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DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Radiation Laboratory

THE EFFECT OF ALS LIGHTS ON THE ILS ANTENNA BEAM

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Final Report on ASE Contract F 203

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I INTRODUCTION

This report covers a five month study (October 1972 to March 1973) performed for ASE, Inc. under contract number F203. The objective of the study was to determine the scattering effects due to three different types of supports used for the lights in Approach Lighting Systems (ALS). More specifically, the objective was to determine the effect of the ALS supports on the Instrument Landing System (ILS) antenna beam and the results were to be used by ASE under their contract with the Federal Aviation Administration (FAA) which called for the design fabrication and installation of supports which were optimum from the standpoint of scattering effects and frangibility. The formal work statement was as follows:

1. Perform forward scattering tests on three sets of light support structures supplied by ASE.

2. Perform scale model tests with a localizer antenna on a flat terrain with a Category II Approach Lighting System.

Interest in this project results from FAA's desire to provide direct ILS information for an aircraft preparing to land on the runway in either the "forward" or "reverse" direction. For this to be possible it is necessary to have two ILS systems, one facing in each direction along the runway. This makes it necessary to install the localizer antenna system on the extended center line of the runway amid the lights of the ALS, as shown in Fig. 1. This raises the obvious question -- will the light support poles distort the antenna beam of the localizer antenna and introduce bearing errors in the information to be used by the pilots? The localizer operates at 108-112 MHz and it radiates a dual beam pattern which provides guidance in the horizontal plane. It was reasoned that the error would be negligible if the forward scatter due to the ALS supports in front of the antenna was very small. In our study we measured the forward scatter due to three light support systems, one of which had been designed to cause minimum scattering.

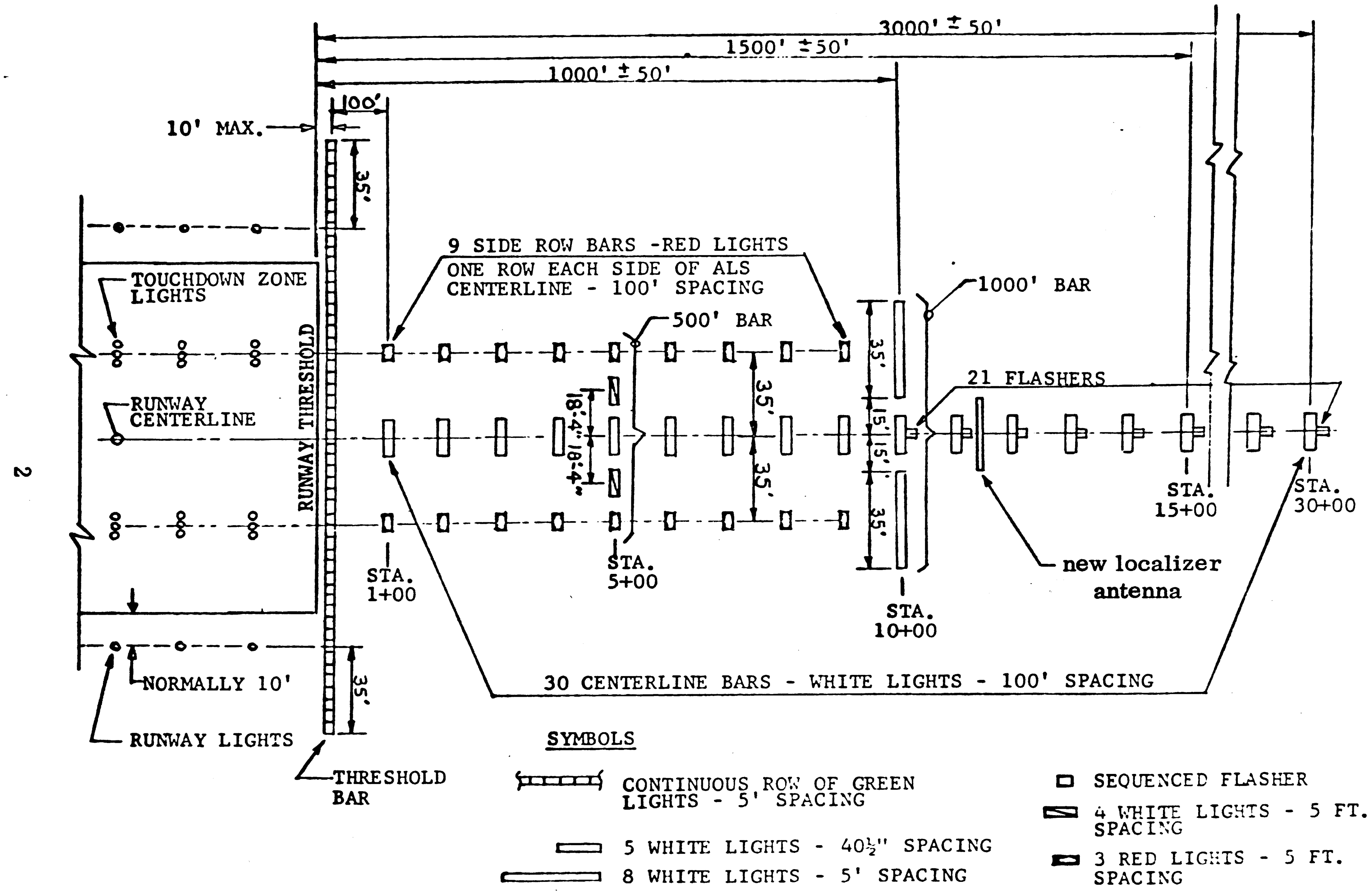


Figure 1: Shows Localizer Antenna Location Amid ALS Lights

Although not pertinent to our scattering study, it should be noted that the ALS supports were required to have a frangible construction. The intent, of course, was to prevent serious damage to the aircraft in case of a collision with ALS poles.

In Section II descriptions are given of the three ALS support systems. As would be expected from the work statement, the experimental work divides itself into two major parts — one involving a model study and the other using full scale light supports. The model experiments and results are discussed in Section III and the full scale work is discussed in Section IV. In Section V we discuss the agreement or lack thereof between the two sets of measurements and we present some concluding remarks.

II DESCRIPTION OF ALS SUPPORT SYSTEMS

Under terms of our agreement with ASE we were to measure the scattering from three designated light support systems. We refer to these as the Canadian poles, the Belgian poles and the ASE poles, indicating country of origin for the first two types. The ASE poles were designed by ASE, Inc. for the present FAA objective. The full scale poles which we measured were all approximately 20 feet in height (less one foot for insertion in the ground support receptacle). In an actual installation the pole height varies from 19 feet in the vicinity of the ILS antenna (Station 1118) to 0.5 foot at a distance of approximately 900 feet in front of the antenna (Station 200; refer to Fig. 1).

2.1 The Canadian Supports

The Canadian poles or towers consist of two vertical sections one above the other and each triangular in cross section. A pipe 2.375 inches in diameter and about 4 feet long extends 21.5 inches above the top of the upper section and its extension can be adjusted, thus controlling the overall height.

The height of the lower section is 90 inches and its triangular cross section is 9 inches on a side. The three vertical pipes of this section are 0.54 inches in diameter. Rigidity is provided by three 0.305 inch diameter truss members which weave back and forth between the vertical members on each of the three sides of the tower. The spacing between points of contact of the truss with the vertical pipe is about 9.5 inches and at these points the truss is crimped to the vertical member. The second section of the tower is 119 inches high and is the same in design as the first section except that the spacing between the vertical members is reduced to 6.5 inches. A photograph of six towers assembled for a full scale test is shown in Fig. 2. Standard ALS lights are mounted on top of each pole.

2.2 The Belgian Supports

The Belgian supports or towers are in the form of tapered triangular masts. The three vertical members are hollow tubes 0.978 inches in diameter. Center

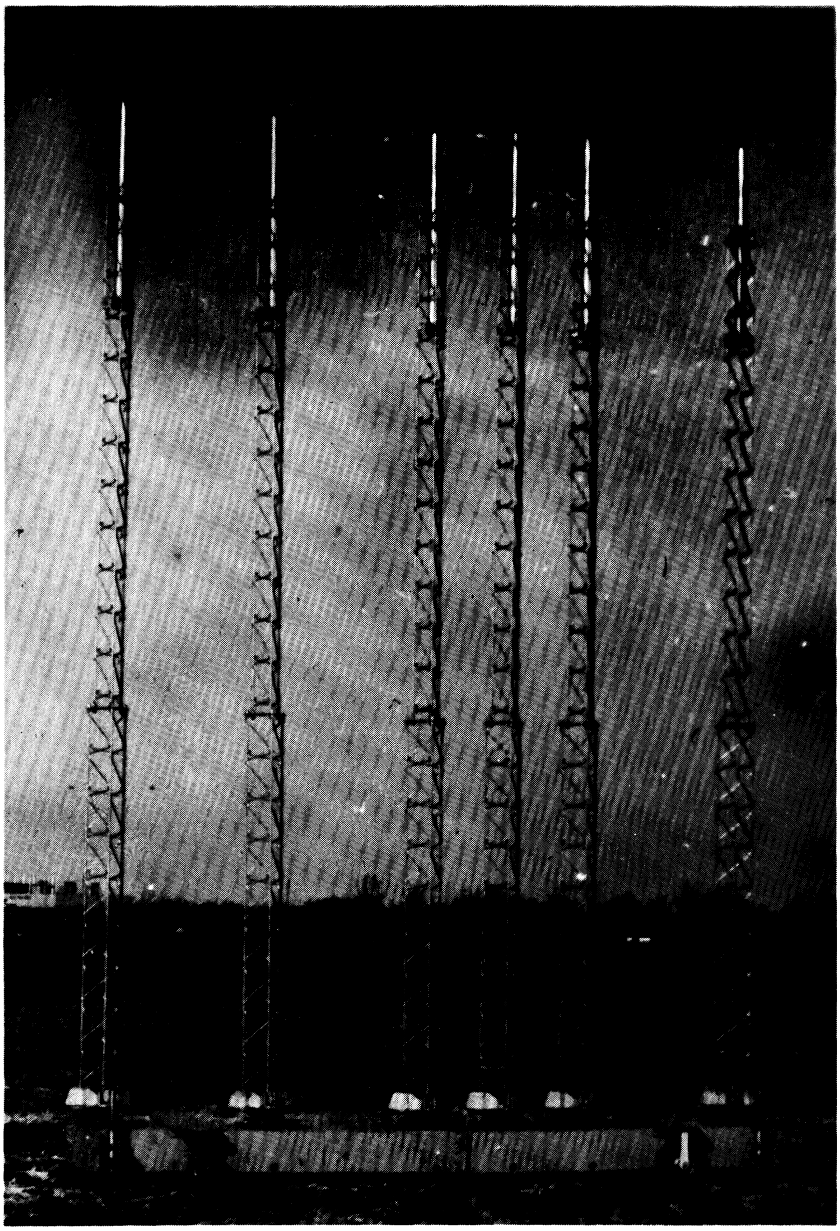
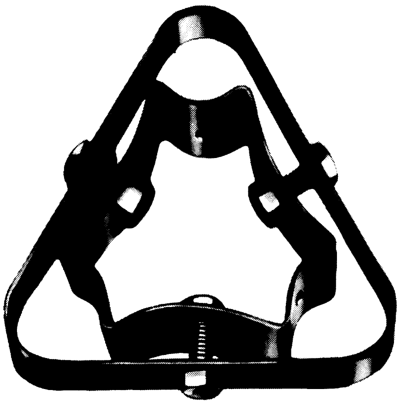
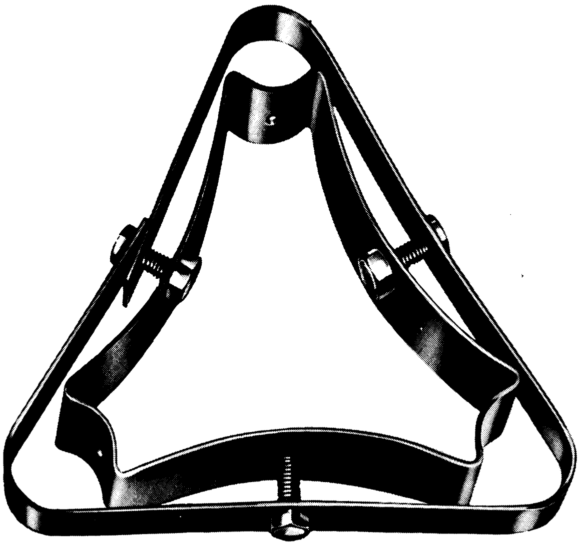


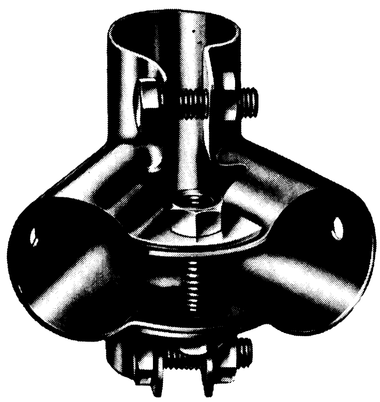
Figure 2: Canadian Light Supports as Arranged in the Full Scale Measurements



Part 3 - Stay Triangle - Small



Part 4 - Stay Triangle - Large



Part 5 - Bracing Clip - 3 used with three interconnecting tubes 0.978" in diameter.

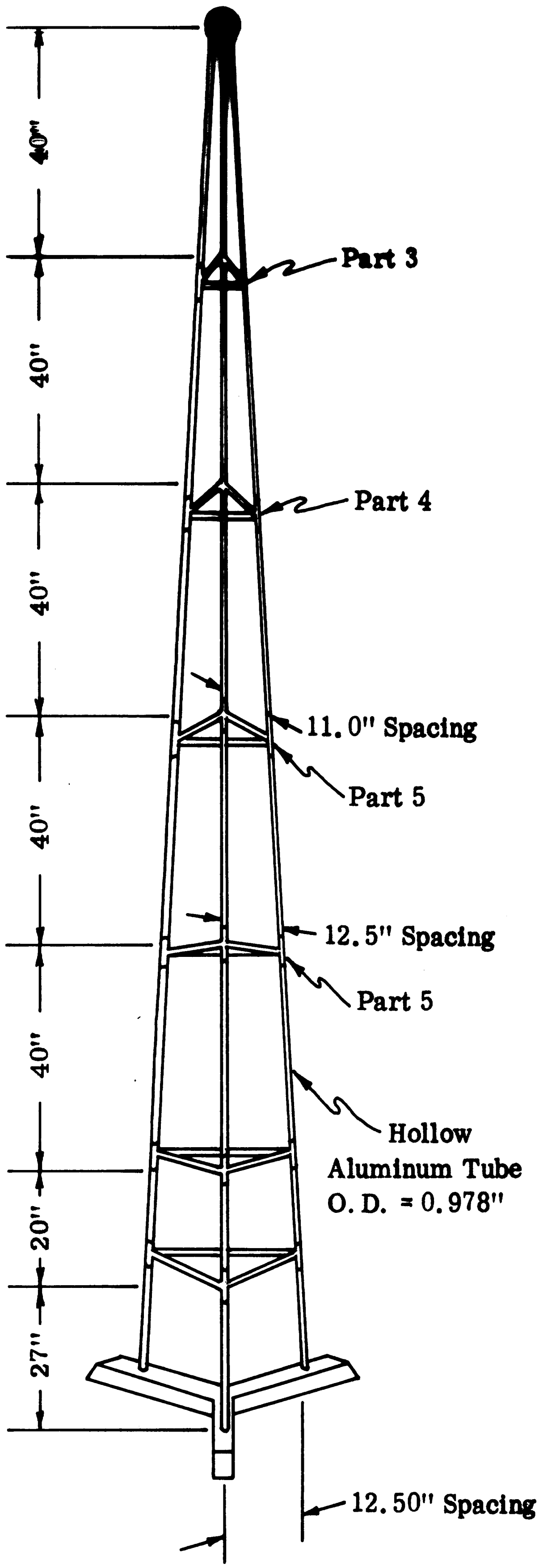


Figure 3: Sketch of the Belgian Tower with Photographs of Cross Bracing Parts.

to center spacing at the base is 12.5 inches; this tapers to 1.25 inches at the top. Horizontal ties or cross members are used at intervals of 39 inches. A sketch of the mast with photographs of the cross members is shown in Fig. 3.

2.3 The ASE Supports

The ASE supports consist of a single hollow tapered pipe 20 feet in length. The base diameter is 4.5 inches O.D. There is no taper in the lower section (11 feet) but there is a smooth taper from a diameter of 4.5 inches to 2.875 inches in the upper 9 feet. The ASE pole is shown in Fig. 4.

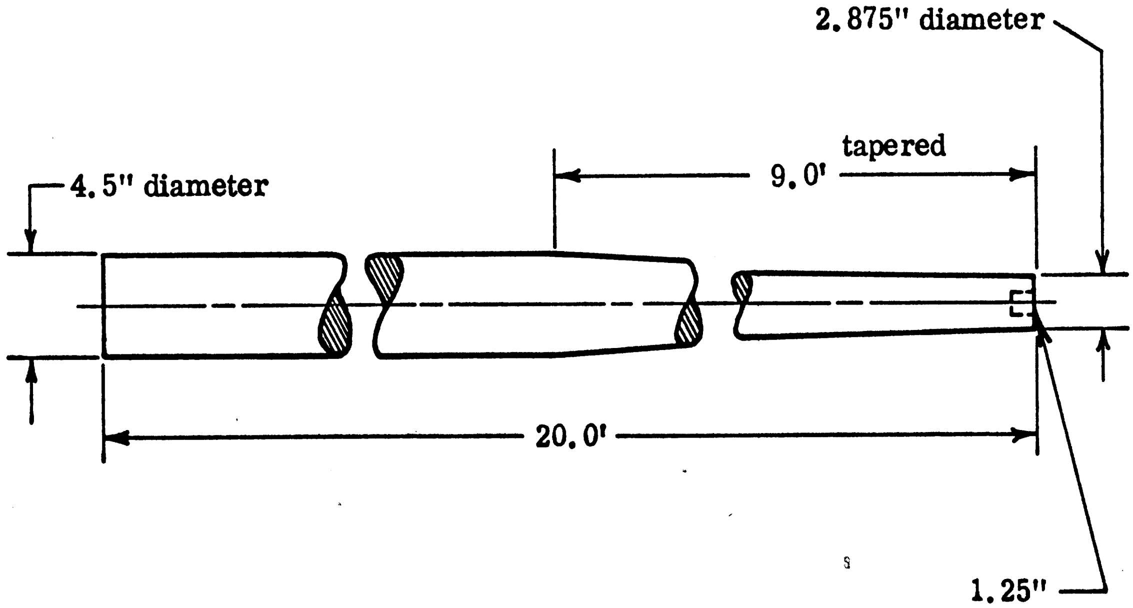


Figure 4: Sketch of ASE Pole

III SCALE MODEL MEASUREMENTS

3.1 Introduction

As the scale model measurements were made first it is appropriate that they be discussed first in this report. It was agreed with ASE and so stated in our proposal that scale model measurements would be made with only two of the three support pole designs. The Belgian and the ASE poles were selected for this study.

The antenna and pole geometry to be studied is based on the arrangement shown in Fig. 1. The localizer antenna to be simulated was designed by the Texas Instrument Company. It is 178 feet long and 18 feet high and it operates in the 108 to 112 MHz band. As indicated in Fig. 1, it is located on the runway center line, at station 1118. In front of the antenna at station 1100 is a set of six poles, each supporting an ALS light which is 17.1 feet above the ground. These poles are on a line perpendicular to the runway center line and five of them are spaced 40.5 inches apart. The sixth pole supports a flasher light and it is located between poles 2 and 3. At station 1000, there is a row of 22 poles and lights, the height here being 15.2 feet. As shown in Fig. 1, the 22 lights include the six center lights plus eight additional lights on each side of the center line. These eight lights are spaced 5 feet between centers and they are centered on a line parallel to the center line at a distance of 35 feet. A row of eleven lights is located at station 900 and additional rows of eleven lights are at 100 foot intervals beyond that. The trend of decreasing height continues with the height at station 900 being 13.3 feet and the height at each successive 100 foot station being 1.9 feet less.

In our model measurements, we were to seek to determine the effect of the rows of poles in front of the Texas Instrument (TI) antenna on bearing information as seen by an aircraft using the localizer approach signal. The model of the TI antenna and the various rows of lights rested on the bare concrete floor of our 100 foot long anechoic room. The aircraft is assumed to be approaching at a 3^o

angle of descent and is simulated by a distant antenna 3^{o} above the plane of the floor.

3.2 Choice of Scaling Ratio

The use of small scale models in antenna and radar scattering measurements has been accepted and practiced for many years. The theoretical justification for scaling has been documented by several workers, for example, by Sinclair (1948). In the present measurements, it was necessary to reduce the size of the antennas, the scatterers and the distances involved to a point where they would be compatible with the space available in the anechoic room. It was important also that the size would not be reduced to such an extent that dimensional tolerances would be too difficult to maintain. The room dimensions are 100 by 30 by 15 feet high. Along with the size reduction, it is necessary to increase the operating frequency and the increase must be by the same scaling ratio. Thus the size of the scatterer, measured in wavelengths, would be the same.

Our choice of the scaling ratio was determined largely by the far field requirements of the localizer antenna. The far field is commonly given as $2D^2/\lambda$ where D is the maximum aperture involved. The aperture of the localizer antenna is 178 feet or 20λ at 110 MHz. Thus $2D^2/\lambda$ is 800λ. We selected a wavelength of 0.1 foot, the frequency is 9836 MHz and the scaling ratio is then 110 MHz/9836 MHz or 0.011. It seemed feasible to scale the antenna and scatterers down in size by a factor of 0.011 and so this scaling ratio was adopted.

3.3 Forward Scatter Measurement Equipment and Techniques

The objective in the forward scatter measurements is to determine the relative amount of energy scattered in the forward direction by the various scatterers when they are illuminated by the beam from the localizer antenna. The difficulty in this measurement is that one must measure the small scattered signal in the presence of the large signal due to unperturbed localizer beam. This is accomplished by feeding the received signal (signal B) into a mixer arrangement where it can be cancelled by signal A directly from the source. Signal A must be equal in amplitude but opposite in phase to signal B. A schematic of the equipment arrangement is shown in Fig. 5. The system is similar to that used by Hiatt et al (1960). It is important

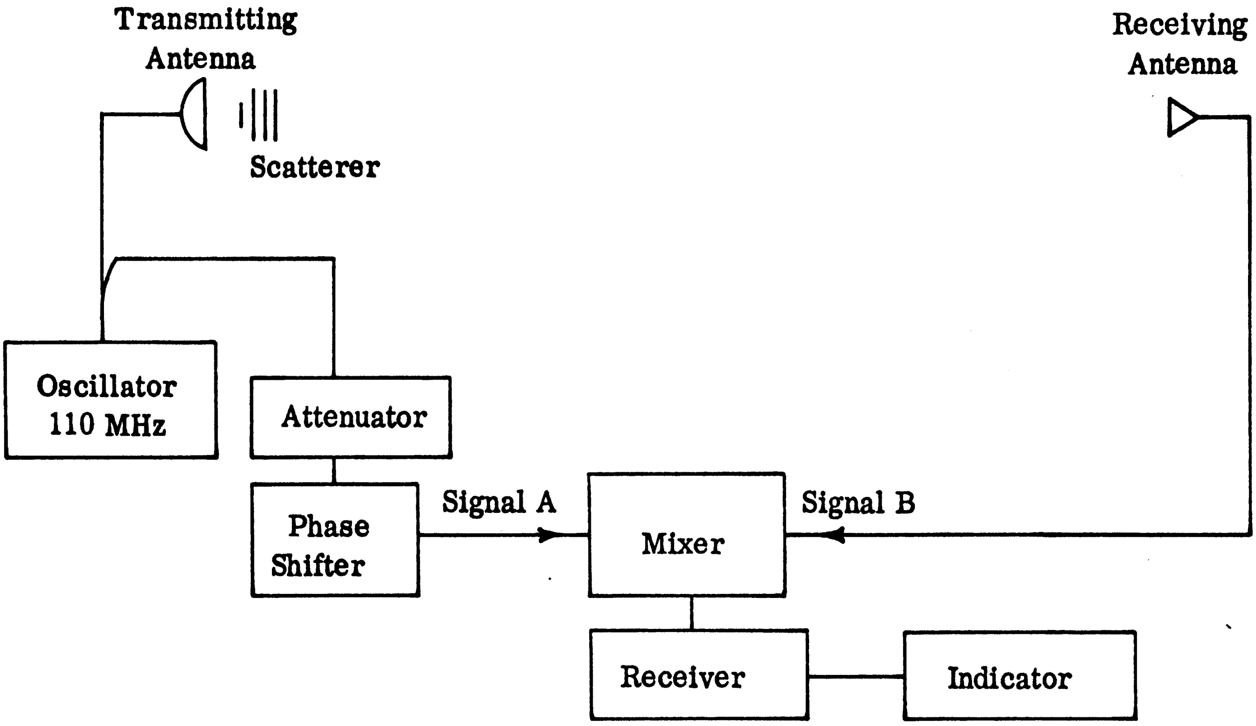


Figure 5: Schematic of Equipment for Forward Scatter Measurements

that the frequency be quite stable since otherwise signal A will not maintain the proper phase and amplitude to cancel signal B. To obtain this stability, the oscillator is phase locked to a crystal controlled stable source. To obtain the needed sensitivity a microwave superheterodyne receiver was used. Waveguide was used for all major transmission line runs to minimize loss due to attenuation.

As a part of our modeling arrangement the transmitting antenna must simulate the localizer antenna. We chose to do this by using a half pillbox antenna with an aperture 20λ (23.40 inches) wide by 1.98λ (2.38 inches) high. Since the pill-box antenna generated a plane wave at its aperture and since its aperture was identical to that of the localizer antenna in terms of wavelengths, it was considered to be a proper model. For the receiving antenna, a waveguide horn with an aperture 6.5 by 8.0 inches was used; the horn was at a distance of 55 feet and at a height so as to be 3^{o} above the room floor. The transmitting antenna and the various scatterers were placed directly on the floor. Both antennas were aligned for horizontal polarization. A photograph of the equipment arrangement for the model measurements is shown in Fig. 6. Several of the components are identified. The receiving antenna rests on the styrofoam cone in the background but cannot be seen as it blends into the background. Eight rows of the ASE poles are seen in this photograph.

3.4 Models

The Belgian models were scaled down versions of the full size towers. Wires, 0.010 inch in diameter were used for the vertical and horizontal members. Only the two lower cross supports were included. All joints were soldered. The lights were simulated by 0.080 inch diameter spheres. A close up view of six towers is seen in the foreground of Fig. 7. They are resting on a strip of styrofoam as they did in the measurements.

The ASE models are shown on the long styrofoam strip in Fig. 7. It proved to be costly and difficult to make an exact model of the ASE pole with a base section 0.050 inch in diameter and a top section that tapered to 0.030 inch in diameter. One such model was made. Measurements showed that with horizontal illumination the difference between its forward scatter characteristics and that of a straight wire 0.050 inch in diameter was insignificant. It was decided, therefore, that straight 0.050 inch wires of the proper length would be used for the ASE poles. The results thus obtained should be considered conservative since the non-tapered model would be expected to scatter more than a true scale model. Spheres, similar to those used with the Belgian poles, were used to model the lights.

Also shown in Fig. 7 are the two reference scatterers used as standards in

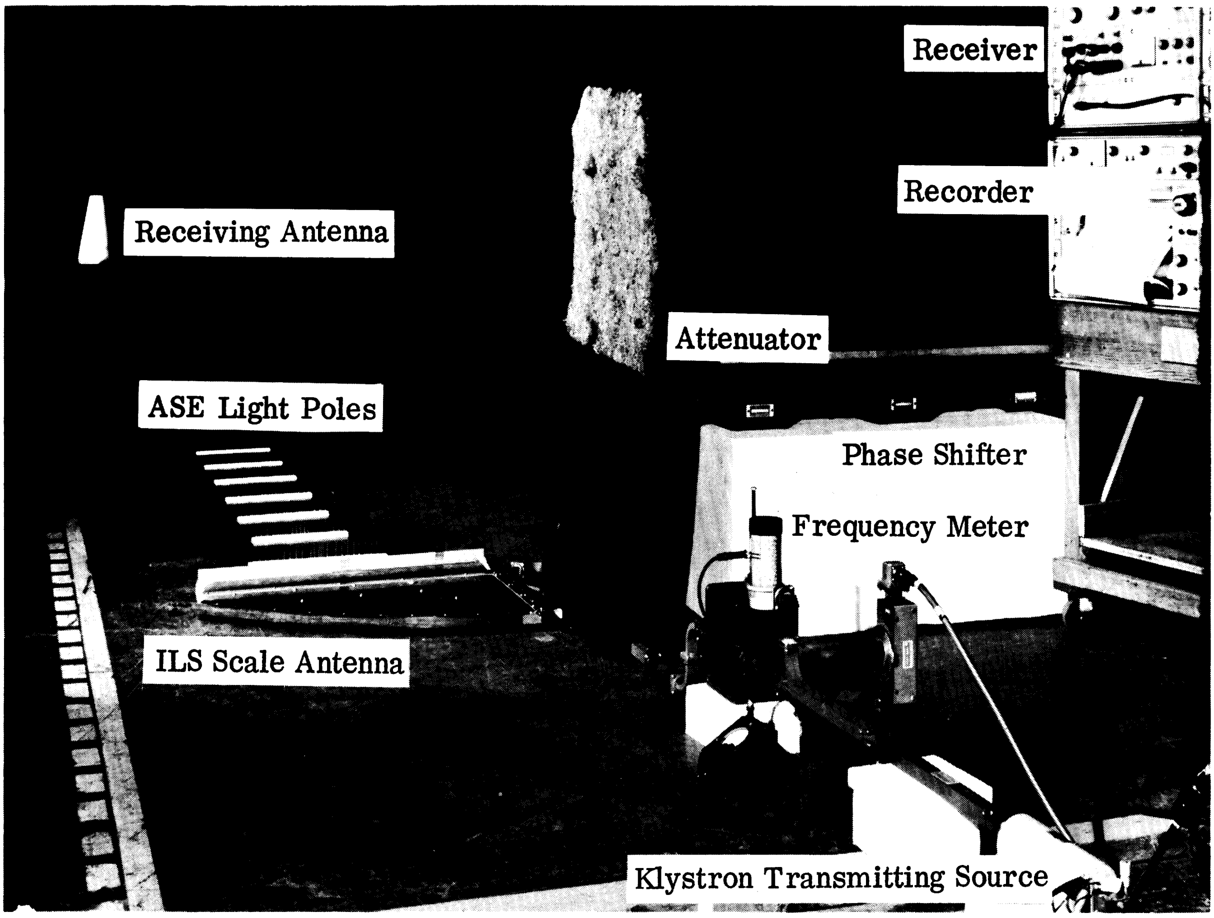


Figure 6: Photograph of Forward Scatter Measuring Equipment in the Anechoic Room.

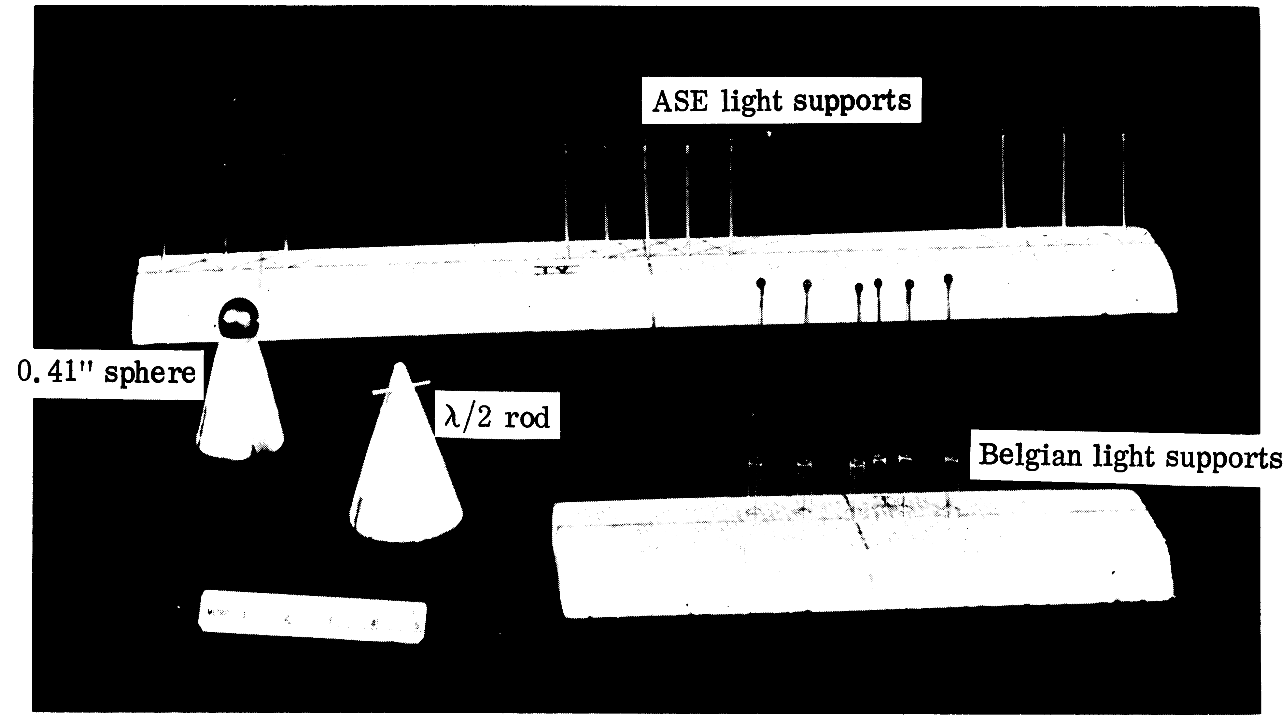


Figure 7: Models of Belgian and ASE Light Supports; also shown are the $\lambda/2$ rod and the 0.41" sphere used as reference scatterers.

the measurements. The horizontal wire, 0.050 inch in diameter and 0.600 inch or approximately $\lambda/2$ long, was used in all of the model measurements. In a few cases the 0.410 diameter sphere was also used as a standard. When used, all poles were removed and the reference was positioned at the point occupied by the first row of poles — at a height of 1.2 inches above the floor.

3.5 Forward Scatter Measurements and Results

With the equipment arranged as in Figures 5 and 6 the first step is to balance out the received signal when no scatterers are present. This is done by a careful adjustment of phase shifter and attenuator that controls signal A. This balance remains at or below the noise of the system for several minutes when the system has stabilized in temperature and frequency. The models were then placed in the positions indicated in Fig. 1 and as shown in Figures 8 and 9. In all cases, the model poles or towers were supported in a thin styrofoam strip. Early in the program we were able to show that the foam strips of the type we used added no measureable contribution to the forward scattered signal.

It was shown also in the early measurements that the level of the forward scattered signal changed very little when additional rows beyond the fourth were added. For this reason and also because the models of the Belgian towers were quite time consuming to fabricate, we made only enough of these models for the first four rows. This did not include the six far out red lights of rows 3 and 4 (see Fig. 1). A comparison of the scattering from four rows of the Belgian poles versus that from a like number of ASE poles was considered to be quite adequate from the standpoint of numbers since a total of 38 poles were involved. The scatter contribution due to the poles in the farther out rows was much less because they were both shorter and in a weaker part of the radiated field.

In all cases the forward scattered field due to the light supports was measured relative to the standard $\lambda/2$ horizontal scatterer described in the preceding section.

In Table I, forward scattering data for ASE poles and lights are presented

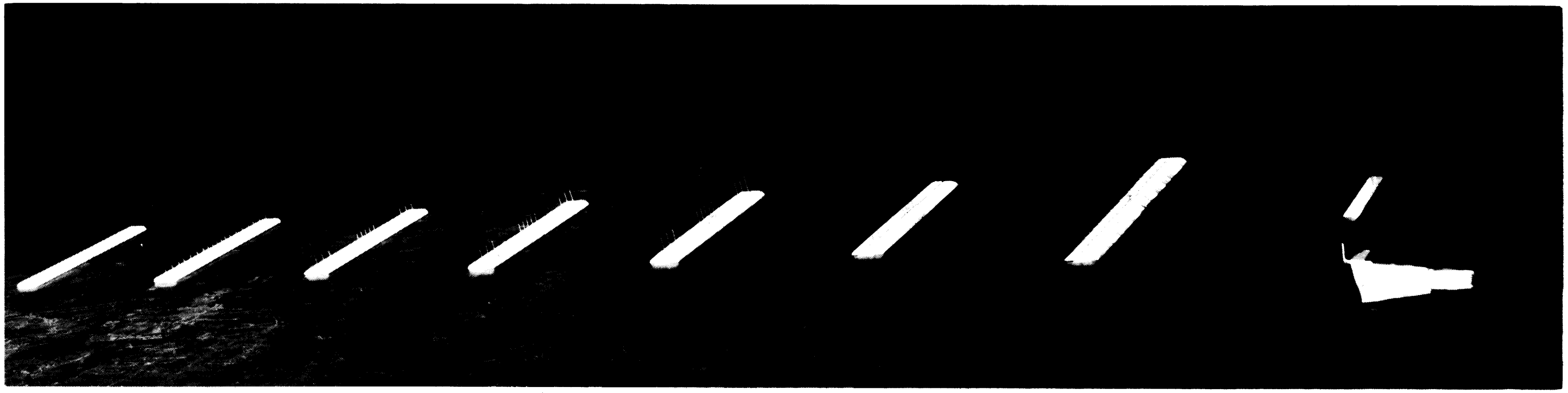


Figure 8: Eight Rows of ASE Poles in Position for Forward Scatter Measurement.

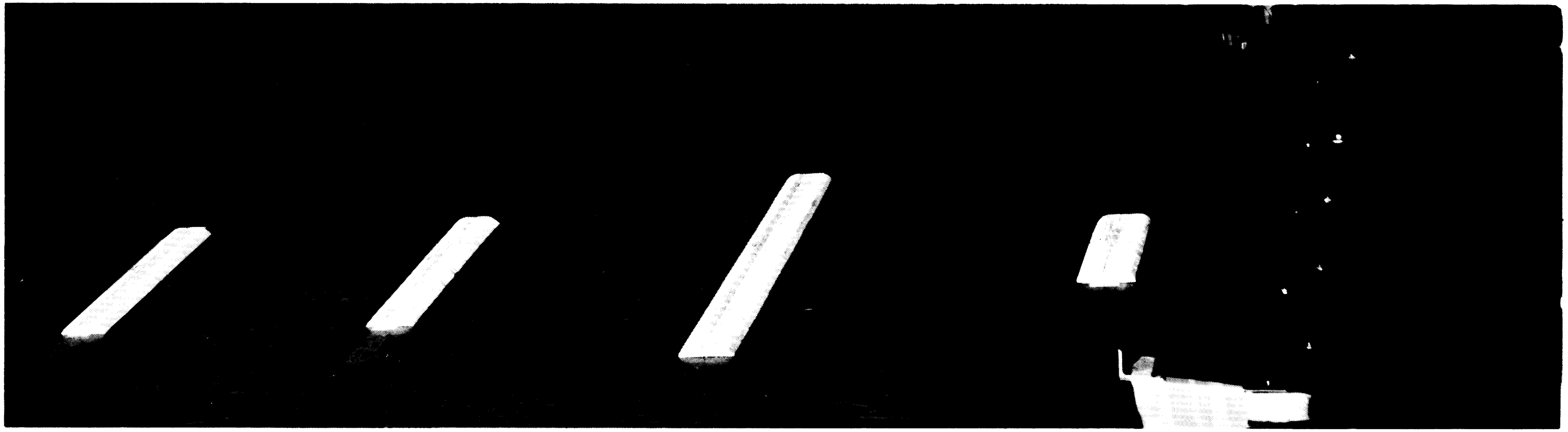


Figure 9: Four Rows of Belgian Light Supports in Position for Forward Scatter Measurement.

Table I

Forward scatter relative to the $\lambda/2$ horizontal wire (in dB)

No. of rows	Frequency	ASE poles and lights			
		9.83 GHz		10.15 GHz	
		without edge lights	with edge lights	without edge lights	with edge lights
4		-16.8	-14.5	-10.9	-10.2
8		-14.9	-15.6	-10.8	-10.5

for two frequencies, for four and eight rows and for the edge lights present and absent. The values given in the table are in decibels (dB) above or below the signal scattered by the $\lambda/2$ standard. (The forward scatter signal from the $\lambda/2$ standard exceeded that from a sphere 0.41 inch in diameter by 7.7 and 5 dB at 9.83 and 10.15 GHz respectively.) Measurements were made at 9.83 and 10.15 GHz, thus simulating full scale measurements 0.011 times the frequencies or 109 and 112 MHz (1 GHz = 10^9 Hz; 1 MHz = 10^6 Hz).

Once the equipment was set up and operating, it was necessary to work with it for a few days before it was possible to get reliable, repeatable data. It was necessary to improve the amplitude and frequency stability and lower the contribution due to noise to the extent possible. These problems were largely due to the smallness of the forward scatter signal to be measured.

Each of the entries in Table I are the average of two or more readings. From a consideration of this data, one sees that it is somewhat inconclusive with respect to the effect of the edge lights or in going from four to eight rows. The differences are generally small enough to be within the accuracy of the measurements. Therefore, in the comparison of the scatter from the ASE versus the Belgian poles, it was felt that there was no need for measurements with eight rows or with the edge lights. One sees from Table I that the level of the forward scatter is about 4 dB higher at 10.15 GHz than at 9.83 GHz. It is important to remember that values in most of the tables are in minus decibels, thus the larger numbers represent lower scattering values.

In Table II the results of the first comparison between ASE and Belgian light supports are presented. Data are given for two frequencies for the case where one row only is present and then with four rows present. No edge lights are present. One can see four comparisons of interest here. At both frequencies the scatter due to the Belgian poles are higher than for the ASE poles and this is true both in the 1 row and in the 4 row comparisons. The difference is significant in at least three out of four of the cases. The smallest difference is in the last comparison but even here the scatter from the Belgian four rows is 1.6 dB higher than from the ASE poles.

Table II

Forward scatter relative to $\lambda/2$ horizontal wire in dB

Number of rows	Frequency 9.83 MHz ASE	Belgian	10.15 MHz ASE	Belgian
1	-16.9	-10.4	-13.9	-10.3
4	-16.8	-13.6	-10.9	- 9.3

In the interest of obtaining more reliable data, we changed our equipment to increase our signal to noise ratio. This was done by replacing the receiving horn with a parabolic reflector antenna having about 6 dB more gain than the horn.

The data obtained with the larger receiving antenna are presented in Table III. The same four comparisons can be made with the data in Table III as were

Table III

Forward scatter relative to $\lambda/2$ horizontal wire in dB
(with larger receiving antenna)

Number of rows	Frequency 9.83 ASE	Belgian	10.15 MHz ASE	Belgian
1	-14.2	-10.0	-15.9	-8.3
4	-14.0	- 7.1	- 6.7	-5.6

done in Table II. It is reassuring to see that the Table III results confirm those of Table II in all instances--even to the smaller difference that occurs for four rows at the higher frequency.

In Table IV the data in Tables II and III are averaged to show the amount by which the forward scatter due to the Belgian light supports exceeds that due to the ASE poles. The averages were obtained by averaging the dB directly; some

Table IV

Forward scatter of the Belgian light supports compared to that of the ASE poles (average values in dB)

No. of rows	Frequency 9.83 GHz	10.15 GHz
1	5.3	5.6
4	5.1	1.3

accuracy is lost here but the method was considered adequate in view of the data. Here we are referring to the fact that it is difficult to get reliable data when the signals being measured are not too much above the noise of the system.

Table IV summarizes the major results of the forward scatter measurements made at the model frequencies. Other model measurements are described in the next section.

3.6 Effect of Light Supports on Localizer Antenna Pattern

During the early forward scatter measurements, before all of the "bugs" had been removed from the measurement setup, it was decided that another means of evaluating the effect of the light supports should be investigated. The critical information needed was whether or not the lights and light support poles interferred with the antenna beam. Even with exact information on the amount of forward scatter, it would be difficult to use this data to predict the extent of the antenna beam distortion. It was believed that the beam distortion could be measured directly by another model arrangement.

The equipment was rearranged as an antenna pattern measurement setup. The pattern of interest was that of the localizer antenna (the Texas Instrument antenna). To determine the effect due to the scatterers it was necessary to take the pattern of the antenna with and without the scatterers present. To do this, the antenna was mounted at the edge of an aluminum ground plane 48 inches in diameter. The ground plane extended about 3.5 feet in front of the antenna. This arrangement was mounted on a large block of styrofoam which in turn was mounted on a conventional antenna turntable. The localizer antenna served as the receiving antenna in these tests. The transmitting antenna was 55 feet distant and at an angle 3^{o} higher than the localizer antenna. A pattern was taken first with the antenna and ground plane alone; the frequency was 9.8 GHz. This is shown in Fig. 10. Patterns were then taken at the same frequency first with one row of ASE poles present (Fig. 10) and then with four rows of ASE poles present, as shown in Fig. 12. In both Figures 11 and 12 the pattern with no scatterers present is also included. This may be difficult to see as in most places the two patterns are exact duplicates. The fact that the two patterns are so similar is taken as evidence that the scatterers would not distort the localizer antenna beam.

In Figures 13 and 14 patterns of the localizer antenna with one and four rows of Belgian light supports are shown. In each of these figures, the pattern of the antenna without scatterers is shown as in Figures 11 and 12. Here, also, the perturbations due to the scatterers are, in our opinion, negligible.

One would conclude from these tests that neither the ASE nor the Belgian light supports would cause significant distortion in the localizer beam. A possible objection to these tests is that they were made with a single, on-axis beam and not with two beams having a cross-over on-axis as with the full scale localizer.

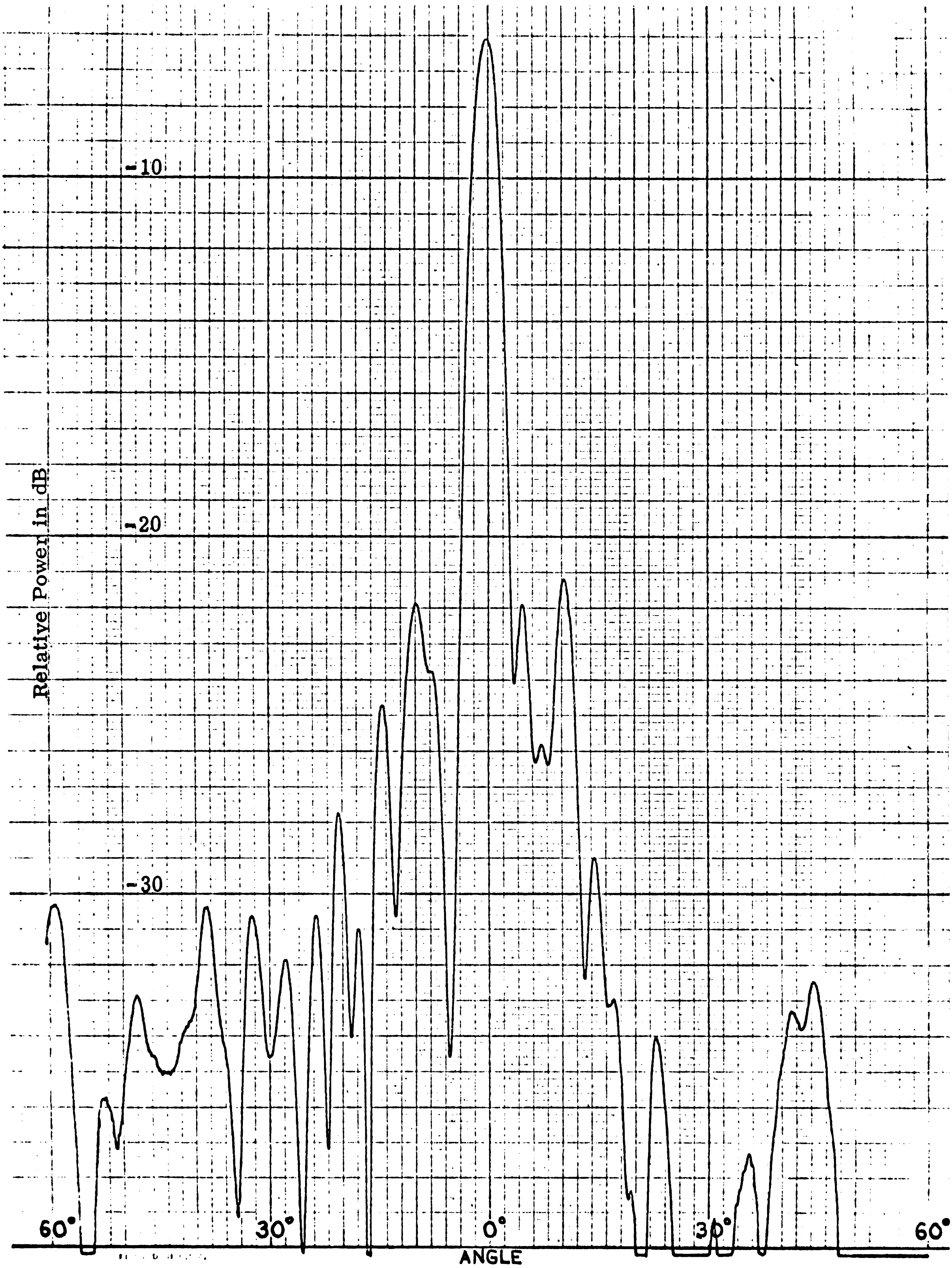


Figure 10: H-Plane Pattern of Scale Model of Localizer Antenna Mounted on a 48" Diameter Ground Plane. Frequency—9.8 GHz.

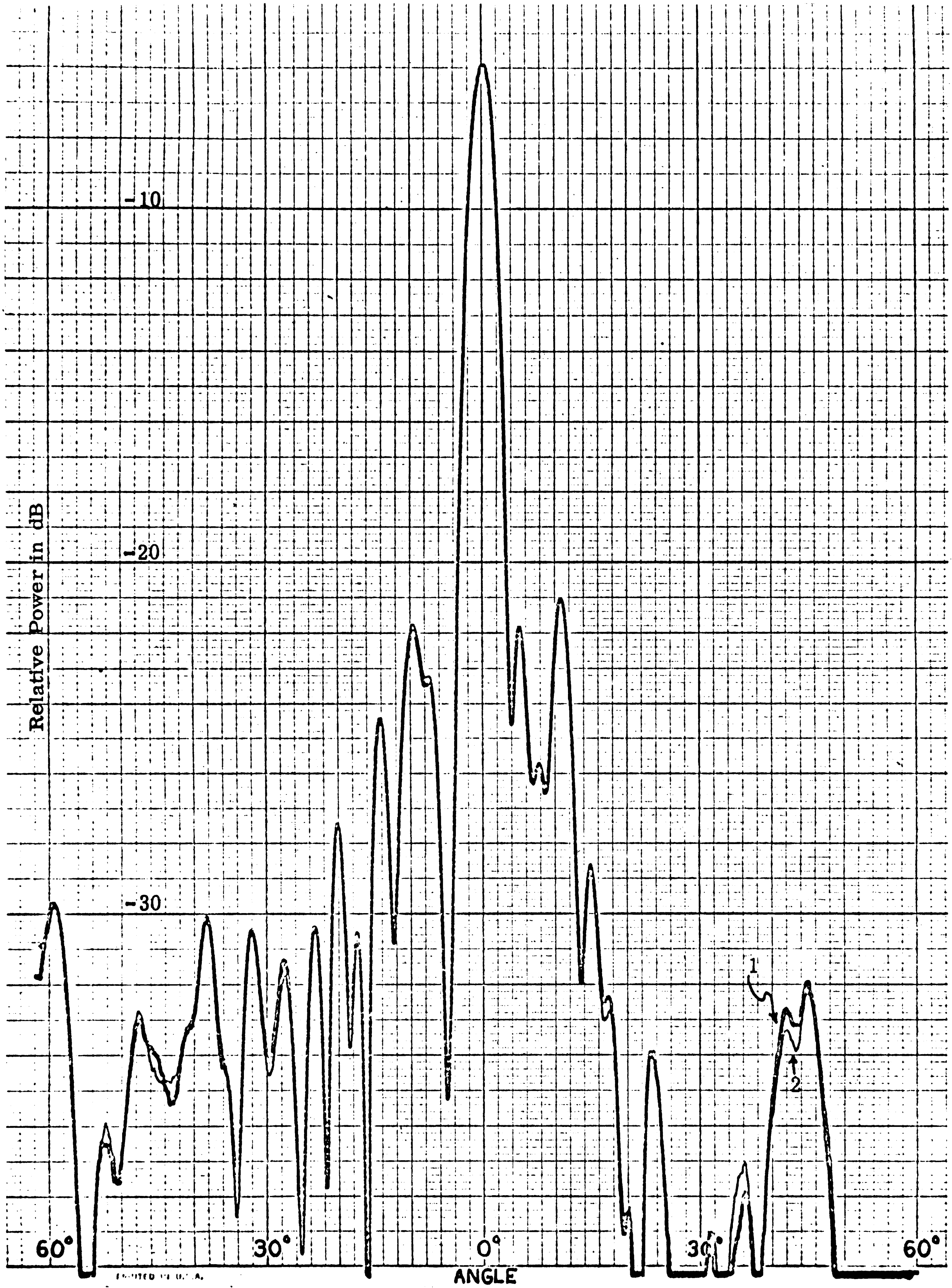


Figure 11: H-Plane Pattern of Scale Model of Localizer Antenna with (1) Ground Plane alone and (2) Ground Plane and one row of ASE Poles. Frequency—9.8 GHz.

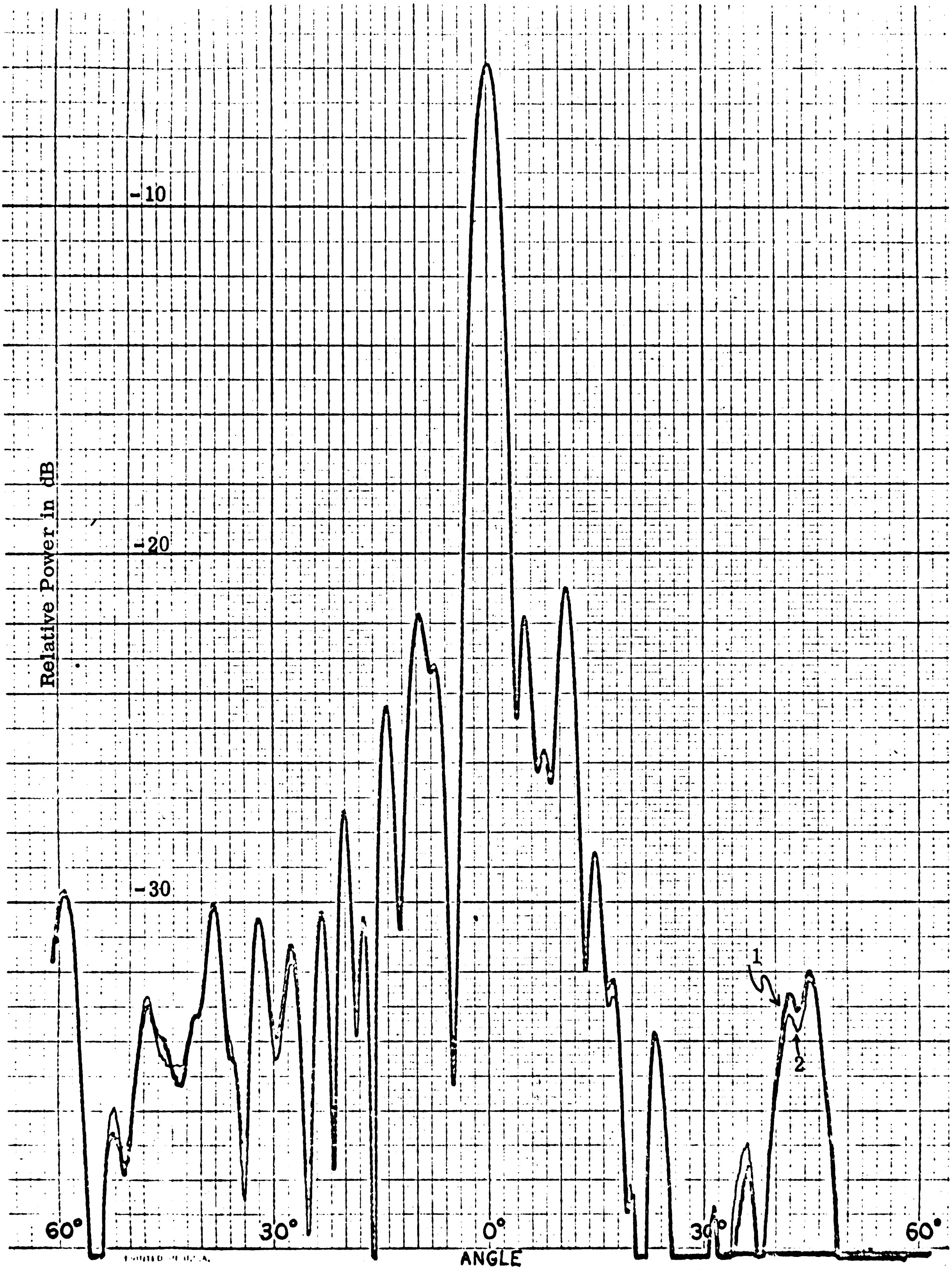


Figure 12: H-Plane Pattern of Scale Model of Localizer Antenna with (1) Ground Plane alone and (2) Ground Plane and four rows of ASE Poles. Frequency — 9.8 GHz.

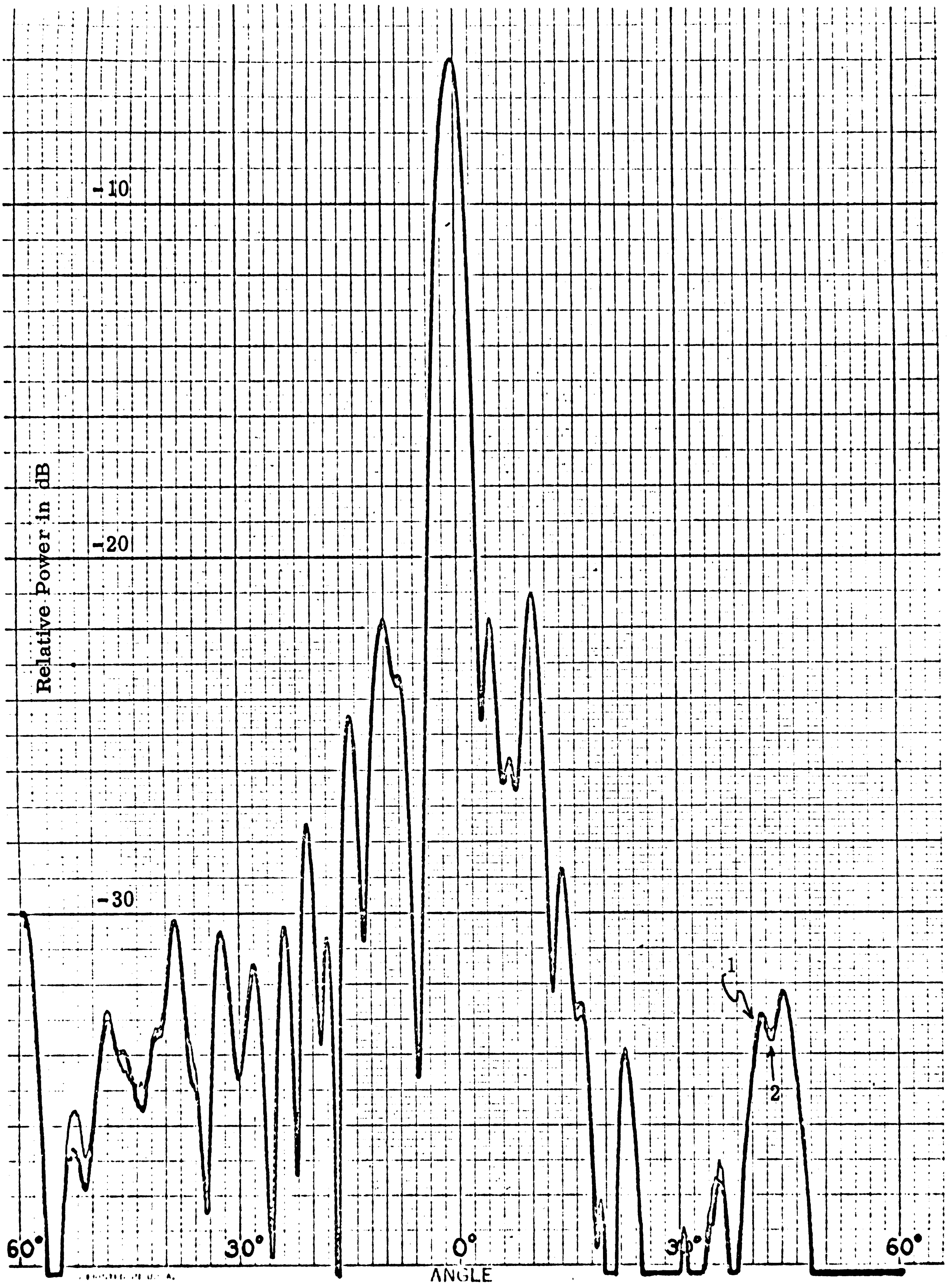


Figure 13: H-Plane Pattern of Scale Model of Localizer Antenna with (1) Ground Plane alone and (2) Ground Plane and one row of Belgian Light Supports. Frequency—9.8 GHz.

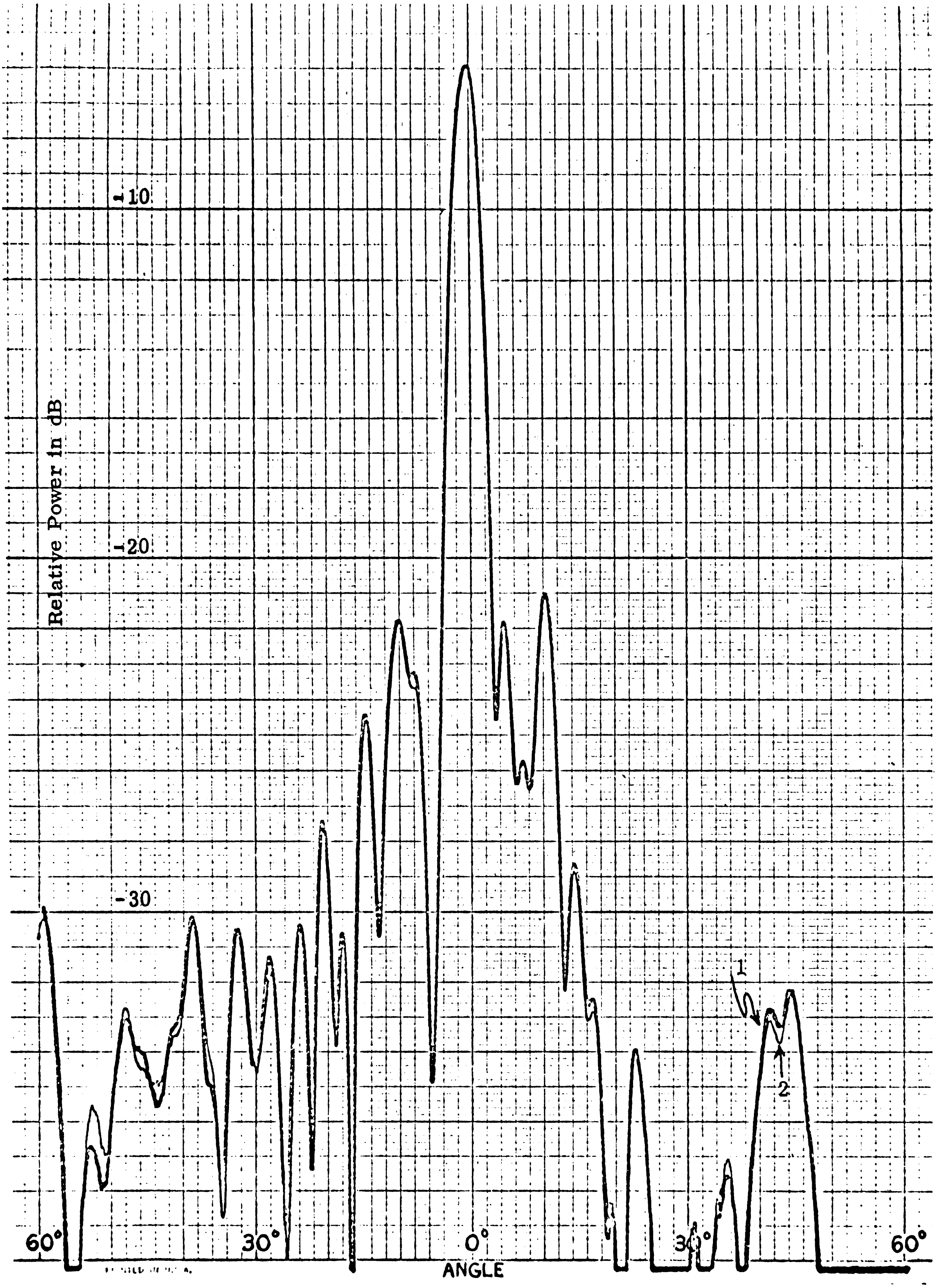


Figure 14: H-Plane Pattern of Scale Model of Localizer Antenna with (1) Ground Plane alone and (2) Ground Plane and four rows of Belgian Light Supports. Frequency — 9.8 GHz.

IV FULL SCALE MEASUREMENTS

In these measurements, the objective was to determine the relative level of the forward scatter signal for an array of six towers or poles for the three designs being considered. These measurements were made at a frequency of 108 MHz.

4.1 Arrangement of Full Scale Light Supports

In the measurements, the six poles or towers were to be positioned on a line perpendicular to the line of sight between the transmitter and receiver as in Fig. 1. Five of the light supports were to have a 40.5 inches, center to center spacing. The sixth support, which was for a flasher light, was positioned halfway between the second and third of the regularly spaced supports. It was necessary to be able to move the scatterers in and out of the antenna beam with a minimum of delay due to the limited time that the electronic equipment would stay in balance. For this reason, ASE supplied a four wheel tower support vehicle on which each of the three sets of supports were mounted when they were being tested. The vehicle was provided with mounting holes, adapters and leveling screws to allow for easy mounting and proper positioning of all three designs. During tests, the vehicle rested in an excavation in the ground which had been properly sized to conceal the vehicle when viewed from the transmitting antenna. This practice was followed to eliminate forward scatter due to the vehicle itself.

A photograph of the vehicle with the Canadian towers in place was shown in Fig. 2.

4.2 The Measurement Range

The outdoor measurement range was layed out in an open field with a separation of 150 feet between the transmitting and receiving antennas. Both of these antennas were multi-element log periodic antenna arrays which had been designed and built in the Radiation Laboratory. The antennas were directed toward each other and positioned at a height to simulate, to the extent possible, the ILS geometry.

The transmitting antenna was 9 feet above the ground, roughly at the mid-height of the TI localizer antenna. This antenna is seen in Fig. 15, which also shows the ALS poles mounted in the test vehicle which rests in the excavation mentioned in the proceeding section.

The receiving antenna is at a height of 20 feet, thus being 3^{o} above the level of the transmitting antenna to simulate an airplane approaching on a 3^{o} descent angle. The receiving antenna is shown in Fig. 16, which also shows the Belgian poles mounted in the nearby test vehicle. The excavation, where the scatterers are positioned during measurements, is halfway between the two antennas. From the last two figures, one can visualize the entire measurement range. The electronic and rf equipment was housed in a small building about 75 feet back of the receiving antenna.

4.3 The Equipment

The equipment is shown in Fig. 17. In general, the components used are the same as those used in the forward scatter model measurements. They differ in appearance, of course, because of the wide difference in frequency. An underground coaxial cable carries the transmitted signal to the distant transmitting antenna. Another cable runs from the receiving antenna into the mixer. The equipment schematic of Fig. 5 is almost equally applicable to the full scale setup.

4.4 Measurements and Results

The difficulties encountered in these measurements were due almost entirely to the problem of maintaining an adequate balance for a sufficiently long time. The balance obtained with no scatterer present was sometimes lost due to frequency drift in the oscillator. At other times instability in the outdoor range due to wind would cause the system to go out of balance.

After the balance was obtained, with no scatterer present, the vehicle was wheeled into place and a reading was taken. The vehicle was then moved away from the range and a check was made to see if the balance had been maintained.

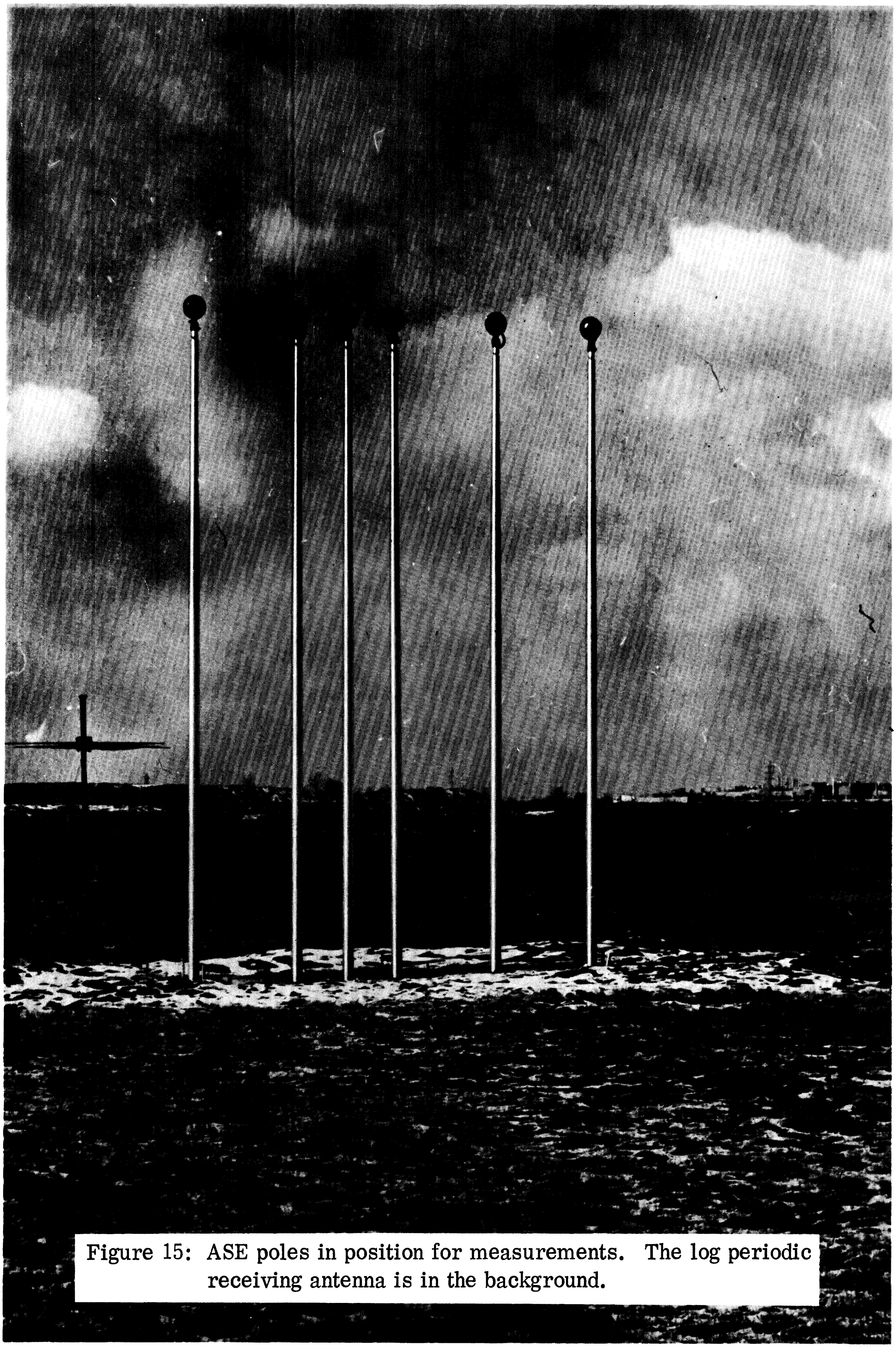


Figure 15: ASE poles in position for measurements. The log periodic receiving antenna is in the background.

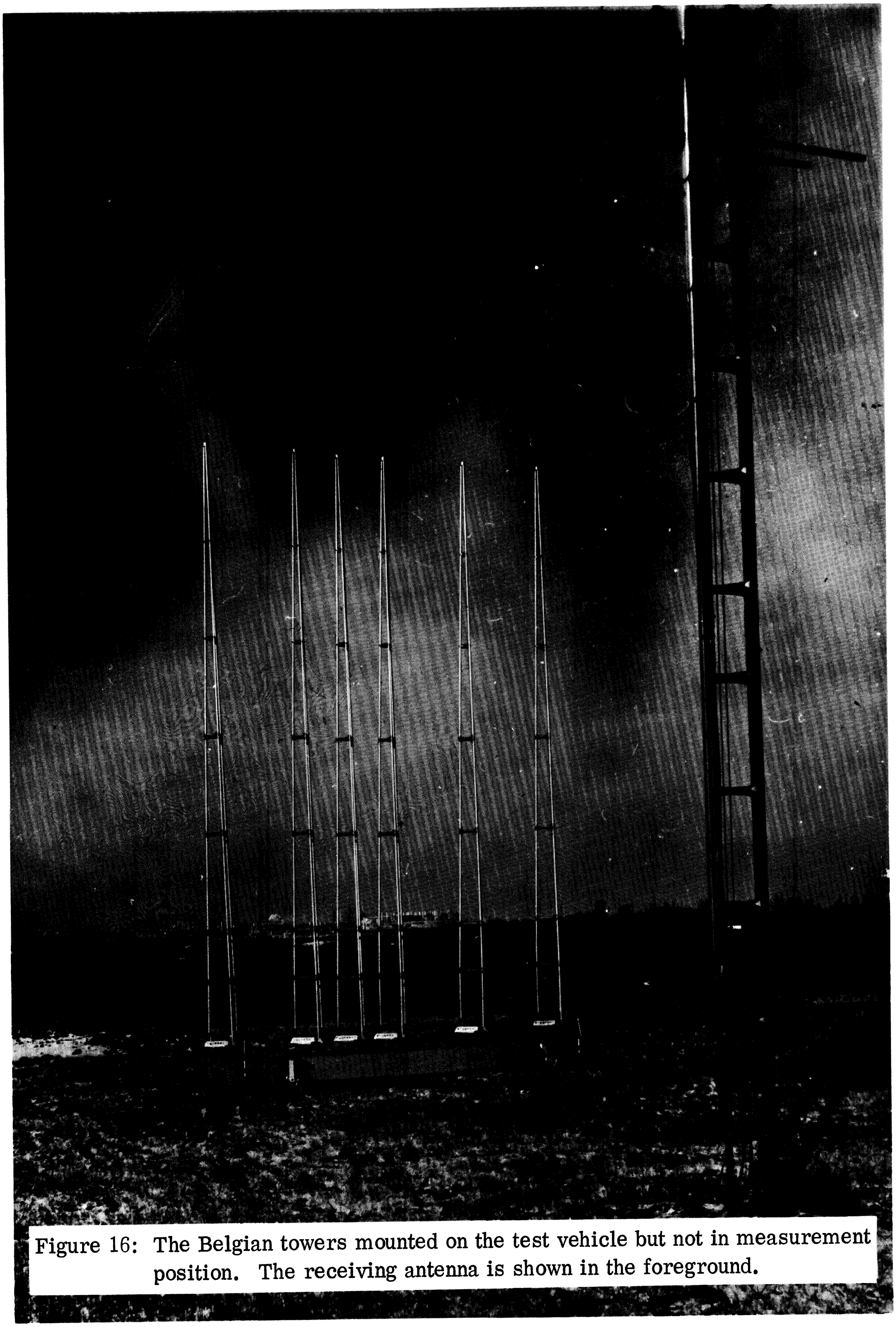


Figure 16: The Belgian towers mounted on the test vehicle but not in measurement position. The receiving antenna is shown in the foreground.

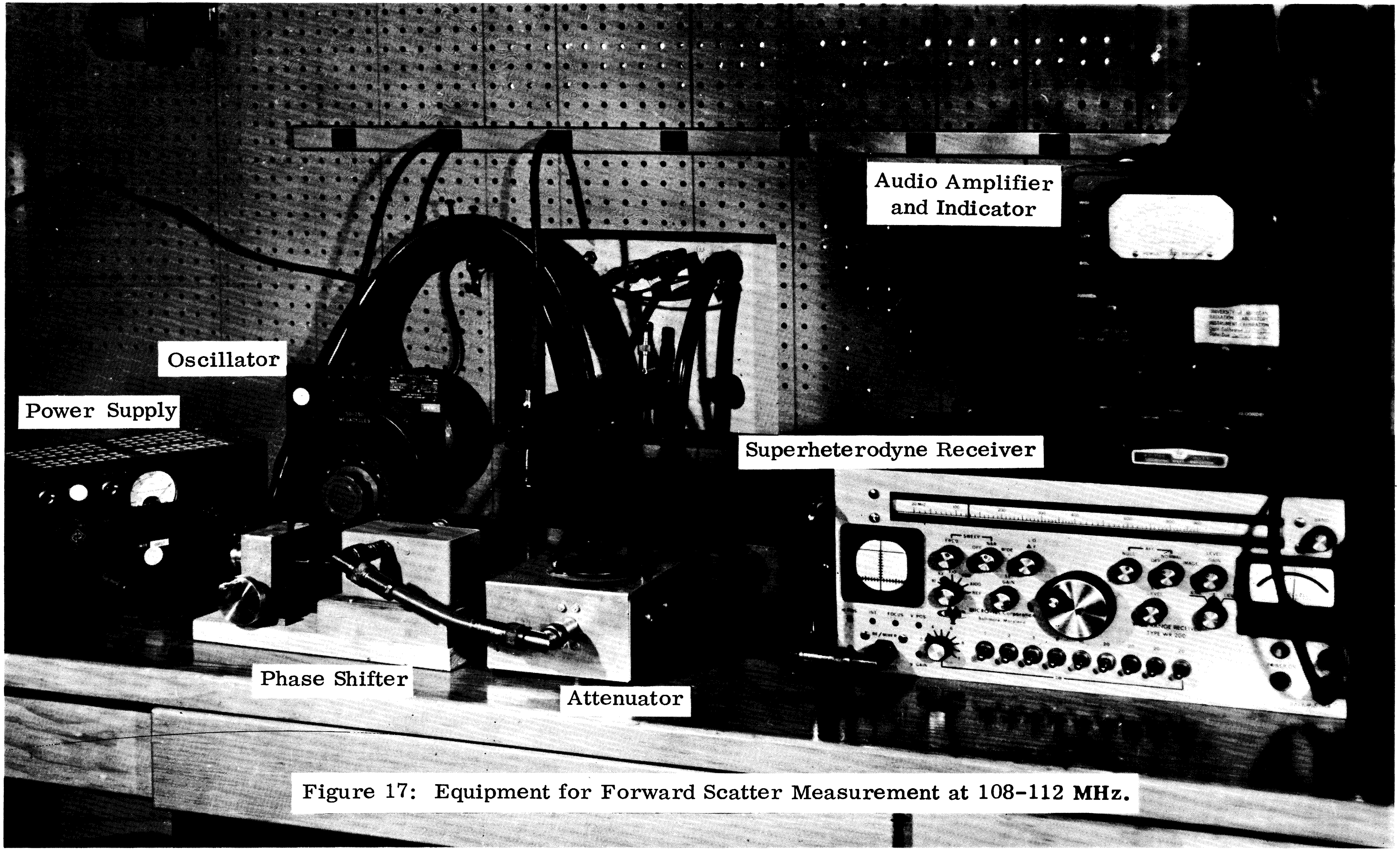


Figure 17: Equipment for Forward Scatter Measurement at 108-112 MHz.

If the system was not in balance, the reading obtained with the scatterer would be discarded.

A $\lambda/2$ rod was used as the reference standard. The rod was aligned horizontally and perpendicular to the incident beam; it rested on a styrofoam support, 4.5 feet high and at the midpoint in the antenna range. The rod should be considered only as a convenient reference device since it was not necessarily located at the scattering center of the vertical poles.

ALS lights were mounted on top of the ASE and Canadian poles during the tests. There was no convenient way to mount the lights on the Belgian poles.

The forward scatter data in Table V was obtained in January. The values given are in dB relative to the $\lambda/2$ reference rod.

Table V

Forward scatter from six vertical light supports
(in dB relative to $\lambda/2$ rod)

ASE	Canadian	Belgian
-10.5	-1.0	+ 9.0
- 9.0	-0.5	+10.0
-11.0	-1.0	+ 9.0
- 9.0	-0.5	

The wide spread in forward scatter versus support type had not been anticipated. The measurements were repeated a few weeks later when the weather was again suitable. An extra effort was made at this time to insure transmitter stability. The standard power supply for the oscillator was replaced with one having much better voltage regulation and this significantly improved our ability to maintain a balance. The second set of results are given in Table VI.

The data in Table VI should be considered more reliable. In those measurements, the use of the special regulated power supply provided cleaner, more stable signals which remained in balance over longer periods.

Table VI

Forward scatter from six vertical light supports relative to $\lambda/2$ rod
(a repeat measurement)

ASE	Canadian	Belgian
-12.9	+1.8	+4.0
-10.8	+3.2	+7.4
		+6.5

An attempt was made to determine the level of forward scatter signal from a full scale ALS light at 108 MHz, the result to be compared to that from a 10 inch diameter sphere. This signal proved to be too small to be detected with our system. This is not too surprising since the scatterer is only one tenth of a wavelength in diameter.

V SUMMARY AND CONCLUSIONS

All objectives of the study have been met. In addition to the work originally planned, forward scatter measurements were made at a second model frequency and several patterns were measured to determine the extent of beam distortion due to the presence of one or more rows of ASE and Belgian light supports.

The level of the signals measured were small in all cases. This was not unexpected since the polarization of the incident signals was perpendicular to the major dimensions of all the scatterers. Moreover, the extent of the scatterers parallel to the polarization was very small. This ranged from $\lambda/30$ for the ASE poles to about 0.12λ for the Belgian towers.

As a result of the low level of the signal the repeatability of the measurements was less than desired. To compensate for this all measurements were repeated three or more times, in most cases, with an entirely new set up. Despite the problem of repeatability, the results were always consistent in relative values. The forward scatter model measurements showed that the Belgian towers scattered from 1.3 to 5.6 dB more than the ASE poles -- depending on frequency and number of rows compared. The full scale measurements consistently ranked the light supports as: (1) ASE, (2) Canadian, (3) Belgian, in order of increasing level of forward scatter. The differences in these levels are shown in Tables V and VI.

REFERENCES

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