

■ **White Papers**

**Mobile to Mobile  
Communications**

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## Mobile to Mobile Communications

### *Overview:*

Much work has been done on base station to mobile communications, where the link topology is such that the base station is typically much higher than the mobile. However, there is less public information available regarding mobile to mobile communications, where operators work in Direct Mode operation. This occurs for tactical military networks and also for PMR and PAMR where operators talk directly to one another without linking via a base station.

This paper seeks to provide some rules of thumb for planning this type of network over a range of frequencies in the VHF and UHF bands. The purpose of this exercise is to provide information for network dimensioning, business case modelling and initial planning in the case where explicit information on transceiver locations are as yet unknown. Using these rules of thumb together with such parameters as power, receiver sensitivity and antenna gain will provide rough range figures for many types of deployed systems. The analysis includes the effects of radio clutter for a typical rural environment purposes. This is compared to a similar analysis including bald earth effects only, which is often – and erroneously – used to determine expected range in such systems.

Although this type of planning should not replace discrete planning using advanced radio planning tools where possible, it fills a gap for the early parts of network design and also acts as a 'sanity check' for later planning activities.

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## Introduction

Mobile to mobile communications are used extensively for military tactical networks, emergency services and professional users of radio networks. In this case, both transceivers are relatively low to the ground, either carried as portable equipment or fitted to vehicles. This generally provides a more adverse radio propagation path than that found when using high or reasonably high base stations communicating to mobile users embedded in radio clutter. There is little published data on this particular type of path. This study looks at these types of path to determine graphs of received field strength in a rural environment. This provides a useful rule of thumb for outline planning and network dimensioning during the early phases of a project when detailed site information is not available, or for dynamic networks where situational awareness prevents such detailed analysis. This is often found in fast moving military, emergency services or incident scenarios.

The analysis is based on the following parameters:

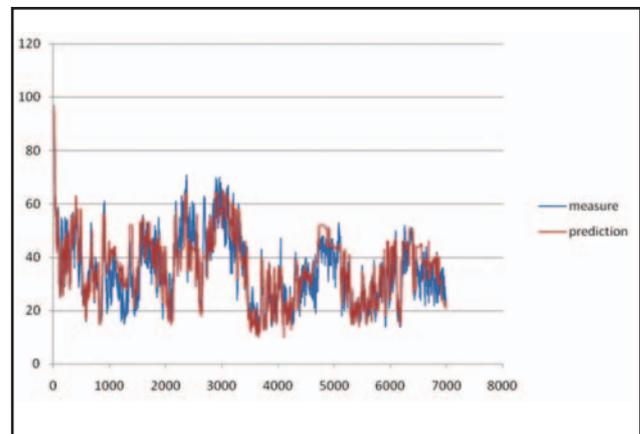
- 1 Watt transmitted power, with no antenna or feeder gains or losses
- Both transceivers are 1.5 metres above local ground

The analysis has been carried out for two conditions; one in which only bald earth terrain effects have been included, and one in which realistic clutter for urbanisation and forestry has been included. The purpose of this is to show the discrepancy typical when only considering terrain effects and ignoring clutter, and then building system performance expectation on these results.

This type of analysis is extremely useful in technology assessment, commercial bid adjudication and contractual compliance proving.

## Method Adopted

Radio planning tools offer a fast and effective method of determining network performance without installing physical equipment, provided that the propagation models employed are properly calibrated and have been proven for the selected application. This means that further physical surveys, which are expensive and time consuming, are not required in order to generate valid results. For this particular analysis, ITU recommendations 525, 526, 833 and corrections for urbanisation have been used (derived from figures that agree with references [4] and [5]). These have been correlated with mean field strength measurements by the ITU and associated organisations, and have also been correlated by ATDI for the purposes of propagation model verification and tuning during many projects. A properly tuned model should give a mean error of 1 dB or less, with standard deviation varying with environment. Figure 1 shows the results of a comparison of measured data with an un-tuned model of the type used in this study. The model included the effects of clutter.

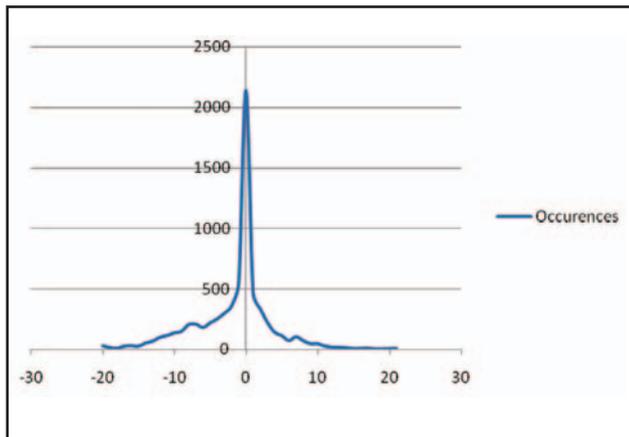


**Figure 1: Example of measured versus predicted data, in this case in the 400 MHz band. The mean error for this survey was 1.5 dB, with a standard deviation of 5.5 dB. The prediction included the effects of clutter.**

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Figure 2 shows the same data displaying the difference between measured and predicted values and the frequency of their occurrence. This shows that the mean error is low and that most differences are within a couple of dB.



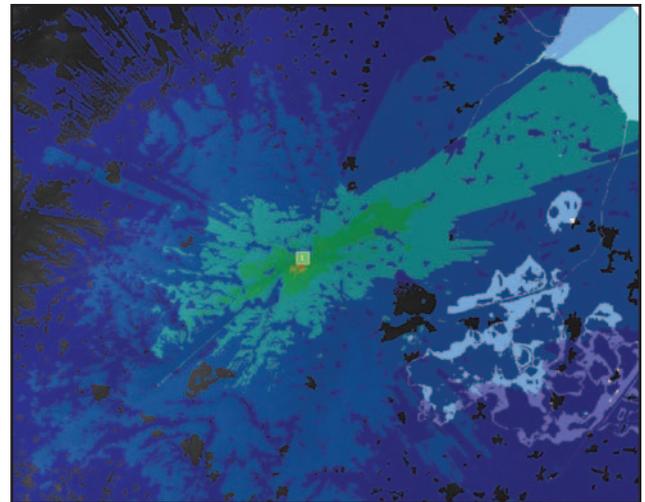
**Figure 2: Difference between measured and predicted data for 6,900 data points in the survey**

In this study, the intention was to use the mean field strength computed by the model and thus the effects of fast fading are not considered.

The following approach was adopted:

- 20 radio sites were selected at random. No attempt was made to select sites advantageous from a radio propagation basis since the nature of mobile to mobile communications is more often predicated by operational requirements rather than attempting to achieve long radio link ranges;
- Coverage predictions for a number of environmental conditions and frequencies were carried out for each. This was carried out on a 50 metre resolution Digital Terrain Map (DTM) based on Ordnance Survey data and using a simple 6-category Ordnance Survey clutter file;

- The predicted field strength was determined for every one-degree angle around each site at one kilometre intervals out to a maximum of 60 km. This gave a sample set of 21,600 per radio site and a total of 432,000 paths;
- The predicted field strength values were sorted by distance and collated to produce the mean value per distance. In this study, the standard deviation was not calculated.



**Figure 3: Example coverage plot from a sample site. The different colours represent bands of field strength predicted.**

The following assumptions were made:

- The model used is applicable to all of the frequencies modelled;
- Although there would be some level of correlation from results obtained from individual sites on closely spaced radials, it was assumed that this would be averaged out by the number of sites and the total number of paths considered;
- The transmitter and receiver antennas were both at 1.5 metres above local ground level, representing either a hand held radio or one fitted to a small vehicle.

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## Results Obtained

Calculations were performed for a 1-Watt mobile operating at 30, 60, 120, 240 and 480 MHz with zero gain antennas for both the situation where clutter was included and where it was not. These are graphed in Figures 4 and 5.

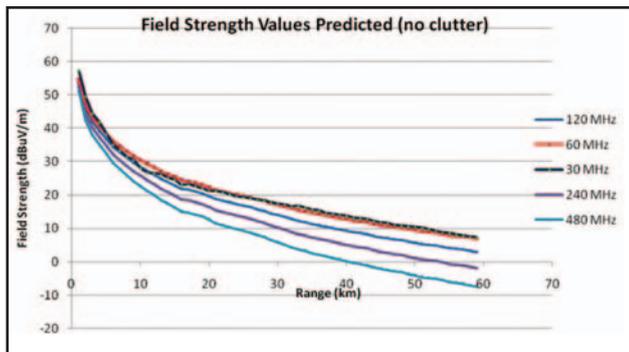


Figure 4: Field strength values predicted without considering clutter. Only terrain effects are included.

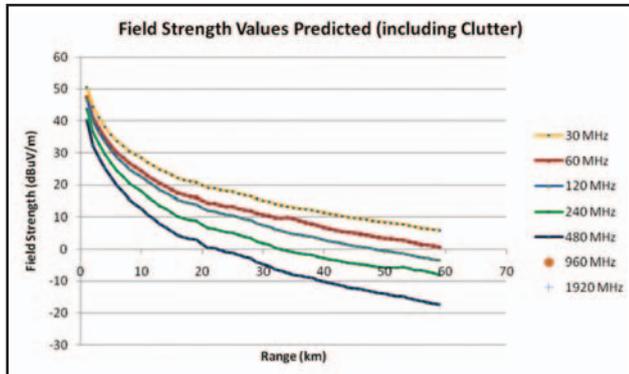


Figure 5: Field strength values predicted including clutter as well as terrain effects.

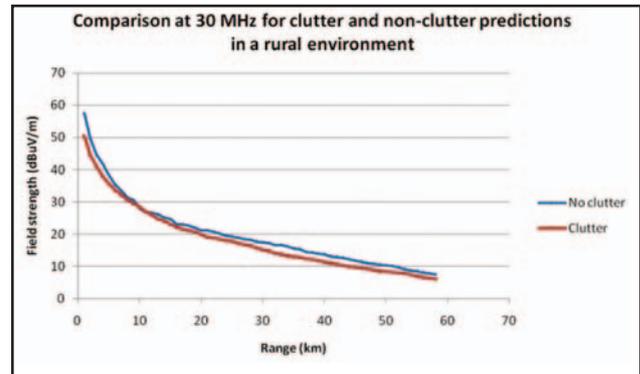


Figure 6: 30 MHz comparison.

At 30 MHz, the difference between the cluttered and non-cluttered prediction was approximately 2 dB.

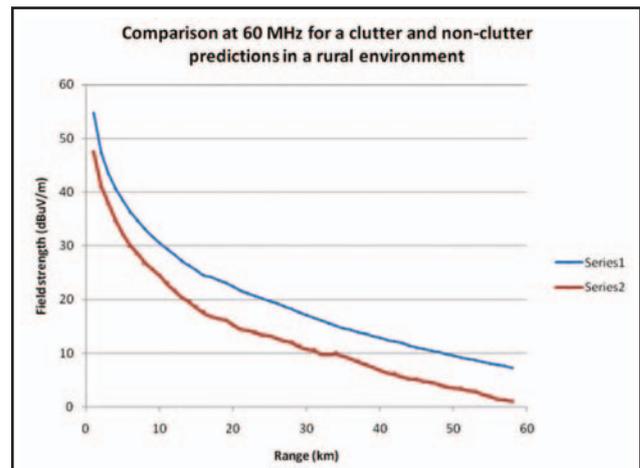


Figure 7: 60 MHz comparison.

At 60 MHz, the difference between the cluttered and non-cluttered prediction was approximately 6 dB.

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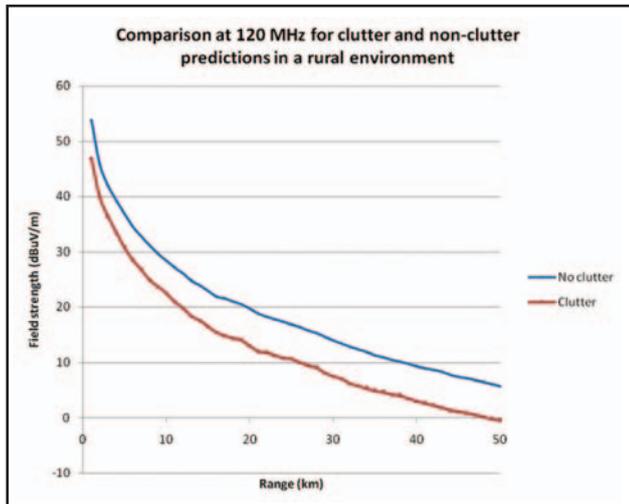


Figure 8: 120 MHz comparison.

At 120 MHz, the difference between the cluttered and non-cluttered prediction was approximately 6-7 dB.

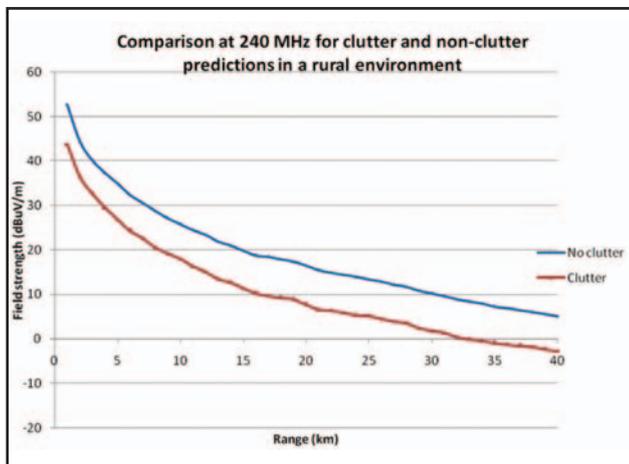


Figure 9: 240 MHz comparison.

At 240 MHz, the difference between the cluttered and non-cluttered prediction was approximately 8-9 dB.

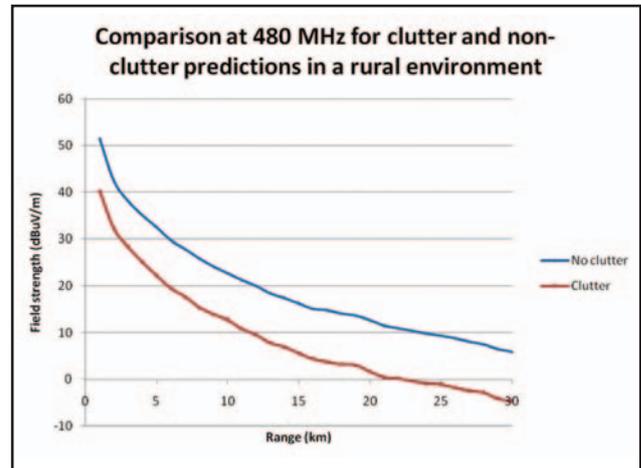


Figure 10: 480 MHz comparison.

At 480 MHz, the difference between the cluttered and non-cluttered prediction was approximately 11 dB.

In all cases, a significant range reduction was observed when clutter was included.

## Using the Results

The results can be simply used by the following steps:

- Determine the dB correction relative to 0 dBW for the actual transmitter under analysis, including the effects of feeder losses and antenna gains / losses;
- Determine the minimum received signal power required at the receiver (including the effects of antenna gain/loss and feeder losses if appropriate);
- Convert the power required into the equivalent field strength based on an isotropic radiator using the following equation:

$$\text{Field strength (dBuV/m)} = \text{Power (dBm)} + 20 \log f + 77.2$$

- From the field strength, subtract the dB correction to determine the offset value to use;
- Read off the expected range from the graphs shown in Figures 7 – 10.

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### Example:

5W transmitter at 120 MHz to a nominal receive power of -90 dBm, with 1 dB antennas on both transmit and receive.

dB correction =  $10 \log 5 = 7$  dB for power + 1 dB for antenna = 8 dB (approximately)

Receiver power =  $-90 + 1 = -89$  dBm

Field strength =  $-89 + 20 \log 120 + 77.2 = 30$  dBuV/m (approximately)

Corrected field strength =  $30 - 8 = 22$  dBuV/m.

Reading this off the relevant figure gives a nominal range of approximately 11 km if clutter is included and 16 km if it is not. Thus, adding the effect of clutter reduces the expected range by 5 km. This is likely to be more realistic, whereas the figure of 16 km will be virtually impossible to achieve in practice. It is vital to use the more realistic figure in radio planning.

### Summary

This paper presented some new figures for outline planning of mobile to mobile communications in the VHF and UHF bands. It showed a relatively simple analysis that nevertheless produced some interesting rule-of-thumb figures. It also highlighted the need to consider realistic environments for range prediction work; too often the author has seen all too optimistic figures used, based on the most rudimentary of link budgets. While these provide temporary comfort to the planner, they ultimately result in failure when these results are not achieved in practice. One of the reasons why this situation arises has been explored in this paper.

### References

1. ITU-R P.525-2 Calculation of Free Space Attenuation
2. ITU-R P.526-8 Propagation by Diffraction
3. ITU-R P.833-4 Attenuation in Vegetation
4. COST 231
5. Man-Made Noise Measurement Programme (AY4119)  
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