

RADIO ENGINEERING
MICROWAVE RADIO
PROPAGATION
PATH LOSS

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1. INTRODUCTION

1.01 The power radiated from a transmitting antenna is ordinarily spread over a relatively large area. As a result, the power available at most receiving antennas is only a small fraction of the radiated power. This difference between the radiated power and the received power is called the radio transmission path loss.

1.02 This section is reissued to include data applicable to additional frequency bands of 18, 29, and 40 GHz.

1.03 The path loss between the transmitting and receiving antennas determines whether or not the received signal will be useful. Accurate predictions of path loss can be made on paths that approximate the ideals of free space; however, on many paths of interest the path geometry and atmospheric conditions differ so much from the ideal that absolute accuracy cannot be expected. Reasonably accurate predictions can be made, however, by taking into account all the factors which can contribute to path loss.

1.04 In addition to the loss caused by spreading or dispersion of energy, a microwave radio signal is affected by such things as rain, water vapor and oxygen content of the atmosphere, temperature variations, atmospheric refractions, and reflections. This section discusses in a general manner, the way in which each of these factors affects the radio signal and presents methods for making a prediction of path loss over a microwave path. Subsequent sections in this series of practices present more detailed information on the causes of path loss.

2. FREE-SPACE PATH LOSS

A. General

2.01 All variations in path loss are normally referred to the fixed loss that would occur between isotropic antennas transmitting or receiving in free space.

2.02 The transmission medium can be described as equivalent to free space when transmitted

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electromagnetic energy travels over a straight line path through a vacuum, or an ideal atmosphere with no absorption or reflection of energy by nearby objects. In such a transmission medium the energy undergoes a loss that varies as the square of the distance.

2.03 An isotropic antenna is used as a reference because it is a convenient theoretical form of radiator. It is generally used as the relative standard for all other microwave antennas, although a half-wave dipole is sometimes used as the reference. By definition, the isotropic antenna radiates power uniformly in all directions and has unity gain. The gain of an actual antenna in free space is the power gain ratio of the antenna relative to the isotropic antenna. For example, a small doublet has a directivity gain of 1.5 (1.76 dB) in the direction of maximum radiation, while a half-wave dipole has a gain of 1.64 (2.15 dB). A typical 8-foot parabolic antenna operating at 6 GHz has a gain of 39 dB over an isotropic antenna.

2.04 The relation of path loss between practical antennas operating in the atmosphere and path loss between theoretical (isotropic) antennas operating in free space can be best explained in terms of practical antenna gain.

B. Received Power With an Isotropic Transmitting Antenna

2.05 Refer to the definitions of 2.02 and 2.03 and imagine a sphere of radius d centered upon the point source (the isotropic antenna). In such an ideal medium as free space, the radiated power density will be equal at all points on the sphere and the total radiated power (P_T) will pass through the surface of the sphere. The surface area of a sphere is expressed as $4\pi d^2$; therefore, the power density at any point on the surface of the sphere will be

$$\text{Power density} = \frac{P_T}{4\pi d^2} \quad (1)$$

2.06 If a receiving antenna with area A_1 is located on the surface of the sphere, the received power (P_R) will be equal to the power density times the area of the antenna, or

$$P_R = \frac{P_T}{4\pi d^2} \cdot A_1 \quad (2)$$

C. Practical Antenna Gain

2.07 Unlike the theoretical isotropic antenna, practical antennas do not radiate equally in all directions. They are practically always designed to focus energy to form a beam. Thus, the power intercepted by the receiving antenna will be dependent upon the orientation of both the transmitting and the receiving antennas. From electromagnetic theory it can be established that for an antenna of arbitrary shape or form, the ratio between gain (G) and the area of antenna (A) is a constant; i.e.,

$$\frac{G}{A} = \text{constant} = \frac{4\pi}{\lambda^2}$$

where λ is the wavelength of the transmitted frequency. Therefore, gain of a practical antenna can be represented by

$$G = \frac{4\pi A}{\lambda^2} \quad (3)$$

Practical antennas have losses which result in their gain being 2 to 3 dB less than theoretical. This is usually taken into account by assigning an effective area to the antenna which is less than its physical area. The ratio between effective area and physical area is often called the antenna efficiency.

D. Determining Free-Space Path Loss

2.08 From the preceding discussion it should now be possible to determine the free-space path loss between two antennas. First, it is necessary to determine the ratio of transmitted power (P_T) radiated by an antenna or area (A_2) to the power received (P_R) by an antenna of area (A_1). If the transmitting antenna were isotropic, the received power, from Eq. (2), would be

$$P_R = \frac{P_T}{4\pi d^2} \cdot A_1$$

where d is the distance between the antennas. However, because a practical antenna has gain, the actual received power is

$$P_R = \frac{P_T}{4\pi d^2} \cdot A_1 \cdot \frac{4\pi}{\lambda^2} \cdot A_2 \quad (4)$$

Thus, the power ratio will be

$$\frac{P_T}{P_R} = \frac{d^2 \lambda^2}{A_1 A_2} \quad (5)$$

Since both transmitting and receiving antenna gains are expressed as $4\pi A/\lambda^2$ Eq. (5) can be rewritten in terms of antenna gain by multiplying both numerator and denominator by $(4\pi\lambda)^2$, then,

$$\frac{P_T}{P_R} = \underbrace{\left(\frac{4\pi d}{\lambda}\right)^2}_{\text{free-space path loss}} \div \left(\underbrace{\frac{4\pi A_1}{\lambda^2}}_{\text{rec. ant. gain}} \cdot \underbrace{\frac{4\pi A_2}{\lambda^2}}_{\text{trans. ant. gain}} \right) \quad (6)$$

2.09 Stated in dB, Eq. (6) becomes the expression for path loss between any two practical antennas situated in free space.

$$\begin{aligned} \text{Path loss} &= 20 \text{ Log } \frac{4\pi d}{\lambda} - 10 \text{ Log } \frac{4\pi A_1}{\lambda^2} \\ &\quad - 10 \text{ Log } \frac{4\pi A_2}{\lambda^2} \quad (7) \end{aligned}$$

The term $(4\pi d/\lambda)^2$ in Eq. (6) is defined as free-space path loss and can be expressed (in terms of frequency and distance) as follows:

$$\begin{aligned} \text{FSL} &= 20 \text{ Log } \frac{4\pi d}{\lambda} \\ &= 20 \text{ Log } 4\pi + 20 \text{ Log } d + 20 \text{ Log } \frac{1}{\lambda} \end{aligned}$$

$$\text{Since } \lambda \text{ (miles)} = \frac{984}{F \text{ (MHz)}} \cdot \frac{1}{5280}$$

$$\begin{aligned} \text{FSL} &= 22 + 20 \text{ Log } d + 20 \text{ Log } F + 20 \text{ Log } \frac{5280}{984} \\ &= 22 + 20 \text{ Log } d + 20 \text{ Log } F + 20 \text{ Log } (5.36) \\ &= 36.6 + 20 \text{ Log } d + 20 \text{ Log } F \quad (8) \end{aligned}$$

2.10 Equation (8) is the expression generally used to determine free-space path loss. Since an isotropic radiator has unity gain, the expression is also used to determine free-space path loss between isotropic antennas. Figure 1 is a nomogram for quickly determining free-space path loss. Figure 2 contains similar information in graphical form for the 2-, 4-, 6-, 11-, 18-, 29-, and 40-GHz common carrier frequency bands. Both figures are constructed from Eq. (8). In addition, Tables A through O provide the free-space path loss for radio channel frequency assignments in the common carrier frequency bands. Tables N and O are, however, limited to representation of low, center, and high frequencies within the 29- and 40-GHz bands. In Tables A through L (2 through 11 GHz) the loss is listed for path lengths of from 1 to 50 miles, while Tables M, N, and O (18 through 40 GHz) are calculated from 0.5 miles to a distance of 10 miles. The information in the tables was calculated by a computer using Eq. (8).

2.11 While the isotropic antenna is most often used as the standard when referring to antenna gain, the gain is occasionally quoted with reference to a half-wave dipole which has a gain of 2.15 dB over the isotropic antenna. Thus, if an antenna is quoted as having a gain of 40 dB over the half-wave dipole, it should be remembered that this represents a gain of 42.15 dB over an isotropic antenna.

3. RAIN LOSS

3.01 At the higher microwave frequencies, rainfall produces very pronounced effects on radio transmission. The actual effect in the microwave range of 4 to 6 GHz is small relative to the losses introduced by other causes of fading. At higher

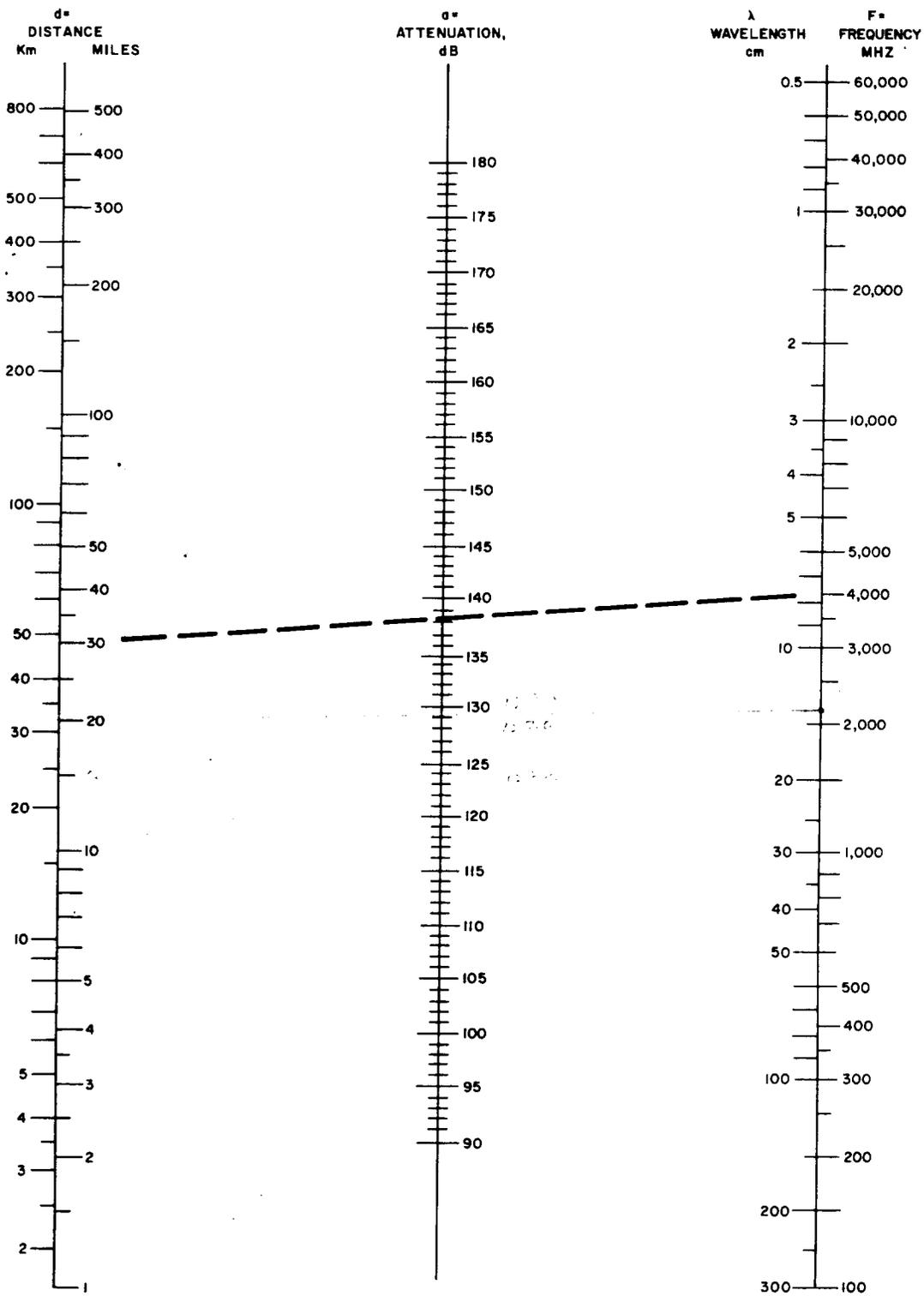


Fig. 1—Nomogram for Solution of Free-Space Path Loss ($FSL = 36.6 + 20 \log d + 20 \log F$) Example Shown: Distance 30 miles, Frequency 4000 MHz; Free-Space Path Loss = 138 dB

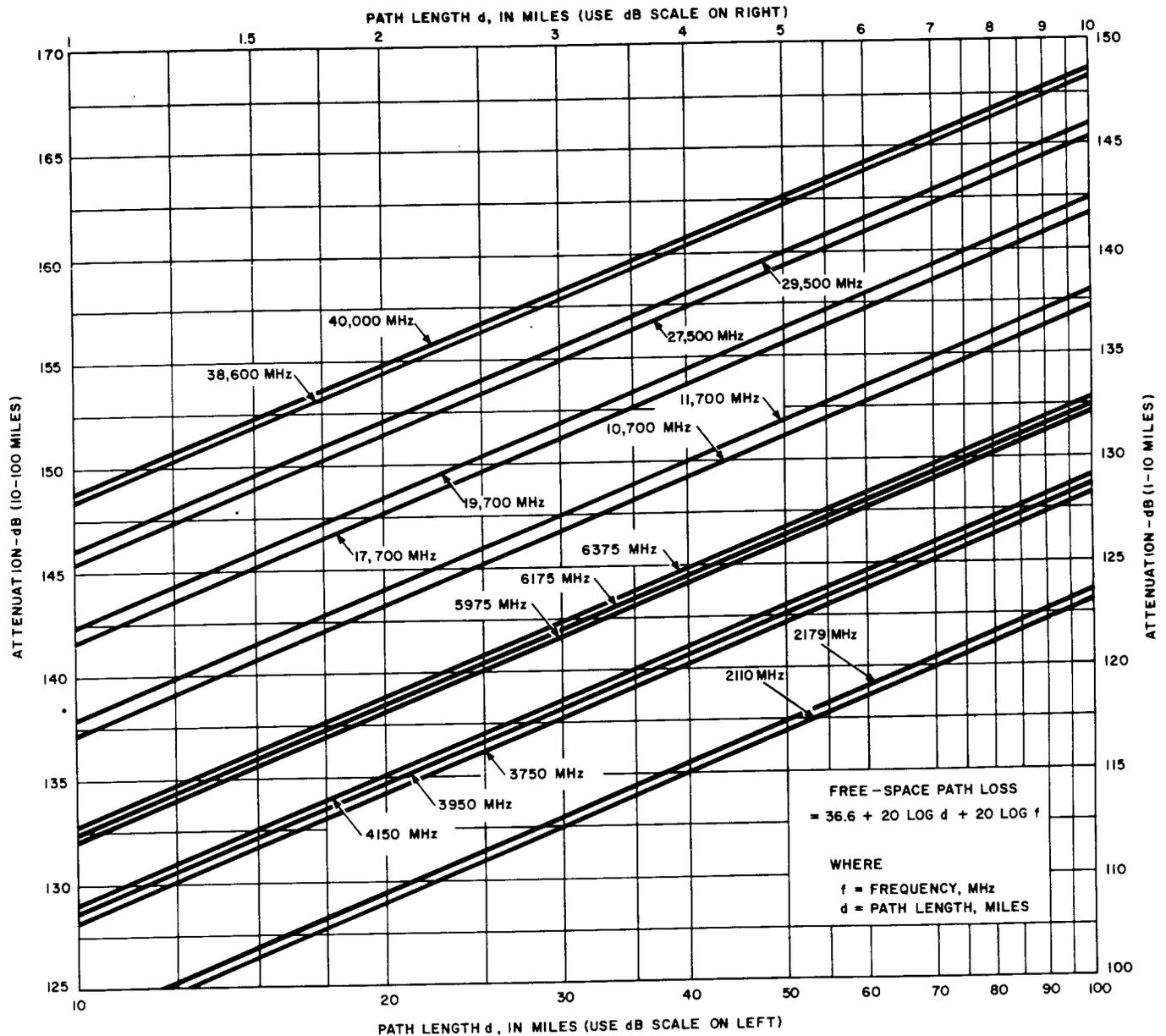


Fig. 2—Free-Space Path Loss Between Isotropic Antennas

frequencies, however, rain attenuates radio transmission to a much greater degree. The radio energy is absorbed and scattered by the raindrops and this effect becomes more pronounced as the wavelength approaches the diameter of the raindrops.

3.02 Figure 3 is a theoretical curve showing the increase in signal attenuation with rainfall for the microwave bands extending from 4 through 29 (30) GHz. The attenuation indicated for the

4- and 6-GHz bands is insignificant. At 11 GHz, however, rainfall rates of 1 inch per hour will cause attenuation of about 1.4 dB per mile, while at 30 GHz this loss increases to approximately 8.5 dB. (Data for rain loss at 40 GHz was not available at time of issue.) It should be noted that heavy rains are generally confined to areas of 1 or 2 square miles; thus, only a portion of a path may be affected. Rain loss is discussed in greater detail in Section 940-310-106.

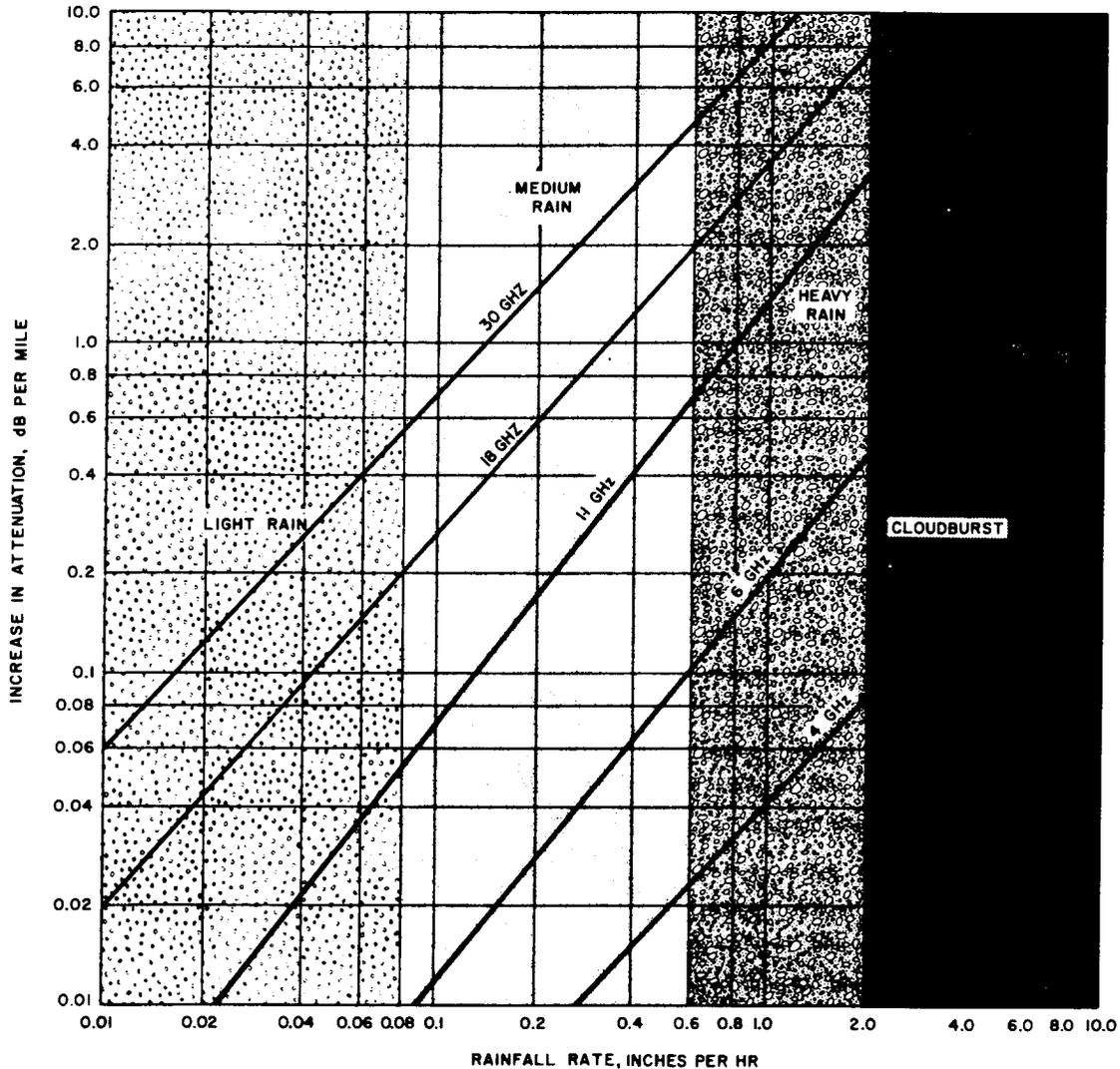


Fig. 3—Attenuation Due to Rainfall

4. OXYGEN AND WATER VAPOR LOSS

4.01 The absorption of radio waves in the atmosphere without water drops (rain) is caused mainly by oxygen molecules and water vapor. Figure 4 illustrates the attenuation caused by this phenomenon as the combined total of oxygen and water vapor loss versus frequency. The molecular notations above the peaks in the curves serve to indicate which agent contributes the greater portion of attenuation at that particular point. As shown by the curve in Fig. 4, the attenuation at frequencies up to 40 GHz is not severe. In addition, the relatively short hop lengths used at 18, 29,

and 40 GHz tend to further minimize the affect of this loss.

5. FADING

5.01 Variations in the atmosphere occur hourly and daily, as well as geographically, and such variations can cause fading. The amount of fading that a particular microwave link will be subject to cannot be predicted with absolute accuracy; however, the behavior of existing microwave systems has been observed over the years and from this it has been determined that two types of fading are prevalent. They are termed beam bending and multipath fading.

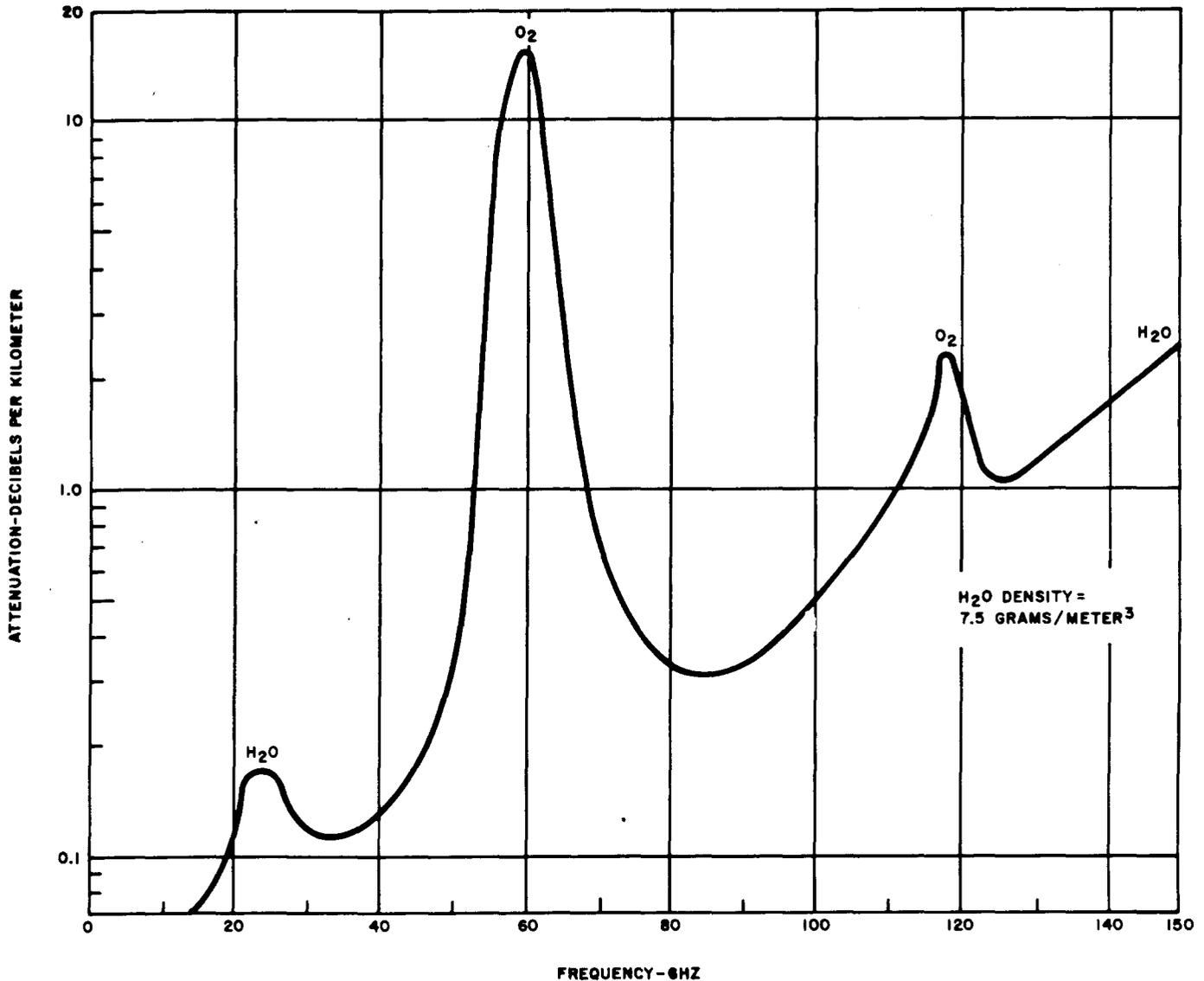


Fig. 4—Total Oxygen and Water Vapor Loss Versus Frequency

A. Beam Bending

5.02 Changes in the index of refraction with height cause beam bending (refractions of the radio wave). The index of refraction can be affected by changes in atmospheric temperature, pressure, and humidity. In the "standard atmosphere" (one that represents average atmospheric conditions), the index of refraction decreases linearly with height causing the transmission beam to bend in the direction of the earth's curvature. With temperature and/or humidity inversions, the index of refraction increases with height. Conversely, other changes in the atmosphere may cause the

index of refraction to decrease more rapidly than normal. Any change from the standard decrease may cause the transmission beam to bend excessively up or down, creating the same effect as an increase or decrease in receiving (or transmitting) antenna height.

5.03 Because atmospheric conditions appear normal over a portion of a radio path, it should not be assumed that these conditions are constant over the entire path. Weather fronts and other localized conditions can affect one part of a path and not another.

5.04 When beam bending is severe, it may cause a hitherto line-of-sight path to degenerate into an obstructed path with a consequent drop in signal level that may last several hours. The effect of the signal level drop and the frequency of its occurrence can be minimized by increasing the path clearance and having adequate fade margin. Beam bending is discussed in detail in Section 940-310-103.

B. Multipath Fading

5.05 Multipath fading is a phenomenon whereby uncontrolled reflection and refraction from layers of air having different densities and boundary conditions cause the microwave beam to split into components which travel to the receiver over slightly different paths. As the length of the microwave path is increased, the number of indirect paths by which the signal may be received increases rapidly. The signals from the various indirect paths, when added to the direct signal, cause rapid field strength variations around the median signal value. In most cases the variations will be completely random, resulting in what is sometimes called Rayleigh fading or Rayleigh distributed signals (from Lord Rayleigh's scattering law). Multipath fading causes very short outages, or hits, on a system. Typically, a very deep fade will last approximately 1 to 5

seconds. Over a major portion of the continental United States, fading, caused by multipath reception, is most pronounced during the months of July through October, but varies, of course, with the particular geographic location. Figure 5 is a curve, based on the Rayleigh scattering law, that can be used to determine the probability that a received signal will fall below or above some value during a multipath fade condition. Fading is discussed in greater detail in Sections 940-310-102, -103, and -115.

6. CONCLUSIONS

6.01 Under normal transmission conditions, the path loss of a typical line-of-sight microwave link should closely approximate the calculated free-space loss. This is assuming proper installation of antennas to provide a transmission path with adequate clearance over intervening objects. However, since complete data on the propagation conditions of a particular path are rarely available, allowances should be made for the detrimental effects of *abnormal* transmission conditions. For example, sufficient clearance should be provided so that beam blocking, because of inverse bending, is not encountered for more than a small percentage of time.

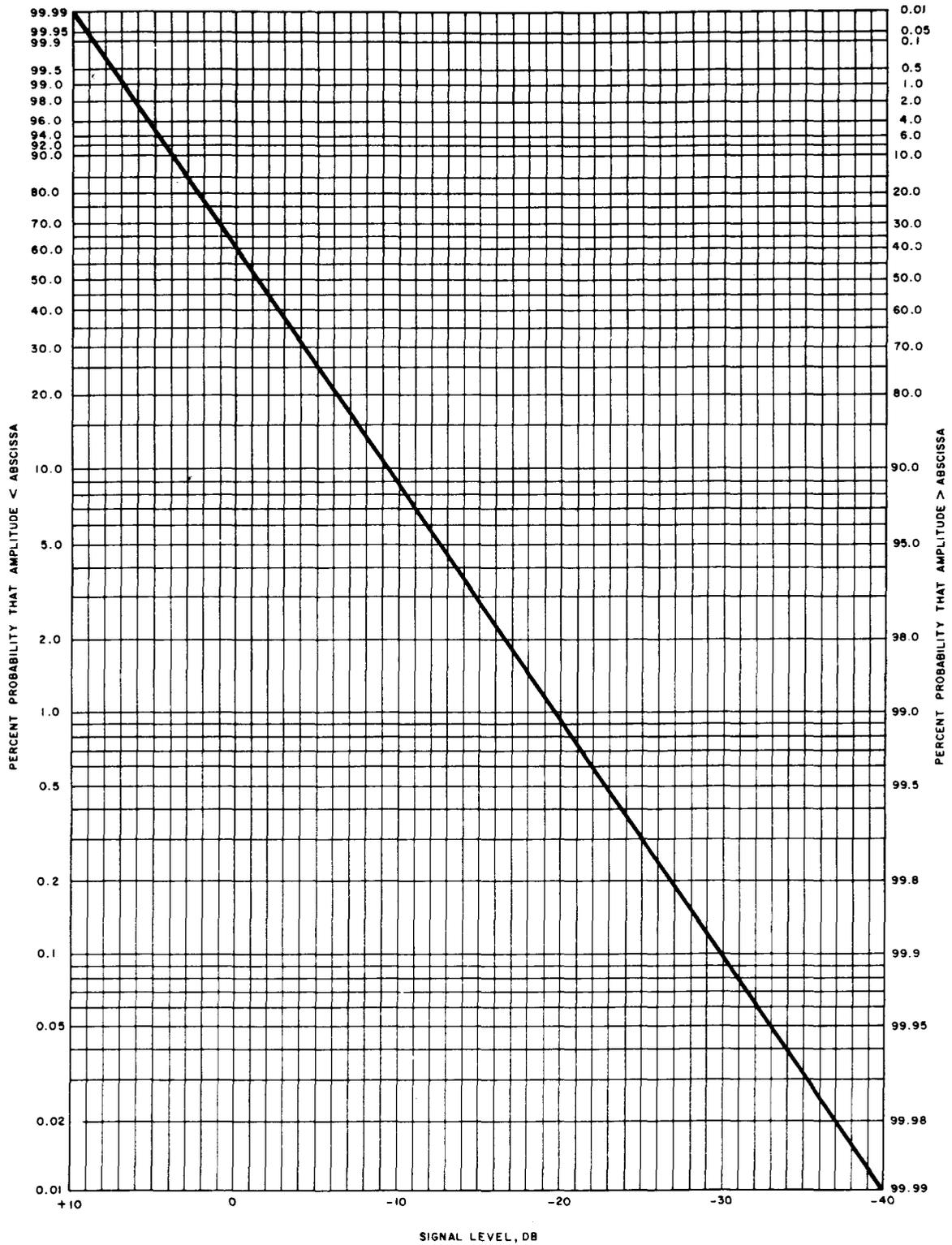


Fig. 5—Rayleigh Probability Distribution

TABLE A

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHZ)					
	2111.0	2114.6	2118.2	2121.8	2125.4	2129.0
1	103.07	103.09	103.10	103.11	103.13	103.14
2	109.09	109.11	109.12	109.14	109.15	109.16
3	112.61	112.63	112.64	112.66	112.67	112.69
4	115.11	115.13	115.14	115.16	115.17	115.19
5	117.05	117.06	117.08	117.09	117.11	117.12
6	113.63	118.65	118.66	118.68	118.69	118.71
7	119.97	119.99	120.00	120.02	120.03	120.05
8	121.13	121.15	121.16	121.18	121.19	121.21
9	122.16	122.17	122.18	122.20	122.21	122.23
10	123.07	123.09	123.10	123.11	123.13	123.14
11	123.90	123.91	123.93	123.94	123.96	123.97
12	124.65	124.67	124.68	124.70	124.71	124.73
13	125.35	125.36	125.38	125.39	125.41	125.42
14	125.99	126.01	126.02	126.04	126.05	126.07
15	126.59	126.61	126.62	126.64	126.65	126.67
16	127.15	127.17	127.18	127.20	127.21	127.23
17	127.68	127.69	127.71	127.72	127.74	127.75
18	128.18	128.19	128.21	128.22	128.24	128.25
19	128.65	128.66	128.68	128.69	128.70	128.72
20	129.09	129.11	129.12	129.14	129.15	129.16
21	129.51	129.53	129.54	129.56	129.57	129.59
22	129.92	129.93	129.95	129.96	129.98	129.99
23	130.31	130.32	130.33	130.35	130.36	130.38
24	130.67	130.69	130.70	130.72	130.73	130.75
25	131.03	131.04	131.06	131.07	131.09	131.10
26	131.37	131.38	131.40	131.41	131.43	131.44
27	131.70	131.71	131.73	131.74	131.76	131.77
28	132.01	132.03	132.04	132.06	132.07	132.09
29	132.32	132.33	132.35	132.36	132.38	132.39
30	132.61	132.63	132.64	132.66	132.67	132.69
31	132.90	132.91	132.93	132.94	132.96	132.97
32	133.17	133.19	133.20	133.22	133.23	133.25
33	133.44	133.46	133.47	133.49	133.50	133.51
34	133.70	133.71	133.73	133.74	133.76	133.77
35	133.95	133.97	133.98	134.00	134.01	134.03
36	134.20	134.21	134.23	134.24	134.26	134.27
37	134.43	134.45	134.46	134.48	134.49	134.51
38	134.67	134.68	134.70	134.71	134.73	134.74
39	134.89	134.91	134.92	134.94	134.95	134.97
40	135.11	135.13	135.14	135.16	135.17	135.19
41	135.33	135.34	135.36	135.37	135.39	135.40
42	135.54	135.55	135.57	135.58	135.59	135.61
43	135.74	135.75	135.77	135.78	135.80	135.81
44	135.94	135.95	135.97	135.98	136.00	136.01
45	136.13	136.15	136.16	136.18	136.19	136.21
46	136.33	136.34	136.36	136.37	136.38	136.40
47	136.51	136.53	136.54	136.56	136.57	136.59
48	136.70	136.71	136.72	136.74	136.75	136.77
49	136.87	136.89	136.90	136.92	136.93	136.95
50	137.05	137.06	137.08	137.09	137.11	137.12

TABLE B

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHZ)					
	2161.0	2164.6	2168.2	2171.8	2175.4	2179.0
1	103.27	103.29	103.30	103.32	103.33	103.35
2	109.29	109.31	109.32	109.34	109.35	109.37
3	112.82	112.83	112.85	112.86	112.87	112.89
4	115.32	115.33	115.34	115.36	115.37	115.39
5	117.25	117.27	117.28	117.30	117.31	117.33
6	118.84	118.85	118.87	118.88	118.89	118.91
7	120.18	120.19	120.20	120.22	120.23	120.25
8	121.34	121.35	121.36	121.38	121.39	121.41
9	122.36	122.37	122.39	122.40	122.42	122.43
10	123.27	123.29	123.30	123.32	123.33	123.35
11	124.10	124.12	124.13	124.15	124.16	124.17
12	124.86	124.87	124.89	124.90	124.92	124.93
13	125.55	125.57	125.58	125.60	125.61	125.62
14	126.20	126.21	126.23	126.24	126.25	126.27
15	126.30	126.81	126.82	126.84	126.85	126.87
16	127.36	127.37	127.39	127.40	127.41	127.43
17	127.88	127.90	127.91	127.93	127.94	127.95
18	128.38	128.39	128.41	128.42	128.44	128.45
19	128.85	128.86	128.88	128.89	128.91	128.92
20	129.29	129.31	129.32	129.34	129.35	129.37
21	129.72	129.73	129.75	129.76	129.78	129.79
22	130.12	130.14	130.15	130.17	130.18	130.19
23	130.51	130.52	130.54	130.55	130.57	130.58
24	130.88	130.89	130.91	130.92	130.94	130.95
25	131.23	131.25	131.26	131.28	131.29	131.30
26	131.57	131.59	131.60	131.62	131.63	131.65
27	131.90	131.92	131.93	131.94	131.96	131.97
28	132.22	132.23	132.25	132.26	132.27	132.29
29	132.52	132.54	132.55	132.57	132.58	132.59
30	132.82	132.83	132.85	132.86	132.87	132.89
31	133.10	133.12	133.13	133.14	133.16	133.17
32	133.38	133.39	133.41	133.42	133.43	133.45
33	133.64	133.66	133.67	133.69	133.70	133.72
34	133.90	133.92	133.93	133.95	133.96	133.98
35	134.16	134.17	134.18	134.20	134.21	134.23
36	134.40	134.41	134.43	134.44	134.46	134.47
37	134.64	134.65	134.67	134.68	134.70	134.71
38	134.87	134.88	134.90	134.91	134.93	134.94
39	135.10	135.11	135.12	135.14	135.15	135.17
40	135.32	135.33	135.34	135.36	135.37	135.39
41	135.53	135.54	135.56	135.57	135.59	135.60
42	135.74	135.75	135.77	135.78	135.80	135.81
43	135.94	135.96	135.97	135.99	136.00	136.02
44	136.14	136.16	136.17	136.19	136.20	136.21
45	136.34	136.35	136.37	136.38	136.40	136.41
46	136.53	136.54	136.56	136.57	136.59	136.60
47	136.72	136.73	136.74	136.76	136.77	136.79
48	136.90	136.91	136.93	136.94	136.96	136.97
49	137.08	137.09	137.11	137.12	137.14	137.15
50	137.25	137.27	137.28	137.30	137.31	137.33

TABLE C

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHZ)							
	3710	3730	3750	3770	3790	3810	3830	3850
1	107.97	108.01	108.06	108.11	108.15	108.20	108.24	108.29
2	113.99	114.04	114.08	114.13	114.17	114.22	114.27	114.31
3	117.51	117.56	117.60	117.65	117.70	117.74	117.79	117.83
4	120.01	120.06	120.10	120.15	120.19	120.24	120.29	120.33
5	121.95	121.99	122.04	122.09	122.13	122.18	122.22	122.27
6	123.53	123.58	123.62	123.67	123.72	123.76	123.81	123.85
7	124.87	124.92	124.96	125.01	125.06	125.10	125.15	125.19
8	126.03	126.08	126.12	126.17	126.22	126.26	126.31	126.35
9	127.05	127.10	127.15	127.19	127.24	127.28	127.33	127.37
10	127.97	128.01	128.06	128.11	128.15	128.20	128.24	128.29
11	128.80	128.84	128.89	128.94	128.98	129.03	129.07	129.12
12	129.55	129.60	129.65	129.69	129.74	129.78	129.83	129.87
13	130.25	130.29	130.34	130.39	130.43	130.48	130.52	130.57
14	130.89	130.94	130.98	131.03	131.08	131.12	131.17	131.21
15	131.49	131.54	131.58	131.63	131.68	131.72	131.77	131.81
16	132.05	132.10	132.14	132.19	132.24	132.28	132.33	132.37
17	132.58	132.62	132.67	132.72	132.76	132.81	132.85	132.90
18	133.07	133.12	133.17	133.21	133.26	133.30	133.35	133.40
19	133.54	133.59	133.64	133.68	133.73	133.77	133.82	133.87
20	133.99	134.04	134.08	134.13	134.17	134.22	134.27	134.31
21	134.41	134.46	134.51	134.55	134.60	134.64	134.69	134.73
22	134.82	134.86	134.91	134.96	135.00	135.05	135.09	135.14
23	135.20	135.25	135.30	135.34	135.39	135.43	135.48	135.52
24	135.57	135.62	135.67	135.71	135.76	135.80	135.85	135.89
25	135.93	135.97	136.02	136.07	136.11	136.16	136.20	136.25
26	136.27	136.31	136.36	136.41	136.45	136.50	136.54	136.59
27	136.60	136.64	136.69	136.73	136.78	136.83	136.87	136.92
28	136.91	136.96	137.00	137.05	137.10	137.14	137.19	137.23
29	137.22	137.26	137.31	137.36	137.40	137.45	137.49	137.54
30	137.51	137.56	137.60	137.65	137.70	137.74	137.79	137.83
31	137.80	137.84	137.89	137.93	137.98	138.03	138.07	138.12
32	138.07	138.12	138.16	138.21	138.26	138.30	138.35	138.39
33	138.34	138.39	138.43	138.48	138.52	138.57	138.62	138.66
34	138.60	138.64	138.69	138.74	138.78	138.83	138.87	138.92
35	138.85	138.90	138.94	138.99	139.03	139.08	139.13	139.17
36	139.09	139.14	139.19	139.23	139.28	139.33	139.37	139.42
37	139.33	139.38	139.43	139.47	139.52	139.56	139.61	139.65
38	139.56	139.61	139.66	139.70	139.75	139.79	139.84	139.89
39	139.79	139.84	139.88	139.93	139.97	140.02	140.07	140.11
40	140.01	140.06	140.10	140.15	140.19	140.24	140.29	140.33
41	140.22	140.27	140.32	140.36	140.41	140.45	140.50	140.55
42	140.43	140.48	140.53	140.57	140.62	140.66	140.71	140.75
43	140.64	140.68	140.73	140.78	140.82	140.87	140.91	140.96
44	140.84	140.88	140.93	140.98	141.02	141.07	141.11	141.16
45	141.03	141.08	141.13	141.17	141.22	141.26	141.31	141.35
46	141.22	141.27	141.32	141.36	141.41	141.45	141.50	141.55
47	141.41	141.46	141.50	141.55	141.60	141.64	141.69	141.73
48	141.59	141.64	141.69	141.73	141.78	141.82	141.87	141.91
49	141.77	141.82	141.87	141.91	141.96	142.00	142.05	142.09
50	141.95	141.99	142.04	142.09	142.13	142.18	142.22	142.27

TABLE D

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHZ)							
	3870	3890	3910	3930	3950	3970	3990	4010
1	108.34	108.38	108.42	108.47	108.51	108.56	108.60	108.64
2	114.36	114.40	114.44	114.49	114.53	114.58	114.62	114.66
3	117.88	117.92	117.97	118.01	118.06	118.10	118.14	118.19
4	120.38	120.42	120.47	120.51	120.55	120.60	120.64	120.68
5	122.31	122.36	122.40	122.45	122.49	122.54	122.58	122.62
6	123.90	123.94	123.99	124.03	124.08	124.12	124.16	124.21
7	125.24	125.28	125.33	125.37	125.41	125.46	125.50	125.55
8	126.40	126.44	126.49	126.53	126.57	126.62	126.66	126.71
9	127.42	127.46	127.51	127.55	127.60	127.64	127.69	127.73
10	128.34	128.38	128.42	128.47	128.51	128.56	128.60	128.64
11	129.16	129.21	129.25	129.30	129.34	129.38	129.43	129.47
12	129.92	129.96	130.01	130.05	130.10	130.14	130.18	130.23
13	130.61	130.66	130.70	130.75	130.79	130.84	130.88	130.92
14	131.26	131.30	131.35	131.39	131.44	131.48	131.52	131.57
15	131.86	131.90	131.95	131.99	132.03	132.08	132.12	132.17
16	132.42	132.46	132.51	132.55	132.60	132.64	132.68	132.73
17	132.94	132.99	133.03	133.08	133.12	133.17	133.21	133.25
18	133.44	133.49	133.53	133.57	133.62	133.66	133.71	133.75
19	133.91	133.95	134.00	134.04	134.09	134.13	134.18	134.22
20	134.36	134.40	134.44	134.49	134.53	134.58	134.62	134.66
21	134.78	134.82	134.87	134.91	134.96	135.00	135.04	135.09
22	135.18	135.23	135.27	135.32	135.36	135.41	135.45	135.49
23	135.57	135.61	135.66	135.70	135.75	135.79	135.83	135.88
24	135.94	135.98	136.03	136.07	136.12	136.16	136.20	136.25
25	136.29	136.34	136.38	136.43	136.47	136.52	136.56	136.60
26	136.63	136.68	136.72	136.77	136.81	136.86	136.90	136.94
27	136.96	137.01	137.05	137.10	137.14	137.18	137.23	137.27
28	137.28	137.32	137.37	137.41	137.46	137.50	137.54	137.59
29	137.58	137.63	137.67	137.72	137.76	137.80	137.85	137.89
30	137.88	137.92	137.97	138.01	138.06	138.10	138.14	138.19
31	138.16	138.21	138.25	138.30	138.34	138.38	138.43	138.47
32	138.44	138.48	138.53	138.57	138.62	138.66	138.70	138.75
33	138.71	138.75	138.79	138.84	138.88	138.93	138.97	139.01
34	138.96	139.01	139.05	139.10	139.14	139.19	139.23	139.27
35	139.22	139.26	139.31	139.35	139.39	139.44	139.48	139.53
36	139.46	139.51	139.55	139.59	139.64	139.68	139.73	139.77
37	139.70	139.74	139.79	139.83	139.88	139.92	139.96	140.01
38	139.93	139.98	140.02	140.06	140.11	140.15	140.20	140.24
39	140.16	140.20	140.25	140.29	140.33	140.38	140.42	140.46
40	140.38	140.42	140.47	140.51	140.55	140.60	140.64	140.68
41	140.59	140.64	140.68	140.72	140.77	140.81	140.86	140.90
42	140.80	140.84	140.89	140.93	140.98	141.02	141.07	141.11
43	141.00	141.05	141.09	141.14	141.18	141.23	141.27	141.31
44	141.20	141.25	141.29	141.34	141.38	141.43	141.47	141.51
45	141.40	141.44	141.49	141.53	141.58	141.62	141.66	141.71
46	141.59	141.63	141.68	141.72	141.77	141.81	141.86	141.90
47	141.73	141.82	141.87	141.91	141.95	142.00	142.04	142.09
48	141.96	142.00	142.05	142.09	142.14	142.18	142.23	142.27
49	142.14	142.18	142.23	142.27	142.32	142.36	142.40	142.45
50	142.31	142.36	142.40	142.45	142.49	142.54	142.58	142.62

TABLE E

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHZ)							
	4030	4050	4070	4090	4110	4130	4150	4170
1	108.69	108.73	108.77	108.82	108.86	108.90	108.94	108.98
2	114.71	114.75	114.79	114.84	114.88	114.92	114.96	115.00
3	118.23	118.27	118.32	118.36	118.40	118.44	118.48	118.53
4	120.73	120.77	120.81	120.86	120.90	120.94	120.98	121.02
5	122.67	122.71	122.75	122.79	122.84	122.88	122.92	122.96
6	124.25	124.29	124.34	124.38	124.42	124.46	124.50	124.55
7	125.59	125.63	125.67	125.72	125.76	125.80	125.84	125.89
8	126.75	126.79	126.83	126.88	126.92	126.96	127.00	127.05
9	127.77	127.81	127.86	127.90	127.94	127.98	128.03	128.07
10	128.69	128.73	128.77	128.82	128.86	128.90	128.94	128.98
11	129.51	129.56	129.60	129.64	129.69	129.73	129.77	129.81
12	130.27	130.31	130.36	130.40	130.44	130.48	130.53	130.57
13	130.97	131.01	131.05	131.09	131.14	131.18	131.22	131.26
14	131.61	131.65	131.70	131.74	131.78	131.82	131.86	131.91
15	132.21	132.25	132.29	132.34	132.38	132.42	132.46	132.51
16	132.77	132.81	132.86	132.90	132.94	132.98	133.02	133.07
17	133.30	133.34	133.38	133.42	133.47	133.51	133.55	133.59
18	133.79	133.84	133.88	133.92	133.96	134.01	134.05	134.09
19	134.26	134.30	134.35	134.39	134.43	134.47	134.52	134.56
20	134.71	134.75	134.79	134.84	134.88	134.92	134.96	135.00
21	135.13	135.17	135.22	135.26	135.30	135.34	135.39	135.43
22	135.54	135.58	135.62	135.66	135.71	135.75	135.79	135.83
23	135.92	135.96	136.01	136.05	136.09	136.13	136.18	136.22
24	136.29	136.33	136.38	136.42	136.46	136.50	136.55	136.59
25	136.65	136.69	136.73	136.77	136.82	136.86	136.90	136.94
26	136.99	137.03	137.07	137.11	137.16	137.20	137.24	137.28
27	137.31	137.36	137.40	137.44	137.48	137.53	137.57	137.61
28	137.63	137.67	137.72	137.76	137.80	137.84	137.88	137.93
29	137.93	137.98	138.02	138.06	138.11	138.15	138.19	138.23
30	138.23	138.27	138.32	138.36	138.40	138.44	138.48	138.53
31	138.51	138.56	138.60	138.64	138.68	138.73	138.77	138.81
32	138.79	138.83	138.88	138.92	138.96	139.00	139.04	139.09
33	139.06	139.10	139.14	139.19	139.23	139.27	139.31	139.35
34	139.32	139.36	139.40	139.44	139.49	139.53	139.57	139.61
35	139.57	139.61	139.65	139.70	139.74	139.78	139.82	139.86
36	139.81	139.86	139.90	139.94	139.98	140.03	140.07	140.11
37	140.05	140.09	140.14	140.18	140.22	140.26	140.31	140.35
38	140.28	140.33	140.37	140.41	140.45	140.50	140.54	140.58
39	140.51	140.55	140.59	140.64	140.68	140.72	140.76	140.80
40	140.73	140.77	140.81	140.86	140.90	140.94	140.98	141.02
41	140.94	140.99	141.03	141.07	141.11	141.16	141.20	141.24
42	141.15	141.19	141.24	141.28	141.32	141.36	141.41	141.45
43	141.36	141.40	141.44	141.48	141.53	141.57	141.61	141.65
44	141.56	141.60	141.64	141.68	141.73	141.77	141.81	141.85
45	141.75	141.79	141.84	141.88	141.92	141.96	142.01	142.05
46	141.94	141.99	142.03	142.07	142.11	142.15	142.20	142.24
47	142.13	142.17	142.21	142.26	142.30	142.34	142.38	142.43
48	142.31	142.35	142.40	142.44	142.48	142.52	142.57	142.61
49	142.49	142.53	142.58	142.62	142.66	142.70	142.75	142.79
50	142.67	142.71	142.75	142.79	142.84	142.88	142.92	142.96

TABLE F

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHZ)							
	5945.2	5960.0	5974.8	5989.7	6004.5	6019.3	6034.2	6049.0
1	112.06	112.09	112.11	112.13	112.15	112.17	112.19	112.21
2	118.08	118.11	118.13	118.15	118.17	118.19	118.21	118.24
3	121.61	121.63	121.65	121.67	121.69	121.71	121.74	121.76
4	124.11	124.13	124.15	124.17	124.19	124.21	124.23	124.26
5	126.04	126.07	126.09	126.11	126.13	126.15	126.17	126.19
6	127.63	127.65	127.67	127.69	127.71	127.73	127.76	127.78
7	128.97	128.99	129.01	129.03	129.05	129.07	129.10	129.12
8	130.13	130.15	130.17	130.19	130.21	130.23	130.25	130.28
9	131.15	131.17	131.19	131.21	131.24	131.26	131.28	131.30
10	132.06	132.09	132.11	132.13	132.15	132.17	132.19	132.21
11	132.89	132.91	132.94	132.96	132.98	133.00	133.02	133.04
12	133.65	133.67	133.69	133.71	133.73	133.76	133.78	133.80
13	134.34	134.36	134.39	134.41	134.43	134.45	134.47	134.49
14	134.99	135.01	135.03	135.05	135.07	135.09	135.12	135.14
15	135.59	135.61	135.63	135.65	135.67	135.69	135.71	135.74
16	136.15	136.17	136.19	136.21	136.23	136.25	136.28	136.30
17	136.67	136.69	136.72	136.74	136.76	136.78	136.80	136.82
18	137.17	137.19	137.21	137.23	137.26	137.28	137.30	137.32
19	137.64	137.66	137.68	137.70	137.73	137.75	137.77	137.79
20	138.08	138.11	138.13	138.15	138.17	138.19	138.21	138.24
21	138.51	138.53	138.55	138.57	138.59	138.62	138.64	138.66
22	138.91	138.93	138.96	138.98	139.00	139.02	139.04	139.06
23	139.30	139.32	139.34	139.36	139.38	139.41	139.43	139.45
24	139.67	139.69	139.71	139.73	139.75	139.78	139.80	139.82
25	140.02	140.04	140.07	140.09	140.11	140.13	140.15	140.17
26	140.36	140.39	140.41	140.43	140.45	140.47	140.49	140.51
27	140.69	140.71	140.73	140.76	140.78	140.80	140.82	140.84
28	141.01	141.03	141.05	141.07	141.09	141.11	141.14	141.16
29	141.31	141.33	141.36	141.38	141.40	141.42	141.44	141.46
30	141.61	141.63	141.65	141.67	141.69	141.71	141.74	141.76
31	141.89	141.91	141.93	141.96	141.98	142.00	142.02	142.04
32	142.17	142.19	142.21	142.23	142.25	142.27	142.30	142.32
33	142.43	142.46	142.48	142.50	142.52	142.54	142.56	142.58
34	142.69	142.72	142.74	142.76	142.78	142.80	142.82	142.84
35	142.95	142.97	142.99	143.01	143.03	143.05	143.07	143.10
36	143.19	143.21	143.23	143.25	143.28	143.30	143.32	143.34
37	143.43	143.45	143.47	143.49	143.51	143.54	143.56	143.58
38	143.66	143.68	143.70	143.72	143.75	143.77	143.79	143.81
39	143.89	143.91	143.93	143.95	143.97	143.99	144.01	144.04
40	144.11	144.13	144.15	144.17	144.19	144.21	144.23	144.26
41	144.32	144.34	144.36	144.38	144.41	144.43	144.45	144.47
42	144.53	144.55	144.57	144.59	144.62	144.64	144.66	144.68
43	144.73	144.76	144.78	144.80	144.82	144.84	144.86	144.88
44	144.93	144.95	144.98	145.00	145.02	145.04	145.06	145.08
45	145.13	145.15	145.17	145.19	145.21	145.24	145.26	145.28
46	145.32	145.34	145.36	145.38	145.41	145.43	145.45	145.47
47	145.51	145.53	145.55	145.57	145.59	145.61	145.64	145.66
48	145.69	145.71	145.73	145.75	145.78	145.80	145.82	145.84
49	145.87	145.89	145.91	145.93	145.95	145.98	146.00	146.02
50	146.04	146.07	146.09	146.11	146.13	146.15	146.17	146.19

TABLE G

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHZ)							
	6063.8	6078.6	6093.5	6108.3	6123.1	6137.9	6152.8	6167.6
1	112.24	112.26	112.28	112.30	112.32	112.34	112.36	112.38
2	118.26	118.28	118.30	118.32	118.34	118.36	118.38	118.40
3	121.78	121.80	121.82	121.84	121.86	121.88	121.90	121.93
4	124.28	124.30	124.32	124.34	124.36	124.38	124.40	124.42
5	126.22	126.24	126.26	126.28	126.30	126.32	126.34	126.36
6	127.80	127.82	127.84	127.86	127.88	127.90	127.93	127.95
7	129.14	129.16	129.18	129.20	129.22	129.24	129.26	129.29
8	130.30	130.32	130.34	130.36	130.38	130.40	130.42	130.44
9	131.32	131.34	131.36	131.38	131.41	131.43	131.45	131.47
10	132.24	132.26	132.28	132.30	132.32	132.34	132.36	132.38
11	133.06	133.08	133.11	133.13	133.15	133.17	133.19	133.21
12	133.82	133.84	133.86	133.88	133.90	133.92	133.95	133.97
13	134.51	134.54	134.56	134.58	134.60	134.62	134.64	134.66
14	135.16	135.18	135.20	135.22	135.24	135.26	135.28	135.31
15	135.76	135.78	135.80	135.82	135.84	135.86	135.88	135.90
16	136.32	136.34	136.36	136.38	136.40	136.42	136.44	136.47
17	136.84	136.87	136.89	136.91	136.93	136.95	136.97	136.99
18	137.34	137.36	137.38	137.40	137.43	137.45	137.47	137.49
19	137.81	137.83	137.85	137.87	137.90	137.92	137.94	137.96
20	138.26	138.28	138.30	138.32	138.34	138.36	138.38	138.40
21	138.68	138.70	138.72	138.74	138.76	138.79	138.81	138.83
22	139.08	139.11	139.13	139.15	139.17	139.19	139.21	139.23
23	139.47	139.49	139.51	139.53	139.55	139.58	139.60	139.62
24	139.84	139.86	139.88	139.90	139.92	139.95	139.97	139.99
25	140.19	140.22	140.24	140.26	140.28	140.30	140.32	140.34
26	140.54	140.56	140.58	140.60	140.62	140.64	140.66	140.68
27	140.86	140.88	140.91	140.93	140.95	140.97	140.99	141.01
28	141.18	141.20	141.22	141.24	141.26	141.28	141.31	141.33
29	141.48	141.50	141.53	141.55	141.57	141.59	141.61	141.63
30	141.78	141.80	141.82	141.84	141.86	141.88	141.90	141.93
31	142.06	142.08	142.11	142.13	142.15	142.17	142.19	142.21
32	142.34	142.36	142.38	142.40	142.42	142.44	142.47	142.49
33	142.61	142.63	142.65	142.67	142.69	142.71	142.73	142.75
34	142.87	142.89	142.91	142.93	142.95	142.97	142.99	143.01
35	143.12	143.14	143.16	143.18	143.20	143.22	143.24	143.26
36	143.36	143.38	143.40	143.43	143.45	143.47	143.49	143.51
37	143.60	143.62	143.64	143.66	143.68	143.71	143.73	143.75
38	143.83	143.85	143.87	143.89	143.92	143.94	143.96	143.98
39	144.06	144.08	144.10	144.12	144.14	144.16	144.18	144.20
40	144.28	144.30	144.32	144.34	144.36	144.38	144.40	144.42
41	144.49	144.51	144.53	144.55	144.58	144.60	144.62	144.64
42	144.70	144.72	144.74	144.76	144.79	144.81	144.83	144.85
43	144.91	144.93	144.95	144.97	144.99	145.01	145.03	145.05
44	145.10	145.13	145.15	145.17	145.19	145.21	145.23	145.25
45	145.30	145.32	145.34	145.36	145.38	145.41	145.43	145.45
46	145.49	145.51	145.53	145.55	145.58	145.60	145.62	145.64
47	145.68	145.70	145.72	145.74	145.76	145.78	145.80	145.83
48	145.86	145.88	145.90	145.92	145.95	145.97	145.99	146.01
49	146.04	146.06	146.08	146.10	146.12	146.15	146.17	146.19
50	146.22	146.24	146.26	146.28	146.30	146.32	146.34	146.36

TABLE H

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHZ)							
	6197.2	6212.0	6226.9	6241.7	6256.5	6271.4	6286.2	6301.0
1	112.42	112.45	112.47	112.49	112.51	112.53	112.55	112.57
2	118.45	118.47	118.49	118.51	118.53	118.55	118.57	118.59
3	121.97	121.99	122.01	122.03	122.05	122.07	122.09	122.11
4	124.47	124.49	124.51	124.53	124.55	124.57	124.59	124.61
5	126.40	126.42	126.45	126.47	126.49	126.51	126.53	126.55
6	127.99	128.01	128.03	128.05	128.07	128.09	128.11	128.13
7	129.33	129.35	129.37	129.39	129.41	129.43	129.45	129.47
8	130.49	130.51	130.53	130.55	130.57	130.59	130.61	130.63
9	131.51	131.53	131.55	131.57	131.59	131.61	131.63	131.65
10	132.42	132.45	132.47	132.49	132.51	132.53	132.55	132.57
11	133.25	133.27	133.29	133.31	133.34	133.36	133.38	133.40
12	134.01	134.03	134.05	134.07	134.09	134.11	134.13	134.15
13	134.70	134.72	134.75	134.77	134.79	134.81	134.83	134.85
14	135.35	135.37	135.39	135.41	135.43	135.45	135.47	135.49
15	135.95	135.97	135.99	136.01	136.03	136.05	136.07	136.09
16	136.51	136.53	136.55	136.57	136.59	136.61	136.63	136.65
17	137.03	137.05	137.06	137.10	137.12	137.14	137.16	137.18
18	137.53	137.55	137.57	137.59	137.61	137.63	137.65	137.67
19	138.00	138.02	138.04	138.06	138.08	138.10	138.12	138.14
20	138.45	138.47	138.49	138.51	138.53	138.55	138.57	138.59
21	138.87	138.89	138.91	138.93	138.95	138.97	138.99	139.01
22	139.27	139.29	139.31	139.34	139.36	139.38	139.40	139.42
23	139.66	139.68	139.70	139.72	139.74	139.76	139.78	139.80
24	140.03	140.05	140.07	140.09	140.11	140.13	140.15	140.17
25	140.38	140.40	140.43	140.45	140.47	140.49	140.51	140.53
26	140.72	140.74	140.77	140.79	140.81	140.83	140.85	140.87
27	141.05	141.07	141.09	141.11	141.13	141.16	141.18	141.20
28	141.37	141.39	141.41	141.43	141.45	141.47	141.49	141.51
29	141.67	141.69	141.71	141.73	141.76	141.78	141.80	141.82
30	141.97	141.99	142.01	142.03	142.05	142.07	142.09	142.11
31	142.25	142.27	142.29	142.31	142.33	142.36	142.38	142.40
32	142.53	142.55	142.57	142.59	142.61	142.63	142.65	142.67
33	142.80	142.82	142.84	142.86	142.88	142.90	142.92	142.94
34	143.05	143.08	143.10	143.12	143.14	143.16	143.18	143.20
35	143.31	143.33	143.35	143.37	143.39	143.41	143.43	143.45
36	143.55	143.57	143.59	143.61	143.63	143.65	143.67	143.70
37	143.79	143.81	143.83	143.85	143.87	143.89	143.91	143.93
38	144.02	144.04	144.06	144.08	144.10	144.12	144.14	144.16
39	144.25	144.27	144.29	144.31	144.33	144.35	144.37	144.39
40	144.47	144.49	144.51	144.53	144.55	144.57	144.59	144.61
41	144.63	144.70	144.72	144.74	144.76	144.78	144.80	144.82
42	144.89	144.91	144.93	144.95	144.97	144.99	145.01	145.03
43	145.09	145.11	145.14	145.16	145.18	145.20	145.22	145.24
44	145.29	145.31	145.34	145.36	145.38	145.40	145.42	145.44
45	145.49	145.51	145.53	145.55	145.57	145.59	145.61	145.63
46	145.68	145.70	145.72	145.74	145.76	145.78	145.80	145.82
47	145.87	145.89	145.91	145.93	145.95	145.97	145.99	146.01
48	146.05	146.07	146.09	146.11	146.13	146.15	146.17	146.19
49	146.23	146.25	146.27	146.29	146.31	146.33	146.35	146.37
50	146.40	146.42	146.45	146.47	146.49	146.51	146.53	146.55

TABLE I

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB)							
	FREQUENCY (MHZ)							
	6315.9	6330.7	6345.5	6360.3	6375.2	6390.0	6404.8	6419.6
1	112.59	112.61	112.63	112.65	112.67	112.69	112.71	112.73
2	118.61	118.63	118.65	118.67	118.69	118.71	118.73	118.75
3	122.13	122.15	122.17	122.19	122.21	122.23	122.25	122.27
4	124.63	124.65	124.67	124.69	124.71	124.73	124.75	124.77
5	126.57	126.59	126.61	126.63	126.65	126.67	126.69	126.71
6	128.15	128.17	128.19	128.21	128.23	128.25	128.27	128.29
7	129.49	129.51	129.53	129.55	129.57	129.59	129.61	129.63
8	130.65	130.67	130.69	130.71	130.73	130.75	130.77	130.79
9	131.67	131.69	131.71	131.74	131.76	131.78	131.80	131.82
10	132.59	132.61	132.63	132.65	132.67	132.69	132.71	132.73
11	133.42	133.44	133.46	133.48	133.50	133.52	133.54	133.56
12	134.17	134.19	134.21	134.23	134.25	134.27	134.29	134.31
13	134.87	134.89	134.91	134.93	134.95	134.97	134.99	135.01
14	135.51	135.53	135.55	135.57	135.59	135.61	135.63	135.65
15	136.11	136.13	136.15	136.17	136.19	136.21	136.23	136.25
16	136.67	136.69	136.71	136.73	136.75	136.77	136.79	136.81
17	137.20	137.22	137.24	137.26	137.28	137.30	137.32	137.34
18	137.69	137.72	137.74	137.76	137.78	137.80	137.82	137.84
19	138.16	138.18	138.21	138.23	138.25	138.27	138.29	138.31
20	138.61	138.63	138.65	138.67	138.69	138.71	138.73	138.75
21	139.03	139.05	139.07	139.09	139.11	139.14	139.16	139.18
22	139.44	139.46	139.48	139.50	139.52	139.54	139.56	139.58
23	139.82	139.84	139.86	139.88	139.91	139.93	139.95	139.97
24	140.19	140.21	140.23	140.25	140.27	140.29	140.32	140.34
25	140.55	140.57	140.59	140.61	140.63	140.65	140.67	140.69
26	140.89	140.91	140.93	140.95	140.97	140.99	141.01	141.03
27	141.22	141.24	141.26	141.28	141.30	141.32	141.34	141.36
28	141.53	141.55	141.57	141.59	141.61	141.63	141.65	141.67
29	141.84	141.86	141.88	141.90	141.92	141.94	141.96	141.98
30	142.13	142.15	142.17	142.19	142.21	142.23	142.25	142.27
31	142.42	142.44	142.46	142.48	142.50	142.52	142.54	142.56
32	142.69	142.71	142.73	142.75	142.77	142.79	142.81	142.83
33	142.96	142.98	143.00	143.02	143.04	143.06	143.08	143.10
34	143.22	143.24	143.26	143.28	143.30	143.32	143.34	143.36
35	143.47	143.49	143.51	143.53	143.55	143.57	143.59	143.61
36	143.72	143.74	143.76	143.78	143.80	143.82	143.84	143.86
37	143.95	143.97	143.99	144.01	144.03	144.05	144.07	144.10
38	144.19	144.21	144.23	144.25	144.27	144.29	144.31	144.33
39	144.41	144.43	144.45	144.47	144.49	144.51	144.53	144.55
40	144.63	144.65	144.67	144.69	144.71	144.73	144.75	144.77
41	144.85	144.87	144.89	144.91	144.93	144.95	144.97	144.99
42	145.05	145.07	145.10	145.12	145.14	145.16	145.18	145.20
43	145.26	145.28	145.30	145.32	145.34	145.36	145.38	145.40
44	145.46	145.48	145.50	145.52	145.54	145.56	145.58	145.60
45	145.65	145.67	145.69	145.71	145.73	145.76	145.78	145.80
46	145.84	145.86	145.89	145.91	145.93	145.95	145.97	145.99
47	146.03	146.05	146.07	146.09	146.11	146.13	146.15	146.17
48	146.21	146.23	146.25	146.28	146.30	146.32	146.34	146.36
49	146.39	146.41	146.43	146.45	146.47	146.49	146.51	146.53
50	146.57	146.59	146.61	146.63	146.65	146.67	146.69	146.71

TABLE J

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHZ)							
	10715	10755	10795	10835	10875	10915	10955	10995
1	117.18	117.21	117.25	117.28	117.31	117.34	117.37	117.40
2	123.20	123.23	123.27	123.30	123.33	123.36	123.39	123.43
3	126.72	126.76	126.79	126.82	126.85	126.88	126.92	126.95
4	129.22	129.25	129.29	129.32	129.35	129.38	129.41	129.45
5	131.16	131.19	131.22	131.26	131.29	131.32	131.35	131.38
6	132.74	132.78	132.81	132.84	132.87	132.90	132.94	132.97
7	134.08	134.11	134.15	134.18	134.21	134.24	134.27	134.31
8	135.24	135.27	135.31	135.34	135.37	135.40	135.43	135.47
9	136.27	136.30	136.33	136.36	136.39	136.43	136.46	136.49
10	137.13	137.21	137.25	137.28	137.31	137.34	137.37	137.40
11	138.01	138.04	138.07	138.11	138.14	138.17	138.20	138.23
12	138.76	138.80	138.83	138.86	138.89	138.92	138.96	138.99
13	139.46	139.49	139.52	139.56	139.59	139.62	139.65	139.68
14	140.10	140.14	140.17	140.20	140.23	140.26	140.30	140.33
15	140.70	140.73	140.77	140.80	140.83	140.86	140.89	140.93
16	141.26	141.30	141.33	141.36	141.39	141.42	141.46	141.49
17	141.79	141.82	141.85	141.89	141.92	141.95	141.98	142.01
18	142.29	142.32	142.35	142.38	142.41	142.45	142.48	142.51
19	142.76	142.79	142.82	142.85	142.88	142.92	142.95	142.98
20	143.20	143.23	143.27	143.30	143.33	143.36	143.39	143.43
21	143.63	143.66	143.69	143.72	143.75	143.79	143.82	143.85
22	144.03	144.06	144.09	144.13	144.16	144.19	144.22	144.25
23	144.42	144.45	144.48	144.51	144.54	144.58	144.61	144.64
24	144.78	144.82	144.85	144.88	144.91	144.95	144.98	145.01
25	145.14	145.17	145.20	145.24	145.27	145.30	145.33	145.36
26	145.48	145.51	145.54	145.58	145.61	145.64	145.67	145.70
27	145.81	145.84	145.87	145.90	145.94	145.97	146.00	146.03
28	146.12	146.16	146.19	146.22	146.25	146.28	146.32	146.35
29	146.43	146.46	146.49	146.53	146.56	146.59	146.62	146.65
30	146.72	146.76	146.79	146.82	146.85	146.88	146.92	146.95
31	147.01	147.04	147.07	147.10	147.14	147.17	147.20	147.23
32	147.28	147.32	147.35	147.38	147.41	147.44	147.48	147.51
33	147.55	147.58	147.62	147.65	147.68	147.71	147.74	147.77
34	147.81	147.84	147.87	147.91	147.94	147.97	148.00	148.03
35	148.06	148.09	148.13	148.16	148.19	148.22	148.25	148.29
36	148.31	148.34	148.37	148.40	148.44	148.47	148.50	148.53
37	148.54	148.58	148.61	148.64	148.67	148.71	148.74	148.77
38	148.78	148.81	148.84	148.87	148.91	148.94	148.97	149.00
39	149.00	149.03	149.07	149.10	149.13	149.16	149.19	149.23
40	149.22	149.25	149.29	149.32	149.35	149.38	149.41	149.45
41	149.44	149.47	149.50	149.53	149.57	149.60	149.63	149.66
42	149.65	149.68	149.71	149.74	149.77	149.81	149.84	149.87
43	149.85	149.88	149.91	149.95	149.98	150.01	150.04	150.07
44	150.05	150.08	150.11	150.15	150.18	150.21	150.24	150.27
45	150.24	150.28	150.31	150.34	150.37	150.41	150.44	150.47
46	150.44	150.47	150.50	150.53	150.56	150.60	150.63	150.66
47	150.62	150.65	150.69	150.72	150.75	150.78	150.81	150.85
48	150.81	150.84	150.87	150.90	150.93	150.97	151.00	151.03
49	150.98	151.02	151.05	151.08	151.11	151.15	151.18	151.21
50	151.16	151.19	151.22	151.26	151.29	151.32	151.35	151.38

TABLE K

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHZ)							
	11035	11075	11115	11155	11245	11285	11325	11365
1	117.44	117.47	117.50	117.53	117.60	117.63	117.66	117.69
2	123.46	123.49	123.52	123.55	123.62	123.65	123.68	123.71
3	126.98	127.01	127.04	127.07	127.14	127.17	127.20	127.23
4	129.48	129.51	129.54	129.57	129.64	129.67	129.70	129.73
5	131.42	131.45	131.48	131.51	131.58	131.61	131.64	131.67
6	133.00	133.03	133.06	133.09	133.16	133.19	133.22	133.26
7	134.34	134.37	134.40	134.43	134.50	134.53	134.56	134.59
8	135.50	135.53	135.56	135.59	135.66	135.69	135.72	135.75
9	136.52	136.55	136.58	136.62	136.68	136.72	136.75	136.78
10	137.44	137.47	137.50	137.53	137.60	137.63	137.66	137.69
11	138.26	138.30	138.33	138.36	138.43	138.46	138.49	138.52
12	139.02	139.05	139.08	139.11	139.18	139.21	139.25	139.28
13	139.72	139.75	139.78	139.81	139.88	139.91	139.94	139.97
14	140.36	140.39	140.42	140.45	140.52	140.55	140.58	140.61
15	140.96	140.99	141.02	141.05	141.12	141.15	141.18	141.21
16	141.52	141.55	141.58	141.61	141.68	141.71	141.74	141.77
17	142.05	142.08	142.11	142.14	142.21	142.24	142.27	142.30
18	142.54	142.57	142.60	142.64	142.71	142.74	142.77	142.80
19	143.01	143.04	143.07	143.11	143.18	143.21	143.24	143.27
20	143.46	143.49	143.52	143.55	143.62	143.65	143.68	143.71
21	143.88	143.91	143.94	143.97	144.04	144.08	144.11	144.14
22	144.28	144.32	144.35	144.38	144.45	144.48	144.51	144.54
23	144.67	144.70	144.73	144.76	144.83	144.87	144.90	144.93
24	145.04	145.07	145.10	145.13	145.20	145.24	145.27	145.30
25	145.40	145.43	145.46	145.49	145.56	145.59	145.62	145.65
26	145.74	145.77	145.80	145.83	145.90	145.93	145.96	145.99
27	146.06	146.09	146.13	146.16	146.23	146.26	146.29	146.32
28	146.38	146.41	146.44	146.47	146.54	146.57	146.60	146.64
29	146.68	146.72	146.75	146.78	146.85	146.88	146.91	146.94
30	146.98	147.01	147.04	147.07	147.14	147.17	147.20	147.23
31	147.26	147.29	147.33	147.36	147.43	147.46	147.49	147.52
32	147.54	147.57	147.60	147.63	147.70	147.73	147.76	147.80
33	147.81	147.84	147.87	147.90	147.97	148.00	148.03	148.06
34	148.07	148.10	148.13	148.16	148.23	148.26	148.29	148.32
35	148.32	148.35	148.38	148.41	148.48	148.51	148.54	148.57
36	148.56	148.59	148.63	148.66	148.73	148.76	148.79	148.82
37	148.80	148.83	148.86	148.89	148.96	148.99	149.03	149.06
38	149.03	149.06	149.09	149.13	149.20	149.23	149.26	149.29
39	149.26	149.29	149.32	149.35	149.42	149.45	149.48	149.51
40	149.48	149.51	149.54	149.57	149.64	149.67	149.70	149.73
41	149.69	149.72	149.75	149.79	149.86	149.89	149.92	149.95
42	149.90	149.93	149.96	150.00	150.06	150.10	150.13	150.16
43	150.11	150.14	150.17	150.20	150.27	150.30	150.33	150.36
44	150.31	150.34	150.37	150.40	150.47	150.50	150.53	150.56
45	150.50	150.53	150.56	150.59	150.66	150.70	150.73	150.76
46	150.69	150.72	150.75	150.79	150.86	150.89	150.92	150.95
47	150.88	150.91	150.94	150.97	151.04	151.07	151.10	151.13
48	151.06	151.09	151.12	151.16	151.22	151.26	151.29	151.32
49	151.24	151.27	151.30	151.33	151.40	151.43	151.47	151.50
50	151.42	151.45	151.48	151.51	151.58	151.61	151.64	151.67

TABLE L

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHZ)							
	11405	11445	11485	11525	11565	11605	11645	11685
1	117.72	117.75	117.78	117.81	117.84	117.87	117.90	117.93
2	123.74	123.77	123.80	123.83	123.86	123.89	123.92	123.95
3	127.27	127.30	127.33	127.36	127.39	127.42	127.45	127.48
4	129.76	129.79	129.82	129.85	129.88	129.91	129.94	129.97
5	131.70	131.73	131.76	131.79	131.82	131.85	131.88	131.91
6	133.29	133.32	133.35	133.38	133.41	133.44	133.47	133.50
7	134.62	134.66	134.69	134.72	134.75	134.78	134.81	134.84
8	135.78	135.81	135.85	135.88	135.91	135.94	135.97	136.00
9	136.81	136.84	136.87	136.90	136.93	136.96	136.99	137.02
10	137.72	137.75	137.78	137.81	137.84	137.87	137.90	137.93
11	138.55	138.58	138.61	138.64	138.67	138.70	138.73	138.76
12	139.31	139.34	139.37	139.40	139.43	139.46	139.49	139.52
13	140.00	140.03	140.06	140.09	140.12	140.15	140.18	140.21
14	140.65	140.68	140.71	140.74	140.77	140.80	140.83	140.86
15	141.24	141.27	141.31	141.34	141.37	141.40	141.43	141.46
16	141.81	141.84	141.87	141.90	141.93	141.96	141.99	142.02
17	142.33	142.36	142.39	142.42	142.45	142.48	142.51	142.54
18	142.83	142.86	142.89	142.92	142.95	142.98	143.01	143.04
19	143.30	143.33	143.36	143.39	143.42	143.45	143.48	143.51
20	143.74	143.77	143.80	143.83	143.86	143.89	143.92	143.95
21	144.17	144.20	144.23	144.26	144.29	144.32	144.35	144.38
22	144.57	144.60	144.63	144.66	144.69	144.72	144.75	144.78
23	144.96	144.99	145.02	145.05	145.08	145.11	145.14	145.17
24	145.33	145.36	145.39	145.42	145.45	145.48	145.51	145.54
25	145.68	145.71	145.74	145.77	145.80	145.83	145.86	145.89
26	146.02	146.05	146.08	146.11	146.14	146.17	146.20	146.23
27	146.35	146.38	146.41	146.44	146.47	146.50	146.53	146.56
28	146.67	146.70	146.73	146.76	146.79	146.82	146.85	146.88
29	146.97	147.00	147.03	147.06	147.09	147.12	147.15	147.18
30	147.27	147.30	147.33	147.36	147.39	147.42	147.45	147.48
31	147.55	147.58	147.61	147.64	147.67	147.70	147.73	147.76
32	147.83	147.86	147.89	147.92	147.95	147.98	148.01	148.04
33	148.09	148.12	148.15	148.18	148.21	148.24	148.27	148.30
34	148.35	148.38	148.41	148.44	148.47	148.50	148.53	148.56
35	148.60	148.63	148.66	148.69	148.73	148.76	148.78	148.81
36	148.85	148.88	148.91	148.94	148.97	149.00	149.03	149.06
37	149.09	149.12	149.15	149.18	149.21	149.24	149.27	149.30
38	149.32	149.35	149.38	149.41	149.44	149.47	149.50	149.53
39	149.54	149.57	149.60	149.63	149.66	149.69	149.72	149.75
40	149.76	149.79	149.82	149.85	149.88	149.91	149.94	149.97
41	149.98	150.01	150.04	150.07	150.10	150.13	150.16	150.19
42	150.19	150.22	150.25	150.28	150.31	150.34	150.37	150.40
43	150.39	150.42	150.45	150.48	150.51	150.54	150.57	150.60
44	150.59	150.62	150.65	150.68	150.71	150.74	150.77	150.80
45	150.79	150.82	150.85	150.88	150.91	150.94	150.97	151.00
46	150.98	151.01	151.04	151.07	151.10	151.13	151.16	151.19
47	151.16	151.20	151.23	151.26	151.29	151.32	151.35	151.38
48	151.35	151.38	151.41	151.44	151.47	151.50	151.53	151.56
49	151.53	151.56	151.59	151.62	151.65	151.68	151.71	151.74
50	151.70	151.73	151.76	151.79	151.82	151.85	151.88	151.91

◆TABLE M◆

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHz)								
	17810	18030	18250	18470	18700	18930	19150	19370	19590
0.5	115.59	115.70	115.80	115.91	116.02	116.12	116.22	116.32	116.42
1.0	121.61	121.72	121.83	121.93	122.04	122.14	122.24	122.34	122.44
1.5	125.14	125.24	125.35	125.45	125.56	125.66	125.77	125.86	125.96
2.0	127.63	127.74	127.85	127.95	128.06	128.16	128.26	128.36	128.46
2.5	129.57	129.68	129.78	129.89	130.00	130.10	130.20	130.30	130.40
3.0	131.16	131.26	131.37	131.47	131.58	131.69	131.79	131.88	131.98
3.5	132.49	132.60	132.71	132.81	132.92	133.02	133.12	133.22	133.32
4.0	133.65	133.76	133.87	133.97	134.08	134.18	134.28	134.38	134.48
4.5	134.68	134.78	134.89	134.99	135.10	135.21	135.31	135.41	135.50
5.0	135.59	135.70	135.80	135.91	136.02	136.12	136.22	136.32	136.42
5.5	136.42	136.53	136.63	136.74	136.84	136.95	137.05	137.15	137.25
6.0	137.18	137.28	137.39	137.49	137.60	137.71	137.81	137.91	138.00
6.5	137.87	137.98	138.08	138.19	138.30	138.40	138.50	138.60	138.70
7.0	138.52	138.62	138.73	138.83	138.94	139.04	139.15	139.24	139.34
7.5	139.11	139.22	139.33	139.43	139.54	139.64	139.74	139.84	139.94
8.0	139.68	139.78	139.89	139.99	140.10	140.20	140.31	140.40	140.50
8.5	140.20	140.31	140.41	140.52	140.63	140.73	140.83	140.93	141.03
9.0	140.70	140.80	140.91	141.01	141.12	141.23	141.33	141.43	141.53
9.5	141.17	141.27	141.38	141.48	141.59	141.70	141.80	141.90	142.00
10.0	141.61	141.72	141.83	141.93	142.04	142.14	142.24	142.34	142.44

Note: 18700 MHz is center frequency of 240-MHz band segment allocated to narrow-band use.

◆TABLE N◆

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHz)		
	27500	28500	29500
0.5	119.37	119.68	119.98
1.0	125.39	125.70	126.00
1.5	128.91	129.22	129.52
2.0	131.41	131.72	132.02
2.5	133.35	133.66	133.96
3.0	134.93	135.24	135.54
3.5	136.27	136.58	136.88
4.0	137.43	137.74	138.04
4.5	138.45	138.76	139.06
5.0	139.37	139.68	139.98
5.5	140.19	140.50	140.80
6.0	140.95	141.26	141.56
6.5	141.64	141.96	142.25
7.0	142.29	142.60	142.90
7.5	142.89	143.20	143.50
8.0	143.45	143.76	144.06
8.5	143.98	144.29	144.58
9.0	144.47	144.78	145.08
9.5	144.94	145.25	145.55
10.0	145.39	145.70	146.00

◆TABLE O◆

DISTANCE (MILES)	FREE-SPACE PATH LOSS (DB) FREQUENCY (MHz)		
	38600	39300	40000
0.5	122.31	122.47	122.62
1.0	128.33	128.49	128.64
1.5	131.85	132.01	132.16
2.0	134.35	134.51	134.66
2.5	136.29	136.45	136.60
3.0	137.87	138.03	138.18
3.5	139.21	139.37	139.52
4.0	140.37	140.53	140.68
4.5	141.40	141.55	141.71
5.0	142.31	142.47	142.62
5.5	143.14	143.30	143.45
6.0	143.89	144.05	144.20
6.5	144.59	144.75	144.90
7.0	145.23	145.39	145.54
7.5	145.83	145.99	146.14
8.0	146.39	146.55	146.70
8.5	146.92	147.08	147.23
9.0	147.42	147.57	147.73
9.5	147.89	148.04	148.20
10.0	148.33	148.49	148.64