

AD-A161 732

②
DNA-TR-84-412

DIRECT COURSE EXPERIMENT NO. 7360
A System for Recording Radio Noise from the DIRECT COURSE Event

J.B. Murphy
Science Applications International Corporation
Corporate C³ Program Office
P. O. Box 371
Stow, MA 01775-0371

11 May 1984

Technical Report

CONTRACT No. DNA 001-83-C-0117

Approved for public release;
distribution is unlimited.

THIS WORK WAS SPONSORED BY THE DEFENSE NUCLEAR AGENCY
UNDER RDT&E RMSS CODE X326083469 Q93QMXVDC0001 H2590D.

DTIC FILE COPY

Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, DC 20305-1000

DTIC
ELECTE
NOV 14 1985
S D
B

85 8 29 058

Destroy this report when it is no longer needed. Do not return to sender.

PLEASE NOTIFY THE DEFENSE NUCLEAR AGENCY,
ATTN: STTI, WASHINGTON, DC 20305-1000, IF YOUR
ADDRESS IS INCORRECT, IF YOU WISH IT DELETED
FROM THE DISTRIBUTION LIST, OR IF THE ADDRESSEE
IS NO LONGER EMPLOYED BY YOUR ORGANIZATION.



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A161732

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b RESTRICTIVE MARKINGS	
2a SECURITY CLASSIFICATION AUTHORITY N/A since UNCLASSIFIED		3 DISTRIBUTION AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.	
2b DECLASSIFICATION/DOWNGRADING SCHEDULE N/A since UNCLASSIFIED		5 MONITORING ORGANIZATION REPORT NUMBER DNA-TR-84-412	
4 PERFORMING ORGANIZATION REPORT NUMBER SAIC-84/1774		6a NAME OF MONITORING ORGANIZATION Director Defense Nuclear Agency	
6a NAME OF PERFORMING ORGANIZATION Science Applications Int'l Corp	6b OFFICE SYMBOL (if applicable)	7a ADDRESS (City, State, and ZIP Code) Washington, DC 20305-1000	
6c ADDRESS (City, State, and ZIP Code) Corporate C3 Program Office P.O. Box 371 Stow, MA 01775-0371		7b ADDRESS (City, State, and ZIP Code)	
8a NAME OF FUNDING SPONSORING ORGANIZATION	8b OFFICE SYMBOL (if applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DNA 001-83-C-0117	
8c ADDRESS (City, State, and ZIP Code)		10 SOURCE OF FUNDING NUMBERS	
		PROGRAM ELEMENT NO 62715H	PROJECT NO Q93QMXV
		TASK NO 0	REPORT ACCESSION NO DH008393
11 TITLE (Include Security Classification) DIRECT COURSE EXPERIMENT NO. 7360, A System for Recording Radio Noise from the DIRECT COURSE Event			
12 PERSONAL AUTHOR(S) J.B. Murphy			
13a TYPE OF REPORT Technical Report	13b TIME COVERED FROM 830107 TO 831031	14 DATE OF REPORT (Year, Month, Day) 840511	15 PAGE COUNT 64
16 SUPPLEMENTARY NOTES This work was sponsored by the Defense Nuclear Agency under RDT&E RMSS Code X326083469 Q93QMXVD00001 H2590D.			
17 COSAT GROUPS		18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	Dust-Induced Noise RF Interference	
18	3	14-Channel Instrumentation Recorder Instrumentation Recorder	
19	4	IRIG Analog Recording	
19 ABSTRACT (Continue on reverse if necessary and identify by block number) This report documents the design and fabrication of the wideband noise recording unit developed for DIRECT COURSE experiment No. 7360. A complete set of drawings is included.			
20 DISTRIBUTION AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED UNLIMITED <input checked="" type="checkbox"/> SAME AS PPT <input type="checkbox"/> DTIC USERS		21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a NAME OF RESPONSIBLE INDIVIDUAL Betty L. Fox		22b TELEPHONE (Include Area Code) (202) 325-7042	22c OFFICE SYMBOL DNA STTI

DD FORM 1473, 84 MAR

83 APP Edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

18. SUBJECT TERMS (Continued).

Dust-Induced Lightning
High Explosive Testing
Impulsive Noise

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
	List of Illustrations	2
	List of Tables	4
1	INTRODUCTION	5
1-1	BACKGROUND	5
1-2	OBJECTIVES	8
2	Equipment Design	11
2-1	General	11
2-2	TECHNICAL SPECIFICATIONS	16
 <u>Appendices</u>		
A	Noise Recording System Drawings	A-1
B	Rental Equipment Specifications	B-1

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	



LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	Atmospheric noise statistics	6
2	Typical HF data link performance	7
3	Frequency utilization chart	9
4	Noise recording system	12
5	EMI 7000-A recorder	13
6	Experiment 7360 electronics chassis	14
7	Empire NF-105 field strength meter	15
8	Expected values of atmospheric noise	17
9	Variation of radio noise with frequency	18
10	Data on noise variability and character	21
A-1	Physical configuration (deployed)	A-2
A-2	Noise recording system block diagram	A-3
A-3	600 KHz crossed loop antennas	A-4
A-4	Loop antenna section B-B	A-5
A-5	Loop antenna section C-C	A-6
A-6	220 MHz horizontal yagi	A-7
A-7	15 MHz vertical monopole	A-8

LIST OF ILLUSTRATIONS (Concluded)

<u>Figure</u>		<u>Page</u>
A-8	50 MHz horizontal yagi	A-9
A-9	Voltage regulator 15 V ^{AC}	A-10
A-10	Power supply regulator 11 VDC	A-11
A-11	15.1 MHz local oscillator	A-12
A-12	15.1 MHz local oscillator	A-13
A-13	10-600 KHz differential front-end	A-14
A-14	1.5/2.3 MHz L.O. buffer/mixer	A-15
A-15	Frequency converter 10 MHz to 2.3 MHz	A-16
A-16	50 MHz local oscillator	A-17
A-17	220 MHz band pass filter	A-18
A-18	15 MHz band pass filter	A-19
A-19	50 MHz band pass filter	A-20
A-20	2 MHz butterworth low pass filter	A-21
A-21	10 MHz distribution amplifier	A-22
A-22	220 MHz local oscillator	A-23
A-23	I.F. processing amplifier 10-600 KHz	A-24
A-24	Multi-channel frequency converter block diagram	A-25
P-1	EMI-7000A instrumentation recorder	B-2
B-2	EMI-7000A specification sheet	B-3
B-3	EMPIRE/NF-105 Noise and field intensity meter	B-4
B-4	EMPIRE/NF-105 accessory antenna case	B-5
B-5	EMPIRE/NF-105 block diagram	B-6

LIST OF TABLES

<u>TABLE</u>		<u>PAGE</u>
1	Noise recording system channel configuration	10
2	Median atmospheric noise power as a function of frequency	19
3	Median Vertical E-field strength as a function of frequency	19
4	Upper decile (90%) E-field strength from 10-600KHz	20
5	Predicted upper decile noise values	22
6	Calculated minimum detectable vertical E-field at loop antenna terminals	23
7	Minimum front-end input voltage for a +10 dbSNR	23
8	Electrical performance of noise measuring system	24

SECTION 1

INTRODUCTION

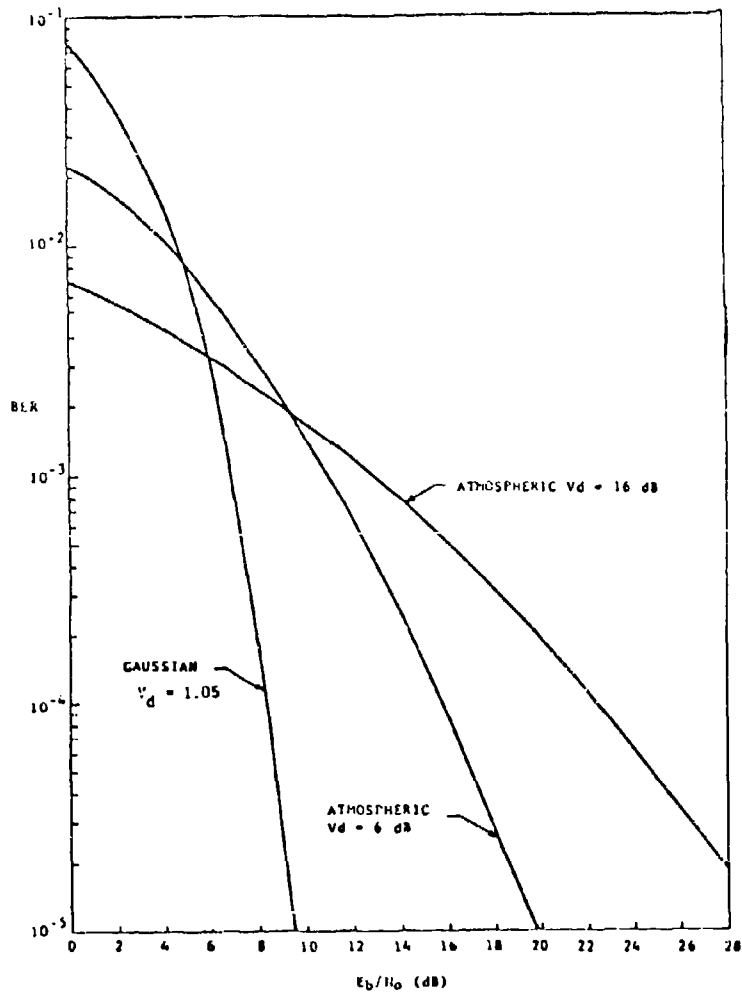
1-1 BACKGROUND

Voice and data radio communication systems are extremely critical to U.S. Strategic and Theater C3 systems. The performance of these radio links is limited by external noise of various types: atmospheric, galactic, thermal and event-induced. This experiment is principally concerned with the impulsive noise generated by high energy explosive tests. Figure 1 shows representative atmospheric noise statistics parametric in voltage deviation, V_d , the measure of impulsiveness, in dB. The figure shows that as V_d increases, the bit error rate (BER) increases at high E_b/N_0 and decreases at lower values of E_b/N_0 .

A typical HF system must be designed to have a sufficiently high signal to noise ratio (SNR) to operate in or to the right of the cross-hatched region depicted in Figure 2. For an SNR greater than approximately 30 dB, the character error rate (CER) will typically be less than 0.001.

V_d , which results from lightning is assumed to follow a gaussian distribution, however on a local scale, V_d is non-gaussian.

There are well documented but little understood observations of lightning in dust and volcanic clouds. Since these phenomena appear to exhibit an impulsive behavior similar to lightning, they may have very serious effects on communication systems.



- IMPULSIVENESS, V_d , RMS TO AVERAGE NOISE ENVELOPE VOLTAGE
- PULSE DURATION
- PULSE SPACING

Figure 1. Atmospheric noise statistics.

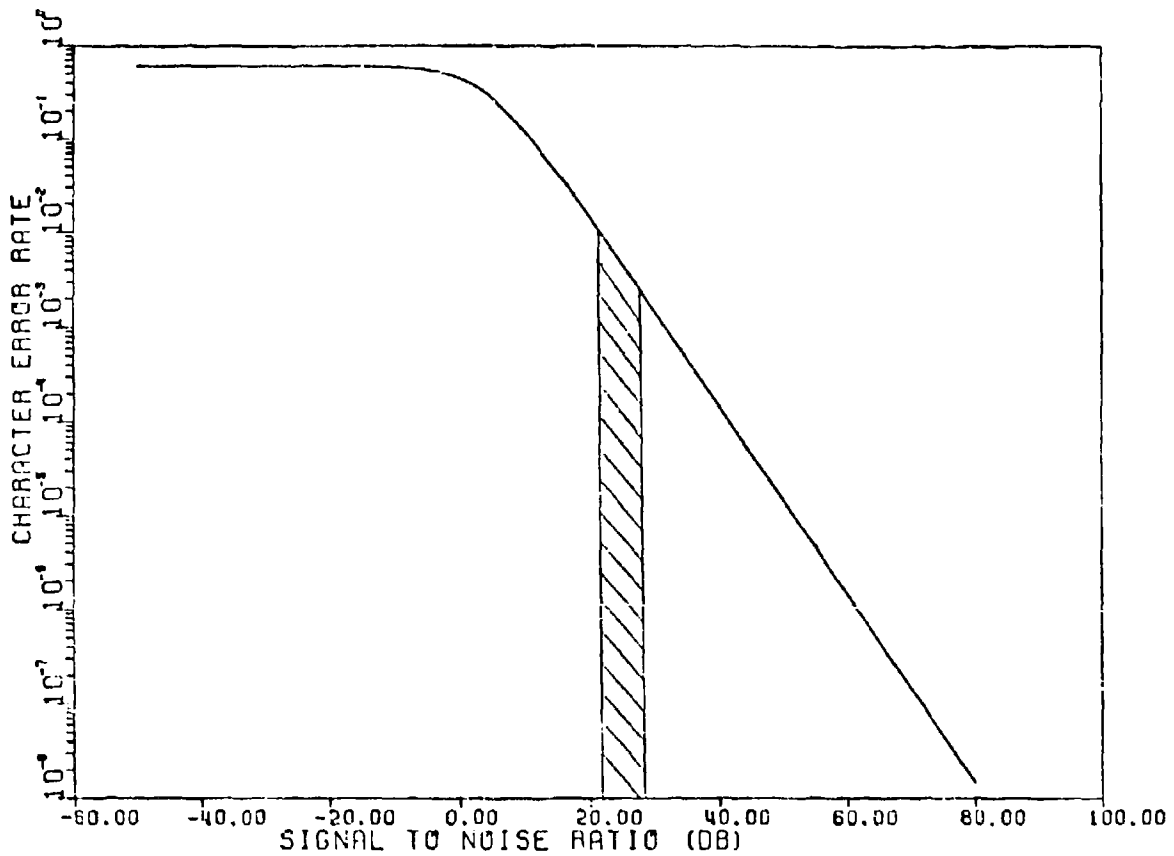


Figure 2. Typical HF data link performance.

A similar mechanism for dust cloud generation is large yield nuclear ground bursts. The purpose of this experiment is to use high explosive (HE) testing to simulate the dust effects of a nuclear ground burst with the hope of understanding the charging mechanisms in order to model them in a way that can be scaled to nuclear proportions.

1-2 OBJECTIVES.

The major goal of this experiment is to obtain high fidelity, wideband (10-600 KHz) analog recordings of the time domain signals that occur in the multiple frequency bands of interest to DNA/BMO/BMD, as a result of the DIRECT COURSE High Explosive event.

These recordings were made on a 14-channel EMI-7000A, IRIG specification, dc powered instrumentation recorder deployed at the test site. Figure 3 illustrates typical government frequency utilizations together with the bands selected for Experiment 7360 recording.

The noise recording system is designed to operate in bands designated in Table 1 with low and high gain channels to insure an adequate dynamic range of 70dB.

Additionally, provisions were made to allow taking field strength measurements of one or more known signals in each frequency band. This data will be used to determine the relative amplitude of the noise impulses.

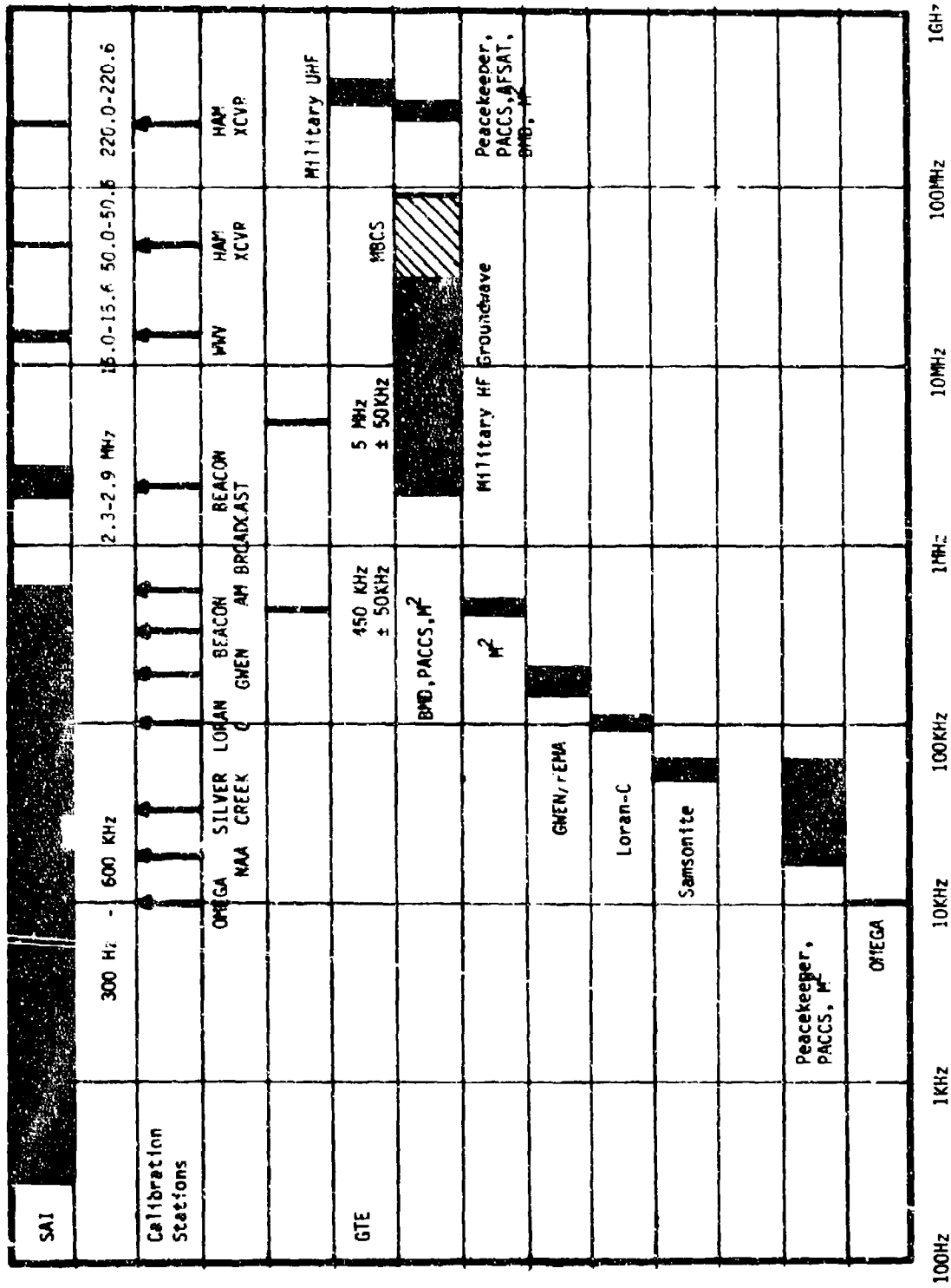


Figure 3 Frequency Utilization Chart

Table 1. Noise recording system channel configurations.

Channel	Frequency	Gain	Antenna
1	0.3-600 KHz	Low	Orthogonal(1) Loop
2	0.3-600 KHz	High	Orthogonal(1) Loop
3	0.3-600 KHz	Low	Broadside(2) Loop
4	0.3-600 KHz	High	Broadside(2) Loop
5	2.3-2.9 MHz	Low	Vertical Monopole
6	2.3-2.9 MHz	High	Vertical Monopole
7	15.0-15.6 MHz	Low	Vertical Monopole
8	15.0-15.6 MHz	High	Vertical Monopole
9	50.0-50.6 MHz	Low	Horizontal Yagi
10	50.0-50.6 MHz	High	Horizontal Yagi
11	220.0-220.6 MHz	Low	Horizontal Yagi
12	220.0-220.6 MHz	High	Horizontal Yagi
13*	----	----	-----
14*	----	----	-----

(1) Main beam pointed toward ground-zero (GZ)
(2) Null pointed toward GZ

NOTE: The EM1-7000A has 14 channels. Only 12 were used in this experiment.

SECTION 2 EQUIPMENT DESIGN

2-1 GENERAL.

Figure 4 is a block diagram of noise recording system showing all major elements. The equipment consists of several components designed around the EMI-7000A 14-channel instrumentation recorder. Figure 5 gives a summary of the recorder specifications.

Figure 6 shows the three main chassis designed and built under subcontract by RADANT Systems, Inc., 255 Hudson Road, Stow, MA. Appendix A contains the system specifications provided by the subcontractor. In the left foreground is the chassis containing power supply and its regulation circuit boards, the 10 MHz distribution amplifier, the local oscillators (in shielded boxes), and the 220 MHz front-end electronics.

In the left background is the chassis containing the front-end preamplifiers, the mixer stages and the channel splitters for the 15, 50 and 220 MHz channels. On the right is the 12-channel delay equalization amplifier.

Figure 7 shows the Empire NF-105 field strength meter and its accessories. This piece of equipment is used to measure the absolute field strengths of the marker beacons, such as Cutler, ME, on 17.8 kHz and Loran-C on 100 kHz, in order to later determine relative field strengths of the recorded noise.

- 14 DIRECT TRACKS:
 - 0.3-600 KHZ B.W. @ 120 IPS
 - 40 DB SNR
- 1" IRIG SPEC # 106.73
- DC POWERED, 24 V, 16 AMPS
- 26 x 16 x 15"
- 51 LBS
- 8.5 MINS/TAPE REEL (AMPEX 797)

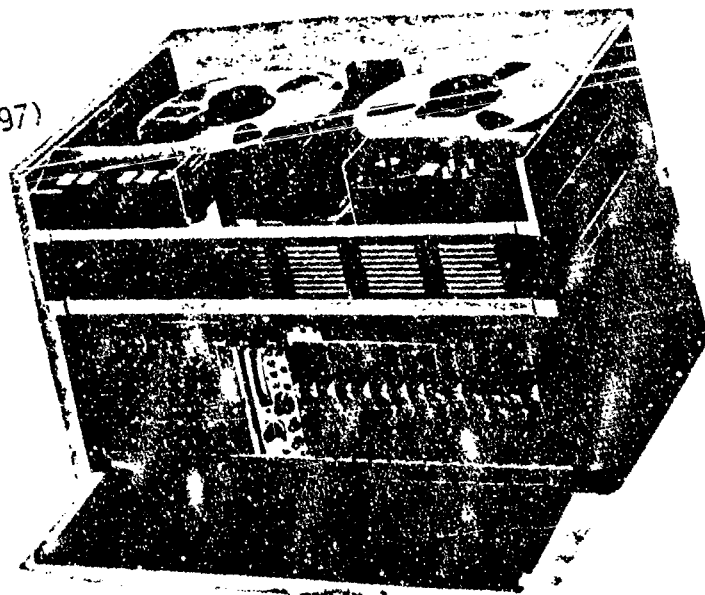


Figure 5. EMI 7000-A recorder.

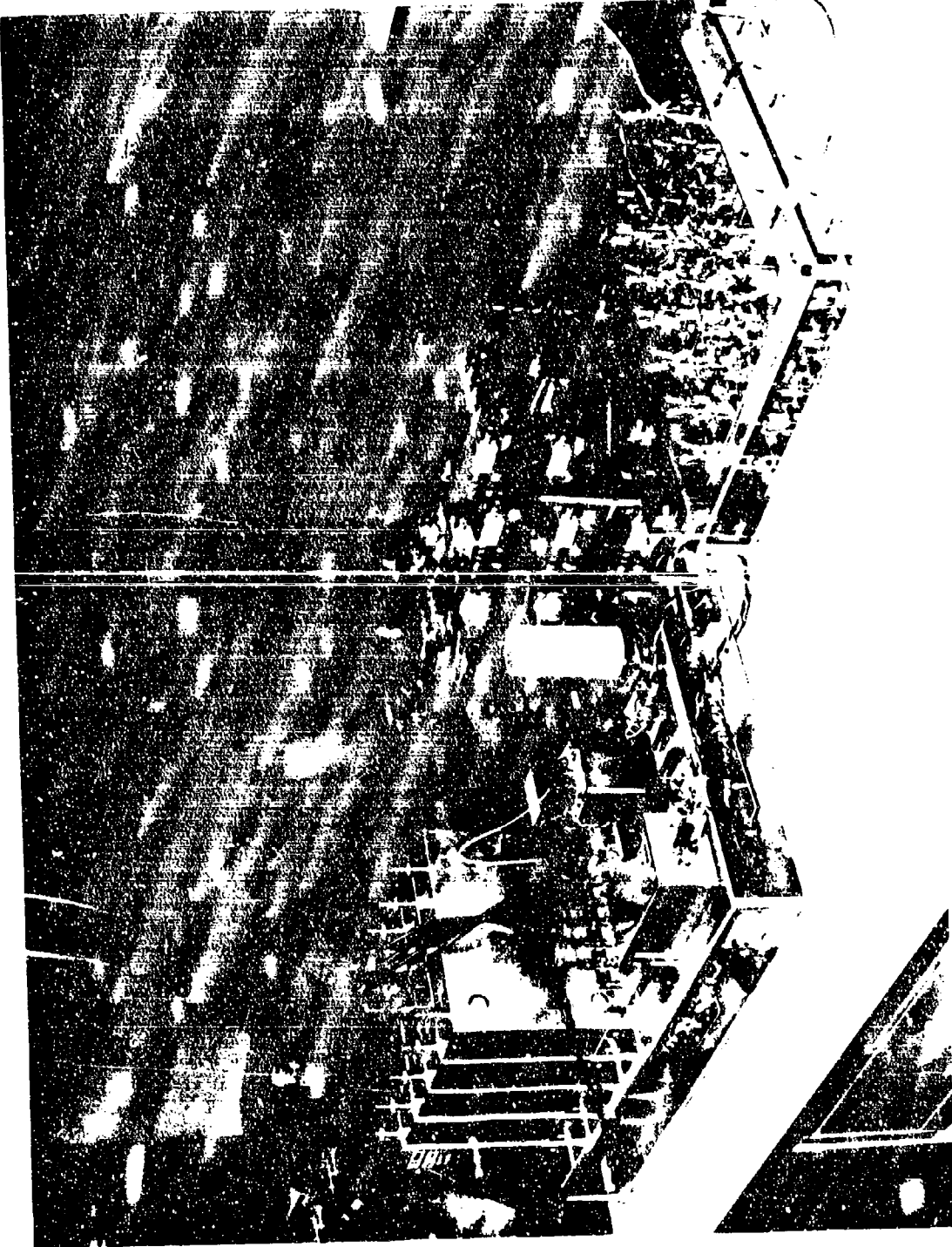


Figure 6. Experiment 7360 electronics chassis

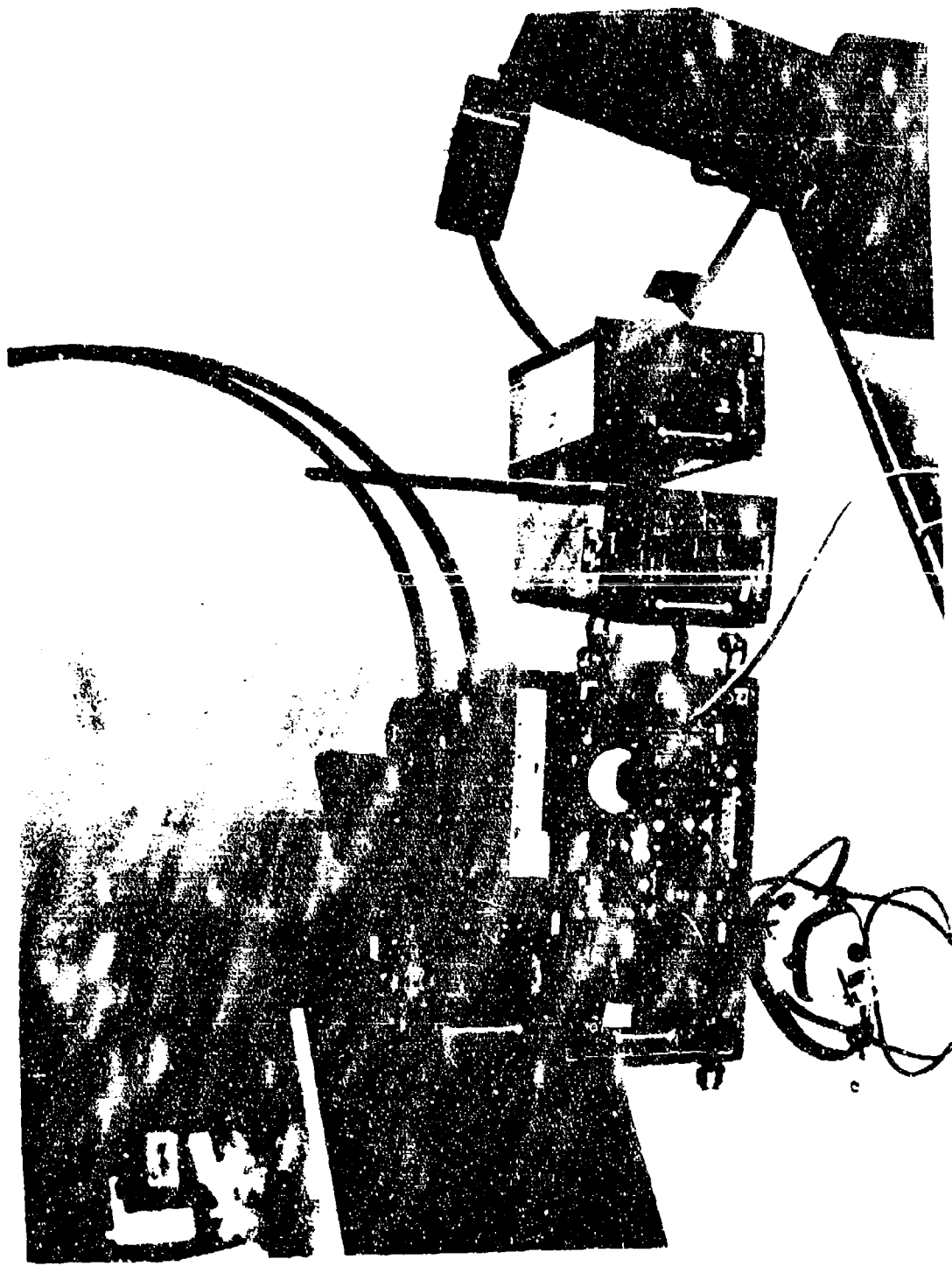


Figure 7. Empire NF-105 field strength meter

2-2 TECHNICAL SPECIFICATIONS.

Since four bands are outside the 600 kHz recorder bandwidth, it is necessary to heterodyne each with a local oscillator and mixer. This process is similar to the RF-IF conversion found in a superheterodyne receiver. In the 10-600 kHz bands, the actual frequency will be preserved. Thus, Cutler, ME on 17.8 kHz will appear at 17.8 kHz on its respective channel and Loran-C on 100 kHz will appear at 100 kHz, etc. In the other bands, however, since the FR must be mixed down to a baseband frequency of 10-600 KHz, all recorded signals will appear with a relative offset in the baseband. For instance, WWV on 2.5 MHz would be found at 200 kHz on playback since it lies 200 kHz above 2.3 MHz, which is the bottom edge of the 2.3-2.9 MHz channel.

The 10-600 KHz bands use two electrostatically shielded and crossed-loop antennas, each one meter in diameter and made with eight turns. This type of antenna was chosen instead of an E-Field sensor because it reduces near-field pickup and provides an azimuthally directional pattern which can be used to cancel out the effects of the atmospheric noise.

Figure 8 taken from CCIR Report 322-2¹, shows that for Autumn between the hours of 1200-1600 UT in the southwestern United States, the value of the effective antenna noise factor in dB (F_{am}) is 40 dB at 1 MHz. Then from Figure 9 the corrected values of F_{am} can be determined for the frequencies of interest. These results are presented in Table 2.

¹"Characteristics and Applications of Atmospheric Radio Noise Data", Report 322-2, International Telecommunications Union (ITU), International Radio Consultative Committee (CCIR), 1983

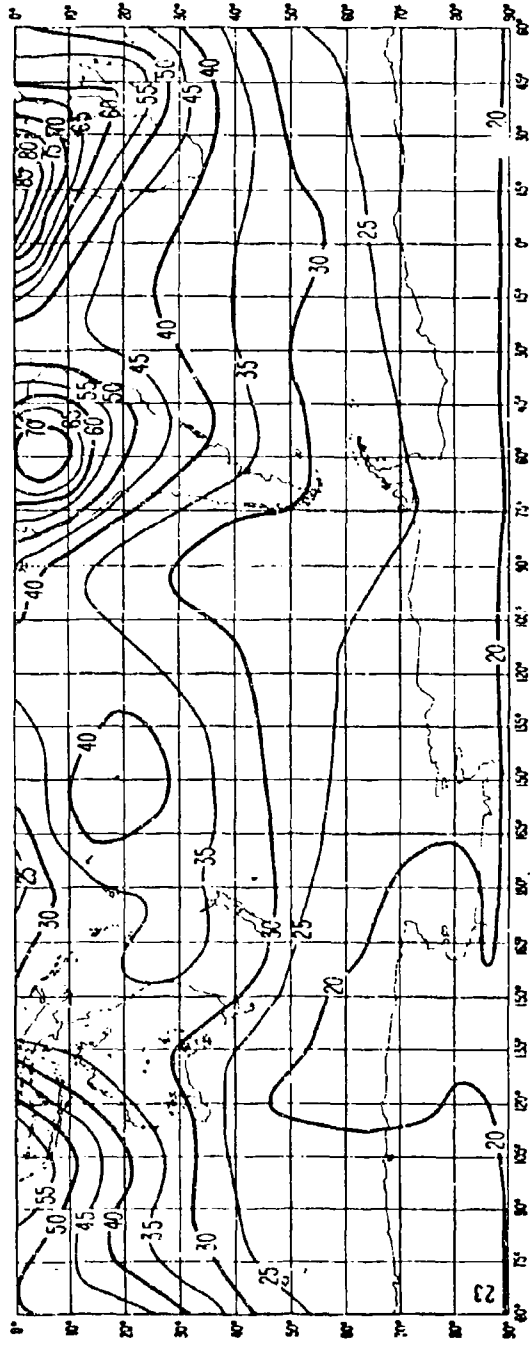
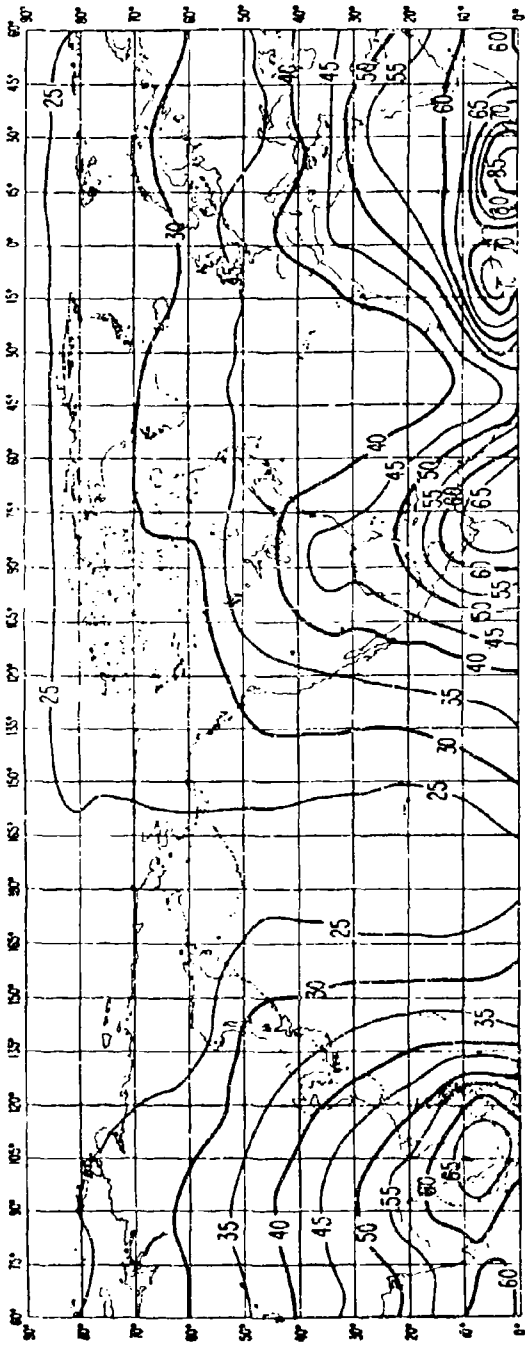


Figure 8. Expected values of atmospheric noise.

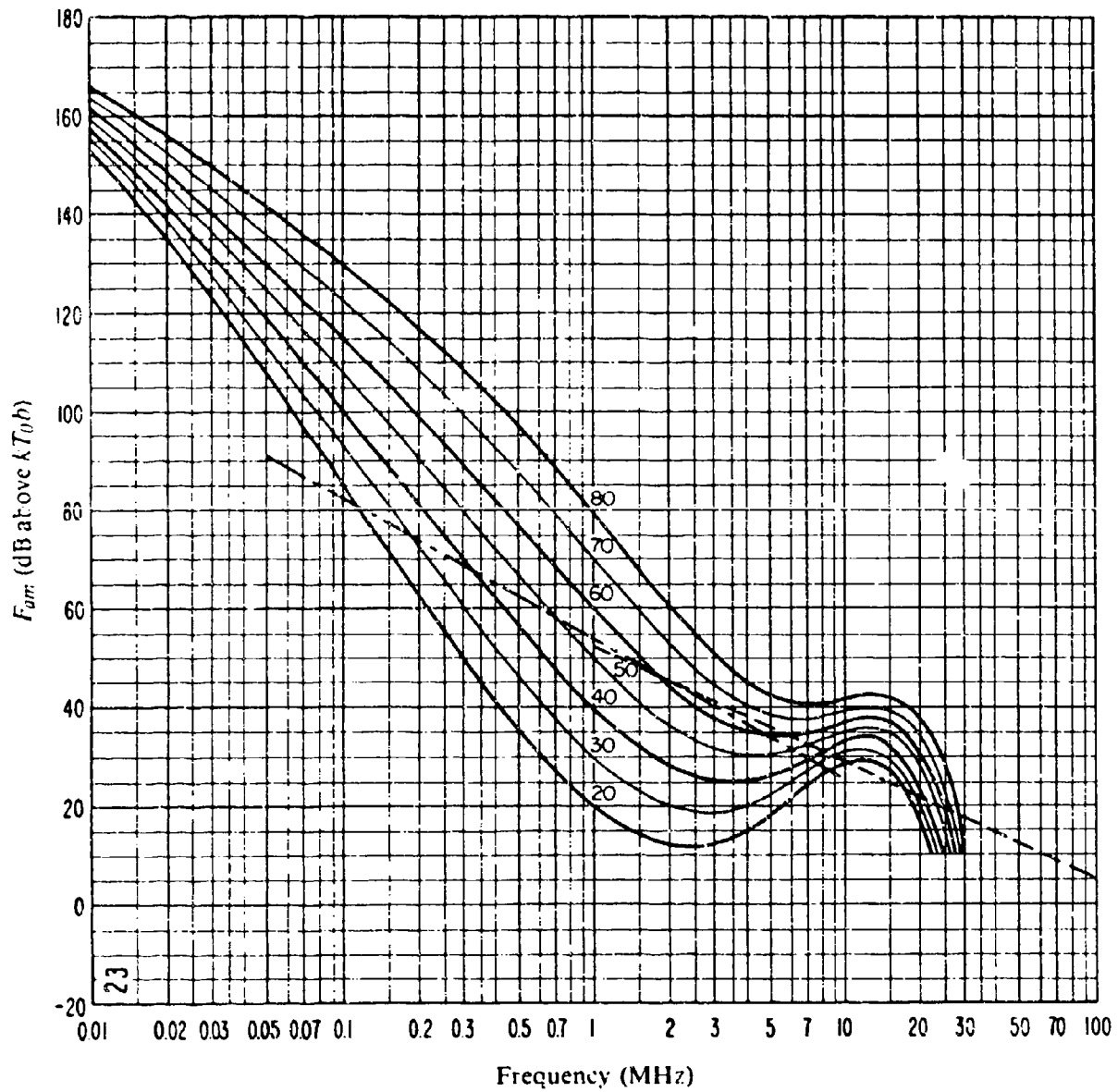


Figure 9. Variation of radio noise with frequency.

Table 2. Median atmospheric noise power as a function of frequency.

F _{am} = 157 dB	for f= 10 kHz
= 142 dB	for f= 20 kHz
= 115 dB	for f= 60 kHz
= 100 dB	for f= 100 kHz
= 70 dB	for f= 300 kHz
= 51 dB	for f= 600 kHz

The equivalent median (50%) vertical electric field strength (E_n) in dB referenced to 1_μV/m in a 10 kHz bandwidth is given by Equation (2) in Reference 1.

$$E_n = F_{am} - 55.5 + 20 \log(\text{Frequency in MHz}) \quad (1)$$

Table 3 illustrates values for several frequencies in the range of interest.

Table 3. Median vertical E-field strength versus frequency.

E _n = 61.50 dB/1 _μ V/m	@ 10 kHz
= 52.52 dB "	" @ 20 kHz
= 35.06 dB "	" @ 60 kHz
= 24.50 dB "	" @ 100 kHz
= 4.04 dB "	" @ 300 kHz
= -8.94 dB "	" @ 600 kHz

Figure 10 provides an upper decile (90%) correction to the median (50%) noise values. This means that the corrected values will only be exceeded 10 percent of the time for the 1200-1600 hour block. The resulting upper decile noise values are shown in Table 4.

Table 4. Upper decile (90%) E-field strength from 10-600KHz.

$E_n = 65.50 \text{ dB/uV/m @ 10 kHz}$
$= 61.52 \text{ dB " " @ 20 kHz}$
$= 50.06 \text{ dB " " @ 60 kHz}$
$= 41.00 \text{ dB " " @100 kHz}$
$= 21.74 \text{ dB " " @300 kHz}$
$= 8.26 \text{ dB " " @600 kHz}$

The voltage induced in a loop antenna is given by the following equation²

$$V_{in} = 2.094 * 10E-8 * F * E * A * n \quad (2)$$

where V_{in} - voltage at the loop antenna terminals,

F = frequency in Hz

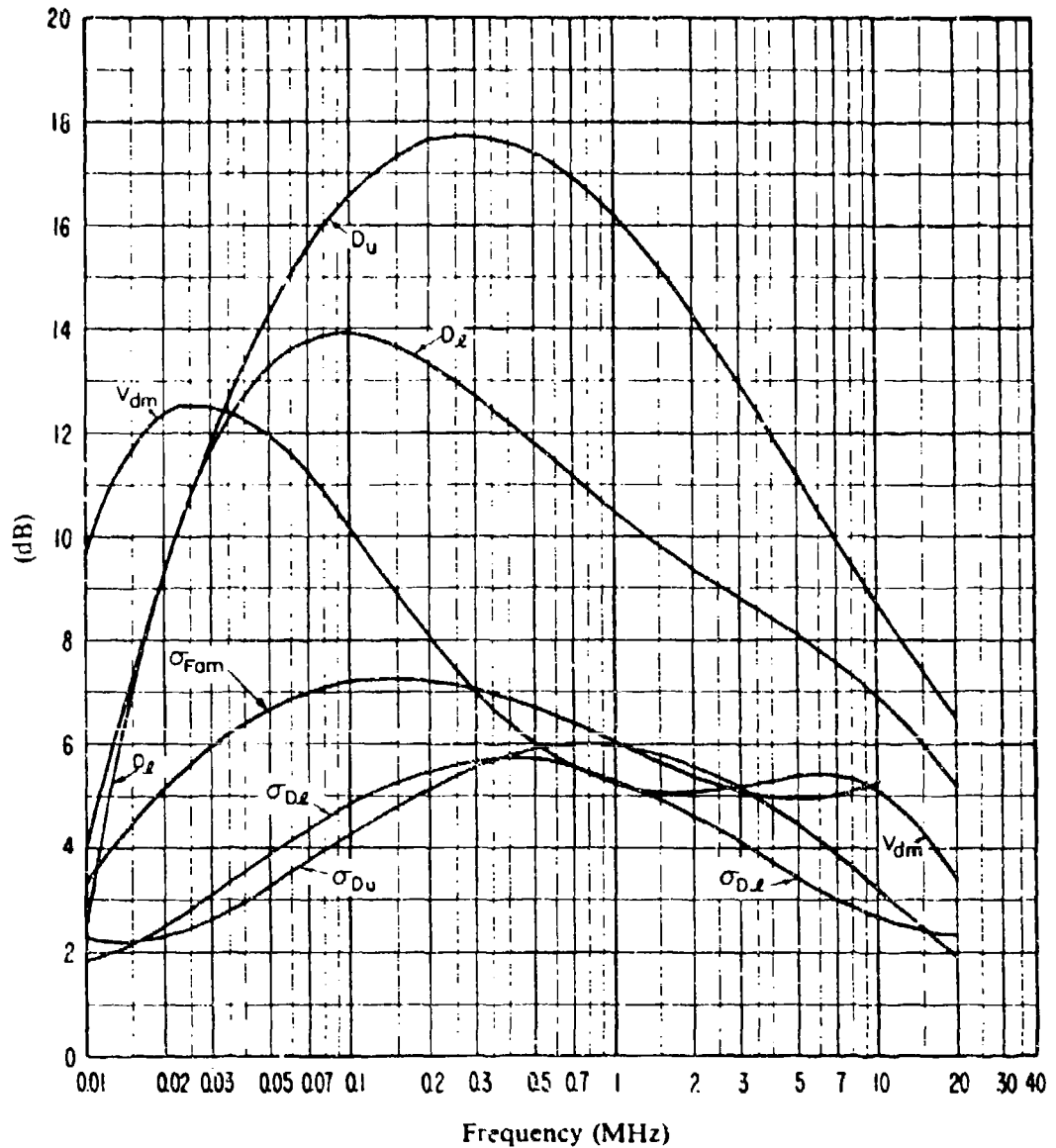
E = field of strength in V/m

A = area of loop in square meters

n = number of turns in the loop

For the predicted upper decile noise values, the output voltage at the loop terminals, assuming the loop lies in the plane of the noise, is presented in Table 4.

2 "Antenna Engineering Handbook", JASIK, McGraw-Hill, 1961



$\sigma_{F_{am}}$: Standard deviation of values of F_{am}
 D_u : Ratio of upper decile to median value, F_{am}
 σ_{D_u} : Standard deviation of values of D_u
 D_l : Ratio of median value, F_{am} , to lower decile
 σ_{D_l} : Standard deviation of value of D_l
 V_{dm} : Expected value of median deviation of average voltage.
 The values shown are for a bandwidth of 200 Hz.

Figure 10. Data on noise variability and character.

Table 5. Predicted upper decile noise values.

$V_{in} = 2.48 \text{ uV @ } 10 \text{ kHz}$
$= 3.13 \text{ uV @ } 20 \text{ kHz}$
$= 2.51 \text{ uV @ } 60 \text{ kHz}$
$= 1.48 \text{ uV @ } 100 \text{ kHz}$
$= 0.47 \text{ uV @ } 300 \text{ kHz}$
$= 0.29 \text{ uV @ } 600 \text{ kHz}$

The detectable signal level threshold for the 10-600 kHz band channels was experimentally determined to be 0.18 uV (measured in 10 kHz bandwidth) at the input to the field-effect transistor stage, contained in loop housing.

By rearranging (2) the minimum detectable vertical electric field strength in a 10 kHz bandwidth is equal to:

$$\text{MDF (V/m)} = \frac{0.18 \times 10E-6}{2.094 \times 10E-8 \text{ F} \times \text{A} \times \text{n}} \quad (3)$$

Calculating the values for the bands under consideration, we find MDF levels as tabulated in Table 6.

Table 6. Calculated minimum detectable vertical E-field at loop antenna terminals.

MDF = 137.0 $\mu\text{V}/\text{m}$ = 42.73 dB/ $\mu\text{V}/\text{m}$ @ 10 kHz
= 68.4 $\mu\text{V}/\text{m}$ = 36.70 dB/ $\mu\text{V}/\text{m}$ @ 20 kHz
= 22.8 $\mu\text{V}/\text{m}$ = 27.16 dB/ $\mu\text{V}/\text{m}$ @ 60 kHz
= 13.7 $\mu\text{V}/\text{m}$ = 22.73 dB/ $\mu\text{V}/\text{m}$ @100 kHz
= 4.6 $\mu\text{V}/\text{m}$ = 13.26 dB/ $\mu\text{V}/\text{m}$ @300 kHz
= 2.3 $\mu\text{V}/\text{m}$ = 7.23 dB/ $\mu\text{V}/\text{m}$ @600 kHz

Therefore, by comparing Tables 4 and 6 it is evident that the loop antennas are atmospheric noise limited.

Accordingly, a method which allows separating the atmospheric noise from any event-produced noise was included in the design. This was achieved by orienting the crossed-loops so one was in the plane of the great circle path between GZ and the observation site for maximum response and the other positioned broadside or nulled on the GZ.

For the remaining channels, the minimum front-end input voltage required for a +10 dB SNR was experimentally determined and is presented in Table 7.

Table 7. Minimum front-end input voltage for +10 dB SNR.

Frequency (MHz)	Vmin (μV)
2.3 - 2.9	1.58
15.0 - 15.6	0.63
50.0 - 50.6	0.63
220.0 - 220.6	0.63

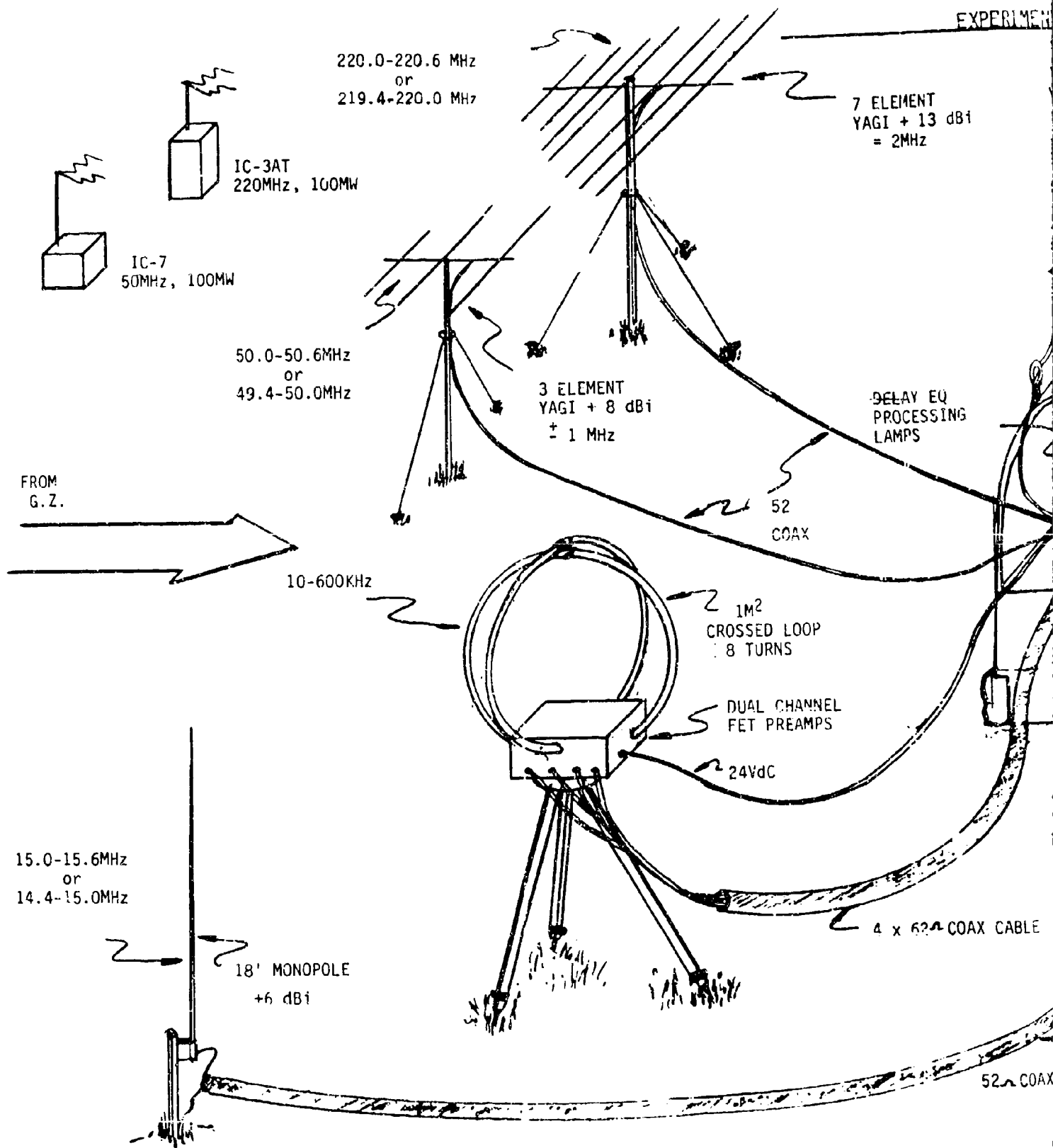
By using a different technique it is possible to calculate the values of the predicted noise recording system performance over the remaining frequency bands, shown in Table 8.

Table 8. Electrical performance of noise measuring system.

Frequency Range	Minimum Detectable E-Field (+10 dB SNR & 10 kHz B.W.)	Rise Time (uSec)	Dynamic Range (dB)	Group Delay (usec)
10.0 - 600.0 kHz	137.0 uV/m @ 10 kHz 2.3 uV/m @ 600 kHz	0.7	70	Flat to 100
2.3 - 2.9 MHz	3.2 uV/m	0.7	70	Flat to 100
15.0 - 15.6 MHz	1.1	0.7	70	Flat to 100
50.0 - 50.6 MHz	0.8 uV/m	0.7	70	Flat to 100
220.0 - 220.6 MHz	0.5 uV/m	0.7	70	Flat to 100

APPENDIX - A
NOISE RECORDING SYSTEM DRAWINGS

Detailed drawings of the noise recording system equipment are presented in Figures A-1 thru A-24.



EXPERIMENT 7360 PHYSICAL CONFIGURATION

5 MAR 84 REV A

ELEMENT
AGI + 13 dBi
= 2MHz

2.3 MHz
WHIP ANTENNA

FREQUENCY
SOURCES

8 PASSENGER VAN

DELAY EQ
PROCESSING
LAMPS

2-CAR
BATTERIES

EM 1
7000 M

MIXERS,
AMPS,
FILTERS

4 x 52Ω COAX CABLE

52Ω COAX

EMPIRE MODEL 105
FIELD STRENGTH
METER
14KHz - 400 MHz

Figure A-1. Physical Configuration (deployed).

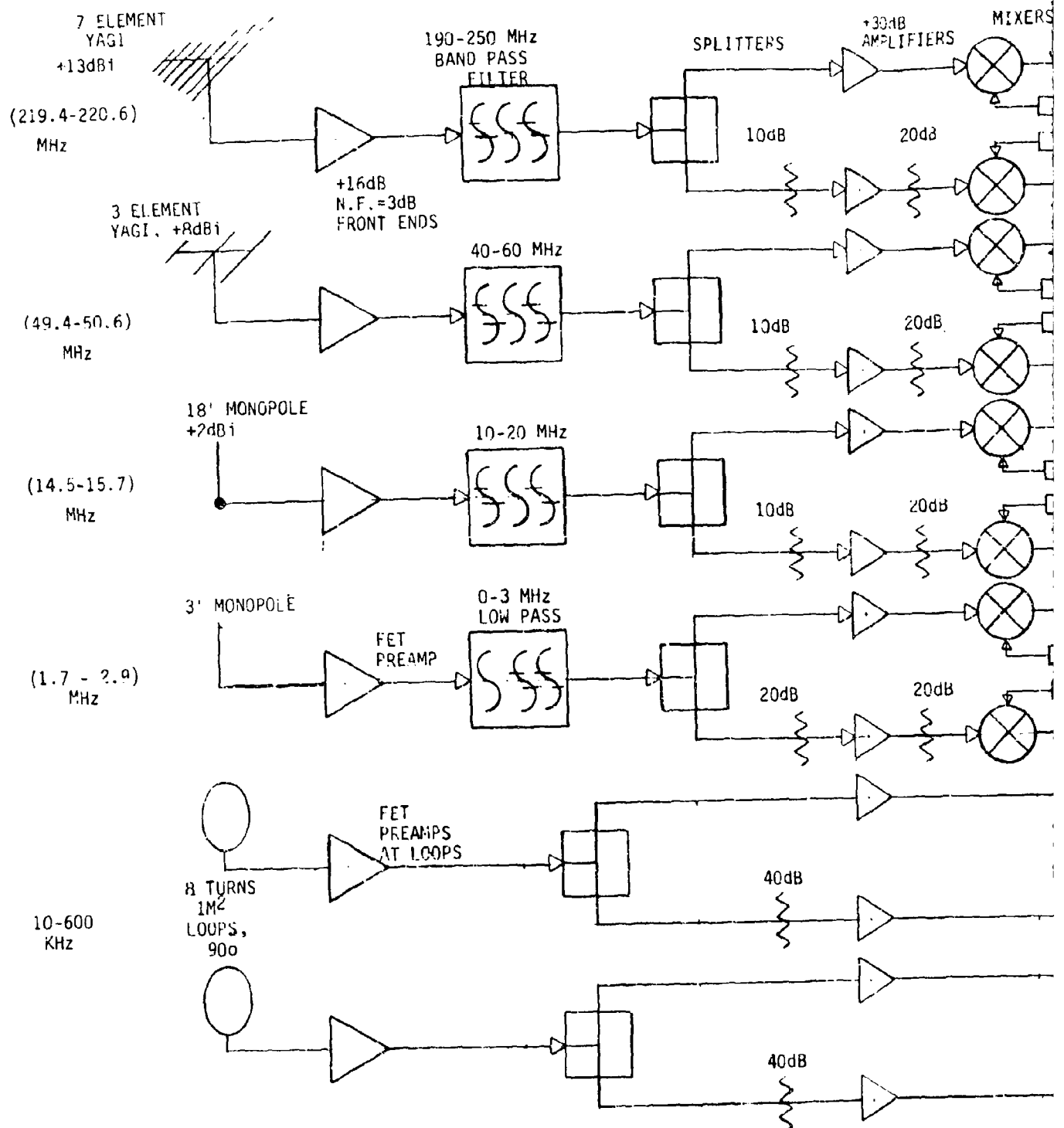


Figure A-2. Noise recording system block diagram.

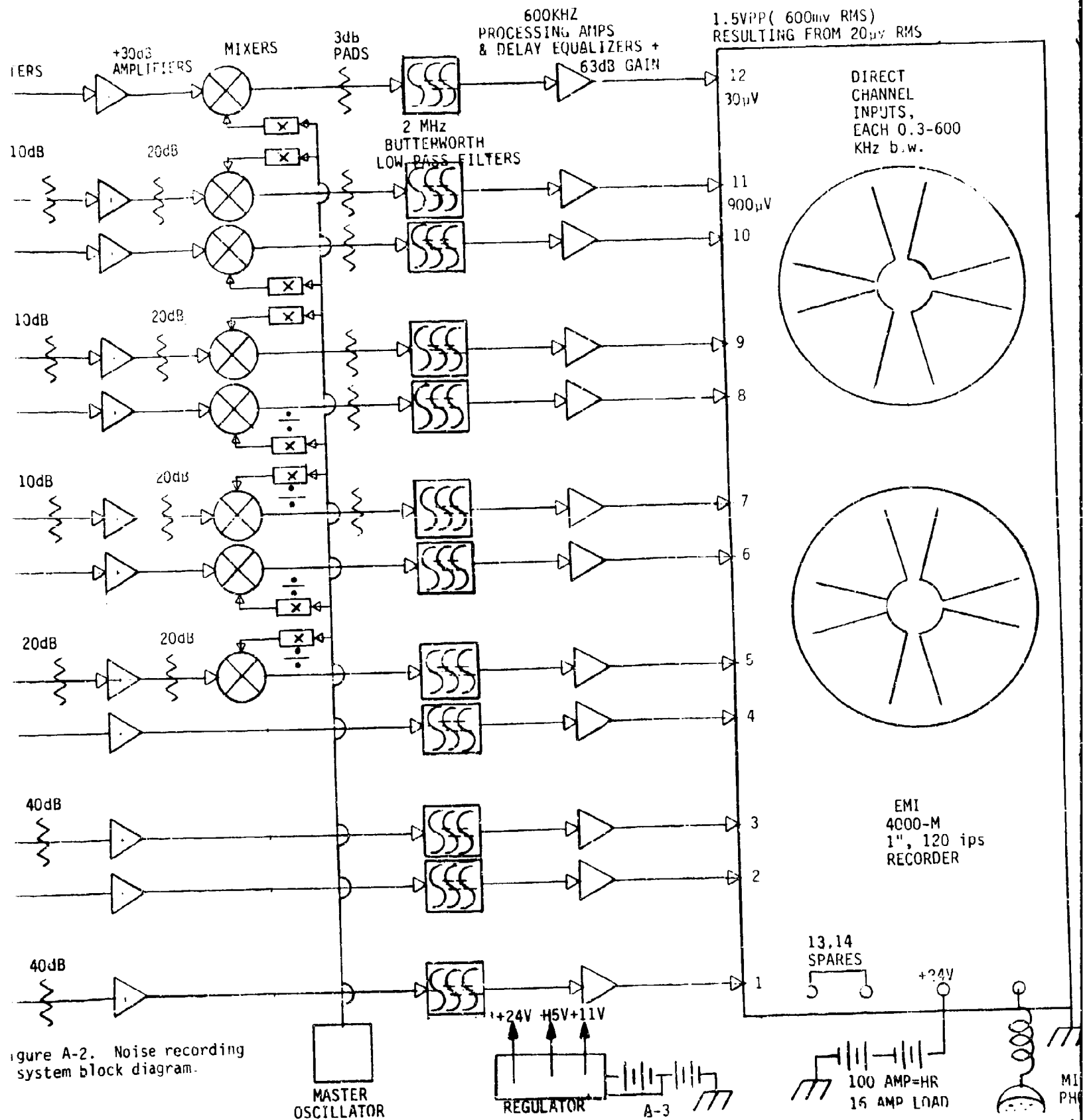


Figure A-2. Noise recording system block diagram.

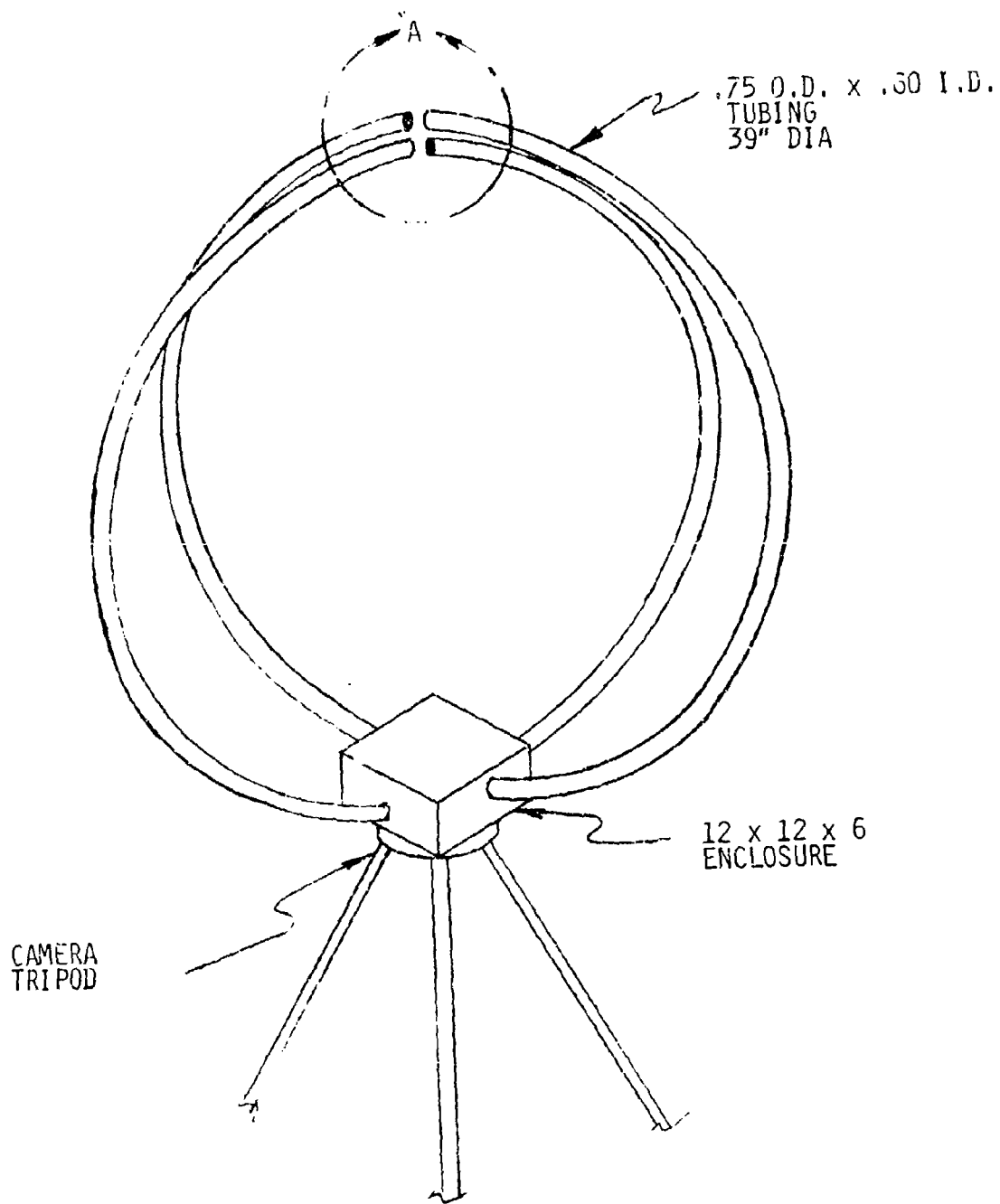
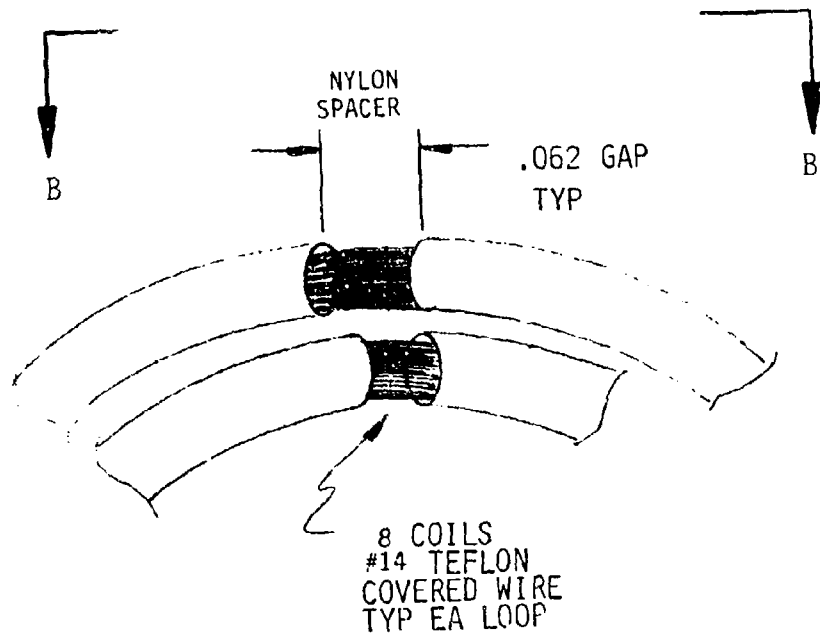


Figure A-3. 600 kHz crossed loop antenna



DETAIL A

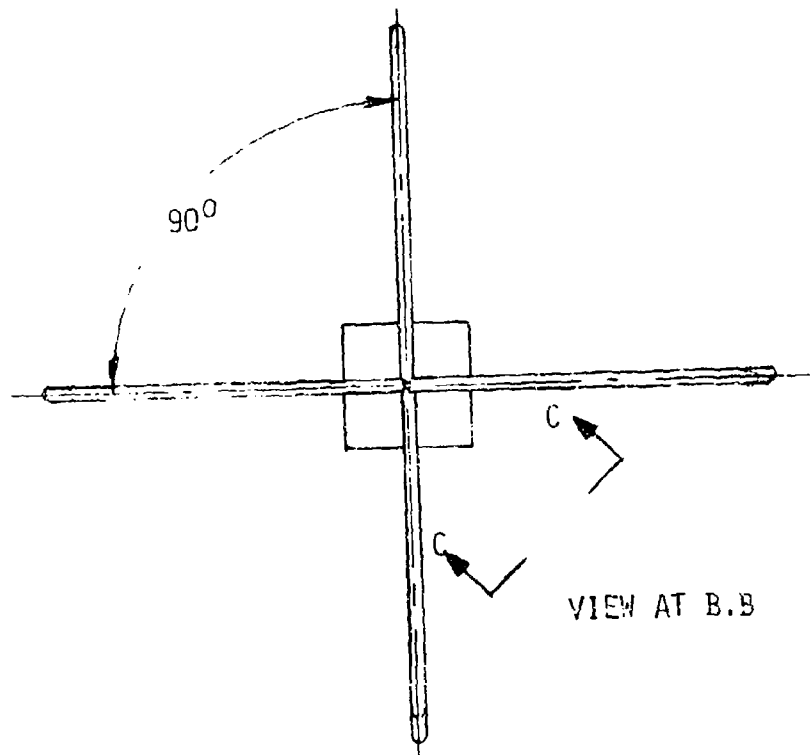
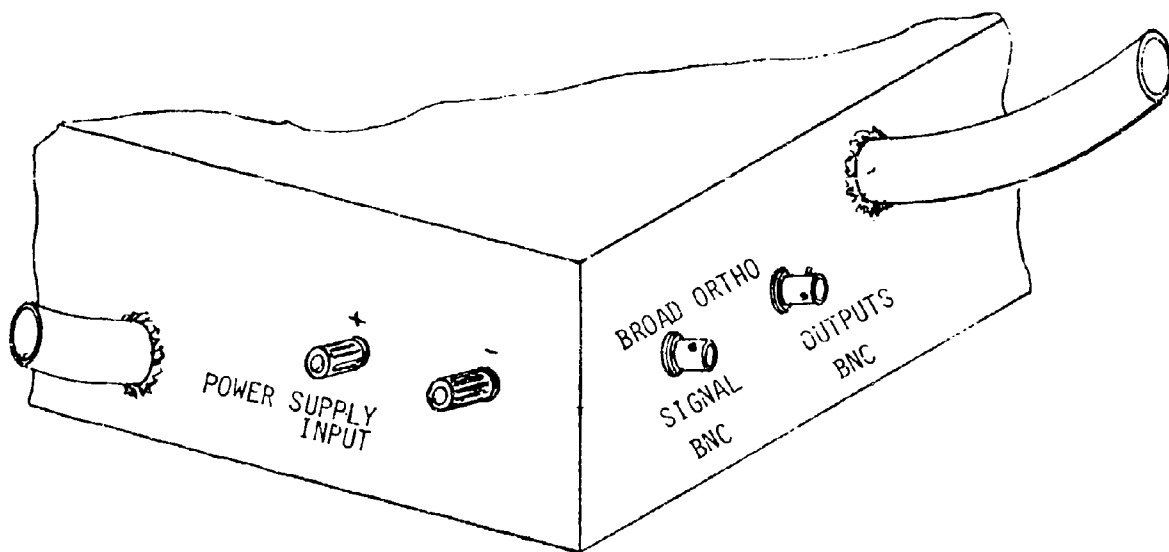


Figure A-4. Loop antenna section B-B.



VIEW AT C-C

Figure A-5. Loop antenna section C-C.

ASSEMBLY PICT

VHF

TYPICAL
HARDWARE
ARRANGEMENT
(not to scale)

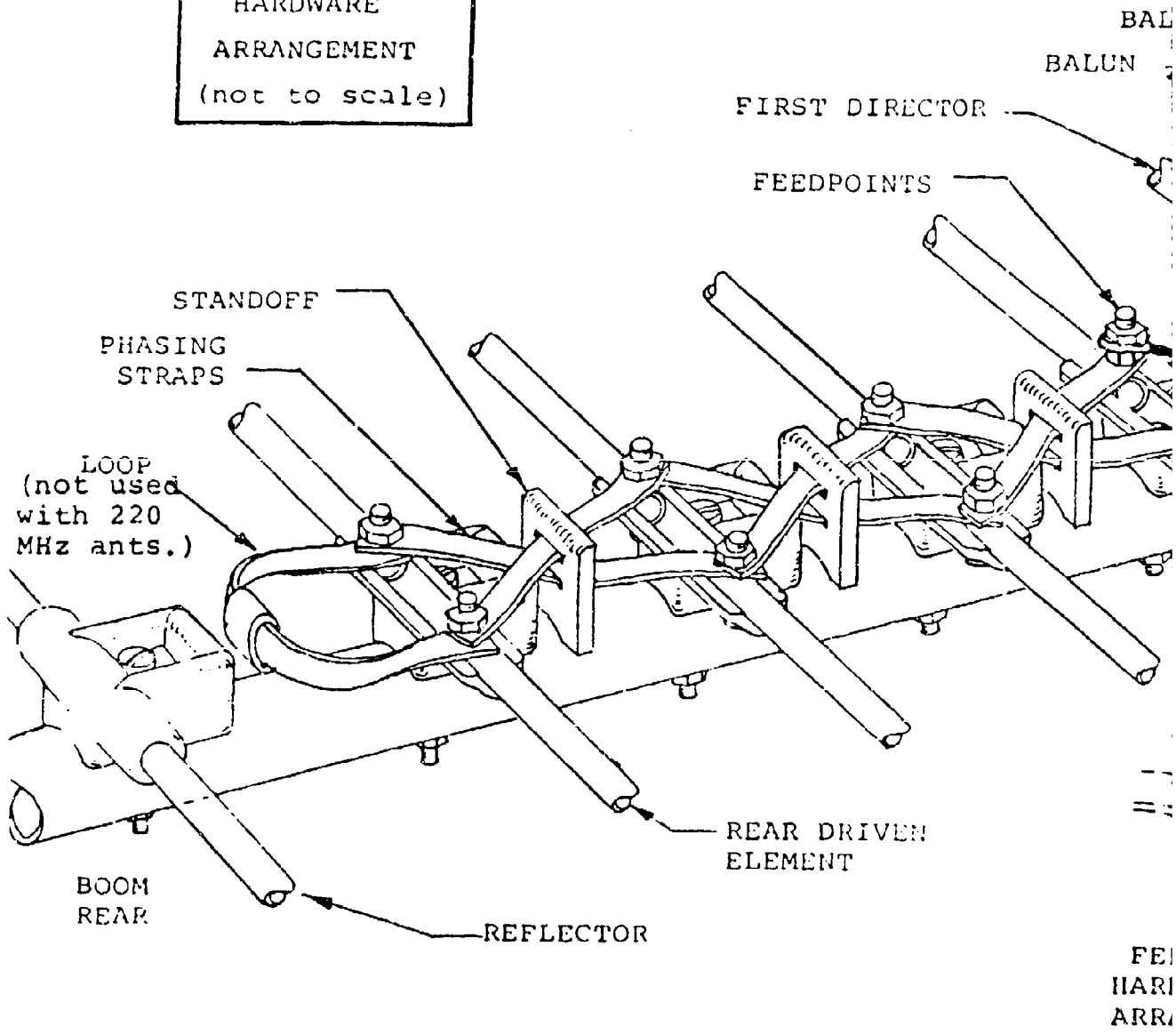
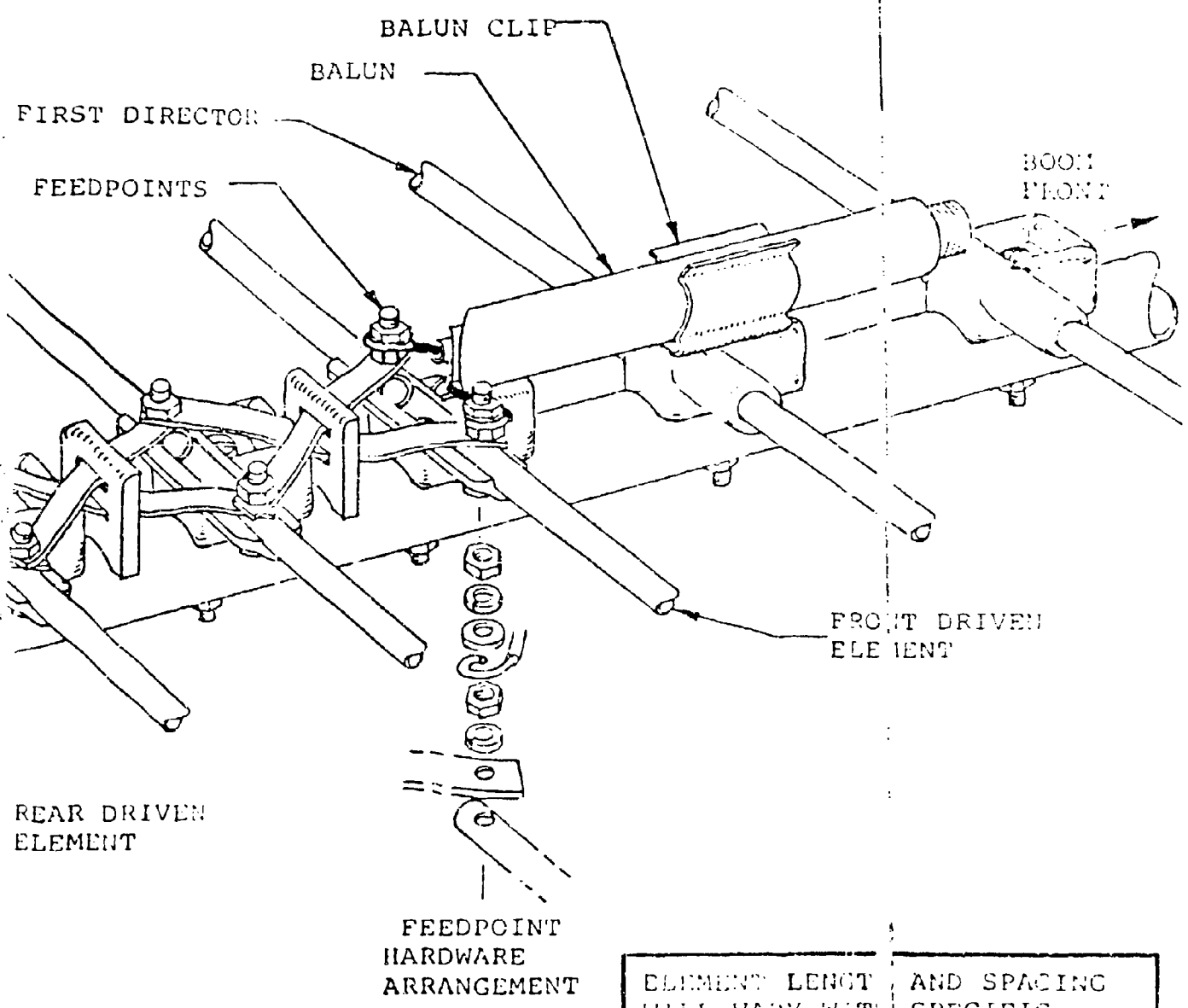


Figure A-6. 220 MHz horizontal yagi.

SEMBLY PICTORIAL

VHF



ELEMENT LENGTH AND SPACING WILL VARY WITH SPECIFIC ANTENNA MODEL. SEE DIMENSION SHEET SUPPLIED WITH ANTENNA.

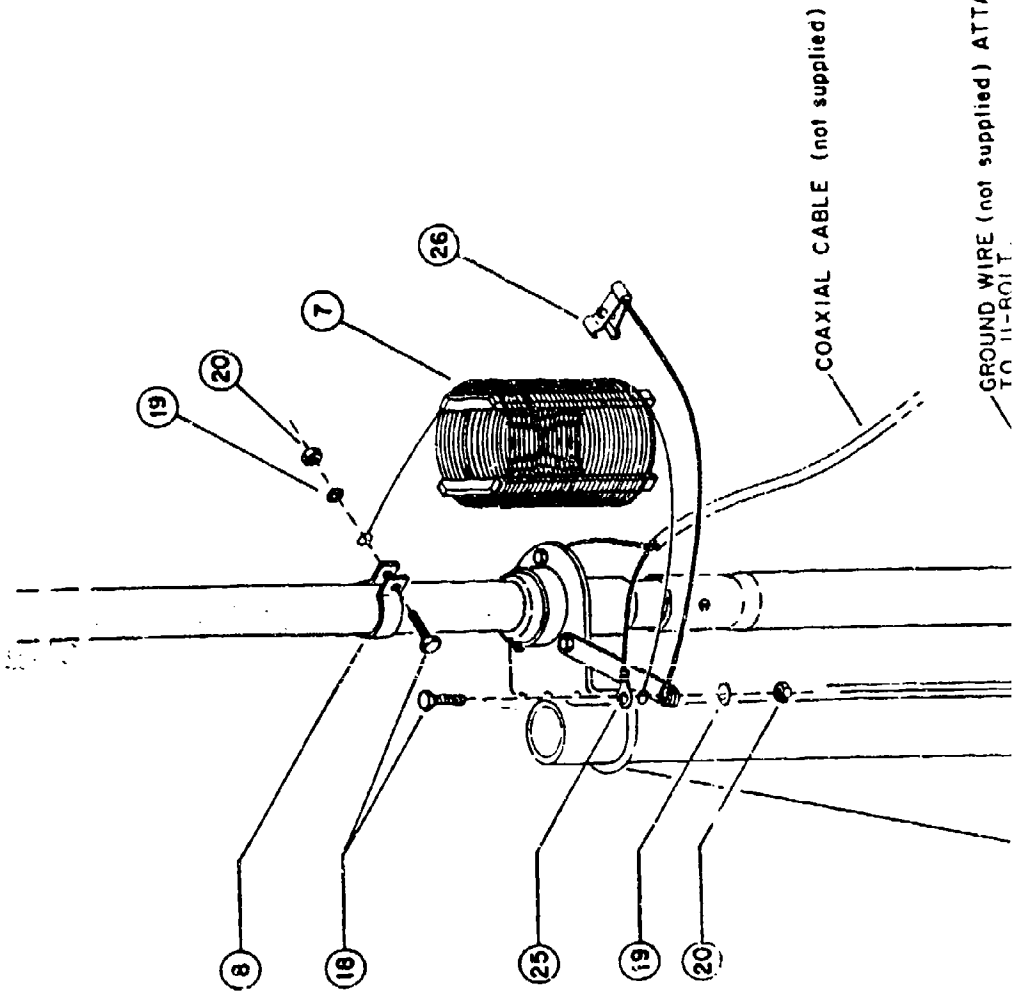
Select the M3 section ($\frac{1}{4}$ " x $53\frac{1}{2}$ "") and slip the end with the smallest hole into the M2 section. Align the holes and fasten with two #8 screws (item 13).

Select the M4 section ($\frac{1}{4}$ " x $53\frac{1}{2}$ "") and slip the end with the smallest hole into the M3 section. Align the holes and fasten with two #8 screws (item 13).

Select the M5 section ($7/16$ " x 54 "") and slip the drilled end into the M4 section. Align the holes and fasten with a #10-24 x 1 " bolt, nut, and lockwasher. (item 15, 16, and 17)

Place a $7/16$ " caplug on the end of the antenna.

AO-1935-C-005



Item No.	Description
7	Coil, Inductor
8	Clamp, $7/8$ "
18	Bolt, $1/4$ "-20 x 1 ", hex head
19	Lockwasher, $1/4$ ", internal
20	Nut, $1/4$ "-20, hex
21	U-bolt, $5/16$ " x $1.5/8$ " x $2.1/4$ "
22	Lockwasher, $5/16$ ", split
23	Nut, $5/16$ "-16, hex
25	Solder lug, $1/4$ " ring
26	Assembly, Inductor clip

GROUND WIRE (not supplied) ATTACHED TO II-PORT

- 8 Lamp, 7/6
- 16 Bolt, 1/4"-20 x 1", hex head
- 19 Lockwasher, 1/4", internal
- 20 Nut, 1/4"-20, hex
- 21 U-bolt, 5/16" x 1 5/8" x 2 1/4"
- 22 Lockwasher, 5/16", split
- 23 Nut, 5/16"-18, hex
- 25 Solder lug, 1/4" ring
- 26 Assembly, inductor clip

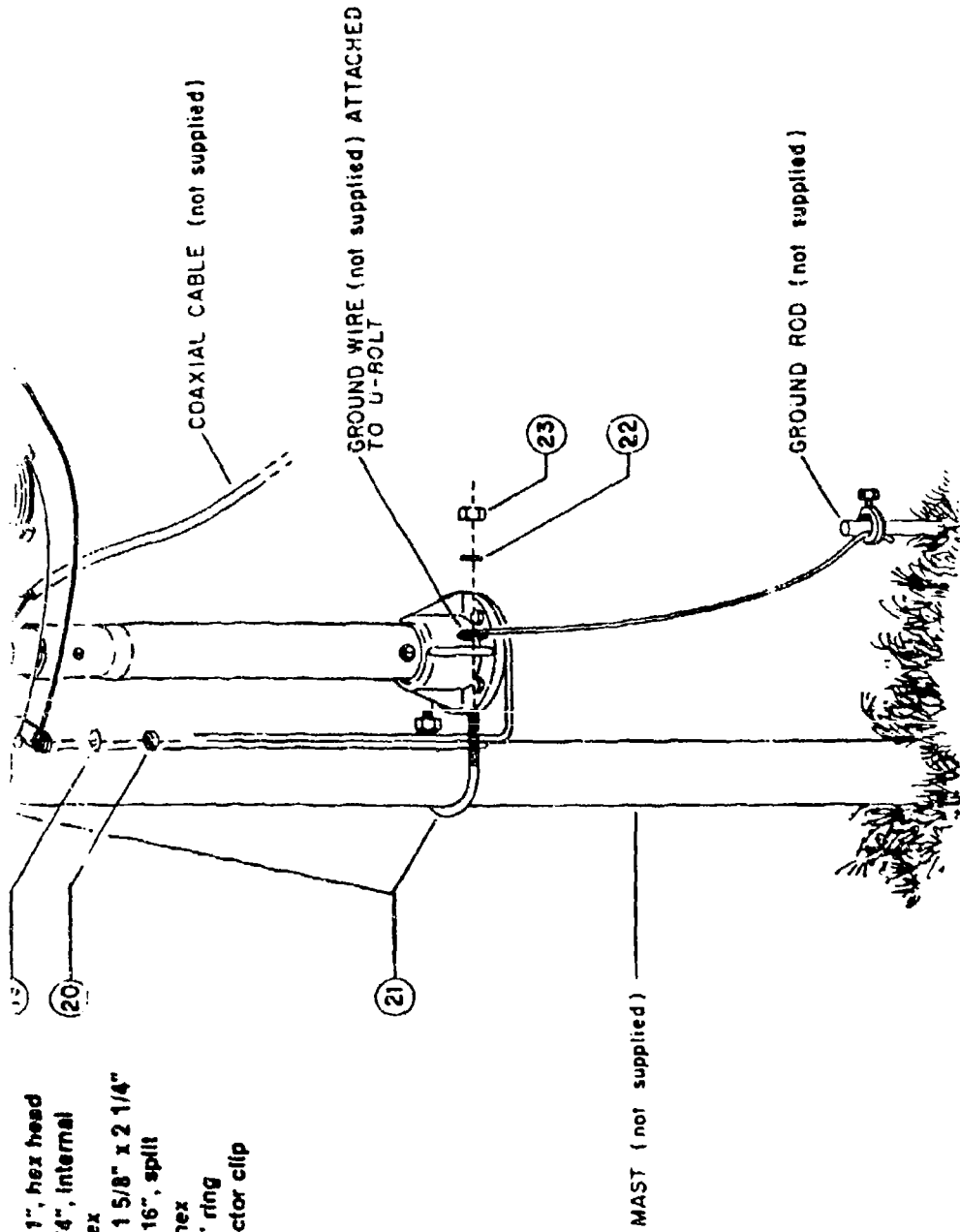
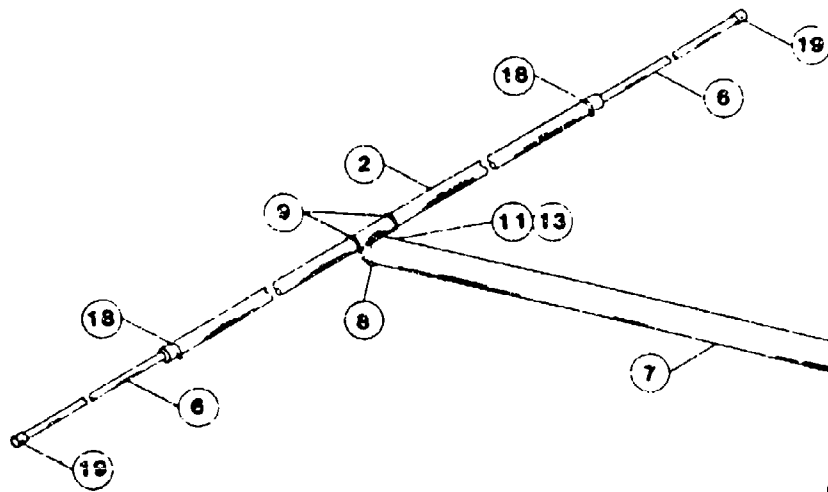
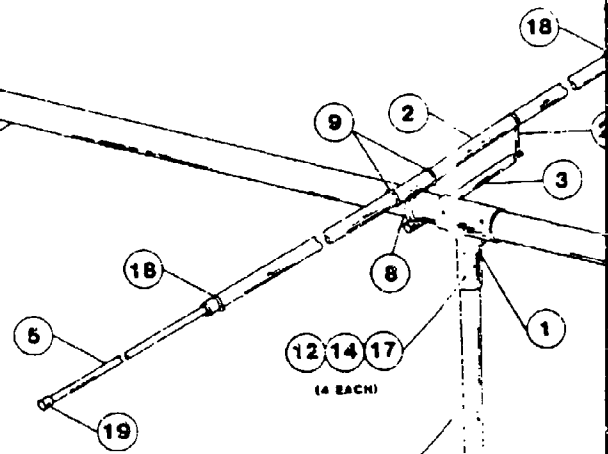


Figure A-7. 15 MHz vertical monopole.

DIRECTOR



DRIVEN



1 1/4" MAST
(NOT SUPPLIED)

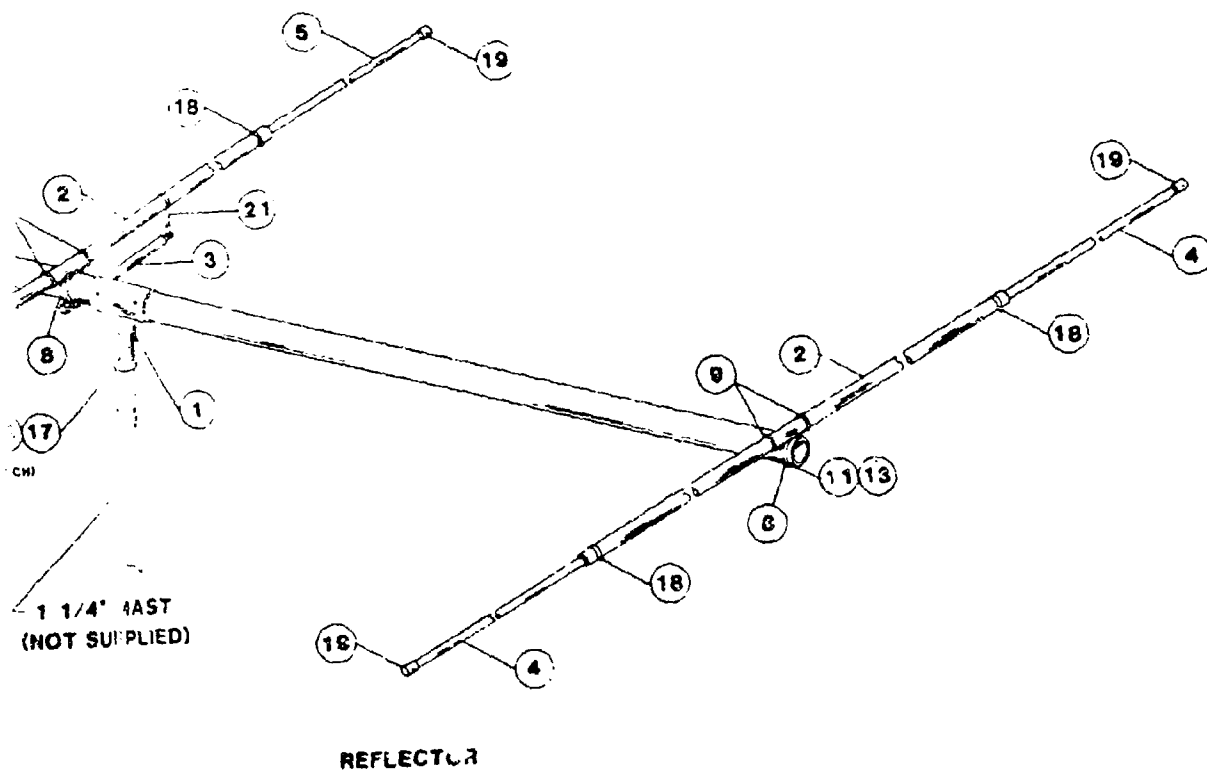


Figure A-8. 50 mhz horizontal yagi.

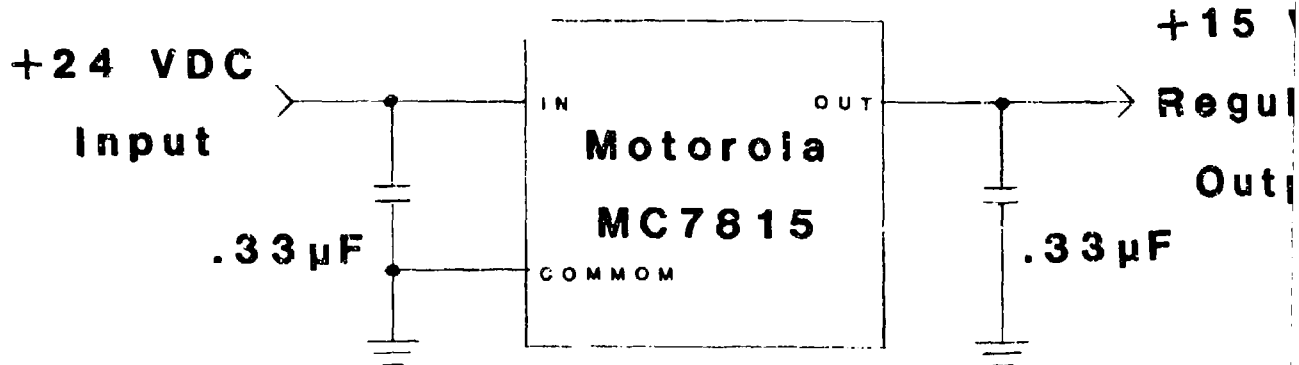


Figure A-9. Voltage regulator
15 VDC.

		G8	G5	G4	G3	G2	G1	ITEM	SIZE	
		QTY PER ASSY								
		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES							CONT NO.	
		.XX DECIMAL		.XXX DECIMAL					DR <i>D. Van</i>	APPD
		± —		± —						
		ANGLES		SURFACE QUAL					DRFTG	CHK
		± —		— √ MAX						
									ENGRG	DEV
									E/M	PROJ <i>D.</i>
NEXT ASSY		USED ON							MFG	
APPLICATION										

REVISIONS			
ZONE	LTR	DESCRIPTION	DATE APPROVED


+15 VDC

→ Regulated

Output

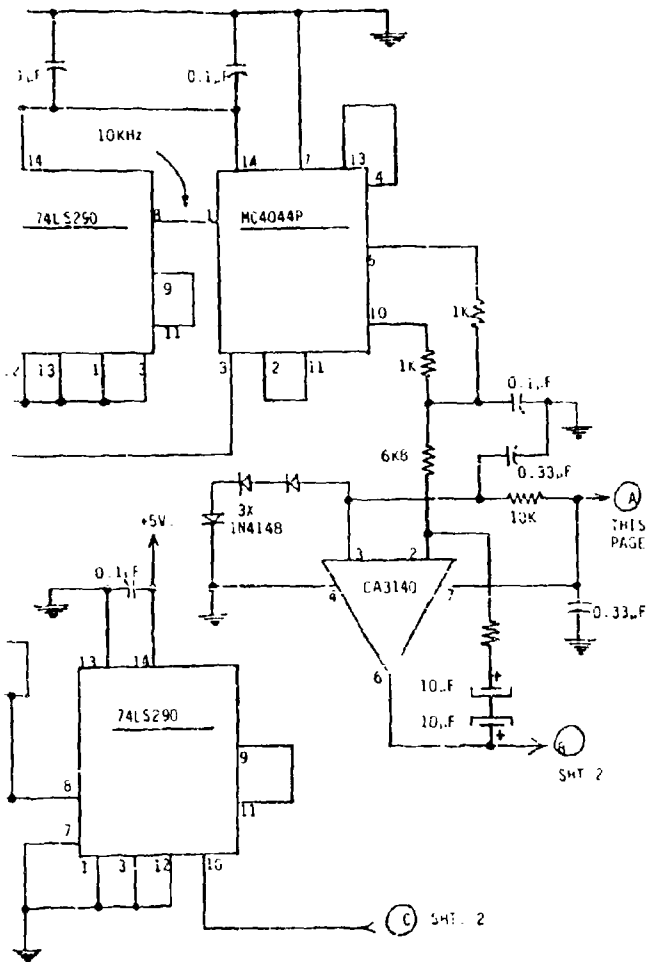
.33 μF




3	G2	G1	ITEM	SIZE	PART NUMBER	DESCRIPTION
SSY			PARTS LIST			
SPECIFIED IN INCHES			CONT NO.		 RADANT SYSTEMS, INC. 255 HUDSON ROAD STOW, MASSACHUSETTS (617) 562-3868	
XX DECIMAL			DR <i>D. Van Dusen</i> DATE <i>15 FEB 83</i>			
±			APPD			
FACE QUAL			CHK			
✓ MAX			DEV			
ENGRG			E/M		Voltage Regulator 15 VDC	
PROJ <i>D. Rogers 15 k 8 84</i>			SIZE B	CO E IDENT		
SCALE —			SHEET OF			

A-10 DO NOT SCALE PRINT

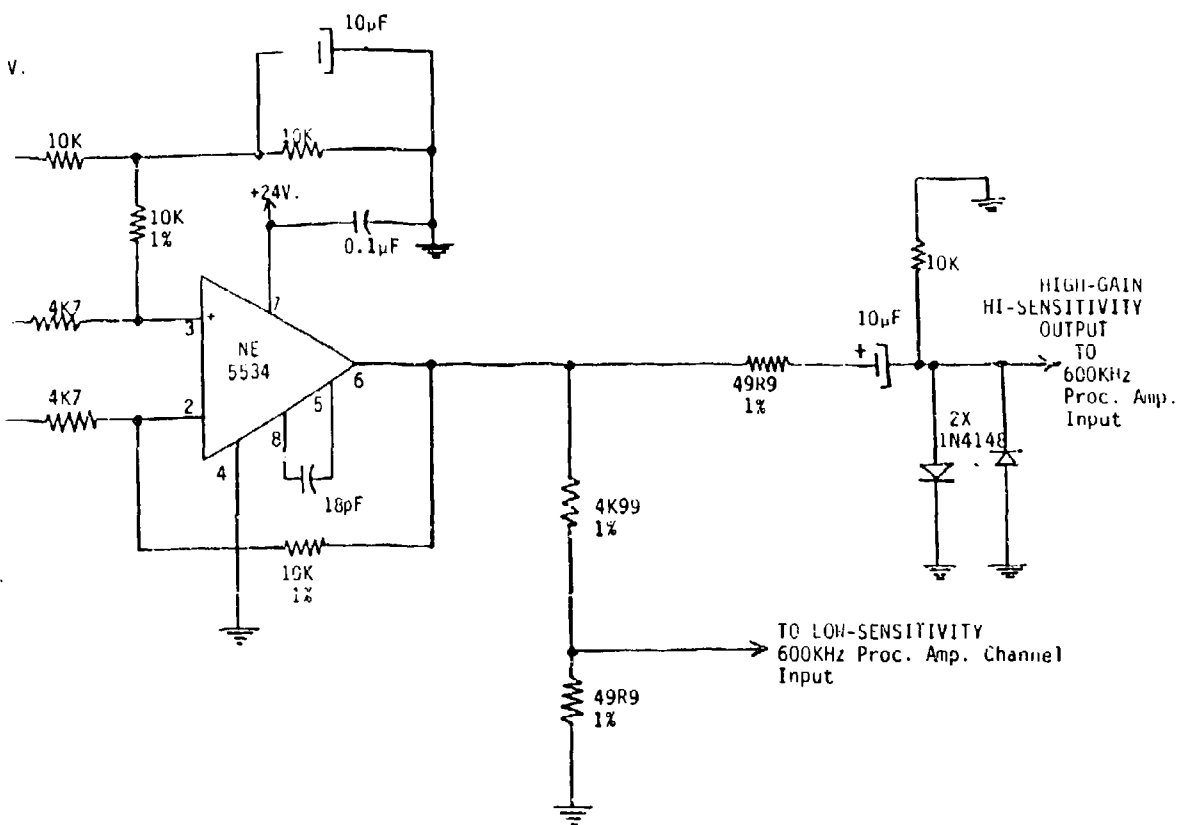
2




CONT NO.		 RADANT SYSTEMS, INC.	255 HUDSON ROAD STOW, MASSACHUSETTS (617) 562-3866	
DR	DATE		LOCAL OSCILLATOR 15.1 MHz	
DFTG	C.E. TALBOT JUL 26, 83			
APPD				
CHK				
ENGRG				
DEV		SIZE	CODE IDENT	DRAWING NO.
E/M		B		-580
PROJ		SCALE		SHEET 1 OF 2

A-12 NO NET SCALE PRINT

2



GAIN 28db CN HIGH-SENSITIVITY FROM DIFFERENTIAL LOOP ANTENNA
TERMINALS (START-FINISH) to PROC. AMP. INPUT

CONT NO.		 RADANT SYSTEMS, INC.	266 HUDSON ROAD STOW, MASSACHUSETTS (617) 562-3866	
DR	DATE		FRONT END 10-600 KHz (DIFFERENTIAL)	
D.B. TALBOT	JUL 27, 83			
APPD				
CHK				
DEV				
ENGRG	E/M	SIZE	CODE IDENT	DRAWING NO.
	PROJ			-587
		SCALE		SHEET OF

A-14 DO NOT SCALE PRINT

2

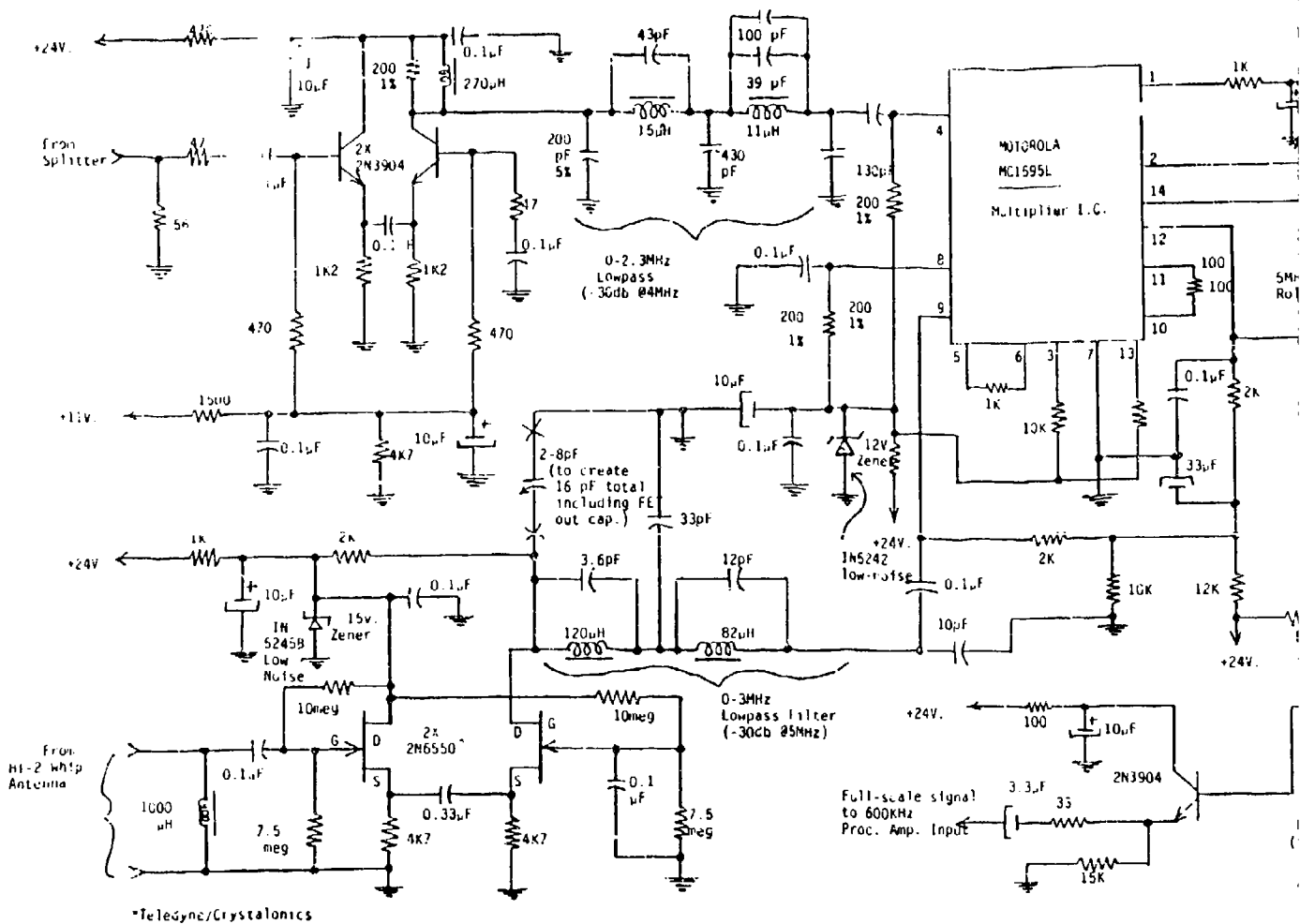
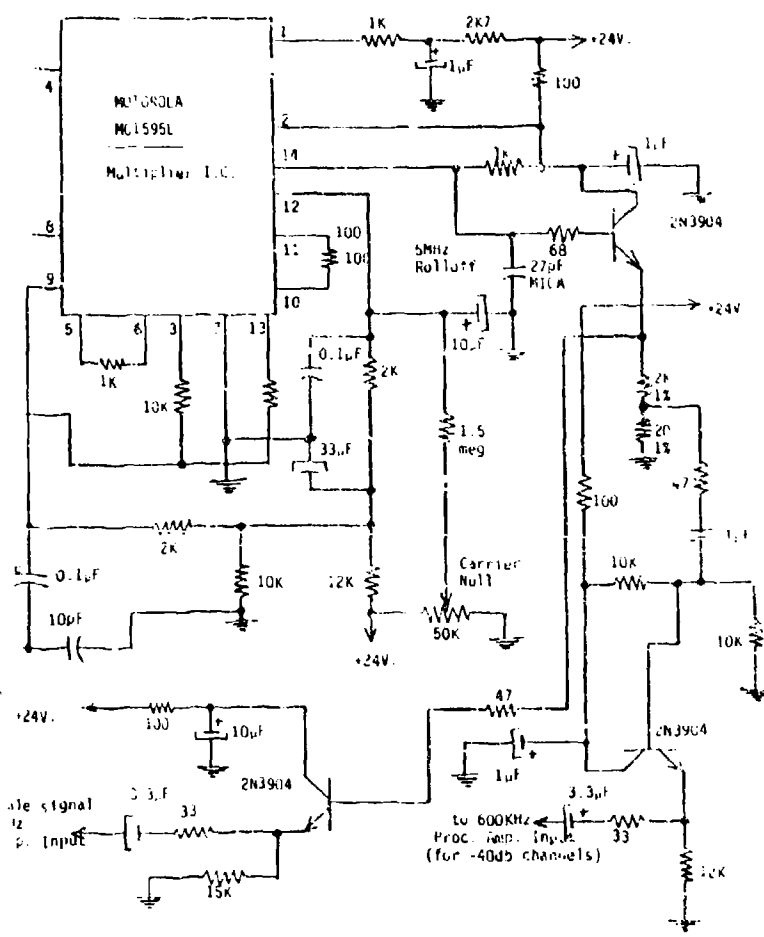



Figure A-14. 1.5/2.3 MHz L.O. Buffer/Mixer.

CONT NO.	
DRFTG	DR
	D.B.
	APPD
ENGRG	CHK
	DEV
	E/M
PROJ.	



5/2.3 MHz L.O.

CONT NO.		 RADANT SYSTEMS, INC.	255 HUDSON ROAD STOW, MASSACHUSETTS (617) 552-3266	
DR	DATE		L.O. BUFFER, MIXER & FET FRONT END (2.3 MHz)	
DRFTG	D.B. TALBOT Jul 24, 83			
APPD				
CHK				
ENGRG	DEV	SIZE	CODE IDENT	DRAWING NO.
	E/M	B		-589
	PROJ.	SCALE		SHEET 1 OF 1

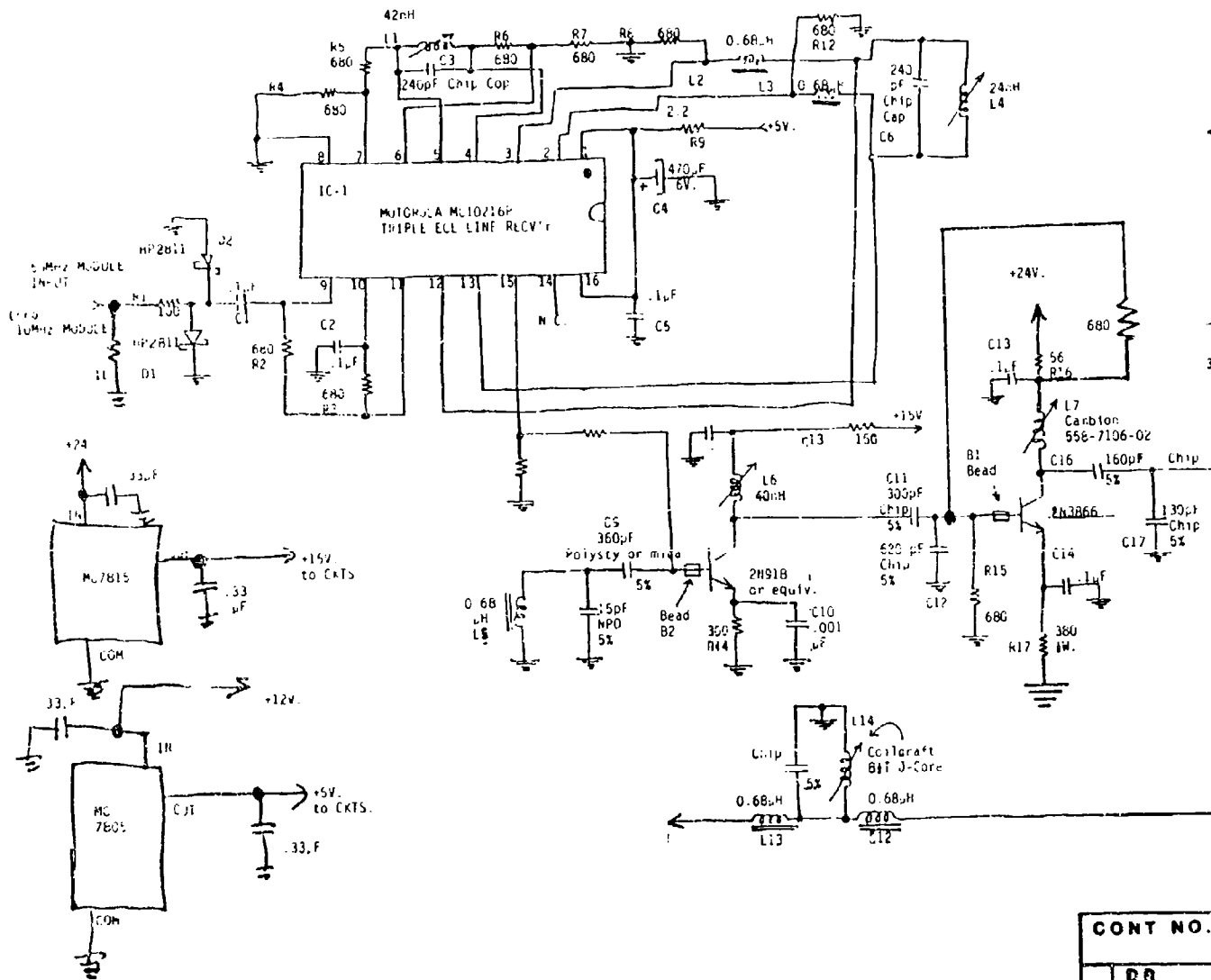
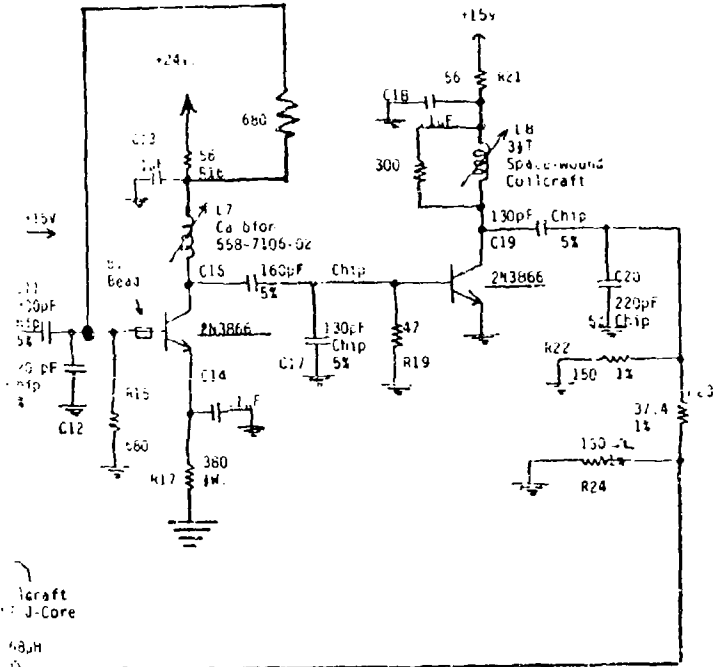
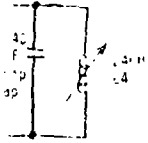



Figure A-16. 50 MHz local oscillator.

CONT NO.	
DFTG	DR
	APPD
	CHK
ENGRG	DEV
	E/M
	PROJ



CONT NO.		 RADANT SYSTEMS, INC.	285 HUDSON ROAD STOW, MASSACHUSETTS (617) 582-3868	
DR	DATE		LOCAL OSCILLATOR 50 MHz	
DRFTG	D. E. TALBOT 5-18-83			
APPD				
CHK				
DEV				
ENGRG	E/M	SIZE	CODE IDENT	DRAWING NO.
	PROJ	B		-579
		SCALE		SHEET 1 OF 1

DO NOT SCALE PRINT

A-17

2

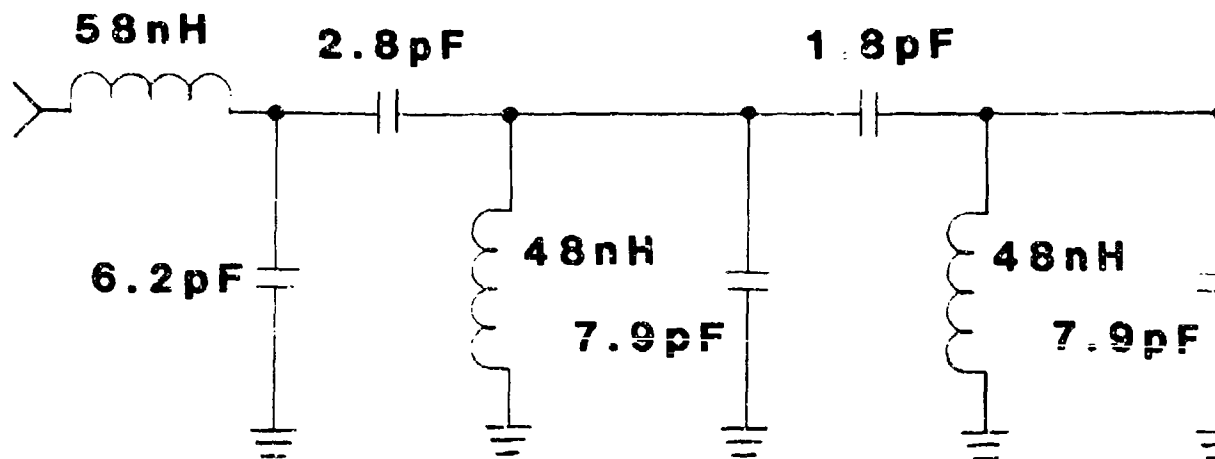
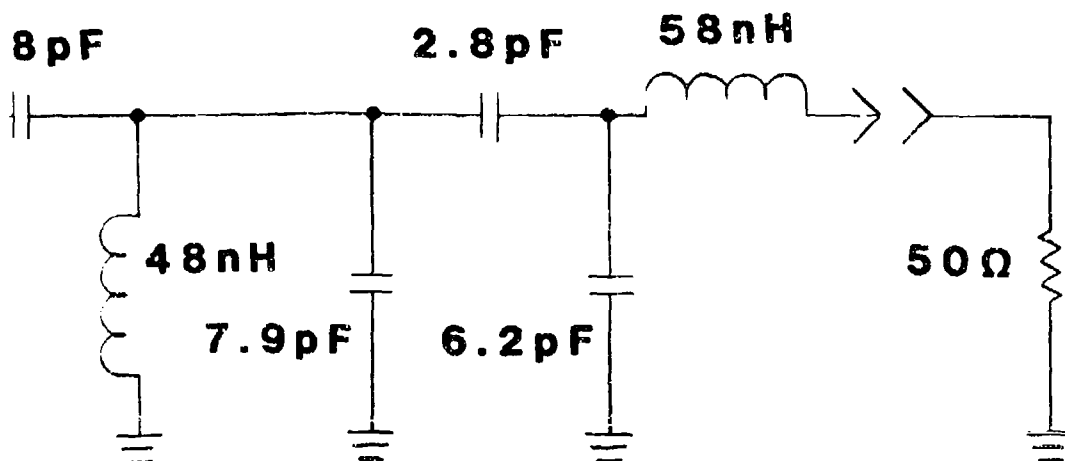


Figure A-17. 220 MHz band pass filter.

		G6	G5	G4	G3	G2	G1	ITEM	SIZE	
		QTY PER ASSY							CONT NO.	
		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES							DR	
		.XX DECIMAL			.XXX DECIMAL				APPD	
		±			±				CHK	
		ANGLES			SURFACE QUAL				DEV	
		±			√ MAX				E/M	
									ENGRG	
									PRD	
NEXT ASSY		USED ON							MFG	
APPLICATION										


REVISIONS			
ZONE	LYR	DESCRIPTION	DATE



Note:

MHz band

- All Coils assumed to have $Q_0 \geq 120$ at 220 MHz

G3	G2	G1	ITEM	SIZE	PART NUMBER	DESCRIPTION
ASSY			PARTS LIST			
UNLESS SPECIFIED DIMENSIONS ARE IN INCHES .XXX DECIMAL ± SURFACE QUAL √ MAX			CONT NO.		 RADANT SYSTEMS, INC. 286 HUDSON ROAD STOW, MASSACHUSETTS (617) 662-3868	
DRAFT			DR	DATE	220 MHz 50Ω Bandpass Filter	
ENGR			APPD	15 FEB 84		
			CHK			
			DEV			
			E/M		SIZE CODE IDENT DRAWING NO. B -583	
			PROJ	15 FEB 84	SCALE SHEET OF /	

DO NOT SCALE PRINT

2

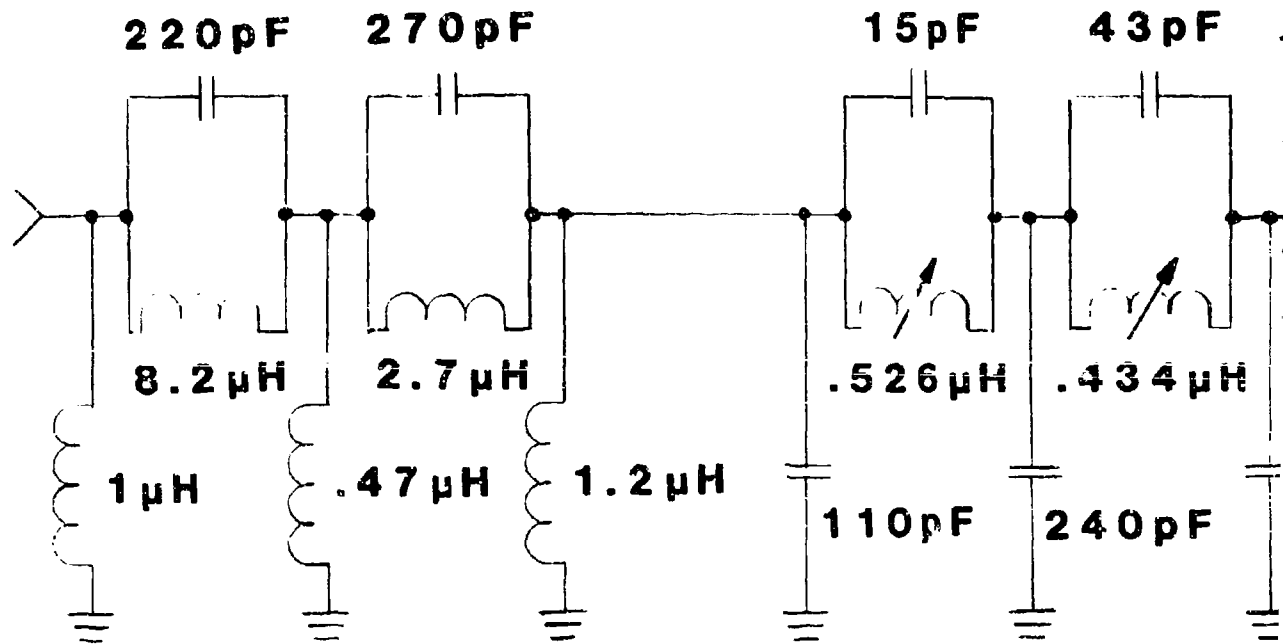
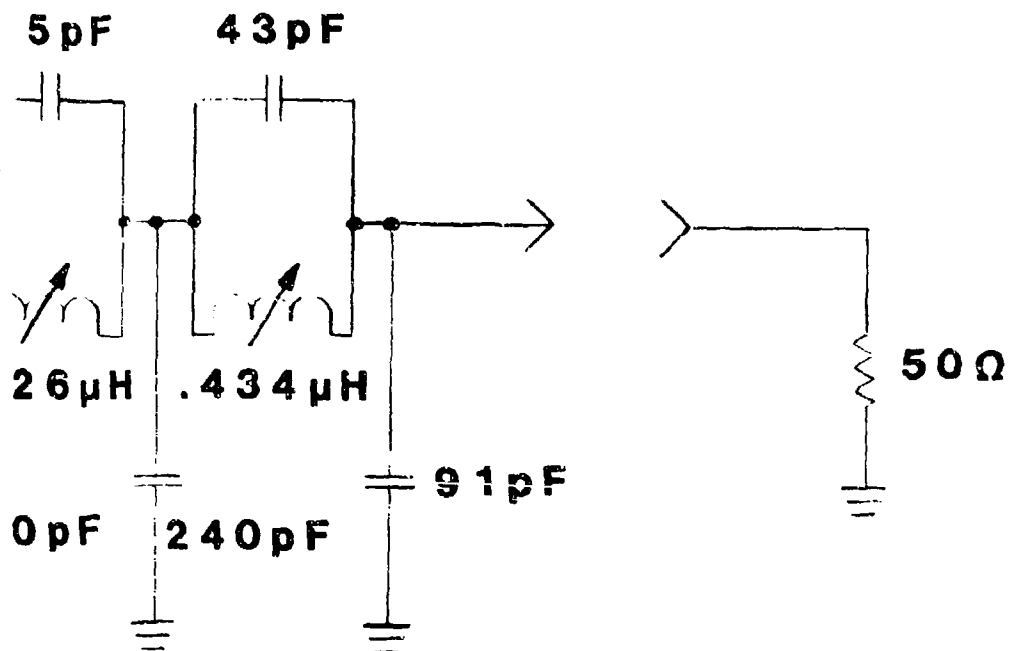



Figure A-18. 15 MHz band pass filter.

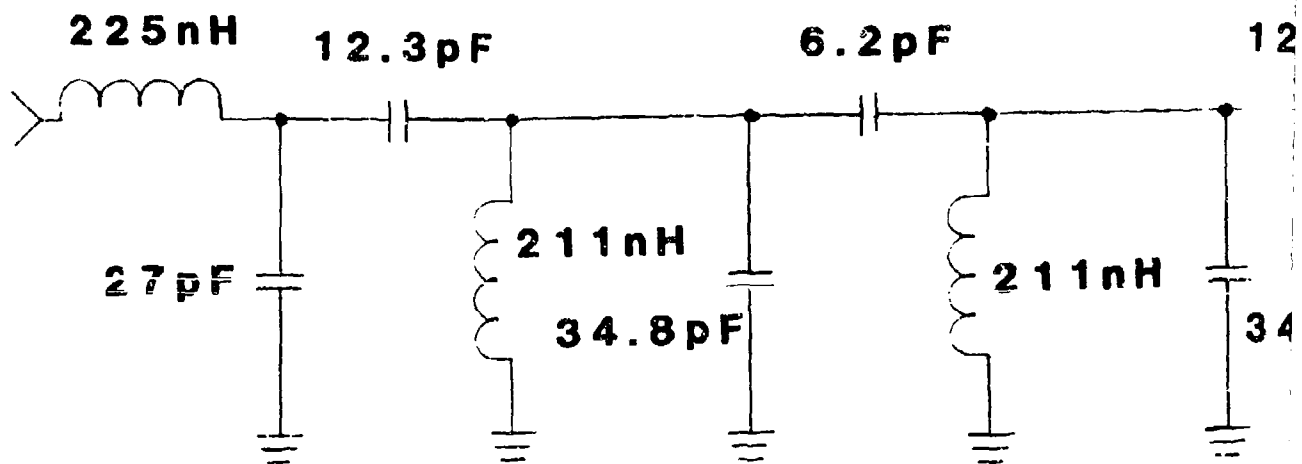
		G6	G5	G4	G3	G2	G1	ITEM	SIZE	
		QTY PER ASSY								
		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES							CONT NO.	
		.XX DECIMAL		.XXX DECIMAL					DRAFT	DR <i>K. Vial</i>
		±		±						APPD
		ANGLES		SURFACE QUAL						CNK
		±		√ MAX					ENGRG	DEV
										E/M
										PROJ <i>J. Long</i>
NEXT ASSY		USED ON		MFG						

REVISIONS			
ZONE	LTR	DESCRIPTION	DATE



G3	G2	G1	ITEM	SIZE	PART NUMBER	DESCRIPTION
R ASSY			PARTS LIST			
UNLESS SPECIFIED DIMENSIONS ARE IN INCHES DECIMAL PLACES ± SURFACE QUAL √ MAX			CONT NO.		 RADANT SYSTEMS, INC. 255 HUDSON ROAD STOW, MASSACHUSETTS (617) 562-3866	
			DR	DATE		
ENGRG			DR		15 MHz Bandpass Filter	
			APPD			
ENGRG			CHK		SIZE CODE IDENT DRAWING NO. B -582	
			DEV			
ENGRG			E/M		SCALE SHEET OF	
			PROJ			
			<i>J. Lopez</i> 15 FEB 84		SHEET OF	

DO NOT SCALE PRINT

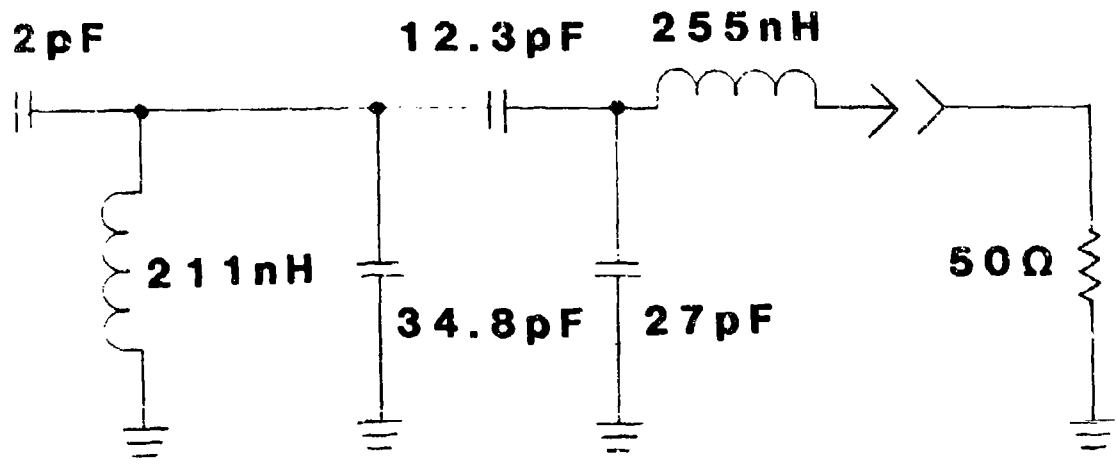


Note:

Figure A-19. 50 MHz band pass filter.


G6	G5	G4	G3	G2	G1	ITEM	SIZE
QTY PER ASSY							
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES						CONT NO.	
.XX DECIMAL .XXX DECIMAL						DR <i>Kg</i>	APPD
± ±							CHK
ANGLES SURFACE QUAL						ENGRG	DEV
± √ MAX							E/M
						PROJ	<i>D.R.</i>
NEXT ASSY		USED ON		MFG			

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED



Note:

1. ALL COILS ARE ASSUMED TO HAVE $Q_0 \geq 120$ at 220 MHz
9. 50 Mhz band pass

G4	G3	G2	G1	ITEM	SIZE	PART NUMBER	DESCRIPTION
PER ASSY				PARTS LIST			
OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES DECIMAL .XXX DECIMAL ± SURFACE QUAL ✓ MAX				CONT NO.		 RADANT SYSTEMS, INC. 255 HUDSON ROAD STOW, MASSACHUSETTS (617) 682-3888	
				DR	DATE		
				APPR			
				CHK			
				DEV			
ENGRG				E/M		50 MHz 50 OHM BANDPASS FILTER	
PROJ				DATE			
				SIZE		CODE IDENT	DRAWING NO.
				B			-584
				SCALE		SHEET / OF	

DO NOT SCALE PRINT
A-20

2

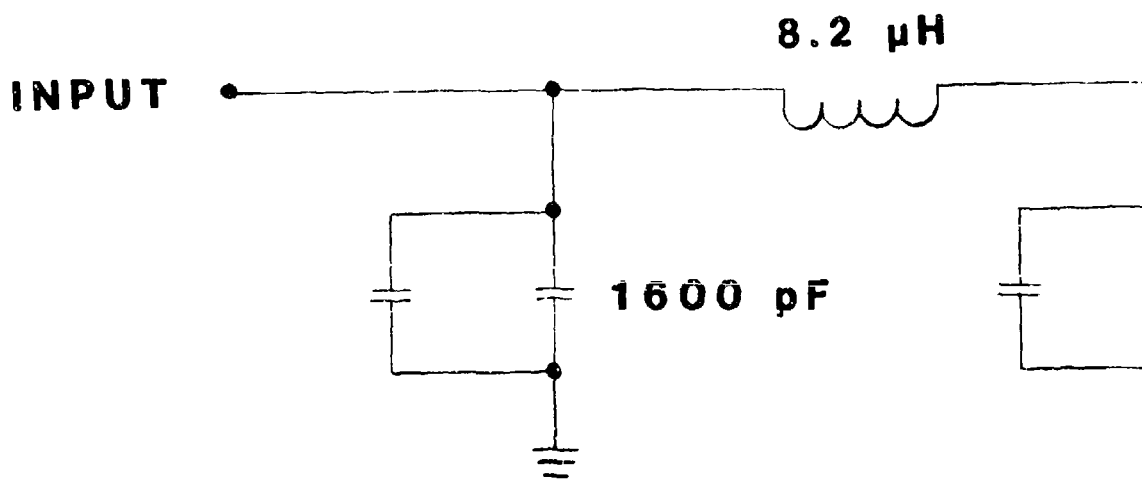


Figure A-20. 2 MHz butterworth low pass filter.

		G6	G5	G4	G3	G2	G1	ITEM	SIZE	PA	
		QTY PER ASSY									
		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES						CONT NO.			
		.XX DECIMAL		.XXX DECIMAL				DR			
		±		±				APPD			
		ANGLES		SURFACE QUAL				CHK			
		±		√ MAX				DEV			
								E/M			
								PROJ			
NEXT ASSY	USED ON	MFG						R. Page			
APPLICATION											

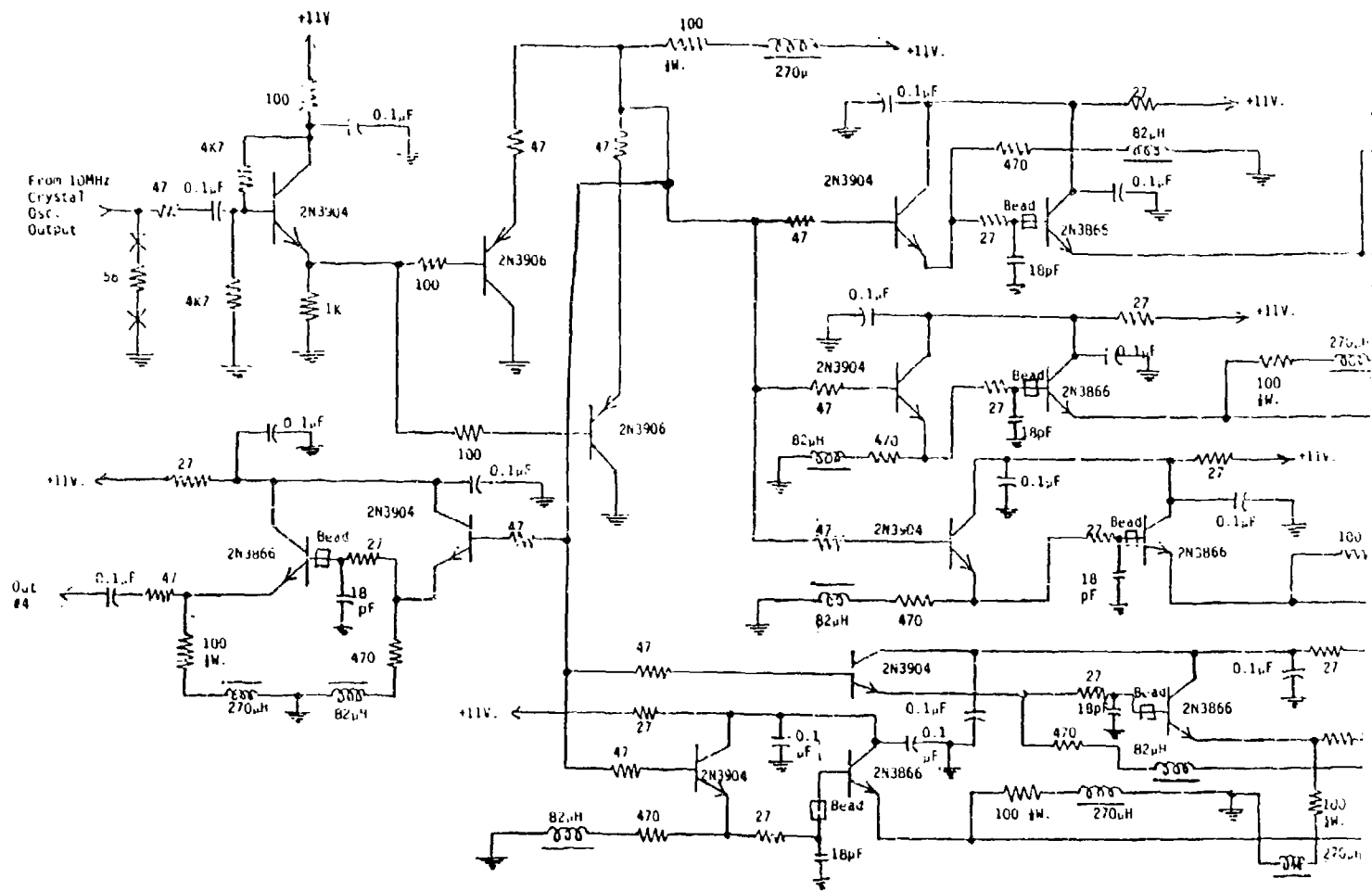
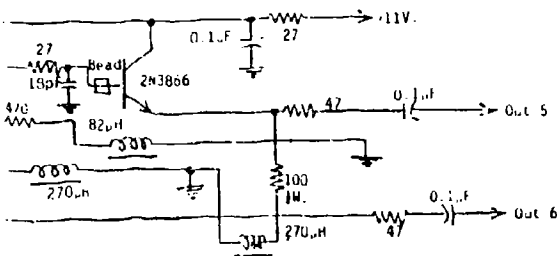
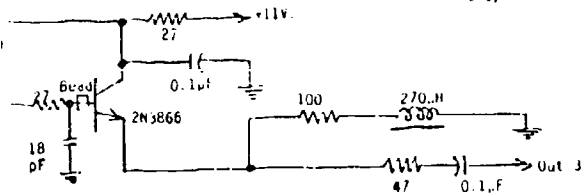
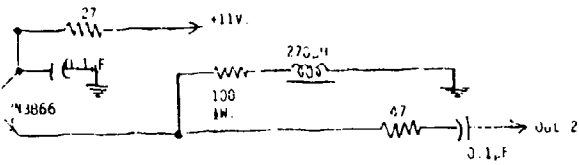
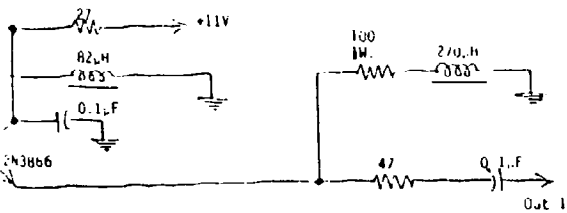
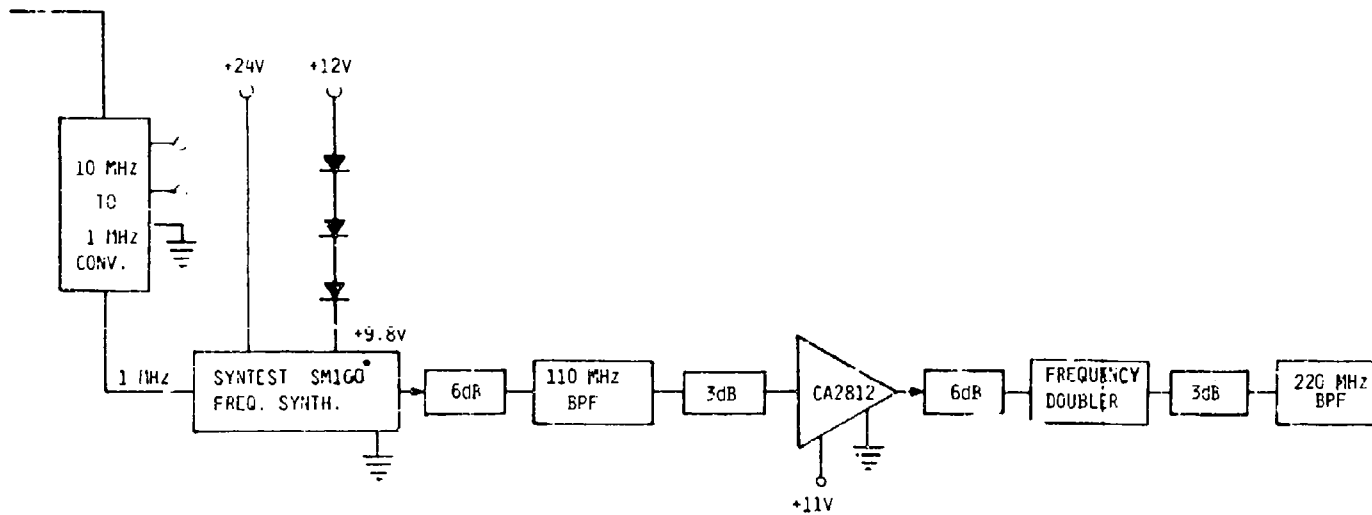


Figure A-21. 10 MHz distribu-
tion amplifier.

CONT NO.	
DRFTG	DBTAL
	APPD
	CHK
ENGRG	DEV
	E/M
	PROJ



CONT NO.			RADANT SYSTEMS, INC.		255 HUDSON ROAD STOW, MASSACHUSETTS (617) 562-3666	
DATE JUL 23, 83			DISTRIBUTION AMPLIFIER 10 MHz			
DRFTG	APPD	SIZE				
	CHK	B			-588	
ENGRG	DEV	SCALE		-		SHEET 1 OF 1
	E/M	PROJ				
tribu-						

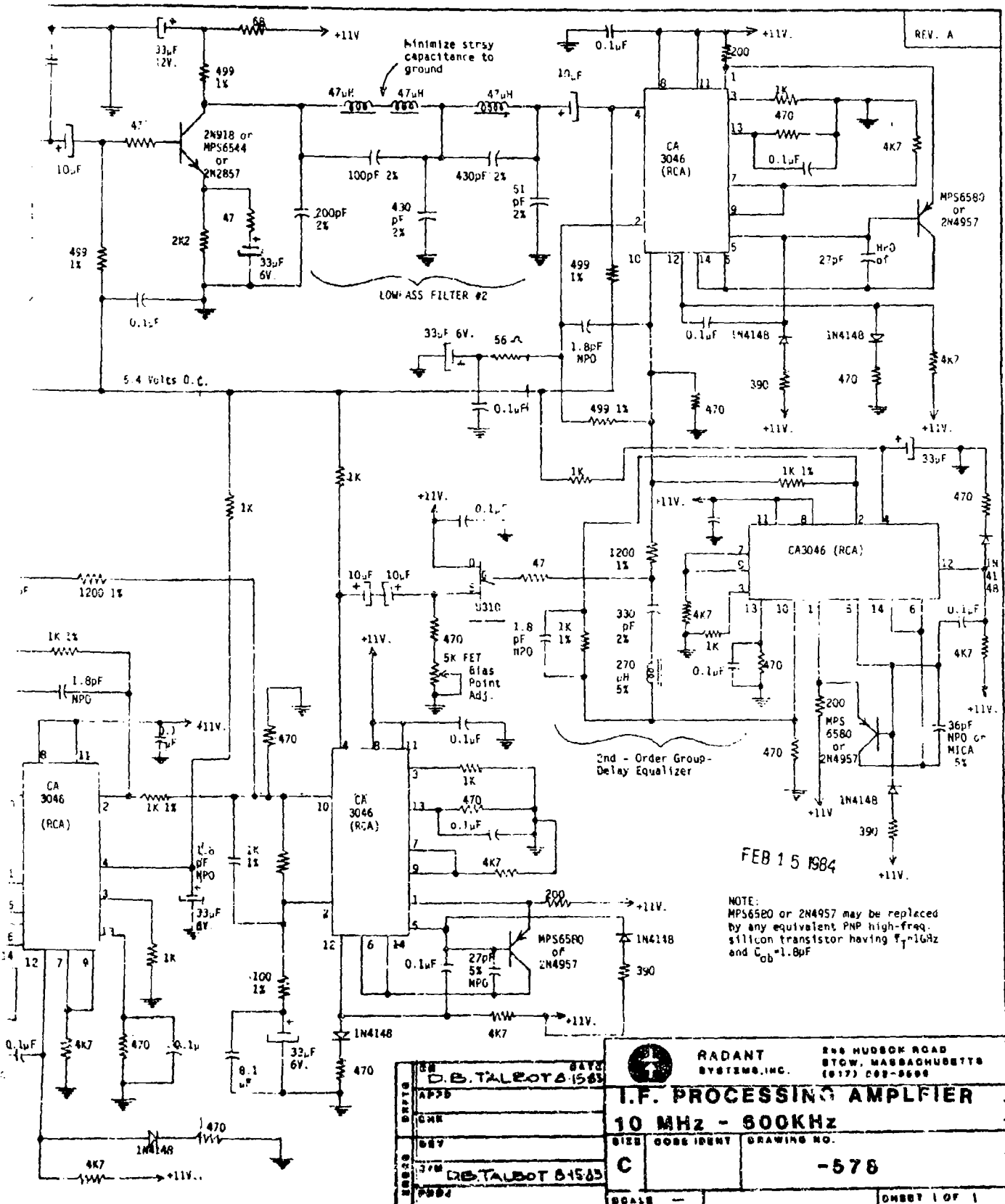


BPF = BANDPASS FILTER

*** CODE WIRED for 110MHz Output**

Figure A-22. 220 MHz local oscillator.

Q1	Q2	Q4	Q3	Q7	B1
QTY PER ASSY					
UNLESS OTHERWISE SPECIFIED					
DIMENSIONS ARE IN INCHES					
TOLERANCES					
XX DECIMAL .XX DECIMAL					
± - ± -					
ANGLES SURFACE QUAL					
± - - ✓ MAX					
NEXT ASSY		USED ON		MFG	
APPLICATION					



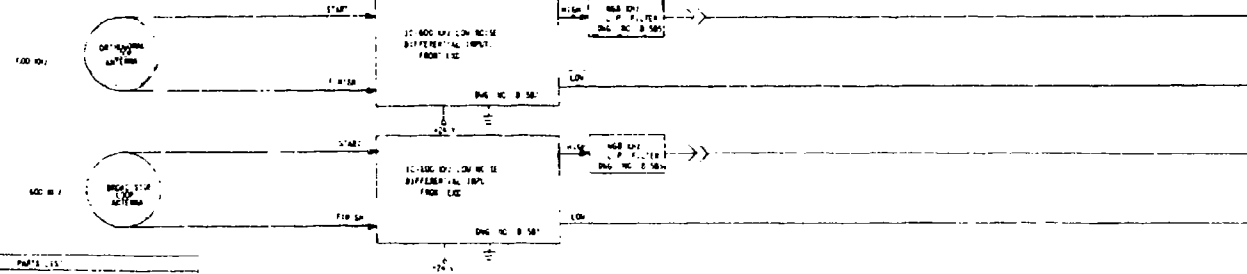
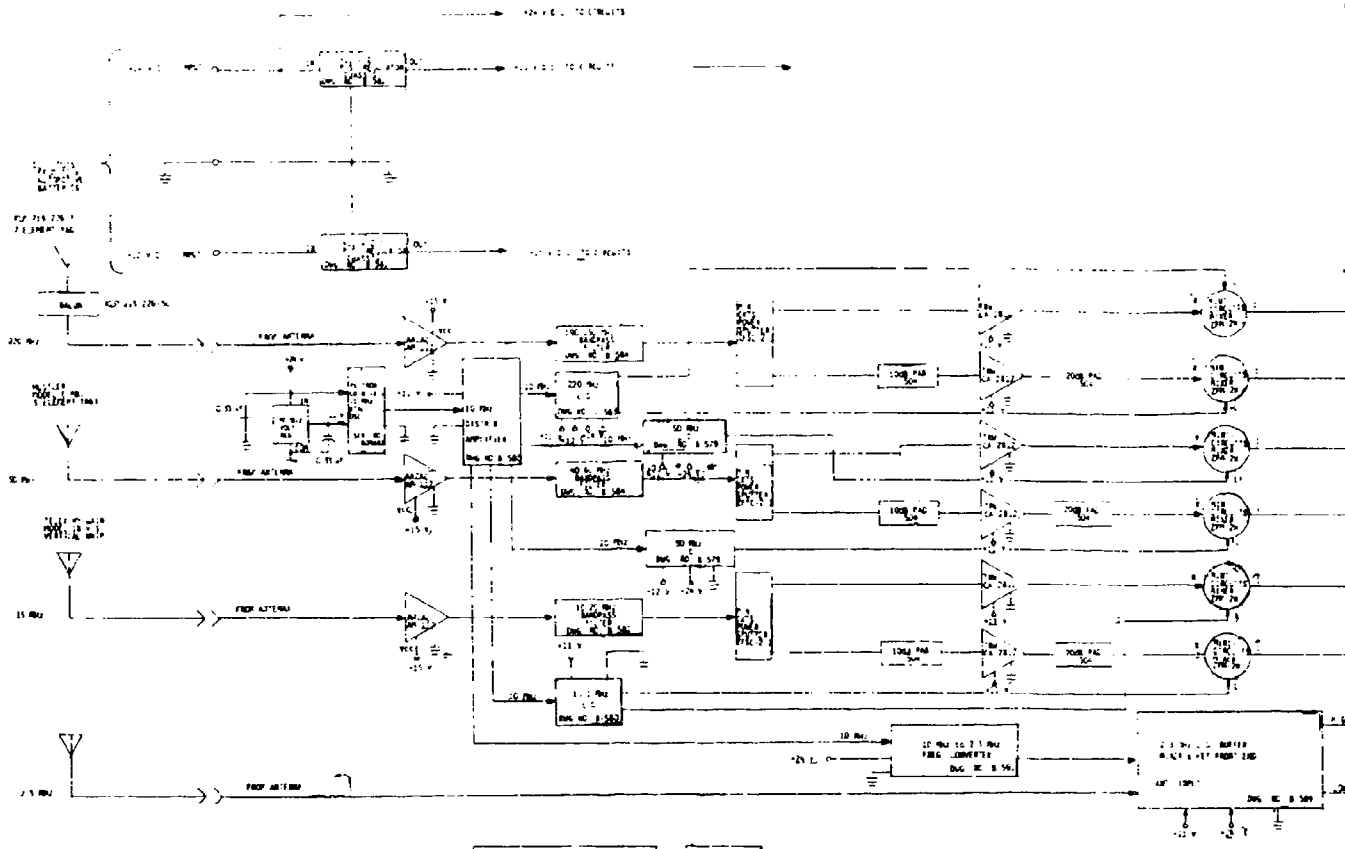
FEB 15 1984

NOTE:
MPS6580 or 2N4957 may be replaced
by any equivalent PNP high-freq.
silicon transistor having $f_T \geq 10\text{MHz}$
and $C_{ob} = 1.8\text{pF}$

DRG	8470	RADANT SYSTEMS, INC. 200 HUDSON ROAD BOSTON, MASSACHUSETTS (617) 689-8600
APPD	D.B. TALEBOT 81583	
CHK		I.F. PROCESSING AMPLIFIER 10 MHz - 600kHz
DES		
DRG	8470	SIZE CODE IDENT DRAWING NO.
APPD	D.B. TALEBOT 81583	C -578
CHK		SCALE - SHEET 1 OF 1

DO NOT SCALE PRINT
A-24

2



DESCRIPTION	QWG NO.
200 MHz ANTENNA	0 101
100 MHz ANTENNA	0 102
50 MHz ANTENNA	0 103
15 MHz ANTENNA	0 104
7.5 MHz ANTENNA	0 105
100 MHz FILTER	0 106
20 MHz FILTER	0 107
10 MHz FILTER	0 108
100 MHz AMPLIFIER	0 109
20 MHz AMPLIFIER	0 110
10 MHz AMPLIFIER	0 111
10 MHz TO 10 MHz FREQUENCY CONVERTER	0 112
10 MHz TO 10 MHz BUFFER	0 113
100 MHz OUTPUT	0 114
50 MHz OUTPUT	0 115
15 MHz OUTPUT	0 116
7.5 MHz OUTPUT	0 117

Figure A-24. Multi-Channel Frequency converter block diagram.

APPENDIX - B
RENTAL HARDWARE SPECIFICATIONS

Specifications for the rental equipment are presented in Figures B-1 through B-5.

SE7000M WIDEBAND

The most compact analog instrumentation
tape recorder available, combining the
capacity and performance of laboratory
installation with the versatility and operational
simplicity of a fully portable general purpose
field recorder.



EMI

Figure B-1. EMI-7000 instrumentation
recorder

TRANSPORT SPECIFICATION

TAPE TRANSPORT

Controls (local):

FAST FORWARD, FAST REVERSE, RUN, FORWARD, REVERSE, RECORD, STOP, FOWARD, REVERSE, eight tape speeds by rotary SW, TAPE TRACKS (4 positions) for AUTOMATIC or TAPES, COMPENSATION LOCAL REMOTE, Push button illumination indicates from and accents.

Controls (remote):

All local controls except FOWARD and LOCAL REMOTE, selected by three lines; local tape speed change inhibited in REMOTE condition.

Remote status indication:

A separate multi-way output socket is provided giving I.T.C. status indicator or following conditions: REVERSE, FAST FORWARD, FAST REVERSE, SYNC. FWD., SYNC. REV., STOP, RECORD.

Flutter:

Measured per MIL-STD-883C Method 2000.1 (10/73)

Tape Speed		Flutter Bandwidth	Flutter % P-P	
cm/s	(ips)		Tzch	Servo
304	(120)	0.2 Hz to 10 kHz	0.20	0.20
152	(60)		0.20	0.20
76	(30)		0.20	0.20
38	(15)		0.30	0.30
19	(7.5)		0.35	0.45
9.5	(3.75)		0.45	0.55
4.75	(1.875)		0.55	0.85
2.37	(0.9375)		0.85	

Start time:

Less than 6 sec. to sync at 304 cm/s (120 ips)

Stop Time:

Less than 1 sec. from 304 cm/s (120 ips)

Transport features:

Optical flow tape sensors
Tape clamped meter
Fail safe in event of supply failure

Reels:

Precision up to 26.67 cm (10 1/2 in.)
maximum 76 cm (3 in.) hubs

Tape width:

2.54 cm (1 in.) or 1.27 cm (1/2 in.)
Performance established using 2.54 cm (1 in.) tape

Tape:

25.4 μ m (0.001 in.) Also suitable for use with 12.7 μ m (0.0005 in.) base
Performance established with SDDS recommended 25.4 μ m (0.001 in.) base instrumentation tape unless stated otherwise.

Tape speed accuracy:

$\pm 0.5\%$ at all speeds (tachometer mode)

Power Supply

A choice of built-in interchangeable power units is available with SE7000M systems

AC unit:

95V to 130V a.c. 48 Hz to 430 Hz
90V to 250V a.c. 48 Hz to 60 Hz
Equipment sensitivity is unaffected by voltage, frequency variations within the ranges specified. Consumption—400 VA.

DC unit:

20V to 39V d.c. without adjustment.
(7ch record/reproduce or 4ch record plus monitor or 4ch reproduce)

Environment

Temperature and humidity:

The system, excluding tape limitations, can be operated and stored in categories A, A2, B1, B2 and B3 of DEF STD 001.

TABLE A Extreme values as follows—

	Operating	Storage
Humidity	5% to 95% (Non-Condensing)	5% to 95% (Condensing)

Temperature:

7000M: 0°C to +40°C, -40°C to -70°C

Vibration:

Including automotive rail way, shipping, caravan, aircraft and passenger aircraft. Additional information regarding specific applications available upon request.

Altitude:

7000: up to 30,000 ft. operating
7000M: up to 50,000 ft. storage.

Physical

SE7000M

Size:

65 cm x 44 cm x 38 cm
(25.6 in. x 17.3 in. x 15 in.)

Weight:

45 kg (99 lb) for complete 4 channel system excluding tape and tripod.

Headstacks

All headstacks, where applicable, comply with RIG 106-75 and are warranted for 1000 hours against failure with recommended tape.

Options

Tape width conversion kit:

Kits are available to permit field conversion of tape width 1.27 cm (1/2 in.) to 2.54 cm (1 in.) (Code TWW) or 2.54 cm (1 in.) to 1.27 cm (1/2 in.) (Code TWH). Conversion takes approximately 30 minutes.

Protective cover (CP):

A quilted PVC cover to provide protection for the recorder during transport of field trials etc.

Servo track reproduce module (TM)

Plugs into relevant reproduce module position in place of data module. Amplifies and equalises control track signal before it is routed to capstan servo circuits. Setting up is facilitated by use of integral LED.

Dynamic skew (I.T.D.E.):

The relative periodic time displacement of an event recorded in a multiplex on two tracks within a 2.54 cm (1 in.) headstack as observed on playback over a 10 sec. period is as follows:

Tape speed	I.T.D.E. μ s (zero-peak)		
	ADJACENT TRACKS		
	7 track	14 track	0.001 base tape
304 (120)	0.16	0.16	1
152 (60)	0.33	0.33	2
76 (30)	0.66	0.66	4
38 (15)	1.32	1.32	8
19 (7.5)	2.64	2.64	16
9.5 (3.75)	5.28	5.28	32
4.75 (1.875)	10.56	10.56	64
2.37 (0.9375)	21.12	21.12	128

Time base error (TBE):

Applicable to Tape Servo mode only

Measured per MIL-STD-883C

(Class B) at 100 Hz

Tape Speed	Time Base Error
cm/s (ips)	Zero-to-peak (μ s)
304 (120)	0.2
152 (60)	0.3
76 (30)	0.55
38 (15)	1.0
19 (7.5)	2.0
9.5 (3.75)	4.0
4.75 (1.875)	6.0
2.37 (0.9375)	12.0

The reference frequency is 200 kHz at 304 cm/s (120 ips) and pro-rata for other speeds. TAPE or TRACK modes are selected by illuminated push buttons. TRACK mode is automatically selected during STOP TAPE signal. The capstan can also be phase locked to an external oscillator for non-standard tape speed operation.

Reversal time:

12 sec. to change from 120 ips FWD to 120 ips REV

Fast mode:

Less than 6 ms for 1400 m (4600 ft) under constant tension capstan control.

Capstan servo:

During the recording process the rotational speed of the capstan is controlled by phase comparison of a pulse train derived from an integral optical tachometer with pulses from an internal reference frequency generator. The resulting error signals are used to modify the instantaneous speed of the capstan.

If the reference frequency is recorded on to one tape track during the recording process the recorded signal can be used on playback in place of the tachometer output. This is possible to reconstitute the timebase of the original data record to very fine limits.

Tape servo bandwidth:

In excess of 250 Hz

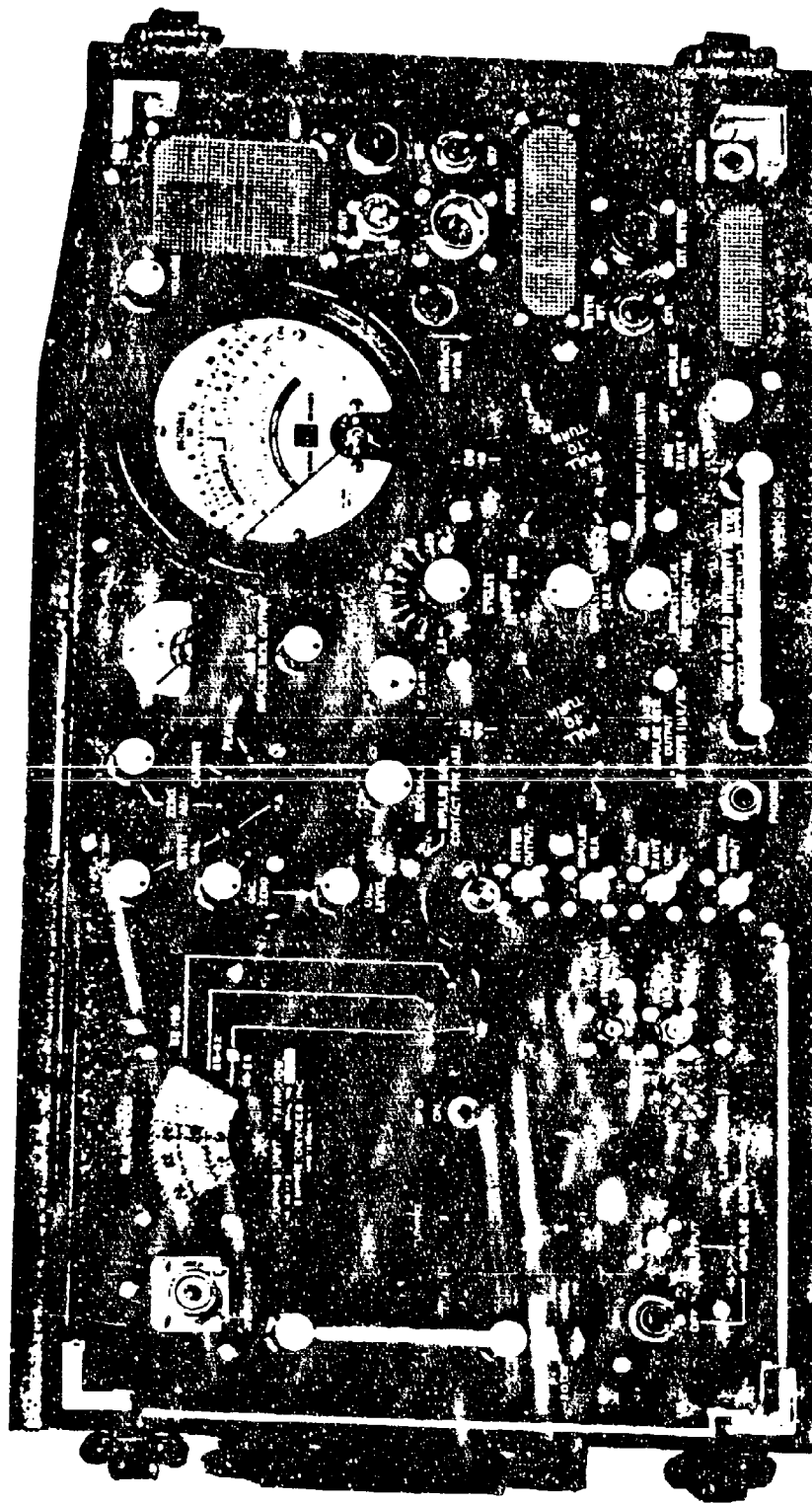


Figure B-3. EMPJRE/NF-105 noise and field intensity meter.

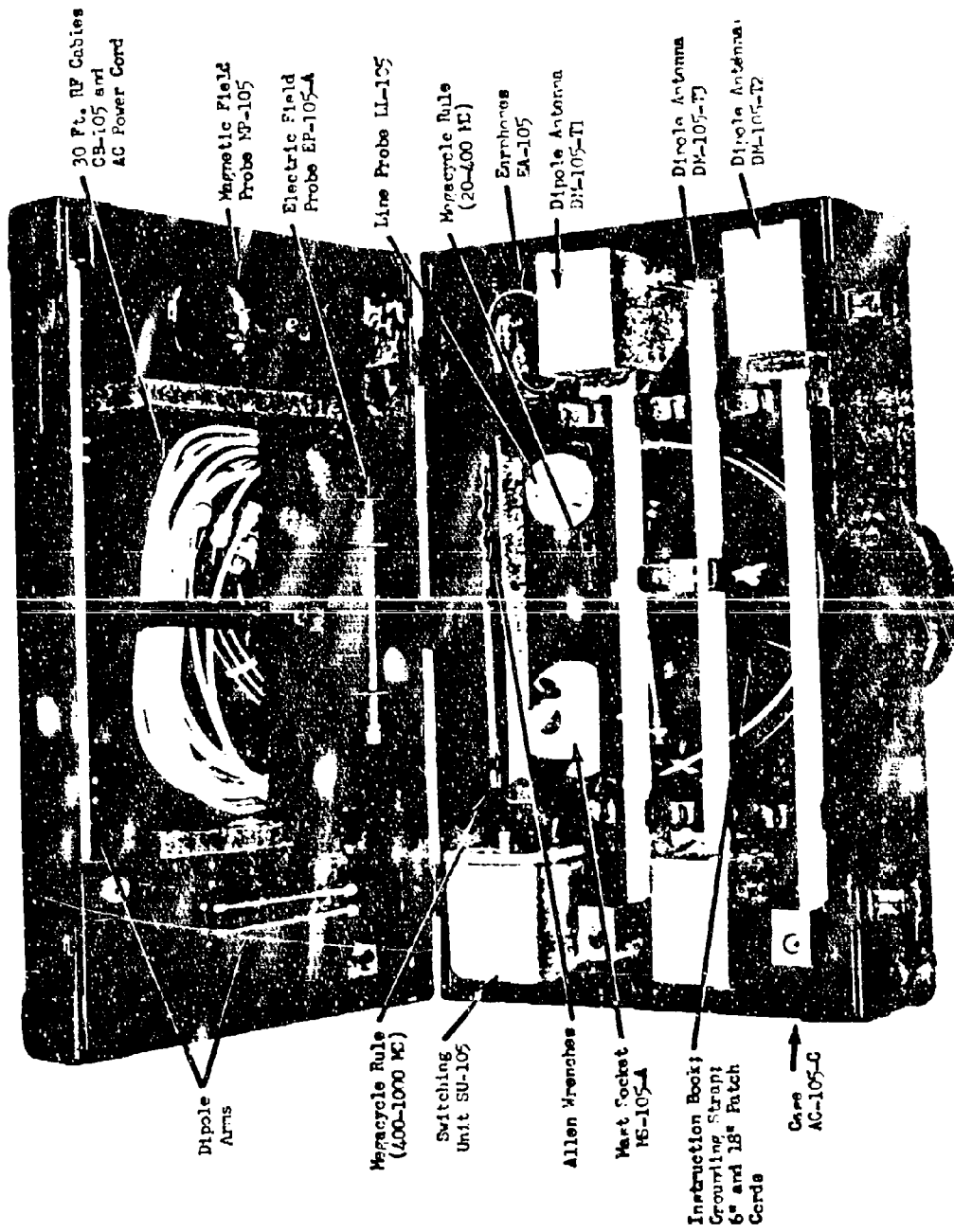
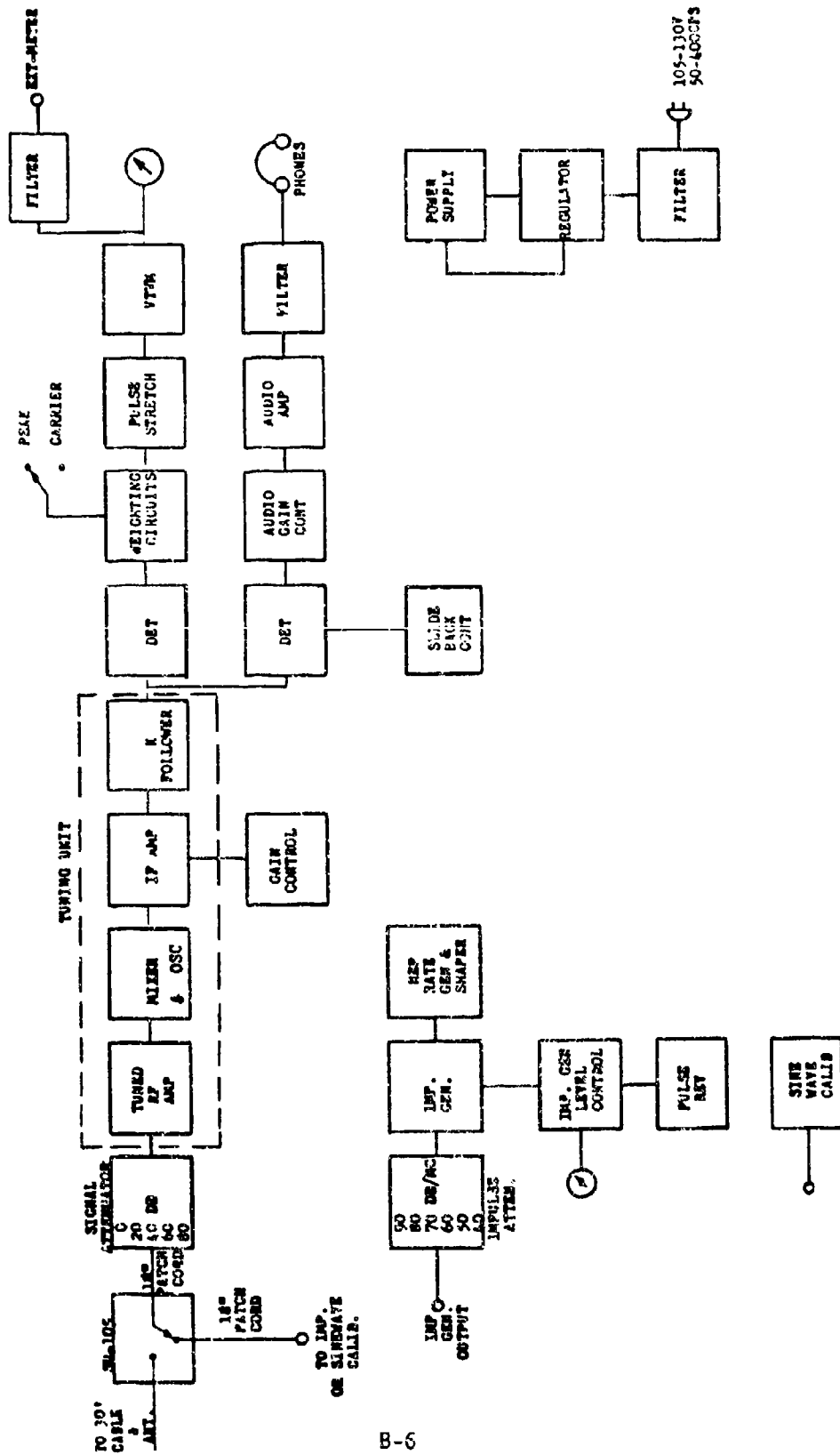


Figure B-4. EMPIRE/NF-105 accessory antenna case.



B-6

BLOCK DIAGRAM
NF-105

Figure B-5. EMPIRE/NF-105 block diagram.

B-6742

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

Defense Communications Eng Ctr
 ATTN: Code R123, Tech Library
 ATTN: Code R400
 ATTN: Code R720, C. Stansberry
 ATTN: R111, N. Sica
 ATTN: R130, P. Savaggi

Defense Intelligence Agency
 ATTN: DB 4C2, D. Spohn
 ATTN: RTS-2A, Tech Library
 ATTN: RTS-2B

Defense Nuclear Agency
 4 cy ATTN: RALE
 4 cy ATTN: STTI-CA

Defense Technical Info Ctr
 12 cy ATTN: DD

Field Command, Defense Nuclear Agency
 ATTN: FCLMC, H. Putnam
 ATTN: FCPR
 ATTN: FCIT, W. Summa
 ATTN: FCTXE

Joint Chiefs of Staff
 ATTN: J-3 Strategic Operations Div

Joint Strat Tgt Planning Staff
 ATTN: JLAA
 ATTN: JIK, DNA Rep
 ATTN: JLKC
 ATTN: JLKS
 ATTN: JPSS
 ATTN: JPTM
 3 cy ATTN: JPPFD

National Communications System
 ATTN: NCS-TS

National Security Agency
 ATTN: Chief A Group, J. Amato
 ATTN: R-52, O. Van Gunten

Under Secy of Def for Rsch & Eng
 ATTN: Strat & Space Sys (OS)
 ATTN: Strat & Theater Nuc For, B. Stephan

DEPARTMENT OF THE ARMY

BMD Advanced Technology Center
 ATTN: ATC-R
 ATTN: ATC-T

BMD Systems Command
 ATTN: BMDSC-HW

Harry Diamond Laboratories
 ATTN: DELHD-NW, J. Rosado, 20060
 ATTN: DELHD-NW-E, 21000
 ATTN: DELHD-NW-EA, 21100
 ATTN: DELHD-NW-EB, 21200
 ATTN: DELHD-NW-EC, 21300
 ATTN: DELHD-NW-ED, 21400
 ATTN: DELHD-NW-EE, 21500
 ATTN: DELHD-NW-P, 2024C
 ATTN: DELHD-TA-L, 81100, Tech Library

DEPARTMENT OF THE ARMY (Continued)

US Army Communications Command
 ATTN: ATSI-CJ-MD
 ATTN: CC-ENGR
 ATTN: CC-OC-SAP
 ATTN: CC-OPS-OS
 ATTN: CC-OPS-PD

USA Ballistic Res Lab
 ATTN: DRDAR-BLA-S, Tech Library
 ATTN: DRDAR-BLE

USA Comm-Elec Eng Instal Agcy
 ATTN: CCC-CED-SES

USA Engineer Div Huntsville
 ATTN: T. Bolt

USA Missile Command
 ATTN: Documents Section

DEPARTMENT OF THE NAVY

Naval Surface Weapons Center
 ATTN: Code F30
 ATTN: Code F32, E. Rathbun

Naval Surface Weapons Center
 ATTN: Code F-56

Naval Weapons Center
 ATTN: Code 343, FKA6A2, Tech Svcs

Ofc of the Dep Ch of Naval Ops
 ATTN: NOP 981
 ATTN: NOP 981N

Strategic Systems Proj Office
 ATTN: NSP-2301, M. Meserole
 ATTN: NSP-43, Tech Library

DEPARTMENT OF THE AIR FORCE

AF Aeronautical Sys Div
 ATTN: ASD/FNACE, J. Corbin

Air Force Weapons Lab
 ATTN: NT
 ATTN: NTN
 ATTN: NTYC, M. Schneider
 ATTN: NTYEE, C. Baum
 ATTN: NTYEP, W. Page
 ATTN: SUL

Electronic Systems Division
 ATTN: SCS-1E

Rome Air Development Ctr
 ATTN: TSLO

Sacramento Air Logistics Center
 ATTN: MPEAE, R. Dallinger

Space Command
 ATTN: DEE

Space Division
 ATTN: YXM

DEPARTMENT OF THE AIR FORCE (Continued)

Strategic Air Command
ATTN: DEMCE
ATTN: CLEPM
ATTN: DGCSO
ATTN: INAO
ATTN: NRI/SIINFC
ATTN: SAC/SIP
ATTN: XPC
ATTN: SAC/SIZ
ATTN: XPFC
ATTN: XPFS

DEPARTMENT OF ENERGY

Emergency Electric Power Adm
US Dept of Energy EP 421
ATTN: L. O'Neill

OTHER GOVERNMENT AGENCIES

Central Intelligence Agency
ATTN: OSWR/NEP
ATTN: OSWR/STD/MTS

Federal Emergency Manage Agcy
ATTN: OPIR, M. Murtha
ATTN: SL-EM, J. Hain

NORAD
ATTN: NORAD/OSYX

DEPARTMENT OF ENERGY CONTRACTORS

University of California
Lawrence Livermore National Lab
ATTN: L-156, H. Cabalan
ATTN: Tech Info Dept Library

Los Alamos National Laboratory
ATTN: B. Noel

Sandia National Laboratories
ATTN: M. Morris
ATTN: Org 2322, E. Hartman

DEPARTMENT OF DEFENSE CONTRACTORS

Aerospace Corp
ATTN: Library

Agabian Associates
ATTN: Library

Allin Corp
ATTN: Dept 6401

American Telephone & Tele Co
ATTN: W. Edwards

BDM Corp
ATTN: Corporate Library

BDM Corp
ATTN: Library

Boeing Co
ATTN: Kent Tech Library
ATTN: R. Scheppe, MS 9F-01

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Booz-Allen & Hamilton, Inc
ATTN: J. Gurgin
ATTN: L. Albright

Booz-Allen & Hamilton, Inc
ATTN: R. Chrisner
ATTN: Tech Library

Computer Sciences Corp
ATTN: A. Schiff

Dikewood Corp
ATTN: Tech Library for D. Pirio
ATTN: Tech Library

EG&C Wash Analytical Svcs CTR
ATTN: C. Giles

Electro-Magnetic Applicats Inc
ATTN: D. Merewether

General Electric Co
ATTN: J. Peden

General Electric Co
ATTN: Tech Library

General Research Corp
3 cy ATTN: Tech Info Office

Georgia Institute of Technology
ATTN: Res & Sec Coord for H. Denny

Grumman Aerospace Corp
ATTN: L-01 35

GTE Government Systems Corp
ATTN: L. Lesinski
ATTN: R. Steinhoff

IIT Research Institute
ATTN: I. Mindel

Institute for Defense Analyses
ATTN: Tech Info Services

IRT Corp
ATTN: B. Williams
ATTN: R. Stewart

IRT Corp
ATTN: R. Leahy

JAYCOR
ATTN: D. Higgins

JAYCOR
ATTN: E. Wenas

JAYCOR
ATTN: Library

JAYCOR
ATTN: R. Poll

Kaman Sciences Corp
ATTN: W. Rich

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Kaman Sciences Corp
ATTN: L. Conrad

Kaman Tempo
ATTN: DASIAC

Kaman Tempo
ATTN: DASIAC

Lutech, Inc
ATTN: F. Tesche

Mission Research Corp
ATTN: EM Group

Mission Research Corp
ATTN: A. Chodorow

Mission Research Corp
ATTN: W. Ware

Mitre Corp
ATTN: M. Fitzgerald

Pacific-Sierra Research Corp
ATTN: H. Erode, Chairman SAGE

R&D Associates
ATTN: C. Knowles
ATTN: C. Mc
ATTN: Document Control
ATTN: P. Haas
ATTN: W. Karzas

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Rand Corp
ATTN: LIB-D

Rand Corp
ATTN: B. Bennett

Rockwell International Corp
ATTN: G. Morgan

Science & Engrg Associates, Inc
ATTN: V. Jones

Science Applications Inc
2 cy ATTN: J. Murphy

Science Applications Intl Corp
ATTN: W. Chadsey

Science Applications, Inc
ATTN: E. O'Donnell

SRI International
ATTN: A. Whitson
ATTN: M. Tarrasch

Teledyne Brown Engineering
ATTN: F. Leopard
ATTN: J. Whitt

Tek Electronics & Defense Sector
ATTN: J. Penar

Harris Corp
ATTN: A. Strain
ATTN: V Pres & Mgr Progs Div