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Boulder Laboratories

SERVICE AREA OF AN AIRBORNE TELEVISION STATION

BY M.T. DECKER

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS
Technical Note

35

October, 1959

Service Area of an Airborne Television Station

by

M. T. Decker

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ABSTRACT

As a step in the evaluation of a proposed airborne television network, the service to be expected from an airborne station has been calculated for a wide variety of operating conditions. The use of basic transmission loss to describe the radio propagation effects enables the results to be used when equipment parameters are changed as system requirements and economic considerations dictate.

SERVICE AREA OF AN AIRBORNE TELEVISION STATION

by

M. T. Decker

INTRODUCTION

In order to assist in the evaluation of a proposed airborne educational television network, the National Bureau of Standards has undertaken a study to determine the coverage to be expected from such stations, and an analysis of station and channel requirements for a nation-wide system. The purpose of this paper is to show the service to be expected from a single airborne station under a wide variety of operating conditions.

It is the aim of the report to present various calculations in a flexible manner such that the system designer may change at will any of the factors which he controls and then determine the resulting effect on the system. For this reason the "radio propagation factors" which are controlled by nature, not man, are separated from the "hardware factors" which, within limits, may be changed as system requirements and economic considerations dictate. A natural choice of parameters on this basis is the commonly used "basic transmission loss" [1]. Briefly, the basic transmission loss is the ratio of power supplied to the terminals of a loss-free isotropic transmitting antenna to the power available at the terminals of a loss-free isotropic receiving antenna, expressed in decibels. The basic propagation information is this basic transmission loss as a function of the geometry of the propagation path, including effects of antenna heights, distance between antennas, the atmosphere. and the earth itself. The characteristics of the actual equipment, including transmitter and receiver performance, antenna gains, various losses, etc., will then limit the basic transmission loss which may be tolerated by the system, still maintaining satisfactory operation. This "maximum allowable basic transmission loss", together with the above described basic transmission loss as a function of geometry, will determine the coverage to be expected.

Of course, most of the radio propagation factors and some of the equipment characteristics are not invariant with time and/or location. Hence certain variabilities will be introduced along with a definition of grade of service and the probability of receiving such a grade of service.

BASIC TRANSMISSION LOSS

Figures 1 to 19 show the calculated basic transmission loss L_b as a function of distance for various combinations of transmitting and receiving antenna heights and for frequencies of 575 Mc and 785 Mc. For these calculations the earth was assumed to be a smooth sphere having ground constants of σ (conductivity) = 5×10^{-14} (emu) and ϵ (relative dielectric constant) = 15. A horizontally homogeneous atmosphere with an exponential vertical gradient of refractive index was used to account for the bending of radio rays [2]. This model is felt to be more closely representative of the actual atmosphere than the linear gradient often used and accounted for by the "4/3 earth" concept.

A curve showing the long-term median of basic transmission loss was first calculated in three parts. This curve is labeled "50%" in the figures. The surface value of refractive index used in the model atmosphere was 316.2908, as derived from data taken throughout the United

States *. The portion of the curve lying within line of sight was calculated by simple ray theory [3], and the characteristic lobe structure is evident. Beyond the line of sight the diffracted energy was calculated by the method developed by Norton, Rice and Vogler [4], and combined with the energy due to atmospheric scattering as calculated by Rice, Longley and Norton [5]. These three portions of the curve were then smoothly connected to form the median basic transmission loss curve. In order to include the effect of long-term time variability, i.e. the variability of hourly medians, the additional curves labeled 1%, 10%, 90%, and 99% were included. The within line-of-sight curves were calculated by using different values of refractive index at the earth's surface in the model atmosphere. The values chosen represent the values which are exceeded 1% and 99% of the time respectively in the United States. This method is similar to the practice of allowing for varying degrees of radio ray bending by the use of different effective earth radii, but, of course, allows the use of the improved atmospheric model. The long-term time variability for the beyond line-of-sight fields has been taken from the empirically derived curves of reference 5 which indicate the difference between median fields and fields for other percentages of the time, as a function of the angular distance, the angle between horizon rays from transmitter and receiver. These curves have also been

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* The choice of a surface refractive index of 316.2908 and the less accurate but simpler assumption of a linear gradient of refractive index result, for an assumed 6370 kilometer actual radius, in an effective earth's radius of 9000 kilometers. Under these conditions the line of sight distance d from an antenna h meters above a smooth earth may be found from $d = 3\sqrt{2h}$ where d is in kilometers and h is in meters.

modified to be a function of frequency.

The curves are presented for three transmitting and three receiving antenna heights and for two frequencies in the UHF television band. Figures 1 through 10 are calculated for 575 Mc, the center of the lower half of the UHF-TV band, while figures 11 through 19 are at 785 Mc, the center of the upper half of the band. All of the figures with the exception of figure 4 are calculated for horizontal polarization. Figures 3 and 4 may be compared to indicate the difference to be expected between the two polarizations over a smooth earth. The decrease in magnitude of the reflection coefficient for vertical polarization as the grazing angle increases results in nulls which are not as deep as are those for horizontal polarization. Use of vertical polarization could be advantageous for this reason. In addition, the alternate use of vertical and horizontal polarization for geographically adjacent cochannel stations would result in an improvement in the rejection of the interfering station.

It should be noted that the variation of basic transmission loss with time at one distance is not necessarily correlated with the transmission loss at any other distance, hence the entire curve need not shift at one time as could be inferred from the plot.

SERVICE

The term "service" as used in this study may be defined as follows: In the absence of interfering signals, service exists at a receiving location during any hour for which the hourly median signal received from the transmitting station exceeds the receiver noise power by a specified ratio. In the presence of interference, this service exists when the signal from the desired station exceeds the sum of the noise power and interfering signal power by a specified ratio.
The term "grade of service" requires that service shall exist

for more than some specified percentage of all hourly medians. This percentage as used in this study is taken to be 99% and will be referred to as "99% grade of service".

VARIABILITY OF TRANSMISSION LOSS

Variations of the basic transmission loss from the computed median have been divided into three categories. The first, the long-term variation of hourly median basic transmission loss has been included in the L_b versus distance curves. Second, there are variations with time which occur within the hour. These short-term time variations may arise from various sources, including the irregularity of the aircraft antenna pattern which combines with the aircraft motion to produce varying fields at the receiver. Reflections of small magnitude from irregular terrain or other objects, the effect of inhomogeneities in the atmosphere, which may change with aircraft motion may also introduce short-term fading. These short-term effects have been allowed for in this study by an increase in the required long-term median signal-to-noise ratio which is required for satisfactory operation. An examination of many aircraft antenna patterns (including the 1948 Westinghouse-Martin B-29 antenna used for Stratovision flight tests) indicates that an allowance of approximately 10 db should be made for a 99% grade of service. The third source of variability arises from the fact that the earth is not a smooth sphere, but has many irregularities. This means that some locations will be better for receiving signals than others, or put another way, not all locations at a given distance may receive satisfactory service. In order to allow for this variation it was assumed that service as determined by long- and short-term time variations alone could be expected at 50% of the locations at any distance and that the probability of service with respect to location could be represented by a log-normal distribution with a standard deviation of 6 db [6].

MAXIMUM ALLOWABLE BASIC TRANSMISSION LOSS

Equipment parameters are used to determine the amount of transmitter power which may be lost between transmitter output terminals and receiver input terminals and still maintain satisfactory operation of the receiving set. The following factors should be considered:

Transmitter power, db above 1 watt	P_t
Transmitter line losses, db	L_t
Transmitting antenna gain, db above an isotropic radiator	G_t
Receiving antenna gain, db above an isotropic radiator	G_r
Receiver line losses, db	L_r
Required signal power at receiver, db above 1 watt	P_r

The transmitter power and the signal power at the receiver should have comparable specifications in the case of modulated signals such as television. That is, if the transmitter power is referred to the peak of the synchronizing pulse, receiver power should be specified in the same manner.

The required signal power at the receiver may be determined from the receiver bandwidth, noise figure, and required signal-to-noise ratio. The required signal-to-noise ratio must include a consideration of the required steady signal to produce a picture satisfactory to viewers, plus an allowance for short-term time variations as indicated above. Various studies of required signal-to-noise ratios have been made [7, 8]. Curves published by the Television Allocations Study Organization (TASO) indicate that 50% of the viewers rate a picture passable or better if the signal-to-noise ratio is 27 db. Similar studies by the National Bureau of Standards indicated that a 26 db ratio would be satisfactory. The TASO study indicated that a ratio of 38 db is required before 95% of the viewers rated a picture passable or better. The lower figure is used as an example but the system designer may consider other values. An allowance of 10 db for short-term fading has been included in the examples of maximum allowable transmission loss presented here.

The required receiver signal power expressed in dbw may now be determined from

$$P_r = 10 \log_{10} ktb + F + R$$

where k = Boltzman's constant (1.38×10^{-23})

t = absolute temperature in degrees K, here taken to be 288.48°, so that $10 \log_{10} kt = -204$ dbw/cycle

b = effective bandwidth in cycles per second, approximated here by the 3 db bandwidth

F = receiver noise figure in db

R = required signal-to-noise ratio in db.

Finally then, the maximum allowable basic transmission loss $L_{b(max)}$ may be expressed

$$L_{b(max)} = P_t - L_t + G_t + G_r - L_r - 10 \log_{10} b - F - R + 204$$

As an example of this calculation, consider current commercial UHF receiver performance characteristics as reported in reference 7 (Table III, p. 121), and a 1 kw transmitter.

P_t	1 kw	30 dbw
L_t		2 db
G_t		4 db
G_r	equivalent to a 1.5 meter parabolic antenna	18 db
L_r	30 meters of RG8/ U coaxial transmission line with fittings	8 db
10 log b	based on "average" equipment bandwidth of 20 Mc.	73 db
F	based on "average" equipment	13 db
R	based on signal-to-noise ratio of 27 db and 10 db for short-term fading	37 db

Then

$$L_{b(max)} = 30 - 2 + 4 + 18 - 8 - 73 - 13 - 37 + 204 = 123 \text{ db}$$

A brief examination of the L_b versus distance curves indicates that this equipment performance would be completely unsatisfactory if reliable service is to be maintained to any reasonable distance.

Consider next the improvement to be gained by the use of equipment built to more exacting standards. The receiver bandwidth is decreased to 6 Mc, the noise figure to 10 db, antenna gains increased, and line losses reduced by the use of better transmission line. The terms in the $L_{b(max)}$ equation then become:

$P_t = 30$
$L_t = 1$
$G_t = 5$
$G_r = 20$
$L_r = 3$
$10 \log b = 67.8$
$F = 10$
$R = 37$

then $L_{b(max)} = 30 - 1 + 5 + 20 - 3 - 67.8 - 10 - 37 + 204 = 140.2$ db

Further improvement in $L_{b(max)}$ could be made in a number of ways depending on the technical and economic limitations. The power transmitted from the aircraft could be increased, better antennas used, or receivers with lower noise figures might be employed if service is not limited by interfering signals or man-made noise at the receiving location.

DIVERSITY RECEIVING ANTENNAS

An examination of figures 1 to 19 indicates that for certain transmitter-to-receiver distances the use of vertically spaced diversity receiving antennas would be advantageous in reducing the signal fading which may result from ground reflections as the aircraft moves. Experimental evidence indicates that these nulls as shown in the figures may be present, especially where lower receiving antennas (10 meters) facing a smooth unobstructed foreground are used.

The calculated lobe diagrams are based on a perfectly smooth earth, resulting in high reflection coefficients, a condition not always met over actual terrain at these frequencies. Hence, it would be expected that only the nulls at the greatest ranges (lowest grazing angles) would be very deep. Thus, depending upon the maximum allowable basic transmission loss, and antenna height, the nulls at shorter distances would not affect the service.

A space diversity system as envisioned for this application would consist of two antennas separated vertically on a single tower. Maxima and minima of signal strength exist along this tower and their locations are, in general, a function of frequency and terrain, and the range over which aircraft height and distance from the aircraft to the receiver are expected to vary. The heights of the receiving antennas are chosen such that one of them will always be near a maximum. Suitable electronic selection techniques would allow the stronger of the signals from these antennas to be used for the television picture.

Approximate calculation of the heights of the maxima and minima, and hence the proper location of the antennas, is simple for propagation over a smooth earth. This type of calculation gives a rough idea of the location of nulls and maxima, but in actual installations the locations may be so modified by terrain irregularities as to require measurement of signal strength as a function of height above ground for known aircraft locations.

If either the transmitting or receiving antenna height is low and the distance between them is large compared to their heights (as is the case in the present study) the following approximate relation may be used to find the height of a maximum or minimum over a smooth earth with effective radius of 9000 kilometers and in a linear gradient atmosphere: [9]

$$h_r = \frac{4500\, n \lambda d}{18 h_t - d^2}$$

where h_r = height of maximum or minimum at the low antenna, meters

h_t = high antenna height, meters

d = distance between antennas, kilometers

λ = wave length, meters

n = 1, 2, 3, 4, ··· and is odd for a maximum and even for a minimum

A correction may be applied to this calculation to allow for radio ray refraction by an exponential refractive index gradient instead of by the linear gradient atmosphere. Since there is less total bending in the exponential atmosphere, a ray leaving the earth at a given initial angle above the horizon will reach a given altitude at a lesser distance than will a ray in a linear atmosphere. The above results may be approximately corrected for this effect in the following manner. The distance at which the heights of maxima and minima are desired is first selected. This is the distance in the exponential gradient atmosphere. The distance to be used in the above formula is somewhat greater than this and may be found by the use of figure 20, adding the appropriate Δd to the original distance chosen. The resulting height, h_r, is then applicable to the distance in the exponential atmosphere. Successive values of n are used to find the maxima and minima heights at this distance.

Three examples of this calculation are given in figures 21, 22, and 23. These approximate locations of maxima and minima agree quite closely with those shown in figures 1 to 19 which were done with a more exact method by a digital computer. Figures 21 and 22 show the effect of a change in frequency with the aircraft at one altitude, while figures 22 and 23 show a change in altitude at a fixed frequency. The heights of the receiving antennas should be chosen such that one of them will always be near a maximum, considering expected changes in both distance and altitude.

COVERAGE

A single circle drawn on the surface of the earth does not adequately describe the coverage of a television station. It is better described by an indication of the percent of locations receiving a given grade of service at any given distance. For this reason no radius of coverage has been mentioned in this report, but an indication of the overall coverage performance of a system may be gained from figures 24 and 25. It was assumed that by the use of suitable antenna locations with space diversity arrangements where necessary, and with maximum receiving antenna heights of 30 meters, the basic transmission loss could be maintained for 99% of all hours above the value found by combining a line which has 3 db less loss than the free-space transmission loss with the 99% curve near the horizon. This assumption is considered applicable to 50% of the locations at any distance . For a given $L_{b(max)}$ and the previously mentioned location variability the percent of locations receiving the 99% grade of service may be determined. This has been done and the results plotted for a range of $L_{b(max)}$ values from 135 to 150 db, and for various transmitting antenna heights. The improvement to be gained from increasing either the maximum allowable basic transmission loss or the aircraft altitude may be readily seen in these figures.

Illustrations of the relative number of locations which could be served by an airborne station are shown in figures 26, 27, and 28. If service were obtained everywhere throughout an area, the number of locations which could receive service at any distance would be proportional to the circumference (or radius) of a circle at this distance. In the present case, however, the probability of receiving service decreases with increasing distance from the transmitter, so that at some point the relative number of locations receiving service decreases in spite of the larger radius. In the figures the relative number of locations receiving service at a given distance is proportional to the height of the curve, and the total number of receiving locations is proportional to the area under the curve. It was assumed that the aircraft was circling at a fixed altitude with a radius of 15 kilometers, and that the location probability applicable to a given increment of area is that which would apply with the aircraft at the far side of the circle.

The following tabulation lists the effective areas under the curves of figures 26, 27, and 28. This effective area is defined as the summation of incremental areas multiplied by the probability of receiving service in each of these areas.

Frequency	Aircraft Altitude	$L_{b(max)}$	Effective Area
575 Mc	7500 m	140 db	305,000 km^2
		145	352,000
		150	379,000
785 Mc	7500 m	140 db	271,000 km^2
		145	335,000
		150	372,000
785 Mc	5000 m	140 db	191,000 km^2
		145	226,000
		150	246,000

CONCLUSIONS

An examination of the basic transmission loss curves together with calculations of the maximum allowable transmission loss indicates that the system will require the use of carefully designed equipment with maximum possible transmitter power and lowest possible receiver noise figures. Currently available "average" commercial UHF-TV receiving sets as listed in the TASO report are probably not adequate for this system.

A useful and versatile description of coverage has been presented in figures 24 and 25. They are applicable to a wide variety of system conditions and the subsequent figures have been derived from them. Other figures similar to figures 26, 27 and 28 may of course be easily obtained from them.

In order to achieve the system performance indicated in this report it may be necessary to employ diversity receiving antennas at certain distances. The requirement will depend on the range of variation expected in aircraft height and distance and on the unobstructed effective heights available at the receiver. It is likely that measurements will be required to establish the need for a diversity system at the various receiving locations.

It would be highly desirable to instrument the initial system for careful measurement of transmission loss over an extended period of time. A careful evaluation of the usefulness of diversity receiving antennas should be made.

Further theoretical work will be carried out to estimate the number of aircraft and portion of frequency spectrum required for efficient coverage of the entire United States.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Kenneth A. Norton, "System loss in radio wave propagation," NBS Journal of Research (D: Radio Propagation) 63D, 53-57, July-August, 1959.

[2] B. R. Bean and G. D. Thayer, "Models of the atmospheric radio refractive index," Proc. IRE, 47, 5, 740-755, May, 1959.

[3] R. S. Kirby, J. W. Herbstreit and K. A. Norton, "Service range for air-to-ground communications at frequencies above 50 Mc," Proc. IRE, 40, 5, 525-536, May, 1952.

[4] K. A. Norton, P. L. Rice and L. E. Vogler, "The use of angular distance in estimating transmission loss and fading range for propagation through a turbulent atmosphere over irregular terrain," Proc. IRE, 43, 10, 1488-1526, October, 1955.

[5] P. L. Rice, A. G. Longley and K. A. Norton, "Prediction of the cumulative distribution with time of ground wave and tropospheric wave transmission loss. Part I--The prediction formula," NBS Technical Note 15 (PB 151374) July, 1959.

[6] R. S. Kirby, "Measurement of service area for television broadcasting," IRE Trans. on Broadcast Transmission Systems, BST-7, 23-30, February, 1957.

[7] "Engineering aspects of television allocations," Report of the Television Allocations Study Organization to the Federal Communications Commission, March 16, 1959.

[8] Kenneth A. Norton, Addendum to Reference "E" to the Federal Communications Commission Ad Hoc Committee for the Evaluation of the Radio Propagation Factors Concerning the Television and Frequency Modulation Broadcasting Services in the Frequency Range Between 50 and 250 Mc, November 16, 1950.

[9] Reference Data for Radio Engineers, International Telephone and Telegraph Corporation, 4th Edition, 1956, p. 810.

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 7500 METERS GROUND ANTENNA HEIGHT 10 METERS
FREQUENCY 575 Mc HORIZONTAL POLARIZATION

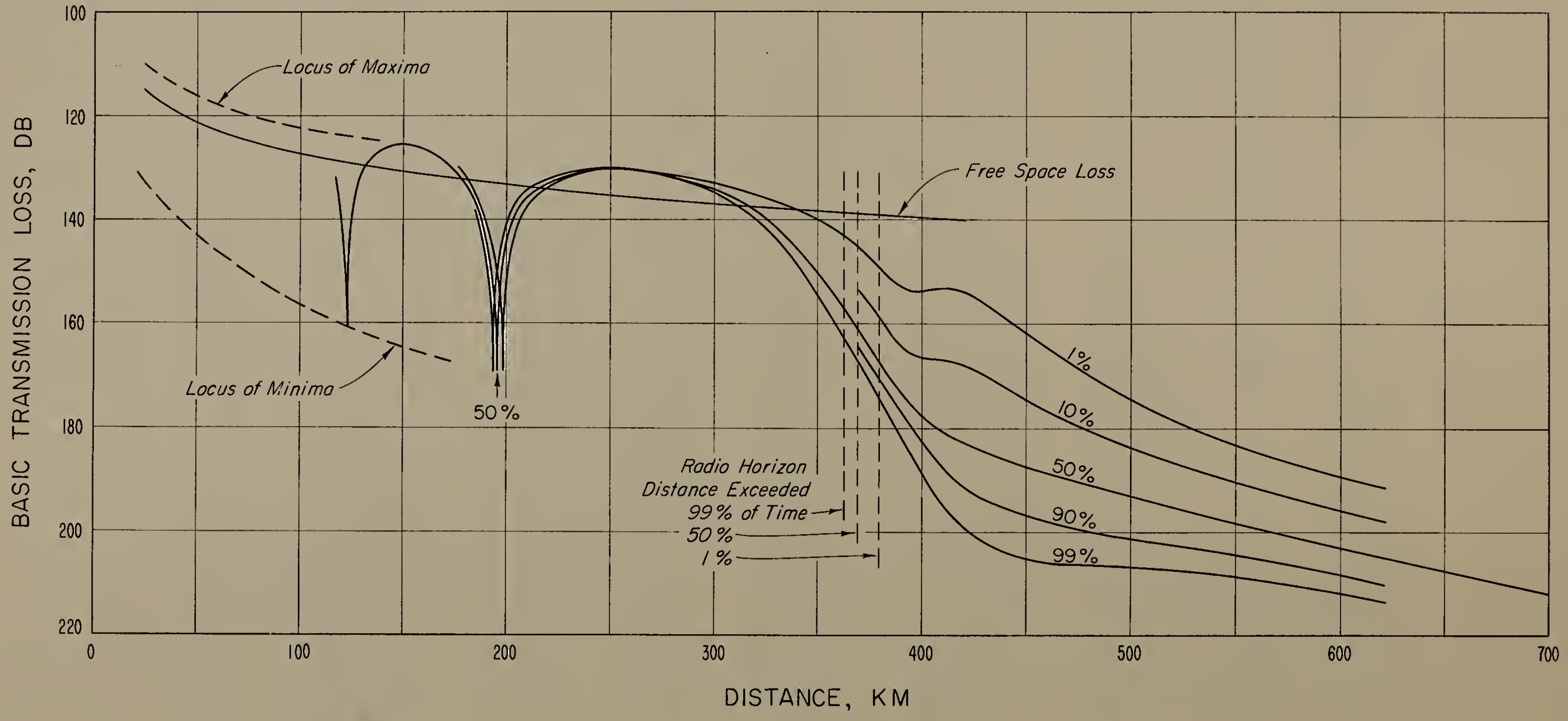


Figure 1

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 7500 METERS GROUND ANTENNA HEIGHT 15 METERS
FREQUENCY 575 Mc HORIZONTAL POLARIZATION

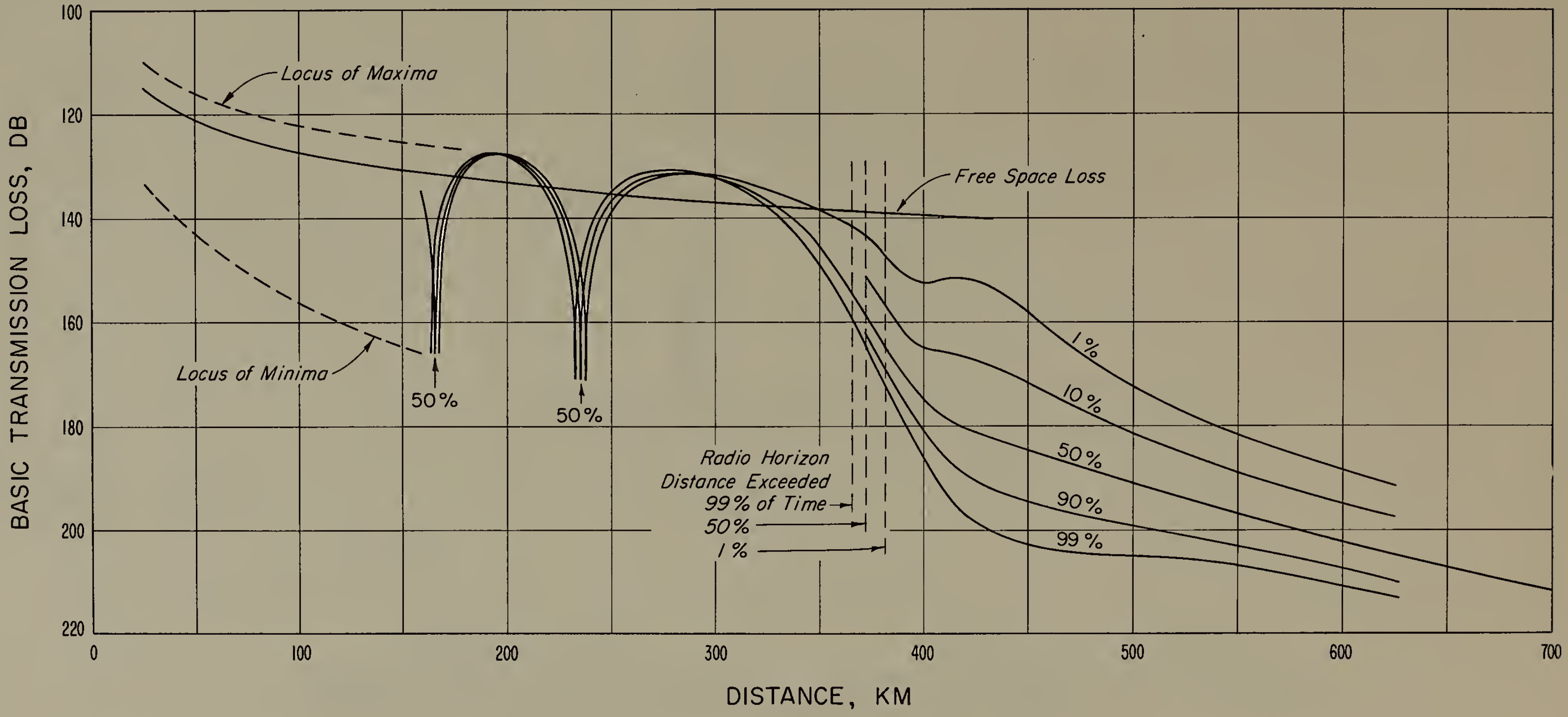


Figure 2

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY

AIRCRAFT HEIGHT 7500 METERS   GROUND ANTENNA HEIGHT 30 METERS
FREQUENCY 575 Mc   HORIZONTAL POLARIZATION

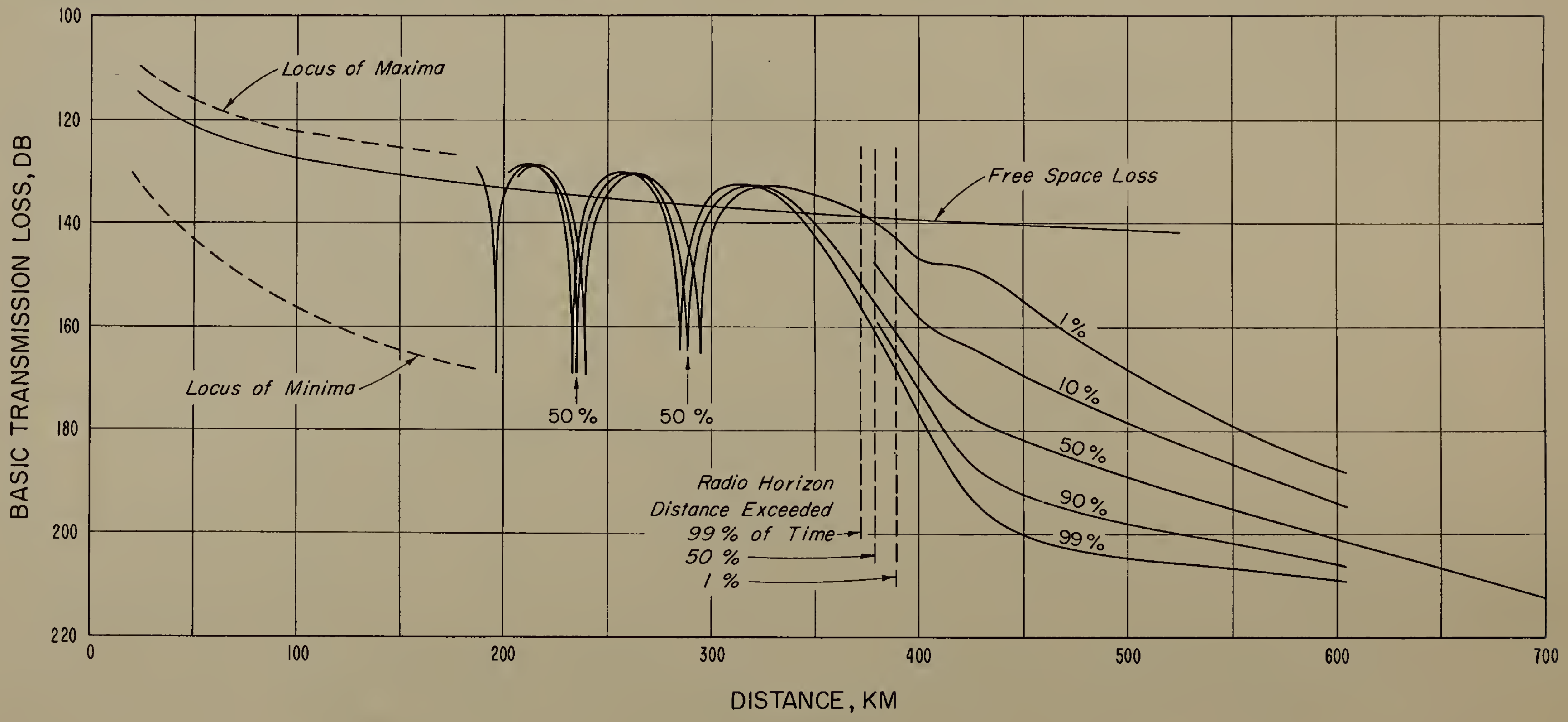


Figure 3

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 7500 METERS GROUND ANTENNA HEIGHT 30 METERS
FREQUENCY 575 Mc VERTICAL POLARIZATION

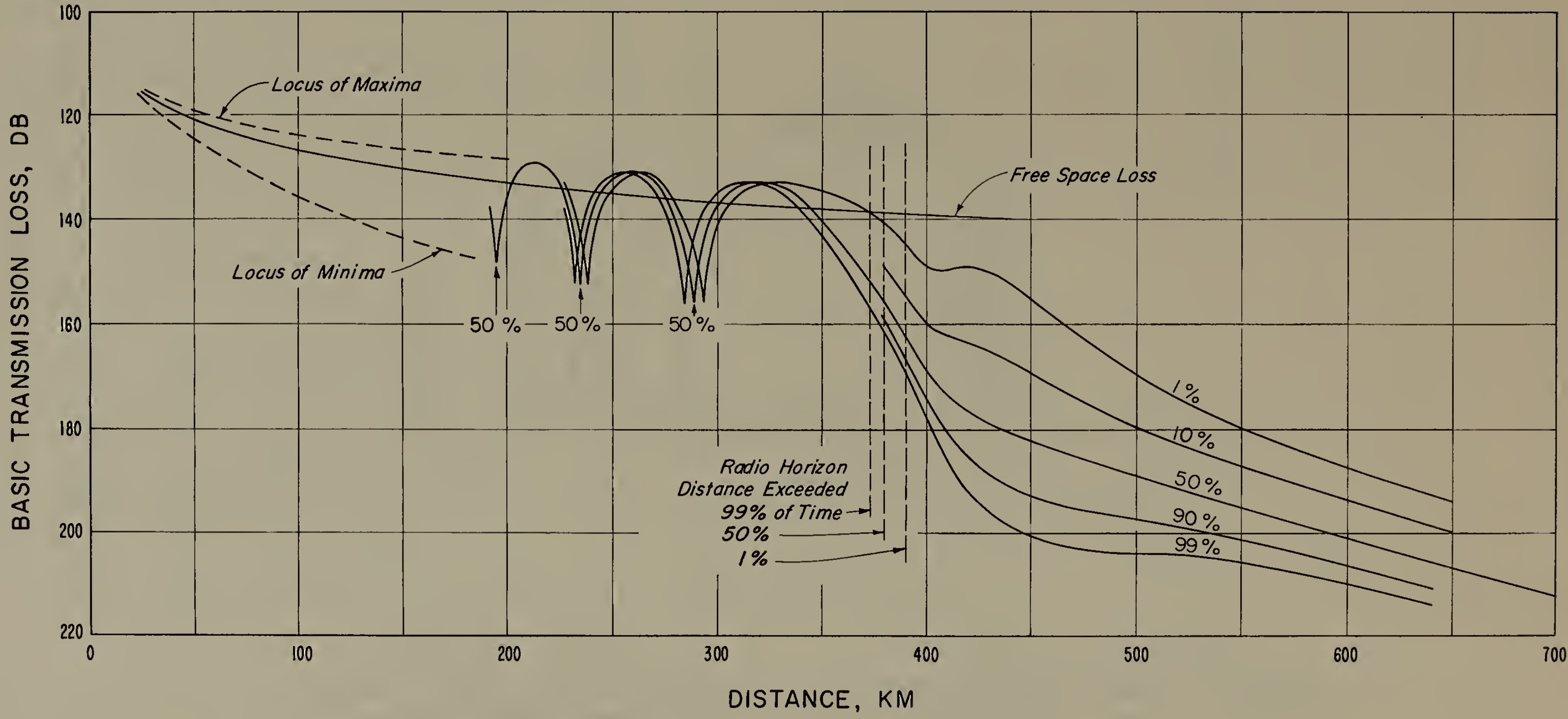


Figure 4

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 10,000 METERS GROUND ANTENNA HEIGHT 10 METERS
FREQUENCY 575 Mc HORIZONTAL POLARIZATION

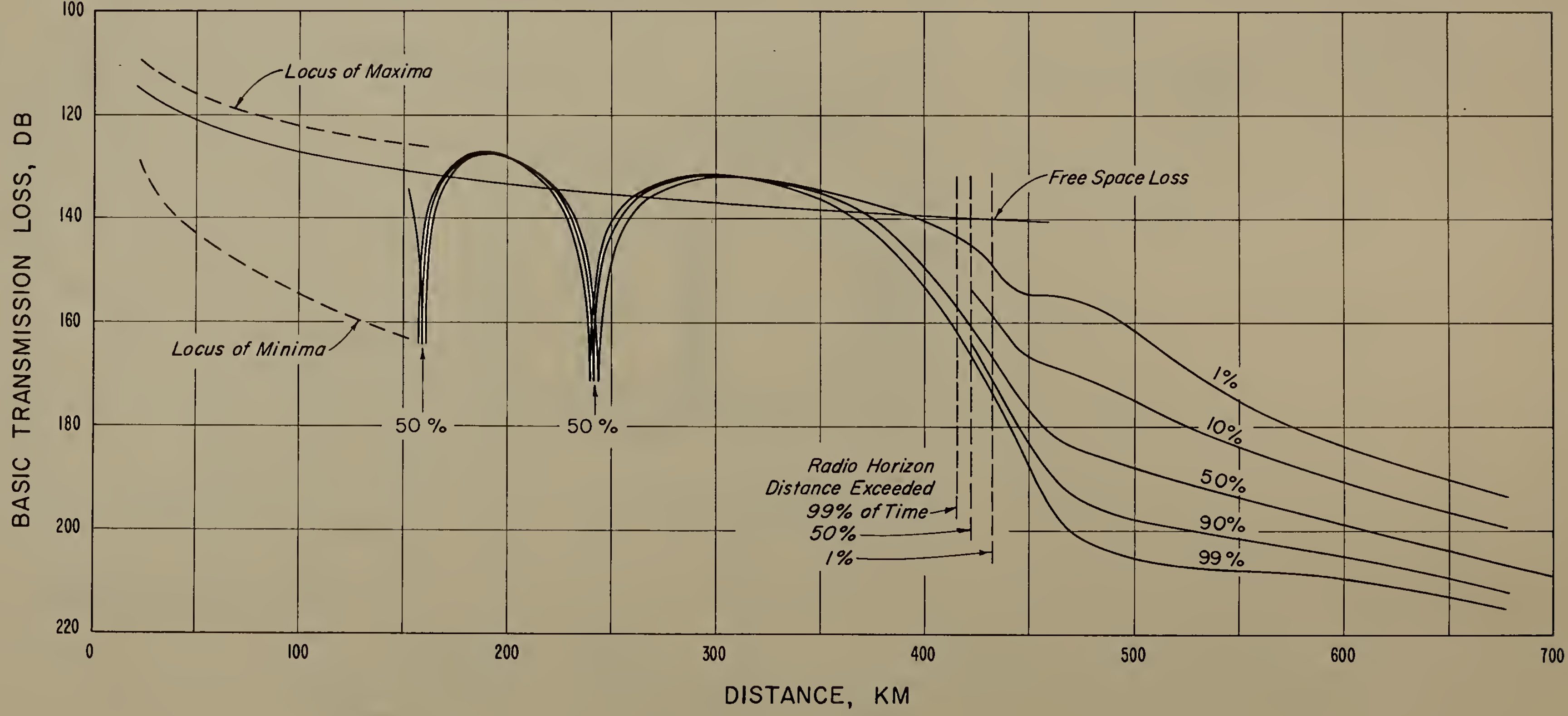


Figure 5

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 10,000 METERS GROUND ANTENNA HEIGHT 15 METERS
FREQUENCY 575 Mc HORIZONTAL POLARIZATION

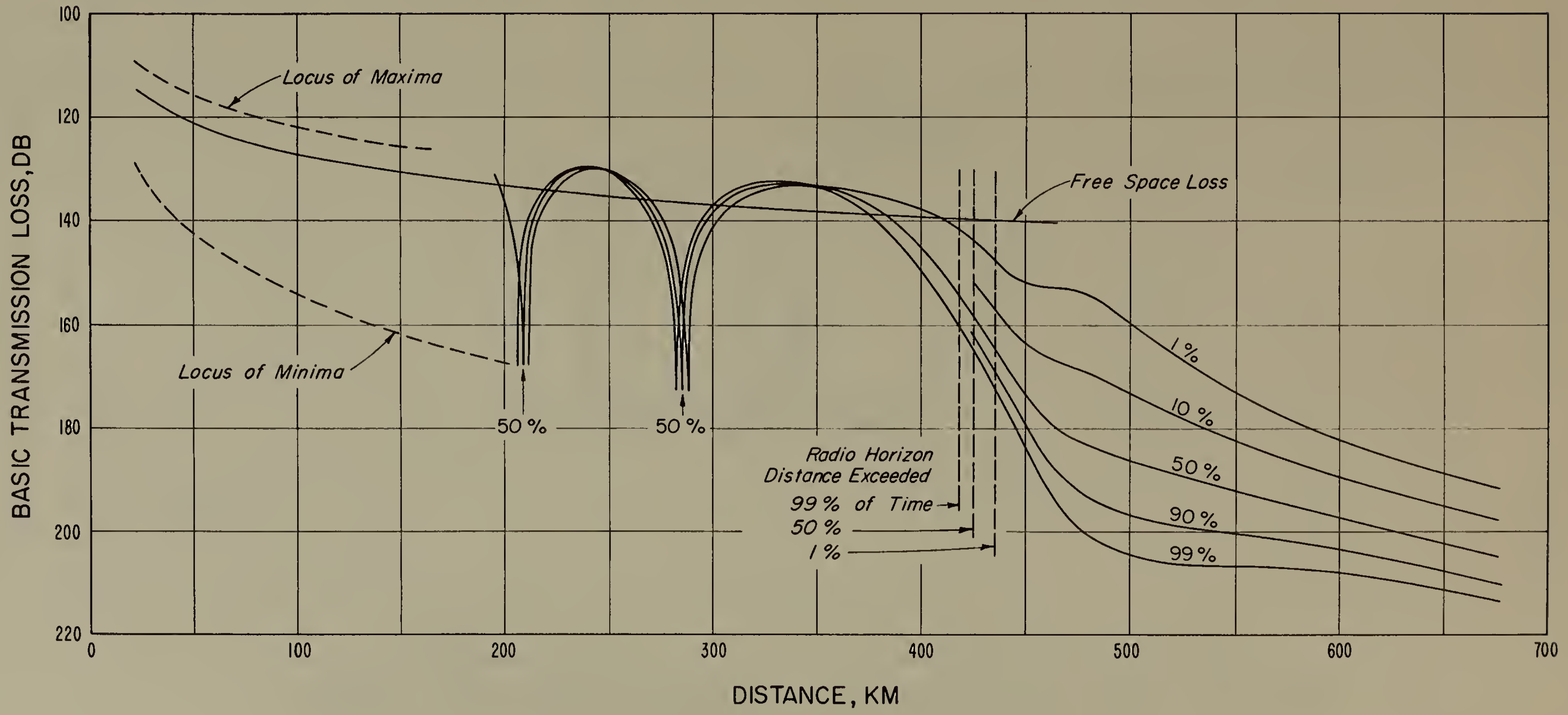


Figure 6

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 10,000 METERS GROUND ANTENNA HEIGHT 30 METERS
FREQUENCY 575 Mc HORIZONTAL POLARIZATION

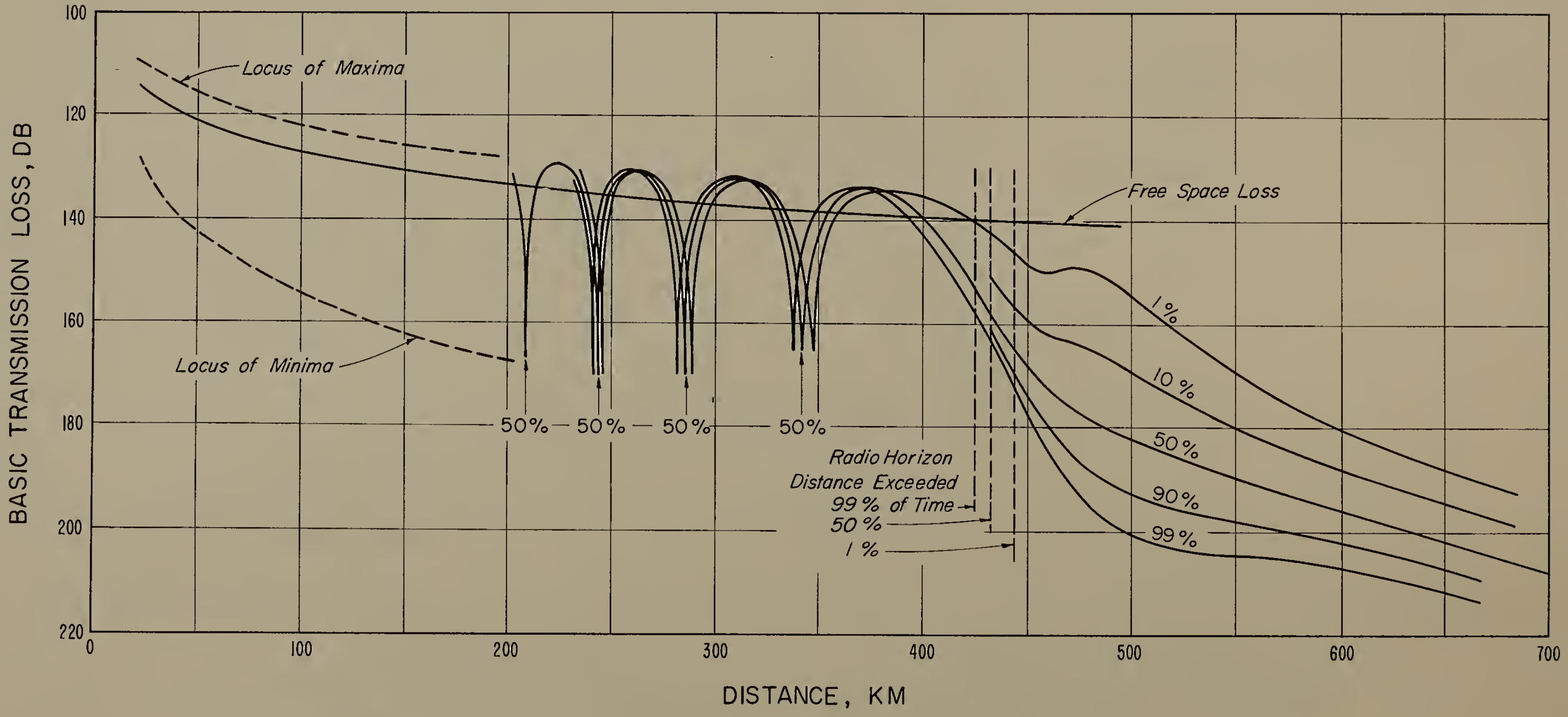


Figure 7

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 15,000 METERS GROUND ANTENNA HEIGHT 10 METERS
FREQUENCY 575 Mc HORIZONTAL POLARIZATION

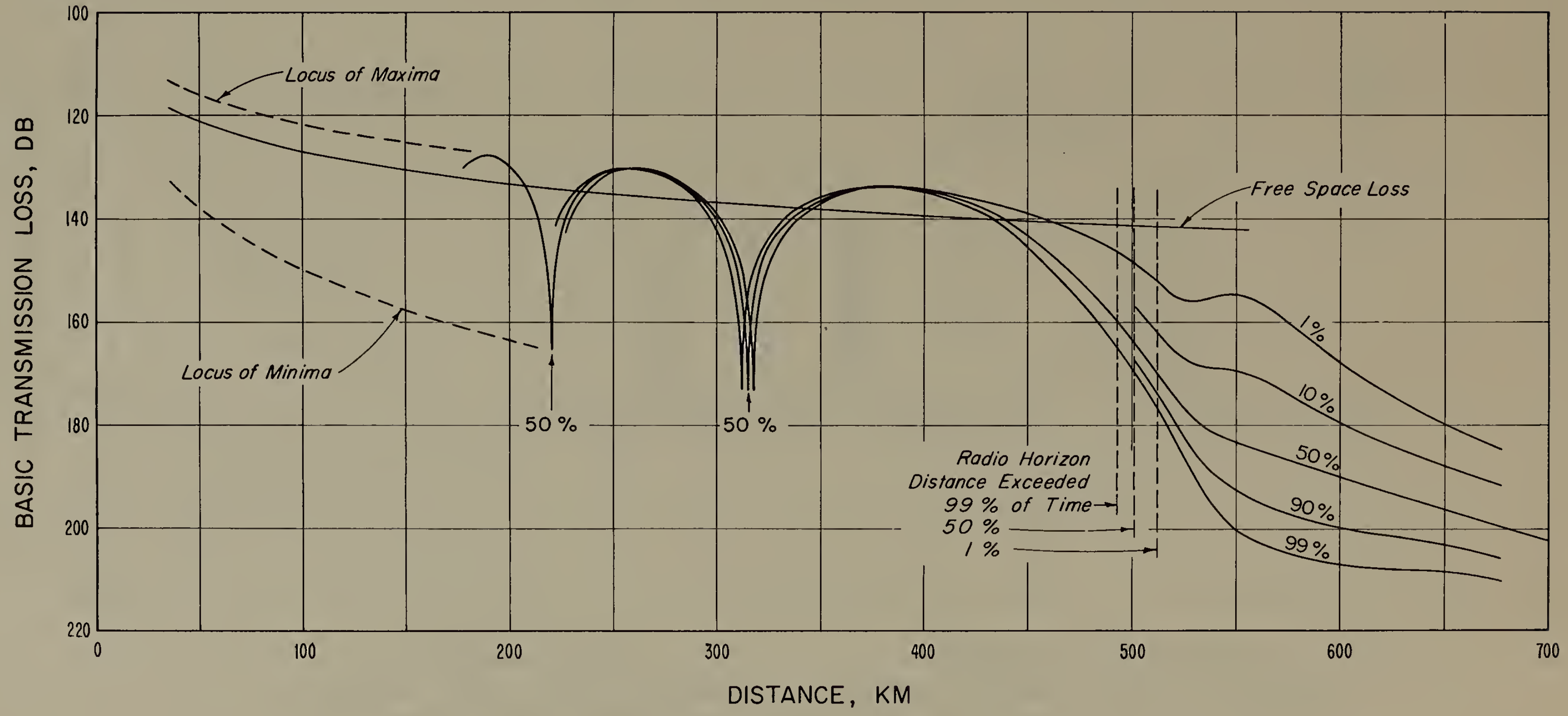


Figure 8

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY

AIRCRAFT HEIGHT 15,000 METERS GROUND ANTENNA HEIGHT 15 METERS
FREQUENCY 575 Mc HORIZONTAL POLARIZATION

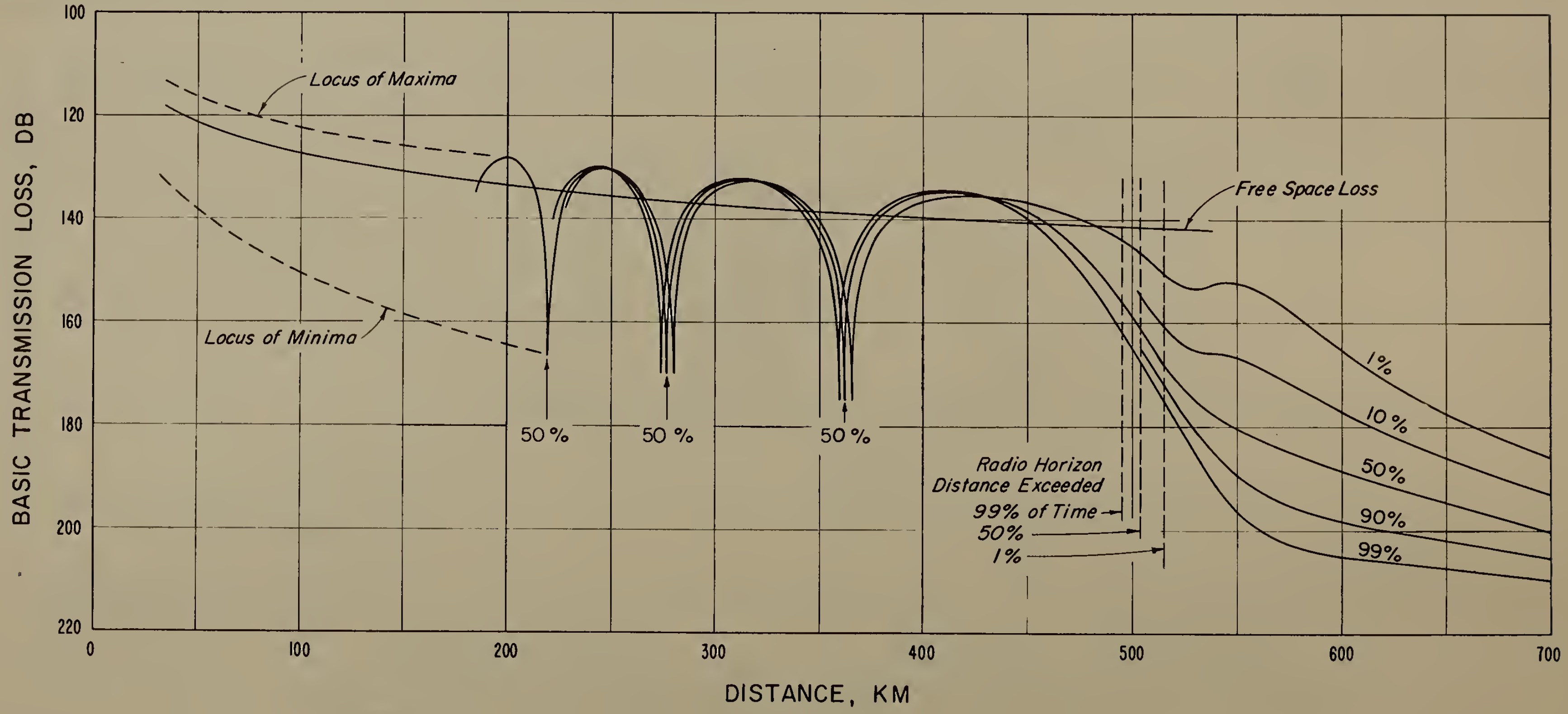


Figure 9

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY

AIRCRAFT HEIGHT 15,000 METERS — GROUND ANTENNA HEIGHT 30 METERS

FREQUENCY 575 Mc — HORIZONTAL POLARIZATION

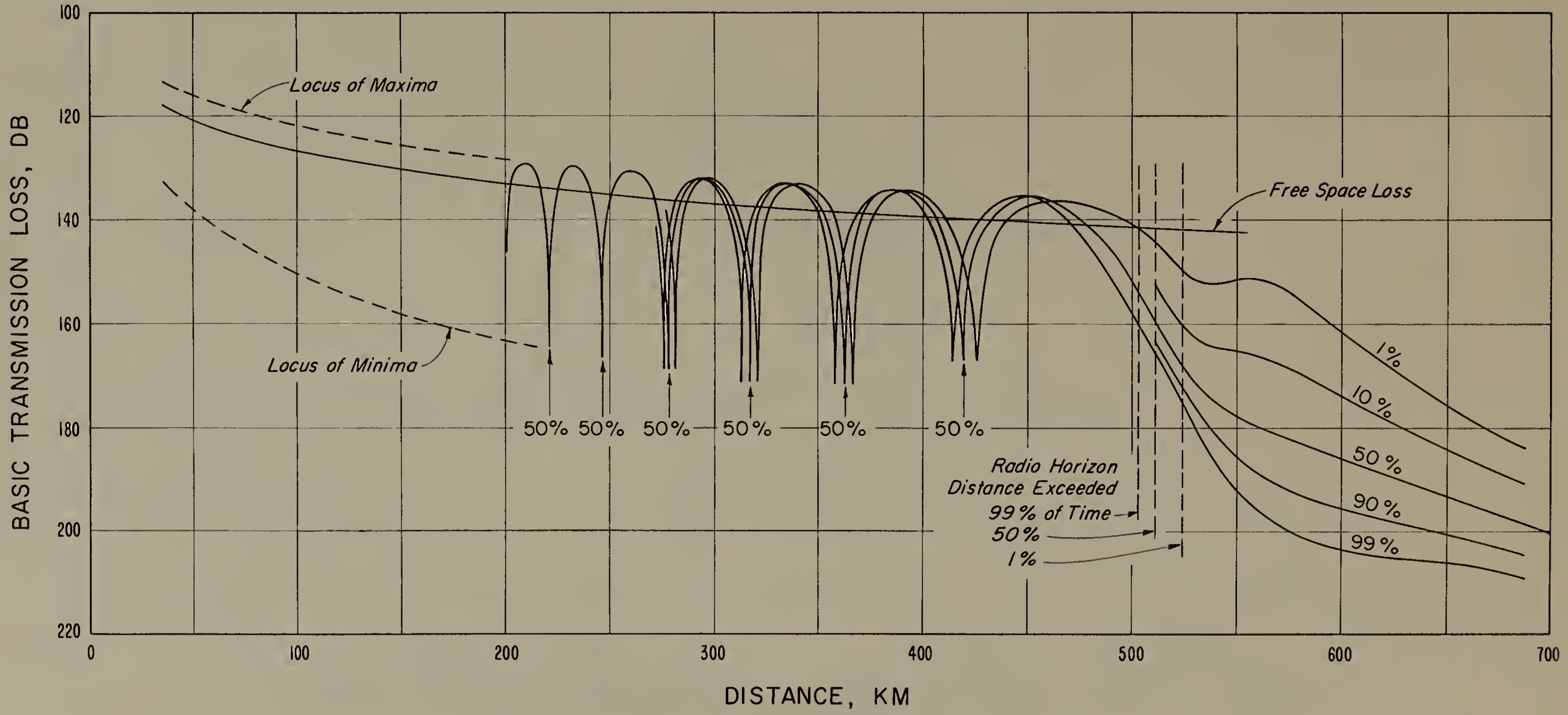


Figure 10

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 7500 METERS　　GROUND ANTENNA HEIGHT 10 METERS
FREQUENCY 785 Mc　　HORIZONTAL POLARIZATION

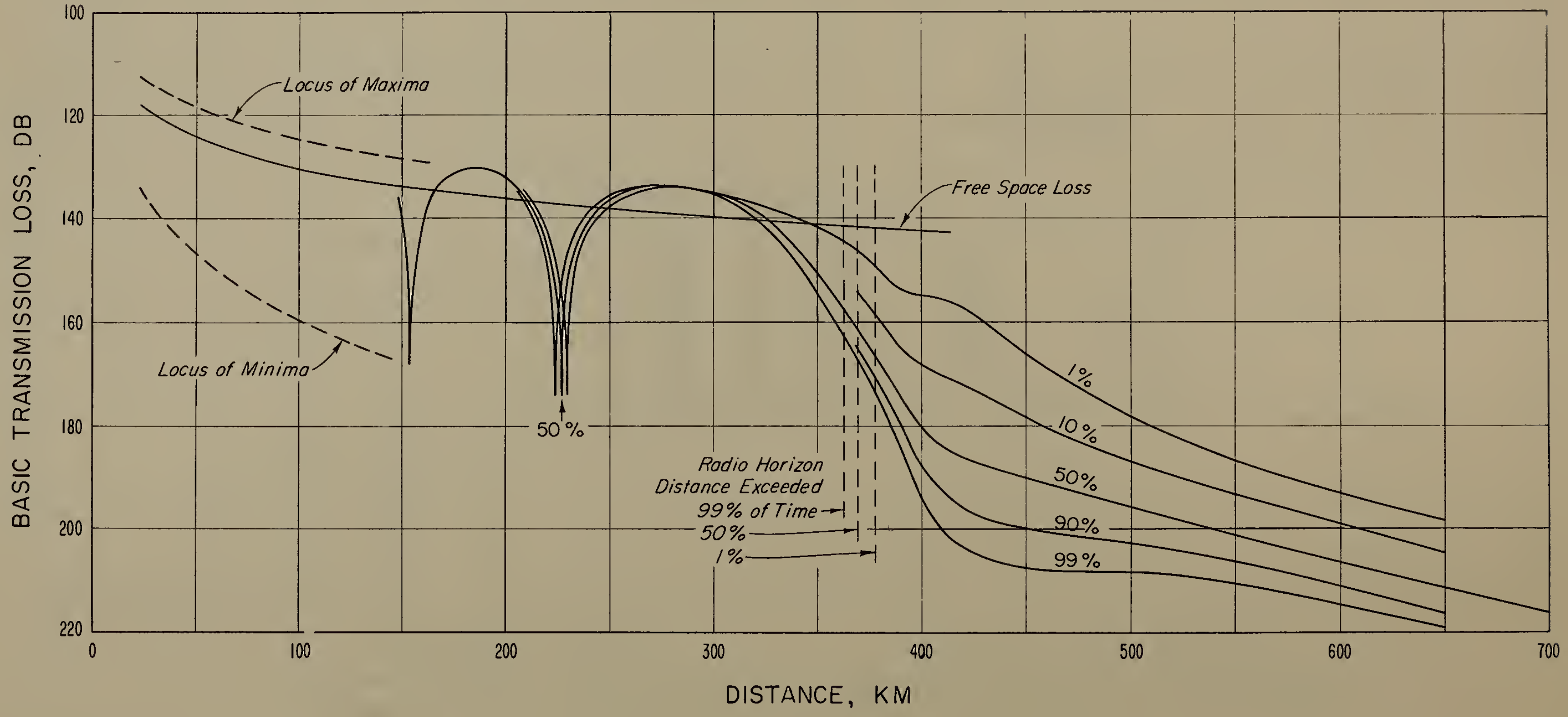


Figure 11

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 7500 METERS GROUND ANTENNA HEIGHT 15 METERS
FREQUENCY 785 Mc HORIZONTAL POLARIZATION

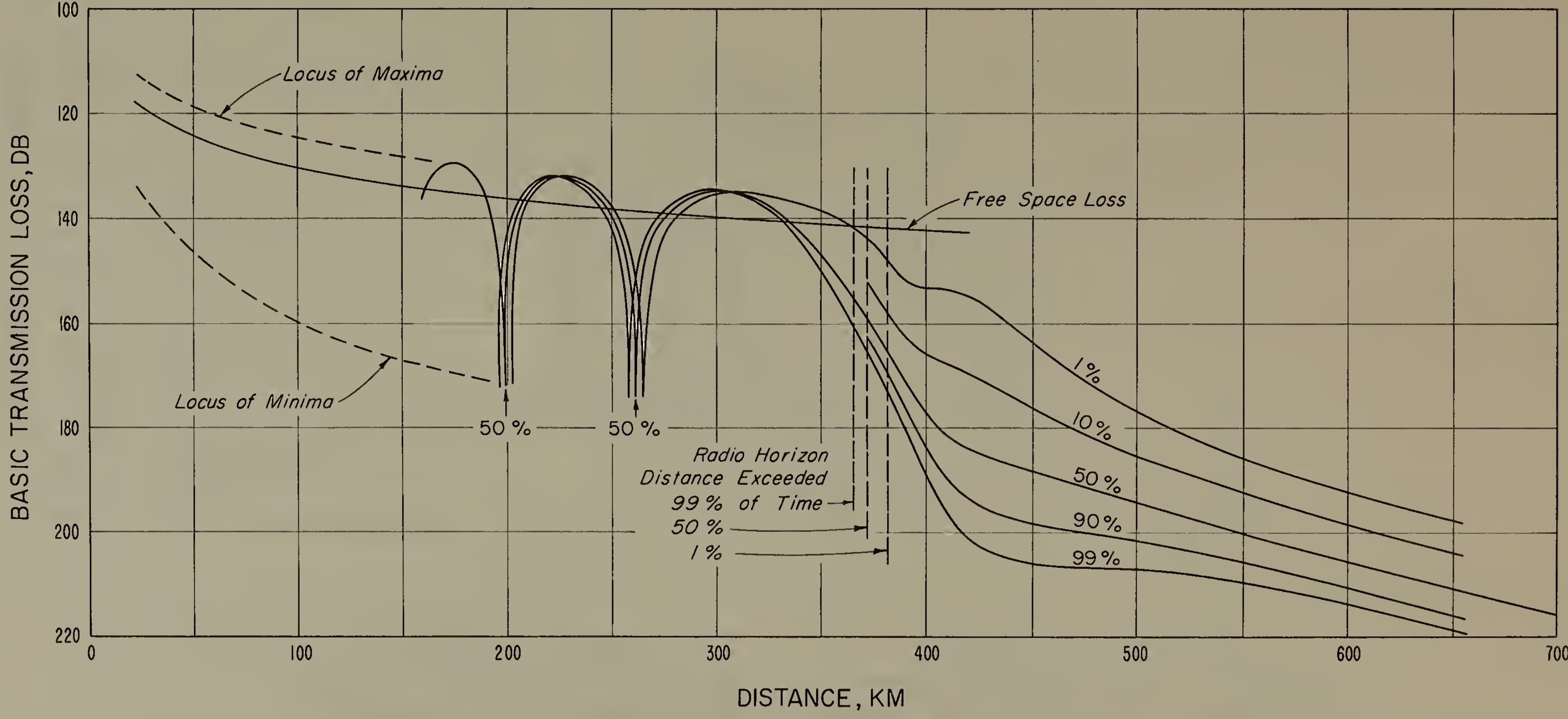


Figure 12

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 7500 METERS GROUND ANTENNA HEIGHT 30 METERS
FREQUENCY 785 Mc HORIZONTAL POLARIZATION

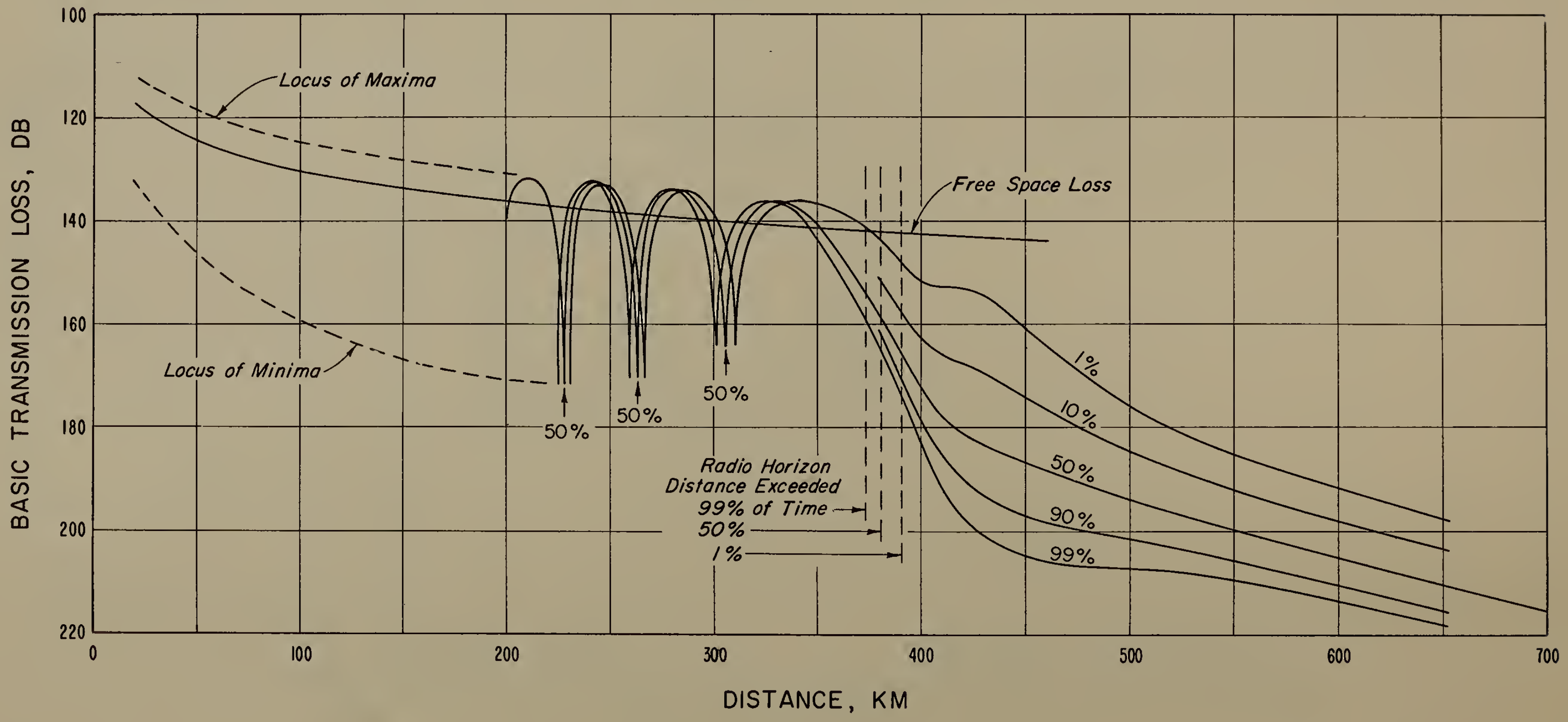


Figure 13

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 10,000 METERS
FREQUENCY 785 Mc
GROUND ANTENNA HEIGHT 10 METERS
HORIZONTAL POLARIZATION

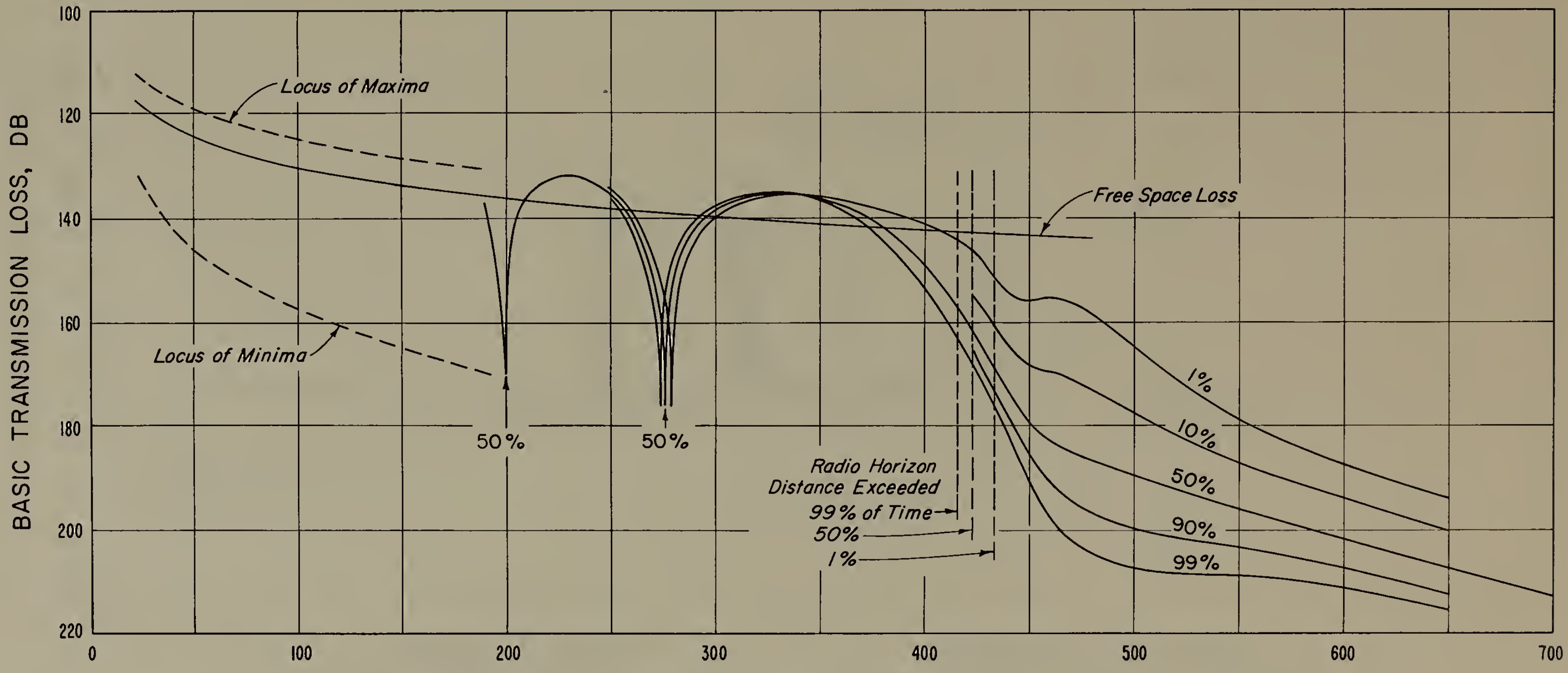


Figure 14

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 10,000 METERS GROUND ANTENNA HEIGHT 15 METERS
FREQUENCY 785 Mc HORIZONTAL POLARIZATION

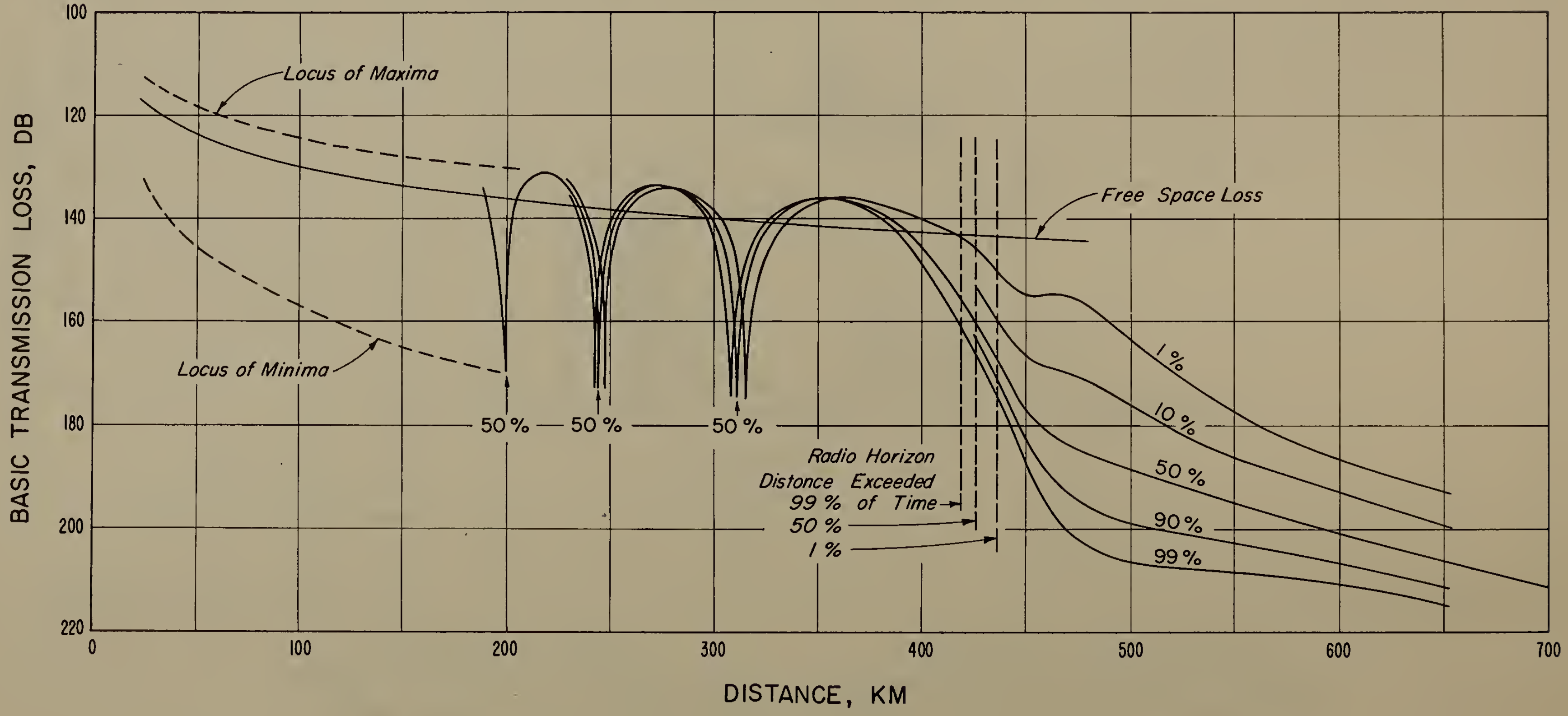


Figure 15

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 10,000 METERS GROUND ANTENNA HEIGHT 30 METERS
FREQUENCY 785 Mc HORIZONTAL POLARIZATION

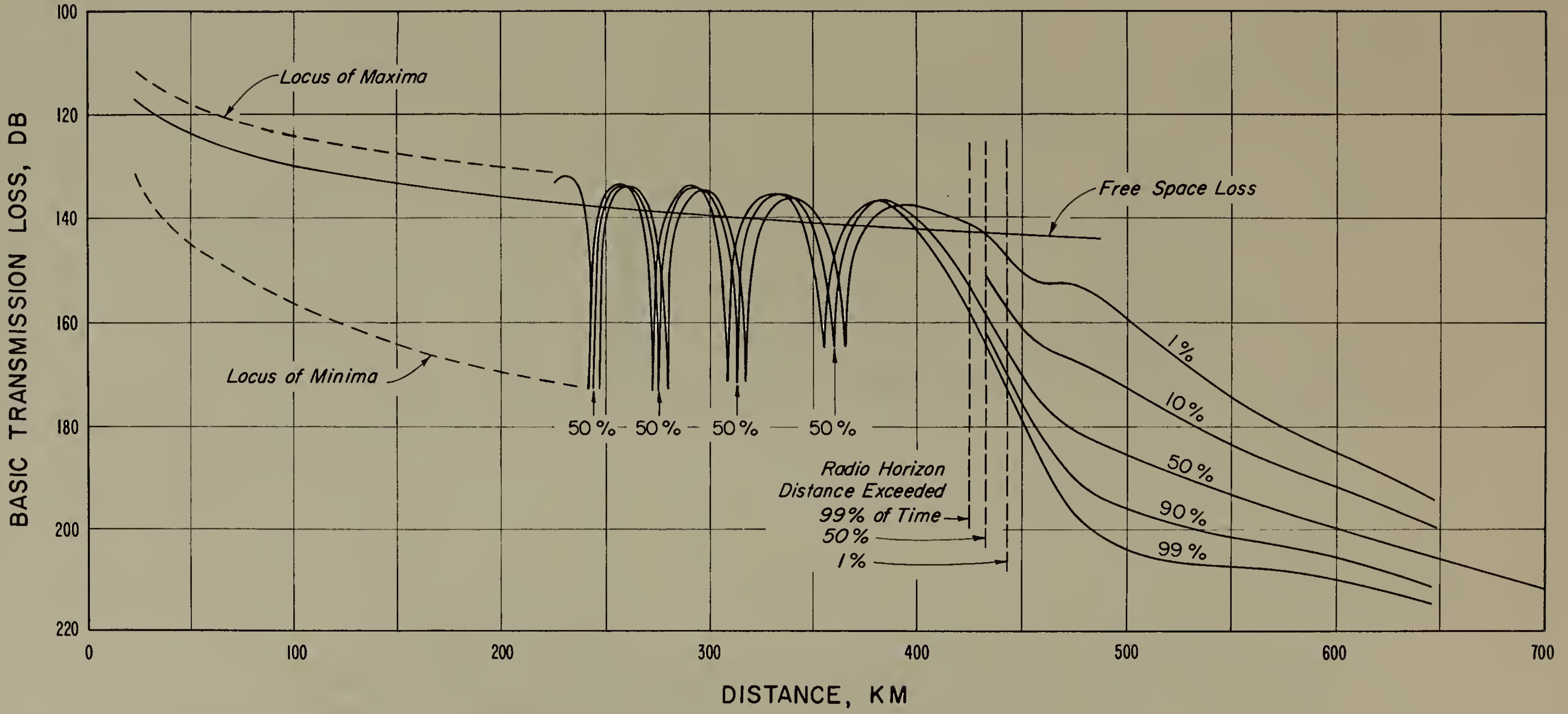


Figure 16

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 15,000 METERS GROUND ANTENNA HEIGHT 10 METERS
FREQUENCY 785 Mc HORIZONTAL POLARIZATION

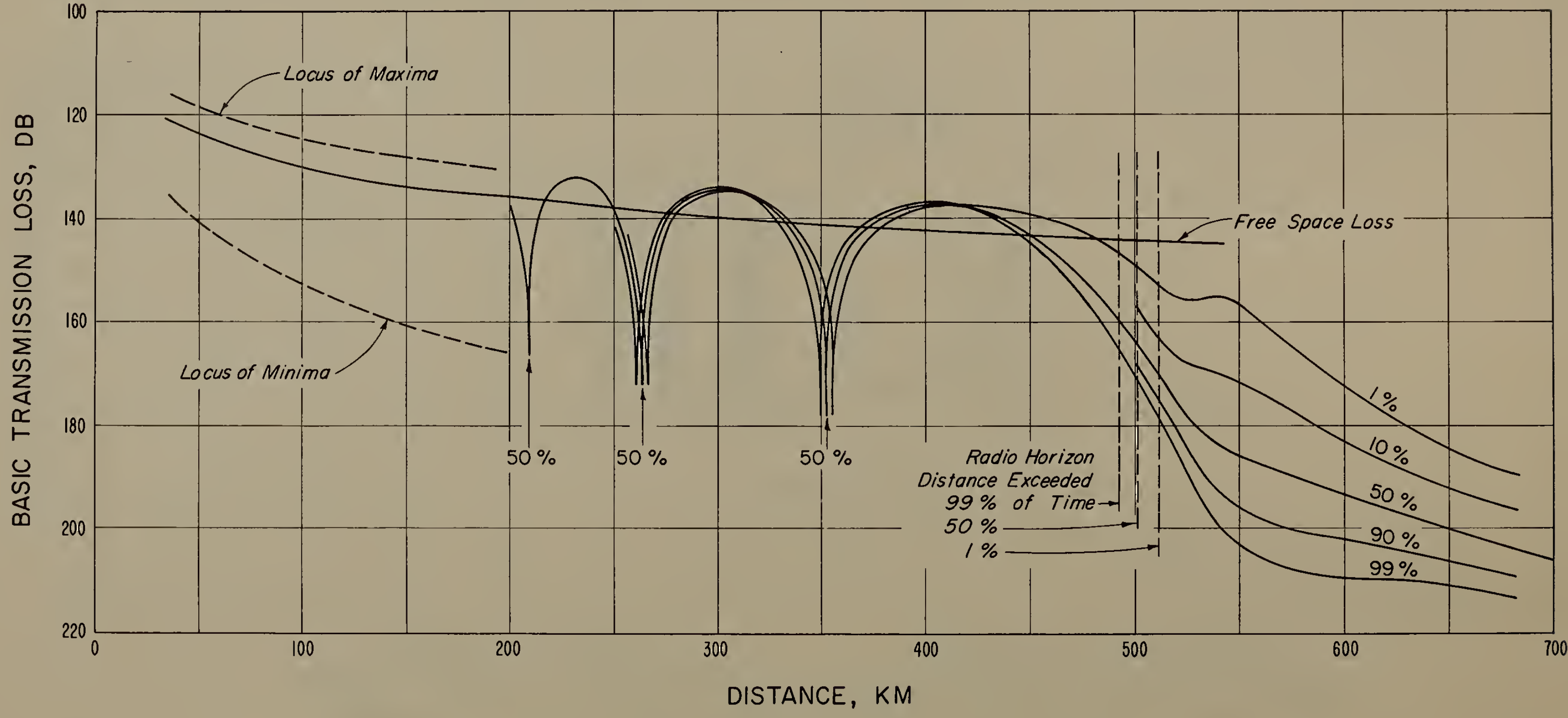


Figure 17

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 15,000 METERS   GROUND ANTENNA HEIGHT 15 METERS
FREQUENCY 785 Mc   HORIZONTAL POLARIZATION

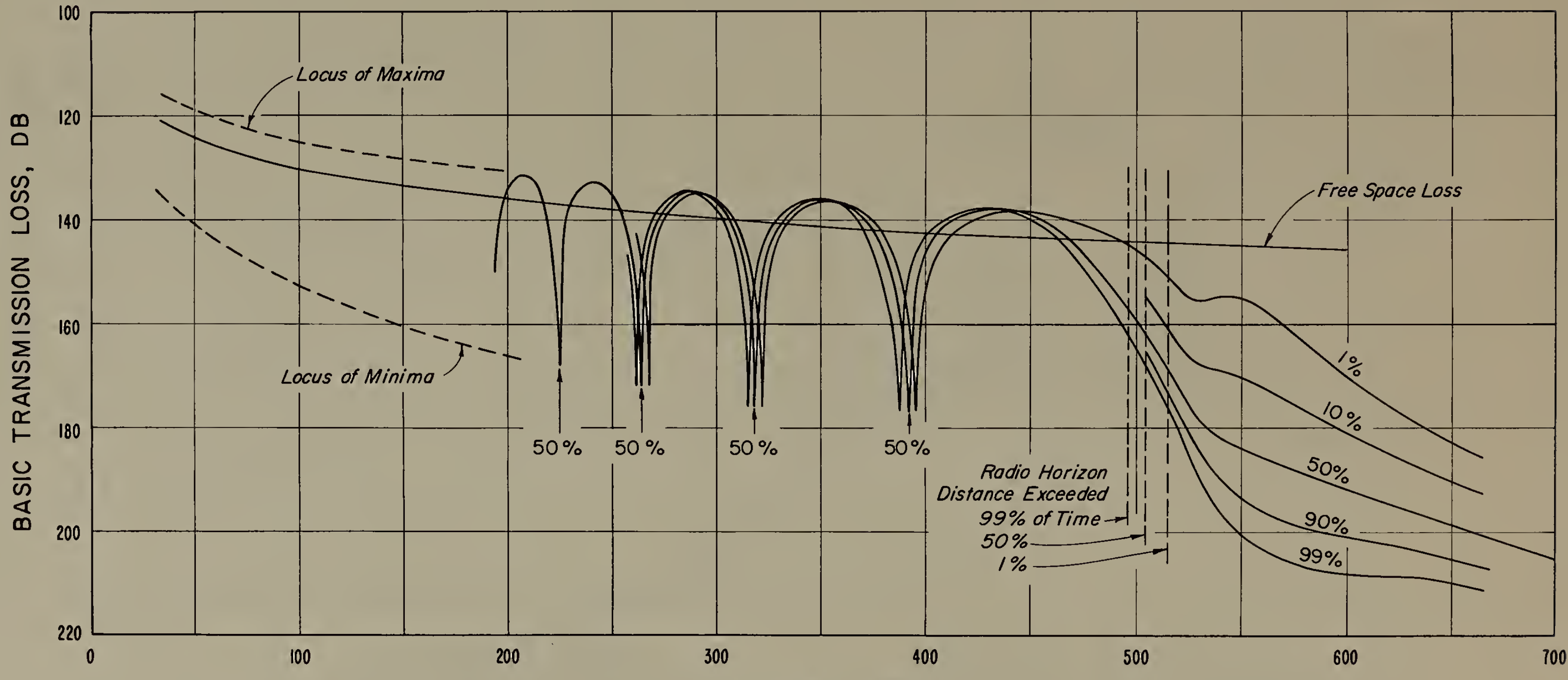


Figure 18

BASIC TRANSMISSION LOSS VS DISTANCE

PROPAGATION OVER SMOOTH EARTH SHOWING LONG-TERM TIME VARIABILITY
AIRCRAFT HEIGHT 15000 METERS GROUND ANTENNA HEIGHT 30 METERS
FREQUENCY 785 Mc HORIZONTAL POLARIZATION

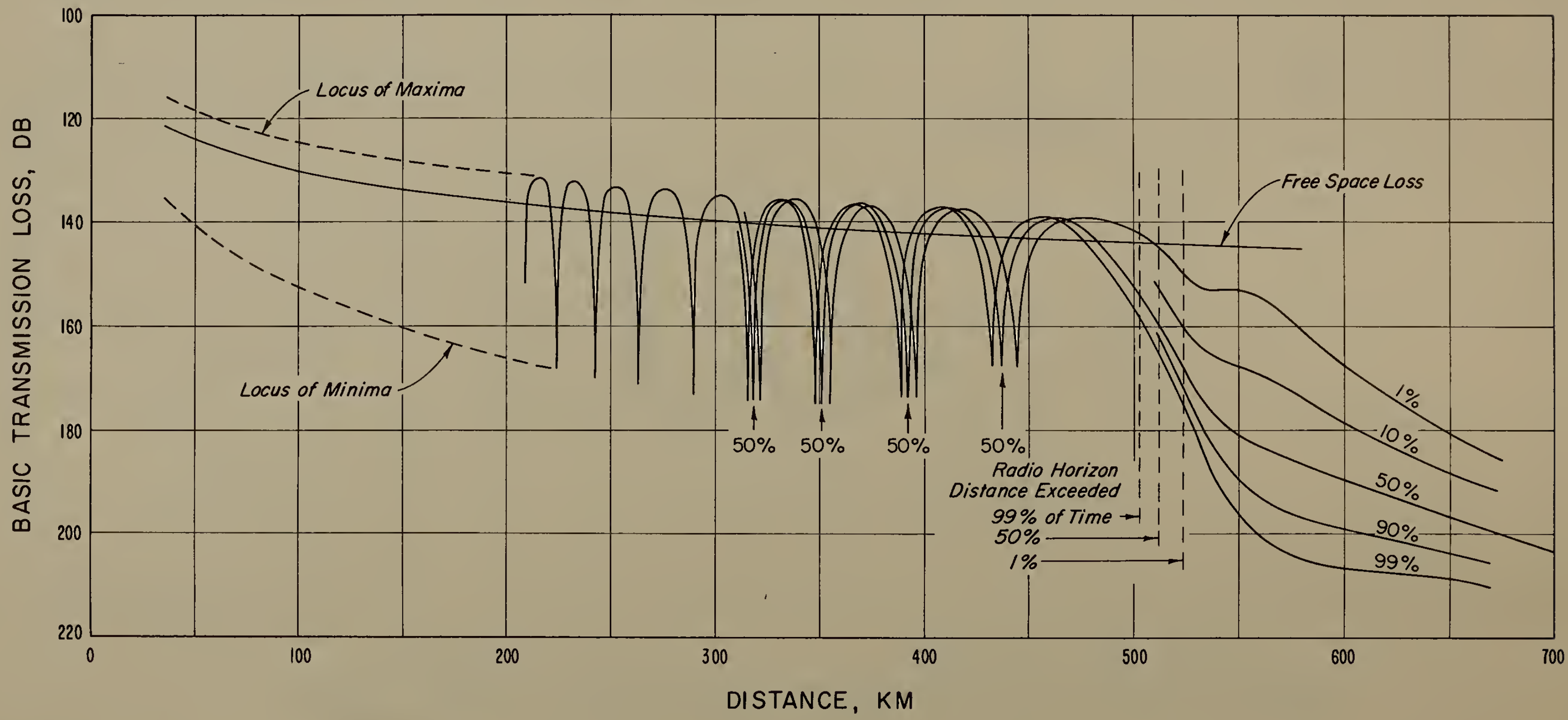


Figure 19

DISTANCE CORRECTION FOR USE WITH ATMOSPHERE HAVING AN EXPONENTIAL GRADIENT OF REFRACTIVE INDEX

EFFECTIVE EARTH RADIUS 9,000 KM

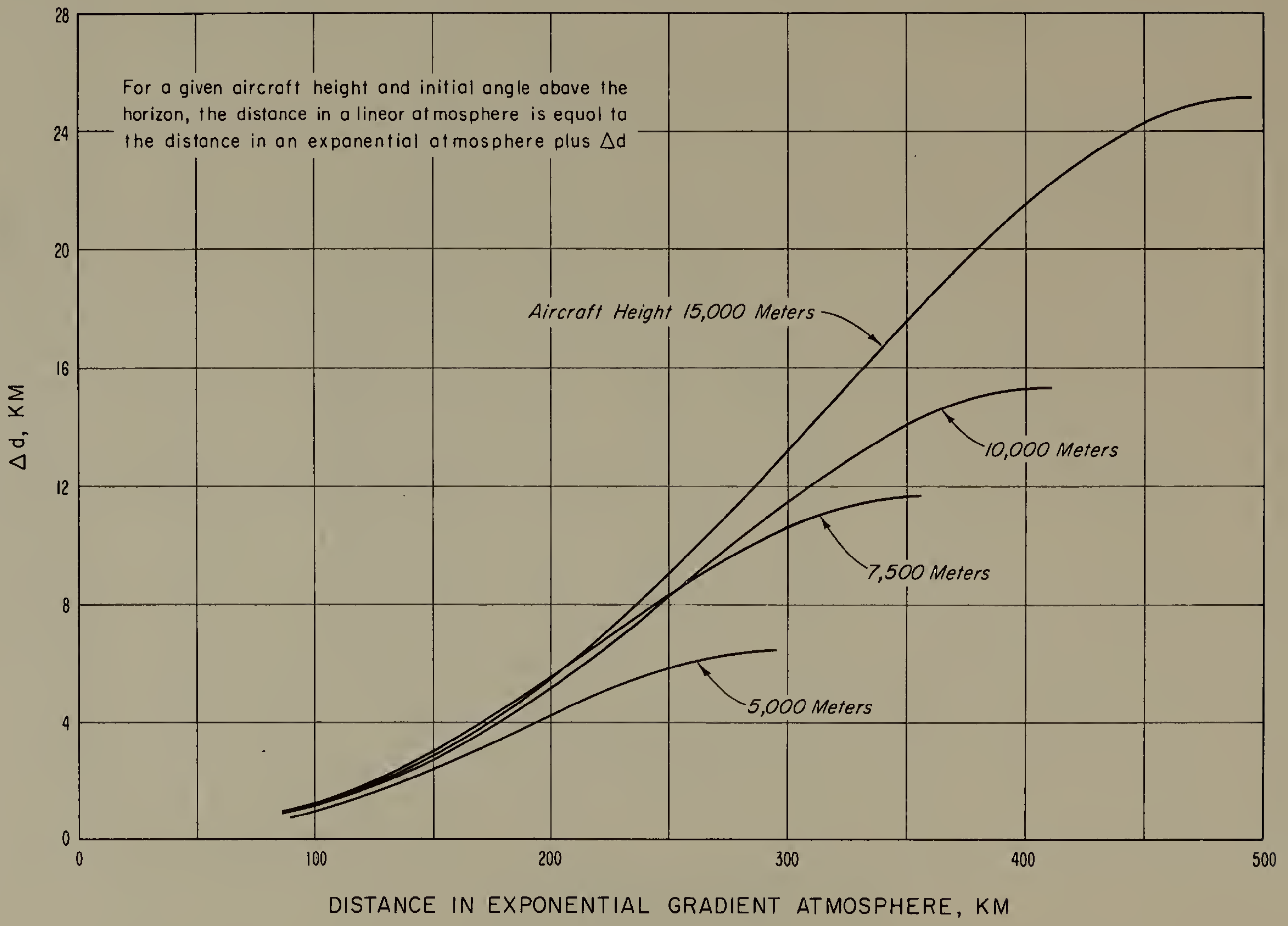


Figure 20

LOCATION OF MAXIMA AND MINIMA OVER A SMOOTH EARTH

AIRCRAFT HEIGHT 7500 METERS
FREQUENCY 575 Mc

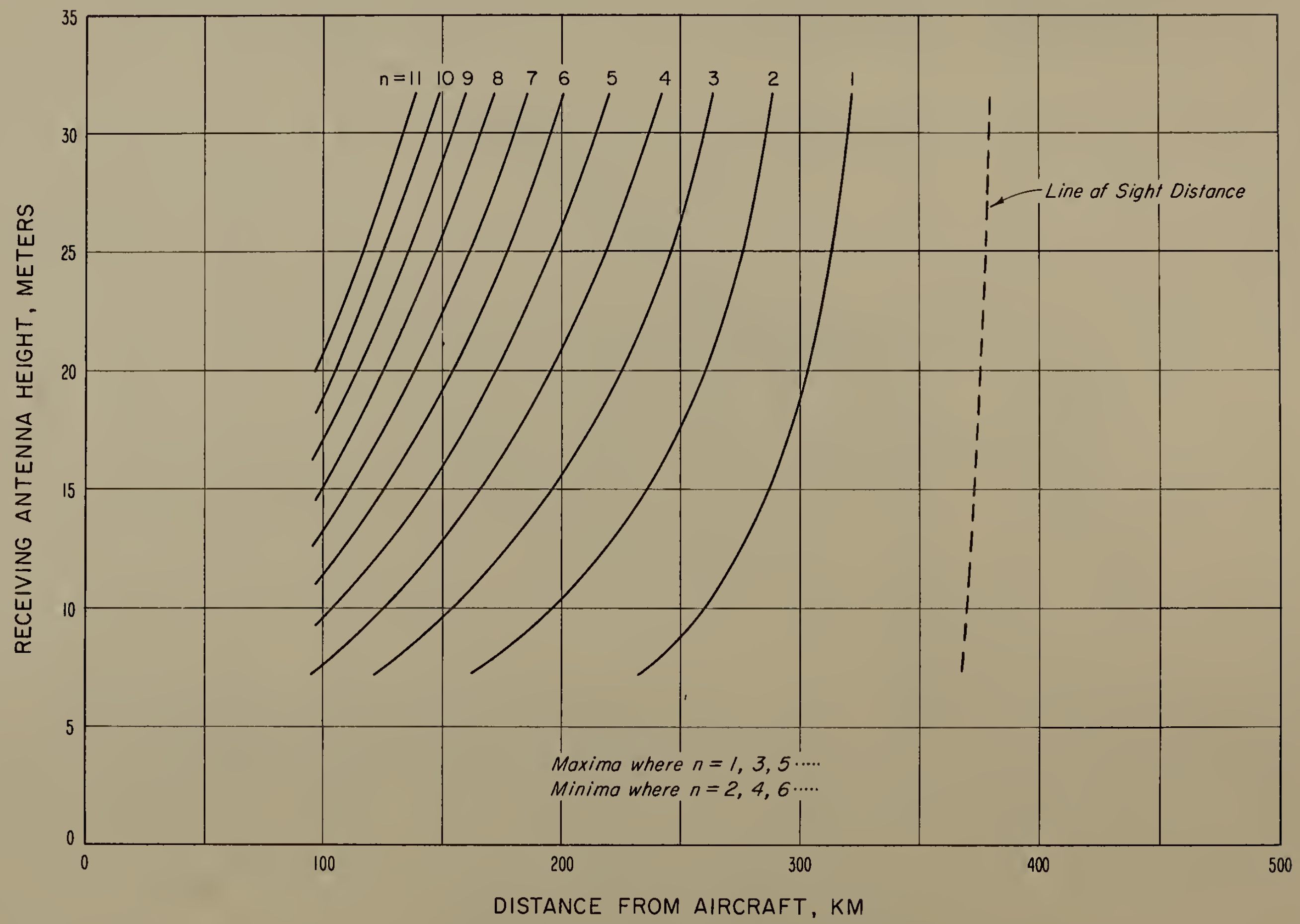


Figure 21

LOCATION OF MAXIMA AND MINIMA OVER A SMOOTH EARTH

AIRCRAFT HEIGHT 7500 METERS
FREQUENCY 785 Mc

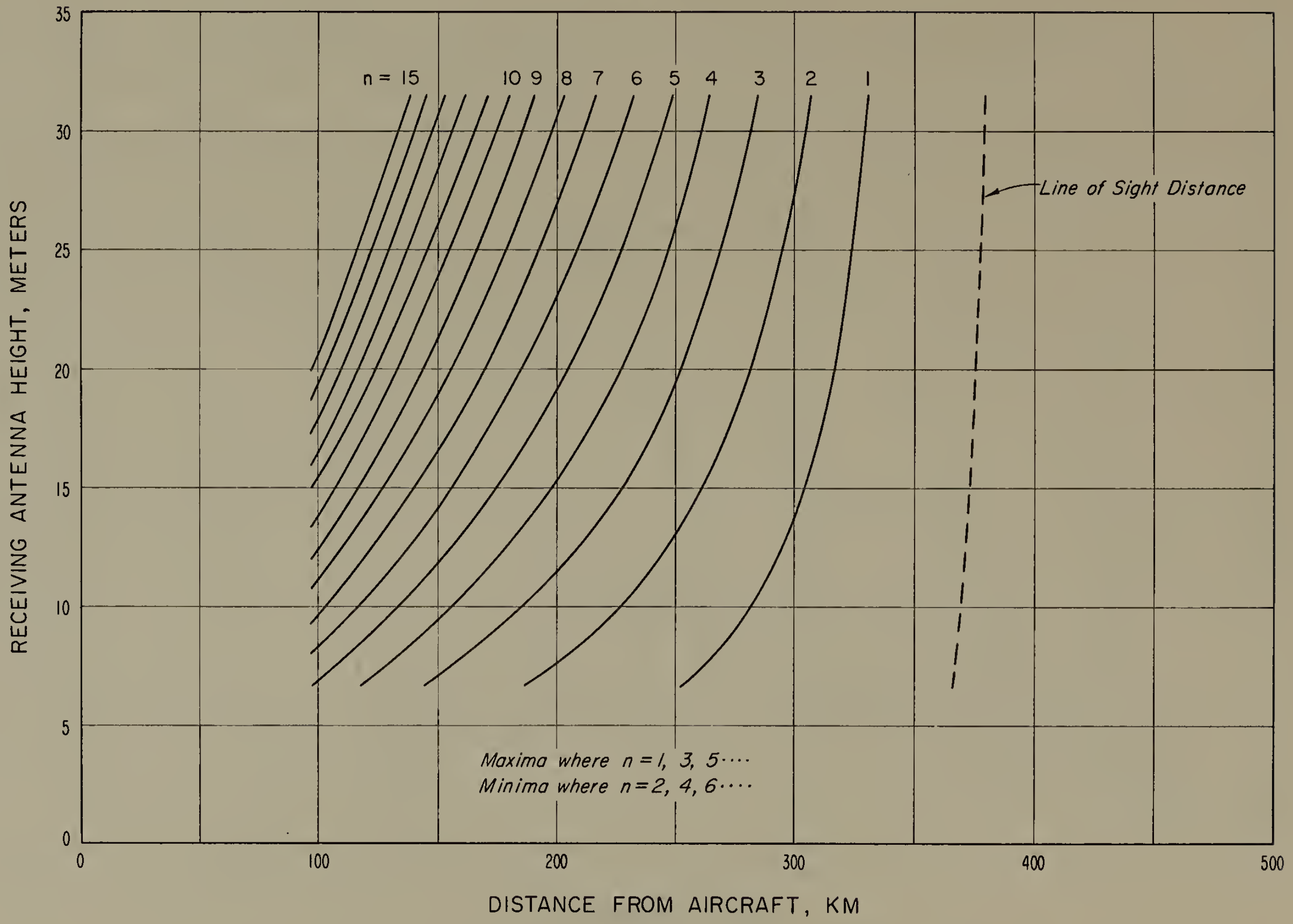


Figure 22

LOCATION OF MAXIMA AND MINIMA OVER A SMOOTH EARTH

AIRCRAFT HEIGHT 5,000 METERS
FREQUENCY 785 Mc

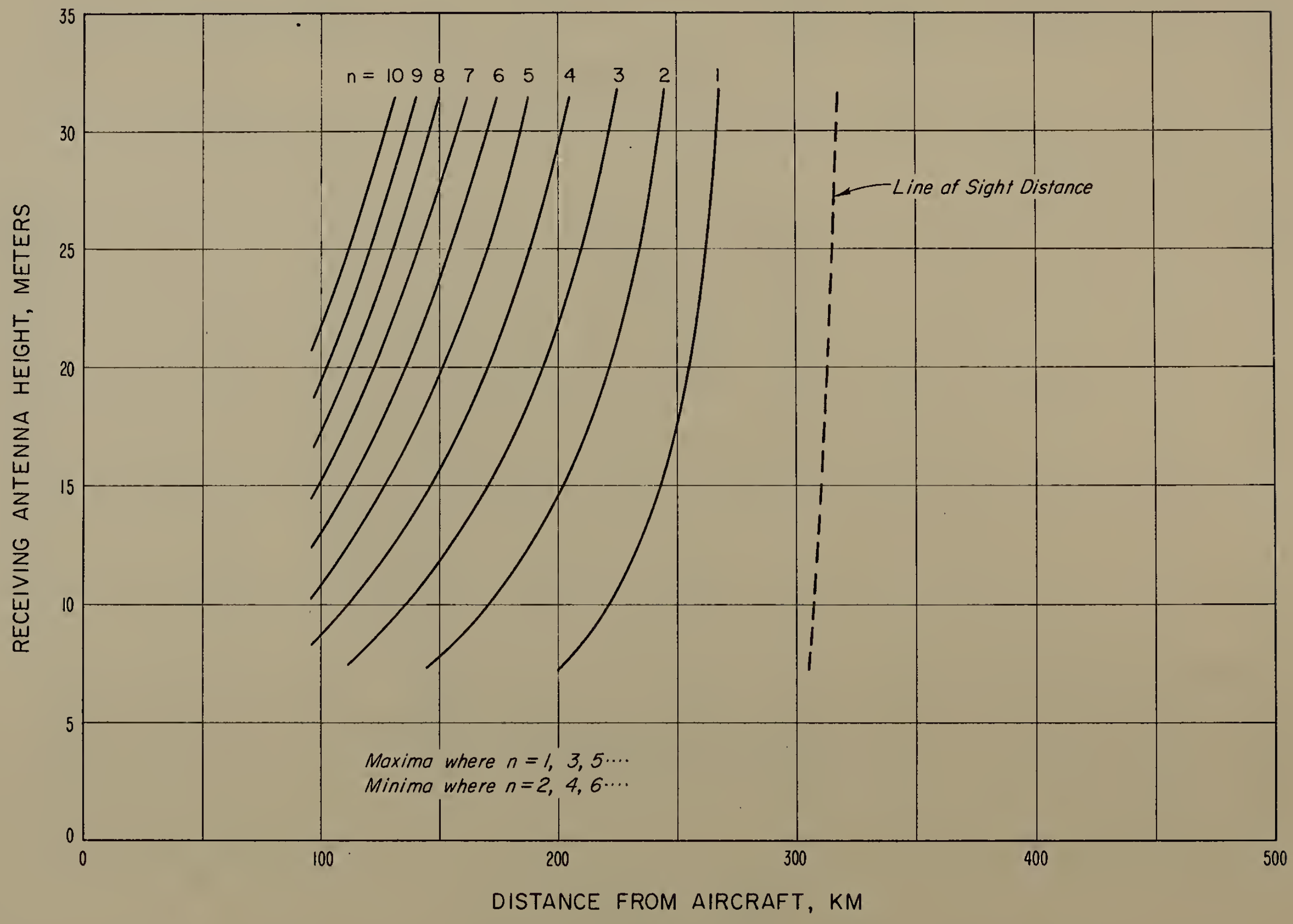


Figure 23

PERCENT OF LOCATIONS RECEIVING 99% GRADE OF SERVICE
VS DISTANCE FROM TRANSMITTER
FREQUENCY 575 Mc

MAXIMUM ALLOWABLE BASIC TRANSMISSION LOSS AS NOTED
TRANSMITTING ANTENNA HEIGHT 7,500, 10,000 OR 15,000 METERS AS NOTED
RECEIVING ANTENNA MAXIMUM HEIGHT 30 METERS WITH SPACE DIVERSITY AS REQUIRED

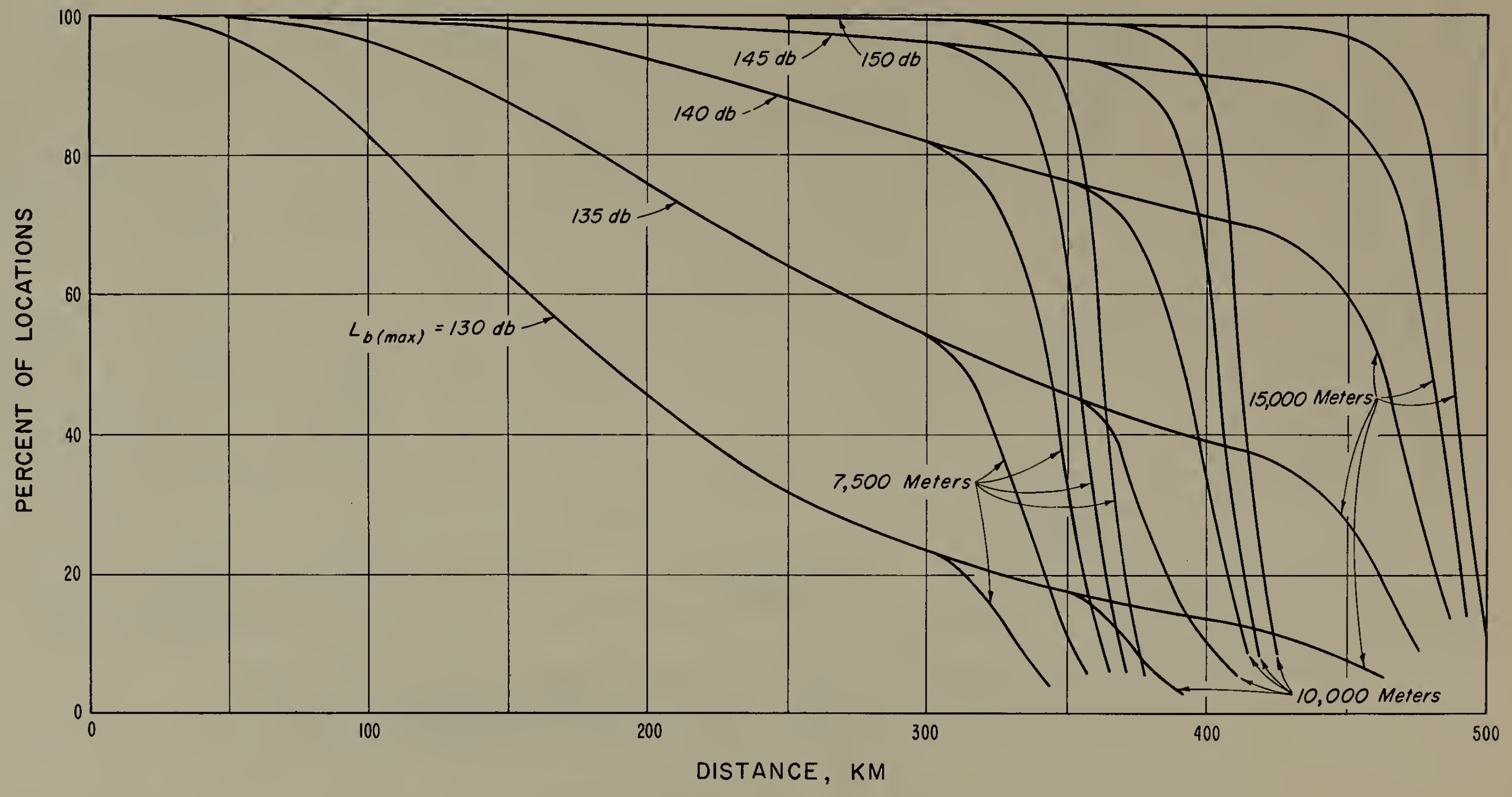


Figure 24

PERCENT OF LOCATIONS RECEIVING 99% GRADE OF SERVICE
VS DISTANCE FROM TRANSMITTER
FREQUENCY 785 Mc

MAXIMUM ALLOWABLE BASIC TRANSMISSION LOSS AS NOTED
TRANSMITTING ANTENNA HEIGHT 5,000, 7,500, 10,000 OR 15,000 METERS AS NOTED
RECEIVING ANTENNA MAXIMUM HEIGHT 30 METERS WITH SPACE DIVERSITY AS REQUIRED

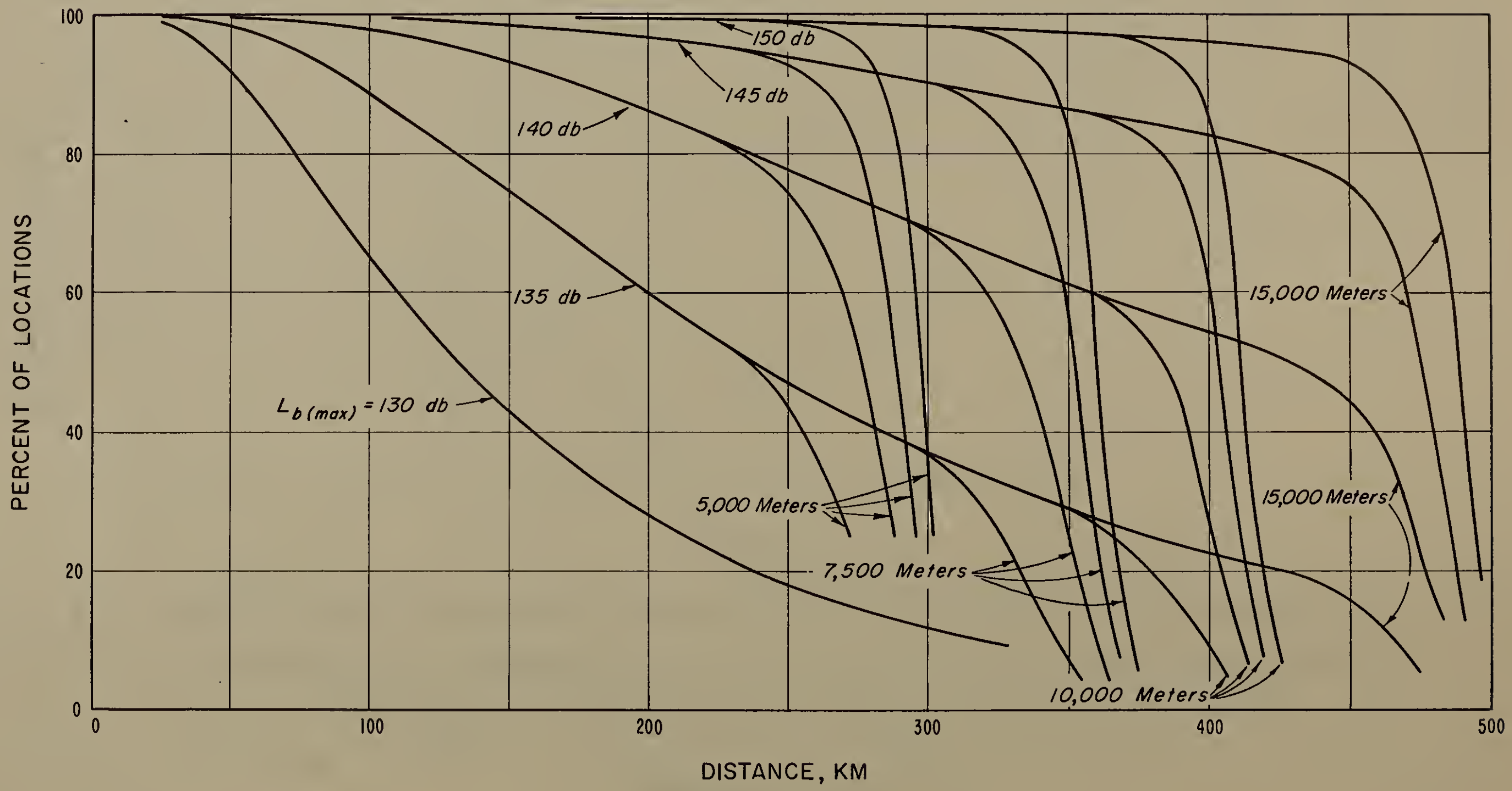


Figure 25

RELATIVE NUMBER OF LOCATIONS RECEIVING SERVICE
FREQUENCY 575 Mc

AIRCRAFT CIRCLING WITH 15 KILOMETERS RADIUS
AT ALTITUDE OF 7500 METERS

RECEIVING ANTENNA HEIGHT MAXIMUM OF
30 METERS WITH DIVERSITY AS REQUIRED

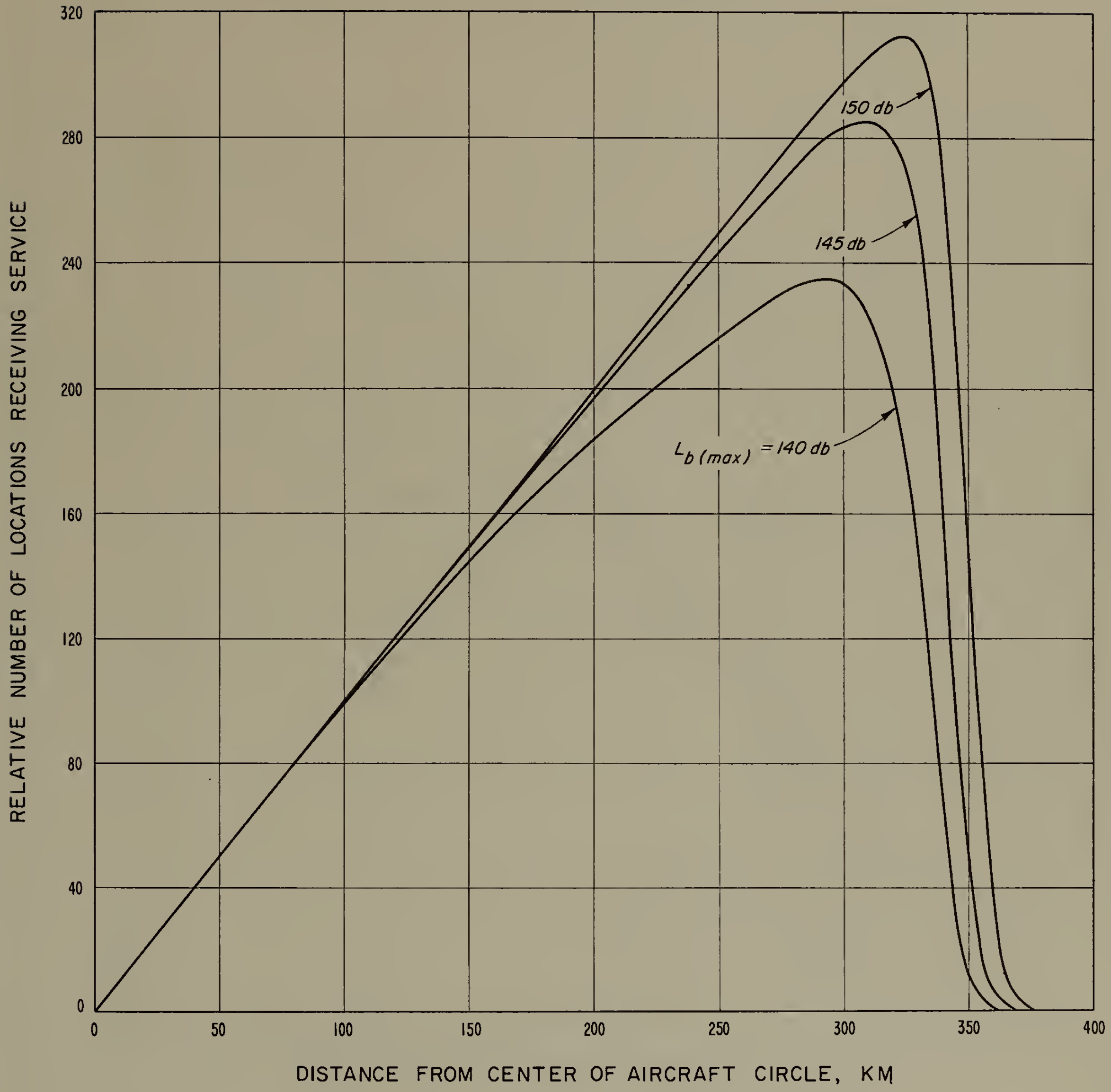


Figure 26

RELATIVE NUMBER OF LOCATIONS RECEIVING SERVICE
FREQUENCY 785 Mc

AIRCRAFT CIRCLING WITH 15 KILOMETERS RADIUS
AT ALTITUDE OF 7500 METERS

RECEIVING ANTENNA HEIGHT MAXIMUM OF
30 METERS WITH DIVERSITY AS REQUIRED

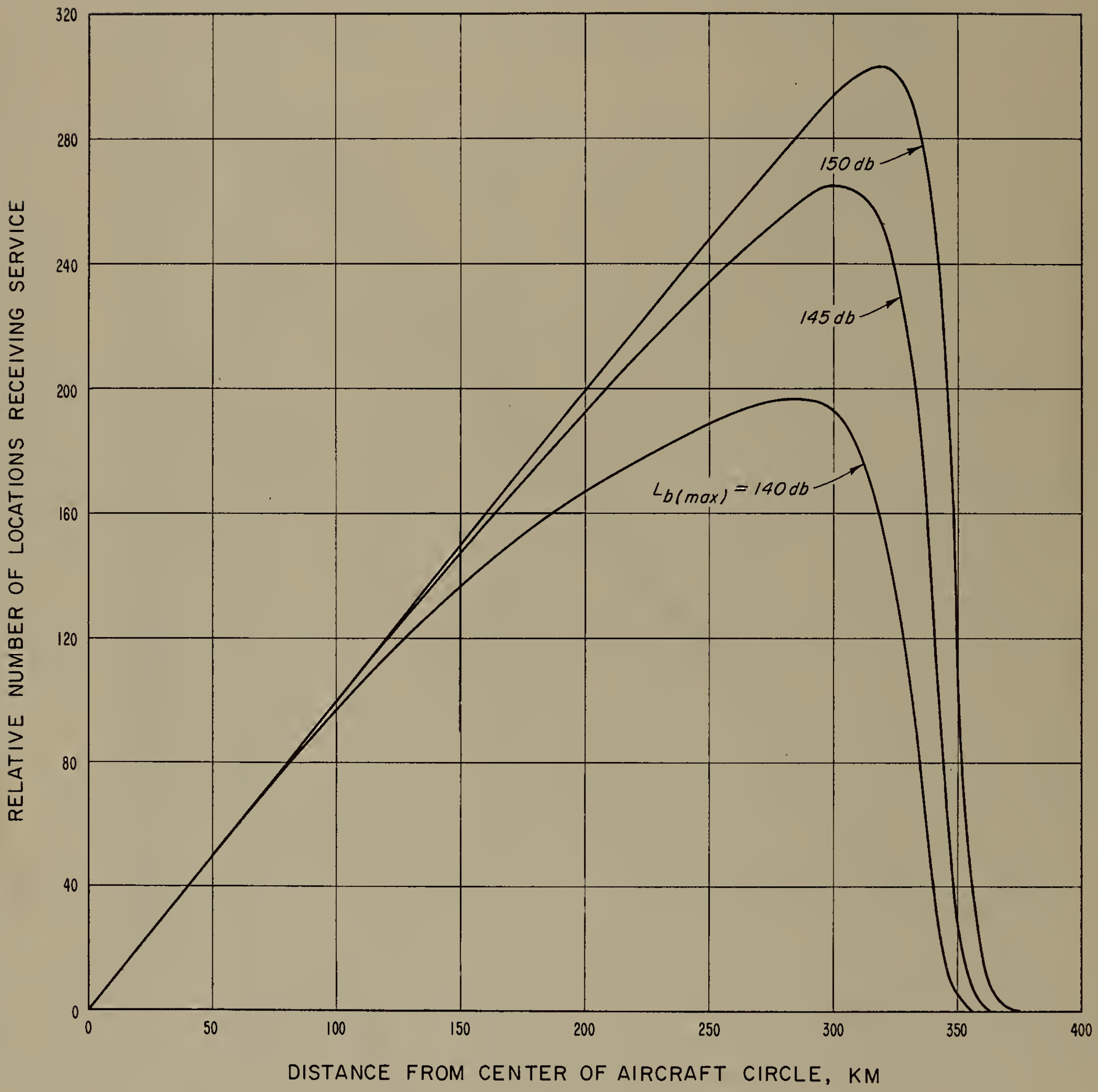
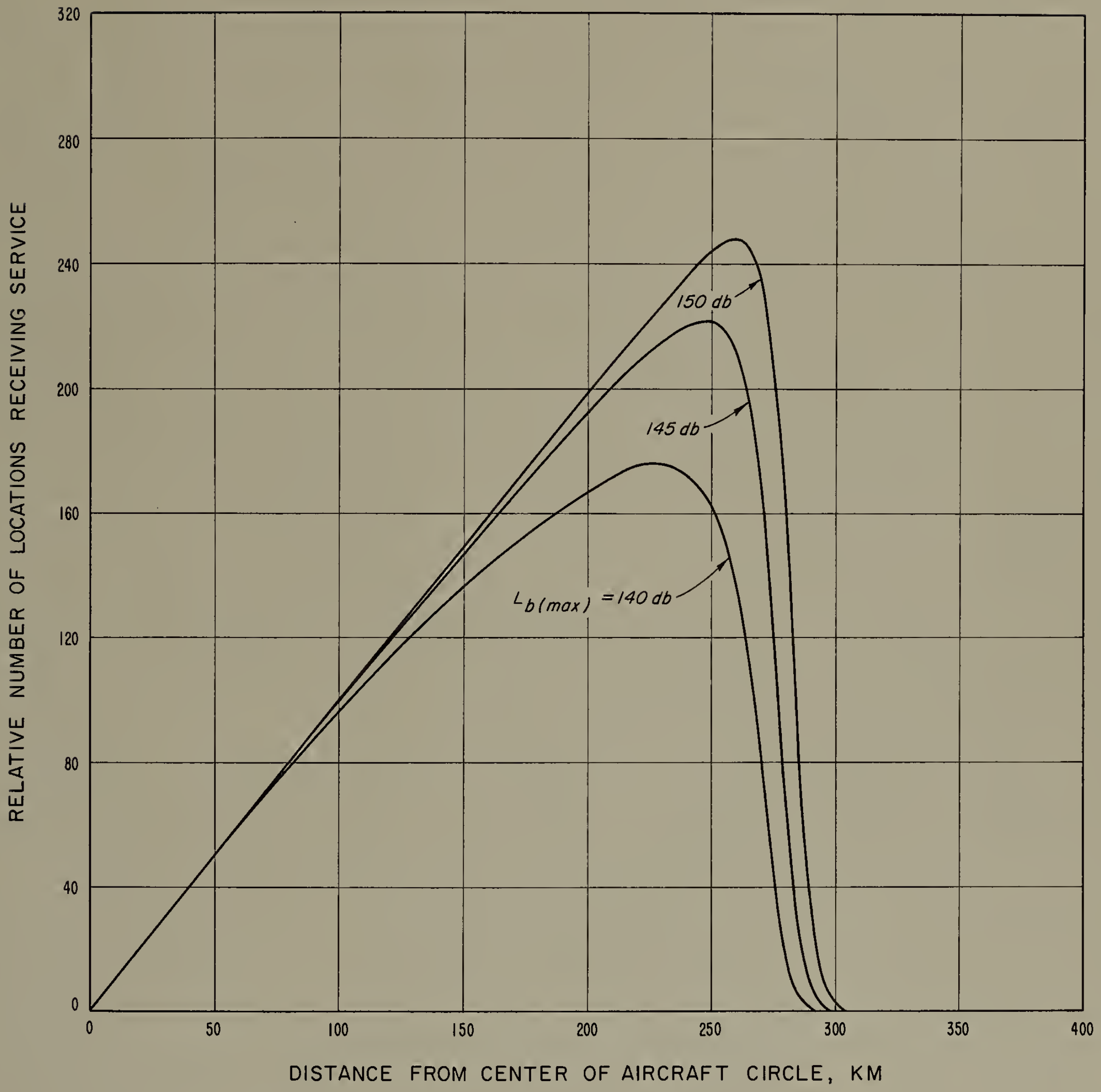


Figure 27



RELATIVE NUMBER OF LOCATIONS RECEIVING SERVICE
FREQUENCY 785 Mc

AIRCRAFT CIRCLING WITH 15 KILOMETERS RADIUS
AT ALTITUDE OF 5,000 METERS

RECEIVING ANTENNA HEIGHT MAXIMUM OF
30 METERS WITH DIVERSITY AS REQUIRED

Figure 28

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 and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer. Concreting Materials.

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

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research. Radio Warning Services. Airglow and Aurora. Radio Astronomy and Arctic Propagation.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Research. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation Obstacles Engineering. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Electronic Calibration Center. Microwave Physics. Microwave Circuit Standards.

Radio Communication and Systems. Low Frequency and Very Low Frequency Research. High Frequency and Very High Frequency Research. Ultra High Frequency and Super High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Systems Analysis. Field Operations.


NBS