Base Station Diversity Investigation of Mobile Radio at 450 MHz

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- Background of the project
- The investigation
- Measurement results
- Discussion and conclusions

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1. Background

- Mobile radio channel:
  - Signals are combined constructively/destructively which results in the *multipath fading* problem.
- Solutions: ***diversity*** systems
  - The main idea is that copies of the signal/data with independent statistics should be received.
  - It could be in the frequency domain, time domain or the space domain.
  - ***Antenna diversity***: space, polarisation, and pattern.

Antenna diversity

- Theory
  - Well developed, but new diversity schemes and applications are still being proposed and implemented.
  - Combining methods:
    - *Selection diversity*: choosing the signal with the highest signal to noise ratio (SNR) from one of the branches at every instant.
    - *Maximal ratio combining*: signals weighted proportionately to their SNR and then summed.
    - *Equal gain combining*: signals are weighted by a constant before summing.

Antenna diversity

- The most important parameters
  - *Mean power at each branch*
  - *Correlation coefficient*
  - *Diversity gain*

$$\rho_{12} = \frac{\left\langle \left(z_1 - \langle z_1 \rangle\right)^* \left(z_2 - \langle z_2 \rangle\right) \right\rangle}{\sqrt{\left\langle \left| z_1 - \langle z_1 \rangle \right|^2 \right\rangle} \sqrt{\left\langle \left| z_2 - \langle z_2 \rangle \right|^2 \right\rangle}}$$

- Experiments/measurements
  - To validate and test diversity systems developed
  - Most investigations were conducted above 800 MHz
  - 450 MHz: private/special services, very little work
  - Scaling? X

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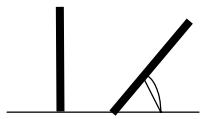
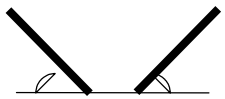
2. The investigation

- Base-station antenna configurations

Config. A 

 Config. B

Config. C 

 Config. D

- For both space and polarisation
- ***Objective***: *to identify the best configuration for uplink, if the space is limited*

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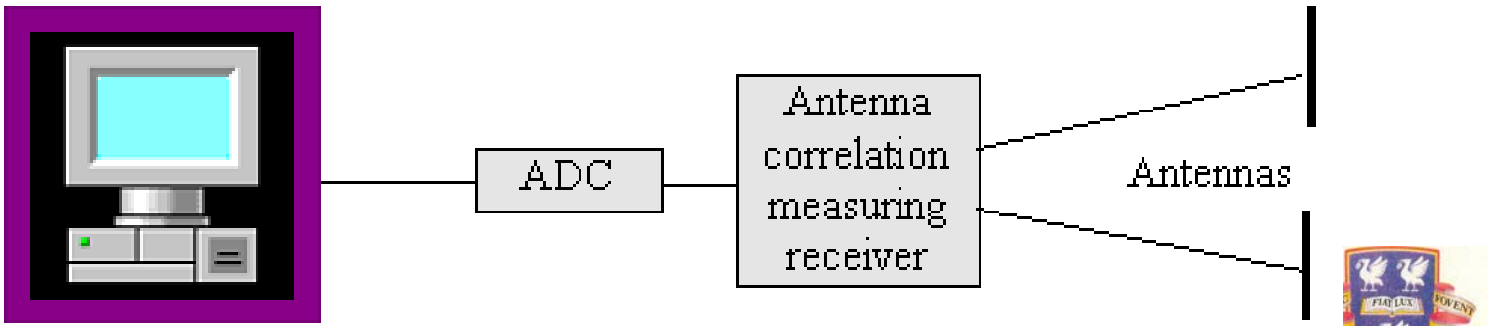
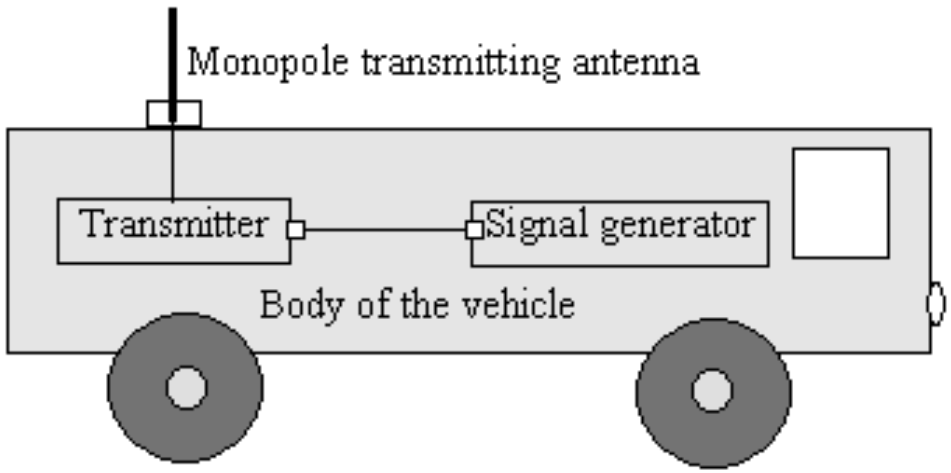
Measurement system set-up: **base station**

- Half-wavelength dipole antennas with VSWR < 2
- Receiving *I(t)* and *Q(t)* at each branch
- Sampling frequency > 600 Hz (over 100 sample/λ)
- Dynamic range > 50 dB
- 30 m above the ground



Measurement system set-up: **mobile station**

- Transmitter power 10W CW at 456 MHz
- Monopole antenna, 1.5 m above the ground
- Speed: 4m/s or 15 Km/h
- Three routes: LOS, partial LOS, and NLOS



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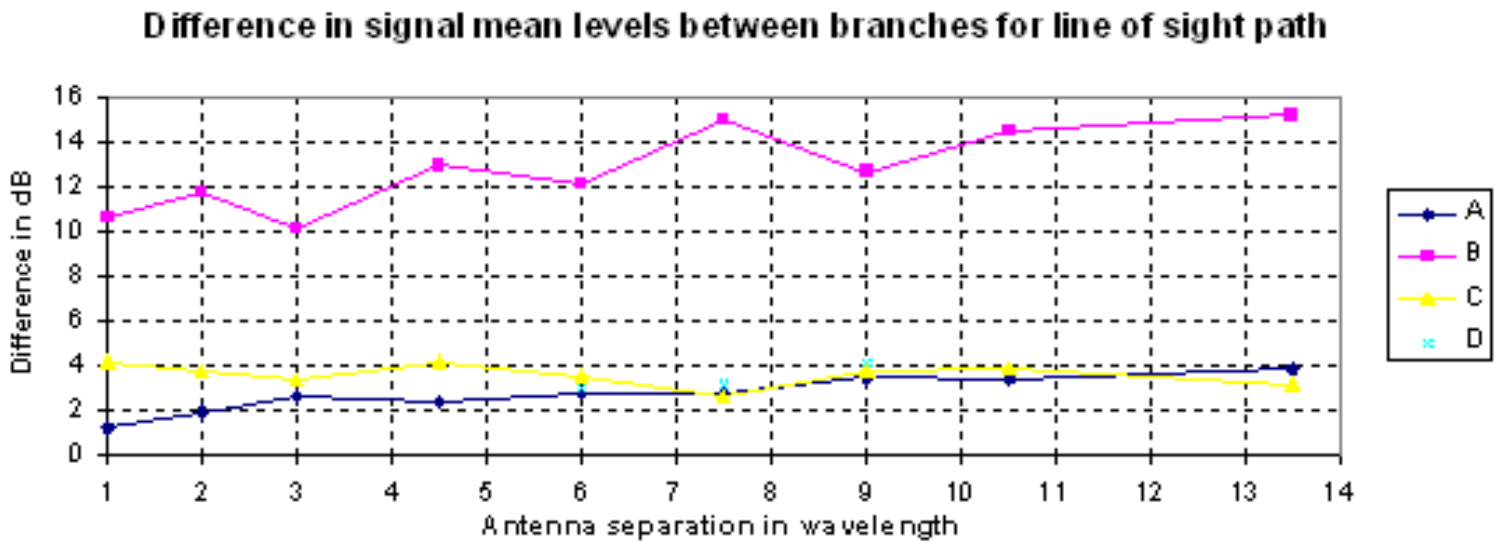
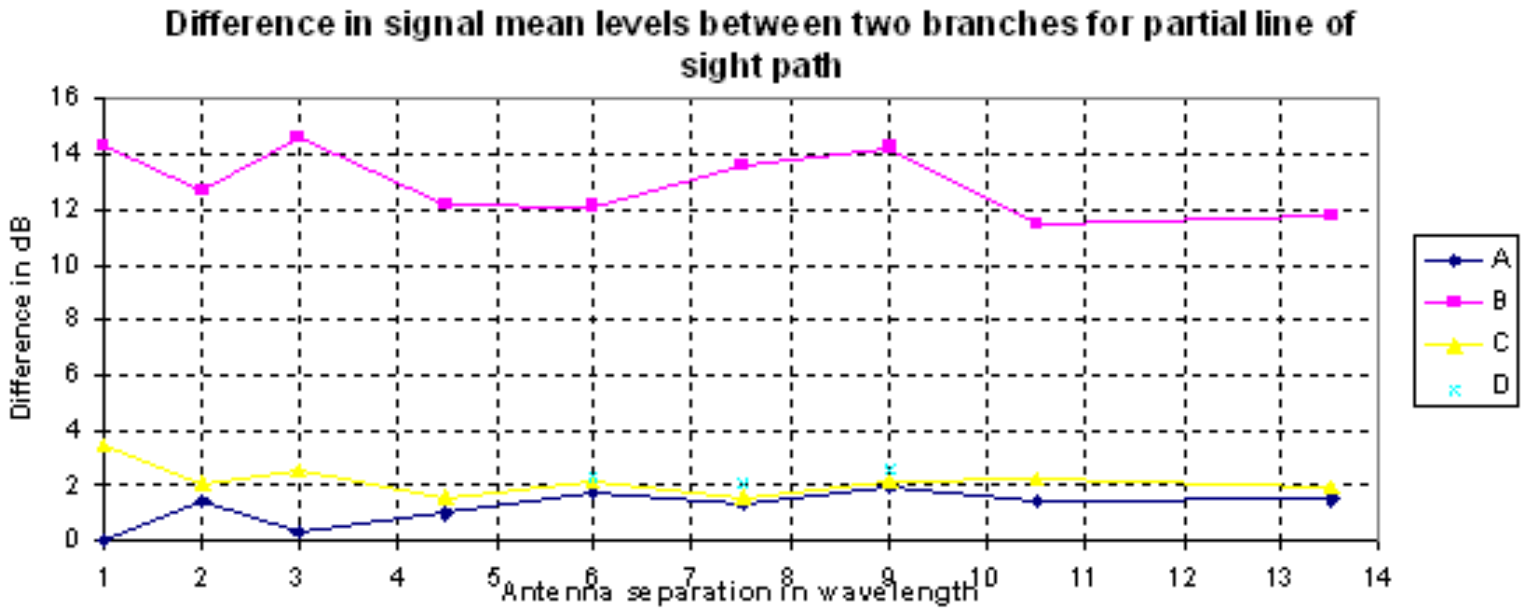
3. Measurement Results



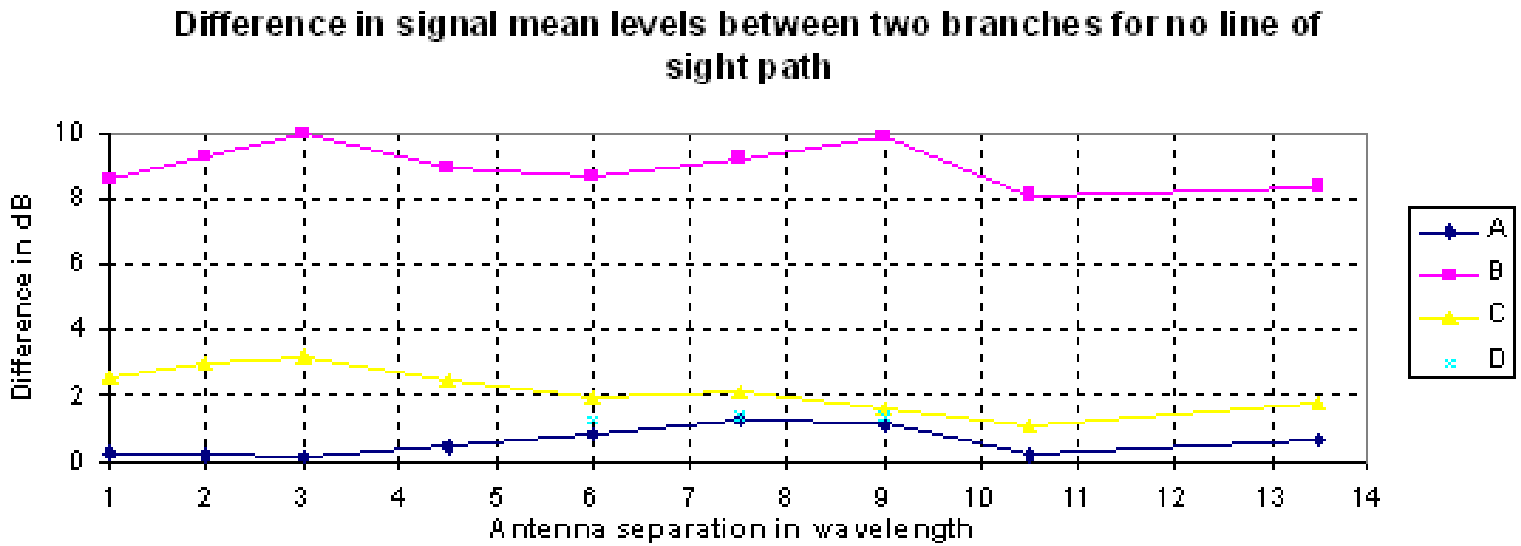
- Significant difference (13 dB) for B
- 2-4 dB difference for other configurations

3. Measurement Results



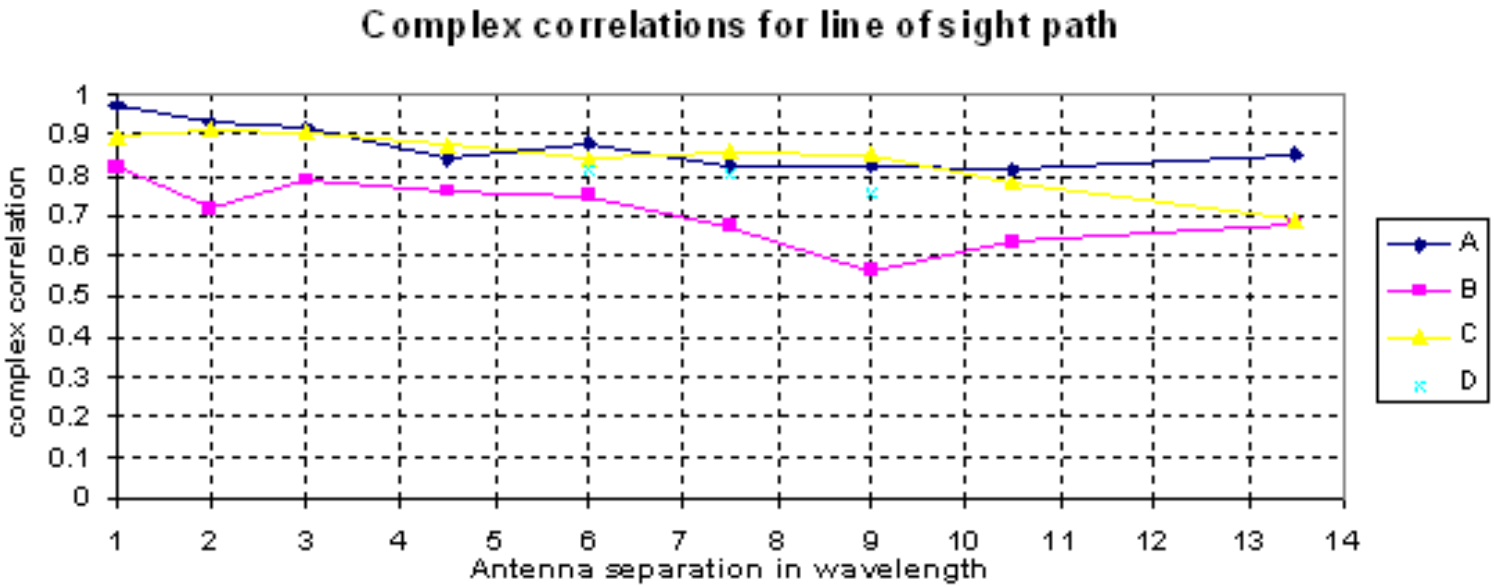
- Significant difference (13 dB) for B
- About 2 dB difference for other configurations

3. Measurement Results



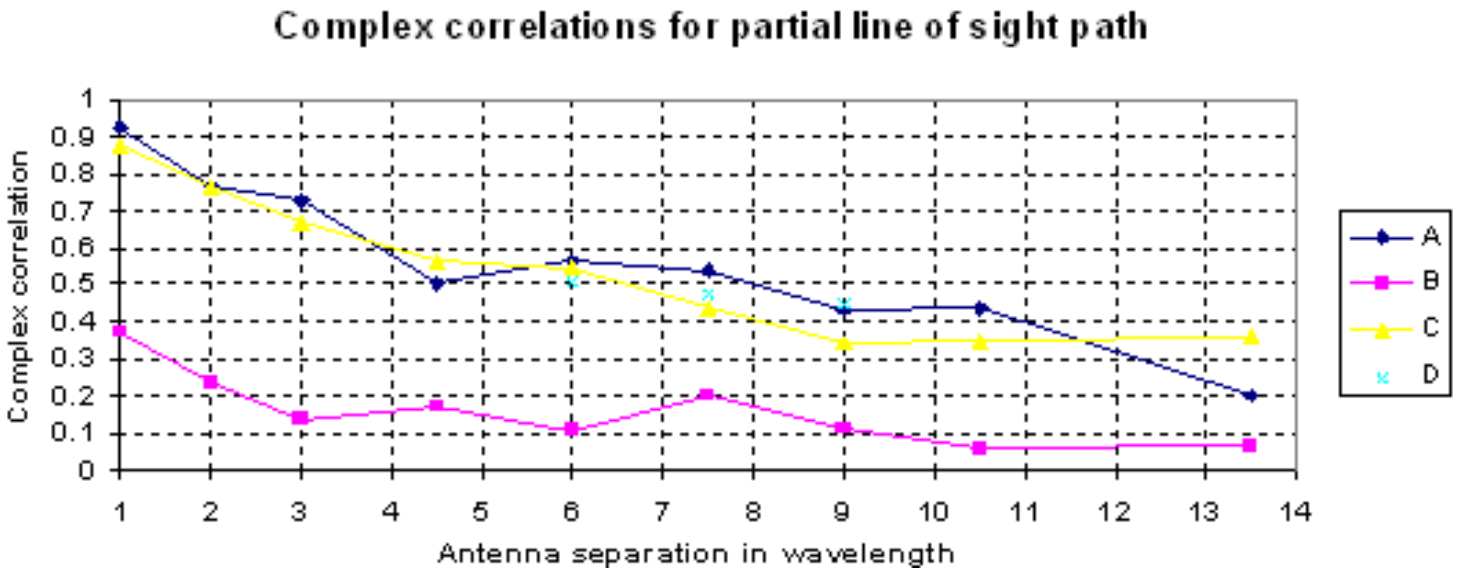
- About 9 dB for B
- About 1 dB difference for other configurations

Complex correlation: LOS



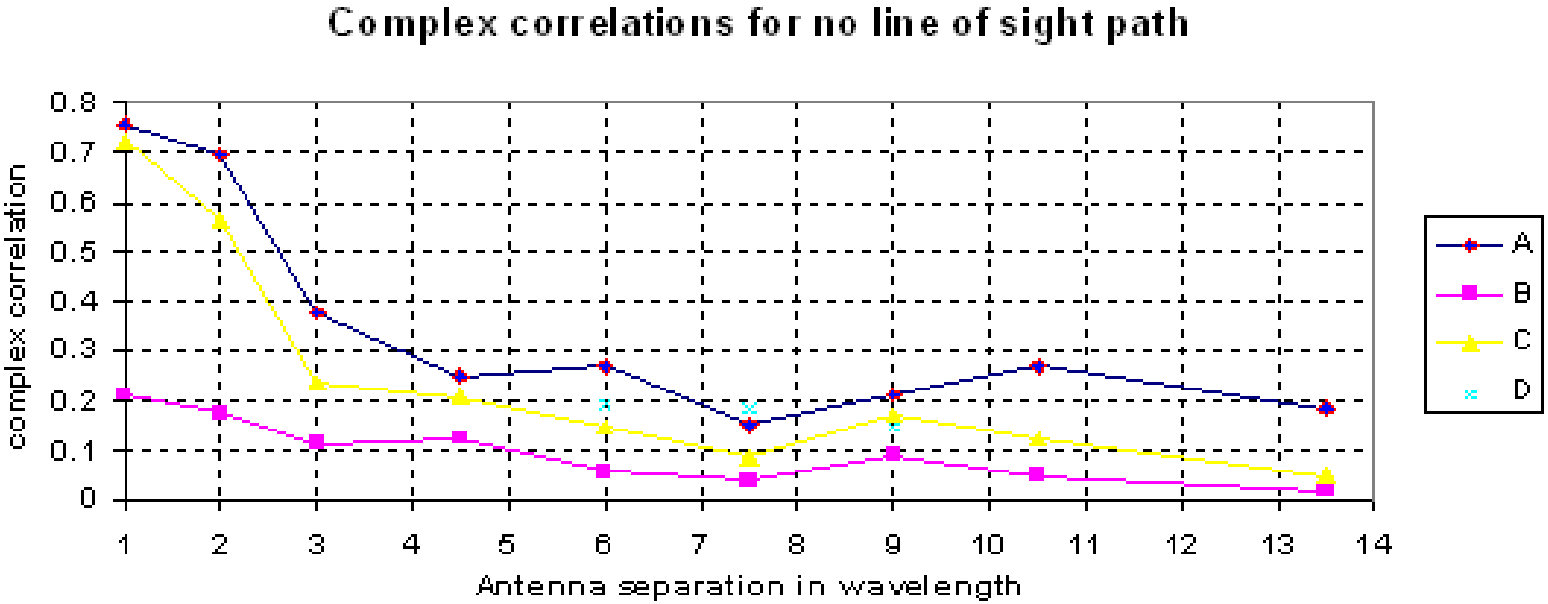
- B has the smallest correlation coefficient

Complex correlation: partial LOS



- Again, B has the smallest correlation coefficient

Complex correlation: NLOS



- And again, B has the smallest correlation coefficient
- A seems to have the largest correlation coefficient

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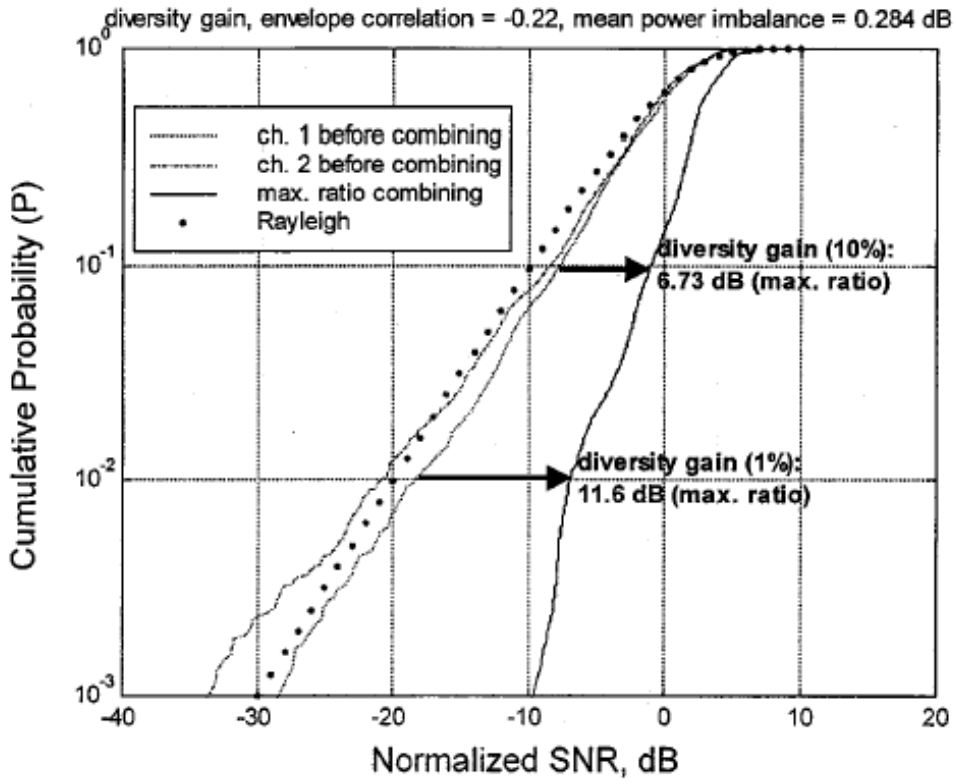
Diversity Gain

G = [signal level of CPD at 10% of the combiner output in dB
- signal level of CPD at 10% of the reference signal in dB]



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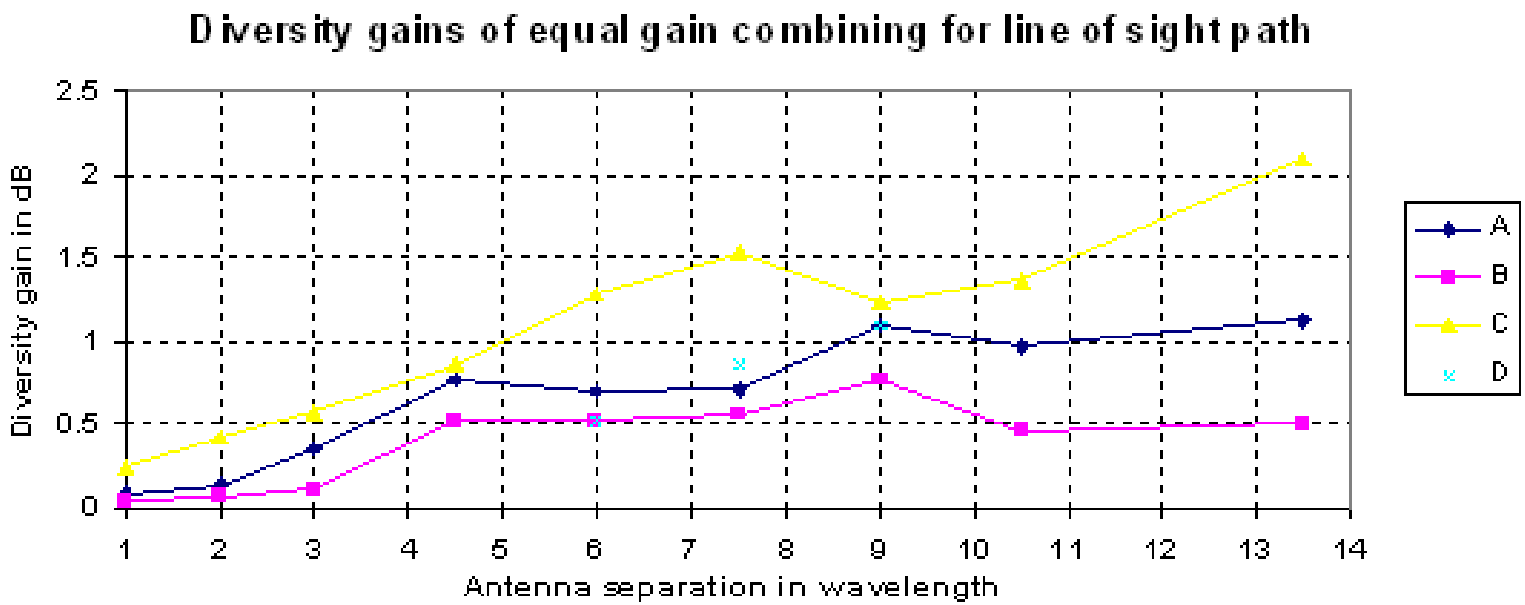
Diversity Gain: LOS



- B: smallest
- C: largest

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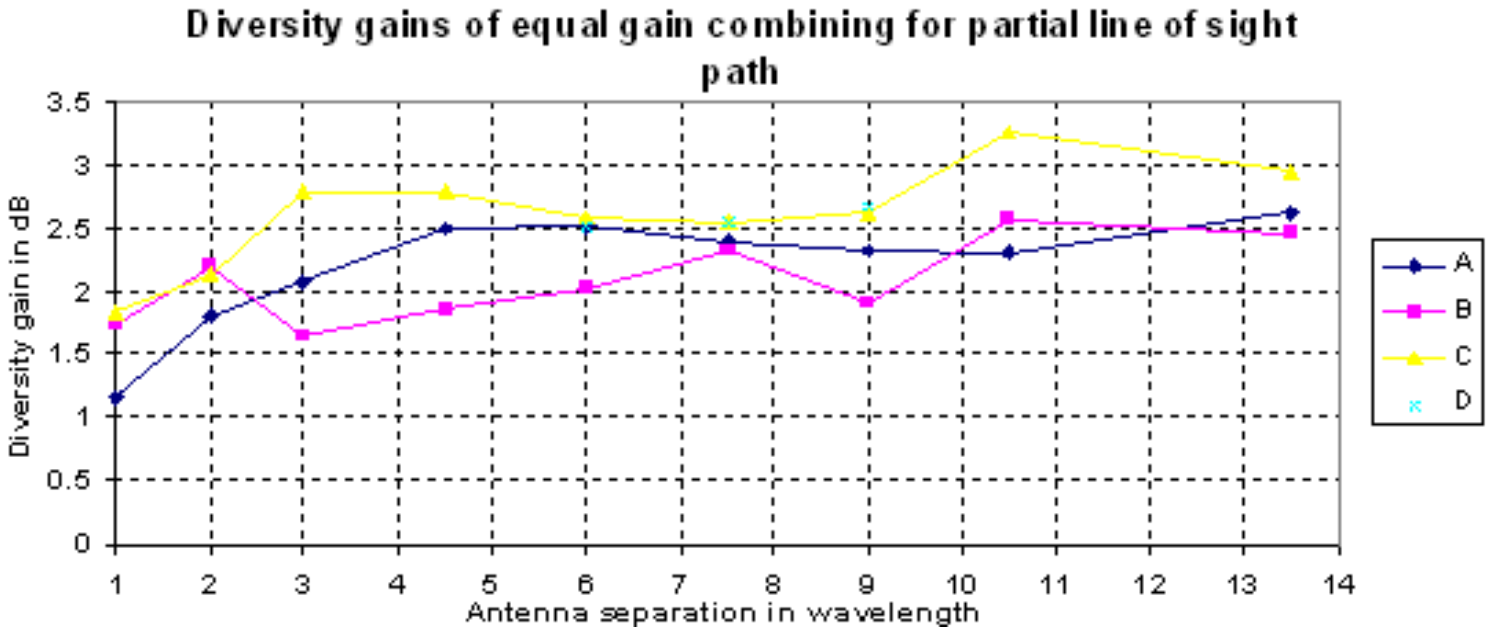
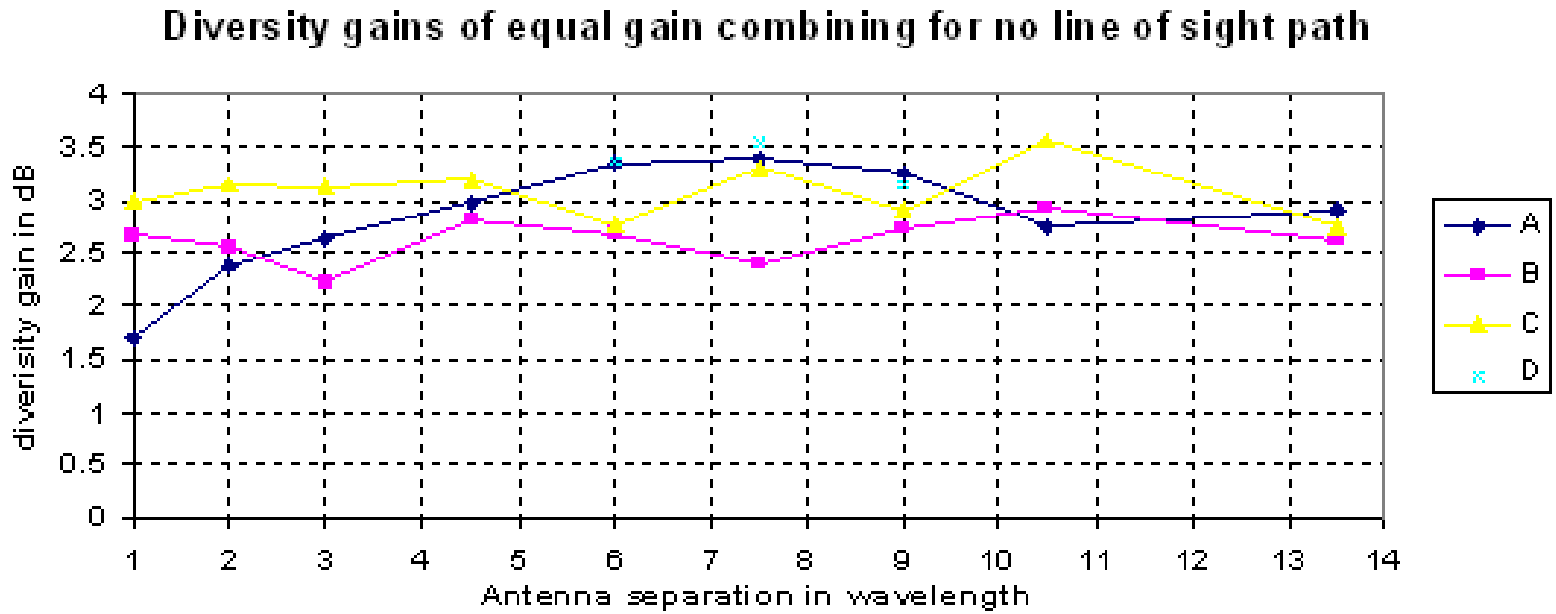
Diversity Gain: partial LOS



- B: smallest ?
- C and D largest

Diversity Gain: NLOS



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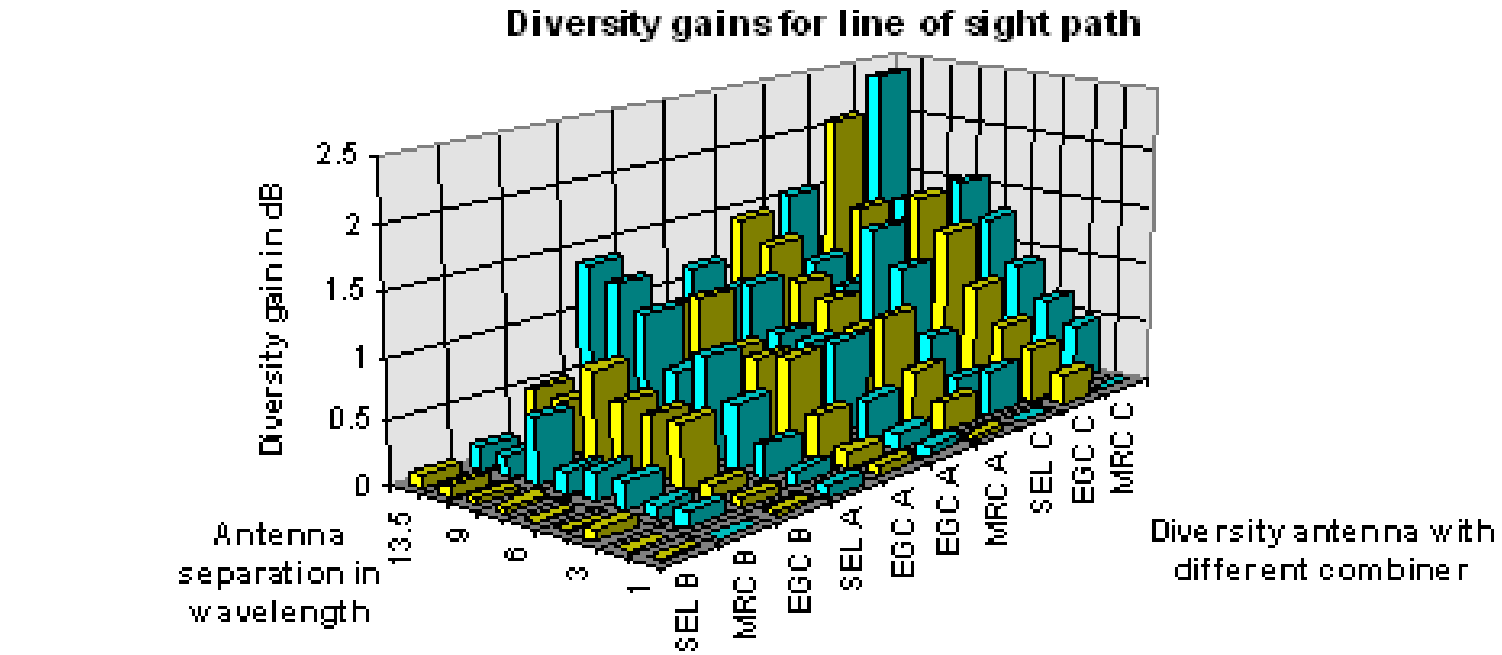
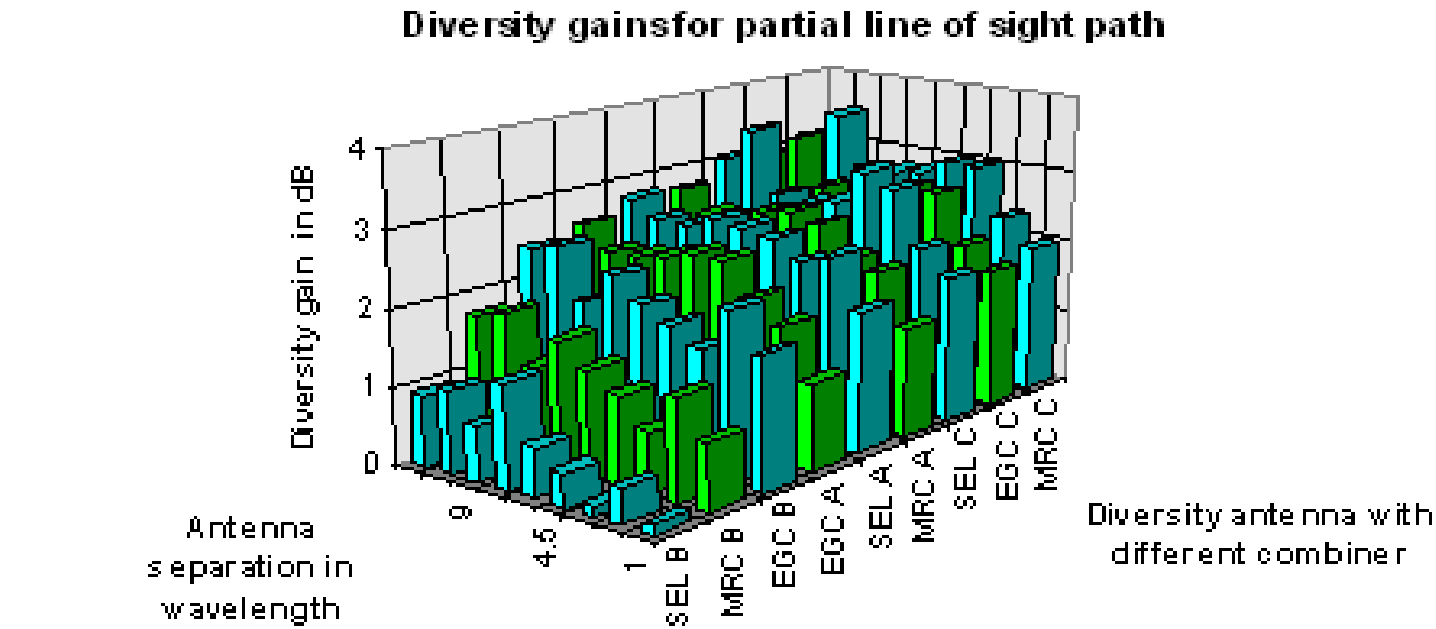
Diversity gain: LOS



SEL : Selection diversity EGC : Equal gain combining MRC : Maximal ratio combining

- MRC C

Diversity gain: partial LOS



SEL : Selection diversity EGC : Equal Gain combining MRC : Maximal ratio combining

- MRC C and SEL C

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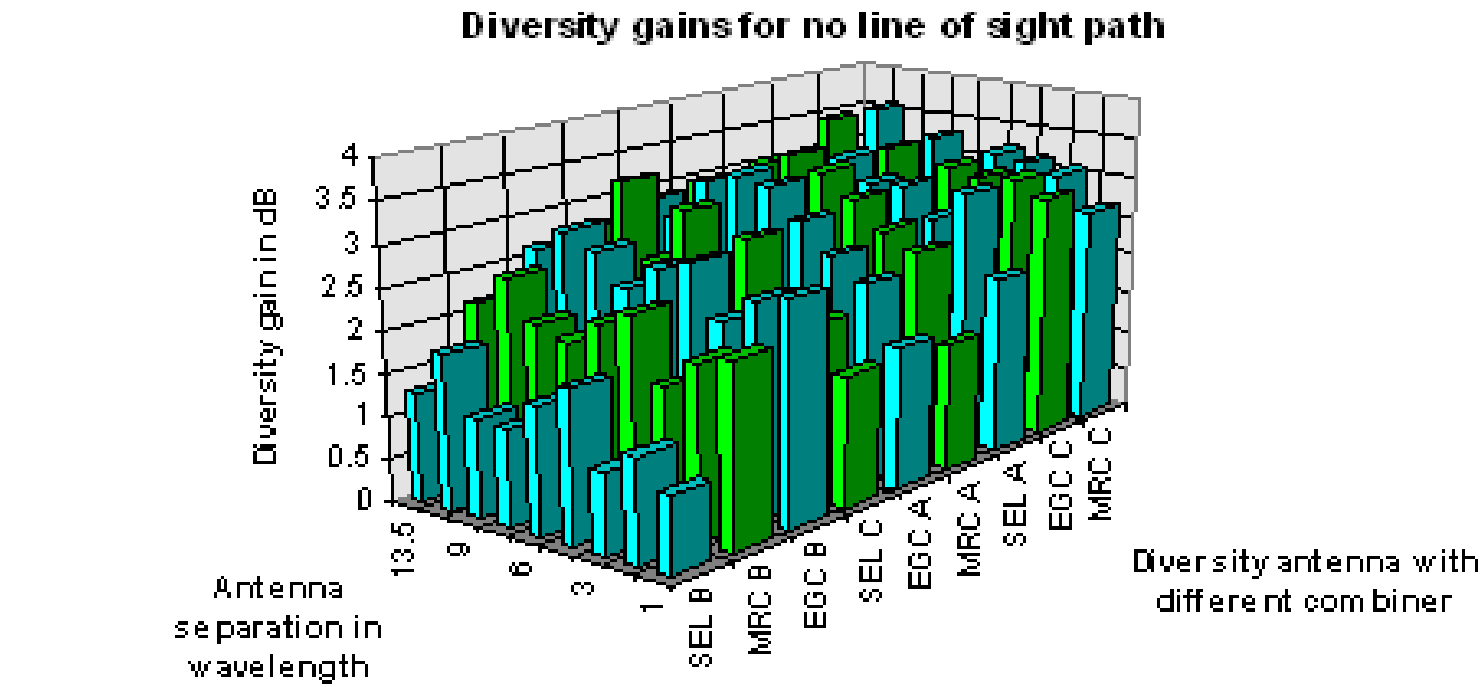
Diversity gain: NLOS



SEL : Selection diversity EGC : Equal gain combining MRC : Maximal ratio combining

- MRC C and EGC C

4. Discussion and Conclusions

- *The overall winner is C with a separation of 3λ (2m)*
  - about 3.5 dB diversity gain at 10% level
  - about 7.9 dB diversity gain at 1% level
  - Smaller than that at higher frequencies
- *Configuration A with a separation of 3λ (2m)*
  - about 2.6 dB diversity gain at 10% level
  - about 6.0 dB diversity gain at 1% level
- *Additional gains can be obtained by using both the spatial and polarisation arrangement for the same separation.*

Discussion and Conclusions

- Accuracy and Repeatability for diversity gain (10%)
  - The same route: difference < 0.3 dB
  - Different route: up to 1 dB
  - Different positions: up to 0.7 dB
  - Different mobile antenna orientation: up to 0.7 dB
- Time-consuming
- Better characterisation approach is required
  - In door facilities, such as reverberation chamber?

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