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DESIGN AND INSTALLATION OF THREE FORWARD SCATTER TEST PATHS IN THE ARCTIC FOR MEASURING EFFECTS OF LOW ENERGY SOLAR COSMIC RAYS

by

P. P. Viezbicke

Appendix

by

G. F. Montgomery

NBS

U.S. DEPARTMENT OF COMMERCE

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FOREWORD

This work was carried out under project 85520, Arctic Forward Scatter. The site surveys, design, equipment procurement, and installation at terminal points of the three forward scatter test paths were carried out with funds on P. O. Number T-15237(G), April 17, 1963, from National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas. In compliance with purchase order request this final report includes site surveys and equipment inventory.

The RF section of the receiver described in the Appendix was modified. The modification details will be supplied separately.

Abstract

This report describes transmitter and receiver systems used in measuring effects of low energy solar cosmic rays (mostly protons) over three HF forward scatter test paths in the arctic. Five-element Yagi antennas, overlooking smooth terrain or water, are employed at terminal points of each path and are mounted at optimum heights above ground.

The main beam of radiation is directed to the path midpoint, using a scattering volume height of 85 km. Transmissions over each path are recorded on specially designed, calibrated, narrow bandwidth equipment. The data, presented on strip chart recordings, are interpreted and studied particularly for ionospheric absorption effects resulting from the mesospheric ionization produced by solar cosmic rays.

DESIGN AND INSTALLATION OF THREE FORWARD SCATTER TEST PATHS IN THE ARCTIC FOR MEASURING EFFECTS OF LOW ENERGY SOLAR COSMIC RAYS

P. P. Viezbicke

1. Introduction

Forward scatter techniques [Bailey, Bateman, and Kirby, 1955] have been employed in Alaska and later in the Greenland-Iceland region to observe the effects of proton flux [Bailey, 1962, 1964]. It was possible to study these effects only considerably after an event had occurred, and useful observations were obtained only during a period of high solar activity. With the advent of the Apollo program an awareness was growing of the need to observe solar-cosmic events in real time. Moreover, there was a need to investigate the infrequent and much less intense solar cosmic-ray events that could be expected to occur during the period of low solar activity defined by the IQSY program. A suitable observing program in the arctic would also complement in a particularly valuable way a similar program of measurements to be carried out in the antarctic at the same time under NSF-IQSY sponsorship.

To meet the needs of such a program, three forward scatter test paths were installed in the arctic. Two paths are located in Alaska, the third in Canada, as indicated on the map in figure 1. The three paths were selected to represent a useful range in longitude, to provide observations from a possible conjugate to one of the antarctic paths, and to provide observations from a position slightly outside the polar cap where the effects of a higher and changing magnetic cutoff could be studied. To make the observations more sensitive to small events, the various test paths were operated at frequencies near 23 Mc/s rather than in the 32-36 Mc/s range employed in an earlier communication system.

This program was initiated on April 17, 1963 and completed during the early spring of 1964. The scope of the project involved system design calculation (table 1), site surveys conducted in Alaska and Canada, and the procurement and installation of transmitter and receiver systems together with the necessary antennas at the selected sites.

2. Site Survey

Selection of the antenna site and the determination of the correct height of the antenna above ground plays an important role in the successful operation of the system. The site should be nearly flat, free from obstacles, and extend in the direction of the opposite terminal for a sufficient distance to provide for the first Fresnel zone. This zone contributes to the gain of the system by allowing the plane-wave ground reflection lobe to be properly formed.

The extent of the zone over a plane earth includes an area bounded by the geometrical figure presented in figure 2. It is within this zone that the ground reflected energy undergoes a phase shift of 180 degrees or less from the reference ray and reinforces the direct ray at an angle of departure α.

The problem of the effect of departure from terrain smoothness is difficult to resolve. One requirement is that bumps on the smooth surface are not greater than $h/4$, where h is the antenna height above ground. In some cases, the selected site may be located on high ground, overlooking lower sloping terrain or water. These features can be used advantageously and shorter towers can be employed and still maintain the effective design height over the geometric ground reflection point. Three of the six sites in the Arctic exhibited terrain features that were used to this advantage.

Table 1

SYSTEMS DESIGN DATA FOR THE ARCTIC TEST PATHS

Stations Transmitting	Stations Receiving	Path Length km	Bearing T to R	Bearing R to T	Coordinates of Path midpoint	Proton Cutoff Mev	Operating Frequency Mc/s	Antenna Height (meters)	Angle of Departure (degrees)	Geometric gnd.reflt.pt. (meters)	Fresnel Zone Dimensions (distance from antenna) Near Edge (meters)	Far Edge (meters)	Width (meters)
Barrow 71°-18'N 156°-45'W	Anchorage 61°-17'N 149°-50'W	1156	160°-55'	347°-24'	66°-20'N 152°-31'W	25	23.187	33	5.9	350	51	2000	195
Annette Island 55°'15'N 131°-37'N	Fairbanks 64°-45'N 147°-36'W	1376	326°-43'	132°-48'	60°-14'N 138°-28'W	68	23.365	41	4.2	550	100	3500	260
Frobisher Bay 63°-40'N 67°-45'W	Great Whale River 55°-15'N 77°-40'W	1091	215°-14'	26°-40'	59°-32'N 73°-20'W	3	23.44	28	6.5	250	37	1400	170

Specific sites for the three test paths located in Alaska and Canada are presented in area topographic maps, drawings, and photographs. Figures 3 through 11 show specific details of the transmitter and receiver sites in Alaska. Figures 12 through 17 provide similar information for the Canadian sites.

At Barrow, the transmitter, towers, and antenna are located at the National Bureau of Standards field station as shown on the topographic map of figure 3. A photograph of the field station and antenna system is presented in figures 4 and 5. Since the antenna is sited over level smooth terrain, it was mounted at the design height of 33 meters. At Anchorage, the receiver building and antenna are sited at Elmendorf Air Force Base overlooking the Knik Arm of Cook Inlet. In contrast to the former, the terrain in front of the antenna slopes in the direction of propagation and was used advantageously to employ shorter towers. Although the antenna was mounted at a height of 16.8 meters above ground, the effective design height of 33 meters was maintained over the geometric ground reflection point. An area topographic map showing the location of the receiver site at Anchorage and a photograph of the installation are shown in figures 6 and 7. NBS personnel stationed at Barrow and Anchorage operate and maintain the equipment for this path.

At Annette Island, the transmitter trailer and antennas are sited on sloping terrain overlooking a bay in the direction of propagation. A topographic map of the island showing the location of the site and a photograph of the installation are shown in figures 8 and 9. The selected site was 6 meters above mean sea level. For this reason, the antenna was mounted at a height of 35 meters above ground instead of the 41 meter design height over level ground. The facility was installed and maintained by FAA personnel.

The receiver station, near Fairbanks, is sited in wooded terrain near a NASA minitrack station. Because of relatively smooth terrain features, the antenna was mounted at the design height of 41 meters above ground. The station is operated and maintained by staff members of the Geophysical Institute, University of Alaska.

In Canada, the transmitter installation at Frobisher Bay is sited on an abandoned airstrip (designated as the West 40 site) and is located approximately 2 kilometers southwest of the community of Frobisher Bay. As shown in the topographic map of the area, figure 12, the area in front of the antenna, although limited in extent, is smooth level ground. The extent of this level area measured 0.85 kilometers, approximately 0.6 of the distance to the far edge of the Fresnel zone. Beyond the smooth reflecting area, the terrain slopes downward toward the bay. This restriction in the foreground area is not considered to constitute a significant detriment to the antenna performance. The width of the area is approximately 170 meters. Photographs of the completed installation are presented in figures 13 and 14.

The receiver site at Great Whale River is located approximately 2 kilometers north of the airstrip as shown on the map of figure 15. The towers and antennas are located on a plateau and overlook an extremely flat area in the direction of propagation. The smooth area, as at Frobisher Bay, extends to approximately 0.6 of the distance to the far edge of the Fresnel zone and was followed by rolling terrain. It is 180 meters wide at its narrowest point, or slightly greater than the design width. Since the selected site was 4 meters higher than the foreground area, the antenna was mounted 24 meters above the ground instead of the 28 meter design height. A photograph of the receiver building and the antenna installation is presented in figures 16 and 17.

3. Systems Design

In carrying out the investigation over an experimental path, continuous signal intensity recordings are made of horizontally polarized CW transmissions. The system consists of nearly ideally-sited transmitter and receiver facilities which are separated by the path length L, resulting in a propagation trajectory with an angle of departure α in keeping with midpoint ionospheric scattering from a height of 85 kilometers. A detailed study has recently been made concerning the calculation of optimum antenna heights for practical cases of interest in ionospheric scatter work [Merrill, 1958, 1959]. This study employs a model atmosphere and incorporates spherical divergence, near horizon diffraction correction, parallax, and refractive defocusing using an ionospheric reflection height of 85 km. Although the data presented by Merrill do not include antenna height versus path length curves for frequencies below 30 Mc/s, lobe alinement antenna heights were extrapolated from those presented for the different path lengths at an operating frequency of 23 Mc/s. These heights, together with path lengths, bearings, and Fresnel zone dimensions for the different paths are presented in table 1.

3.1. Antenna System

Identical five-element Yagi antennas are used at the transmitter and receiver sites. Each antenna is located at such an effective height above ground as to have its main lobe of radiation directed toward a point 85 km above the path midpoint. In physical construction, the antennas are designed to withstand the adverse weather conditions encountered in polar regions where wind velocities of 120 mph can occur and where the temperatures may range from plus 80 to minus 110 degrees Fahrenheit.

The antenna was designed to operate at a frequency of 23.3 ± 0.5 Mc/s. It is 0.8λ long with elements equally spaced at 0.2 wavelengths. Figure 18 presents dimensions and spacings of elements and indicates materials used in fabrication, mounting, and interconnection details.

Prestressed medium tempered 60-61T6, 3-inch diameter aluminum pipe is used for the boom. A splice is placed between the second and third directors and reinforced with a four-foot telescoping plug secured with 1/2 by 4-inch aluminum bolts and nuts.

The elements consist of 1 - 5/8 inch O.D. five-foot long tubes located at 8 foot 5 - 1/2 inch intervals along the boom and are fitted into holes, centered and heliarc welded into the boom. The outer parts of the elements, constructed of 1 - 1/2 inch O.D. aluminum tubing, are fabricated into two equal lengths. One length is force fitted with an aluminum plug and is designed to telescope into its matching counterpart at the center of the boom. Markers, scribed on the elements, facilitate centering the elements on the boom.

The gain of the antenna is 9.2 db relative to a half-wave dipole at the same height and is characterized with E and H plane half-power beamwidths of 45 and 60 degrees, respectively. Measured radiation patterns of the antenna are presented in figures 19 and 20.

The input impedance to the antenna is approximately 200 ohms. A one-half wavelength long, four to one impedance matching network transforms the balanced 200 ohms impedance to 50 ohms unbalanced. Foamflex coaxial cable connects the antenna to a double-stub tuner located near the base of the tower. Additional lengths of foamflex connect to receiving or transmitting equipment located in a nearby trailer or building. Interconnection details of the antenna system are presented in figure 18.

3.2. Transmitting System

Identical antennas and equipment are used at the three arctic transmitting stations.* The 1 kw transmitter, with its associated control and recording equipment, is designed to operate on a fixed frequency in the range of 23 to 24 Mc/s. Compact in design, the transmitter and one rack of associated control and monitoring equipment occupies limited space. At Frobisher Bay, the equipment is located in a portable 8 by 8 foot insulated building that is completely wired, fan vented, and heated. The building is mounted on skids and is readily transportable. A magnesium trailer, with detachable running gear, is used to house equipment at Annette Island. At Barrow, the equipment is housed at the NBS field station. The transmitter and receiver stations operate from a single-phase, 3-wire, 220-volt 60-cycle source. The Arctic Research Laboratory furnishes the power to the NBS field station at Barrow, but emergency standby power is available at the site. The USAF furnishes power to its receiver counterpart at Anchorage. The FAA serves the transmitter facility at Annette Island. The local power company serves the receiving site at Fairbanks, Alaska. At Frobisher Bay in Canada, power is delivered by the Canadian Power Company. At Great Whale River, the RCAF delivers power to the receiving site.

A block diagram of the transmitting system is shown in figure 21. It consists essentially of a high stability, 1 part in 10^8 per day, frequency standard, multiplier, driver, and a 1 kw power amplifier which connects to and is matched to the 50 ohm antenna system. A program clock

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* It should be noted that the transmitters employed in the antarctic for the NSF-IQSY paths are not identical with those used in the arctic, though the power output is the same.

operates a keying circuit used to break the signal typically for three minutes at half-hour intervals to permit observation of the background noise (or interference when present) at the receiving site. The transmitters used in the tests are of NBS design and originally rated at 3 kw power output. Since tests were to be carried out at reduced power, the transmitters were modified and use 4-400 tubes instead of the original 4-1000 tubes. Circuit diagrams of the amplifier, multiplier, driver, power supplies, and control circuits are presented in figures 22 through 26. A photograph of the transmitter and associated control equipment is presented in figure 27.

The impedance and corresponding standing wave ratio of the antenna system at transmitter and receiver installations are checked periodically. A diode bridge device, standardized to 50 ohms, is used to measure the SWR of the antenna system. Instruction on its use accompany the instrument.

The transmitting forward and back power are measured and recorded continuously on a dual channel strip chart recorder. Full scale deflection of the recording pens corresponds to 1 kw average power. Since the experiment required a maximum power of 500 watts, the transmitter forward power is adjusted to and maintained at this half scale level on the strip chart recorder. The back power indication is zero and will not deviate therefrom unless the antenna system becomes detuned or differs significantly from 50 ohms in impedance. The strip chart pen recorders not only monitor signal transmissions, but keep a record of transmitting off time at the half-hourly breaks and other outages and fluctuations. These recordings are used to correct, if necessary, the receiver signal-intensity data. Every day entries are made in the station log as well as on the strip chart record. Information relative to station location, frequency, date, antenna system behavior, and general notes are recorded.

3.3 Receiving system

Monitoring and recording of the CW transmissions are carried out with narrow-band recording equipment. A block diagram and photograph of the equipment are presented in figures 28 and 29, respectively. The receiving and recording equipment, normally mounted and housed in portable buildings, function as complete self-contained receiver facilities. As such, each includes laboratory constructed receivers, a high stability crystal oscillator, d-c amplifier, strip chart pen recorders, associated power supplies, and line voltage regulators. Each unit is temperature controlled by electric heaters and air conditioning equipment. A laboratory-constructed signal generator complete with pads and step attenuators is used to calibrate the equipment. Schematic diagrams of the calibrating signal generator are presented in figures 30 and 31. A description of the receiver detailing design, circuitry, and operation is presented in the Appendix.

The narrow-band recording receivers, designed to operate on an assigned frequency near 23 Mc/s, were designed and constructed by the Electronics Division, NBS, Washington, D. C. The associated high-stability frequency standard controls a multiplier circuit, the output of which is used as a local oscillator in the receiver. The frequency standard is commercially available. The multiplier circuit is described in and included with the receiver manual.

The transmissions are recorded with a receiver which has a characteristic post-detection bandwidth of 25 cycles per second. It is essentially a single-conversion receiver, with a noise figure of approximately 4dB at 23 Mc/s. It has a 1000 c/s IF and by the use of special electronic techniques has an image rejection of 26 dB. The post-detection averaging time constant is 12 seconds and serves to smooth the rapid signal fluctuations. The second detector output is logarithmically proportional to the receiving input voltage. A built-in d-c amplifier provides the necessary voltage to drive a pen recorder. At present each receiving station is equipped with two identical receivers and three chart recorders. One measures signal intensity and is calibrated from +40 dB above one microvolt to receiver noise, R, on two identical pen recorders. The second receiver extends this calibration to 70 dB (nominal) and is primarily used to record signal intensity when sporadic-E propagation occurs.

An oscilloscope built into the receiver is used to tune the receiver to the transmitter operating frequency. The receiver output is connected to one set of deflection plates; a secondary 1000 c/s tuning fork frequency standard is connected to the second set of oscilloscope plates. The resulting Lissajous pattern is used to indicate the accuracy to which the receiver is tuned. It is monitored throughout the calibration process.

The receiver calibration is made with the crystal controlled generator in series with two 50 ohm step attenuators connected as shown in figure 28. The 6 dB pad (mounted inside the generator - see figure 31) permits calibration of the receiver in terms of antenna open-circuit voltage. The available power at the matched antenna is equal to $E^2/4R$ where E is the equivalent antenna open-circuit voltage and R is the characteristic 50 ohm impedance.

A calibration is made at least once during each 24-hour interval. The signal generator output meter is set to a calibration mark on the face of the generator output meter. This level corresponds to 60 dB above 1 μV or 1000 microvolts. An additional 20 dB is inserted in the calibrating step attenuator to reduce the signal generator output to 100 microvolts or 40 dB. The calibration is made in 5 dB steps from +40 dB to receiver noise. A sample calibration chart is presented in figure 32. The sporadic-E receiver is calibrated to a higher level, nominally 70 dB above 1 μV, to permit an adequate display of high-intensity sporadic-E signals.

The pen recorders, with a chart speed drive of three inches per hour, are used to trace strip chart records of signal intensity and background noise levels. During the course of recording, pertinent data are written on the chart by the operator. These include: path, frequency, transmission line impedance, date, time, observer's initials, and other information such as antenna SWR, weather, interference, and equipment or antenna malfunctions.

The strip charts are removed from the recorder daily. Each chart represents a 24-hour record of data starting and ending at 0000 hours UT. At the end of each week the strip chart recordings from transmitter as well as receiver stations are sent to the sponsoring agencies for further scaling and analysis. In Alaska, all data are sent to NBS, Boulder, Colorado. In Canada, all data are sent to the Bartol Research Foundation, Swarthmore, Pennsylvania. The latter organization is responsible for the operation and maintenance of the Canadian path.

4. Summary

Fully equipped transmitter and receiver facilities for three forward scatter test paths in the arctic were installed in order to permit studies of low energy (roughly 10 to 300 Mev) solar cosmic ray events. The antenna systems are sited over nearly flat ground or water, particularly including an area occupied by the first Fresnel zone. Yagi antennas, exhibiting moderate gain and beamwidth characteristics, are used at the transmitting and receiving sites. Continuous signal intensity recordings are made of CW transmissions at the receiver locations. The resulting data are analyzed and absorption effects in signal levels are used to identify solar cosmic ray events and to determine the variation with time of the intensity of the solar cosmic rays above magnetic cutoff or atmospheric cutoff (about 10 Mev), whichever is higher.

5. Acknowledgements

Appreciation is extended to D. C. Whittaker and W. B. Harding for their valuable assistance in regard to instrumentation of the transmitting and receiving equipment.

6. References

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Merrill, R. G. (Sept. 10, 1958), Radiation patterns in the lower ionosphere and Fresnel zones for elevated antennas over spherical earth, NBS Report 5599.

Merrill, R. G. (March 18, 1959), Optimum antenna height for ionospheric scatter propagation, NBS Report 6047.

7. Equipment Inventory

EQUIPMENT INVENTORY AT THE DIFFERENT STATIONS

NBS Number	Acq Date	Div		Value	Project	PO Number	Description		Mfg	Model	Serial
College, Alaska											
s00141	16 3	852 0	5o	00041 5	52 0	02842 2	recorder		ea	a601c	146637
s00144	16 3	852 0	5o	00041 5	52 0	02842 2	recorder		ea	a601c	146635
s00163	16 3	852 0	5o	00035 2	52 0	02854 9	voltmeter		hp	410c	31100272
s00180	26 3	852 0	5o	00033 6	52 0	02828 3	power supply	reg	dbc	25847a	88184
s00190	26 3	852 0	5o	00038 2	52 0	02827 6	regulator	reg	srsn	r1010	192
s00198	26 3	852 0	5o	00035 6	52 0	02918 1	voltmeter	null	hp	413ar	13900659
s00201	26 3	852 0	5o	00012 6	52 0	02880 6	attenuator		hp	355d	21801987
s00207	26 3	852 0	5o	00012 6	52 0	02880 6	attenuator		hp	355d	21801873
s00208	26 3	852 0	5o	00063 5	52 0	02828 2	oscillator		mli	rd146	107
122774	26 3	852 0	5o	00035 6	52 0	02918 1	voltmeter	null	nas a	413ar	31500837
122918	26 3	852 0	5o	00013 4	52 0	03263 7	air cond		nas a	rh601bz	03ux02595
123387	26 3	852 0	5o	00065 0	52 0	03263 3	building	port	nas a	8x8	none
Annette, Alaska											
122567	26 3	852 0	5o	00015 0	52 0	02841 6	coupler	direct	nas a	645a	131
s00183	26 3	852 0	5o	00033 6	52 0	02828 3	power supply	reg	dbc	25847a	88188
s00175	26 3	852 0	5o	00044 6	52 0	02882 1	meter	power	hp	431b	30101857
s00176	26 3	852 0	5o	00044 6	52 0	02882 1	meter	power	hp	431b	30101850
s00165	16 3	852 0	5o	00014 6	52 0	02880 6	mount	thrmstr	hp	478a	8956
s00158	16 3	852 0	5o	00035 2	52 0	02854 9	voltmeter		hp	410c	31100233
s00155	16 3	852 0	5o	00018 2	52 0	02841 7	clock	control	swcc	25-12	83104
s00166	16 3	852 0	5o	00014 6	52 0	02880 6	mount	thrmstr	hp	478a	8958
Anchorage, Alaska											
s00142	16 3	852 0	5o	00041 5	52 0	02842 2	recorder		ea	a601c	146633
s00151	16 3	852 0	5o	00019 3	52 0	02841 9	combiner	hf	arc	h20	14
s00157	16 3	852 0	5o	00041 5	52 0	02855 5	recorder		ea	a601c	147176
s00162	16 3	852 0	5o	00035 2	52 0	02854 9	voltmeter		hp	410c	31100201
s00164	16 3	852 0	5o	00012 6	52 0	02827 5	attenuator		hp	355c	21901887
s00182	26 3	852 0	5o	00033 6	52 0	02828 3	power supply	reg	dbc	25847a	88185
s00188	26 3	852 0	5o	00038 2	52 0	02827 6	regulator	reg	srsn	r1010	
s00194	26 3	852 0	5o	00063 5	52 0	02828 2	oscillator	crystal	mli	rd146	434
s00196	26 3	852 0	5o	00035 6	52 0	02918 1	voltmeter	null	hp	413ar	13900697
s00200	26 3	852 0	5o	00035 6	52 0	02918 1	voltmeter	null	hp	413ar	13900606
s00204	26 3	852 0	5o	00012 6	52 0	02880 6	attenuator		hp	355d	21801974
s00205	26 3	852 0	5o	00012 6	52 0	02880 6	attenuator		hp	355d	21802022
122917	26 3	852 0	5o	00013 4	52 0	03263 7	air cond		nas a	rh601bz	03ux02900
123388	26 3	852 0	5o	00065 0	52 0	03263 3	building	port	nas a	8x8	none
124742	16 4	852 0	5o	00016 6	52 0	03681 1	transformer		nas a		
Barrow, Alaska											
s00159	16 3	852 0	5o	00035 2	52 0	02854 9	voltmeter		hp	410c	31100290
s00168	16 3	852 0	5o	00014 6	52 0	02880 6	mount	thrmstr	hp	478a	8968
s00169	16 3	852 0	5o	00014 6	52 0	02880 6	mount	thrmstr	hp	478a	8987
s00177	26 3	852 0	5o	00044 6	52 0	02882 1	meter	power	hp	431b	30101866
s00178	26 3	852 0	5o	00044 6	52 0	02882 1	meter	power	hp	431b	30101858
122565	26 3	852 0	5o	00015 0	52 0	02841 6	coupler	direct	nas a	645a	130
Great Whale PQ, Canada											
s00140	16 3	852 0	5o	00041 5	52 0	02842 2	recorder		ea	a601c	146636
s00143	16 3	852 0	5o	00041 5	52 0	02842 2	recorder		ea	a601c	146634
s00152	16 3	852 0	5o	00019 3	52 0	02841 9	combiner	hf	arc	h20	15
s00160	16 3	852 0	5o	00035 2	52 0	02854 9	voltmeter		hp	410c	31100287
s001/1	16 3	852 0	5o	00017 5	52 0	02843 6	oscillator		acc	fd3812z	2694
s00172	16 3	852 0	5o	00017 5	52 0	02843 6	oscillator		acc	fd3812z	2693
s00181	26 3	852 0	5o	00033 6	52 0	02828 3	power supply	reg	dbc	25847a	88186
s00184	26 3	852 0	5o	00012 6	52 0	02880 6	attenuator	step	hp	355c	21901800
s00189	26 3	852 0	5o	00038 2	52 0	02827 6	regulator	reg	srsn	r1010	191
s00193	26 3	852 0	5o	00063 5	52 0	02828 2	oscillator	crystal	mli	rd146	435
s00197	26 3	852 0	5o	00035 6	52 0	02918 1	voltmeter	null	hp	413ar	13900604
s00199	26 3	852 0	5o	00035 6	52 0	02918 1	voltmeter	null	hp	413ar	13900654
s00203	26 3	852 0	5o	00012 6	52 0	02880 6	attenuator		hp	355d	21801986
s00206	26 3	852 0	5o	00012 6	52 0	02880 6	attenuator		hp	355d	21802014
Frobisher NWT, Canada											
s00192	26 3	852 0	5o	00044 6	52 0	02902 1	meter	power	hp	431b	30101951
122564	26 3	852 0	5o	00015 0	52 0	02841 6	coupler	direct	nas a	645a	132
122566	26 3	852 0	5o	00015 0	52 0	02841 6	coupler	direct	nas a	645a	133
122854	16 4	852 0	5o	00077 6	52 0	02827 5	oscillator	freq	nas a	101a	22000322
s00156	16 3	852 0	5o	00018 2	52 0	02841 7	clock	control	swcc	25-12	91627
s00161	16 3	852 0	5o	00035 2	52 0	02854 9	voltmeter		hp	410c	31100240
s00167	16 3	852 0	5o	00014 6	52 0	02880 6	mount	thrmstr	hp	478a	8798
s00170	16 3	852 0	5o	00014 6	52 0	02880 6	mount	thrmstr	hp	478a	4864
s00179	26 3	852 0	5o	00033 6	52 0	02828 3	power supply	reg	dbc	25847a	88187
s00187	26 3	852 0	5o	00038 2	52 0	02827 6	regulator	reg	srsn	r1010	
s00191	26 3	852 0	5o	00044 6	52 0	02902 1	meter	power	hp	431b	30101963
Boulder, Colorado											
s00147	16 3	852 0	5o	00018 2	52 0	02841 /	clock	control	swcc	25-12	91050
s00148	16 3	852 0	5o	00018 2	52 0	02841 /	clock	control	swcc	25-12	194043
s00149	16 3	852 0	5o	00018 2	52 0	02841 /	clock	control	swcc	25-12	156209
s00150	16 3	852 0	5o	00019 3	52 0	02841 9	combiner	hf	arc	h20	13
s00153	16 3	852 0	5o	00019 3	52 0	02841 9	combiner	hf	arc	h20	16
s00154	16 3	852 0	5o	00018 2	52 0	02841 /	clock	control	swcc	25-12	91538
s00173	16 3	852 0	5o	00017 5	52 0	02843 6	oscillator		acc	fd3812z	2692
s00174	16 3	852 0	5o	00017 5	52 0	02843 6	oscillator		acc	fd3812z	2691
s00185	26 3	852 0	5o	00012 6	52 0	02880 6	attenuator	step	hp	355c	21901842
s00186	26 3	852 0	5o	00012 6	52 0	02880 6	attenuator	step	hp	355c	21901825
s00195	26 3	852 0	5o	00035 6	52 0	02918 1	voltmeter	null	hp	413ar	13900664
s00202	26 3	852 0	5o	00012 6	52 0	02880 6	attenuator		hp	355d	21802020
1225/2	26 3	852 0	5o	00011 0	52 0	03124 0	attenuator		nas a	at50	none
122573	26 3	852 0	5o	00011 0	52 0	03124 0	attenuator		nas a	at50	none
122852	16 4	852 0	5o	0007/ 6	52 0	02827 5	oscillator	freq	nas a	101a	22000327
122853	16 4	852 0	5o	00077 6	52 0	02827 5	oscillator	freq	nas a	101a	22000324
122922	26 3	820 0	5o	00222 7	52 0	03062 7	room	shield	nas a	8 x 8	none

B- 47838

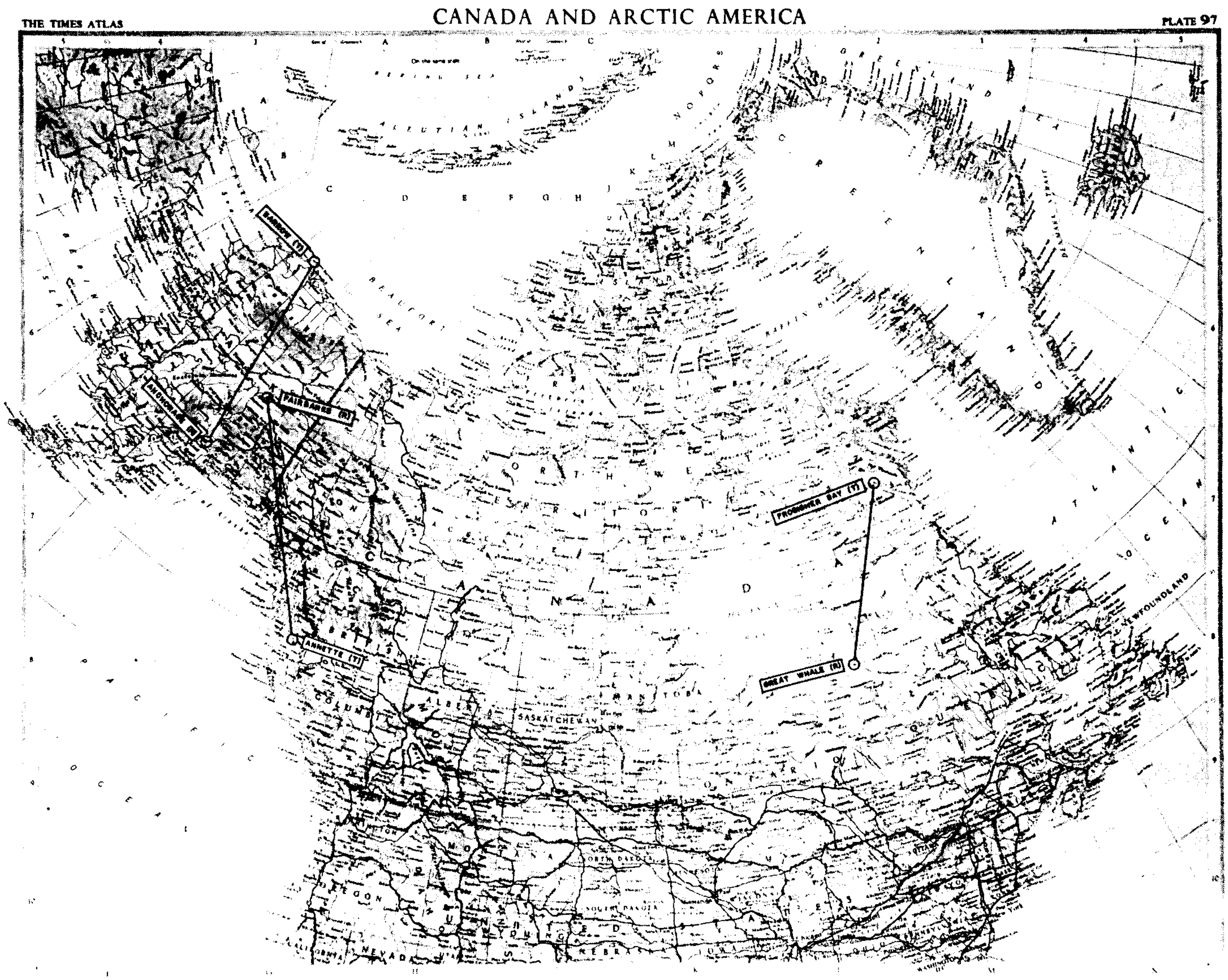


Figure 1. Location of the forward scatter test paths in the arctic

B- 47839

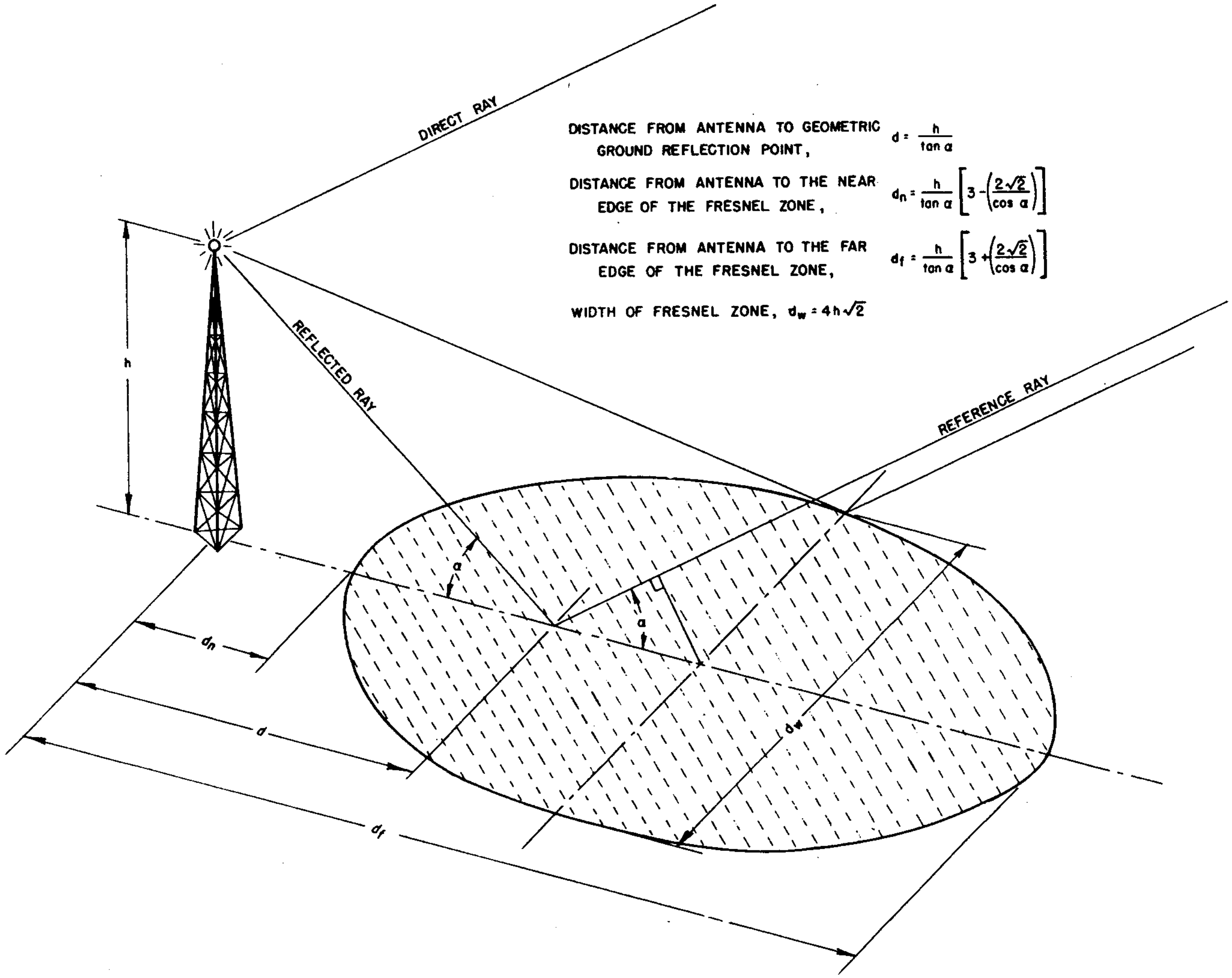


Figure 2. Geometry of first Fresnel zone over a plane earth

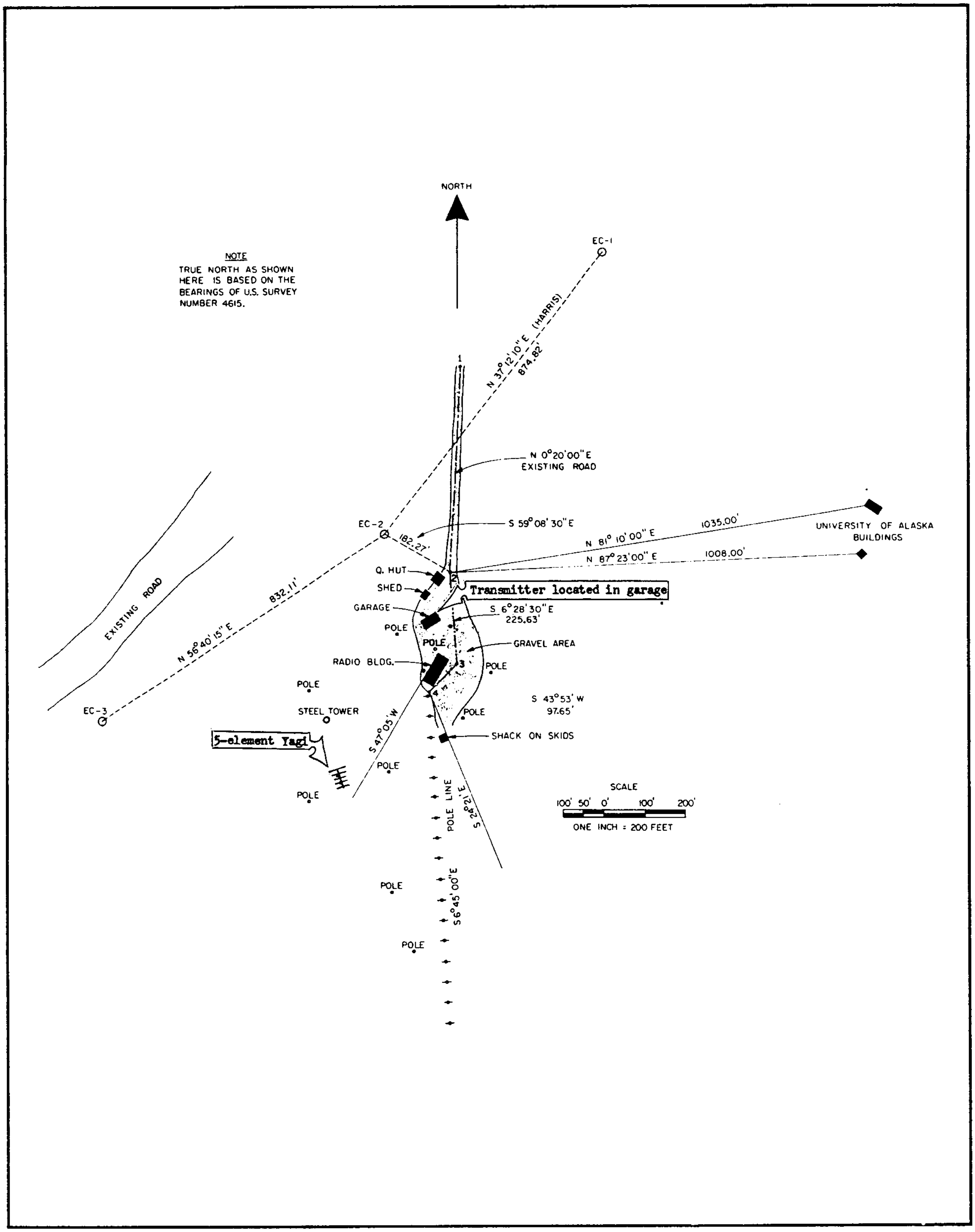


Figure 3. Topographic map of the Barrow transmitter site

Figure 4. Photograph of the NBS field station at Barrow, Alaska

B- 52018

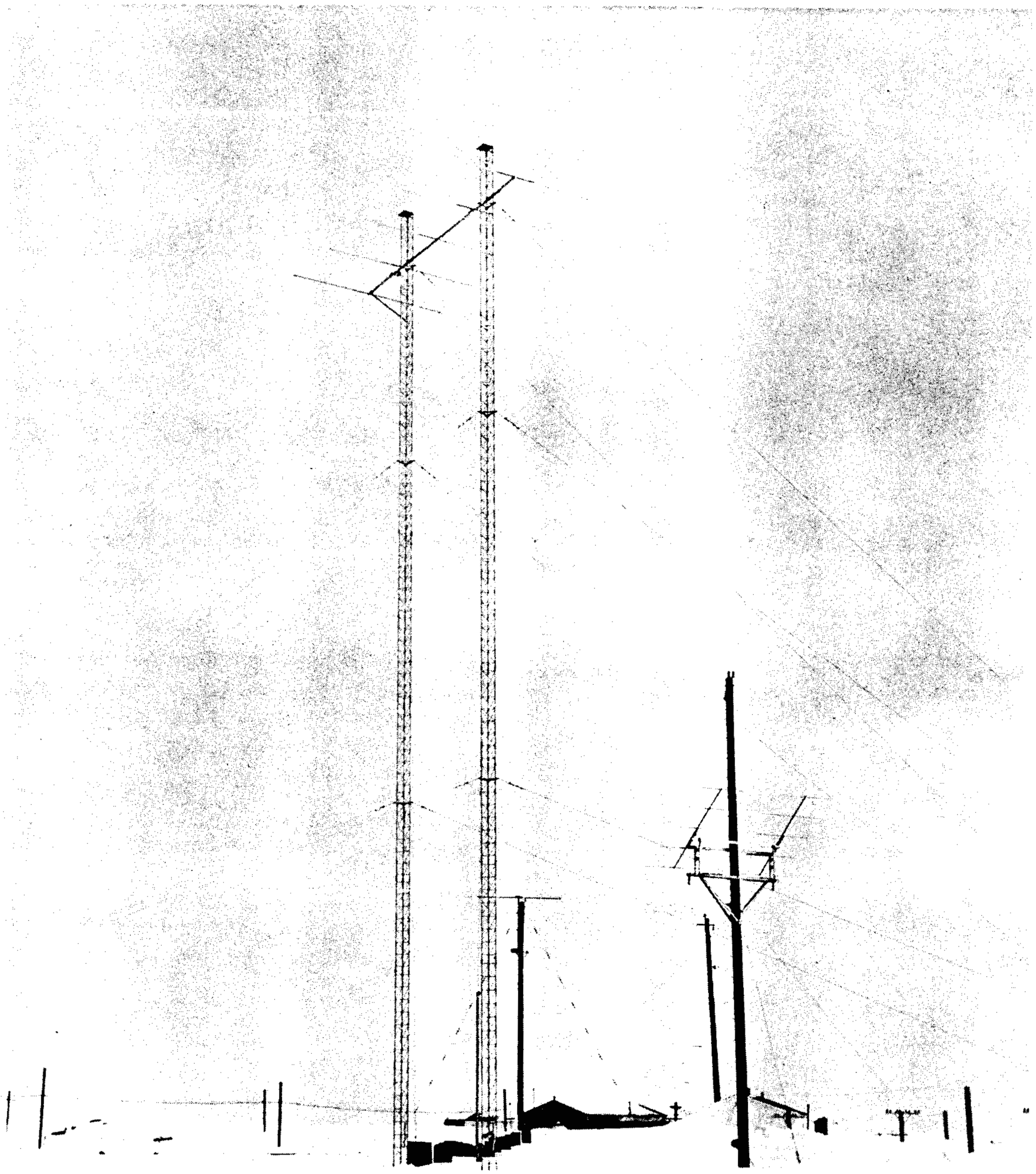


Figure 5. Photograph of the antenna installation at Barrow, Alaska

B- 52019

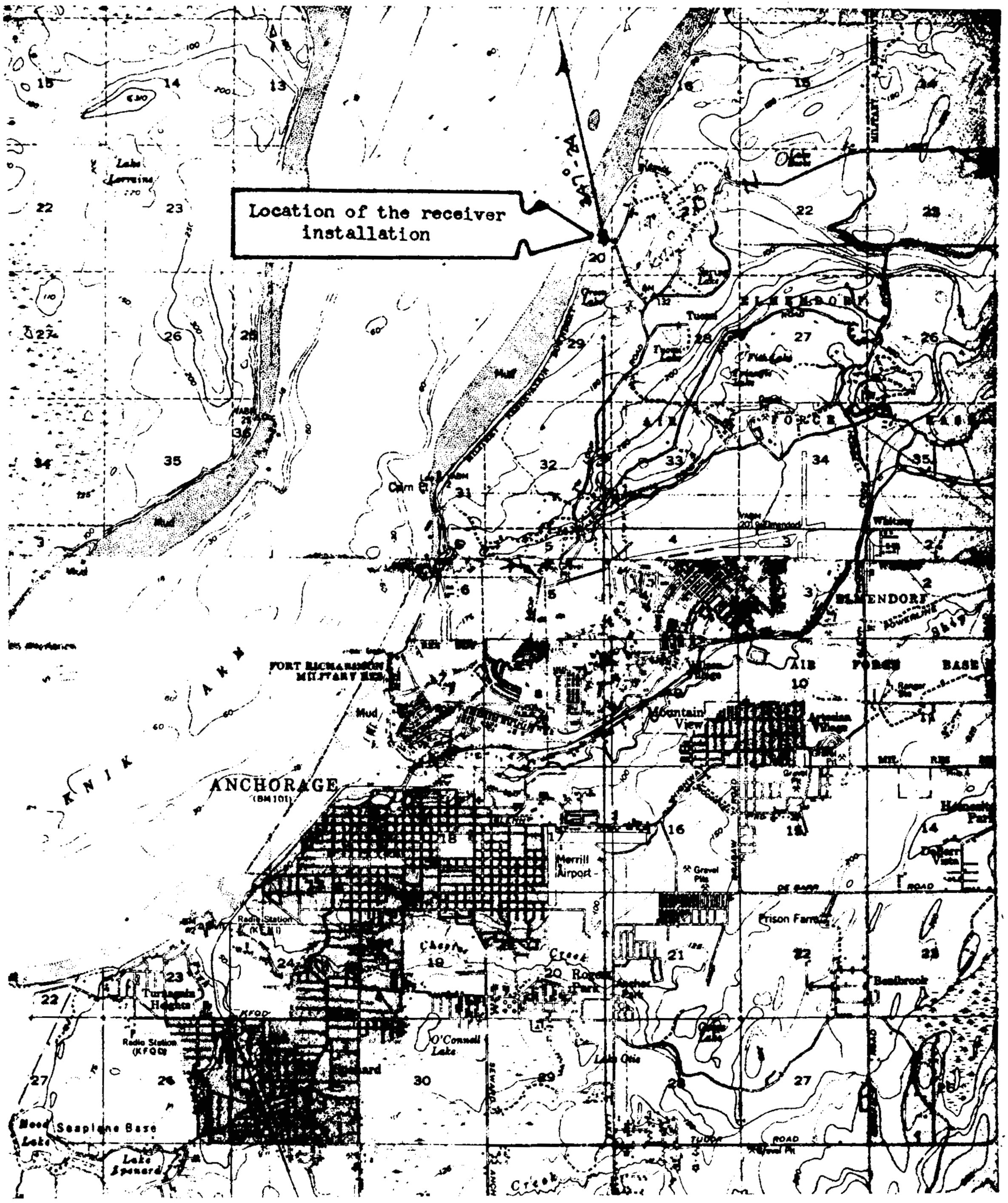


Figure 6. Topographic map of Anchorage area showing location of receiver installation

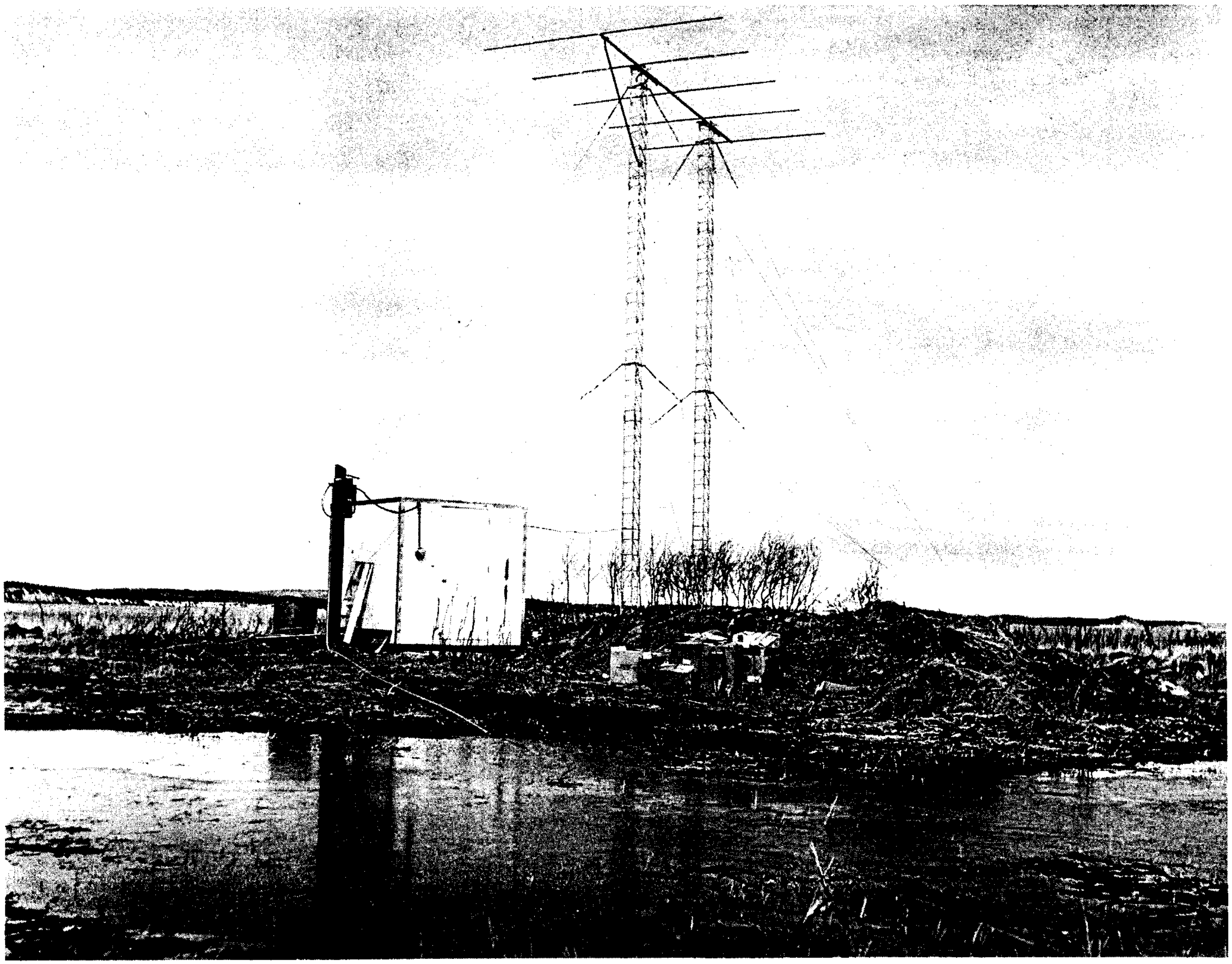


Figure 7. Photograph of the receiver facility at Anchorage, Alaska

B- 52013

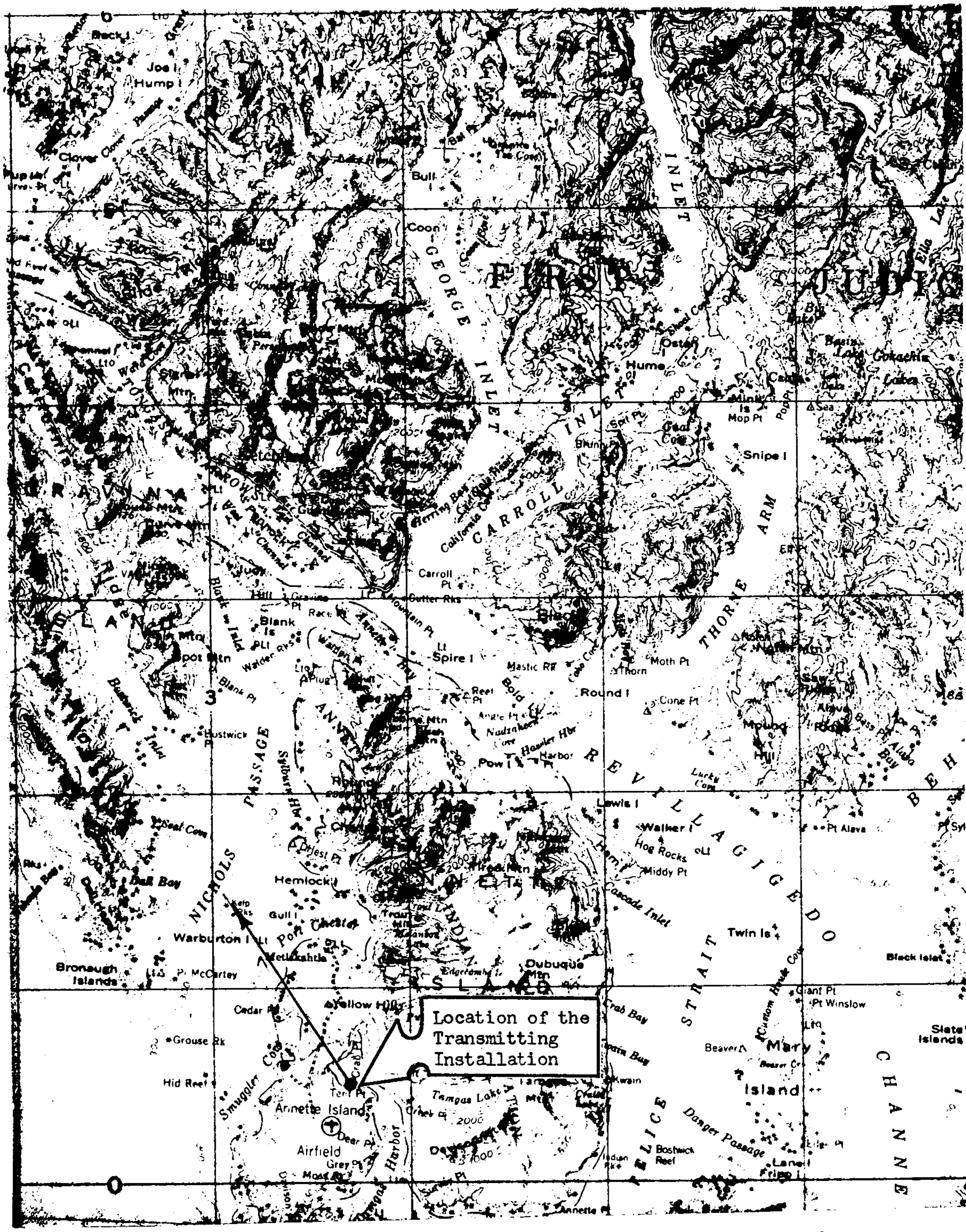


Figure 8. Topographic map of Annette Island showing location of transmitter facility

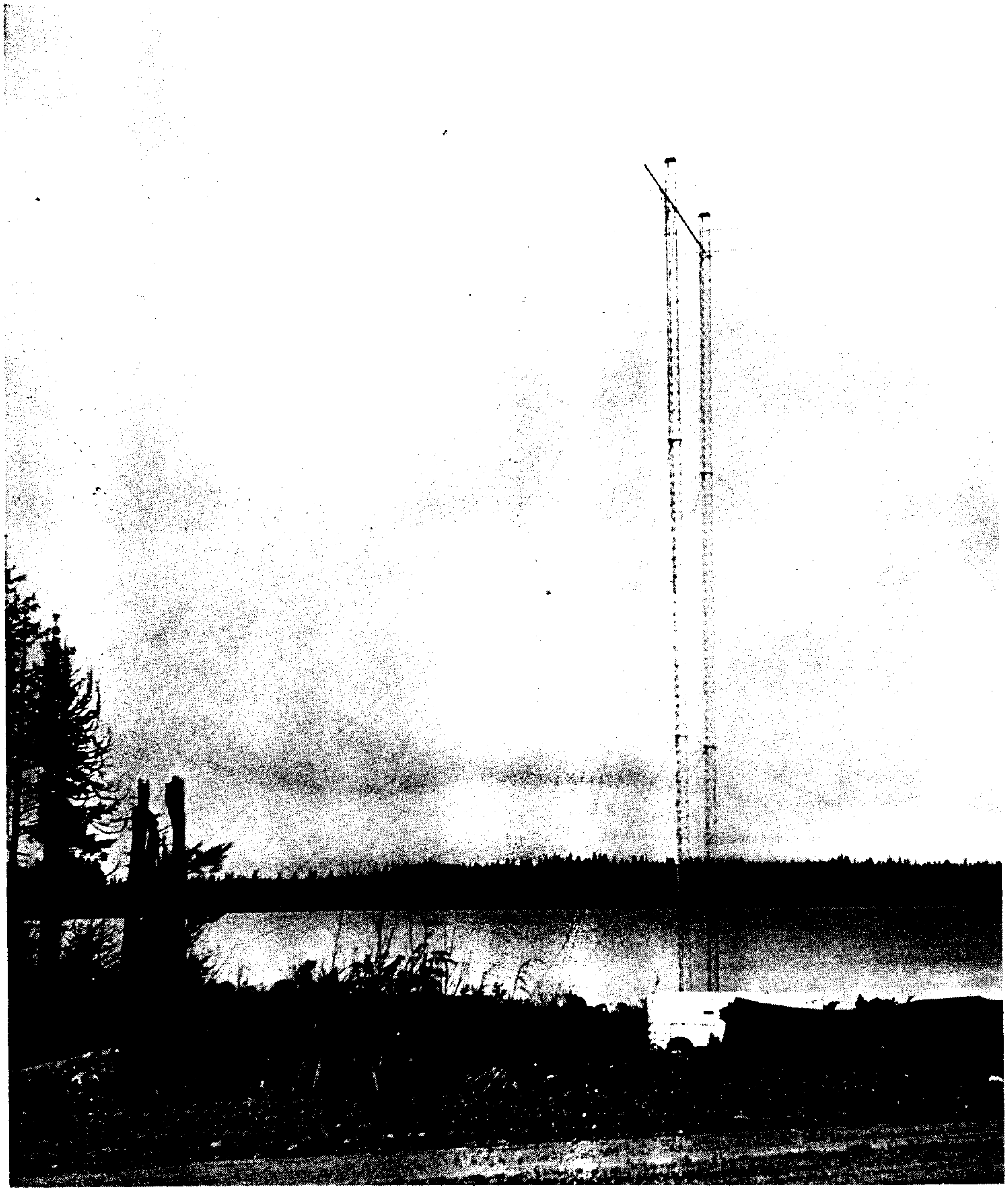


Figure 9. Photograph of the transmitter installation at Annette Island, Alaska

Figure 10. View of the receiver site near Fairbanks, Alaska

B- 52014

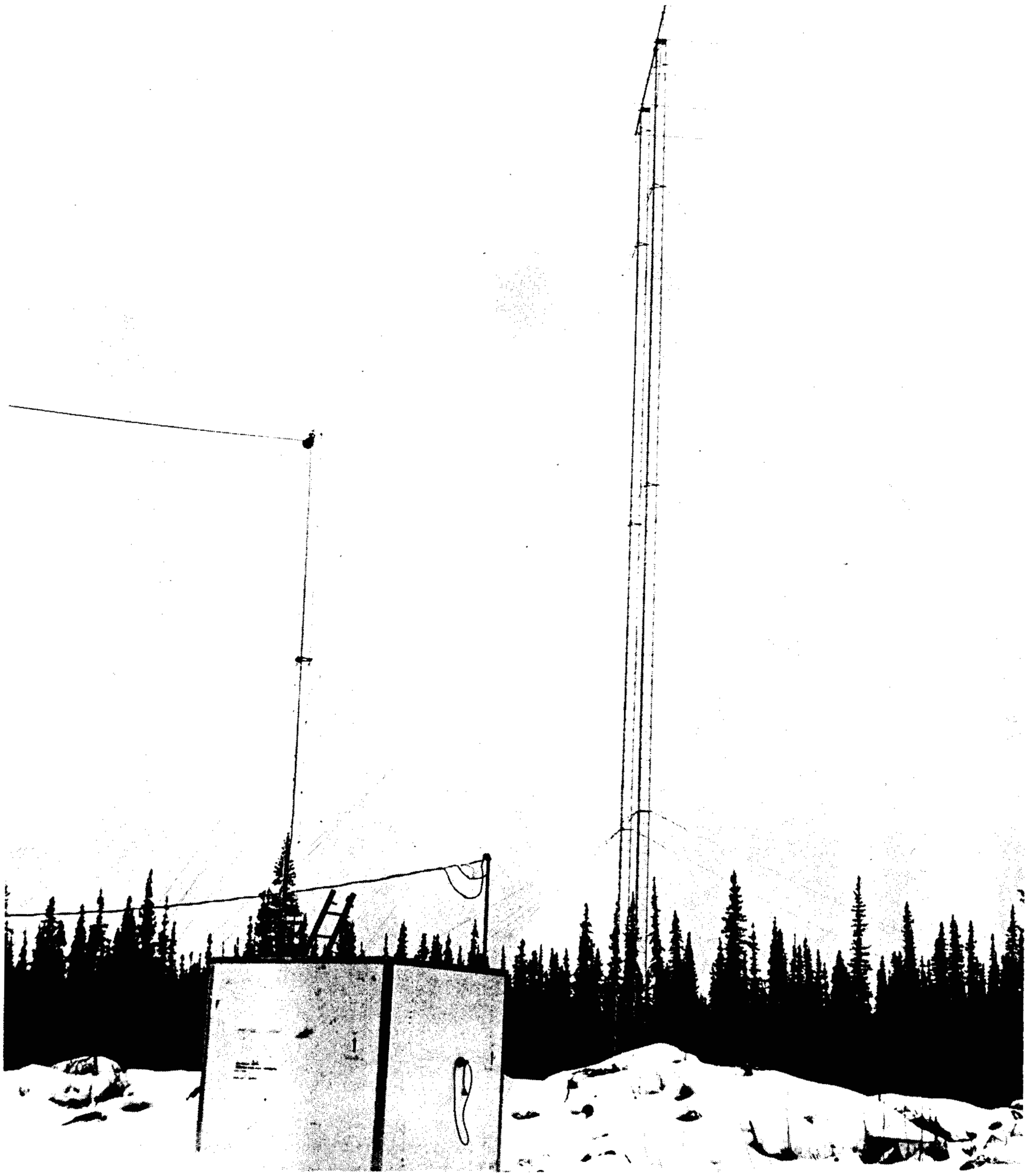


Figure 11. Photograph of the receiver facility near Fairbanks, Alaska

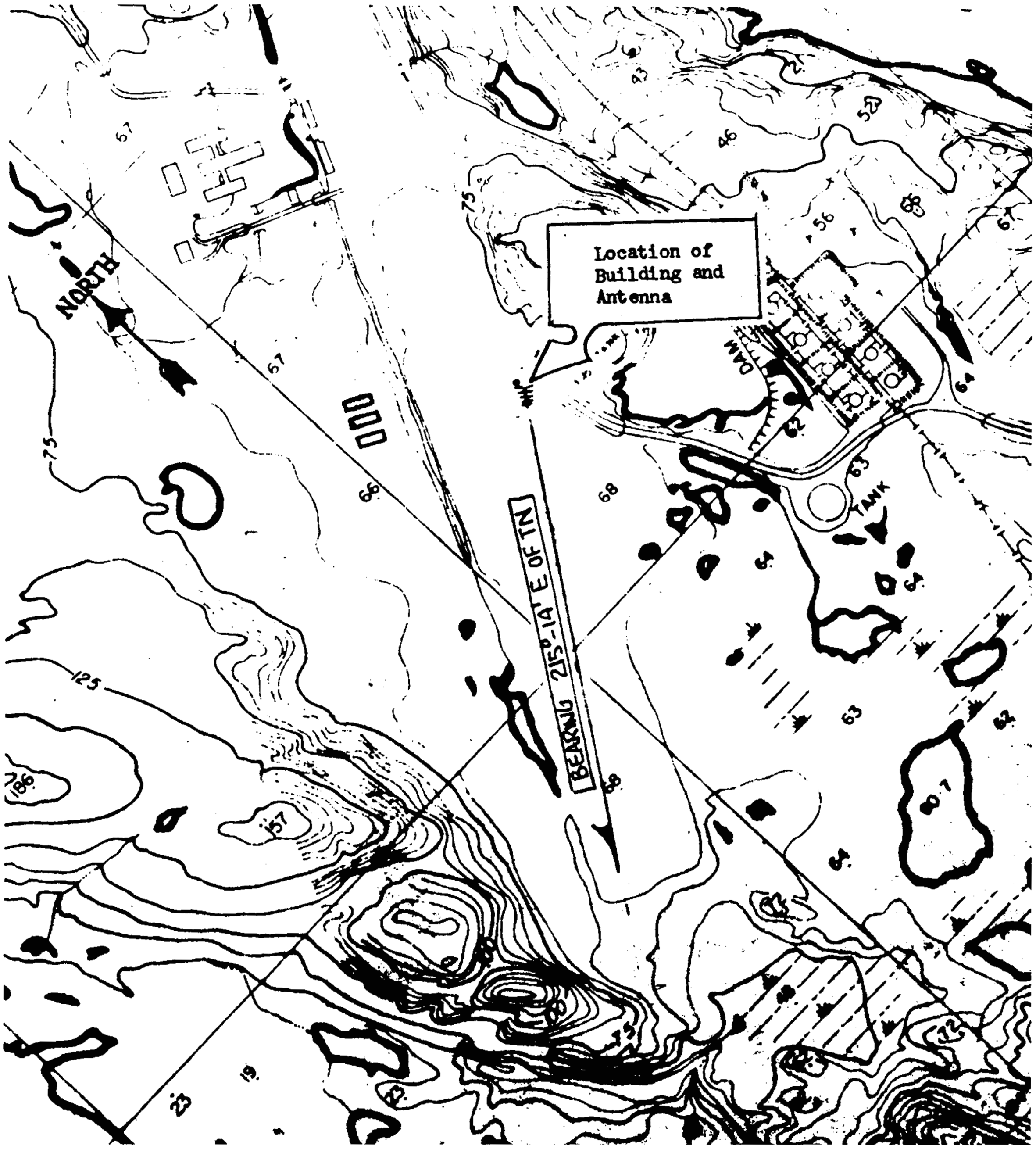


Figure 12. Topographic map of the West 40 site showing location of the transmitter facility at Frobisher Bay, Canada

B- 52028

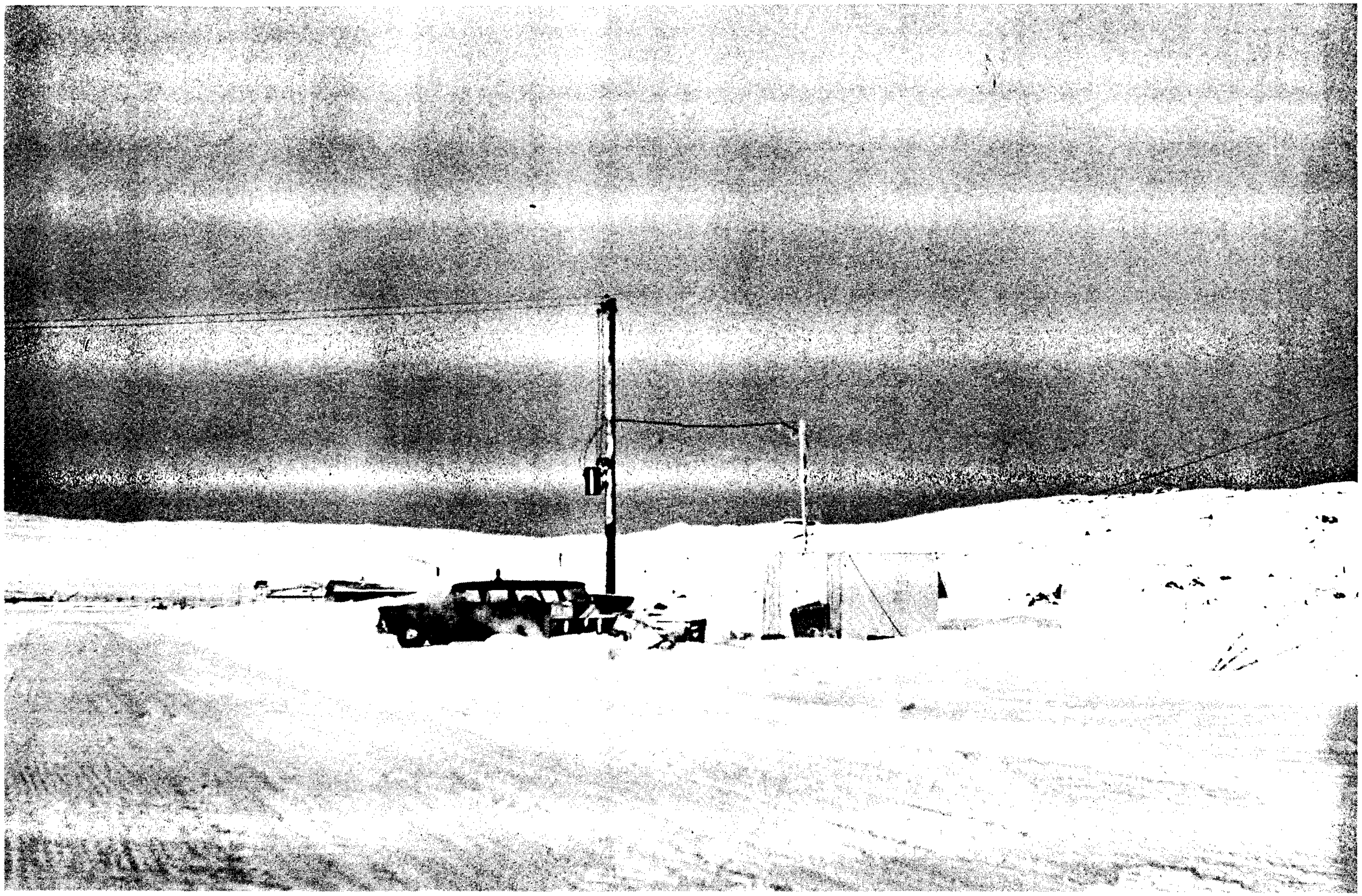


Figure 13. Photograph of the transmitter building at Frobisher Bay, Canada

B- 52015

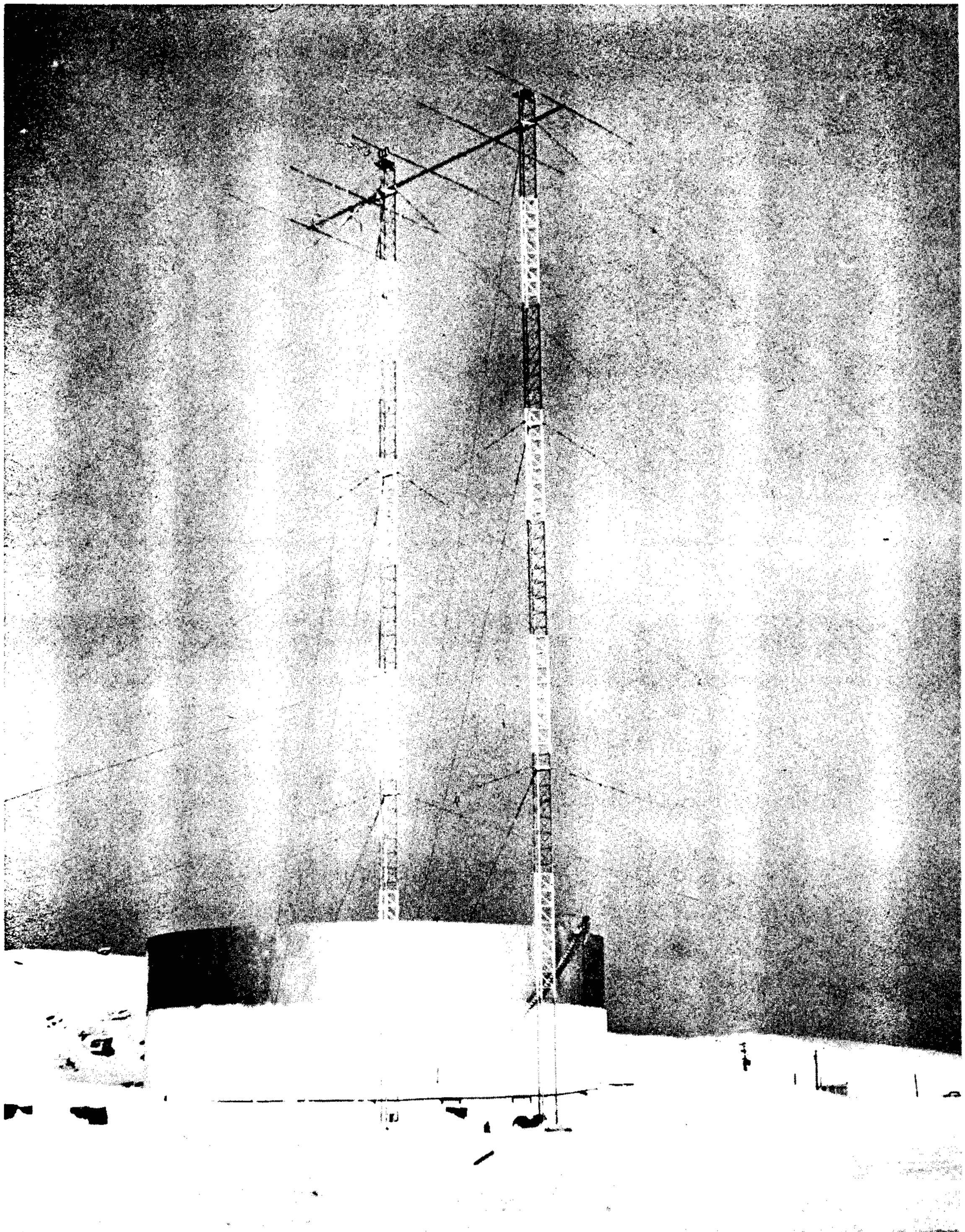


Figure 14. Photograph of the antenna installation at Frobisher Bay, Canada

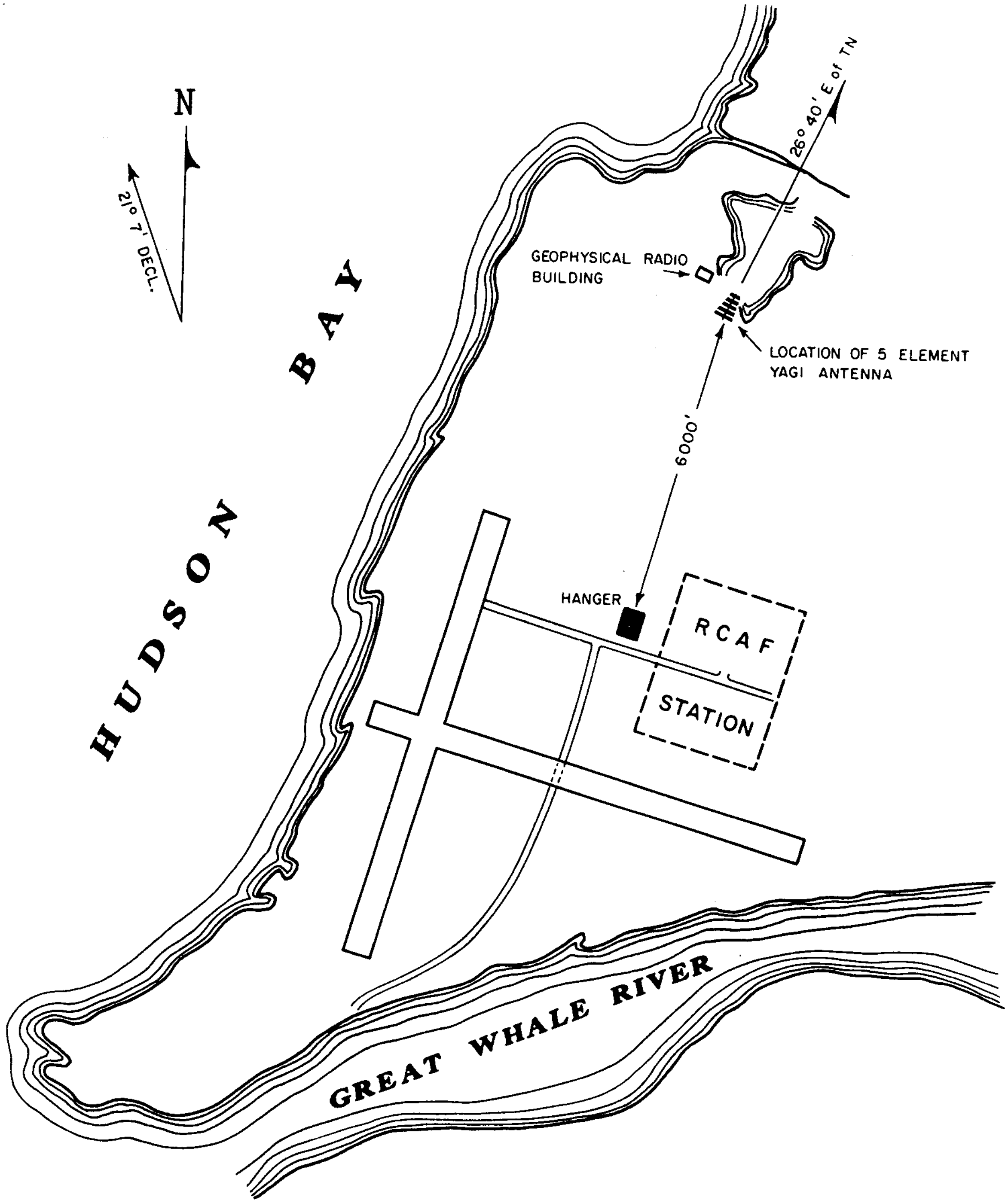


Figure 15. Map of the Great Whale River area showing location of the receiver site

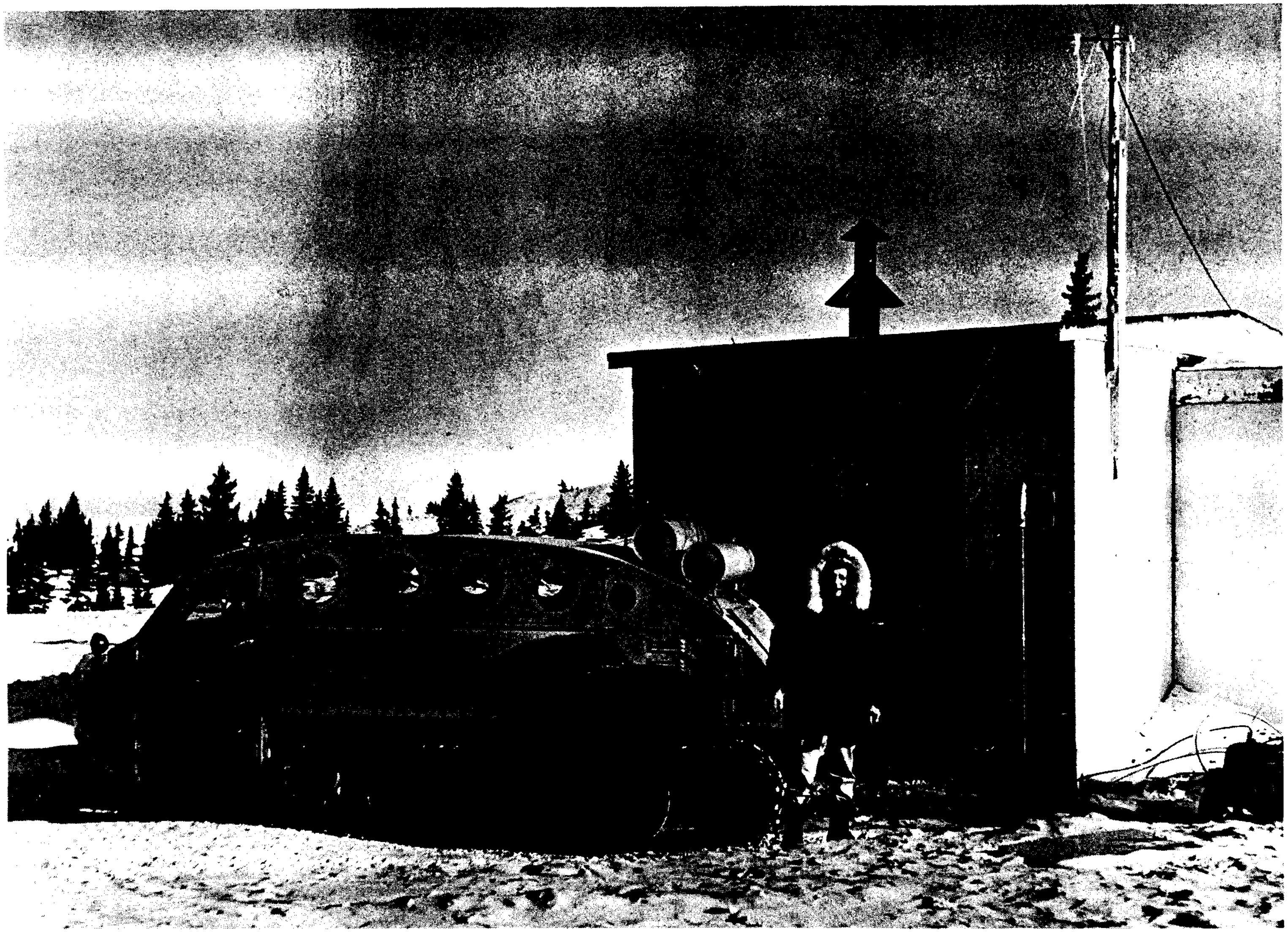


Figure 16. View of the receiver building at Great Whale River, Canada

B- 52016

Figure 17. View of the antenna installation at Great Whale River, Canada

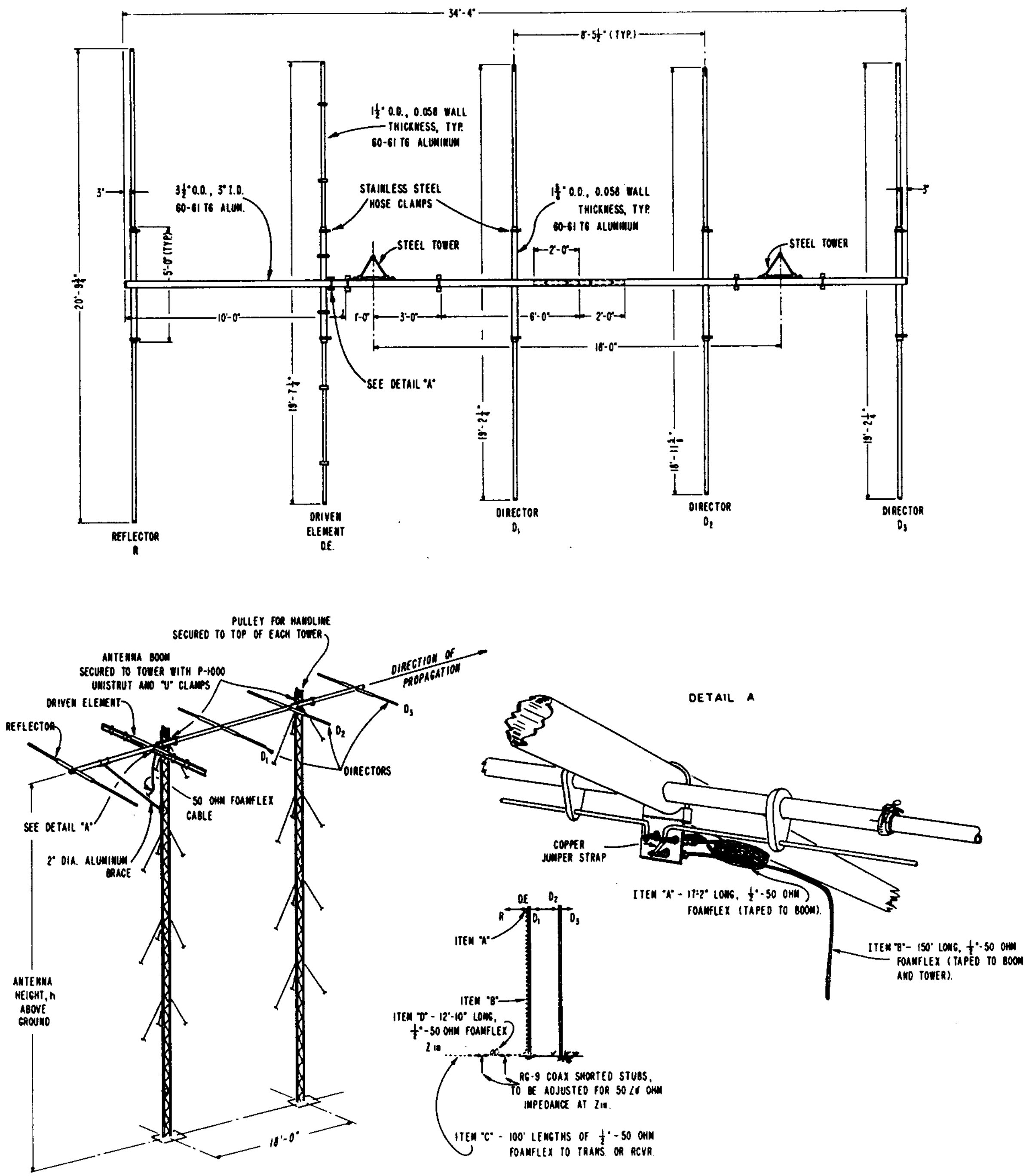


Figure 18. The 23 Mc/s five-element Yagi antenna design showing dimensions, mounting, and connection details

B- 46028

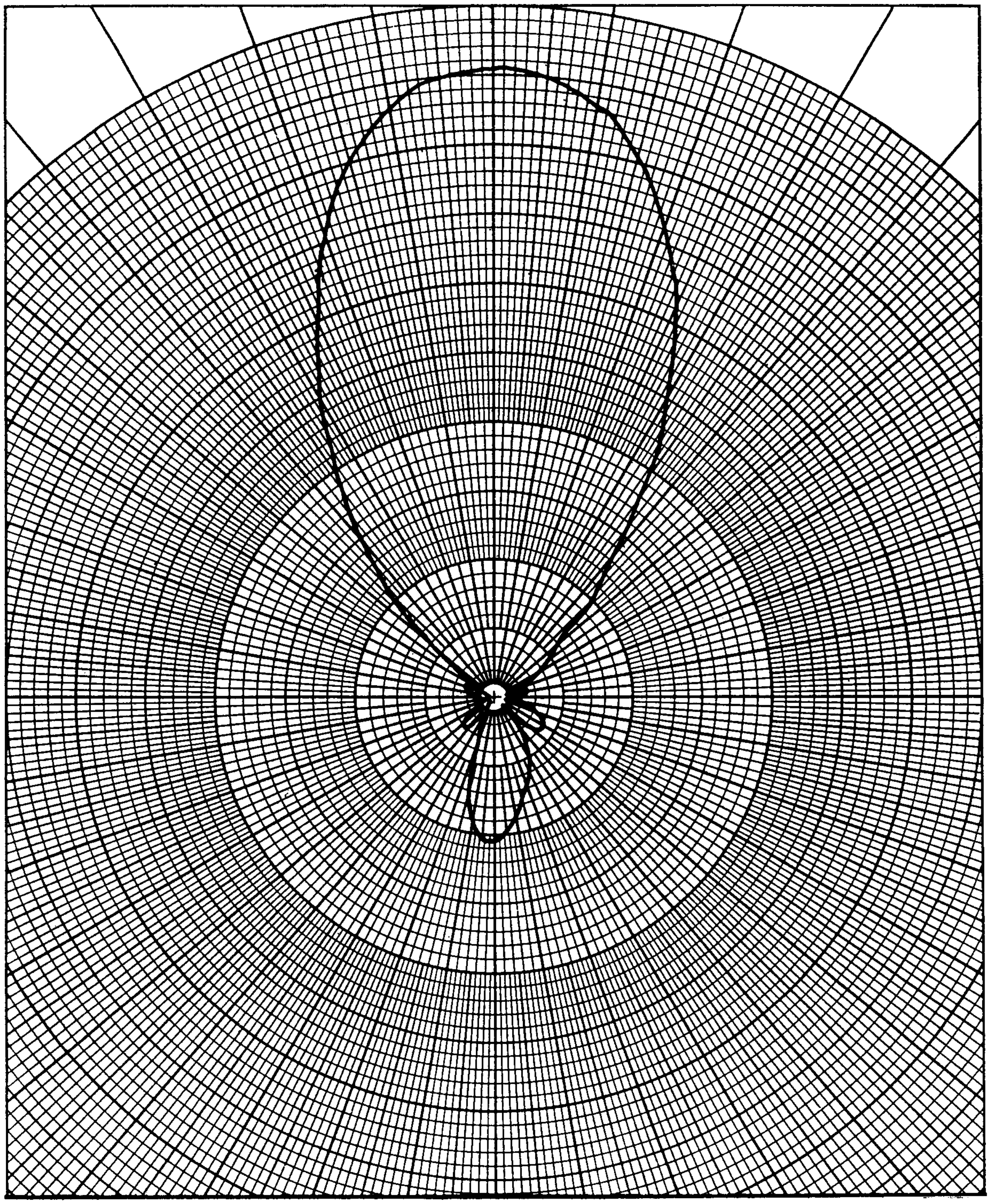


Figure 19. Radiation pattern in the E-plane of the five-element 0.8 wavelength long Yagi antenna (Deflection proportional to voltage)

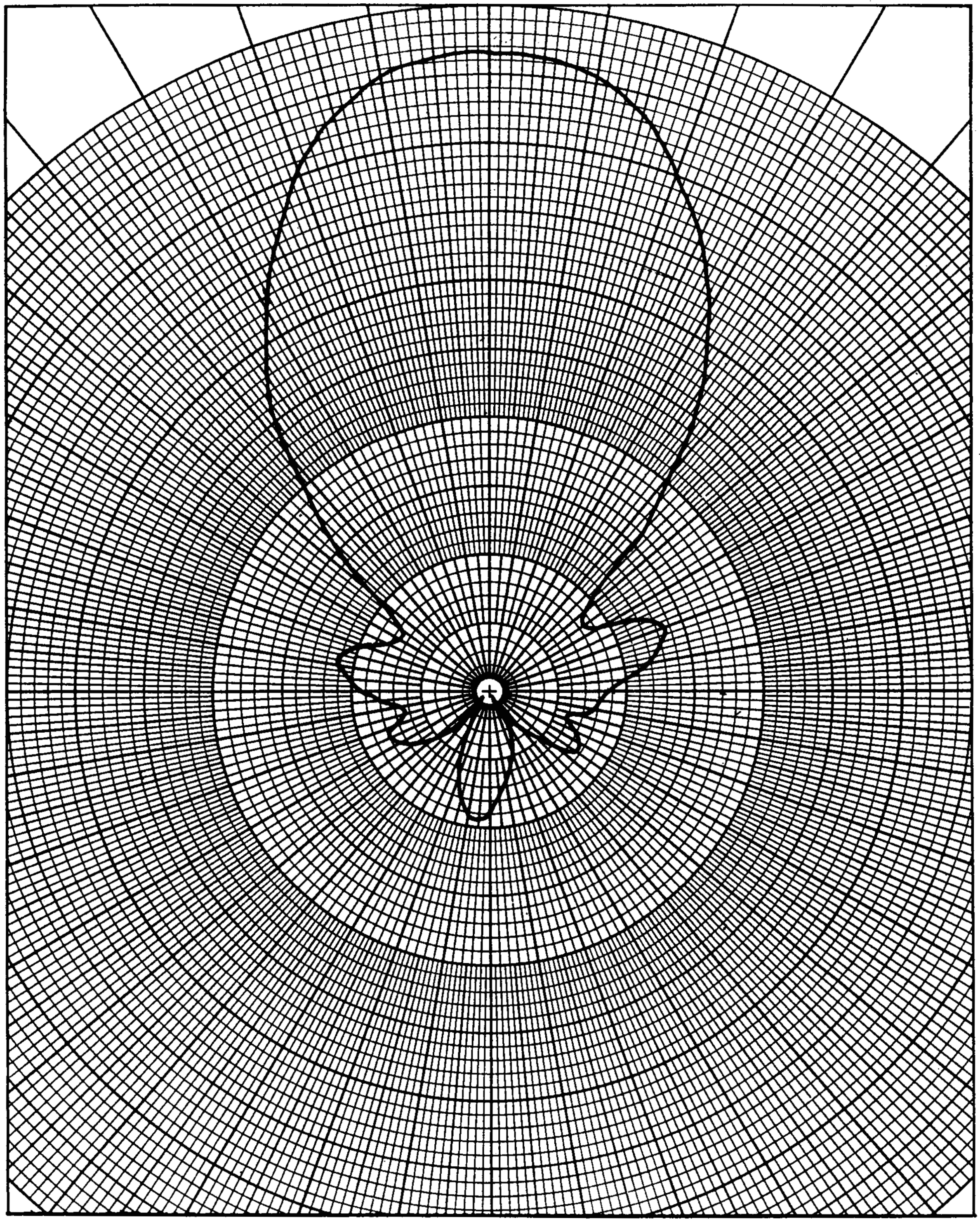


Figure 20. Radiation pattern in the H-plane of the five-element 0.8 wavelength long Yagi antenna
(Deflection proportional to voltage)

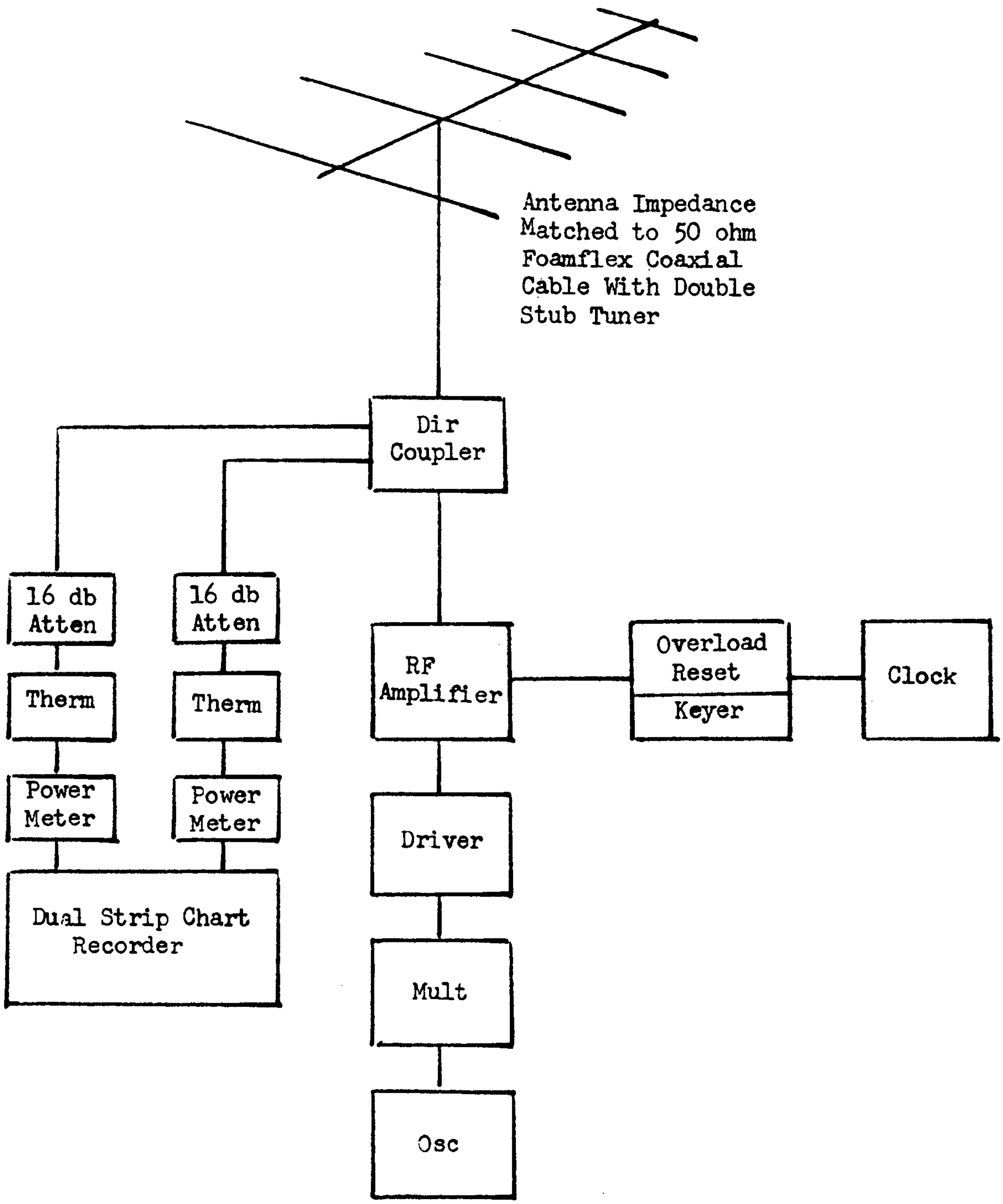


Figure 21. Block diagram of the transmitting system

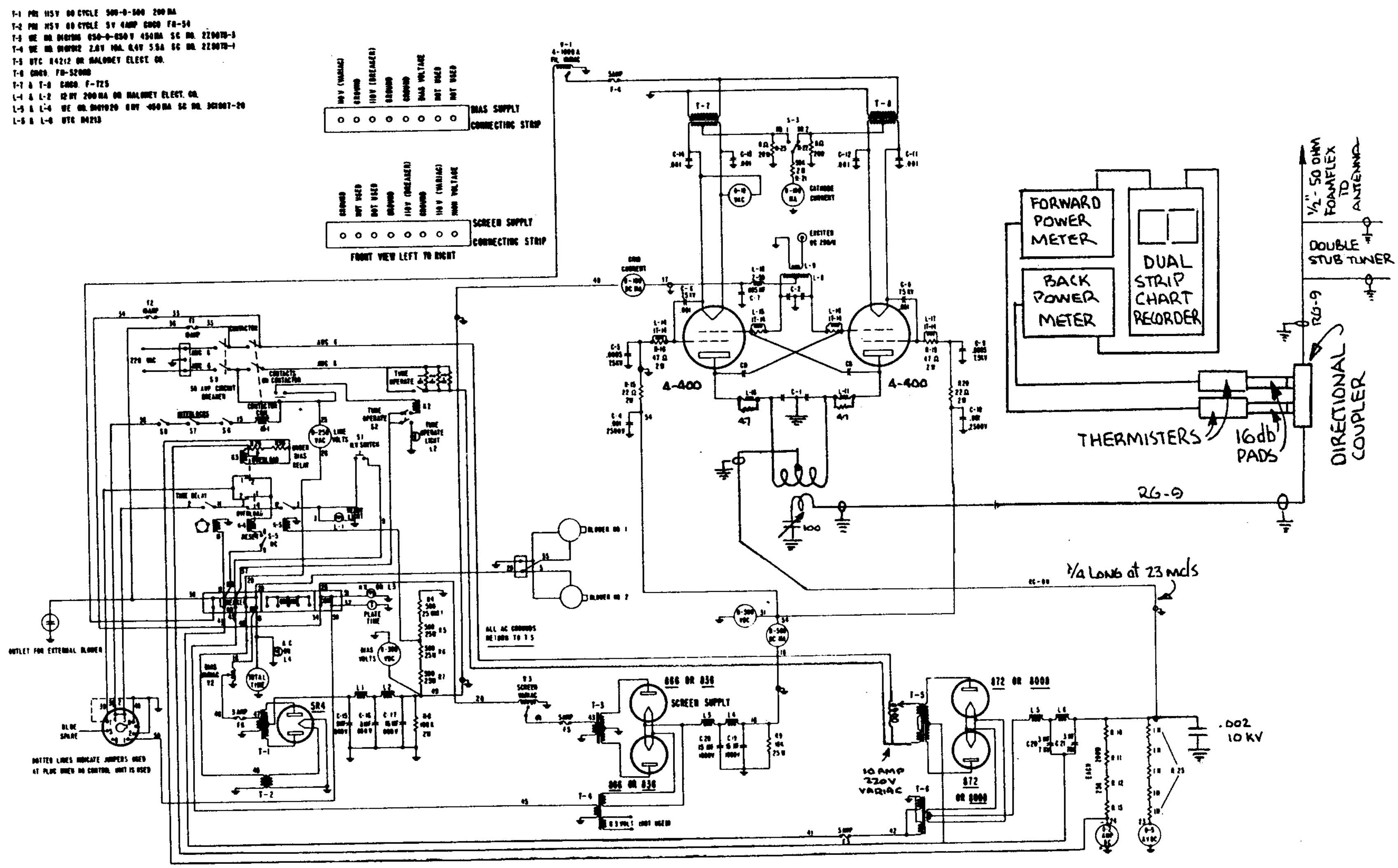


Figure 22. Diagram of the power amplifier - including power supplies and protective devices

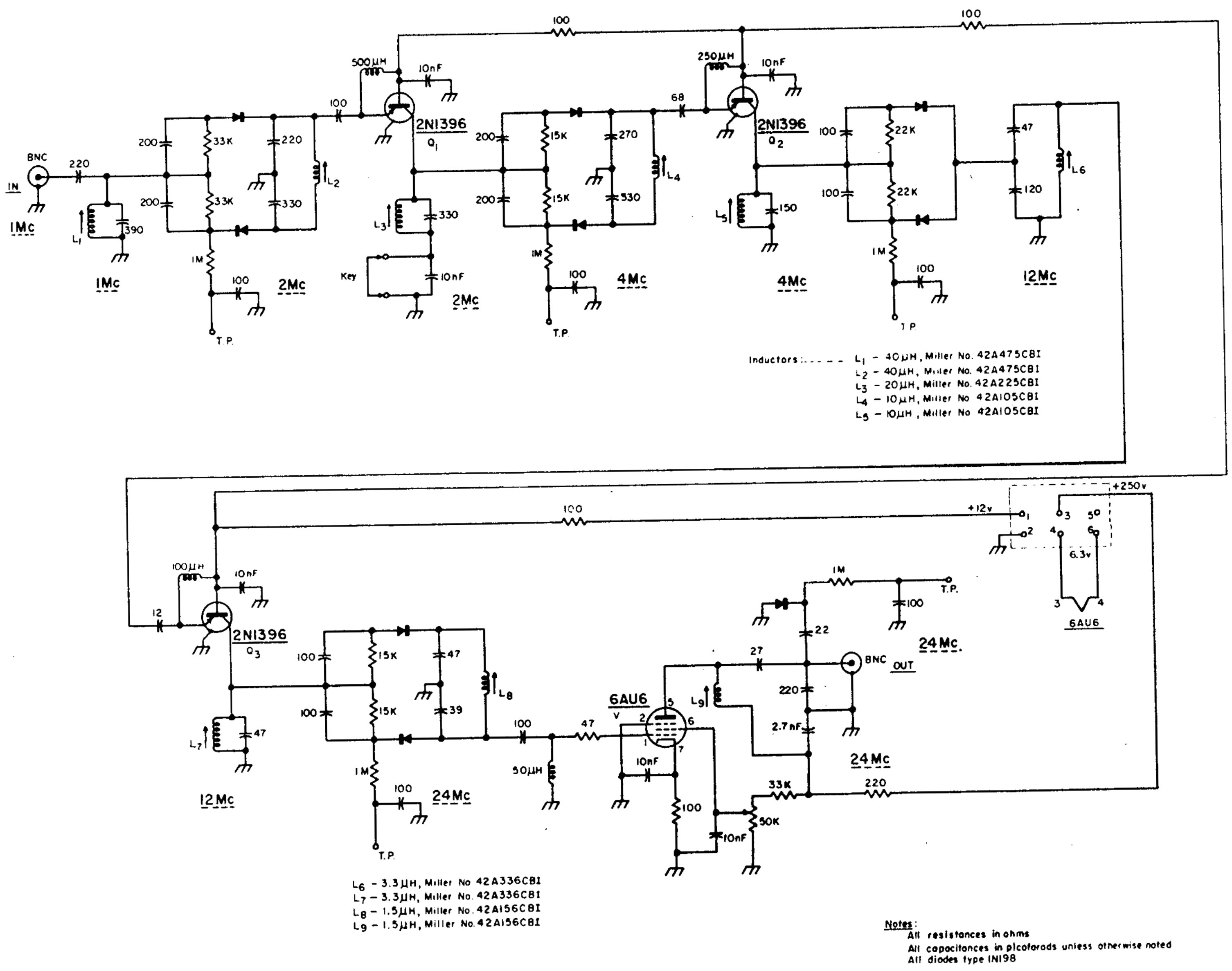
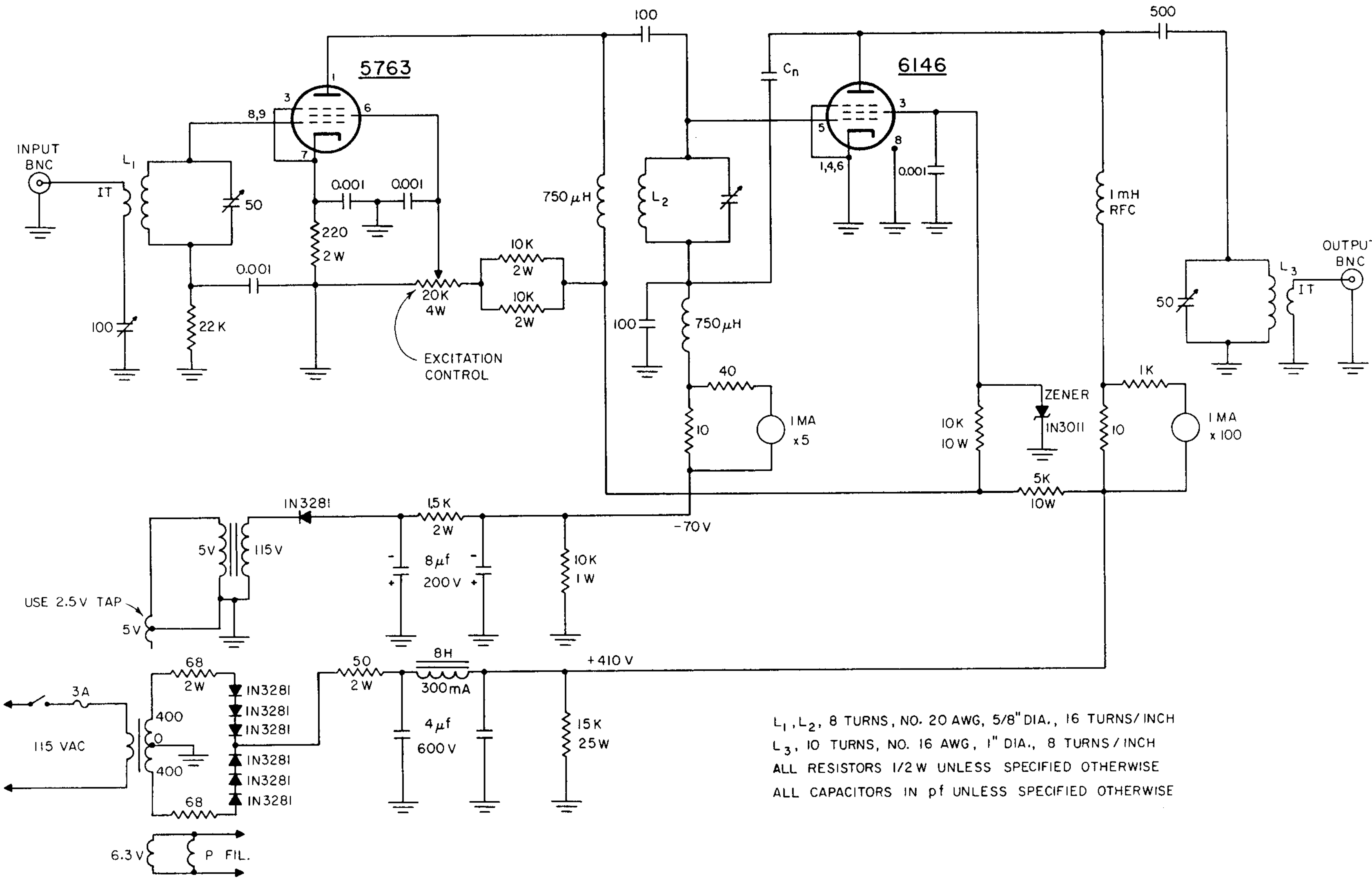


Figure 23. Frequency multiplier schematic diagram



L1, L2, 8 TURNS, NO. 20 AWG, 5/8" DIA., 16 TURNS/INCH
L3, 10 TURNS, NO. 16 AWG, 1" DIA., 8 TURNS/INCH
ALL RESISTORS 1/2 W UNLESS SPECIFIED OTHERWISE
ALL CAPACITORS IN pf UNLESS SPECIFIED OTHERWISE

Figure 24. Schematic diagram of the driver amplifier and power supply

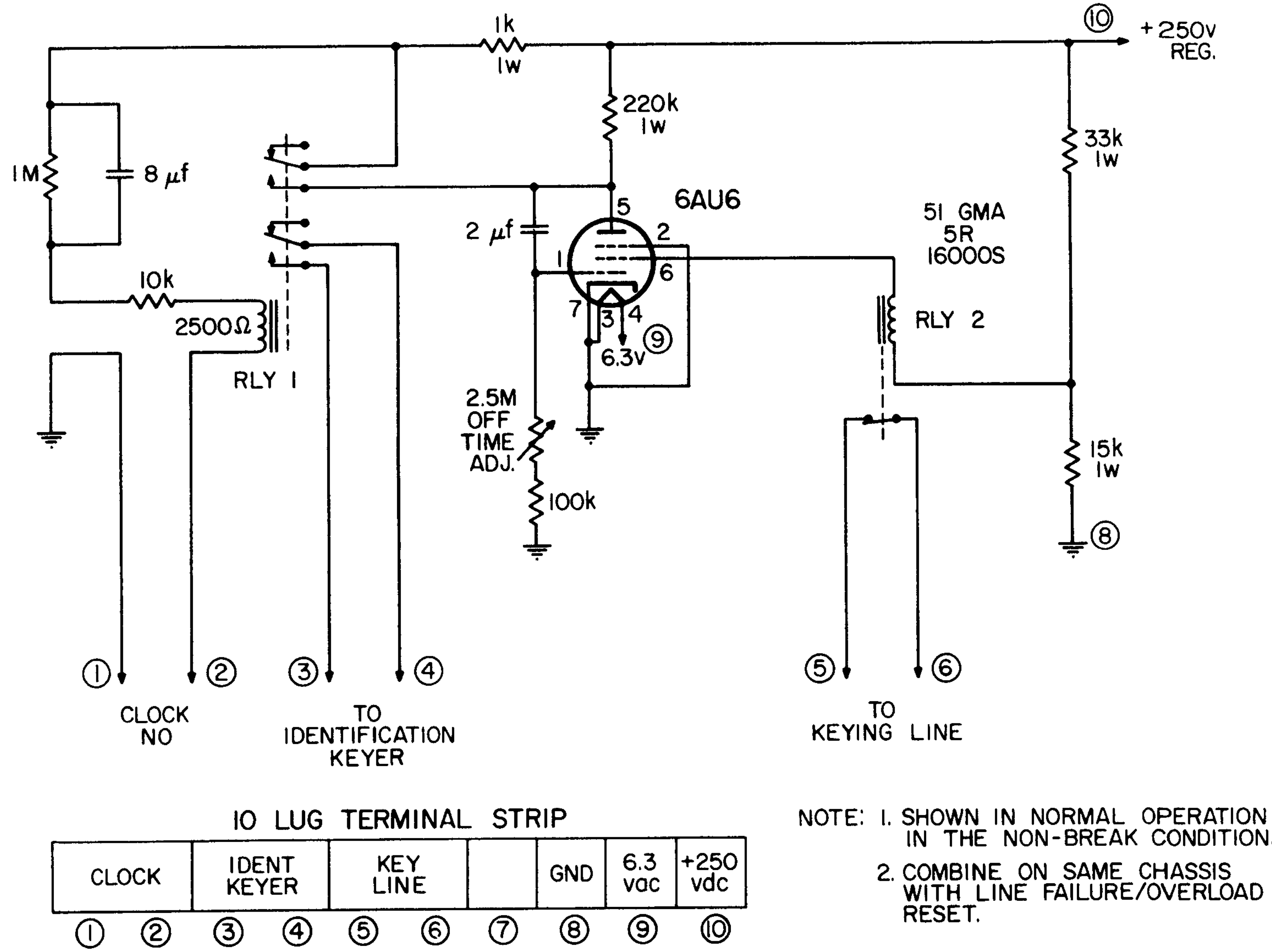


Figure 25. Wiring diagram of the break keyer

B- 42259

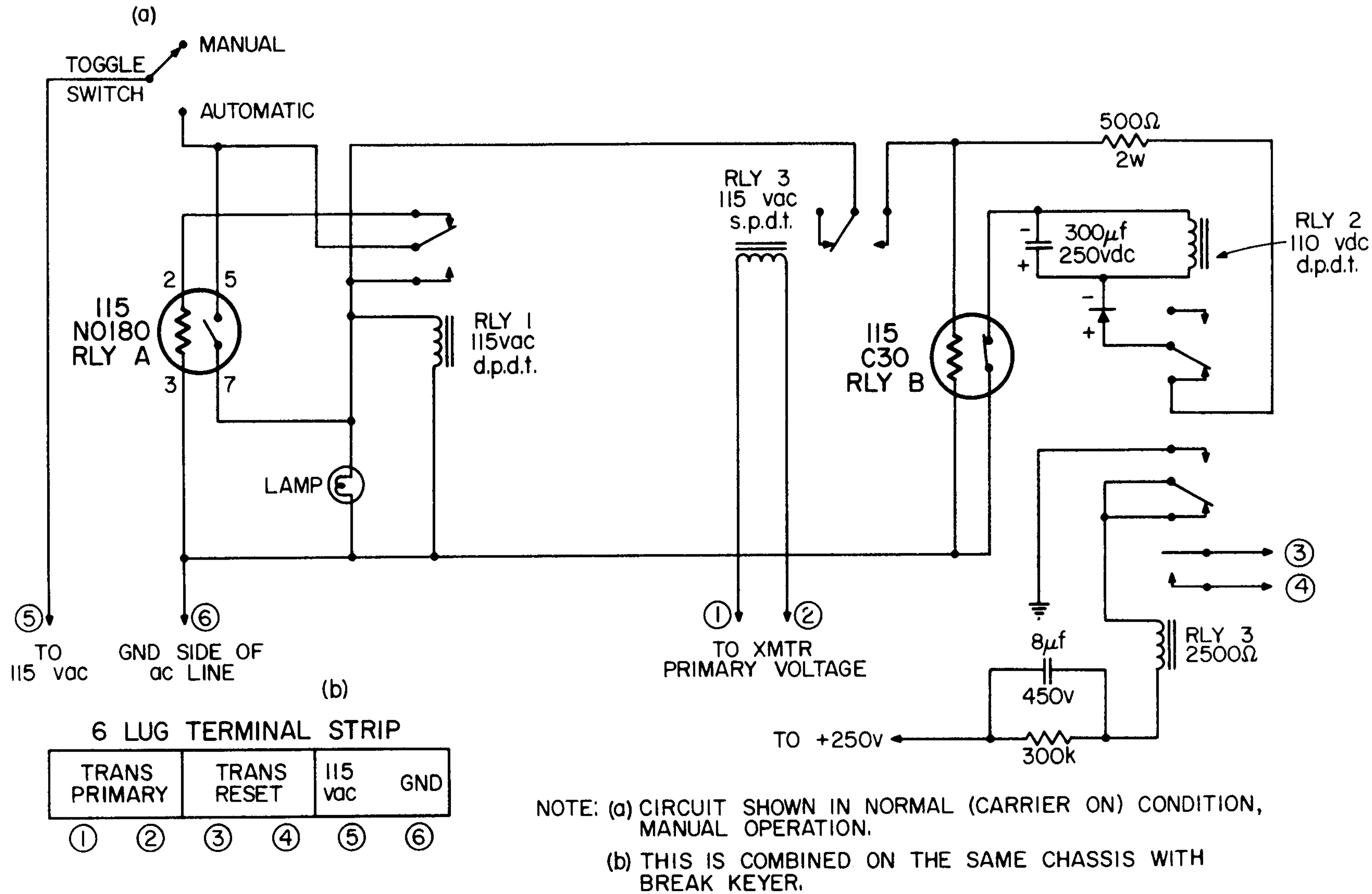


Figure 26. Schematic diagram of the line failure/overload reset

B- 42260

Figure 27. View of the power amplifier and associated control equipment

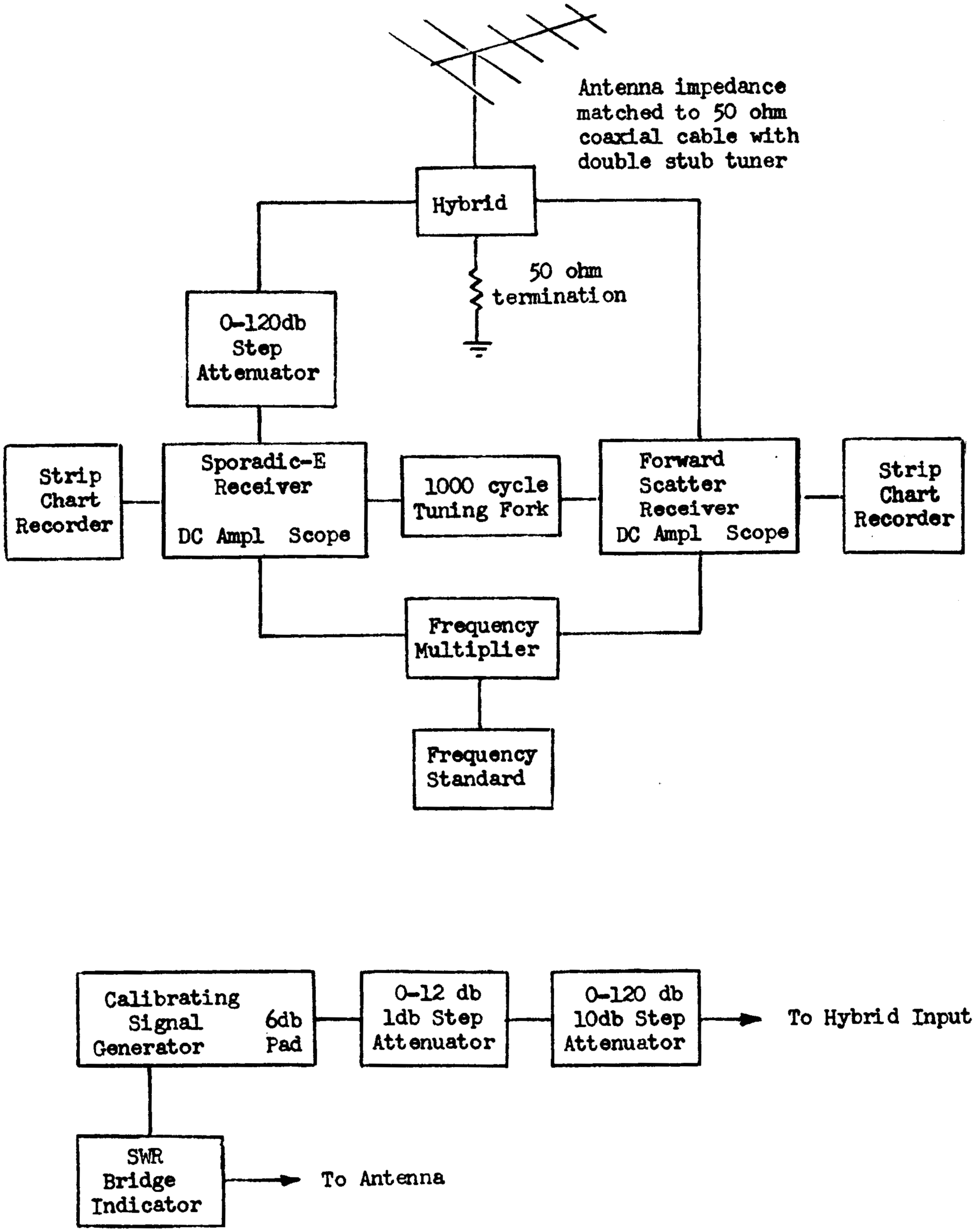


Figure 28. Block diagram of the receiving system

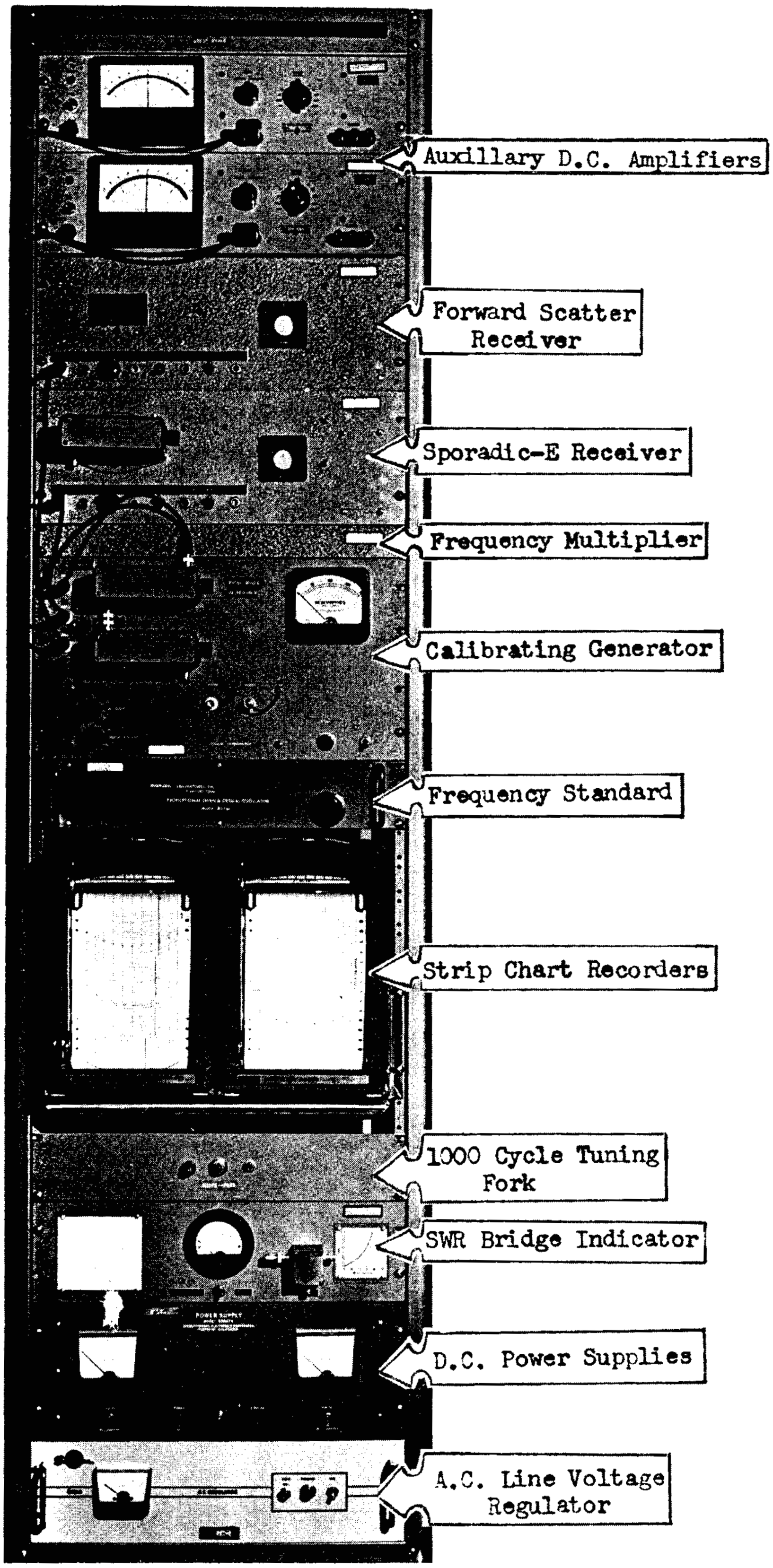


Figure 29. Photograph of the receiving equipment

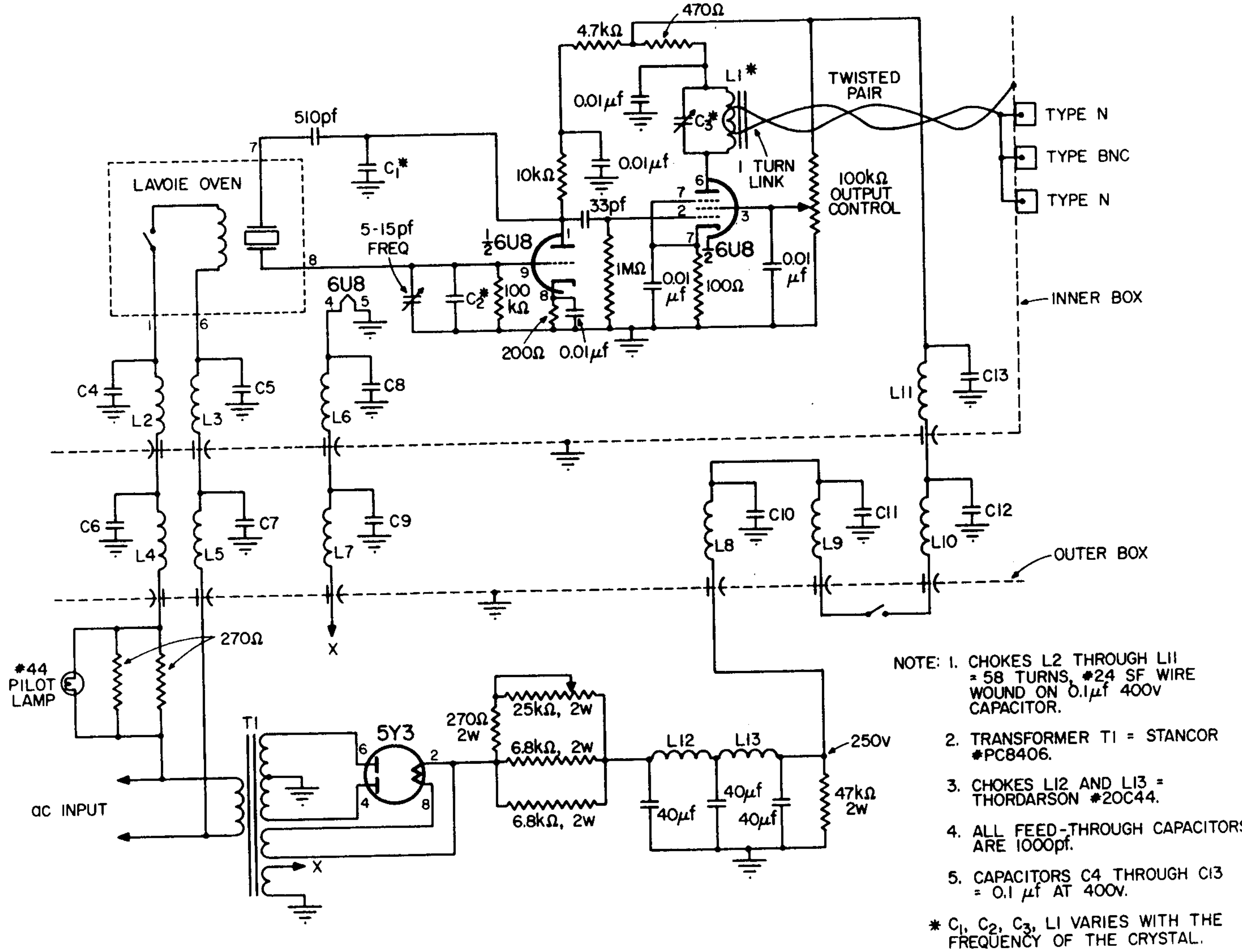


Figure 30. Crystal controlled signal generator schematic diagram

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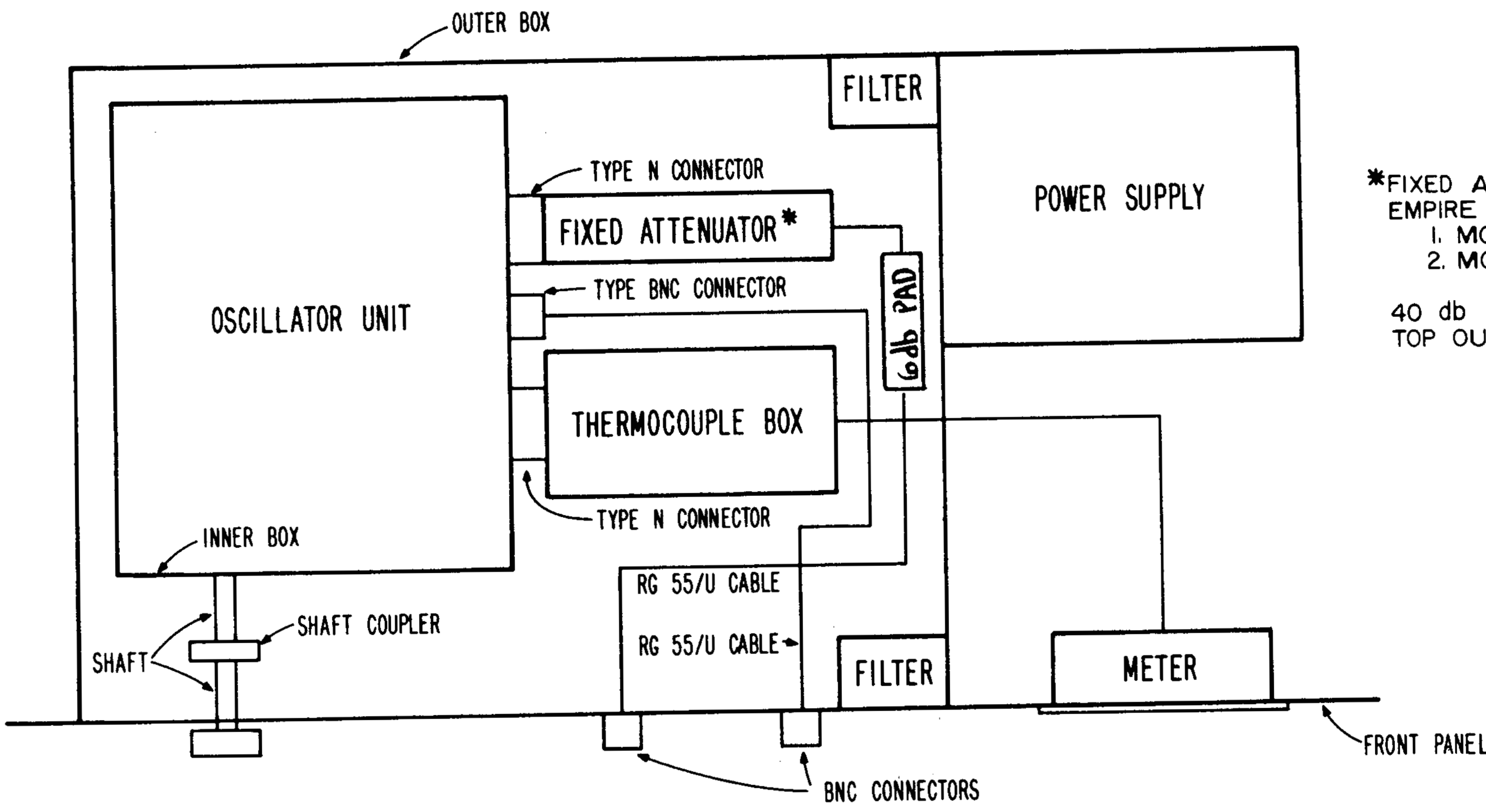


*FIXED ATTENUATORS BY EMPIRE DEVICES, INC.
1. MODEL AT-50, 60 db
2. MODEL AT-50, 40 db

40 db PAD FASTENED TO TOP OUTSIDE COVER.

TOP VIEW

Figure 31. Top view of signal generator showing location of component parts

B- 42263

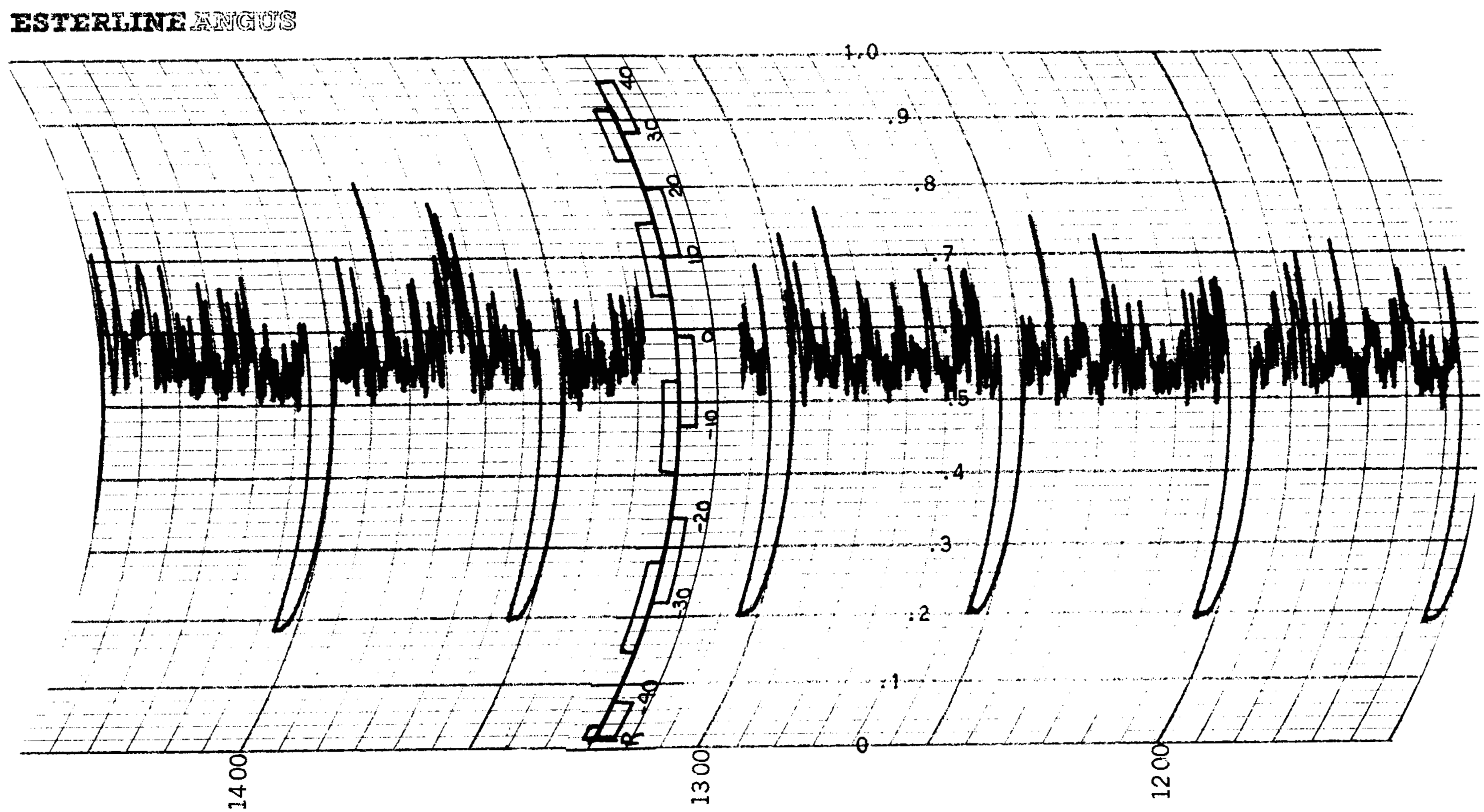


Figure 32. Sample strip chart calibration

B- 52027

Appendix

Narrow-Band Heterodyne Recording Receiver Instructions

G. Franklin Montgomery

1. Summary

The receiver, represented in figures A-1 through A-8, is designed to record the amplitude of a continuous wave 24 Mc/s radio signal.* The 50 ohm antenna feeds a 12AU7 cascode amplifier at 24 Mc/s. The input coil is L2, the cathode coil is L3, and the cascode plate coil is L4. Coil L1 is a shunt antenna trap, to be used only for rejecting a local transmission. When not used, its slug should be backed all the way out (counterclockwise).

The 12AU7 cascode stage feeds a 6BJ6 pentode at 24 Mc/s. Its plate coil is L5, which is also loosely coupled to L6. L5 and L6 feed a pair of diode balanced mixers. The 12 Mc/s local-oscillator voltage for these mixers is generated by the frequency multiplier on a separate 1 3/4-inch panel.

The RF circuits L2 through L5 should be peaked on a high-side 24 Mc/s signal. L6 and the IMAGE NULL potentiometer are then simultaneously (two hands) adjusted to null a low-side 24 Mc/s signal.

The diode mixers feed audio phase-shift circuits and transistor amplifiers that combine the mixer outputs and deliver the combination to a BNC output connector at 1 kc. This output then passes a narrow-band filter and is fed to the 1 kc IF amplifier.

The IF amplifier begins with three triode-connected 6BJ6 stages. The first stage is shock mounted. A 12AU7 section is used for audio (headphones, loudspeaker, and monitor oscilloscope input). The other

*The receiver tunes to a fixed frequency in the 23 to 24 Mc/s range.

triode section drives a balanced diode detector, yielding both negative and positive d-c outputs. The negative output is used for AVC. The positive output operates the 12AU7 recording meter amplifier.

In the linear position (up) of the front-panel LINEAR/AVC switch, there is no AVC, and the receiver gain is controlled entirely with the IF GAIN control, which follows the first 6BJ6 IF stage. Maximum full-scale Esterline-Angus (E-A) meter sensitivity is approximately 0.2 microvolt (open-circuit 50 ohms), although this voltage depends considerably on antenna input circuit adjustment, etc.

Several AVC characteristics are available. In the AVC position (down) of the LINEAR/AVC switch, the three 6BJ6 triodes receive negative signal bias. The relative amount of this bias is adjustable with the AVC LEVEL control, permitting expansion of the meter scale. If more compression is wanted, or if strong signals are to be recorded, bias can be applied additionally to the 6BJ6 RF stage through the AVC toggle switch on the RF chassis. All AVC bias is removed when the front-panel LINEAR/AVC switch is in the linear (up) position.

The zero adjustment for the 12AU7 meter amplifier is on the front panel (METER ZERO). A small dither at 60 c/s is introduced to overcome static friction of the E-A pen. The E-A meter terminals on the IF chassis terminal strip are at +100 volts and should be avoided with the power on.

2. Operating Data

Power supply:

30 milliamperes d-c at +100 volts, regulated.

2.1 amperes a-c at 6.3 volts, 60 c/s.

10 watts at 117 volts, 60 c/s.

Antenna impedance: 50 ohms, unbalanced.

Recorder: 1 milliampere, 1400 ohms, Esterline-Angus, Model AW.

Terminals:

Front panel

Antenna (ANT), type BNC coaxial connector.

Headphones (PHONES), standard phone jack.

RF chassis

Antenna (ANT), type BNC coaxial connector.

Local-oscillator input (12 Mc/s IN), type BNC.

Intermediate-frequency output (1 kc OUT), type BNC, connected to input of band-pass filter.

Band-pass filter

Intermediate-frequency input (1 kc IN), type BNC.

Intermediate-frequency output (OUT), type BNC, connected to 1 kc input of IF chassis.

IF chassis

1 kc input, unmarked, type BNC.

AVC line external connection (RF AVC), screw terminal.

1 kc signal for monitor oscilloscope (SCOPE), connected to terminal (V) on oscilloscope amplifier, screw terminal.

Direct-current signal for Esterline-Angus recorder (METER), screw terminals. CAUTION: These terminals are at +100 volts to ground.

1 kc signal for 4 ohm loudspeaker (SPK), screw terminals.

Cathode-follower direct-current signal output (AUX), screw terminals. This output is offset approximately +4 volts to ground. It is provided as an auxiliary signal for a recorder other than the Esterline-Angus.

Oscilloscope amplifier chassis

Vertical deflection (V) and horizontal deflection (H) inputs, screw terminals.

Controls:

Front Panel

AUDIO GAIN controls the 1 kc signal amplitude delivered to the monitor oscilloscope, headphones, or loudspeaker. It has no effect on other receiver adjustments.

AVC LEVEL controls the amplitude of direct voltage used as AVC grid bias for the variable-gain stages. The amplitude of this bias is maximum with the AVC LEVEL control full counterclockwise.

AVC FILTER switches the capacitance in the smoothing or averaging circuit that follows the detector. The time constant of this circuit is 30 seconds* with the switch on (up) and 0.30 seconds with the switch off (down).

METER ZERO adjusts the zero-signal or rest position of the recorder pen.

LINEAR/AVC switches the receiver from linear recording to approximately logarithmic recording. LINEAR is up.

IF GAIN controls the gain of the IF chassis beyond the first stage. Full gain is full clockwise.

RF chassis

AVC switches the grid bias of the 6BJ6 amplifier (V2) from fixed to AVC bias. Bias is applied when the switch is on (up).

IMAGE NULL is an alinement adjustment made in conjunction with L6. See RF chassis circuit description.

*The time constant of this circuit was changed to 15 seconds.

Tube and transistor complement:

4 ea. 6BJ6

5 ea. 12AU7

3 ea. 2N414 (Satisfactory substitutes: 2N404, 2N1305)

3 ea. 2N1396

1 ea. 1EP1 (cathode-ray tube)

3. General Description

The receiver described here is designed to record the amplitude of a fading, continuous wave, 24 Mc/s radio signal. The receiver bandwidth is approximately 25 c/s. A radio-frequency (RF) signal supplied to the receiver is amplified, converted to intermediate frequency (IF), filtered, rectified, time-averaged, and used finally to deflect the pen of a strip chart recorder. The pen deflection can be chosen optionally to be either (a) linearly proportional to an average of signal amplitude or (b) approximately proportional to the logarithm of an average of signal amplitude.

An essentially similar receiver was developed previously at the National Bureau of Standards for use at 50 Mc/s and 36 Mc/s. In designing the present receiver, the objective was to improve both the electrical design and the mechanical construction of the original set. The prior receiver (not including its local oscillator) required a local-oscillator voltage of exceptional spectral purity, used thirteen vacuum tubes of three types, and was annoyingly microphonic. In comparison, the present set requires no special purity of its local-oscillator voltage, uses three transistors and seven vacuum tubes of two types, and is much less microphonic. It occupies less volume than the all-vacuum-tube receiver and is mechanically sturdier. A separate frequency multiplier is included to provide the local-oscillator voltage from a stable source at approximately 1 Mc/s. It uses three transistors and obtains its power from the receiver chassis.

4. Theory of Operation

The antenna signal is first amplified at radio frequency (see block diagram). It is then modified in phase by a pair of tuned circuits whose output voltages differ by 90 degrees. Each of these outputs is separately converted to intermediate frequency (1 kc) in a balanced mixer, with both mixers using the same local-oscillator voltage. The two 1-kc signals are modified by a pair of resistance-capacitance phasing networks and are then added in a common amplifier.

The purpose of the twin frequency conversions, in combination with the RF and IF phase shifts, is to eliminate the receiver image response that lies 2 kc from the signal frequency in the direction of the 24 Mc/s harmonic of the local-oscillator frequency. The sense of the net phase difference produced by the RF and IF networks determines whether the signal will be accepted above or below the local-oscillator harmonic frequency. Reversing the sense of the phase change produced by either pair of networks reverses this relationship.

The combined IF signal is filtered by a band-pass filter whose response is centered at 1 kc. It is this filter that chiefly determines the receiver's selectivity and bandwidth.

Following the filter is a relatively unselective resistance-coupled amplifier. Its first three stages use remote-cutoff vacuum tubes. Their output is approximately proportional to the logarithm of signal amplitude when automatic-volume-control (AVC) grid bias is used. The output voltage of the amplifier is rectified and filtered. It is then used as AVC bias and as the input to a direct-coupled amplifier that deflects the recording milliammeter.

A separate monitor amplifier, using the 1-kc signal as its input, provides inputs for a monitor oscilloscope and for headphones.

5. Circuit Description

Radio-frequency chassis

The two sections of a 12AU7 are connected as a cascode amplifier (VI). A 12AU7 has only moderate transconductance, but it has a relatively long grid base or bias range. Both sections are operated at a grid bias of approximately 2.5 volts, and this relatively large bias should be helpful in preserving immunity to overload or desensitization from strong adjacent-frequency signals.

The required source (antenna) impedance is 50 ohms, one terminal grounded. The input inductor L2 and the adjustable 7-45 pF coupling capacitor are tuned for minimum noise figure, an adjustment that is made most conveniently using a thermionic diode noise source.

Inductor L1 and its 7-45 pF series capacitor comprise a shunt trap for rejecting interference at one frequency. Since both the series capacitor and the inductor are adjustable, it is possible to set the rejection frequency within a wide range above and below 24 Mc/s. If the rejection frequency is close to 24 Mc/s, then the trap setting and the settings of L2 and its coupling capacitor will interact. Careful adjustments are required in this circumstance so that the signal sensitivity will not be degraded. When the trap is not used, its series capacitor should be set near minimum capacitance and L1 should be set near minimum inductance (screwdriver adjustment full counterclockwise). Inductors L3 and L4 are both tuned to signal frequency. The tuning of L3 will appear to be relatively broad.

The gimmick capacitor is intended to neutralize the internal capacitance from plate 6 to grid 2. Its adjustment (by bending the wire fed through the partition astride the 12AU7 socket) is not especially critical. Maladjustment is indicated by RF oscillation or by very sharp tuning of L2 and L4. In this case, the stage will be found to oscillate with the feedthrough wire set either close to or far from the winding of L2. These positional extremes of oscillation should be located by trial, and the wire should then be set halfway between them.

The second section of the 12AU7 is also used as a source of direct current for the receiver's transistor stages (at +12 volts) and for the transistor stages in the frequency multiplier (at +6 volts) for the local-oscillator voltage. Grid 7 is returned to a voltage divider at approximately +12 volts, and the d-c drop in the cathode network is used as the transistor supply. The plate current for each 12AU7 section is approximately 5 milliamperes.

A 6BJ6 pentode amplifier (V2) follows the cascode. This stage is neutralized by returning its screen grid to a low-potential point of the tuned plate circuit L5. The voltage at this point is determined by the 1.5-nF bypass capacitor and is out of phase with the voltage at the plate. Consequently, the grid-circuit current due to plate voltage acting upon the grid-plate capacitance is neutralized by an opposite current due to screen voltage acting upon the grid-screen capacitance. The choice of screen bypass capacitance is not critical, and this stage is quite stable. The control-grid d-c return connects to a toggle switch so that AVC bias can be applied to this stage when wanted. With the grid return grounded, the cathode current is approximately 7 milliamperes.

Tuned circuit L6 is loosely coupled to L5, and each circuit drives a balanced mixer formed of a pair of point-contact germanium rectifiers. When L6 is tuned properly, its signal voltage leads (by 90 degrees) the signal voltage developed at L5. Both mixers are also driven by a 12 Mc/s local-oscillator input supplied from L7. For an optimal amplitude of this 12 Mc/s voltage, the d-c drop across each rectifier's 4.7K load resistor is approximately 0.5 volt. This voltage drop is not critical, and it is more important that all four drops be equal than it is that they be exactly 0.5 volt.

The outputs of the mixers are at audio frequency (1 kc) and are balanced to ground. Each output is fed to a resistance-capacitance phase shifter, the phase-shifter constants being chosen to produce a differential shift of 90 degrees between the two network outputs at 1 kc. Transistor emitter-follower amplifiers Q1 and Q2 combine the two outputs proportionally in the potentiometer labeled IMAGE NULL, and the combination is amplified by the transistor common-emitter stage Q3.

The transistor stages are direct-coupled, and the collector direct current of the output transistor Q3 remains at approximately 1 milliampere regardless of moderate changes in transistor parameters. Note the 100-ohm degenerative emitter resistor in the output stage. This resistor is located at the output end of the mixer circuit board and is a convenient means for adjusting the overall amplification of this section of the receiver.

To aline the RF section, adjust circuits L2 through L5 for maximum receiver output using a 24 Mc/s input signal whose frequency is 1 kc above the 24 Mc/s harmonic of the local oscillator source. Adjust circuit L7 for maximum receiver output, although this maximum will be very broad if the frequency multiplier has been properly tuned.

Retune the signal source to a frequency 1 kc below the local-oscillator harmonic. Adjust L6 and the IMAGE NULL potentiometer simultaneously for minimum output.

Intermediate-frequency filter

The band-pass filter couples the 1-kc output of the RF chassis to the input of the IF chassis. The filter produces a resonant voltage amplification; at 1 kc, the ratio of IF chassis input voltage to RF chassis open-circuit output voltage is approximately 4.

The filter contains two tuned circuits using toroidal inductors. Careful initial tuning of the filter yields a half-power bandwidth of 25 c/s.

Intermediate-frequency chassis

The IF amplifier consists of three resistance-coupled stages using 6BJ6 tubes connected as triodes (V3, V4, V5) and a fourth stage using one section of a 12AU7 (V6A). The first 6BJ6 is shock-mounted to reduce its microphonic response to vibration. The interstage resistance-capacitance networks provide a broad band-pass characteristic centered approximately at 1 kc. The fourth stage V6A drives a balanced detector yielding equal positive and negative output voltages. Each voltage is filtered in a low-pass RC section whose time constant can be set at either 0.30 second or 30 seconds.* The negative voltage can be used either in full or partly attenuated as AVC bias for the 6BJ6 stages, including the RF stage V2 if wanted.

The positive voltage drives grid 2 of a 12AU7 balanced amplifier (V7) for the recording meter. Amplifier resistances have been chosen to critically damp an Esterline-Angus 1-milliampere recorder movement. Approximately 1 volt at 60 c/s is applied to grid 7 as a dither signal to overcome the static friction of the recorder pen.

*The time constant was changed to 15 seconds.

The 1-kc output of V5 is separately amplified by a 12AU7 section (V6B) and is available for driving the monitor oscilloscope, headphones, loudspeaker, or for other uses.

Frequency multiplier

If the receiver is to operate successfully with a bandwidth of 25 c/s, the local-oscillator voltage required by the balanced mixers must be stable in frequency. It is assumed that the receiver will be used with a stable oscillator at approximately 1 Mc/s as the ultimate source of the local-oscillator voltage. The frequency multiplier generates the twelfth harmonic of this 1 Mc/s voltage for use as the local-oscillator input. With the mixer circuit shown, the second harmonic of the 12 Mc/s input must be 1 kc less than the signal frequency. The oscillator frequency F_o for a given signal frequency F_s is therefore

$$F_o = (1/24)(F_s - 1),$$

where both frequencies are in kilocycles per second.

The multiplier consists of three stages. In each stage, a harmonic of the input to that stage is first generated by a rectifier network, is then filtered, and finally is amplified by a tuned class-B transistor amplifier. The transistors Q4, Q5, Q6 draw no current when there is no input. For full output, the 1 Mc/s input required is approximately 1 volt across 50 ohms, or 20 milliwatts.

To aline the frequency multiplier, begin at the 1 Mc/s input end and connect a d-c vacuum-tube voltmeter to the nearest test point. Adjust L1 for maximum voltmeter reading. Connect the voltmeter to the second test point and adjust L2 and L3 for maximum readings. Connect to the third test point and adjust L4 and L5 for maximum. Connect to the last test point and adjust L6 and L7 for maximum. Voltmeter readings at all test points normally range from 3 to 6 volts.

Oscilloscope amplifier

A Millen No. 90911 oscilloscope is included for use as a tuning aid. A 1-kc source, with which the band-pass filter has been previously alined, supplies the horizontal deflection signal. The vertical deflection signal is supplied by the receiver's IF amplifier. Correct tuning is indicated by an elliptical oscilloscope trace. A very bright dot or trace should not be used, as the small cathode-ray tube screen burns easily.

Both deflection signals must be amplified to produce usable deflections. The amplifier chassis contains two separate unbalanced-input to balanced-output amplifiers. Each uses a 12AU7 connected as a phase inverter (V8, V9). The overall voltage amplification is approximately 20.

6. Electrical Measurements

The following measurements are typical. From one receiver to another, differences in voltages and currents of as much as twenty percent can be expected because of component variations. Larger measurement deviations are suspect and may be due to component aging or failure. All voltage measurements are made with ground as the zero-voltage reference. D-c measurements are made with a vacuum-tube voltmeter whose input resistance is 10 megohms.

IF chassis

The d-c detector voltage E_d is the voltage measured at the junction of one diode rectifier terminal and its 150K load resistor. One diode produces a positive E_d; the other diode produces an equal but negative E_d. E_{in} is the rms voltage of the 1-kc input measured at the IF chassis input connector with the band-pass filter disconnected.

With the LINEAR/AVC switch in the LINEAR position (up), IF GAIN control full clockwise, the detector voltage for full-scale (1-mA) deflection of the Esterline-Angus (E-A) recorder is:

$$E_d = 6 \text{ volts}$$

$$E_{in} = 1.2 \text{ millivolts}$$

At the point where the amplifier begins to overload:

$$E_d = 18 \text{ volts}$$

$$E_{in} = 3.6 \text{ millivolts.}$$

With the LINEAR/AVC switch in the AVC position (down) IF GAIN full clockwise, AVC LEVEL maximum (full counterclockwise), and full-scale E-A recorder deflection:

$$E_{in} = 60 \text{ millivolts.}$$

For one-tenth-scale recorder deflection:

$$E_{in} = 100 \text{ microvolts}$$

With the LINEAR/AVC switch in the AVC position, IF GAIN full clockwise, AVC LEVEL minimum (full clockwise), and full-scale E-A recorder deflection:

$$E_{in} = 7 \text{ millivolts.}$$

For one-tenth-scale recorder deflection:

$$E_{in} = 90 \text{ microvolts.}$$

For calculation purposes, the voltage amplification of the 1-kc band-pass filter is 4. Therefore, with the filter in the circuit, the open-circuit voltage of a 2000-ohm, 1-kc source required to produce the outputs in these examples is E_{in} divided by 4.

RF chassis

The gain of the RF chassis is fixed, in that no controls are provided for adjusting it routinely, with one exception. The exception is the optional use of AVC at the second RF amplifier V2. It is possible, however, to adjust the overall amplification by a factor of 3 to 4 with a simple modification. A 100-ohm resistor is shown in series with the emitter of the output transistor Q3. Increasing this resistance will reduce the amplification; reducing the resistance will increase the amplification. Typically, short-circuiting the resistor increases the amplification by a factor of 3. The following measurements were made with the 100-ohm resistor short-circuited.

The gain of the RF chassis also depends on other adjustments, especially upon the settings of the antenna input circuit and rejection trap. In these measurements, the receiver was operated as a unit with the band-pass filter in place. The antenna circuit was adjusted for minimum noise figure, which was 4 decibels. E_{rf} is the rms open-circuit voltage of the 50-ohm source.

With the LINEAR/AVC switch set to LINEAR (up), IF GAIN full clockwise, the full-scale E-A recorder deflection:

$$E_{rf} = 0.2 \text{ microvolts.}$$

With the IF GAIN reduced to accommodate greater inputs, the first IF stage V3 begins to saturate with:

$$E_{rf} = 100 \text{ microvolts.}$$

With the LINEAR/AVC switch set to AVC (down), RF AVC off (down), IF GAIN full clockwise, AVC LEVEL full counterclockwise, and full-scale recorder deflection:

$$E_{rf} = 10 \text{ microvolts.}$$

With the IF GAIN reduced to accommodate greater inputs, the transistor amplifier Q3 begins to saturate with:

$$E_{rf} = 1 \text{ millivolt.}$$

With the LINEAR/AVC switch set to AVC (down), RF AVC on (up), IF GAIN full clockwise, AVC LEVEL full counterclockwise, and full-scale recorder deflection:

$$E_{rf} = 150 \text{ microvolts.}$$

With the IF GAIN reduced to permit greater inputs, the RF amplifier begins to saturate with:

$$E_{rf} = 5 \text{ millivolts.}$$

An important result is illustrated by this series of measurements. For any setting of the receiver controls and for any choice of circuit adjustments (such as the value of emitter resistor for Q3), there is a certain antenna input that will produce receiver overload. If the signal record is to be valid, the receiver must be operated well below overload. Consequently, it is most necessary to take into account whether the observed signal is strong or weak, whether it fluctuates over a large dynamic range or a small one, and to adjust the receiver to accommodate this range below its overload input voltage.

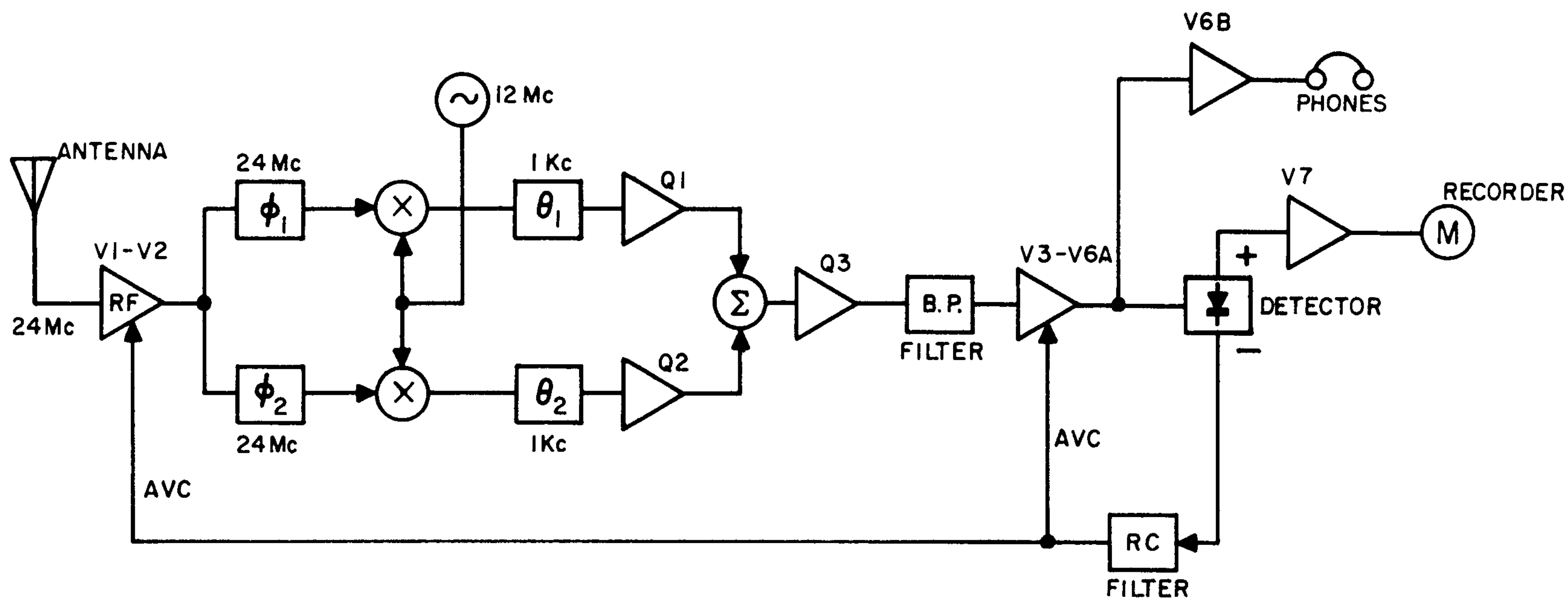


Figure A-1. Block diagram 24 Mc receiver

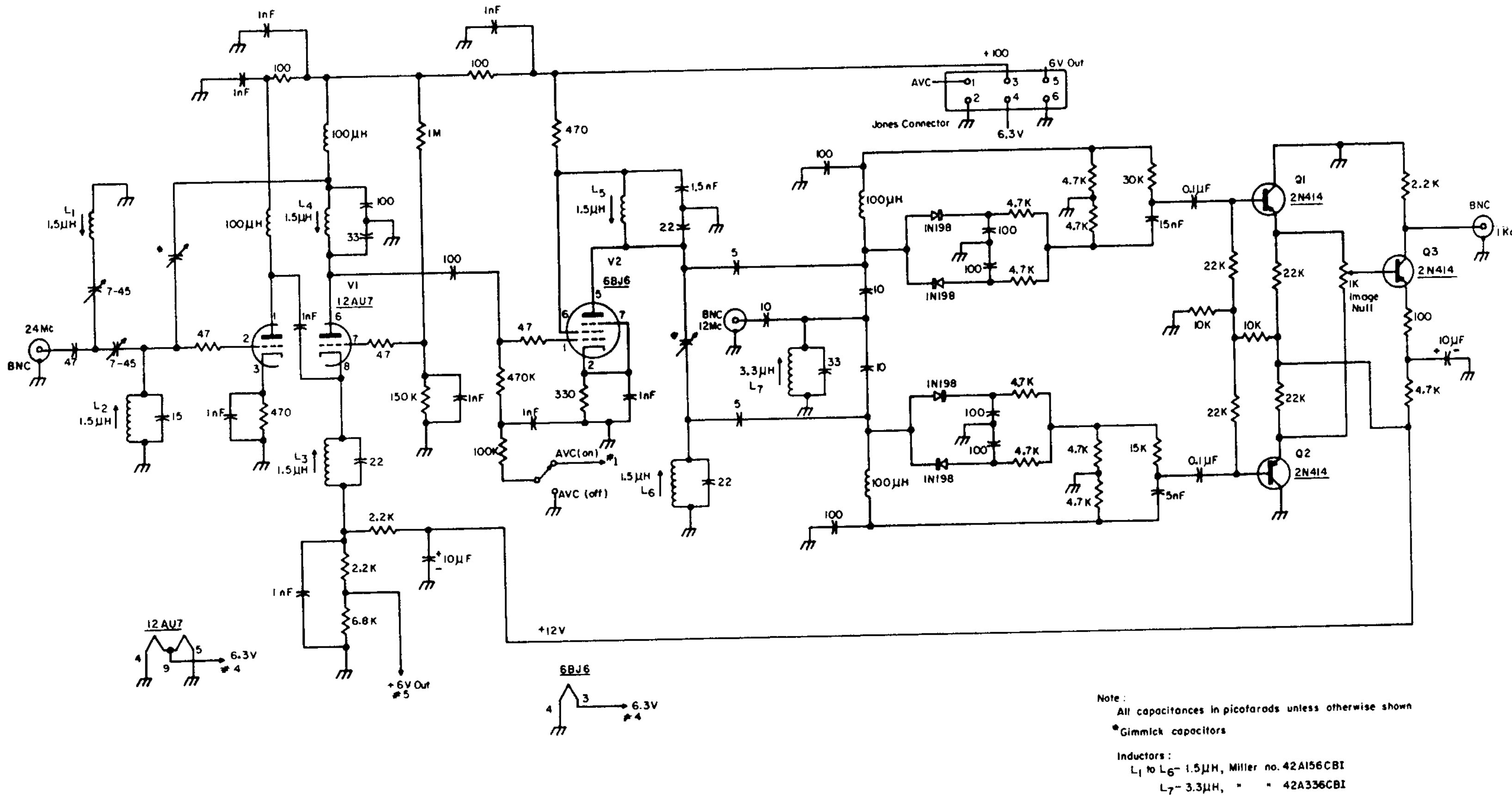
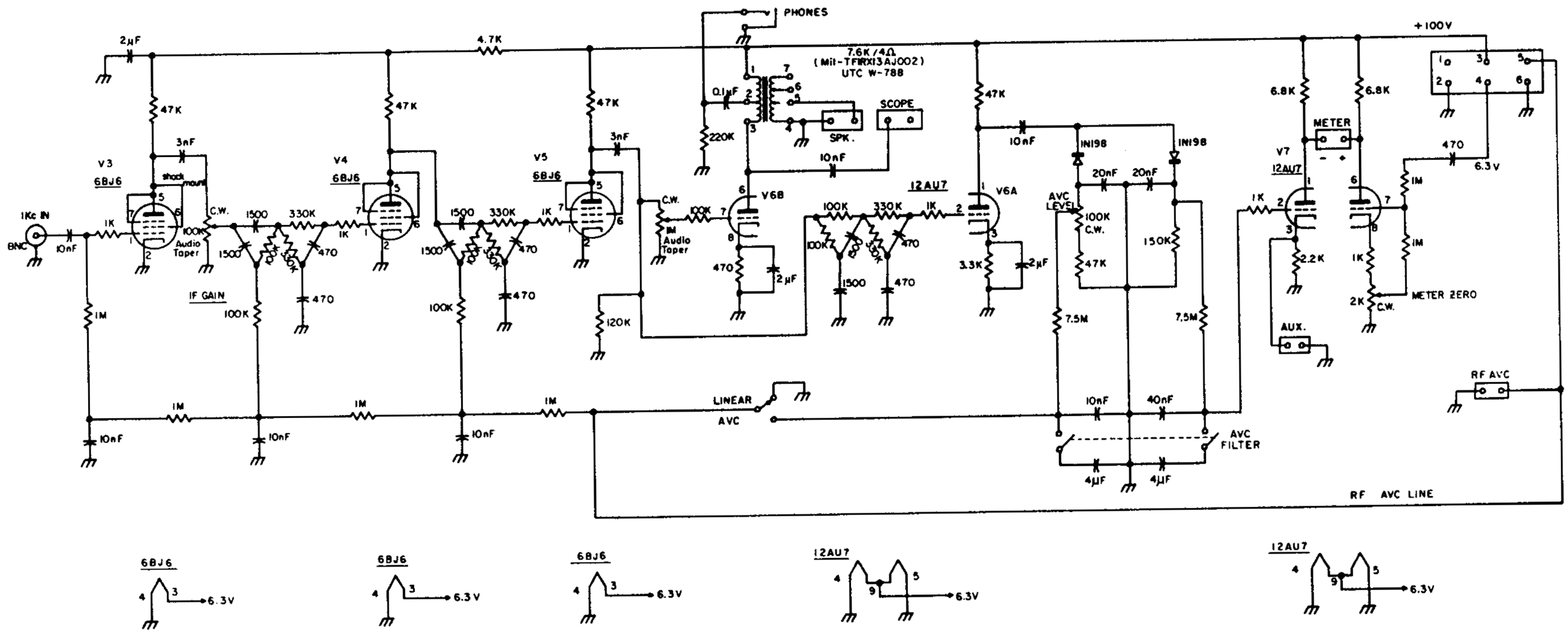


Figure A-2. Schematic diagram of the receiver RF amplifier



Note:
All capacitances in picofarads unless otherwise shown.

Figure A-3. Schematic diagram of the receiver 1 kc IF amplifier and detector

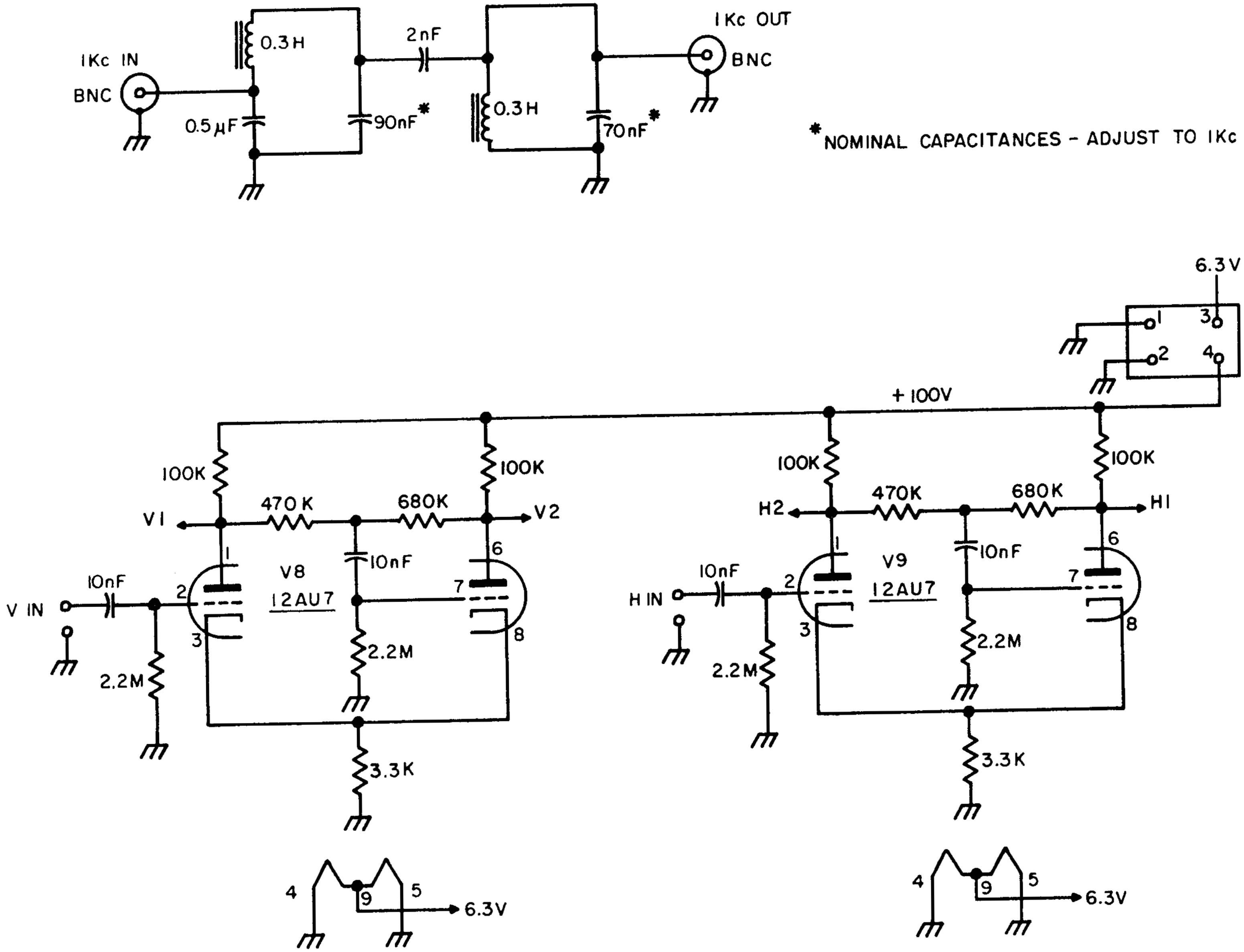
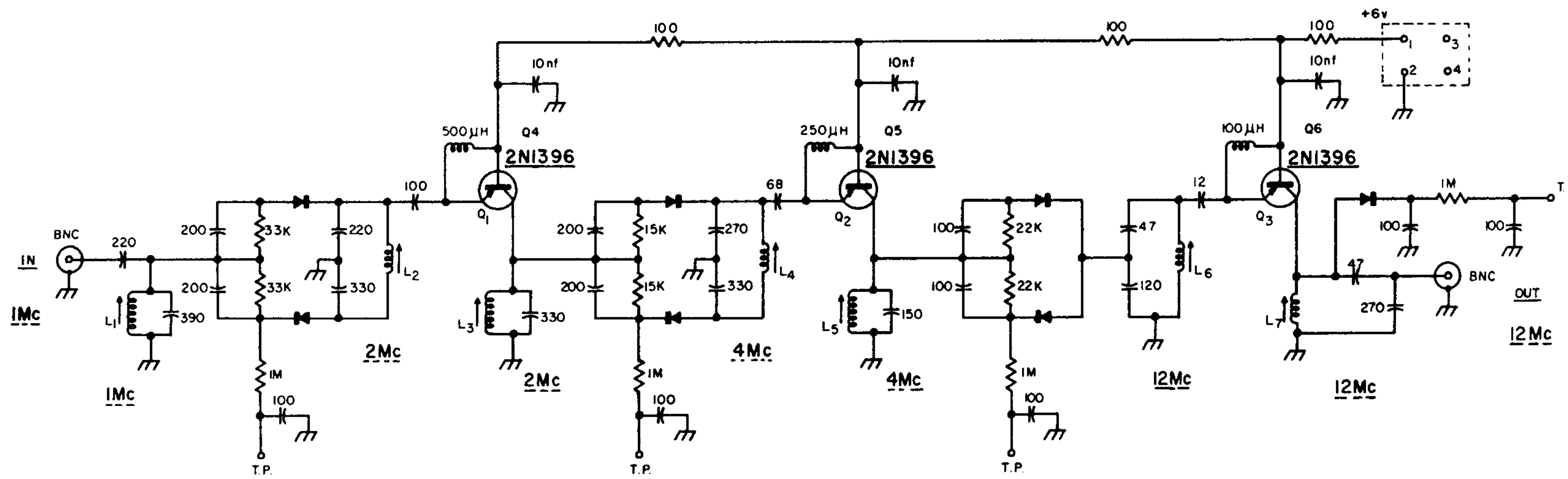


Figure A-4. Filter and scope amplifier



INDUCTORS

L_1 -	40μH,	Miller No	42A475CBI
L_2 -	40μH,	" "	"
L_3 -	20μH,	" "	42A225CBI
L_4 -	10μH,	" "	42A105CBI
L_5 -	10μH,	" "	"
L_6 -	3.3μH,	" "	42A336CBI
L_7 -	3.3μH,	" "	"

Notes:

All resistances in ohms
All capacitances in picofarads unless otherwise noted
All diodes type IN198

Figure A-5. Schematic diagram of the frequency multiplier

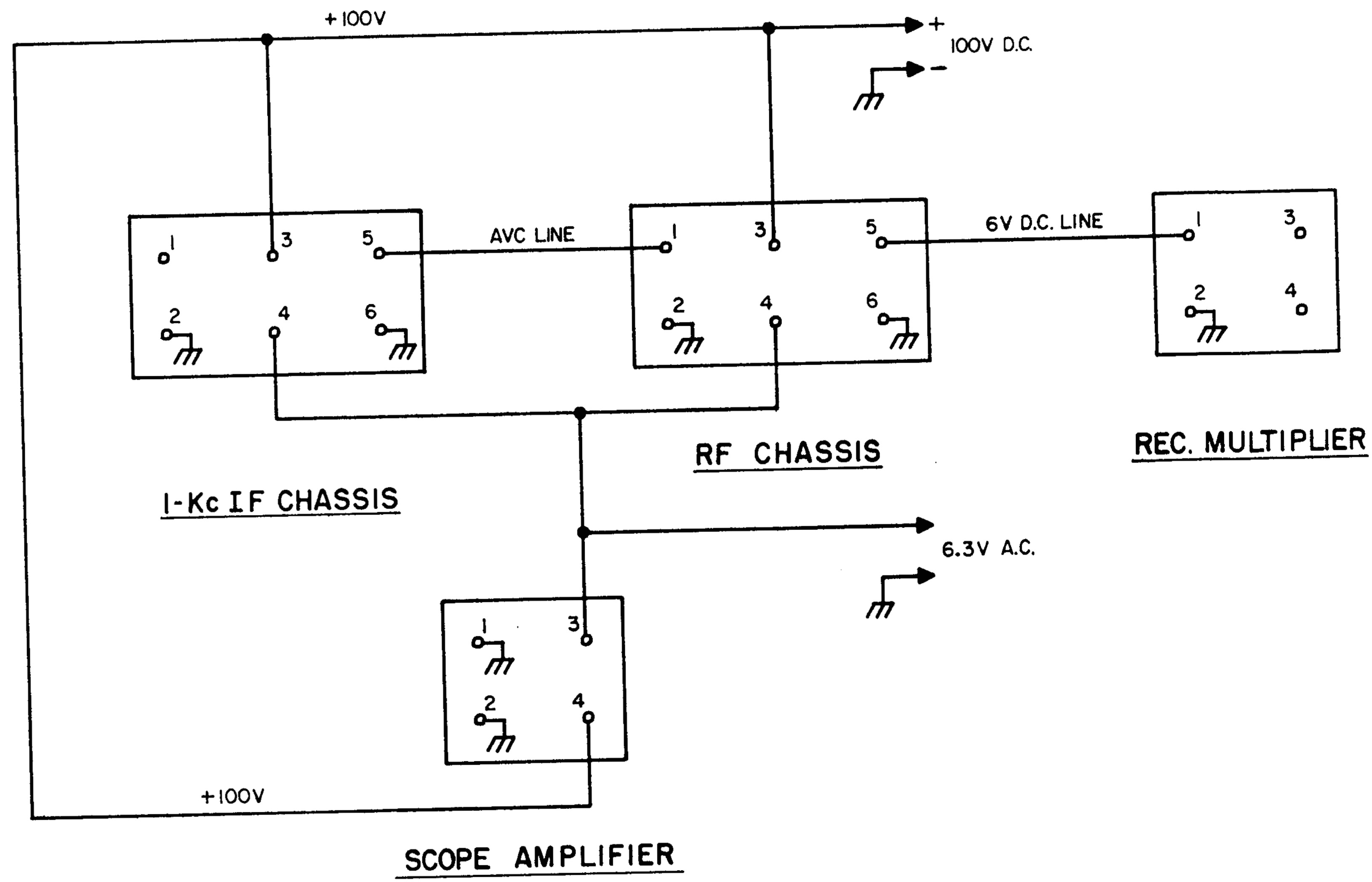


Figure A-6. Jones plug diagram

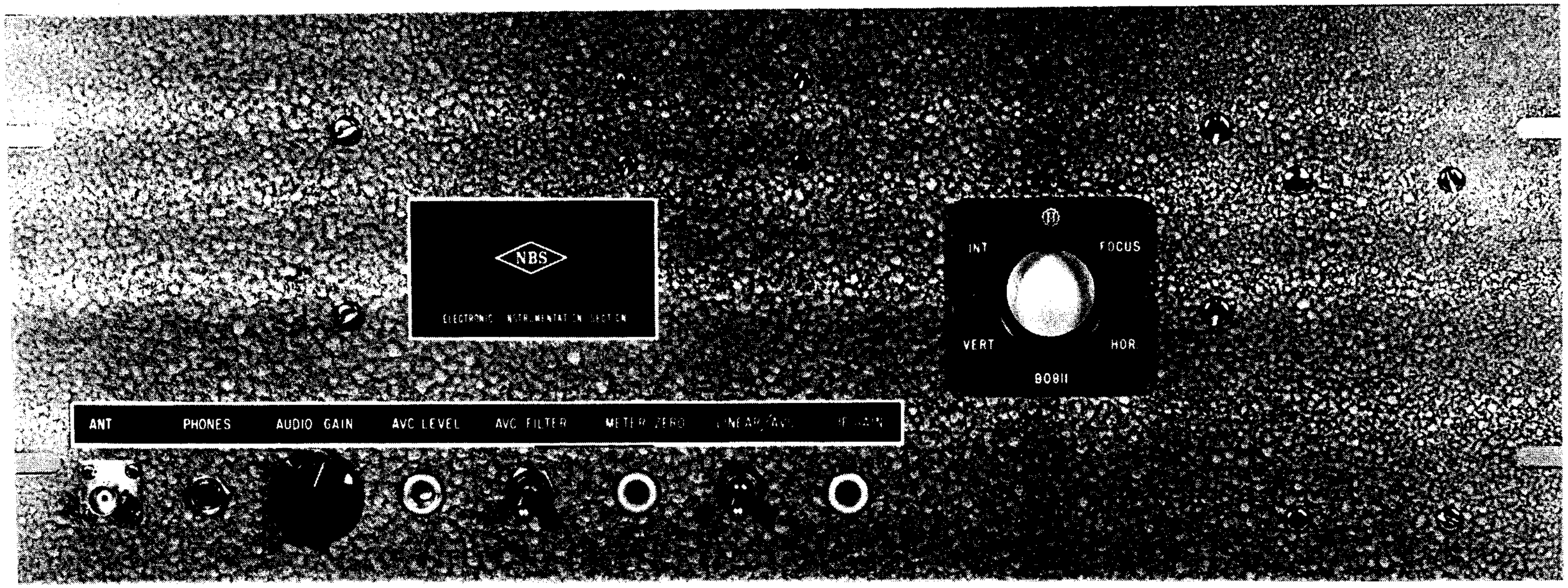


Figure A-7. Front view of the receiver

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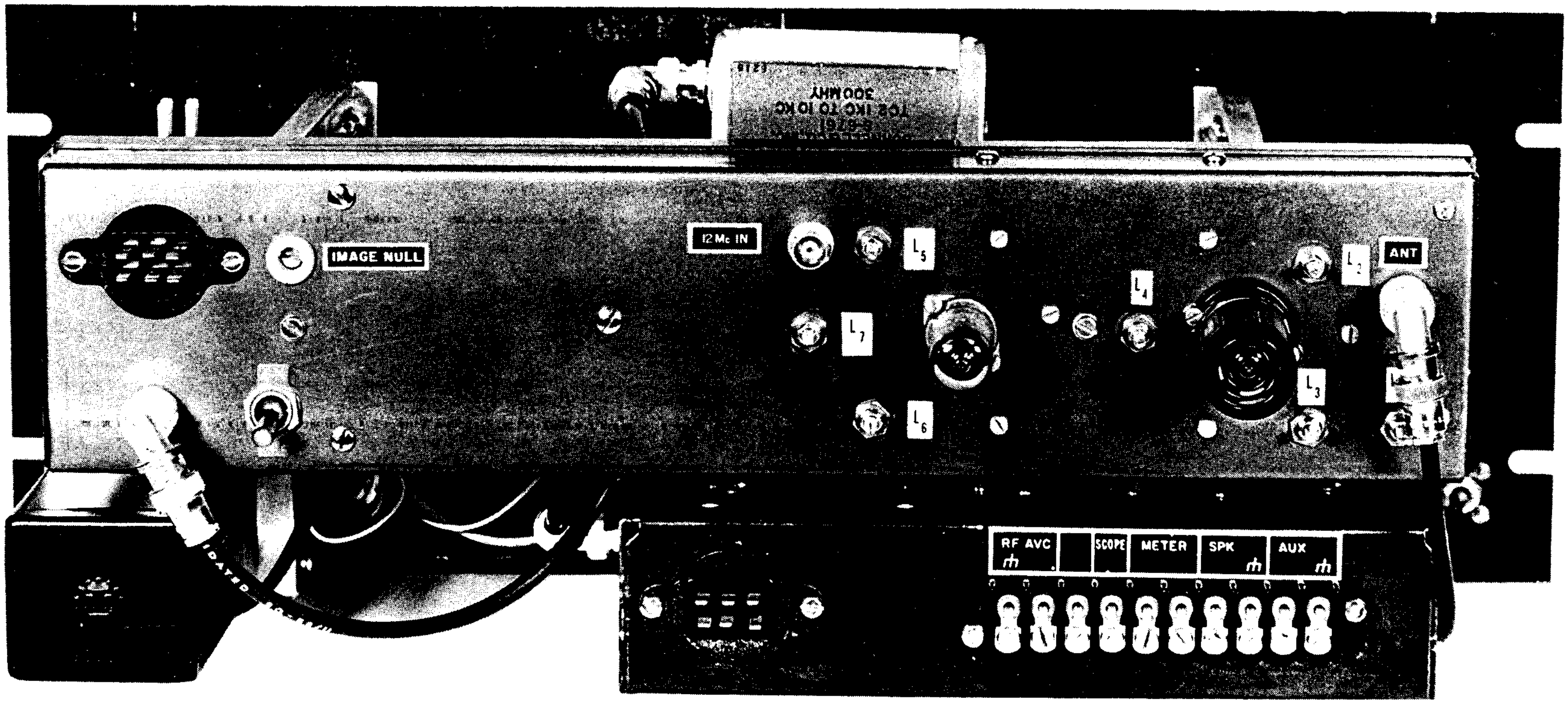

Figure A-8. Rear view of the receiver

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