Wideband Channel Characteristics for Indoor Reception of Satellite Transmissions at 2.4 GHz

ISART
Boulder, 27 February 2007

ÆGIS spectrum engineering

Outline

BRITISH NATIONAL SPACE CENTRE

S@TCOM study

- Requirement for data
- Previous studies
- The wideband channel
- Design
- Measurement campaign
- Data reduction
- Results
- Conclusions

Requirement for wideband data

- **Satellite systems are proposed that will offer (some degree) of indoor coverage**
  - IMT-2000 systems at ~2 GHz
  - Galileo at 1.2 / 1.5 GHz
  - S-DAB at 1.5 GHz
- **System designers therefore need to understand the nature of the wideband satellite-indoor channel**
  - Inform choice of modulation characteristics
  - Impact of polarisation
  - Elevation dependence

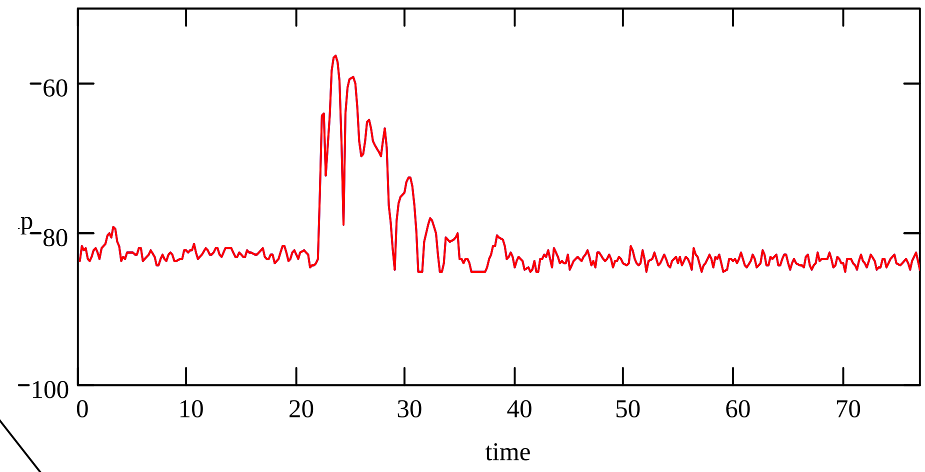
ÆGIS

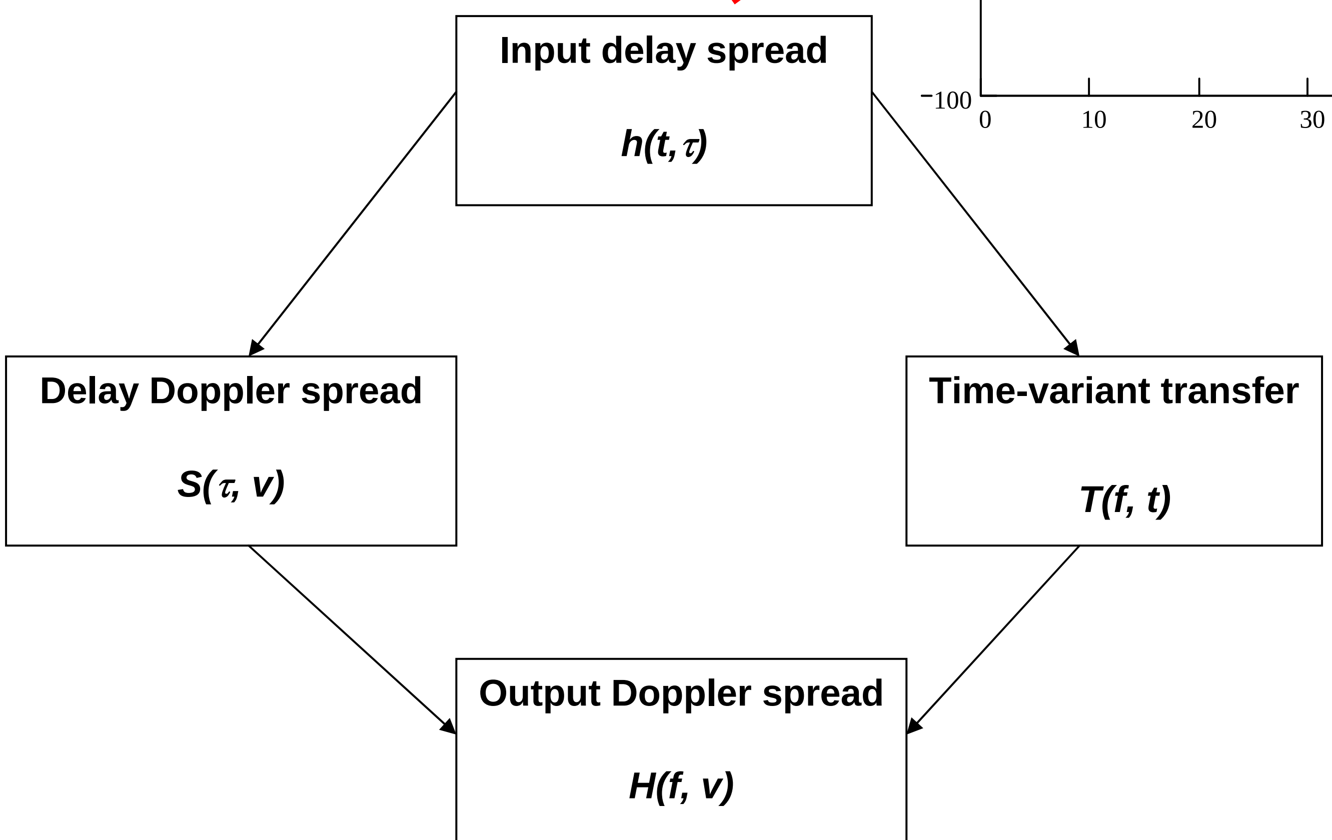
Previous studies

- **Aegis study on building penetration loss at 1-5 GHz**
  - Used helium balloon to explore variety of elevation angles
  - Results presented at ICAP ’03
- **Wideband outdoor-indoor measurements at cellular frequencies & 2.4 GHz**
  - Generally near-horizontal paths

ÆGIS

The wideband channel (1)





The wideband channel (2)

Mean delay:

$$T_d = \frac{\sum_{i=1}^{n} P_i \tau_i}{\sum_{i=1}^{n} P_i}$$

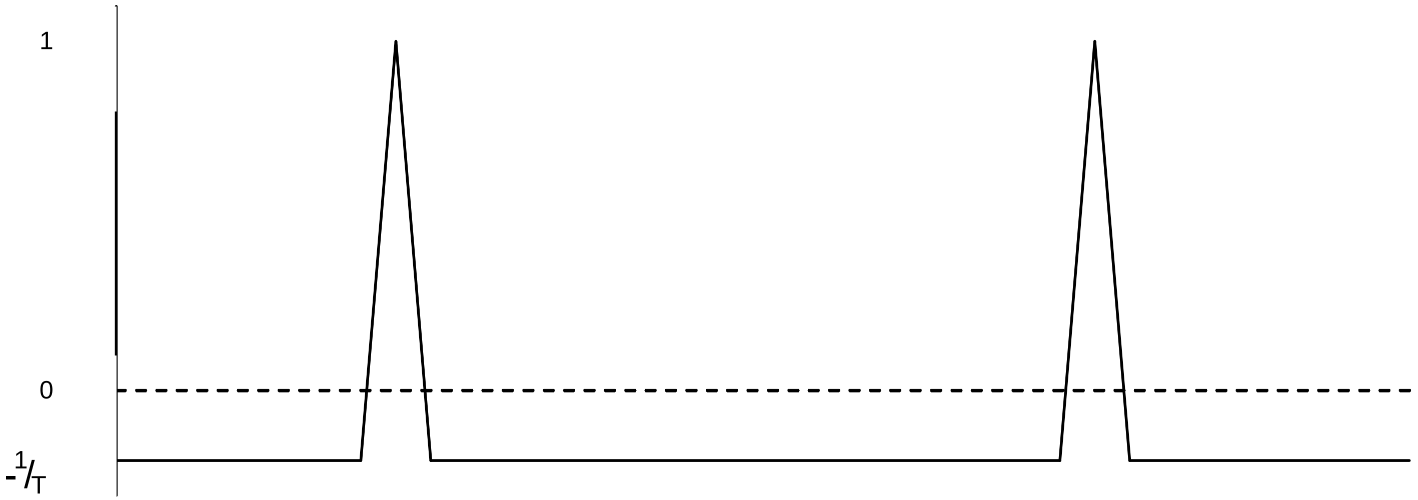
Delay Spread:

$$S = \sqrt{\frac{1}{P_t}\sum_{i=1}^{n} p_i \tau_i^2 - T_d^2}$$

(P.1407)

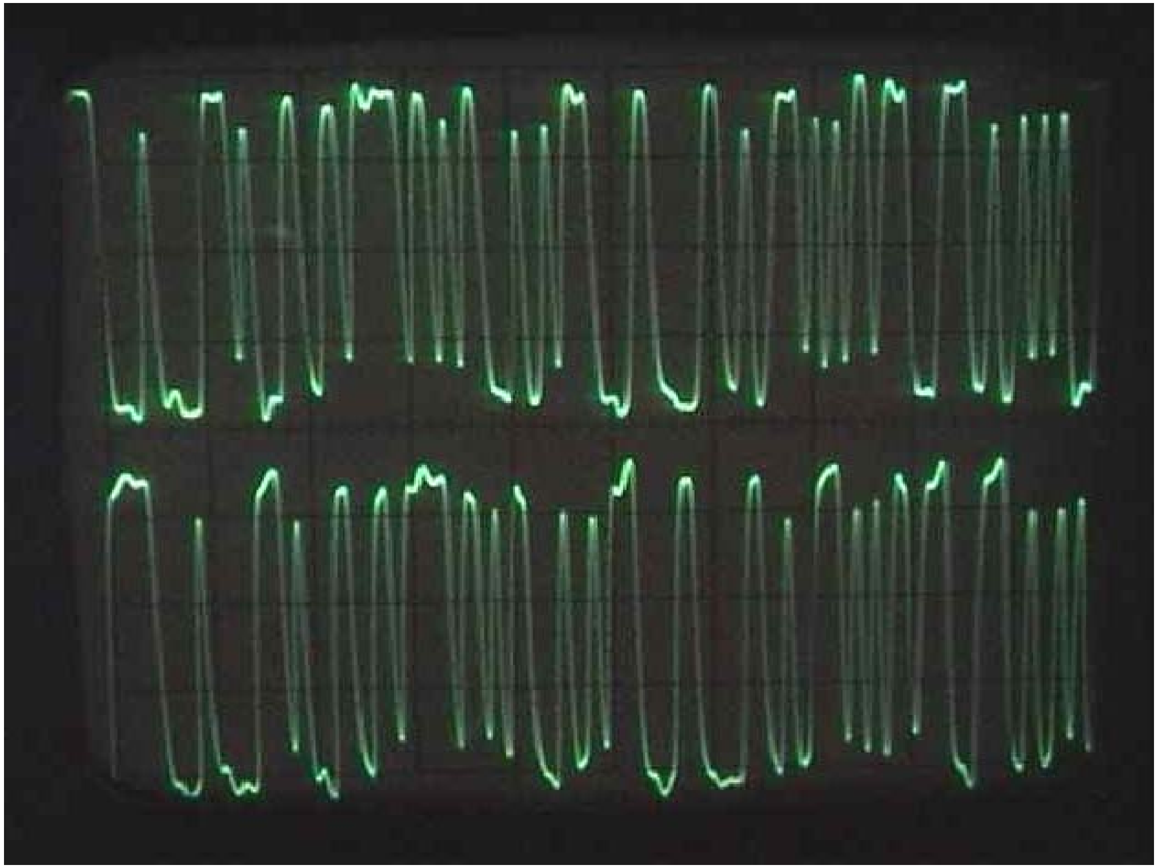
Experimental approach (2)

Autocorrelation of PN sequence



Experimental approach (1)

Channel sounder used the 'sliding correlator' approach



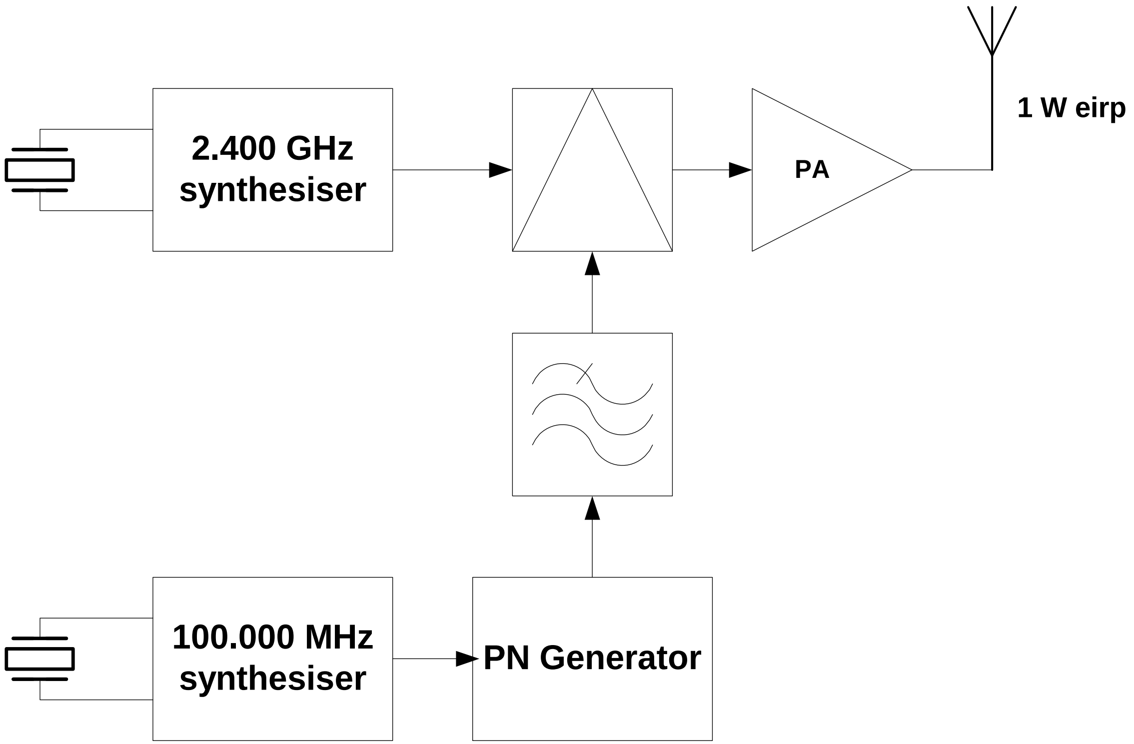
Experimental approach (3)

Sounder parameters

Carrier frequency	**2400 MHz**
Chip rate	**100 Mb/s**
Sequence length	**511 bits**
dynamic range (max)	**54 dB**
Slip rate	**12 kHz**
IF Filter BW	**24 KHz**
Scaling factor	**8,167**
IF frequency	**45 MHz**

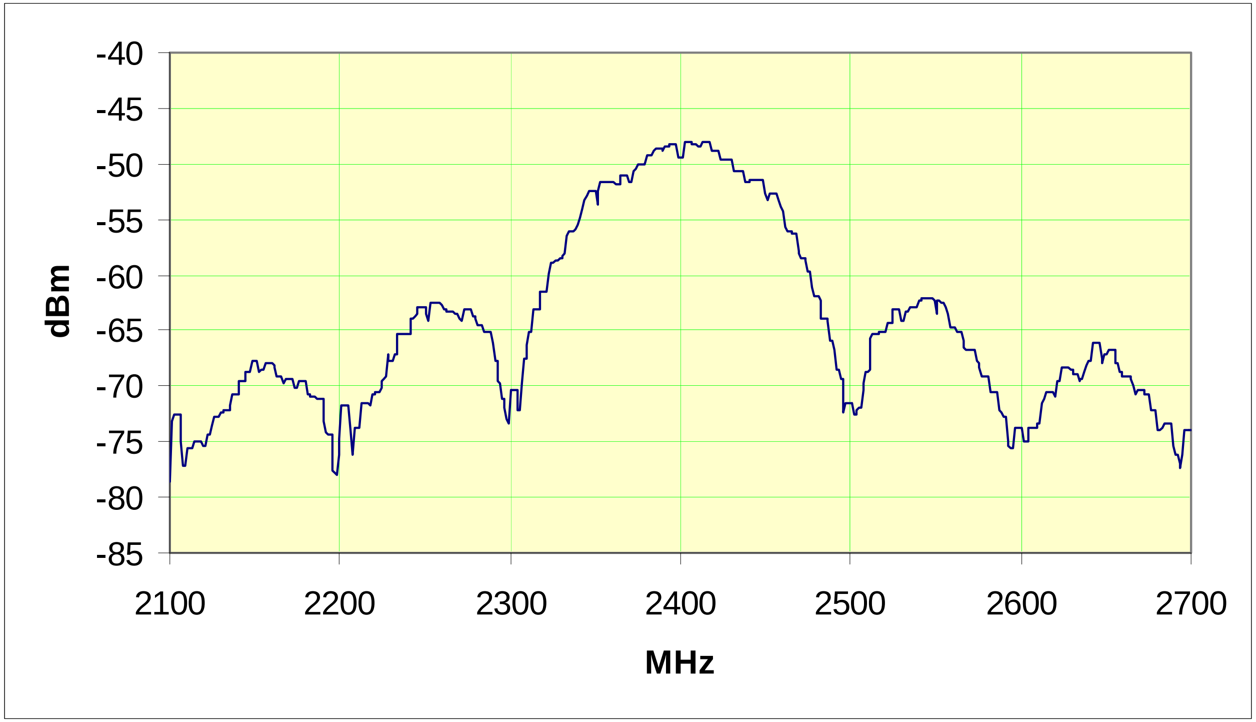
ÆGIS

Transmitter design (1)



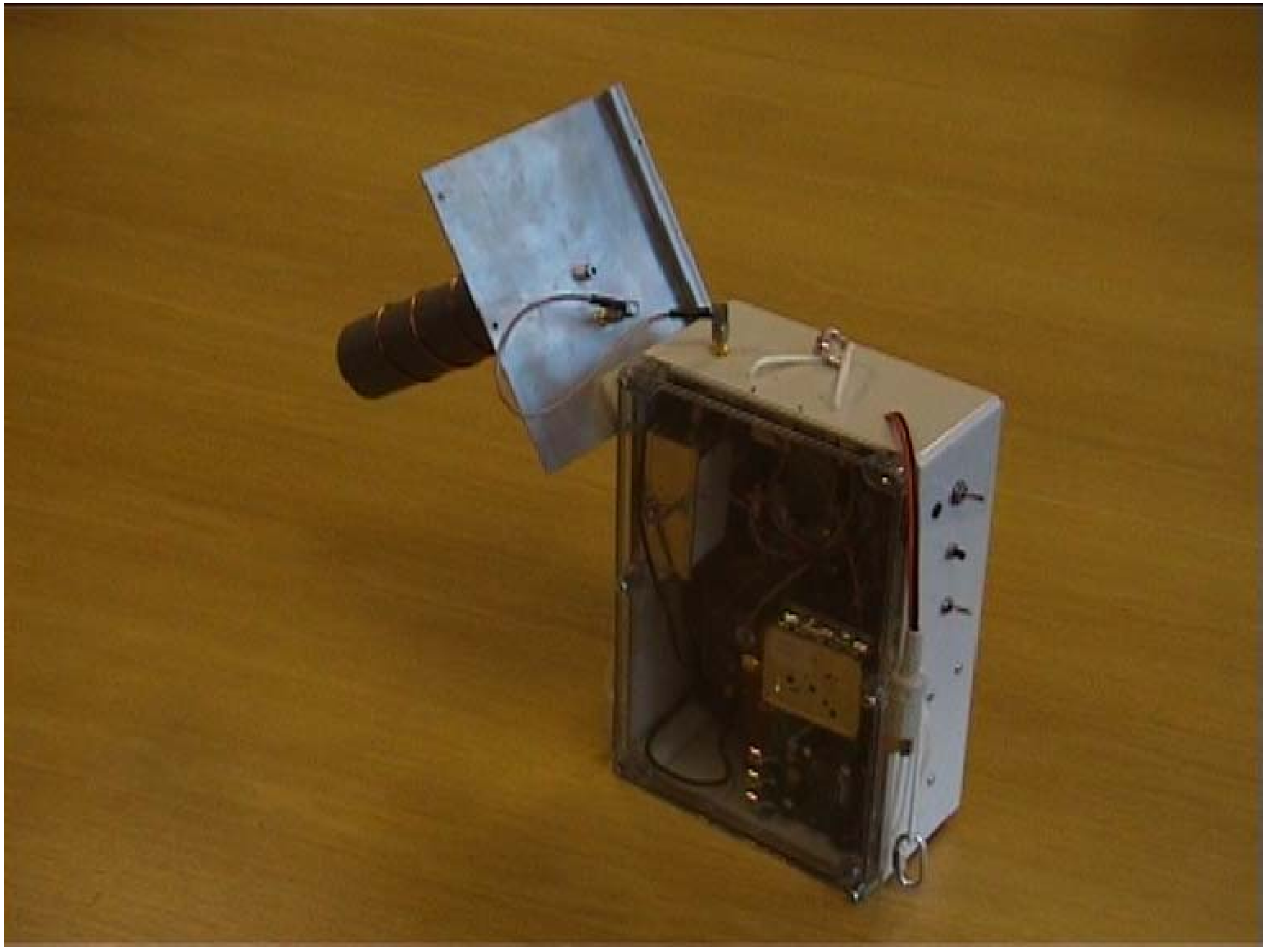
Transmitter design (2)

Transmitted spectrum (without filter)



Transmitter design (3)

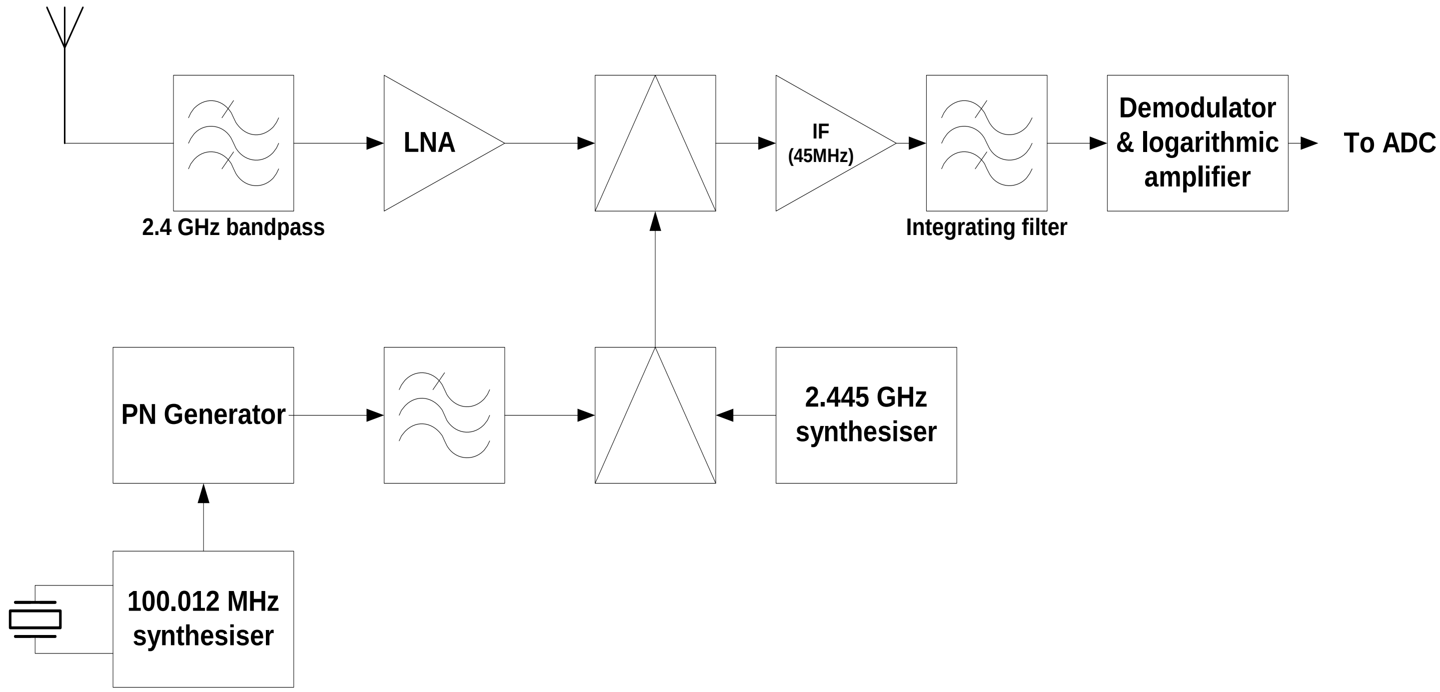
Balloon payload



ÆGIS

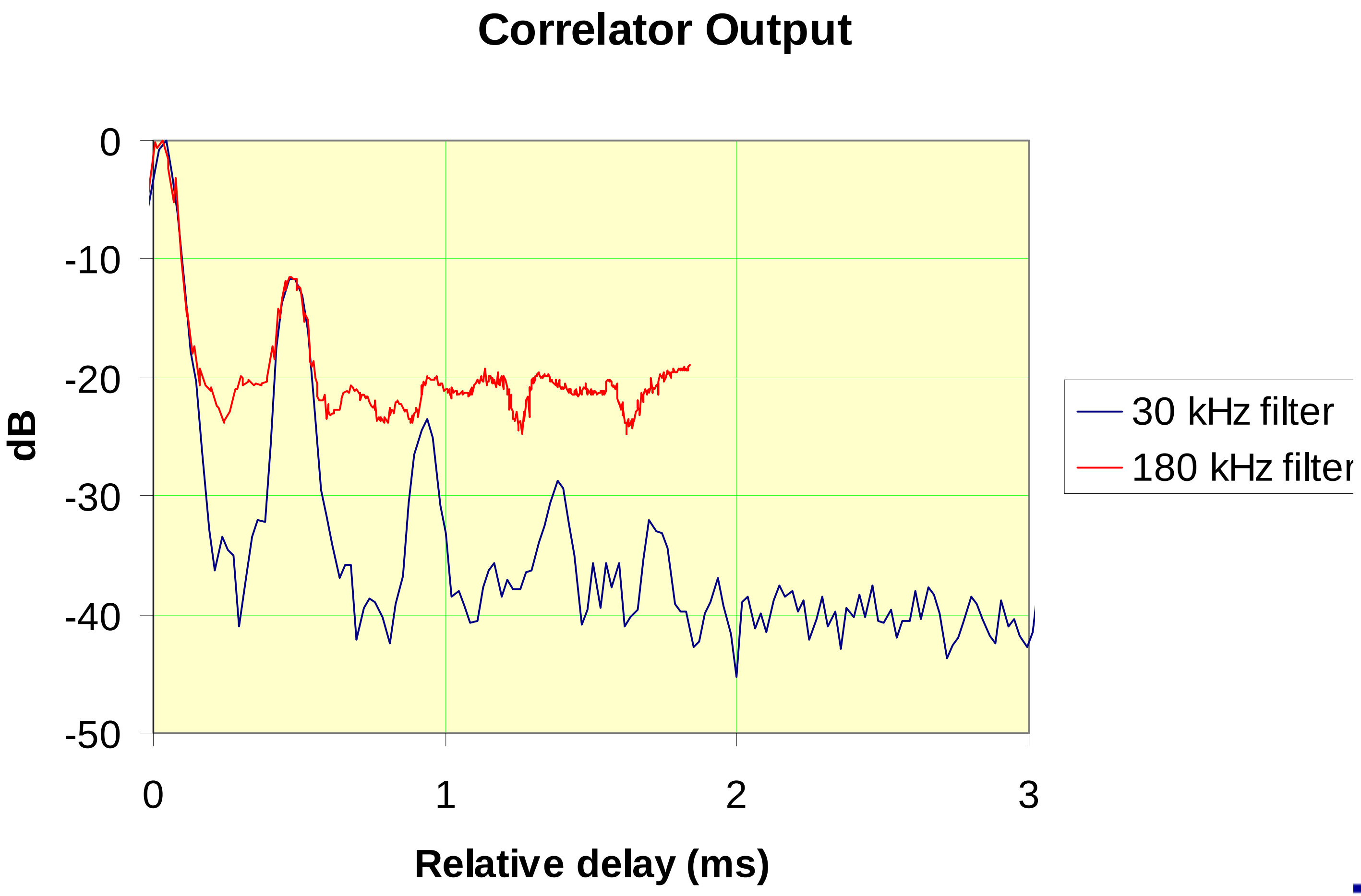
Receiver design (1)

Simplified, low-cost, architecture



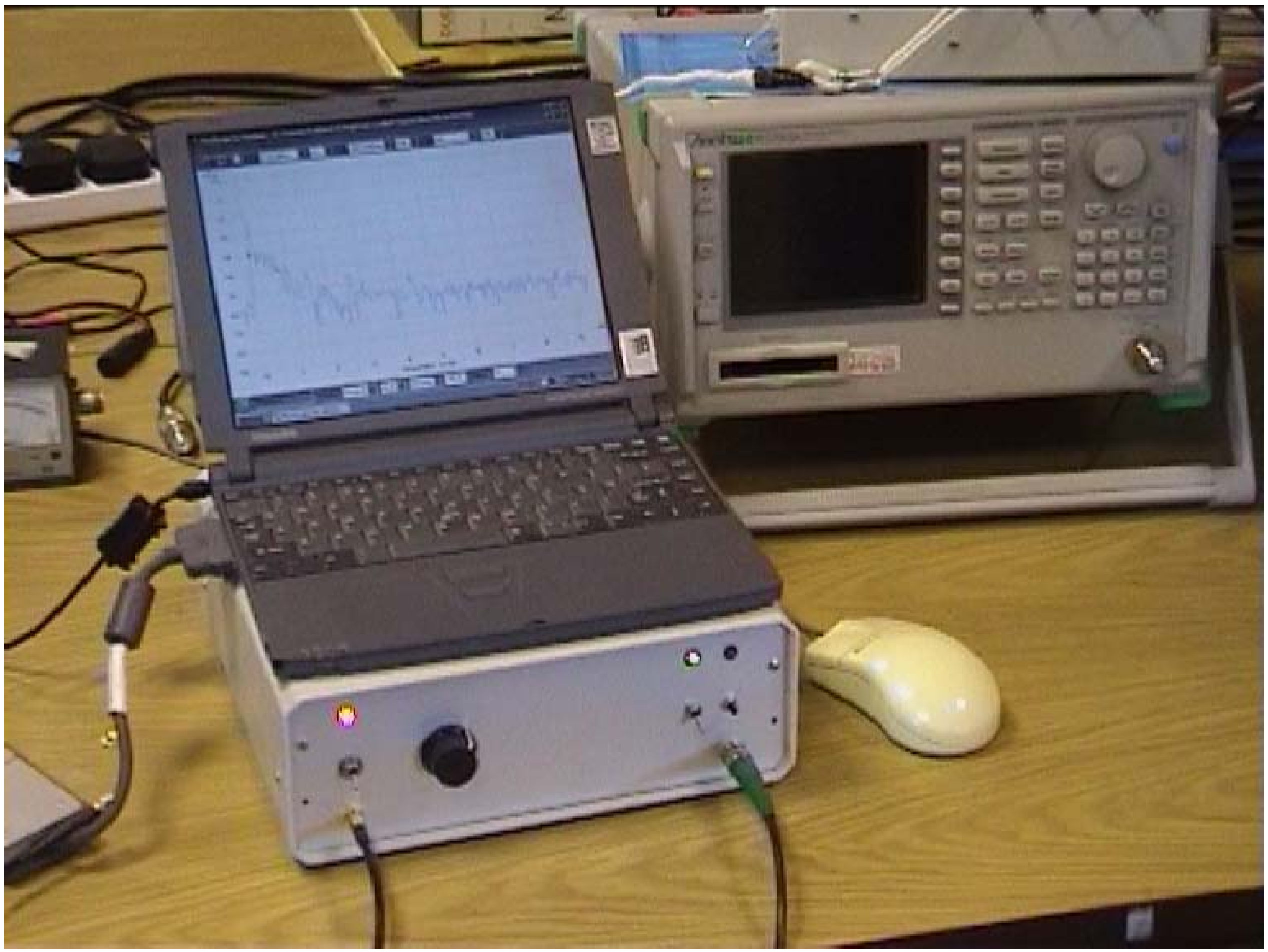
Receiver design (2)

Performance of integrating filter



Receiver design (3)

Correlating receiver

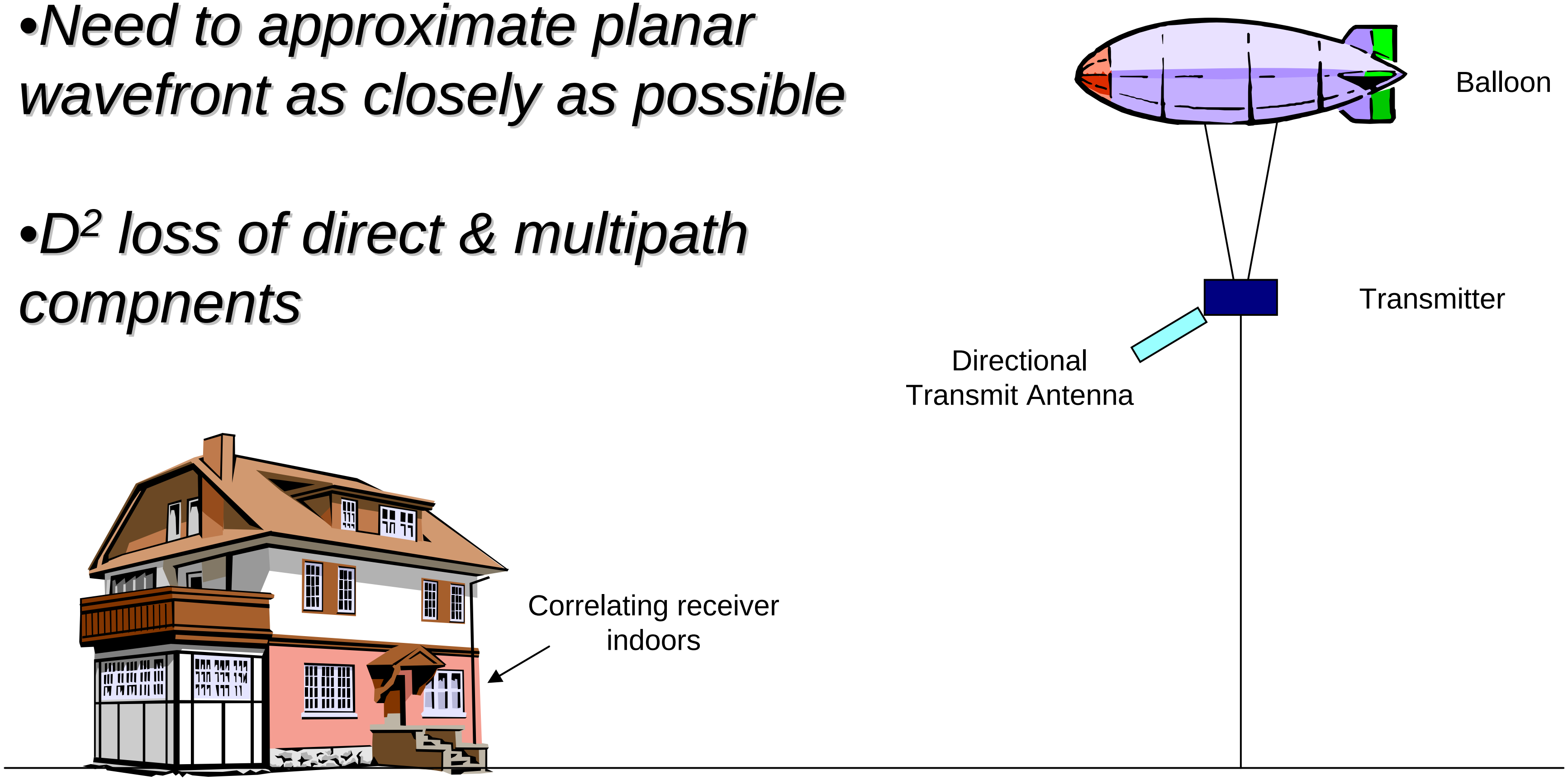


ÆGIS

Measurement campaign (1)

- *Need to approximate planar wavefront as closely as possible*

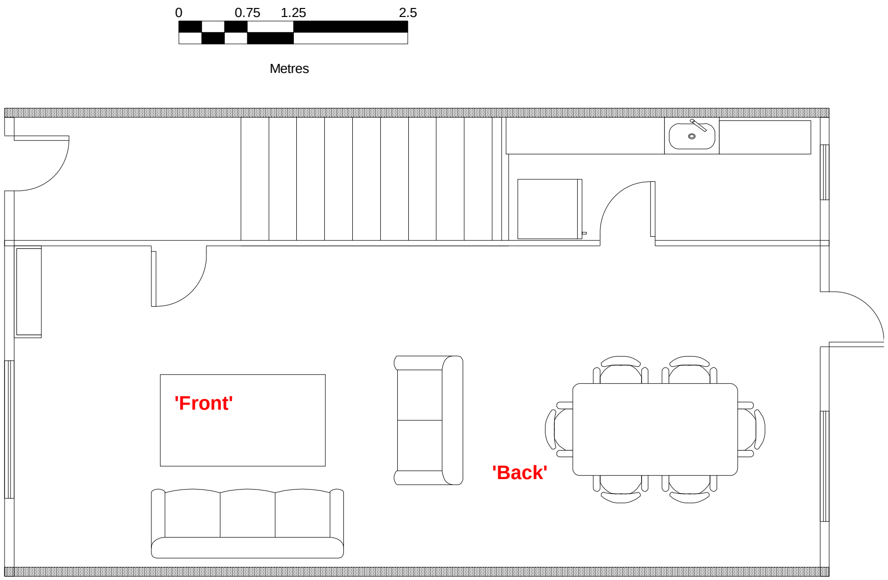
- *D^2 loss of direct & multipath compnents*

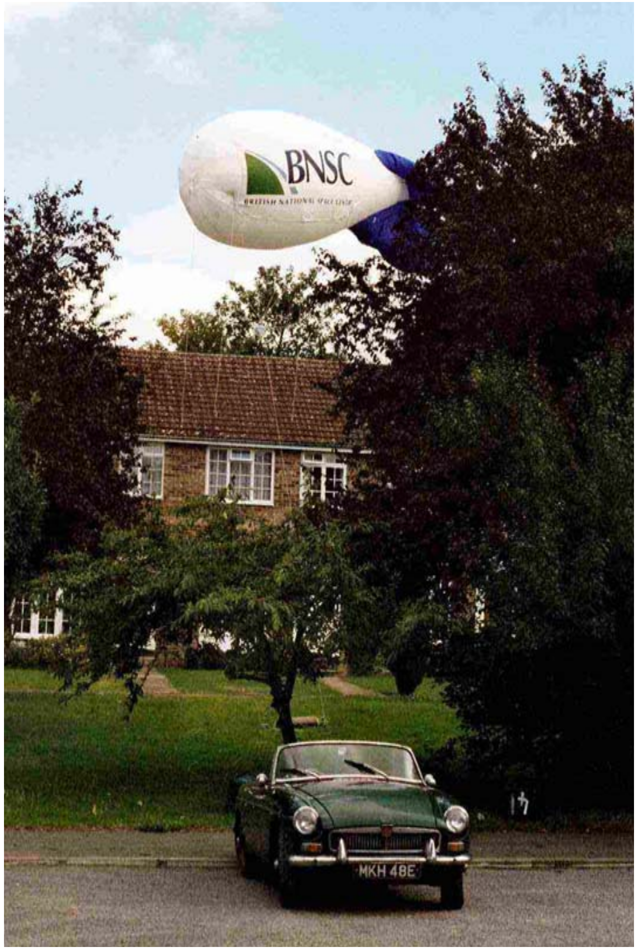


Measurement campaign (2)

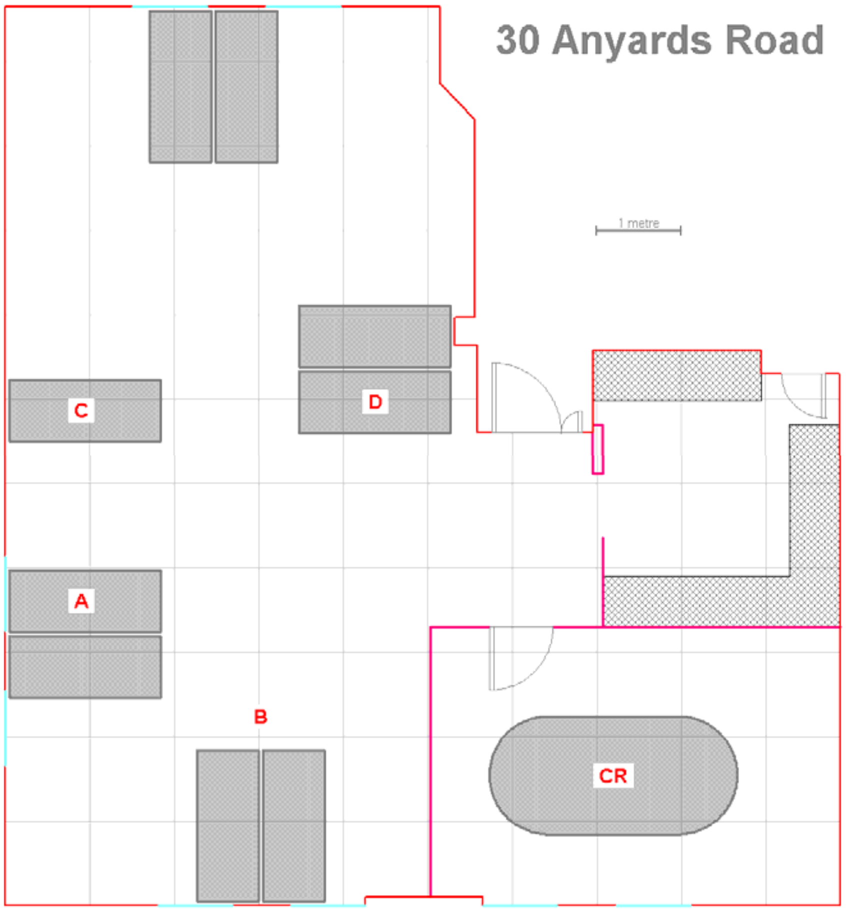
CP antenna design

Measurement locations (1)

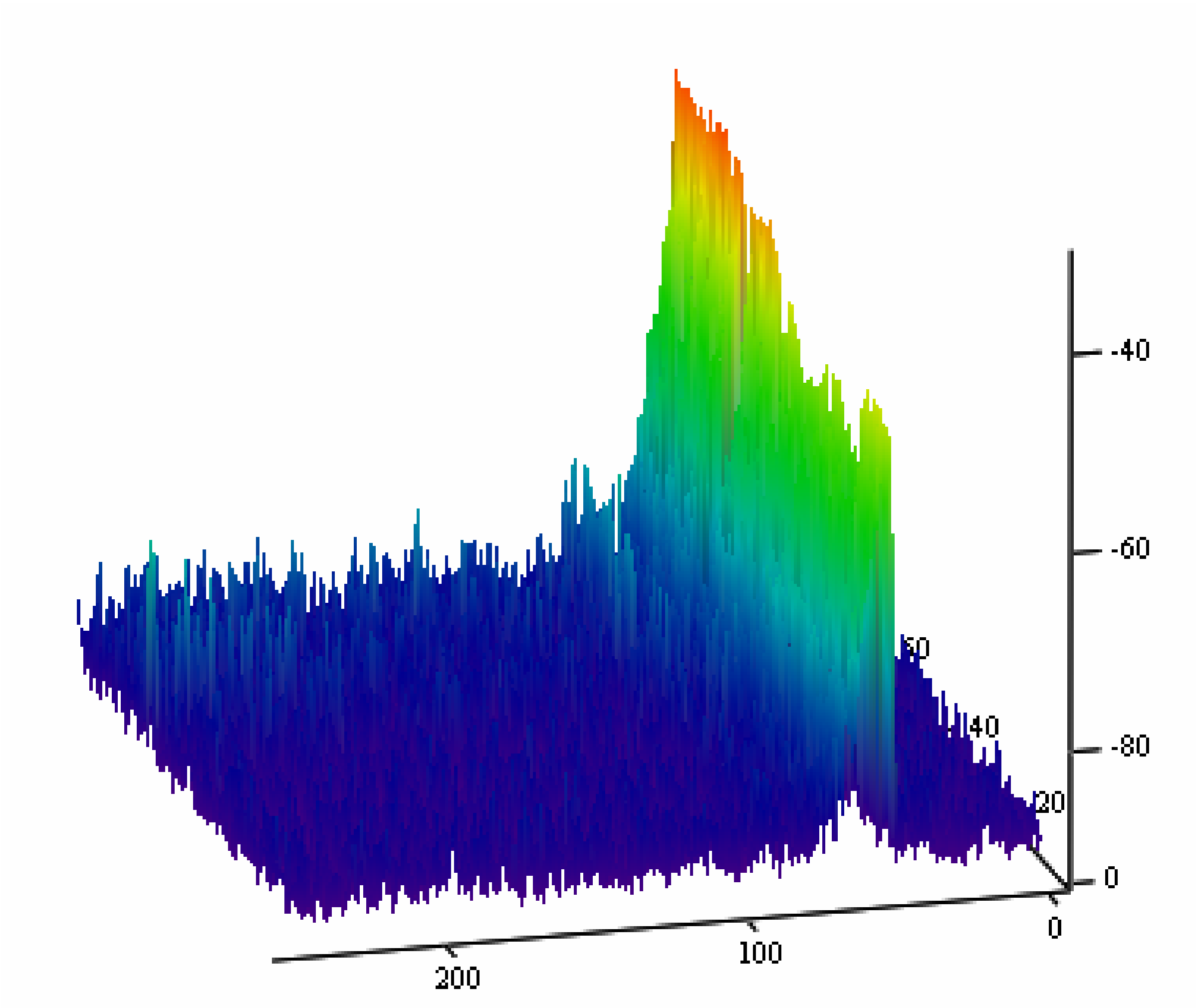




Measurement locations (2)

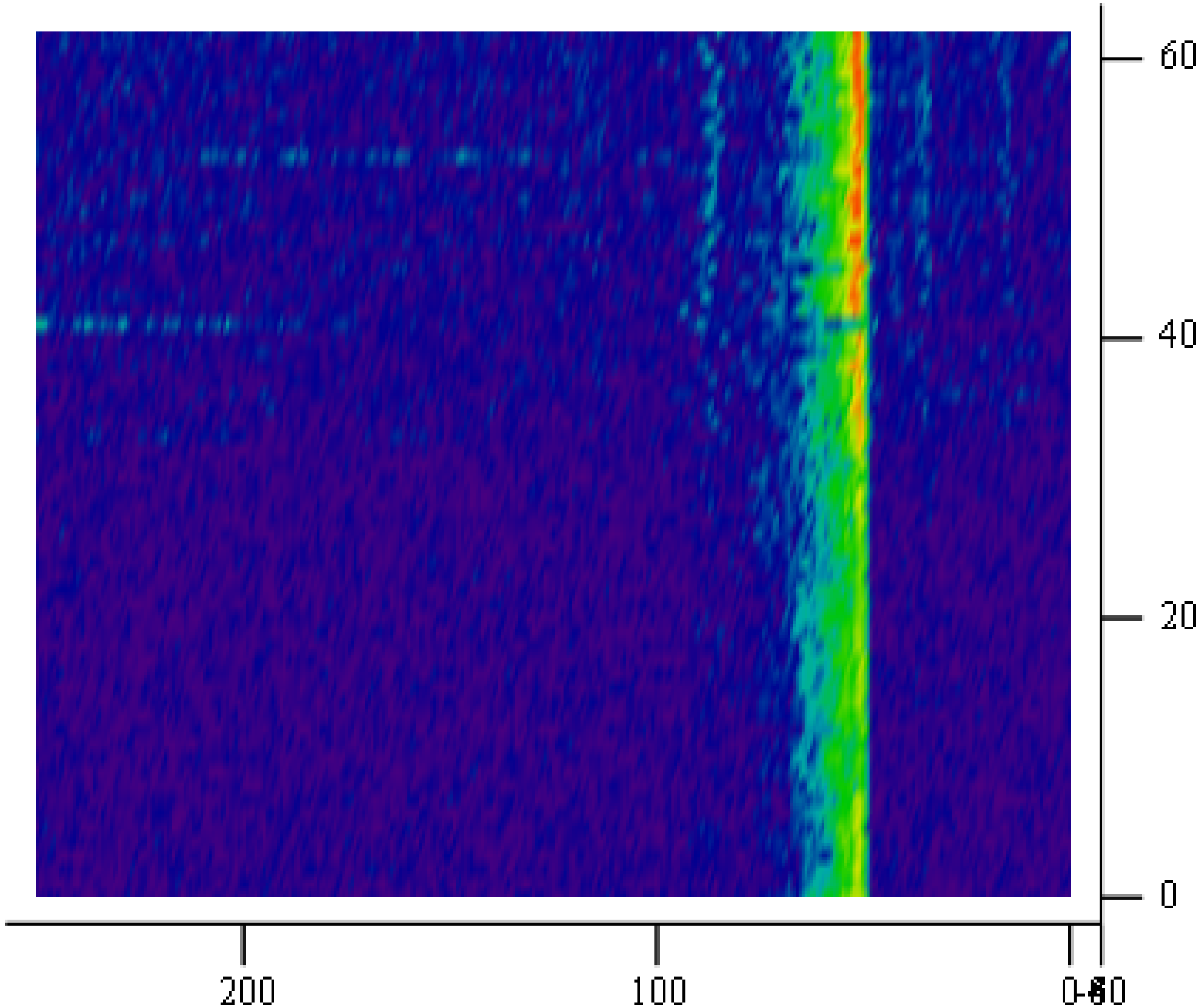


Data reduction (1)



Time-series of channel temporal response

Data reduction (2)

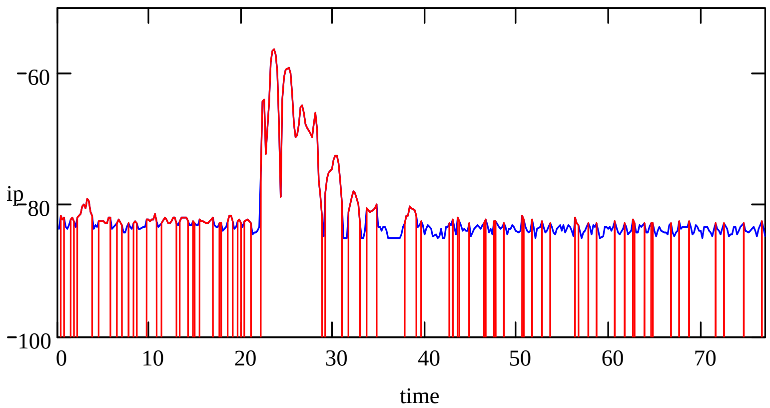


new acf db

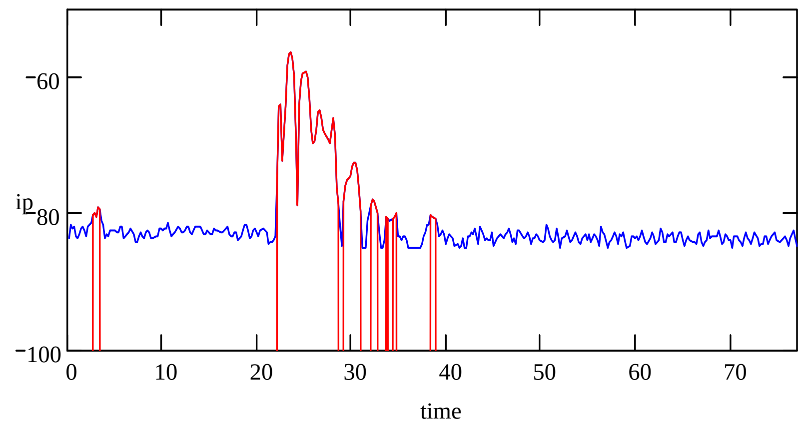
Data reduction (3)

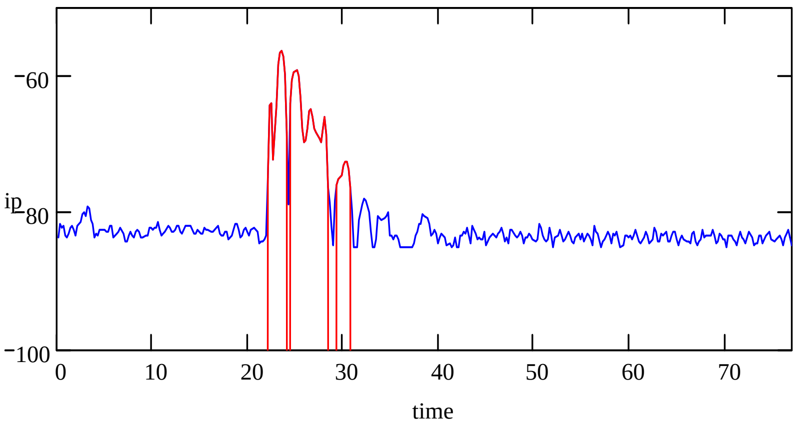
- **Antenna pointing**
  - Need to discard results where overall received power <-3dB w.r.t. boresight
- **Clipping level**
  - Manual inspection & setting of appropriate level

Data reduction (4)



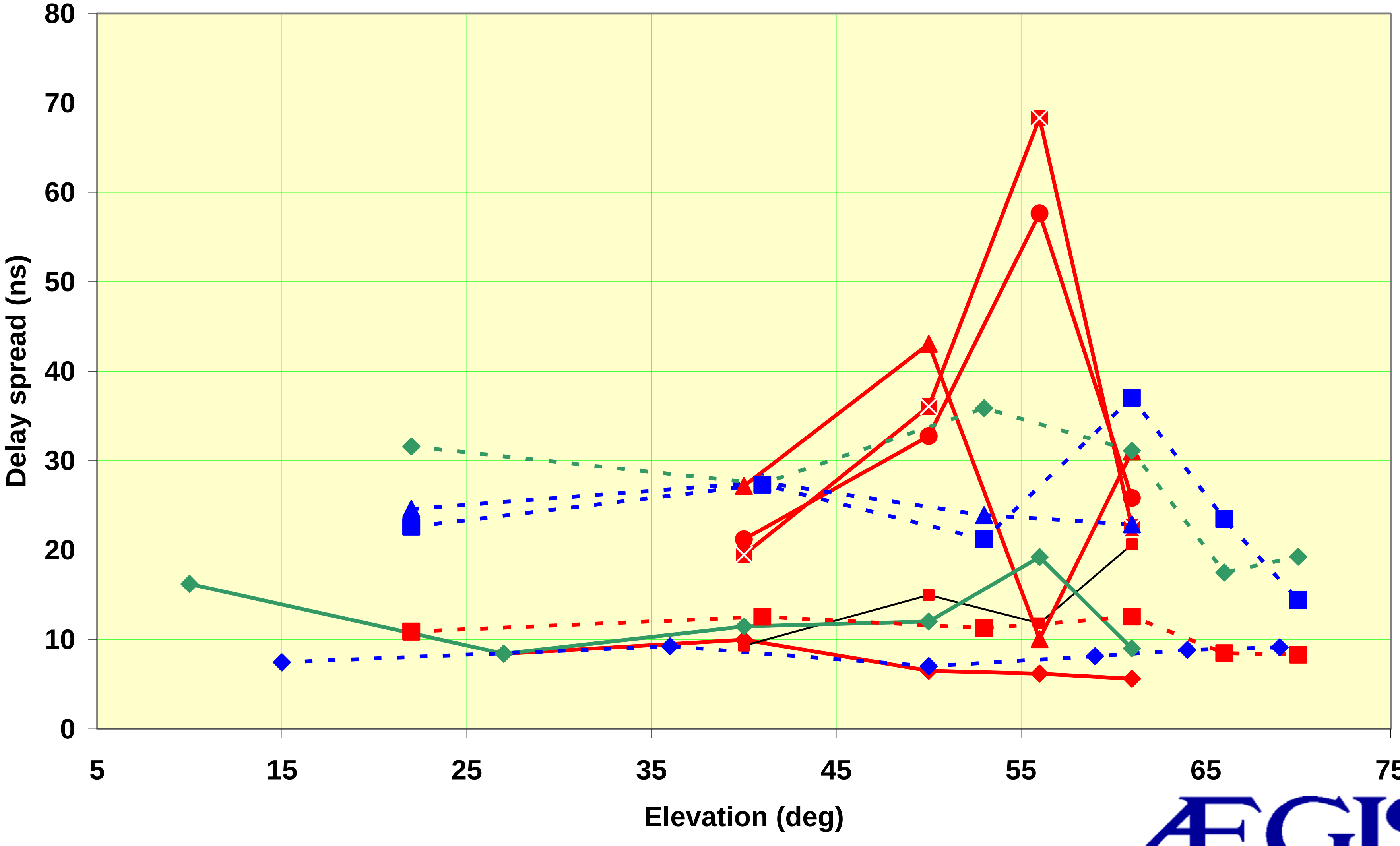
Clipping levels



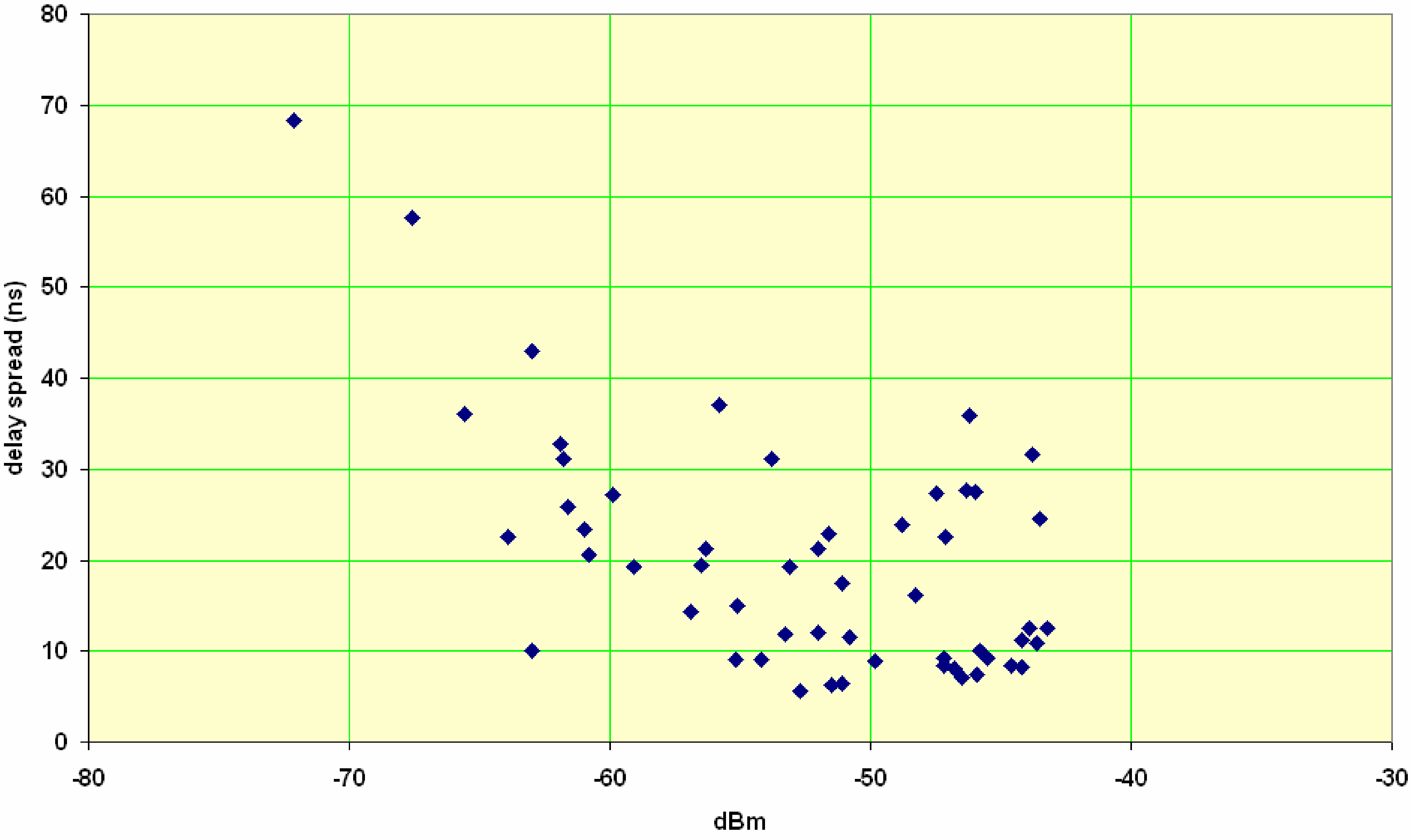


ÆGIS

Overall results

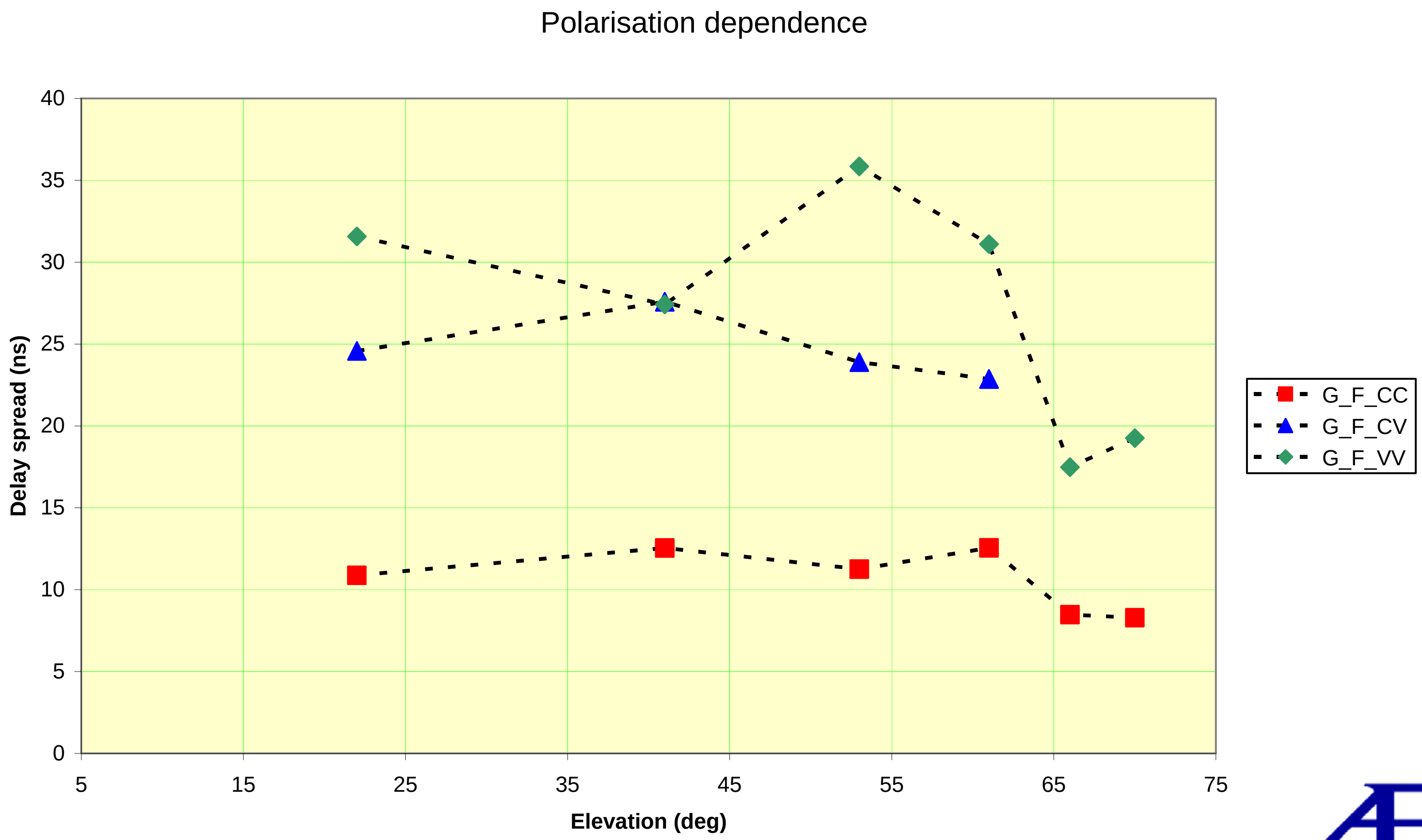


Delay spread vs. loss

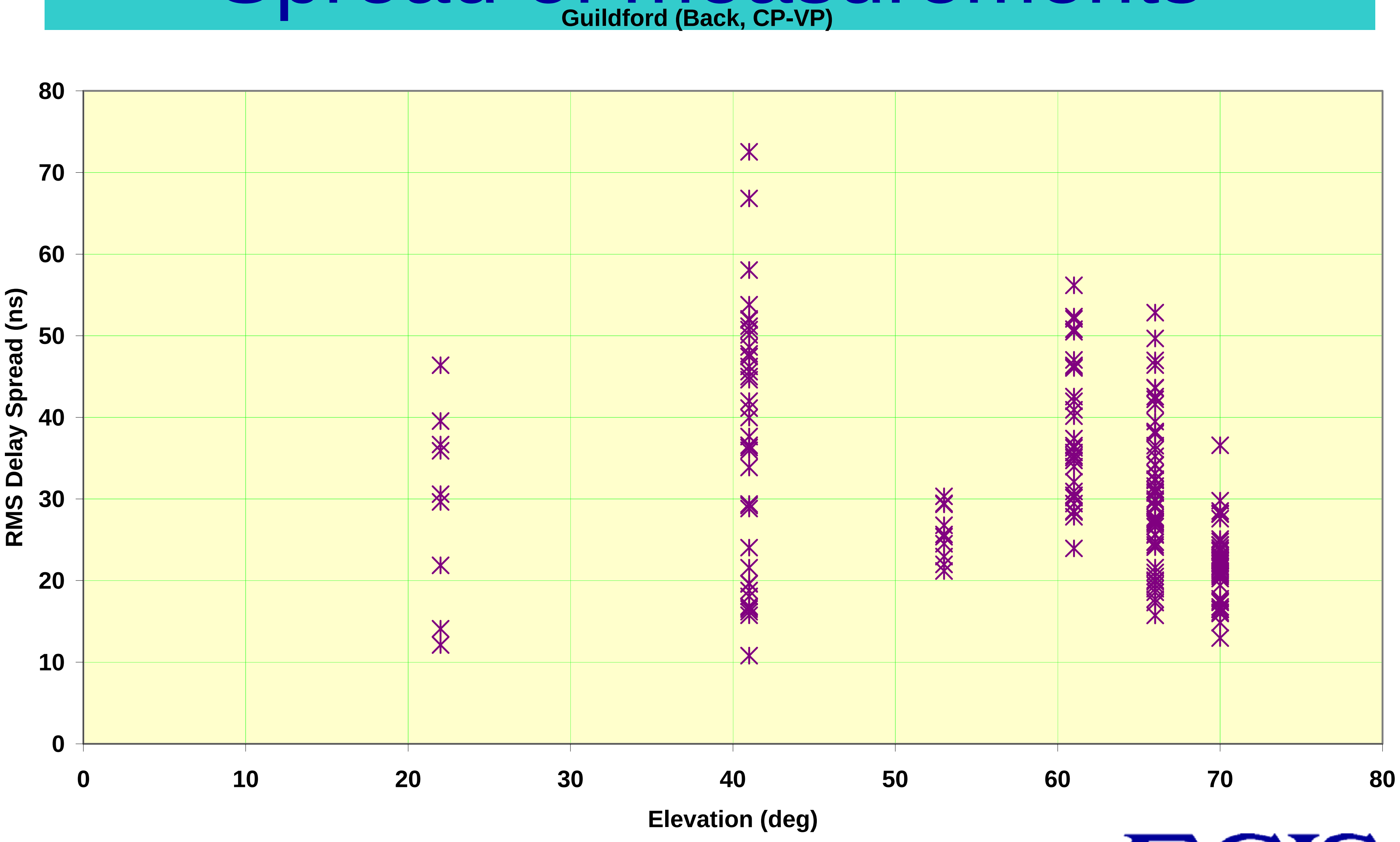


Polarisation dependence

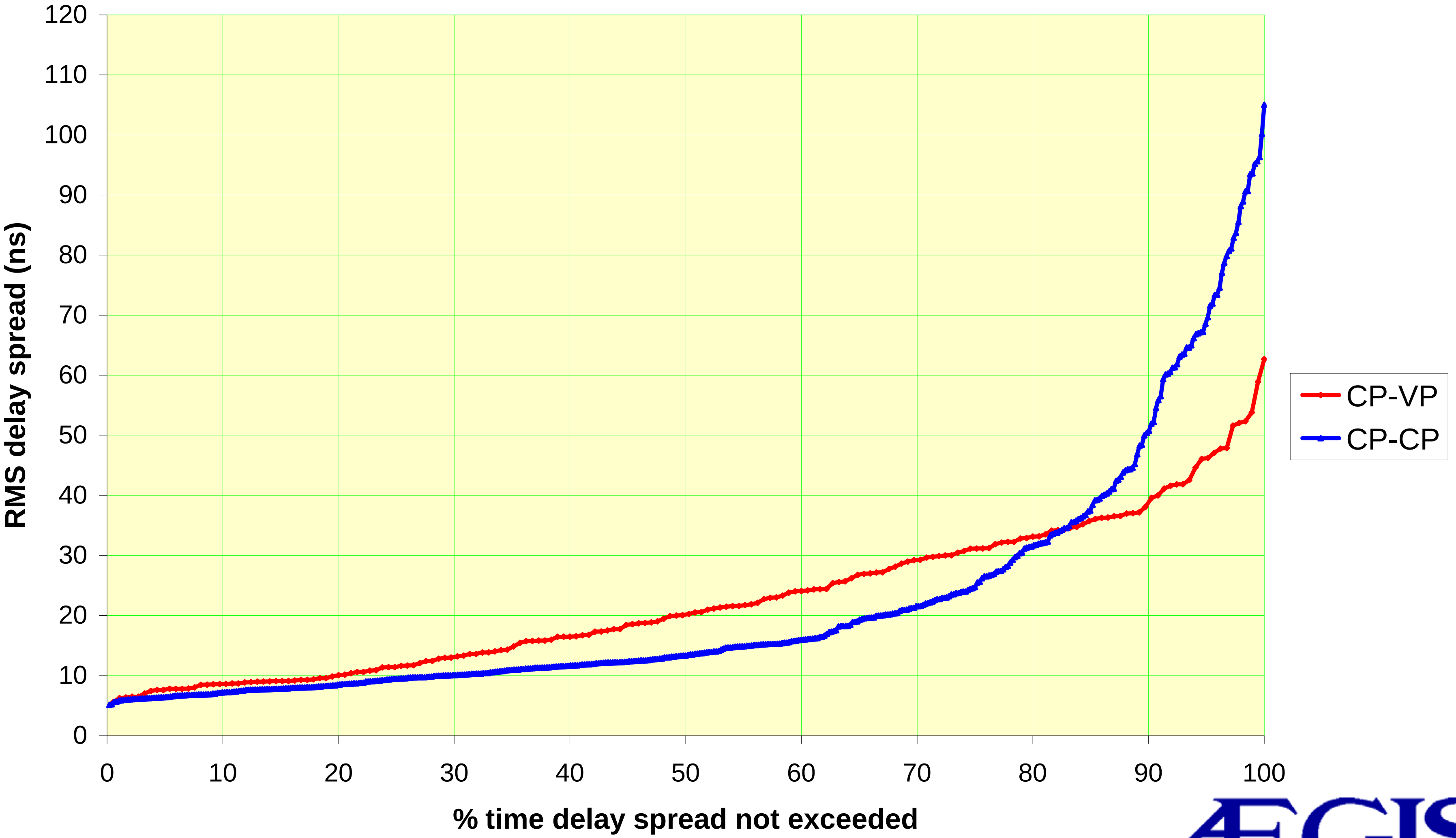
- *Strongest multipath componets from 1st order reflections*
- *Rejected by mutually CP antennas*



Spread of measurements

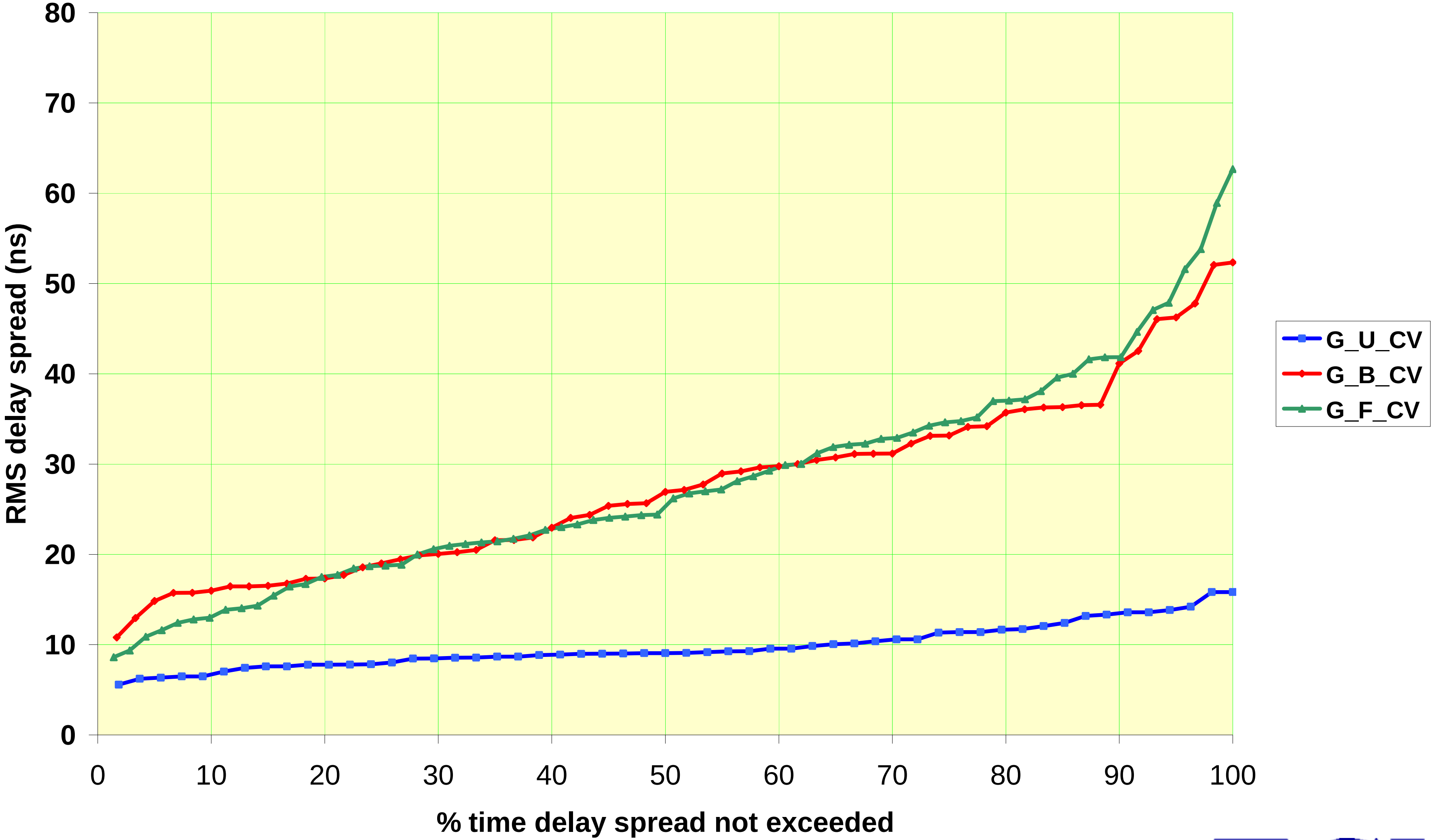


Overall cumulative statistics



ÆGIS

CP-VP statistics



ÆGIS

Leeds University measurements

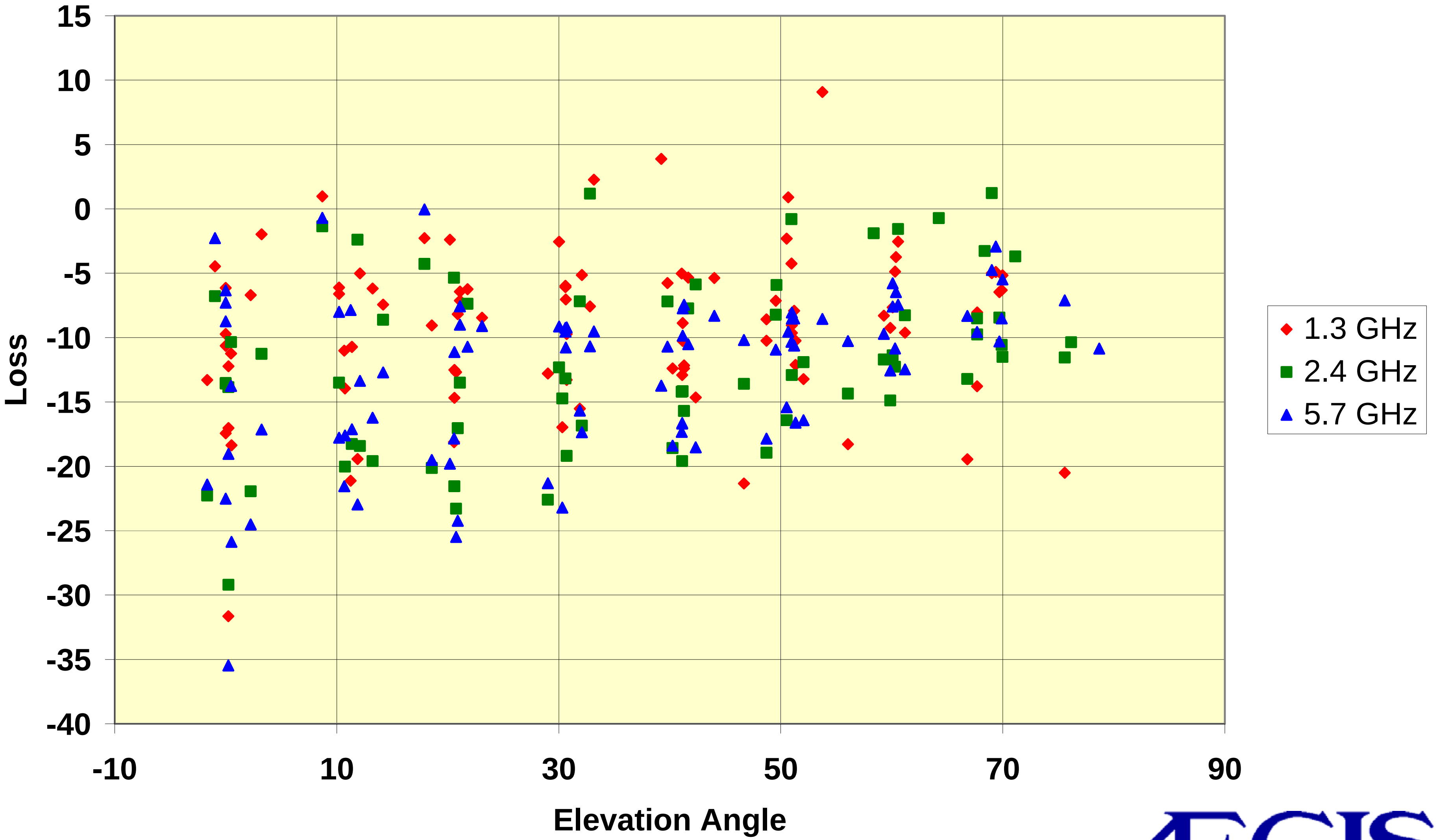
- **A related S@TCOM project**
  - ‘Galileo discriminators for urban and indoor environment and exploitation of the mass market”
  - Astrium / Roke Manor / Leeds University
- **Sounder operated at 1.6 GHz**
  - ‘Spectrum-friendly’ modulation
  - Results comparable to Aegis findings

Leeds University measurements

- **median delay spread**
  - Leeds: 30-65 ns
  - Aegis: 10-80 ns
- **benign location – range of delay spread**
  - Leeds: 11-60 ns
  - Aegis: 9-62 ns
- **worst location – range of delay spread**
  - Leeds: 9 - 193 ns
  - Aegis: 5 -105 ns

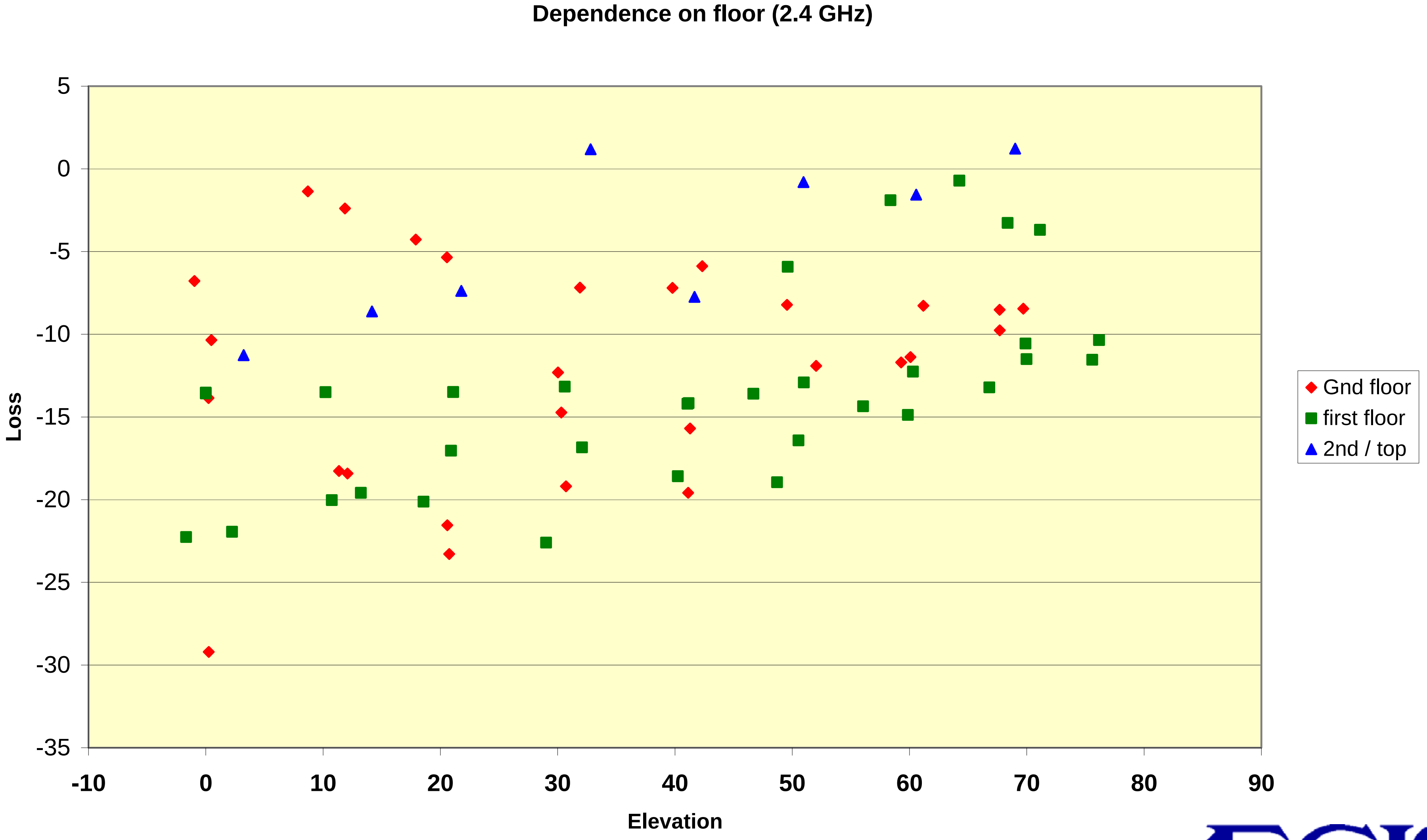
ÆGIS

Building loss measurements

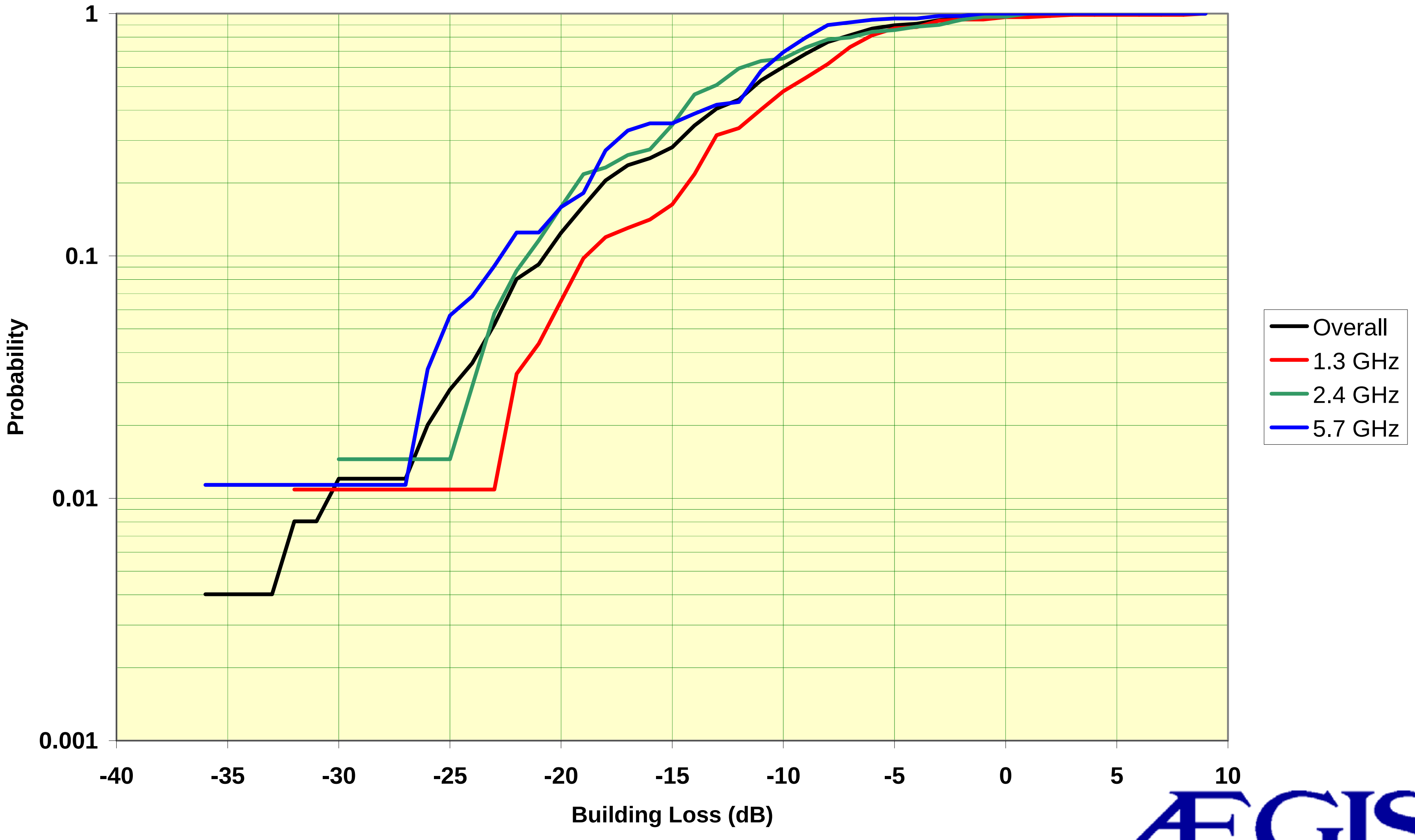


ÆGIS

Building loss measurements



Building loss measurements



ÆGIS

Conclusions

- **Indoor satellite channel exhibits great variability**
- **Median delay spread typically 10-80ns**
  - Possible ISI for systems with 10-100 MHz bandwidth
  - Worst case delay extends to 105ns in current study
- **CP antennas minimise delay spread**
- **Building median penetration typically 12dB**
  - Some bandwidth & elevation dependence

ÆGIS

Thank you!

Richard Rudd
Aegis Systems Limited
www.aegis-systems.co.uk

ÆGIS