this period. The only bid response was from Varian Associates of Canada, LTD. at a cost of $24,250 and 8 months delivery after receipt of order. Georgia Tech is reviewing this bid at this time pending evaluation of alternate transmitter design approaches.

A schedule of development activities on the Advanced Airborne Millimeter Wave Imaging System (AAMWIS) is shown in Figure 1. A design review is presently scheduled for the 7th of January 1980 with the technical sponsor and the 21st of January 1980 for presentation of the finalized design report to the sponsor and procurement initiation of long lead items, such as the transmitter.

Figure 2 is a revised conceptual block diagram for the AAMWIS incorporating some of the changes under consideration. These include addition of a low noise preamplifier with a wide dynamic range for use in both the active and passive 95 GHz receiver channels, a lower sideband image reject filter for improved signal-to-noise ratio in the 95 GHz active receiver, and an increase in IF amplifier bandwidth of 2 to 4 GHz to improve the sensitivity of the passive receiver channels. An investigation of the type transmitter required for nadir raster scan or side looking (staring) modes is underway.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems to report at this time.

WORK TO BE PERFORMED NEXT PERIOD

Design of the 220 GHz passive receiver channel, shown at top of Figure 2, will begin. The approach will be to configure this receiver in a package similar to the current 140 GHz radiometer system developed for NRL under contract N00173-77-C-0130. The 220 GHz radiometer package will be designed to provide effective shielding against EMI encountered in the environment of the P3 aircraft.

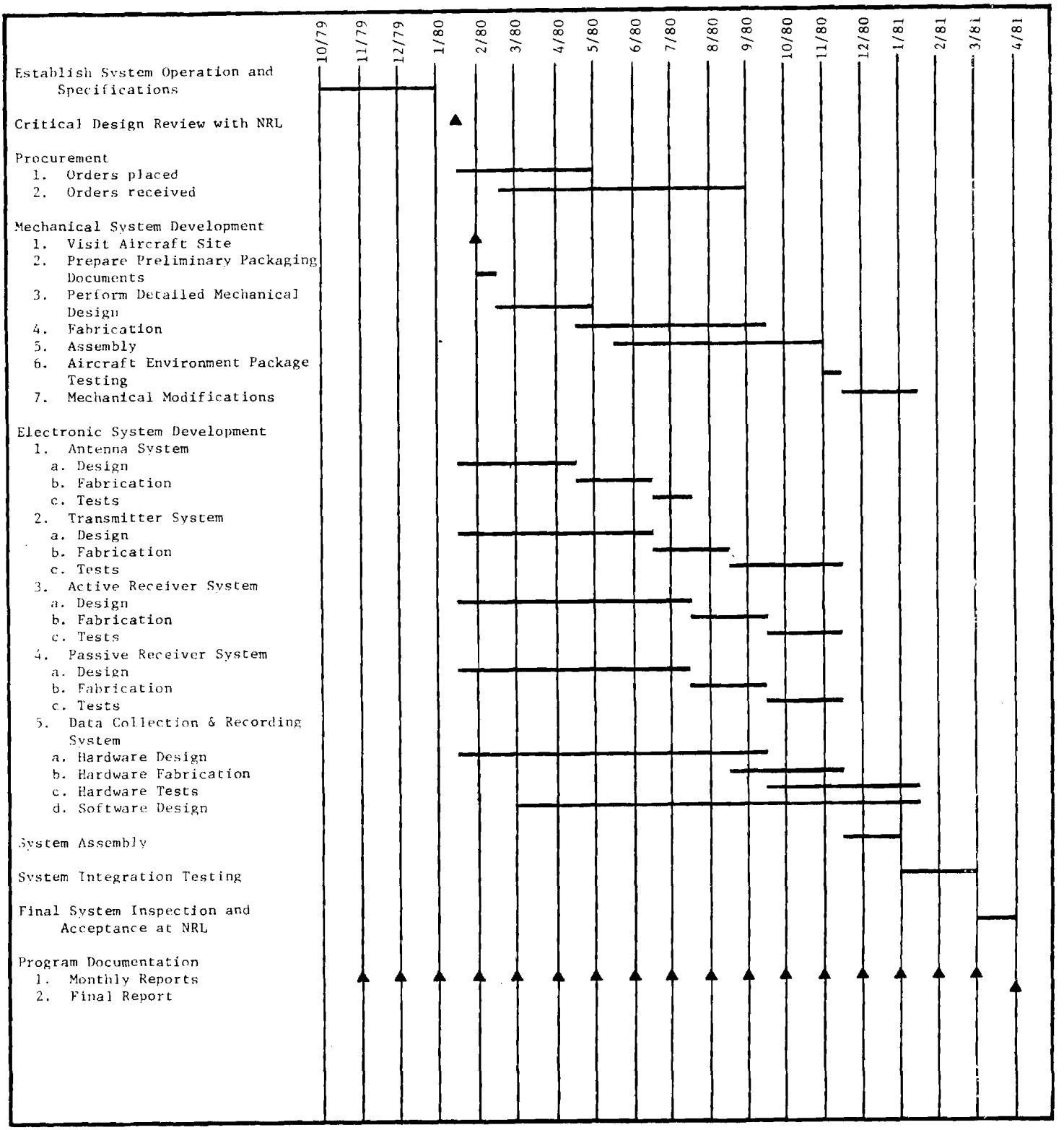


Figure 1. AAMWIS Program Schedule Activities.

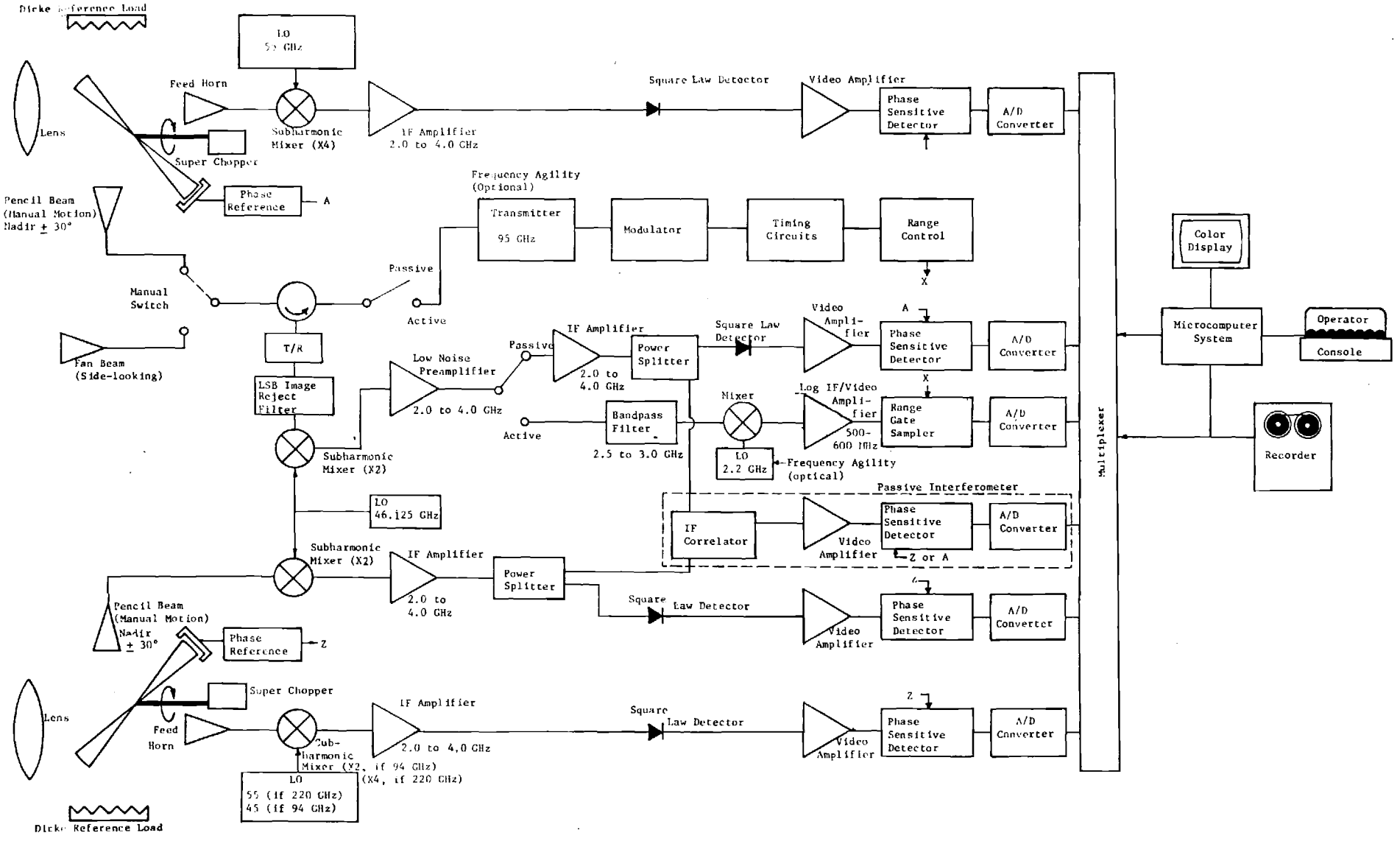


Figure 2. Advanced Airborne Millimeter Wave Imaging System (AAMWIS): Revised Block Diagram

In preparation for the design study review in early January 1980, investigations will continue on the transmitter system to be recommended for the initial data flight program using the AAMWIS. Studies will continue on the required signal processing system as impacted by the pulse width of the defined transmitter. Primary modes for data measurements to be considered include: nadir raster scan using the existing scanner built by NRL to perform active and passive measurements at 95 GHz for wave height investigation; and side viewing (staring) measurements with best possible range processing of the shortest transmitted pulse.

Cost Information

The following charges have been incurred against the contract during period 1 November through 30 November 1979

	Expended	Encumbered
Personal Services (PS)	$ 7,892.27	-0-
Materials and Supplies	-0-	-0-
Travel	-0-	-0-
Overhead (@ 76% of PS)	5,998.13	-0-
Retirement (@ 10.51% of PS)	829.48	-0-
TOTAL	$14,719.88	-0-

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$1,795.82	85
Senior Research Scientists/Engineers	-0-	-0-
Research Scientists II/Engineers II	3,566.83	266
Research Scientists I/Engineers I	2,191.71	202
Technicians/Draftsmen	-0-	-0-
Students	-0-	-0-
Secretarial/Clerical/Other	337.91	57
TOTAL	$7,892.27	610

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 76.614.00	$13,744.06	$ 62,869.94
Materials and Supplies	156,500.00	-0-	156,500.00
Travel and Shipping	2,000.00	-0-	2,000.00
Computer	-0-	-0-	-0-
Overhead	57,041.00	10,445.49	46,595.51
Retirement	8,052.00	1,444.50	6,607.50
Encumbered	---	---	---
FUNDING	$300,207.00	$25,634.05	$274,572.95

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 8% of the proposed task has been completed.

A-2488 (REVISION)

Cost Information

The following charges have been incurred against the contract during period 1 October through 31 October 1979.

	Expended	Encumbered
Personal Services (PS)	$ 5,851.79	-0-
Materials and Supplies	-0-	-0-
Travel	-0-	-0-
Overhead (@ 76% of PS)	4,447.36	-0-
Retirement (@ 10.51% of PS)	615.02	-0-
TOTAL	$10,914.17	-0-

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$1,831.73	86
Senior Research Scientists/Engineers	-0-	-0-
Research Scientists II/Engineers II	3,116.18	233
Research Scientists I/Engineers I	852.43	79
Technicians/Draftsmen	-0-	-0-
Students	-0-	-0-
Secretarial/Clerical/Other	51.45	9
TOTAL	$5,851.79	407

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 76,614.00	$ 5,851.79	$ 70,762.21
Materials and Supplies	156,000.00	-0-	156,000.00
Travel and Shipping	2,500.00	-0-	2,500.00
Computer	-0-	-0-	-0-
Overhead	57,041.00	4,447.36	52,593.64
Retirement	8,052.00	615.02	7,436.98
Encumbered	---	---	---
FUNDING	$300,207.00	$10,914.17	$289,292.83

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 4% of the proposed task has been completed.

A-2488

Monthly Progress Report No. 3

Report Period
1 December through 31 December 1979

Report Prepared
16 January 1980

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

J. M. Schuchardt
J. A. Gagliano

Contract N00173-79-C-0389
(A-2488)

Prepared For

Naval Research Laboratory
Washington, D.C. 20375

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

Work continued on the transmitter design/options for the AAMWIS to be used on the P-3 aircraft. Under consideration is a pulsed extended interaction oscillator (EIO) developed by Varian Associates of Canada Ltd. and a pulsed magnetron model M5163 built by English Electric Valve (EEV) of Great Britian. Attachment 1 is a quotation received from Varian on an EIO Model VKB-2443S2 with specifications as shown. The pulse length of 5 μs is the level at which the tube would be tested at Varian. Georgia Tech personnel indicate that a modulator could be designed at Georgia Tech to provide a minimum of 10 ns pulse width output. This is greater than the desired width of 2 ns as indicated by the technical monitor to provide 1 foot range resolution. Table 1 describes a 2 ns/40 ns selectable pulse width transmitter using an EEV Magnetron (M5163) which has been tested at 5 ns by EEV. Georgia Tech personnel would develop the modulation technique to operate this tube at 2 ns. Table 2 describes the package configuration for this transmitter approach to be installed in the P-3 aircraft. Since the magnetron tube has a limited lifetime of approximately 200 hours, it is recommended that a spare tube be available for the P-3 data flights. Georgia Tech has an EEV Magnetron Tube (Model M5163) in-house which could be used during the early development phase of the pulse modulator until the tube purchased on the project is delivered. Latest delivery date estimates on either the EIO or the magnetron is approximately 9 months.

Calculations have been performed on the IF amplifier gain requirements for the 220 GHz passive receiver. Figure 1 is a block diagram of the receiver channel from the antenna input port to the video amplifier output port. The assumption is made that the video amplifier output, V_o, swings approximately 3 volts over the antenna temperature range of 50°K to 350°K. With a video gain of 1000, the output of the square law detector will swing approximately 3 millivolts. Figure 2 is a plot of a typical square law detector transfer characteristic.

Table 1

95 GHz Transmitter Preliminary Specifications
Using a Magnetron Tube

RF Output:	1 kW peak output 2 ns/40 ns pulse width (selectable) 10 kHz max prf
Tube:	EEV Magentron (M5163)
Pedestal Modulator:	40 ns pulse at 10 kHz 8 kV at 10 A at 0.0004 duty 32 W rated output 70 W input
Short Pulse Mod:	5 ns pulse (2 ns RF) at 10 kHz 2 kV at 10 A at 0.00005 duty 1 W rated output 25 W input Switch tube EEV CK 1164 (10 A/ns)

Table 2.

95 GHz Transmitter Preliminary Packaging Configuration Using a Magnetron Tube

RF Package

1) Transmitter (Magnetron)
2) Pedestal Modulator
3) Short Pulse Modulator
4) Timing Circuits For Two Thyratrons

Estimated Size 12" x 12" x 24"

Control Package

1) AC Power and Transmitter Turn On Sequencing
2) Low Voltage Power Supplies 3-4
3) High Voltage Power Supplies For Pedestal Modulator
4) High Voltage Power Supplies For Short Pulse Modulator

Estimated Size 19" Relay Rack x 24" High

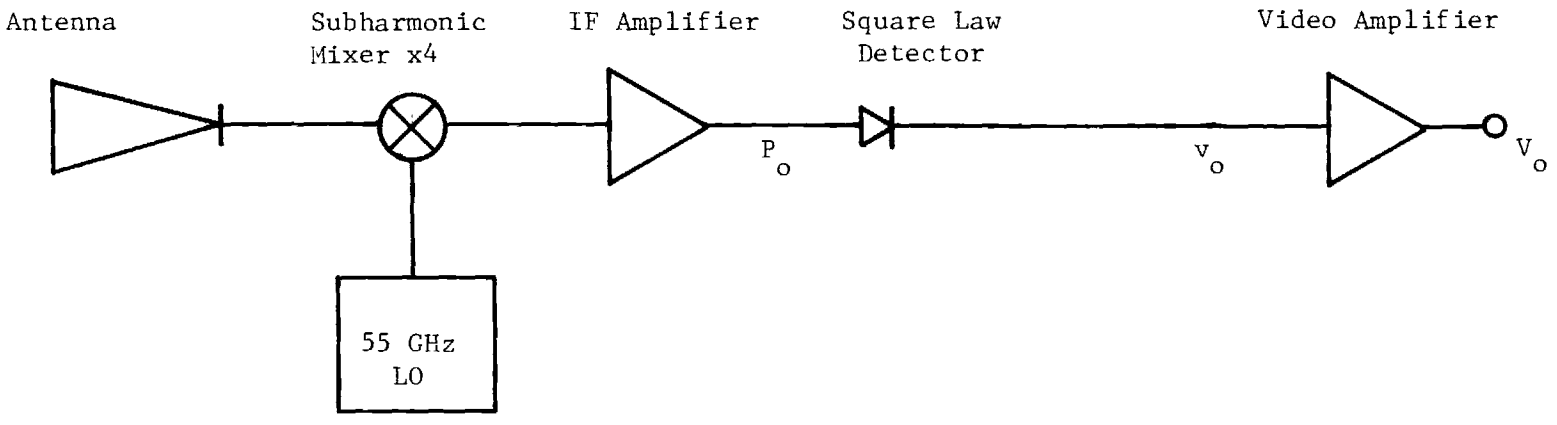


Figure 1. 220 GHz Passive Receiver Block Diagram

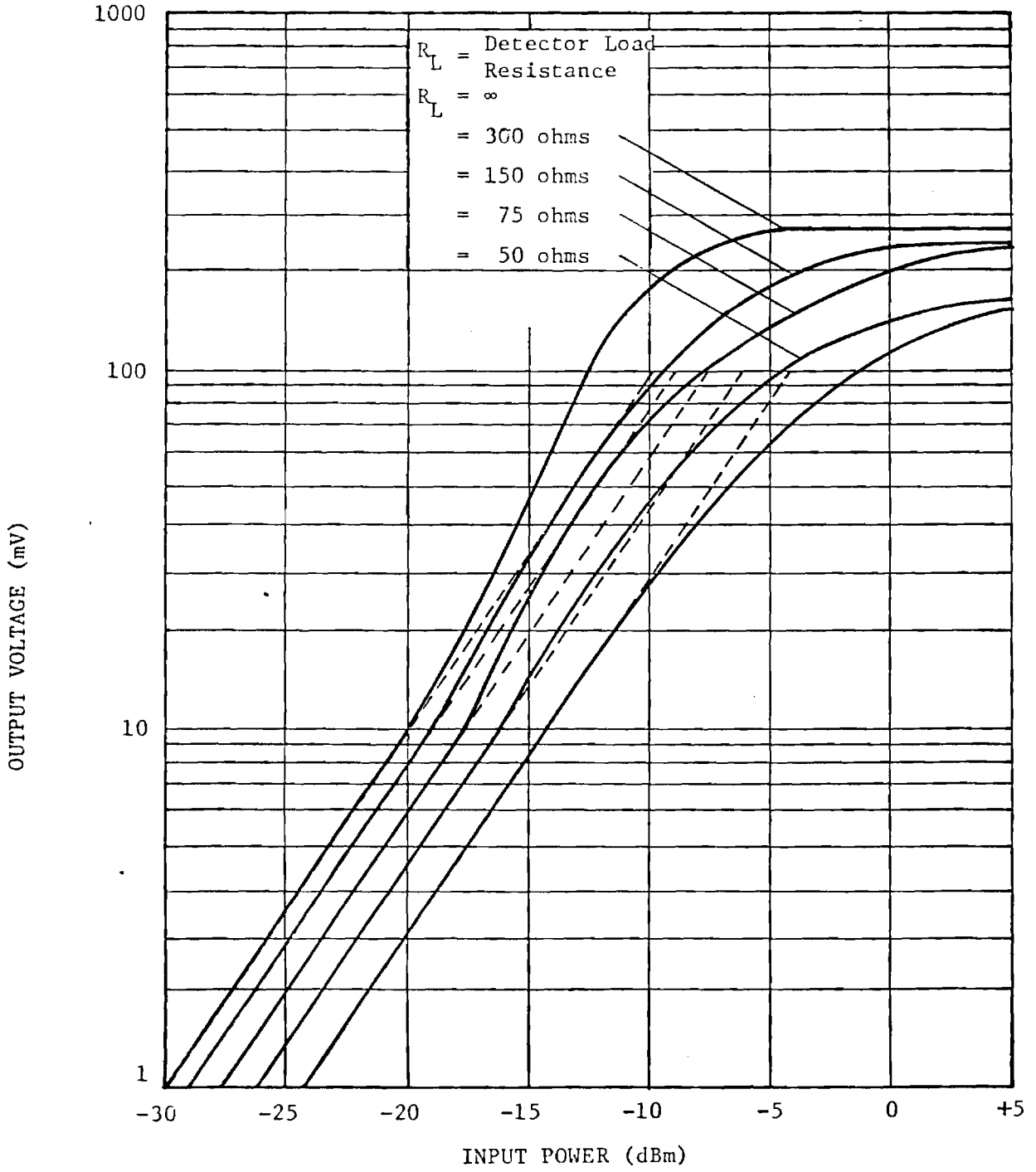


Figure 2. Typical Tunnel Detector Transfer Characteristics

Assuming that the video amplifier input resistance is 300 Ω, then the nominal input power, P_o, of the square law detector is -25 dBm (3.16 μwatts). The system gain, G_{sys}, is given by:

$$G_{sys} = \frac{P_o}{k\, T_{sys}\, B}$$

where k = Boltzman's constant = 1.38×10^{-23}

B = system bandwidth = 3 GHz

T_{sys} = system noise temperature

$= T_A + T_{RF} + T_{MIXER} + T_{IF}$

For T_A = Antenna input temperature = 250°K nominal

T_{RF} = lens plus cabling temperature = 170°K

T_{MIXER} = subharmonic mixer noise temperature = 2400°K

T_{IF} = IF amplifier noise temperature = 1380°K

Then T_{sys} = 250°K + 170°K + 2400°K + 1380°K

= 4200°K

Therefore $G_{sys} = \frac{P_o}{k\, T_{sys}\, B}$

$$= \frac{3.16\ \mu\text{watts}}{(1.38 \times 10^{-23})(4200)(3 \times 10^{9})}$$

= 18,173 (42.6 dB)

The IF amplifier gain, G_{IF}, is given by:

$$G_{IF} = G_{sys} + \alpha + L_C$$

where α = RF losses = 2 dB

L_c = Mixer conversion loss

= 8 dB

Then

G_{IF} = 42.6 dB + 2.0 dB + 8.0 dB

= 52.6 dB

Problems Encountered During This Period

No problems to report at this time.

Work To Be Performed Next Period

A design study review will be held with the scientific officer to determine the transmitter configuration to be used on AAMWIS. Work will continue on the 220 GHz receiver portion of the system, including the preparation of request for bids on the IF amplifier to be used in this channel. A prototype phase sensitive detector (analog lock-in amplifier) will be built and tested.

Attachment No. 1

Pulsed Extended Interaction (EIO)
Quotation No. 80-0174-02
from Varian Associates

varian associates of canada ltd.
45 river drive/georgetown/ontario

quotation

no. 80-0174-02

Please direct your order or inquiries referencing this quotation number to:

Georgia Institute of Technology
888 Hemphill ave., N.W.
Atlanta, Georgia 30332

Attn: Debbie Dawkings, procurement

Varian Electron Device Group
500 Wynn Drive
Suite 301-f
Huntsville Alabama 35805
Attn: Doug Kennedy

Telephone No. (205) 837-9225

F. Q-20-601-A2488-000-1-80-71440

Date	price quotation expires 30 days after date hereof	Terms	FOB Point	Fed. Sales Tax Extra ☒	Prov. Sales Tax Extra ☒	Duty Extra ☒ Duty Included ☐
9/79		Net 30	Factory			

QTY.	Model/Part No.	DESCRIPTION	UNIT PRICE	TOTAL
1	VKB-2443S2	Varian Pulsed Extended Interection Oscillator per the following specifications: Power Output: 1 KW peak Center Frequency: 95 GHZ Duty Cycle: 0.005 Pulse Length: 5 microseconds Note: The VKB-2443 S2 is forced air cooled and utilizes Samarium Cobalt Magnets	$24,250	$24,250

include the following on your order
rdance with Varian Quotation No. 80-0174-02

1-04 (FRONT) R11/74 P2/75 (T & C VACL 7411 HLB)

varian associates of canada ltd.

ELIVERY SCHEDULE 8 Months A.R.O.

BY Douglas G. Kennedy

ECOMMENDED SHIPPING METHOD Air Best

THIS QUOTATION IS SUBJECT TO AND INCLUDES TH
TERMS AND CONDITIONS ON THE REVERSE SIDE.

CUSTOMER

Cost Information

The following charges have been incurred against the contract during period 1 December through 31 December 1979.

	Expended	Encumbered
Personal Services (PS)	$11,078.35	$ -0-
Materials and Supplies	6.83	
Travel	-0-	
Overhead (@ 76% of PS)	8,118.66	
Retirement (@ 10.51% of PS)	1,134.25	
TOTAL	$20,338.09	-0-

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ 2,844.01	134
Senior Research Scientists/Engineers	1,202.57	70
Research Scientists II/Engineers II	5,415.16	404
Research Scientists I/Engineers I	1,095.86	101
Technicians/Draftsmen	-0-	-0-
Students	286.03	
Secretarial/Clerical/Other	234.72	
TOTAL	$11,078.35	799

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 76,614.00	$18,800.91	$ 57,813.09
Materials and Supplies	156,500.00	6.83	156,493.17
Travel and Shipping	2,000.00	-0-	2,000.00
Computer	-0-	-0-	-0-
Overhead	57,041.00	13,987.81	43,053.19
Retirement	8,052.00	1,945.90	6,106.10
Encumbered	-0-	-0-	-0-
FUNDING	$300,207.00	$34,741.45	$265,465.55

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 12 % of the proposed task has been completed.

A-2488

Monthly Progress Report No. 4

Report Period

1 January through 31 January 1980

Report Prepared

February 18, 1980

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

J. M. Schuchardt
J. A. Gagliano

Contract N00173-79-C-0389
(A-2488)

Prepared For

Naval Research Laboratory
Washington, D.C. 20375

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed This Period

The design study review was held between Georgia Tech personnel and the NRL scientific officier to review the status of the Advanced Airborne MIllimeter Wave Imaging System (AAMWIS). In regard to the 95 GHz transmitter portion of AAMWIS, a 2 ns pulse transmitter magnetron tube, built by English Electric Value (EEV), which would achieve higher spatial resolution than the earlier discussed 10 ns transmitter, is under consideration. A dual-element active receiver would be part of the 95 GHz radar system. A block diagram of the 95 GHz transmitter/ receiver concept is shown in Figure 1. The three outputs shown are analog signals fed to the P-3 aircraft government furnished equipment (GFE). The passive portion of AAMWIS will consist of a 220 GHz single channel radiometer which would be a stand-alone system designed to be compatible with the P-3 aircraft environment.

The improved spatial resolution associated with the shortening of the transmitted pulse length results in revised cost estimates for the AAMWIS. The limited lifetime of the magnetron tube of about 200 hours will necessitate the addition of a spare tube. Likewise, the design of the timing and control logic will result in more development time for the shorter pulse length of 2 ns.

Problems Encountered During This Period

No problems to report at this time.

Work To be Performed Next Period

A preliminary design layout of the 220 GHz radiometer front-end will begin. Consideration will be given to the effects of RFI observed in the P-3 aircraft on the operation of the passive receiver. Laboratory measurements using available RF components will investigate the effect of good shielding techniques on the sensitivity of the passive receiver. Specifications of the long lead parts such as the 55 GHz Gunn Diode Oscillator and IF amplifier will continue.

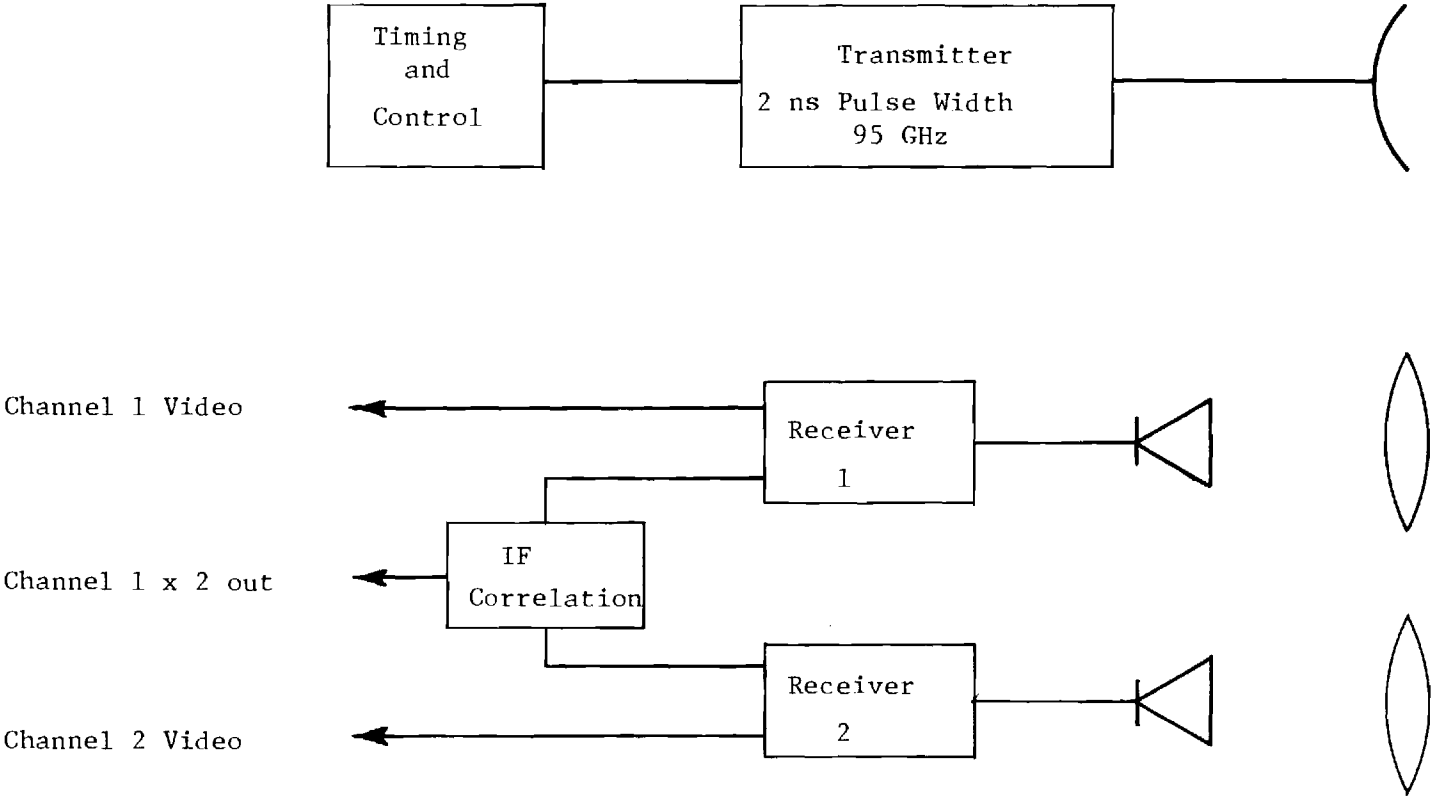


Figure 1. 95 GHz Transmitter/Dual Receiver Block Diagram.

A-2488

Cost Information

The following charges have been incurred against the contract during period 1 January through 31 January 1980.

	Expended	Encumbered
Personal Services (PS)	$ 7,869.27	$ -0-
Materials and Supplies	67.71	(39.95)
Travel	-0-	-0-
Overhead (@ 76% of PS)	6,281.53	-0-
Retirement (@ 10.51% of PS)	760.14	-0-
TOTAL	$14,978.65	$(39.95)

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ 560.41	26
Senior Research Scientists/Engineers	2,215.61	130
Research Scientists II/Engineers II	898.80	67
Research Scientists I/Engineers I	2,994.48	276
Technicians/Draftsmen	636.69	112
Machinists	350.42	43
Secretarial/Clerical/Other	212.86	36
TOTAL	$7,869.27	690

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 76,614.00	$26,670.18	$ 49,943.82
Materials and Supplies	156,500.00	74.54	156,385.51
Travel and Shipping	2,000.00	-0-	2,000.00
Computer	-0-	-0-	-0-
Overhead	57,041.00	20,269.34	36,771.66
Retirement	8,052.00	2,706.04	5,345.96
Encumbered	-0-	39.95	-0-
FUNDING	$300,207.00	$49,760.05	$250,446.95

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 17 % of the proposed task has been completed.

A-2488

Monthly Progress Report No. 5

Report Period

February 1-February 29, 1980

Report Prepared

March 24, 1980

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

J. M. Schuchardt
J. A. Gagliano

Contract N00173-79-C-0389
(A-2488)

Prepared For

Naval Research Laboratory
Washington, D.C. 20375

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed This Period

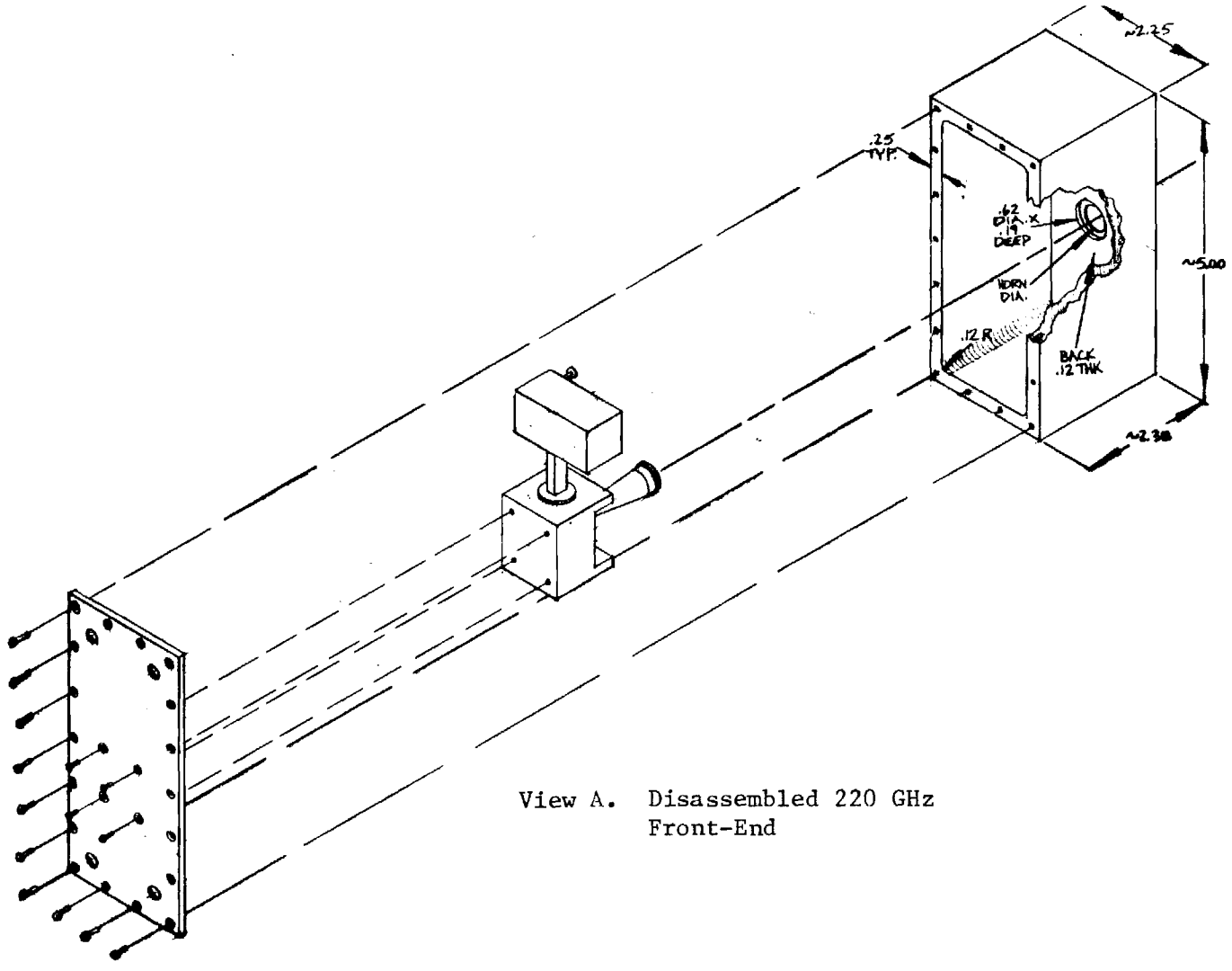
The preliminary design layout of the 220 GHz radiometer front-end including feedhorn, mixer, and solid state local oscillator is progressing. Figure 1 shows the configuration of the 220 GHz front-end package with components disassembled (view A) and mounted (view B). The design was performed keeping in mind the need to integrate the 220 GHz front-end package into the existing radiometer system (developed for NRL under contract N00173-77-C-0130) which was recently modified for improved RFI protection in the P3 aircraft environment.

Problems Encountered During This Period

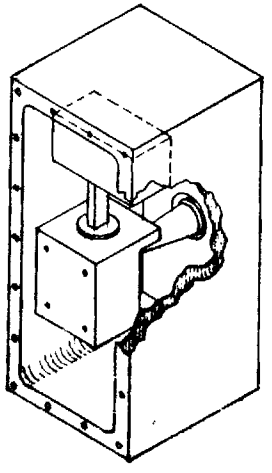
No problems to report at this time.

Work To Be Performed Next Period

Revised statement of work will be prepared and submitted as a contract modification to NRL for review during the next period. Material requests will be prepared and submitted to pertinent vendors for quotes on the 220 GHz radiometer long lead items.



View A. Disassembled 220 GHz Front-End



View B. Assembled 220 GHz Package

Figure 1. 220 GHz Radiometer Front-End Preliminary Layout

A-2488

Cost Information

The following charges have been incurred against the contract during period 1 February Through 29 February 1980.

	Expended	Encumbered
Personal Services (PS)	$ 498.57	$ -0-
Materials and Supplies	59.07	(32.60)
Travel	-0-	-0-
Overhead (@ 76% of PS)	378.91	-0-
Retirement (@ 10.51% of PS)	52.40	-0-
TOTAL	$ 988.95	$ (32.60)

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ (560.41)	(27)
Senior Research Scientists/Engineers	1,660.06	98
Research Scientists II/Engineers II	(483.29)	(36)
Research Scientists I/Engineers I	-0-	-0-
Technicians/Draftsmen	10.37	2
Students	(209.78)	(37)
Secretarial/Clerical/Other	81.62	14
TOTAL	$ 498.57	14

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 76,614.00	$ 27,168.75	$ 49,445.25
Materials and Supplies	156,500.00	133.61	156,359.04
Travel and Shipping	2,000.00	-0-	2,000.00
Computer	-0-	-0-	-0-
Overhead	57,041.00	20,648.25	36,392.75
Retirement	8,052.00	2,758.44	5,293.56
Encumbered	-0-	7.35	-0-
	$300,207.00	$50,716.40	$249,490.60

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 17% of the proposed task has been completed.

Monthly Progress Report No. 6

Report Period

March 1 - March 31, 1980

Report Prepared

April 23, 1980

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

J. M. Schuchardt
J. A. Gagliano

Contract N00173-79-C-0389
(A-2488)

Prepared For

Naval Research Laboratory
Washington, D.C. 20375

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed This Period

Specifications on the solid state local oscillator for the 220 GHz radiometer front-end was prepared and submitted to selected vendors. Two power sources, under consideration for the local oscillator, are a 55 GHz device to drive a mixer at one-fourth the signal frequency or a 110 GHz device to drive a mixer at one-half the signal frequency. The 55 GHz device will most likely be a Gunn-diode oscillator. The 110 GHz device will be either a 110 GHz Gunn-diode oscillator or a 55 GHz Gunn-diode oscillator coupled with a solid state doubler. Specifications submitted for vendors review are listed in Table I. The 220 GHz radiometer will operate in a P-3 aircraft and the local oscillator should be able to withstand the small vibrations associated with this environment. Since space in the radiometer is very limited an outline drawing of the device or package dimensions was requested to be furnished with the vendor's bid. Delivery information was also be furnished with the bids.

Problems Encountered During This Period

No problems to report at this time.

Work To Be Performed Next Period

Efforts will continue on issuing material requests on other long lead items required for the radiometer's front-end. It is expected that bids will be returned for review from the vendors on the local oscillator as specified in Table 1.

TABLE I

220 GHz Radiometer Solid State Local Oscillators
Specifications Summary

Center Frequency	55GHz	110GHz
Power Output	50mW	25mW
Tunability (Mechanical)	$\pm$ 100MHz	$\pm$ 100MHz
Frequency Temperature Coefficient	3.5MHz/^{o}C	3.5MHz/^{o}C
Power Temperature Coefficient	0.04dB/^{o}C	0.04dB/^{o}C
Spurious Signal Level	-100dBc 5MHz-10,000MHz	-100dBc 5MHz-10,000MHz
Operating Voltage and Current	$\sim$3.1V, Less Than 2 Amps	$\sim$3.1V, Less Than 2 Amps
Operating Load	Meets Specs Under All Loads	Meets Specs Under All Loads
Operating Temp	35 $\pm$ 5^{o}C	35 $\pm$ 5^{o}C
AM Noise	-100dBc min 1KHzBW at 10KHz	-100dBc min 1KhzBW at 10KHz
Power Surge	None	None
RF to dc Isolation	80dB Insertion Loss 500MHz to 10,000MHz	80dB Insertion Loss 500MHz to 10,000MHz
Flange	UG599/U	UG387/U
Waveguide	WR-15	WR-10

A-2488
Cost Information

The following charges have been incurred against the contract during period 1 March through 31 March 1980.

	Expended	Encumbered
Personal Services (PS)	$(4,586.78)	$ -0-
Materials and Supplies	22.78	56.10
Travel	-0-	-0-
Overhead (@ 76% of PS)	(3,485.95)	-0-
Retirement (@ 10.51% of PS)	(461.47)	-0-
TOTAL	$(8,511.42)	$ 56.10

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ (729.37)	-0-
Senior Research Scientists/Engineers	(860.45)	-0-
Research Scientists II/Engineers II	(1,252.79)	-0-
Research Scientists I/Engineers I	(1,513.16)	-0-
Technicians/Draftsmen	(166.14)	-0-
XXXXXXXXXX Students	(196.11)	-0-
Secretarial/Clerical/Other	131.24)	22
TOTAL	$ (4,586.78)	22

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 76,614.00	$ 29,556.88	$ 47,057.12
Materials and Supplies	156,500.00	156.39	156,280.16
Travel and Shipping	2,000.00	-0-	2,000.00
Computer	-0-	-0-	-0-
Overhead	57,041.00	22,463.24	34,577.76
Retirement	8,052.00	2,985.60	5,066.40
Encumbered	-0-	63.45	-0-
	$ 300,207.00	$ 55,225.56	$ 244,981.44

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 18 % of the proposed task has been completed.

Monthly Progress Report No. 7

Report Period

1 April through 30 April 1980

Report Prepared

May 26, 1980

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

J.M. Schuchardt
P.A. Maresca

Contract N00173-79-C-0389
(A-2488)

Prepared For

Naval Research Laboratory
Washington, D.C. 20375

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED THIS PERIOD

Bids on the solid state local oscillator for the 220 GHz radiometer front-end were received from selected vendors. The list of vendors that reviewed the specifications for the local oscillator are shown on the following page. Two vendors, Alpha Industries, INC., and Central Microwave Company made bids on a 55 GHz Gunn-diode oscillator, while Alpha Industries also made a bid on a 110 GHz Gunn-diode oscillator. Copies of these two bids are shown on the two pages following the vendor list. The probable power source will be a 55 GHz device to drive a mixer at one-fourth the signal frequency.

Mechanical drawings of the 220 GHz package were constructed. Figure I shows a top view of the Lens, Reflector Plate, and Local Oscillator. The Local Oscillator is stacked on top of the mixer; therefore, the mixer is not shown in Figure I. The 220 GHz package end view is shown in Figure II. This shows the position of the 220 GHz Horn, mixer, and local oscillator relative to the lens.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems to report at this time.

WORK TO BE PERFORMED NEXT PERIOD

A mid-plan progress meeting will be held with the sponsor to review the status of the program.

VENDOR LIST

Central Microwave Company
3701M Mueller
St. Charles, MO 63301
(314)723-4700

Alpha Industries, Inc.
TRG Division
20M Sylvan Road
Woburn, MA 01801
(617)935-5105

Hughes Aircraft Company
Electron Dynamics Division
3100 West Lomita Boulevard
Torrance, CA 90509
(213)534-2121

Varian Assoc. Electron Devices Group
611M Hansen Way
Palo Alto, CA 94303
(415) 493-4000

Epsilon Lambda
28 S. Water St.
Batavia, IL 60510
(312) 879-6006

GEORGIA INSTITUTE OF TECHNOLOGY

PROCUREMENT OFFICE

888 HEMPHILL AVE., N.W. ATLANTA, GEORGIA 30332

TELEPHONE 894-5000

PLEASE RETURN THIS QUOTATION REQUEST TO THE ADDRESS ABOVE.

QUOTATION REQUEST NO. Q-20-601-A2488-000 7-80-71440

REQUEST FOR QUOTATION

THIS IS NOT AN ORDER

READ CONDITIONS ON BACK

TO:

Alpha Industries, Inc.
TRG Division
20M Sylvan Road
Woburn, MA 01801

TRG QUOTE #A-8493

APR 14 1980

PLEASE IDENTIFY INQUIRIES BY QUOTATION REQUEST NUMBER AND REQUESTED RETURN DATE OR OF SEALED BID OPENING DATE

☐ IF CHECKED, ALL REFERENCE HEREIN TO THE STATE PURCHASING DIVISION IS HEREBY CHANGED TO READ: GEORGIA INSTITUTE OF TECHNOLOGY. IF AWARDED, BID AWARD WILL BE MADE BY GEORGIA INSTITUTE OF TECHNOLOGY.

RETURN QUOTE BY 5:00 P.M. ON	SEALED BIDS ONLY: OPENING TIME 3:30 P.M.	IT IS AGREED THAT GEORGIA TECH WILL ACCEPT TITLE OF OUR CHASED GOODS ONLY WHEN RECEIVED REGARDLESS OF FOB POINT. SEE PARAGRAPH 6 OF CONDITIONS ON REVERSE
4/23	4/23 1980	

PLEASE SUBMIT ITEMIZED PRICES FOR MATERIALS LISTED BELOW. SUBSTITUTIONS IF ANY MUST BE CLEARLY INDICATED.

ITEM NO.	QUANTITY AND UNIT	DESCRIPTION	NET UNIT PRICE	NET TOTAL
		PRICES ARE F.O.B. GEORGIA TECH UNLESS SPECIFIED OTHERWISE		
1	1 ea	55 GHz local Oscillator per spec. MLF/REF-A-2488-1	$1,235.	$1,235.
2	1 ea	110 GHz Local Oscillator per spec. MLF/REF-A-2488-1	$10,500.	$10,500.
		Alpha PLEASE NOTE: Alpha Industries, Inc. will have a manufacturing shutdown from Friday, July 18, 1980 until Monday, August 4, 1980.		
		IMPORTANT: READ INSTRUCTIONS ON BACK	NET GRAND TOTAL	$ 11,735.

Item 1-120 days ARO

QUOTATION NO. A-8493 DATE 4/15/80 WE SUBMIT THE ABOVE PRICES AND AGREE TO MAKE DELIVERY IN Item 2-180 ARO FROM RECEIPT OF ORDER. THIS ORDER IS GOOD FOR 30 DAYS FROM THE LIMITATION DATE SET FOR RECEIVING BIDS. MY TERMS FOR PAYMENT ARE AS FOLLOWS Net-30 days.

BY SUBMITTING THE ABOVE IT IS EXPRESSLY AGREED THAT UPON PROPER ACCEPTANCE OF ANY OR ALL ITEMS BY THE STATE PURCHASING DEPARTMENT A CONTRACT SHALL BE CREATED. IT IS FURTHER UNDERSTOOD THAT ON NON-SEALED BIDS THE STATE PURCHASING DEPARTMENT MAY OBTAIN FURTHER BIDS. ON BOTH SEALED AND NON-SEALED BIDS, THE STATE PURCHASING DEPARTMENT MAY REJECT ANY AND ALL BIDS AND/OR REBID THE ENTIRE OFFERING.

THE UNDERSIGNED CERTIFIES THAT ALL OF THE PROVISIONS OF THE ACT OF 1956 ENTITLED "STATE EMPLOYEES AND OFFICIALS TRADING WITH THE STATE" HAVE BEEN COMPLIED WITH IN FULL. AFFIANT REALIZES THAT THE TRANSACTIONS WITH THE STATE LAW IGA. LAWS 1956, PP. 34-43) HAS BEEN REPEALED AND REPLACED BY GEORGIA CRIMINAL CODE SECTION 26-2506.

NAME OF BIDDER Alpha Industries, Inc. BY X William J. Ronis

William J. Ronis-Div. Mkt. Mgr.

SECTION ABOVE TO BE COMPLETED BY BIDDER BEFORE RETURNING QUOTATION

REMOVE CARBON - RETURN ORIGINAL AND YELLOW COPY

PROCUREMENT OFFICE

[illegible] HEMPHILL AVE., N.W. ATLANTA, GEORGIA 30332

TELEPHONE 894-5000

PLEASE RETURN THIS QUOTATION REQUEST TO THE ADDRESS ABOVE

REQUEST NO. 7-80-71440

REQUEST FOR QUOTATION

THIS IS NOT AN ORDER

READ CONDITIONS ON BACK

TO:

Central Microwave Company
3701M Mueller
St. Charles, MO 63301

PLEASE IDENTIFY INQUIRIES BY QUOTATION REQUEST NUMBER AND REQUESTED RETURN DATE OR OF SEALED BID OPENING DATE.

☐ IF CHECKED, ALL REFERENCE HEREIN TO THE STATE PURCHASING DIVISION IS HEREBY CHANGED TO READ: GEORGIA INSTITUTE OF TECHNOLOGY. IF AWARDED, BID AWARD WILL BE MADE BY GEORGIA INSTITUTE OF TECHNOLOGY.

RETURN QUOTE BY 5:00 P.M. ON [illegible]

SEALED BIDS ONLY: OPENING TIME 3:30 P.M. 4/23 1980

IT IS AGREED THAT GEORGIA TECH WILL ACCEPT TITLE OF PURCHASED GOODS ONLY WHEN RECEIVED, REGARDLESS OF F.O.B. POINT. SEE PARAGRAPH 8 OF CONDITIONS ON REVERSE

PLEASE SUBMIT ITEMIZED PRICES FOR MATERIALS LISTED BELOW. SUBSTITUTIONS IF ANY MUST BE CLEARLY INDICATED.

ITEM NO.	QUANTITY AND UNIT	DESCRIPTION	NET UNIT PRICE	NET TOTAL
		PRICES ARE F.O.B. GEORGIA TECH UNLESS SPECIFIED OTHERWISE		
1	1 ea	55 GHZ local Oscillator per spec. MLF/REF-A-2488-1	$907.50	$907.50
2	1 ea	110 GHZ Local Oscillator per spec. MLF/REF-A-2488-1	NO BID	
		IMPORTANT: READ INSTRUCTIONS ON BACK	NET GRAND TOTAL $	

QUOTATION NO. N/A DATE 4-16-80 WE SUBMIT THE ABOVE PRICES AND AGREE TO MAKE DELIVERY IN 60 DARO DAYS FROM RECEIPT OF ORDER. THIS ORDER IS GOOD FOR 30 DAYS FROM THE LIMITATION DATE SET FOR RECEIVING BIDS. MY TERMS FOR PAYMENT ARE AS FOLLOWS Net 30, FOB St. Charles, MO

IN SUBMITTING THE ABOVE IT IS EXPRESSLY AGREED THAT UPON PROPER ACCEPTANCE OF ANY OR ALL ITEMS BY THE STATE PURCHASING DEPARTMENT A CONTRACT SHALL BE CREATED. IT IS FURTHER UNDERSTOOD THAT ON NON-SEALED BIDS THE STATE PURCHASING DEPARTMENT MAY OBTAIN FURTHER BIDS. ON BOTH SEALED AND NON-SEALED BIDS, THE STATE PURCHASING DEPARTMENT MAY REJECT ANY AND ALL BIDS AND/OR REBID THE ENTIRE OFFERING.

THE UNDERSIGNED CERTIFIES THAT ALL OF THE PROVISIONS OF THE ACT OF 1956 ENTITLED "STATE EMPLOYEES AND OFFICIALS TRADING WITH THE STATE" HAVE BEEN COMPLIED WITH IN FULL. AFFIANT REALIZES THAT THE TRANSACTIONS WITH THE STATE LAW (GA. LAWS 1959, PP. 34-44) HAS BEEN REPEALED AND REPLACED BY GEORGIA CRIMINAL CODE SECTION 26-2306.

NAME OF BIDDER CENTRAL MICROWAVE COMPANY BY James F. Caldwell

SECTION ABOVE TO BE COMPLETED BY BIDDER BEFORE RETURNING QUOTATION

REMOVE CARBON — RETURN ORIGINAL AND YELLOW COPY

TOP VIEW

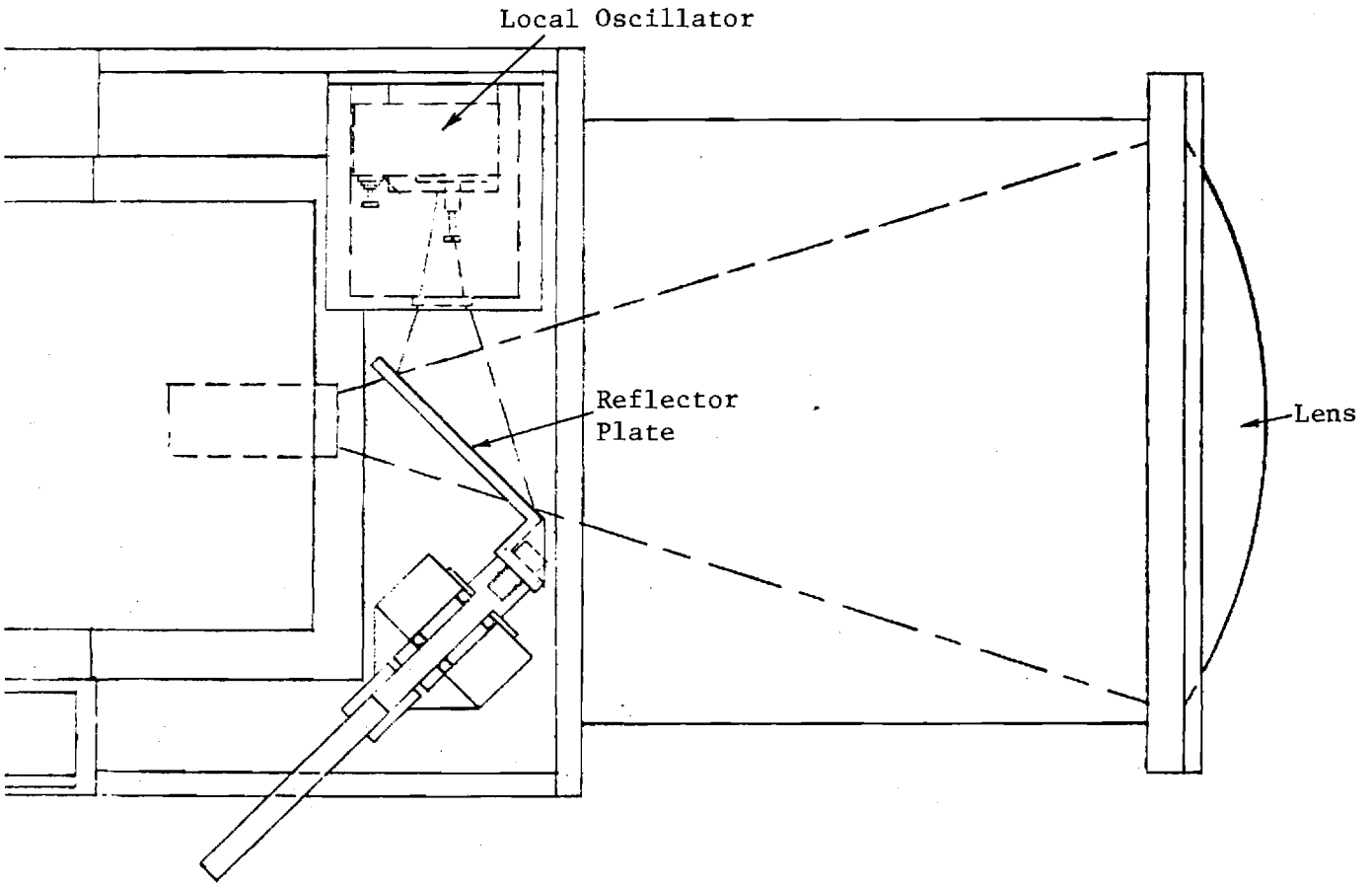


Figure I. Proposed Location of 220 GHz Package in 140 GHz System

END VIEW

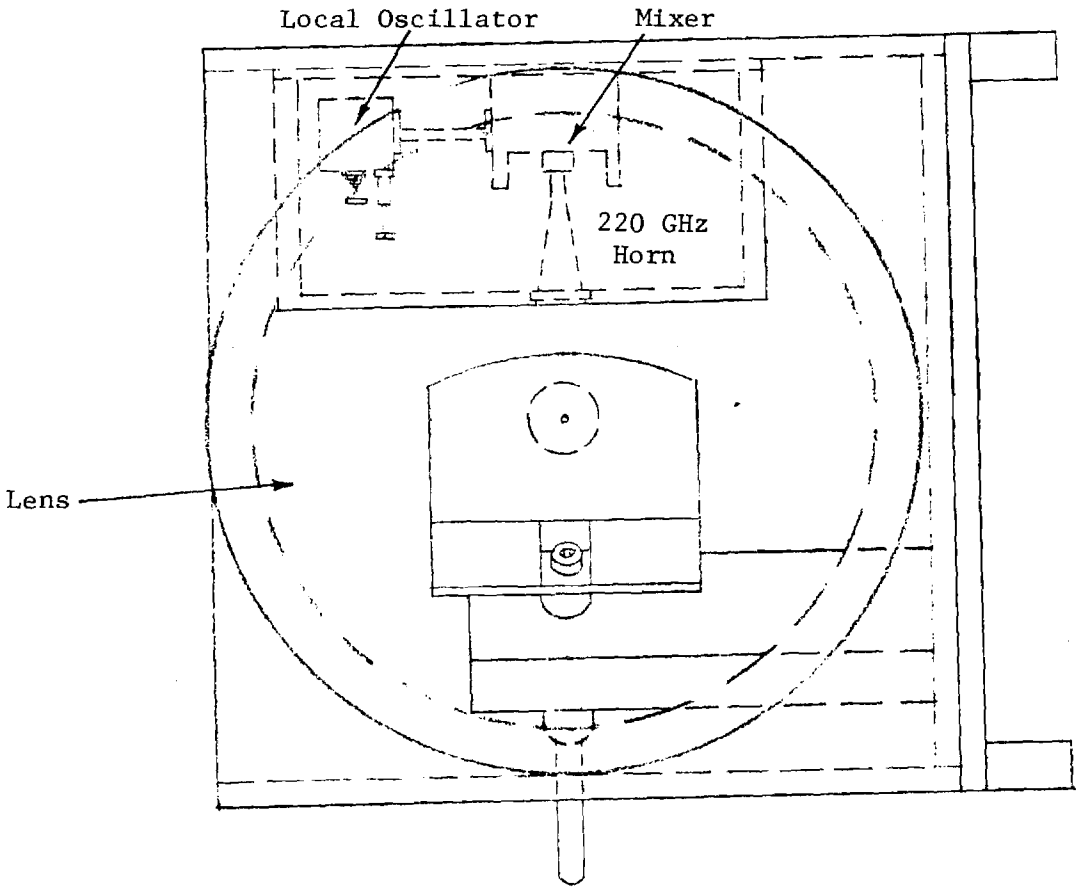


Figure II. Proposed Location of 220 GHz Package in 140 GHz System

Cost Information

The following charges have been incurred against the contract during period 1 April through 30 April, 1980.

	Expended	Encumbered
Personal Services (PS)	$2,192.50	$ - 0 -
Materials and Supplies	69.55	(31.34)
Travel	- 0 -	- 0 -
Overhead (@ 76% of PS)	1,666.30	- 0 -
Retirement (@ 10.51% of PS)	176.19	- 0 -
TOTAL	$4,104.54	$ (31.34)

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ - 0 -	- 0 -
Senior Research Scientists/Engineers	- 0 -	- 0 -
Research Scientists II/Engineers II	940.26	70
Research Scientists I/Engineers I	596.96	55
Technicians/Draftsmen	- 0 -	- 0 -
Students	509.30	89
Secretarial/Clerical/Other	23.20	4
TOTAL	$2,069.72	218

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$76,614.00	$31,749.38	$44,864.62
Materials and Supplies	156,500.00	225.94	156,241.95
Travel and Shipping	2,000.00	- 0 -	2,000.00
Computer	- 0 -	- 0 -	- 0 -
Overhead	57,041.00	24,129.54	32,911.46
Retirement	8,052.00	3,161.79	4,890.21
Encumbered	- 0 -	32.11	- 0 -
	$300,207.00	$59,298.76	$240,908.24

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 20 % of the proposed task has been completed.

A2488

Monthly Progress Report No. 8

Report Period

1 May through 31 May 1980

Report Prepared

June 26, 1980

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

J. M. Schuchardt

Contract N00173-79-C-0389
(A-2488)

Prepared For

Naval Research Laboratory
Washington, D.C. 20375

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED THIS PERIOD

Design efforts on the 220 GHz radiometer have continued. This design will be adjusted to accommodate certain improvements in the 140 GHz radiometer.

Additional efforts on the 95 GHz transmitter are under way. Revised cost estimates are being prepared prior to the ordering of the long lead high priced items.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems to report.

WORK TO BE PERFORMED NEXT PERIOD

The final design of the 220 GHz radiometer will be reviewed via a visit to NRL. It has been suggested that a consultant, Mr. Wilson of the Jet Propulsion Laboratory, work with Georgia Tech in the area of shielding the radiometer for operation in the P3 aircraft. Provisions to do this will be pursued.

A-2488
Cost Information

The following charges have been incurred against the contract during period 1 May through 31 May 1980.

	Expended	Encumbered
Personal Services (PS)	$ 4,383.07	$ -0-
Materials and Supplies	70.37	(26.56)
Travel	-0-	-0-
Overhead (@ 76% of PS)	3,331.13	-0-
Retirement (@ 10.51% of PS)	460.66	-0-
TOTAL	$ 8,245.23	$ (26.56)

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ -0-	-0-
Senior Research Scientists/Engineers	454.75	27
Research Scientists II/Engineers II	637.32	48
Research Scientists I/Engineers I	2,348.07	216
Technicians/Draftsmen	653.53	80
Students	289.40	51
Secretarial/Clerical/Other	-0-	-0-
TOTAL	$4,383.07	422

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 76,614.00	$ 36,132.45	$ 40,481.55
Materials and Supplies	156,500.00	296.31	156,203.69
Travel and Shipping	2,000.00	-0-	2,000.00
Computer	-0-	-0-	-0-
Overhead	57,041.00	27,460.67	29,580.33
Retirement	8,052.00	3,592.03	4,459.97
Encumbered	-0-	5.55	(5.55)
FUNDING	$300,207.00	$ 67,487.01	$232,719.99

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 22 % of the proposed task has been completed.

A-2488

Monthly Progress Report No. 9

Report Period
1 June through 30 June 1980

Report Prepared

22 July 1980

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

J. M. Schuchardt
J. A. Gagliano
R. E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared For

Naval Research Laboratory
Washington, D.C. 20375

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED THIS PERIOD

The following changes and improvements are being incorporated into the design for the A-2488 radiometer. These are the result of a reevaluation of system specifications using the Aerospace Corporation 90 GHz system as a baseline, and the addition of recently available state-of-the-art components. Design changes now being implemented include:

1) Adding components and/or capability for switch selectable operation at 220 GHz
   a) Reflector and actuator control circuit
   b) Separate 220 GHz components enclosure
   c) IF diode selector switch and control circuit
   d) 220 GHz LO, horn, mixer, preamp/IF

Another design goal is to incorporate changes that will improve RFI rejection and system noise figures. These modifications will take into account noise produced by aircraft avionics and power systems:

1) RF component shielding improvements
   a) All RF components located in an isolated enclosure
   b) Improved input filters for input/output to RF enclosure
2) Isolate radiometer systems from aircraft power system
   a) Low pass filter at input of dc to dc converter
   b) dc to dc converter with isolated outputs
   c) Low pass filter for all dc supplies
   d) Remove all high current signals from radiometer power supplies
   e) All control signals to high current devices are opto-isolated
3) Component noise improvement
   a) Low noise preamplifiers
   b) Redesign video amplifier for lower noise and operation at dc.

Because of procurement lead times for components needed for operation at 220 GHz, initial operation will be limited to the 140 GHz channel. However, we anticipate minimal effort to achieve operation at 220 GHz when these become available.

Incorporation of the above components and modifications should result in a significant improvement in system performance. Other than the procurement delay for certain RF components, no other problems or delays are apparent at this time.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

None.

WORK TO BE PERFORMED NEXT PERIOD

Work will continue on the radiometer. A visit to NRL to review the design status will be made in July.

A-2488
Cost Information

The following charges have been incurred against the contract during period 1 June through 30 June 1980.

	Expended
Personal Services (PS)	$ 5,949.65
Materials and Supplies	48.62
Travel	1,336.83
Overhead (@ 76% of PS)	4,521.73
Retirement (@ 10.51% of PS)	587.06
TOTAL	$12,443.89

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ 373.61	18
Senior Research Scientists/Engineers	454.75	27
Research Scientists II/Engineers II	1,059.07	79
Research Scientists I/Engineers I	2,950.84	272
Technicians/Draftsmen	272.80	48
Students	706.52	86
Secretarial/Clerical/Other	132.06	22
TOTAL	$ 5,949.65	552

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$76,614.00	$37,988.43	$38,625.57
Materials and Supplies	156,500.00	344.93	156,149.52
Travel and Shipping	2,000.00	1,336.83	663.17
Computer	-0-	-0-	-0-
Overhead	57,041.00	28,871.21	28,169.79
Retirement	8,052.00	3,748.85	4,303.15
Encumbered	-0-	5.55	-0-
	$300,207.00	$72,295.80	$227,911.20

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 24% of the proposed task has been completed.

A-2488

Monthly Progress Report No. 10

Report Period

1 July through 31 July 1980

Report Prepared

August 21, 1980

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

J. M. Schuchardt
J. J. McSheehy

Contract N00173-79-C-0389
(A-2488)

Prepared For

Naval Research Laboratory
Washington, D.C. 20375

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

Design modifications involving items discussed during the design review meeting at NRL have been finalized. Fabrication of a new control unit and radiometer enclosure is continuing at this time.

Problems Encountered In This Period

The 14 conductor radiometer test cable supplied by NRL is made with unshielded wire and will not allow full system noise tests before installation in the aircraft.

Work To Be Performed During The Next Period

Assembly and testing of the radiometer system will continue.

Cost Information

The following charges have been incurred against the contract during period 1 July through 31 July 1980.

	Expended	Encumbered
Personal Services (PS)	$ 5,372.45	$ -0-
Materials and Supplies	264.33	497.26
Travel	-0-	972.00
Overhead (@ 76% of PS)	3,921.89	-0-
Retirement (@ 10.51% of PS)	446.09	-0-
TOTAL	$10,004.76	$1,469.26

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ 104.99	4
Senior Research Scientists/Engineers	335.27	17
Research Scientists II/Engineers II	437.36	28
Research Scientists I/Engineers I	3,086.41	251
Technicians/Draftsmen	-0-	-0-
Students	1,357.15	243
Secretarial/Clerical/Other	51.27	8
TOTAL	$5,372.45	551

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 76,614.00	$43,360.88	$ 33,253.12
Materials and Supplies	156,500.00	609.26	155,393.48
Travel and Shipping	2,000.00	1,336.83	(308.83)
Computer	-0-	-0-	-0-
Overhead	57,041.00	32,793.10	24,247.90
Retirement	8,052.00	4,194.94	3,857.06
Encumbered	-0-	1,469.26	-0-
FUNDING	$300,207.00	$83,764.27	$216,442.73

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 28 % of the proposed task has been completed.

A-2488

Monthly Progress Report No. 11

Report Period
August 1 through August 31, 1980

Report Prepared
September 17, 1980

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D. C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED THIS PERIOD

A design review was held with Dr. Hollinger (NRL) to discuss the 220 GHz radiometer design. Several options for switching the 140 and 220 GHz front-ends were reviewed. A beam switching mirror was the first option. This would be moved by a stepper motor. This motor would stick a few inches outside of the radiometer box and would require additional circuitry to drive the motor. This circuitry has been allowed for in the design of the radiometer system. A second candidate for the switching mechanism would be a mirror moved by a latching solenoid device. However, no such device has yet been located which has the required translation or rotation required to move the mirror as far as it needs to go.

The third technique is to use a wire grid with properly spaced wires. This device would not need to be moved. It uses a polarization sensitive diplexing technique and is oriented in such a way as to reflect the 220 GHz energy to the 220 GHz feed horn and transmit the 140 GHz energy to the 140 GHz feed horn. To use this technique the 140 and 220 GHz horns must use perpendicular polarizations. This technique is a low loss, simple method to achieve the switching and could eventually lead to simultaneous 140 and 220 GHz measurements with additional IF amps and video electronics. Another advantage to this technique over the others is the absence of the additional circuitry to drive the motors and thus eliminating the associated switching voltage transients that would be generated by these switches.

The disadvantage to this method is that the 220 GHz energy would not be correctly polarized with respect to the calibration loads now used in NRL's P-3 radiometer system. Previous experience with cross polarized reflection measurements made on these loads indicates an error of a few percent in absolute accuracy may be present. This may be circumvented by the use of pyramidal calibration loads which absorb both polarizations equally well.

Another set of options discussed with Dr. Hollinger was the use of X2 or X4 subharmonic mixers. The tradeoffs are in cost and performance. A decision on which mixer to use will be made in November during the test flights. At this time data should be available from a X4 subharmonic mixer and a decision can be made.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems to report at this time.

WORK TO BE PERFORMED NEXT PERIOD

The radiometer electronics will be tested. The polarization diplexing scheme will be analyzed. Other mechanical switching techniques will also be investigated.

A-2488

Cost Information

The following charges have been incurred against the contract during period 1 August through 31 August 1980.

	Expended	Encumbered
Personal Services (PS)	$ 5,445.71	$ -0-
Materials and Supplies	781.86	5,473.22
Travel	560.19	(792.00)
Overhead (@ 76% of PS)	3,975.37	-0-
Retirement (@ 10.51% of PS)	360.14	-0-
TOTAL	$11,123.27	$4,681.22

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ -0-	-0-
Senior Research Scientists/Engineers	335.27	17
Research Scientists II/Engineers II	583.15	38
Research Scientists I/Engineers I	2,216.67	180
Technicians/Draftsmen	50.02	6
Students	2,204.22	394
Secretarial/Clerical/Other	56.38	9
TOTAL	$5,445.71	644

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 76,614.00	$ 48,806.59	$ 27,807.41
Materials and Supplies	156,500.00	1,391.12	149,138.40
Travel and Shipping	2,000.00	1,897.02	(77.02)
Computer	-0-	-0-	-0-
Overhead	57,041.00	36,768.47	20,272.53
Retirement	8,052.00	4,555.08	3,496.92
Encumbered	-0-	6,150.48	-0-
FUNDING	$300.207.00	$ 99,568.76	$200,638.24

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 33% of the proposed task has been completed.

A-2488

Monthly Progress Report No. 12

Report Period
September 1 through September 30, 1980

Report Prepared
October 20, 1980

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D. C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED THIS PERIOD

The electronics required for the 220 GHz radiometer are completed and have been tested. These have been installed in the same control box as the 140 GHz radiometer which has been rebuilt. The 140 GHz radiometer baseplate has been rebuilt and the components remounted to allow room for the 220 GHz radiometer front-end. A switch has been installed on the control box panel to switch between 140 and 220 GHz operation. It currently only allows 140 GHz operation and will be made functional upon installation of the 220 GHz front end.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems to report at this time.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

Work will be done to analyze the diplexing of the 140 and 220 GHz front-ends. Information on the X4 220 GHz subharmonic mixer performance should be available so that a decision can be made on the mixer selection for the 220 GHz system.

A-2488

Cost Information

The following charges have been incurred against the contract during period 1 September through 30 September 1980.

	Expended	Encumbered
Personal Services (PS)	$ 7,953.74	$0
Materials and Supplies	1,103.05	674.12
Travel	67.20	(180.00)
Overhead (@ 76% of PS)	5,806.24	0
Retirement (@ 10.51% of PS)	705.76	0
TOTAL	$15,635.99	$494.12

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ 419.98	18
Senior Research Scientists/Engineers	167.63	9
Research Scientists II/Engineers II	291.58	19
Research Scientists I/Engineers I	3,863.85	314
Technicians/Draftsmen	1,535.16	173
Students	1,601.23	286
Secretarial/Clerical/Other	74.31	11
TOTAL	$7,953.74	830

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$ 56,760.33	$ 13,463.67
Materials and Supplies	168,265.00	2,494.17	159,126.23
Travel and Shipping	2,000.00	1,964.22	35.78
Computer	0	0	0
Overhead	52,376.00	42,574.71	9,801.29
Retirement	7,342.00	5,260.84	2,081.29
Encumbered	0	6,644.60	0
	$300,207.00	$115,698.87	$184,508.12

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 38% of the proposed task has been completed.

A-2488

Monthly Progress Report No. 13

Report Period
October 1 through October 31, 1980

Report Prepared
November 20, 1980

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED THIS PERIOD

The polarization diplexing scheme for allowing the sharing of the same lens for the 140 and 220 GHz system has been analyzed. The expected increase in losses due to this diplexer are about 0.5 dB. The diplexer can be mounted in the system and requires no electronics for switching. The electronics portion of the 220 GHz radiometer has been extensively tested so that it will perform in the P3 aircraft environment.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems to report at this time.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

The decisions on polarization scheme and mixer type for use at 220 GHz will be made after discussions with the technical monitor.

Cost Information

The following charges have been incurred against the contract during period 1 October through 31 October 1980

	Expended	Encumbered
Personal Services (PS)	$ 4,764.12	$ -0-
Materials and Supplies	2,563.44	(1,282.18)
Travel	-0-	-0-
Overhead (@ 76% of PS)	3,477.81	-0-
Retirement (@ 10.51% of PS)	361.72	-0-
TOTAL	$11,167.09	$(1,282,18)

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ -0-	-0-
Senior Research Scientists/Engineers	-0-	-0-
Research Scientists II/Engineers II	-0-	-0-
Research Scientists I/Engineers I	2,133.88	174
Technicians/Draftsmen	1,012.78	114
Students	1,460.60	261
Secretarial/Clerical/Other	156.86	24
TOTAL	$ 4,764.12	573

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$ 61,524.45	$ 8,699.55
Materials and Supplies	177,858.00	5,057.61	167,437.97
Travel and Shipping	2,000.00	1,964.22	35.78
Computer	-0-	-0-	-0-
Overhead	52,376.00	46,052.52	6,323.48
Retirement	7,342.00	5,622.56	1,719.44
Encumbered	-0-	5,362.42	-0-
	$309,800.00	$125,583.78	$184,216.22

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 40% of the proposed task has been completed.

A-2488

Monthly Progress Report No. 14

Report Period
November 1 through November 30, 1980

Report Prepared
December 15, 1980

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

1.0 WORK PERFORMED DURING THIS PERIOD

During this period a meeting was held with Dr. James P. Hollinger of NRL in which several decisions were made concerning the 220 GHz radiometer to be built on this program. These are:

1) A polarization diplexer will be used to share the lens antenna; and

2) A X2 subharmonic mixer will be used for the front-end.

This will involve the purchase of a 108 GHz solid state local oscillator. These decisions were made based on estimated sensitivity and available space in the radiometer box.

2.0 PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems were encountered.

3.0 WORK TO BE PERFORMED NEXT PERIOD

Necessary parts will be ordered for the 220 GHz radiometer front-end.

Cost Information

The following charges have been incurred against the contract during period 1 November through 30 November 1980.

	Expended	Encumbered
Personal Services (PS)	$ 818.68	$ -0-
Materials and Supplies	1,042.28	(549.87)
Travel	-0-	-0-
Overhead (@ 76% of PS)	597.63	-0-
Retirement (@ 10.51% of PS)	61.07	-0-
TOTAL	$2,519.66	$(549.87)

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ (419.98)	0
Senior Research Scientists/Engineers	-0-	0
Research Scientists II/Engineers II	(874.73)	0
Research Scientists I/Engineers I	1,062.42	86
Technicians/Draftsmen	782.02	88
Students	264.85	47
Secretarial/Clerical/Other	4.10	1
TOTAL	$ 818.68	222

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$ 62,343.13	$ 7,880.87
Materials and Supplies	177,858.00	6,099.89	166,945.56
Travel and Shipping	2,000.00	1,964.22	35.78
Computer	-0-	-0-	-0-
Overhead	52,376.00	46,650.15	5,725.85
Retirement	7,342.00	5,683.63	1,658.37
Encumbered	-0-	4,812.55	-0-
FUNDING	$309,800.00	$127,553.57	$182,246.43

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 41 % of the proposed task has been completed.

Monthly Progress Report No. 15

Report Period
December 1 through December 31, 1980

Report Prepared
January 15, 1981

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R.E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED THIS PERIOD

During this period discussions were held at NRL with Dr. J. P. Hollinger concerning the 220 GHz portion of the 140/220 GHz radiometer. At that time, it was decided to use a X2 subharmonic mixer pumped with a 108 GHz solid state local oscillator. A polarization diplexer was chosen as the device that will be used to share the same aperture.

The mixer body has been machined, polished and plated, and is awaiting the arrival of the stripline circuits for final assembly and testing. The local oscillator, the 2-4 GHz PIN diode switch, the 2-4 GHz band pass filters and the 2-4 GHz bias tee have been ordered. The 2-4 GHz IF amplifiers have already been received and tested.

The electronics have been flight tested in the P-3 aircraft during the use of the 140 GHz portion of the radiometer. This system will be returned for the addition of the 220 GHz front end and the 2-4 GHz amplifiers and other IF components after these flights.

PROBLEMS ENCOUNTERED

No problems to report at this time.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

During the next period, the corrugated horn antenna and diplexer designs will begin.

A-2488

Cost Information

The following charges have been incurred against the contract during period 1 December through 31 December 1980.

	Expended	Encumbered
Personal Services (PS)	$ 269.21	$ -0-
Materials and Supplies	72.30	(68.04)
Travel	149.14	-0-
Overhead (@ 73% of PS)	196.52	-0-
Retirement (@ 11.11% of PS)	25.25	-0-
TOTAL	$ 712.42	$ (68.04)

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$209.99	8
Senior Research Scientists/Engineers	-0-	-0-
Research Scientists II/Engineers II	-0-	-0-
Research Scientists I/Engineers I	-0-	-0-
Technicians/Draftsmen	-0-	-0-
Students	42.00	8
Secretarial/Clerical/Other	17.22	3
TOTAL	$269.21	19

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$ 62,612.34	$ 7,611.66
Materials and Supplies	177,858.00	6,172.19	166,941.30
Travel and Shipping	2,000.00	2,113.36	(113.36)
Computer	-0-	-0-	-0-
Overhead	52,376.00	46,846.67	5,529.33
Retirement	7,342.00	5,708.88	1,633.12
Encumbered	-0-	4,744.51	-0-
FUNDING	$309,800.00	$128,197.95	$181,602.05

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 41 % of the proposed task has been completed.

A-2488

Monthly Progress Report No. 16

Report Period
January 1 through January 31, 1981

Report Prepared
February 20, 1981

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED THIS PERIOD

The assembly of the X2 220 GHz subharmonic mixer has begun. Diodes and whiskers have been mounted on the run-in pins. The rest of the assembly will begin upon the arrival of the 0.0025 inch quartz substrate suspended stripline circuits.

PROBLEMS ENCOUNTERED

No problems to report at this time.

WORK TO BE PERFORMED NEXT PERIOD

The 2-4 GHz IF amplifiers will be integrated into the system once the 140/220 GHz radiometer is returned to Georgia Tech.

A-2488

Cost Information

The following charges have been incurred against the contract during period 1 January through 31 January 1981.

	Expended	Encumbered
Personal Services (PS)	$ 2,841.17	$ -0-
Materials and Supplies	4,763.40	6,859.45
Travel	-0-	-0-
Overhead (@ 73% of PS)	2,074.05	-0-
Retirement (@ 11.11% of PS)	226.09	-0-
TOTAL	$ 9,904.71	$6,859.45

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ -0-	0
Senior Research Scientists/Engineers	1,091.39	57
Research Scientists II/Engineers II	-0-	0
Research Scientists I/Engineers I	839.95	68
Technicians/Draftsmen	-0-	0
Students	806.15	144
Secretarial/Clerical/Other	103.68	16
TOTAL	$2,841.17	285

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$ 65,453.51	$ 4,770.49
Materials and Supplies	177,858.00	22,539.55	155,318.45
Travel and Shipping	2,000.00	2,113.36	(113.36)
Computer	-0-	-0-	-0-
Overhead	52,376.00	48,920.72	3,455.28
Retirement	7,342.00	5,934.97	1,407.03
Encumbered	-0-	11,603.96	-0-
	$309,800.00	$144,962.11	$164,837.89

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 47 % of the proposed task has been completed.

4-2488

Monthly Progress Report No. 17

Report Period
February 1 through February 28, 1981

Report Prepared
March 15, 1981

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

The 140/220 GHz radiometer's circuits were damaged due to an incorrect cable hook-up during lab tests at NRL. These circuits are being repaired. The new 2-4 GHz IF amplifier has been installed.

PROBLEMS ENCOUNTERED

No problems to report at this time.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

The repair of the system electronics will continue. System testing with the new IF amplifier will begin.

Cost Information

The following charges have been incurred against the contract during period 1 February through 28 February 1981.

	Expended	Encumbered
Personal Services (PS)	$ 4,613.07	$ -0-
Materials and Supplies	190.06	(92.34)
Travel	0	-0-
Overhead (@ 73% of PS)	3,367.54	-0-
Retirement (@ 11.11% of PS)	391.74	-0-
TOTAL	$ 8,562.41	$(92.34)

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ -0-	0
Senior Research Scientists/Engineers	898.35	47
Research Scientists II/Engineers II	619.70	40
Research Scientists I/Engineers I	1,883.63	153
Technicians/Draftsmen	-0-	0
Students	1,087.10	194
Secretarial/Clerical/Other	124.29	19
TOTAL	$4,613.07	453

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$70,066.58	$ 157.42
Materials and Supplies	177,858.00	11,125.65	155,220.73
Travel and Shipping	2,000.00	2,113.36	(113.36)
Computer	-0-	-0-	-0-
Overhead	52,376.00	52,288.26	87.74
Retirement	7,342.00	6,326.71	1,015.29
Encumbered	-0-	11,511.62	-0-
	$309,800.00	$153,432.18	$156,367.82

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 50% of the proposed task has been completed.

Monthly Progress Report No. 18

Report Period
March 1 through March 31, 1981

Report Prepared
April 15, 1981

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

The 140/220 GHz radiometer's circuits have been repaired and are currently being tested. Assembly and testing of the system for the next set of data flights has begun. The radiometer now shows a minimum detectable temperature of 0.06 K (one second integration time) at 140 GHz with the new IF amplifiers.

The circuits for the 220 GHz X2 subharmonic mixer have arrived. Assembly of this mixer has begun.

The 220 GHz corrugated feed has been designed. The RF layout of the front-end has begun. The mechanical drawings for the 220 GHZ RFI box have been started.

PROBLEMS ENCOUNTERED

No problems to report at this time.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

The 108 GHz local oscillator will arrive. Testing of the new 220 GHz subharmonic mixer will begin. The mechanical layout of the 220 GHz RF front-end will continue. The system will be delivered to NRL for a set of data flights in May.

A-2488

Cost Information

The following charges have been incurred against the contract during period 1 March through 31 March, 1981.

	Expended	Encumbered
Personal Services (PS)	$ 7,668.35	$ -0-
Materials and Supplies	221.45	11,390.03
Travel	6.12	-0-
Overhead (@ 76% of PS)	5,597.89	-0-
Retirement (@ 10.51% of PS)	821.97	-0-
TOTAL	$ 14,315.78	$ 11,390.03

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ 209.99	9
Senior Research Scientists/Engineers	1,086.93	56
Research Scientists II/Engineers II	2,548.02	166
Research Scientists I/Engineers I	2,695.77	219
Technicians/Draftsmen	823.30	101
Students	269.90	41
Secretarial/Clerical/Other	34.44	5
TOTAL	$ 7,668.35	597

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$ 77,734.93	$ (7,510.93)
Materials and Supplies	177,858.00	11,347.10	143,609.25
Travel and Shipping	2,000.00	2,119.48	(119.48)
Computer	-0-	-0-	-0-
Overhead	52,376.00	57,886.15	(5,510.15)
Retirement	7,342.00	7,148.68	(193.32)
Encumbered	-0-	-0-	-0-
Total	$ 309,800.00	$ 156,236.34	$ 130,662.01

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 50 % of the proposed task has been completed.

Monthly Progress Report No. 19

Report Period
April 1 through April 30, 1981

Report Prepared
May 15, 1981

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe
J. A. Scheer

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

Repair and testing of the 140/220 GHz radiometer's circuits has been completed. The system has been returned to NRL for another set of data flights based out of Hawaii. The 140 GHz portion now has a 10.5 dB system noise figure with a 0.066K minimum detectable temperature (one second integration time).

The 220 GHz X2 subharmonic mixer assembly and testing has begun. The 108 GHz local oscillator has been received. The 220 GHz corrugated horn has been designed for a 0.5° beam width. Due to space problems, it was necessary to use the smallest feed horn design and, thus, illuminate the entire lens. The housing for the 220 GHz front-end has also been designed.

PROBLEMS ENCOUNTERED

There are no problems to report at this time.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

The 220 GHz corrugated feed horn will be ordered. Mechanical design of 220 GHz RF brackets will be completed. Machining of the 220 GHz RF enclosure and brackets will begin. Assembly and testing of the 220 GHz subharmonic mixer will continue.

'rogress During Reporting Period

During the reporting period most of the major RF components were selected and rdered. The transmitter and pulser have also been ordered. The delivery dates for he pulser and receiver components range from near term to September, 1981. The ransmitter will be delivered some time between October and December, 1981.

It appears that the transmitter is the limiting item, in terms of delivery. eorgia Tech is attempting to arrange for the loan of a similar tube from the vendor o that modulator development can progress.

A trip was made to the transmitter vendor to evaluate the prototype focus lectrode control EIO. It was determined that an injection signal is required to btain the pulse stability required for a two to four nanosecond pulse.

A wideband current probe has been developed to aid in the evaluation of the short ulse waveforms in the transmitter circuits.

Development of a wideband detector and video amplifier was begun. Two approaches re being evaluated, a full wave detector using zero-bias schottky diodes, and a ouble balanced mixer approach. The double balanced mixer is expected to be a more table design at the expense of dynamic range, and the full wave detector is expected o have more dynamic range, at the expense of some stability.

lans for the Next Reporting Period

Ordering of the last of the major components will be done during the next month. hese include the high voltage power supplies, low voltage supplies, and receiver omponents such as filters and attenuators. Design effort will continue on the control ircuits and wideband receiver circuits. Incoming tests will be performed on any omponents received from vendors.

Fabrication and packaging details will begin being finalized with delivery of the ulser, which is expected in June. Some question still remains concerning how much of he system can be packaged into the pulser chassis.

Cost Information

The following charges have been incurred against the contract during period 1 April through 30 April, 1981

	Expended	Encumbered
Personal Services (PS)	$ 12,821.51	$ -0-
Materials and Supplies	720.21	54,732.30
Travel	-0-	-0-
Overhead (@ 73% of PS)	9,359.71	-0-
Retirement (@ 11.11% of PS)	1,169.66	-0-
TOTAL	$ 24,071.09	$ 54,732.30

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ -0-	-0-
Senior Research Scientists/Engineers	2,459.75	128
Research Scientists II/Engineers II	2,612.57	170
Research Scientists I/Engineers I	3,735.71	304
Technicians/Draftsmen	2,659.11	308
Students	993.33	178
Secretarial/Clerical/Other	361.04	55
TOTAL	$ 12,821.51	1.143

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$ 90,556.44	$ (20,332.44)
Materials and Supplies	177,858.00	12,067.31	88,156.74
Travel and Shipping	2,000.00	2,119.48	(119.48)
Computer	-0-	-0-	-0-
Overhead	52,376.00	67,245.86	(14,869.86)
Retirement	7,342.00	8,318.34	(976.34)
Encumbered	-0-	77,633.95	(77,633.95)
TOTAL	$ 309,800.00	$ 257,941.38	$ 51,858.62

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 83 % of the proposed task has been completed.

Monthly Progress Report No. 20

Report Period
May 1 through May 31, 1981

Report Prepared
June 15, 1981

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

The radiometer has been returned to Georgia Tech for the addition of the 220 GHz front-end. The 220 GHz feed horn has been ordered. The mechanical design of the 220 GHz enclosure and brackets is complete.

The X2 220 GHz subharmonic mixer work is continuing. So far, 14 dB mixer/IF noise figures (DSB) have been measured with a 2-4 GHz IF. Improvements in performance are expected.

The polarization sensitive beam splitter has been designed. This device allows two high frequency feed horns with perpendicularly oriented polarizations to use the same lens antenna. The 220 GHz energy will be reflected by the quasi-optical polarization diplexer, and the 140 GHz energy will pass through it. The expected losses are less than 0.3 dB. The diplexer should consist of metal strips photolithographically etched on a thin, circular piece of mylar plastic. This will be held in place by a metal bracket at a 45° angle between the two feed horns. A typical grid period would be 100 μm. The strip width will be 50 μm. The mylar thickness would be 13 μm. The device will be large enough to make spill-over loss negligible.

PROBLEMS ENCOUNTERED

There are no problems to report at this time.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

The machining of the 220 GHz brackets and the RF enclosure will begin. Work will continue on the 220 GHz X2 mixer development.

Cost Information

The following charges have been incurred against the contract during period 1 May through 31 May 1981.

	Expended	Encumbered
Personal Services (PS)	$ 6,416.53	-0-
Materials and Supplies	2,782.39	$ 3,817.76
Travel	9.72	-0-
Overhead	4,684.07	-0-
Retirement	636.41	-0-
TOTAL	$ 14,529.12	$ 3,817.76

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ -0-	-0
Senior Research Scientists/Engineers	1,945.77	101
Research Scientists II/Engineers II	2,250.56	147
Research Scientists I/Engineers I	933.12	76
Technicians/Draftsmen	1,223.87	142
Students	35.55	6
Secretarial/Clerical/Other	27.66	4
TOTAL	$ 6,416.53	476

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$ 96,972.00	$(26,748.97)
Materials and Supplies	177,858.00	96,301.41	81,556.59
Travel and Shipping	2,000.00	2,129.20	(129.20)
Computer	-0-	-0-	-0-
Overhead	52,376.00	71,929.93	(19,553.93)
Retirement	7,342.00	8,954.75	(1,612.75)
Encumbered	-0-	-0-	-0-
TOTAL	$ 309,800.00	$276,288.26	$ 33,511.74

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 89% of the proposed task has been completed.

A-2488

Monthly Progress Report No. 21

Report Period
June 1 through June 30, 1981

Report Prepared
July 1981

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AMMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED THIS PERIOD

The parts for the 220 GHz radiometer enclosure and polarization diplexer bracket are being machined. These will be finished in late July. The 220 GHz front end is still being assembled and tested for noise figure.

PROBLEMS ENCOUNTERED

No problems have occurred during this period.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

System assembly and testing will begin. Work will continue on improving the 220 GHz front end performance.

A-2488

Cost Information

The following charges have been incurred against the contract during period 1 June through 30 June, 1981.

	Expended	Encumbered
Personal Services (PS)	$ 6,683.07	$ -0-
Materials and Supplies	13,267.13	(10,396.53)
Travel	-0-	-0-
Overhead (@ 76% of PS)	4,878.64	-0-
Retirement (@ 10.51% of PS)	603.93	-0-
TOTAL	25,432.77	$ (10,396.53)

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ -0-	0
Senior Research Scientists/Engineers	1,269.72	66
Research Scientists II/Engineers II	1,934.64	126
Research Scientists I/Engineers I	206.87	17
Technicians/Draftsmen	3,200.85	371
Students	36.76	7
Secretarial/Clerical/Other	34.23	5
TOTAL	$ 6,683.07	592

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$ 103,656.04	$ (33,432.04)
Materials and Supplies	177,858.00	99,172.01	87,685.99
Travel and Shipping	2,000.00	2,129.20	(129.20)
Computer	-0-	-0-	-0-
Overhead	52,376.00	76,808.57	(24,432.57)
Retirement	7,342.00	9,558.68	(2,216.68)
Encumbered	-0-	-0-	-0-
TOTAL	$ 309,800.00	$ 291,324.50	$ 18,475.50

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 94 % of the proposed task has been completed.

Monthly Progress Report No. 22

Report Period
July 1 through July 31, 1981

Report Prepared
August 15, 1981

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R.E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

The parts for the 220 GHz radiometer (housing, brackets, polarization diplexer holder, and baseplate) have been machined. System assembly has begun. New semi-rigid cables and a new wiring harness are being made. The 2-4 GHz SPDT switch has been tested and works well. A tenative delivery date has been set for August 31, 1981.

PROBLEMS ENCOUNTERED

It has been determined that the solid state LO is considerably more noisy than anticipated. This device apparently degrades the noise figure of the 220 GHz, by between 5- 7 dB based on tests made with and without a LO bandpass filter. Discussions will be held with the vendor to determine what can be done to rectify this problem. Alternate filtering techniques will be considered to clean up the LO.

The rate of expenditures indicates that the project will run out of funds during the next period. Should this happen, work will have to temporarily stop on this project until additional funds are available.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

The system assembly will be finished. System testing will begin, and based on these results the 140/220 GHz radiometer may also be delivered to NRL for flight testing.

A-2488

Cost Information

The following charges have been incurred against the contract during period July 1 through July 31, 1981

	Expended	Encumbered
Personal Services (PS)	4,058.94	-
Materials and Supplies	4,421.95	67,175.22
Travel	0	0
Overhead (@ 7.5% of PS)	3,044.21	0
Retirement (@ 11.11% of PS)	305.53	0
TOTAL	11,830.63	67,175.22

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	0	0
Senior Research Scientists/Engineers	0	0
Research Scientists II/Engineers II	0	0
Research Scientists I/Engineers I	1,088.71	79
Technicians/Draftsmen	1,640.77	149
Students	1,271.40	136
Secretarial/Clerical/Other	58.06	8
TOTAL	4,058.94	372

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	70,224.00	107,714.98	(37,490.98)
Materials and Supplies	177,858.00	32,538.78	78,144.00
Travel and Shipping	2,000.00	2,129.20	(129.20)
Computer	0	0	0
Overhead	52,376.00	79,852.78	(27,476.78)
Retirement	7,342.00	9,864.21	(2,522.21)
Encumbered	0	67,175.22	0
FUNDING	309,800.00	299,275.17	10,524.83

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 97 % of the proposed task has been completed.

A-2488

Monthly Progress Report No. 23

Report Period
August 1 through August 31, 1981

Report Prepared
September 15, 1981

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R.E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

The 140/220 GHz radiometer was tested and shipped to NRL for flight tests and data flights which will take place during the next three months in Maryland and Greenland. The 140 GHz portion of the radiometer had a 10.5dB system noise figure and the 220 GHz portion had a 16dB noise figure when shipped.

The rexolite lens loss was measured to be about 2.0-2.5dB at 220 GHz. This adds significantly to the 220 GHz system noise figure. A new TPX lens will have only 0.6dB loss. A new lens is being prepared.

PROBLEMS ENCOUNTERED

The vendor for the noisy LO which degrades the 220 GHz radiometer's noise figure could not suggest a quick fix for this problem. It is recommended that a bandpass filter be built and retrofitted into the system at a future date.

Due to increased materials costs this program is nearly out of funds. Until additional funds are available work will continue at a much reduced rate until funds are depleted at which point work on this project will have to stop. New financial summary statements and estimates are being prepared. Work on the radar portion of the project has stopped to allow the remaining funds to be used to build the new lens.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

A new 6" TPX lens will be designed and machined. Cost estimates for completion of the program will be prepared.

Cost Information

The following charges have been incurred against the contract during period August 1-August 31, 1981

	Expended	Encumbered
Personal Services (PS)	$4,236.14	0
Materials and Supplies	3,606.92	2,325.10
Travel	0	0
Overhead (@ 75% of PS)	3,177.10	0
Retirement (@11.11% of PS)	390.05	0
TOTAL	$11,410.21	$2,325.10

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	0	0
Senior Research Scientists/Engineers	0	0
Research Scientists II/Engineers II	585.82	34
Research Scientists I/Engineers I	1481.95	107
Technicians/Draftsmen	1327.96	176
Students	725.25	117
Secretarial/Clerical/Other	115.16	16
TOTAL	$ 4236.14	420

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	70,224.00	111,951.12	(41,727.12)
Materials and Supplies	177,858.00	36,145.70	76,862.18
Travel and Shipping	2,000.00	2,129.20	(129.20)
Computer	0	0	0
Overhead	52,376.00	83,029.88	(30,653.88)
Retirement	7,342.00	10,254.26	(2,912.26)
Encumbered	0	64,850.12	0
FUNDING	$309,800.00	$308,360.28	$ 1,439.72

Based on present full funding, the funding and equivalent man hours are insufficient to complete the task. Approximately 90% of the proposed task has been completed.

Monthly Progress Report No. 24

Report Period
September 1 through September 30, 1981

Report Prepared
October 15, 1981

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R.E. Forsythe

Contract N00173-79-C-0389
(A-2488)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

Work on the new TPX lens has continued. It has been designed and built but a problem developed with the glue which is used to hold the two pieces together. Apparently the glue was not cured long enough.

This particular material only comes in one inch thick slabs and the lens is thicker than one inch so two pieces are needed. This thickness problem appeared on another program and was solved using a combination of glue, two slabs, and four special TPX posts to assemble and machine the lens. The glue is for RF continuity and the posts provide mechanical rigidity. Another TPX lens is being prepared.

Problems Encountered

The project is currently showing a negative balance due to an unexpected increase of costs for materials and supplies for the 95 GHz radar.

Work to be Performed During the Next Period

The TPX lens will be completed.

Cost Information

The following charges have been incurred against the contract during period September 1 - September 30, 1981.

	Expended	Encumbered
Personal Services (PS)	$ 598.41	-
Materials and Supplies	9,556.17	($8,063.07)
Travel	0	-
Overhead (@ 75% of PS)	448.81	-
Retirement (@ 11.11% of PS)	64.16	-
TOTAL	$10,667.55	$8,063.07

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	0	0
Senior Research Scientists/Engineers	$234.37	11
Research Scientists II/Engineers II	0	0
Research Scientists I/Engineers I	0	0
Technicians/Draftsmen	343.09	38
Students	0	0
Secretarial/Clerical/Other	20.95	3
TOTAL	$598.41	3

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$112,549.53	($42,325.53)
Materials and Supplies	177,858.00	102,488.92	75,369.08
Travel and Shipping	2,000.00	2,129.20	(129.20)
Computer	-	-	-
Overhead	52,376.00	83,478.69	(31,102.69)
Retirement	7,342.00	10,318.42	(2,976.42)
Encumbered			
FUNDING	$309,800.00	$310,964.76	$ (1,164.76)

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 100% of the proposed task has been completed.

Monthly Technical Report No. 25
and
Monthly Cost and Performance Report No. 25

Report Period
October 1 through October 31, 1981

Report Prepared on
November 15, 1981

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date: 9/28/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 3/27/82 (Mod. P00003)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

The new TPX lens experienced similar problems that occurred earlier with the first lens, and this work was discontinued. Alternate materials (teflon and high density polyethelene) were investigated for use as a new lens. These materials were tested for losses at 220 GHz and were found to be comparable to TPX at this frequency. A new teflon lens was fabricated and shipped to NRL during this period, and was flown in the 140/220 GHz radiometer system during data flights by NRL. Improvements of about 0.5 dB at 140 GHz and 1.7 dB at 220 GHz are expected.

Estimates of funds needed to complete this project were sent to NRL for evaluation.

The 140/220 GHz radiometer was flown by NRL in Greenland and took imaging data. No problems appeared with the radiometer during these flights, indicating reliable performance under adverse weather conditions.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems occurred during this period.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

The project is currently out of funds. Work will resume on this contract when more funds become available.

Cost Information

The following charges have been incurred against the contract during period October 1 through October 31, 1981.

	Expended	Encumbered
Personal Services (PS)	333.85	0
Materials and Supplies	4,736.58	(3,449.50)
Travel	0	0
Overhead (@ 75% of PS)	250.39	0
Retirement (@ 11.11% of PS)	37.22	0
TOTAL	$5,358.04	(3,449.00)

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	0	0
Senior Research Scientists/Engineers	0	0
Research Scientists II/Engineers II	0	0
Research Scientists I/Engineers I	0	0
Technicians/Draftsmen	321.15	29
Students	0	0
Secretarial/Clerical/Other	12.70	2
TOTAL	333.85	31

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$112,883.38	(42,659,38)
Materials and Supplies	177,858.00	103,776.50	74,018.50
Travel and Shipping	2,000.00	2,129.20	(129.20)
Computer	0	0	0
Overhead	52,376.00	83,729.08	(31,353.08)
Retirement	7,342.00	10,355.64	(3,073.64)
Encumbered	$309,800.00	$312,873.80	(3,073.80)

FUNDING

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 101% of the proposed task has been completed.

Monthly Technical Report No. 26
and
Monthly Cost and Performance Report No. 26

Report Period
November 1 through November 30, 1981

Report Prepared on
December 15, 1981

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date: 9/28/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 3/27/82 (Mod. P00003)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

No work has been done on this project during this period.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems occurred during this period.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

The project is currently out of funds. Work will resume on this contract when more funds become available.

A-2488

Cost Information

The following charges have been incurred against the contract during period November 1 through November 30, 1981.

	Expended	Encumbered
Personal Services (PS)	$ 31.11	-
Materials and Supplies	6,680.50	$6,640.00
Travel	0	-
Overhead (@ 73% of PS)	23.33	-
Retirement (@ 11.11% of PS)	3.61	-
TOTAL	$6,738.55	$6,640.00

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	-	0
Senior Research Scientists/Engineers	-	0
Research Scientists II/Engineers II	-	0
Research Scientists I/Engineers I	-	0
Technicians/Draftsmen	31.11	
Students	-	0
Secretarial/Clerical/Other	-	0
TOTAL	$31.11	3

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$112,914.49	(42,690.49)
Materials and Supplies	177,858.00	103,817.00	74,041.50
Travel and Shipping	2,000.00	2,129.20	(129.20)
Computer	0	0	0
Overhead	52,376.00	83,752,41	(31,376.41)
Retirement	7,342.00	10,359.25	(3,017.25)
FUNDING	$309,800.00	$312,972.35	(3,172.35)

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 101% of the proposed task has been completed.

Monthly Technical Report No. 27
and
Monthly Cost and Performance Report No. 27

Report Period
December 1 through December 31, 1981

Report Prepared on
January 22, 1982

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date: 9/28/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 3/27/82 (Mod. P00003)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

No work has been done on this project during this period.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems occurred during this period.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

The project is currently out of funds. Work will resume on this contract when more funds become available.

Cost Information

The following charges have been incurred against the contract during period December 1 through 31, 1981.

	Expended	Encumbered
Personal Services (PS)	$ 722.14	
Materials and Supplies	471.97	$482.25
Travel	0	
Overhead (@ 75% of PS)	541.61	
Retirement (@ 11.11% of PS)	83.70	
TOTAL	$1,819.42	$482.25

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	$ 0	0
Senior Research Scientists/Engineers	0	0
Research Scientists II/Engineers II	0	0
Research Scientists I/Engineers I	660.72	47
Technicians/Draftsmen	0	0
Students	0	0
Secretarial/Clerical/Other	61.42	8
TOTAL	$722.14	55

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	$113,636.63	($43,412.63)
Materials and Supplies	177,590.92	103,806.72	$74,051.28
Travel and Shipping	2,000.00	2,129.20	(129.20
Computer	0	0	0
Overhead	52,376.00	84,294.02	(31,918.02)
Retirement	7,342.00	10,442.95	(3,100.95)
Encumbered			
FUNDING	$309,800.00	$314,309.52	($ 4,509.52)

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 101% of the proposed task has been completed.

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Monthly Technical Report No. 28

Monthly Technical Report No. 29

and

Monthly Cost and Performance Report No. 29

Report Period
February 1 through February 29, 1982

Report Prepared on
March 25, 1982

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date: 9/28/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 3/27/82 (Mod. P00003)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

No work has been done on this project during this period.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems occurred during this period.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

This project is currently out of funds. Work will resume on this contract when more funds are made available.

Cost Information

The following charges have been incurred against the contract during period February 1-28, 1982.

	Expended	Encumbered
Personal Services (PS)	0	
Materials and Supplies	$7.10	
Travel	0	
Overhead (@ 55% of PS)	0	
Retirement (@ 11.59% of PS)	0	
TOTAL	$7.10	

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers		
Senior Research Scientists/Engineers		
Research Scientists II/Engineers II	None	
Research Scientists I/Engineers I		
Technicians/Draftsmen		
Students		
Secretarial/Clerical/Other		
TOTAL		

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$70,224.00	$113,636.63	($43,412.63)
Materials and Supplies	177,858.00	65,415.20	74,052.80
Travel and Shipping	2,000.00	2,129.20	(129.20)
Computer	0	0	0
Overhead	52,376.00	84,294.02	(31,918.02)
Retirement	7,342.00	10,442.95	(3,100.95)
Encumbered	0	38,390.00	0
FUNDING	$309,800.00	$314,308.00	($ 4,508.00)

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 101 % of the proposed task has been completed.

Monthly Technical Report No. 30

and

Monthly Cost and Performance Report No. 30

Report Period
March 1 through March 31, 1982

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R.E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date: 9/28/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 3/27/82 (Mod. P00003)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 20332

WORK PERFORMED DURING THIS PERIOD

No work has been done on this project during this period.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems occurred during this period.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

This project is currently out of funds. Work will resume on this contract when more funds are made available.

A-2488

Cost Information

The following charges have been incurred against the contract during period

	Expended	Encumbered
Personal Services (PS)	$ 12.70	$ 0
Materials and Supplies	390.00	390.00
Travel	0	0
Overhead (@ 55% of PS)	9.53	0
Retirement (@ 11.59% of PS)	0	0
TOTAL	$412.23	$390.00

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Scientists/Engineers	0	0
Senior Research Scientists/Engineers	0	0
Research Scientists II/Engineers II	0	0
Research Scientists I/Engineers I	0	0
Technicians/Draftsmen	0	0
Students	0	0
Secretarial/Clerical/Other	$12.70	2
TOTAL	$12.70	2

The current financial status of the contract is as follows:

	Budget As Proposed	Expended	Free Balance
Personal Services (PS)	$ 70,224.00	113,649 .23	($43,425.33
Materials and Supplies	177,858.00	65,805.20	74,052.80
Travel and Shipping	2,000.00	2,129.20	(129.20)
Computer	0	0	0
Overhead	52,376.00	84,303.55	(31,927.55)
Retirement	7,342.00	10,442.95	(3,100.95)
Encumbered	0	38,000.00	0
FUNDING	$309,800.00	$314,330.23	($4,530.23)

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 101% of the proposed task has been completed.

Monthly Technical Report No. 31

and

Monthly Cost and Performance Report No. 31

Report Period
April 1 through April 30, 1982

DEVELEOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date:	9/28/79
Expiration Date:	3/27/81 (Original)
Expiration Date:	3/27/81 (Mod. P00003)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

No work has been done on this project during this period.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems occurred during this period.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

This project is current out of funds. Work will resume on this contract when more funds are made available.

Project Number A-2488

Cost Information

The following charges have been incurred against the contract during the period April 1 - April 30, 1982.

	Expended	Encumbered
Personal Services (PS)	$1,459.79	None
Materials and Supplies	21.98	
Computer	0.00	
Retirement (@ 11.59% of PS)	72.02	
Travel	0.00	
Overhead (@ 55% of Direct Charges)	1,094.84	
Equipment	0.00	
TOTAL	$2,648.63	

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$70,224.00	$115,109.12		(44,885.12)
Materials & Supplies	177,858.00	103,827.18		74,030.82
Computer	0.00	0.00		0.00
Retirement	7,342.00	10,517.97		(3,172.97)
Travel & Shipping	2,000.00	2,129.20		(129.20)
Overhead	52,376.00	85,398.39		(33,022.39)
Equipment	0.00	0.00		0.00
AS PROPOSED	$309,800.00	$316,978.86		(7,178.86)

*55% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 102% of the proposed task has been completed.

Monthly Technical Report No. 32

and

Monthly Cost and Performance Report No. 32

Report Period
May 1 through May 31, 1982

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date: 9/28/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 3/27/82 (Mod. P00003)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

No work has been done on this project during this period.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems occurred during this period.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

This project is current out of funds. Work will resume on this contract when more funds are made available.

Project Number A-2488

Cost Information

The following charges have been incurred against the contract during the period May 1 - May 31, 1982 .

	Expended	Encumbered
Personal Services (PS)	$4,962.21	0.00
Materials and Supplies	10.20	(11,500.00)
Computer	0.00	0.00
Retirement (@ 11.59% of PS)	543.50	0.00
Travel	0.00	0.00
Overhead (@ 55% of Direct Charges)	3,721.66	0.00
Equipment	0.00	0.00
TOTAL	$9,237.57	(11,500.00)

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$70,224.00	120,071.33		(49,847.33)
Materials & Supplies	177,858.00	92,337.38		85,520.62
Computer	0.00	0.00		0.00
Retirement	7,342.00	11,058.47		(3,716.47)
Travel	2,000.00	2,129.20		(129.20)
Overhead	52,376.00	89,120.05		(36,744.05)
Equipment	0.00	0.00		0.00
AS PROPOSED	$404,136.00	$314,716.43		(4,916.43)

*55% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 78% of the proposed task has been completed.

Monthly Technical Report No. 33

and

Monthly Cost and Performance Report No. 33

Report Period
June 1 through June 30, 1982

Report Prepared on
July 15, 1982

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe
J. A. Scheer

Contract N00173-79-C-0389
EES Project A-2488

Effective Date: 9/28/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 3/27/82 (Mod. P00003)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

The 220 GHz radiometer front end has been removed from the radiometer for testing and evaluation. The system noise figures were measured to be 9.75 dB at 140 GHz and 15 dB at 220 GHz. An investigation into improving the 220 GHz sensitivity has begun. Such techniques as IF matching, choice of IF frequency, IF combining, reduction of LO noise, and improving the mixer noise figure will be investigated.

All of the millimeter wave hardware for the 95 GHz radar except for the EIO, is in hand. The circuits which have been developed include: timing and control circuits, pulse amplifier, detector/video amplifier, and the switch driver for the ferrite switch.

Figure 1 is a block diagrm of the radar system as presently envisioned. All the major components are now delivered to Georgia Tech with the exception of the Varian Extended Interaction Oscillator (EIO). This device is the new design incorporating a focus electrode. The original unit did not meet the minimum power output specification (1 kW) and is being rebuilt by Varian.

Since the last reporting period, the order for the pulser (modulator) has been cancelled. Originally, the system was to use a purchased pulser, but problems with the vendor have forced a modification to that concept. The present plan is for use of a Georgia Tech developed pulser for the EIO.

The bulk of the remaining work lies in two areas, fabrication and assembly of the circuits and microwave components into a system and development of the pulser for the EIO. It is envisioned that, with the exception of a power supply assembly and a control panel, the basic system will fit into a single chassis for easy replacement of the radiometer during flight tests.

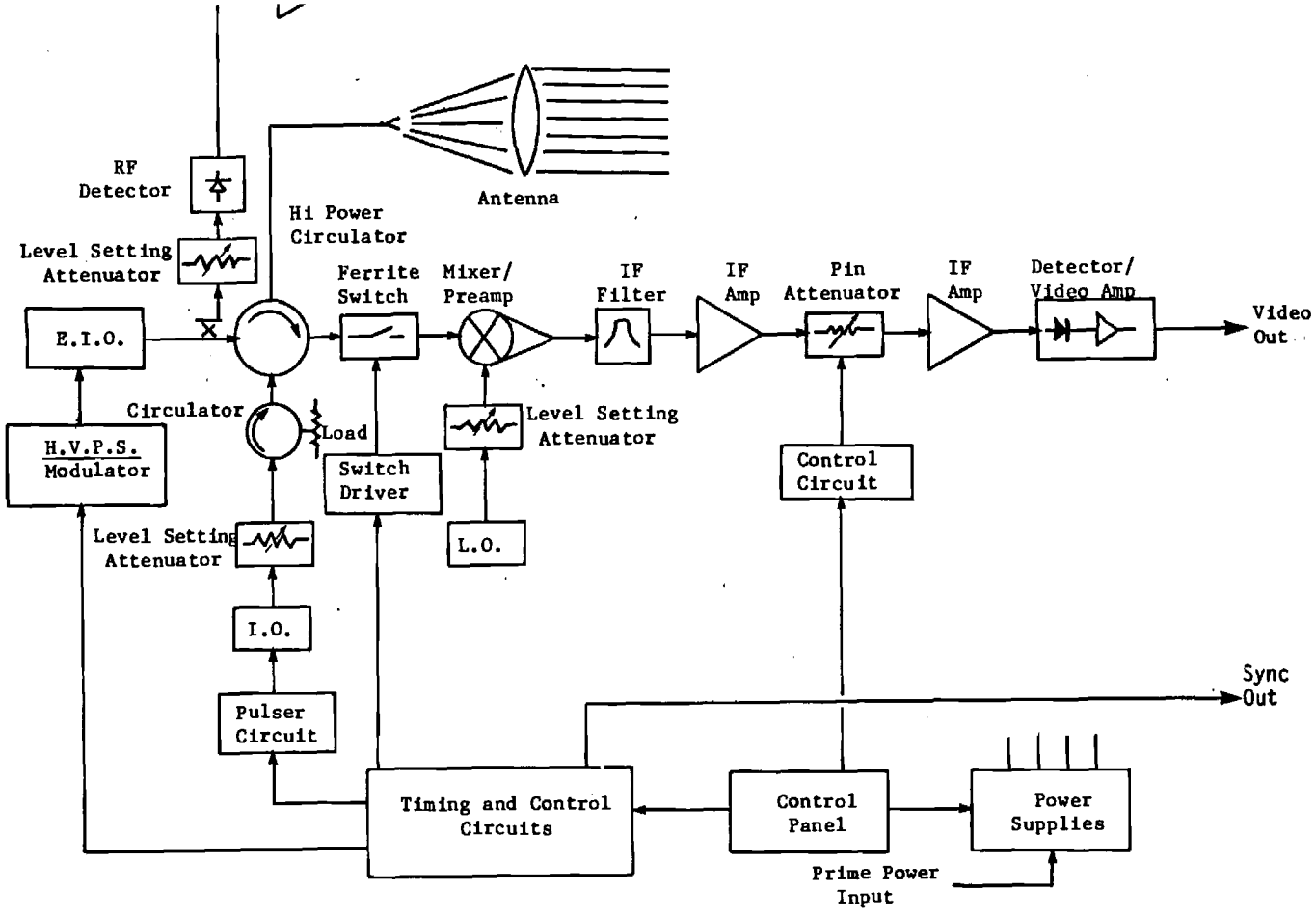

Figure 1. 95 GHz High Resolution Imaging Radar Block Diagram.

Besides the EIO pulser two additional circuits need to be built. These are the injection oscillator (I.O.) pulser circuit and the PIN attenuator control circuit. The I.O. pulser turns the oscillator on prior to transmit time to provide an injection signal into the EIO for stable starting. This oscillator is turned off at the end of the transmit pulse to provide maximum receiver sensitivity. The PIN attenuator will provide 0, 10, or 20 dB of IF attenuation, selectable by the operator, to avoid receiver saturation during tests in which strong target returns are experienced.

Figure 2 provides a rough indication of the expected system performance. Table 1 lists the radar parameters used in determining the signal to noise performance shown in Figure 2.

Problems Encountered During This Period

No problems occurred during this period.

Work To Be Performed During The Next Period

The following list describes the radar tasks to be addressed - either begun or completed - during the next reporting period.

- Test millimeter components
  - Local Oscillators
  - Ferrite Devices
  - Detector/Video amplifier
- Develop I.O. pulse circuit
- Develop PIN Attenuator Control Circuit
- Develop Modulator
- Begin System Fabrication

In addition techniques for improving the 220 GHz radiometer will continue to be investigated.

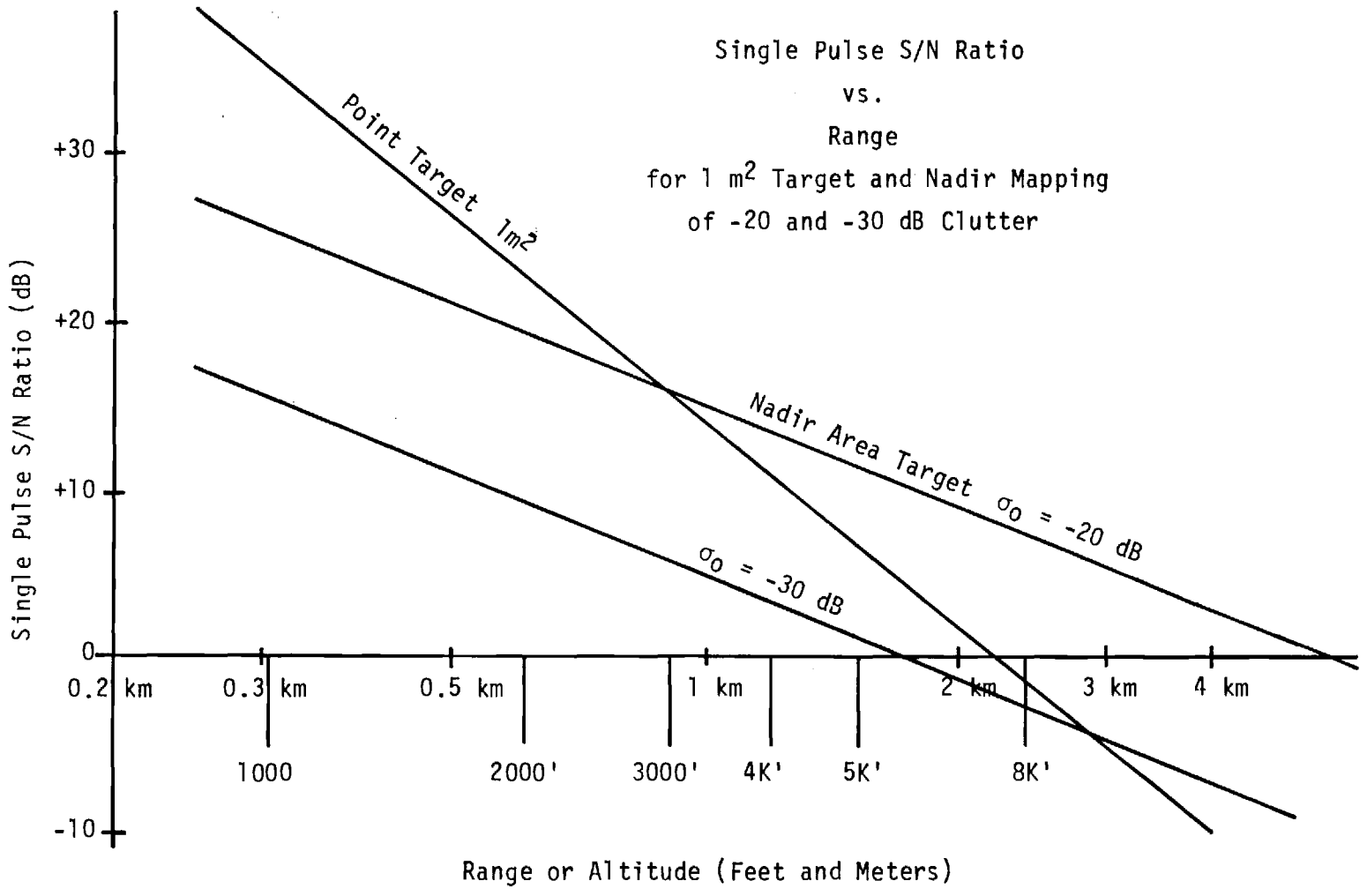

Figure 2. S/N Ratio Performance

TABLE 1 - RADAR PARAMETERS

PARAMETER	VALUE
Peak Power	1 kW
Antenna Gain	45 dB
Wavelength	3.2 mm
Target	1 m^2, σ_o = 20 dB, -30 dB
Bandwidth	500 MHz
Noise Figure	10 dB
System Losses	10 dB

Project Number A-2488

Cost Information

The following charges have been incurred against the contract during the period June 1 - June 30, 1982 .

	Expended	Encumbered
Personal Services (PS)	$6,372.78	NONE
Materials and Supplies	34.89	
Computer	0.00	
Retirement (@ 11.59% of PS)	632.14	
Travel	0.00	
Overhead (@ 55% of Direct Charges)	3,288.25	
Equipment	0.00	
TOTAL	$10,328.06	

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$119,388.00	$126,444.11		(7,056.11)
Materials & Supplies	183,858.00	92,372.27		91,485.73
Computer	0.00	0.00		0.00
Retirement	13,040.00	11,690.61		1,349.39
Travel	2,000.00	2,129.20		(129.20)
Overhead	85,850.00	92,408.30		(6,558.30)
Equipment	0.00	0.00		0.00
AS PROPOSED	$404,136.00	$325,044.49		$79,091.51

*55% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 80% of the proposed task has been completed.

Monthly Technical Report No. 34
and
Monthly Cost and Performance Report No. 34

Report Period
July 1 through July 31, 1982

Report Prepared
August 1982

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date: 9/28/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 3/27/83 (Mod. P00004)

Prepared for
Naval Research Laboratory
Washington, D.C. 20375

Prepared by
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

The 220 GHz radiometer improvement techniques are still being investigated. It has been decided that an additional IF channel will be provided for both the 140 and 220 GHz radiometers. A 100-1000 MHz IF channel with an anticipated noise figure of 12 dB will be added at 220 GHz and a 500-1000 MHz IF channel with an anticipated noise figure of 8 dB will be added at 140 GHz. The expected improvement factors in sensitivity are 1.22 at 140 GHz (0.049K, down from 0.061K at one second integration time) and 1.67 at 220 GHz (0.12K, down from 0.2K at one second integration time). The parts have been ordered. Delivery is expected in late September or early October of 1982.

A noise figure measurements was performed at 140 GHz using the 220 GHz mixer during this period. It showed a 7 dB total system noise figure (including horn loss) over a 1-2 GHz IF bandwidth with no additional IF matching network. The IF noise figure was about 2 dB.

Problems Encountered During The Period

No problems occurred during this period.

Work to be Performed During the Next Period

The 140/220 GHz radiometer will be examined to determine the placement of the new components. Parts will be tested as they arrive. The IF diplexers will be designed.

Project Number A-2488

Cost Information

The following charges have been incurred against the contract during the period 7/1-7/31/82.

	Expended	Encumbered
Personal Services (PS)	$11,095.27	0.00
Fringe Benefits	1,922.05	0.00
Materials and Supplies	99.00	0.00
Computer	0.00	0.00
Travel	0.00	0.00
Overhead (@ 55% of Direct Charges)	6,214.50	0.00
Equipment	0.00	0.00
TOTAL	$19,330.82	

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$119,388.00	$137,539.38		(18,151,38)
Fringe Benefits	13,040.00	13,662.66		(622.66)
Materials & Supplies	183,858.00	86,261.23	31,625.50	91,485.73
Computer	0.00	0.00		0.00
Travel & Shipping	2,000.00	2,129.20		(129.20)
Overhead	85,850.00	98,622.80		(12,772.80)
Equipment	0.00	0.00		0.00
AS PROPOSED	$404,136.00	$317,925.31	$31,625.50	$54,484.19

*55% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 80% of the proposed task has been completed.

Monthly Technical Report No. 35
and
Monthly Cost and Performance Report No. 35

Report Period
August 1 through August 31, 1982

Report Prepared
September 1982

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date: 9/28/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 3/27/83 (Mod. P00004)

Prepared for
Naval Research Laboratory
Washington, D.C. 20375

Prepared by
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During this Period

During this period work has continued on the development of the 94 GHz radar as well as the improvements to the 220 GHz radiometer.

Mechanical assembly of the 94 GHz radar has begun and this work is nearly completed. The EIO has not yet arrived but all subsystems and circuits have been checked out and perform as expected.

The 220 GHz radiometer video combiner circuit has been designed and assembly has begun. The new IF amplifiers have arrived as well as some of the new IF filters. The design of the IF diplexer has begun.

Problems Encountered During this Period

No problems have occurred during this period.

Work to be Performed During the Next Period

The 94 GHz radar electrical assembly and integration will begin as well as system testing. The EIO should arrive during this next period.

The 220 GHz radiometer will be tested for noise figure with the new IF amplifiers and work will continue on the new video combiner/amplifier as well as the IF diplexer.

Project Number _____

Cost Information

The following charges have been incurred against the contract during the period 8/1 - 8/31/82 .

	Expended	Encumbered
Personal Services (PS)	$ 4,365.16	0.00
Materials and Supplies	2,154.50	1,142.99
Computer	0.00	0.00
Fringe Benefits	481.66	0.00
Travel	0.00	0.00
Overhead (@ 55% of Direct Charges)	3,304.62	0.00
Equipment	0.00	0.00
TOTAL	$10,305.94	1,142.99

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$119,388.00	$141,904.54		(22,516.54)
Materials & Supplies	183,858.00	68,125.77	32,768.49	82,963.74
Computer	0.00	0.00		0.00
Fringe Benefits	13,040.00	14,144.32		(1,104.32)
Travel & Shipping	2,000.00	2,129.20		(129.20)
Overhead	85,850.00	101,927.42		(16,077.42)
Equipment	0.00	0.00		0.00
AS PROPOSED	$404,136.00	$328,231.25	$32,768.49	$43,136.26

*55% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 90% of the proposed task has been completed.

A 2488

Monthly Technical Report No. 36
and
Monthly Cost and Performance Report No. 36

Report Period
September 1 through September 30, 1982

Report Prepared
October 1982

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date:	9/18/79
Expiration Date:	3/27/81 (Original)
Expiration Date:	3/27/83 (P00004)

Prepared for
Naval Research Laboratory
Washington, DC 20375

Prepared by
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

During this period the 95 GHz radar mechanical and electrical assembly has been completed and system testing has begun. All of the parts, including the EIO have arrived.

The 220 GHz radiometer video combiner/amplifier circuit has been completed. Work is continuing on system testing and on the IF diplexer development.

Problems Encountered During This Period

No problems occurred during this period.

Work to be Performed During the Next Period

The 94 GHz radar system testing will continue. The 220 GHz radiometer system testing and IF diplexer development will continue.

Project Number A-2488

Cost Information

The following charges have been incurred against the contract during the period 9/1 - 9/30/82 .

	Expended	Encumbered
Personal Services (PS)	$12,787.57	0.00
Materials and Supplies	3,286.76	($2,158.87)
Computer	0.00	0.00
Fringe Benefits	2,093.05	0.00
Travel	9.00	0.00
Overhead (@ 47.2% of Direct Charges)	8,579.24	0.00
Equipment	0.00	0.00
TOTAL	$26,755.63	($2,158.57)

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$171,804.70	$154,692.11		(17,112.59)
Materials & Supplies	87,668.76	71,412.53	30,609.62	(14,353.39)
Computer	0.00	0.00		0.00
Fringe Benefits	17,935.03	16,237.37		(1,697.66)
Travel & Shipping	2,113.36	2,138.20		(24.84)
Overhead	124,614.15	110,506.67		(14,107.48)
Equipment	0.00	0.00		0.00
AS PROPOSED	$404,136.00	$354,986.88	$30,609.62	$18,539.50

*47.2% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 95% of the proposed task has been completed.

MONTHLY TECHNICAL Report No. 37
and
Monthly Cost and Performance Report No. 37

Report Period
October 1 through October 31, 1982

Report Prepared
November 1982

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date:	9/18/79
Expiration Date:	3/27/81 (Original)
Expiration Date:	3/27/83 (P00004)

Prepared for
Naval Research Laboratory
Washington, DC 20375

Prepared by
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

Further system integration tests have been performed on the 95 GHz radar during this period. Problems occurred with the timing and control circuits. These problems were caused by some transistors which were sensitive to noise and switching at the wrong time. This problem has been isolated and solved.

The 220 GHz radiometer testing and development is continuing.

Problems Encountered During This Period

No technical problems occurred during this period. The current negative balance of funds is due to some incorrect personnel services charges during this period. This problem should be rectified within the next two months.

Work to be Performed During The Next Period

The 95 GHz radar system testing will continue. The 220 GHz radiometer improvements will also continue.

Project Number A-2488

Cost Information

The following charges have been incurred against the contract during the period 10/1 - 10/31/82.

	Expended	Encumbered
Personal Services (PS)	$10,880.67	0.00
Materials and Supplies	3,254.39	($2,536.67)
Computer	0.00	0.00
Benefits (@ 21% of PS)	2,088.60	0.00
Travel	0.00	0.00
Overhead (@ 47.2% of Direct Charges)	7,657.56	0.00
Equipment	0.00	0.00
TOTAL	$23,881.22	($2,536.67)

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$171,804.70	$165,572.78		($6,231.92)
Materials & Supplies	87,668.76	74,666.92	28,072.95	(15,071.11)
Computer	0.00	0.00		0.00
Benefits	17,935.03	18,325.97		390.94
Travel & Shipping	2,113.36	2,138.20		(24.84)
Overhead	124,614.15	118,164.23		6,449.92
Equipment	0.00	0.00		0.00
AS PROPOSED	$404,136.00	$378.868.10	$28,072.95	($2,805.05)

*47.2% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 95% of the proposed task has been completed.

MONTHLY TECHNICAL REPORT No. 38
and
Monthly Cost and Performance Report No. 38

Report Period
November 1 through November 30, 1982

Report Prepared
March 1983

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R.E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date:	9/18/79
Expiration Date:	3/27/81 (Original)
Expiration Date:	3/27/83 (P00004)

Prepared for
Naval Research Laboratory
Washington, DC 20375

Prepared by
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

Further system integration tests have been performed on the 95 GHz radar during this period. Problems occurred with the modulator's high voltage supply. This problem is being worked on.

The 220 GHz radiometer testing and development is continuing.

Problems Encountered During This Period

No technical problems occurred during this period. The current negative balance of funds is due to some incorrect personnel services charges. Additional problems with funds have occurred due to the charging of overhead on the purchase of the EIO under Georgia Tech's new policy of charging overhead to purchases. Hopefully this problem can be solved.

Work to be Performed During the Next Period

The 95 GHz radar system testing will continue. The 220 GHz radiometer improvements will also continue.

Project Number A-2488

Cost Information

The following charges have been incurred against the contract during the period 11/1 - 11/30/82 .

	Expended	Encumbered
Personal Services (PS)	$2,235.55	0.00
Materials and Supplies	27,099.29	(26,197.41)
Computer	0.00	0.00
Benefits (@ 21% of PS)	440.29	0.00
Travel	0.00	0.00
Overhead (@ 47.2% of Direct Charges)	14,053.86	0.00
Equipment	0.00	0.00
TOTAL	$43,828.99	(26,197.41)

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$171,804.70	$167,808.33		$3,996.37
Materials & Supplies	87,668.76	101,766.21	$1,875.54	(15,972.99)
Computer	0.00	0.00		0.00
Benefits	17,935.93	18,766.26		(831.23)
Travel & Shipping	2,113.36	2,138.20		(24.84)
Overhead	124,614.15	132,218.09		(7,603.94)
Equipment	0.00	0.00		0.00
AS PROPOSED	$404,136.00	$422,697.09	$1,875.54	(20,436.63)

*47.2% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 97% of the proposed task has been completed.

MONTHLY TECHNICAL REPORT No. 39
and
Monthly Cost and Performance Report No. 39

Report Period
December 1 through December 31, 1982

Report Prepared
March 1983

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-0389
EES Project A-2488

Effective Date: 9/18/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 3/27/83 (P00004)

Prepared for
Naval Research Laboratory
Washington, DC 20375

Prepared by
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

System integration tests have been performed on the 95 GHz radar during this period. The radar's solid state Gunn exciter failed and has been sent back for repair.

The 220 GHz radiometer testing and development is continuing.

Problems Encountered During This Period

No technical problems occurred during this period. The current negative balance of funds is due to the problems cited last period. Steps are being taken to alleviate this problem.

Work to be Performed During the Next Period

The 95 GHz radar system testing will continue. The 220 GHz radiometer improvements will also continue.

Project Number A-2488

Cost Information

The following charges have been incurred against the contract during the period 12/1 - 12/31/82.

	Expended	Encumbered
Personal Services (PS)	$ 0.00	$0.00
Materials and Supplies	978.89	(910.30)
Computer	0.00	0.00
Benefits (@ 21% of PS)	0.00	0.00
Travel	0.00	0.00
Overhead (@ 47.2% of Direct Charges)	462.04	0.00
Equipment	0.00	0.00
TOTAL	$1,440.93	($910.30)

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$171,804.70	$167.808.33		$3,996.37
Materials & Supplies	87,668.76	102,745.10	$965.24	(16,041.58)
Computer	0.00	0.00		0.00
Benefits	17,935.03	18,766.26		(831.23)
Travel & Shipping	2,113.36	2,138.20		(24.84)
Overhead	124,614.15	132,680.13		(8,065.98)
Equipment	0.00	0.00		0.00
AS PROPOSED	$404,136.00	$424,138.02	$965.24	($20,967.26)

*47.2% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 95% of the proposed task has been completed.

MONTHLY TECHNICAL REPORT No. 40
and
Monthly Cost and Performance Report No. 40

Report Period
January 1 through January 31, 1983

Report Prepared
March 1983

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date:	9/18/79
Expiration Date:	3/27/81 (Original)
Expiration Date:	3/27/83 (P00004)

Prepared for
Naval Research Laboratory
Washington, DC 20375

Prepared by
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

The exciter is still being repaired for the 95 GHz radar. The 220 GHz radiometer testing and development is continuing.

Problems Encountered During This Period

No technical problems occurred during this period. The current negative balance of funds is still being worked on.

Work to be Performed During the Next Period

The 95 GHz radar system testing will continue. The 220 GHz radiometer improvements will also continue.

Project Number A-2488

Cost Information

The following charges have been incurred against the contract during the period 1/1 - 1/31/83.

	Expended	Encumbered
Personal Services (PS)	($2,503.40)	0.00
Materials and Supplies	25.07	($19.50)
Computer	0.00	0.00
Benefits (@ 21% of PS)	(472.69)	0.00
Travel	0.00	0.00
Overhead (@ 47.2% of Direct Charges)	(1,392.88)	0.00
Equipment	0.00	0.00
TOTAL	($4,343.90)	(19.50)

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$171,804.70	$165,304.93		$6,499.77
Materials & Supplies	87,668.76	102,770.17	945.74	(16,047.15)
Computer	0.00	0.00		0.00
Benefits	17,935.03	18,293.57		(358.54)
Travel & Shipping	2,113.36	2,138.20		(24.84)
Overhead	124,614.14	118,164.23		(5,802.84)
Equipment	0.00	0.00		0.00
AS PROPOSED	$404,136.00	$419,794.12	$945.74	($16,603.86)

*47.2% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 99% of the proposed task has been completed.

MONTHLY TECHNICAL REPORT No. 41
and
Monthly Cost and Performance Report No. 41

Report Period
February 1 through February 28, 1983

Report Prepared
March 1983

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R.E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date: 9/18/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 3/27/83 (P00004)

Prepared for
Naval Research Laboratory
Washington, DC 20375

Prepared by
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

The 95 GHz radar system testing is complete. Problems with the Gunn exciter are still continuing. The 220 GHz radiometer testing and development is continuing.

Problems Encountered During This Period

No technical problems occurred during this period. The current negative balance of funds is still being worked on.

Work to be Performed During the Next Period

The 95 GHz radar system will be delivered. The 220 GHz radiometer improvements will also continue and delivery is expected soon.

Project Number A-2488

Cost Information

The following charges have been incurred against the contract during the period 12/1 - 12/31/83 .

	Expended	Encumbered
Personal Services (PS)	$0.00	$0.00
Materials and Supplies	86.84	(60.99)
Computer	0.00	0.00
Benefits (@ 21% of PS)	24.04	0.00
Travel	0.00	0.00
Overhead (@ 47.2% of Direct Charges)	52.33	0.00
Equipment	0.00	0.00
TOTAL	$163.21	($60.99)

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$170,540.15	$165,304.93		$5,235.22
Materials & Supplies	88,388.76	102,857.01	$884.75	(15,353.00)
Computer	0.00	0.00		0.00
Benefits	17,609.32	18,317.61		(708.29)
Travel & Shipping	2,113.36	2,138.20		(24.84)
Overhead	125,484.41	118,164.23		(5,855.17)
Equipment	0.00	0.00		0.00
AS PROPOSED	$404,136.00	$419,957.33	$884.75	($16,706.08)

*47.2% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 99% of the proposed task has been completed.

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Monthly Technical Report No. 42

Monthly Technical Report No. 43

MONTHLY TECHNICAL REPORT No. 44

and

MONTHLY COST AND PERFORMANCE REPORT No. 44

Report Period
May 1 through May 31, 1983

Report Prepared
June 1983

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R.E. Forsythe

Contract N000173-79-C-0389
EES Project A-2488

Effective Date: 9/18/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 3/27/83 (P00004)*

Prepared for
Naval Research Laboratory
Washington, DC 20375

Prepared by
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

*To be extended

WORK PERFORMED DURING THIS PERIOD

The 220 GHz radiometer has been delivered for flights onboard the P-3 aircraft. Optimum performance could not be obtained because the LO would not turn on with the system's power supply when it was tuned for the lowest noise figure. It was mistuned slightly to allow it to turn on with this power supply. To turn it on at the best mixer/LO operating point requires a circuit that produces a higher voltage at first, then slowly comes down to the operating voltage.

The 95 GHz radar is essentially completed. The Gunn/exciter has been returned and the problems that caused the burnouts seem to have been solved. Delivery is expected by the end of the next period.

PROBLEMS ENCOUNTERED

No problems were encountered during this period. The apparent negative balance of funds is still being investigated.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

The radar will be completed and delivered. The final report will be started.

Project Number A-2488

Cost Information

The following charges have been incurred against the contract during the period 5/1 - 5/31/83 .

	Expended	Encumbered
Personal Services (PS)	$0.00	$0.00
Materials and Supplies	3.06	0.00
Computer	0.00	0.00
Benefits (@ 21% of PS)	0.00	0.00
Travel	0.00	0.00
Overhead (@ 47.2% of Direct Charges)	1.44	0.00
Equipment	0.00	0.00
TOTAL	$4.60	$0.00

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$170,540.15	$165,304.93		$5,235.22
Materials & Supplies	88,388.76	102,970.20	$758.05	(15,339.49)
Computer	0.00	0.00		0.00
Benefits	15,609.32	18,317.61		(708.29)
Travel & Shipping	2,113.36	2,138.20		(24.84)
Overhead	125,484.41	131,393.00		(5,908.59)
Equipment	0.00	0.00		0.00
AS PROPOSED	$404,136.00	$420,123.94	$758.05	($16,745.99)

*47.2% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 99% of the proposed task has been completed.

MONTHLY TECHNICAL REPORT NO. 45

and

MONTHLY COST AND PERFORMANCE REPORT No. 45

Report Period

June 1 through June 30, 1983

Report Prepared

July 1983

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R.E. Forsythe

Contract N000173-79-C-0389
EES Project A-2488

Effective Date: 9/18/79
Expiration Date: 3/27/81 (Original)
Expiration Date: 9/30/83 (P00005)

Prepared for
Naval Research Laboratory
Washington, DC 20375

Prepared by
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Period

The 140/220 GHz radiometer was returned for repair and was subsequently shipped directly to Norway for a set of data flights. The 220 GHz mixer had failed primarily because of the mechanical pressure placed on it by the RFI cover. The mixer was repaired and the cover was adjusted to fit properly. Additional padding was added to reduce microphonics. The video amplifier wiring was resoldered to also help reduce microphonics. The instrument performed well with no failures during the flights onboard NRL's P-3 aircraft in Norway.

Work on the final report has started.

Problems Encountered

No problems were encountered during this period. Progress is being made on the negative balance of funds.

Work to be Performed During the Next Period

The final report is to be continued.

Project Number A-2488

Cost Information

The following charges have been incurred against the contract during the period 6/1-6/30/83.

	Expended	Encumbered
Personal Services (PS)	($2,678.26)	-0-
Materials and Supplies	(9.10)	-0-
Computer	-0-	-0-
Benefits (@ 21% of PS)	(335.43)	-0-
Travel	-0-	-0-
Overhead (@ 47.2% of Direct Charges)	(1,416.48)	-0-
Equipment	-0-	-0-
TOTAL	($4,439.27)	-0-

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Engineers		
Senior Research Engineers		
Research Engineers		
Assistant Research Engineers		
Student Assistants		
Technicians, Machinists		
Clerical		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services(PS)	$172,323.96	$162,626.67		$9,697.29
Materials & Supplies	86,560.77	102,961.10	$758.05	(17,158.38)
Computer	-0-	-0-	-0-	-0-
Benefits	19,220.35	17,982.18		1,238.17
Travel & Shipping	2,113.36	2,138.20		(24.84)
Overhead	123,917.56	129.976.52		(6,058.96)
Equipment	-0-	-0-		-0-
AS PROPOSED	$404,136.00	$415,684.67	$758.05	($12,306.72)

*47.2% O.H. on all direct charge encumberances.

Based on present partial funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 99% of the proposed task has been completed.

Monthly Technical Reports No. 46-53

and

Monthly Cost and Performance Reports No. 46-53

Report Period
July 1, 1983 through February 28, 1984

DEVELOPMENT OF AN ADVANCED AIRBORNE MILLIMETER WAVE IMAGING SYSTEM (AAMWIS)

R. E. Forsythe

Contract N00173-79-C-0389
EES Project A-2488

Effective Date:	9/28/79
Expiration Date:	3/27/81 (Original)
Expiration Date:	3/27/84 (Mod. P00006)

Prepared for

Naval Research Laboratory
Washington, D.C. 20375

Prepared by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

WORK PERFORMED DURING THIS PERIOD

The 94 GHz radar was accepted by NRL. The final report Volume I was completed and delivered as well as the 140/220 GHz radiometer. The final report Volume II follows.

PROBLEMS ENCOUNTERED DURING THIS PERIOD

No problems occurred during this period.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

The project has ended. The final report Volume II will be delivered soon.

Project Number A-2488

COST INFORMATION

The following charges have been incurred against the contract during the contract period 9/28/79 - 3/27/84.

	Expended	Encumbered
Personal Services (PS)	0.00	None
Materials and Supplies	0.00	
Computer	0.00	
Benefits (@ 11.59% of PS)	0.00	
Travel	0.00	
Overhead (@ 55 % of Direct Charges)	0.00	
Equipment	0.00	
TOTAL	0.00	

The breakdown of personal services is as follows:

	Dollars	Approximate Hours
Principal Research Scientists/Engineers		
Senior Research Scientists/Engineers		
Research Scientists II/Engineers II		
Research Scientists I/Engineers I		
Technicians/Draftsmen/Machinists		
Students Assistants		
Secretarial/Clerical/Other		
TOTAL		

The current financial status of the contract is as follows:

	Budget as Proposed	Expended	Encumbered*	Free Balance
Personal Services (PS)	$155,414.80	$155,414.80		0.00
Materials & Supplies	104,137.76	104,137.76		0.00
Computer	0.00	0.00		0.00
Benefits	16,323.49	16,287.40		36.09
Travel & Shipping	2,138.20	2,138.20		0.00
Overhead	126,121.75	126,157.84		(36.09)
Equipment	0.00	0.00		0.00
TOTAL	$404,136.00	$404,136.00		0.00

* 55% overhead on all direct charge encumbrances.

Based on present partial funding, approximately 100% of the proposed task has been completed.

A-2488

ADAPTIVE MILLIMETER WAVE IMAGING SYSTEM
Volume I 220 GHz Radiometer

Prepared by

GEORGIA INSTITUTE OF TECHNOLOGY
A Unit of the University System of Georgia
Engineering Experiment Station
Atlanta, Georgia 30332

September 1983

FINAL REPORT AND INSTRUCTION MANUAL

Prepared for

NAVAL RESEARCH LABORATORY
WASHINGTON, D. C. 20375

Contract No. N00173-77-C-0389

Final Technical Report and Instruction Manual

ADAPTIVE MILLIMETER WAVE IMAGING SYSTEM

Volume I 220 GHz Radiometer

R. E. Forsythe

September 1983

Contract No. N00173-77-C-0389

Georgia Tech Project No. A-2488

For

Naval Research Laboratory
Washington, D. C. 20375

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
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4. TITLE *(and Subtitle)* Adaptive Millimeter Wave Imaging System		5. TYPE OF REPORT & PERIOD COVERED Final Report & Instruction Manual, 1979-1983
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR*(s)* R. E. Forsythe		8. CONTRACT OR GRANT NUMBER*(s)* N00173-77-C-0389
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16. DISTRIBUTION STATEMENT *(of this Report)*

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18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*
Radiometer, Imaging, High Resolution, low noise, multi-frequency (140 and 220 GHz), Remote Control, millimeter wave, horns/lens antennas, RF diplexing, subharmonic mixer, solid state receivers, broadband

20 ABSTRACT *(Continue on reverse side if necessary and identify by block number)*
A 220 GHz radiometer was designed, constructed, and delivered to NRL for high resolution airborne imaging. Improvements were made to a 140 GHz radiometer to add the 220 GHz front-end to make it a dual frequency radiometer.

D FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

SUMMARY

This report documents the design and construction of a 220 GHz radiometer that is to be used as part of an adaptive millimeter wave imaging system for use onboard a P-3 aircraft. The 220 GHz radiometer uses an all solid state, low noise, broadband, room temperature receiver that employs a 220 GHz subharmonically pumped mixer. A six-inch Teflon lens is shared with a 140 GHz radiometer (made on a related program) using a low loss, broadband polarization diplexer. Remote switching between 140 GHz and 220 GHz operation is provided. Dual IF amplifiers and video combining of the two signals helps reduce the minimum detectable temperature by increasing the bandwidth.

PREFACE

This report was prepared by the Electromagnetics Laboratory of the Engineering Experiment Station, Georgia Institute of Technology under NRL contract N00173-79-C-0389. The contract technical monitor was Dr. Ben Yaplee. The contract period was from September 1979 to September 1983. This document describes the work done under this contract relating to passive imaging. This document can also be considered as an update on a previous report [1] since it also describes improvements on the 140 GHz radiometer delivered on contract N00173-77-C-0130. The work related to active imaging at 94 GHz is reported in Volume II of the final report on this contract.

The author of this report was Mr. R. E. Forsythe. The views and conclusions in this document are those of the author and should not be interpreted as necessarily representing the official policies of the Naval Research Laboratory or the U.S. Government.

The author would like to acknowledge the contributions made by the following individuals: S. M. Halpern, J. A. Gagliano, J. M. Schuchardt, and D. O. Gallentine of Georgia Tech, and Dr. J. P. Hollinger of NRL.

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1.0 INTRODUCTION

This report describes the development of a new sensor to be used as part of an advanced airborne millimeter wave imaging system. This new sensor, a 220 GHz radiometer is to be used by the Naval Research Laboratory for imaging purposes. The key motivation in the development of this sensor is to extend the passive imaging capabilities of NRL to the next atmospheric window above 140 GHz, (a 140 GHz passive sensor has already been developed by Georgia Tech for NRL on a previous program).

The 220 GHz radiometer was added to the 140 GHz radiometer that was previously delivered by incorporating a new 220 GHz front end which shares the same lens antenna and post IF electronics as the 140 GHz radiometer. Remote switching between frequencies is provided by the control unit so that data can be obtained at both frequencies during the same flight. The advantage of moving up in frequency is that a higher spatial resolution for a given antenna size can be obtained. The disadvantages are found in reduced contrast due to higher atmospheric loss and higher minimum detectable temperatures for a given sampling rate.

The radiometer, shown in Figures 1 and 2, is mounted in the belly of NRL's P-3 aircraft during data flights. It views a rotating 45 degree mirror with calibration loads located above the mirror. Calibration is provided by measuring the output voltage of the radiometer as the mirror rotates and reflects the RF energy of the calibration loads into the lens of the radiometer. The scene below is reflected into the radiometer during the downlooking portion of the rotation of the mirror and a line-by-line image of the ground is generated. This scenario is shown in Figure 3. The remote control unit, shown in Figures 4 and 5, is located in the passenger area and is rack mounted next to NRL's quick look TV display which provides NRL scientists with a constantly updated false color image generated by the

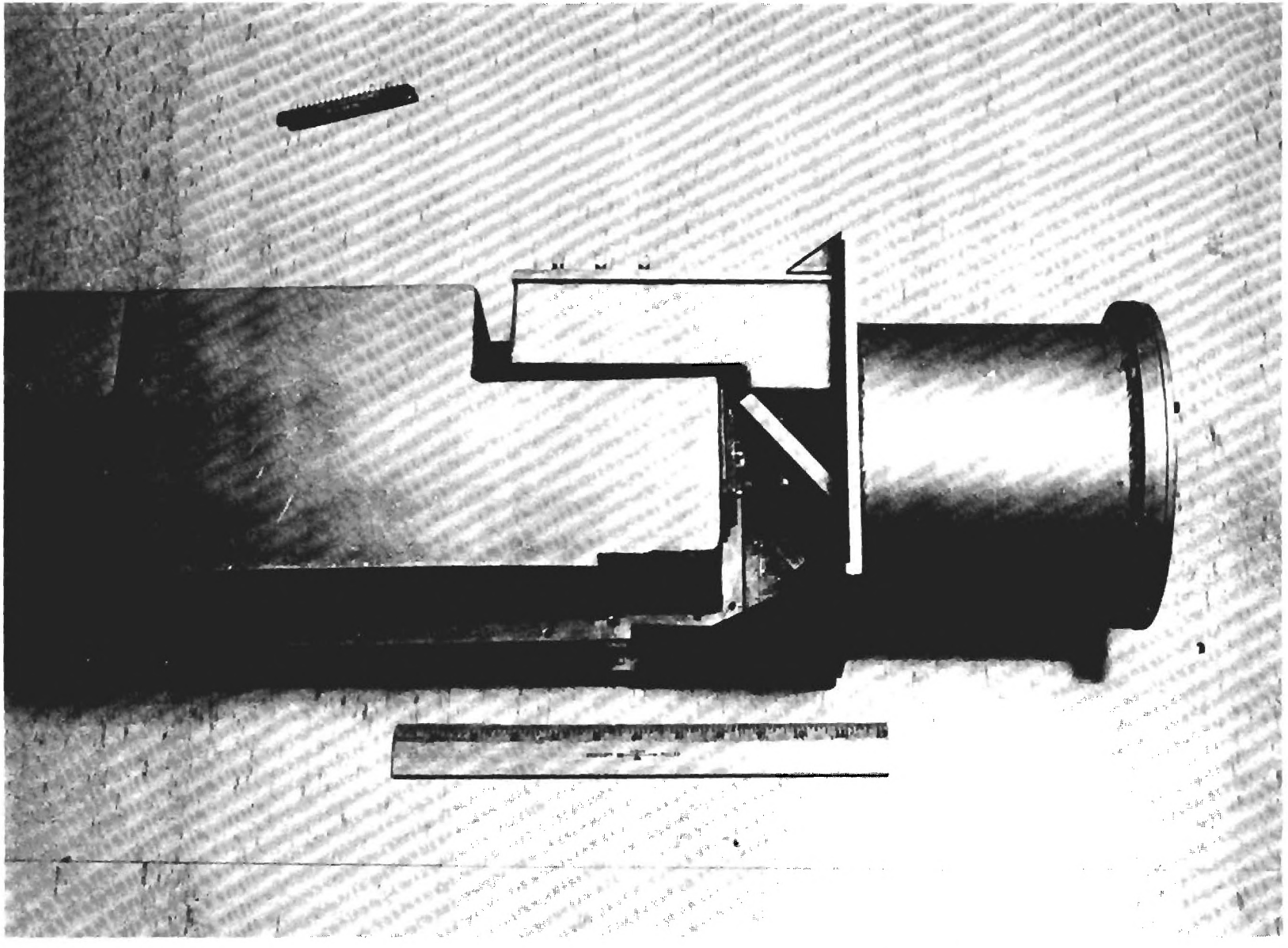

Figure 1. 140/220 GHz Radiometer (RFI Cover On).

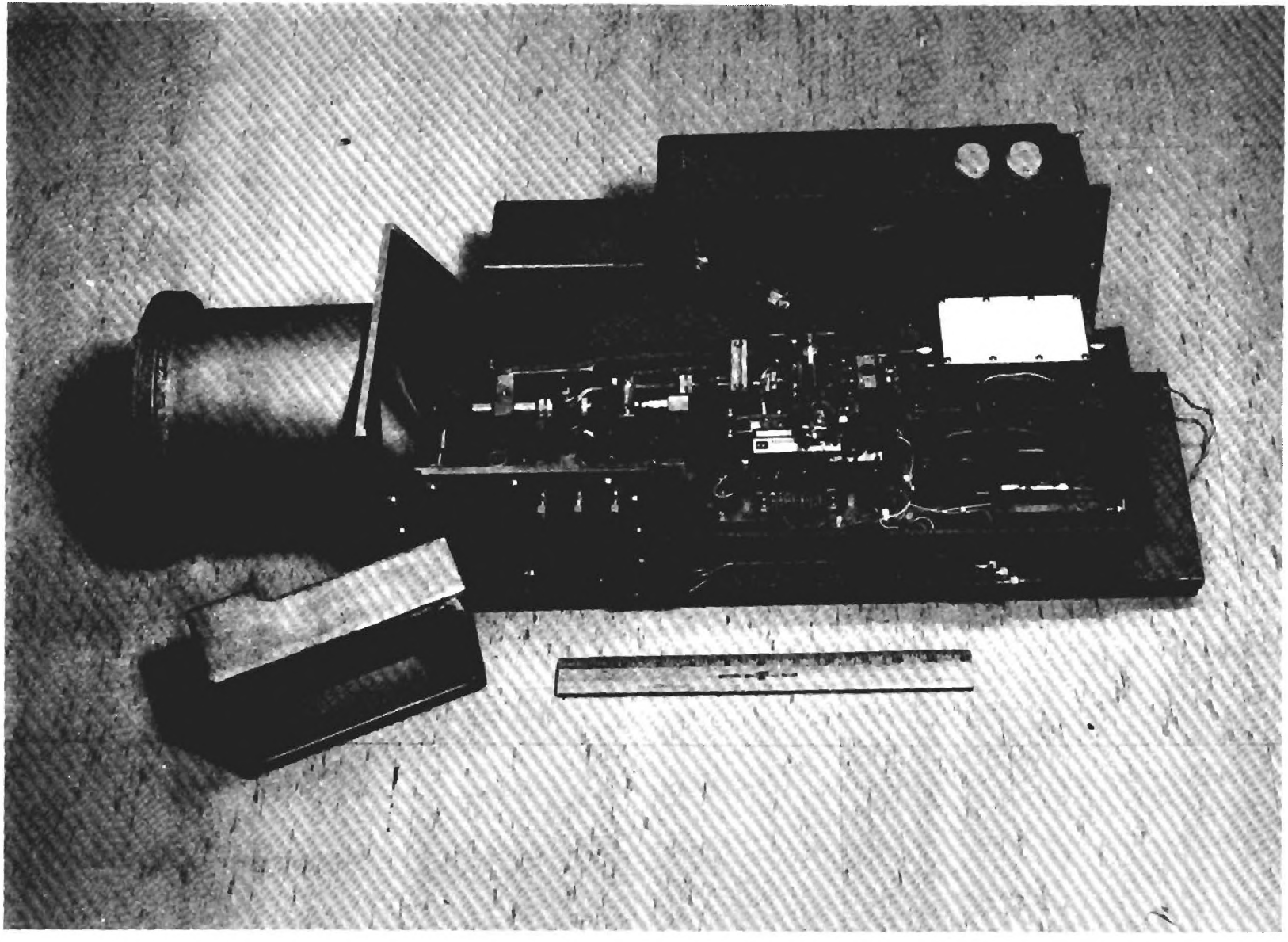

Figure 2. 140/220 GHz Radiometer (Cover Removed).

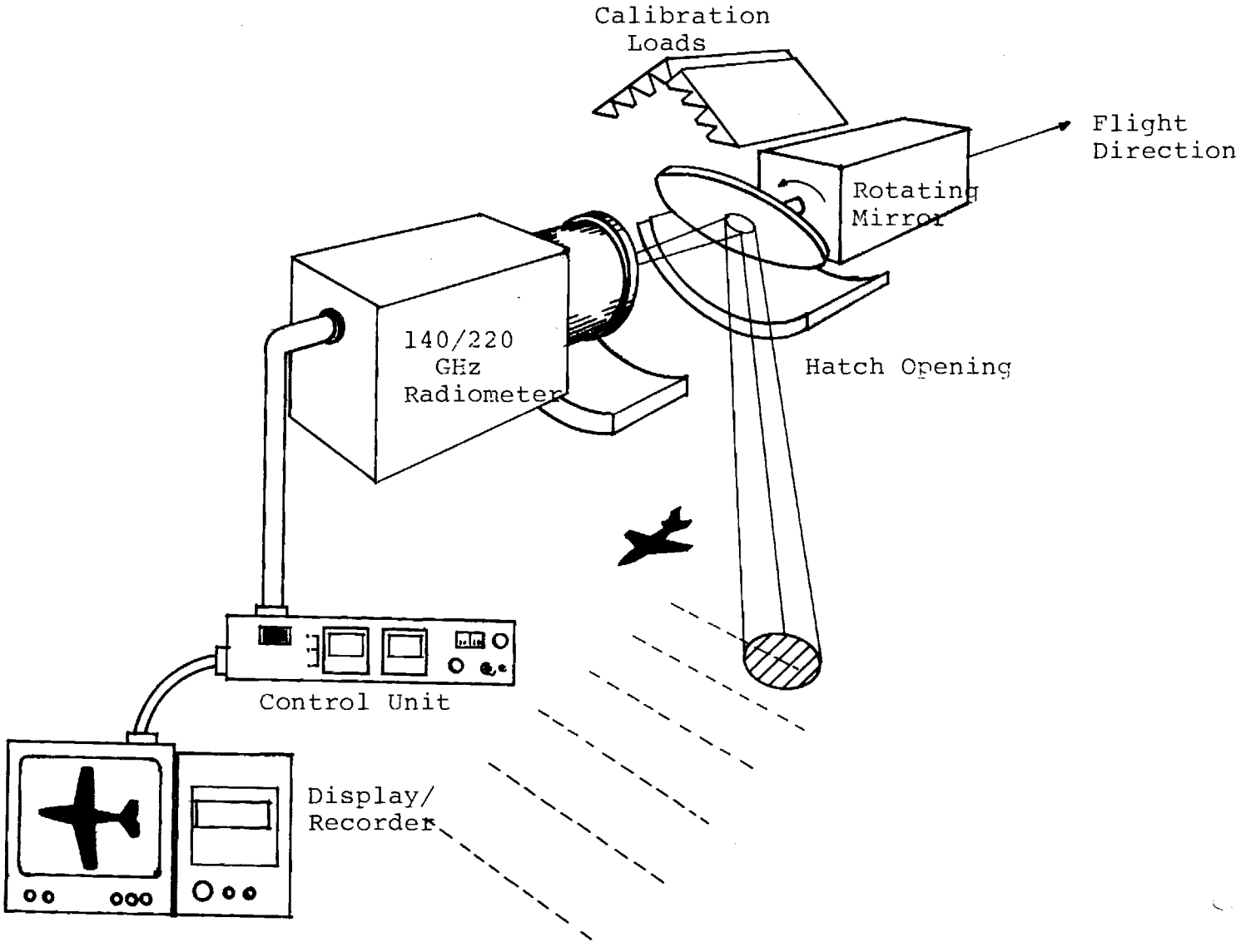

Figure 3. Passive Imaging using an Airborne Radiometer.

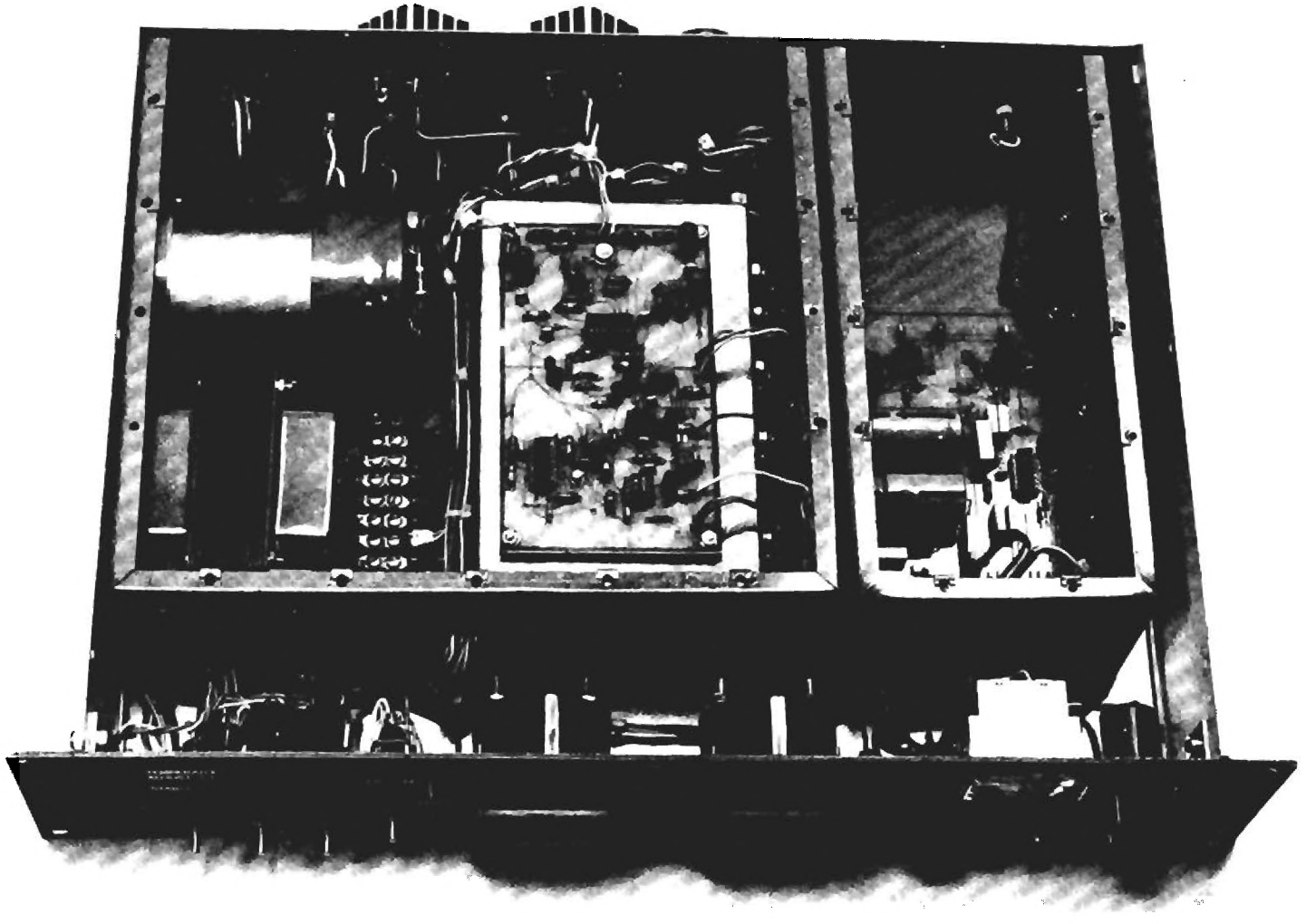

Figure 4. Radiometer Control Unit (Cover Removed).

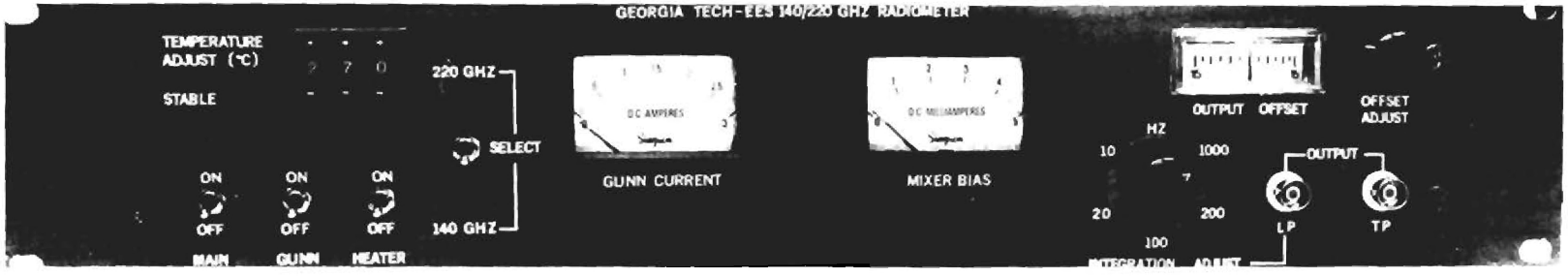

Figure 5. Control Unit Front Panel.

radiometer's output voltages. This data is also stored on NRL's data acquisition system and later processed to correct for geometrical distortions as well as pitch and roll effects.

2.0 220 GHz RADIOMETER DESCRIPTION

This radiometer is essentially an upgraded version of the 140 GHz radiometer previously developed on contract N00173-77-C-0130. A complete report has already been provided which contains the details of this radiometer [1]. Therefore, this portion of the report will concentrate primarily on the changes and improvements to this radiometric sensor. For a complete overview of the radiometer the previous report should also be reviewed.

The principal improvements that have been made to this radiometer are:

1) The addition of a 220 GHz front end;
2) The replacement of a Rexolite lens with a new, low loss, Teflon lens;
3) The replacement of the old 1.5-3.0 GHz IF amplifiers (that were used on the 140 GHz radiometer) with broader band, lower noise 2-4 GHz IF amplifiers for both the 140 GHz and 220 GHz radiometers;
4) The addition of another parallel IF channel covering 0.1-1.0 GHz (for the 220 GHz radiometer only) to improve sensitivity;
5) The addition of a summing video amplifier to combine the outputs of the parallel IF systems of the 220 GHz radiometer;
6) The addition of a solid state LO regulator/select circuit that determines which LO is to be turned on (140 or 220 GHz) via remote control;
7) The addition of a low loss, broadband polarization sensitive beam splitter that allows both the 140 GHz

and 220 GHz feed horns to share the same lens; and

8) The addition of a 2-4 GHz SPDT switch and control circuit allowing the sharing of the 2-4 GHz post IF amplifier.

A block diagram of the radiometer is given in Figure 6. The RF energy (140 or 220 GHz) is incident on the lens and focused to the two horns. The polarization diplexer, located at a 45 degree angle to the lens reflects the vertically polarized 220 GHz energy to the 220 GHz horn while it passes the 140 GHz energy, which is horizontally polarized, to the 140 GHz feed horn. The 220 GHz energy is then downconverted using a subharmonically pumped mixer and a 108 GHz, solid state, local oscillator. The IF is then separated by a low loss diplexer into two bands, 0.1-1.0 GHz and 2.0-4.0 GHz. These parallel IFs are then amplified and square law detected. These two output voltages are then combined in a summing amplifier. This single output voltage is then connected to the remote control unit with a long BNC cable where it is amplified again. The dc offset and the integration time can be adjusted from the remote control unit. The entire radiometer is dc coupled and operates in a total power mode to maximize sensitivity. Drift due to gain variations does not have any appreciable effect on the sensitivity because of the short integration times (less than 0.25 msec) and the fast calibration rate of between 8-10 Hz. A performance summary and a list of system features are provided in Tables I and II.

2.1 Antenna Subsystem

The antenna RF subsystem, diagrammed in Figure 7, consists of a 6 inch, low loss, Teflon lens, a polarization diplexer, and two feed horns (one for each frequency). The Teflon lens was made in order to reduce the RF losses that were present with the old Rexolite lens that had been used in the 140 GHz radiometer.

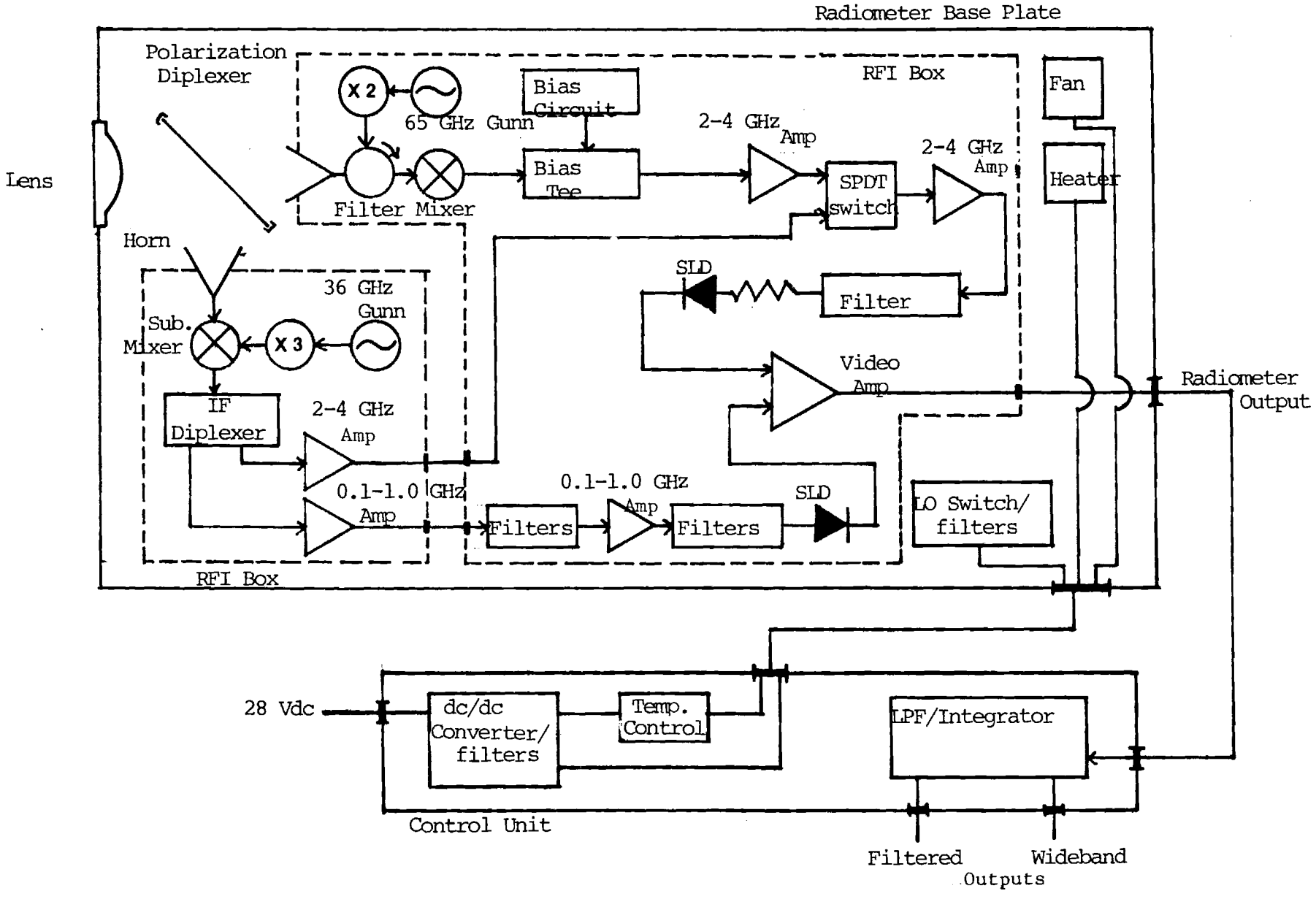

Figure 6. Block Diagram of 140/220 GHz Radiometer.

Table 1

140/220 GHz Performance Summary

Item	140 GHz Sensor	220 GHz Sensor	
LO Frequency	135 GHz	108 GHz	
IF Frequency	2-4 GHz	0.1-1.0 GHz	2.0-4.0 GHz
Total System Noise Figure (DSB)	9.8 dB	12.0 dB	14.0 dB
Total Receiver Noise Temperature	2480K	4306K	6994K
ΔT_{min} at τ = 1 sec (T_A = 290K)	0.058K	0.15K (0.11K Combined)	0.16K

Table 2

140/220 GHz RADIOMETER SYSTEM FEATURES

Item	Performance
Mode of operation	dc coupled, total power radiometer
Power supply voltage	26-29 Vdc
Power supply ripple rejection	No change in output of radiometer for 0.6 V p-p ripple on power supply, 10 Hz - 1 kHz
Electronic isolation	Complete electrical isolation of system electronics from aircraft chassis
RFI shielding	Shielded box with RFI gaskets on all seams, RFI feed throughs on all power supplies
Temperature control	Continuous, direct reading, control of system temperature to $\pm 0.5^{\circ}C$ of setting, up to $20^{\circ}C$ above ambient
Integration time	Adjustable from 0.001-0.1 seconds via control panel switch, parallel wideband output on front panel
Output offset control on control panel	± 10 Vdc
Power interrupt	No damage to system, no change in radiometer output for 0.5 second interrupt during full operation
Dual frequency operation	140 or 220 GHz operation provided
Microphonics	Output of system is not disturbed by aircraft vibrations

Table 2 (cont'd)

Antenna	1^{o} beamwidth at 140 GHz, 0.6^{o} at 220 GHz, 6" lens shared via polarization diplexer
Remote control unit	Remote electronic switching between 140 or 220 GHz sensors
IF channels	Dual IFs increase 220 GHz bandwidth, shared 2-4 GHz post IF/video reduced equipment cost and space
Local oscillators	All solid state Gunn/multipliers

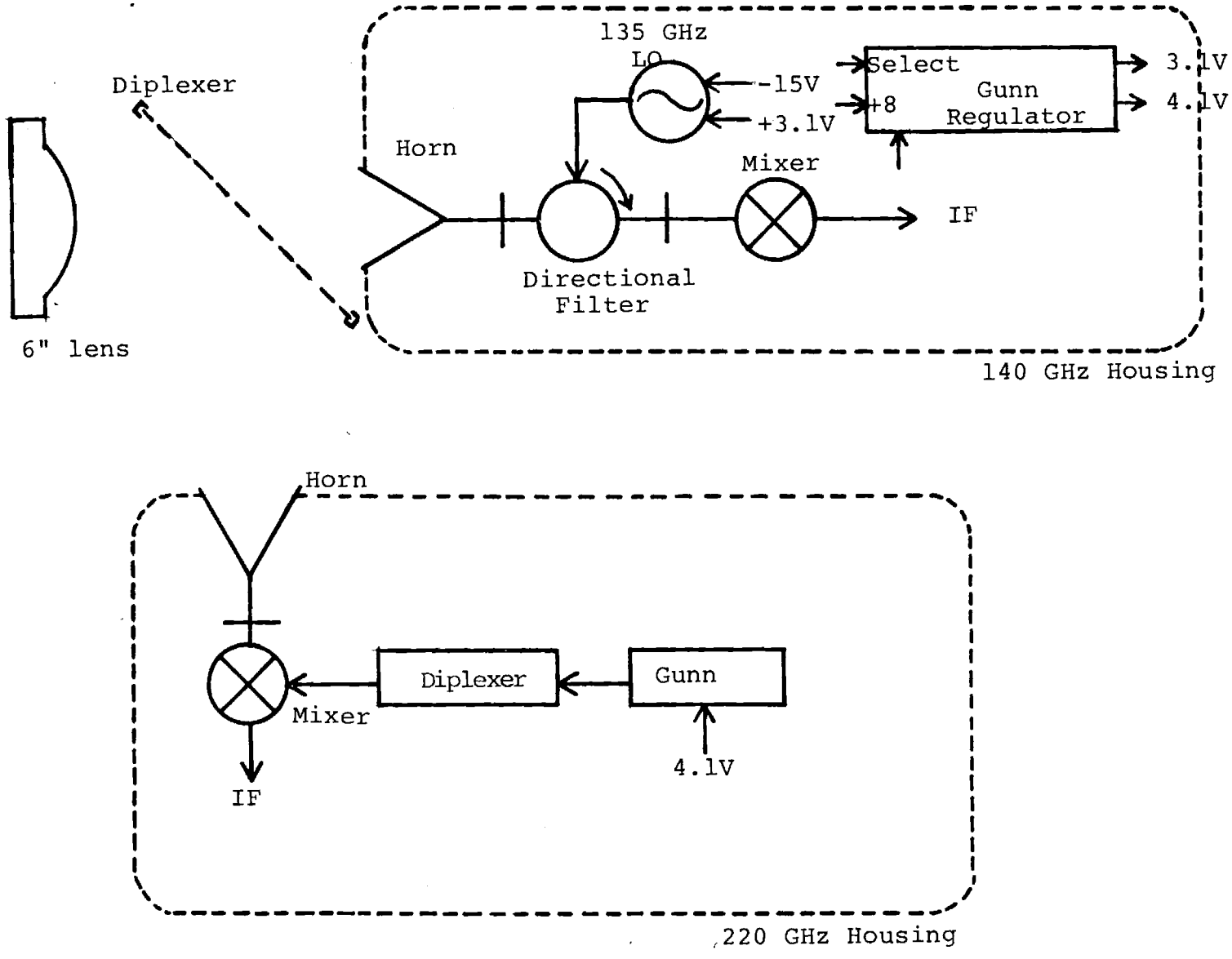

Figure 7. RF Layout of 140/220 GHz Radiometer.

An improvement of about 0.35 dB at 140 GHz and 2.0 dB at 220 GHz was realized by the replacement of the Rexolite lens with the Teflon lens. The total lens loss (about 0.4 dB at both 140 and 220 GHz) is primarily due to reflection losses at the two dielectric to air interfaces of the lens. This lens has a focal length of about 9 inches and a maximum depth of about 1 inch.

The polarization diplexer is a broadband, low loss, device that allows the sharing of one lens by two horns. It acts, in this case, as a broadband frequency diplexer by passing the horizontally polarized energy at 140 GHz to the 140 GHz horizontally polarized receiver. All vertically polarized energy is reflected, including that at 220 GHz. Therefore, by rotating the 220 GHz receiver properly this energy is reflected onto the 220 GHz horn.

The polarization diplexer consists of a series of parallel, photolithographically etched metallic lines on a thin Mylar sheet. The total loss in the mismatched sense (reflected vertical polarization) is greater than 30 dB. The loss measured in a matched orientation (for instance, horizontally polarized energy passes through vertically oriented wires) is less than 0.05 dB.

The horns are corrugated conical horns which provide a Gaussian beam shape which is ideal for feeding lens type antennas. Photographs of the diplexer and horn arrangements are shown in Figures 8 through 11.

2.2 Subharmonic Mixers

Subharmonic mixers, employing antiparallel diodes are highly desirable for low noise, broadband system applications. Some of their most notable features are that they have low noise, low loss, LO AM noise cancellation, and no need for external bias circuitry [2,3]. Most importantly, they require only one-half or one-fourth the signal frequency as sources for local oscillators. Mixers of this type have been developed at Georgia Tech

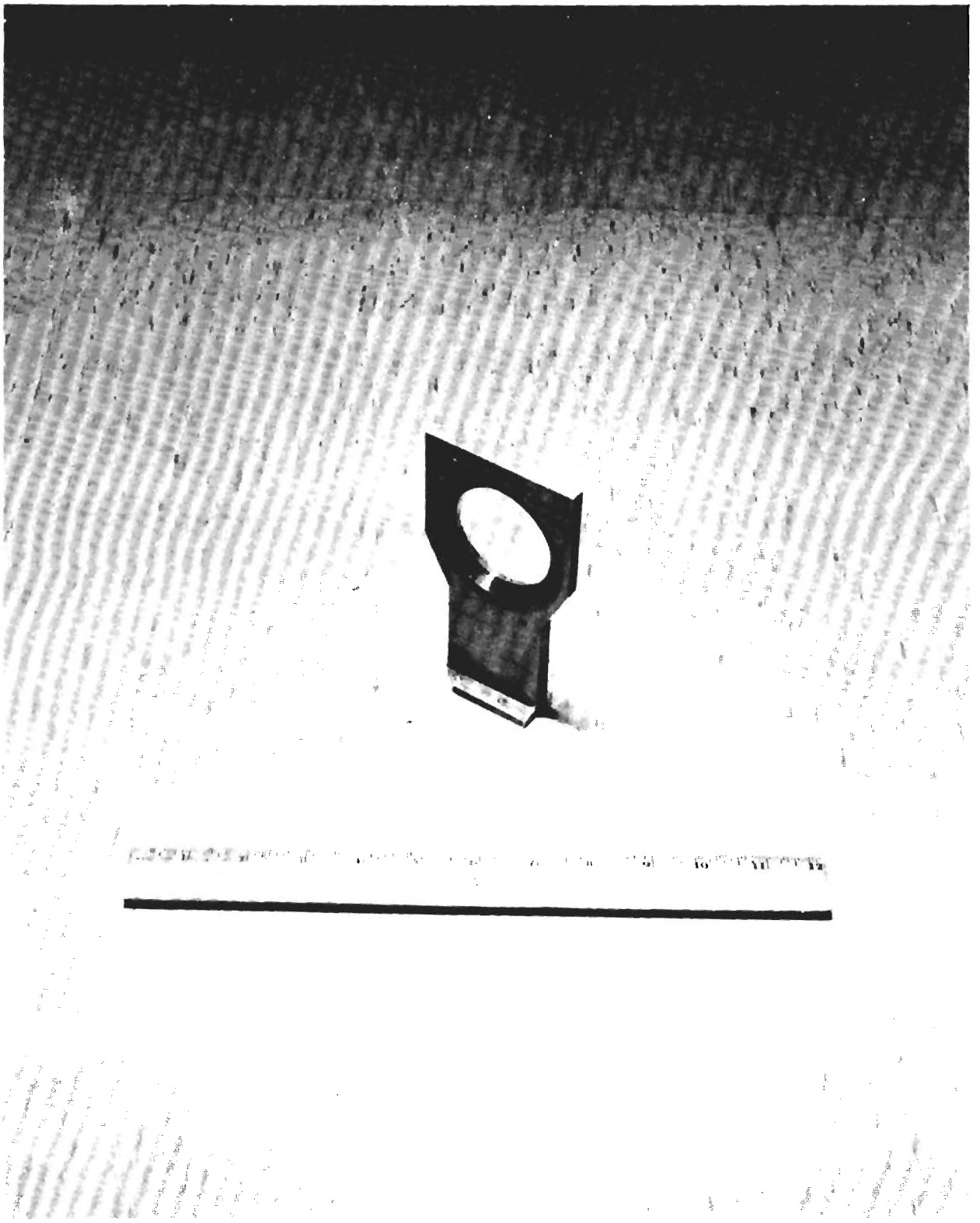

Figure 8. Quasi-Optical Polarization/Frequency Diplexer.

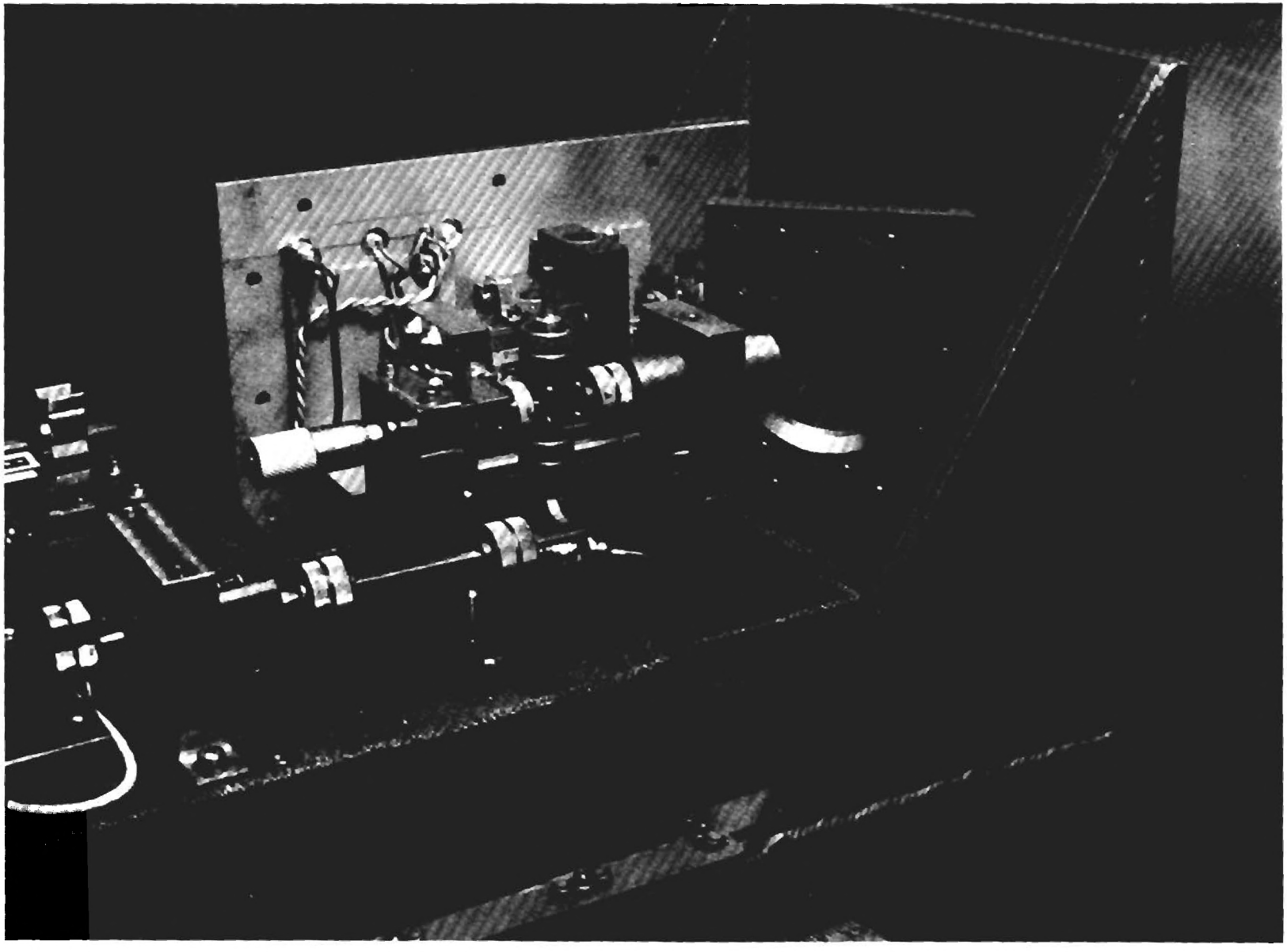

Figure 9. 140/220 GHz Front End (Side View).

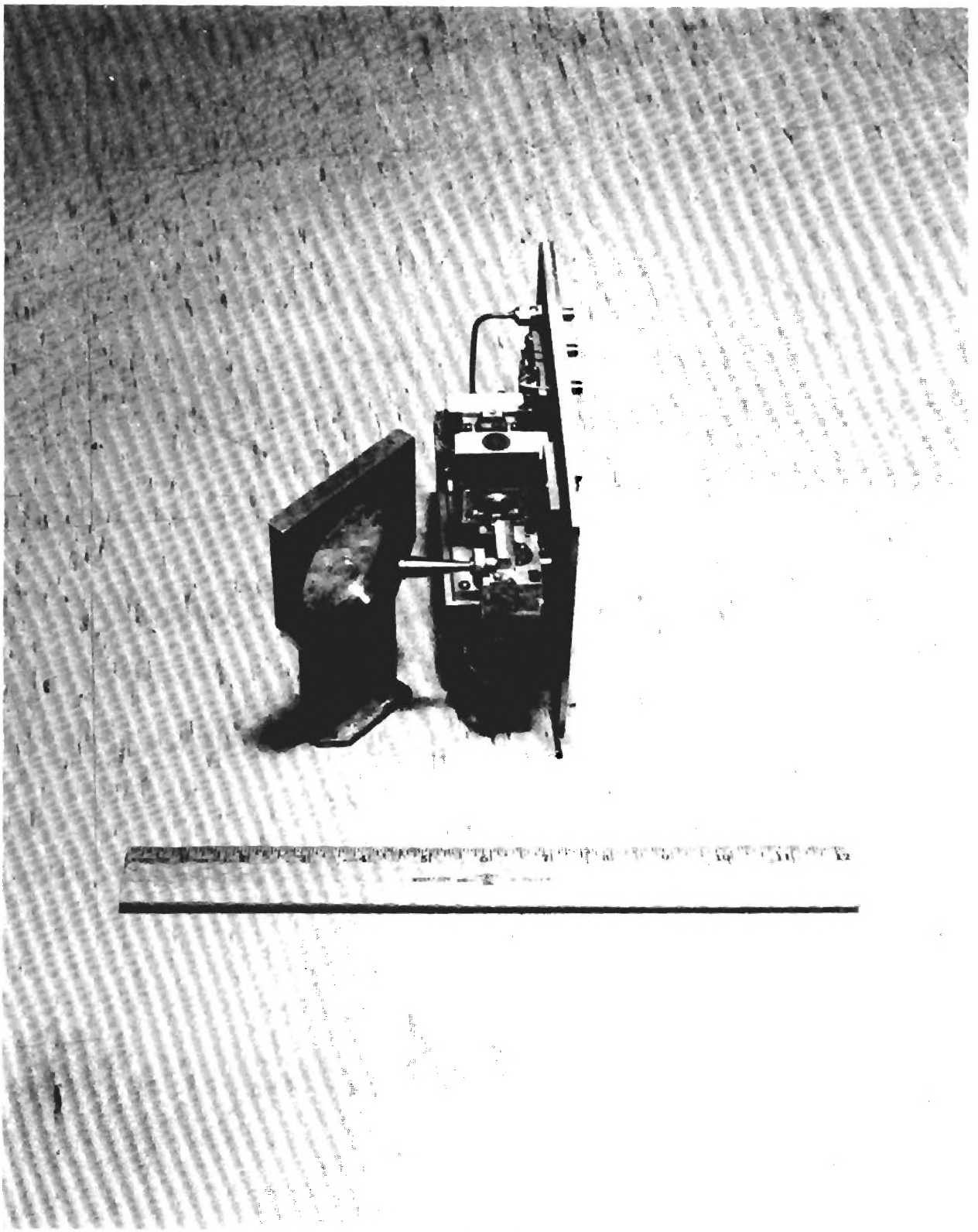

Figure 10. 220 GHz Front End with Diplexer.

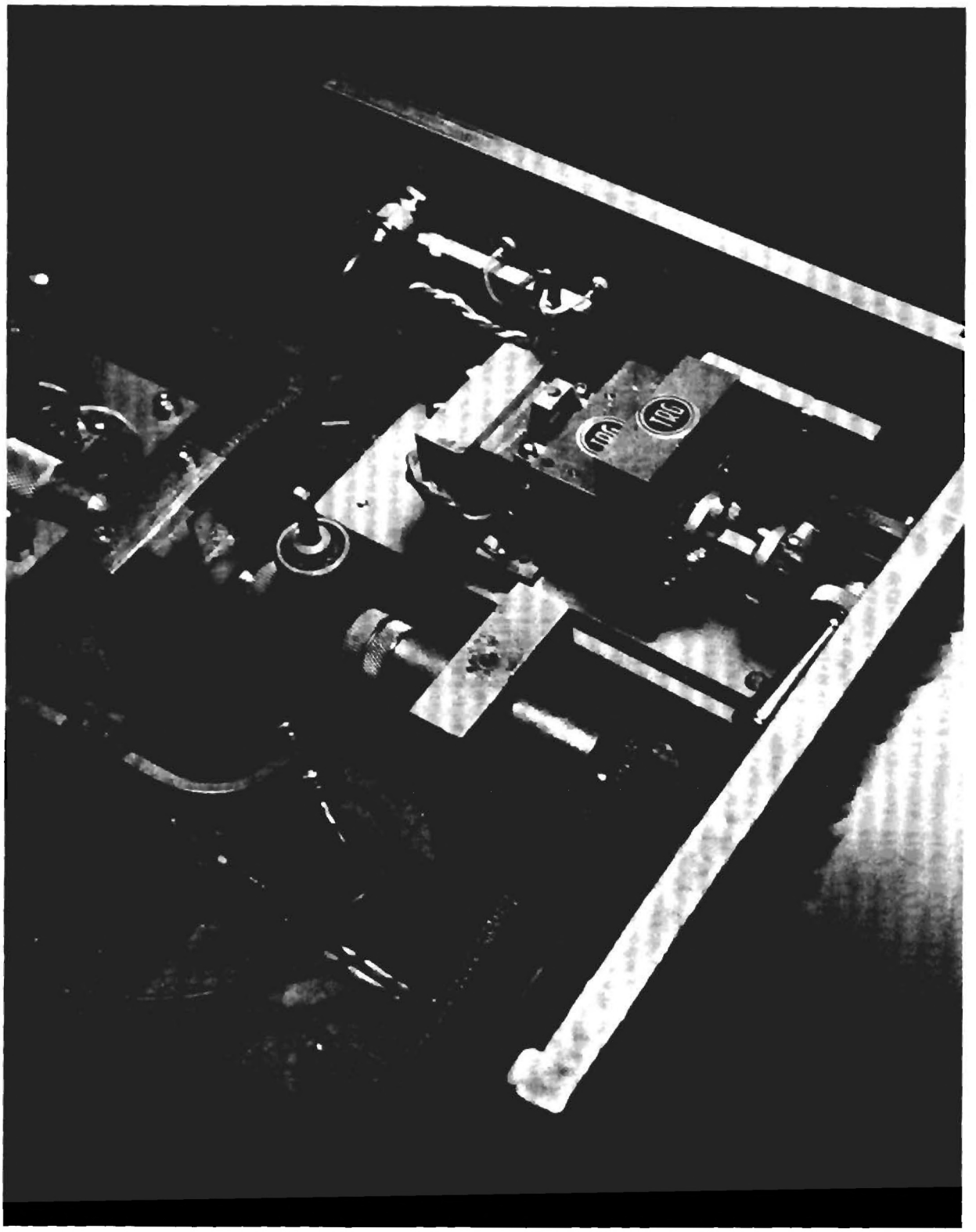

Figure 11. 140/220 GHz RF Components (Top View, Diplexer Removed).

particularly for use at 140-220 GHz. The mixer circuits were originally designed with a low frequency (6.8 GHz) model and scaled according to electromagnetic scaling laws, to 220 GHz. The mixer is a hybrid structure which consists of two waveguides (LO and RF) and a suspended substrate stripline circuit, oriented orthogonally to each other, as shown in Figure 12. This circuit is located in the center of the E-plane of the LO waveguide. Only the edge of the circuit can be seen when looking down this waveguide. The LO is then reflected by the IF filter and passed by the LO filter to the antiparallel diode pair. An adjustable LO backshort is provided for maximum coupling of the LO energy to the diodes. The signal waveguide is linearly tapered to half height WR-5 waveguide. The diodes are mounted in this waveguide. An adjustable backshort is provided for RF matching of the diodes to the signal. The LO filter reflects the signal energy and prevents it from leaving the signal waveguide. It also helps match the diodes to the signal. The IF is passed by both filters to the IF output port which is an SMA connector whose center conductor is connected to the substrate's center conductor by a soldered gold ribbon. Photographs of these mixers are given in Figures 13 and 14.

The diodes are Schottky barrier diodes formed in a planar array on the face of a 0.010" by 0.005" by 0.005" GaAs chip. The circuit is completed by an ohmic contact made by a 0.0005" Niauro whisker that has been etched to a fine point. Two chips are used. One is placed on top of the signal waveguide facing down and the other is on the bottom facing up. Separate contact of one diode on each chip is made in the following manner. A whisker and diode chip are carefully mounted on the end of a substrate which has been glued in place in the body structure. Another whisker is mounted on a 0.032" diameter pin and another diode chip is mounted on a separate pin. These pins are then pushed into the mixer body from the bottom. When the diodes are

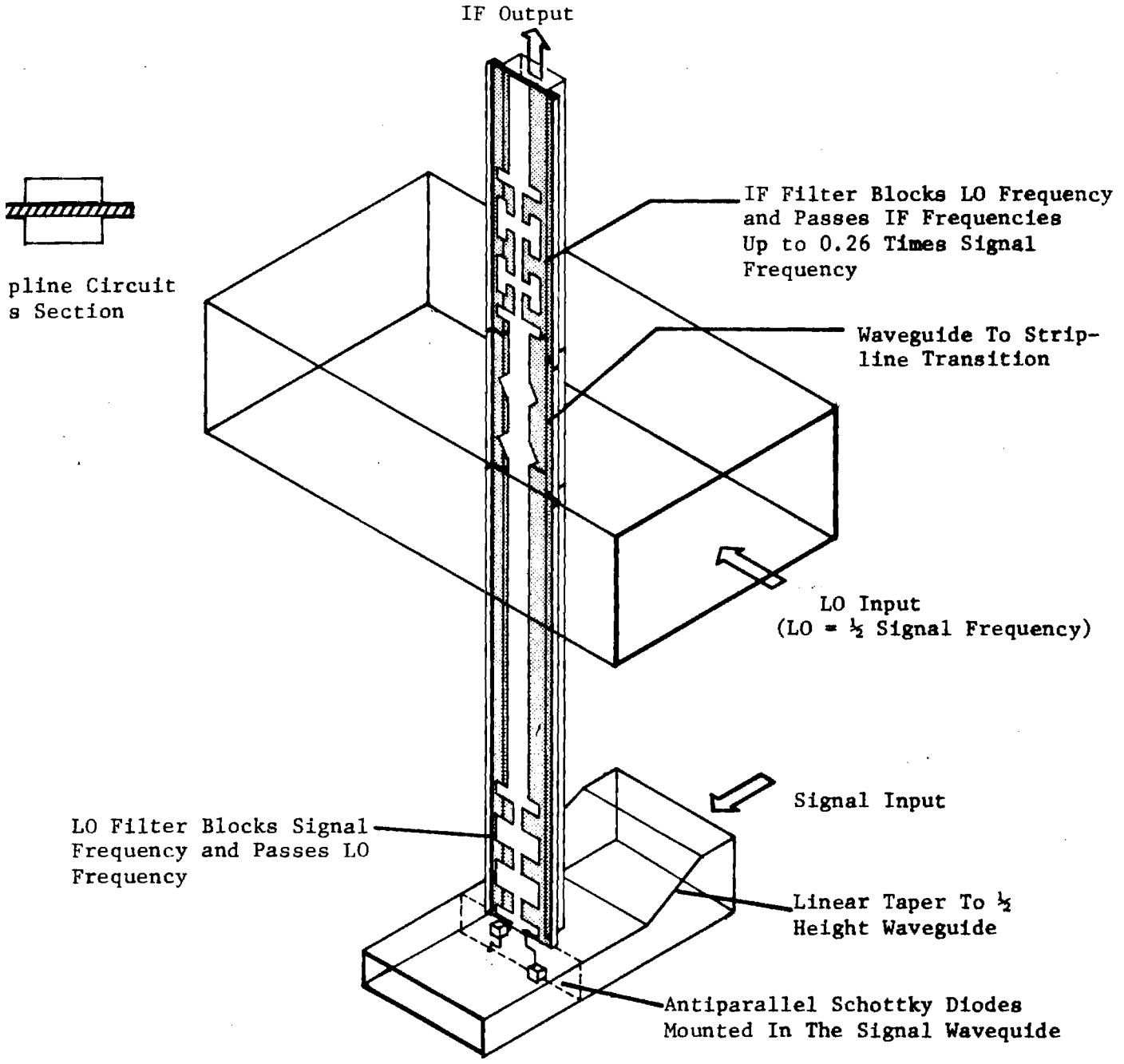

Figure 12. Functional Schematic of Subharmonic Mixer.

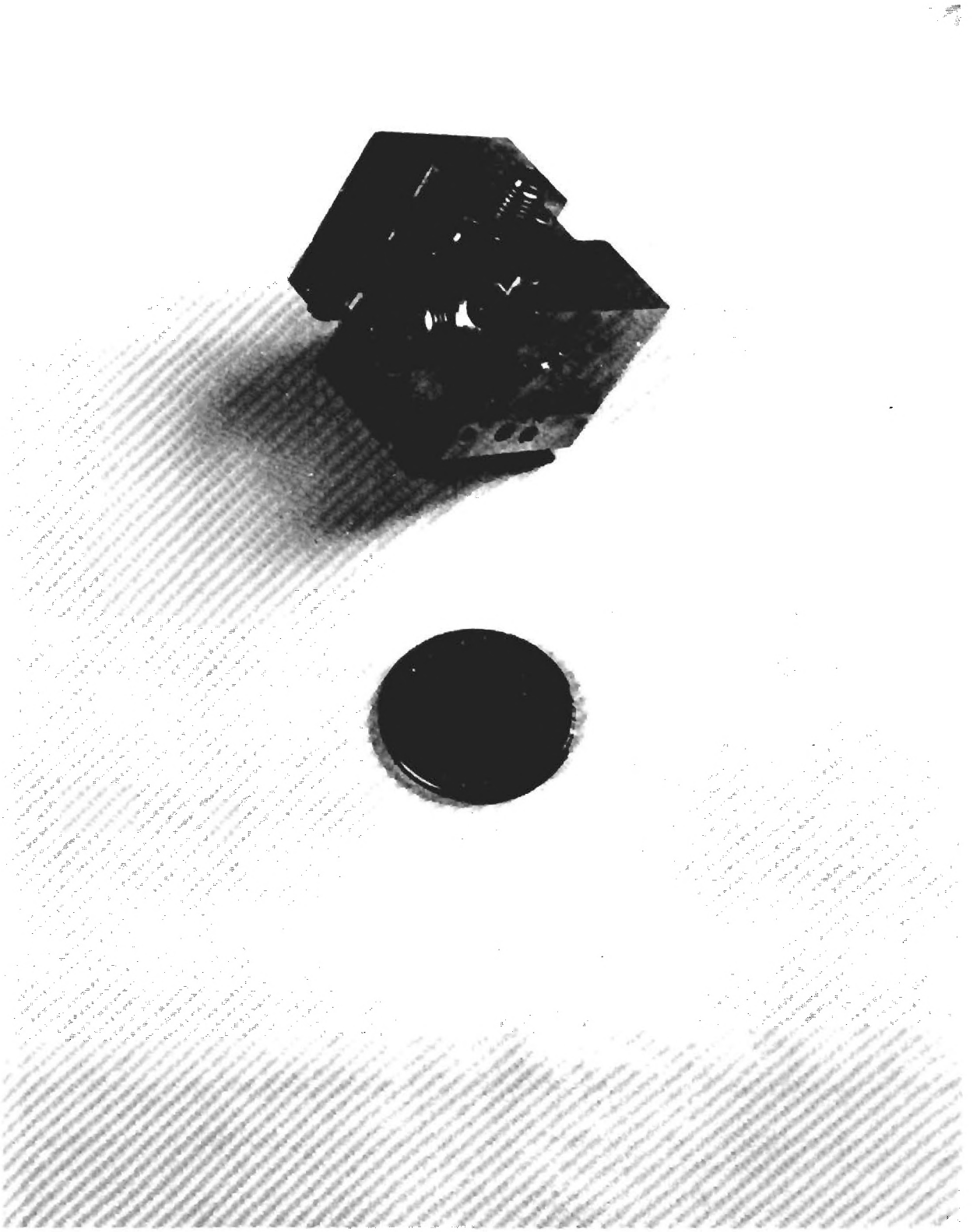

Figure 13. 140 to 220 GHz Subharmonic Mixer.

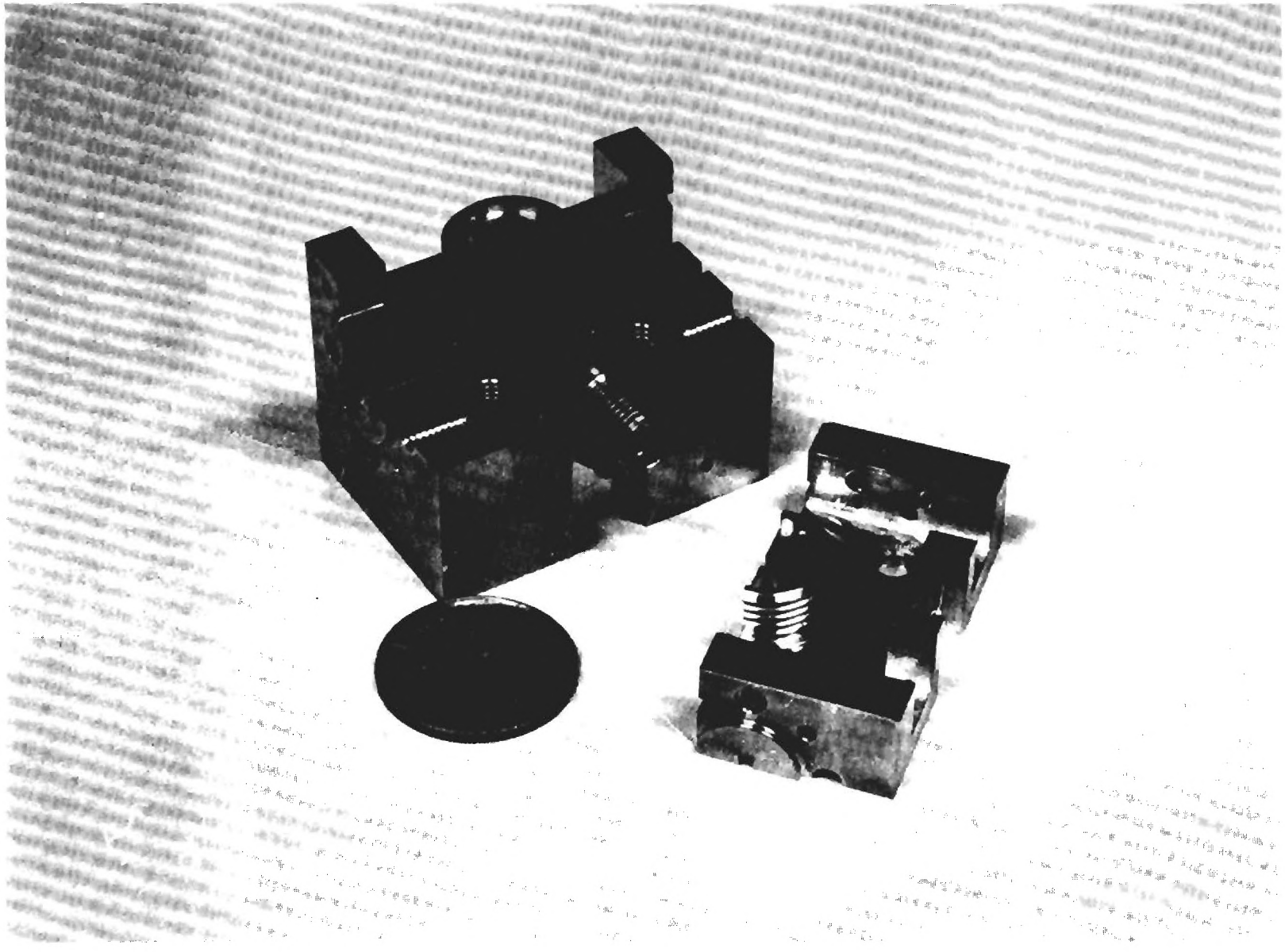

Figure 14. Photograph of Partially Assembled Subharmonic Mixer.

close to the whiskers, the pins are pushed in with a differential micrometer while being viewed with a microscope. The circuit is electrically monitored for dc characteristics with a curve tracer and the ohmic contacts are examined under an SEM. The mixer body is then assembled and tested for noise figure in an automatic noise figure test set-up using a chopper, cold load, and an HP-85 computer.

Such mixers have been built and tested at 140 to 220 GHz using both one-half and one-quarter frequency LOs. The results obtained with these mixers are given in Table 3. The 220 GHz receiver is shown in Figure 15. The data at 220 GHz contains additional contributions to the noise figure other than mixer conversion loss alone. Part of the problem is an estimated 2 dB increase in noise figure due to noise from the Gunn/tripler LO at 108 GHz. An additional 1-2 dB improvement could also be obtained over narrower (octave) bandwidths using IF matching techniques.

2.3 IF/Video Subsystem

The IF/video subsystem, diagrammed in Figure 16, utilizes broadband, low noise IF amplifiers. It is highlighted by the following features:

1) Dual IF channels for the 220 GHz radiometer to increase bandwidth and sensitivity;
2) A low loss microstrip diplexer, designed and built at Georgia Tech;
3) A 2-4 GHz IF/video channel which is shared between both the 140 and 220 GHz radiometers; and
4) A summing video amplifier with adjustable gain plus a remote switching feature that allows switching between 140 GHz (single IF channel) or 220 GHz (dual IF channel, summing required).

The IF energy of the 220 GHz mixer is connected to the input of the microwave diplexer. This diplexer is a parallel

Table 3

GEORGIA TECH'S SUBHARMONIC MIXER PERFORMANCE SUMMARY*

Mixer Type	LO Frequency (GHz)	RF Frequency (GHz)	Noise Figure DSB (dB)
X2	91	183	4.5
X2	108	215-217	8.25
X2	108	212-220	9.65
X4	55	219-221	8.0
X2	70	139-141	3.5

*Includes contributions due to LO noise.

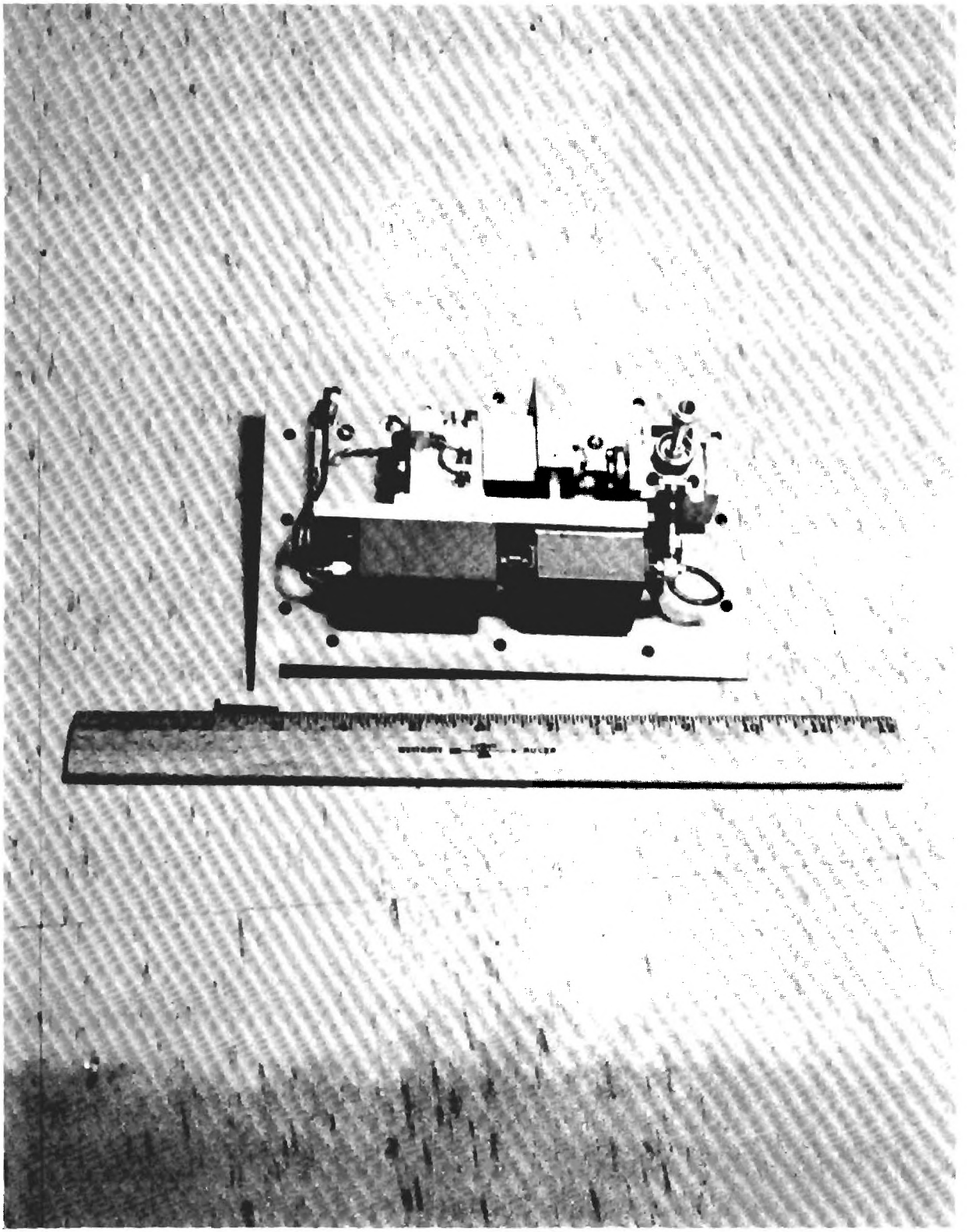

Figure 15. 220 GHz Solid State RF Front End.

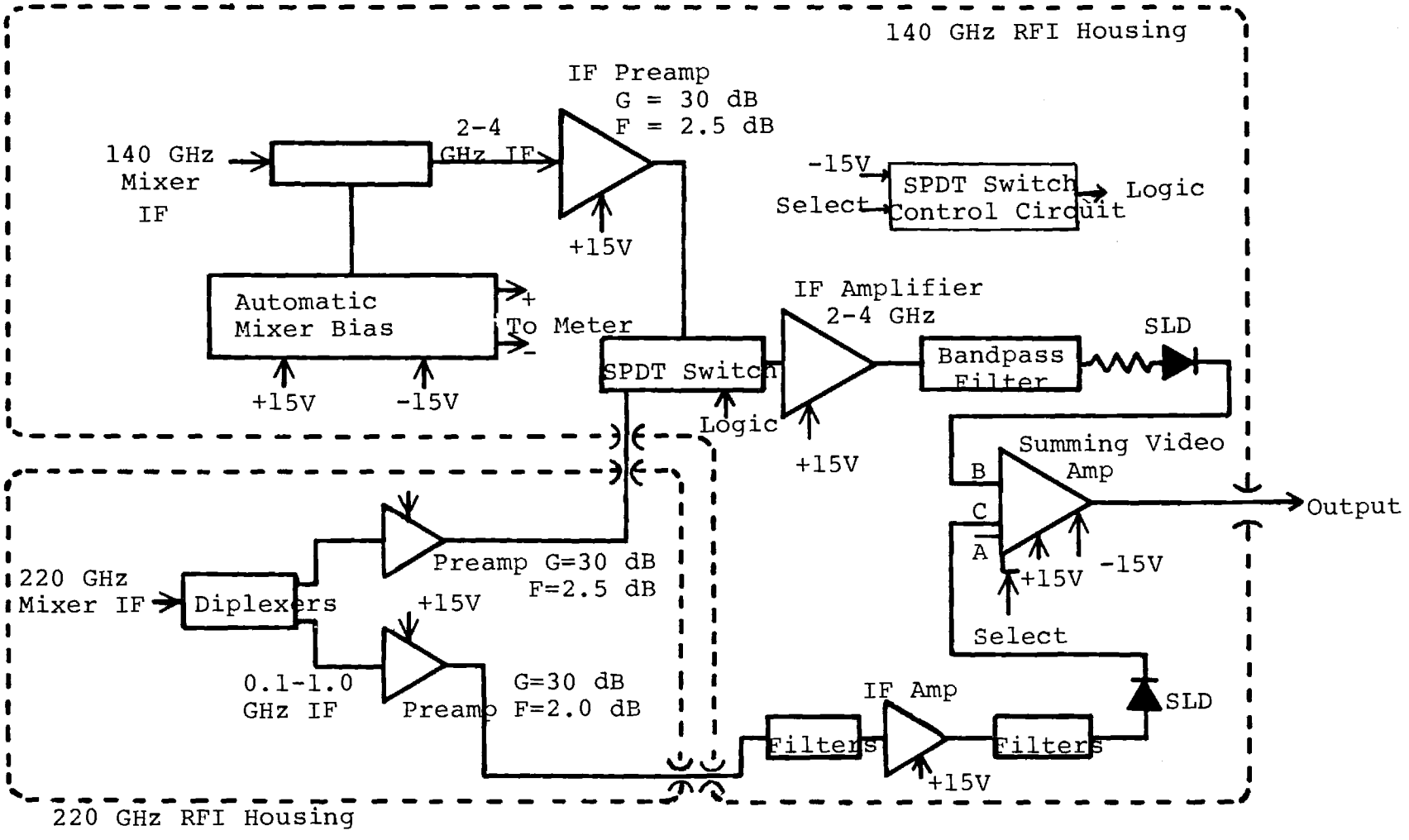

Figure 16. 140/220 GHz Radiometer's IF/Video Subsystem Layout.

combination of low pass and high pass, single ended filters with a crossover frequency of about 1.4 GHz. The circuit was optimized using COMPACT and then constructed on microstrip using duroid as a dielectric because of its low loss characteristics at microwave frequencies. The diplexer, shown in Figure 17, is contained in a 0.85"x0.6"x2.2" aluminum housing.

The outputs are connected via semi-rigid cables to two IF preamps, one for the 0.1 to 1.0 GHz IF, and one for 2.0 to 4.0 GHz IF. The outputs of these preamps are then fed through the 220 GHz shielded box to the 140 GHz shielded box using semi-rigid cable where the rest of the IF/video subsystem is contained.

The 0.1 to 1.0 GHz IF is first heavily filtered using a cascade of low and high pass filters, then amplified again to drive the square law detector (SLD) and filtered again prior to the SLD. The large amount of filtering, particularly the two 12 pole, low pass filters, is required due to the need to reduce interference from aircraft transmitters at about 1.1 GHz. The output voltage of the SLD is then fed into one input of the summing amplifiers (A).

The output of the 2-4 GHz IF preamp is connected via a SPDT switch to the second 2 to 4 GHz IF amplifier. This output is then bandpass filtered, attenuated (to insure the SLD is in the square law region) and square law detected. The output voltage of the SLD is then connected to the other input to the video amplifier (B).

The video amplifier actually has three inputs (A, B, and C). Only B and C are utilized in the current configuration. The select voltage (discussed later) which controls 140 or 220 GHz operation can choose between adding A+B or B+C to generate the output voltage. This is to anticipate future growth for a dual IF at 140 GHz. The additional IF would be connected to input A of the video amplifier. The current 140 GHz front end is not compatible with this concept due to the bandwidth of the LO

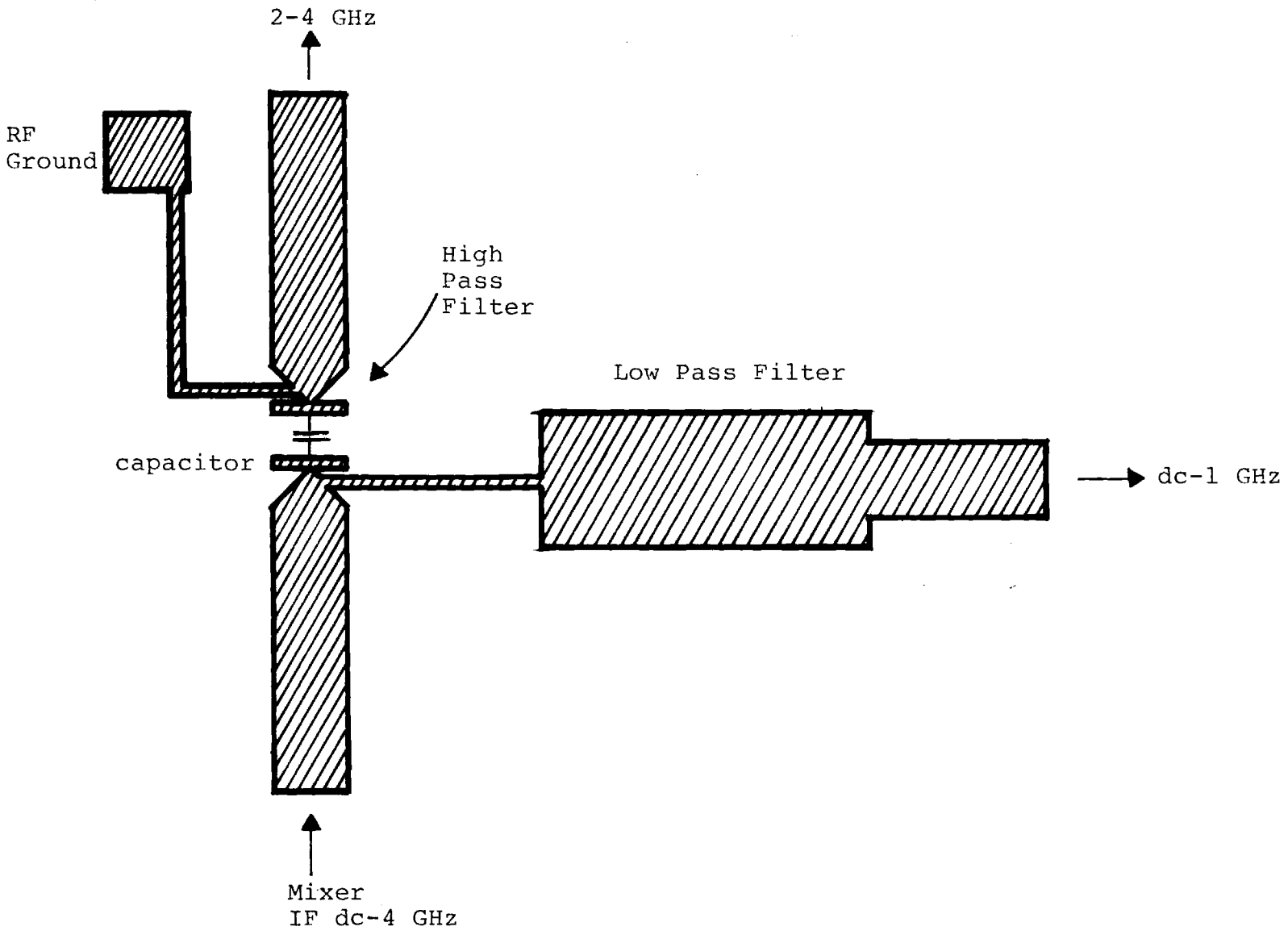

Figure 17. Layout for Microstrip IF Diplexer.

injection filter. However, the use of a subharmonic mixer or a balanced fundamental mixer at 140 GHz would allow this option to be implemented.

2.4 Remote Control Unit/Electronics

The control unit is a direct wired control unit connected via cables to the radiometer. It provides the following functions: power on/off; 140/220 GHz select; Gunn on/off; temperature select; Gunn current monitor; mixer current monitor (140 GHz mixer only); integration time adjustments; dc offset control, for long term drift; output monitor and two BNC radiometer outputs (one broadband and one low pass filtered according to the integration time select switch). All of these functions are on the front panel of the control unit. The back of the unit has connections for the cables from the radiometer. The control unit also houses the dc to dc converter, power line filters, video amplifiers/low pass integration circuits, and the temperature control circuit.

The electronic circuits have been described in detail in the previously mentioned report except for the operation of the 140/220 GHz switch [1]. This switch supplies a signal (0 or 5 Vdc) to the radiometer to control whether the 140 or 220 GHz radiometer is operating. This voltage controls the IF switch, the LO regulator and the video amplifier. The LO regulator circuit, shown in Figure 18, is controlled directly by this voltage. The video amplifier circuit, shown in Figure 19, is also controlled by this voltage. The 2-4 GHz IF switch, however, requires a special control circuit which has been mounted on the 140 GHz LO baseplate. The signal voltage supplied to the radiometer to determine 140 or 220 GHz operation controls this special circuit which in turn controls the switch which connects the 2-4 GHz IF preamp of the 220 GHz radiometer to the 2-4 GHz IF post amplifier of the 140 GHz radiometer when the control unit freque-

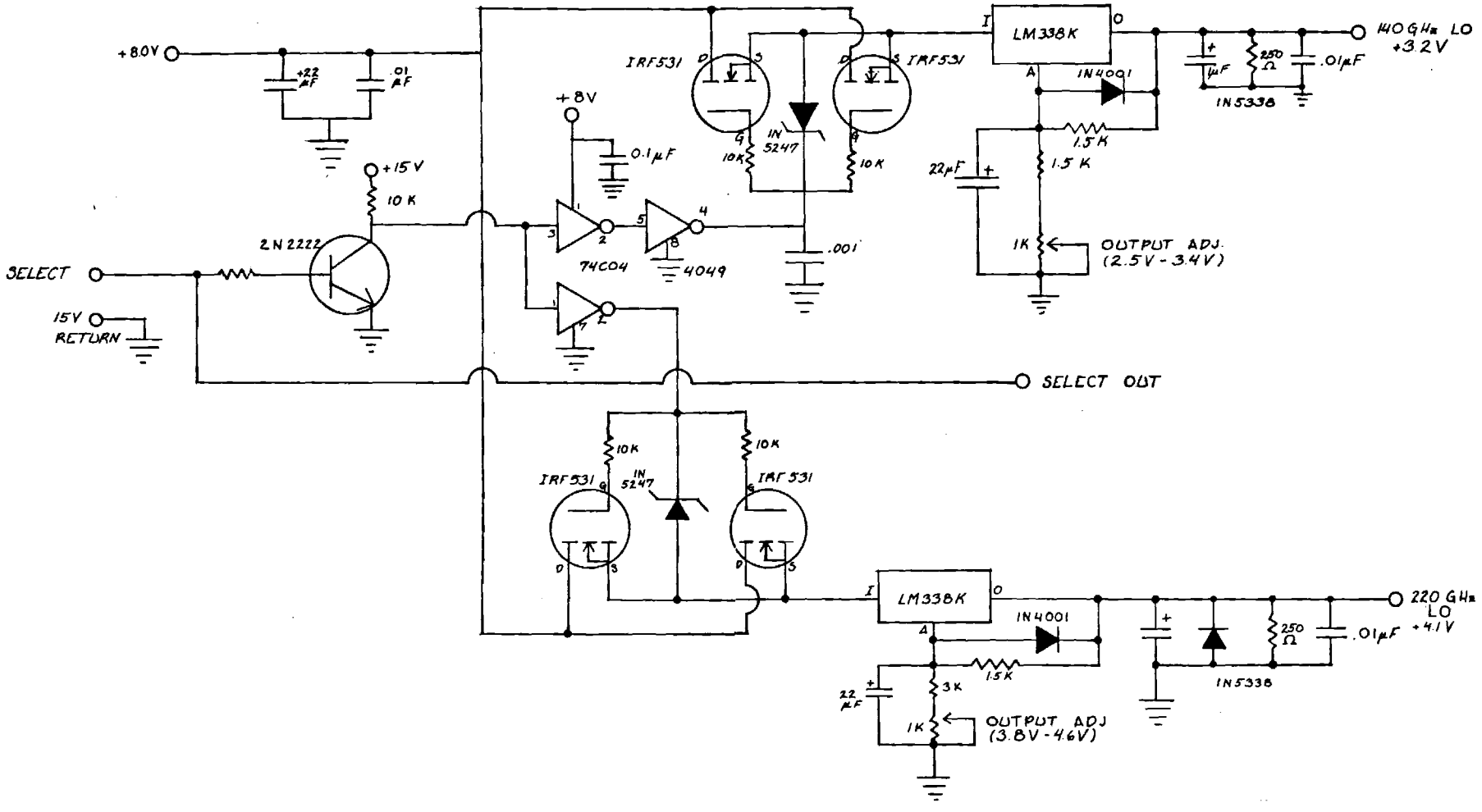

Figure 18. LO Regulator Switch Circuit Diagram.

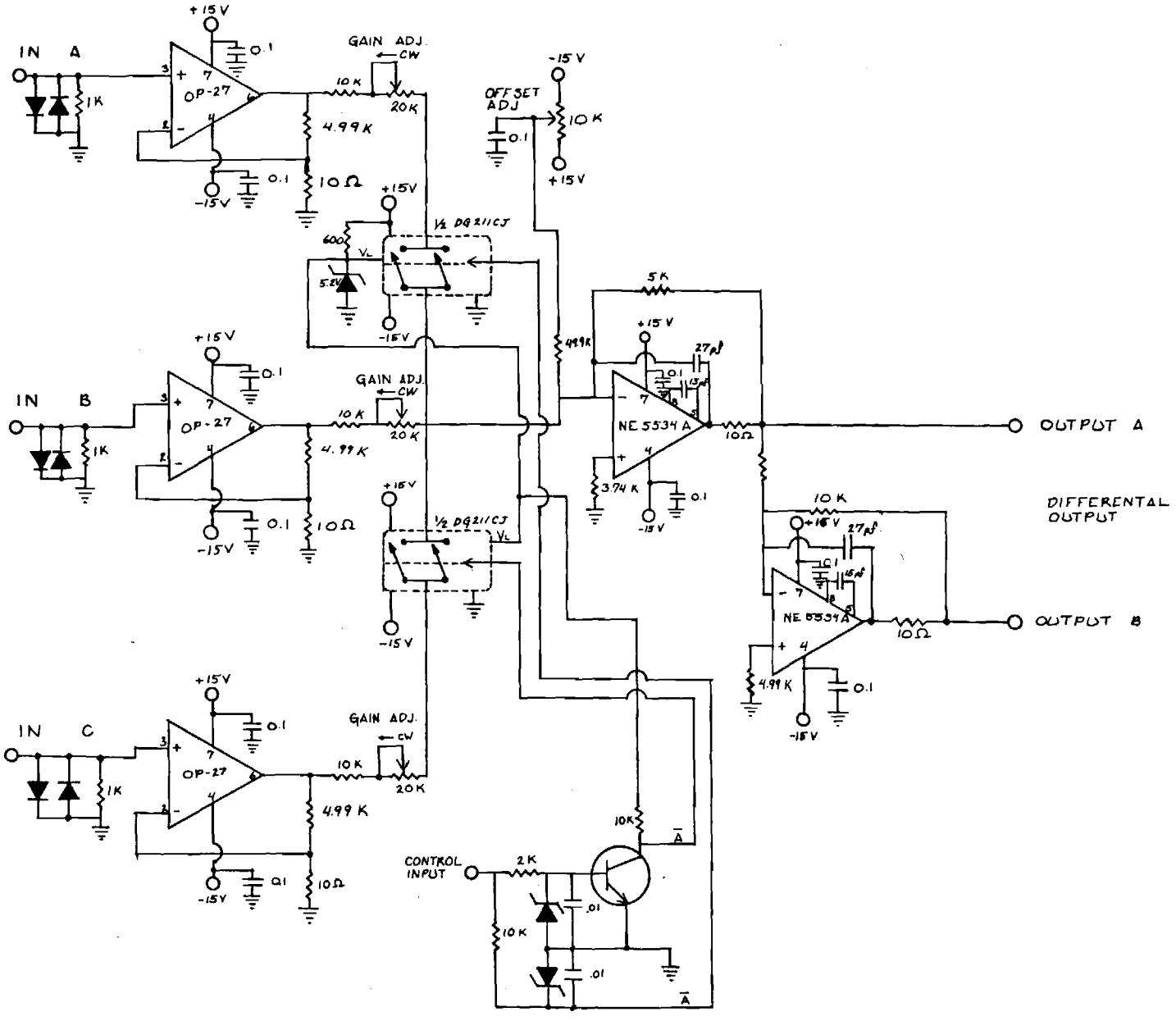

Figure 19. Low Noise Summing Video Amplifier Circuit.

ncy select switch is set to 220 GHz. For additional diagrams and schematics for this 140/220 GHz radiometer, please refer to Reference 1.

3.0 RADIOMETER OPERATION/CALIBRATION

This system is completely automatic with few adjustments required during normal operation. The system is operated as follows:

1. Hook-up
   a) Connect a 28 Vdc power supply to the connector in back of the control unit with all switches off.
   b) Connect the radiometer power cable between the control unit and the radiometer.
   c) Connect the BNC output of the radiometer to the BNC connector in the back of the control unit.
   d) The output can now be monitored on either of the two outputs (LP or TP) on the front of the control unit.
2. Radiometer turn-on (Refer to Figure 6)
   a) Turn on the three switches on the left side of the control panel starting with the far left (power, Gunn, heaters).
   b) Allow time for the system to stabilize (about 30 minutes). The stable light will turn on when the base plate reaches $\pm 0.5^{o}C$ of setting. Be sure not to set the temperature too high (above 10-15^{o}C) above ambient or it will take longer for the system to stabilize. The selectable temperature setting is read off the front panel with the reading 300 corresponding to 30.0^{o}C.
3. Radiometer turn-off
   a) Turn off the previously mentioned three switches

from right to left.

4. Radiometer calibration

a) Turn on the system.

b) Set the integration time to 0.1 seconds.

c) Alternately view calibration loads and observe the voltages corresponding to viewing the different loads.

d) Adjust the offset voltage to be sure no electronics are saturated for temperatures expected during the data run.

e) System gain (G) in K/volt can be calculated by

$$G = \frac{T_{hot} - T_{cold}}{V_{hot} - V_{cold}}$$

f) System ΔT_{min} can be measured by setting the integration time to 0.001 seconds and measuring V_{rms}. Then ΔT_{min} is given by

$$\Delta T_{min} = GV_{rms}$$

g) The average T_{sys} can then be calculated by

$$T_{sys} = \Delta T_{min} \sqrt{B_{IF}}$$

5. Video amplifier calibration

The gain adjustment for the video amplifier proceeds as follows (220 GHz operation only):

a) Turn on the radiometer and allow it time to settle (about 30 min.);

b) Disconnect the low band input to video amplifier;

c) Measure the voltage output when the radiometer is viewing two calibration loads at different temperatures (record V_1 and V_2 corresponding to T_1 and T_2);

d) Also measure V_{rms} using T_2 and a 1 msec integration time;

e) Reconnect the low band channel at the input to the video amplifier and disconnect the high band channel;

f) Perform the same measurements as c) and d) above for the low band channel and get V_1', V_2' and V_{rms}';

g) Adjust the gain (G) in K/V of each channel so that

$$\frac{G}{G'} = \left(\frac{\Delta T_{min}}{\Delta T'_{min}}\right)^2$$

where:

$$\Delta T_{min} = GV_{rms};$$

$$\Delta T'_{min} = G'V_{rms};$$

$$G = \frac{T_2 - T_1}{V_2 - V_1}; \text{ and}$$

$$G' = \frac{T_2 - T_1}{V_2' - V_1'} .$$

This adjustment will provide optimum weighting of the two channels for minimum noise.

4.0 CONCLUSIONS/RECOMMENDATIONS

A 220 GHz radiometer has been developed and delivered to NRL for low noise, high resolution, imaging onboard a P-3 aircraft. Improvements in sensitivity can be obtained by using a cleaner LO or by proper LO filtering. One problem that arose during the final tuning and testing was that the 108 GHz LO would not turn on remotely when the receiver was tuned for minimum noise. Thus, some degradation in noise figure occurred due to the need to mistune the LO away from the minimum noise level so that it could be turned remotely. It was found that the LO would turn on when turned for minimum noise if the Gunn voltage was first raised to 6 Vdc and then lowered to 4.1 Vdc. A modification to the LO voltage supply could solve this problem. Also an isolator could be added between the LO and mixer; however, there is not enough room for this device in the current configuration. A breakdown of the contributions to noise figure is given in Table 4.

Other modifications to this radiometer could include:

1. Using a lower noise 140 GHz receiver using a subharmonic or balanced fundamental mixer;
2. Adding a dual IF system for the 140 GHz radiometer;
3. Providing simultaneous 140/220 GHz operation;
4. Replacing either the 140 or 220 GHz sensor with a 35 or 94 GHz sensor for simultaneous multifrequency measurements;
5. Adding another sensor at 94 GHz using a frequency sensitive surface; or
6. Reconfiguring the system and adding additional channels for a focal plane array type of radiometer.

Table 4

140/220 GHz NOISE FIGURE SUMMARY

	140 GHz	220 GHz	
		0.1-1.0 GHz IF	2.0-4.0 GHz IF
Lens Loss (dB)	0.4	0.4	0.4
Diplexer Loss (dB)	0.05	0.05	0.05
Horn Loss (dB)	0.6	1.0	1.0
LO Injection (dB)	0.7	N/A	N/A
DSB Mixer/LO Noise (dB)	5.55	8.25	9.65
IF Diplexer Loss (dB)	N/A	0.3	0.4
IF Preamp Noise Figure (dB)	2.5	2.0	2.5
Receiver Noise Figure (dB)	9.8	12.0	14.0

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2) M. Cohn, J. Degenford, and B. Newman, "Harmonic Mixing with an Antiparallel Diode Pair," IEEE-MTT Vol. MTT-8, pp. 667-673, August 1975.

3) P. Henry, B. Glance, and M. Schneider, "Local Oscillator Noise Cancellation in the Subharmonically Pumped Stripline Power Converter," IEEE-MTT, Vol. MTT-5, pp. 254-257, May 1976.

4) R. E. Forsythe and S. M. Halpern, "Subharmonic Mixers for 183 to 225 GHz," IEEE Conf. on IR and MM Waves, Miami, FL, December 1981.

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ADAPTIVE MILLIMETER WAVE IMAGING SYSTEM
Volume II 94 GHz Radar

Prepared by

GEORGIA INSTITUTE OF TECHNOLOGY
A Unit of the University System of Georgia
Engineering Experiment Station
Atlanta, Georgia 30332

1984

May 1984

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WASHINGTON, D. C. 20375

Contract No. N00173-79-C-0389

Final Technical Report
Georgia Tech Project No. A2488

ADAPTIVE MILLIMETER WAVE IMAGING SYSTEM

Volume II 94 GHz Radar

J.A. Scheer, H.P. Haas, J.C. Butterworth

Prepared For

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Washington, D.C. 20375
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report documents the design and construction of a 94 GHz radar that is to be used as of an adaptive millimeter wave imaging system for use onboard a P-3 aircraft. The z radar uses an all solid state, low noise, broadband, room temperature receiver and xtended interaction oscillator transmitter. A nine-inch Teflon lens is used as the na.

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E OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Include Area Code) 22c. OFFICE SYMBOL

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PREFACE

This report was prepared by the Radar and Instrumentation Laboratory of the Engineering Experiment Station, Georgia Institute of Technology under NRL contract N00173-79-C-0389. The contract technical monitor was Mr. Al Miller. The contract period was from September 1979 to March 1984. This document describes the work done under this contract relating to active imaging.

The authors would like to acknowledge the contributions made by the following individuals: D. L. Ladd and G. C. Conrad formerly of Georgia Tech, Al Miller and Ben Yaplee of NRL.

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SECTION 1
INTRODUCTION

1.1 OVERVIEW

This final report documents the performance analysis and operation of the high resolution imaging 94 GHz radar system developed for the Naval Research Laboratory under Contract No. N00173-79-C-0389. The radar system is designed to be interchangeable with the radiometer employed in the AIMWIS program. It will be flown in the P-3 to provide high resolution imaging when used in the mapping mode. The system can also be used from a laboratory, roof, or bridge position for general instrumentation purposes.

1.2 SCOPE

This report discusses the performance analysis for the system and gives a brief guide to system operations.

Section 2 includes a description of the radar system and a discussion of the system performance parameters. Section 3 outlines the operation of the radar through the radar control panel. Appendix A includes system diagrams, cable diagrams, and circuit schematics.

SECTION 2
SYSTEM DESCRIPTION

2.1 OVERVIEW

This section is an analysis of the performance characteristics of the high resolution imaging 94 GHz radar system. Figure 1 is a block diagram of the radar system. Signal-to-noise ratio curves are generated for point targets and extended clutter targets. Point target cross sections of 1 m^2 and 10 m^2 and area targets (ground clutter) having average cross section per unit area values (σ^o) of -20 dB and -30 dB are considered. Analysis for the extended targets is done for the 90° (nadir) depression case, where the spot size is determined by the beamwidth.

2.2 SYSTEM PARAMETERS

2.2.1 SIGNAL-TO-NOISE RATIO

The power received (P_r) from a target with cross section σ is found from:

$$P_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4 L_s L_{atm}}$$

where:

P_t = transmitted power
G = antenna gain
λ = wavelength
σ = target cross section
R = range-to-target
L_s = system losses
L_{atm} = atmospheric losses

The noise power, P_n, is found from:

$$P_n = KTB_nF_n$$

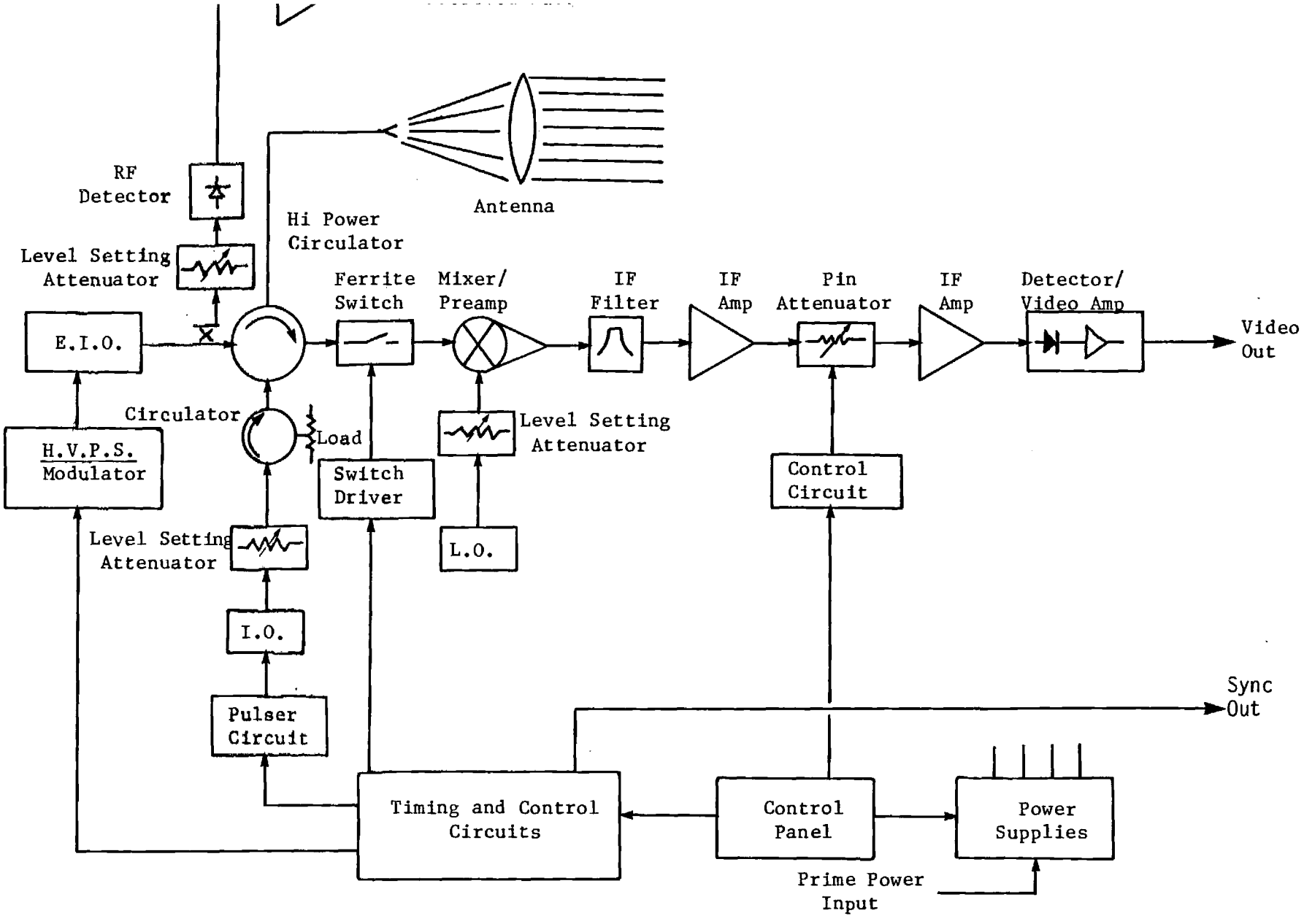


Figure 1. 95 GHz high resolution imaging radar block diagram.

where:

K = Boltzmann's constant

T = temperature

B_n = noise bandwidth

F_n = noise figure

The ratio of received power to noise power is, therefore:

$$S/N = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4 K T B_n F_n L_s L_{atm}}$$

Table 1 lists the radar system parameters.

TABLE 1. SYSTEM PARAMETERS

Transmit Power	1 kW peak
Antenna Gain	45 dB
Beamwidth	1° pencil
Frequency	94 GHz
Noise Figure	9.6 dB
Bandwidth	500 MHz
System Losses	5.7 dB
Atmospheric Losses	0.5 dB/km
Pulse Width	2 or 50 ns
Pulse Repetition Frequency (PRF)	10.2 kHz
Polarization	Vertical
IF Frequency	3 GHz
Dynamic Range	40 dB - Instantaneous
	60 dB - Total

Using the approach of adding logarithms instead of multiplying absolute values, one develops the following table for computation of a single point target on the curve of signal-to-noise versus range.

P_T	1000 watts	+30 dB
G^2	45 dB/way (1^o pencil)	+90 dB
λ^2	3.16 mm	-50 dB
σ^3	1 m^2	0
$(4\pi)^3$	1984	-33 dB
R^4	1 km	-120 dB
L_s	5.7 dB	-5.7 dB
L_{atm} (clear)	.5 dB/km	-.5 dB (1 km)
KT	4 x 10^{-21}	+204 dB
B_n	500 MHz	-87 dB
F_n	7 dB(DSB)	-9.6 dB(SSB)
S/N for 1 m^2 @ 1 km in clear air =		18.2 dB (single pulse)

For an extended target, whose extent is determined by the beamwidth, the target cross section increases with increasing distance by a factor of R^2 where R is the distance. The rate of falloff in this case is $1/R^2$ instead of $1/R^4$ as with the point target. At a range of 1 km, the extended target size (σ) is:

$$\sigma = \sigma^o \pi r^2$$

where r is the radius of the spot illuminated by the antenna beam. At an altitude of 1 km the system antenna illuminates a spot having an area of 240 m^2.

Figure 2 shows the signal-to-noise ratio analysis results for two point targets and two values of clutter reflectivity. It can be seen that the maximum range at which reliable detection will occur (10 dB S/N ratio) is about 10,000 ft. Obviously for larger targets, this range will be extended. The minimum range for the system is about 500 feet, providing S/N ratios in excess of 60 dB.

2.2.2 DYNAMIC RANGE

The receiver dynamic range is analyzed in this section. Figure 3 shows the block diagram of the receiver components which are used in the analysis

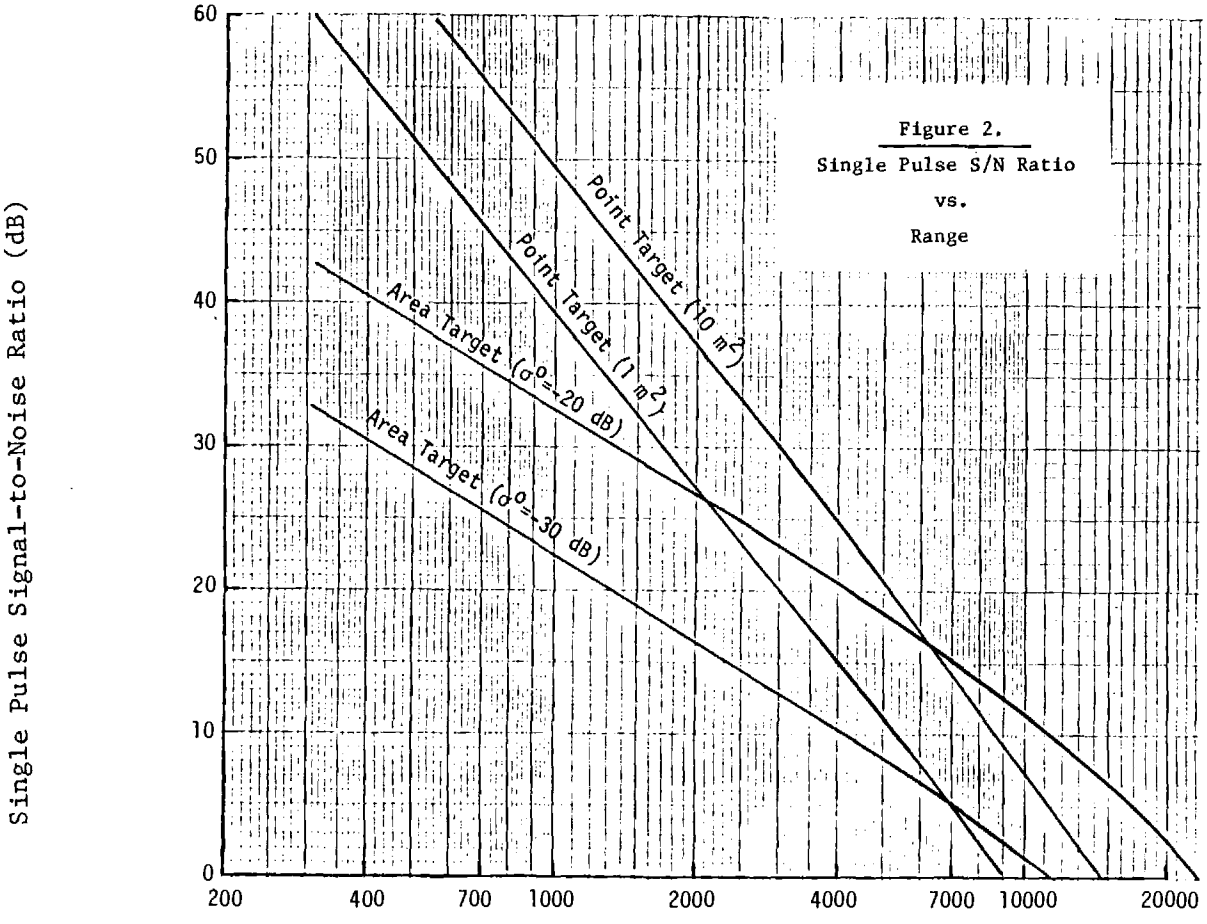


Figure 2. Single pulse S/N ratio vs. range.

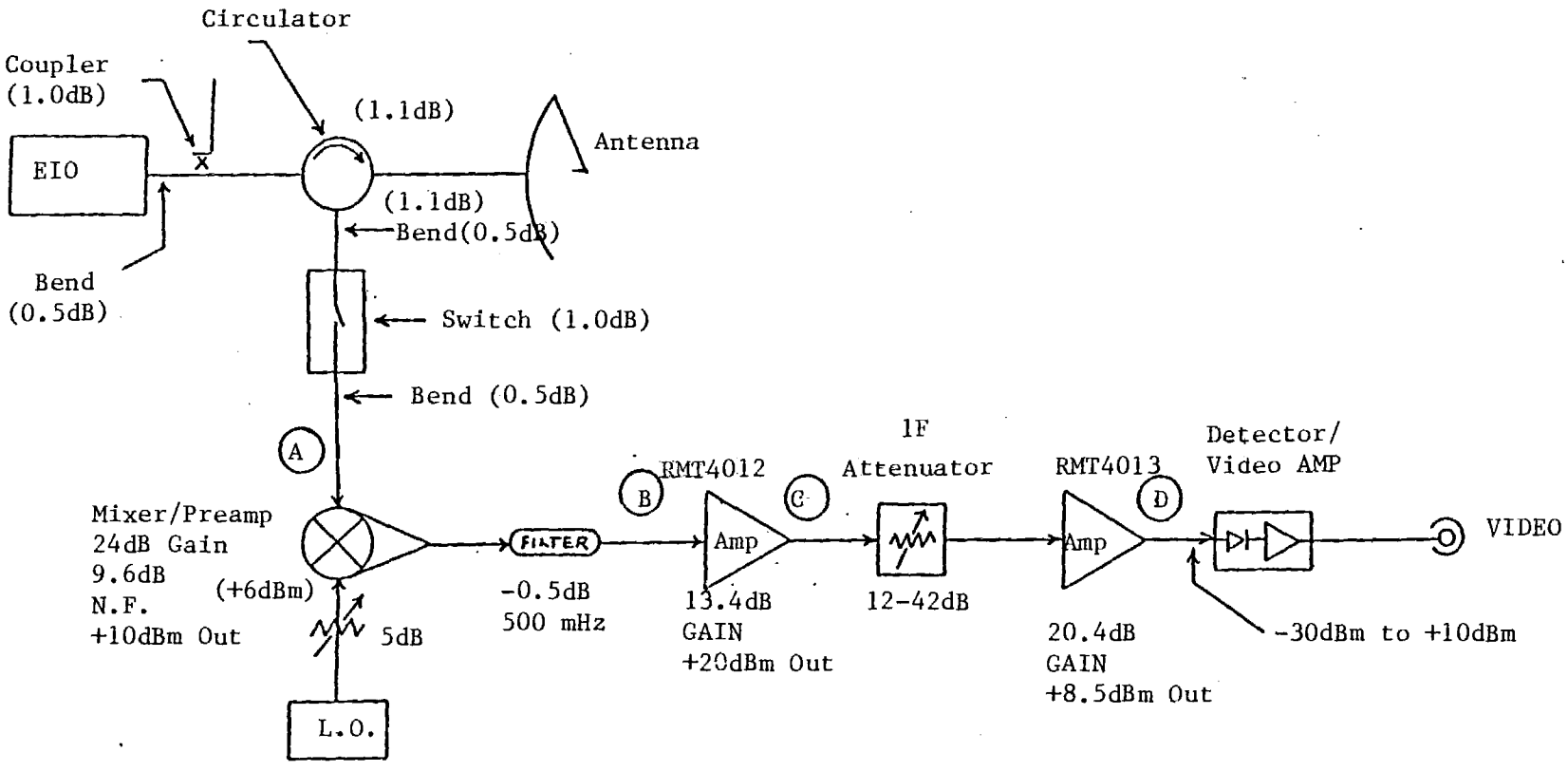


Figure 3. Receiver block diagram.

and lists the important characteristics of these components. The selection and design of these elements is such that a nearly optimum use of the receiver dynamic range is achieved. The system noise level is determined by the mixer/preamplifier noise figure (9.6 dB) and the receiver bandwidth (500 MHz).

$P_n = KTB_nF_n$ yields -77 dBm equivalent noise at the input to the mixer. The mixer/preamp has 24 dB gain, producing -53 dBm noise level out. The filter has a 0.5 dB loss and the first IF amp (AMT 4012) has 13.4 dB gain, providing -40.1 dBm noise. The PIN attenuator has 12 dB attenuation and the 2nd IF amplifier (AMT 4013) has 20.4 dB gain, providing a noise level of -31.7 dB into the detector. This is matched quite well to sensitivity of the detector.

Table 2 shows the signal level at various points in the receiver chain for various signal levels into the system, and for appropriate settings of IF attenuation. The system has an instantaneous dynamic range of 40 dB, limited by the dynamic range of the video detector, and an overall dynamic range of 60 dB, limited on the low end by the system noise level and on the high end by the mixer/preamp saturation point. For signal-to-noise ratios up to 40 dB, there is no need to employ IF attenuation. Under most cases, as shown in Figure 2, the signal-to-noise ratio will not exceed 40 dB so there will seldom be occasion to use the IF attenuator.

TABLE 2. RECEIVER SIGNAL LEVELS

Power at A (dBm)	Power at B (dBm)	Power at C (dBm)	Attenuator Setting (dBm)	Power at D (dBm)
-77 (noise)	-53.5	-40.1	12	-31.7
-67	-43.5	-30.1	12	-21.7
-57	-33.5	-20.1	12	-11.7
-47	-23.5	-10.1	12	-1.7
-37	-13.5	-0.1	12	+8.3*
-27	-3.5	9.9	22	8.3*
-17 (preamp)	+6.5	19.9*	32	8.3*
-14 (saturation)	+9.5*	22.9*	32	11.3*

* This point is at (or near) saturation.

SECTION 3
SYSTEM OPERATION

3.1 OVERVIEW

The 94 GHz radar system is operated via the switches located on the radar control panel, illustrated in Figure 4. The selectable functions on the control panel are POWER, STANDBY, RADIATE, PULSE WIDTH, and IF ATTENUATOR.

The system comprises three main units; the power supply, the control panel, and the radar transmitter/receiver unit. The radar system requires only single phase, 60 Hz, 115 Vac primary power applied to a connector on the power supply. All dc working voltages are generated within the unit for operation.

3.2 POWER SWITCH

Power to the radar system is controlled by the POWER double-pole, single-throw toggle switch located on the control panel. The POWER switch controls the power supplies that provide the dc voltages necessary for system operation. The power supply voltages used in the system are +28 Vdc, +15 Vdc, +8 Vdc, +5 Vdc and -15 Vdc. When the toggle switch is in the OFF position, all power supplies are disconnected from the radar unit. When the switch is in the ON position, all dc voltages are applied to the radar unit and the green power indicator lamp located above the switch is lit. The dc power supplies operate from 60 Hz, 115 Vac.

3.3 STANDBY AND RADIATE SWITCHES

The STANDBY and RADIATE switches are both push-button switches and control the on/off status of the transmitter. When power is first applied to the system by the POWER switch, the system is on and the ON light is illuminated, confirming that +28 V is applied to the system. After a nominal 2 minute warm-up period, the STANDBY light will come on, indicating that the system is ready for transmit mode. To turn the transmitter on,

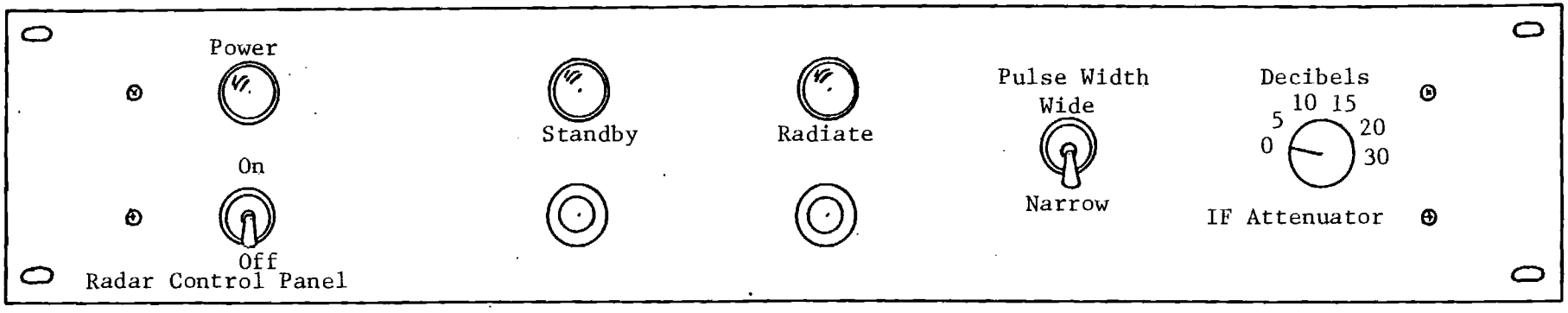


Figure 4. Control panel.

depress the RADIATE pushbutton switch. The yellow STANDBY indicator lamp will go off and the red RADIATE indicator lamp will light up. If power is supplied to the system, and the 2 minute warm-up period has expired, either the STANDBY or RADIATE indicator lamps should be lit.

3.4 PULSE WIDTH SWITCH

The PULSE WIDTH switch is a double-pole, double-throw switch that controls the transmitter pulse width. In the NARROW position, a pulse of 2 ns is transmitted. In the WIDE position, a pulse of 50 ns is transmitted. The pulses are transmitted at a PRF of 10.2 kHz when the radar is in the RADIATE mode.

3.5 IF ATTENUATOR SWITCH

The IF attenuator switch is a six-position rotary switch that sets the amount of attenuation at the input of the second IF amplifier (AMT4013). The purpose of the attenuator is to increase the overall dynamic range of the receiver by preventing the second IF amplifier from saturating at signal-to-noise ratios greater than 40 dB. The attenuation can be increased from 0 dB to 5 dB, 10 dB, 15 dB, 20 dB, or 30 dB. When set at maximum attenuation (30 dB), the attenuator provides approximately 20 dB more dynamic range to the system, allowing the detection of large targets with signal-to-noise ratios of 60 dB without saturating the receiver. Under normal conditions, however, the signal-to-noise ratio will be below 40 dB, so no IF attenuation should be necessary.

SECTION 4

SYSTEM, CABLE, AND SCHEMATIC DIAGRAMS

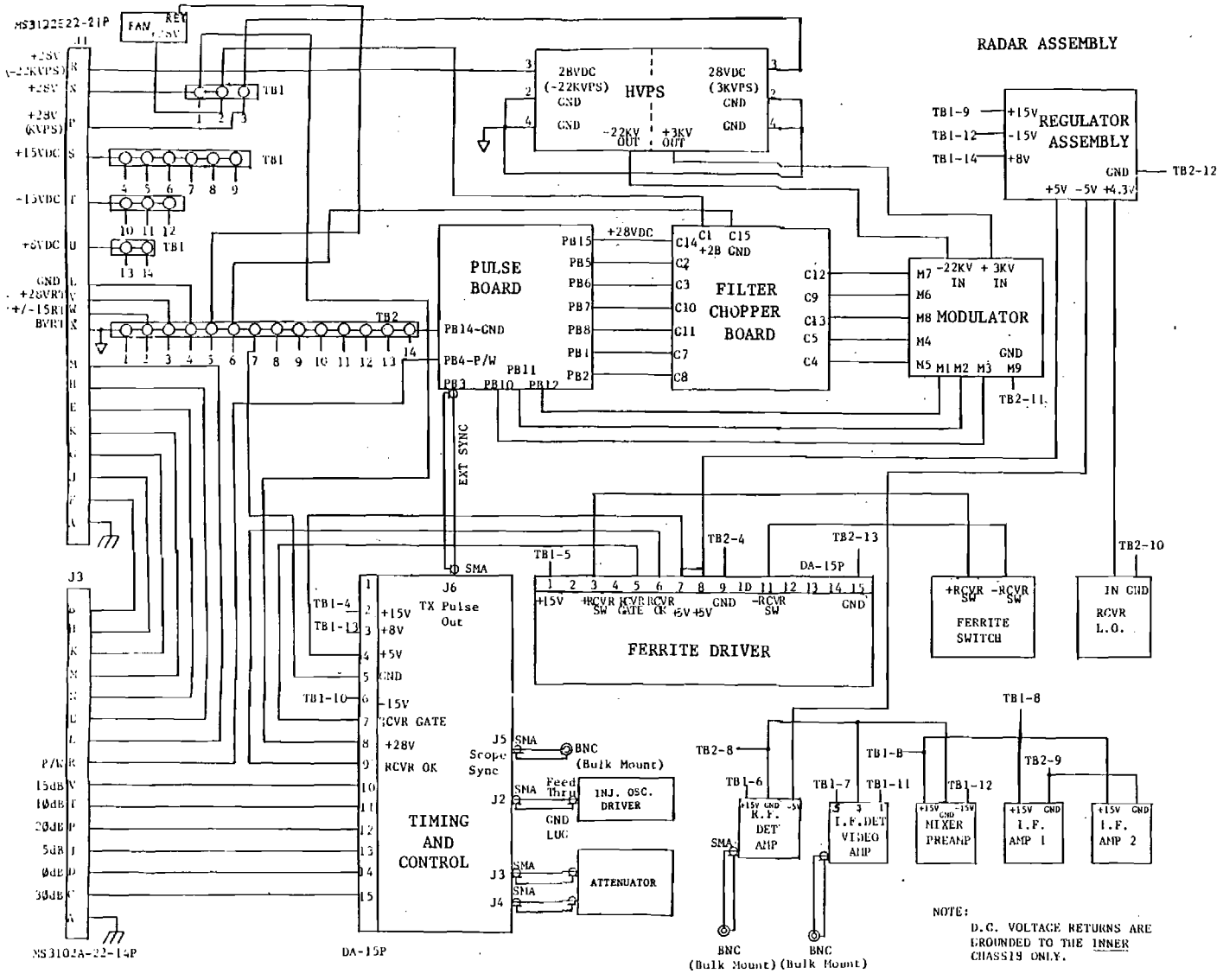


Figure 5. Radar system assembly.

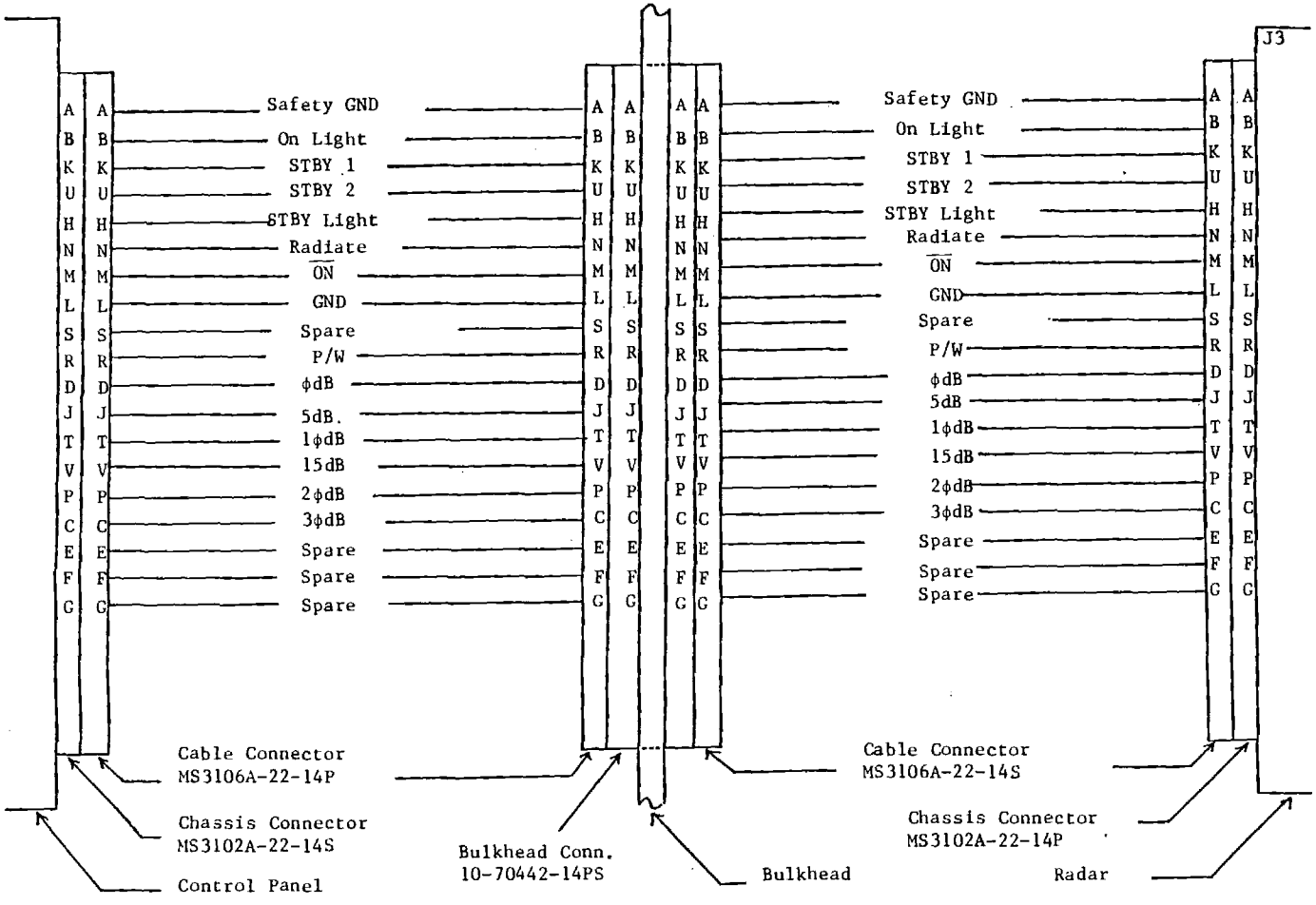


Figure 6. Control panel - to - radar cable.

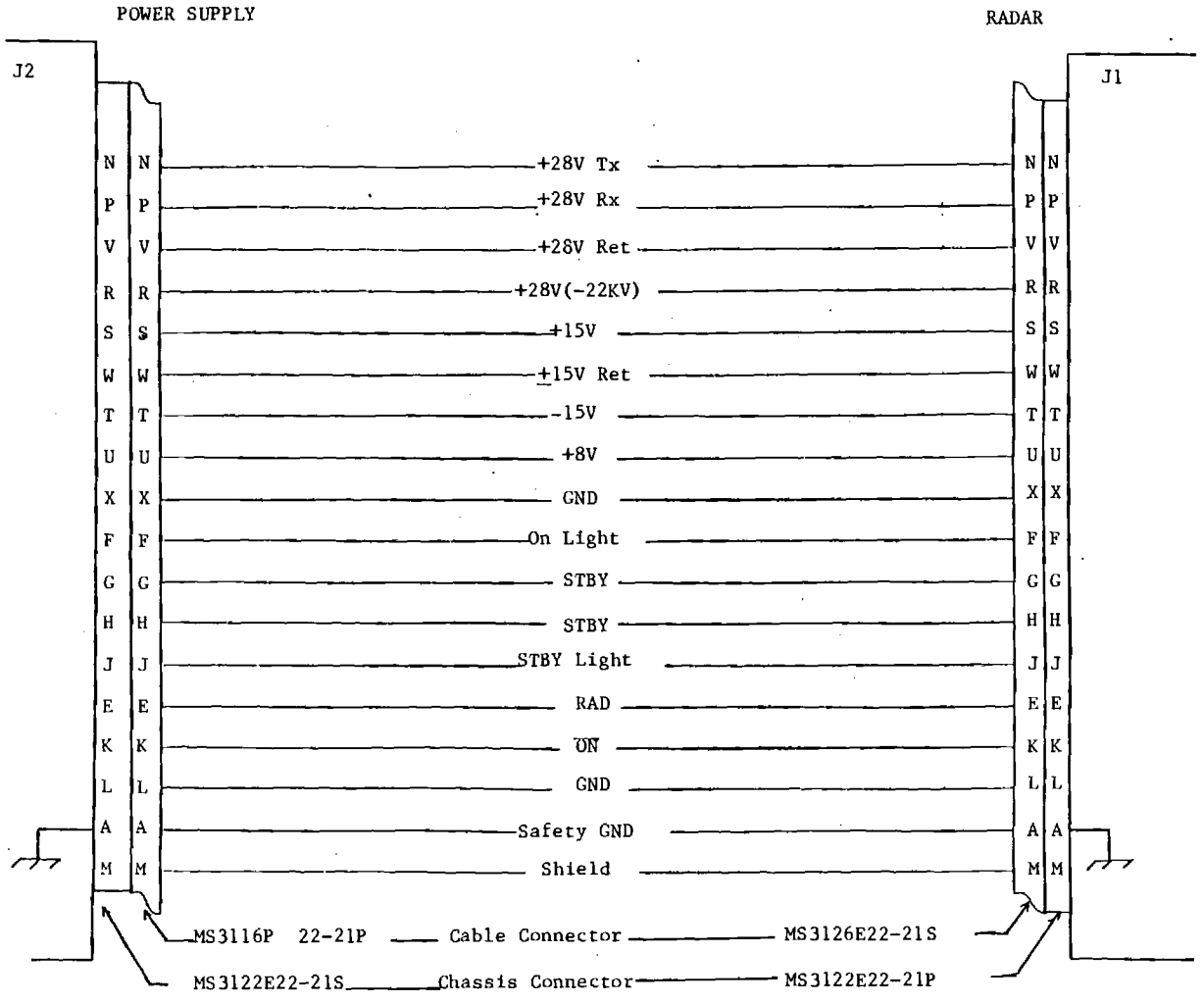


Figure 7. Power supply - to - radar cable.

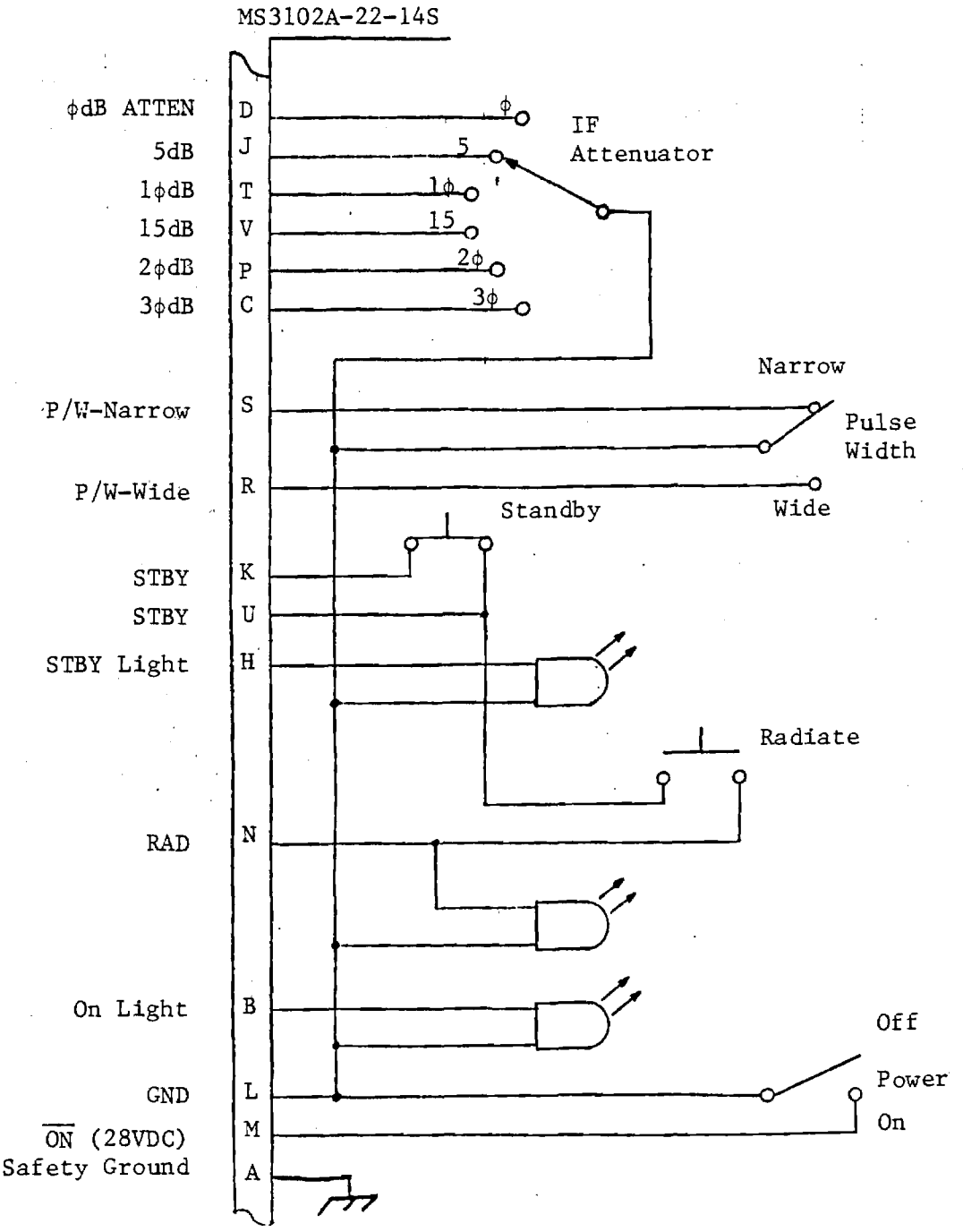


Figure 8. Control panel.

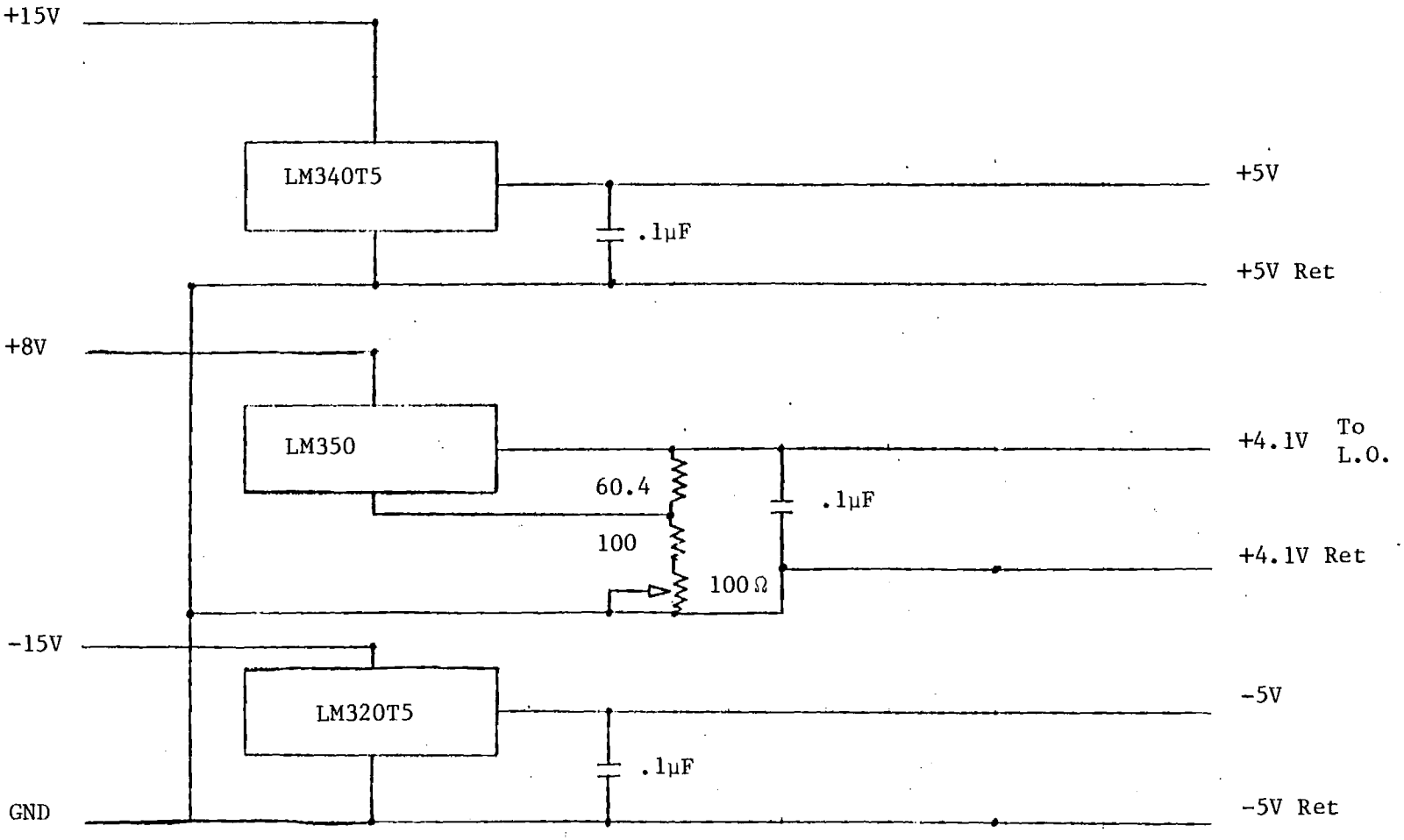


Figure 9. Voltage regulator assembly.

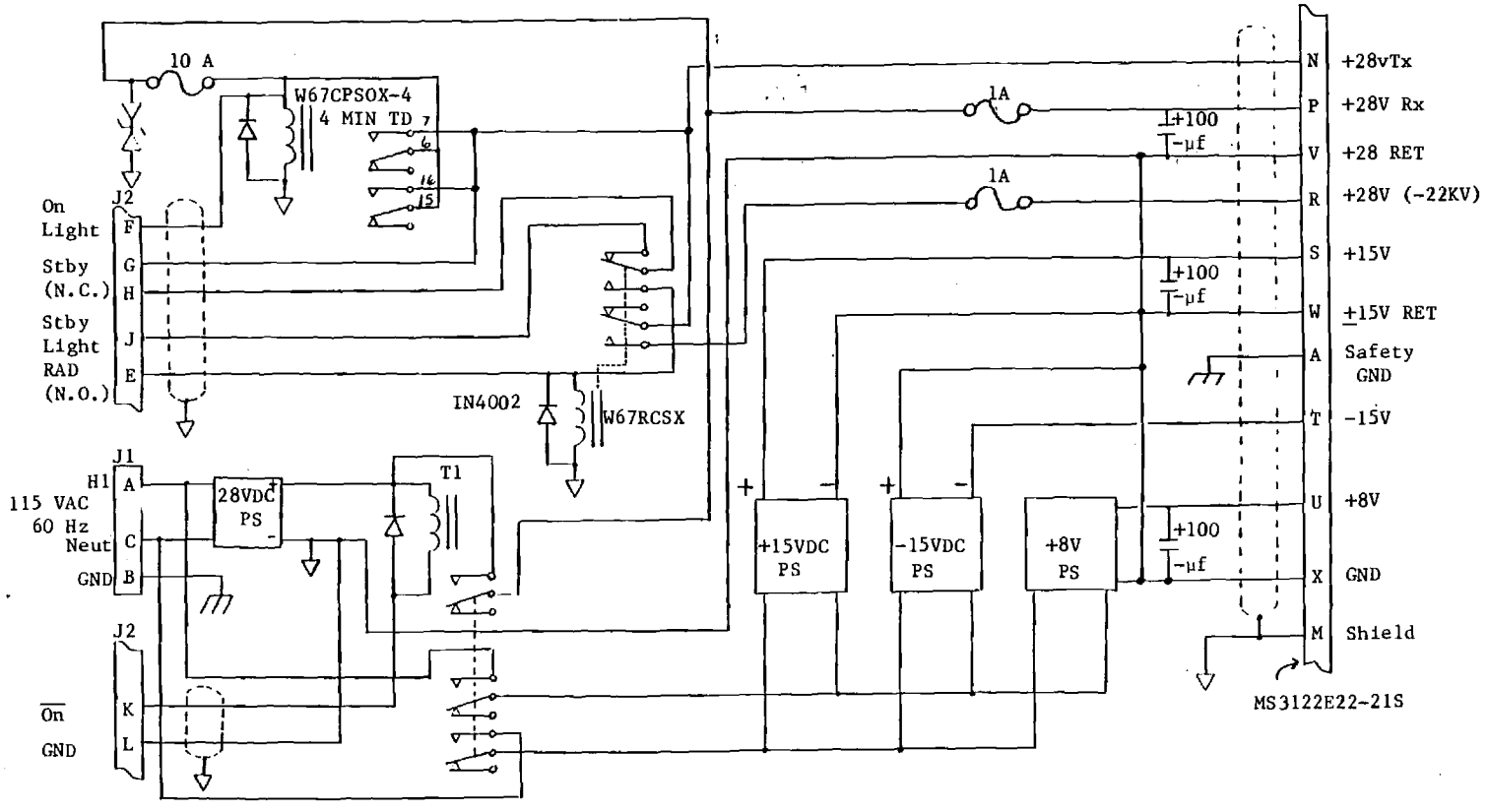


Figure 10. Power supply assembly.

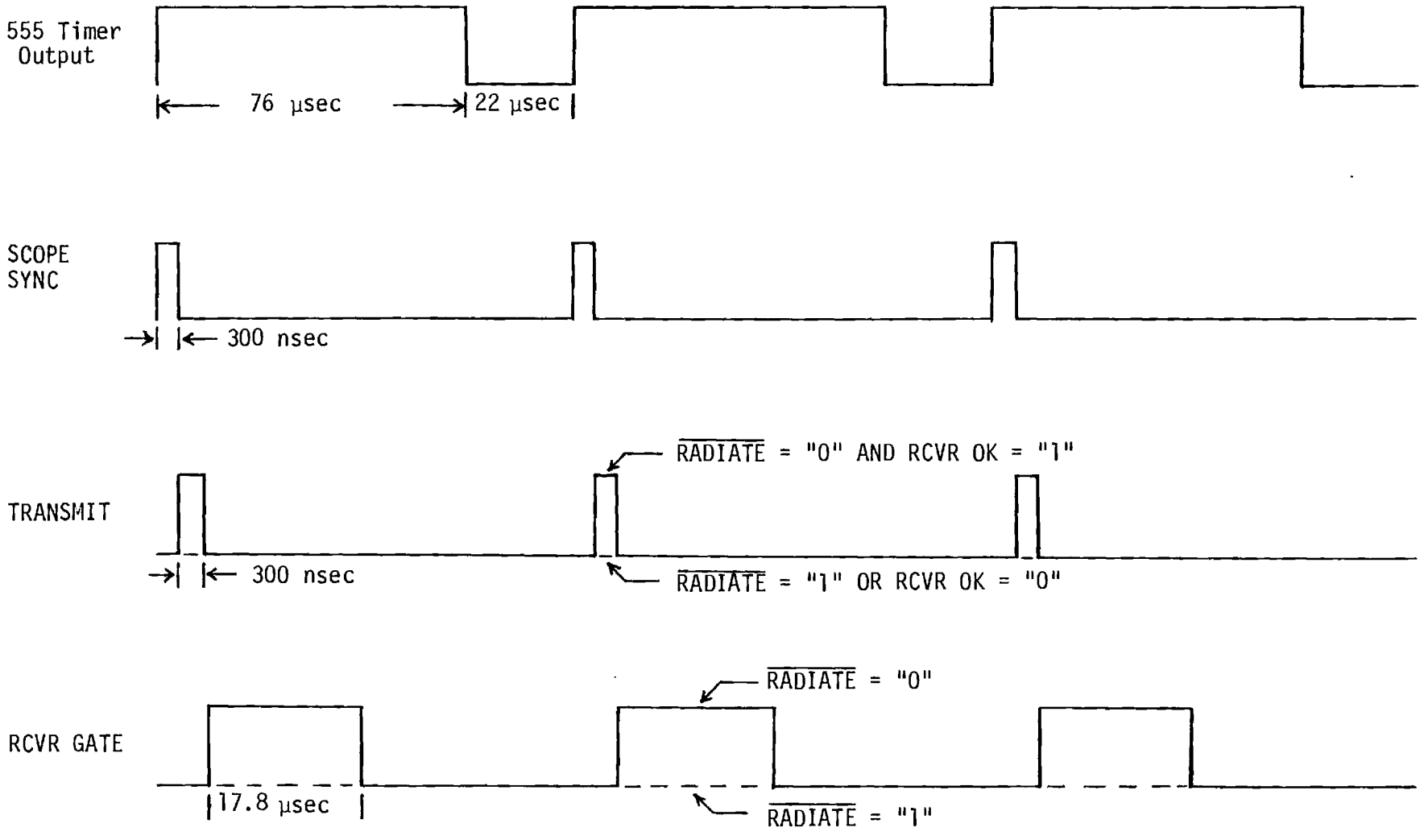


Figure 11. Timing diagram for timing and control circuitry.

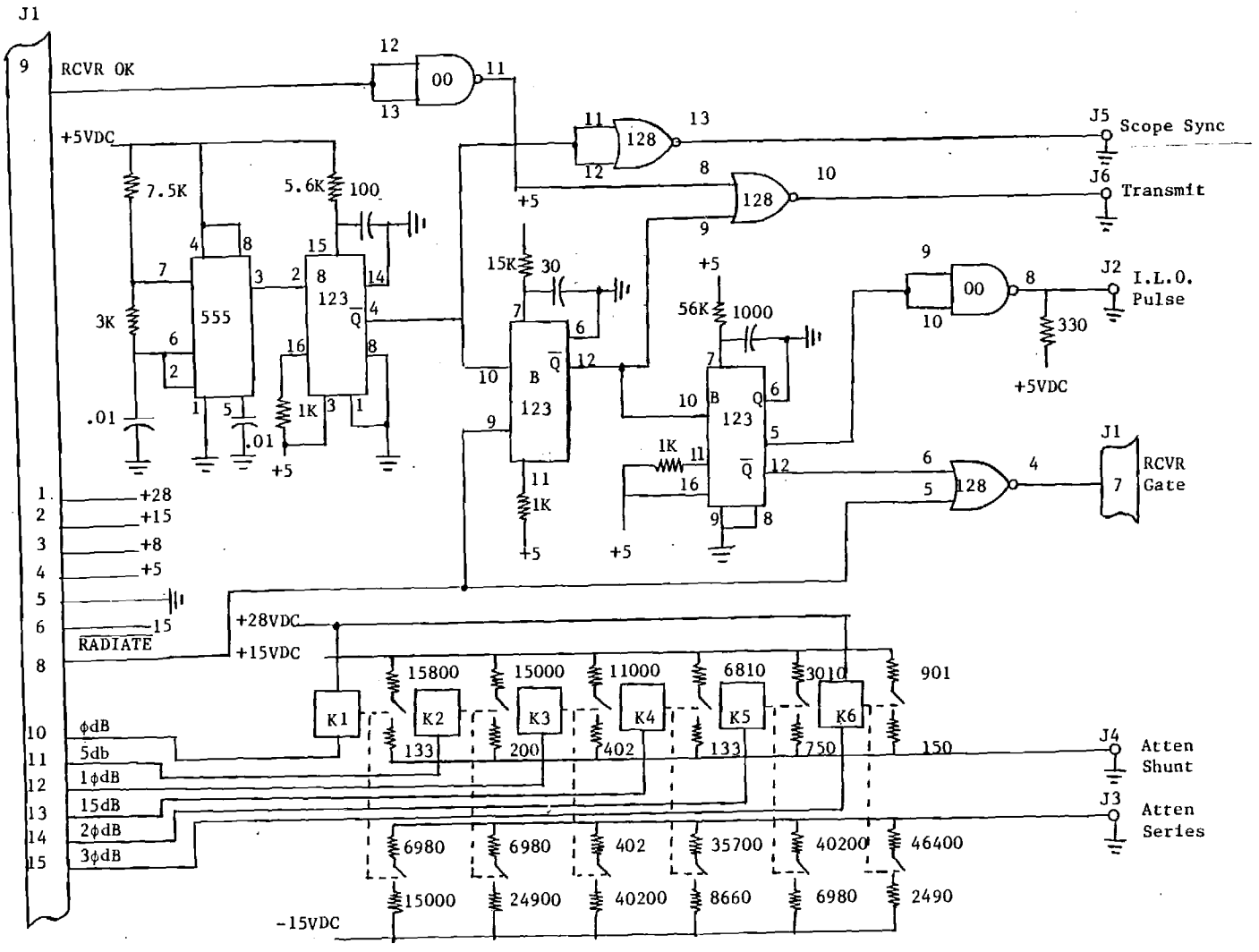


Figure 12. Timing and control assembly.

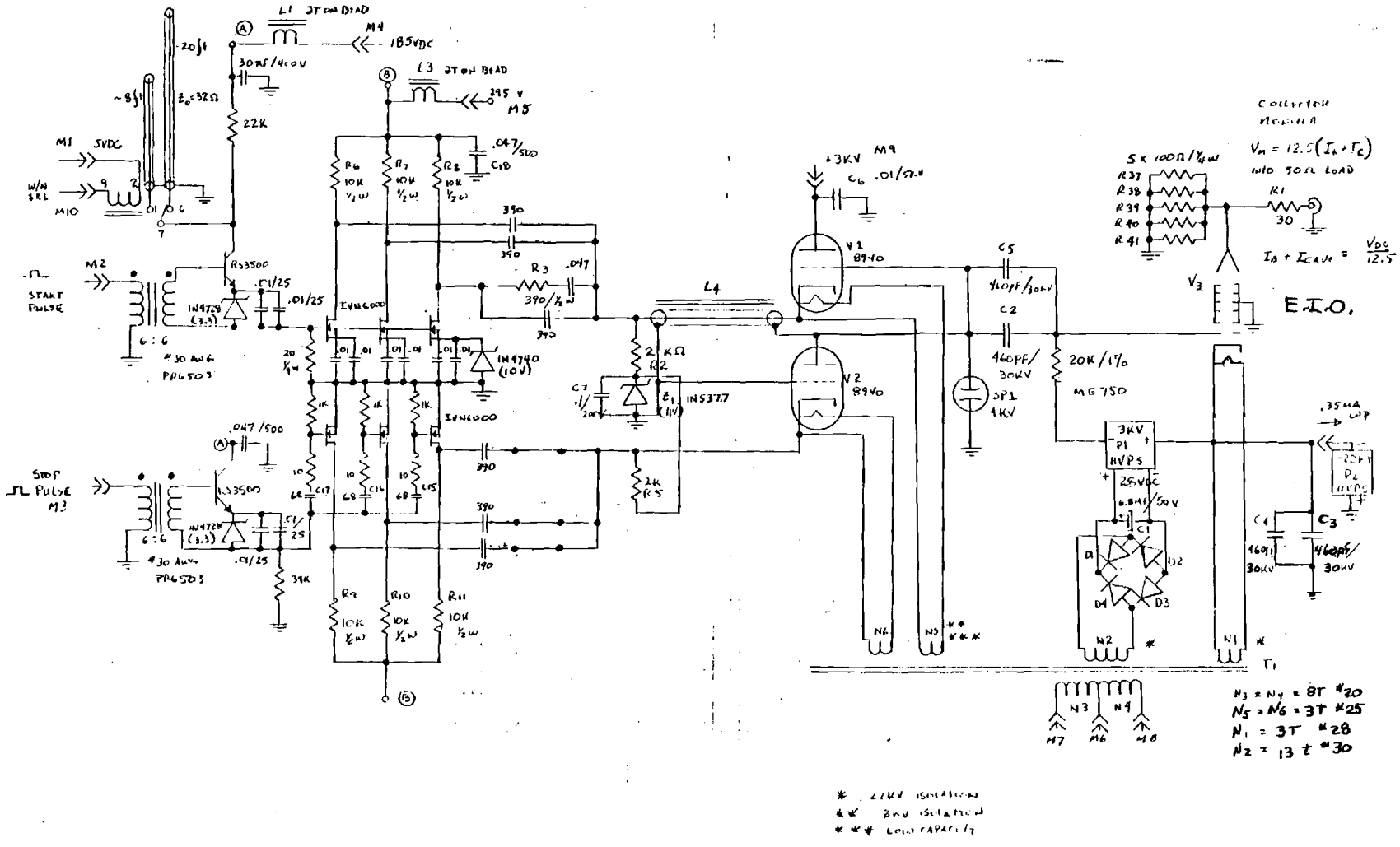


Figure 13. Modulator circuit.

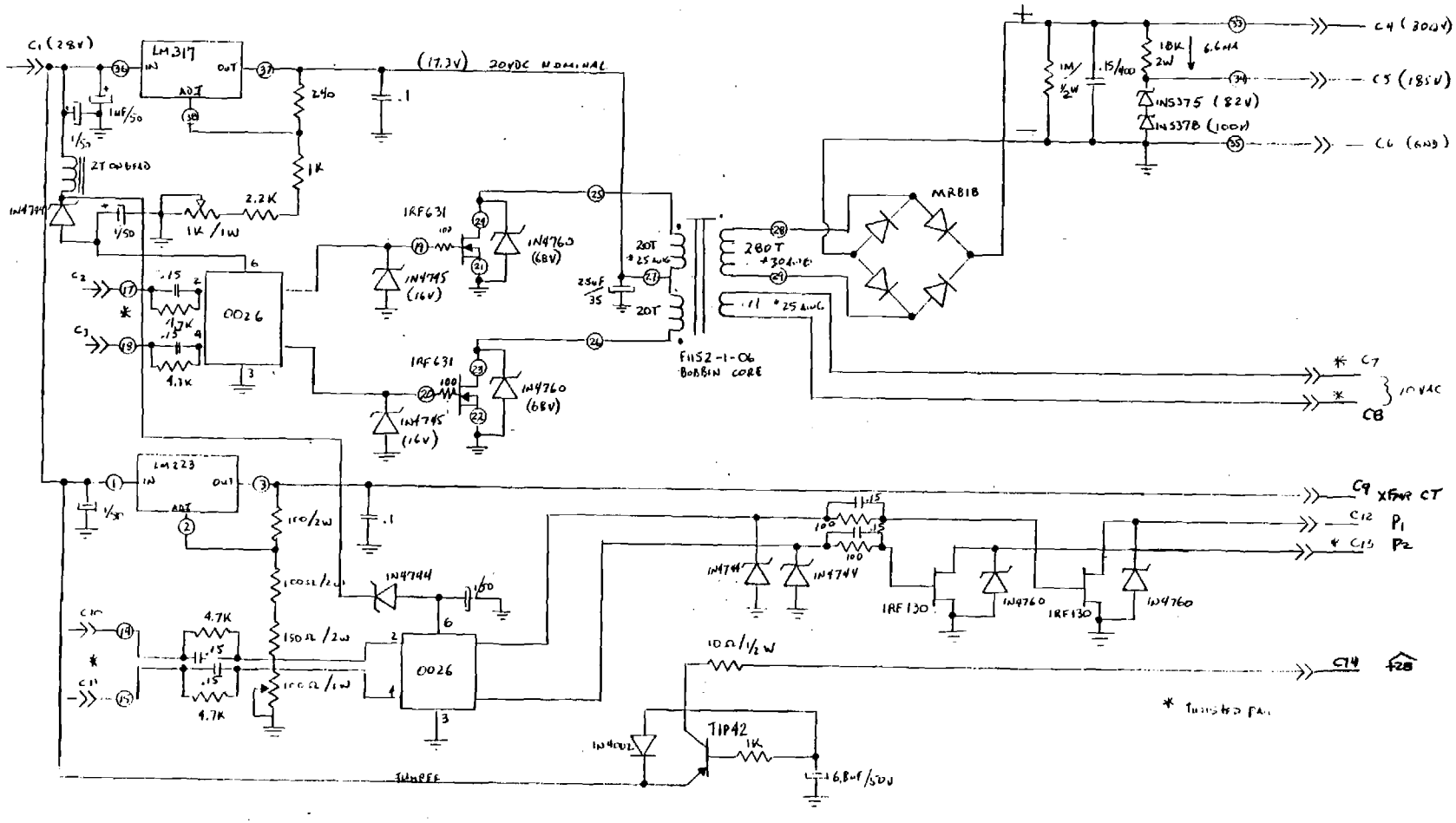


Figure 14. Filament chopper circuitry.

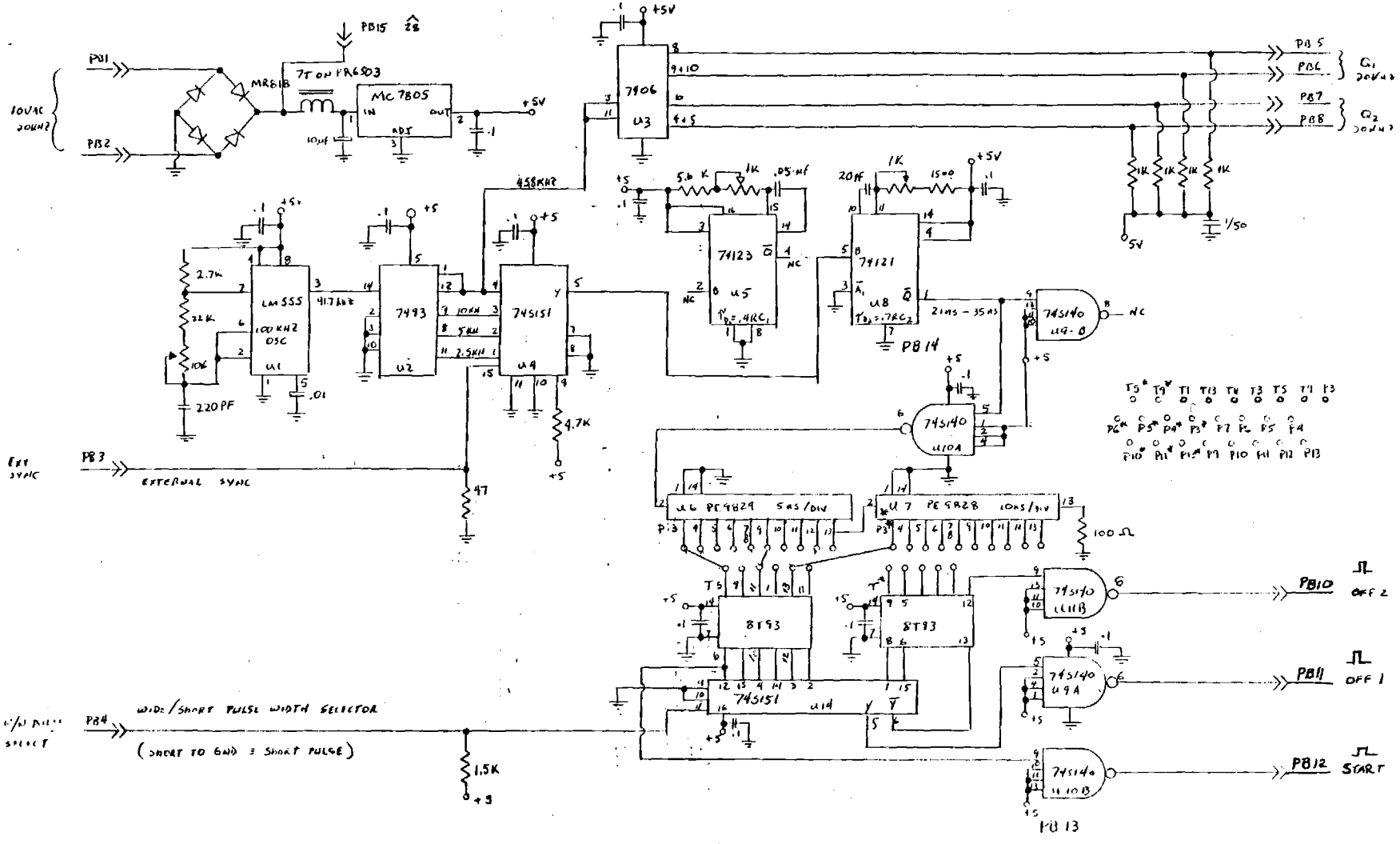


Figure 15. Pulse board.

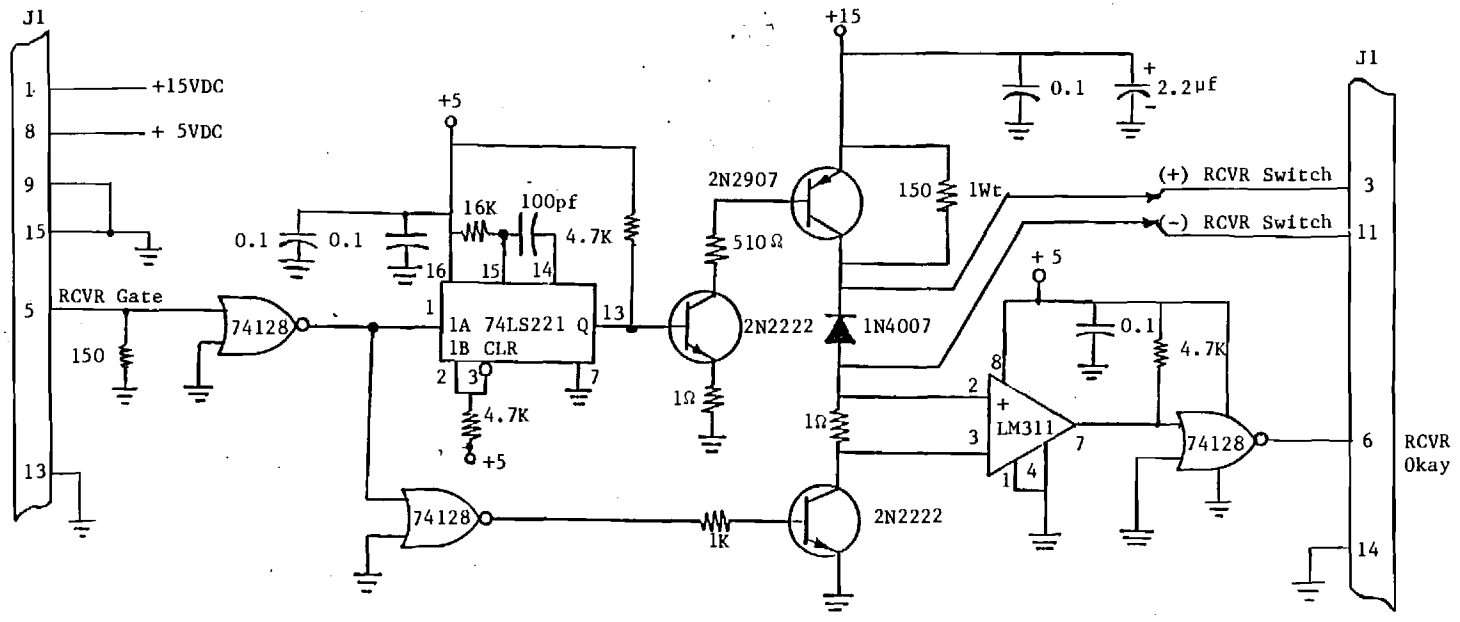


Figure 16. Ferrite switch driver.

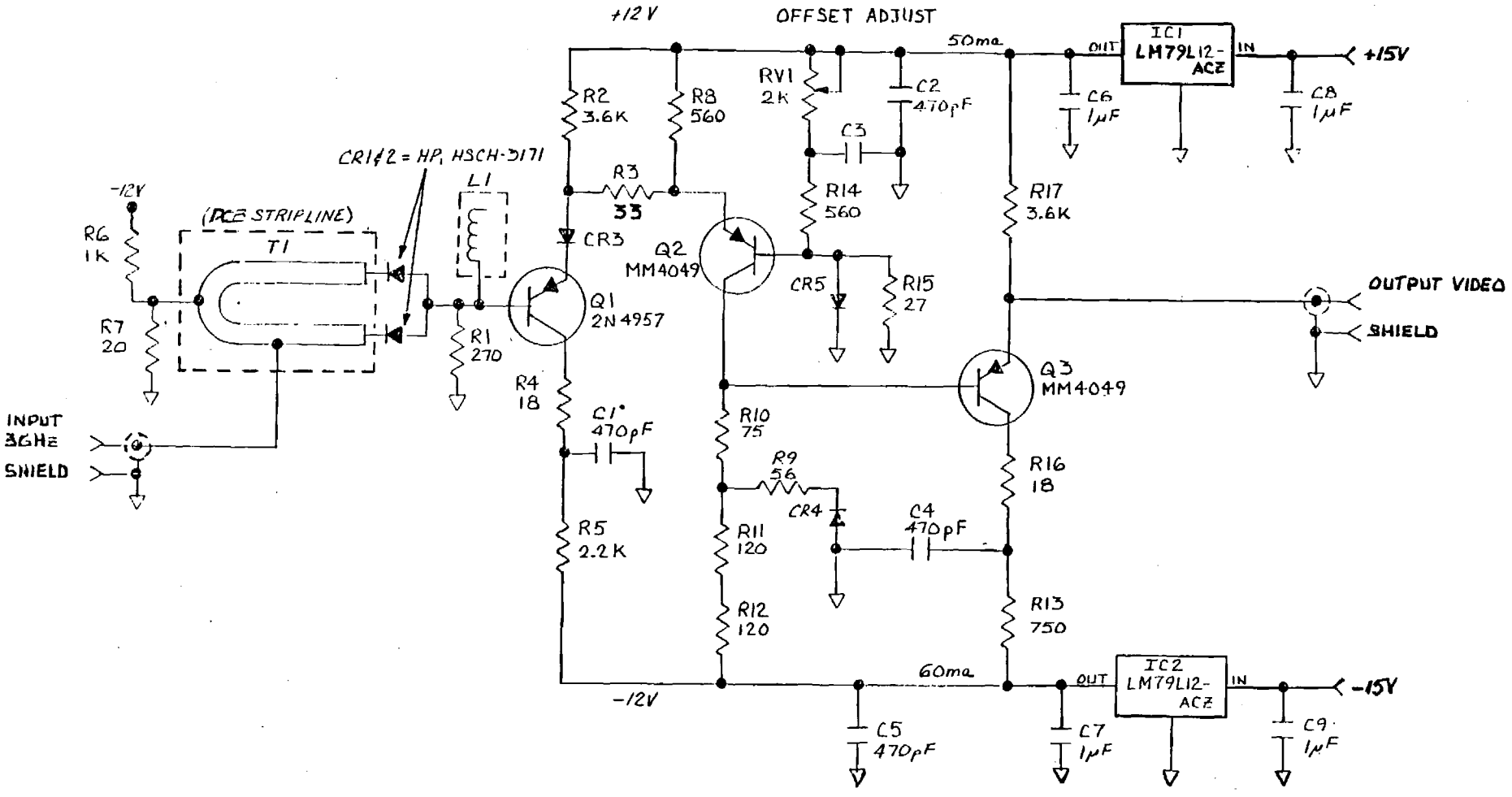


Figure 17. Video Detector/Amplifier

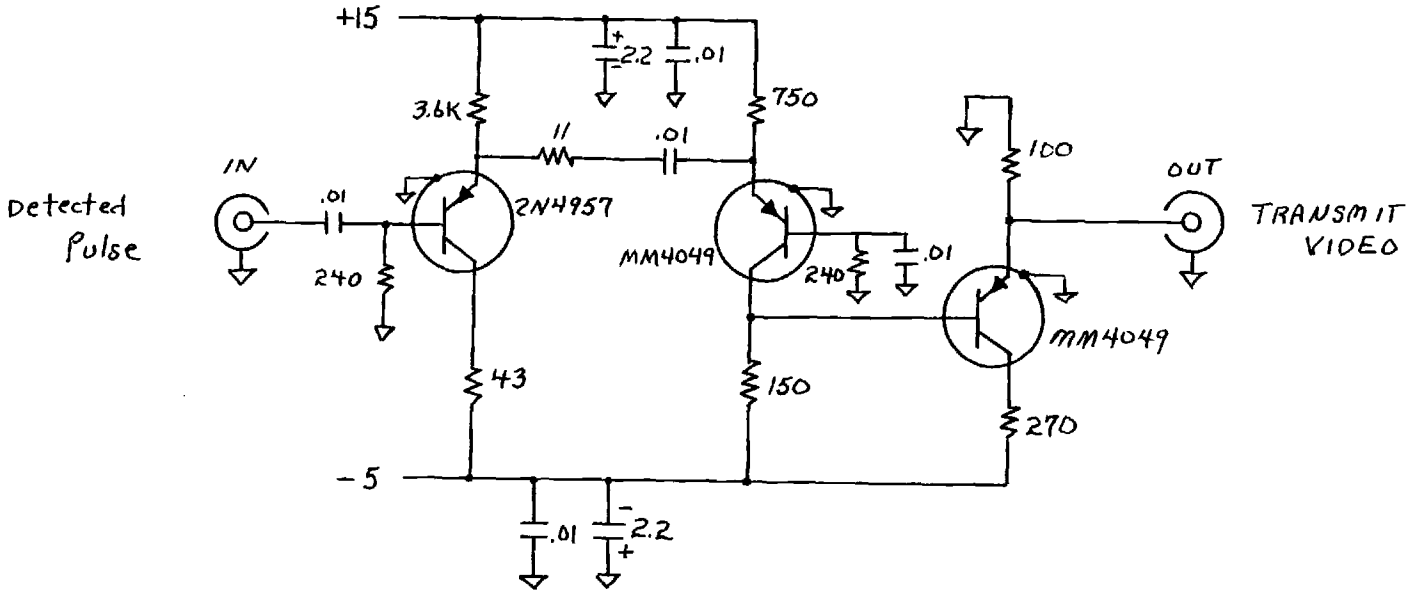


Figure 18. RF detector amplifier.

SECTION 5

ANTENNA PATTERNS

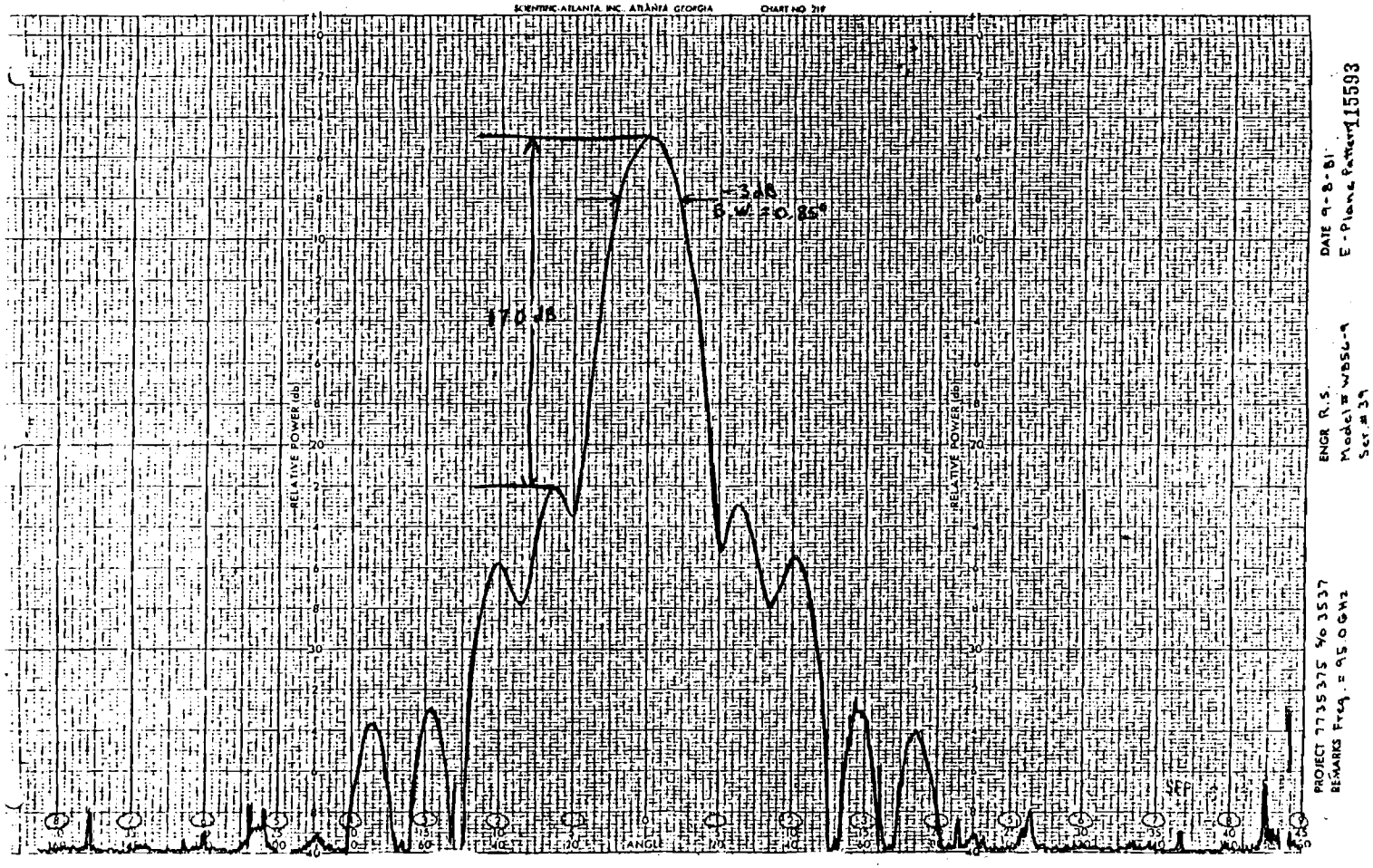


Figure 19. E-plane pattern.

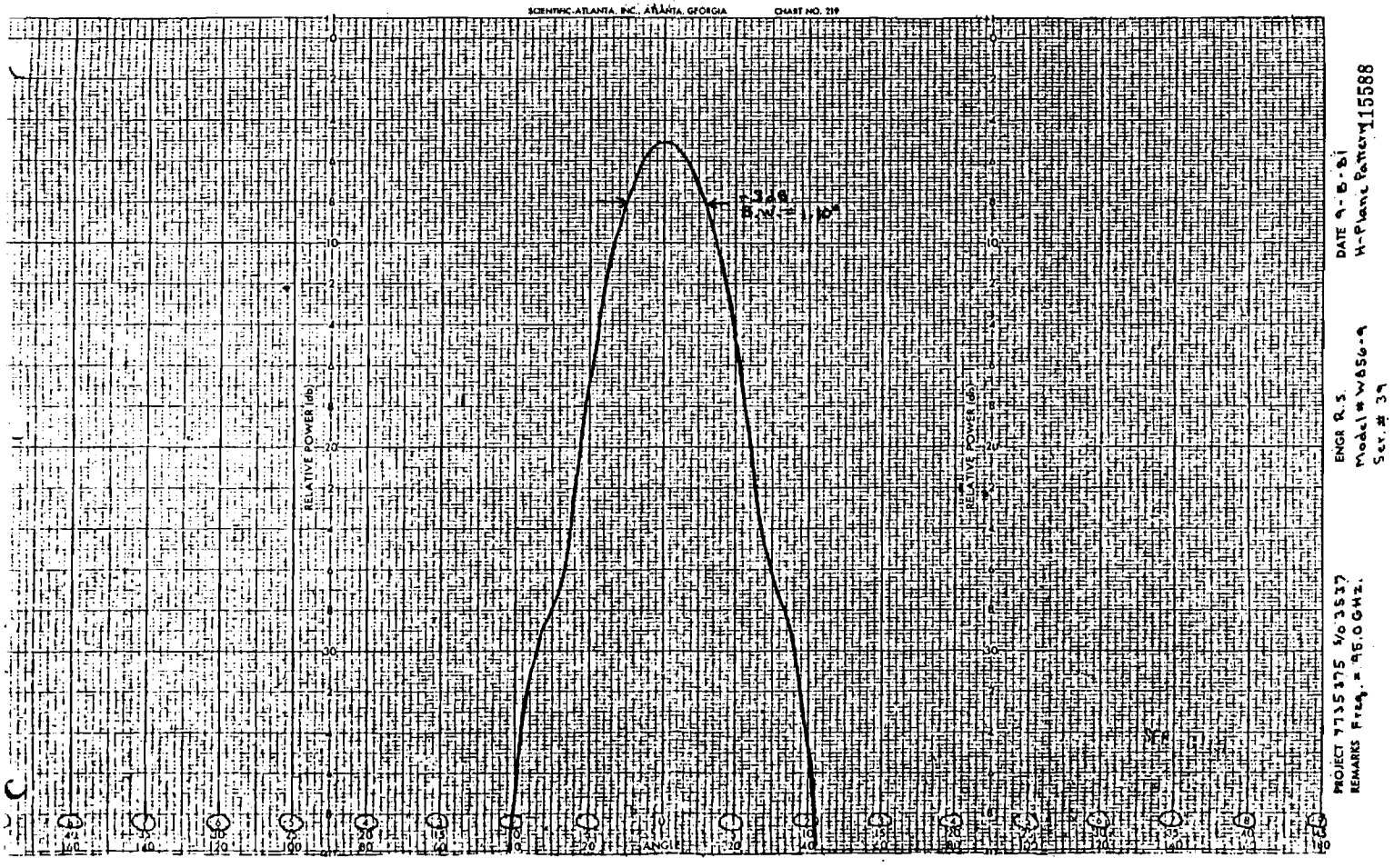


Figure 20. H-plane pattern.

SECTION 6

GRIDDED EXTENDED

INTERACTION OSCILLATOR

INSTRUCTION MANUAL

GRIDDED EXTENDED INTERACTION OSCILLATOR

OPERATING INSTRUCTIONS

VARIAN CANADA INC.
45 River Drive
Georgetown, Ontario, Canada

varian
canada

Tel: (416) 457-4130
TWX: 610-492-2641
Telex: 069-7502

GRIDDED EXTENDED INTERACTION OSCILLATOR OPERATING INSTRUCTIONS

INTRODUCTION:

These operating instructions provide basic information for installing and operating the Pulse Millimeter E.I.O.s. Additional information is given in the Engineering Specification and Test Performance Sheets. The Test Performance Sheet contains test results at specific frequencies for the individual tube. Requests for copies of this publication or additional information should be addressed:

Varian Canada Inc.
45 River Drive,
Georgetown, Ontario
Canada L7G 2J4

PROTECTIVE MEASURES:

Equipment in which these tubes are used should provide protection as described below. In addition, installation and operating precautions must be observed and absolute ratings must not be exceeded.

HIGH VOLTAGE:

Voltage required for the operation of this tube are extremely dangerous to personnel; equipment should be designed with protective interlock circuits which make accidental contact with these voltages impossible.

CURRENT LIMITING:

While every effort has been made to ensure that all electrode spacings within the tube are fully sufficient to withstand the applied voltages an occasional breakdown is not impossible. Since most power supplies use large capacitors for filtering purposes the energy dumped into the tube when a breakdown occurs can be sufficient to damage it beyond repair. It is strongly recommended therefore that a 1000 ohm resistor is used in series with the high voltage supplies unless the peak current is limited in some other way.

HEATER VOLTAGE:

The heater voltage must be supplied from an isolated transformer or DC supply which has adequate insulation. One side of the heater supply (the positive side if DC is used) must be connected to the cathode.

BODY:

The body is normally grounded, this connection includes the R.F. circuit and anode. Ground straps internally connect the body to the magnetic circuit assembly.

The body to cathode (beam) voltage determines both the beam current, when the tube is biased on, and the beam velocity through the R.F. circuit. The beam voltage has an optimum value which changes with frequency. Operation at other than optimum beam voltage will reduce the power output and provide some electronic tuning.

The body has very limited power handling abilities. The absolute ratings limit body dissipation by specifying average body current. However, because the beam is poorly focussed at conditions other than beam fully on, maximum values for pulse rise and fall times and beam cut-off current are also specified.

COLLECTOR:

A collector insulated from the body is provided in order that the body current may be monitored. The collector must always be operated at or close to body potential.

GRID:

This electrode is more correctly called an aperture grid. It provides a means whereby the cathode current may be controlled. However, the electron gun is correctly focussed only when the grid is at cathode potential.

When defocussed most of the cathode current will be intercepted by the body (the effect of this is discussed under the paragraph entitled BODY).

The value of negative grid voltage required to cut-off the beam current will increase as the beam voltage is increased. The minimum cut-off voltage at a particular beam voltage may be determined by reducing the grid bias voltage until 100 microamps beam current is drawn.

GRID -(contd)

The grid dissipates negligible* power unless it becomes positive with respect to the cathode. For normal operation the grid will either be at cathode potential or negative with respect to the cathode. If an attempt is made to use the (positive) grid current to clip the switching pulse it is important not to exceed the rating for grid power.

*. The energy involved here is less than a few milliwatts. When at/or very near cathode potential the grid may receive thermal electrons.

MICROWAVE RADIATION:

Precautions should be taken to prevent exposure of personnel to the microwave fields produced by this tube.

Refer to: American National Standard Safe Levels of Microwave Radiation, published by the I.E.E.E., 345 East 47th Street, New York, N.Y. 10017, entitled A.N.S.I. C95.1.

INTERLOCK SYSTEM:

Interlocks should be built into the system to remove or prevent the application of Beam Voltage if any of the absolute ratings are exceeded.

INSTALLATION INSTRUCTIONS:
HANDLING:

Magnetic materials, tools, etc. must be kept at least 2 inches away from the tube. The tube should be handled by its yoke (painted RED). Never handle the tube by the collector fins, electrical leads or tuner.

MOUNTING:

The E.I.O. may be mounted in any orientation using the 8-32 mounting and grounding holes. (See outline drawing).

Keep magnetic materials at least 2 inches away from the tube.

INSTALLATION INSTRUCTIONS (contd)

COOLING:

This tube is forced air cooled. Body temperature should be measured at the ground lug, collector temperature at the screw connector.

Maximum temperatures at these points are specified in the absolute ratings. It is the users responsibility to ensure that these figures are not exceeded. In order to monitor the temperature the lead must be removed, a thermocouple attached and lead replaced. However, 15CFM of air at 20°C and at sea level directed on the collector fins through a one square inch aperture from a distance of one inch, will normally provide sufficient cooling.

ELECTRICAL CONNECTIONS:

YELLOW	-	HEATER	BROWN (MOUNTING SCREWS)	-	BODY
WHITE	-	CATHODE	GREEN	-	GRID
BLUE	-	COLLECTOR			

The high voltage lead wires are not suitable for running adjacent to a ground plane. An air gap or increased insulation may be necessary to eliminate corona.

RF CONNECTIONS:

The tube is provided with a WR10 (.050" x .100") waveguide and a flange to mate with either:

1) UG 387/U modified
2) MIL-F-3922/67B-010
3) Ring alignment

IT IS ESSENTIAL THAT THE MATING FLANGE BE FLAT

This connection must be made with care in order to avoid gaps between the mating surfaces and to avoid overtightening the flange screws.

The method of flange connections are shown in Fig. 21 - 23.

The tube window is .001" thick, under no circumstances allow solid objects to enter the output waveguide.

Waveguide pressurization should not be needed however dust and small guide imperfections often cause electrical breakdown at power levels at little more than 1 KW so pressurization may be desirable. Refer to the absolute ratings for the maximum allowed waveguide pressure.

INSTALLATION INSTRUCTIONS (contd)

TUNER OPERATION:

The tuner is on the opposite face of the tube to the waveguide output flange. Clockwise rotation raises the frequency.

No attempt must be made to dismantle the tuning mechanism. Should the tuner appear to be malfunctioning, contact VARIAN CANADA, INC. for advice.

Mechanical stops are provided which normally allow the tube to be tuned somewhat beyond the specified frequency range. Damage could result if an attempt is made to tune beyond the range allowed by the stops. Unnecessary tuning should be avoided.

The trimmable tuner is designed to make up for mechanical tolerances in frequency sensitive components in the tube. It should therefore only be used to bring the tube on to the required frequency, and for occasional adjustments. The tuning diaphragm will survive several hundred complete tuning cycles but it does have a finite life. The only tool required to change frequency is a screwdriver.

OPERATING INSTRUCTIONS:

The tube is connected to the power supplies as shown in Fig. 24 and protected as discussed previously. This is similar to the circuit used at Varian. It is assumed that all power supplies are off and their controls set at zero before proceeding.

Under no circumstances exceed the maximum current specified in the individual tube operating instructions. This would be possible if the grid were to go positive WRT the cathode. The tube may also be connected to the power supplies as shown in Figure 25 and 26.

a) Before applying any voltages it is recommended that the following check list be covered:

   1) Collector connected to power supply positive (normally ground)
   2) Body connected to ground.
   3) Heater, cathode and grid leads connected to their respective supplies and adequately insulated.
   4) Forced air flow is adequate.
   5) Ensure, by the use of trips, adjustment stops,etc. that the absolute ratings will not be exceeded. (Note i)

OPERATING INSTRUCTIONS (contd)

Pay special attention to average power dissipation on the electrodes.

6) Personnel will not be subject to exposure from the microwave fields.

b) Switch on heater.

c) Switch on and increase the grid bias voltage to a value required to cut-off the cathode current at the proposed beam voltage. Note i and ii.

d) Switch on and increase beam voltage to a value appropriate to the desired frequency of operation. Note i and ii.

e) Switch on pulser. Note i, ii and iii.

f) Adjust the tuner until the tube oscillates at the desired frequency. If the beam voltage has been set correctly the tube should now be operating at the peak of the mode. i.e. the maximum power output. However in most cases it will be necessary to optimize the beam voltage if the maximum possible power is required. Since this results in some electronic tuning, a small tuner adjustment will be required to obtain a specific frequency. Working in this way, the maximum power output at a given frequency may be obtained.

NOTES

i) See absolute ratings page 39.

ii) See test data supplied with tube.

iii) The tube is on when the grid is at cathode potential i.e. the grid pulse amplitude should be equal to the bias voltage.
If the grid pulse is provided by an adjustable supply (as in circuit Fig. 25) the requirement that grid potential be equal to cathode potential may be set by adjusting the grid pulse for minimum body current. Do not exceed the maximum rating for body dissipation during this operation.

SHIPPING INSTRUCTIONS:

In the event of the tube being returned to the manufacturer or shipped to any other point by conventional carrier:

(1) Cover the W/G output.

(2) Place the E.I.O. in styrofoam cutouts, ensure that the collector fins and gun cover are clear, they must not take the weight of the tube.

(3) Fit the packaged E.I.O. into the foam lining inside the container.

(4) Seal the container.

(5) Identify the package as called for by your carrier.

If the original containers are not available, please contact Varian of Canada before shipping the tube. Tubes shipped without following these instructions will likely be damaged and could void the warranty.

ABSOLUTE RATINGS:

For tube: VKB2445T1 E0302J2

Note that a single rating may be the limitation and simultaneous operation at more than one rating may not be possible.

	MIN	MAX	UNITS
Cathode to Body (ground) voltage	-	22.0	KV
Cathode to Grid voltage	-	3.0	KV
Heater Voltage	6.1	6.5	VOLTS
Collector to body voltage	-	2000	VOLTS
Beam cut-off current	-	0.1	mA
Beam current	-	3.5	mA Ave.
Body current	-	0.5	mA Ave.
Grid power	-	0.5	watts
Pulse length	-	20	microsecs
Pulse rise time	-	5.0	microsecs
Pulse fall time	-	5.0	microsecs
Duty cycle	-	.005	
Waveguide pressurization	-	30	lbs./sq in
Cooling air flow (across the collector)	15	-	CFM
Heater warm up time	1	-	mins.
Collector temperature	-	150	°C
Body temperature	-	100	°C
Load VSWR (All Phases)	-	2:1	

VARIAN CANADA INC.

Test Data for Extended Interaction Oscillator

Model No. VKB 2445T1 Serial No. E0302J2

Test Frequency (GHz)	Power Output (W) Peak	Beam Voltage (kV) wrt cathode	Beam Current (mA) Peak	Body Current (mA) Peak	Grid Bias Voltage (kV) wrt cathode	Electron Tuning Range (MHz)
94.0	1230	+20.21	630	65	- 2.7	190
95.0	1030	+21.00	660	72	- 2.8	265
96.0	1200	+21.00	660	88	- 2.8	200

Average Test Data Calculated using: Ave Value = peak value x duty

Max Duty = .005

Average Beam Current = 3.3 mA

Average Body Current = 0.5 mA

Heater Current = 0.94 A @ 6.3 V	
Coolant Flow = 60 CFM of Air @ 12"	
Tested by: Ed Sokol	Date Tested: 31 August 82
Date Inspected:	Inspected by:
Customer: Georgia Institute of Technology	Sales Order No.: 5230 5762A
Date Shipped:	CM Number:

METHOD OF ASSEMBLY TO E.I.O. COMBINATION FLANGE.

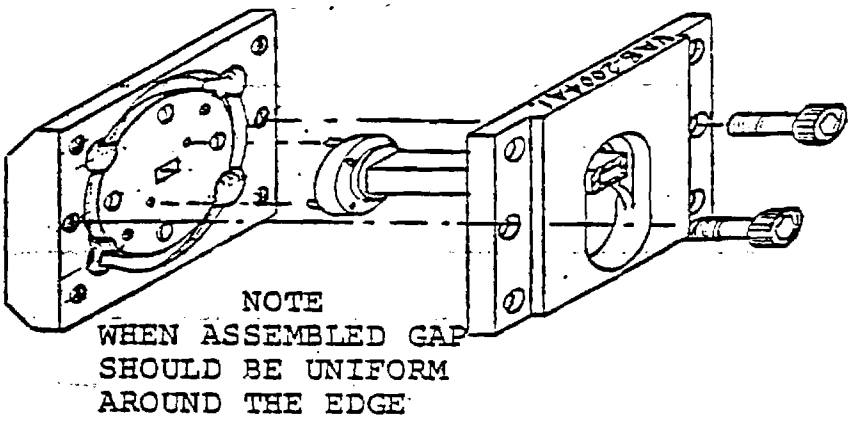


Figure 21. Submillimeter contact flange (FXR type).

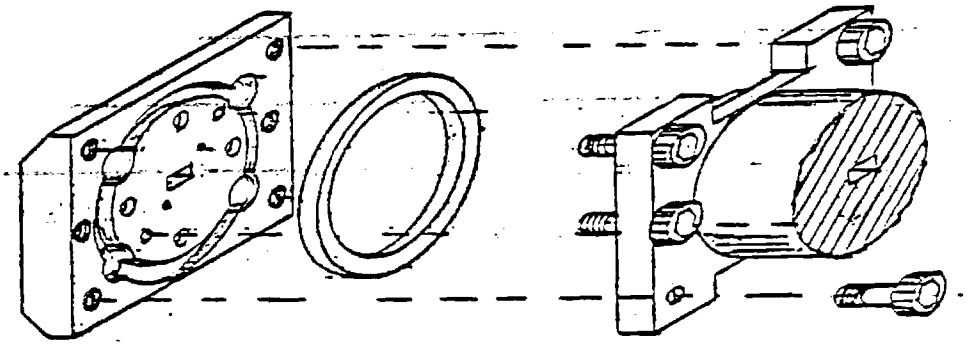


Figure 22. Ring alignment flange.

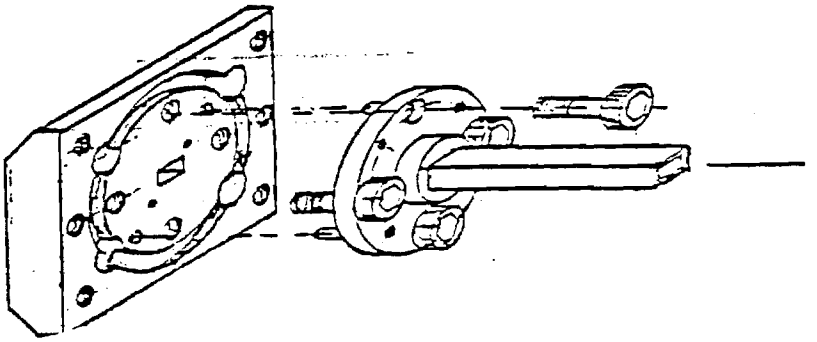
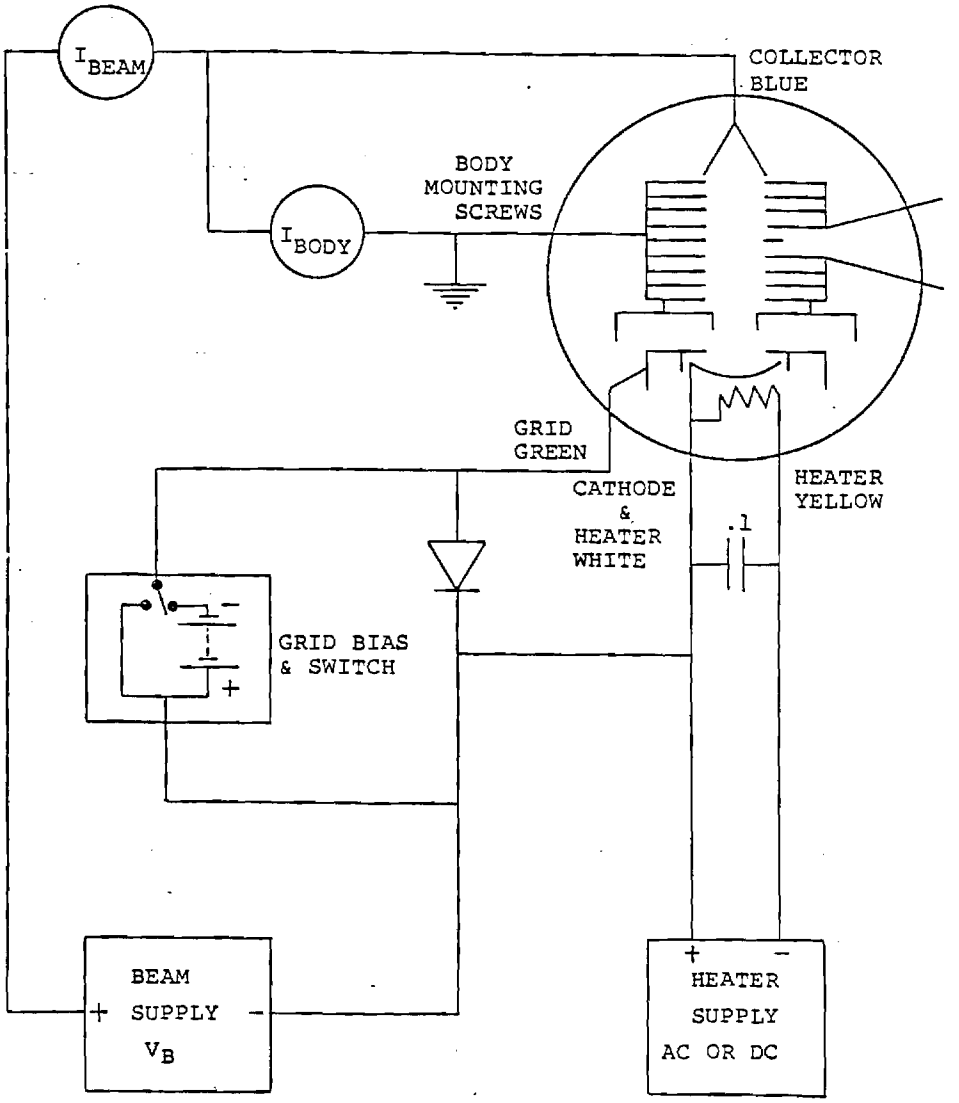


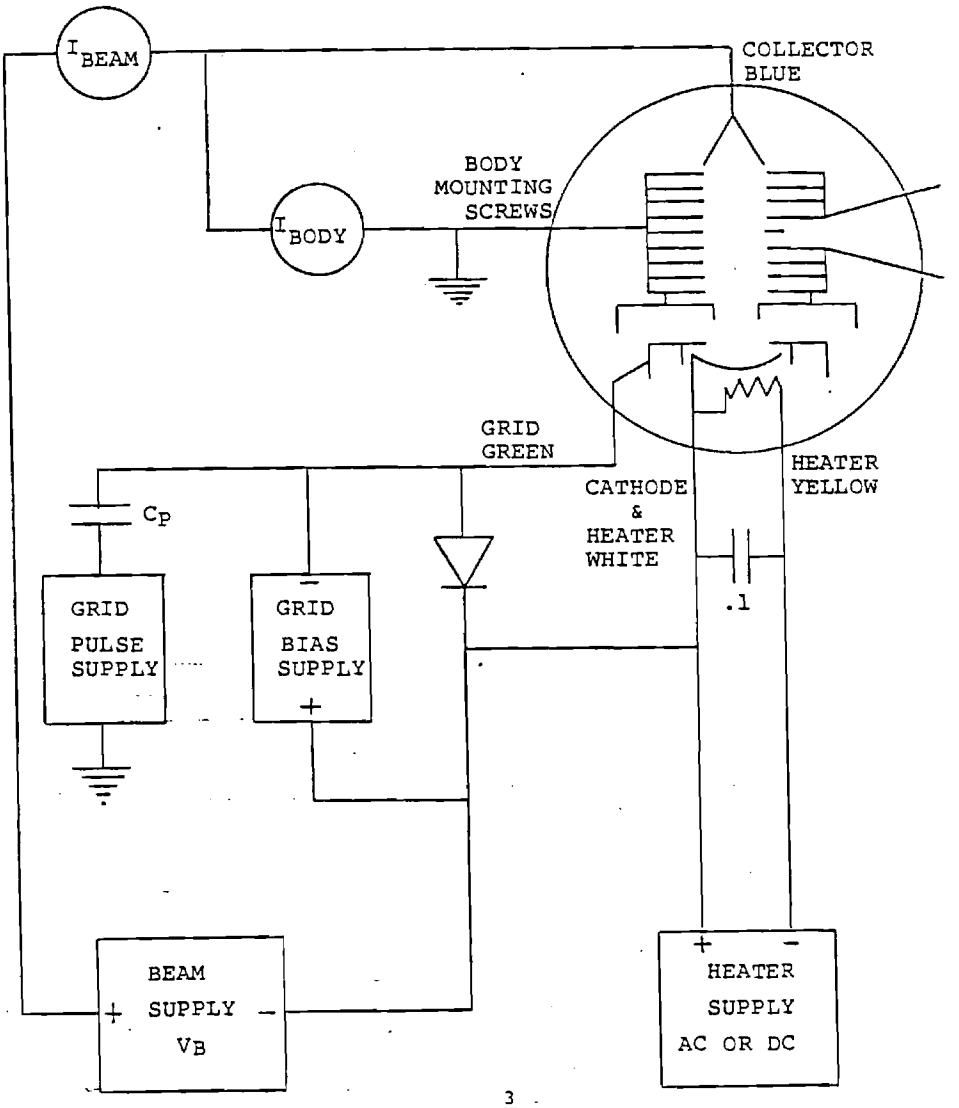
Figure 23. Millimeter contact flange (UG 385/U type).



1) BEAM CURRENT = $.2 \times 10^{-6} V_B^{\frac{3}{2}}$ AMPS APPROX

2) DIODE PREVENTS GRID FROM BECOMING POSITIVE W.R.T. CATHODE

Figure 24. Typical circuit for switched grid bias supply for a gridded EIO.



1) BEAM CURRENT = $.2 \times 10^{-6} V_B^{\frac{3}{2}}$ AMPS APPROX

2) CAPACITANCE C_P CHOOSEN ACCORDING TO REQUIRED PULSE LENGTH VOLTAGE RATING IS THE SUM OF BEAM PLUS BIAS VOLTAGE.

3) DIODE PREVENTS GRID FROM BECOMING POSITIVE W.R.T. CATHODE.

Figure 25. Typical circuit for a capacitor coupled grid pulsed EIO.

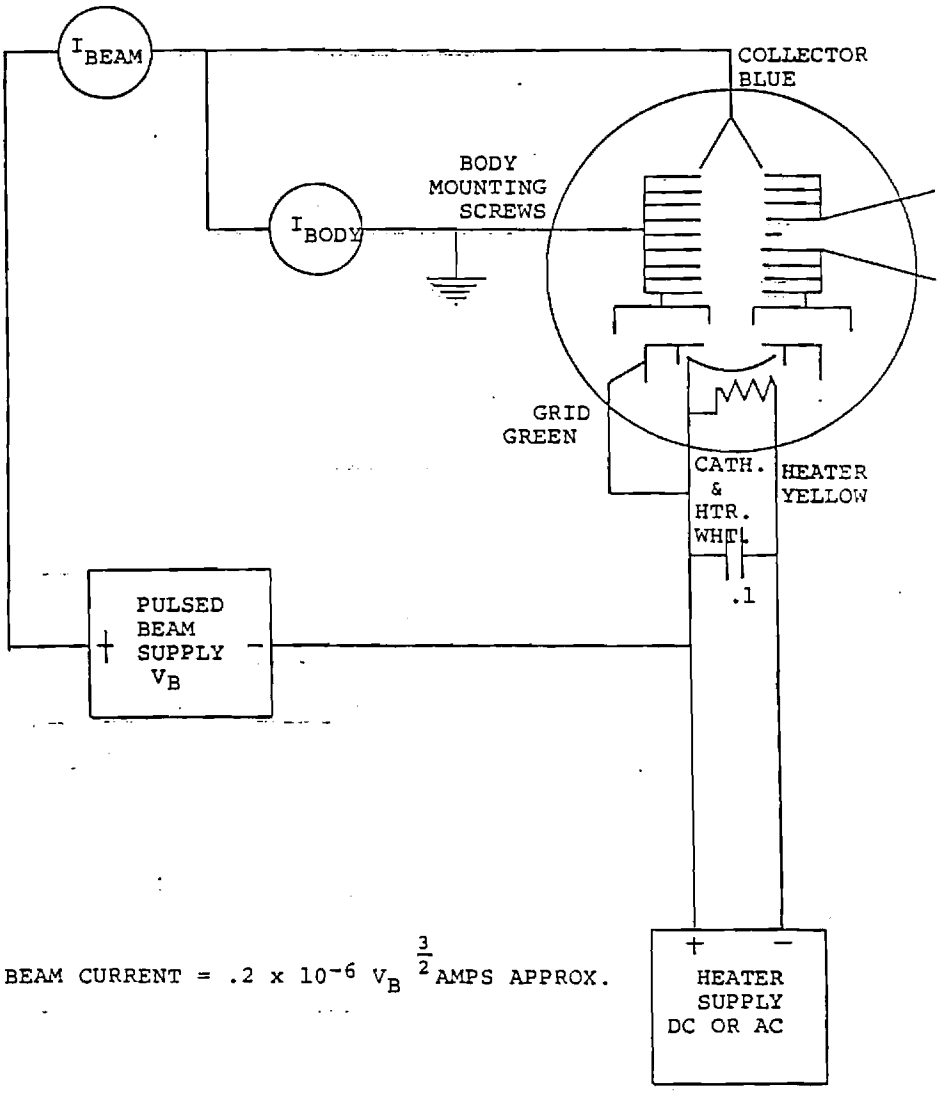


Figure 26. Typical circuit for a gridded EIO operated from a single power supply.

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OPERATING HAZARDS

READ THE FOLLOWING INSTRUCTIONS AND TAKE ALL NECESSARY PRECAUTIONS

OPERATING INSTRUCTIONS

This information is provided to help you establish safe operating conditions for both you and your Varian microwave tube.

Use the Test Performance Sheet and Operating Instructions with the information given in this sheet to help you operate this tube in a safe and efficient manner. The Test Performance Sheet is an individual record of the test conditions and test results obtained at the factory. The Operating Instructions give special considerations and precautions to be followed to obtain best performance.

Do not operate this tube except in accordance with proper operating instructions, these precautions, and any additional information provided by Varian Tube Division representatives. Address any questions regarding the safe and proper use of this tube to:

Varian Canada, Inc.
45 River Drive
Georgetown, Ontario, Canada

WARNING – SERIOUS HAZARDS EXIST IN THE OPERATION OF ALL MICROWAVE TUBES

The operation of all microwave tubes involves the follow hazards.

a. HIGH VOLTAGE – Normal operating voltages can be deadly.

b. MICROWAVE RADIATION – Microwave radiation can cause serious personal injury which can be fatal.

c. X-RAY RADIATION – High voltage tubes can produce dangerous X-rays.

Read the following instructions and take all necessary precautions. Varian as a component supplier can assume no responsibility for any damage or injury resulting from the operation of Varian microwave tubes.

HIGH VOLTAGE

Operating voltages for microwave tubes range from about 200 volts to over 150 kilovolts. Since these voltages can be deadly, the equipment must be designed properly and operating precautions must be followed. Design equipment so the operator cannot come in contact with high voltages. Enclose high voltage circuits and terminals and provide interlocking switch circuits to open the primary circuits of the power supply and discharge high voltage condensers whenever access is required.

MICROWAVE RADIATION

Exposure of the human body to microwave radiation in excess of 10 milliwatts per square centimeter is unsafe, and the output of many microwave tubes exceeds this level. For this reason, the rf energy must be contained properly by waveguides and shielding. Arrangements should be made to prevent exposure of personnel to strong rf fields in the vicinity of microwave tubes and in front of antenna systems. (Ref: Proc. IRE, Vol. 49, No. 2, pp. 427 - 477, Feb. 1961.)

X-RAY RADIATION

Electronic tubes operating at voltages higher than 15 kilovolts produce progressively more dangerous X-ray radiation as the voltage is increased. Therefore, many high power microwave tubes are potential X-ray hazards. Provide adequate X-ray shielding on all sides of these tubes, as well as the modulator and pulse transformer tanks. Make periodic checks on the X-ray levels and never operate high voltage tubes without adequate X-ray shielding being in place. (Ref: "Medical X-ray Protection up to Three Million Volts," National Bureau of Standards Handbook 76. Available from Superintendent of Documents, Washington D.C., 20402, Price: 25 cents.)

DANGER – BERYLLIUM OXIDE CERAMICS AVOID BREATHING DUST OR FUMES

Some Varian high power microwave tubes contain Beryllium Oxide Ceramics. Avoid performing any operation on the ceramic parts of these tubes which produce dust or fumes. In particular, avoid operations such as grinding, grit blasting, and acid cleaning. BERYLLIUM OXIDE DUST AND FUMES ARE HIGHLY TOXIC AND BREATHING THEM CAN RESULT IN SERIOUS PERSONAL INJURY OR DEATH. If a tube fails and a broken window is suspected, the tube should be carefully removed from the mating waveguide and the output flange of the tube should be sealed with tape.

Disposal of used tubes containing Beryllium Oxide must be done in a manner which will ensure that personnel in the disposal operation will be safeguarded and that personnel in any possible salvage operation will be fully warned. If proper disposal presents a problem, Varian is prepared to offer disposal service for tubes containing this material. Tubes should be returned prepaid with a written authorization to Varian to dispose of the tubes.

Although Varian tubes containing Beryllium Oxide Ceramics are marked with a warning label at Varian, because of the possibility of an obliterated or missing label, we strongly urge that Varian be contacted prior to performing any work on the ceramic portions of any Varian high power microwave tubes.

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WARRANTY

MICROWAVE TUBES, EQUIPMENT AND COMPONENTS
VARIAN CANADA, INC.

WARRANTY

Microwave Tubes, Equipment and Components ("Products") sold by Varian Canada, Inc., are warranted against defects in workmanship and material when used under normal operating conditions within the respective Varian specified ratings and in accordance with Varian operating instructions. The applicable Microwave Tube warranty period shall commence on the date of shipment from Varian Canada, Inc. and extend for a specified number of hours of operation of the filament or heater, or for a specified number of months following the date of shipment thereof, whichever first occurs. The applicable number of hours of operation of the filament or heater included in the warranty for a Microwave Tube depends upon the type of tube. The most common periods of warranty are listed below:

CODES		
Warranty Code	Warranted Filament or Heater Operation (hours)	Maximum Adjustment Period (months)
WM	Unlimited	12
B	100	6
E	200	12
G	500	12
K	1000	12
L	2000	12
S	5000	12
V	7500	18
W	7500	24

Equipment and passive Components (including electromagnets, solenoids, filters, loads, circulators, couplers, waveguide windows, diplexers, and other passive devices) are warranted for unlimited hours of operation during the one year period following date of shipment thereof.

ADJUSTMENTS

Repair, or at Varian's option, replacement of the Product or defective parts therein shall be the sole and exclusive remedy under valid warranty claims; provided that Varian may, as an alternative for Microwave Tubes, elect to refund an equitable portion of the purchase price of the Product in accordance with the following adjustment criteria.

If a Microwave Tube fails from causes covered by this warranty within the warranted hours of operation and maximum adjustment period, a pro rata adjustment, based on the selling price, will be made as follows:

$$\text{Adjustment} = (\text{Applicable Selling Price}) \times \left[\frac{(\text{Warranted Hours} - \text{Hours of Operation at Failure})}{\text{Warranted Hours}}\right]$$

No adjustment will be made for failure beyond the warranted hours of operation or beyond the maximum adjustment period. In all cases failure shall be deemed to have occurred no more than seven days before the first date on which notice of failure is received by Varian.

Varian shall have no obligations under this warranty unless the applicable warranty period (number of hours of operation of the filament or heater, and/or number of months from date of shipment) is specified on Varian's quotation, or is otherwise agreed to in writing by Varian. In the event Customers and/or users of any Microwave Tube subject to warranty claim fail to keep accurate records of the number of hours of operation of the filament or heater, Varian, in its sole discretion, may reject any such claim or determine probable usage of the Product.

This warranty is expressly in lieu of and excludes all warranties of any kind express or implied, including warranties of merchantability and of fitness for particular purpose, use or application, and all other obligations or liabilities on the part of Varian, unless such other warranties, obligations or liabilities are expressly agreed to in writing by Varian.

LIABILITIES

Varian's aggregate liability for damages shall not exceed the payment, if any, received by Varian for the unit of Product or service furnished or to be furnished, as the case may be, which is the subject of claim or dispute. In no event shall Varian be liable for incidental, consequential or special damages, howsoever caused. No action, regardless of form, arising out of, or in any way connected with Products or services furnished by Varian, may be brought by Customer more than one (1) year after the cause of action has accrued. All patent liability of Varian shall be determined solely in accordance with the standard Terms and Conditions of Sale, Electron Device Group, Varian Associates, Inc.

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RETURN PROCEDURES

WARRANTY CLAIM

All claims under warranty must be made promptly after occurrence of circumstances giving rise to the claim and must be received within the applicable warranty period by Varian or its authorized representative. Varian reserves the right to reject any warranty claim not promptly reported. After expiration of the applicable warranty period, Microwave Tubes, Power Supplies and Components are not subject to adjustment.

Unnecessary expense and loss of time often can be avoided by calling the local Varian Field Office before returning a Product to the factory. Returned Products are frequently found to be within performance specifications required of new Products. The Varian representative may be able to determine the trouble and obtain satisfactory performance from the Product. This may save shipping time and expense and minimize equipment down time.

WARRANTY CLAIM FORM

Before any Product is returned for repair and/or adjustment, written authorization from Varian for the return and instructions as to how and where the Product should be shipped must be obtained. The Product type and serial numbers and a full description of the circumstances giving rise to the warranty claim should be included. Such information will help establish the cause of failure and expedite adjustment or repair. For this purpose, a Warranty Claim Form is shipped with each Product.

IMPORTANT

If goods are to be returned from outside Canada, the customer must first contact Varian Canada, Inc. for special instructions regarding customs. Otherwise costly duty charges may be incurred and charged to the customer.

Any Product returned without a completed claim form will be considered to have met all contractual requirements. Both the Product and the completed claim form must be submitted to Varian prior to expiration of the applicable warranty period.

TRANSPORTATION AND PACKAGING

Any Product returned to Varian for examination must be sent prepaid via the means of transportation indicated as acceptable by Varian. Varian reserves the right to reject any warranty claim on any item that has been altered or has been shipped by nonacceptable means of transportation. Returned Products should be carefully packed in the original container, and unless otherwise indicated, shipped to:

VARIAN CANADA, INC.
45 River Drive
Georgetown, Ontario,
Canada

Attn: Returned Products

AUTHORIZATION FOR EVALUATION

When any Product is returned for examination and inspection, or for any other reason, Customer and its shipping agency shall be responsible for all damage resulting from improper packing or handling, and for loss in transit, notwithstanding any defect or nonconformity in the Product. By returning a Product, the owner grants Varian permission to open and disassemble the Product as required for evaluation. In all cases Varian has sole responsibility for determining the cause and nature of failure, and Varian's determination with regard thereto shall be final.

If it is found that Varian's Product has been returned without cause and is still serviceable, the Customer will be notified and the Product returned at its expense; in addition, a charge for testing and examination may, at Varian's sole discretion, be made on Products so returned.

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WARRANTY CLAIM FORM
FOR
MICROWAVE TUBES, EQUIPMENT AND COMPONENTS

Varian Canada, Inc.

PROPER COMPLETION OF THIS FORM IS VITALLY IMPORTANT TO THE PROMPT AND EFFICIENT HANDLING OF PRODUCT WARRANTY CLAIMS.

I. This claim form, properly completed, must accompany any returned Product and be received by Varian Canada, Inc. prior to expiration of the adjustment period. Compliance with this requirement assures the user of the most prompt and thorough service possible. A Product returned within the adjustment period, but without the completed Warranty Claim Form, will be treated as out of warranty.

II. Complete the following information regarding the Product being returned:

A. Product Type: Varian Part No._____ Serial No._____

Customer Part No._____

B. Customer Purchase Order No._____

Date of Purchase Order _____

C. Control Specification Number _____ Dated _____

(Check one) Document of VA ☐ your company ☐

D. Contract Warranty (either Varian Warranty code or specification paragraph)

_____

Filament Hours _____ Warranty Adjustment Began_____

Adjustment Time _____ (months) Expires_____

III. Claim is made against warranty based on the following:

A. Specification(s) not met by the Product (list by specification and paragraph number):

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PLEASE FILL IN FOR FAILED PRODUCTS

(Place an "X" in the appropriate box to show what variance from normal was seen at the time of tube failure.)

Product Serial No. / Type No.	Date Installed	Date Failed	Filament Hours	Radiate Hours	Filament Current		Beam Current		Helix or Body Current		Hi Voltage Arcs		W/G Arcs		Coolant Flow		Mech. Problems		Electro-Magnet Current	
					Lo	Hi	Lo	Hi	Nml	Hi	No	Yes	No	Yes	Nml	Lo	No	Yes	Nml	Lo

*It is necessary to have the Product serial number rather than the system serial number.

B. Describe the circumstances and/or sequence of events under which the Product failed. Include remarks relating to installation problems, system anomalies, etc.

IV. System used in _____

Serial No. _____

V. Purchaser's Name _____

Address _____

_____

Claim made by: _____

Person to contact for additional information:

Name _____

Telephone _____

VI. Repair or Replacement to be sent to:

Name _____

Address _____

_____

(Signature)

_____

(Date)

Return completed form promptly, with Product, to:

Varian Canada, Inc.
45 River Drive
Georgetown, Ontario
Canada

Telephone: (416) 457-4130
TWX: 610-492-2641
TELEX: 069-7502

Attn: Returned Products