NBS REPORT

7272

INSERTION LOSS OF A BRICK WALL AT UHF

PROPERTY OF
SOUTHWEST RESEARCH INSTITUTE LIBRARY
SAN ANTONIO, TEXAS

by

G. D. Gierhart, L. G. Hause
J. E. Farrow, and M. T. Decker

NBS

DOCUMENT SECTION

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
BOULDER LABORATORIES
Boulder, Colorado

U.S
0

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to government agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. Research projects are also performed for other government agencies when the work relates to and supplements the basic program of the Bureau or when the Bureau's unique competence is required. The scope of activities is suggested by the listing of divisions and sections on the inside of the back cover.

Publications

The results of the Bureau's research are published either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three periodicals available from the Government Printing Office: The Journal of Research, published in four separate sections, presents complete scientific and technical papers; the Technical News Bulletin presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: Monographs, Applied Mathematics Series, Handbooks, Miscellaneous Publications, and Technical Notes.

A complete listing of the Bureau's publications can be found in National Bureau of Standards Circular 460, Publications of the National Bureau of Standards, 1901 to June 1947 ($1.25), and the Supplement to National Bureau of Standards Circular 460, July 1947 to June 1957 ($1.50), and Miscellaneous Publication 240, July 1957 to June 1960 (Includes Titles of Papers Published in Outside Journals 1950 to 1959) ($2.25); available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

NATIONAL BUREAU OF STANDARDS PUBLICATIONS AND REPORTS

The Bureau receives a number of inquiries from librarians and others regarding the nature and availability of National Bureau of Standards Reports and their relationship to the Bureau's formal publications program. The following explanation of this series has been prepared to answer such inquiries.

NBS Reports are used as the means of reporting to Government agencies or other sponsors the results of investigations on research projects. They often contain preliminary, unevaluated results, but whether preliminary or complete many of these reports have the status of private communications for the sponsoring agencies and become the property of those agencies. For this reason some reports are not available for distribution. A very limited number of any report is printed and made available to the author, and the distribution of these is controlled by him. When his supply is exhausted, that report is considered out of print.

Since NBS Reports have not received the rigid editorial review accorded formal Bureau publications, these should not be reproduced in whole or in part, nor should they be referred to in the open literature unless permission is obtained in writing from the Technical Information Office.

Bureau publications include two periodicals: Journal of Research, with its sections (A. Physics and Chemistry, B. Mathematics and Mathematical Physics, C. Engineering and Instrumentation), and the Technical News Bulletin.

Also, there are several non-periodical Bureau publications, such as Monographs, Technical Notes, Handbooks, and Miscellaneous Publications.

All Bureau publications are sold by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. The Bureau does not maintain a stock of any publications listed for sale.

The Technical News Bulletin affords the best means of keeping abreast of NBS publications. In addition to concise summary articles of current NBS work, this monthly periodical lists all papers by NBS staff members, both in Bureau publications and outside journals.

☐ The publication you requested may be purchased for $________ from the Superintendent of Documents, Government Printing Office, Washington, D. C. 20402.

☐ We have no publication dealing with the specific subject of your inquiry. However, we are enclosing material which describes the work of the Bureau in the general area of your inquiry.

☐ The publication you requested is out of print. It may be available in your local library.

☐ We cannot identify the publication you requested. Please verify that it is a National Bureau of Standards' publication, and provide more complete information.

☐ The publication/information you requested is not available from the National Bureau of Standards. We suggest that you write to:

☐ REMARKS:

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
BOULDER, COLORADO 80301

August 29, 1966

IN REPLY REFER TO: 640

*

Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78206

Dear Gentlemen:

Subject:

Your request for Boulder Laboratories material has been referred to me.

XXX The requested material is enclosed.

____ The requested material has been sent under separate cover.

____ The statement on the reverse side of this sheet will explain why we cannot fulfill your request.

____ Your letter has been forwarded to the Washington office which is more familiar with the subject of your request.

Your interest in the work of the Boulder Laboratories is greatly appreciated.

Sincerely yours,

Maxine Kirby

Maxine Kirby
Scientific Documentation Division

NBS INSTITUTES FOR SCIENCE AND TECHNOLOGY
INSTITUTE FOR BASIC STANDARDS
INSTITUTE FOR MATERIALS RESEARCH
INSTITUTE FOR APPLIED TECHNOLOGY

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT	NBS REPORT
8370-11-83471	7272

June 26, 1962

INSERTION LOSS OF A BRICK WALL AT UHF

by

G. D. Gierhart, L. G. Hause
J. E. Farrow, and M. T. Decker

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
BOULDER LABORATORIES
Boulder, Colorado

IMPORTANT NOTICE

NATIONAL BUREAU OF ST
ments intended for use withi
is subjected to additional evc
tion, or open-literature listin
mission is obtained in writing
25, D. C. Such permission is
been specifically prepared if

Approved for public release by the
Director of the National Institute of
Standards and Technology (NIST) on
October 9, 2015.

progress accounting docu-
rts is formolly published it
ation, reprinting, reproduc-
not authorized unless per-
of Standards, Washington
y for which the Report hos
es for its own use.

TABLE OF CONTENTS

INSERTION LOSS OF A BRICK WALL AT UHF

by

G. D. Gierhart, L. G. Hause
J. E. Farrow, and M. T. Decker

ABSTRACT

Measurements of the effects of inserting a brick wall into a radio propagation path are reported. The technique used for measuring "insertion loss" at frequencies of 518 Mc/s and 1046 Mc/s is described. Distributions of the resulting data indicate the variability of insertion loss with changes in measurement location. The median insertion loss at both frequencies was on the order of 2.5 db.

1. INTRODUCTION

Measurements have been made to determine the "insertion loss" associated with a brick wall placed between transmitting and receiving antennas of a radio propagation path. Here "insertion loss" refers to the ratio (in decibels) of power received without the wall in the path to that received with the wall in the path.

The determination of insertion loss caused by an object in a radio propagation path is a problem that has existed for many years and a number of simple cases have been solved. Almost every modern text on electromagnetics has a commentary on the electrical and magnetic properties of materials and their effect on wave propagation in certain simple cases. These cases often involve restrictions on the type of wave as well as the media. Concepts such as reflection coefficient, wave impedance, etc. are used. The case of a plane wave incident on a region of parallel, homogeneous slabs of infinite extent has been solved [Wait, 1958] and insertion loss can be expressed in terms of the geometry and physical constants involved; all slabs need not have the same physical constants. However, problems involving complicated geometries and many media encountered in practice are very often so difficult as to defy theoretical solution. A few measurements have been made of the effects of trees and buildings at certain frequencies [Head, 1960; McPetrie and Ford, 1946] and techniques capable of incorporating statistical information about such objects into service predictions [Gierhart, Miller, Johnson, and Barsis, 1962] have been developed.

The determination of insertion loss caused by a brick wall placed in a propagation path is complicated by the variety of materials used in the wall and the geometry required to specify their locations. Many types of walls are encountered in practice. Assumptions used to make a theoretical study for a specific wall may be acceptable at one frequency and not at another. It is likely that flaws in materials or even surface roughness could be important at some frequencies. Because of the complexity of the theoretical approach an empirical one was taken. However, it should be realized that even with a theoretical solution experimental verification would be highly desirable.

The empirical approach is not without difficulties, some of which are caused by the same factors that complicate the theoretical approach and new ones which are due to the mechanics of making measurements. For example, the separation of energy into reflected, absorbed, and transmitted quantities would involve complicated measurements along with theoretical considerations. Therefore, only the gross effect of inserting a wall into a propagation path was considered, i.e., received energy with and without the wall in the path.

Measurements were made behind a brick wall placed in the far field of a radiating antenna for two frequencies, 518 Mc/s and 1046 Mc/s. In this report measurements involving similar parameters (polarization and/or frequency and/or location) are compared. A statistical presentation of the data is included, from which a general idea of the insertion loss and its variability can be obtained.

2. EXPERIMENTAL SET UP

A ground plan of the experimental set up is shown in Figure 1. The transmitting equipment was housed in the trailer and the receiving equipment in the truck. Coaxial cables, RG-8/U, were used as r-f transmission lines to the antennas. The power lines to the trailer and from the trailer to the truck were on the ground. A center line profile of the terrain between the transmitting antenna and the wall is also shown in Figure 1. Figures 2 and 3 are photographs that show most of the items depicted in Figure 1. An oblique view of the wall and the transmitting antenna is shown in Figure 4 and a photograph with a similar perspective is shown in Figure 5. The coordinate system used throughout this report is defined in Figure 4.

Details of the wall structure are shown in Figure 6. The wall is 8 feet tall, 8 feet wide, and 9 inches thick. A 2x4 stud is centered in the wall and other studs are located at 16, 32, and 48 inches off center. Clay facing bricks having a nominal size of 2-1/4 x 3-3/4 x 8 inches were used with metal wall ties spaced 6 courses apart vertically and about 32 inches center-to-center horizontally. Boards 1 inch thick were used to close the top and sides of the structure. A tarpaulin covered the wall when measurements were not being made to protect it from the weather.

The equipment used is listed in Table I. Functionally the equipment used at the two frequencies was the same. It was necessary to use a coaxial tee, crystal detector, d-c amplifier, and Esterline-Angus Recorder with the 1046 Mc/s oscillator to monitor its power output; the 518 Mc/s generator has an internal monitor. The radar receiver, signal generator, and d-c amplifier performed the same function at 1046 Mc/s as the field intensity meter used at 518 Mc/s.

TABLE I

Equipment Used

518 Mc/s	1046 Mc/s
Transmitting	
General Radio UHF Generator Type 1021-P2 Range 250-920 Mc/s	General Radio Unit Oscillator Type 1218-A Range 900-2000 Mc/s
UHF Generator has internal output monitor	Coaxial tee, crystal detector, d-c amplifier and strip chart recorder
Corner reflector, dipole fed	Parabolic reflector, 3 wavelengths in diameter

TABLE I (Continued)

518 Mc/s	1046 Mc/s
Receiving	
Half-wave dipole	Corner reflector and half-wave dipole
RCA Field Intensity Meter Type BW-3A, MI-19385 Range 470-900 Mc/s	AN/APR-4 radar receiver with TN-19/APR-4 tuning unit Range 975-2200 Mc/s
	Aircraft Radio UHF Generator Type H-12 Range 900-2100 Mc/s
	General Radio Direct-current Amplifier Type 715-A
Esterline-Angus Recorder Model AW 1 ma d-c	Esterline-Angus Recorder Model AW 5 ma d-c

The antennas used for monitoring were half-wave dipoles; see Figure 3.

Model S-1000 Sorensen Voltage Regulators were used.

3. EXPERIMENTAL PROCEDURES

Measurements were taken of relative power at the receiving antenna terminals at various (x, y, z) antenna locations for comparison to that available when the antenna was at a reference location. In each case, measurements used for comparison had the same frequency and antenna polarization. The four references used are listed in Table II.

TABLE II

Reference Measurements

Reference Code	Polarization	Frequency Mc/s	Location (x, y, z) inches
H_5	Horizontal	518	0, 48, - 8
V_5	Vertical	518	0, 48, - 8
H_{10}	Horizontal	1046	0, 48, -10
V_{10}	Vertical	1046	0, 48, -10

In order to measure relative power, the receiver output was calibrated against a standard provided by a variable piston attenuator and a constant signal source. A stationary monitor antenna was connected to the receiver periodically during the experiment; this together with the power output monitor at the transmitter provided a check on equipment performance. The receiver calibration was also checked periodically. This assured proper allowance for changes in equipment performance when such factors as changes in ambient temperature occurred.

The mobile antenna mount used for the receiving antenna is shown in Figure 5. The notched vertical member of the mount and the wire-wrapped two-by-two near the base of the mount are part of a switching arrangement used in conjunction with a chronograph pen on an Esterline-Angus Recorder to allow the simultaneous recording of relative power and receiving antenna location as the antenna was moved either vertically or horizontally. This together with the ability to move the receiving antenna from a distance greatly facilitated data taking.

Most of the measurements were made continuously over paths in one of the coordinate directions in the region behind the wall. The paths did not always pass through the reference location; for these paths data taken along other paths were used to refer the measurements to the reference measurement. For example, received power in decibels relative to that received at H_5 along the line $x = 0$, $0 \leq y \leq 72$, and $z = -10$ inches can be obtained directly from measurements taken along this line since the reference location is on this line; then the resulting relative power level at $x = 0$, $y = 72$, and $z = -10$ inches can be used to reference measurements taken along $-48 \leq x \leq 48$, $y = 72$, and $z = -10$ inches by assuming that both measurement runs should yield the same relative power level at their common point. Samples of the "raw data," plotted in terms of relative power, for both frequencies are shown in Figure 7.

The method used to refer measurements assumes that relative power measurements are repeatable. As a result any disagreement between measurements taken under the same conditions (frequency, polarization, and location) is automatically eliminated for most of the data. However, some data taken at 1046 Mc/s are the exception in that reference measurements were made just before each run and they provide an indication of the degree to which measurements could actually be repeated. These data are shown in Figure 7 and were referenced by using the reference measurements taken before each run. The points marked by crosses on Figure 7a are data taken from Figure 7b and vice versa; in these cases agreement is within 0.5 decibels.

The insertion loss, L_I, associated with the wall is measured in terms of the available power at the receiving antenna terminals with and without the wall in the propagation path. The power with the wall, P_w, was measured at various locations behind the wall. To obtain an equivalent measure without the wall, P_o, it was necessary to take the measurement in front of the wall. This means that the z coordinate is different for each pair of measurements and corresponding allowance must be made to the observations. The parameters listed below will be used in the following discussion of how this allowance was made.

P_w = Power measured at the receiver antenna terminals with the wall in the propagation path.

P_o = Power that would be measured at the receiver antenna terminals without the wall in the transmission path.

(x_t, y_t, z_t) = Coordinates of the transmitting antenna.

z_p = Location of the reference plane in front of the wall.

If we assume that measurements of P_o will vary inversely as the square of the distance from the transmitting antenna (actual measurements taken beside the wall varied in this manner over the small distance range involved), this correction is made in the following manner. Consider two locations, one in front of the wall at (x_o, y_o, z_p) and the other at (x_o, y_o, z) behind the wall, where

$$|(x_t, y_t, z_t) - (x_o, y_o, z_p)| \cong |z_t - z_p|$$

and

$$|(x_t, y_t, z_t) - (x_o, y_o, z)| \cong |z_t - z|$$

then

$$P_o(z) = P_o(z_p)\left[\frac{z_t - z_p}{z_t - z}\right]^2 \tag{1}$$

and

$$L_I = 10 \log_{10} \frac{P_o(z)}{P_w(z)} = 10 \log_{10} \frac{P_o(z_p)\left[\frac{z_t - z_p}{z_t - z}\right]^2}{P_w(z)}$$

or

$$L_I = 10 \log_{10} P_o(z_p) - 10 \log_{10} P_w(z) + 20 \log_{10}\left[\frac{z_t - z_p}{z_t - z}\right] \text{ decibels.} \tag{2}$$

Since the power at the antenna terminals was measured only relative to the power at an arbitrary reference location, P_R, only the quantities $10 \log \frac{P_o(z_p)}{P_R}$ and $10 \log \frac{P_w(z)}{P_R}$ are known. However, the reference power term cancels out as follows when the relative powers are used to determine insertion loss; i.e.,

$$10 \log_{10} \frac{P_o(z_p)}{P_R} - 10 \log_{10} \frac{P_w(z)}{P_R} = 10 \log_{10} P(z_p) - 10 \log_{10} P_w(z) \tag{3}$$

At 518 Mc/s $(z_t - z_p) = 2280$ inches and for 1046 Mc/s $(z_t - z_p) = 2240$ inches. For both 518 Mc/s and 1046 Mc/s $(z_t - z) = 2289 - z$ inches.

No measurements were actually made in front of the wall at 518 Mc/s. Instead interpolation was used. A composite curve that is an average of several height gain curves taken beside the wall, see Figure 8, was displaced in such a manner as to keep the decibel level constant for a particular height above ground, see Figure 9a. A similar method of interpolation was used at 1046 Mc/s except that a height-gain curve taken in front of the wall, see Figure 10a, was used; the effect of reflections from the wall was considered negligible because of the directivity of the receiving antenna. The results of the interpolations are shown in Figures 9b and 10b for 518 Mc/s and 1046 Mc/s, respectively. An indication of the validity of this interpolation technique is provided by the crosses on Figure 10b which are actual measured values.

4. TERRAIN EFFECTS

The experiment was not conducted over level ground and no correction was made for this in the calculation of insertion loss. One possible way to adjust the raw data is to observe the amount of displacement necessary to adjust a horizontal x-direction run, see Figure 4, taken in front of the wall to a constant decibel level and making the same adjustment to a similar (frequency and polarization) run made at the same height behind the wall, see Figure 11a. Height gain effects could be adjusted by a similar method in which a vertical run in front of the wall would be adjusted to a constant decibel level, see Figure 11b. However, this correction was not used in the calculation of insertion loss since it would change a measurement taken without the wall by the same amount as one taken with the wall in the path; i.e., the insertion loss is the same whether or not a correction of this type is made. While these adjustments may be informative in comparisons such as those in Figures 11a and 11b they may also be misleading because of the implication that insertion loss is independent of the manner in which the wall is illuminated.

5. DIFFRACTION EFFECTS

Since the wall used had finite dimensions in the x-y plane a certain amount of energy arrives at the receiver by diffraction around the edges. To investigate these diffraction effects a special set of measurements was made with the wall covered by aluminum sheets and compared with a similar set made without the aluminum covering. Such comparisons are shown in Figures 12 and 13 for 518 Mc/s and 1046 Mc/s, respectively.

The measurements mentioned above were used as guides to define a "measurement volume" behind the wall in which diffraction could be neglected and insertion loss measurements outside this volume were disregarded. Actually, a different volume was used for each frequency; they are defined by the dimensions A, B, and C listed in Table III and shown in Figure 4.

TABLE III

Dimensions of Measurement Volume
(see Figure 4)

Frequency Mc/s	A Inches	B Inches	C Inches
518	48 (-24" $\leq x \leq$ 24")	36 (30" $\leq y \leq$ 66")	24 (-32" $\leq z \leq$ -8")
1046	48 (-24" $\leq x \leq$ 24")	24 (36" $\leq y \leq$ 60")	24 (-34" $\leq z \leq$ -10")

6. EXPERIMENTAL RESULTS

The curves shown in Figures 14a and 16b compare raw data taken along a path in front of the wall with that taken behind the wall on a similar path. The frequency, polarization, and coordinate direction (the coordinate axis to which the runs were parallel) applicable to the comparisons made in these figures are listed in Table IV.

TABLE IV

Figures Comparing Raw Data

Figure Number	Frequency Mc/s	Polarization	Runs In
14a*	518	Horizontal	x direction
14b*	518	Horizontal	y direction
15a	1046	Horizontal	x direction
15b	1046	Horizontal	y direction
16a	1046	Vertical	x direction
16b	1046	Vertical	y direction

---

* Interpolation was used to draw the curve representing available power in front of the wall, see Figures 8 and 9.

Values of insertion loss calculated from raw data taken at 1046 Mc/s with horizontal polarization are compared with values calculated from similar data taken over the same path with vertical polarization in Figure 17. Runs taken in the x direction, y direction, and -z direction (parallel to the z axis and behind the wall) are compared in a, b, and c of Figure 17, respectively.

Values of insertion loss calculated from data taken at 518 Mc/s with horizontal polarization are compared with values calculated from similar data taken over the same path at 1046 Mc/s in Figure 18. Runs taken in the x direction and the y direction are compared in a and b of Figure 18, respectively.

Measurements taken with the measurement volume specified in the Diffraction Effects section were converted to insertion loss by the method outlined in the section on Experimental Procedures and used to draw two cumulative distributions, one for each frequency. These curves specify that at least a certain percentage of insertion loss values in the volume considered were so many decibels or greater. The volume considered at 518 Mc/s contained 364 samples and that considered at 1046 Mc/s contained 975 samples. Figure 19 shows both distributions. The median values of these distributions are 2.3 and 2.4 decibels for 518 Mc/s and 1046 Mc/s, respectively.

Using these distributions a range of insertion loss included in a specific percentage range can be determined. For example, 50% (between 25% and 75%) of insertion loss values are within 3 db (insertion loss values ranging from 4 to 1 db) of each other at 518 Mc/s. Table V lists several such percentage range and insertion loss range combinations.

TABLE V

Insertion Loss Range

	Insertion Loss Range in Decibels	
Percentage Range	518 Mc/s	1046 Mc/s
50% (25% to 75%)	3.0 (4.0 to 1.0)	1.2 (3.1 to 1.9)
80% (10% to 90%)	5.5 (5.9 to 0.4)	2.3 (3.7 to 1.4)
90% (5% to 95%)	6.9 (7.0 to 0.1)	2.9 (4.1 to 1.2)
98% (1% to 99%)	9.9 (-0.1 to 9.8)	4.1 (0.8 to 4.9)

7. CONCLUSION

The attenuation of signals at 518 and 1046 Mc/s passing through a section of a brick wall was measured. When diffraction effects are taken into account by defining a volume within which they are negligible, the resulting measurements are considered to be typical of those which might be observed within a building having similarly constructed walls.

The results are presented in the form of probability distributions of insertion loss. This represents added loss over and above what would be present without the obstruction. For example, Figure 19 states that 5% of the possible locations would be expected to have an insertion loss less than 2.4 at 518 Mc/s. Similarly, only 1% of the possible locations would be expected to have an insertion loss greater than 10 db at 518 Mc/s.

These measurements were designed in such a manner as to minimize the effects of uneven illumination of the wall, reflections from other nearby objects, and diffraction around or over the wall. The net effect of including such factors would be expected to have its greatest effect upon the slope of the distribution and least on the insertion loss associated with the median. There are so many possible variations on the effect of actual building configuration that these results should be considered only as typical results. Too much reliance should not be placed upon them for predicting insertion loss under actual building conditions. Further experiments are planned to obtain similar data at other frequencies and with other types of walls.

8. ACKNOWLEDGEMENTS

The authors wish to acknowledge the participation of personnel in the Propagation-Terrain Effects Section of the National Bureau of Standards in planning the experiment and analyzing the data. The wall was constructed by F. H. Sloan and his group, drafting was done by J. C. Harman and his group, and the manuscript was typed by Mrs. D. J. Hunt.

The authors also wish to thank Messrs. R. S. Kirby and J. W. Herbstreit for their review and suggestions.

9. REFERENCES

Bapu Seetaram, H. T., and M. N. Gadre, Distortion of polar diagram due to interposition of wooden screen in vicinity of a VHF radiator, Journal of the Institution of Telecommunication Engineers (New Delhi) 3, No. 2, 140-156 (Mar. 1957).

Barsis, A. P., Translation of Investigation of properties of laminated materials at radio frequencies by Dr. J. Grosskopf, NBS Report 5084 (June 5, 1957).

Gierhart, G. D., J. S. Miller, M. E. Johnson, and A. P. Barsis, The prediction of service volumes for air navigation facilities, NBS Report 7238 (1962).

Decker, M. T., R-F attenuation by building materials, NBS Report 6003 (1958).

Head, H. T., The influence of trees on television field strengths at ultra-high frequencies, Proc. IRE 48, No. 6, 1016-1020 (June 1960).

Josephson, B., and A. Blomquist, The influence of moisture in the ground, temperature and terrain on ground wave propagation in the VHF-band, IRE Trans. on Antennas and Propagation, AP-6, No. 1, 169-172 (Apr. 1958).

McPetrie, J. S., and L. H. Ford, Some experiments on the propagation over land of radiation of 9.2 cm wavelength, especially on the effects of obstacles, Jour. IEE 93, Pt. IIIA, No. 3, 517-531 (1946).

Megaw, E. C. S., Experimental studies of the propagation of very short radio waves, Jour. IEE 93, Pt. IIIA, No. 1, 79-97 (1946).

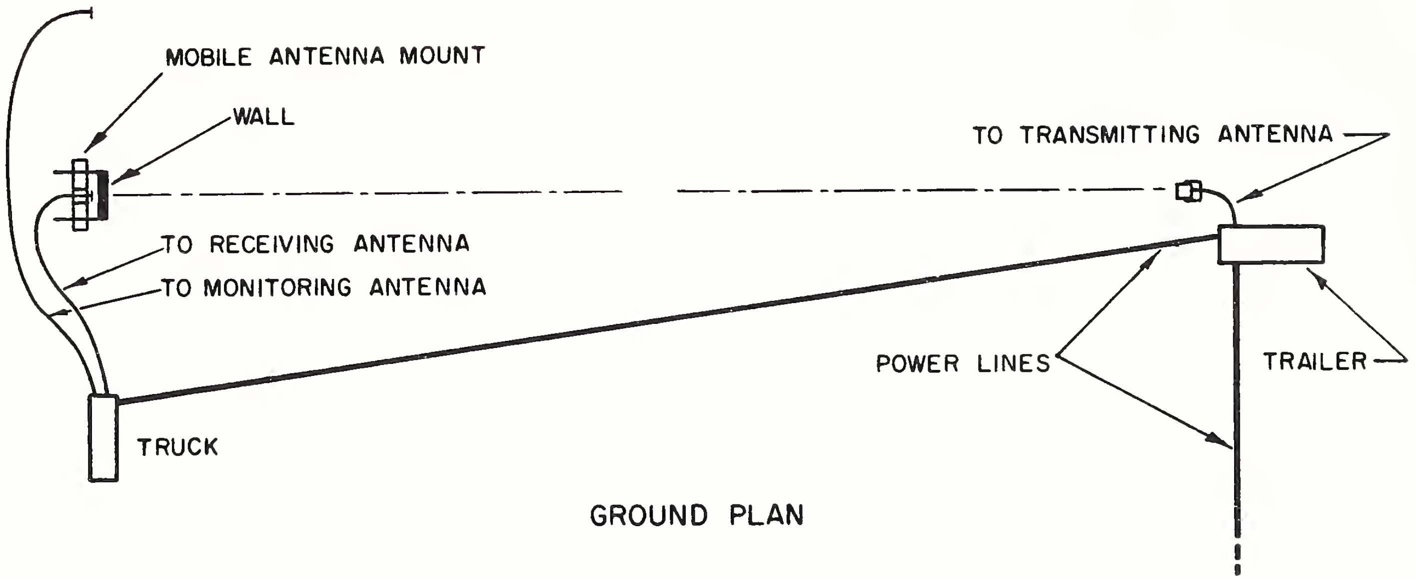
Megaw, E. C. S., Some effects of obstacles on the propagation of very short radio waves, Jour. IEE 95, Pt. III, No. 34, 97-105 (Mar. 1948).

Saxton, J. A., and J. A. Lane, VHF and UHF reception, Wireless World 61, No. 5, 229-232 (May 1955).

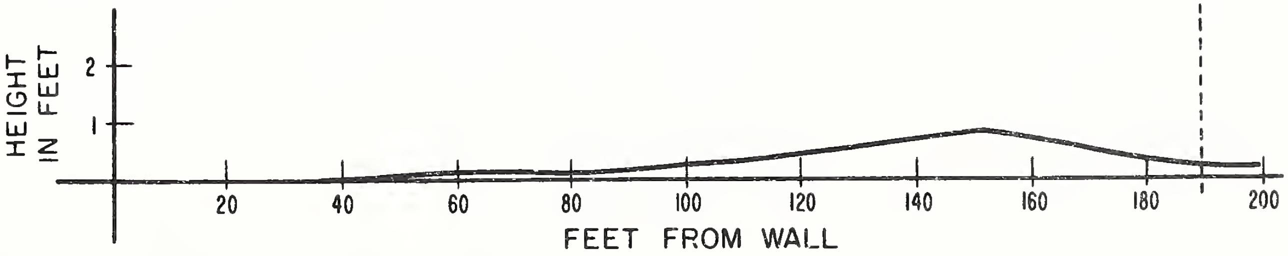
Trevor, B., Ultra-high-frequency propagation through woods and underbrush, RCA Review 5, No. 1, 97-100 (July 1940).

Wait, J. R., Transmission and reflection of electromagnetic waves in the presence of stratified media, J. Research NBS 61, No. 3, 205-232 (Sept. 1958).

GROUND PLAN AND TERRAIN



GROUND PLAN



CENTER-LINE TERRAIN PROFILE
(VERTICAL SCALE EXAGGERATED)

FIGURE 1

B- 34084

EXPERIMENTAL SET UP

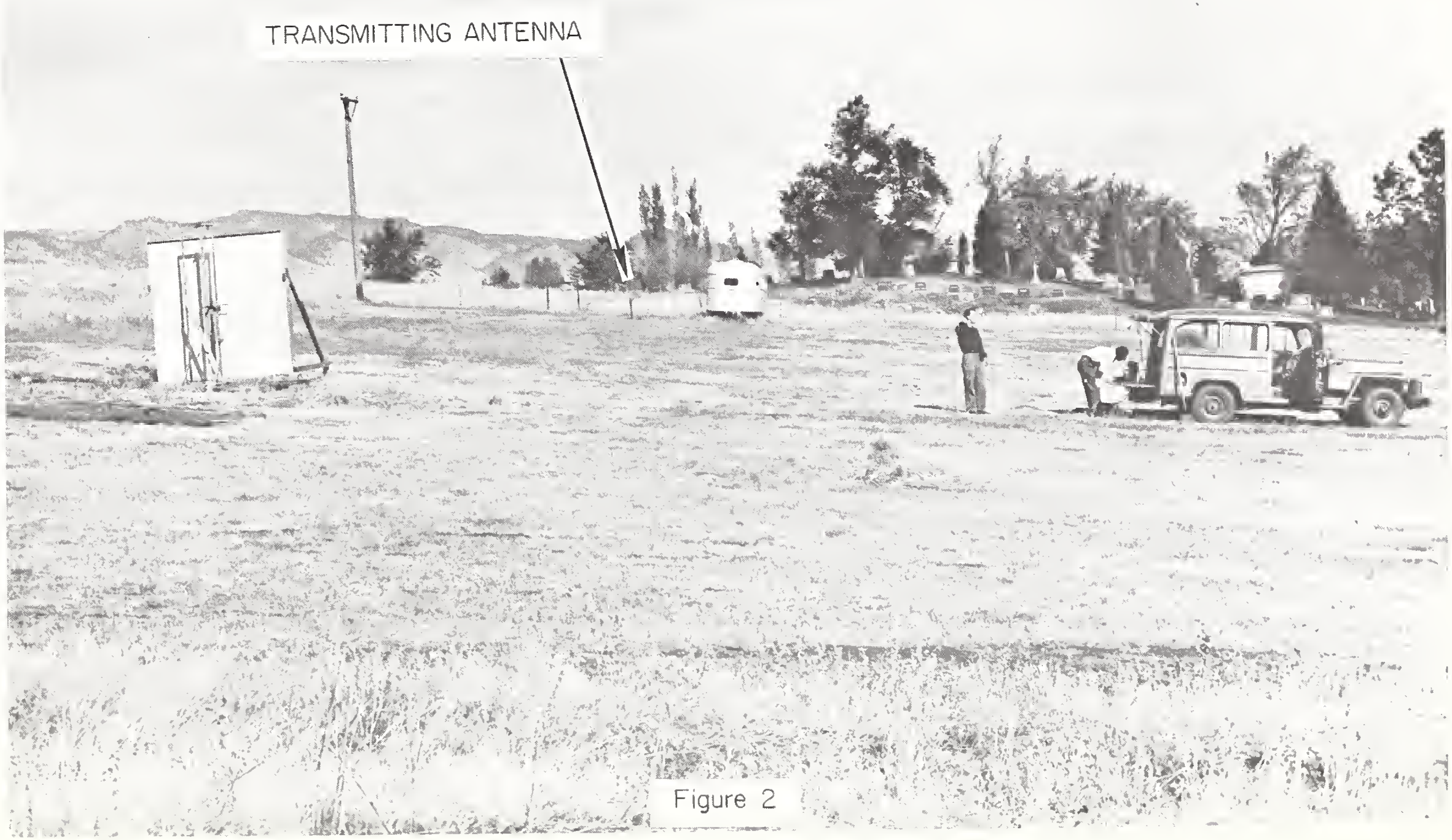


Figure 2

RECEIVING ANTENNAS

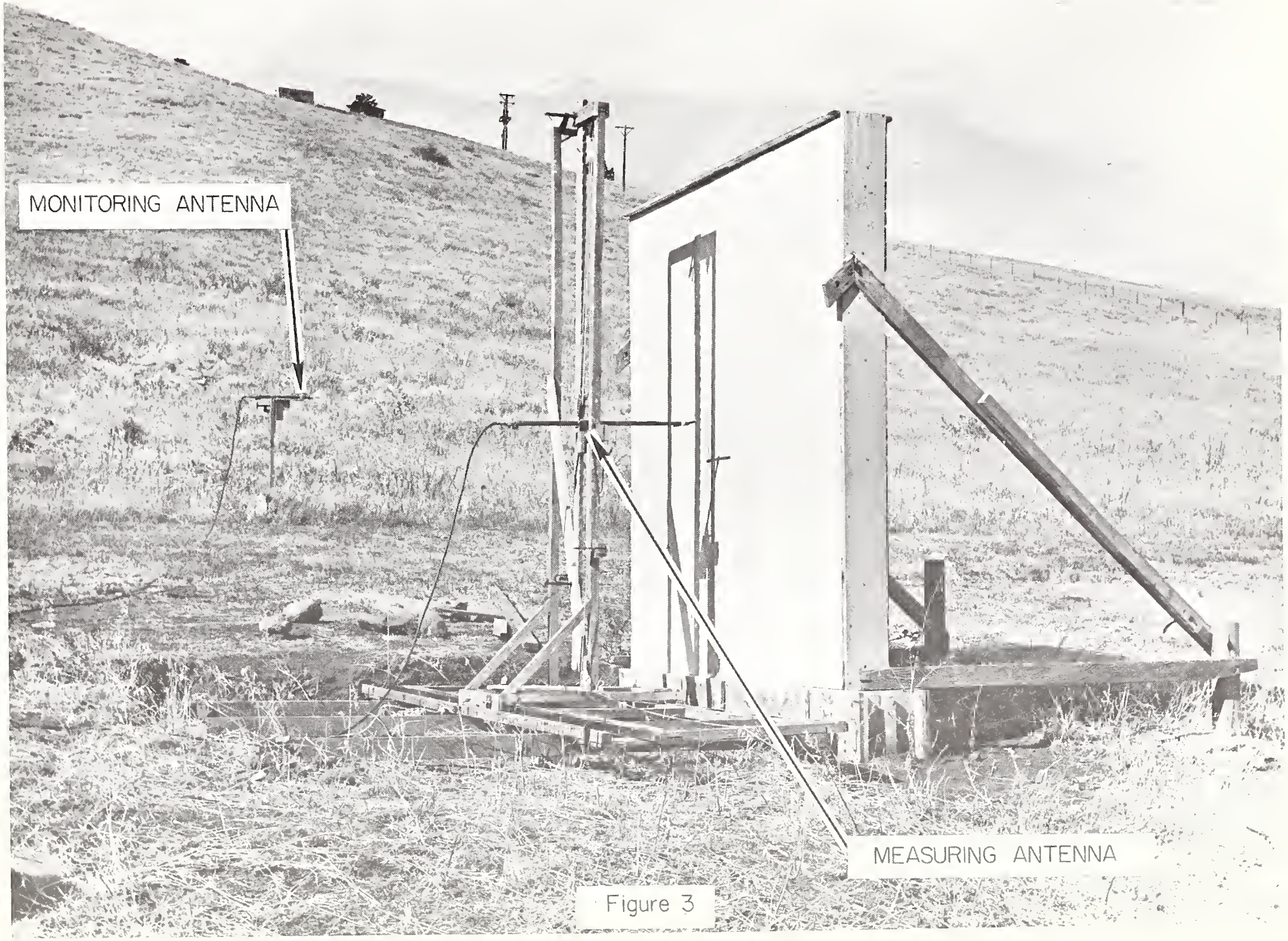


Figure 3

B-34066

OBLIQUE VIEW

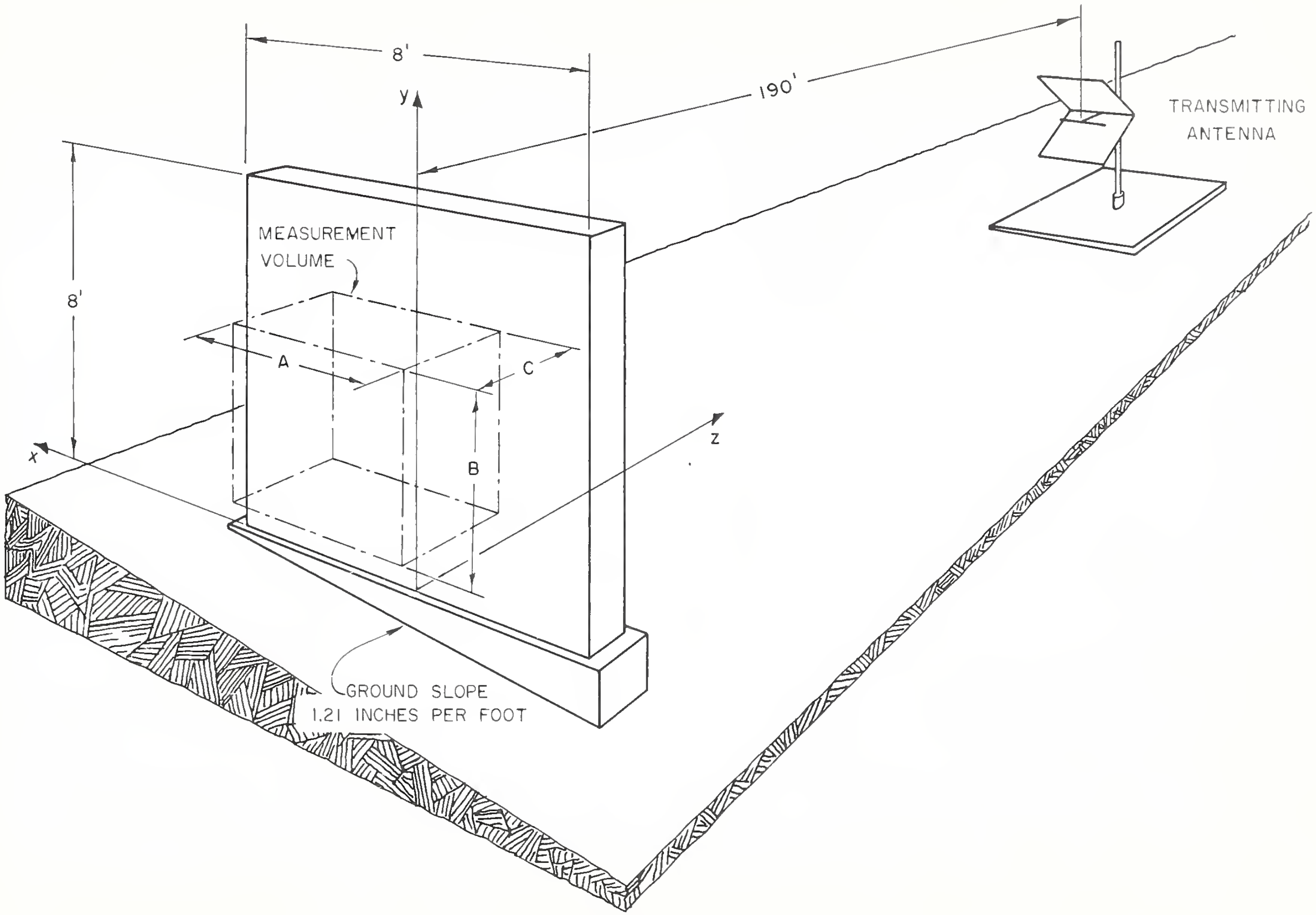


FIGURE 4

B- 34083

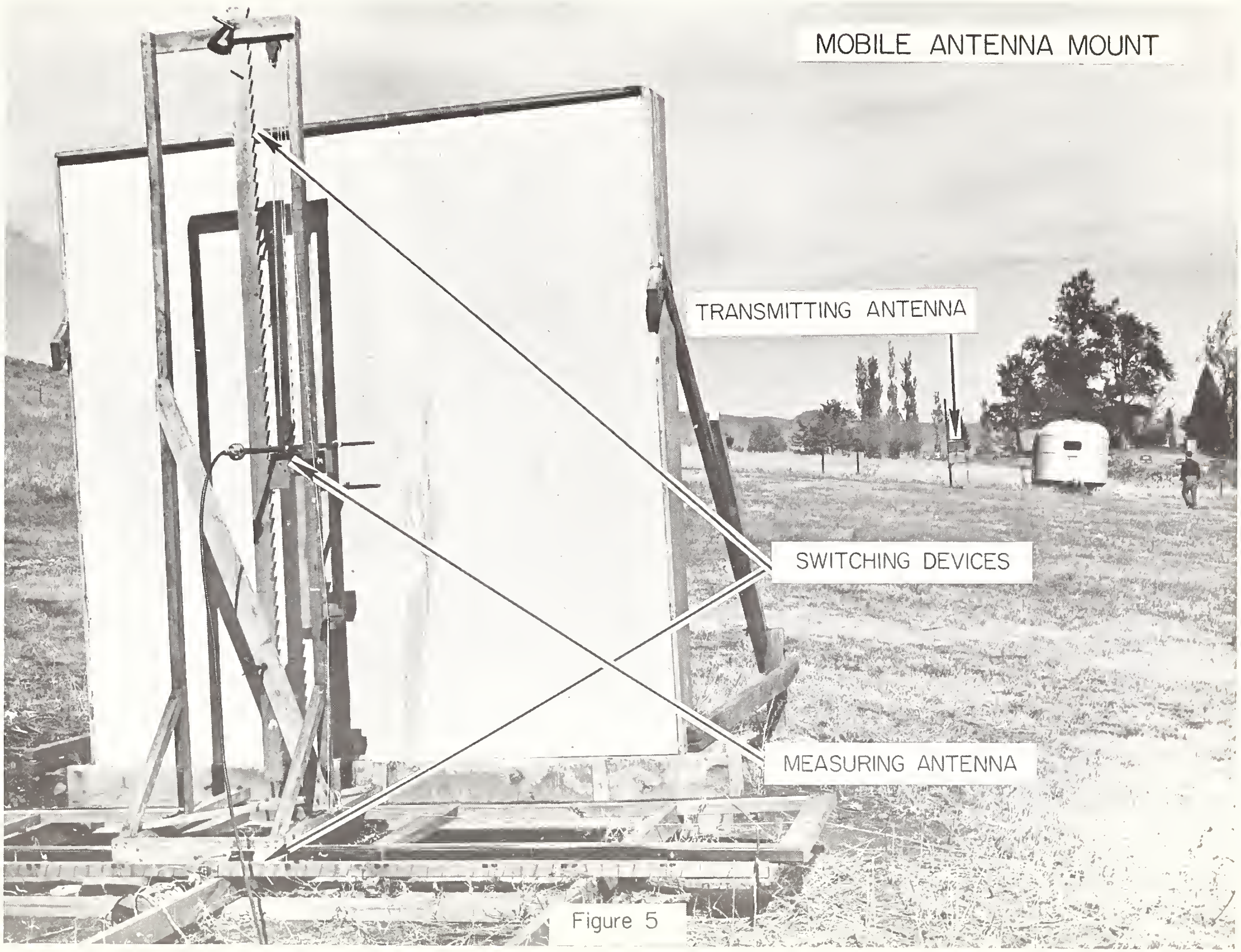


Figure 5

B-34068

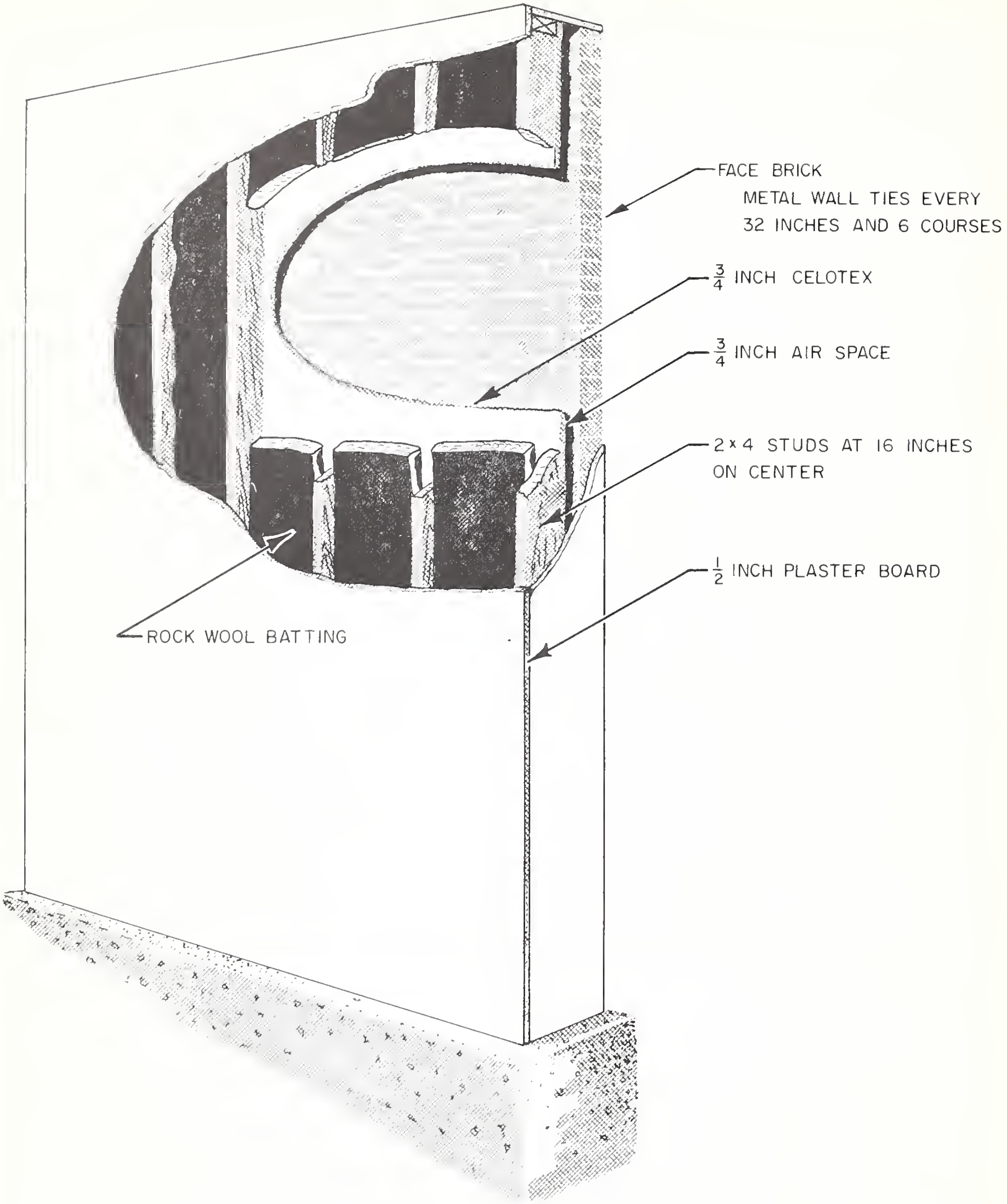

FACE BRICK
METAL WALL TIES EVERY
32 INCHES AND 6 COURSES
$\frac{3}{4}$ INCH CELOTEX
$\frac{3}{4}$ INCH AIR SPACE
2 x 4 STUDS AT 16 INCHES
ON CENTER
$\frac{1}{2}$ INCH PLASTER BOARD
ROCK WOOL BATTING

Figure 6

RELATIVE RECEIVED POWER VERSUS LOCATION
HORIZONTAL POLARIZATION

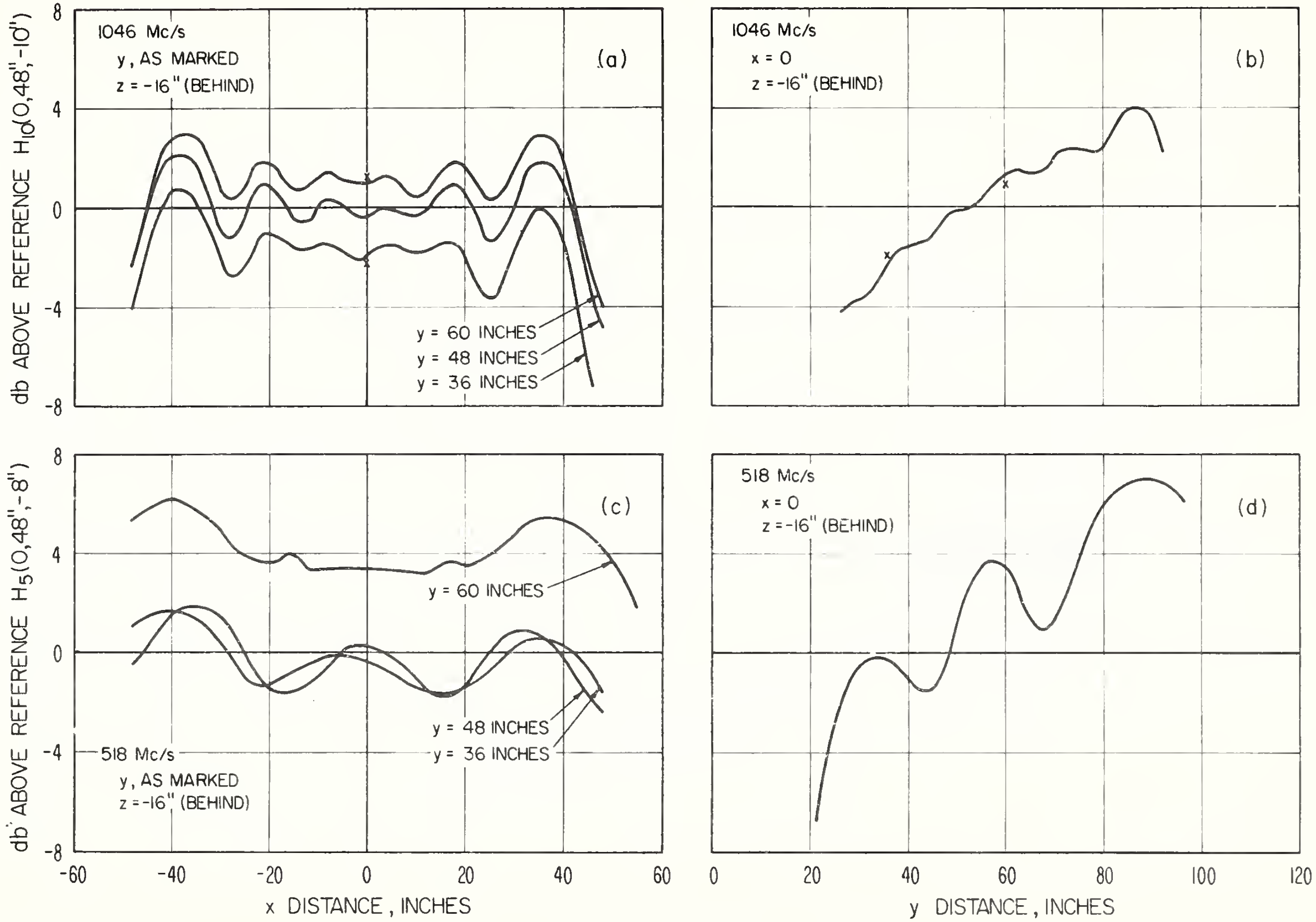


Figure 7

HEIGHT GAIN CURVES BESIDE WALL
518 Mc/s HORIZONTAL POLARIZATION

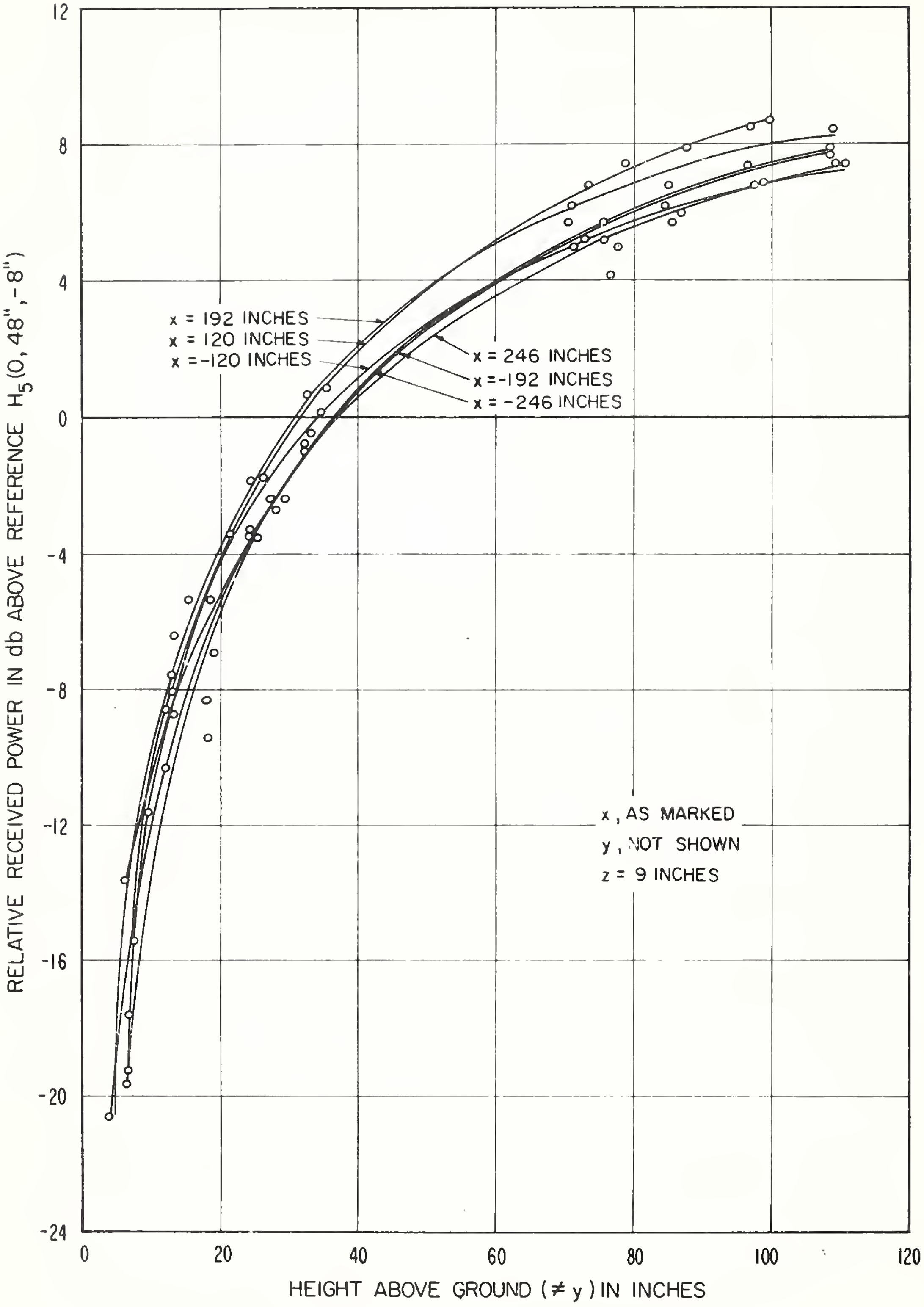


Figure 8

B- 34080

RELATIVE RECEIVED POWER IN PLANE OF WALL FRONT
518 Mc/s   HORIZONTAL POLARIZATION   z = 9 INCHES

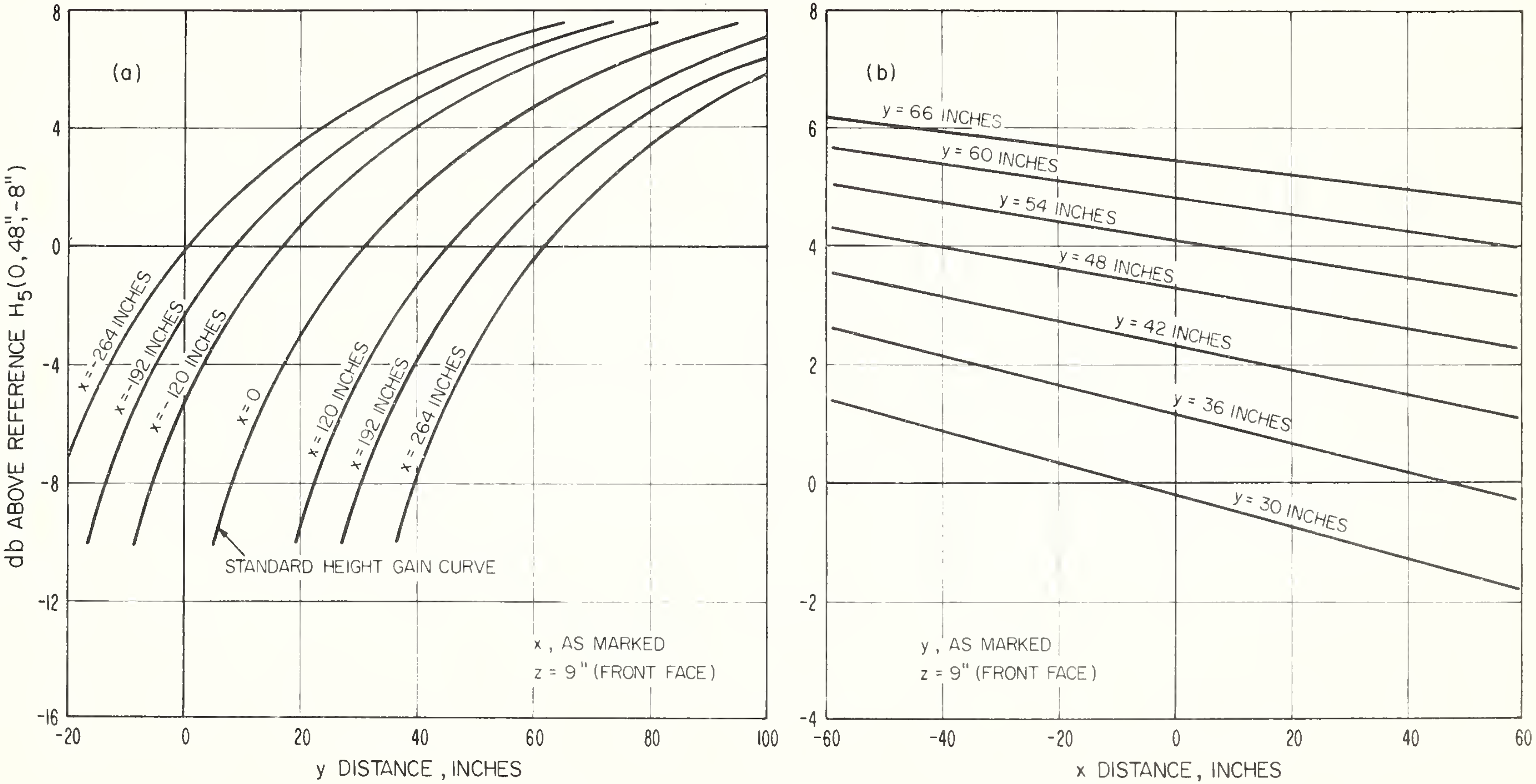


Figure 9

B-34079

RELATIVE RECEIVED POWER IN FRONT OF WALL
1046 Mc/s HORIZONTAL POLARIZATION

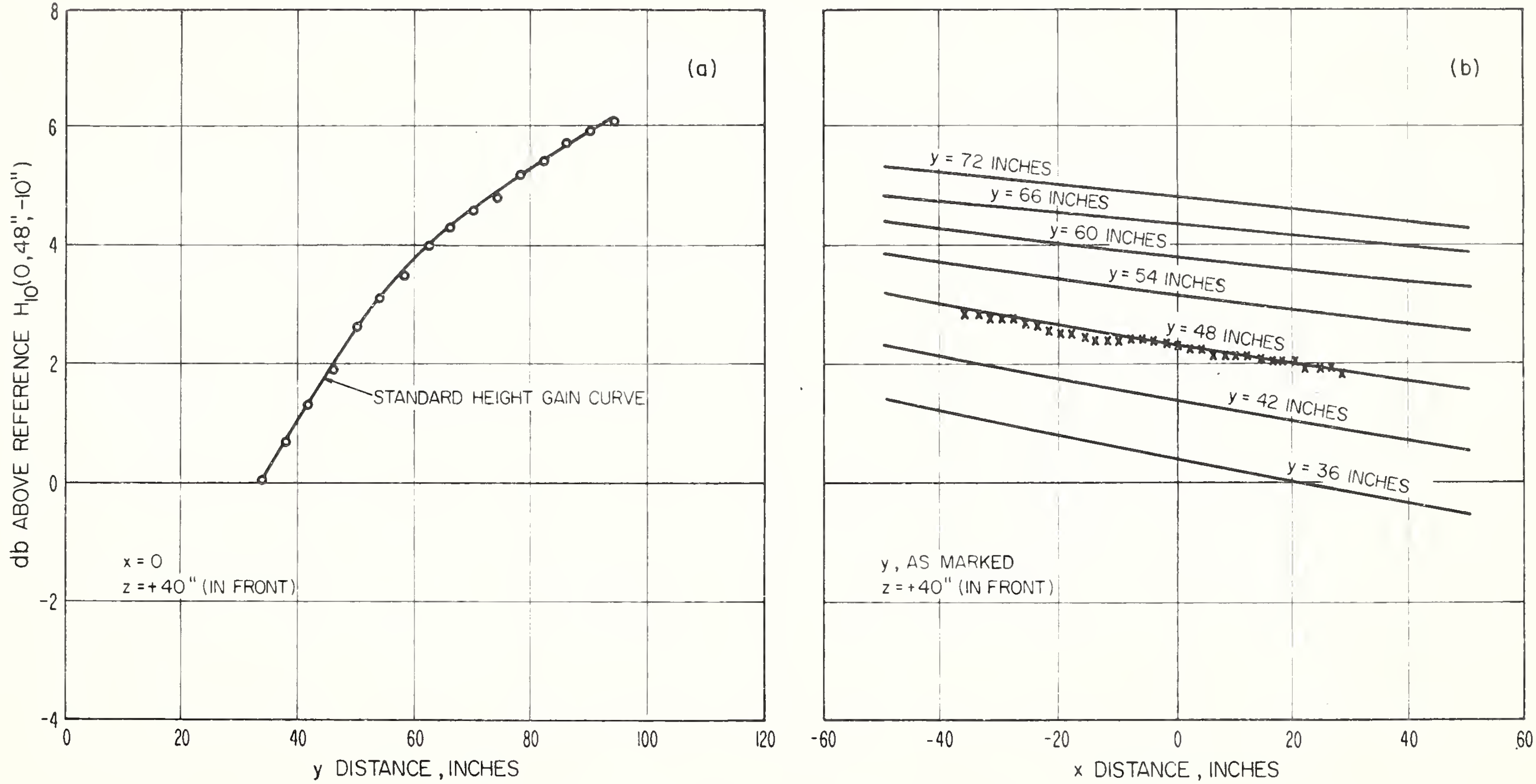


Figure 10

B-34078

POSSIBLE CORRECTION TO REMOVE GROUND SLOPE EFFECTS FROM DATA
518 Mc/s HORIZONTAL POLARIZATION

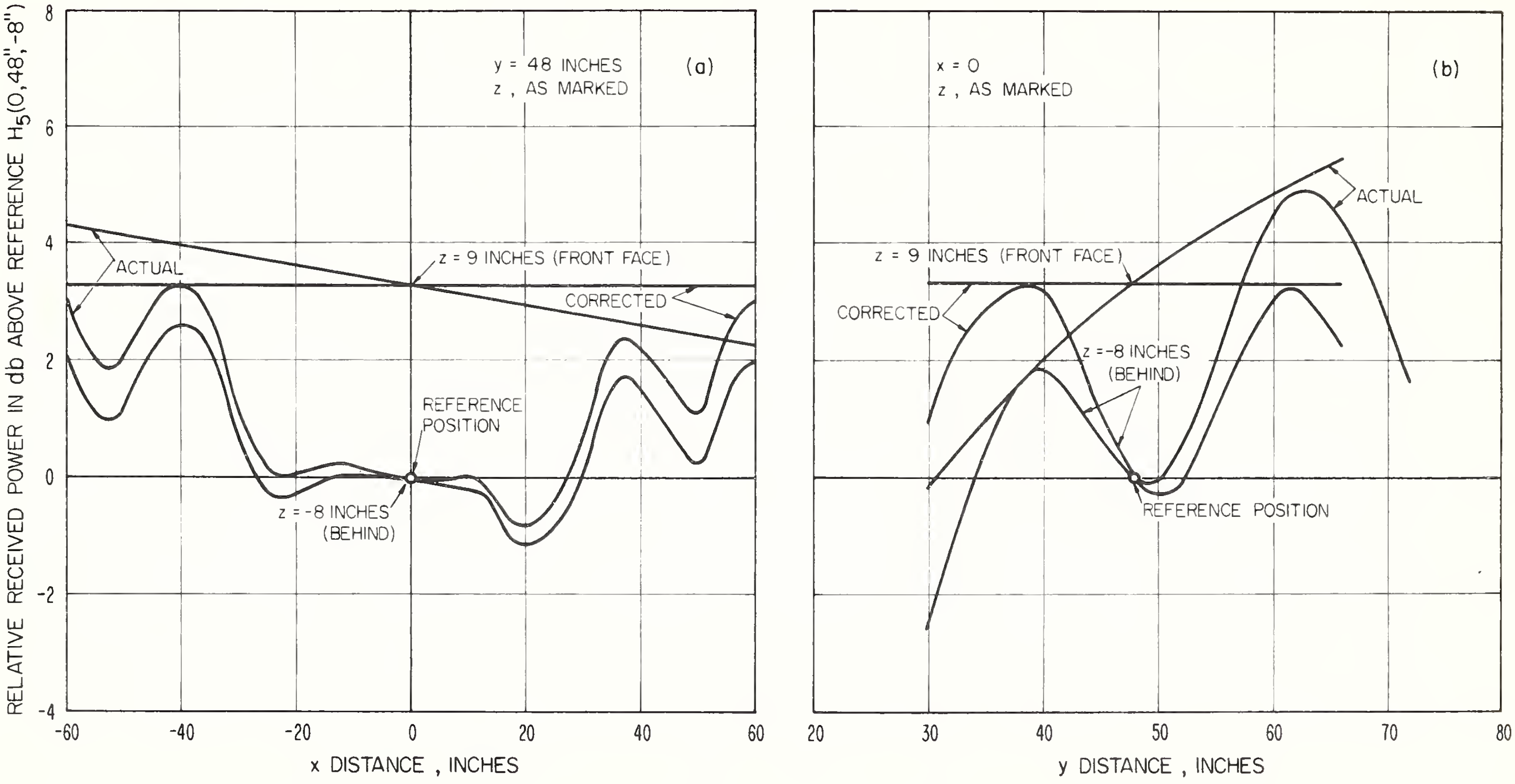


Figure 11

RELATIVE RECEIVED POWER WITH AND WITHOUT ALUMINUM SHEETS COVERING WALL FRONT
518 Mc/s HORIZONTAL POLARIZATION

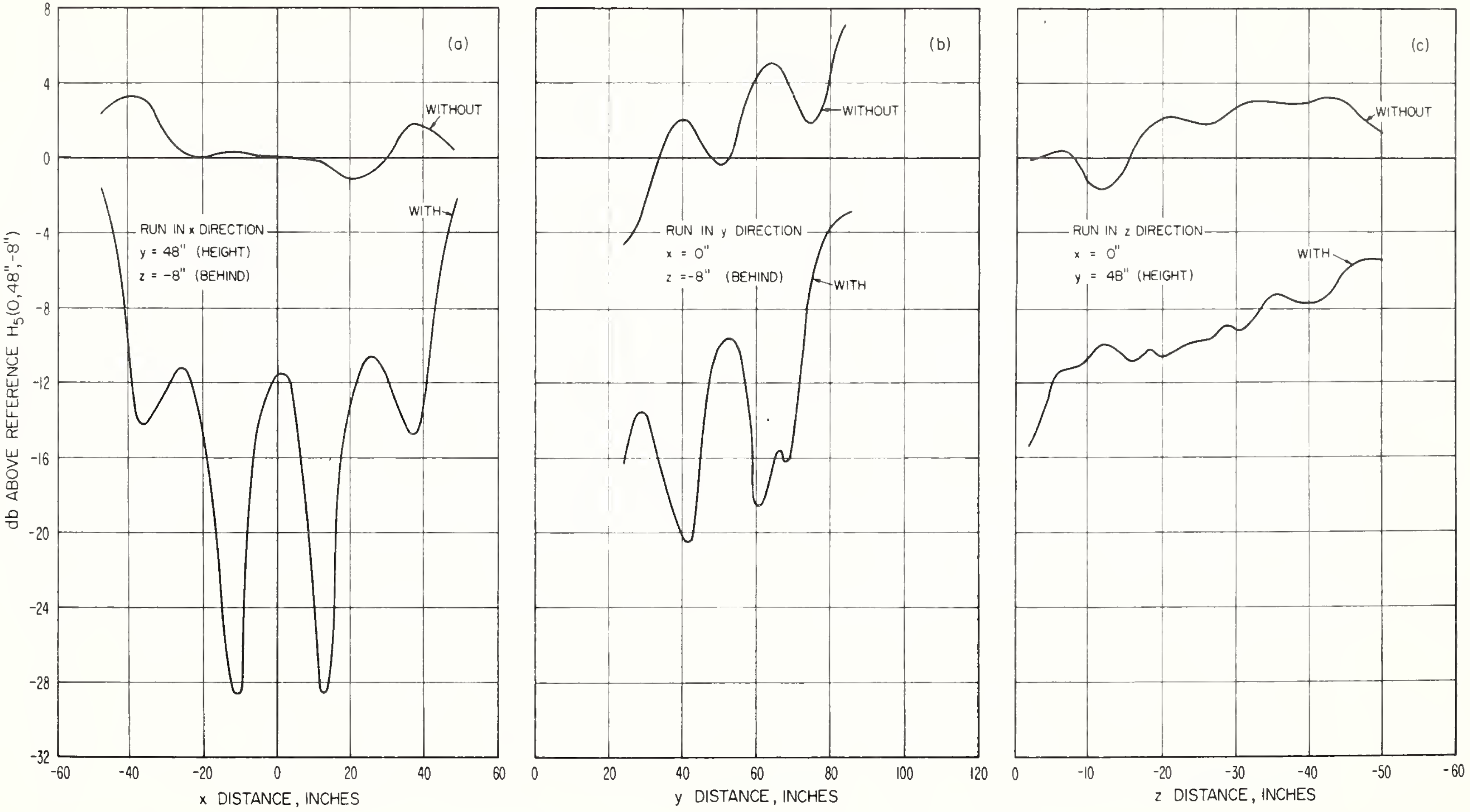


Figure 12

RELATIVE RECEIVED POWER WITH AND WITHOUT ALUMINUM SHEETS COVERING WALL FRONT
1046 Mc/s HORIZONTAL POLARIZATION

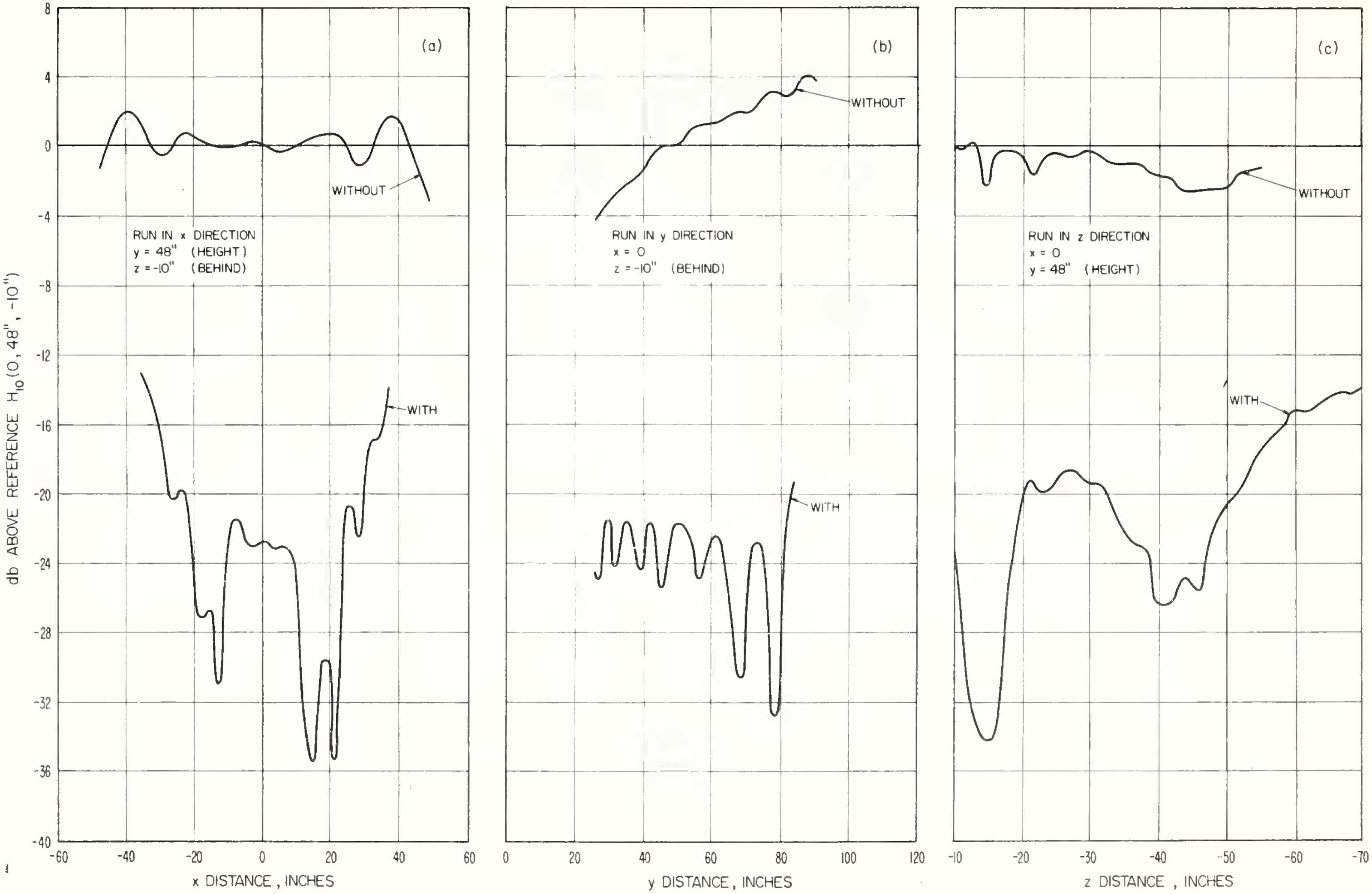


Figure 13

RELATIVE RECEIVED POWER VERSUS LOCATION
518 Mc/s HORIZONTAL POLARIZATION

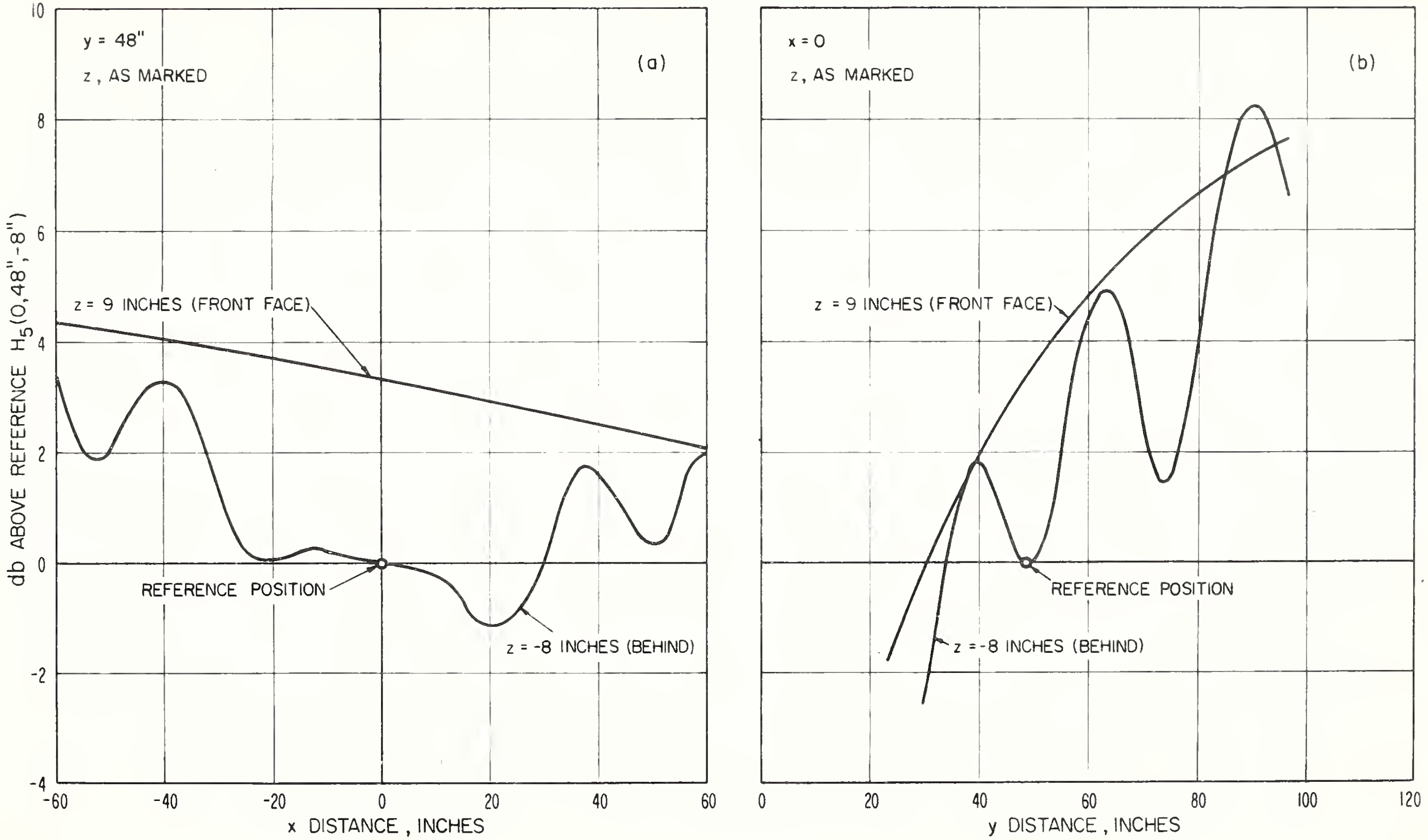


Figure 14

RELATIVE RECEIVED POWER VERSUS LOCATION
1046 Mc/s HORIZONTAL POLARIZATION

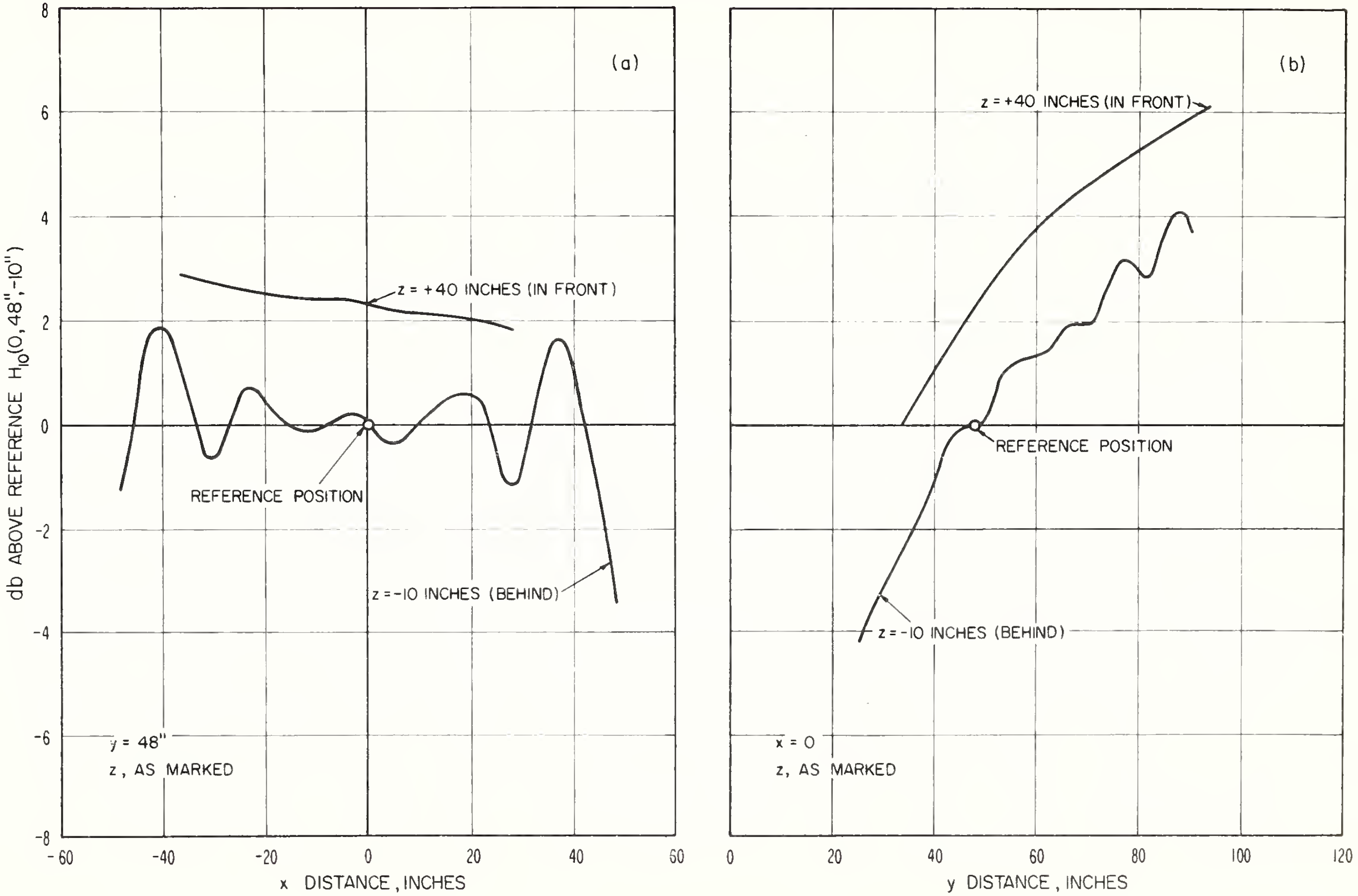


Figure 15

RELATIVE RECEIVED POWER VERSUS LOCATION
1046 Mc/s VERTICAL POLARIZATION

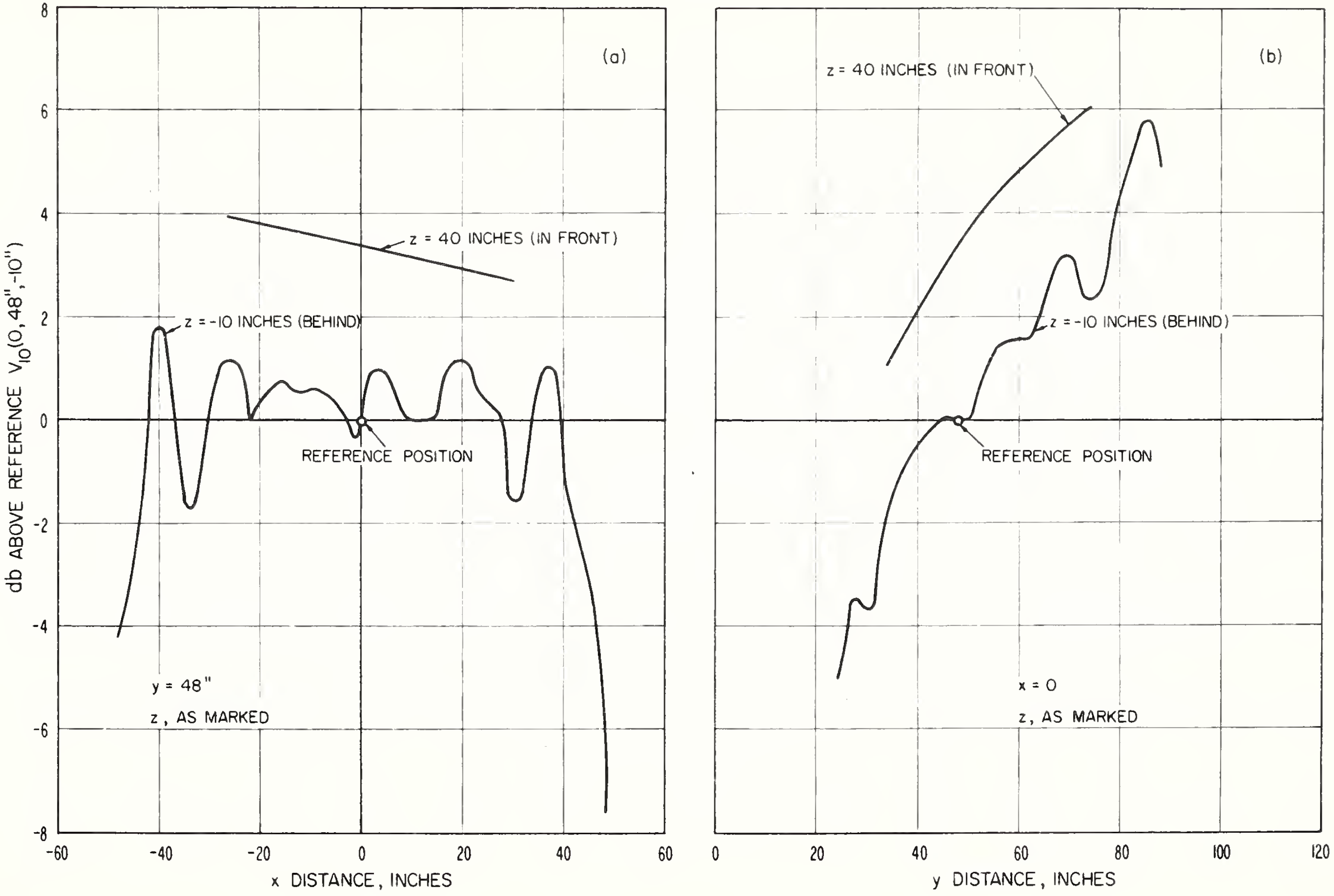


Figure 16

INSERTION LOSS VALUES VERSUS LOCATION
1046 Mc/s

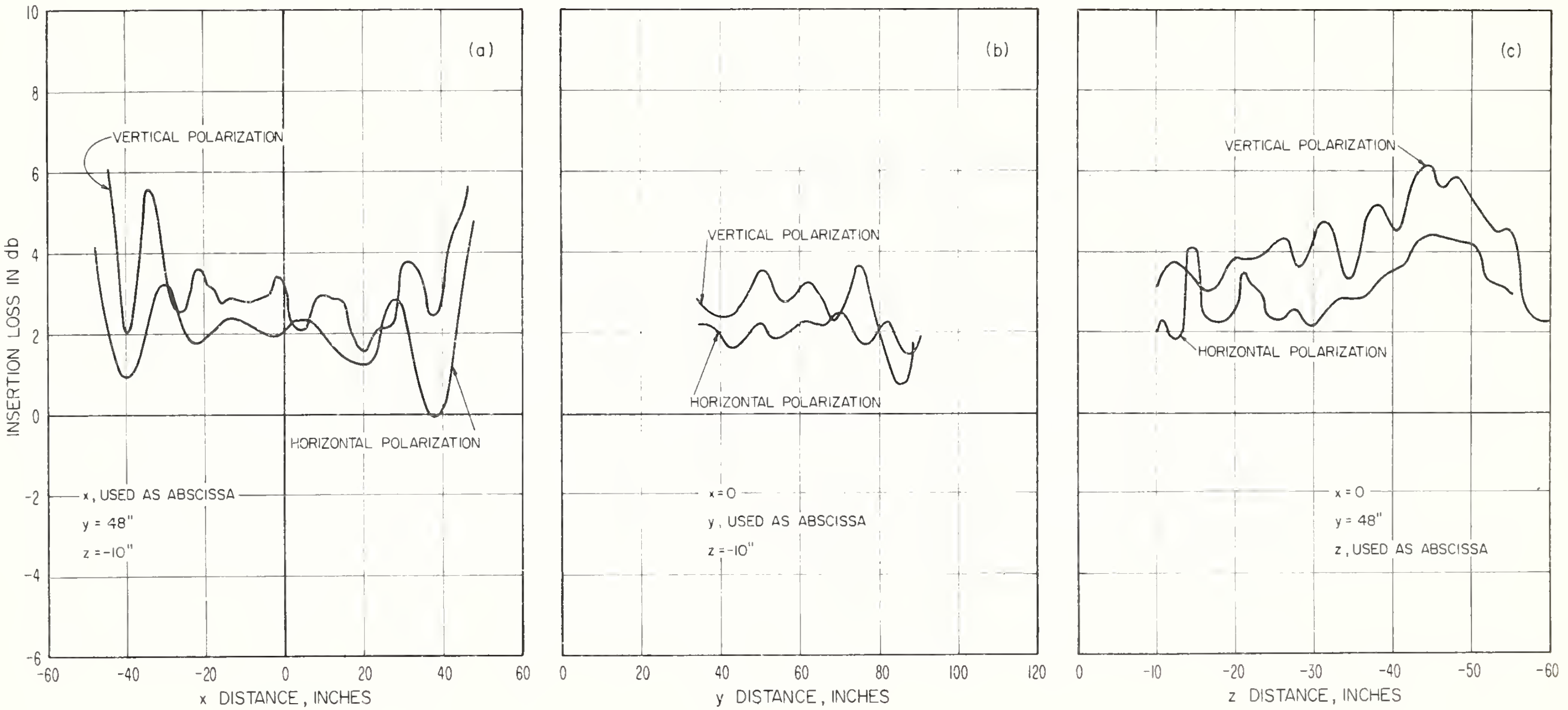


Figure 17

B-34071

INSERTION LOSS VALUES VERSUS LOCATION
HORIZONTAL POLARIZATION

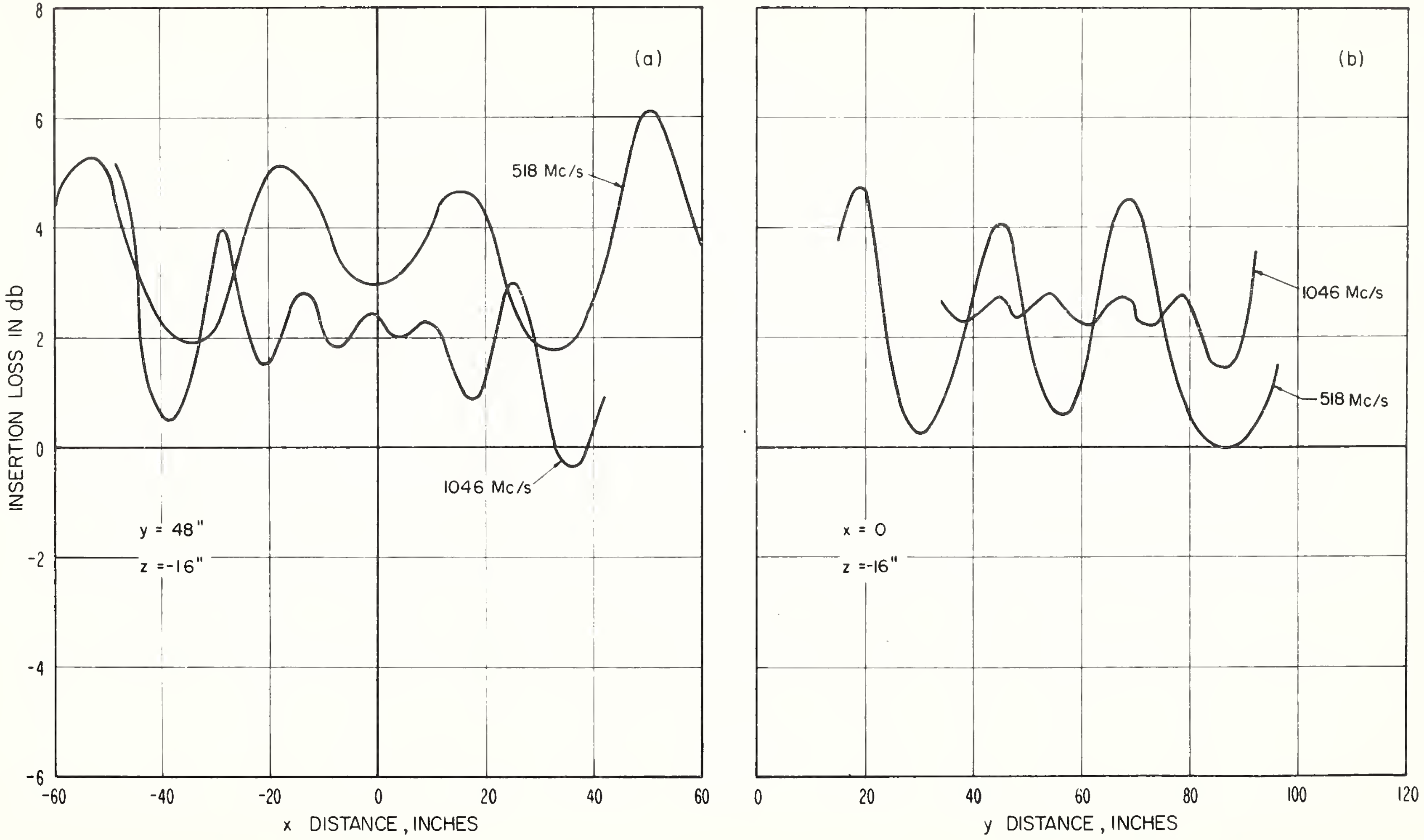


Figure 18

B-34070

DISTRIBUTION OF INSERTION LOSS DUE TO PLACING
THE WALL IN THE TRANSMISSION PATH

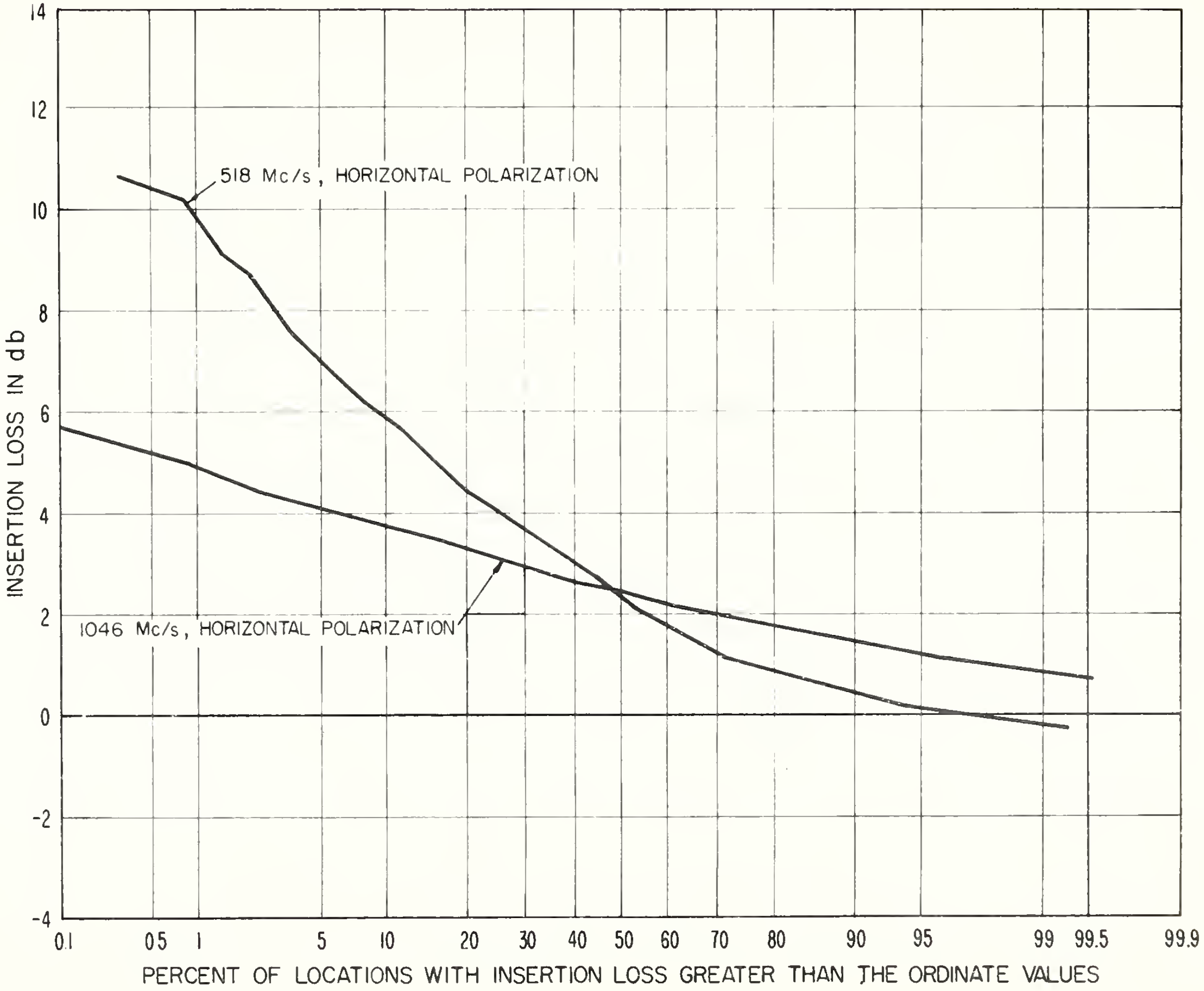


Figure 19

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D. C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics. High Voltage.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research. Crystal Chemistry.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Polymers. Macromolecules: Synthesis and Structure. Polymer Chemistry. Polymer Physics. Polymer Characterization. Polymer Evaluation and Testing. Applied Polymer Standards and Research. Dental Research.

Metallurgy. Engineering Metallurgy. Microscopy and Diffraction. Metal Reactions. Metal Physics. Electrolysis and Metal Deposition.

Inorganic Solids. Engineering Ceramics. Glass. Solid State Chemistry. Crystal Growth. Physical Properties. Crystallography.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials. Metallic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

Data Processing Systems. Components and Techniques. Computer Technology. Measurements Automation. Engineering Applications. Systems Analysis.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Solid State Physics. Electron Physics. Atomic Physics.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Molecular Kinetics. Mass Spectrometry.

Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering Laboratory. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

CENTRAL RADIO PROPAGATION LABORATORY

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services. Vertical Soundings Research.

Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

Radio Systems. Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

RADIO STANDARDS LABORATORY

Radio Physics. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time-Interval Standards. Millimeter-Wave Research.

Circuit Standards. High Frequency Electrical Standards. Microwave Circuit Standards. Electronic Calibration Center.

USCOMM-NBS-BL

Department of Commerce
National Bureau of Standards
Boulder Laboratories
Boulder, Colorado

Official Business

NBS

Postage and Fees Paid
U. S. Department of Commerce