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Over-Tree Propagation Measurements-Phase 2

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General Introduction

Abstract: Measurements were made of signal levels in the 2-m and 1.2-m bands in the 'shadow' region associated with "wooded/cleared" boundaries at two sites in summer (maximum foliation) and winter (minimum foliation). The observed **Path-loss** for both sites (called Sites #1 and #2 respectively) is given. In general, it is found that the path-loss at both sites mainly shows anomalous behaviour inasmuch as there is little or no decrease in path-loss as the distance from the boundary increases, and that there is no clear correlation between path-loss along the 'downstream' path with seasonal change in foliation. All observations were made with **vertical** polarization.

General Site-Characteristics

In general, an attempt had been made, for Phase 1 of this study (see the Report for 1990-1), to locate sites which would have a flat-topped wooded area, some several hundred wavelengths long along the propagation path, and then a flat, clear area, also some hundreds of wavelengths long. Due to time constraints, such 'ideal' sites were not found (and perhaps do not exist) in the immediate vicinity of Halifax. By default, the two sites finally selected appeared to be relatively satisfactory approximations to the 'ideal'. However, it turned out that the obstacle (Cowie Hill) associated with Site #2 was inadvertently overlooked at the time of deciding on the sites.

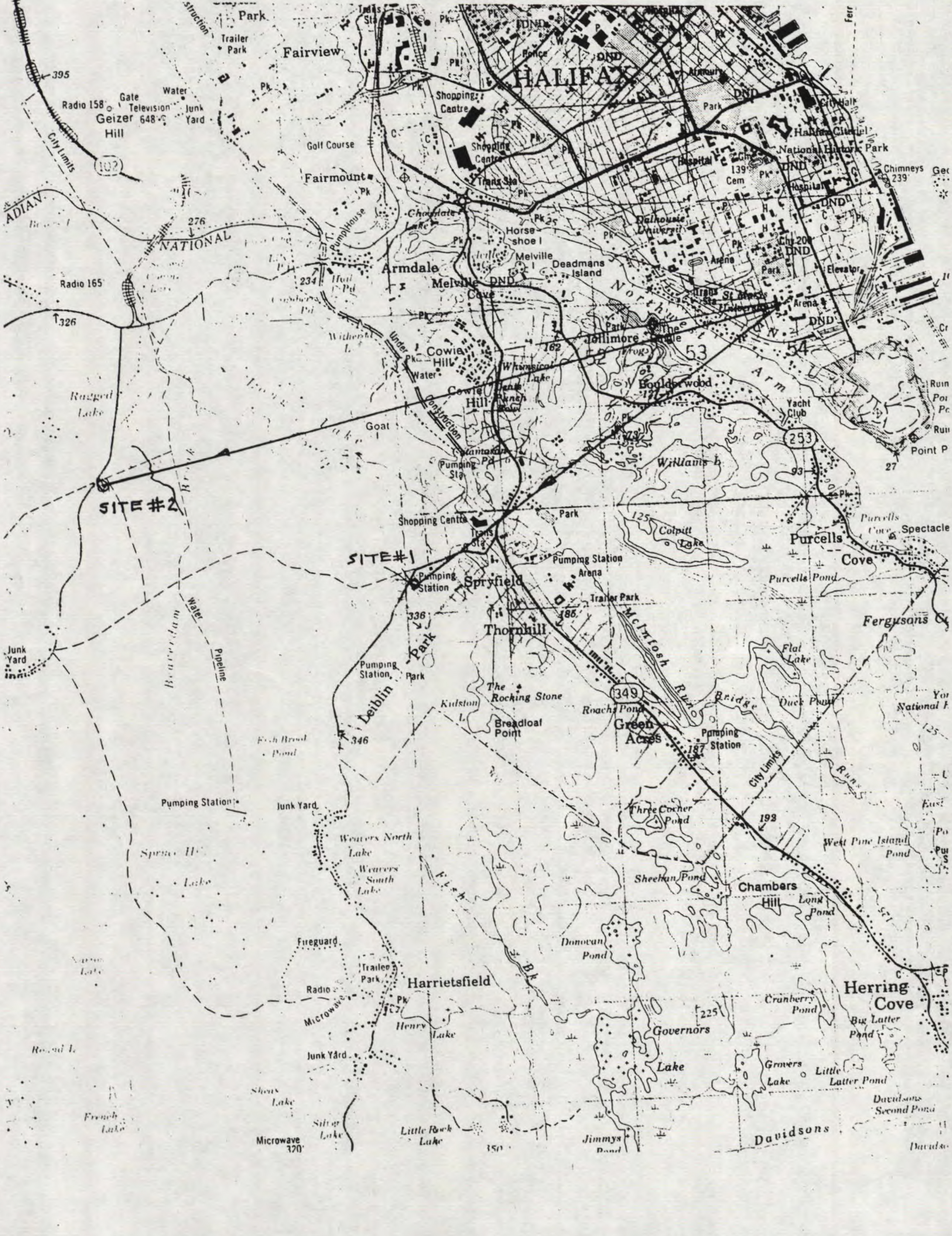
It might be added that even if 'ideal' sites had been available, the observed data would still--at the very least--contain a component associated with reflections from the surface of the cleared area. That is, the observed data would consist--at the very least--of the expected component associated with diffraction from the discontinuity at the boundary between the wooded and cleared areas, and a component due to reflections from the surface of the cleared area.

The sites are in Halifax County, Nova Scotia, as shown in the map in **Figure 1**. The distance from the transmitter (located on the roof of Saint Mary's University Administration Building) to Site #1 is 4.7 km, and the distance to Site #2 is 7 km. The line-of-sight path to Site #1 is practically unobstructed (penetrating the bottom of the first Fresnel zone only slightly), whereas the path to Site #2 has a significant obstruction (penetrating the first Fresnel zone beyond the line-of-sight) at the mid-point (Cowie Hill). The profile sections for these two paths are given in Appendix A.

Aerial views of the immediate area at the sites are given in **Figures 2** and **3**. These aerial views give some indication of the conditions at the sites, especially the extent of the wooded area along the line-of-sight path. The trees associated with Site #1 are a mixture of deciduous and coniferous, whereas those at Site #2 are almost exclusively coniferous. Photographs of the two sites in both summer and winter are shown in **Figures 4** and **5**.

It should also be noted here that the path from the transmitter site (at Saint Mary's University) to each of the two sites contains a significant amount of wooded areas, mostly deciduous. This factor will play a role in Chapter 4, where some reasons are offered for anomalous path-loss behaviour.

Figure 1: View of Halifax and the Halifax County area, showing the two propagation paths used in this investigation. Elevation profiles for the two paths are given in Appendix A.



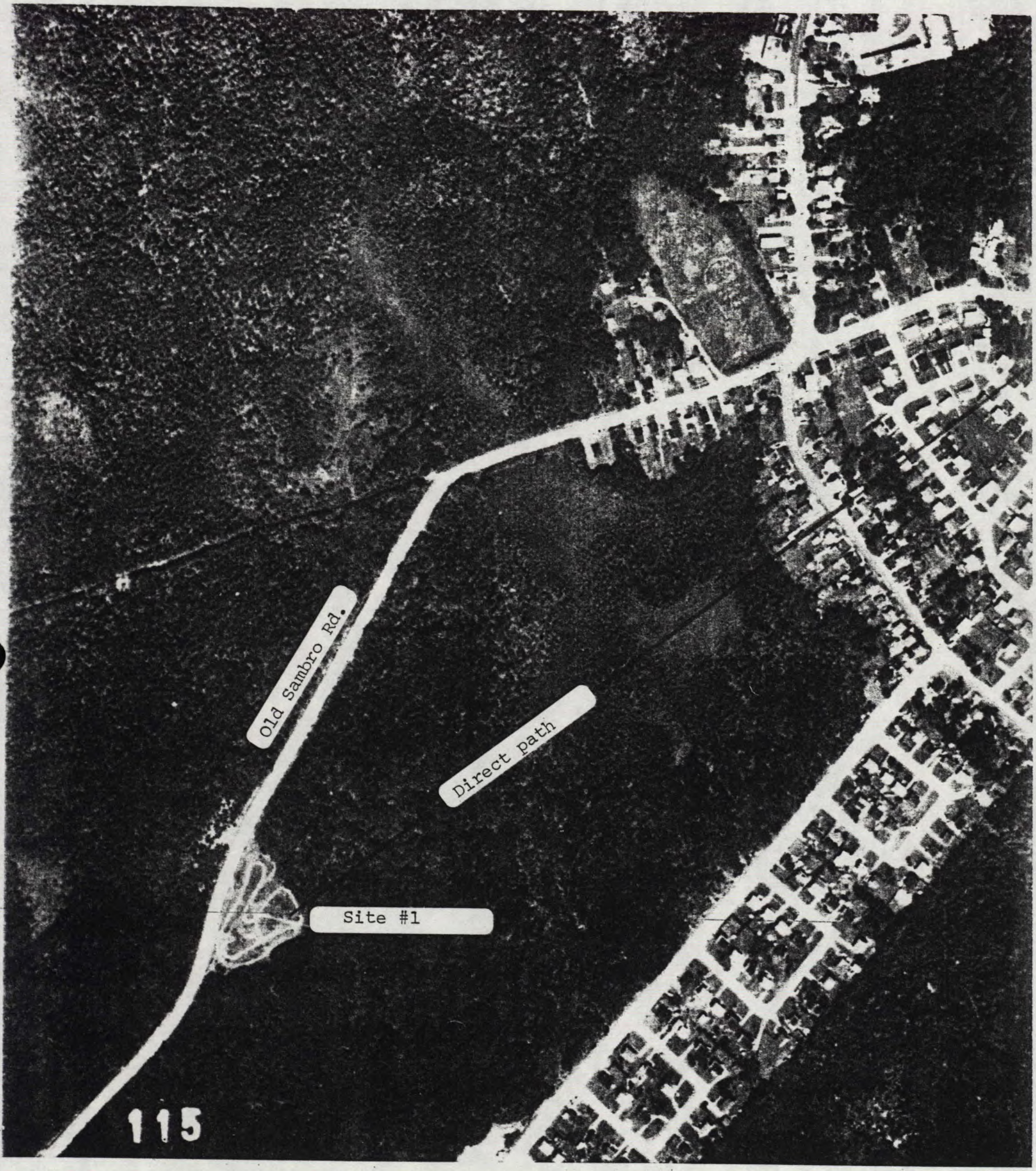


Figure 2: Aerial view of Site #1, indicating the extent of the wooded area and the boundaries of the cleared area.

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Figure 3. Aerial view of Site #2, indicating the extent of the wooded area and the boundaries of the cleared area (parking lot).

Figure 4 View of the wooded region at Site #1. The view is along the direct propagation path between the transmitting antenna (located on the roof of Saint Mary's University) and the receiving antenna. Note the higher ground on both sides of the clearing, as well as the curvature of the boundary to the right of the path. The wooded area is estimated to be at least 300 meters deep along the path. The significant feature in the photographs is the noticeable change in foliage at the working boundary between summer and winter conditions.

Figure 5 View of the wooded region at Site #2 in both summer and winter, looking directly towards the transmitting antenna. The boundary line between the wooded and cleared areas is approximately perpendicular to the direct propagation path (in the centre of the photograph) for at least 100 m on each side of the intersection point. There is some rocky debris forming a "fence" running parallel to the boundary about 15 m from the boundary, and is approximately 1 m high. The ground-level is perhaps 0.5 m lower than the parkinglot-level between this "fence" and the boundary, and is overgrown with small bushes (approximately 1 m high). Note the lamp standard (wooden pole) to the right of the propagation-path, and the power line running from this structure to its 'companions' on either side. It is being assumed that these objects have an insignificant effect on the propagation for the purposes of this study. The significant feature is the relatively similar foliage between summer and winter conditions.

Site #1 (Old Sambro Rd) Characteristics

The distance between transmitter and receiver is approximately 5 km. The trees were estimated to have an average height of 11 m at the boundary.

The site was considered to be sufficiently level, on the basis of visual inspection only, although there was, in fact, a "slight" (2% approximately) downward slope in ground level with increasing distance away from the wooded/cleared boundary. The wooded area, again on the basis of visual inspection only, was taken to be sufficiently homogeneous vis a vis tree height and tree density. The photographs in **Figure 4** give a view of the site looking towards the sending end of the path both in summer and in winter. First, it is seen that there are tree tops protruding above the average tree-top level by approximately 2 m. The distance between these protruding tree tops was estimated to be some 5 m on the average. Second, it is seen that the foliage is noticeably less in winter than in summer.

The cleared ground area at the wooded/cleared boundary was approximately 1 m higher--for a distance of approximately 9 m (slightly less than in the previous Report)--than the rest of the cleared area. It was decided, therefore, that the data in this 9 m interval would not be representative of the constant-height observations being maintained in this study; hence, no measurements were made within this interval.

For the winter measurements at 145 MHz, the cleared area was rather muddy (but no snow). When it was finally possible to make measurements at 225 MHz (some 2 months later), the ground was covered by hard-packed snow, perhaps a half-metre deep.

Figure 6 is a sketch of the boundary, viewed from above.

Site #2 (Exhibition Grounds) Characteristics

The cleared site (hard-packed parking lot surface) was considered to be sufficiently level on the basis of visual inspection only. The wooded area (primarily coniferous)--again on the basis of visual inspection only--was taken to be sufficiently homogeneous vis à vis tree height and tree density. The photographs in **Figure 5** give a view of the boundary looking towards the sending end of the path in both summer and winter. It is seen that there are tree tops protruding above the average tree-top level by approximately 2m. The distance between these protruding tree tops was estimated to be some 5m on the average. Note that the difference between summer and winter foliation is insignificant on the basis of a simple visual inspection. This would imply that the path-loss at this site should not be noticeably dependent on season. Evidently, this expectation prescinds from all considerations pertaining to the season-dependent water-content in the leaves, etc.

The cleared-ground area immediately at the wooded/cleared boundary was approximately 0.5m lower than the rest of the cleared area for a distance of approximately 15m. Observations were made within this 15-m interval in spite of the discontinuity in the ground-level. Due to very severe weather conditions in the Halifax area during the period from mid-January to mid-March, a snow-bank (approximately 1.5 m high and perhaps 3 m wide) was formed by the snow-removal activities, forming an obstacle at the above-mentioned discontinuity. Presumably, this discontinuity in ground-level would need to be taken into account when interpreting the path-loss behaviour within this interval. **Figure 7** is a sketch of the boundary, viewed from above.

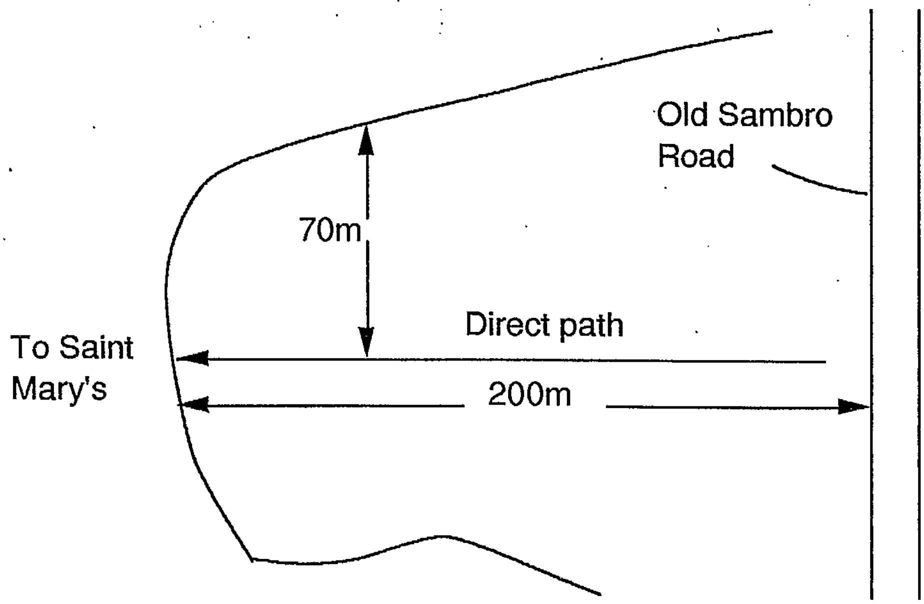

Figure 6 Sketch of the wooded/cleared boundary at Site #1. The distances are nominal only.

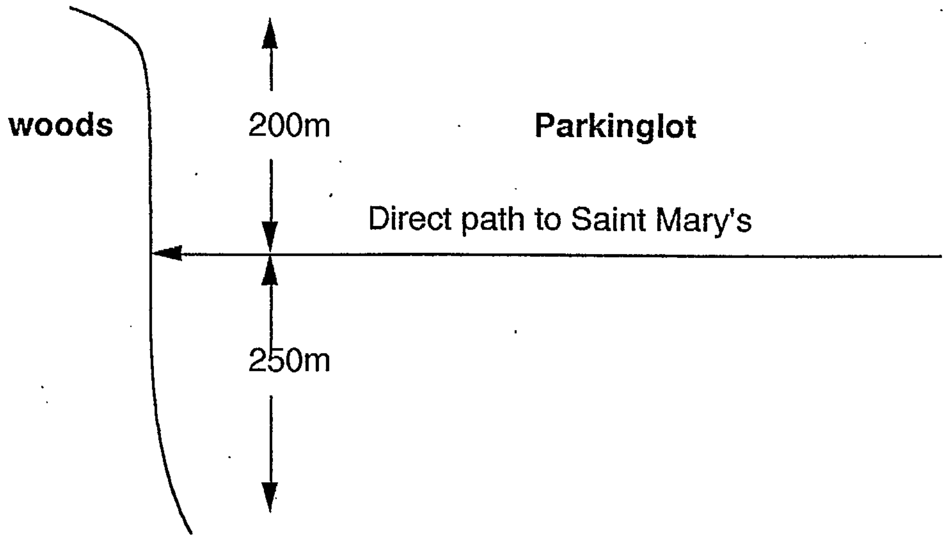

Figure 7 Sketch of the wooded/cleared boundary at Site #2, viewed from above. The distances are nominal only.

Measurement Procedures

Transmitted power was measured by using a calibrated power meter inserted into the transmission line near the antenna. Since the VSWR was observed (using a reflectometer) to be negligible, the uncertainty in the power going to the antenna is taken to be less than 1 db.

At the receiving site, a measuring-tape was strung out on the ground along the line-of-sight path away from the boundary in a down-stream direction. The mast supporting the antenna was then placed on the tape at 2-m intervals, out to 100 m. At least three measurement-runs were made and the results were averaged. It is estimated that the uncertainty in placement of the antenna from one run to another was no more than 10 cm. The antenna-height was 1.6 m, simulating the roof-top level of a typical passenger car.

Equipment

The receiver for the **2-m band (144 and 145 MHz)** was a synthesized amateur-radio type, modified to produce an agc (automatic gain control) voltage. This voltage drove a microammeter. An external GaAs-fet preamplifier (approximately 20 db gain) was used to provide adequate sensitivity. A commercial turret-type attenuator was placed between the antenna and the preamplifier input to avoid over-driving the receiver's agc circuit.

The receiver for the **1.2-m band (222 and 225 MHz)** was a commercial TV Field Strength meter, modified to tune to this band. An external GaAs-fet preamplifier (approximately 20 db gain) was used to provide adequate sensitivity.

In both cases, receiver system-sensitivity was calibrated with a calibrated VHF/UHF signal generator (HP-608). The output power-level of the generator, in turn, was compared with a commercial power-meter (Narda). The uncertainty in the receiver system-sensitivity is estimated to be approximately 1 db.

The transmitters were crystal-controlled, home-built, continuous wave systems, keyed every 10 seconds with the station call-sign (VE1SMU). An SWR reflectometer is part of the system, allowing the forward and reflected power levels to be easily monitored. The coded keying prevented any accidental confusion between the signal from the transmitter at Saint Mary's University and other signals. The transmitting antenna was situated on the roof of the Administration Building, and was approximately 20 m above ground level. The frequencies used for the summer measurements were 144 and 222 MHz respectively. A need to avoid interference in one case and equipment changes in another resulted in using two other transmitters (and two other frequencies) for the winter measurements: 145 and 225 MHz, respectively. It is assumed that the difference in frequencies has no significant effect on these path-loss measurements.

Overall 'measurement system uncertainty', consisting of uncertainties in receiver sensitivity calibration, antenna gains (transmitting and receiving), and transmitted power, is estimated to be no more than 3 or 4 db. The uncertainty in distance (from transmitter to receiver) measurements is taken to be insignificant. The uncertainty in locating the receiving antenna, from one run to another, at any given distance from the wooded/cleared boundary is estimated to be no more than 10 cm. However, this particular uncertainty is presumed to affect the observed signal level, but not the uncertainty of the measurement system itself.

Since some of the winter data was obtained under damp conditions (including occasional light drizzle), results of a previous test (see last year's Report) were invoked in this current study. It will be recalled that a laboratory test was made to determine empirically the effect of water contamination on the gain of the receiving antenna (a 10 dbd amateur-grade yagi). Water was sprayed on the entire antenna, especially at the feed-point, to simulate a situation where the entire antenna could be covered with water during an observation in the field. The change in signal strength before and after moistening was negligible, in the sense that the received signal decrease after moistening was some small fraction of a db.

The receiving antennas for both 144/5 and 222/225 MHz were dipoles, with an assumed gain of approximately 2 dbi.

The transmitting antenna for the **144 MHz** measurements on Aug.24 and 25, 1991, was a yagi (approx. 11 dbd gain) aimed at the mid-point of the two sites. The manufacturer's beam-width specifications were then used to calculate the effective power in the direction of each of the two sites. On Aug.30, 1991, the transmitting antenna was a dipole. The winter measurements on **145 MHz** used the same yagi as above.

For summer measurements on **222 MHz** and winter measurements on **225 MHz**, however, the transmitting antenna was a dipole, again assumed to have a gain of approximately 2 dbi. With reference to the tests made (on a yagi) to determine the effect of 'dampness' on antenna performance, it was assumed that dampness would have even less of an effect on these dipoles, since they were military-grade items, formerly mounted atop Tracker aircraft operating out of Halifax out over the broad Atlantic!

Calculation of Observed Path-loss

In general, it is being assumed that the observed path-loss is to be calculated from

$$\text{Path-loss} \equiv 10\log(P_{transmitted}/P_{received}),$$

where $P_{received}$ is the power received by the receiving antenna, and $P_{transmitted}$ is the power being launched by the transmitting antenna. For the simplified case of unity-gain (isotropic antennas at both ends of the path), the path-loss PL would be:

$$\begin{aligned} PL &= 10\log[P_{tx}/P_{rx}] \\ &= 10\log[P_{tx}/(V^2/Z)], \end{aligned}$$

where V is the signal level at the receiver input (in volts) and Z is the input impedance (assumed to be resistive) at this input. Expressing V in terms of microvolts (call this $V(\mu)$) would give

$$\begin{aligned} PL &= 10\log[P_{tx}Z\times10^{12}/V^2(\mu)] \\ &= 10\log P_{tx} + 10\log 50 + 120 - 20\log V(\mu) \end{aligned}$$

Finally, incorporating the antenna gains (both in dbi), we have

$$PL = 10\log P_{tx} + 10\log 50 + 120 + A_{tx} + A_{rx} - 20\log V(\mu) \text{ db}$$

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Figure 2-1a

Expected path-loss: 98 dB

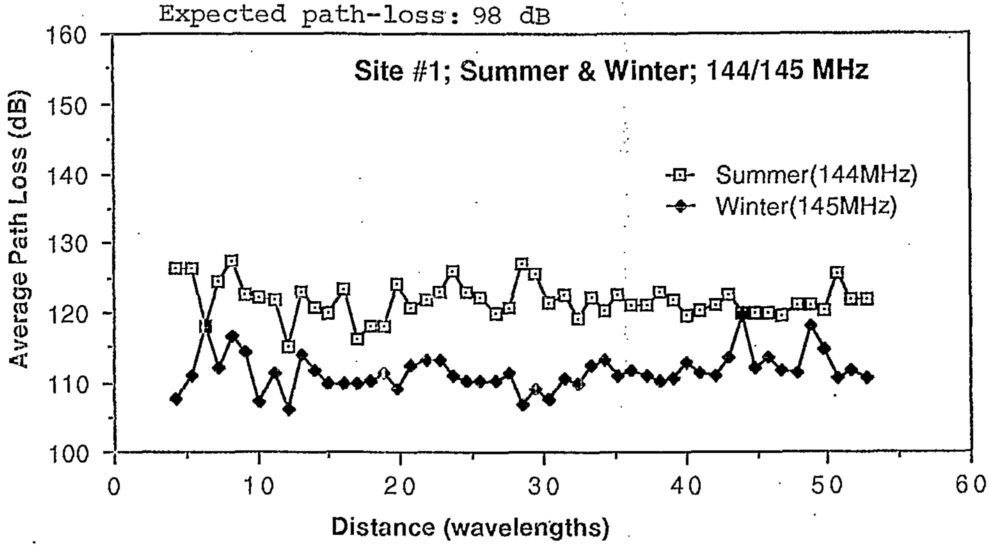
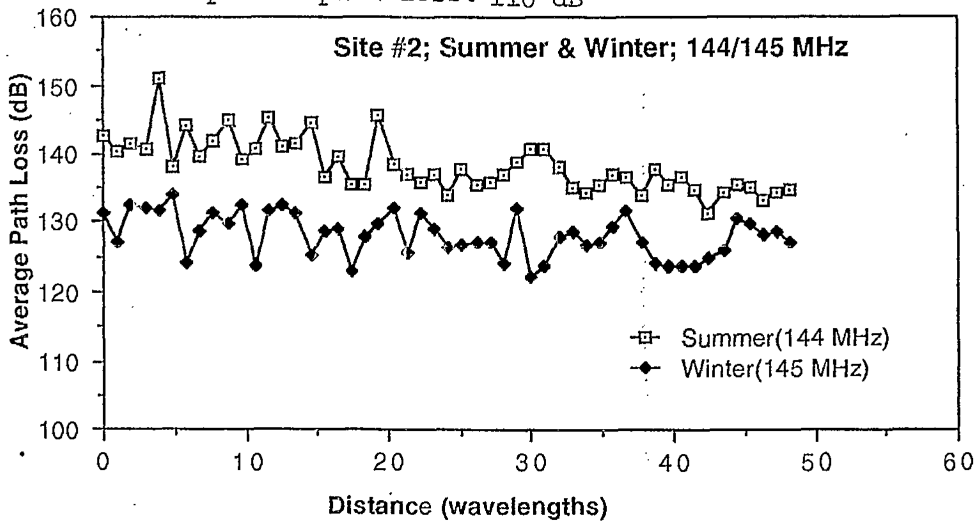


Figure 2-1b

Expected path-loss: 110 dB



Chapter 2: 144/5 MHz: Summer and Winter Path-loss at both Sites

Path-loss as a function of distance (in terms of wavelength) at Sites #1 and #2 for both Summer and Winter are shown in **Figures 2-1a** and **2-1b** respectively. At Site #1, for both summer and winter, there appears to be no trend towards decreasing path-loss with increasing distance from the wooded/cleared boundary. On the other hand, there is such a trend in the summer data at Site #2 (but not in the winter data).

There appears to very little difference between Summer and Winter path-loss behaviour as a function of site inasmuch as the difference between Summer and Winter at Site #1 appears to be similar to that for Site #2. Recall that Site #1 has a larger content of deciduous trees near the boundary, which means that seasonal effects would presumably be more significant at this site.

There is, approximately, a constant 10 db difference between Summer and Winter behaviour at Site #2, which is mainly coniferous near the boundary, and would be expected to show little--if any--seasonal effect. In addition to possible seasonal variations in the water-content of trees, there is also the conjecture that the measured path-loss is affected significantly by whatever trees stand in the propagation-path, all the way from the transmitting site to the receiving site. Since the intervening terrain in question does (on the basis of a cursory visual inspection) contain a significant quantity of deciduous trees, then the seasonal effect at Site #2 (and perhaps even more so at Site #1) is not a surprise. A more detailed survey of this matter is beyond the scope of this study.

To give some indication of the scatter in the path-loss data, separate Summer and Winter plots are given in **Figures 2-2a, 2-2b, 2-3a,** and **2-3b** respectively.

Further discussion of the results appears in Chapter 4, where the data for the three bands studied over the past two years (2-m; 1.2-m, and 0.7-m) will be compared.

Figure 2-2a

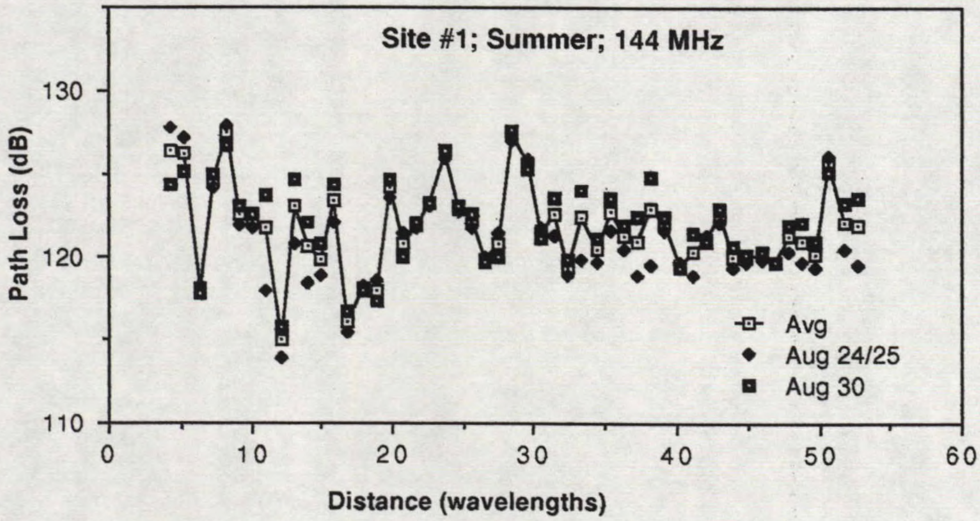
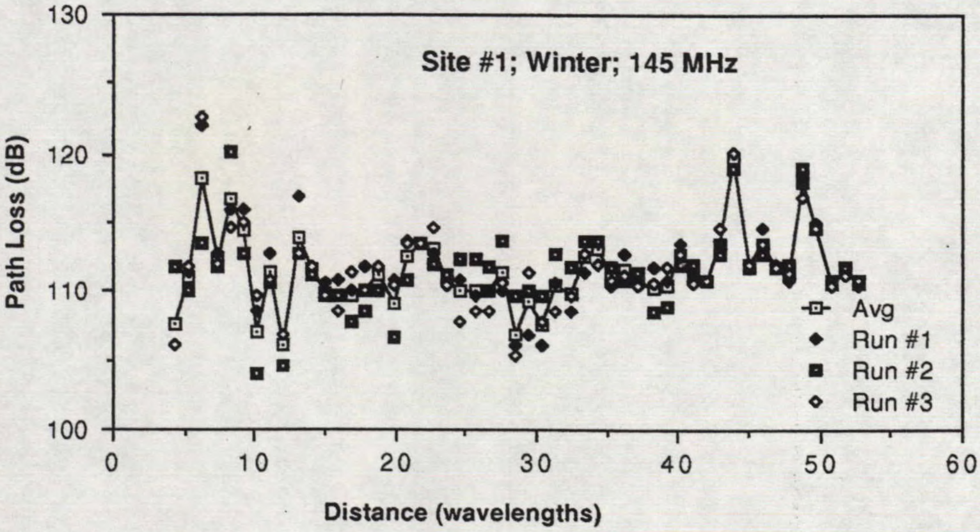


Figure 2-2b



Figures 2-2a and 2-2b: Separate summer and winter data displays for Site #1 (Old Sambro Rd.) to give some indication of the scatter in the data. The solid line is the averaged behaviour. The wavelength is taken to be 2.1 metres for both frequencies. The averaged summer behaviour is based on a total of eight runs, whereas it is three runs for winter.

Figure 2-3a

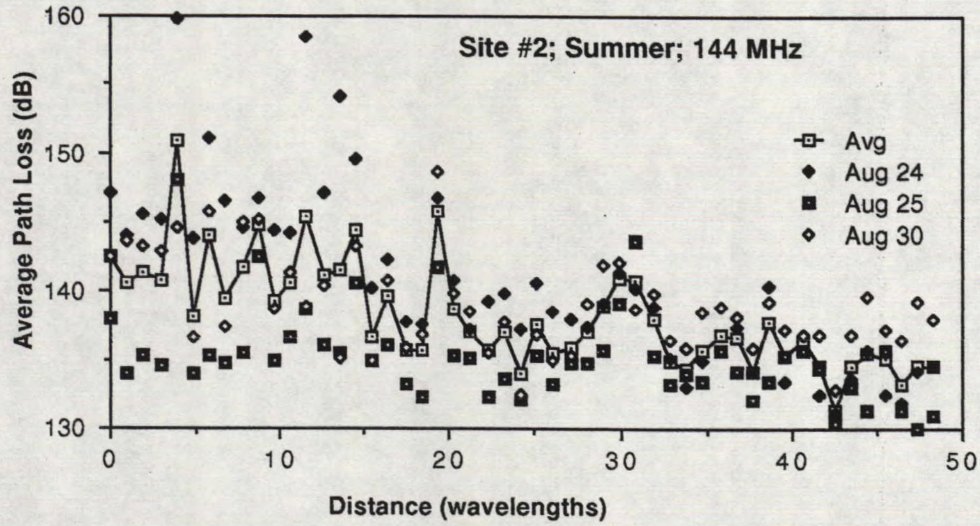
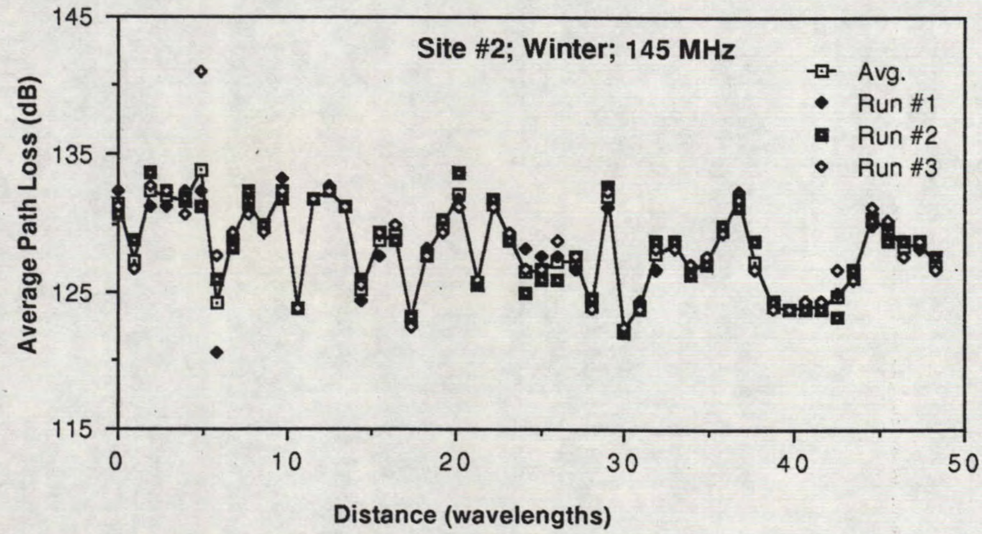


Figure 2-3b



Figures 2-3a and 2-3b: Separate summer and winter data displays for Site #2 (Exhibition Grounds) to give some indication of the scatter in the data. The solid line is the averaged behaviour. The wavelength is taken to be 2.1 metres for both frequencies. The averaged summer behaviour is based on a total of eight runs, whereas it is three runs for winter.

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Figure 3-1a

Expected path-loss: 99 dB

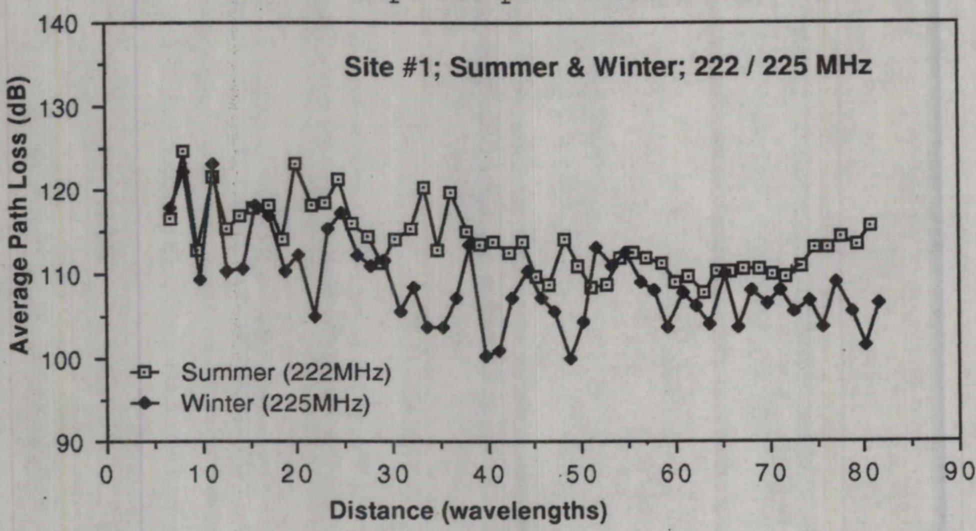
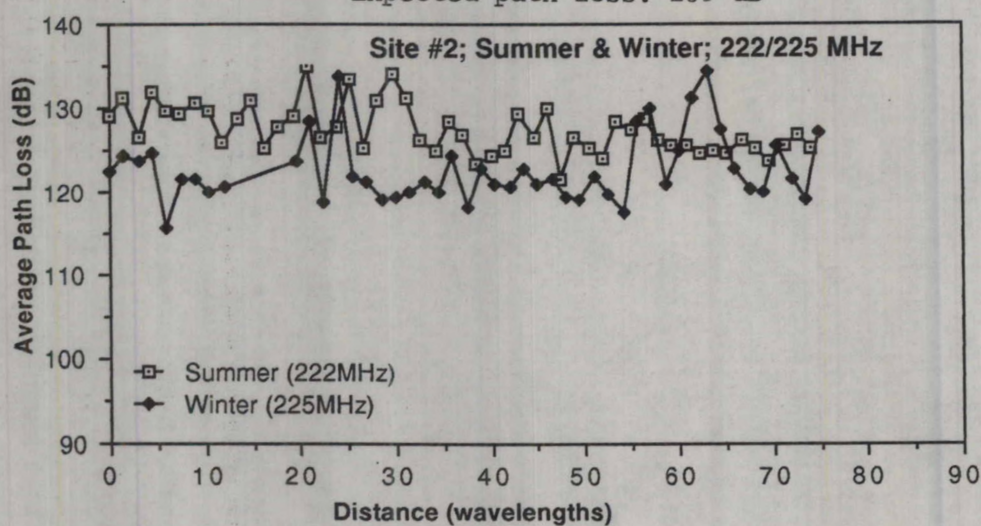


Figure 3-1b

Expected path-loss: 109 dB



Chapter 3: 222/225 MHz: Summer and Winter Path-loss at both Sites

Path-loss as a function of distance (in terms of wavelength) at Sites #1 and #2 for both Summer and Winter are shown in **Figures 3-1a** and **3-1b** respectively. At Site #1, for both summer and winter, there appears to be a trend towards decreasing path-loss with increasing distance from the wooded/cleared boundary. On the other hand, there is no such trend in the Site #2 data.

There appears to very little difference between Summer and Winter path-loss behaviour as a function of site inasmuch as the difference between Summer and Winter at Site #1 appears to be similar to that for Site #2. Recall that Site #1 has a larger content of deciduous trees near the boundary, which means that seasonal effects would presumably be more significant at this site.

As in the 2-m data given in Chapter 2, there is a constant 5 to 6 db difference between Summer and Winter behaviour at Site #2 (this difference was somewhat larger for the 2-m data). Since the boundary at Site #2 is mainly coniferous, it would be expected to show little--if any--seasonal effect. Hence, in addition to possible seasonal variations in the water-content of trees, there is also the conjecture that the measured path-loss is affected significantly by whatever trees stand in the propagation-path, all the way from the transmitting site to the receiving site. Since the intervening terrain in question does (on the basis of a cursory visual inspection) contain a significant quantity of deciduous trees, then the seasonal effect at Site #2 (and perhaps even more so at Site #1) is not a surprise. A more detailed survey of this matter is beyond the scope of this study.

To give some indication of the scatter in the path-loss data, separate Summer and Winter plots are given in **Figures 3-2a**, 3-**2b**, **3-3a**, and **3-3b** respectively.

Further discussion of the results appears in Chapter 4, where the data for the three bands studied over the past two years (2-m; 1.2-m, and 0.7-m) will be compared.

Figure 3-2a

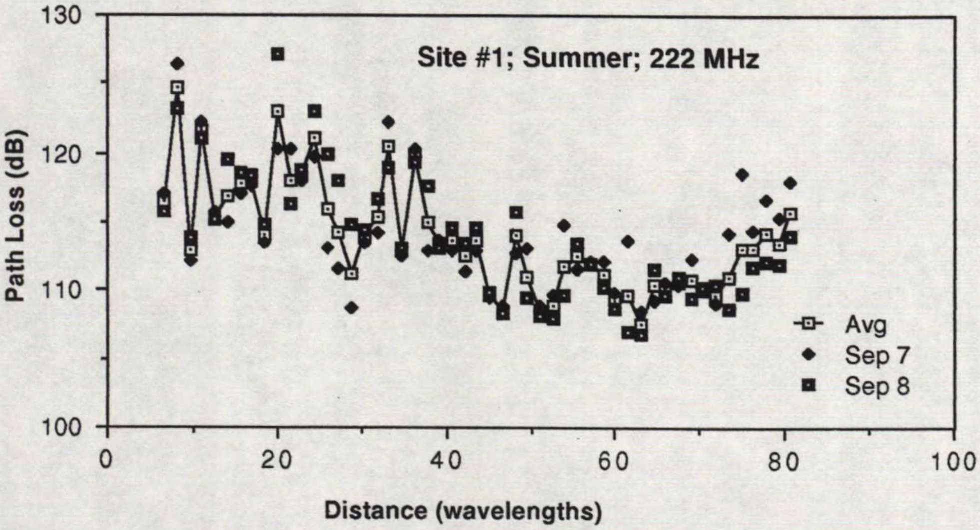
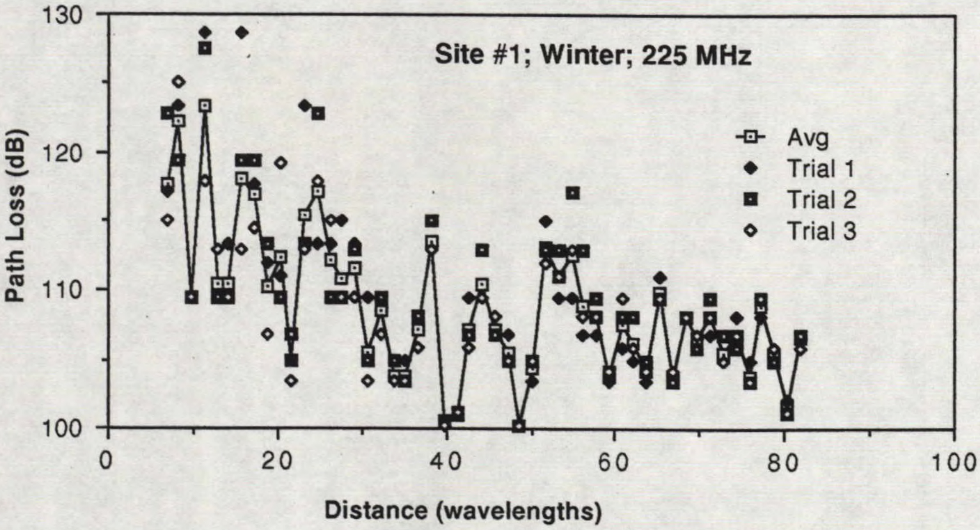


Figure 3-2b



Figures 3-2a and 3-2b: Separate summer and winter data displays for Site #1 (Old Sambro Rd.) to give some indication of the scatter in the data. The solid line is the averaged behaviour. The wavelength is taken to be 1.35 metres. The averaged behaviour is based on a total of six runs (three on each day). runs

Figure 3-3a

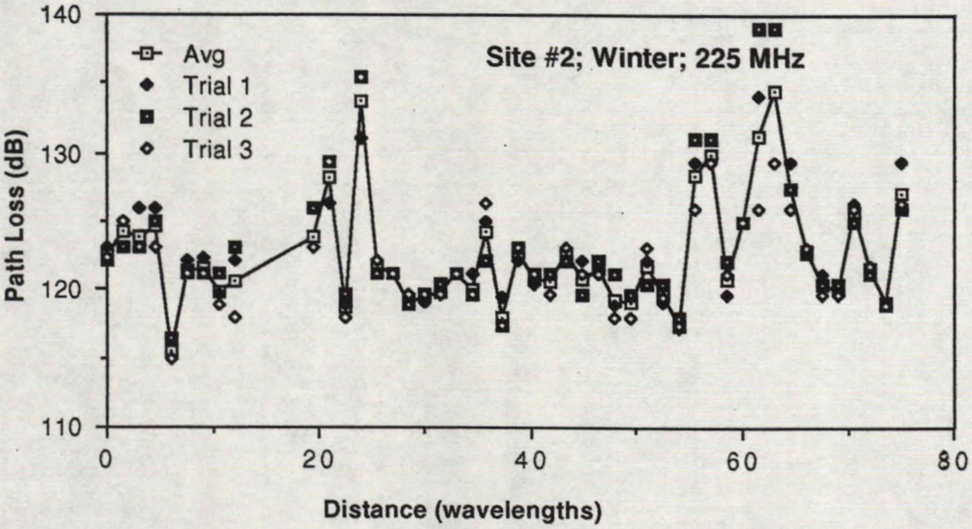
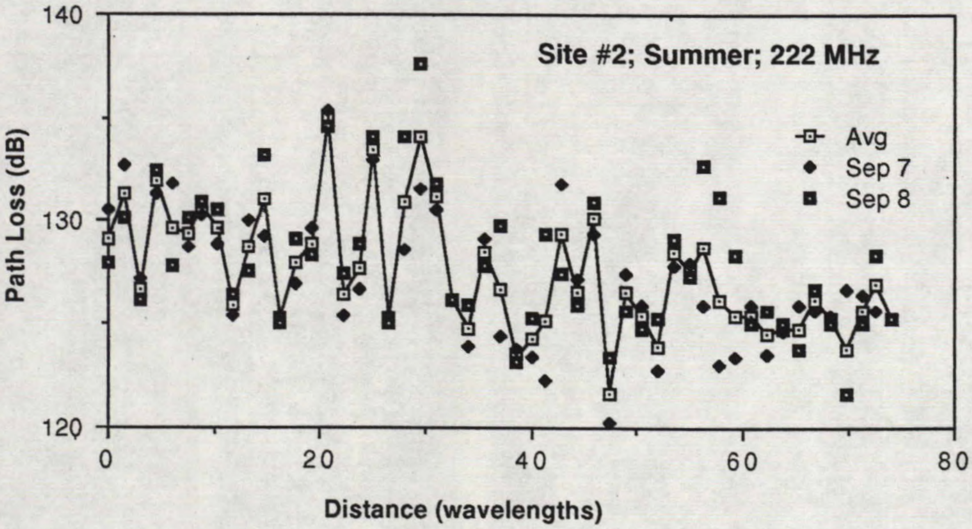


Figure 3-3b



Figures 3-3a and 3-3b: Separate summer and winter data displays for Site #2 (Exhibition Grounds) to give some indication of the scatter in the data. The solid line is the averaged behaviour. The wavelength is taken to be 1.35 metres. The averaged behaviour is based on a total of three runs, all on one day.

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Figure 4-1a

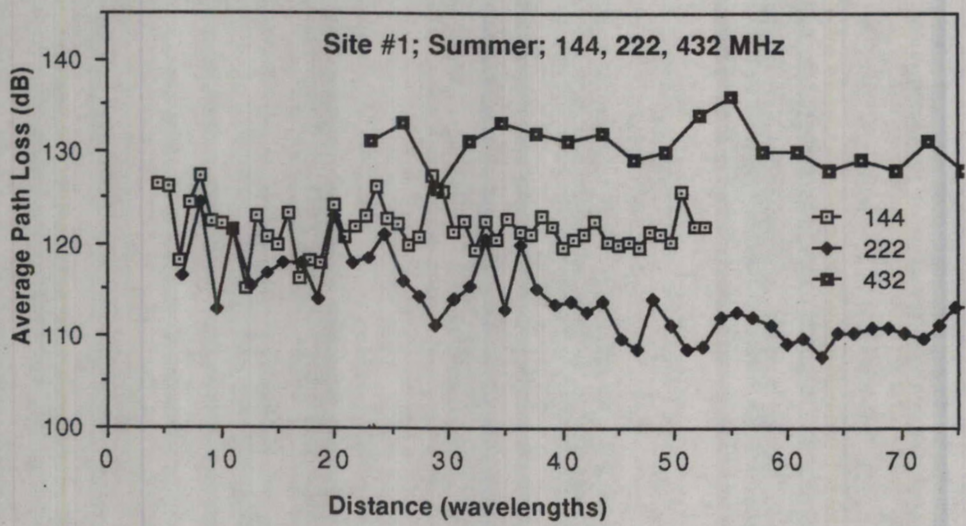
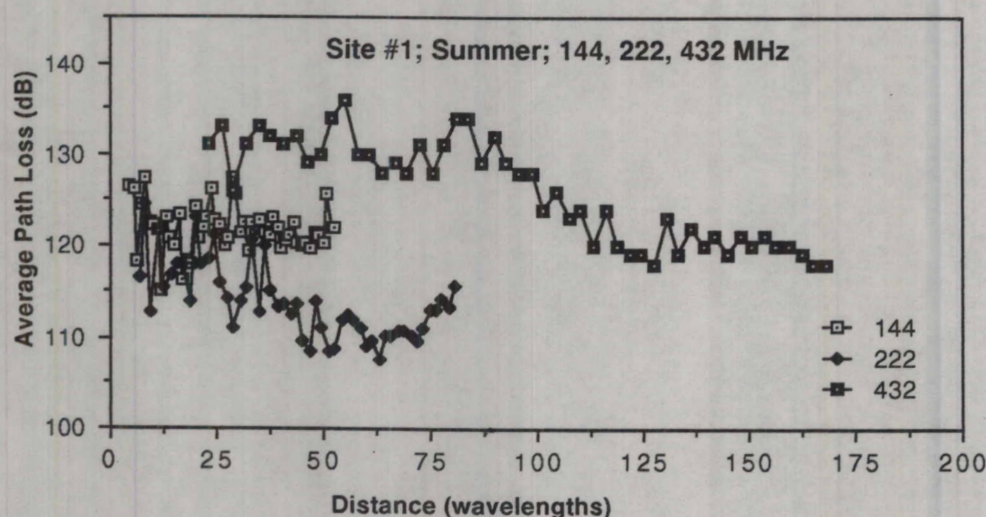


Figure 4-1b



Chapter 4: Comparison of path-loss behaviour for the three bands

1. Summer data at Site #1 for all three bands.

The summer behaviour for Site #1 is shown in **Figures 4-1a and 4-1b**. Note that the data in **Figure 4-1a** is displayed out to only 75 wavelengths to facilitate comparison of the three sets of data, and therefore represents only part of the total data; **Figure 4-1b** shows the total data.

The fact that the data for 432 MHz lies between the other two frequencies is taken to be anomalous. It should be recalled, however, that the 432 MHz data was obtained using a directional antenna (approximately 10 dbi gain) aimed along the propagation path, whereas the other data for the other two frequencies was obtained using a dipole. This difference in antennas implies that the directional properties would tend to discriminate against multi-path components coming in from either side of the 'line-of-sight' propagation-path; this would not be the case for the dipoles. See the Report for the previous year for further discussion of this point.

It should also be kept in mind that there is a one-year difference between measurements made at 432 MHz and those made at the other two frequencies. The significance of this time difference lies in the conjecture that the tree- and foliage-distribution along the path changed noticeably in the course of that one year.

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Figure 4-2a

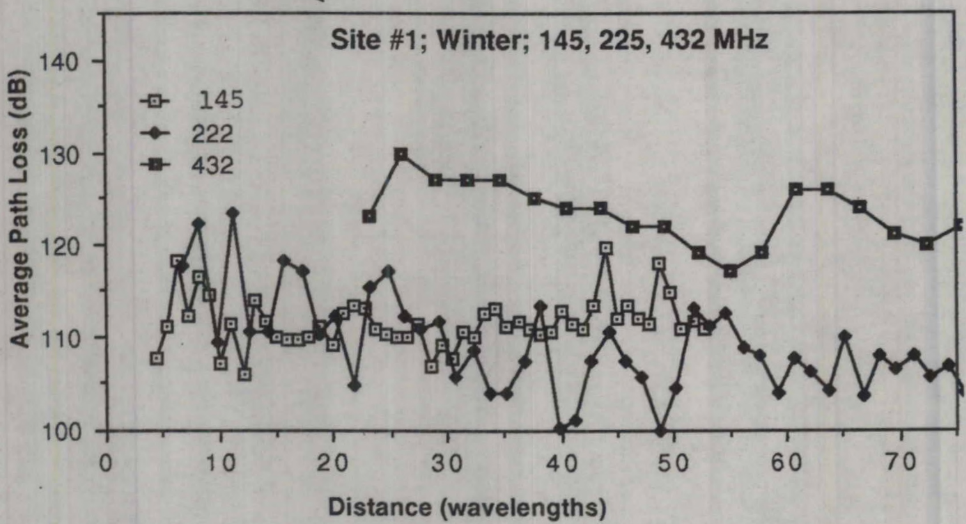
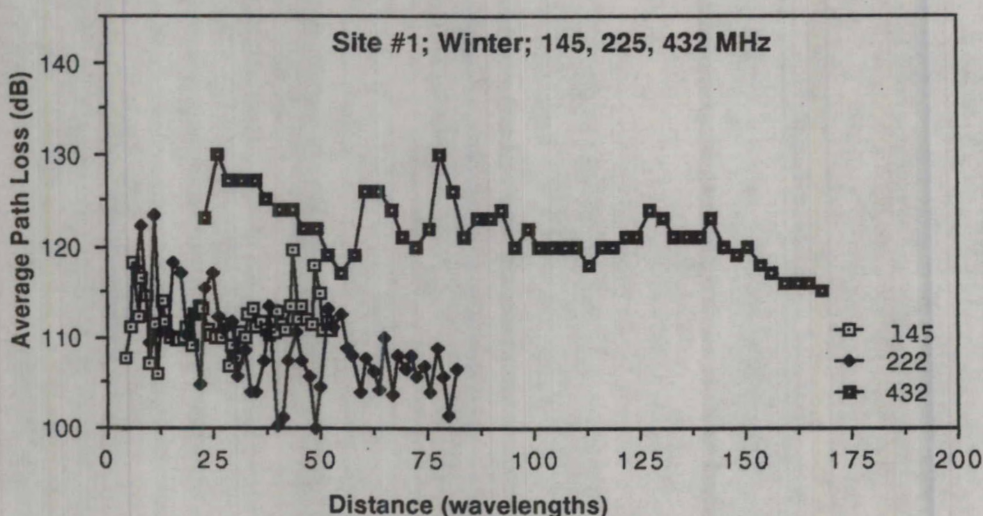


Figure 4-2b



2. Winter data at Site #1 for all three bands.

The winter behaviour for Site #1 is shown in **Figures 4-2a and 4-2b.** Note that the data in **Figure 4-2a** is displayed out to only 75 wavelengths to facilitate comparison of the three sets of data, and therefore represents only part of the total data; **Figure 4-2b** shows the total data.

The fact that the data for 432 MHz lies between the other two frequencies is taken to be anomalous. It should be recalled, however, that the 432 MHz data was obtained using a directional antenna (approximately 10 dbi gain) aimed along the propagation path, whereas the other data for the other two frequencies was obtained using a dipole.

As mentioned earlier, it should also be kept in mind that there is a one-year difference between measurements made at 432 MHz and those made at the other two frequencies. The significance of this time difference lies in the conjecture that the tree- and foliage-distribution along the path changed noticeably in the course of that one year.

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Figure 4-3a

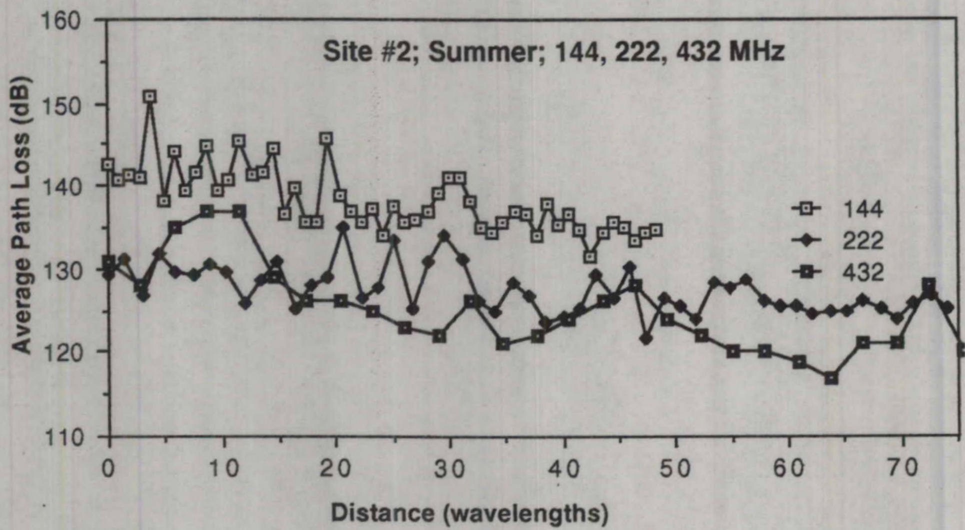
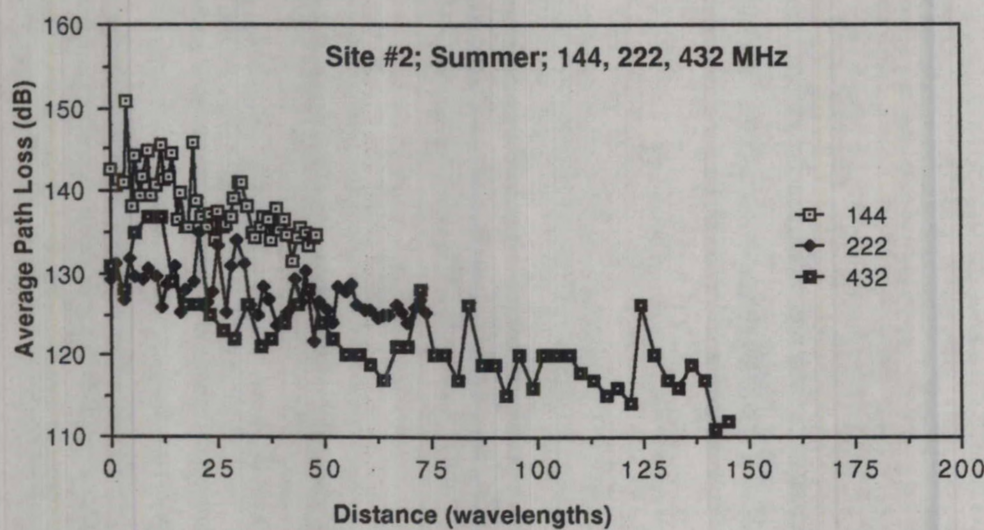


Figure 4-3b



3. Summer data at Site #2 for all three bands.

The summer behaviour for Site #2 is shown in **Figures 4-3a and 4-3b**. The data in **Figure 4-3a** is displayed out to only 75 wavelengths to facilitate comparison of the three sets of data, and therefore represents only part of the total data; **Figure 4-3b** shows the total data.

In this one case, the data for all three frequencies falls into an ordered sequence, as well as showing a decreasing path-loss with increasing distance from the wooded/cleared boundary.

As mentioned above, it should be kept in mind that there is a one-year difference between measurements made at 432 MHz and those made at the other two frequencies. The significance of this time difference lies in the conjecture that the tree- and foliage-distribution along the path changed noticeably in the course of that one year.

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Figure 4-4a

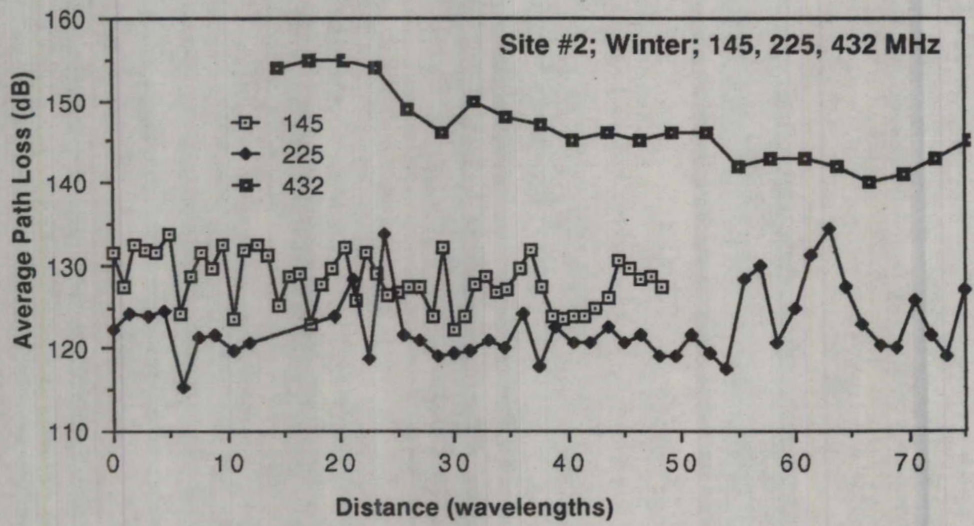
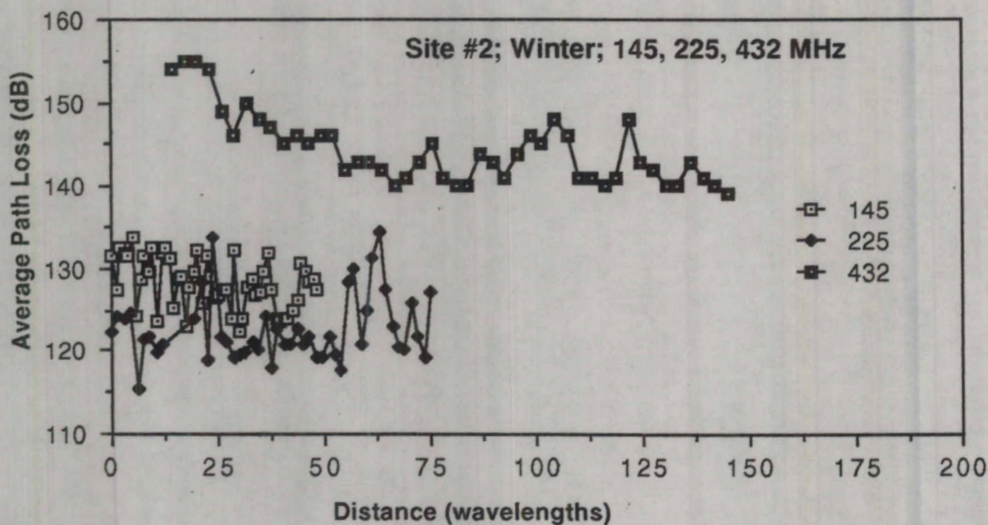


Figure 4-4b



4. Winter data at Site #2 for all three bands.

The winter behaviour for Site #2 is shown in **Figures 4-3a and 4-3b.** Note that the data in **Figure 4-3a** is displayed out to only 75 wavelengths to facilitate comparison of the three sets of data, and therefore represents only part of the total data; **Figure 4-3b** shows the total data.

As already seen in most of the data, the fact that the data for 432 MHz lies between the other two frequencies is taken to be anomalous. Again, it should be recalled that the 432 MHz data was obtained using a directional antenna (approximately 10 dbi gain) aimed along the propagation path, whereas the other data for the other two frequencies was obtained using a dipole.

It should also be kept in mind that there is a one-year difference between measurements made at 432 MHz and those made at the other two frequencies. The significance of this time difference lies in the conjecture that the tree- and foliage-distribution along the path changed noticeably in the course of that one year.

5. Summary

In general, the data is **somewhat** as expected in the sense that **some** of it (although it is by way of exception) shows a decrease in path-loss with increasing distance from the wooded/cleared boundary.

Also, the seasonal dependence for the 1.2-m data at Site #2 (which is mainly coniferous at the boundary) is less pronounced than for the 2-m data at the same site. This smaller seasonal dependence correlates somewhat with the expectation that the coniferous boundary should be season-independent.

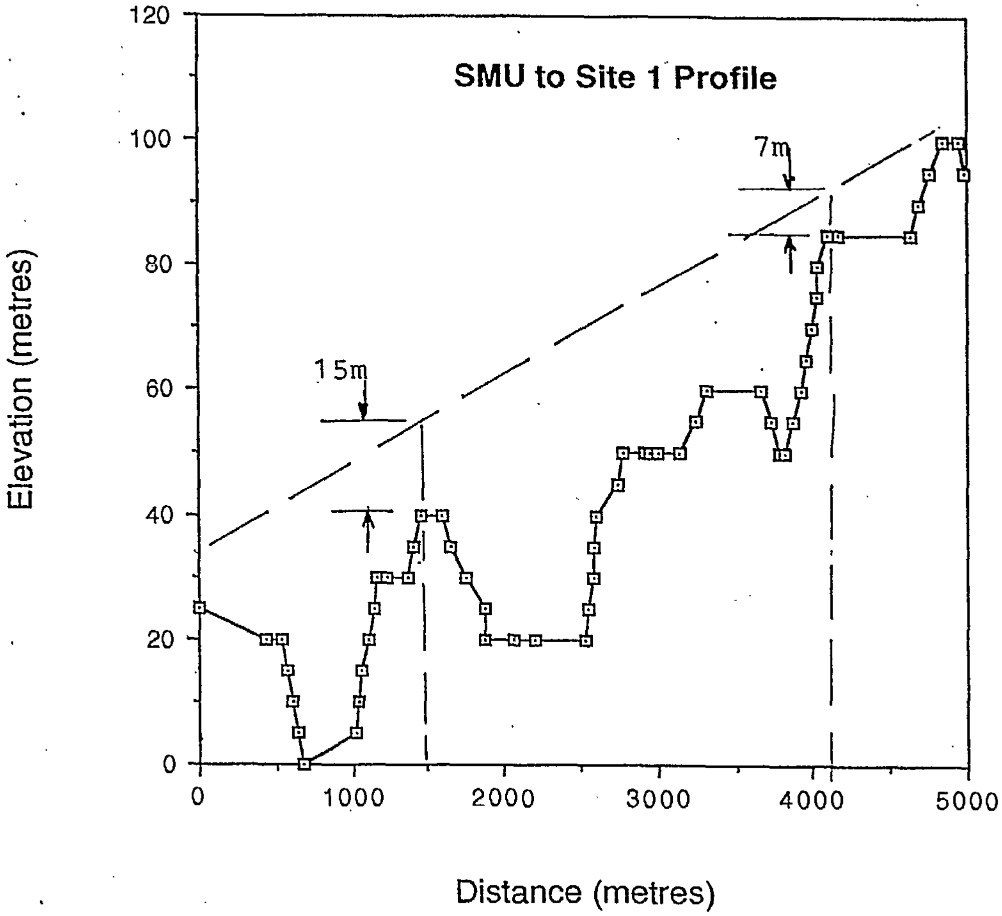
On the other hand, the data is rather anomalous inasmuch as:

1. Generally, the path-loss--in the context of all three frequency-bands--does not follow an ordered sequence relative to frequency at a given site and given season, **except** in one case: that of the summer data at Site #2 (Figures 4-3a and 4-3b). Recall that Site #2 has mainly coniferous trees at the boundary. This inference neglects to take into account the directionality of the measurements in the 0.7-m band. Presumably, if a dipole had been used, then the observed path-loss at 0.7-m would have been somewhat smaller because the dipole would be responding to off-axis components. But this, inference, in turn, neglects multi-path interference effects.

2. The seasonal difference for the 2-m and 1.2-m bands at Site #2 (which has mainly coniferous trees at the boundary) is approximately 10 db, which is taken to be a significant difference. This result is anomalous because the foliage at the boundary (presumably) does not change significantly from one season to another.

3. The 'quasi free-path' path-loss (taking into account Fresnel-zone blocking) is between 10 and 20 db less than observed, depending on season.

4. It is conjectured that the foliage all along path-points between the boundary and transmitter could account for the significant seasonal effect at Site #2, and perhaps could also account for the significant difference between 'expected' and 'observed' path-loss.



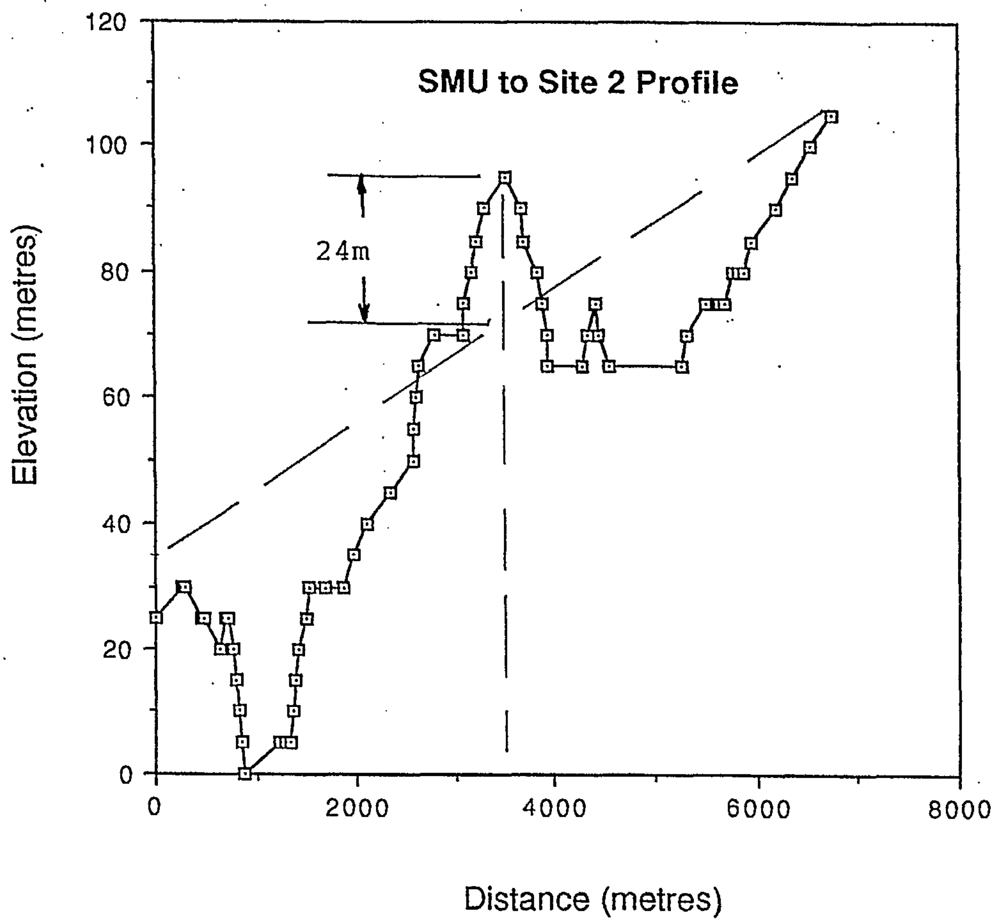
Profile section for Site #1 (Old Sambro Rd)

The transmitting antenna is at the extreme left-hand side, and is approximately 20m above ground level. The obstacle at 1.5km is taken to be 15m below the direct line from transmitter to receiver. The obstacle at slightly over 4km is taken to be 7m.

(tabulated data on p.A-2)

Elevation(m)	"distance"	distance(m)
25	0	0.000
20	4.3	430.000
20	5.4	540.000
15	5.8	580.000
10	6.1	610.000
5	6.5	650.000
0	6.7	670.000
5	10.2	1020.000
10	10.4	1040.000
15	10.6	1060.000
20	11.1	1110.000
25	11.4	1140.000
30	11.6	1160.000
30	12.4	1240.000
30	13.7	1370.000
35	14.0	1400.000
40	14.5	1450.000
40	15.9	1590.000
35	16.5	1650.000
30	17.6	1760.000
25	18.7	1870.000
20	18.8	1880.000
20	20.7	2070.000
20	22	2200.000
20	25.3	2530.000
25	25.6	2560.000
30	25.8	2580.000
35	25.9	2590.000
40	26.1	2610.000
45	27.4	2740.000
50	27.8	2780.000
50	29.2	2920.000
50	29.6	2960.000
50	30.1	3010.000
50	31.5	3150.000
55	32.4	3240.000
60	33.2	3320.000
60	36.6	3660.000
55	37.3	3730.000
50	37.8	3780.000
50	38.2	3820.000
55	38.8	3880.000
60	39.2	3920.000
65	39.5	3950.000
70	39.9	3990.000
75	40.2	4020.000
80	40.3	4030.000
85	40.9	4090.000
85	41.7	4170.000
85	46.4	4640.000
90	46.9	4690.000
95	47.6	4760.000
100	48.4	4840.000
100	49.4	4940.000
95	49.8	4980.000

Data for the Profile section for Site #1. The second column represents relative magnitudes; the third column represents the absolute distances in metres. For purposes of the Report, the quantities in this third column should be rounded off to three significant figures (the Spread-Sheet software was not able to do this operation).



Profile section for Site #2 (Exhibition Grounds)

The transmitting antenna is at the extreme left-hand side, and is approximately 20m above ground level. The dominant obstruction is at 3.5km and is taken to be 24m above the direct line from transmitter to receiver.

(tabulated data on p. A-4)

Elevation(m)	"Distance"	Distance(m)
25	0	0.000
30	2.6	260.000
30	2.9	290.000
25	4.6	460.000
25	4.8	480.000
20	6.4	640.000
25	6.8	680.000
25	7.2	720.000
20	7.7	770.000
15	8.1	810.000
10	8.3	830.000
5	8.5	850.000
0	8.7	870.000
5	12.3	1230.000
5	12.7	1270.000
5	13.4	1340.000
10	13.6	1360.000
15	13.9	1390.000
20	14.1	1410.000
25	14.8	1480.000
30	15.2	1520.000
30	16.7	1670.000
30	18.7	1870.000
35	19.7	1970.000
40	21.1	2110.000
45	23.5	2350.000
50	25.8	2580.000
55	25.9	2590.000
60	26.1	2610.000
65	26.3	2630.000
70	27.8	2780.000
70	30.7	3070.000
75	30.9	3090.000
80	31.5	3150.000
85	32.2	3220.000
90	33	3300.000
95	35.1	3510.000
90	36.7	3670.000
85	37	3700.000
80	38.2	3820.000
75	38.9	3890.000
70	39.3	3930.000
65	39.4	3940.000
65	42.7	4270.000
70	43.3	4330.000
75	44	4400.000
70	44.5	4450.000
65	45.4	4540.000
65	52.7	5270.000
70	53.2	5320.000
75	55	5500.000
75	56.3	5630.000
75	57	5700.000
80	57.8	5780.000
80	58.2	5820.000
80	58.7	5870.000

Data for the Profile section for Site #2. The second column represents relative magnitudes; the third column represents the absolute distances in metres. For purposes of the Report, the quantities in this third column should be rounded off

Elevation(m)	"Distance"	Distance(m)
85	59.5	5950.000
90	61.8	6180.000
95	63.6	6360.000
100	65.4	6540.000
105	67.6	6760.000

Calculation of Expected Path-loss

The general expression for ideal (unobstructed) free-space path-loss is taken to be

$$\text{Path-loss (db)} = 32.5 + 20\log d + 20\log f,$$

where **d** is the distance in km
and **f** is the frequency in MHz

However, the paths to the sites in this Report are not ideal, so that a 'quasi-freespace' path-loss will be estimated, using the Fresnel-zone blocking model defined below. This quantity represents the 'expected' path-loss (taking obstructions into account) and represents the path-loss to the measuring site, prescinding from the effects of the wooded/cleared boundary

Fresnel-Zone Blocking Model

Reference: The ARRL UHF/Microwave Experimenter's Manual, American Radio Relay League, 225 Main St, Newington, CT 06111, 1990, p3-32ff. The graph below is reproduced with permission.

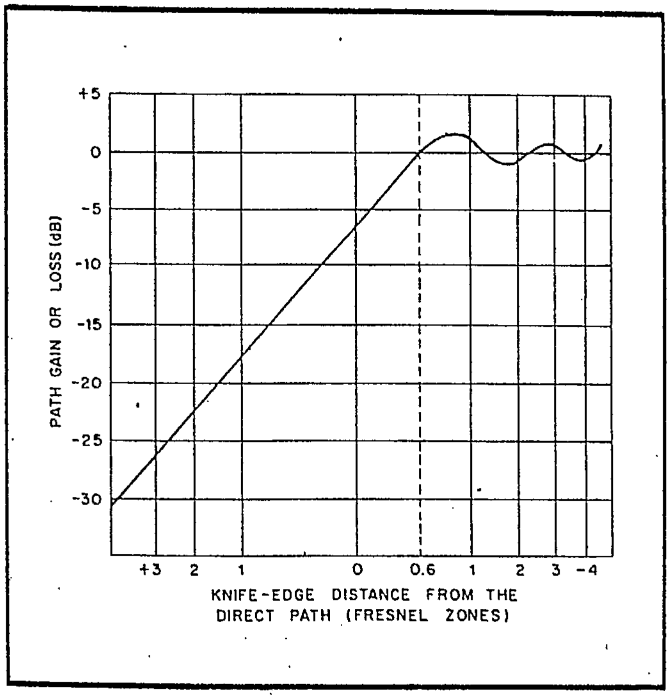
Only the first zone will be considered, and the appropriate expression is

$$F_1 = 17.3(d_1 d_2/fd)^{1/2}, \qquad d = d_1 + d_2$$

where the distances are in metres and **f** is in MHz. This gives the radius of the first Fresnel-zone at the indicated point along the path.

The **knife-edge distance** is then calculated from the actual distance in metres from line-of-sight to the obstruction, and then the corresponding attenuation is obtained from the graph.

For both sites, the calculated 'expected' values are taken to be minimum values, in the sense that they represent only the 'known' factors. Presumably there are 'unknown' factors and these would make the 'expected' path-loss even larger.



Appendix B: Calculations of Expected Path-Loss

Expected Path-loss for Site #1: 144 MHz

For this site, the 'ideal' relationship yields

32.5 + 20log5 + 20log144 = **90 db**.

On the basis of the profile section shown in Appendix A, there is an obstruction, approximately 15m **below** the line-of-sight, at 1.5 km from the transmitting end, and another obstruction, approximately 7m **below** line-of-sight at 4 km. Assuming a simple 'knife-edge' model, these two obstructions introduce an additional loss due to Fresnel zone blocking (assuming first zone only). This additional path-loss is calculated from

$$F_1(4km) = 17.3 \ (4km*1km/(144MHz*5km))^{1/2} = 41m$$

at the "4km" obstruction. At this point, the 'knife-edge' distance is 7/41 = 0.17, which implies approximately 5db attenuation, on the basis of the graph on p.B-2.

$$F_1(1.5km) = 17.3(1.5km*3.5km/(144MHz*5km))^{1/2} = 47m$$

at the 1.5km obstruction. Here, the **knife-edge distance** is 15/47 = 0.31, which implies approximately 3db. Therefore, the total 'quasi free-space' path-loss for this site is **98 db.**

Expected Path-loss for Site #2: 144 MHz

For this site, the 'ideal' relationship yields

32.5 + 20log7 + 20log144 = **93 db**.

On the basis of the profile section shown in Appendix A, there is an obstruction, approximately 24m **above** the line-of-sight, at 3.5 km from the transmitting end, Assuming a simple 'knife-edge' model, this obstruction will introduce an additional loss due to Fresnel zone blocking (assuming first zone only). This additional path-loss is calculated from

$$F_1(3.5km) = 17.3(3.5km3.5km/(144MHz*7km))^{1/2} = 27m$$

Here, the knife-edge distance is 24/27 = .89, which implies approximately 17 db.

Therefore, the total 'quasi free-space' path-loss for this site is taken to be **110 db**.

Expected Path-loss for Site #1: 222 MHz

For this site, the 'ideal' relationship yields

32.5 + 20log5 + 20log222 = **93 db.**

On the basis of the profile section shown in Appendix A, there is an obstruction, approximately 15m **below** the line-of-sight, at 1.5 km from the transmitting end, and another obstruction, approximately 7m **below** line-of-sight at 4 km. Assuming a simple 'knife-edge' model, these two obstructions introduce an additional loss due to Fresnel zone blocking (assuming first zone only). This additional path-loss is calculated from

$$F_1(4km) = 17.3\ (4km*1km/(222MHz*5km))^{1/2} = 33m$$

at the "4km" obstruction. At this point, the 'knife-edge' distance is 7/33 = 0.21, which implies approximately 4db attenuation, on the basis of the graph on p.B-2.

$$F_1(1.5km) = 17.3(1.5km*3.5km/(222MHz*5km))^{1/2} = 38m$$

at the 1.5km obstruction. Here, the **knife-edge distance** is 15/38 = 0.39, which implies approximately 2db.

The expected path-loss is therefore taken to be **99 db.**

Expected Path-loss for Site #2: 222 MHz

For this site, the 'ideal' relationship yields

32.5 + 20log7 + 20log222 = **96 db.**

On the basis of the profile section shown in Appendix A, there is an obstruction, approximately 24m **above** the line-of-sight, at 3.5 km from the transmitting end, Assuming a simple 'knife-edge' model, this obstruction will introduce an additional loss due to Fresnel zone blocking (assuming first zone only). This additional path-loss is calculated from

$$F_1(3.5km) = 17.3(3.5km*3.5km/(144MHz*7km))^{1/2} = 48m$$

Here, the knife-edge distance is 24/48 = 0.5, which implies approximately 13 db.

The expected path-loss is therefore taken to be **109 db.**

Distance (m)	Aug 24/25 PL	Aug 30 PL (dB)	Avg PL (dB)	Red. Dist (λ)
9.000	127.761443	124.266254	126.356365	4.348
11.000	127.124192	125.157673	126.251302	5.314
13.000	118.329925	117.882503	118.111973	6.280
15.000	124.169771	124.926268	124.56447	7.246
17.000	127.974418	126.694451	127.381419	8.213
19.000	122.01564	123.07996	122.580323	9.179
21.000	121.801162	122.629721	122.235171	10.145
23.000	118.089747	123.75204	121.784905	11.111
25.000	113.933633	115.85335	114.998711	12.077
27.000	120.855801	124.589993	123.112457	13.043
29.000	118.452551	122.118639	120.661467	14.010
31.000	118.9176	120.815157	119.969202	14.976
33.000	122.077904	124.266254	123.30848	15.942
35.000	115.54176	116.786346	116.208485	16.908
37.000	118.269255	118.088044	118.179594	17.874
39.000	118.639799	117.34095	118.038751	18.841
41.000	123.593062	124.589993	124.120071	19.807
43.000	121.489061	120.065458	120.835331	20.773
45.000	121.755884	122.118639	121.941048	21.739
47.000	123.087296	123.266574	123.17786	22.705
49.000	125.85335	126.418961	126.145357	23.671
51.000	122.692805	122.987862	122.842838	24.638
53.000	121.725829	122.629721	122.201248	25.604
55.000	120.015618	119.80795	119.913025	26.570
57.000	121.474475	120.065458	120.82686	27.536
59.000	126.958215	127.578509	127.279427	28.502
61.000	125.9504	125.276087	125.626318	29.469
63.000	121.846678	121.104859	121.491588	30.435
65.000	121.301329	123.554527	122.572443	31.401
67.000	118.939342	119.871711	119.430499	32.367
69.000	119.978735	123.954149	122.406268	33.333
71.000	119.784629	121.104859	120.494719	34.300
73.000	121.56236	123.554527	122.671685	35.266
75.000	120.536038	121.954668	121.303022	36.232
77.000	118.98299	122.455912	121.057726	37.198
79.000	119.618273	124.812498	122.949632	38.164
81.000	121.651143	122.455912	122.072142	39.130
83.000	119.701053	119.496719	119.600088	40.097
85.000	119.004896	121.404328	120.368254	41.063
87.000	121.272803	120.9588	121.118639	42.029
89.000	122.172146	122.897	122.549678	42.995
91.000	119.466601	120.674061	120.11216	43.961
93.000	119.796634	120.263625	120.036403	44.928
95.000	119.9298	120.398158	120.17029	45.894
97.000	119.736773	119.80795	119.772507	46.860
99.000	120.406202	121.954668	121.249085	47.826
101.000	119.760668	122.03639	121.045915	48.792
103.000	119.455043	120.9588	120.271684	49.758
105.000	126.023906	125.0412	125.560289	50.725
107.000	120.509916	123.172766	122.042311	51.691
109.000	119.571322	123.554527	122.004421	52.657

=Reduced Distance in units of wavelength.

Data for Fig.2-2a in Chapter 2.

Red Dist (λ)	Aug 24 PL	Aug 25 PL	Aug 30 PL	Avg PL (dB)
0.000	147.105593	137.89455	142.543294	142.514479
0.966	143.979729	133.903103	143.75204	140.544957
1.932	145.615366	135.395775	143.362552	141.457898
2.899	145.158108	134.535083	142.987039	140.89341
3.865	159.873056	148.11414	144.590983	150.859393
4.831	143.819172	134.056839	136.697747	138.191253
5.797	151.104785	135.395775	145.765443	144.088668
6.763	146.565364	134.700533	137.389333	139.551743
7.729	144.548951	135.578643	145.0412	141.722931
8.696	146.741733	142.576214	145.277158	144.865035
9.662	144.343763	134.869196	138.735231	139.316063
10.628	144.242958	136.555614	141.329224	140.709265
11.594	158.563025	138.650321	138.848596	145.353981
12.560	147.013189	136.151546	140.397547	141.187428
13.527	154.160863	135.578643	135.083817	141.607774
14.493	149.496658	140.721133	143.265724	144.494505
15.459	140.286748	134.869196	134.974104	136.710016
16.425	142.331525	136.151546	140.814517	139.765863
17.391	137.735171	133.172766	135.974833	135.62759
18.357	137.547699	132.370422	136.921303	135.613141
19.324	146.697304	141.786043	148.561288	145.681545
20.290	140.810679	135.395775	139.80738	138.671278
21.256	137.125385	135.216678	138.568734	136.970266
22.222	139.287268	132.370422	135.460641	135.70611
23.188	139.873056	133.60356	137.781001	137.085872
24.155	137.125385	132.118639	132.493883	133.912636
25.121	140.721133	135.395775	136.741733	137.619547
26.087	138.528351	133.172766	135.011251	135.570789
27.053	137.89455	134.700533	135.307491	135.967525
28.019	137.424928	134.700533	139.0206	137.048687
28.986	139.100468	135.765443	142.037127	138.967679
29.952	141.416375	139.193366	142.145981	140.918574
30.918	140.286748	143.630341	138.753742	140.890277
31.884	138.9176	135.395775	139.828326	138.047234
32.850	135.0412	133.172766	136.521391	134.911786
33.816	133.079868	134.056839	135.961386	134.366031
34.783	134.926153	133.457575	138.460568	135.614765
35.749	135.765443	135.765443	138.906696	136.812528
36.715	137.424928	134.213346	138.175392	136.604555
37.681	134.266148	132.118639	135.961386	134.115391
38.647	140.501225	133.457575	139.215599	137.7248
39.614	133.361597	135.395775	137.1214	135.292924
40.580	136.835828	135.765443	136.846594	136.482622
41.546	132.455998	134.372725	136.816889	134.548537
42.512	131.104785	130.330631	132.809282	131.414899
43.478	133.652772	133.033789	136.815542	134.500701
44.444	135.765443	131.290785	139.619244	135.558491
45.411	132.455998	135.765443	137.1214	135.11428
46.377	131.87395	131.404328	136.521391	133.266556
47.343	134.160863	130.0328	139.215599	134.469754
48.309	134.589883	130.9588	138.036239	134.528308

Data for Fig.2-3a in Chapter 2.

FS #1 W / PL :145 MHz

Data for Fig.2-2b in Chapter 2.

Red. Dist (λ)	Run #1 (dB)	Run #2 (dB)	Run #3 (dB)	Avg (dB)
4.348	106.036239	111.75204	106.036239	107.558043
5.314	111.457575	110.118639	111.75204	111.079877
6.280	122.110347	113.395775	122.514414	118.244502
7.246	112.700533	111.75204	112.056839	112.160853
8.213	116.040535	120.172146	114.555614	116.61528
9.179	116.040535	112.700533	114.9794	114.45965
10.145	108.535014	103.974833	109.635966	107.0206
11.111	112.700533	110.629721	110.897	111.361607
12.077	106.763855	104.609121	106.763855	105.984696
13.043	116.9176	112.700533	112.700533	113.892234
14.010	111.75204	111.172766	111.75204	111.554615
14.976	110.629721	109.635966	109.635966	109.954741
15.942	110.897	109.635966	108.535014	109.635966
16.908	110.118639	107.744843	111.457575	109.635966
17.874	111.75204	108.535014	110.118639	110.036316
18.841	111.75204	110.118639	111.75204	111.172766
19.807	110.897	106.679933	110.370422	109.104792
20.773	113.765443	110.897	113.395775	112.589894
21.739	113.395775	113.395775	113.395775	113.395775
22.705	112.700533	112.056839	114.555614	113.0412
23.671	110.897	111.172766	110.370422	110.806999
24.638	110.897	112.372725	107.744843	110.118639
25.604	109.635966	112.372725	108.535014	110.036316
26.570	110.118639	111.75204	108.535014	110.036316
27.536	110.118639	113.765443	110.629721	111.361607
28.502	106.036239	109.635966	105.293403	106.792016
29.469	106.763855	110.118639	111.457575	109.215914
30.435	106.036239	109.635966	107.744843	107.682135
31.401	110.629721	112.700533	108.535014	110.455989
32.367	108.535014	111.75204	109.635966	109.87395
33.333	111.457575	113.765443	112.700533	112.589894
34.300	113.765443	113.765443	112.056839	113.157779
35.266	110.370422	111.75204	110.897	110.987944
36.232	112.700533	110.897	111.172766	111.554615
37.198	110.629721	111.457575	110.370422	110.806999
38.164	111.75204	108.535014	110.629721	110.20175
39.130	110.897	108.9588	111.75204	110.455989
40.097	113.395775	112.056839	112.700533	112.700533
41.063	111.172766	112.056839	110.629721	111.266659
42.029	110.897	110.897	110.897	110.897
42.995	113.395775	112.700533	114.555614	113.517246
43.961	120.172146	119.0618	120.172146	119.786043
44.928	112.056839	111.75204	112.056839	111.954057
45.894	114.555614	112.700533	113.395775	113.517246
46.860	112.056839	111.75204	111.75204	111.852446
47.826	110.897	112.056839	111.457575	111.457575
48.792	118.077439	119.0618	116.9176	117.974626
49.758	114.9794	114.555614	114.555614	114.694577
50.725	110.897	110.897	110.370422	110.717895
51.691	111.75204	111.75204	111.172766	111.554615
52.657	110.370422	110.897	110.897	110.717895

FS #2 W / Jan 26 / PL: 145 MHz

Red Dist. (λ)	Run #1 (dB)	Run #2 (dB)	Run #3 (dB)	Avg. (dB)
0.000	132.372725	130.629721	131.172766	131.361693
0.966	126.679933	128.744323	126.679933	127.315125
1.932	131.172766	133.765443	132.700533	132.480517
2.899	131.172766	132.372725	132.372725	131.954149
3.865	132.372725	131.75204	130.629721	131.554527
4.831	132.372725	131.172766	141	133.892119
5.797	120.576214	125.882503	127.558043	124.139458
6.763	128.744323	128.130946	129.404328	128.744323
7.729	131.172766	132.372725	130.629721	131.361693
8.696	129.87395	129.87395	129.404328	129.714492
9.662	133.395775	131.75204	132.372725	132.480517
10.628	123.733543	123.733543	123.733543	123.733543
11.594	131.75204	131.75204	131.75204	131.75204
12.560	132.700533	132.372725	132.372725	132.480517
13.527	131.172766	131.172766	131.172766	131.172766
14.493	124.349822	125.882503	125.436975	125.198944
15.459	127.558043	129.404328	129.404328	128.744323
16.425	128.744323	128.744323	129.87395	129.104859
17.391	123.158108	123.158108	122.514414	122.9382
18.357	128.130946	127.558043	127.558043	127.744843
19.324	129.404328	130.370422	129.404328	129.714492
20.290	131.75204	133.765443	131.172766	132.160759
21.256	125.882503	125.436975	125.882503	125.73144
22.222	131.172766	131.75204	131.172766	131.361693
23.188	128.744323	128.744323	129.404328	128.9588
24.155	128.130946	125.013189	126.679933	126.514483
25.121	127.558043	125.882503	126.679933	126.679933
26.087	127.558043	125.882503	128.744323	127.315125
27.053	126.679933	127.558043	127.558043	127.255308
28.019	123.733543	124.609121	123.733543	124.015667
28.986	131.172766	132.700533	132.372725	132.056839
29.952	122.110347	122.110347	122.514414	122.242925
30.918	124.349822	123.733543	123.733543	123.93419
31.884	126.679933	128.744323	128.130946	127.80795
32.850	128.744323	128.744323	128.130946	128.535014
33.816	126.679933	126.352125	127.0206	126.679933
34.783	127.0206	127.0206	127.558043	127.196078
35.749	129.404328	129.87395	129.404328	129.558142
36.715	132.372725	131.172766	131.75204	131.75204
37.681	126.679933	128.744323	126.679933	127.315125
38.647	124.098039	124.349822	123.733543	124.056817
39.614	123.733543	123.733543	123.733543	123.733543
40.580	123.733543	123.733543	124.349822	123.93419
41.546	123.733543	123.733543	124.349822	123.93419
42.512	125.013189	123.158108	126.679933	124.831324
43.478	125.882503	126.679933	125.882503	126.140316
44.444	129.87395	130.370422	131.172766	130.455912
45.411	129.87395	128.744323	130.370422	129.635966
46.377	128.744323	128.744323	127.558043	128.330631
47.343	128.130946	128.744323	128.744323	128.535014
48.309	127.558043	127.558043	126.679933	127.255308

Data for Fig.2-3b in Chapter 2.

Data for Fig.3-2a in Chapter 3.

Red Dist(λ)	Sep 7 PL(dB)	Sep 8 PL(dB)	Avg PL(dB)
6.667	117.119	115.815	116.442
8.148	126.416	123.139	124.624
9.630	112.059	113.792	112.883
11.111	122.274	121.086	121.660
12.593	115.744	115.131	115.432
14.074	114.936	119.481	116.914
15.556	117.119	118.653	117.852
17.037	117.630	118.362	117.988
18.519	113.406	114.745	114.049
20.000	120.276	127.172	123.057
21.481	120.276	116.253	118.034
22.963	118.080	118.852	118.458
24.444	119.701	122.895	121.152
25.926	113.193	119.926	115.923
27.407	111.609	118.080	114.255
28.889	108.661	114.745	111.181
30.370	113.514	114.497	113.992
31.852	114.315	116.794	115.466
33.333	122.274	118.954	120.456
34.815	112.534	113.140	112.832
36.296	120.276	119.373	119.812
37.778	112.883	117.718	114.968
39.259	113.736	113.140	113.433
40.741	112.883	114.620	113.708
42.222	111.435	113.569	112.437
43.704	112.883	114.682	113.736
45.185	109.446	109.902	109.671
46.667	108.851	108.355	108.599
48.148	112.632	115.674	114.021
49.630	113.036	109.446	111.057
51.111	108.883	108.087	108.476
52.593	109.724	108.058	108.851
54.074	114.745	109.689	111.854
55.556	111.609	113.569	112.534
57.037	112.152	111.876	112.013
58.519	112.246	110.346	111.244
60.000	109.795	108.661	109.210
61.481	113.680	107.042	109.741
62.963	108.476	106.913	107.659
64.444	109.344	111.522	110.365
65.926	110.694	109.689	110.177
67.407	110.384	111.057	110.714
68.889	112.341	109.446	110.773
70.370	110.084	110.195	110.140
71.852	109.110	110.384	109.724
73.333	114.196	108.661	110.995
74.815	118.653	109.866	113.193
76.296	114.497	111.831	113.062
77.778	116.794	112.246	114.226
79.259	115.331	111.967	113.487
80.667	117.988	114.021	115.780

Data for Fig.3-3b in Chapter 3.

Red Dist.(λ)	Sep 7 PL(dB)	Sep 8 PL(dB)	Avg PL(dB)
0.000	130.499	128.000	129.160
1.481	132.682	130.121	131.308
2.963	127.172	126.179	126.662
4.444	131.308	132.437	131.855
5.926	131.742	127.856	129.583
7.407	128.755	130.121	129.412
8.889	130.307	130.893	130.595
10.370	128.915	130.499	129.671
11.852	125.501	126.416	125.947
13.333	129.938	127.576	128.677
14.815	129.243	133.193	130.994
16.296	125.501	125.077	125.287
17.778	126.913	129.078	127.928
19.259	129.584	128.294	128.915
20.741	135.264	134.619	134.936
22.222	125.501	127.439	126.416
23.704	126.661	128.915	127.715
25.185	132.933	134.021	133.459
26.667	125.501	125.077	125.287
28.148	128.600	134.021	130.894
29.630	131.521	137.543	134.021
31.111	130.499	131.742	131.098
32.593	126.179	126.179	126.179
34.074	123.918	125.947	124.873
35.556	129.078	127.856	128.446
37.037	124.478	129.759	126.723
38.519	123.739	123.223	123.477
40.000	123.391	125.287	124.287
41.481	122.274	129.412	125.130
42.963	131.742	127.439	129.326
44.444	127.172	125.947	126.537
45.926	129.412	130.893	130.120
47.407	120.276	123.391	121.694
48.889	127.439	125.721	126.537
50.370	125.947	124.873	125.393
51.852	122.735	125.287	123.918
53.333	127.856	129.078	128.446
54.815	128.000	127.305	127.646
56.296	125.947	132.682	128.677
57.778	123.057	131.098	126.178
59.259	123.391	128.294	125.501
60.741	125.947	125.077	125.501
62.222	123.563	125.721	124.575
63.704	124.673	125.077	124.873
65.185	125.947	123.739	124.773
66.667	125.721	126.661	126.178
68.148	125.501	125.077	125.287
69.630	126.661	121.694	123.827
71.111	126.416	125.077	125.721
72.593	125.721	128.294	126.912
74.000	125.287	125.287	125.287

Data for Fig.3-2b in Chapter 3.

Red Dist(λ)	Trial 1 PL(dB)	Trial 2 PL(dB)	Trial 3 PL(dB)	Avg PL(dB)
6.747	117.021	122.701	115.013	117.682
8.246	123.396	119.404	124.979	122.266
9.745	109.416	109.416	109.416	109.416
11.244	128.721	127.478	117.936	123.276
12.744	109.416	109.416	112.830	110.412
14.243	113.270	109.416	109.416	110.521
15.742	128.721	119.404	112.830	118.131
17.241	117.745	119.404	114.479	116.963
18.741	111.915	113.270	106.918	110.251
20.240	111.000	109.416	119.179	112.276
21.739	104.979	106.918	103.396	104.979
23.238	123.396	113.270	112.830	115.341
24.738	113.270	122.701	117.936	117.137
26.237	113.270	109.416	115.013	112.243
27.736	115.013	109.416	109.416	110.914
29.235	113.270	112.830	109.416	111.661
30.735	109.416	104.979	103.396	105.579
32.234	109.416	109.416	106.918	108.501
33.733	103.396	104.979	103.396	103.892
35.232	104.979	103.396	103.396	103.892
36.732	108.077	108.077	105.895	107.287
38.231	112.830	115.013	112.830	113.499
39.730	100.499	100.499	100.119	100.370
41.229	101.173	100.897	101.173	101.080
42.729	109.416	106.918	105.895	107.287
44.228	109.416	112.830	109.416	110.412
45.727	106.918	106.918	108.077	107.287
47.226	106.918	104.979	104.979	105.579
48.726	100.119	100.119	100.119	100.119
50.225	103.396	104.979	104.979	104.419
51.724	115.013	112.830	111.915	113.158
53.223	109.416	112.830	111.000	110.971
54.723	109.416	117.021	112.830	112.549
56.222	106.918	112.830	108.077	108.924
57.721	106.918	109.416	108.077	108.077
59.220	103.396	104.152	104.152	103.892
60.720	105.895	108.077	109.416	107.673
62.219	104.979	108.077	105.895	106.222
63.718	103.396	104.979	104.152	104.152
65.217	111.000	109.416	109.416	109.913
66.717	103.396	103.396	104.152	103.640
68.216	108.077	108.077	108.077	108.077
69.715	106.918	105.895	106.918	106.563
71.214	106.918	109.416	108.077	108.077
72.714	104.979	106.918	104.979	105.579
74.213	108.077	105.895	106.918	106.918
75.712	104.979	103.396	103.396	103.892
77.211	108.077	109.416	109.416	108.947
78.711	105.895	104.979	105.895	105.579
80.210	102.057	101.173	101.173	101.458
81.709	106.918	106.918	105.895	106.563

FS #2 / W / PL: 225 MHz

Data for Fig.3-3a in Chapter 3.

Red Dist(λ)	Trial 1 PL(dB)	Trial 2 PL(dB)	Trial 3 PL(dB)	Avg PL(dB)
0	123.041	122.057	122.373	122.481
1.499	124.979	123.041	124.979	124.284
2.999	125.895	123.041	123.041	123.892
4.498	125.895	124.979	123.041	124.556
5.997	115.013	116.514	115.013	115.485
7.496	122.057	121.173	121.173	121.458
8.996	122.373	121.173	121.173	121.555
10.495	119.636	121.173	118.959	119.874
11.994	122.057	123.041	117.936	120.718
19.49	123.041	125.895	123.041	123.892
20.99	126.391	129.416	129.416	128.287
22.489	118.959	119.636	117.936	118.815
23.988	131.000	135.437	135.437	133.694
25.487	122.057	121.173	122.057	121.752
26.987	121.173	121.173	121.173	121.173
28.486	118.959	118.959	119.636	119.179
29.985	119.179	119.636	119.636	119.481
31.484	119.636	120.370	119.636	119.874
32.984	121.173	121.173	121.173	121.173
34.483	121.173	119.636	119.636	120.119
35.982	124.979	122.057	126.391	124.284
37.481	119.404	117.375	117.375	118.000
38.981	122.057	123.041	123.041	122.701
40.48	120.370	121.173	121.173	120.897
41.979	121.173	121.173	119.636	120.630
43.478	123.041	122.057	123.041	122.701
44.978	122.057	119.636	121.173	120.897
46.477	121.752	122.057	121.173	121.653
47.976	118.959	121.173	117.936	119.253
49.475	119.636	119.636	117.936	119.031
50.975	122.057	120.370	123.041	121.752
52.474	119.179	120.370	119.404	119.636
53.973	117.196	117.936	117.375	117.497
55.472	129.416	131.000	125.895	128.501
56.972	129.416	131.000	129.416	129.913
58.471	119.636	122.057	121.173	120.897
59.97	124.979	124.979	124.979	124.979
61.469	134.098	138.959	125.895	131.294
62.969	138.959	138.959	129.416	134.521
64.468	129.416	127.478	125.895	127.478
65.967	123.041	122.701	123.041	122.926
67.466	121.173	120.370	119.636	120.370
68.966	120.370	120.370	119.636	120.119
70.465	126.391	124.979	125.895	125.735
71.964	121.752	121.173	121.752	121.555
73.463	119.179	118.959	118.959	119.031
74.963	129.416	125.895	126.391	127.100

Appendix D

Details of Path-loss Calculations

1. Summer (Aug.24 and 25, 1991) measurements on 144 MHz:

Here, the transmitter antenna is rated at 11 dbd (= 13 dbi) gain, with a beam-width of 48°. This antenna was aimed midway between the two sites (separated by 23°). The estimated decrease (fall-off) in the direction of each of the sites is 1 db, The transmitter power is approximately 15 W.

At the receiver, the dipole has a gain of 2 dbi. Hence

$PL = 10\log P_{tx} + 10\log 50 + 120 + (A_{tx}-1) + A_{rx} - 20\log V(\mu)$ becomes

$= 10\log 15 + 10\log 50 + 120 + (13-1) + 2 - 20\log V(\mu)$

$PL = 163 - 20\log V(\mu)$.db.

2. Summer (Aug.30/91) measurements on 144 MHz

Transmitter power is approximately 15 W. Both antennas are dipoles. Hence,

$PL = 10\log P_{tx} + 10\log 50 + 120 + A_{tx} + A_{rx} - 20\log V(\mu)$ becomes

$= 10\log 15 + 10\log 50 + 120 + 2 + 2 - 20\log V(\mu)$

$PL = 152 - 20\log V(\mu)$ db

3. Winter measurements on 145 MHz.

The transmitter power is approximately 15 W; transmitting antenna has 13-1 dbi effective gain along the path.

$PL = 10\log P_{tx} + 10\log 50 + 120 + (A_{tx}-1) + A_{rx} - 20\log V(\mu)$ becomes

$PL = 10\log 15 + 10\log 50 + 120 + (13-1) + 2 - 20\log V(\mu)$;

$PL = 161 - 20\log V(\mu)$ db.

Appendix D

4. Summer measurements on 222 MHz

Transmitter power is approximately 5 W; both antennas are dipoles. Hence

$PL = 10\log P_{tx} + 10\log 50 + 120 + A_{tx} + A_{rx} - 20\log V(\mu)$ becomes

$= 10\log 5 + 10\log 50 + 120 + 2 + 2 - 20\log V(\mu)$

$PL = 148 - 20\log V(\mu)$ db.

5. Winter measurements on 225 MHz.

Transmitter power is approximately 10 W; both antennas are dipoles. Hence,

$PL = 10\log P_{tx} + 10\log 50 + 120 + A_{tx} + A_{rx} - 20\log V(\mu)$ becomes

$= 10\log 10 + 10\log 50 + 120 + 2 + 2 - 20\log V(\mu)$;

$PL = 151 - 20\log V(\mu)$ db

DSS CONTRACT NO: 36001-1-3505

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Phase 2

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