OmniTrax Field Strength Test Report

Submitted to

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1 Introduction

This report describes tests made to establish the compliance of the OmniTrax leaky cable security system with FCC Part 15. The tests made use of OmniTrax prototype processors and OC2 400 meter cable sets installed at:

1) Hammond Farm near Ashton Ontario
2) SITE test area at the Senstar-Stellar facility near Carp Ontario.
3) JWP Test Site near Carleton Place Ontario

Appendix A is a list of equipment used. Appendix B is a table of radial field measurements for the three sites. Site descriptions are included in Appendix C including addresses, test personnel and site photos. Appendix D gives details of the radial field strength procedure.

2 Objectives

OmniTrax transmits a signal on one buried leak-coaxial cable and receives that signal on a parallel leaky cable. Spacing between the receive and transmit cables is about 1.5 meters When a person enters the area near or between the cables there is a small change in the received signal. This change is termed sensitivity and is a function of the transmitted power, the cable design and soil conditions. The received signal from a person can be from -100 dB to -150 dB below the transmitted signal. The variation is primarily due to different soil conditions from one site to the next.

Radiated field strength is also directly proportional to the same three factors - transmitted power, cable design and soil type. The first two factors are under the designers control but soil type is site dependant.

In order to achieve reliable detection it is necessary to transmit enough power to maintain an adequate signal to noise ratio. At the same time it is necessary to limit transmitted power so as not to exceed permitted field strength limits. In order for the system to comply with field strength regulations and at the same time have adequate signal to noise ratio over the expected range of soil conditions it will be necessary to vary the transmit power as a function of soil type.

What is effectively happening is that the gain of the antenna (in the cable) attached to the processor changes from site to site and the transmit power is being adjusted to compensate for the changed antenna. Section 15.203 of the FCC regulations anticipates this situation by allowing for variations in antenna gain for systems “such as perimeter protection systems” that are professionally installed.

Since the OmniTrax transmission is in the frequency range of 26 to 37 MH two different limits apply. Section 15.209 states that below 30 MHz the maximum permitted field is 30 μV/m measured at 30 meters while above 30 MHz the maximum field is 100 μV/m measured at 3 meters. In accordance with ANSI C63.4-2003 below 30 MHz the measurement bandwidth shall be 9 kHz while above 30 MHz the measurement bandwidth shall be 100 kHz. Because OmniTrax uses a spread spectrum signal this change in bandwidth is very significant and results in the limit being effectively much lower above 30 MHz.

The field produced by OmniTrax takes the form of a surface wave over the cables. For this reason the field decays as a modified Bessel function of the first kind for the region nearest the cables. So the measurement at 3 meters is always significantly more than 20 dB higher (the decay expected for a normal antenna) than the measurement at 30 meters. Because the goal is to measure radiated (as opposed to guided fields) the OmniTrax fields have been calculated from the measurement at 30 meters and extrapolated back to 3 meters

There is a precedent for making the measurements above 30 MHz at 30 meters rather than at 3 meters.[1] In this case the limit is extrapolated at 20 dB per decade so that limit used becomes 10 μV/m at 30 meters for frequencies above 30 MHz. The two factors taken together (field limit and bandwidth) mean that the effective limit for OmniTrax drops 22 dB at 30 MHz. For this reason we will concern ourselves primarily with the regulations for frequencies above 30 MHz.

Fortunately field strength and sensitivity both vary in a similar way with soil type so that it is possible to both comply with the field strength limit and at the same time have adequate SNR.

It is proposed to set the OmniTrax transmit power according to

$$TxPower = \frac{-AbsSensdB}{2} - 63 \qquad (1)$$

Where

Tx Power is the power transmitted in dBm as measured with the CISPR 120 kHz bandwidth and quasi peak detector.

AbsSensdB is the absolute sensitivity in dB

For examples the peak sensitivity for the Hammond Site is -94 dB. So the maximum power that can be tramsitted at that site is:

Tx Power = -(-94)/2 -63

Tx Power = -16 dBm

Note that the power is set inversely proportionally to the square root (divide by 2 in dB) of the peak sensitivity. This is because sensitivity depends on the antenna gain of both the receive and transmit cables. The higher the sensitivity the lower the transmitter power that can be allowed and still maintain an acceptable field strength.

In this report it will demonstrated that

1) Field strength is directly related to the square root of the sensitivity.
2) When the Tx power is set according to equation 1 the field strength is within the FCC field strength limits.

The measurements made at each site are:

1) Recording the system sensitivity.

[1] See FCC Part 15:31 f (1) and f(2).

2) Recording the field strength for each cable over the system center line (midway between the two cables).[2]
3) At the four locations of highest field strength over the system center line measuring the field strength out to 30 meters radial distance from the cable.

3 OmniTrax Transmitted Signal

3.1 Field Strength Calculation

Because the field levels are very low it is impractical to measure the fields directly. What has been done is to increase the transmit power to make the fields measurable and then correct the readings for the operational transmit level (as determined by equation 1). The measurements have also been made with a meter measuring 100 kHz bandwidth with a peak detector.[3] At each site the transmit source was also measured with the same settings.

Field strength in dBμV/m is calculated as follows:

$$FieldStrength = MeasuredValue + AntennaFactor + TxPower - TestSignal \qquad (2)$$

Here

MeasuredValue is the signal measured in dBμV

AntennaFactor is in dB and is found from the antenna calibration data.

TxPower is the power calculated from equation (1) for the site in question and is in dBm

TestSignal (dBm) is the signal source used for the test measured with the same bandwidth and other settings as are used for the field measurements.

For example the measured value at the Hammond site for radial 1 at 30 meters, one meter antenna height and vertical polarization is 17.2 μV. The Tx power calculated from equation 1 is (-16) dBm. So the field strength is:

FieldStrength = 17.2 + 13.8 + (-16) -8.2

FieldStrength = 6.8 μV/m

3.2 Tx Power

Figure 1 shows the OmniTrax signal as measured with a CISPR quasi peak meter. The signal uses a carrier at 32.15 MHz and is spread with a direct sequence code with a chip length of 187

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[2] For operation of OmniTrax it does not matter which cable is transmitting and which is receive. What is referred to here is measuring the field of each cable when it is used as the transmit cable.

[3] Making all the measurements with the CISPR 120 kHz bandwidth and quasi-peak detector would be far too time consuming.

nsec. The pseudo random code repeats in approximately 50 msec so that individual spectral lines are not resolved by the 120 kHz CISPR bandwidth.

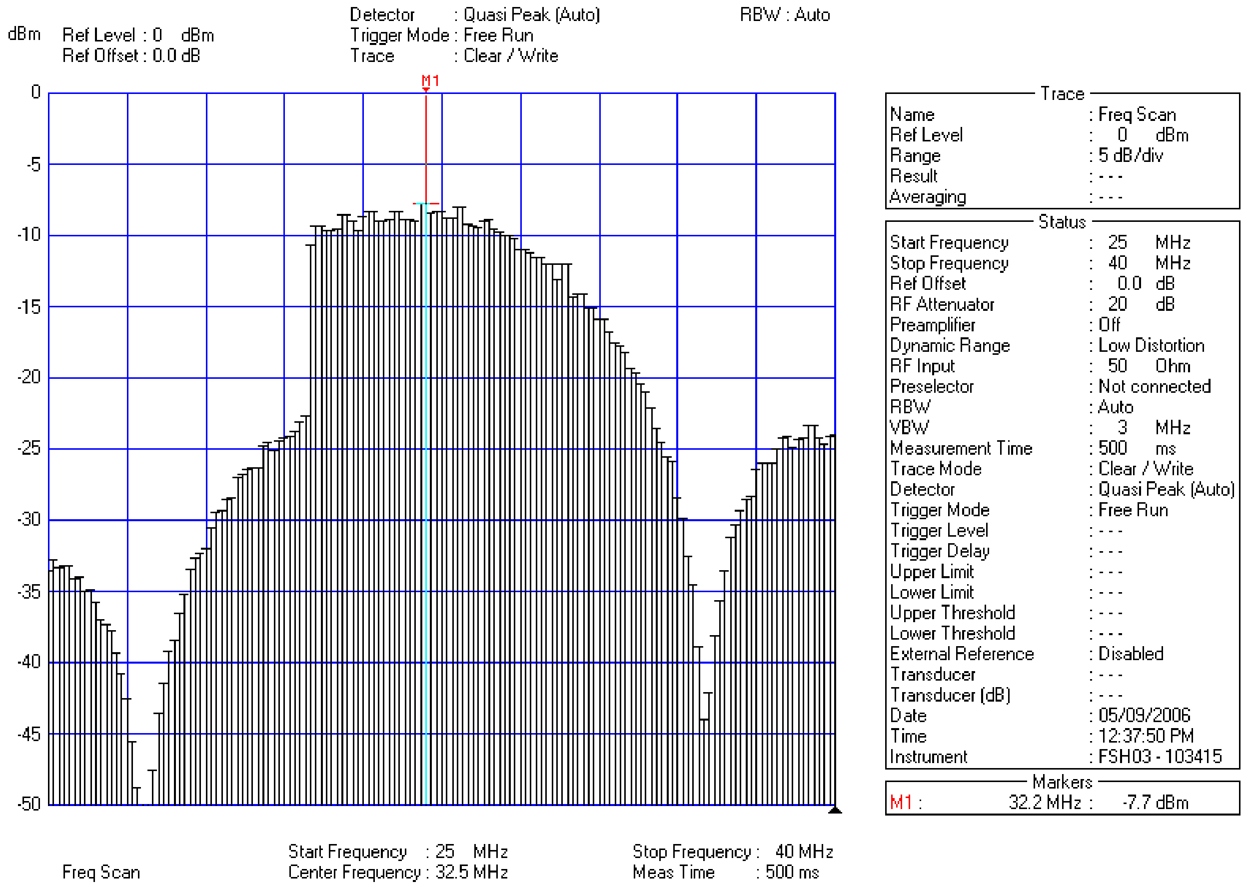

Figure 1 CISPR Measurement of OmniTrax Transmitted Signal

The CISPR bandwidth is 9 kHz below 30 MHz and 120 kHz above 30 MHz. The reading is Quasi Peak. Note the jump at 30 MHz because of the increased bandwidth. Since the measured signal is –7.7 dBm the transmit power for equation 1 is -7.7 dBm.

3.3 Harmonics

Figure 2 shows the OmniTrax signal measured from 0 to 200 MHz

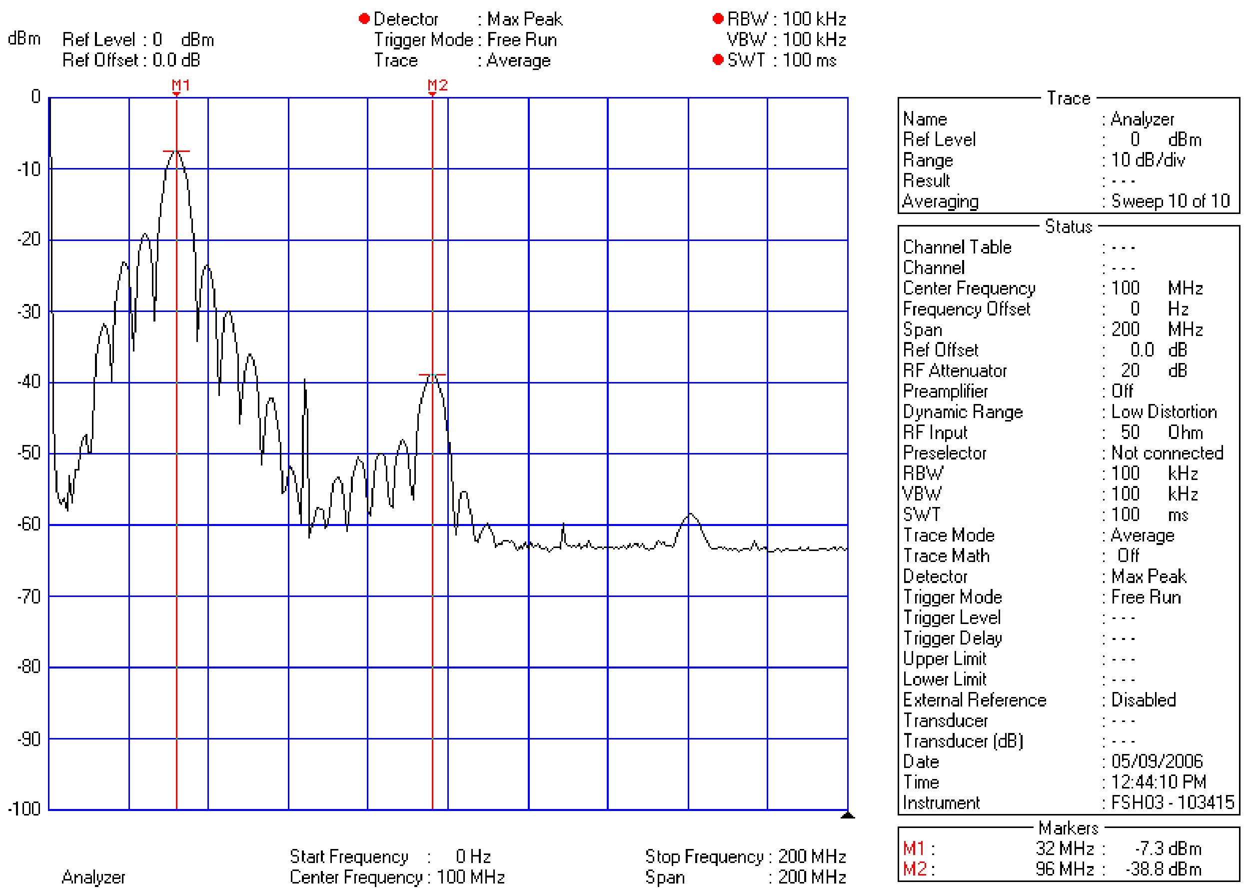

Figure 2 OmniTrax Transmitter Harmonics

Harmonics are observed at 64, 96, 128 and 161 MHz. The biggest is at 96 MHz and it is 21.5 dB below the main peak at 32.15 MHz

4 Measurement Method

4.1 Longitudinal

The field strength was measured every 5 meters along the cable between the two cables with the antenna height above ground (ground to antenna center) set at 1 meter. The field was measured twice – once for each cable acting as the transmit cable.

4.2 Radials

For the radial measurements, the OmniTrax Tx power was set high enough to accurately measure the fields at 30 meters. If the operational power setting from equation 1 had been used the field would have been well below the noise level of the signal received by the biconical antenna. This value was recorded and is used as the test signal in equation 2.

Four areas with relatively high field strength on the longitudinal measurement were chosen to do radial measurements. For each radial, the field strength was measured at 1, 2, 3, 5, 10, 20 and 30 meters, laterally from the transmit cable. Measurements were taken at both 1.0 and 2.0 meters above ground. Some locations were also checked at 3 and 4 meters height but the worst case measurements were always at 1 or 2 meters so the bulk of the measurements are at those antenna heights. For most radials, measurements were made with both horizontal and vertical polarization. In some cases horizontal measurements were only made out to 10 or 20 meters because the horizontal field was below the background noise at longer distances.

5 Results

5.1 Longitudinal Field Strength

The field strength over the center line of the system is shown below for each of the three installations. This is shown for both cables and the locations chosen for the radial measurements are indicated.

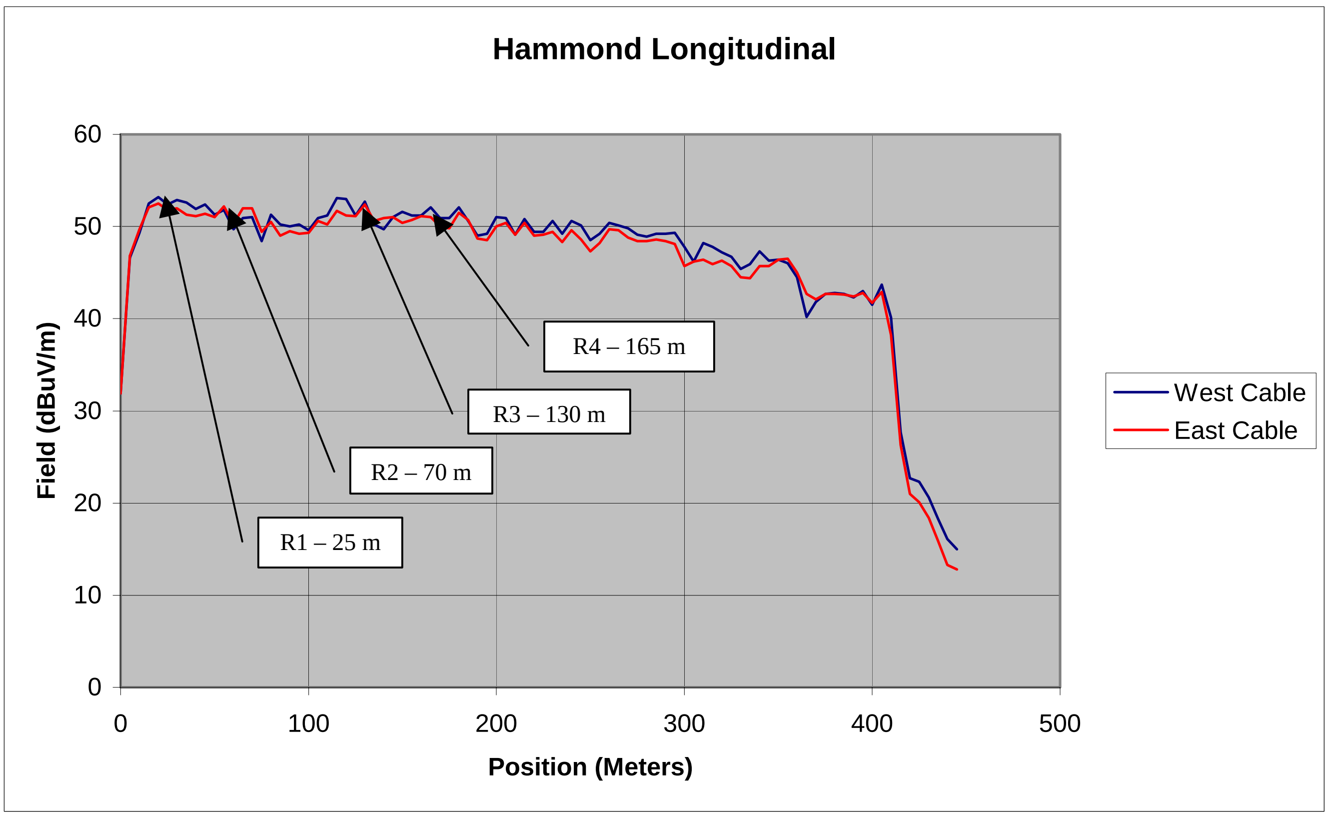

Figure 4 Hammond – Field Over Cables

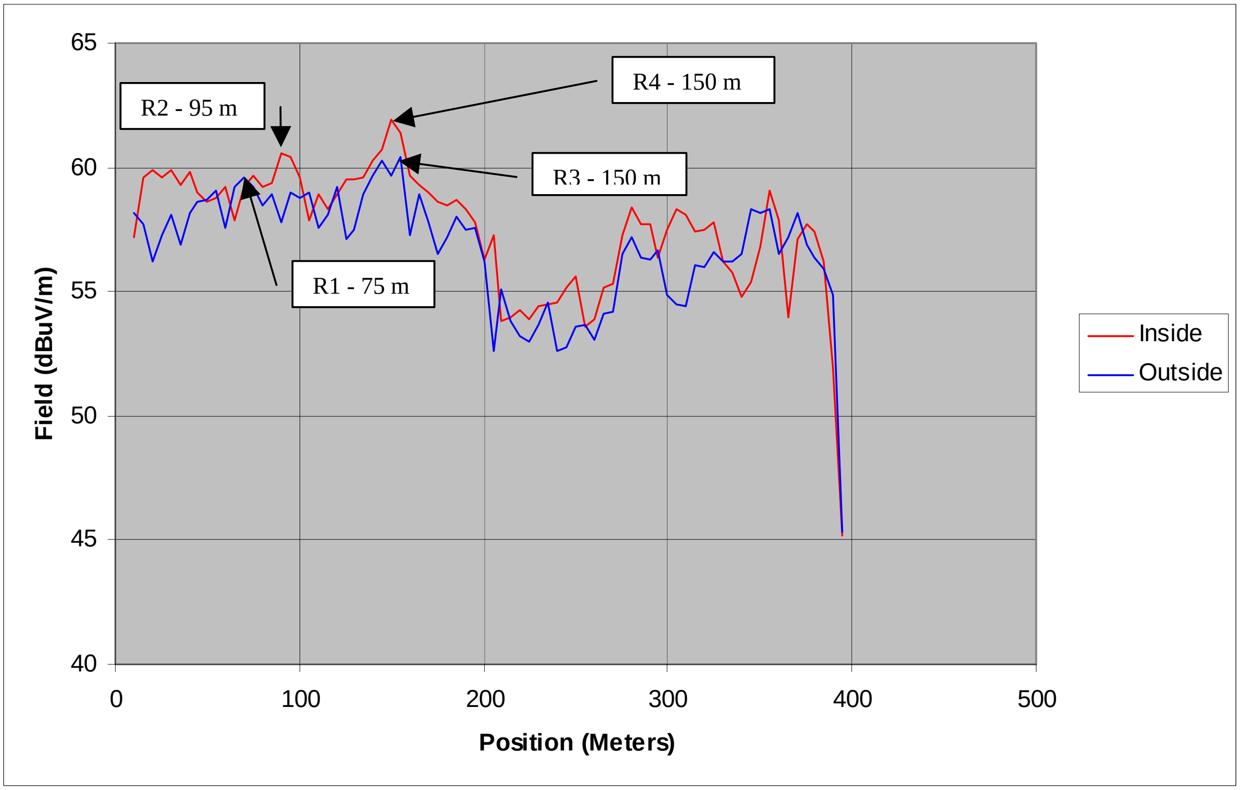

Figure 5 SITE – Field Over Cables

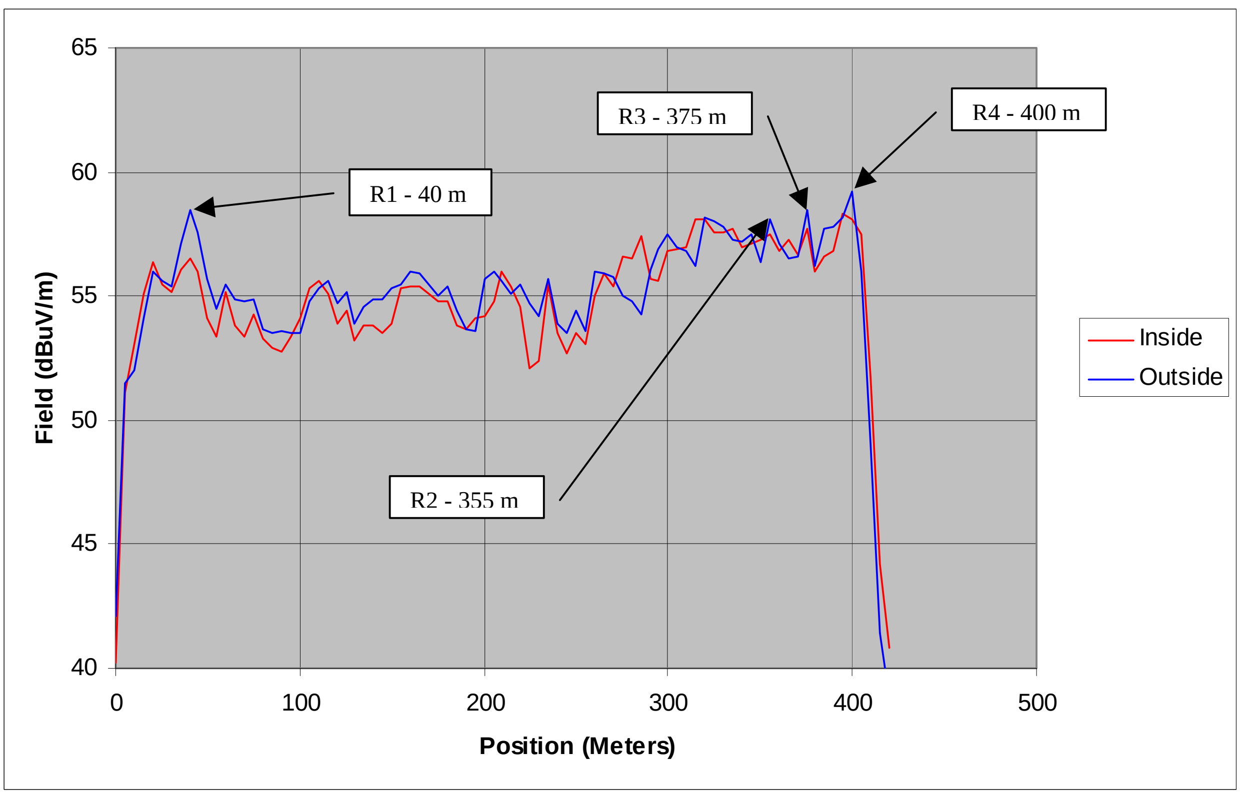

Figure 6 JWP – Field Over Cables

5.2 Sensitivity and Tx&Rx Field Strength

The sensitivity to a person is proportional to the antenna gain of both cables combined. By adding (in dB) the field strength for the two cables together we get a result that is comparable to sensitivity. In the following three charts the sensitivity, measured with a longitudinal walk, is shown together with the field strength for the two cables added (logarithmically) together. This latter curve is proportional to the product of the antenna gains for each cable.

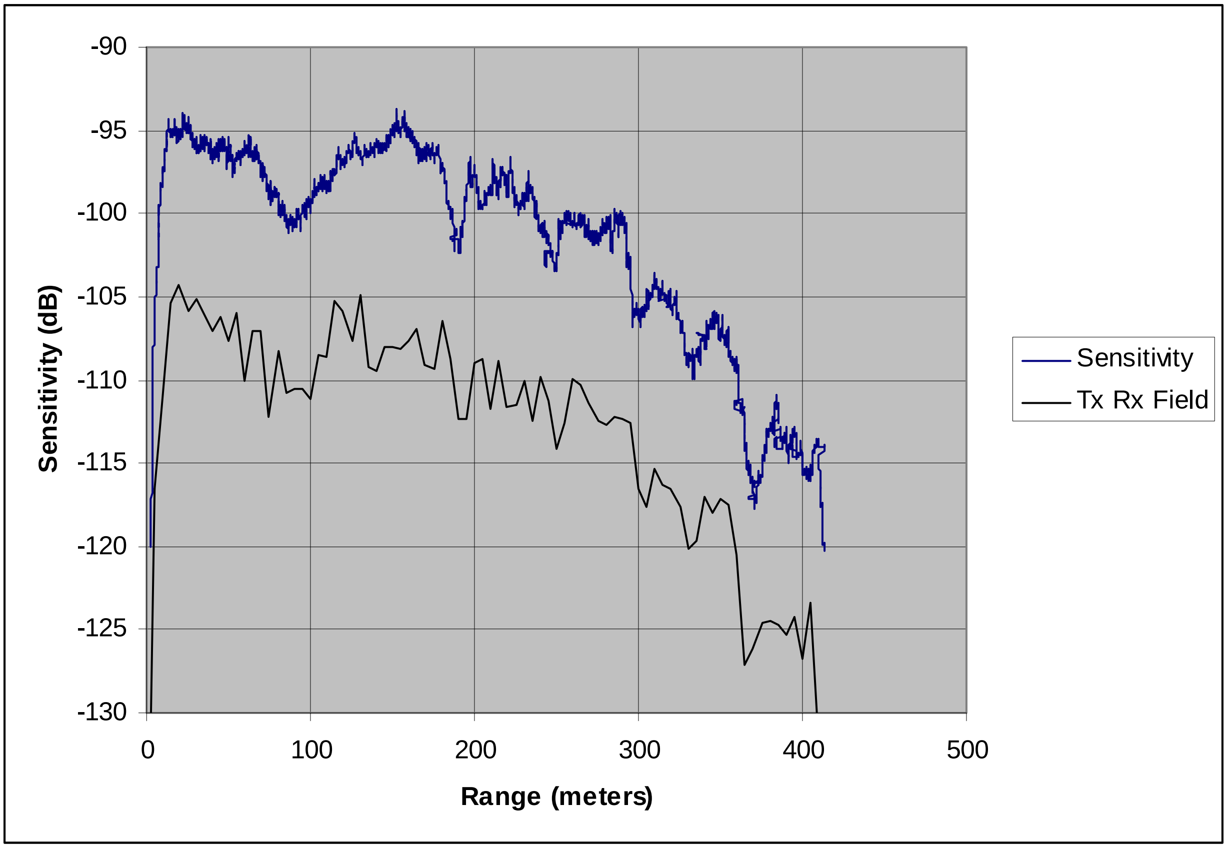

Figure 7 – Hammond Sensitivity and Tx Rx Field

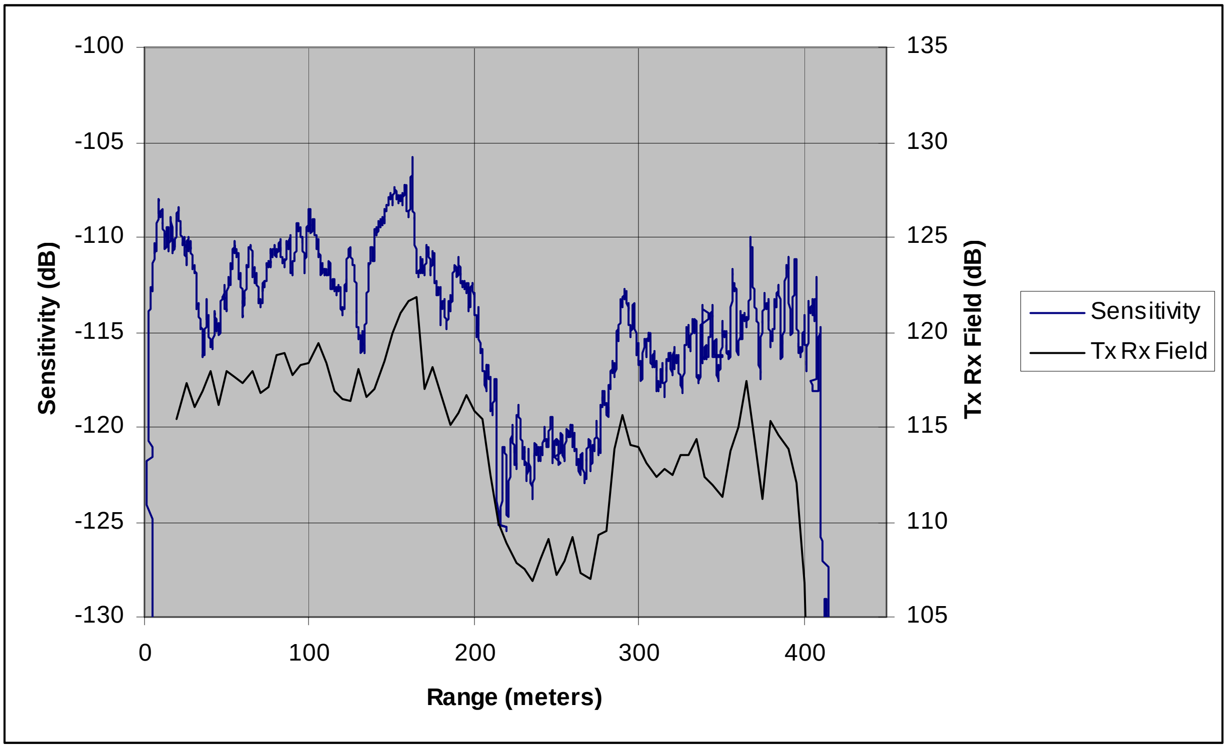

Figure 8 – SITE Sensitivity and Tx Rx Field

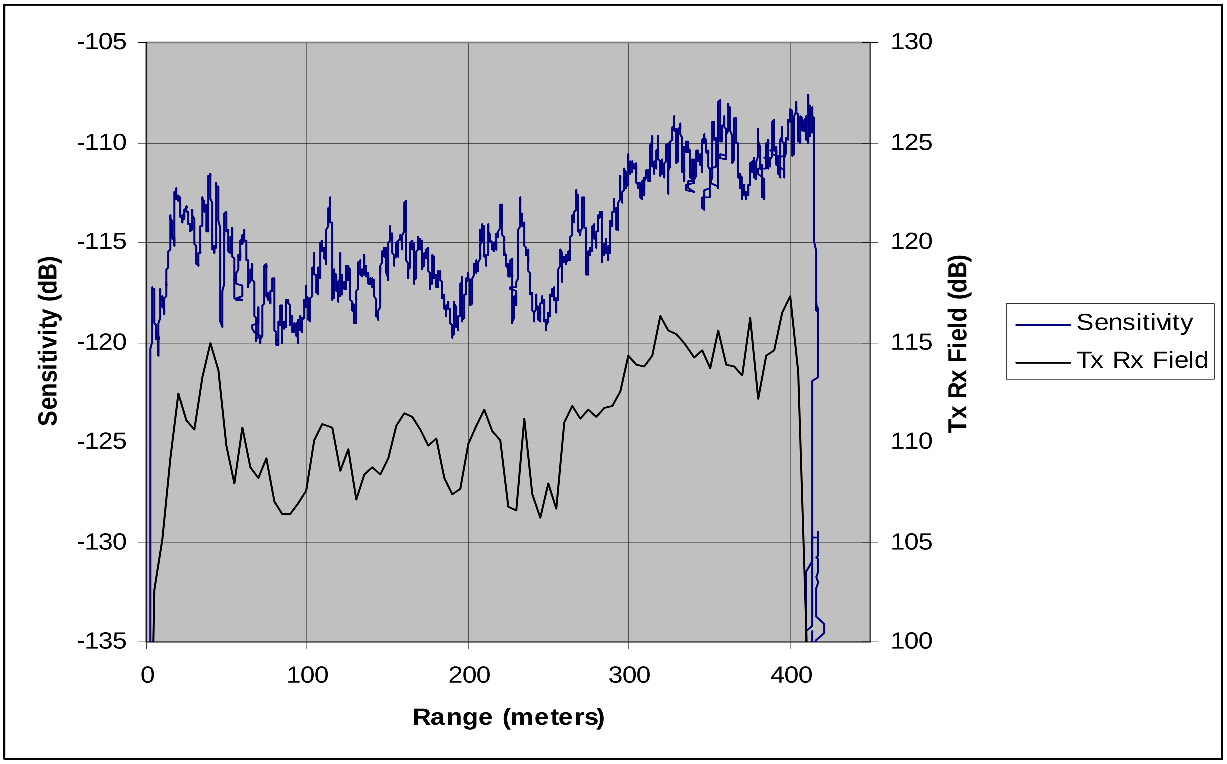

Figure 9 – JWP Sensitivity and Tx Rx Field

Note that the amplitude scale for the walk (left scale) is in absolute dB. This is the response of a target relative to the transmit signal. The combined Tx Rx field data is on the right hand scale. Both the sensitivity and the Tx Rx field data are presented at 5 dB per division.

Note the strong correlation between the sensitivity data and the field data both along the cable at each site and from one site to the next.

From the sensitivity data the transmit power is derived using equation 1 and is shown in Table 1.

	Peak Sensitivity	Transmit Power (dBm)
Hammond	-94	-16.0
SITE	-105	-10.5
JWP	-108	-9.0

Table 1 – Peak Sensitivity and Transmitter Power

For example 108/2 = 54. 54 – 63 = -9.

Hammond Radials

With the transmit power corrected to -16.0 dBm (CISPR 120 kHz) the following radial fields where measured at the Hammond site.

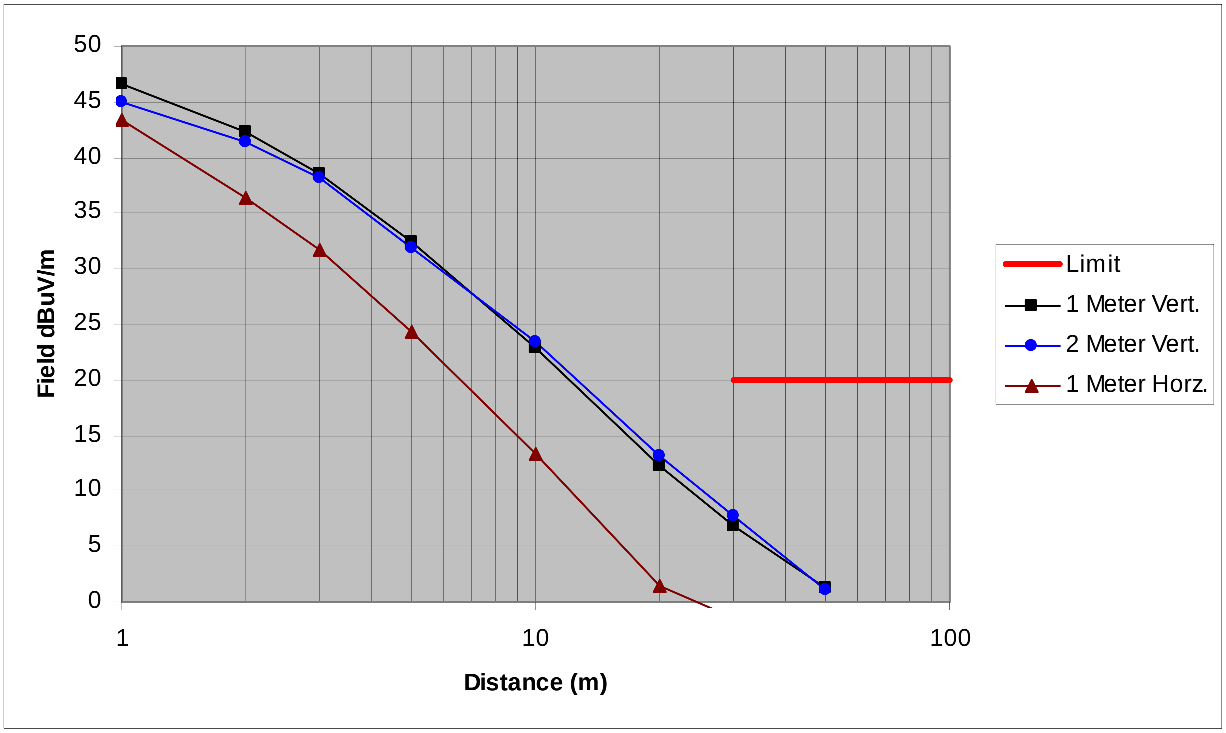

Figure 10 – Hammond Radial 25 meters

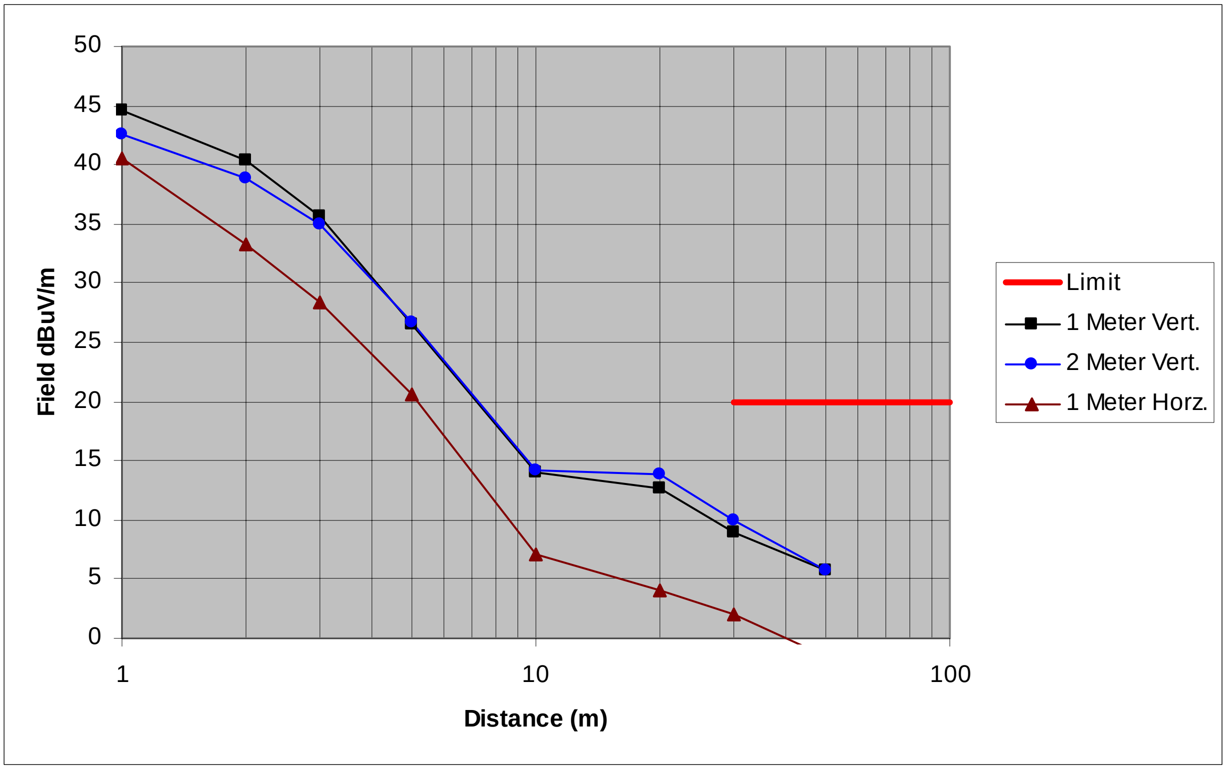

Figure 11 – Hammond Radial 70 meters

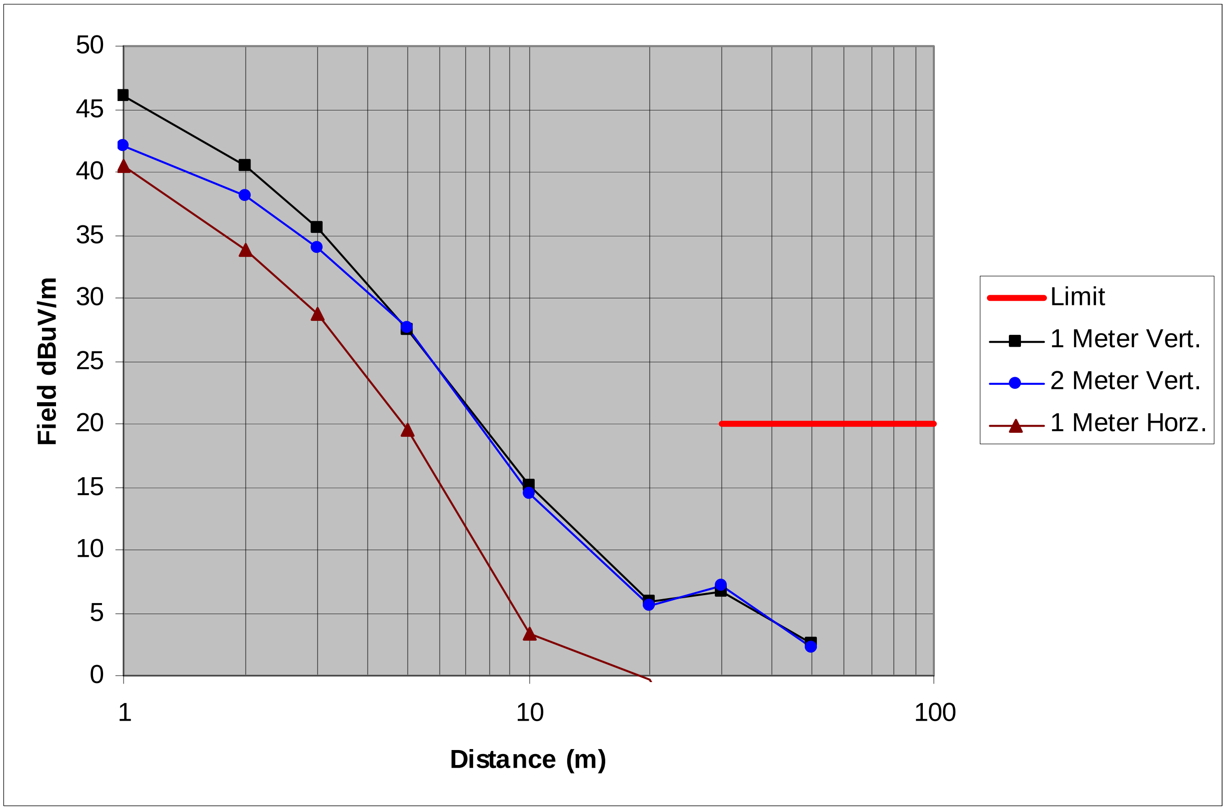

Figure 12 – Hammond Radial 130 meters

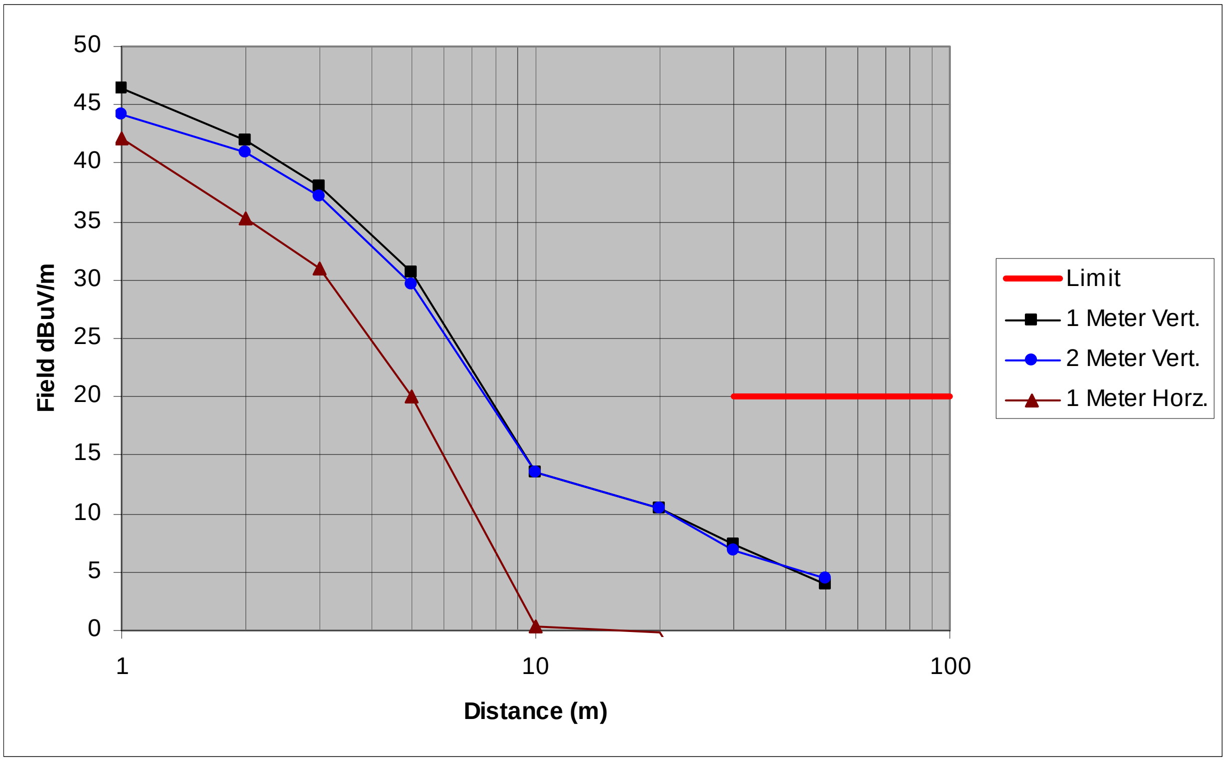

Figure 13 – Hammond Radial 165 meters

5.3 SITE - Radials

With the transmit power corrected to -10.5 dBm (CISPR 120 kHz) the following radial fields where measured at the SITE site.

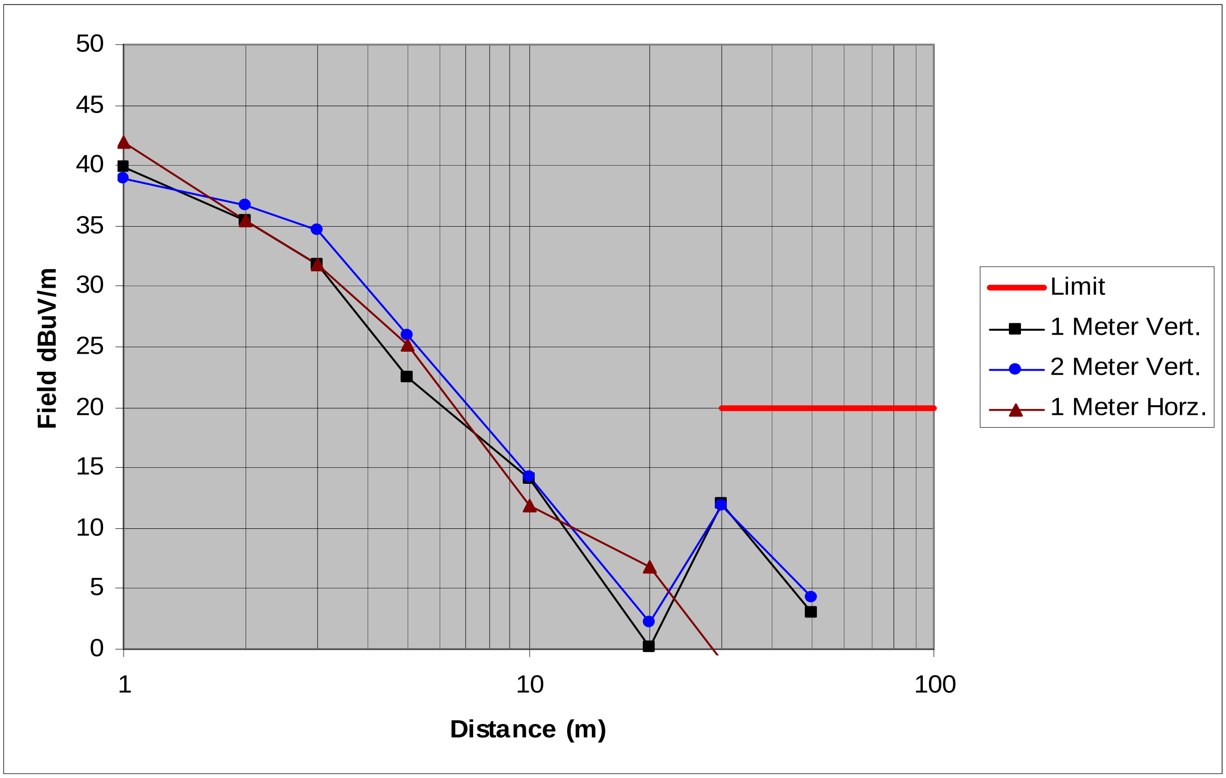

Figure 14 – SITE Radial 75 meters

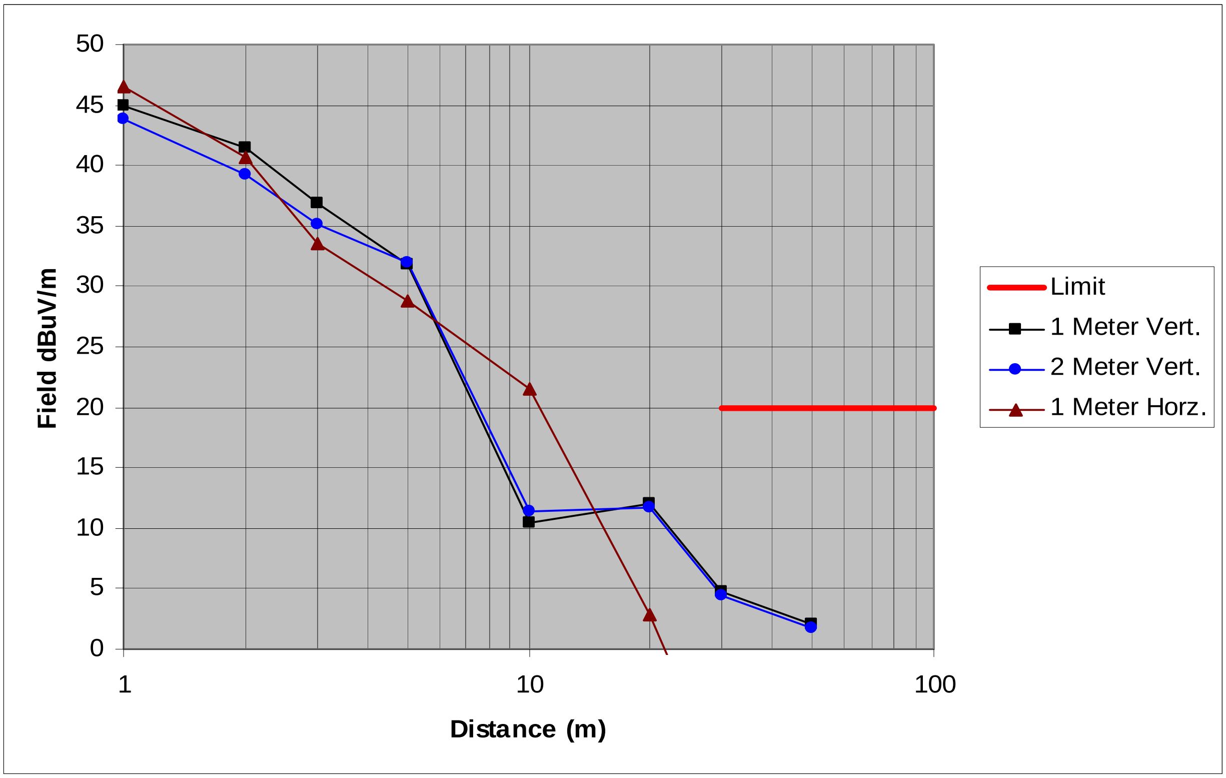

Figure 15 – SITE Radial 95 meters

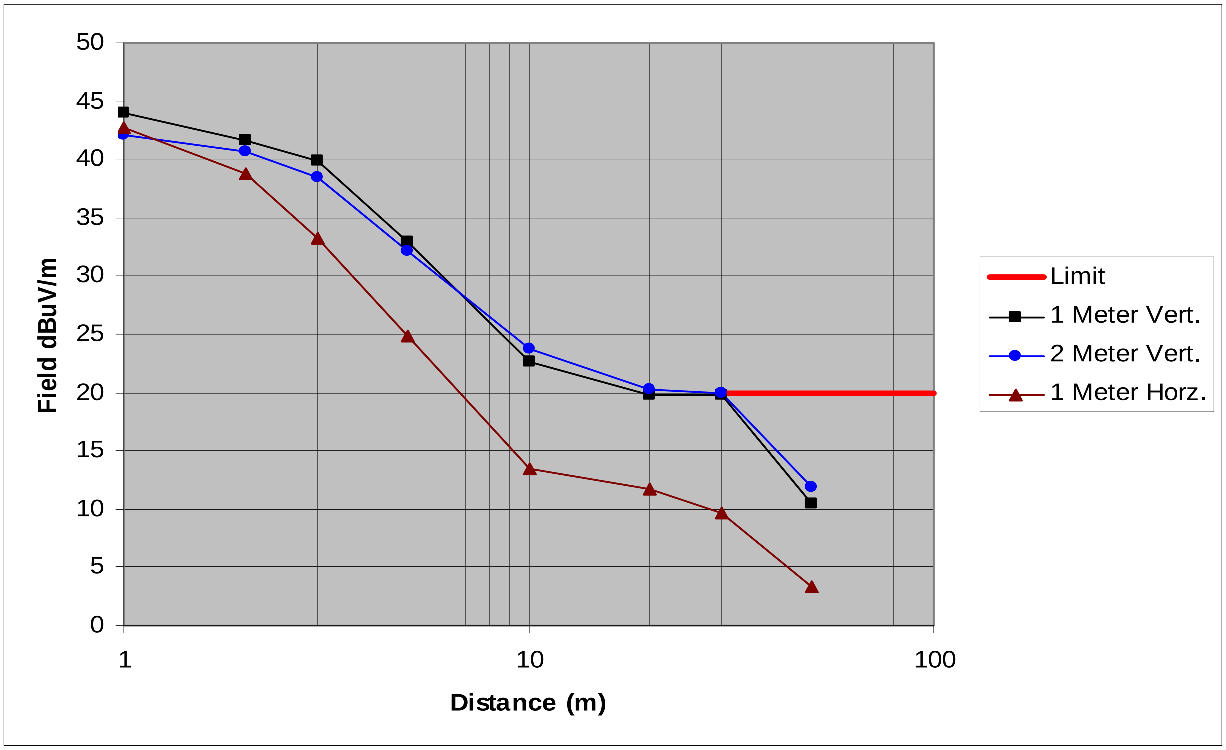

Figure 16 – SITE Radial 150 meters

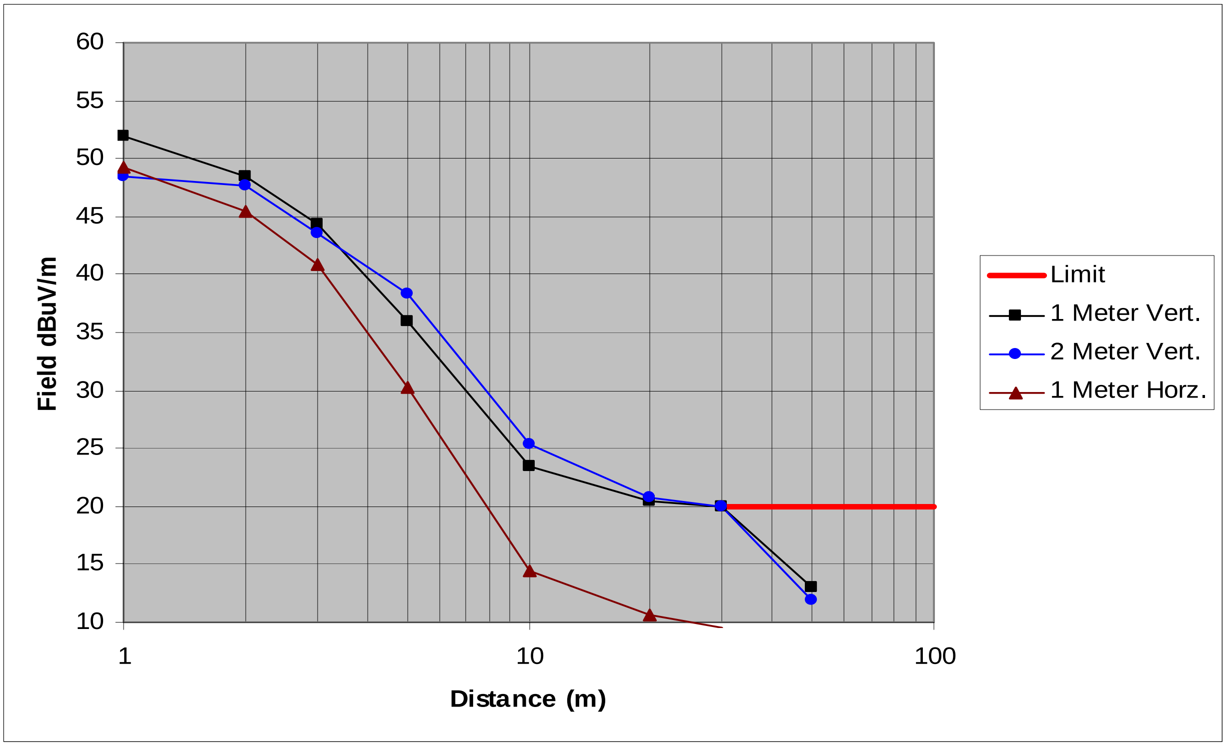

Figure 17 – SITE Radial 150 meters (Tx on Inside Cable)

5.4 JWP Radials

With the transmit power corrected to -9.0 dBm (CISPR 120 kHz) the following radial fields where measured at the JWP site.

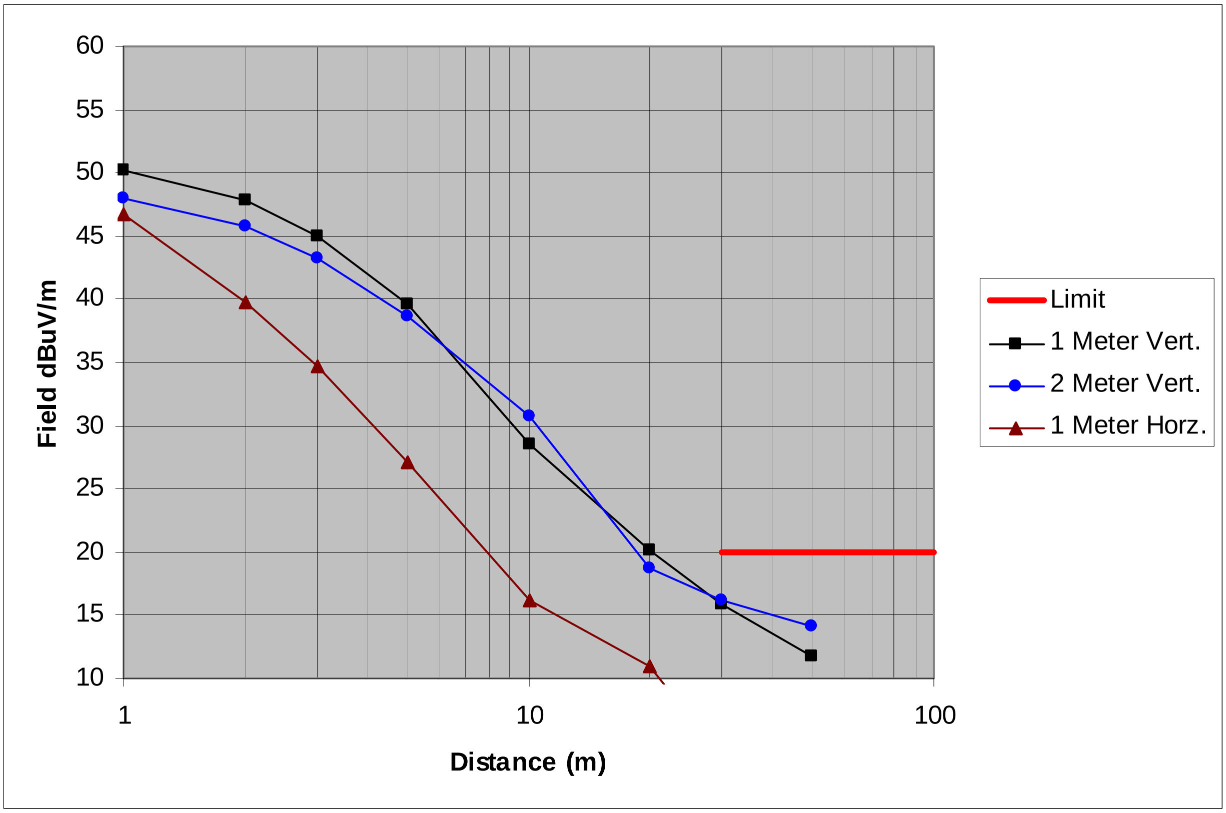

Figure 18 –JWP Radial 40 meters

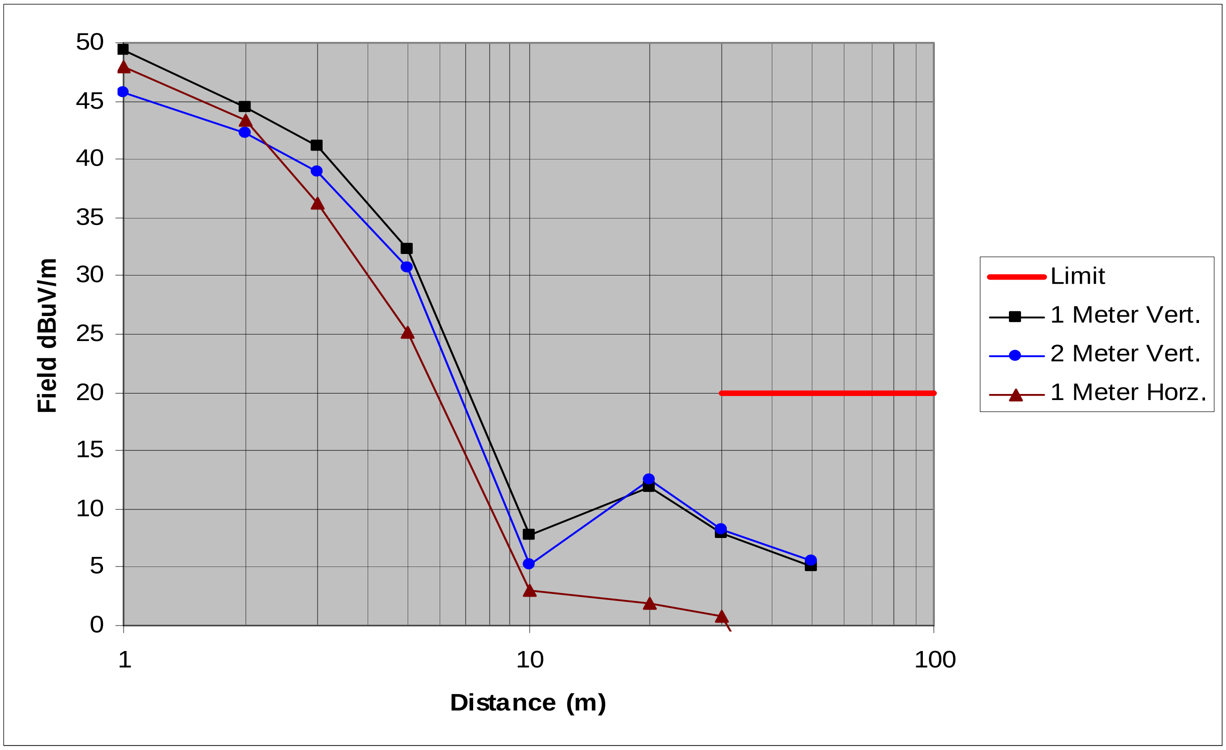

Figure 19 –JWP Radial 355 meters

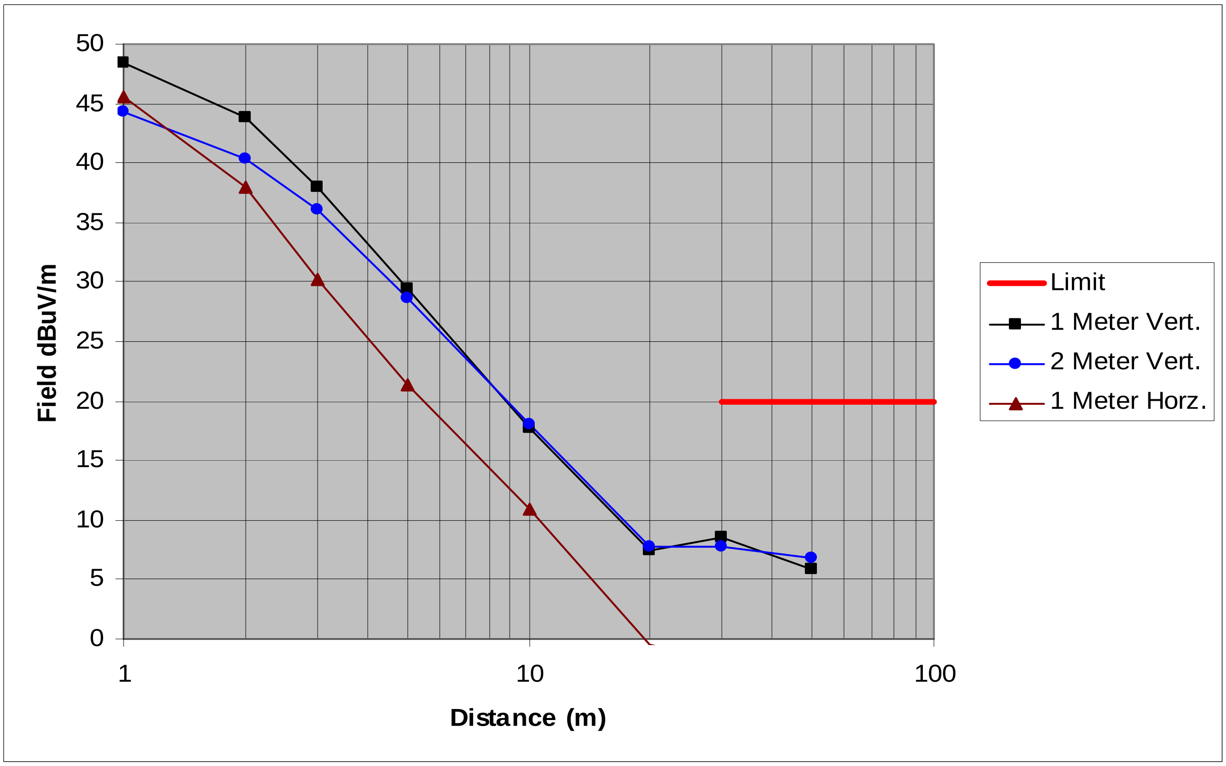

Figure 20 –JWP Radial 375 meters

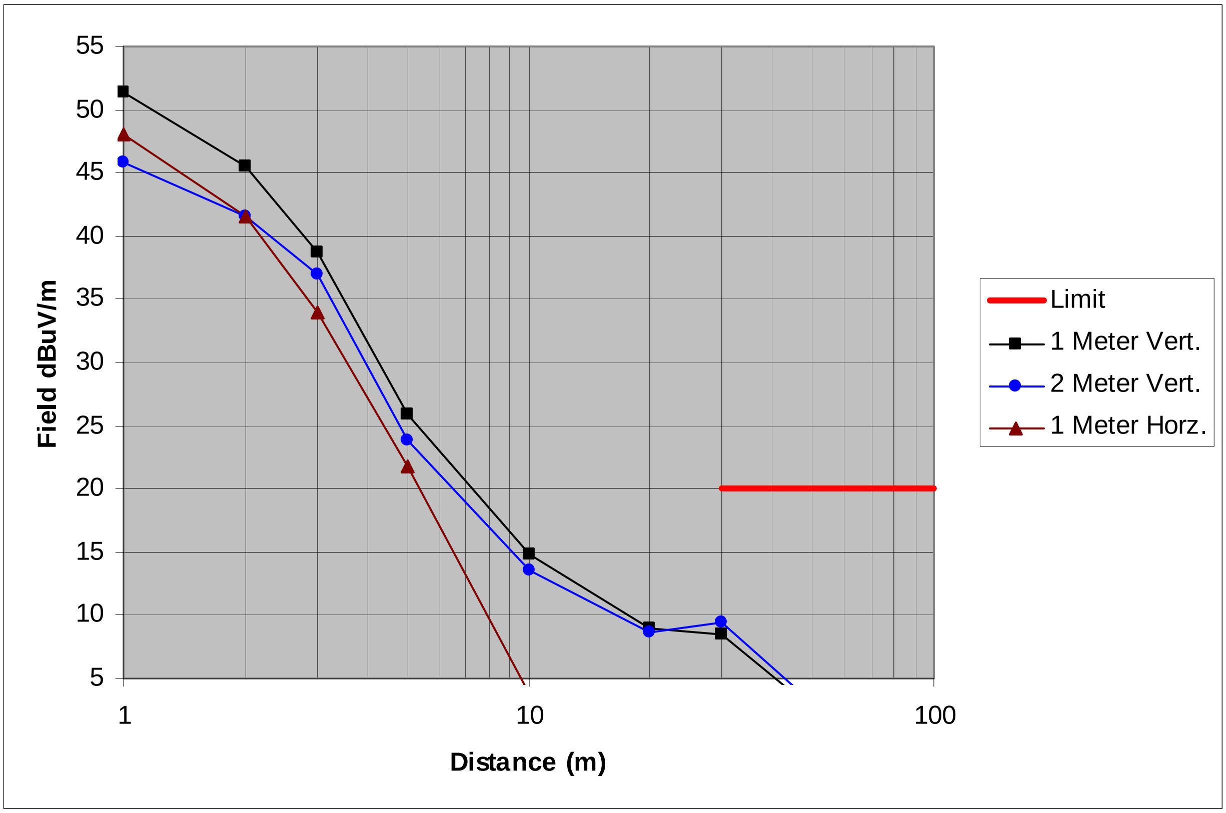

Figure21 –JWP Radial 400 meters

6 Radiated Harmonics

At a number of locations a wide band test was done to check to see if any of the harmonics of the transmitted signal were observable. Figure 14 is a measurement from 0 to 200 MHz

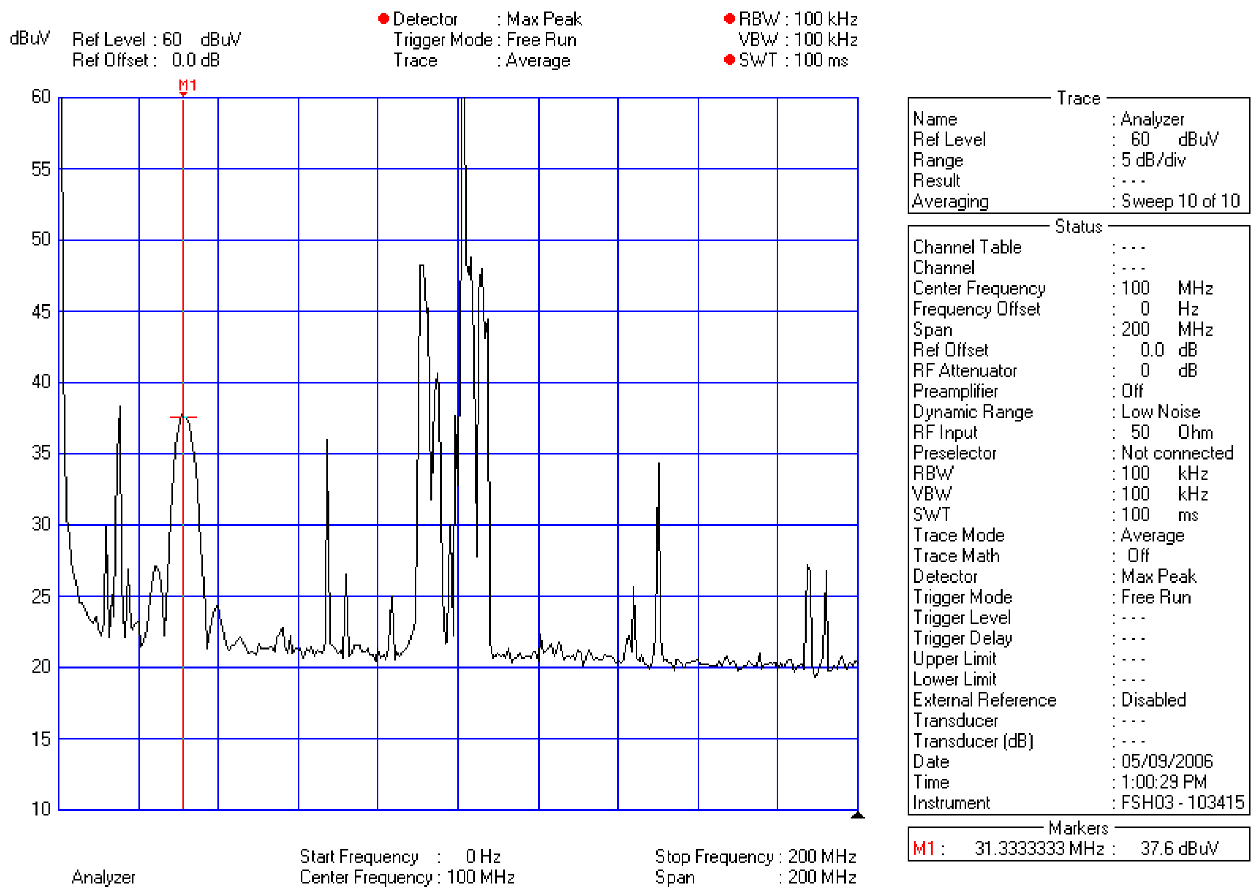

Figure 14 Radiated Field 0 to 200 MHz

As expected the harmonics of the transmission are not significant. Since the largest harmonic is 21 dB below the fundamental and since the cable antenna gain does not change much with frequency the radiated harmonics are well below the fundamental and thus well below the permitted field level. The peaks between 88 and 108 MHz are due to local radio stations. This measurement was made at a distance of 1 meter from the cable with 5.3 dBm transmitter power. Note that all the harmonics are below the noise floor.

See Appendix A for a further discussion of harmonic transmissions.

7 Conclusion

The radiated emission limit is 100 μV/m measured at 3 meters from the system. Extrapolated to 30 meters this becomes 10 μV/m or 20 dBμV/m. When the OmniTrax transmit power is set according to the relationship of equation (1) the field strength measured is below the limit at each location for each site. The spurious and harmonic emissions are also below the radiated emission limit.

Appendix A – Equipment Used

Appendix B - Table of Radial Measurements

Appendix C – Site Drawings and Photos

Appendix D – Measurement Procedure