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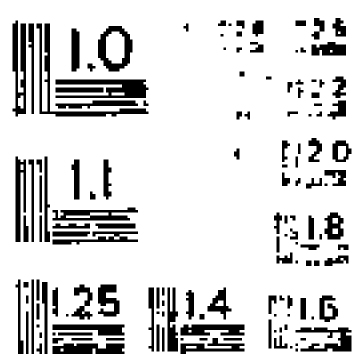

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PROJECT AQUARIUS ANNUAL REPORT (U)

By

R. KRULEE

K. SNOW

1 JUNE 1970

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Sylvania Electronic Systems-Western Division
Electronic Defense Laboratories
Mountain View, California

EDL-G915

Project AQUARIUS Annual Report (U)

Principal Investigator R. Krulee 415/966-2904
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ARPA Order No. 1459

Effective Date of Contract: 2 June 1969

Contract Expiration Date: 30 June 1970

Amount of Contract: $118,864

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by the Office of Naval Research under Contract No. N00014-69-C-0446

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Section 1.

1. (U) (S) INTRODUCTION (U).

For the past year several companies have joined in Project MAY BELL under ARPA sponsorship to investigate the feasibility of detecting low-flying aircraft and Submarine Launched Ballistic Missiles by use of high frequency electromagnetic waves. In particular, a number of tests have been made by Raytheon using a shore-mounted transmitter for generating a surface wave mode while Sylvania has conducted a smaller number of tests using a buoy-mounted transmitter with reception being accomplished via sky-wave at a remote site in Virginia. The transmitters and surface wave receiving sites as well as the controlled aircraft flight patterns have all been on or near the East coast of Florida.

The results of the initial tests of this target detection technique were presented in an earlier report written during this project. In that report it was shown that an aircraft flying approximately 20 km from a 2000 watt low power HF transmitter could be detected. While sufficient detections of aircraft were accomplished to demonstrate the feasibility of such a system, insufficient data has been gathered to date to permit development of a proper system concept to provide a complete coastal defensive system. In particular, there are many parameters that inter-relate the ground-wave-sky wave mode that have not been examined or tested in detail These include variations in frequency, path loss with time of day, season, etc. A firm understanding of how a system can be developed to provide the necessary operational capability does not yet exist.

In this report, the basic parameters that can lead to a system definition for the surface wave-sky wave mode are considered by first evaluating known theory and experimental data. A set of experiments is then

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1. (U) ~~(S)~~ -- Continued.

proposed that can provide the additional details necessary to complete the definition phase of the program. This will involve measurements of the variation in total path loss with respect to .

1) Time
2) Season
3) Frequency
4) Target Aspect Angle
5) Sea State
6) Distance
7) Propagation Mode

The resultant data, when coupled with suitable analysis will provide the necessary evaluation of the following basic system requirements:

1) Probability of detection
2) False Alarm Rate
3) Time Availability
4) Volume of Coverage
5) Number of Sites
6) Power Requirements

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2. (U) ~~(S)~~ SYSTEM CONSIDERATIONS (U).

Since the purpose of this portion of the program is to detect low flying aircraft and missiles at low altitude in order to provide early warning along the sea coasts, where the basic method involves both a surface wave over sea water plus a sky wave to the receiver, it is apparent that a single transmitter will provide essentially a circle of coverage; and hence, many such overlapping circles are needed for reliable detection as shown in Figure 1. It is apparent that more than one receiver site will be required since skip zones are known to exist for sky wave propagation.

More importantly, from a system standpoint, it is necessary to provide a good probability of detection for a significant portion of time while, at the same time, maintaining a reasonable false-alarm rate. Thus, the parameters of the system must be determined in terms of the system requirements with various trade-offs being possible to maximize the cost-effectiveness.

In order to determine the system parameters it is necessary to combine available data with experimentation in such a way that new data is generated with sufficient statistical accuracy to place bounds on the parameters. This process consists of the following steps:

1) State the problem.
2) Formulate the hypotheses.
3) Devise experimental techniques.
4) Examine possible outcomes with reference back to the reason for the problem to assure the experiment provides adequate information.

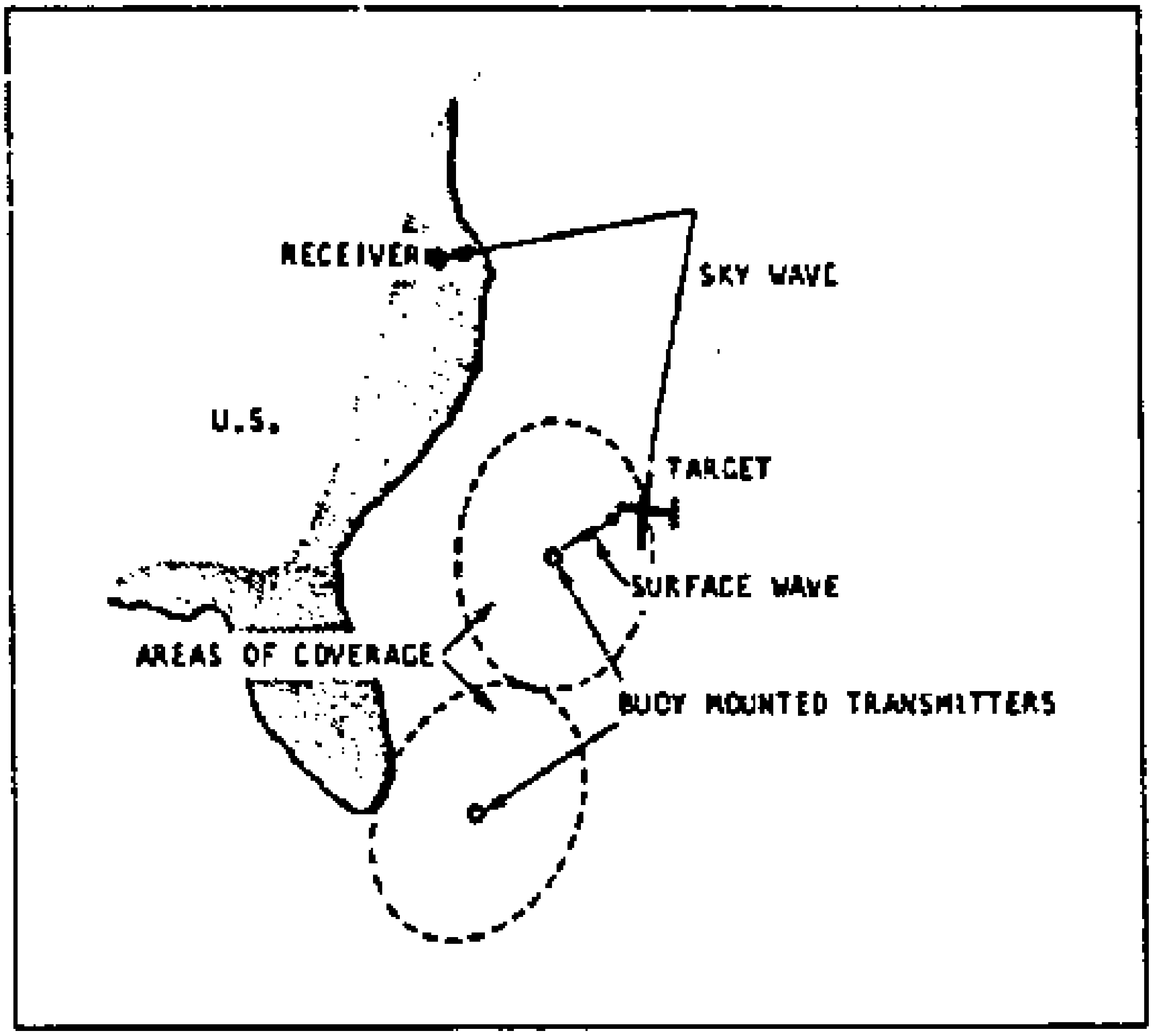

Figure 1. (U) Areas of Coverage for Buoy-Mounted Transmitters (U)

2. (U) (5) -- Continued.

5) Consider the possible results as well as the statistical methods to be applied, to assure that the conditions necessary for the methods to be valid are satisfied.

6) Do the experiment.

7) Apply the statistical methods to the collected data.

8) Draw conclusions, with measures of reliability and confidence limits included, and with due care as to the validity of the conclusions as they apply to the problem and results.

While the above sequence appears to lead in a straight-forward manner to the required results (in this case, the system specifications and parameters), a serious problem arises due to the time-varying statistics of the various paths. For example, the propagation of radio waves over water has been studied in the past by many people (7, 8, 11) however, variations in the path loss occur because of sea state, wind, etc. and the statistics of these variations do not obey any simple law. The same problem of statistical variation will also occur in the radiation patterns from the transmitter antenna, the sky-wave mode and the scattering coefficient of the target.

It should also be noted that the available data on these problem areas does not, in general, represent average values, but usually applies only to the best conditions with a non-zero mean associated with the variations. It should also be noted that most of the data concerning propagation over a sky-wave mode is time dependent with very large changes occurring both for time of day and season of the year. It has also been found that the values are dependent upon geometry and geographical location.

2. (U) ~~(S)~~ -- Continued.

In summary then, the purpose of this set of experiments is to evaluate the statistical variations of the system so that suitable parameters can be selected to provide a good probability of detection for an acceptable percentage of time with a reasonable false alarm rate. The desired parameters will thus have to be selected to accommodate essentially "worst-case" conditions, and these are obviously not changed by taking more data.

Section 3.

3. (U) ~~(S)~~ STATEMENT OF PROBLEM AREAS. (U)

Consider a model which contains a buoy-mounted transmitter with a vertical antenna, a reflecting target flying over the ocean and a receiving site with a high-gain antenna located sufficiently far from the target so that propagation occurs via sky-wave.

The basic problem is to specify the parameters so that a pre-determined signal to noise ratio will be exceeded with high confidence at the receiving site. The following six areas should be investigated:

1) Effective radiated power and antenna coupling.
2) Surface-wave losses to target.
3) Scattering or reflection coefficient of target.
4) Sky-wave losses to receiver.
5) Effective noise at receiver.
6) Receiver antenna gain.

3.1 (U) Effective Radiated Power.

The first problem, that of effective radiated power includes the variations of received power due to motion of the ocean. Thus, if the transmitter power, feedline and antenna efficiencies are known, the far field can be measured and compared with numerous field intensity charts such as those of reference 2. Variations will occur since the sea at these frequencies acts as a reflector which unfortunately is moving with time.

3.2 (U) Surface Wave Losses.

While the surface wave attenuation must be valuated, it may to some extent be inseparable from the above antenna gain problem unless a calm sea and a stable platform are used. A number of theories exist for ground wave propagation and they also include the effects of an elevated target or receiver. It should be noted, that the purpose of this experiment is not to develop a new theory but rather to determine the variations in path loss so that reliable detections can be achieved.

Norton [7] has studied propagation over a spherical earth and has shown that there is significant variation in field strength of a surface wave as a function of height; he considers three regions

$$h = 0$$
$$h \leq (2000/f^{2/3}) \text{ feet}$$
$$h > (2000/f^{2/3}) \text{ feet}$$

where f is in megahertz.

3.2.1 (U) Region 1 - Surface Wave.

When both transmitting and receiving antenna (or target) are near the ocean surface the direct and reflected waves cancel and only the surface wave exists. The important component is the one for vertical polarization because of the high conductivity of sea water which attenuates the horizontal component. Thus, the surface wave attenuation approaches the values given by theory for a perfectly conducting sphere. Barrick [11] has also included the effects due to roughness and has published detailed data for various sea states and frequencies as shown in Figure 2. It should be noted that the basic loss is for a sphere and not a perfectly conducting plane.

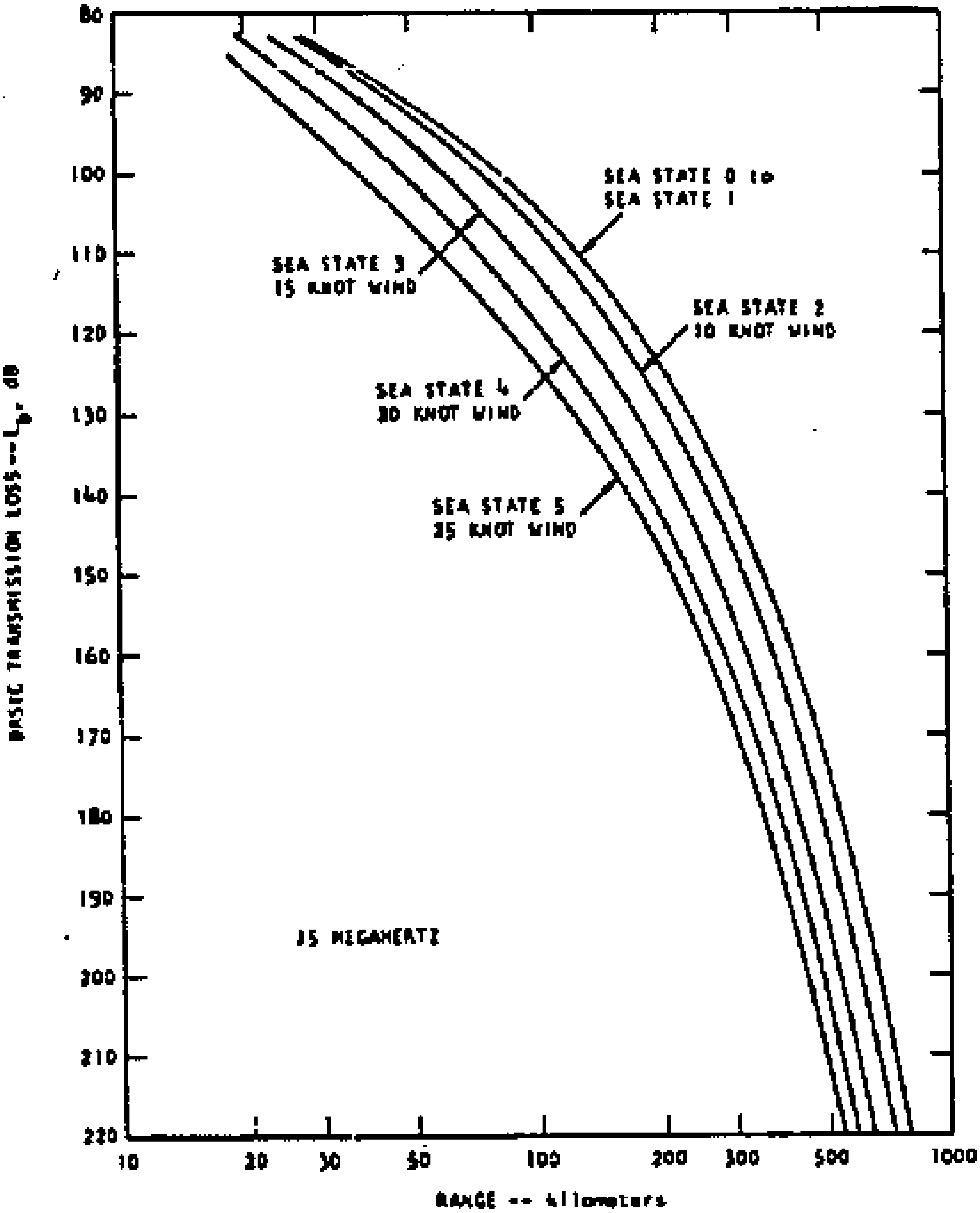

Figure 2. (U) Basic Transmission Loss for Ground Wave Along the Ocean. Propagation in Upwind-Downwind Direction. (U)

3.2.2 (U) Region II - Medium Antenna Heights.

In this region Norton[7] has determined a height-gain function and it is only necessary to multiply the surface wave field by the functions $f(q_1)$, $f(q_2)$ defined by Norton for the transmitting and receiving antenna heights as shown in Figure 3.

3.2.3 (U) Region III - High Antenna.

When the transmitting and/or receiving antenna are high, the earth's curvature affects the field strength both within and beyond line-of-sight points. The basic ground-wave field strength must be multiplied by a factor depending upon whether the path is line-of-sight or not. At sufficiently high altitudes the field intensity has been found to decay exponentially with increasing height.

At points within line-of-sight the earth's curvature must be considered since the plane wave reflection coefficient is different for a curved surface than for a plane. Also the curved surface reflection causes the energy to diverge more than is indicated by the inverse square law, and hence a divergence loss factor must be included. It is apparent that these factors affect not only the transmitter to target path but also the target to receiver path since the target acts as a radiator after reflection. Barrick[11] has also modelled a surface wave and calculated the path loss variations with sea state and height for the HF band. His results are very similar to Norton.

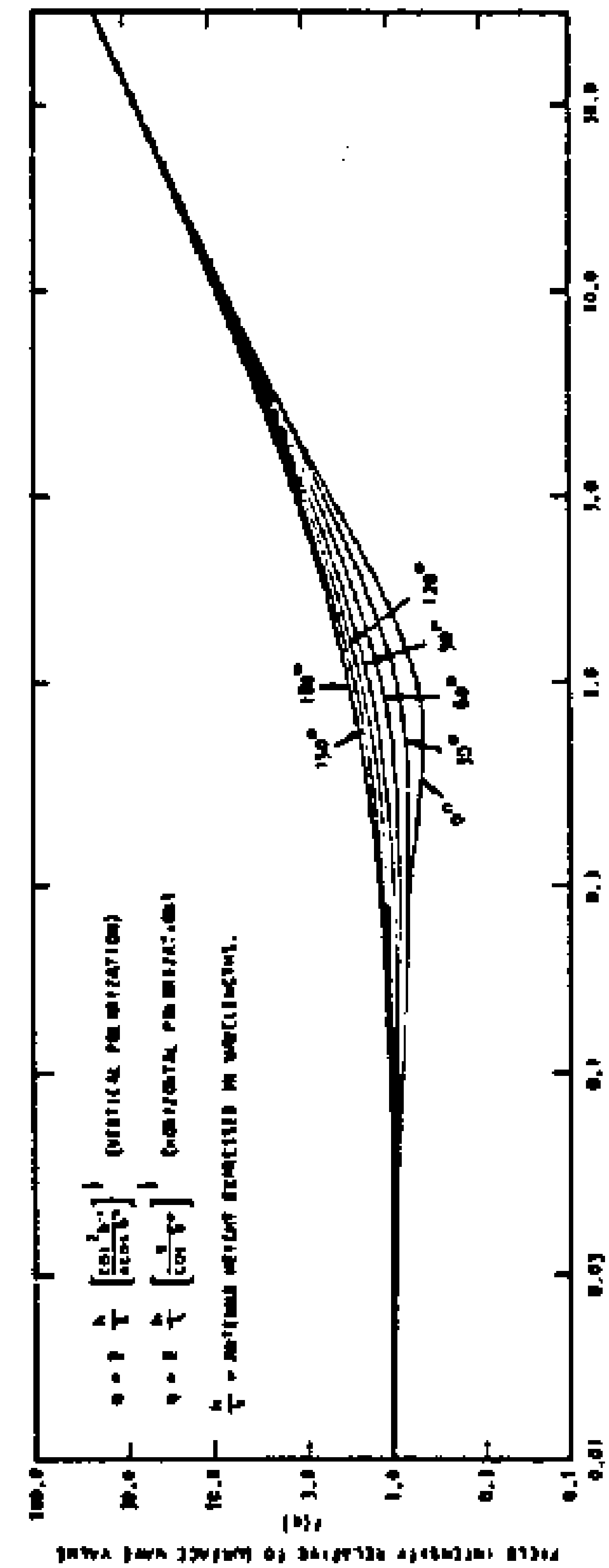

Figure 3. (U) The Variation of Field Intensity with Numberical Antenna Height. (U)

3.3 (U) ~~(S)~~ Effective Target Area.

The evaluation of a meaningful target cross-section for an aircraft is difficult, since a complex target such as an aircraft may be considered as madeup of a large number of independent objects which scatter energy in all directions. Skolnik(9) has shown that the cross-section fluctuation from a "simple" scatterer can vary over a ratio of 4 to 1 which would introduce scintillation in the signal and hence doppler spreading.

Target aspect angle (TAA) can have considerable impact upon the reflected or scattered HF energy impinging on the target. Some of the information available at EDL on the HF radar cross-sections of aircraft and missiles is contained in references 4 and 5, however, it should be emphasized that these measurements were made for back-scattered energy and may not be correct for forward or sideward scattering. The difficulty is that the target area not only affects the amount of required transmitter power, but also because the sizes of typical aircraft and missiles are on the order of a wavelength at these frequencies that the choice of operating frequency may be influenced. Thus, appropriate targets must be evaluated in terms of the goals of this program. Some of their conclusions are:

1. The fine structure (nose cone, tail fins, etc) with dimensions considerably smaller than a wavelength has negligible effect on the cross-section at any aspect, except in the direction of deep nulls where the depth of the null is somewhat affected.

2. The HF broadside cross-sections of rockets and large aircraft are of the order of several hundred square meters.

(U)

3.3 (S) -- Continued.

3. The particular cylinders studied showed a deep null end-on if the length of the cylinder is less than one wavelength. If the length is greater than one wavelength, another null develops at 20° from broadside.

4. The depths of the above nulls can exceed 30 db below the broadside response.

5. The cylinder aspect ratios studied had length to diameter ratios L/D = 10 to 14. A rotation of the cylinder about an axis normal to its longitudinal axis and parallel to the Poynting vector resulted in a slowly varying response (polarization sensitivity) with nulls not exceeding 6 db.

Table I is taken from Reference 5 and shows nulls, null depths, and cross-sections as a function of frequency. Great variations in null depths are shown - as well as large variations between peaks and nulls. For example, the peak-to-null variation of the KC-135 shows 27.3 + (-15) db or a total variation of 42.3 db. It is obvious from these results that both aircraft and missiles present scintillating targets with wide signal variations.

It is interesting to note that only two out-of-plane measurements were made - these on the KC-135. They showed -15 to -19 db nulls at the same frequency. The apparent cross-section did not change significantly, however. Since the impinging RF energy from the buoy antenna will not always be exactly in-plane for an aircraft target, an even more complex null structure can be expected as the out-of-plane angle varies.

TABLE 1. ~~(S)~~ (U) MONOSTATIC HF BACKSCATTER RADIO CROSS SECTIONS FOR AIRCRAFT TARGETS BASED ON X-BAND MODEL RANGE STUDIES (U). (Reference 5)

[redacted]

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TABLE I (U) -- Continued.

[redacted]

Soviet			
BISON	E Polarization	15	1200 (max)
			-18 db (min)
	H Polarization	15	164 (max)
			-12 db (min)
BEAR	E Polarization	15	1800 (max)
	H Polarization	15	1010 (max)
TU-104	E Polarization	15	215 (max)
			-12 to -15 db (min)
TU-16	H Polarization		762 (max)
			-12 db (min)

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(U)
TABLE I (S) -- Continued.

MIG 19	E Polarization	15	450 (max)
	H Polarization	15	50.5 (max) min at -17 db
MIG 21	E Polarization	6	388 (max) -22 db nulls at ±90°
	H Polarization	8.56	816 (max) -25db nulls at ±90° several nulls at ± 90°
MIG 21	E Polarization	15	258 (max) -18 db nulls)
	H Polarization	15	12.4 (max) min of -9 db no nulls

3.4 (U) Sky-Wave Propagation

The frequency chosen for this experiment must be examined carefully so that the disadvantages of HF propagation are minimized. Some of the disadvantages of using HF are:

1) The variability of propagation conditions which could require changes in operating frequency.

2) The large number of possible propagation paths with resulting time dispersion of the signal due to multiple modes of propagation.

3) The large and rapid phase fluctuations.

4) The possibility of high interference rates due to multiple modes of propagation.

For example, Figure 4 shows the typical diurnal variation of the critical frequency at one specific latitude and season for high and low sunspot numbers.

A low frequency is needed to get below the nighttime maximum useable frequency (MUF), and a higher frequency is needed in the daytime that is both below the MUF yet above the region of high absorpiton. Implicit in this discussion of first-order factors is the fact that a lower useable frequency (LUF) exists and is a function of absorption, incident field strengths, receiver noise levels, and receiving site noise environment.

At medium frequencies, it is possible that the groundwave and skywave ranges overlap with the result that severe fading can occur when the two signals are of comparable amplitude. The path length is thus a consideration as well as the frequency chosen for the experiment.

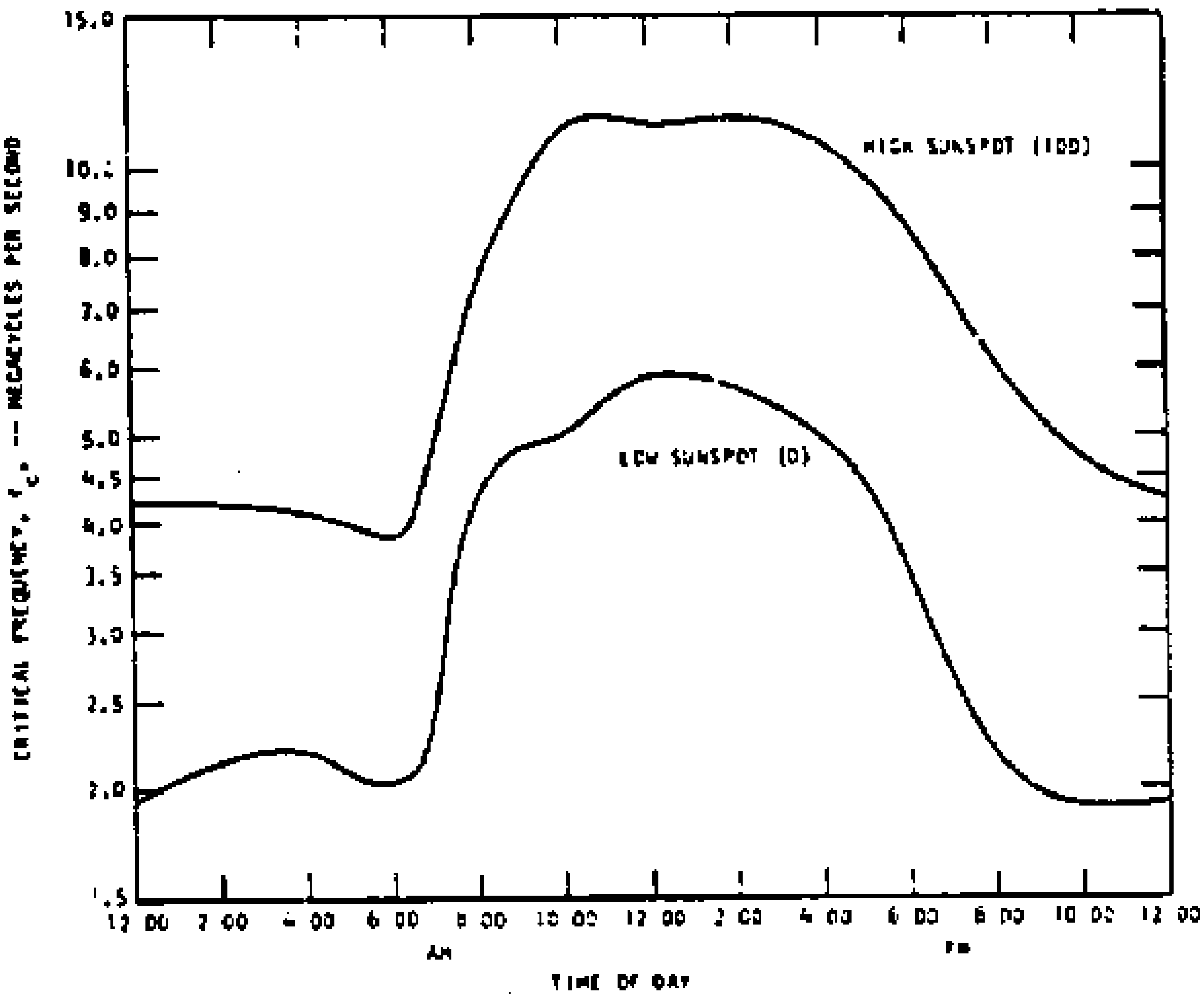

Figure 4. Typical Diurnal Variation of Critical Frequency for January at Latitude 40 degrees (From Ref. 2). (U)

3.4 (U) -- Continued.

Where Figure 4 showed diurnal variations of critical frequency at one latitude for one season of the year, Figure 5 shows typical values of absorption at midday. This is a maximum and depends upon the angle of the sun in relation to the horizon. On short paths, this is the actual path length and not the distance along the earth.

In order to evaluate the proper frequencies of operation, it will be necessary to determine experimentally the variation in path loss with frequency. Certain assumptions can be made to limit the amount of experimentation needed for a manageable program. These are:

1) The receiver site noise environment and minimum detectable signal threshold are accurately known.

2) The effective radiated power (ERP) of the buoy-mounted transmitter and antenna is accurately known or can be predicted.

3) The HF radar cross-section of target aircraft is at least 20 meters^2 at all aspect angles.

4) The receiving site antenna gain is known accurately.

5) The midpoint of the skywave path is known or can be predicted.

6) The ionosphere midpoint is stable or its variation can be predicted.

7) The instrumental inaccuracies are known or can be controlled.

8) The buoy swing or sea state will not affect the measurements of path loss.

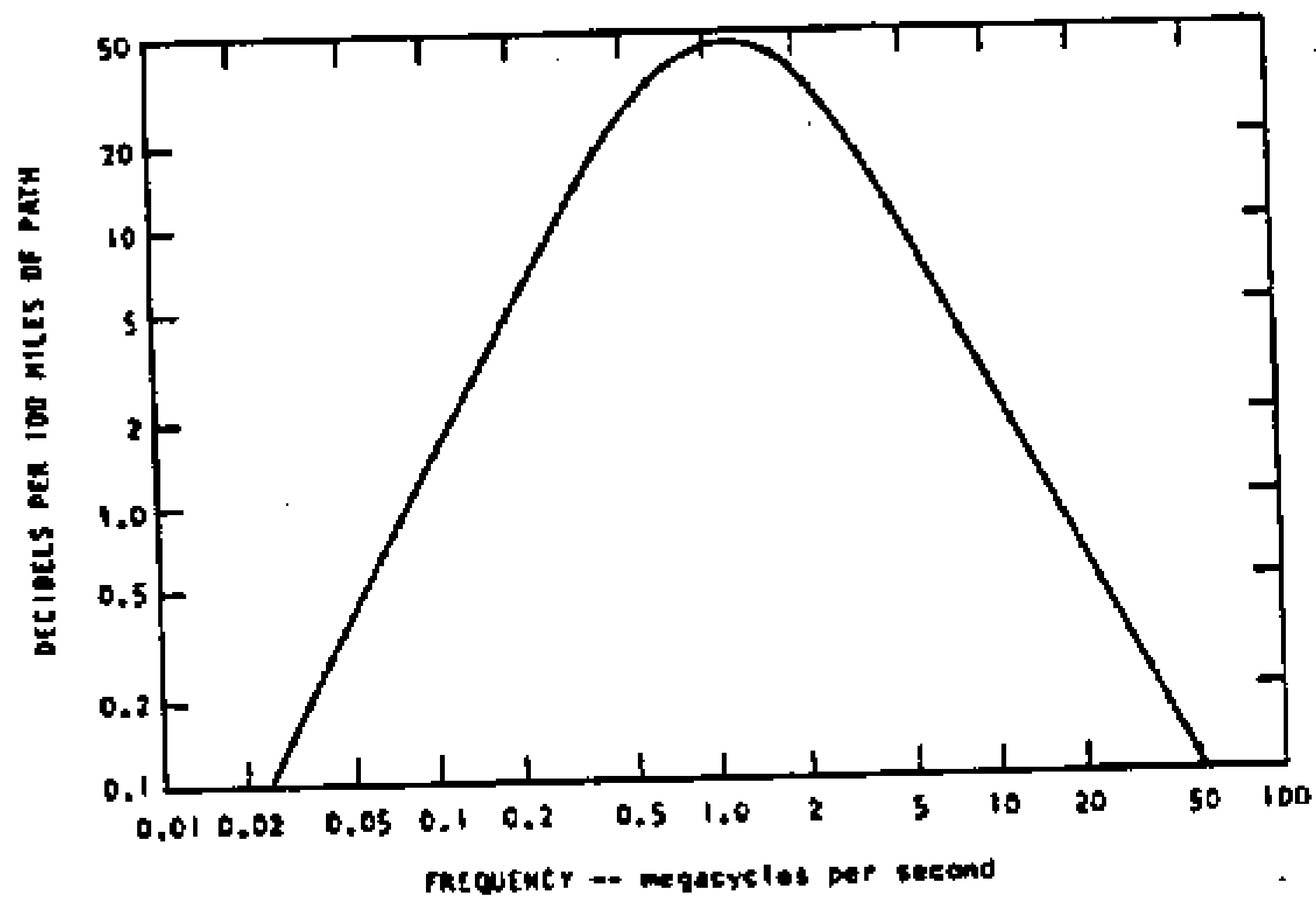

Figure 5. (U) Typical Values of Midday Ionospheric Absorption (From Ref 2) (U)

3.4 (U) -- Continued.

9) The weather effects on the atmospheric refractive index are negligible.

3.5 (U) Noise at the Receiver.

Figure 6 shows typical noise in a 6-kc bandwidth for a latitude of 40° averaged over a year. Summer averages will be a few db higher while winter averages will be a few db lower. The noise level will vary with latitude, however, the particular receiving site is fixed so that more accurate noise determinations could be made and a suitable correction factor applied to any experimental results.

3.6 (U) ~~(S)~~ Receiving Antenna.

The transmitting antenna will be by necessity limited to a simple vertical and may be quite short compared to a wavelength so that its efficiency as a radiator will be low. The receiving antenna can be quite efficient providing the chosen frequency is not too low. Depending upon the spatial separation of arriving signals from more than one buoy, the receiving antenna may have to be rotatable -- or consist of a steerable array so that optimum receiving conditions can exist. The better the receiving antenna, the greater the depression of the LUF.

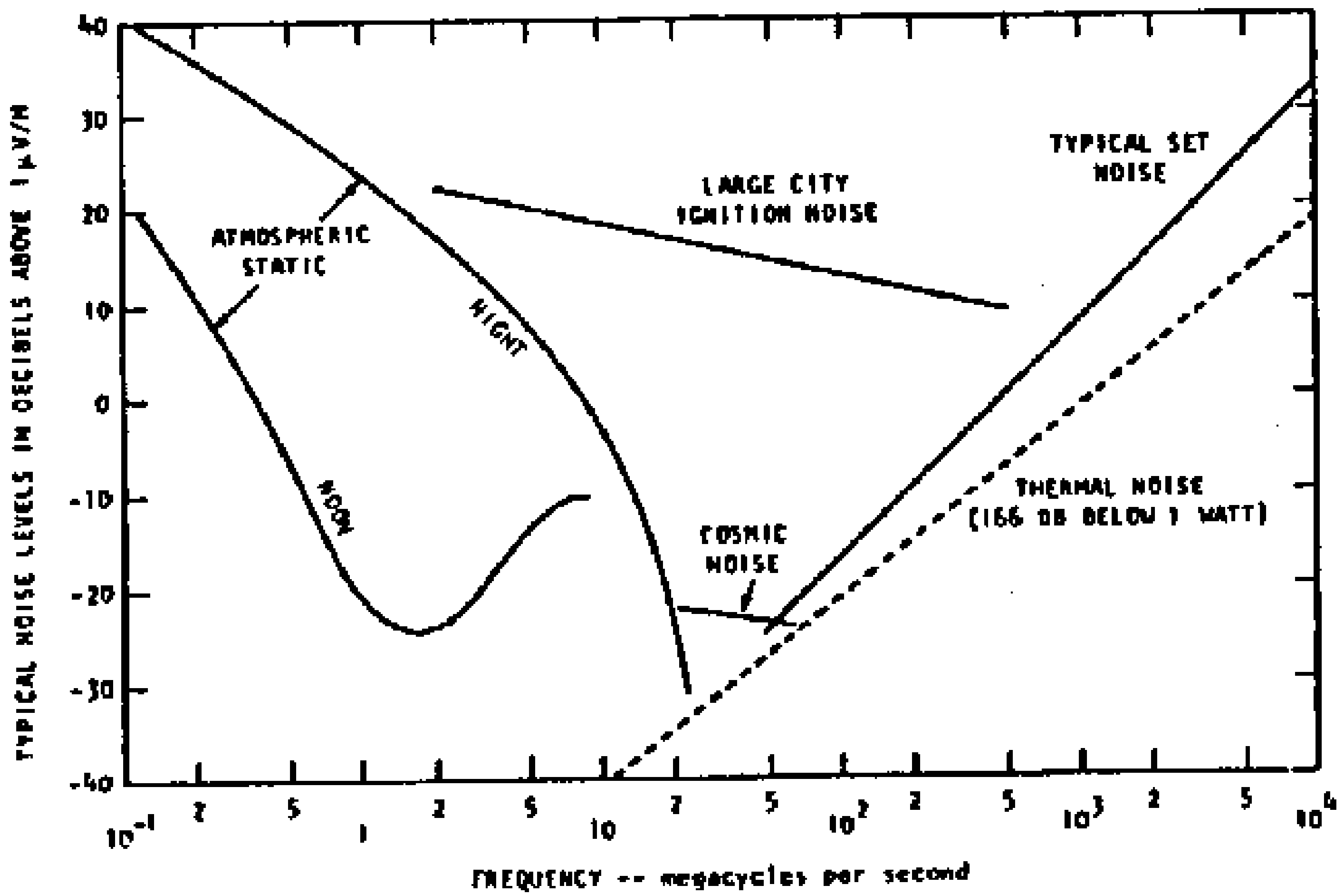

Figure 6. (U) Typical Average Noise Level in a 6-kc Band (Ref 2) (U)

Section 4.

4. (U) ~~(S)~~ EXPERIMENT DESIGN (U).

Because the end measurement of this experiment is related to doppler shift, it becomes apparent that a slow moving vehicle -- such as a surface vessel -- is of limited use as a target in evaluating path loss. In addition, a helicopter platform is considered less desirable because of low speed, unknown cross-section, and rotor modulation effects. A relatively high speed aircraft -- up to Mach 1 as a target vehicle -- appears to be a viable solution, but is subject to some contraints. The aircraft should be large enough to assure an adequately large cross-section, and for over-water operations it should be multi-engined. Since the target is passive, it need not require more than a single seat aircraft, such as the F-101. The cross section of the target aircraft should be known accurately from model measurements.

To cover the effects of diurnal variation, flights must be made often enough during every 24 hours to provide sufficient statistical data. In addition, seasonal variations require that experiments must also be carried out over a period of months so that seasonal effects may be taken into account. It may be possible to linearly interpolate for values over longer period effects such as sunspot number variation, but this is mere conjecture at this time. Additional study is needed to determine the length and frequency of tests.

Since the target aspect angle is a vital parameter, many flight paths may be necessary -- at different altitudes -- to provide sufficient statistical data which may be processed to provide meaningful results. The aircraft should be flown in constant radius circles around the buoy to provide general contours. Cross-hatch flight paths can then be used to provide the

(U)

4. (S) -- Continued.

variable aspect angle data as well as provide check points where the circular paths are intersected. Again, it should be realized that these flights must take place at several different altitudes and should be numerous as possible to provide a sufficient data base for statistical analysis. Reference to Table I included earlier in this report shows the larger values of cross-section are 1800 meters^2 so that an assumed 20m^2 in the equation below represents a worst case.

The reflected power can be expressed as

$$P_{ref} = \frac{P_t G_t \sigma}{(4\pi D)^2} \quad (3)$$

where:

P_{ref} = Power reflected from the target

P_t = Power of the transmitter

G_t = Gain of the transmitting antenna

σ = Target cross section

D = Distance from transmitter to target (same units as σ)

The reflected power (P_{ref}) is calculated for various distances D in Table II assuming an effective radiated power ($P_t G_t$) of 1000 watts. Table II shows the large variation in reflected power with distance or volume of coverage.

(U)
4. (U) -- Continued.

TABLE II. REFLECTED POWER FROM TARGET. (U)

Distance in Miles	Reflected power in dbm
1	-12
2	-18
5	-26
10	-32
20	-38
50	-46
100	-52

A sketch of the basic propagation model is shown in Figure 7 below with various portions of the path labelled.

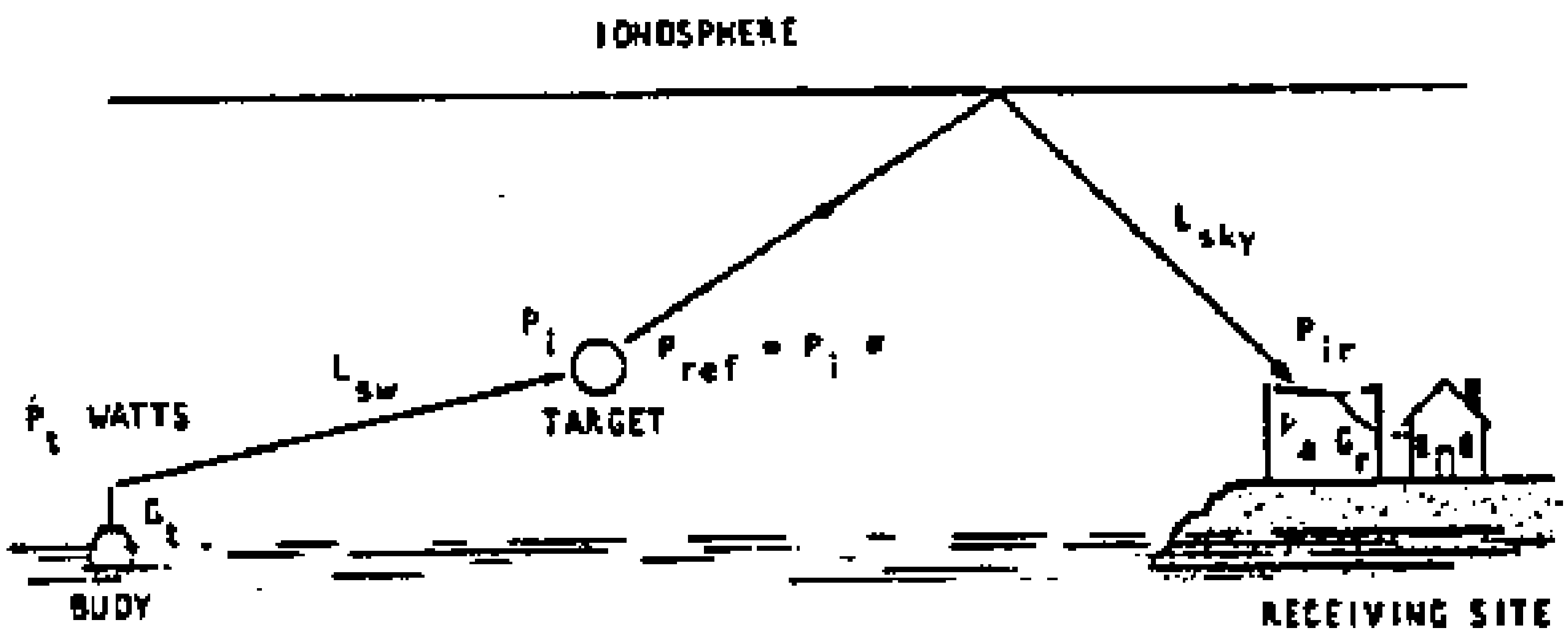

Figure 7 (U) Sketch of Basic Propagation Model. (U)

4. (U) -- Continued.

The following equations apply to this model.

$P_r = T_p - L_{loss} + G_t$ = ERP (in dbm)

T_p = Transmitter Power, L_{loss} = Line loss, and G_t = Antenna Gain

L_{sw} = Surface Wave Losses

P_i = Power Incident on Target

P_{ref} = P_i times Target Reflection Coefficient (see Table II)

L_{sky} = Skywave Path Loss (including ionospheric losses)

P_{ir} = Skywave power incident at receiver antenna

P_a = P_{ir} time G_r = Total Signal Power at receiver ($P_{ir}+G_r$ in dbm)

$$P_a = P_{ref} - L_{sky} + G_r \quad (4)$$

P_{ref} = (P_i) (Reflection Coefficient) where $P_i = P_r - L_{sw}$ (5)

Note that this does not take into account receiver noise figures, bandwidths, nor interference. The standard logarithmic form for free-space transmission loss, L between two isotropic antennas is given by:

$$L = 20 \log_{10} D + 20 \log_{10} f + 36.58 \quad (6)$$

where D is in miles and f is in megahertz. Path loss cannot be less than the free-space loss so that one can, after Norton (8), state the following:

$$L_{trans} = L - G_t - G_r + A \quad (7)$$

where L_{trans} = System Transmission Loss

G_t, G_r = Transmitting and Receiving Antenna gains above isotropic

A = Propagation path loss relative to the free-space value L.

4. (U) ~~(S)~~ -- Continued.

In cases where it is possible to determine the effective values of transmitting and receiving antenna gain, equation (7) may be used to determine the value of A. It becomes impossible, however, to separate the antenna gains under conditions of multipath ionospheric propagation. With multipath propagation the only values that can be measured are P_r and P_a. Thus, one must be satisfied with only an overall transmission path loss value.

To see why this is so, let d_j denote the distance and a_j the voltage attenuation factor corresponding to the j-th ionospheric path. Let g_{tj} and g_{rj} denote the power gains of the transmitting and receiving antennas for this particular path. The average signal power available from the receiving antenna P_a, is then (from Norton - Ref. 8):

$$P_a = P_r \lambda^2 \sum_{j=1}^{m} a_j^2 \, g_{tj} g_{rj} / (4\pi d_j)^2 \qquad (8)$$

This is the generalized form of equation (7) above and is obtained by summing the signal powers available from the separate paths. It is impossible to extract the transmitting and receiving gains from the summation sign, and so it is impossible to separate out either an inverse distance factor, ERP, or the received field intensity.

Referring to Figure 2 and Equations (4) and (5), it appears that one could measure (or calculate) both ERP and the surface wave loss, L_{sw}. The figures given in Table II show total reflected power. If it is assumed that this is equivalent to the power that is reflected toward the ionosphere in the direction of the receiving site, then the target can be considered as a "virtual" transmitter with those values in Table II as the ERP. The sky wave loss, L_{sky}, can be calculated by assuming no other losses than the free-space

4. (U) ~~(S)~~ -- Continued.

loss. This would be approximately true for nighttime conditions, but an absorption factor would have to be added for any portion of the path which is in daylight.

Taking the values from Table II as the target ERP and calculating the path loss for 100, 500, 1000, and 1500 mile skywave distances for a 5 Mcs transmission frequency, we obtain the incident skywave signal power (dbm) at the receiving site (see Table III).

TABLE III (U) INCIDENT SKYWAVE SIGNAL POWER (dbm) (U)

Target ERP dbm	Transmission Distance in Miles			
	100	500	1000	1500
-12	-107	-121	-127	-131
-18	-123	-127	-133	-137
-26	-121	-135	-141	-145
-32	-127	-141	-147	-151
-38	-133	-147	-153	-157
-46	-141	-154	-161	-165
-52	-147	-161	-167	-171

Included in the above table is the assumption of a single hop skywave propagation mode as well as an arbitrary 4 db loss due to ionospheric reflection. This number is conservative since it depends upon the reflection coefficient of the ionosphere, and could be significantly higher (10). In addition any receiving antenna gain is not included in the table.

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Section 5.

5. (U) ANALYSIS.

As mentioned before, the purpose of any experimental program is to develop systems specifications. Therefore, the data taken at best represents sample points from the total possible variation for the various portions of the model. It will then be necessary to apply standard statistical techniques to dete...ine the mean values and the various percentiles about the mean. This in turn can be readily translated into the more usual parameters of power, antenna gain, volume of coverage, etc.

In addition, to the usual analysis, it will be necessary to examine the data to evaluate whether dependence exists on the various portions of the path and also to determine variations with time, geographical location, etc., since it is quite likely that any system would require a control link in order to maintain optimum parameters while accommodating the known variations in the system.

Section 6. UNCLASSIFIED

6. (U) ~~(S)~~ SUMMARY.

The following parameters contribute the most uncertainty to the experiment.

1. Frequency – must be chosen to minimize interference yet provide a sufficiently stable signal with time. In all probability, at least two frequencies will be necessary -- one for daytime use and one for nighttime use.

2. Path Length – the path length must be chosen so as to minimize any possible self-interference problems -- i.e., the ground wave coverage area must not include the receiving site, but the skywave path should be long enough for reliable modes.

3. Target Aspect Angle – the only data available on FAA is data which was taken in the horizontal plane. As such any inclined plane nulls are not plotted, except in two cases on the KC-135 aircraft. Since incident RF energy on the target will not always fall exactly in the horizontal plane (broadside) cross-sections will vary over some unknown range.

4. Null Depth Variations – a given target has shown null variations of over 30 db, therefore, any flight path will have to be carefully controlled so the effects of the nulls may be accounted for.

5. Receiving Site Noise Environment – this is not expected to seriously affect the experiment since the mean value and seasonal variations in ambient noise should be available from CCIR 322.

6. Absorption – this is a variable correction factor and is proportional to the sun's angle with the horizon as well as being frequency sensitive.

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6. (U) -- Continued.

7. Platform - the recommended platform is a multi-engine, high performance aircraft, and preferably one whose cross-section is known.

8. Altitudes - several altitudes for the target will be necessary because the field strength is both altitude and frequency sensitive.

9. Measurement Tolerances - some determination of the possible ranges of tolerance will be needed in all areas of implementation, not only to size the experiment, but to judge its impact on the collected data.

10. Interference - HF interference is a great unknown quantity since it varies considerably from hour to hour and day to day. It may require more than just two frequencies to conduct the experiment. Using higher power sources would decrease the interference problem.

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Section 7.

7. (U) (S) RECOMMENDATIONS.

In summary it is recommended that the proposed experimental program be accomplished in four phases. First, analysis and measurements are needed to evaluate the coupling between the buoy-mounted transmitter and the surface wave which, of course, is vertically polarized. To do this, a variable frequency transmitter will be operated with a shore receiving station to minimize the variables.

Second, additional analysis will be made for target cross-sectional area. This is best accomplished by modelling. Model experiments will also be conducted to evaluate the difference between backscatter and forward scatter.

Third, the path loss must be evaluated. To do this, an airborne transmitter will be used and both the sky wave via the ionosphere and the surface wave will be measured. In this phase, sufficient data must be taken to validate the theoretical results of previous workers (2, 3, 7, 8 and 11) in order to all prediction of time availability with reasonable accuracy. Mode and frequency of propagation will also be optimized during this phase.

Fourth, a preliminary system will be defined as a result of the above investigations. This design will include coverage area, control requirements, and an estimate of detection probability and false alarm rate.

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