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ILS SCALE MODEL FACILITY

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16. Abstract

THIS DOCUMENT DESCRIBES THE DESIGN, INSTALLATION, AND TESTING OF AN ILS SCALE MODEL FACILITY AT SUFFOLK COUNTY AIRPORT, WESTHAMPTON BEACH, NEW YORK. THE MODEL SYSTEM CONSISTS OF A LOCALIZER, GLIDE SLOPE, AND AUTOMATIC TRACKING FACILITIES, WITH A SCALE FACTOR OF 30/1. THE FACILITY PROVIDES COURSE STRUCTURE DEVIATIONS OF LESS THAN ±5uamps AND ±2uamps FROM THEORETICAL FOR GLIDE SLOPE AND LOCALIZER RESPECTIVELY FROM THE OUTER MARKER TO THRESHOLD.

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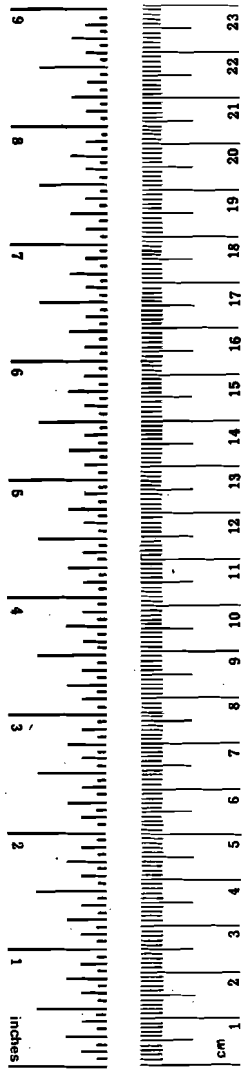
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

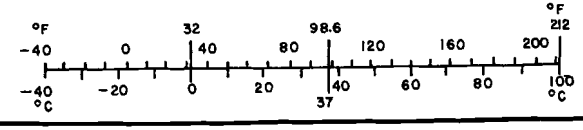
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit tempereture	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

An ILS Scale Model Facility has been installed and tested at Suffolk County Airport, Westhampton Beach, New York. This model facility permits the investigation and analysis of the special electromagnetic scattering problems from terrain and objects around airports, optimization of antenna systems and the study of far field monitor phenomena. Additionally, the planning of sites for ILS installations and the solving of siting problems can be readilly accomplished at a fraction of costs as compared to full scale investigations.

The scale model facility consists of 3 major parts, a localizer facility, a glide slope facility and an automatic-tracking facility. A 30/1 scale factor is used and the localizer operates at a 3.3 GHz and glide slope at 9.9 GHz. The facility covers a paved area 1,000 feet in length and 70 feet wide simulating the last 27,000 feet on the approach from threshold. Nominally, the outer limit is at the outer marker.

An instrumented carriage simulates the airplane as it "flies" down the centerline. The carriage contains a control cab and a vertical mast that holds the receiving antenna. As the carriage moves along a track toward threshold, the antenna is lowered simulating a plane following a fixed glide angle. A conventional ILS receiver feeds a chart recorder to provide a permanent record of the localizer/glide slope facility performance.

This report describes the facility installation and tests that have established the basic performance characteristics of the overall scale model facility. Under idealized conditions, the glide slope exhibited bends less than ± 5 uamps from theoretical; and the localizer facility had bends less than ± 2 uamps from theoretical. This performance is well within the worst case ICAO Category III localizer and glide slope tolerances of ± 5 uamps and ± 20 uamps respectively.

The basic Scale Model Facility characteristics are:

. SCALE FACTOR	30/1
. RANGE	27,000 SCALED FEET (900 FEET)
. ELEVATION	1,200 SCALED FEET (40 FEET)
. GLIDE ANGLE	0.5 TO 4° IN 0.1° STEPS
. FACILITY PAVED AREA	1,000 FEET X 72 FEET
. LOCALIZER COURSE STRUCTURE	$\angle$ 2ua MAXIMUM DISPLACEMENT
. GLIDE SLOPE COURSE STRUCTURE	$\angle$ 5ua MAXIMUM DISPLACEMENT
. LOCALIZER FREQUENCY	3.3 GHz
. GLIDE SLOPE FREQUENCY	9.9 GHz

1.1 SCALE FACTOR

Many factors were considered in the selection of the Scale Factor. The choice was approached with some definite prejudices. First, we wanted to build up the basic signal generating equipment from "off-the-shelf" hardware to avoid costly development of specialized hardware. Our experience with a 1585 MHz Glide Slope system as well as the reports on the Australian Scale Model regarding their early problems contributed to the scale factor decision.

Our contract specified that the model facility should be capable of working into a conventional aircraft receiver. This provided a starting point for an overall system gain analysis. The analysis and a survey of "off-the-shelf" microwave hardware led to the conclusion that X-band (8.2 - 12.4 GHz) was about as high in frequency as one could go with confidence of getting reliable, conservatively rated, components capable of meeting system gain requirements. The selected scale factor for the glide slope followed consideration that at 30:1, the normal tolerances on the flatness of the ground plane of the model glide slope were about equivalent to those attainable with the best paving.

The same scale factor was chosen for the localizer since the advantages of being able to use the same models of buildings, aircraft, etc., are far greater than being able to further reduce the size of the localizer model layout. Further, the tracking system is glide slope limited, since localizer tracking is readilly accomplished once the glide slope tracking problem was solved. The basic frequencies are 110.1 MHz for the localizer and 330:2 MHz for the glide slope. Correspondingly, the microwave frequencies are 3.303 GHz and 9.906 GHz respectively.

The 30:1 scaling allows a large 747 hangar, for example, 1200 by 120 feet high, to be reduced to 40 by 3 feet. This is easy and inexpensive to model and readilly permits testing to check the effects of hangar orientation, multistep designs, and varying front surface contours. Most reflecting objects would, of course, be considerably smaller.

2. INSTALLATION DESCRIPTION

The Scale Model Facility was installed at Suffolk County Airport, Westhampton Beach, New York on an unused taxiway. The taxiway is made of reinforced concrete sections 12 by 20 feet separated by expansion joints. The taxiway is 48 feet wide with 12 foot macadam shoulders on each side. Figure 1 shows the site looking from behind the localizer towards the threshold. The glide slope transmitting tower is visible to the right of the instrumentation carriage. On either side of the taxiway, the ground is relatively flat with sparse vegetation.

The Scale Model layout is shown in Figure 2. Basic system requirements are to provide tracking capability from 26,000 feet to within 1,000 feet of the antenna array. The installation allows minimum of 20 feet (600 scaled feet) overrun at both ends so the actual simulated range is over 27,000 feet to about 400 feet. 920 feet of the "V" rail track is installed with 900 feet of perforated channel along side, as shown in Figure 3. "Chockfast" epoxy is used to secure the track and channel to the concrete surface.

The ILS VHF transmitter modulators are installed in a building 175 feet behind and off to the side from the transmitting antenna array. Very stable foam flex cables carry the VHF carrier and sideband signals to the up converters positioned near the antenna arrays. Figure 4 shows the Localizer and Glide Slope

transmitter modulators. The foamflex cables are routed up between the two chassis; and are connected to the desired unit by a short run of RG-223 coax cable.

The transmitting antenna array is placed in front of the smoothest portion of the taxiway for optimum performance. This section is very flat with variations of under $\pm$1/8 inch. Further away, at various points, there are random high and low regions varying from 1/4 inch to 3/4 inch peaks (or valleys). However, these areas are relatively small sections of the reflecting image planes and their effects are not significant. This has been borne out by the test results.

The taxiway has a downward slope from threshold of 0.28 feet per 100 feet. This essentially produces a constant 0.16 degree glide slope angle bias that is compensated by the initial set up adjustments of the antenna heights.

As substantiated by test results, the unpaved areas on both sides of the taxiway did not affect facility performance. Also, the tar expansion joints between concrete blocks did not cause any noticeable effects.

3. LOCALIZER FACILITY

The localizer facility is shown in Figure 5. The up converter is fed with the carrier and sidebands carried by the foamflex cables. Commercial power supplies provide the regulated d.c. The up converter drives the antenna array via solid coax cables to minimize losses and leakage.

The localizer facility design is summarized here. For the detailed discussion, refer to Interim Report FGS-A414-2.

The localizer signal generating equipment is shown in block diagram form in Figure 6 and in the photograph Figure 7. Frequency spectrum notations are included on the block diagram.

The conventional localizer transmitter-modulator (AIL Type 55) operating at 110.1 MHz produces "carrier and sideband" outputs that are attenuated to levels suitable to modulate the S-band signal. The source of the S-band signal is a high stability, solid state oscillator/multiplier which delivers 20mW at 3.1929 GHz. This signal is split into two 10mW signals which are routed to the balanced mixers (double sideband modulators). At the mixers, the sum and difference frequencies are formed and the unmodulated carrier is suppressed. From the mixers, the modulation products feed the amplifier. The amplifier is tuned to the upper sideband frequency (3.1929 + .1101 = 3.303 GHz) thus, this signal is amplified. The lower sideband and residual carrier components, well outside the 4 MHz bandwidth

of the amplifier, are rejected. After amplification, the carrier and sideband signals are routed through bandpass filters to the model array, shown in Figure 8. It is a scaled 15 V-Ring localizer antenna array that duplicates the azimuth pattern of the typical array.

A block diagram of the down converter is shown in Figure 9. The unit is shown with the receiving horn in the photograph, Figure 10. At the receiving end, the incoming 3.303 GHz signal is mixed with a 3.1929 GHz signal and the conventional 110.1 MHz signals are obtained as the difference frequencies. The sum frequencies are severely attenuated in the transmission line to the receiver and are rejected by the receiver itself. The receiver is a conventional aircraft navigation receiver (Bendix RIA-32A).

Since the down converter local oscillator is not coherent with the transmitter, a beat signal exists. This beat is adjusted (by varying the frequency difference of the two LO's) to be several KHz so that it is effectively filtered out by the receiver.

This method of signal generation leaves the percentage of modulation of the 90 Hz and 150 Hz modulation tones dependent on the conventional localizer transmitter modulator. The 90/150 modulation is unaffected by the up/down conversion.

Note that the adjustment and control of the percentage of modulation of 90 Hz and 150 Hz tones, the adjustment of course width and position is done in the same way for the model array as for the actual ILS installation, because a standard ILS transmitter modulator is the source of the basic carrier and sideband signals.

4. GLIDE SLOPE FACILITY

The Null Reference Glide Slope Facility is shown in Figure 11. The "M" array facility is described later in Section 6. The up converter is located directly behind the transmitting antenna array and tower. Flexible waveguide connects the up converter output to the transmitting antenna. The carrier, sidebands, and d.c. power feed the up converter via appropriate connectors on the rear of the box.

The Glide Slope Facility design is summarized here. For the detailed discussion, refer to the Interim Report FGS-A414-1.

The glide slope signal generating equipment is shown in block diagram form in Figure 12 and in the photograph Figure 13. Frequency spectrum notations are included on the block diagram.

The conventional glide slope transmitter modulator (AIL Type 55) operating at 330.2 MHz, produces "carrier and sideband" outputs that are attenuated to levels suitable to modulate the X-band signal. The source of the X-band signal is a high stability solid state oscillator/multiplier which delivers about 20mW at 9.5757 GHz. This signal is split into two 10mW signals which are routed to the balanced mixers (double sideband modulators). At the mixers, the sum and difference frequencies

are formed and the unmodulated carrier is suppressed. From the mixers, the modulation products feed the amplifier. The amplifier is tuned to the upper sideband frequency (9.5758 + .3302 = 9.906 GHz) thus, this signal is amplified. The lower sideband and residual carrier components, well outside the 10 MHz bandwidth of the amplifier, are rejected. After amplification, the carrier and sideband signals are routed through bandpass filters to the model array.

The glide slope antennas are modeled by waveguide fed pyramidal horns. The horns are mounted on positioning plates which, in turn, are mounted to a "tower". (See Figure 11). Provision is made to vary the height of the antenna above ground and the offset over the scale of any range required for the null reference, sideband reference and M-array configurations.

The glide slope modeling is not concerned with back radiation and to minimize the length of waveguide runs, the up converter is mounted directly behind the "tower". The feed lines to the horns are short lengths of flexible waveguide.

A block diagram of the down converter is shown in Figure 13. A photograph of the unit with the receiving horn is shown in Figure 14. At the receiving end, the incoming 9.906 GHz signal is mixed with a 9.5758 GHz signal and the conventional 330.2 MHz signals are obtained as the difference frequencies. The sum frequencies are severely attenuated in the transmission line

to the receiver and are rejected by the receiver itself. The receiver is the same aircraft navigation receiver used in the localizer facility.

Similarly to the localizer facility, the beat signal is adjusted to be several KHz so it is filtered out by the receiver. Again, the 90 Hz and 150 Hz modulation tones generated by the conventional ILS transmitter modulator are unaffected by the up/down conversion.

5. AUTOMATIC TRACKING FACILITY

The Automatic Tracking Facility contains an instrumented carriage, that is the aircraft on approach, guided by the track as it moves down the runway centerline. The carriage has an integral drive system, a shelter that houses the operator, system controls, aircraft receiving equipment and chart recorder; and a mast assembly supporting a trolley that is positioned as a function of simulated aircraft displacement from threshold and the glide path being followed. See Figure 16 for a close up view of the instrumentation carriage. The Automatic Tracking Facility design is summarized here. For the detailed discussion, refer to Interim Report FGS-A414-3.

The steel carriage supports a vertical forty-two foot aluminum mast at the right front corner. The power source, a 7-1/2 kilowatt motor generator, is mounted towards the right rear and the 6' x 8' equipment shelter is on the left rear corner of the carriage.

A "fifth wheel", Figure 17, attached to the carriage assembly drives a multiturn absolute position digital encoder that generates carriage position data. The horizontal displacement is accurately determined by the sprocket wheel assembly, that rides in the perforated track simulating a rack and pinion, thereby eliminating slippage.

The Control Unit, Figure 18, performs the calculations to obtain the commanded elevation and compares it with the actual. An identical encoder is mounted on the Trolley Drive Assembly to provide a continuous indication of actual trolley height. The control unit then produces command signals to drive the trolley control motor and position it accordingly.

The equipment layout in the carriage shelter is shown in Figure 19. Standard ILS test generators, used to initially check out and calibrate the receiving equipment, are shown in the upper right corner. The carriage motor drive control is mounted on the right wall below the table. The lower righthand rack houses the Interface Unit on top and the Trolley Stepper Motor Drive on bottom. The other rack has the chart control drive; the ILS receiver and the d.c. and 400 Hz power supplies. The Control Unit is at the center of the table. The "dead mans" control, shown attached to the unbilical cord, is directly in front of the Control Unit. The chart recorder is at the left.

6. TESTS

In order to demonstrate the operational characteristics of the ILS Scale Model Facility and compliance with the specifications, a series of tests were conducted. These consisted of simulated approaches in level flight and at various angles and vertical cuts. The former are similar to the usual flight check data; the latter provide data not readily obtained at full scale.

In the course of a run the crosspointer, flag, and AGC outputs of the receiver are plotted on the recorder along with a step function which indicates distance from the facility. The receiver is a Bendix RIA 32A. Its flag output is a go/no go indication and is derived from the monitoring of several internal parameters and does not correspond to the flag trace of the usual flight check recording.

An approach, either level or angle, can be run inbound and/or outbound. This means there is no lost time in going back to the starting point for the next run in. Normally, runs were made with a carriage speed corresponding to 40 knots. This speed and the relatively long time constant of the receiver (.9 sec) give a system time constant about the same as a flight check aircraft.

A vertical cut is obtained by stopping the carriage at any point and running the receiving antenna up or down the mast. Height marks are manually added to the recording as no provision was made to do so automatically.

Scale models of three specific ILS configurations were tested. These were as follows:

1. Fifteen element V-Ring Localizer
2. Null Reference Glide Slope
3. M-Array Glide Slope (Capture Effect Glide slope without the offset frequency clearance signal)

6.1 LOCALIZER

The scale model V-ring array was set up with a course width of 4 degrees. The width setting was accomplished by first mounting the receiving antenna four feet off centerline (120 scaled feet) and positioning the carriage at the proper distance from the localizer (3436 scaled feet for 4°), and then adjusting the sideband output power from the conventional localizer transmitter modulator for full scale deflection (150ua). Data from the following series of runs were recorded:

1. Level run, 1,200 feet altitude, full range
2. Level run, 1,000 feet altitude, full range
3. Level run, 800 feet altitude, full range

4. Level run, 600 feet altitude, full range
5. Level run, 400 feet altitude, full range
6. Level run, 200 feet altitude, full range
7. 3° APPROACH to 9,000 feet from Localizer antenna array, then level at 54 feet* altitude to stop (within 1,000 feet from antenna array)
8. Vertical cut at 9,000 feet from localizer
9. Vertical cut at 12,500 feet from localizer
10. Vertical cut at 25,000 feet from localizer

*54 feet represents the lower limit of vertical travel

The recording obtained on the 3° approach (number 7 above) is reproduced in Figure 20. The most severe band, at about 6,000 feet which meets the ± 2 uamp specification is site dependent. The overall trend to the 90 Hz side is due to a misalignment of the vertical axis of the array and the tracking mast because of the general slope of the site.

As a simple demonstration of the effect of a reflecting object, a metal plate scaling 67 feet high by 73 feet long was placed 3,260 feet from the localizer and 470 feet off centerline on the 150 Hz side. The resultant recording shown in Figure 20 was obtained. This demonstrates in a crude fashion one of the uses of the ILS scale model facility. The system gain with the

V-ring array was adequate at maximum range (27,300 feet) and minimum altitude (54 feet) providing a 2uv input to the receiver. The range of course widths available as set up is from 3.9 to 9.1 degrees. This is achieved by changing the sideband power output from the conventional transmitter/modulator by adjustment of the front panel control. This range can be shifted by varying the fixed attenuation (about 30db) inserted in both carrier and sideband lines between the transmitter/modulator and the up-converter.

6.2 NULL REFERENCE GLIDE SLOPE

The null reference glide slope was set up at the Suffolk County Airport site 400 scaled feet from centerline on the lefthand side of the runway as seen from an approaching aircraft (see Figure 1). Preliminary runs were conducted to set angle, width, and phasing. Adequate range was demonstrated with the reception of a 2.5uv signal at maximum range (27,300 feet) and minimum altitude (54 feet). Although the total range of the path width control was not checked, a range from 0.4 to 1 degree was observed. As with the localizer, the range of width adjustment is dependent on the fixed attenuation inserted between the transmitter/modulator and the up-converter.

The following series of runs were conducted and the data recorded:

1. Level run, 1,200 feet altitude, full range
2. Level run, 1,000 feet altitude, full range
3. Level run, 800 feet altitude, full range
4. Level run, 600 feet altitude, full range
5. Level run, 400 feet altitude, full range
6. Level run, 200 feet altitude, full range
7. 3° APPROACH
8. 2.7^{o} APPROACH
9. 3.3^{o} APPROACH
10. 1.0^{o} APPROACH
11. Vertical cut 1,000 feet from Glide Slope
12. Vertical cut 4,500 feet from Glide Slope
13. Vertical cut 27,000 feet from Glide Slope

The recording obtained on the 3 degree approach is reproduced in Figure 21. The bends are well within the $\pm$5ua requirement. Also shown, is a reproduction of the data obtained with a reflecting obstacle simulating a storage tank, 30 feet in diameter and 36 feet high, located 1,800 feet in front of the glide slope and 480 feet off centerline on the glide slope side. The effect of the obstacle is obvious.

6.3 CAPTURE EFFECT GLIDE SLOPE

The Capture Effect Glide Slope without clearance signal, the M-array, was assembled and set up in the same location as the null reference. Figure 22 shows two views of the M-array and the X-band waveguide feed network. Figure 23 is a block diagram of the feed network.

The array was set up with a series of tests verifying the positioning of the three antennas and the proper distribution of the carrier and sideband signals. The combining network is necessarily inefficient having a loss of about 6db for the carrier. This and the inherent reduction of signal at low angles with the M-array result in no usable signal below about 0.8^{o}.

Data was recorded for a series of runs identical to those taken with the null reference glide slope. The on-path run reproduced in Figure 21C. Figure 21D is a reproduction of an on-path run with the same obstacle in the same location as on the null reference run. The effectivness of the Capture Effect Glide Slope in dealing with such an obstacle is immediately apparent.

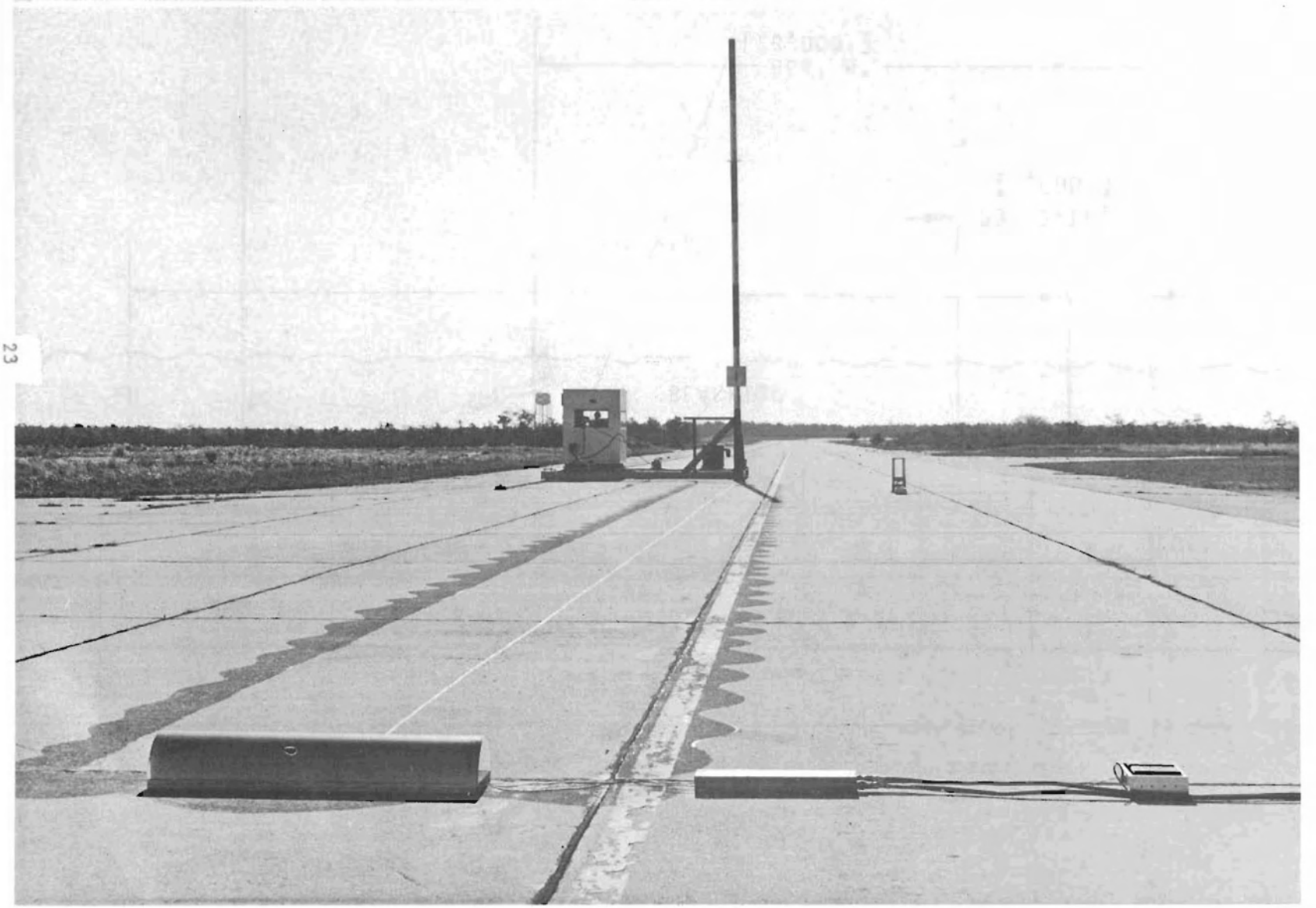
7. CONCLUSION

The ILS Scale Model Facility has demonstrated its compliance with the specified requirements. In particular, under idealized siting conditions of no scattering obstacles, the maximum deviations were 2ua and 5uamps for Localizer and Glide Slope facilities respectively. The effects of obstacles to the course/path structures was shown; and in the case of the Glide Slope, the improvement that results with a Capture Effect System was proven again.

The Automatic Tracking Facility flexibility in providing the easy selection and running of various path angles permits rapid evaluation and analysis of the ILS performance.

The goal of obtaining a cost effective Scale Model Facility that can be used as an operational tool for real world problems with a "quick turn around" has been achieved.

Figure 1. Scale Model View



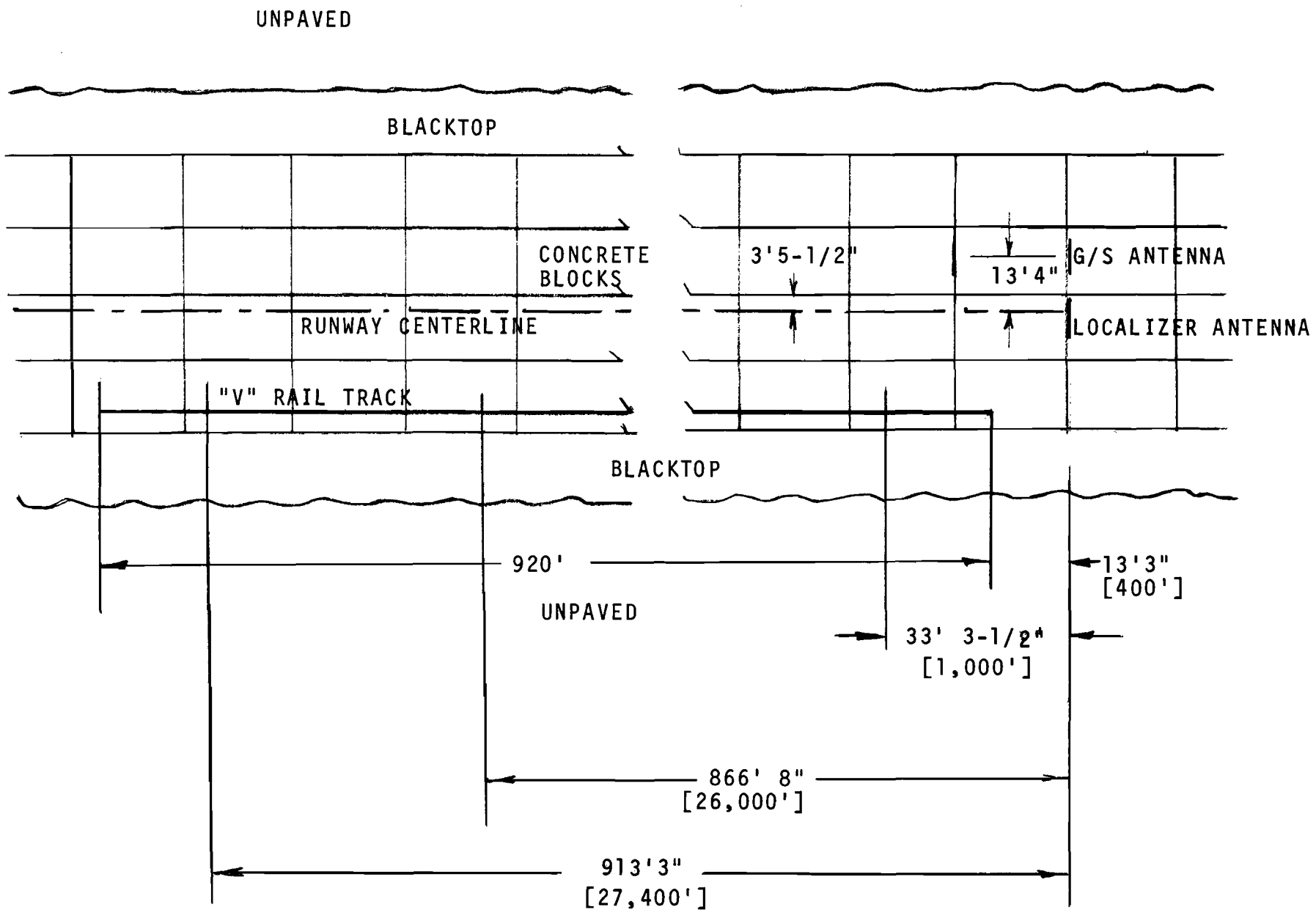


Figure 2. Scale Model Site

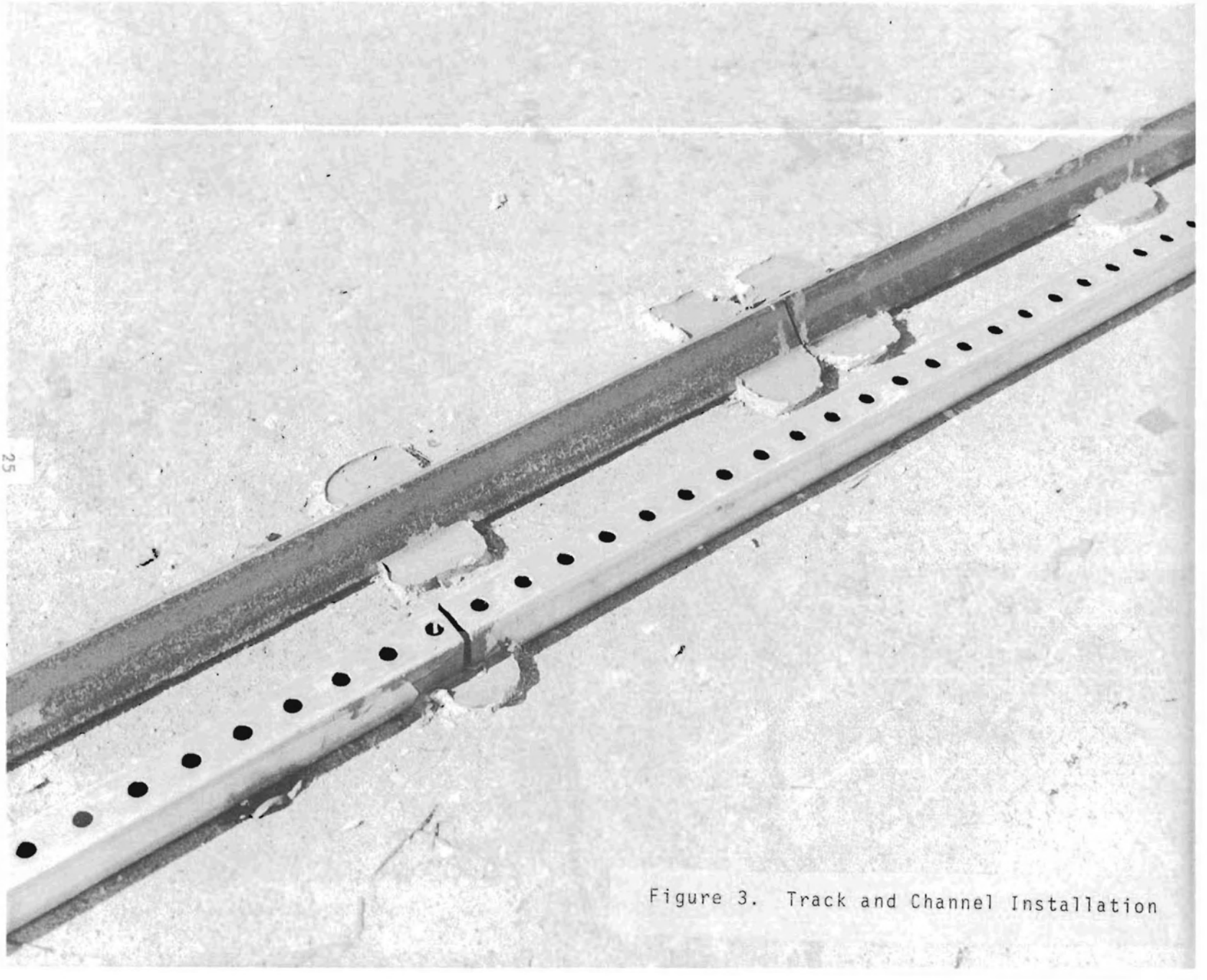


Figure 3. Track and Channel Installation

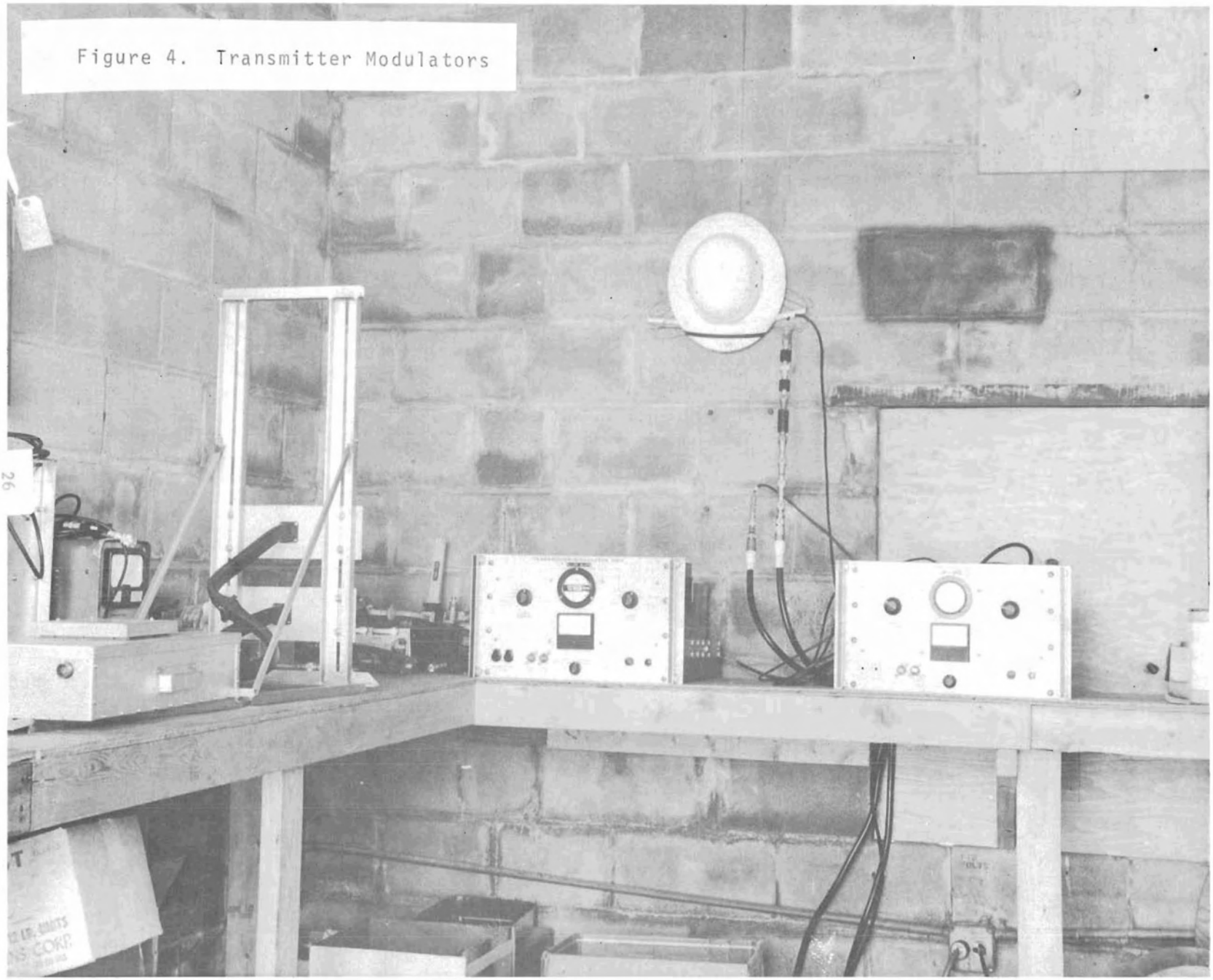


Figure 4. Transmitter Modulators

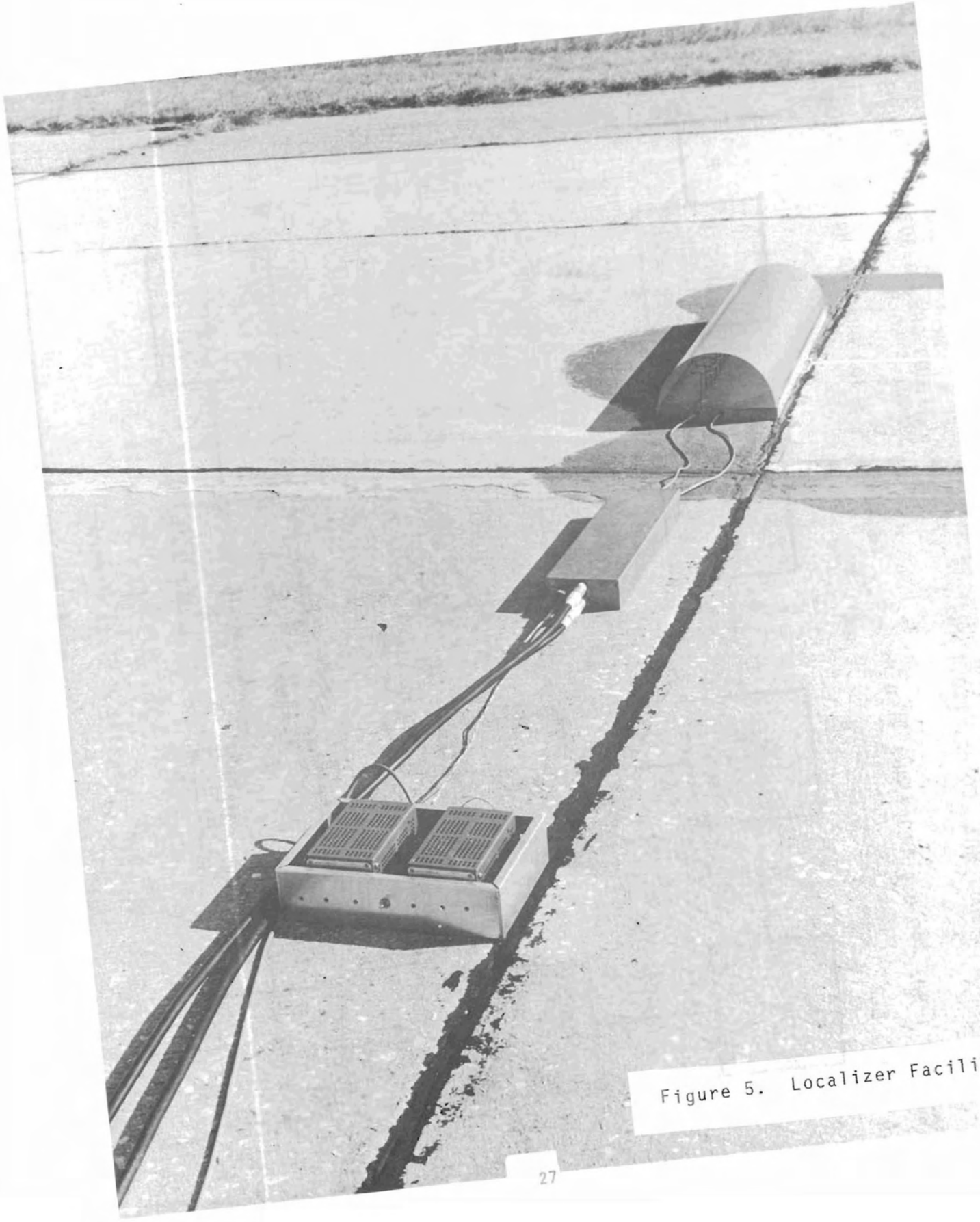


Figure 5. Localizer Facility

A - 3.1929 GHz

B - 110.1 MHz, 110.1 MHz ±90 Hz, 110.1 MHz ±150 Hz

C - 110.1 MHz ±90 Hz, 110.1 MHz ±150 Hz

D - A+B, A-B

E - A+C, A-C

F - A+B - 3.303 GHz, 3.303 GHz ±90 Hz, 3.303 GHz ±150 Hz

G - A+C - 3.303 GHz ±90 Hz, 3.303 GHz ±150 Hz

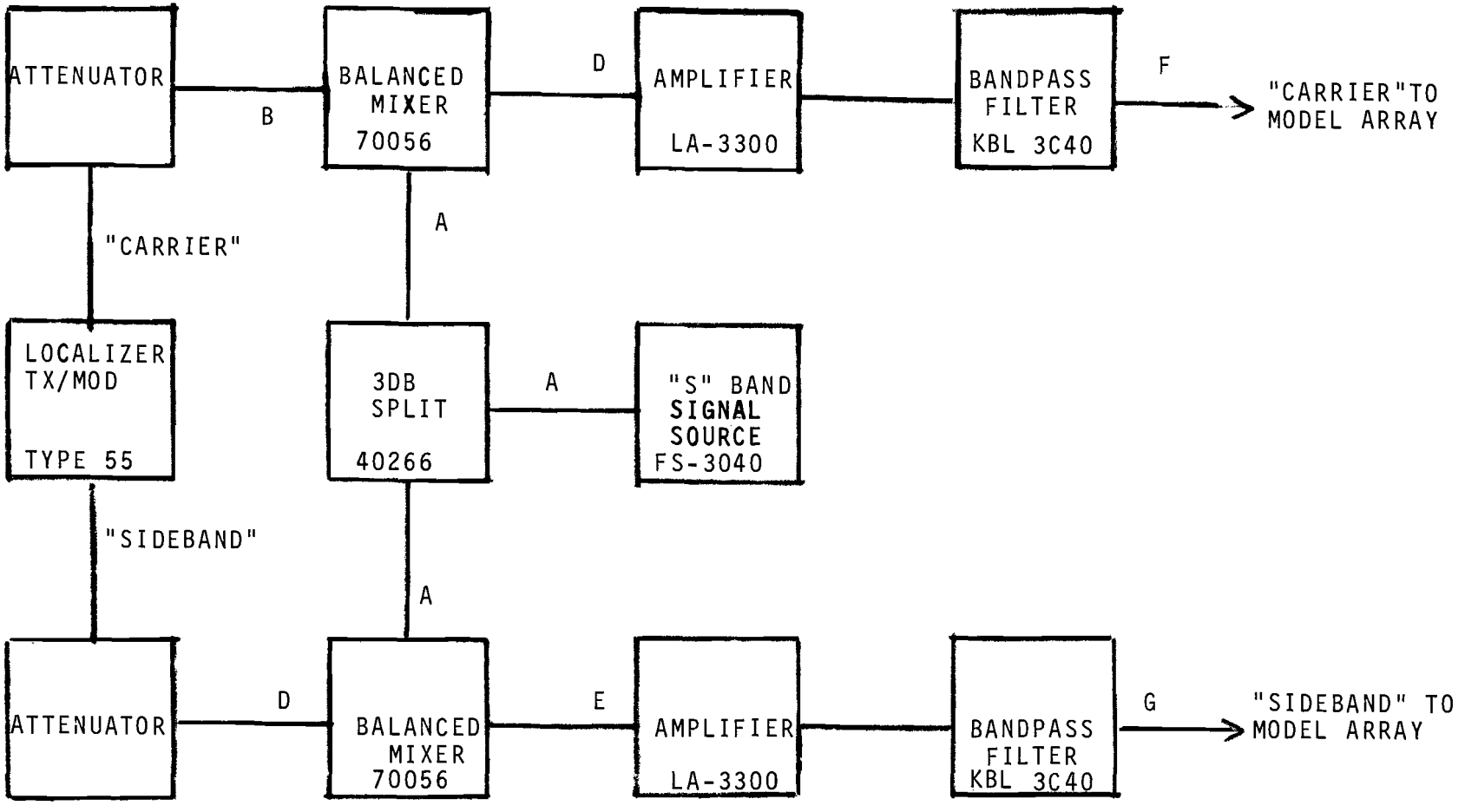


Figure 6. Localizer Block Diagram

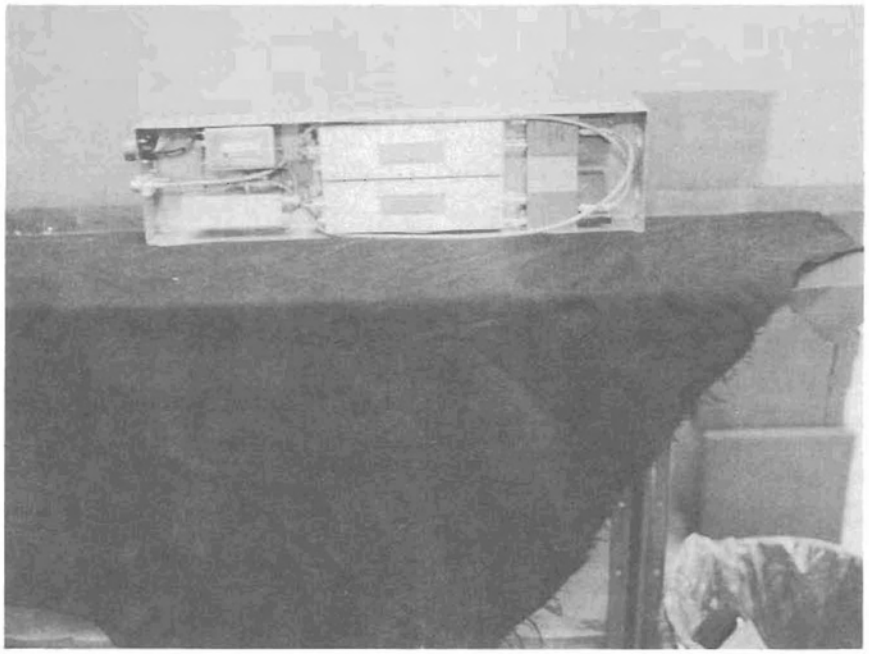


Figure 7. Localizer Up-Converter

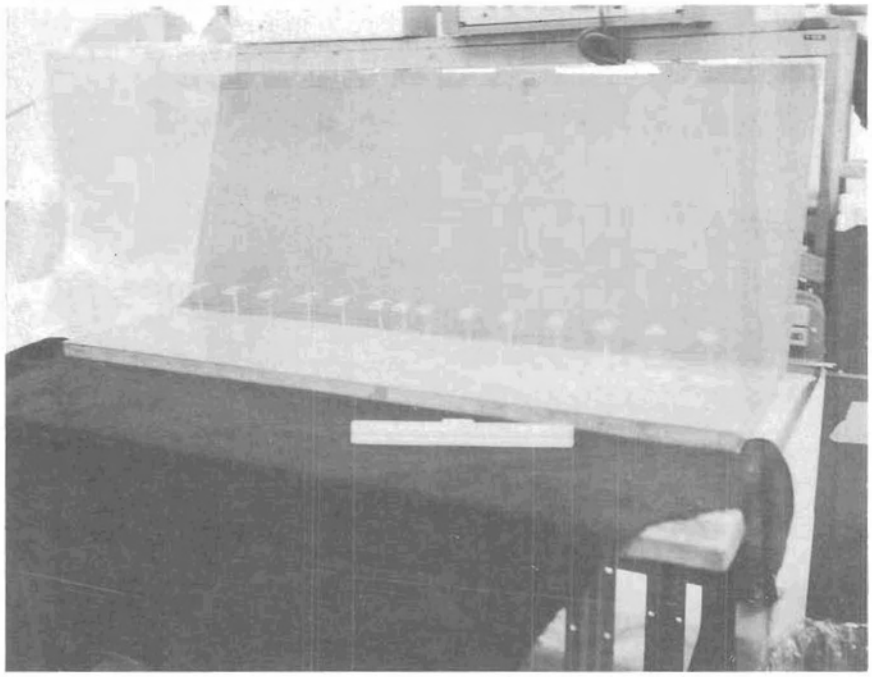
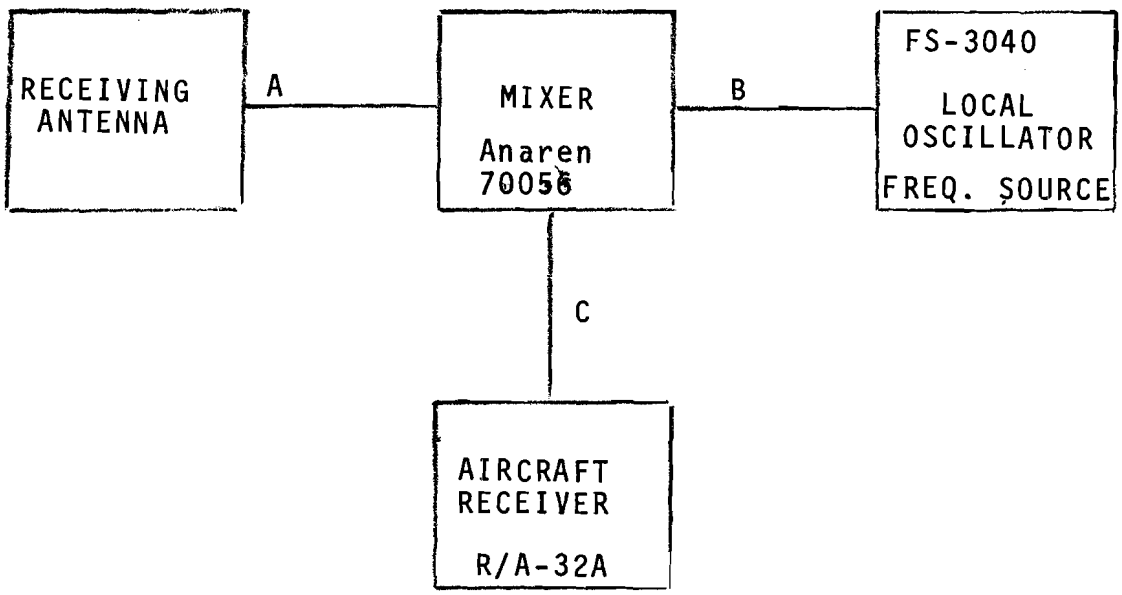


Figure 8. Localizer V-Ring Antenna Array



A - 3.303 GHz, 3.303 GHz ±90 Hz, 3.303 GHz ±150 Hz

B - 3.1929 GHz

C - 6.4959 GHz, ...

110.1 MHz, 110.1 MHz ±90 Hz, 110.1 MHz ±150 Hz

Figure 9. Localizer Down-Converter Block Diagram

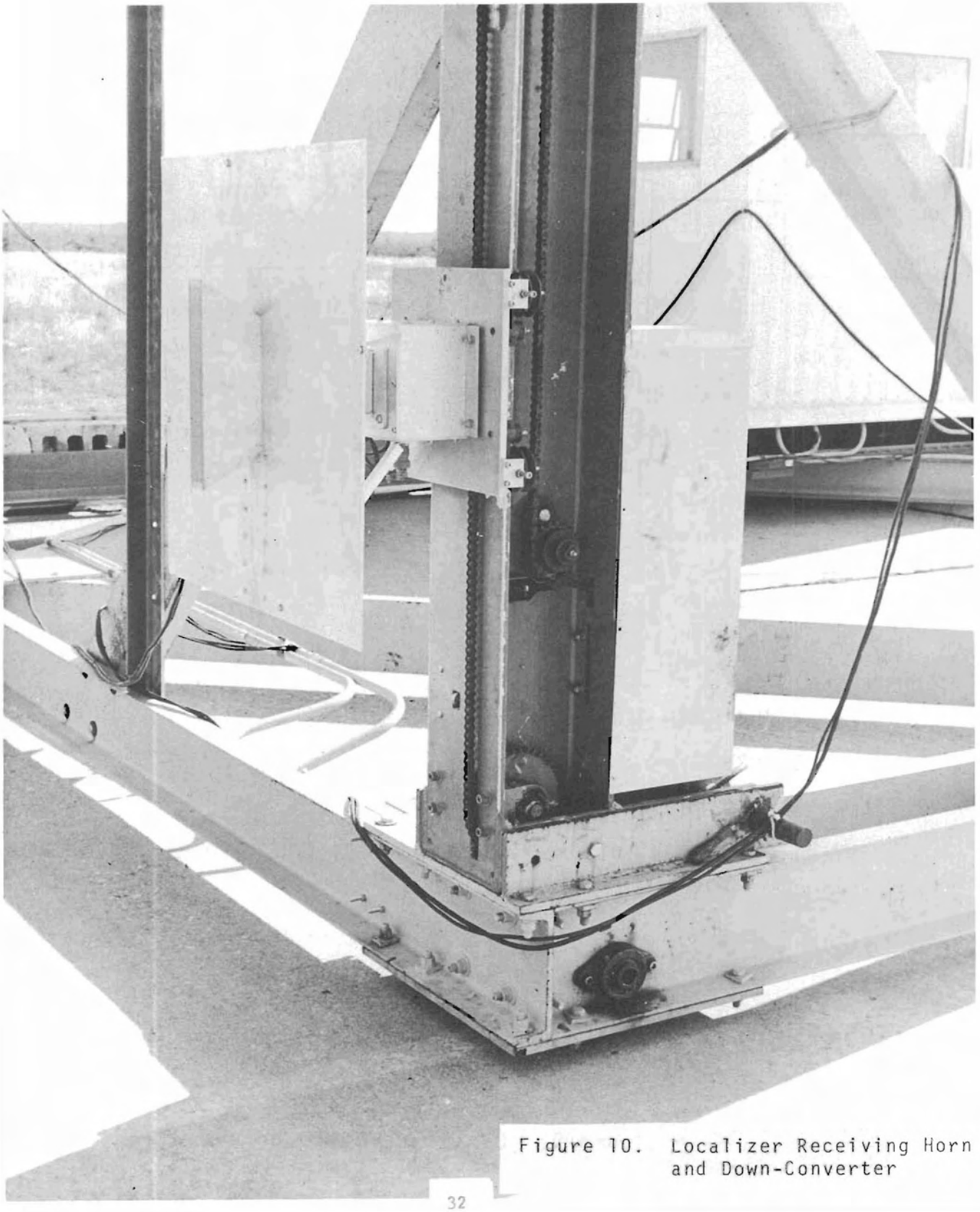


Figure 10. Localizer Receiving Horn and Down-Converter

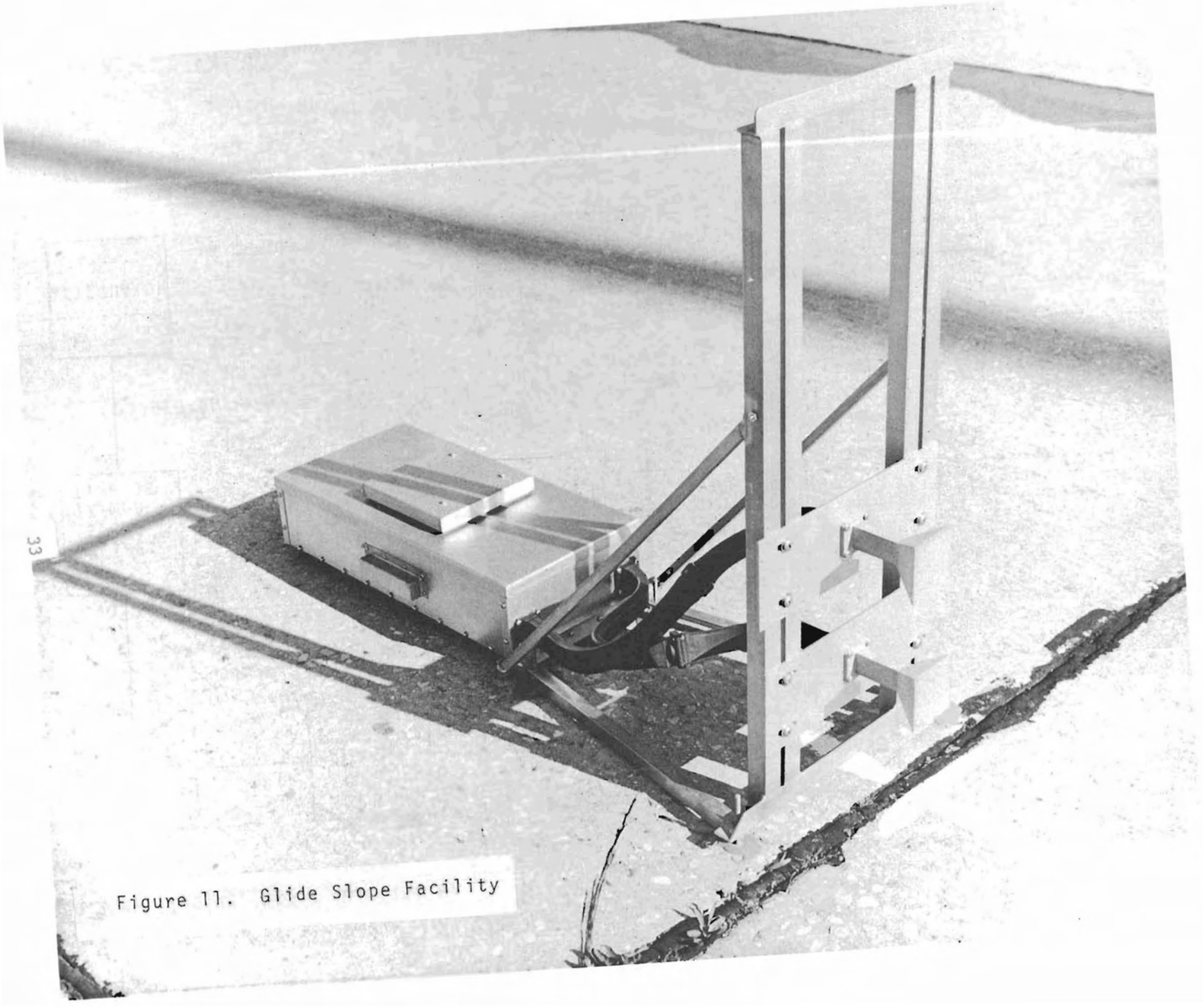


Figure 11. Glide Slope Facility

A - 9.5758 GHz

B - 330.2 MHz, 330.2 MHz ±90 Hz, 330.2 MHz ±150 Hz

C - 330.2 MHz ±90 Hz, 330.2 MHz ±150 Hz

D - A+B, A-B

E - A+C, A-C

F - A+B - 9.906 GHz, 9.906 GHz ±90 Hz, 9.906 GHz ±150 Hz

G - A+C - 9.906 GHz ±90 Hz, 9.906 GHz ±150 Hz

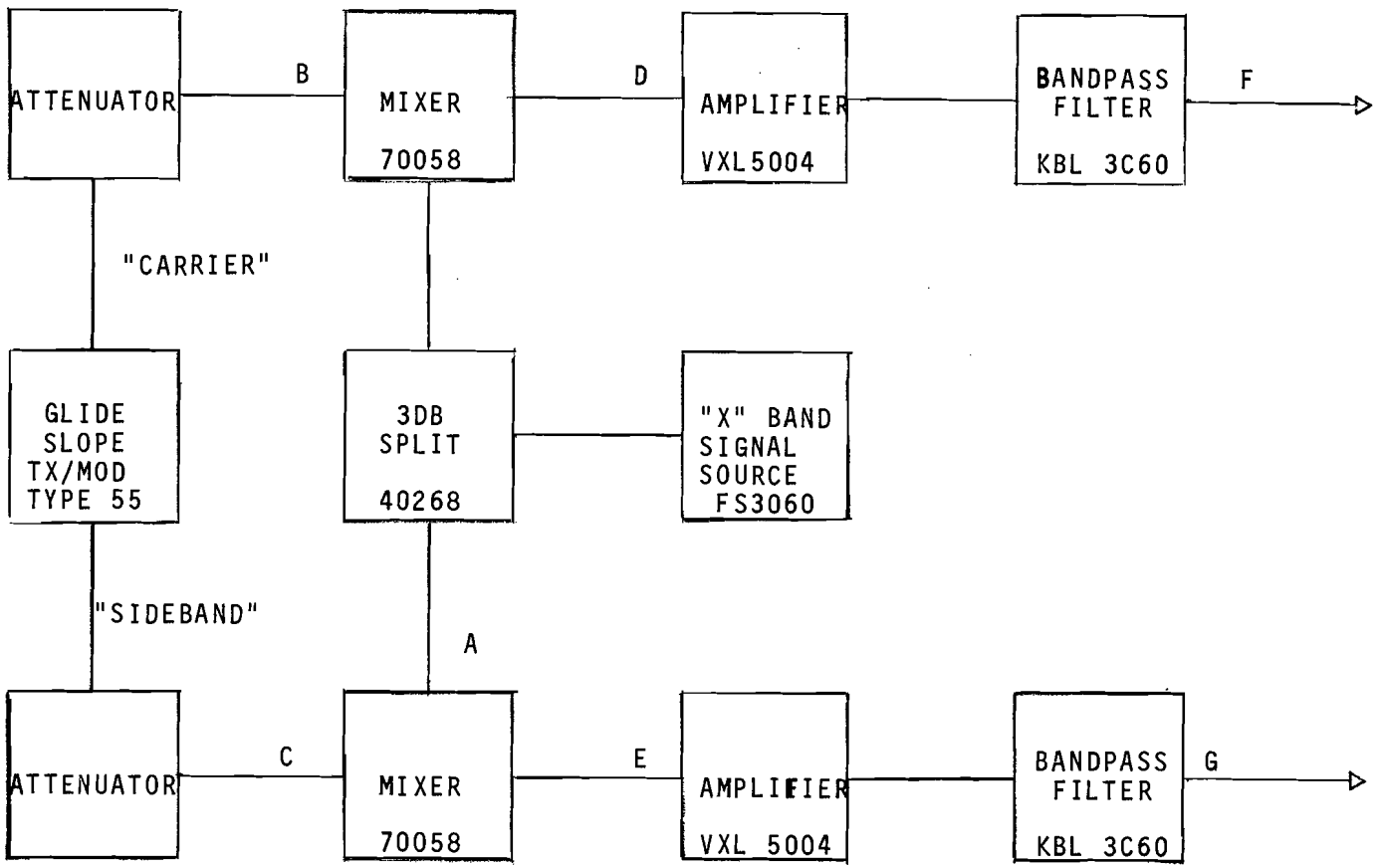


Figure 12. Glide Slope Block Diagram

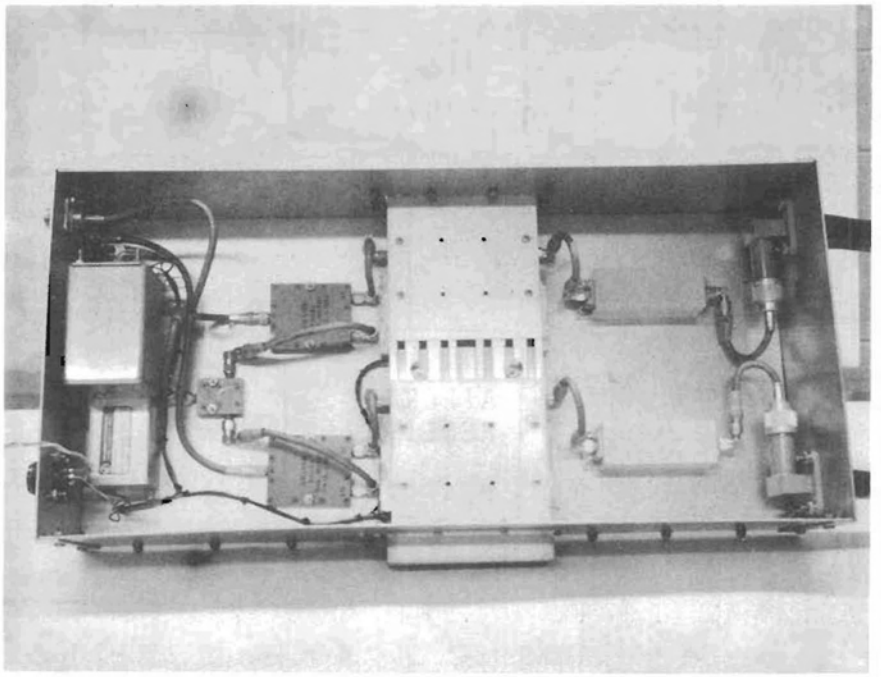
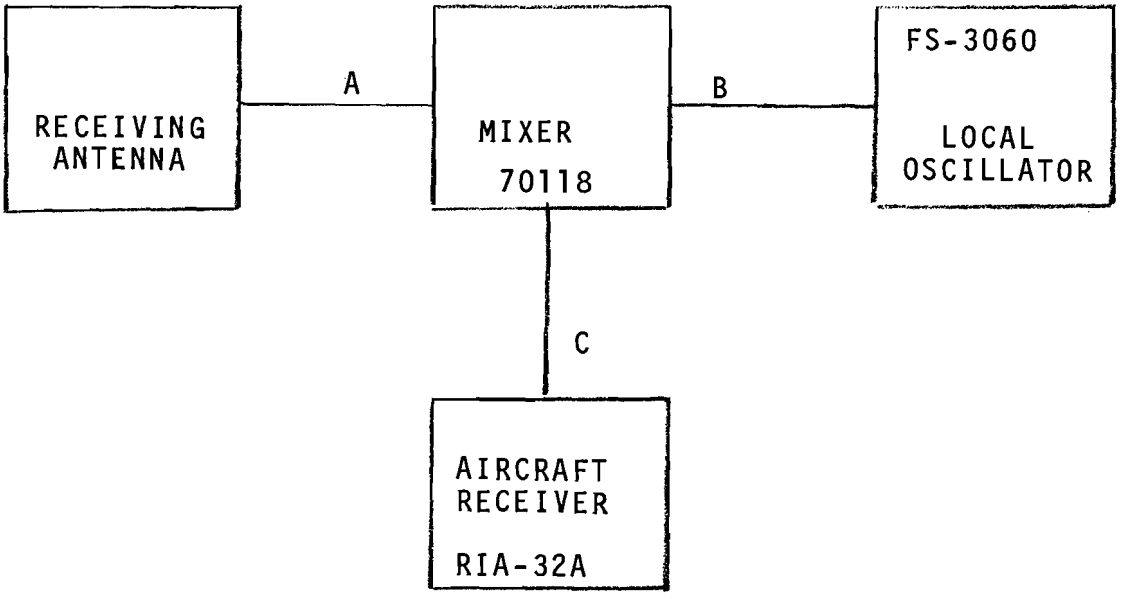


Figure 13. Glide Slope Up-Converter



A - 9.906 GHz, 9,906 GHz ±90 Hz, 9.906 GHz ±150 Hz

B - 9.5758 GHz

C - 19.4818 GHz.....

330.2 MHz, 330.2 MHz ±90 Hz, 330.2 MHz ±150 Hz

Figure 14. Glide Slope Down-Converter Block Diagram

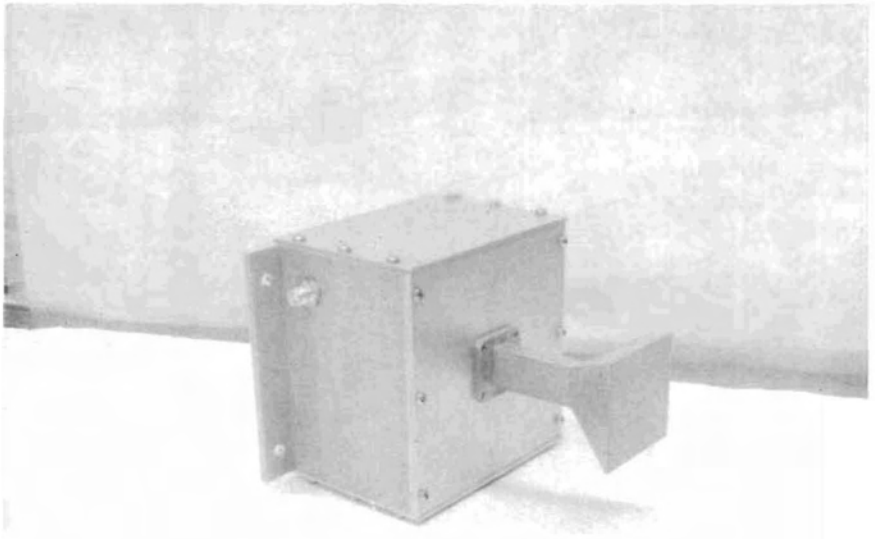


Figure 15. Glide Slope Receiving Horn and Down-Converter

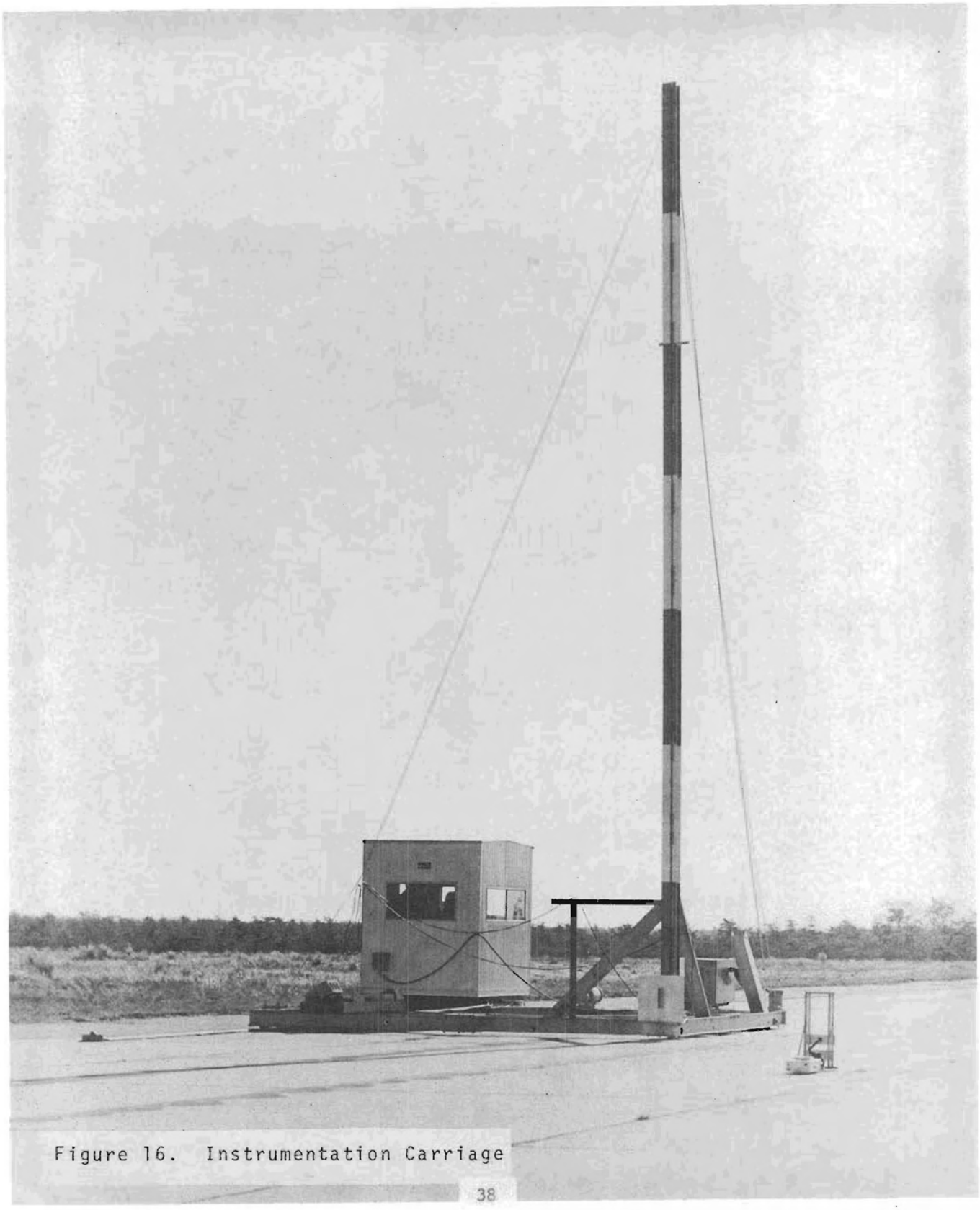


Figure 16. Instrumentation Carriage

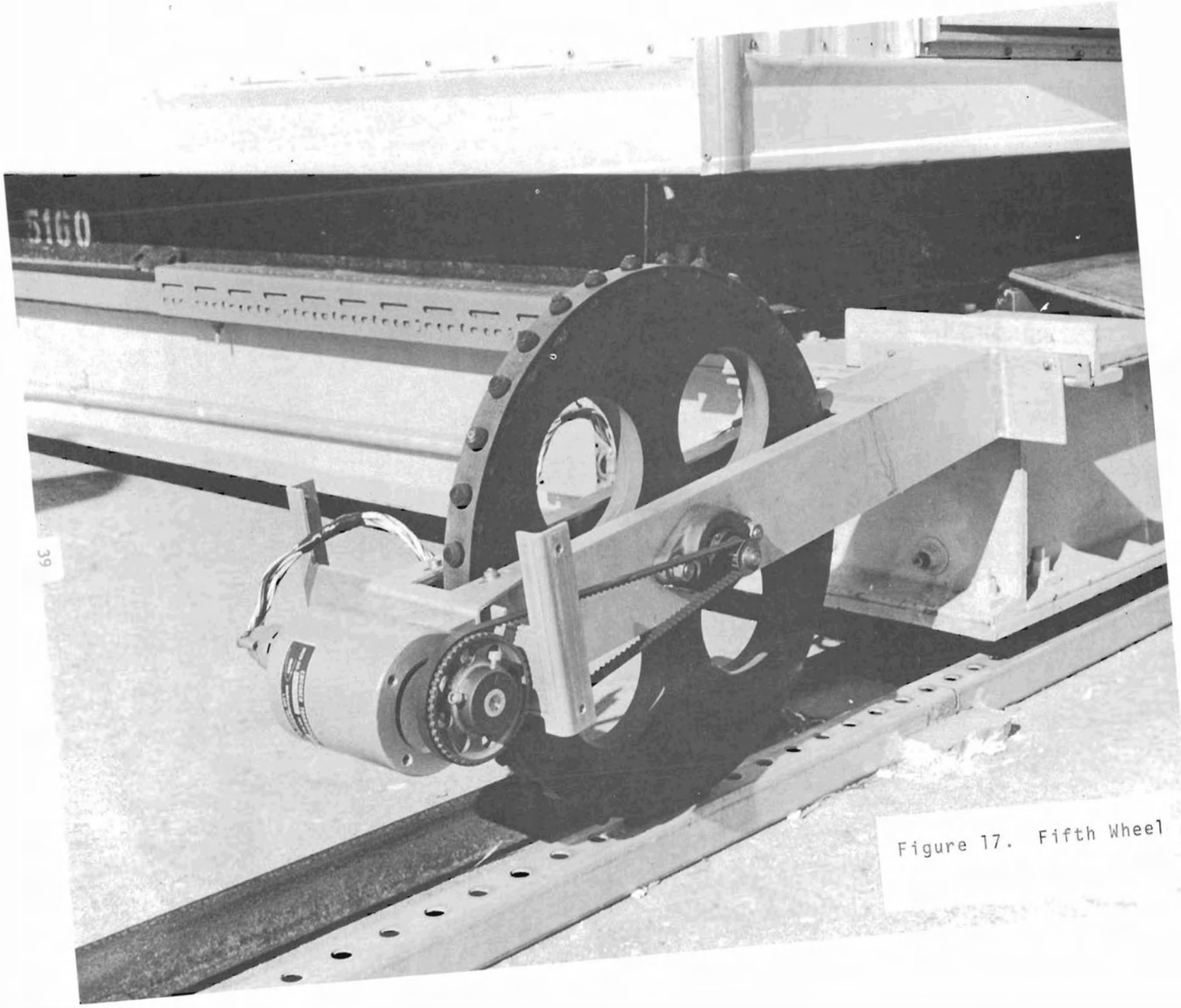
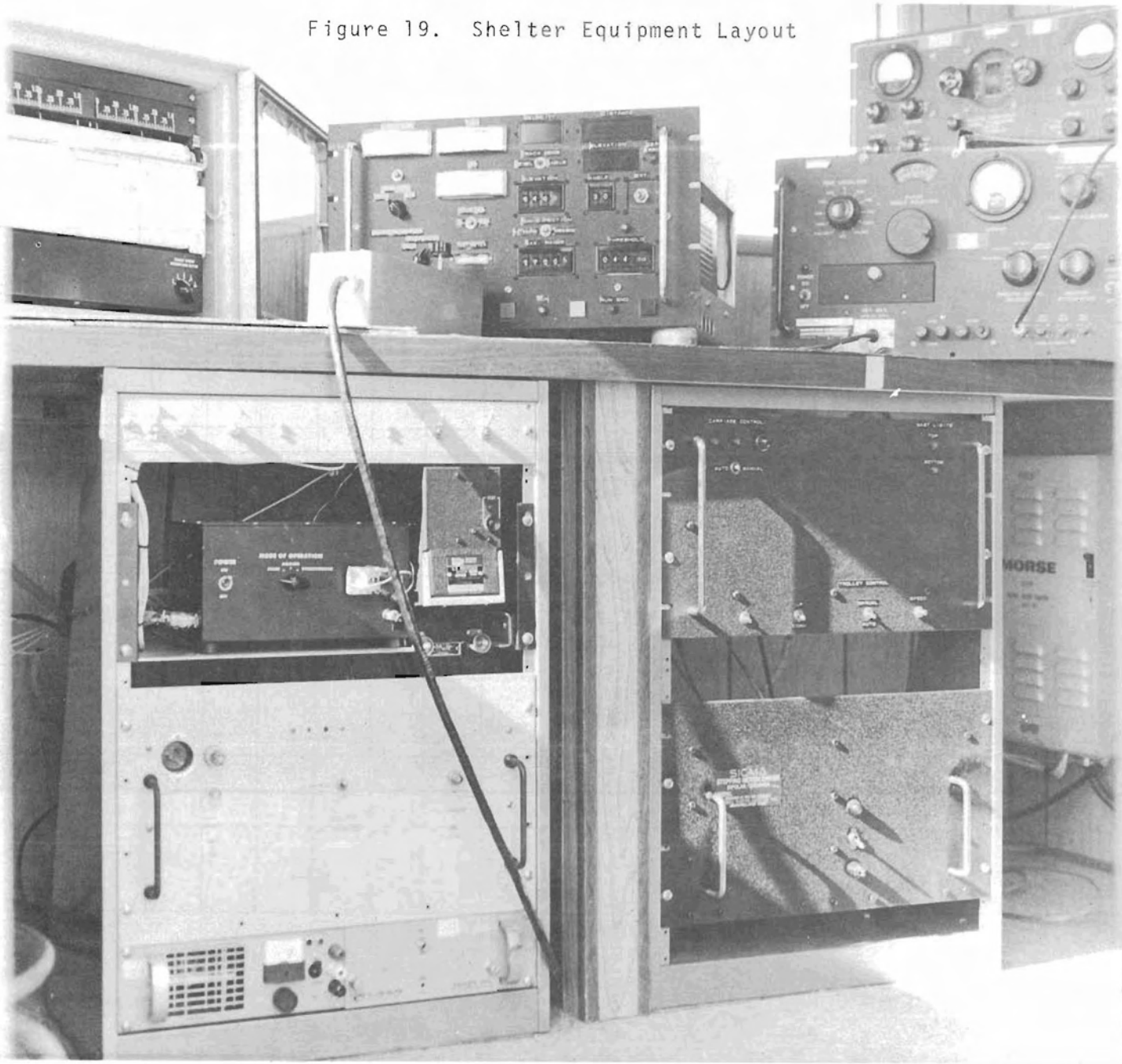
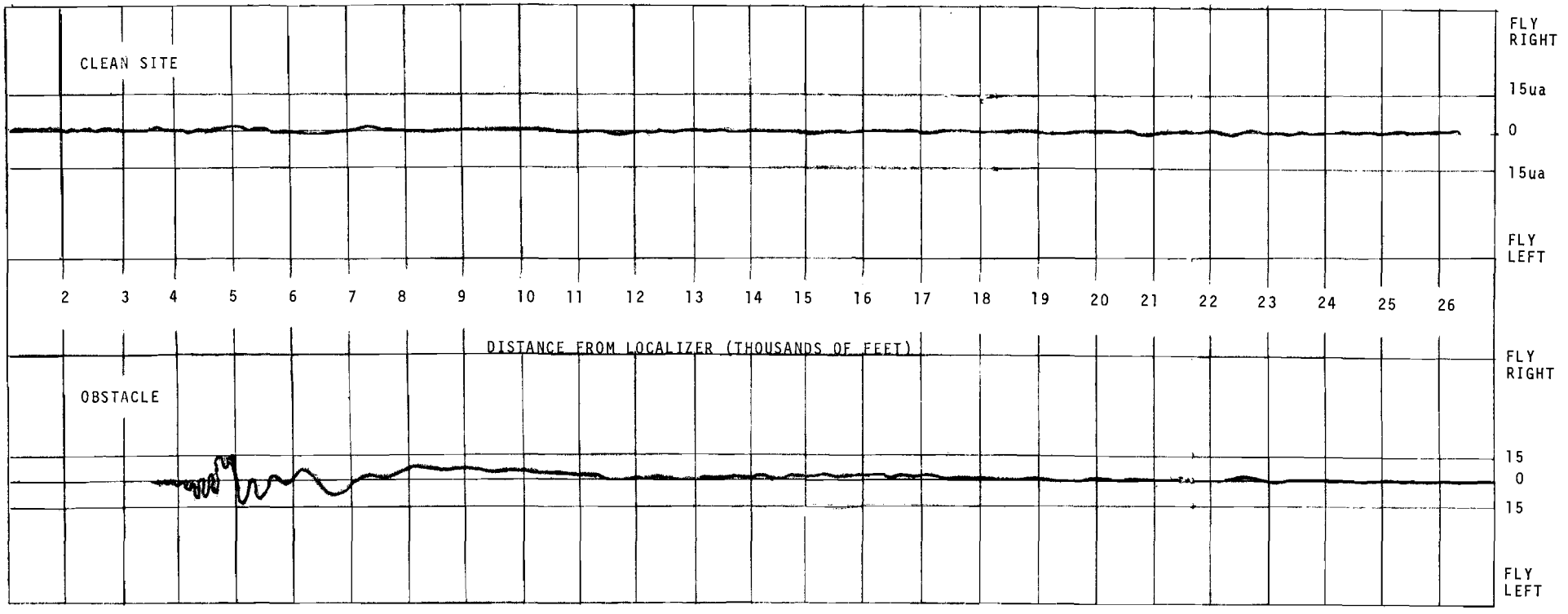


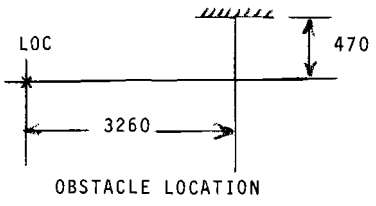
Figure 17. Fifth Wheel

Figure 18. Control Unit

Figure 19. Shelter Equipment Layout

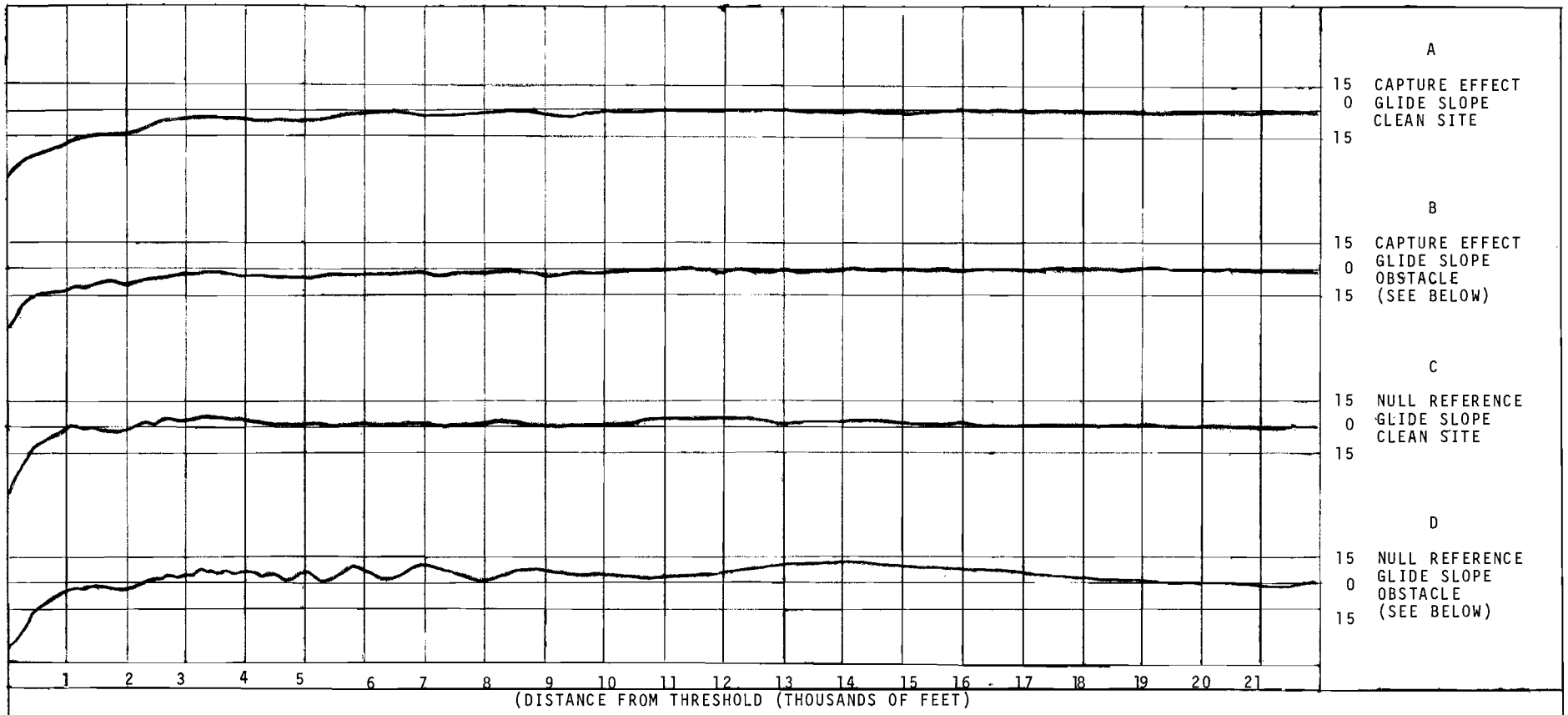


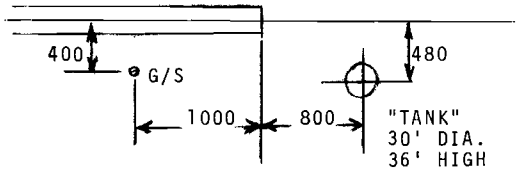




ON COURSE APPROACHES TO SCALE MODEL V-RING LOCALIZER: 3° GLIDE ANGLE TO 9,000 FEET THEN LEVEL AT 55 FEET TO STOP.

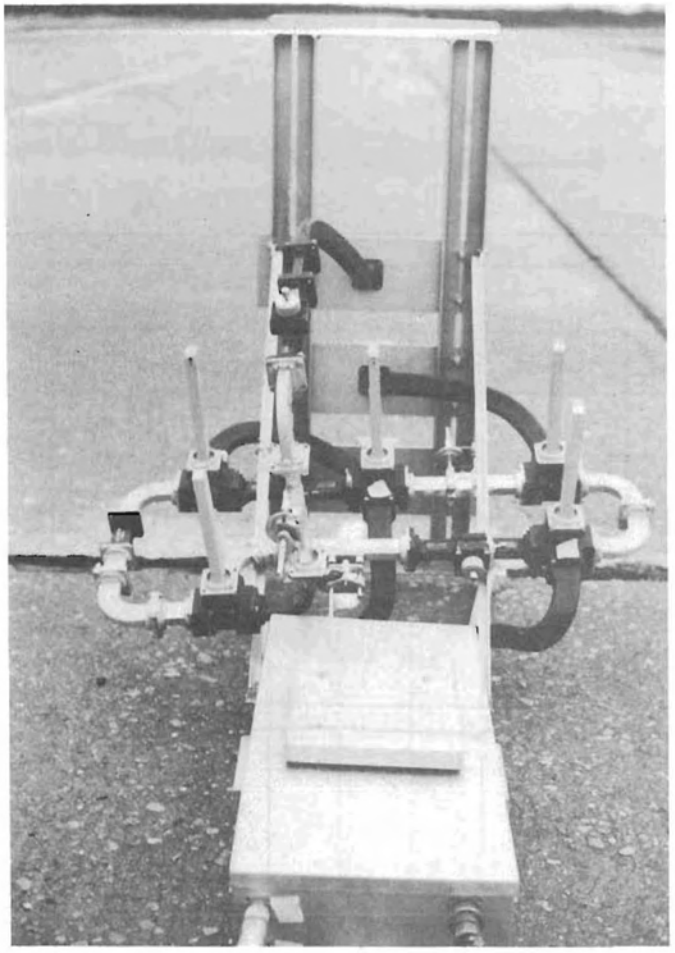
FIGURE 20.





COMPARISON OF NULL REFERENCE AND CAPTURE EFFECT GLIDE SLOPE ON-PATH APPROACHES WITH AND WITHOUT A REFLECTING OBSTACLE (CROSSPOINTER DEFLECTION IN ua)

FIGURE 21.



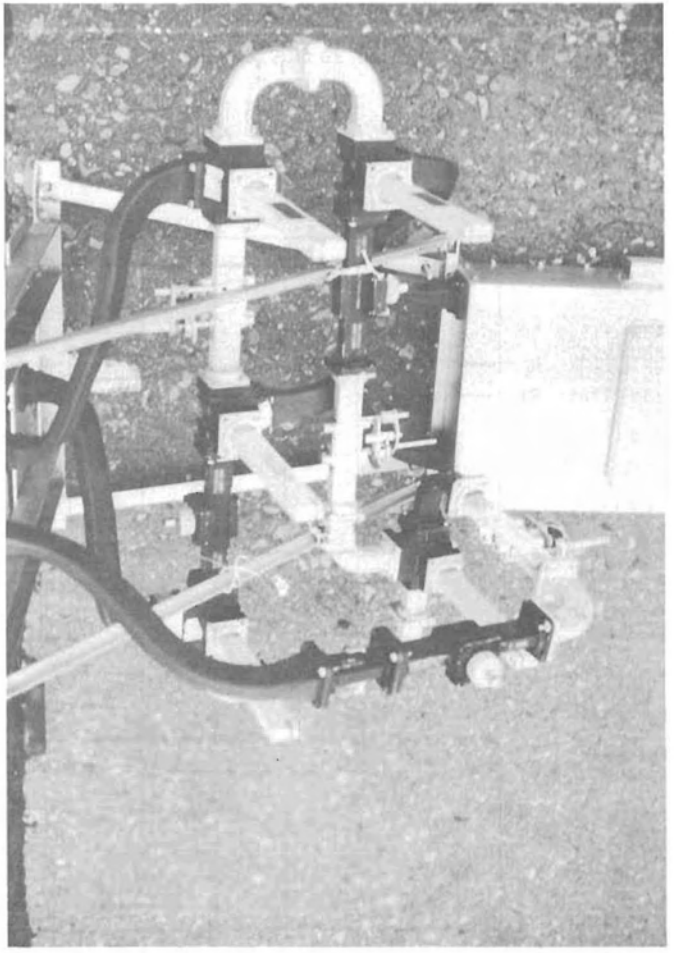


Figure 22. Capture Effect Wave Guide Network

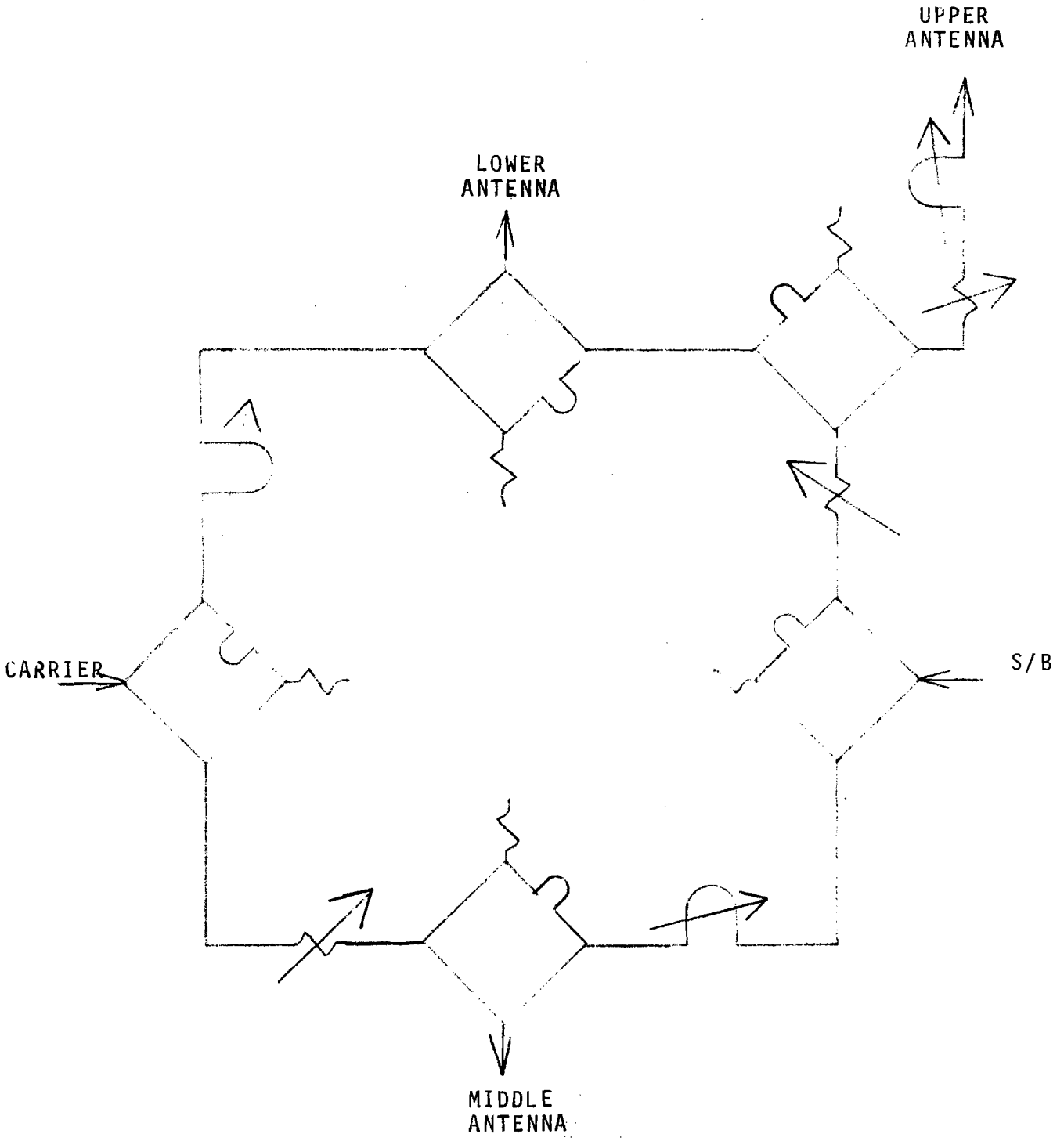


Figure 23. M-Array Combining Network Block Diagram

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