LOCATION VARIABILITY: AN EMPIRICAL STUDY

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ClimDiff
Boulder, 4 June 2008

ÆGIS spectrum engineering

Outline

- Introduction
- Definitions and measurements
- ITU-R treatment
- New measurements
- Data reduction and results
- Conclusions

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Introduction

- **Study undertaken on behalf of OFCOM**
  - An empirical study of location variability
- **Summary of previous measurements**
  - Problems of definition
  - Measurement methods
- **Measurements in London**
  - at 237 MHz, 1.5 GHz and 3.5 GHz
- **Revision of P.1546**
  - New expression for location variability

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Definitions & measurements

Location variability

- **Three fading regimes**

  A: Losses due to bulk terrain effects

  B: Fading due to local shadowing (Location variability)

  - Generally modelled as lognormal distribution

  C: Fading due to multipath interference

  - Tends to Rayleigh for multiple scatterers

- **Physical distinction between B & C, but not between A & B**
  - What is an appropriate scale over which to estimate LV?

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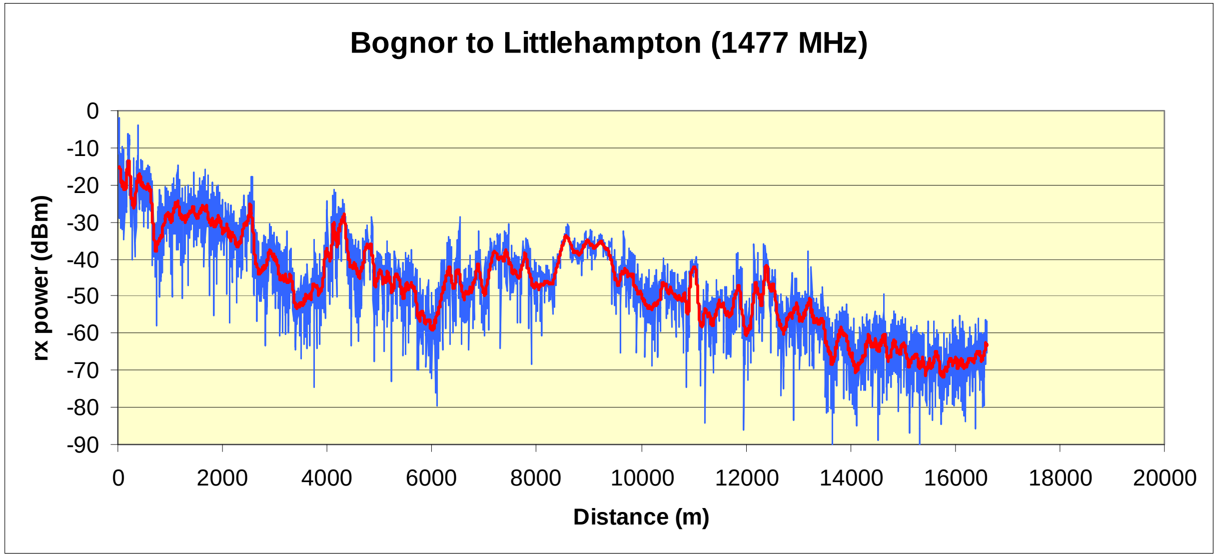
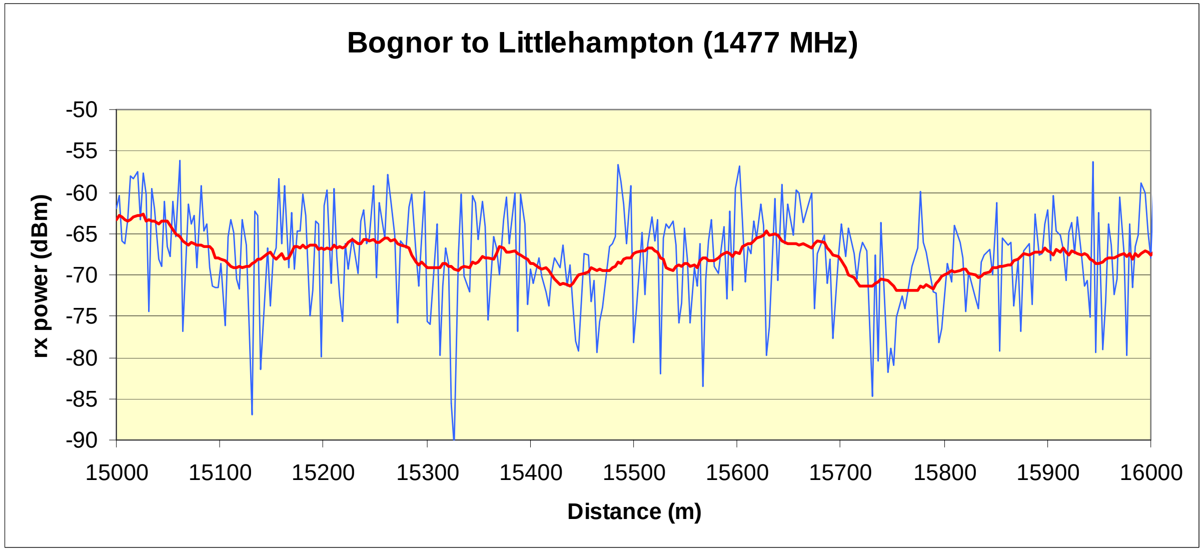
Fading regimes





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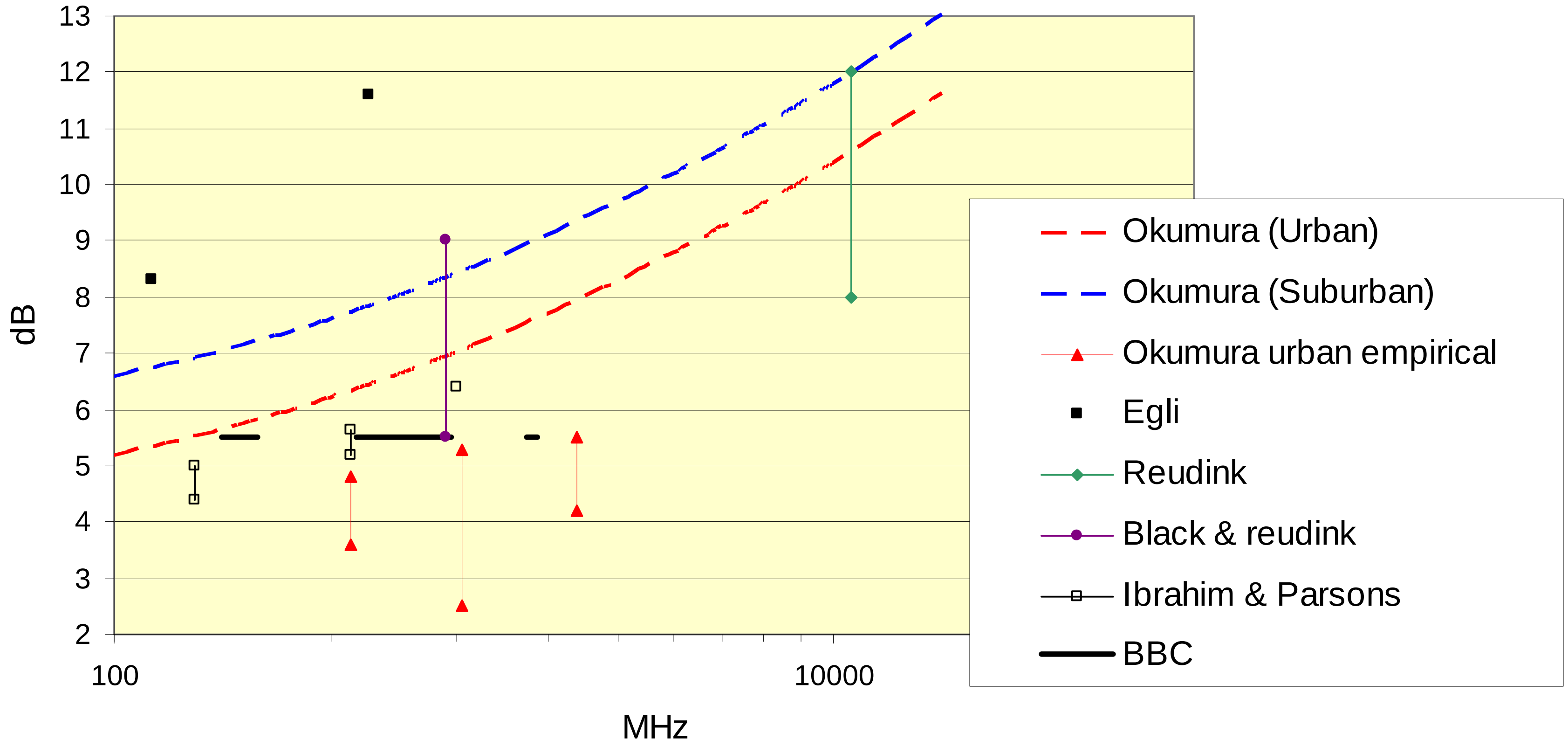
Comparison of measured data



At ~500 MHz, LV is 3.5dB – 11.5dB. If designing for 99% availability this implies uncertainty of 18.6dB!

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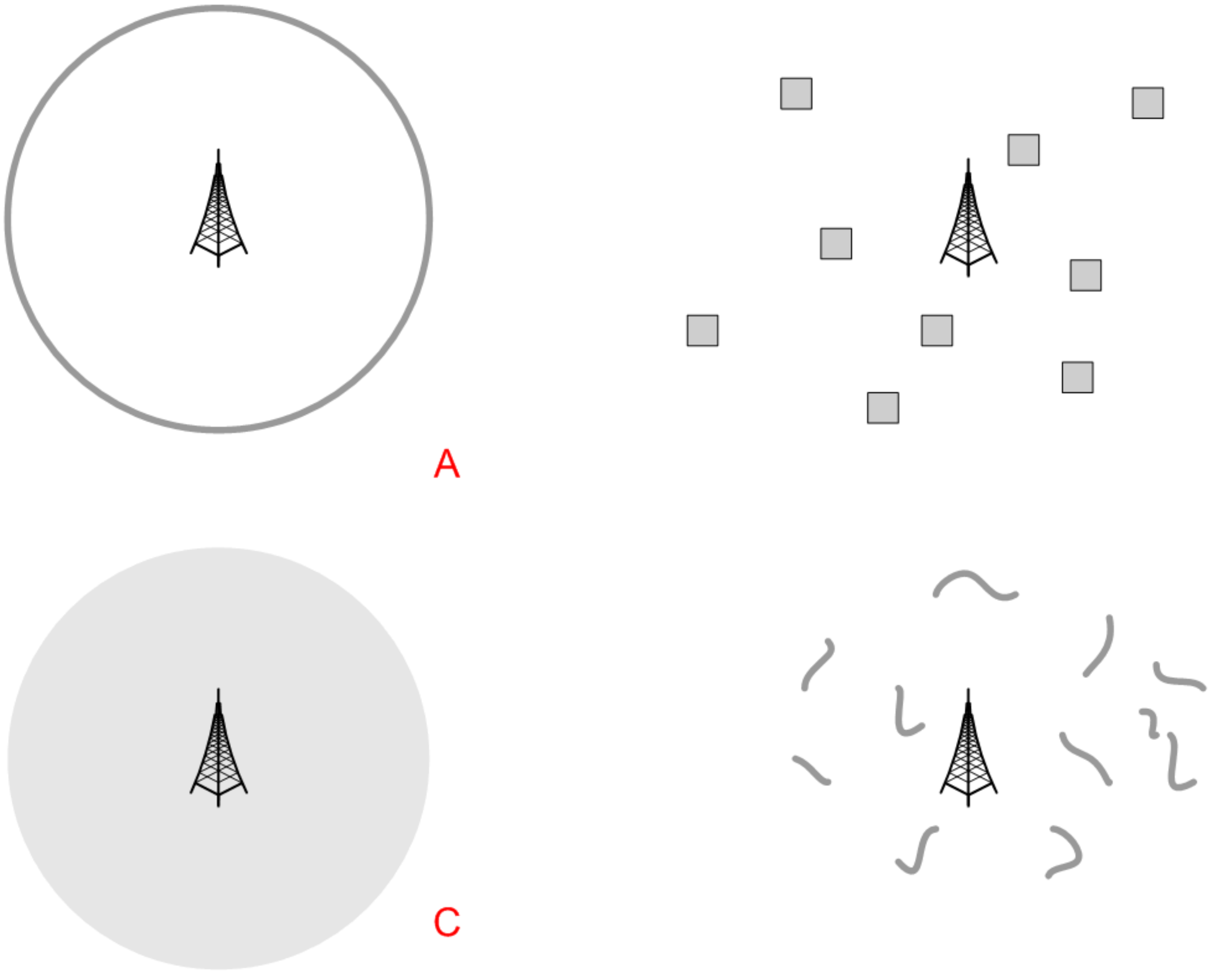
Definitions



A: Constant radius
B: Small areas
C: Wide area
D: Route segments

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Historical measurements

- **LV measurements reported by many workers**
  - Egli (excess loss throughout wide area)
  - Okumura (1.5km distance)
  - Black and Reudink (1x 3 mile area)
  - Parsons (500m squares)
- **…But definition of LV, and measurement methods are very varied**

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Okumura

"In determining the extent of land for which location variability is to be used in the design of the land mobile service, the size of interval or area travelled by the mobile radio car in a period of time taken for one telephone call, may become the accepted standard"

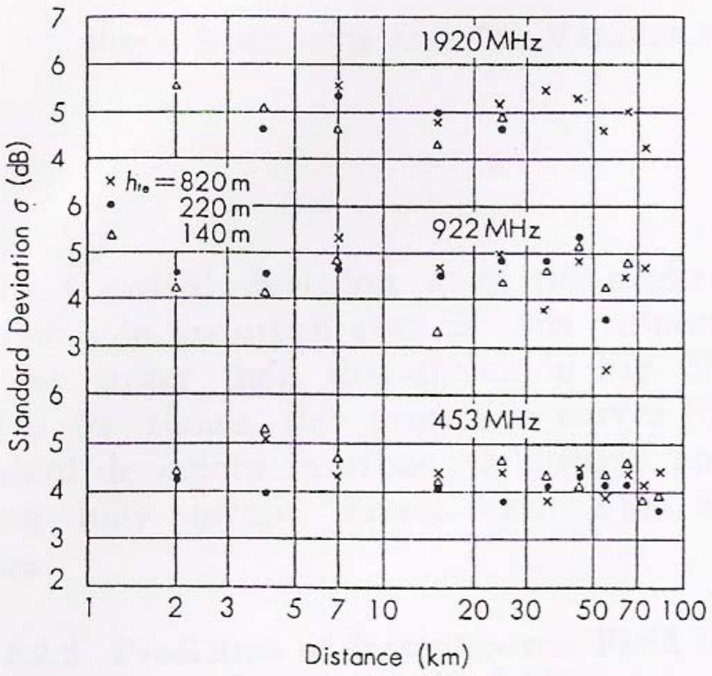

Fig. 38—Measured mean values of standard deviation of small-sector median field strength variation in urban area sampling interval (1~1.5 km).

~5dB Measured over 1-1.5km route

A 3-4 minute call at 60km/hr would occupy 3-4km

Therefore values were inflated:
453 MHz: 4.2dB->5.9 dB
922 MHz: 4.6dB ->6.6dB
1920 MHz: 5.0dB -> 7.4dB

Measurement methods

- **Chart recording or data logging**
- **Continuous or spot measurements**
- **Height?**
- **Antenna directivity?**
- **Data processing**
  - Over what distance to determine local mean (i.e. to average multipath)? [Okumura 20-50m, Parsons 20-40m]
  - Over what distance to determine variability of local mean? [Okumura 1.5/4km, Parsons 500mx500m] – must be related to path loss model

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ITU-R treatment

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Recommendation 312 (1959)

9. Fig. 2 relates the field strength exceeded at 50% of receiving locations to that exceeded at any other required percentage of receiving locations. From the data at present available, it appears that the same curve may be used to obtain approximate results for all of the frequencies, and distances covered by Fig. 1. The curve corresponds to an average standard deviation of 8 db; but in practice the standard deviation may vary from 5 to 11 db, depending on the degree of roughness of the terrain;

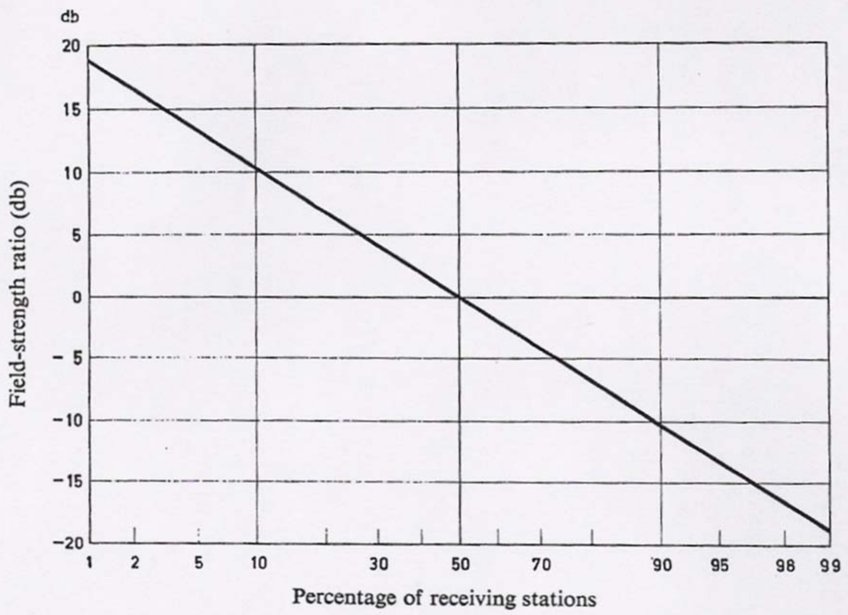


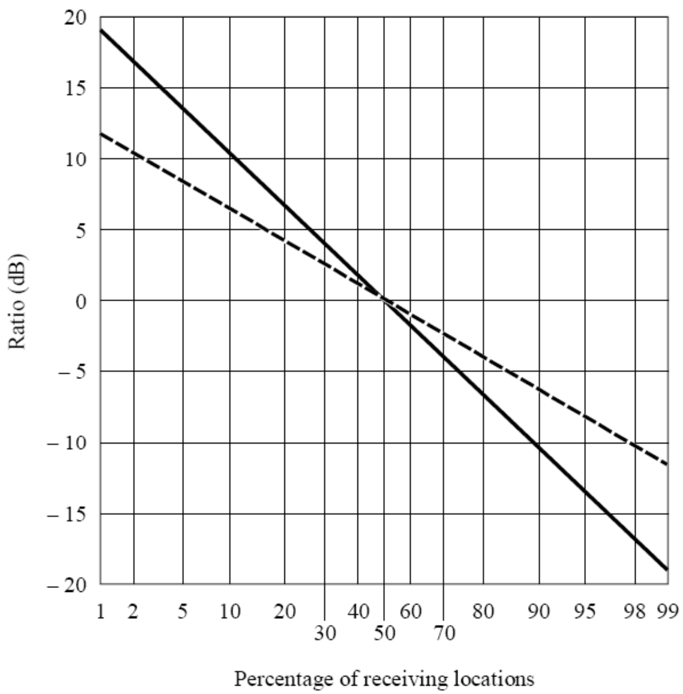
FIGURE 2

Ratios of the field-strengths exceeded at the stated percentages of receiving locations to that exceeded at 50% of the locations.

P.370-7 (1995)

2.1 The curves in Figs. 1a, 2a, 3a and 4a represent field-strength values exceeded at 50% of the locations within any area of approximately 200 m by 200 m and for 50%, 10%, 5% and 1% of the time for land paths where Δh of 50 m is considered representative. For a different value of Δh, a correction should be applied to the curves as shown in Fig. 7. For locations other than 50%, corrections may be obtained from the distribution curve in Fig. 5.

In the case of broadband digital systems having bandwidths of at least 1.5 MHz the dashed line of Fig. 5 should be used. This is to take account of the fact that such systems are less subject to frequency dependent location variation than the analogue systems for which the solid line in Fig. 5 is intended.



But:
"*In area coverage planning, location variability normally refers to the spatial statistics of local ground cover variations with multipath variations averaged*"

New measurements

New measurements

- **Need to revise treatment of LV in P.1546**
  - Improve definition
  - Address the wideband / narrowband issue explicitly
  - Contribute new data

- **Measurements made in London and Bognor Regis**
  - Three frequencies
  - Wideband and narrowband systems

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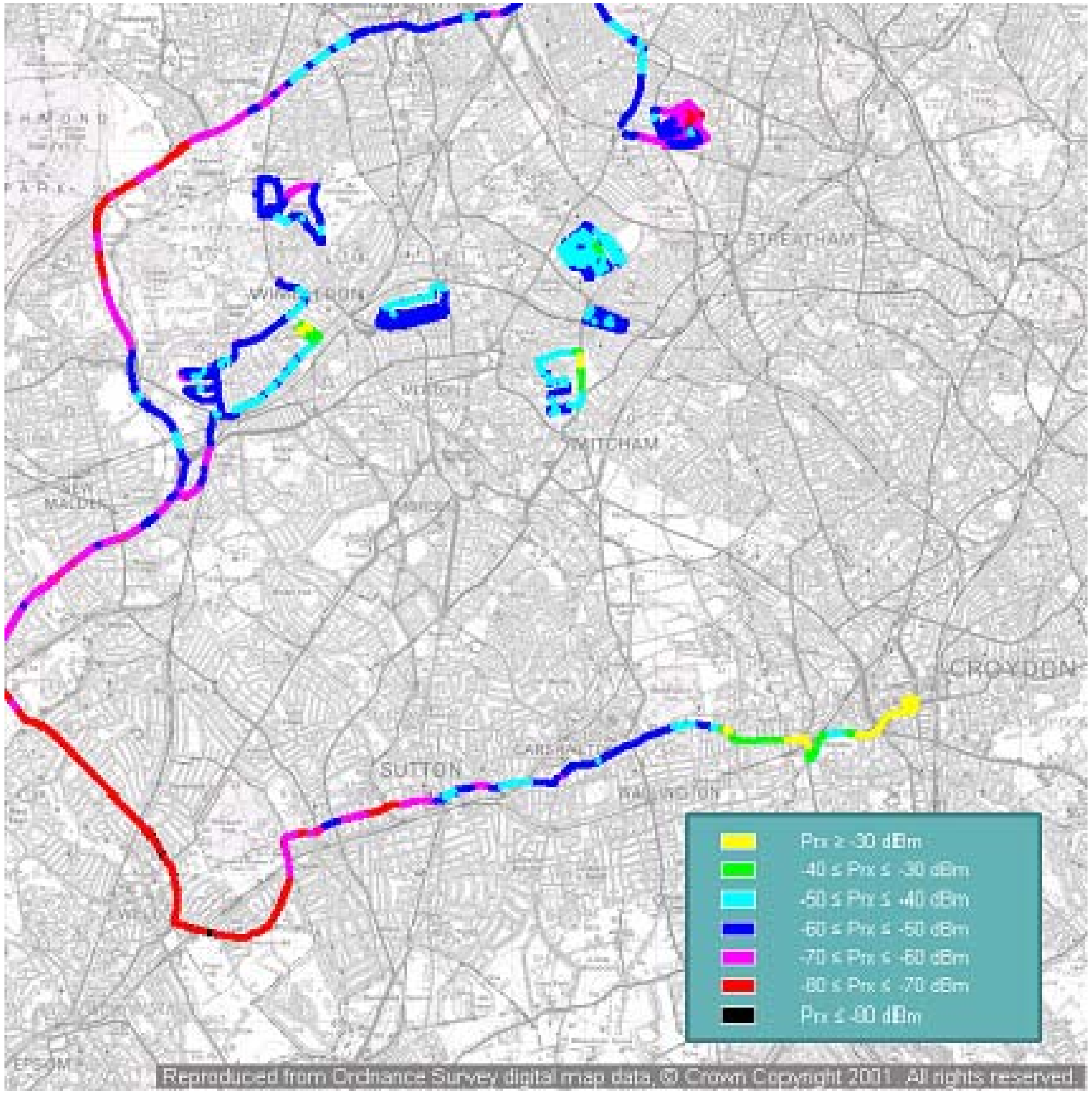
New measurements

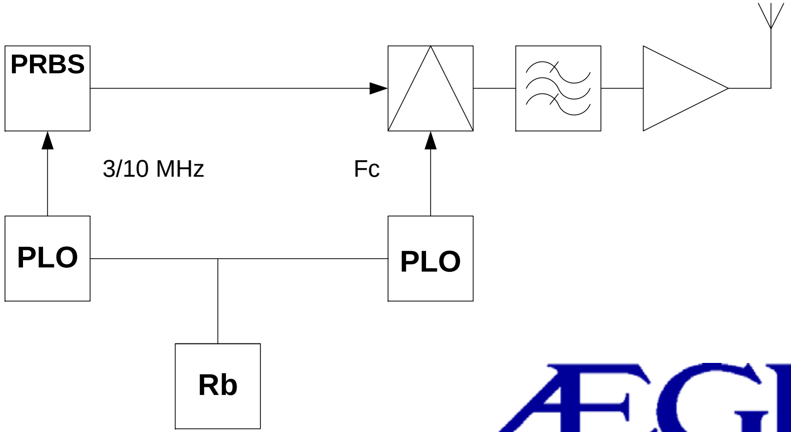


Sounder TX

Chip rate of 2.5 or 10 MHz

237 MHz, 1477 MHz 3430 MHz

100-200W EIRP



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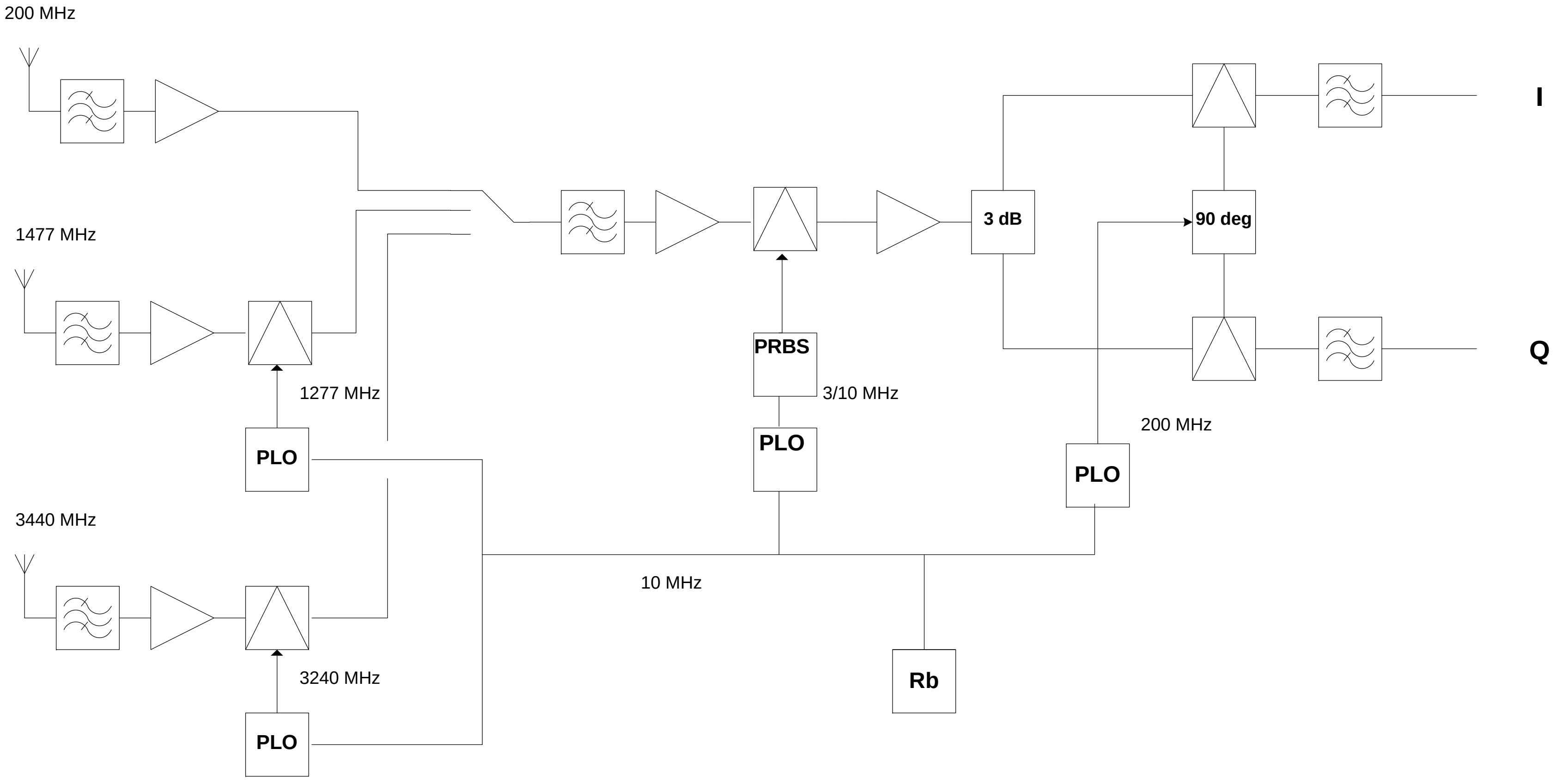
Sounder RX



I&Q outputs captured by 50 MHz ADC
Complex spectrum extracted by FFT
Multiplied by complex conjugate of PN spectrum to give PSD
Wiener-Kinchine relationship gives ACF

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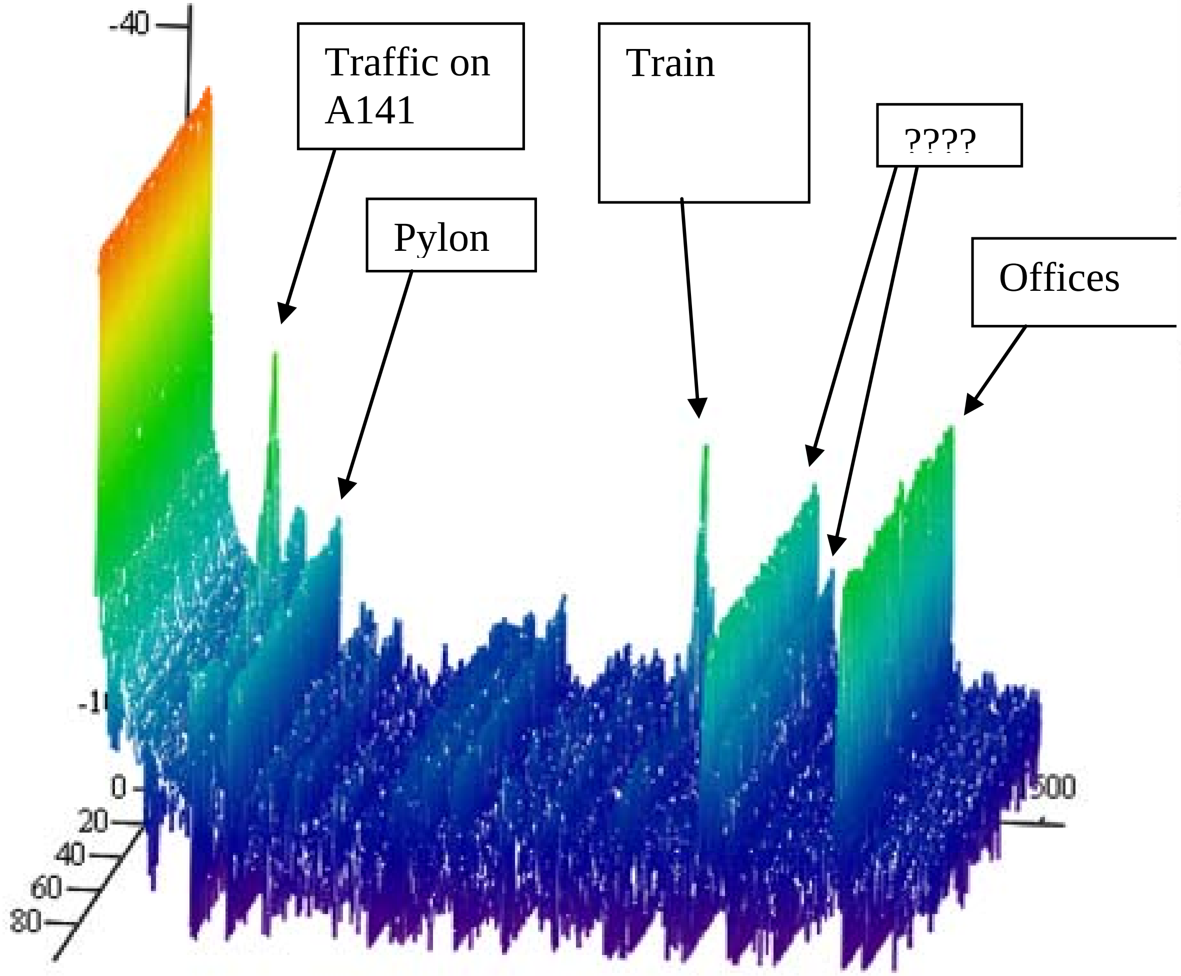
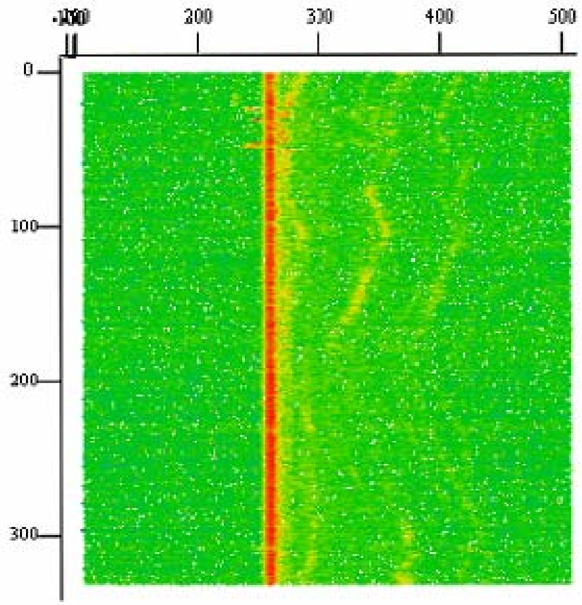
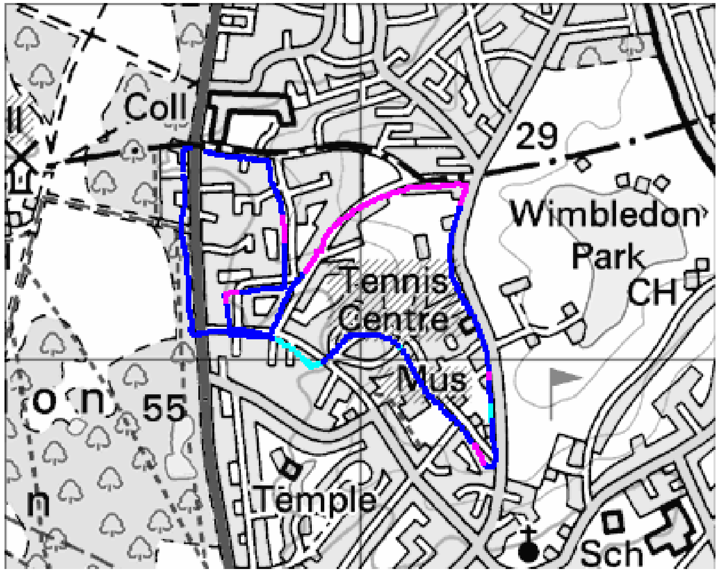
Sounder output





Test routes



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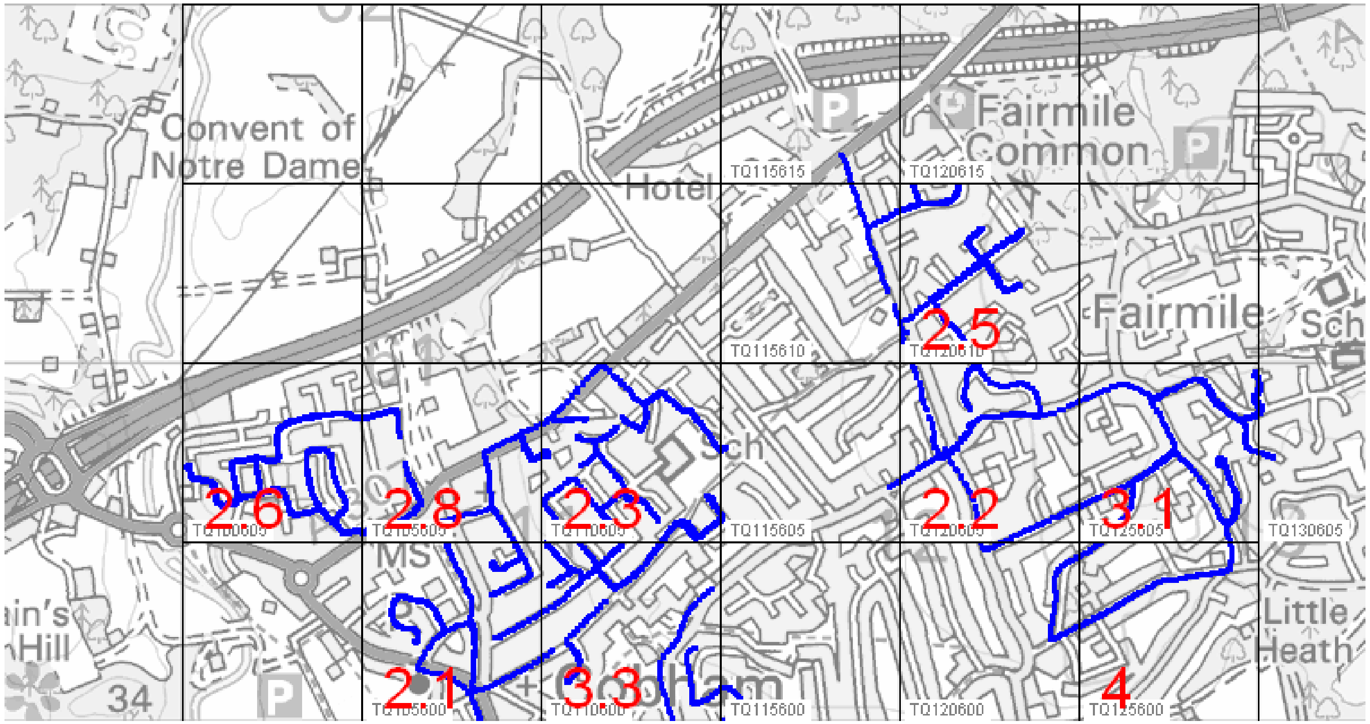
Data reduction and results

Analysis of data

Conflicting requirements to:

- Filter multipath by spatial averaging to find local mean

- But too large an averaging distance will obscure the variation we are seeking - problematic at lower frequencies



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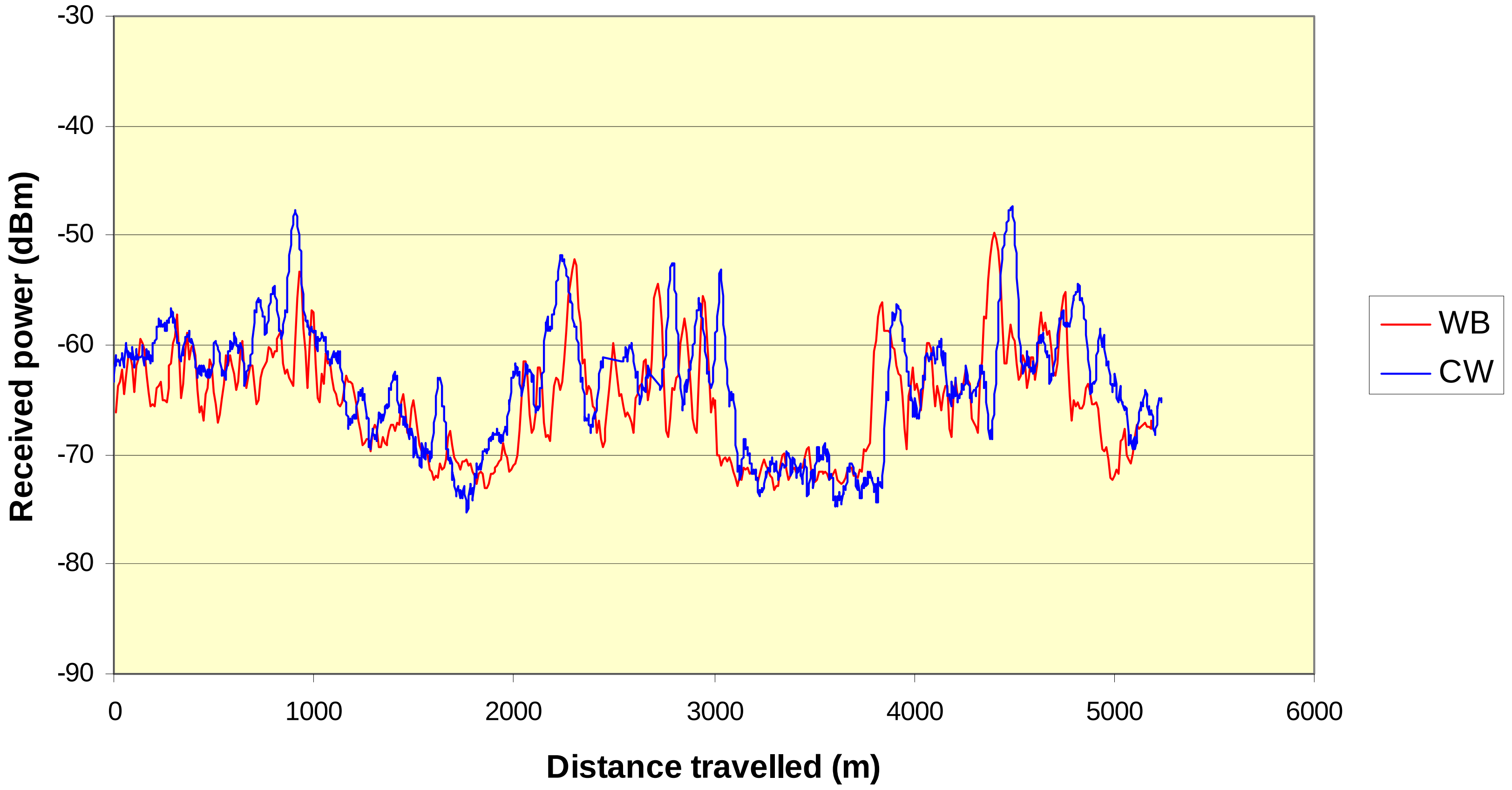
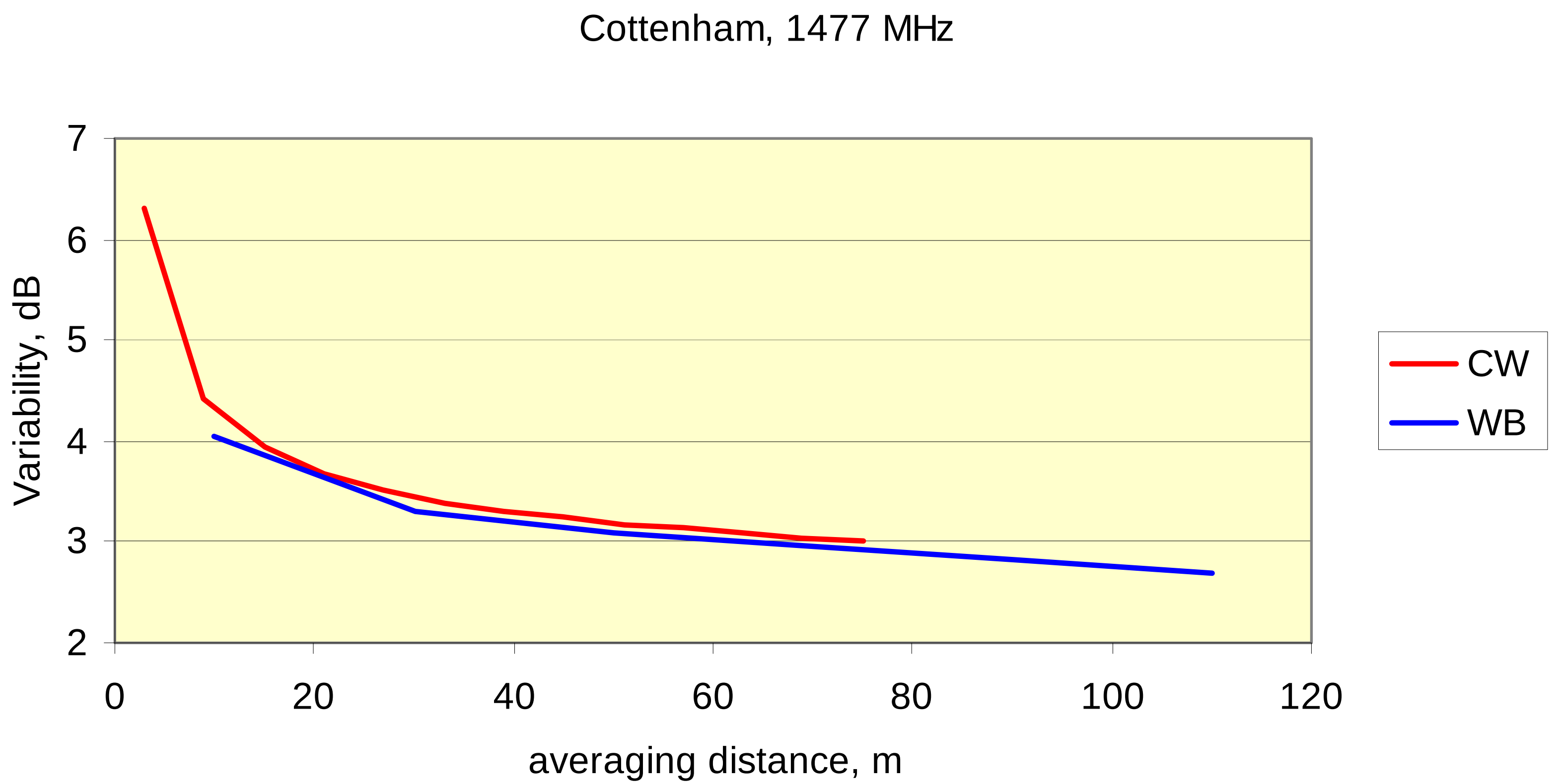
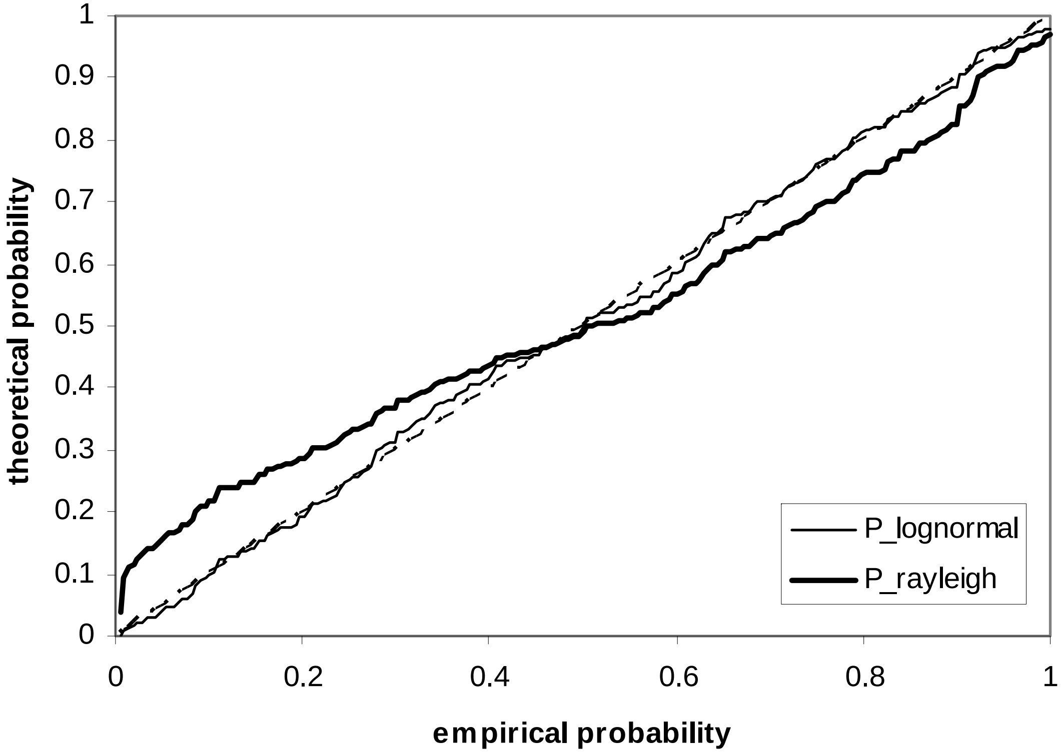
CW vs Wideband

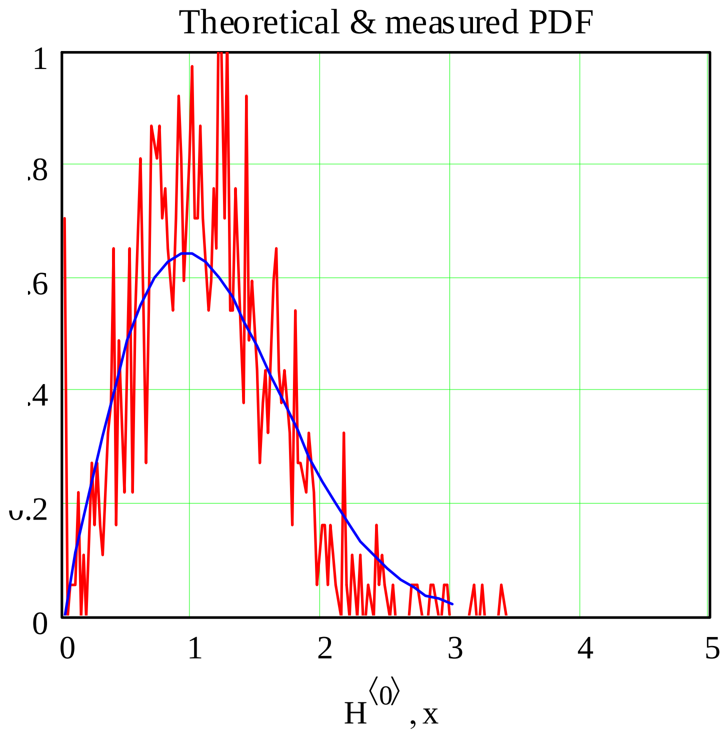


Variability vs. averaging distance

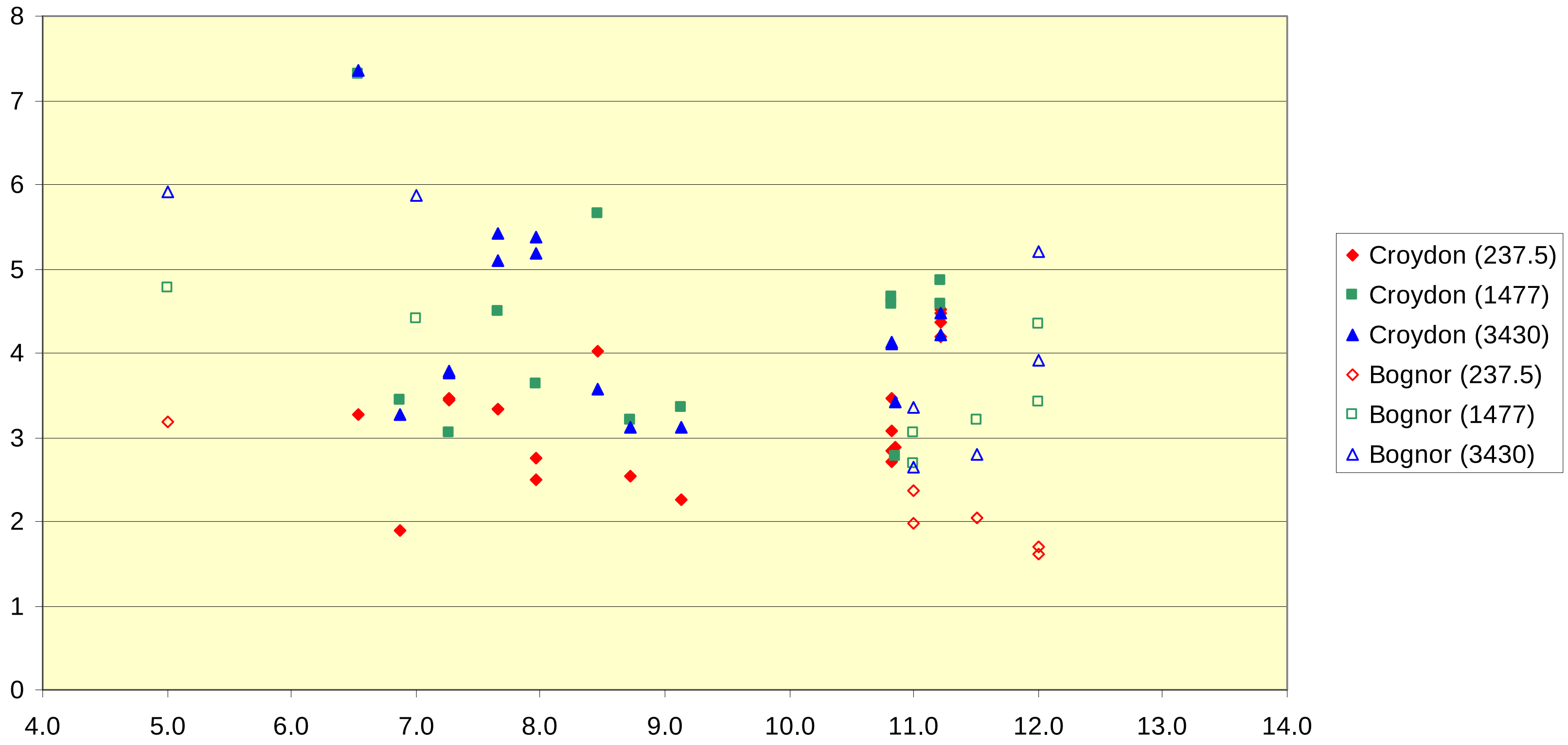


Statistics of filtered data





CW (40m smoothing)



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Summary results

Frequency	Location variability
237 MHz	3.2 dB
1477 MHz	4.2 dB
3430 MHz	4.5 dB

Values of standard deviation are dependent on frequency and environment, and empirical studies have shown a considerable spread. Representative values for urban areas of 500 m × 500 m are given by the following expression:

$$\sigma_L = K + 1.3 \log(f) \quad \text{dB} \qquad (33)$$

where:

K= 1.2, for mobile systems with omnidirectional antennas at car-roof height

f: required frequency (MHz).

For receiving/mobile antennas at other heights, and in other environments, it is expected that different values of K will be appropriate. Furthermore, if the area over which the variability is to apply is greater than 500 m × 500 m, or if the variability is to relate to all areas at a given range, rather than the variation across individual areas, the value of σ_L will be greater.

(From P.1546-2)

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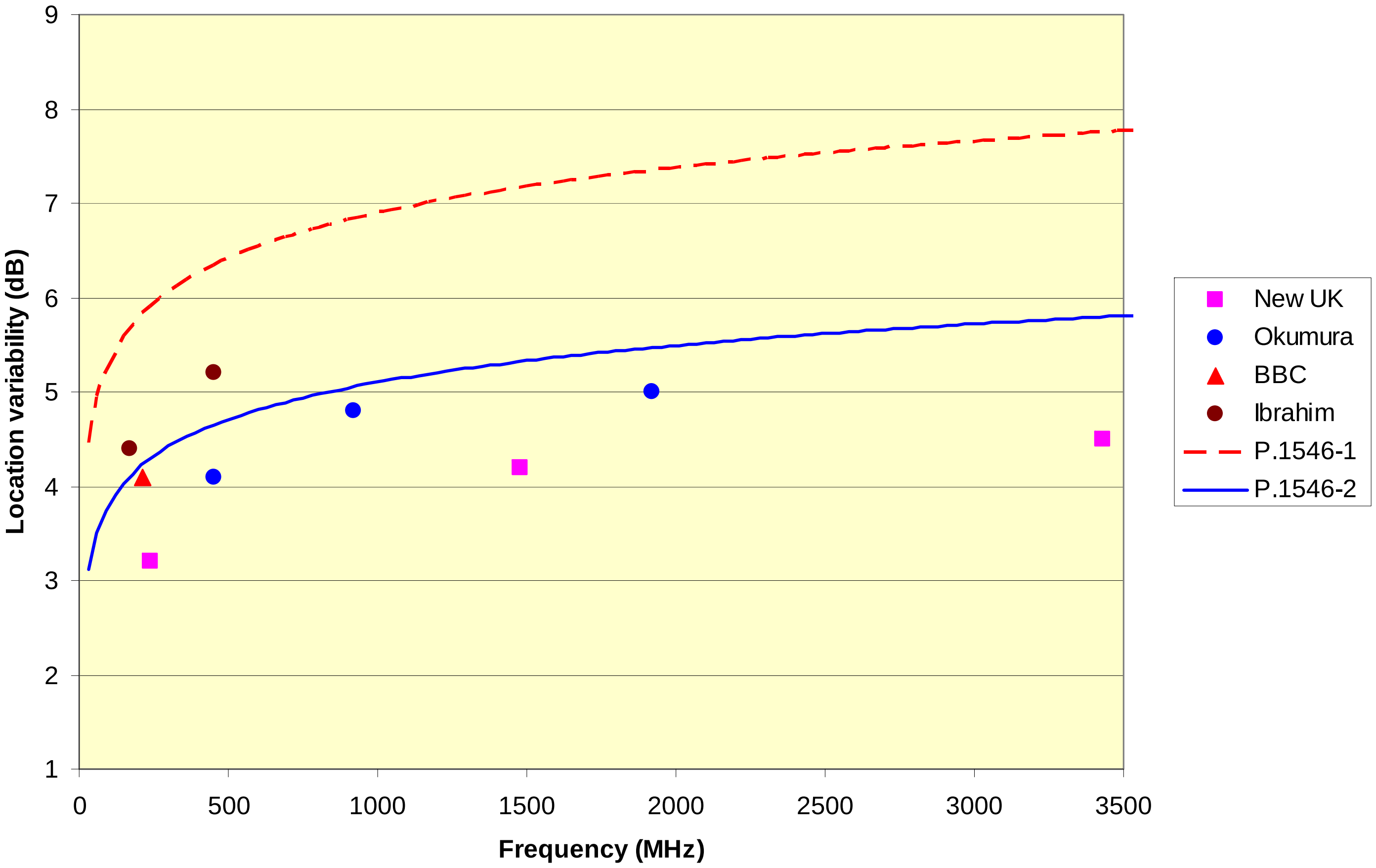
Comparison



9
8
7
6
5
4
3
2
1
Location variability (dB)
0
500
1000
1500
2000
2500
3000
3500
Frequency (MHz)
New UK
Okumura
BBC
Ibrahim
P.1546-1
P.1546-2

Further measurements

- **A by product of a larger study intended to generate data for propagation modelling**
- **Point-area measurements made in rural, suburban and urban areas of the UK**
- **Frequencies: 2.4, 3.4 and 5.7 GHz**
- **Values determined for 500m squares**

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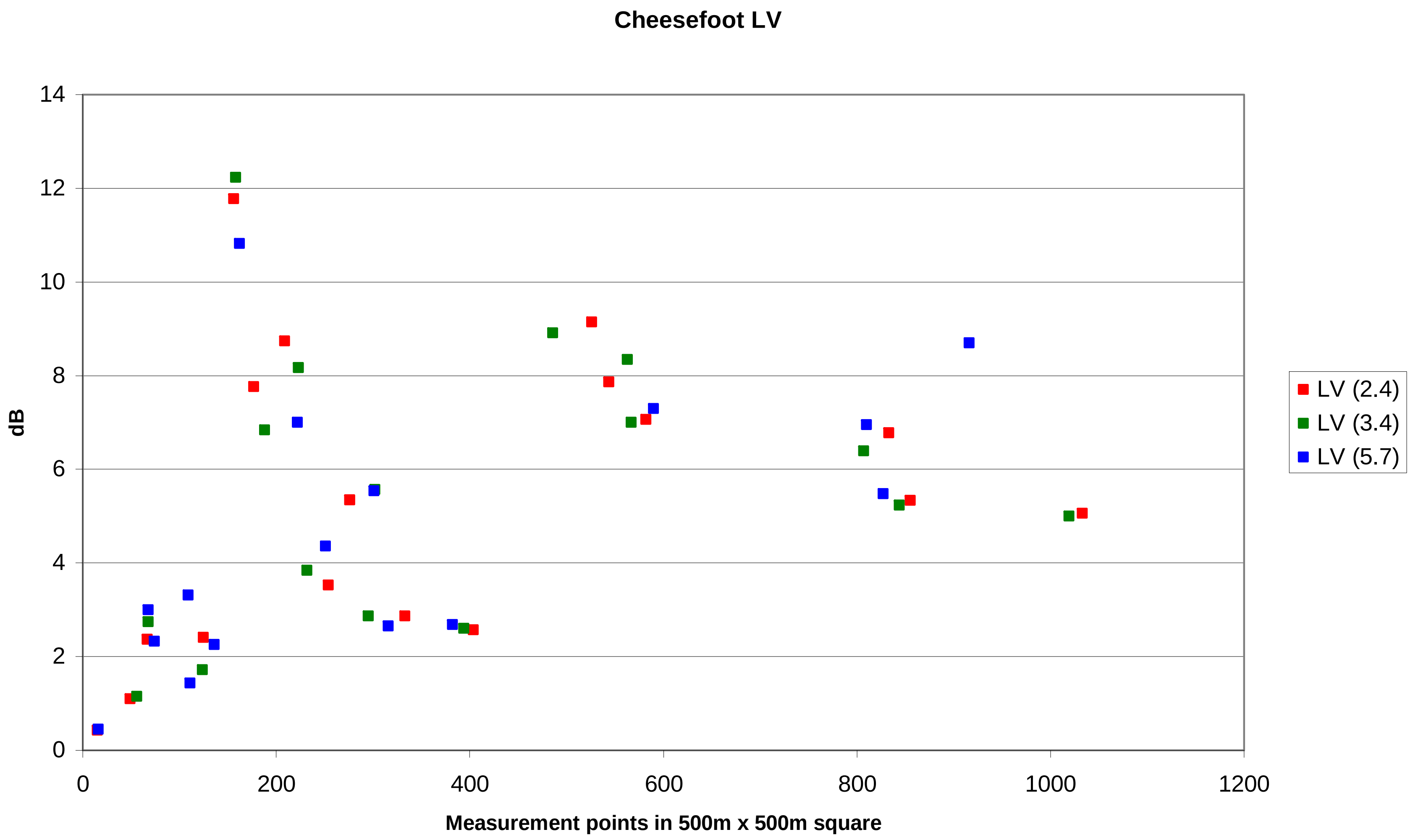
Location variability



Location variability

(dB)	2.4 GHz	3.4 GHz	5.7 GHz
Cheesefoot (Winchester)	6.0	6.0	6.0
Currys (Winchester)	3.4	4.1	4.0
Farm (Croydon)	4.3	4.3	4.4
Park Hill (Croydon)	5.6	5.3	5.5
Overall	**4.8**	**4.9**	**5.0**

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Conclusions

- **Location variability is a deceptively simple parameter**
- **Published values generally not directly comparable**
- **Measurements or data reduction must be tailored to individual propagation model**

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Thank you!

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