AD-A033 346 ROCKWELL INTERNATIONAL RICHARDSON TEX HYBRID MICROEL--ETC F/G 9/5
A PRODUCTION ENGINEERING MEASURE FOR TWO L-BAND SOLID-STATE MIC--ETC(U)
AUG 76 J K MCCOY DAAB07-76-C-0026

UNCLASSIFIED NL

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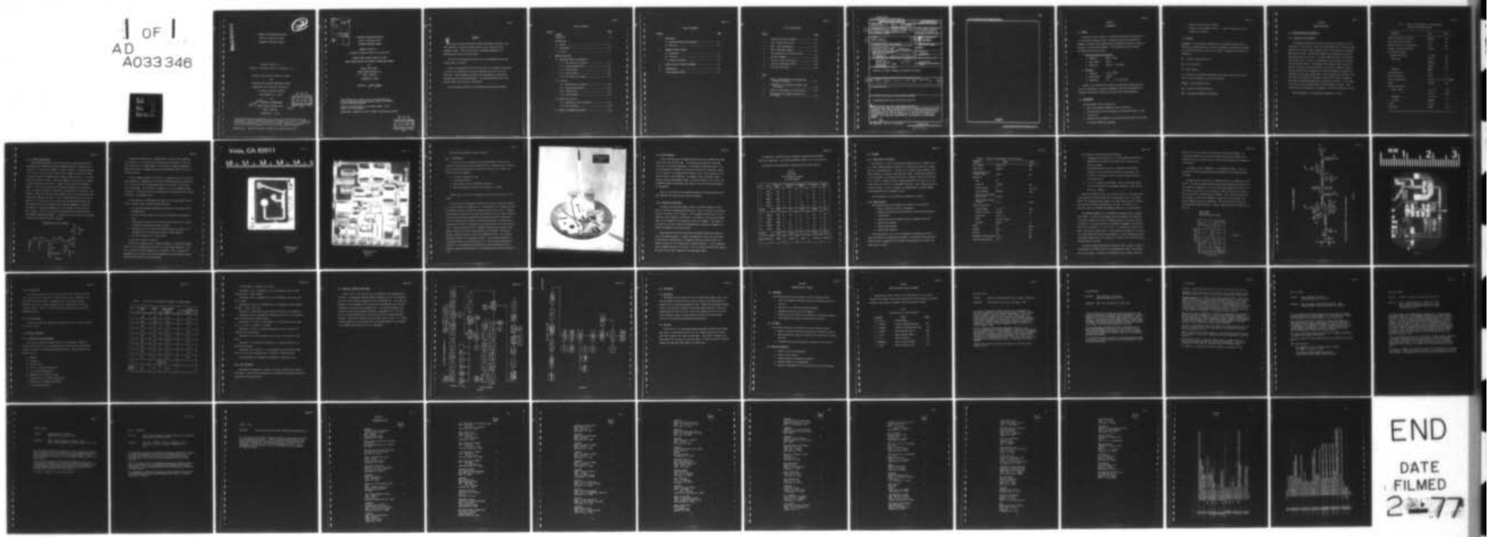
A033346



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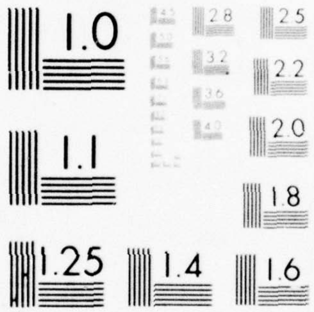

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A PRODUCTION ENGINEERING MEASURE FOR TWO L BAND SOLID STATE MICROWAVE FREQUENCY SOURCES

QUARTERLY REPORT NO. 1

COVERING THE PERIOD 30 APRIL TO 30 AUGUST 1976

PREPARED UNDER CONTRACT DAAB07-76-C-0026

FOR

COMMUNICATIONS SYSTEMS PROCUREMENT BRANCH
PROCUREMENT AND PRODUCTION DIRECTORATE
U.S. ARMY ELECTRONICS COMMAND
FORT MONMOUTH, NJ 07703

BY

409963

ROCKWELL INTERNATIONAL
HYBRID MICROELECTRONICS DIV.
1200 N. ALMA RD.
RICHARDSON, TX 75080

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A PRODUCTION ENGINEERING MEASURE
FOR TWO L BAND SOLID STATE
MICROWAVE FREQUENCY SOURCES

QUARTERLY REPORT NO. 1

COVERING THE PERIOD 30 APRIL TO 30 AUGUST 1976

PREPARED UNDER CONTRACT DAAB07-76-C-0076

MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING PROGRAM

BY

COLLINS RADIO GROUP

HYBRID MICROELECTRONICS DIV.

Rockwell International

1200 N. ALMA RD.

RICHARDSON, TX 75080

WRITTEN BY: JEROME K. MCCOY

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ABSTRACT

This report describes the specifications and approach, and details the work completed in the design and fabrication of two L Band solid state frequency sources. These two devices are a Modulator/Transmitter for Radiosonde applications and an FM Source.

The first set of engineering samples have been completed, and some performance data is available.

Some of the characteristics of thick film that will determine the eventual utility of this technology at microwave frequencies are loss, Q and line definition. These parameters and others will be examined in the materials evaluation portion of the ECOM program. This report describes the work completed to date in this area of investigation.

Plans have been formulated for the second set of engineering samples.

TABLE OF CONTENTS

TABLE OF CONTENTS

Section Page

3 CONCLUSIONS

4 PROGRAM FOR NEXT INTERVAL

LIST OF ILLUSTRATIONS

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
Quarterly Report #1 (Two)

2. GOVT ACCESSION NO.
SLIN 0004AB

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
(6) A Production Engineering Measure for L-Band Solid-State Microwave Frequency Sources.
~~First Quarterly Report~~

5. TYPE OF REPORT & PERIOD COVERED
First Quarterly Report
April 30 thru August 30

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
(10) Jerome K. McCoy

8. CONTRACT OR GRANT NUMBER(s)
(15) DAAB7-76-C-0026
new

9. PERFORMING ORGANIZATION NAME AND ADDRESS
RF Products, Hybrid Microelectronics Division
Collins Radio Group
Richardson, Texas 75080
See cover
409963

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
#2769749

11. CONTROLLING OFFICE NAME AND ADDRESS
PRODUCTION DIVISION P&P
DRSEL-PP-I-P1-1
FT. MONMOUTH, N.J. 07703
(11) 30 Aug 76

12. REPORT DATE
8-30-76

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
DCAS-Dallas
1225 N. Alma Rd.
Richardson, TX 75080
M/S 407-201
(12) 44 p.

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approval for public release, distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
(9) Quarterly rept. no. 1, 30 Apr–30 Aug 76,

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Radiosonde, Oscillator, Thick Film, Linear FM

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the specifications and approach, and details the work completed in the design and fabrication of an L Band Radiosonde Modulator/Transmitter and an L Band FM Source. Q, RF loss and line definition are a few parameters that will be investigated in the thick film evaluation program. Plans have been formulated for the second set of engineering samples.

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SECTION 1
INTRODUCTION

1-1 PURPOSE

The purpose of this contract is to establish the design and producibility of two microwave frequency sources, to improve the ability to produce the component or process and to compile data for production of these two sources on the basis of existing plant capacity. The characteristics of the devices are briefly described as follows:

A. Radiosonde Modulator/Transmitter

1.	Frequency	1680 ± 20 MHz	
2.	Power Output	65 mW	
3.	Modulation	100% AM	0 to 1835 Hz

B. FM Source

1.	Frequency	1375 ± 25 MHz	
2.	Power Output	500 mW	
3.	Modulation	FM	0 to 1 MHz rate

Further, it is a goal of this program to investigate the application of thick film technology in microwave integrated circuits and to determine the processes and materials required for low cost, high volume production.

1.2 REQUIREMENTS

The requirements of this contract are:

1. Deliver 40 engineering samples of each circuit type.
2. Test and deliver, with test reports, 50 confirmatory samples of each circuit type.
3. Establish a pilot production line and fabricate 500 units of each type at a rate of 4000 units per month.

4. Prepare technical data and reports.
5. Determine the requirements and plans to support a production rate of 40,000 units per month.

1.3 GLOSSARY

Radiosonde - A miniature radio transmitter with instruments attach, which is carried by an unmanned baloon to a height of 105,000 ft and dropped by parachute, for broadcasting by means of precise tone signals, information on humidity and temperature.

MIC - Microwave integrated circuit

TBD - To be determined

RF - Radio frequency

Q - A measure of the relationship between stored energy and the rate of dissipation in certain elements, structures or materials

TC Bond - Thermo compression bond

PEM - Production engineering measures

MM&T - Manufacturing Methods and Technology

SECTION 2

NARRATIVE AND DATA

2.1 RADIOSONDE MODULATOR/TRANSMITTER

2.1.1 Description of the Device

The Radiosonde Modulator/Transmitter consisting of a mechanically tuned L-Band thick film oscillator, a thick film hybrid modulator, a negative voltage regulator and a discone antenna comprises 90% of the electronics of Atmospheric Meteorological Probes. The modulator generates and shapes pulses which 100% amplitude modulate an RF carrier. The pulse repetition rate of the modulator which varies from 0 to 950 Hz, is determined by the resistance of the temperature and humidity sensors. The modulator also generates identification frequencies of 1395 Hz, 1630 Hz and 1835 Hz and a reference frequency of 950 Hz. The data, identification frequencies and reference frequency is sequentially telemetered to the ground station when it can be automatically processed. The oscillator can be tuned from 1660 MHz to 1700 MHz and delivers a minimum of 65 mW across the operating band under all operating conditions. The RF signal is fed into a discone antenna having an input impedance of 50 ohms. After testing the entire transmitter is assembled in a protective dielectric housing.

The requirements of the radiosonde are summarized in Table 1.

Table 1. Summary of Requirements for the Radiosonde Modulator/Transmitter Module

PARAMETER	VALUE	UNITS
Frequency (Mechanically Tunable)	1680±20	MHz
Power Output (Coaxial Output)	65 min.	mW
Frequency Stability (vs Temperature)	4 max.	MHz
Frequency Shift with Modulation	150 max.	kHz
Pulse Modulation Rates		
Meteorological Data	25 to 950	pps
Identifiers	1395±115	pps
	1630±115	pps
	1835±75	pps
Reference	950±50	pps
Super-regeneration	None	-
Sensor Base Current	75 max.	µA
Transfer characteristic	per para. 3.2.1.12 of SCS-408A	
Weight	150 max.	gms
Operating Conditions		
Supply Voltage	-20 to -30	Volts
	-24 nom.	Volts
Temperature	-70 to +70	°C
Altitude	105,000	ft
Current	100 max.	ma
Pulse Width	60±20	µsec

2.1.2 Design Considerations

The engineering approach to the oscillator was to simply use the design developed by RCA for ECOM under contract DAAB05-72-C-5830 by converting it to thick film. The oscillator schematic is shown in Figure 1. Its basic operation is as follows: The transistor is biased class A common collector at a current level that maximizes the common emitter voltage transfer ratio S_{21}. This occurs at 60-70 ma collector current. Capacitive feedback at the emitter will produce a negative resistance at the base. A specific value of capacitive feedback (approx. 1.4 Pf) will peak the value of negative resistance in the operating band. To sustain oscillation, the transistor requires that the real part of the impedance looking into the base matching network be less than the absolute value of the base's negative resistance. This is accomplished by putting a low value capacitor (.7 Pf) and a λ/4 line in series with the base and the 50 ohm load. The capacitor and λ/4 line transform the 50 ohm load impedance to a very low resistance and a reactive impedance that is the conjugate of the transistors base reactance. The .46λ line and the variable capacitor form the stabilizer and frequency determining elements. The transistor will oscillate at the frequency where these elements go parallel resonant.

Radiosonde Oscillator Schematic

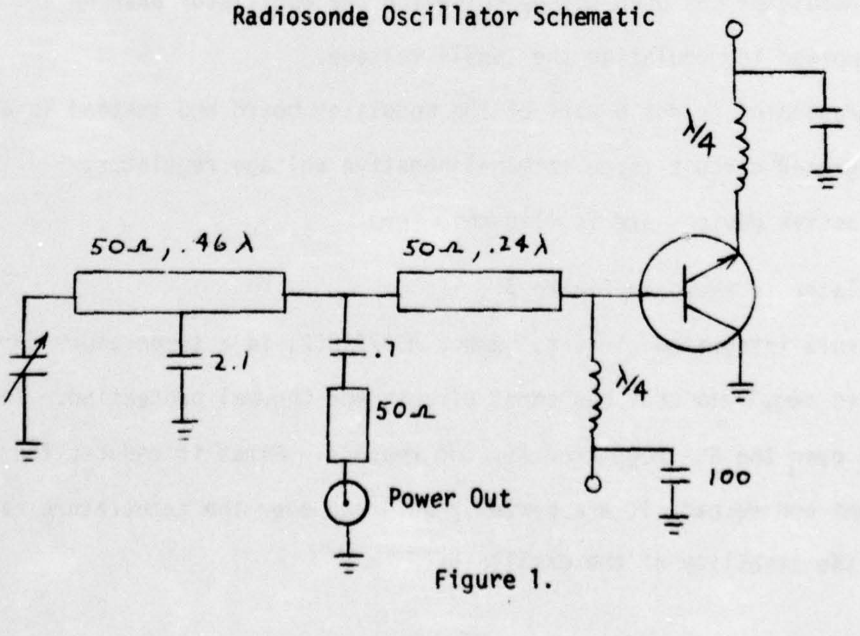


Figure 1.

Temperature stabilization is accomplished by placing a rutile capacitor (TiO_2) approx. 2.1 Pf in shunt with the stabilizer line at about $\lambda/4$ from the end of the line at a voltage minimum. The rutile has a negative temperature coefficient which will compensate the positive temperature coefficient of the ceramic substrate.

The only change involved in this circuit is to convert to thick film and to make adjustments to compensate for electrical differences between thin and thick film. For the first set of engineering samples we are using a fritless PtAg and a fritted PdAg. The oscillator is housed in a 1.2 by 1.1 package as shown in Figure 2. The bias resistors are as specified in the contract and are located on the thick film modulator board.

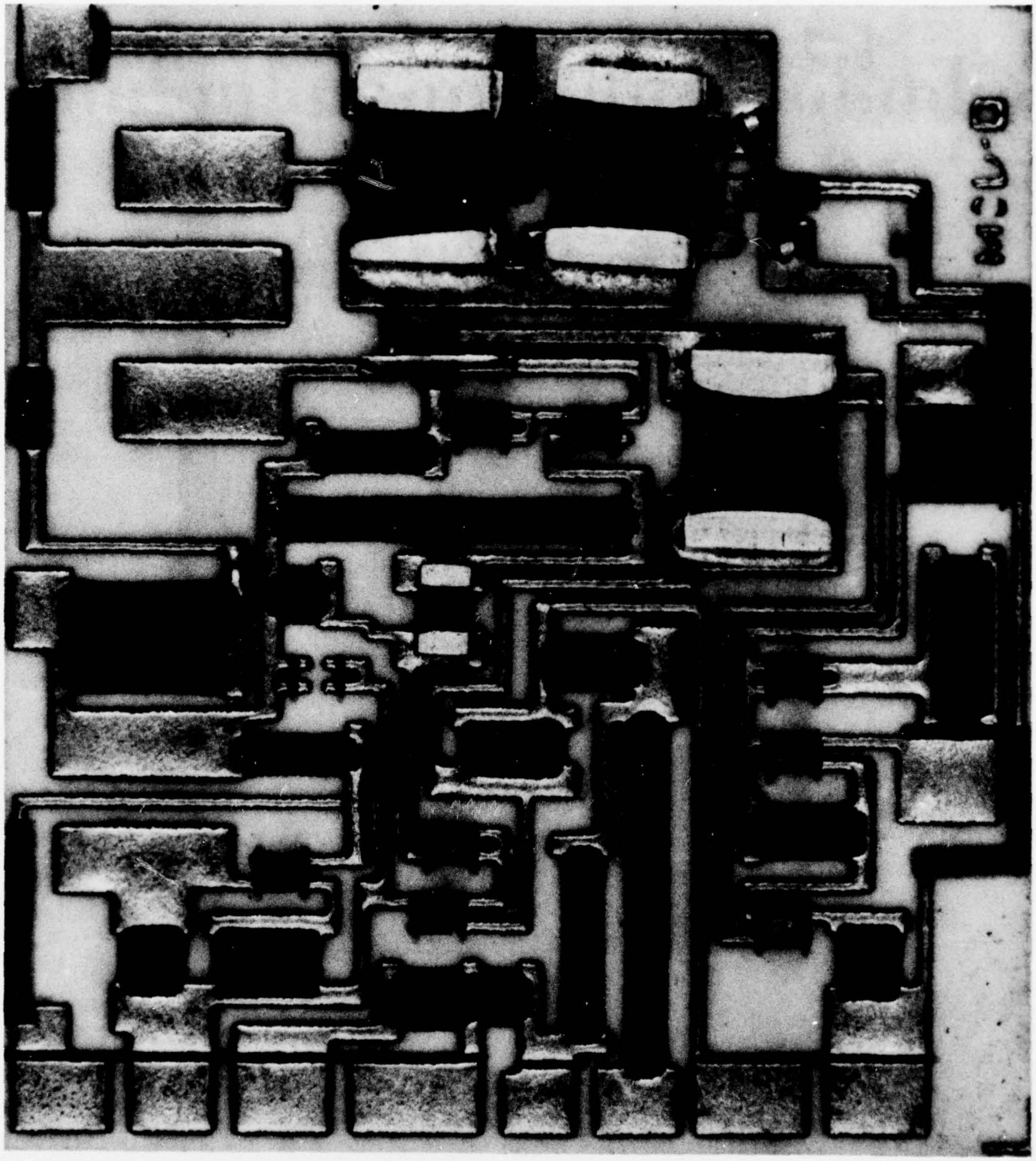
Collins approach to the modulator was again to utilize and improve the RCA design. However, several important charges were made:

1. All modulation-frequency determining resistors are now located on the modulator board.
2. All bias resistors except a test select are located on the modulator board.
3. The modulator has been set up to switch the oscillator base on and off, as opposed to modulating the supply voltage.
4. The regulator is not a part of the modulator board and instead is an integrated circuit three terminal negative voltage regulator.
5. The active devices are in flip-chip form.

The modulator is shown in Figure 3.

The Motorola integrated circuit, number MCP7918CP, is a temperature compensated -18 volts regulator that has short circuit and thermal protection. This IC was chosen over the RCA regulator for two reasons. First it reduces the component count and second, it has better regulation over the temperature range which affect the stability of the oscillator.

ECOM-Radiosonde
Oscillator
Figure 2



ECOM-Radiosonde
Modulator
Figure 3

The radiosonde assembly is shown in Figure 4.

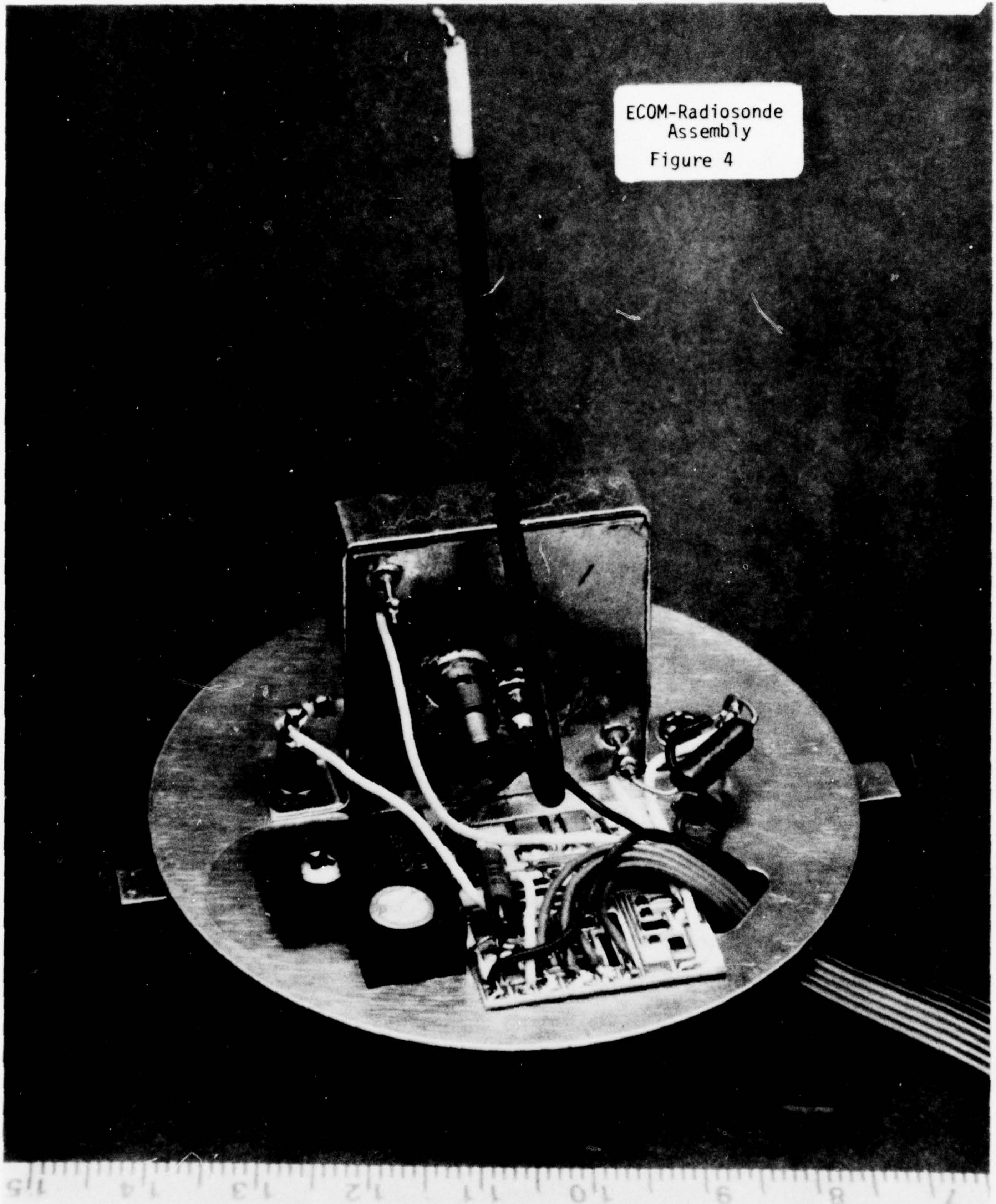
2.1.3 Problem Areas

For the most part the problems involve the performance of the first 10 engineering samples which have just been delivered. Therefore we have not been able to correct the problems only to plan and initiate action on them. The problem areas are in summary:

1. Oscillator frequency too high
2. Oscillator stability
3. Output power too low at temperature extremes
4. Operating temperature range of the regulator is limited.

Problem areas 1 and 2 will be addressed in the Test Data section of this report.

For the first set of engineering samples we are using a regulator designed in a plastic package for commercial use. The decision to use a commercial device was primarily based on availability although cost was also a factor. Although the manufacturers specifications limits the device to an 0°C to +125°C operating range, extensive testing has shown that the regulator performs excellently at -70°C with absolutely no indication of degraded performance. No problem was experienced in turning on regulators that had been turned off and stabilized at -70°C. Further discussions with our component engineers have assured us that thermal stress on the plastic device should not be a problem. We have not, however, committed ourselves to using this commercial device. It is simply a temporary solution to an availability problem. We are and will continue to investigate several of the options open to us. These include; packaging the regulator in a LID (Leadless Inverted Device), using the approved military package or mounting the regulator chip to the modulator board and wire bonding to it.



ECOM-Radiosonde Assembly

Figure 4

2.1.4 Work Performed

In this reporting period 10 Radiosonde units have been assembled and tested using fritted and frittless inks. Two variations were employed in the PdAg oscillators to evaluate improvements in the assembly process and design. This involved mounting the 2N5108 chip transistor directly on the substrate instead of on a pedestle. This change would eliminate a hole in the substrate, one fab part and several labor operations. As reported in the July monthly report, thermal resistance measurements showed a junction to ambient rise of 65°C/w for the 2N5108 mounted on the ceramic and a 68°C/w rise for the transistor mounted on the pedastle.

Plans for the second set of engineering samples and performance goals have been determined and long lead parts have been ordered.

2.1.5 Discussion of Test Data

As shown in the Test Data Summary, Table 2 the center frequency of both types of oscillator averaged about 60 MHz high. This is the result of converting to thick film from a thin film design. It is encouraging that the units oscillated at a higher frequency in that there is no reason to believe that more than minor circuit changes will be necessary to lower the frequency. The length of the stabilizer line will need to be lengthened and the capacitive feedback will need to be adjusted to the correct value.

Investigation of oscillator stability has not been intensively pursued in this first reporting period. Location and capacitance value of the rutile were as specified by the RCA design. As reported in the July monthly report, the PdAg oscillators will not function using a 2N5109 transistor. We are, therefore, using a 2N5108 transistor in its place. This is a high gain device which explains the lower current levels required for the same power output.

The modulation, identification and reference frequencies were extremely stable over temperature. The reference frequency change 14 Hz in the worst case.

An evaluation of the modulation transfer data has not been made yet.

Table 2
Radiosonde
First Engineering Samples
Test Data Summary

Unit #	Matl.	Center Freq. (MHz)	Tuning Range (MHz)	ΔFreq/ΔTemp (MHz)	Power Output (mW)	Current (ma)
8	PdAg	1742	25	7.2	85	66
2	PdAg	1761	39	2	56	67
3	PdAg	1760	63	9	60	71
4	PdAg	1754	30	2.3	63.6	65
5	PdAg	1786	15	4.43	78	79
Average		1760	34	4.98	68.52	69.5
1	PtAg	1722	56	8	85	104
6	PtAg	1716	1	10	99	89
7	PtAg	1690	92	14	76	115
9	PtAg	1739	42	3	84	95
10	PtAg	1696	23	10	75	84
Average		1712	42.8	9	83.8	97.4
Specification		1680	40 min	4 max	65 min	100 max

2.2 FM SOURCE

2.2.1 Description of the Device

The FM Source is a thick film microwave integrated circuit intended for use as a linear frequency modulated transmitter in applications requiring a rugged, low cost, light weight device. It consists of a varactor tuned transistor oscillator followed by a transistor power amplifier stage. The oscillator operates at a fixed frequency of 1375 ±25 MHz and delivers a minimum of 500 mw into a 50 ohm load. The unit is capable of being frequency modulated at any rate up to 1 MHz by application of a signal on a designated input lead. Total frequency deviation is 50 MHz minimum. The unit is housed in a rugged hermetic structure capable of withstanding severe environmental stress.

The requirements for the FM Source are summarized in Table 3.

2.2.2 Design Approach

The following steps were performed in the design of the FM Source:

1. Measure candidate transistor S parameters.
2. Computer optimize and evaluate effects of feed back and transistor configuration.
3. Select device base on computer results, availability and cost.
4. Design tuning network.
5. Design output network
6. Design power amplifier.

Three transistors in chip form were selected as candidates for the FM Source; the NE 021, the 2N5108 and the 2N5109. All three were characterized by measuring their S parameters on an HP Manual Network Analyzer at various bias levels from 1 to 2 GHz.

Table 3. Summary of Requirements for the FM Source

PARAMETER	VALUE	UNITS
RF Frequency	1375 ± 25	MHz
Power Output	500 Min.	mW
Power Variation over Frequency Range	1 Max.	dB
Modulation		
Type	FM	
Deviation	± 25 Min.	MHz
Tuning Voltage	30	Volts p-p
Input Impedance	1000 Min.	ohms
Deviation from constant tuning slope	± 2 Max.	%
Input Voltage @ Center Frequency	15 ± 5	Volts
Operating Conditions		
Supply Voltage	24 ± .25	Volts
Current @ 24 VDC	175 Max.	ma
Temperature	-40 to + 70	°C
Shock	150 (for 11 mscc)	g
Altitude	50,000	ft
Weight	65	grams
AM Noise	-100	dBc
FM Noise	-60	dBc
Frequency Turn On Stability	± 2.5	MHz
Power Turn On Stability	±10	%

Gross analysis of the data shows the following:

1. Transducer gain, 20 log S_{21}, is 0 for the 2N5109, while both the 2N5108 and NE 021 exhibit gain greater than 0 with the latter being the highest.
2. The isolation term, 20 log S_{12}, is greatest for the 2N5108, slightly less for the NE 021 and lowest for the 2N5109. High isolation is desirable in order to minimize loading effects on the tuning circuit.
3. $|S_{11}|$ is largest for the 2N5108. This is a desirable feature as it will be easier to use feedback techniques to make the real port of S_{11} negative.

Because the 2N5108 has gain, high isolation, high $|S_{11}|$, and lowest cost, it was selected as the best choice for the oscillator circuit. The common emitter (CE) configuration was chosen as it offers higher gain and isolation over any other transistor configuration (CC or CB). In addition, it is physically easier to implement the feedback network for a CE configuration.

The feedback parameters, for the 2N5108, were computed using a program called ZFEED. By inputting the common emitter S parameters the program will calculate the effects of various RC feedback networks on the overall network S parameters. The output consists of the network S parameters, the stability factor, K, and Δ where $\Delta = S_{11} S_{22} - S_{12} S_{21}$. For instability K must be less than 1 and Δ must be greater than 1. The intent of the program is to maximize $|S_{11}|$ and to minimize the phase angle spread of S_{11} across the operating band. The network selected was a 4.4 pf capacitor in parallel with a 135 ohm resistor from the emitter to ground.

The varactor diode characteristic of the NEC 1S1619 is shown in Figure 5. On rectangular coordinates, the C-V curve becomes most linear in the greater than 5 volts region. Therefore it was decided to use a voltage, across the diode, of 6 volts to resonate the transistor at the center frequency. By plotting the computer data on the Smith Chart along with the reactance associated with the 6 volt tuning level, a suitable matching network was determined. (See Figure 6).

The network's output impedance, S_{22}, was computed by ZFEED. Using this information an output matching network was determined using standard matching techniques.

The power amplifier consists of a 2N5108 biased class C, common base configuration. The input and output matching networks were determined by mounting the chip transistor, common base, in a fast fixture that brought 50 ohm lines up to the collector and emitter of the transistor. Double stub tuners were used to tune the transistor to maximum gain at 1375 MHz. Then using the HP manual network analyzer, to measure the impedances looking back into the tuners, the optimum impedance levels were determined. This data was used to design the input and output matching networks. Figure 7 shows the thick film layout of the FM Source.

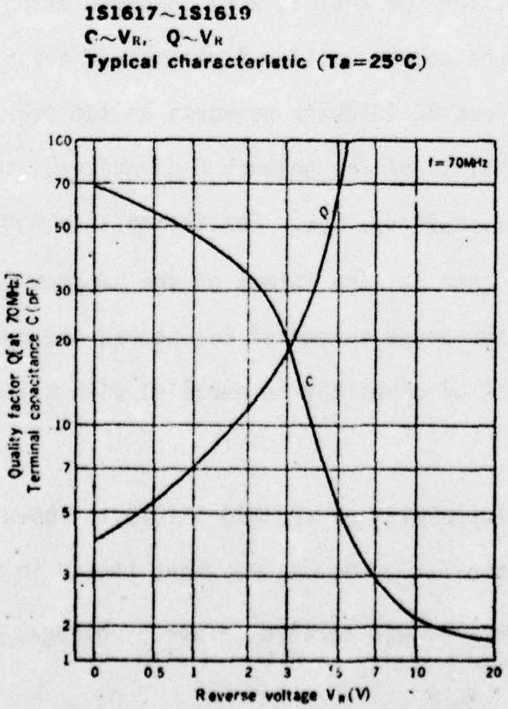
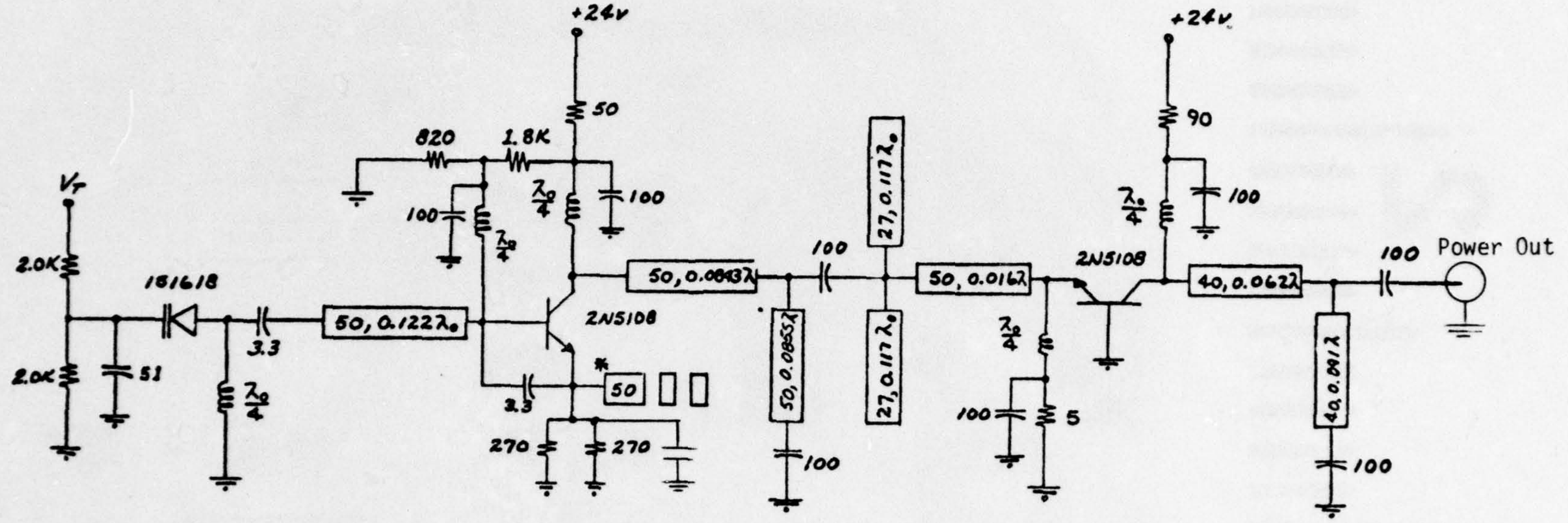


Figure 5

FM SOURCE SCHEMATIC



* LINE LENGTH ADJUSTABLE TO TUNE CENTER FREQUENCY

Figure 6.

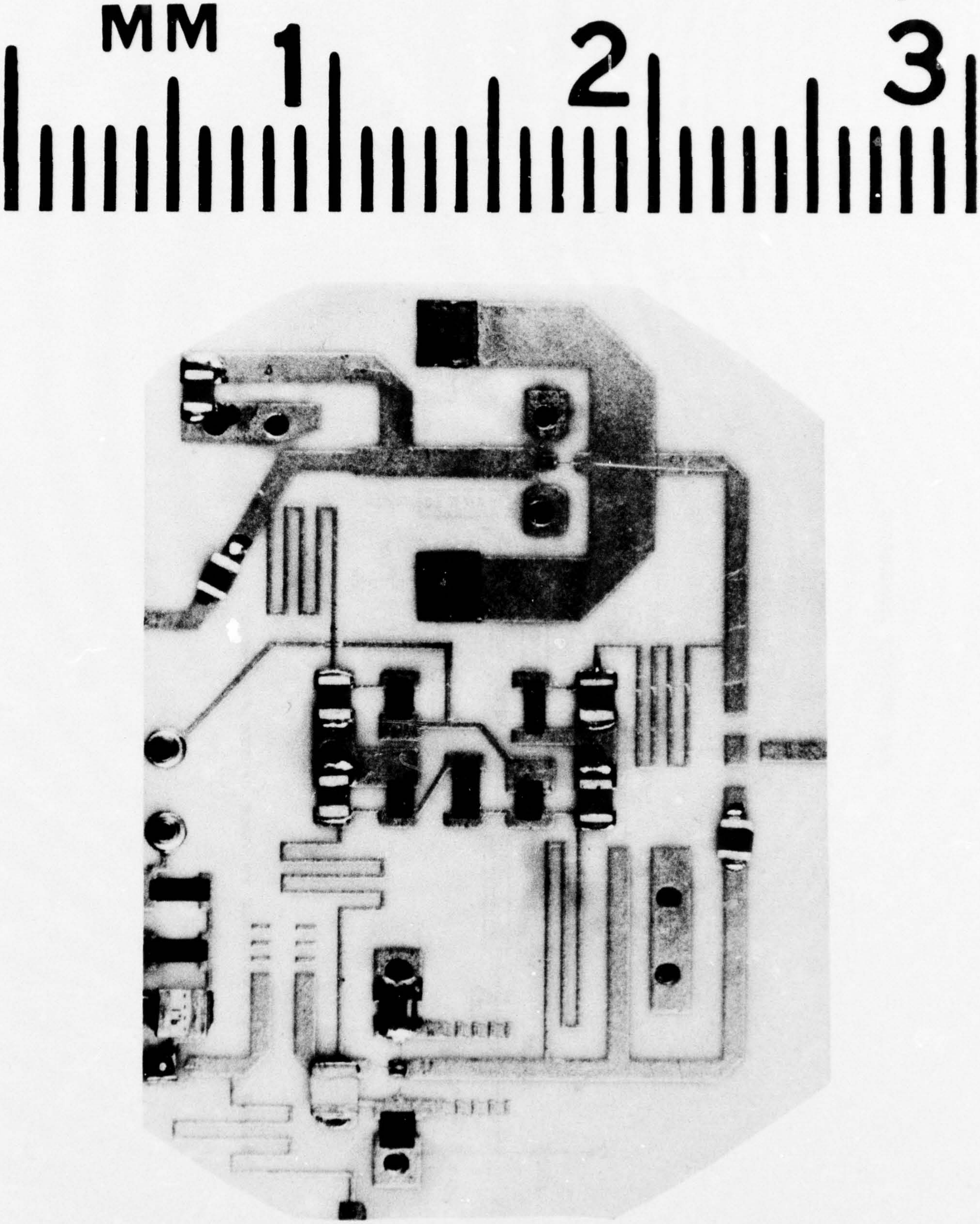


Figure 7.

2.2.3 Problem Areas

The problems encountered in the initial design of the FM Source stem from the fact that the oscillator design is based on small signal S parameters which only yield ball park solutions. Consequently the initial design has been modified to correct the inherent design error and to compensate for the usual parasitic effects. Figure 6 is the final design schematic for the first set of engineering samples.

2.2.4 Work Performed

10 FM Sources have been designed and assembled on thick film using a fritted and a fritless gold.

2.3 MATERIALS EVALUATION

2.3.1 Description of the Experiments

The materials evaluation program consists of 21 experiments designed to provide a data base from which we can determine the best processes and materials for use in low cost, high volume microwave applications. These experiments are designed to test.

1. Adhesion
2. Bondability
3. DC resistivity
4. Rf loss at microwave frequencies
5. Q at microwave frequencies
6. Compatable resistor metal systems
7. Characteristics of thick film capacitors
8. Feasability of screened through holes
9. Line and gap definition

Table 4. FM Source, First Engineering Samples, Test Data Summary

UNIT #	MIN PWR OUT (MW)	CURRENT ma	TUNING VOLTAGE @ 1375 mHz VOLTS	Δ VOLTS for 50 mHz DEVIATION VOLTS
1	580	149	16.6	1.37
2	600	136	11.85	1.62
3	596	135	11.65	.9
4	565	143	20.4	2.16
5	600	146	12.26	3.01
6	604	146	12.62	3.01
7	560	142	11.57	1.13
8	605	137	11.34	.88
9	615	151	11.28	1.38
10	UNIT FAILED			
SPECIFICATION	500	125	15 ±5	

The experiments are summarized as follows:

Experiments 1 and 2, characterize thick film parameters versus varying substrate purity. (96% vs 99.6%)

Experiments 3 and 4, characterize thick film parameters versus mesh size. (325 vs 200)

Experiments 5, 6 and 7, investigate thick film parameters versus substrate thickness. (.025, .040, .060)

Experiment 8, investigate effect of copper plating thick film conductors

Experiments 9 and 10, determine RF characteristics of thick film conductors versus Cu/Ag plating and solder dipping.

Experiments 11, 12 and 13, study adhesion of 5 selected thick film conductors to 3 solders of different tin content.

Experiments 14 and 15, to determine compatable resistor system for the conductors previously tested.

Experiment 16, to study the sensitivity of thick film resistors to load level.

Experiment 17, to determine the feasibility of screen plated holes on 3 substrate thicknesses.

Experiments 18, 19, 20 and 21, to investigate RF and conventional characteristics of thick film capacitors for K = 50 and K = 1200 dielectrics.

These experiments are scheduled for completion in February of 1977.

2.3.2 Work Performed

Substrates for experiments 1 through 7 have been screened and are ready for RF testing. A test fixture for measuring Q on microstrip bar resonators has been received and is being evaluated.

2.4 PROCESSES, EQUIPMENT AND TOOLING

Figures 8 and 9 are flow plans for the production of the Radiosonde and FM Source. The Radiosonde requires separate assembly and test of the modulator and the oscillator before integrating into the radiosonde unit. Four tests are planned, 2 at the subassembly level where we test the modulator and oscillator separately, and 2 tests at the assembly level. For the first assembly level test we will test those parameters specified in paragraph 4.4.1a. The final test is a simple functional test to verify that the unit is operating before shipping. The FM Source requires only prelid and a post lid tests. All testing with the exception of the functional test for the Radiosonde will be performed in our computer controlled test facility (Autotest).

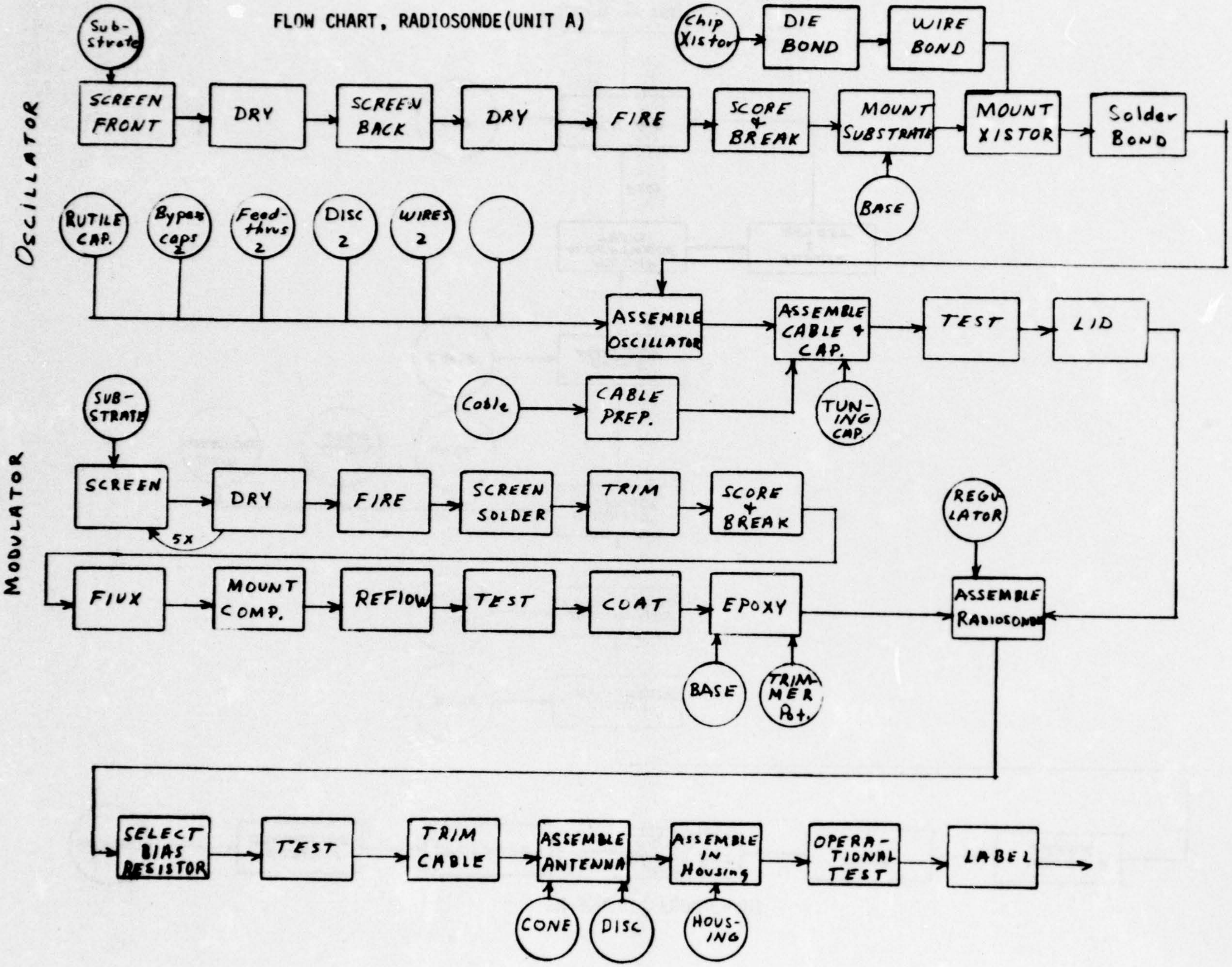

FLOW CHART, RADIOSONDE(UNIT A)

Figure 8

AUG. 10, 1976

FM SOURCE, FLOW CHART

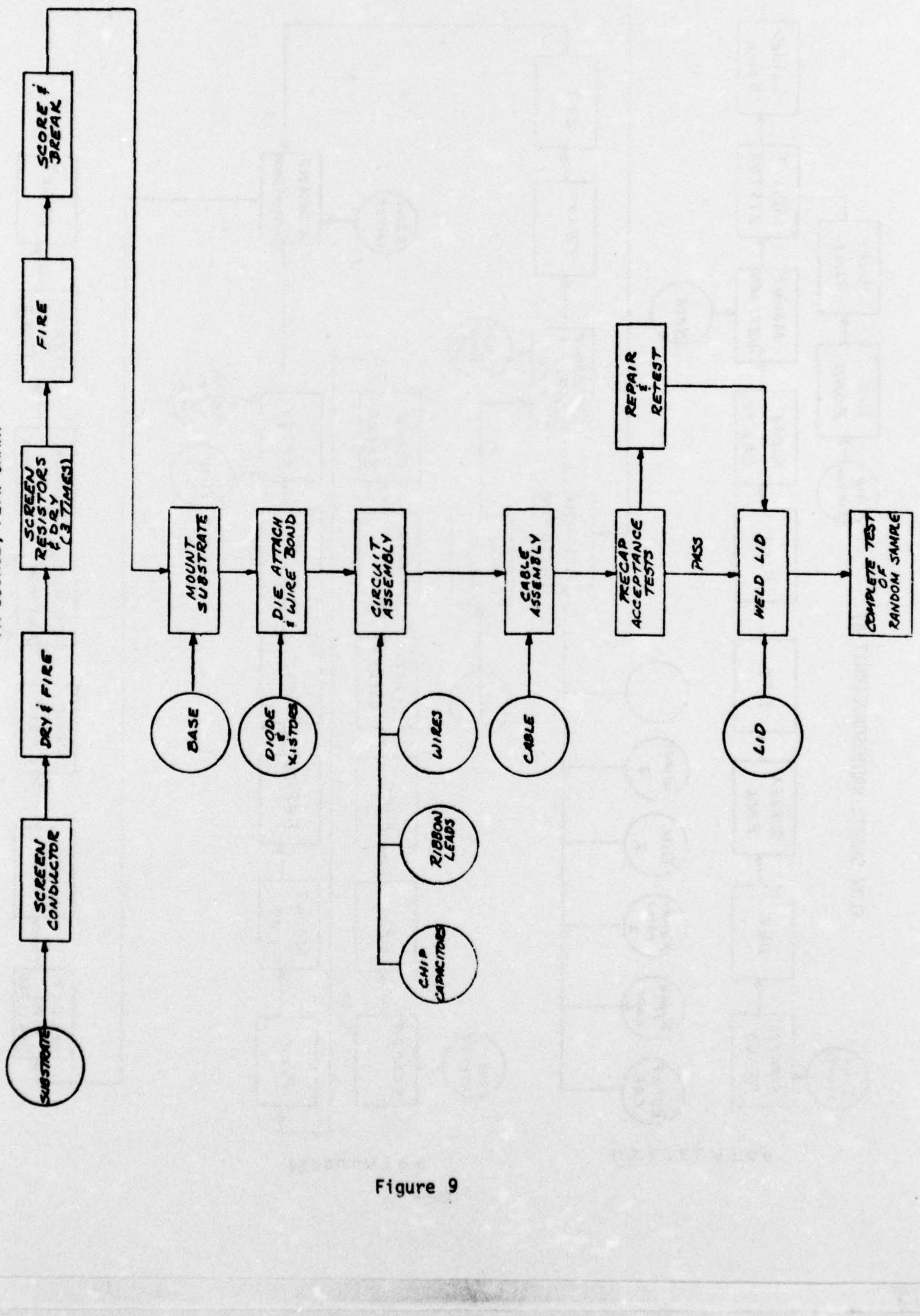


Figure 9

Page 3-2

3.0 CONCLUSIONS

3.1 Radiosonde

Performance results from the first set of engineering samples clearly indicate that design revisions need to be made to stabilize the output power and frequency over the operating temperature range. Despite the performance problems we feel that significant progress has been made toward meeting the overall performance specifications and, that in the design assembly and test of the first set of engineering samples we have become very familiar with the problems involved in building Radiosonde Modulator/Transmitters.

3.2 FM Source

Nine of the 10 first engineering samples performed excellently with repeatable results. Power output was very flat with frequency and all units met or came close to meeting the linearity requirement. More effort is needed on the power amplifier to correct the linearity problem. We feel that overall excellent progress has been made toward meeting the design specs.

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SECTION 4

PROGRAM FOR NEXT INTERVAL

4.1 RADIOSONDE

The following objectives are planned for the next reporting period:

1. Lazer trim modulator resistors using Collins automatic lazer trim facility.
2. Make decision on transistor mounting technique.
3. Temperature stabilize oscillator frequency.
4. Redesign, fabricate and test the second set of engineering samples.
5. Write program for autotest of modulator and oscillator.

4.2 FM SOURCE

The following objectives are planned for the next reporting period:

1. Redesign, fabricate and test the second set of engineering samples.
2. Improve modulation linearity by lowering the input VSWR of the power amplifier.
3. Formulate plans and write program for autotest of the FM Source.

4.3 MATERIAL EVALUATION

1. Complete first seven experiments.
2. Evaluate Q test fixture.
3. Generate artworks for capacitor evaluation.
4. Generate artworks for Q measurements.
5. Complete Q measurements on 25, 40 and 60 mil thick film substrates.

SECTION 5

5.0 IDENTIFICATION OF PROJECT PERSONNEL

The personnel directly related to the ECOM project are list in Table along with the number of hours that they have been involved during this quarter. Resumes of each person is included in this first quarterly report.

Table

Identification of Project Personnel

Personnel	Titles	Hours
W. E. Wilson	Program Manager	
R. E. Shipley	Project Engineer/Group Head	105
H. D. Jenkins	Mechanical Engineer/Group Head	30
F. L. Sachen	Design Engineer (Elec.)	550
L. G. Ward	Design Engineer (Mech.)	158
C. L. Fox	Senior Technician	211
R. Caddenhead	Senior Process Engineer	62
J. K. McCoy	Design Engineer (Elec.)	517

ROY EARL SHIPLEY

POSITION: Manager, Microwave Engineering, RF Products Department

EDUCATION: BSEE, University of Texas at Arlington, 1962

Mr. Shipley is engineering manager responsible for development of advanced RF components in the frequency range from 1-18 GHz. Programs currently under his cognizance include advanced R&D on 18 GHz Gunn sources and IMPATT injection locked oscillators, development of an integrated RF transceiver unit for a 2 GHz tactical digital communications system, development of a subminiature, low cost 2.5 GHz telemetry system for an unusually severe military environment and production engineering of a line of RF hybrid components used in Collins line of sight microwave systems.

Prior to acceptance of engineering management responsibilities in 1974, Mr. Shipley acted as project engineer on a variety of RF components and subsystems at Collins. In the period from 1969 to 1973, he pioneered application of hybrid microcircuit techniques to high power broadband RF amplifiers. Components which evolved from his basic work in this area give Collins a leadership position in RF hybrids. Mr. Shipley holds two patents on RF hybrid devices, and he is a registered professional engineer.

Before joining Collins in 1965, Mr. Shipley was an avionics systems engineer at LTV.

LLOYD GENE WARD

POSITION: Design Engineer, RF Products
Hybrid Microelectronics Division

EDUCATION: BSME, Texas Technological College, 1958

Current responsibility includes the design and direction of other engineers and draftsmen associated with the development of microwave hybrid power amplifiers for MW-328, Combat Grande and B.C. Hydro projects. This activity includes thermal design, structural design, packaging, interconnection and environmental testing. Other responsibilities include the technical support for existing UHF and microwave products in the Hybrid Microelectronics Division.

Previous experience and responsibilities include the mechanical design and development of the power amplifier, AM6721/A, for Air Force Satellite Communications System, digital to voice converter, disc/tape storage devices, CRT displays, and various switching and communications systems.

Mr. Ward holds two patents covering a packaging-interconnect system for a group of cross-bar switches and a card cage design utilizing formed wire card guides.

H. DON JENKINS

Position: Group Head, Mechanical Design, Hybrid Microelectronics Division

Education: BSME, Texas A & M, 1958, and has 12 hours toward a Masters Degree at Southern Methodist University in the field of thermal and fluid science.

Related Experience: Mr. Jenkins joined Collins Radio Company in 1960, and has worked in several areas of communication equipment design. He has primarily been involved in the mechanical packaging of these equipments which include complete structural and thermal analysis with laboratory testing to verify the design. For three and one-half years Mr. Jenkins packaged power amplifiers. This area deals with high dissipation power to volume ratio, which has led to various studies and development of heat removal devices. One such device was an experimental heat exchanger utilizing the heat pipe principle.

During his 2 years in Microwave, Mr. Jenkins was responsible for the mechanical design of multiplex equipment line. In his present position as Mechanical Design Group Head, Mr. Jenkins is responsible for all mechanical design support for non-hybrid products, cost estimating and proposal support on all mechanical designs, design documentation on non-hybrid product designs, and provides mechanical design support for internal process equipment.

Mr. Jenkins has attended various short courses, one of the courses was on The Analysis and Design of Heat Pipes presented by the Engineering and Physical Sciences Extension, U.C.L.A.

Before coming to Collins Radio Company, Mr. Jenkins worked at General Dynamics in the Electronic Division that designed and installed equipments in the B-58 aircraft.

While serving in the U.S. Army, Mr. Jenkins took a six months course in carrier and repeated equipment installation and maintenance. He served the remainder of his two years in field application of the above subject.

Mr. Jenkins is a registered Professional Engineer in the State of Texas.

FRED LEE SACHEN

POSITION: Senior Engineer; RF Products
Hybrid Microelectronics Division

EDUCATION: BSEE (Cum Laude), Kansas State University, 1968
Graduate Studies, Johns Hopkins University, 1969-70

Mr. Sachen joined Collins Radio in April 1974 and has been the project engineer responsible for the development of a solid state, MIC, transmit/receive module for front-end applications in the L-band region.

Prior to joining Collins, Mr. Sachen was with Texas Instruments and Westinghouse Electric where he was engaged in the design, fabrication, and production of MIC components and modules for radar applications. He is experienced in the design of a variety of receiver circuits with particular emphasis on the design of low noise receivers and transistor amplifiers operating in the UHF and microwave spectrum.

Mr. Sachen's experience includes the application of computer aided design and optimization routines to MIC design.

Societies to which Mr. Saches belongs are IEEE, Eta Kappa Nu and Phi Kappa Phi.

Papers published are:

"An Integrated Solid State S-Band Receiver Front End"
1972 GOMAC, San Diego, California

"MIC Low-Noise Transistor Amplifiers Design"
1972 Meeting of the IEEE-GMTT, Baltimore Chapter

WILLIAM E. WILSON

POSITION: Manager, RF Programs, RF Products Business Area

EDUCATION: B.E.E., Cornell University, Ithaca, N.Y., 1964
MSEE, Syracuse University, Syracuse, N.Y., 1969
MBA, University of New Mexico Executive Program,
Albuquerque, N.M, 1975

Mr. Wilson joined Collins Radio/Rockwell International in 1974 as Business Development Manager for the MOS/Components Business Area at Newport Beach, California. During that year he developed a major business plan to establish Collins in the GaAs microwave device and subassembly business. Following approval of the plan he transferred to Dallas to manage and staff the start up phase of the microwave device activity in the Hybrid Microelectronics Division of Collins Radio. In August 1975 he was promoted to Program Manager for the broadband UHF AFSATCOM power amplifier program within Hybrid Microelectronics. Shortly thereafter the RF Products Business Area was segmented as a profit center within HME, and Mr. Wilson assumed the overall program management function for major programs within the new business area, the position he presently holds.

Prior to joining Collins Radio, Mr. Wilson worked 4 years at Sandia Laboratories in Albuquerque, New Mexico where he specialized in microwave device/hybrid microcircuit technology for fuzing radar applications. Prior to that he spent 5 years with the Air Force in the Electron Devices section of Rome Air Development Center managing R/D programs for active microwave device development.

Mr. Wilson is a member of the IEEE and was past section chairman for the Electron Devices Group, Albuquerque, New Mexico chapter. He has presented and published several papers in the general area of solid state microwave devices and circuits.

JEROME K. MCCOY

POSITION:	Design Engineer, RF Products, Hybrid Microelectronics Division
EDUCATION:	BSEE, Virginia Polytechnic Institute, 1974 MSEE, Southern Methodist University, Completion Dec. 1976

Mr. McCoy came to Collins after graduation in 1974. Initial work assignments included design of an S-band amplifier for the ARPA program and assistance in the final design of a 10 watt 2 GHz power amplifier. He has worked extensively in the design of a Filter-Coupler-Switch for use in the AFSCS program.

Prior to joining Collins, Mr. McCoy spent approximately 2 years as a Co-op student for Goddard Space Flight Center (NASA) where he worked on an ION engine control circuitry and on AGC system for an IF amplifier. He also spent several months working for Virginia Polytechnic Institute fabricating the "front end" of a 20 GHz receiver.

Mr. McCoy is a member of the IEEE and Tau Beta Pi.

ROGER L. CADDENHEAD

POSITION:	Senior Process Engineer, Advanced Technology and Engineering, Hybrid Microelectronics Division
EDUCATION:	BS, Major in Chemistry, Minor in Mathematics, 1969 University of Texas at Arlington, Graduate work at same.

Mr. Caddenhead is currently a Senior Process Engineer responsible for material and process development for thick and thin film hybrid microcircuits. He interfaces with manufacturing to improve yields and efficiency and has been responsible for the initial set-up and operation of Collins' thick film lab.

Prior to joining Collins, Mr. Caddenhead was employed by Micropac Industries where he was manager in charge of Manufacturing Engineering and Substrate Manufacturing. His duties encompassed marketing, manufacturing, engineering and administration.

Mr. Caddenhead is a member of the American Chemical Society and has authored several publications in American and European trade journals. He holds four patent disclosures.

CECIL L. FOX

POSITION: Senior Engineering Lab Tech, Hybrid Microelectronics Div.

Mr. Fox joined Collins Radio in August of 1956 as an engineering lab tech, for the Radar Engineering Lab. Since 1966 he has been assigned to the Hybrid Microelectronics RF Products Lab where he is currently the head technician. Besides the usual technician responsibilities Mr. Fox coordinates the activities in the lab, and oversees the test equipment and supplies status.

SECTION 6

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SECTION 7

Z FEED

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C
      COMPLEX S11,S12,S21,S22,DENOM1,Z11,Z12,Z21,Z22,Z11T,Z12T,Z21T,Z22T
      COMPLEX DENOM2,S11T,S12T,S21T,S22T,ZFEED
      REAL MAGS11,MAGS12,MAGS21,MAGS22,K
      DIMENSION A(9),B(9),Z(26)
      READ(8,105) (Z(I),I=1,10)
  105 FORMAT(1H ,4(F4.1,2X,F4.1,4X),E7.1,2X,F4.1)
      READ(8,110) (Z(I),I=11,18)
      READ(8,110) (Z(I),I=19,26)
  110 FORMAT(1H ,4(F4.1,2X,F4.1,4X))
      READ(8,100) NFREQ
  100 FORMAT(I3)
      DO 150 N=1,NFREQ
      JDUMMY=1+N
      READ(8,115) FREQ,(A(L),L=1,8)
  115 FORMAT(I5,4(2X,F6.3,1X,F6.1))
      WRITE(7,120)
  120 FORMAT(1H1)
       WRITE(7,125)
  125 FORMAT(1H )
       WRITE(7,130) FREQ
  130 FORMAT(1H ,5HFREQ=,I5)
       WRITE(7,125)
       WRITE(7,135)
  135 FORMAT(1H ,29HSERIES FEEDBACK ELEMENT (R,X),7X,3HS11,15X,3HS12,15X
      1,3HS21,15X,3HS22,12X,1HK,8X,3HDEL)
       WRITE(7,125)
       DO 50 I=1,7,2
       X=A(I)*COS(3.14159*A(I+1)/180.0)
       Y=A(I)*SIN(3.14159*A(I+1)/180.0)
       A(I)=X
```

```
   50 B(I)=Y
      S11=CMPLX(A(1),B(1))
      S12=CMPLX(A(3),B(3))
      S21=CMPLX(A(5),B(5))
      S22=CMPLX(A(7),B(7))
      DENOM1=(1.0-S11)*(1.0-S22)-S12*S21
      Z11=((1.0+S11)*(1.0-S22)+S12*S21)/DENOM1
      Z12=2.0*S12/DENOM1
      Z21=2.0*S21/DENOM1
      Z22=((1.0+S22)*(1.0-S11)+S12*S21)/DENOM1
      DO 55 J=1,25,2
      ZFEED=CMPLX(Z(J),Z(J+1))
      Z11T=Z11+ZFEED
      Z12T=Z12+ZFEED
      Z21T=Z21+ZFEED
      Z22T=Z22+ZFEED
      DENOM2=(1.0+Z11T)*(1.0+Z22T)-Z12T*Z21T
      S11T=((1.0+Z22T)*(Z11T-1.0)-Z12T*Z21T)/DENOM2
      S12T=2.0*Z12T/DENOM2
      S21T=2.0*Z21T/DENOM2
      S22T=((1.0+Z11T)*(Z22T-1.0)-Z12T*Z21T)/DENOM2
      MAGS11=CABS(S11T)
      ANGS11=180.0*ATAN2(AIMAG(S11T),REAL(S11T))/3.14159
      MAGS12=CABS(S12T)
      ANGS12=180.0*ATAN2(AIMAG(S12T),REAL(S12T))/3.14159
      MAGS21=CABS(S21T)
      ANGS21=180.0*ATAN2(AIMAG(S21T),REAL(S21T))/3.14159
      MAGS22=CABS(S22T)
      ANGS22=180.0*ATAN2(AIMAG(S22T),REAL(S22T))/3.14159
      DEL=S11T*S22T-S12T*S21T
      K=(1.0+(CABS(DEL))**2-MAGS11**2-MAGS22**2)/(2.0*CABS(S12T*S21T))
      WRITE(7,140) Z(J),Z(J+1),MAGS11,ANGS11,MAGS12,ANGS12,MAGS21,ANGS21
     1,MAGS22,ANGS22,K,DEL
  140 FORMAT(1H ,5X,E7.1,4X,E7.1,7X,4(F6.3,2X,F6.1,4X),1X,F6.2,4X,F6.2)
      WRITE(7,125)
   55 CONTINUE
  150 CONTINUE
      STOP
      END
```