Sarris, I., & Nix, AR. (2007). Capacity evaluation of LoS-optimised and standard MIMO antenna arrays at 5.2 GHz. *IEEE 65th Vehicular Technology Conference, 2007 (VTC 2007-Spring)*, 554 - 558. https://doi.org/10.1109/VETECS.2007.125

Capacity Evaluation of LoS-Optimised and Standard MIMO Antenna Arrays at 5.2 GHz

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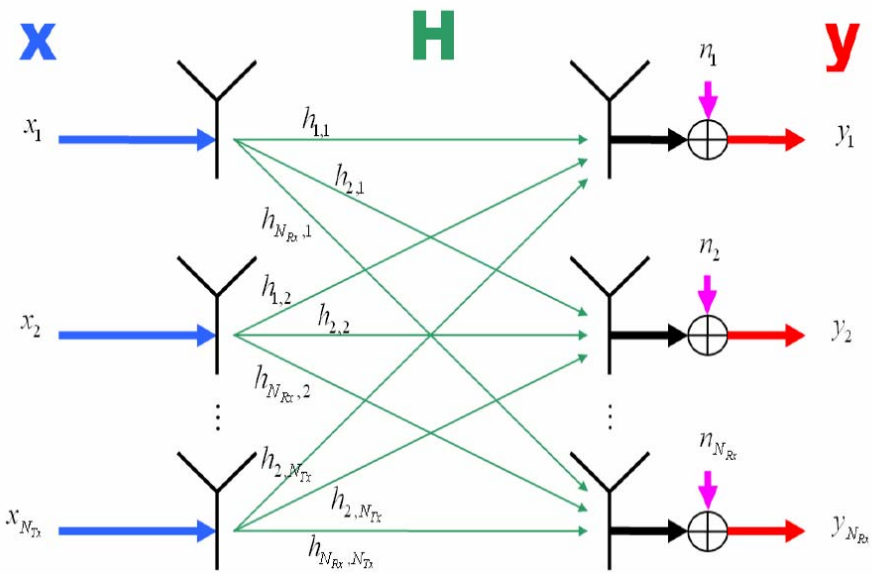
VTC Spring 2007 – 25/05/2007

Presentation Outline

- Introduction to MIMO Communications
- MIMO in Line-of-Sight (LoS)
- Measurement Setup
- Capacity Results
- Ongoing/Further Work
- Conclusions

Introduction to MIMO Communications

- Spatial-Multiplexing MIMO communications systems rely on independent transmission using multiple antenna elements
- The unique spatial signature of each received signal allows the differentiation between signals originating from different antennas
- The input-output relationship in a MIMO system is represented by:
  - $\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{n}$
- $\mathbf{y}$ - received signal vector
- $\mathbf{H}$ - channel response matrix
- $\mathbf{x}$ - transmitted signal vector
- $\mathbf{n}$ - noise at the receiver



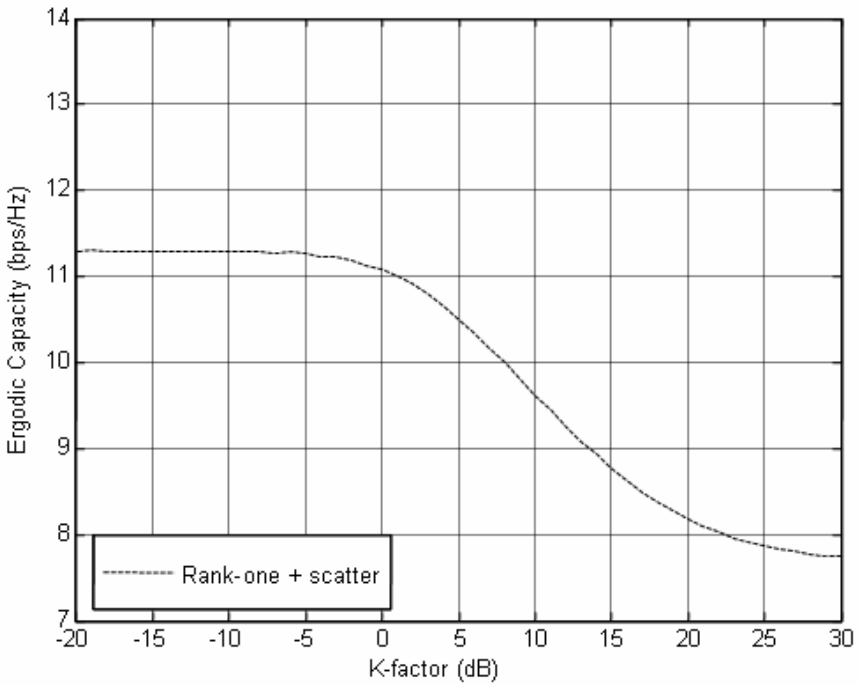
The mutual information of such a system is given by:

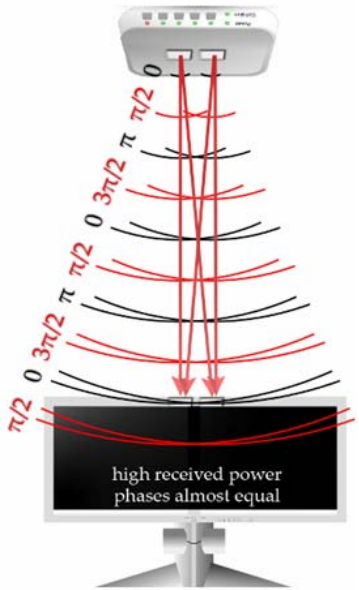
$$C = \log_2\left(\det\left(\mathbf{I}_{n_r} + \frac{\rho}{n_t}\mathbf{H}\mathbf{H}^H\right)\right)$$

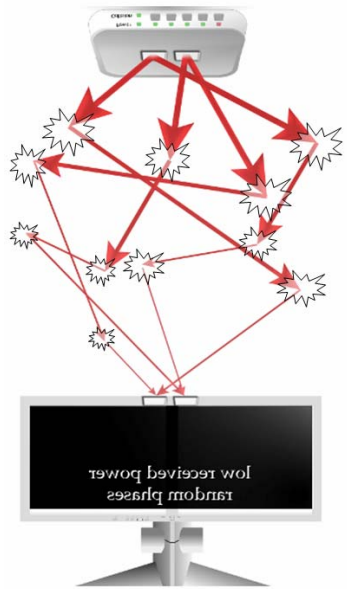
MIMO in Line-of-Sight (LoS)

- In LoS conditions the channel response matrix is commonly modelled as:
- In systems with inter-element spacing of the order of a wavelength the capacity reduces with increasing *K*

$$\mathbf{H} = \sqrt{\frac{K}{K+1}}\mathbf{H}_{LoS} + \sqrt{\frac{1}{K+1}}\mathbf{H}_{NLoS}$$





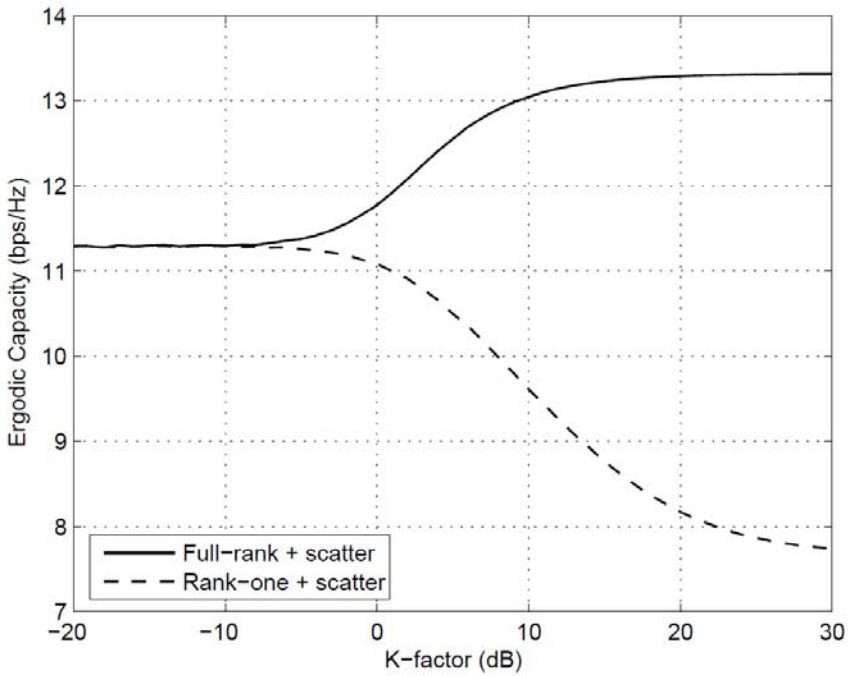


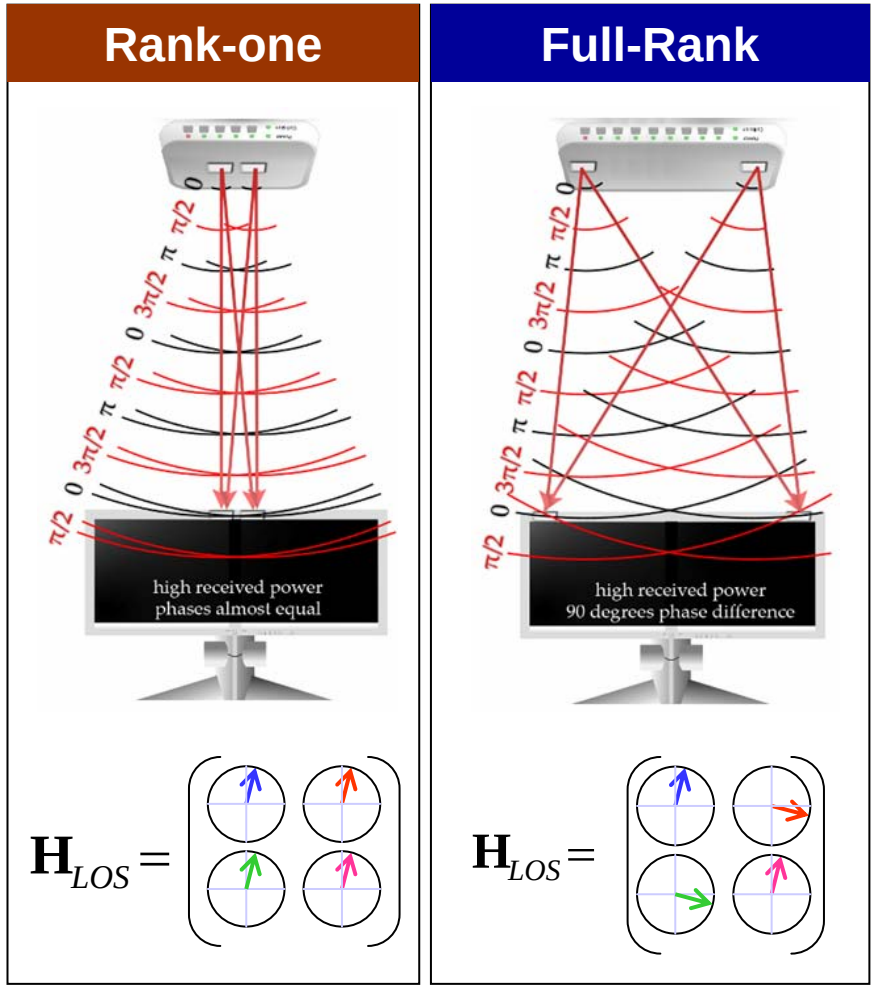
$$\mathbf{H}_{LoS} = \begin{bmatrix} & \\ & \end{bmatrix}$$

$$\mathbf{H}_{NLoS} = \begin{bmatrix} & \\ & \end{bmatrix}$$

Rank-One vs Full-Rank LoS Channel

- It is possible to achieve a full-rank LoS channel response by using specific inter-element spacing
- The capacity then increases with increasing *K*

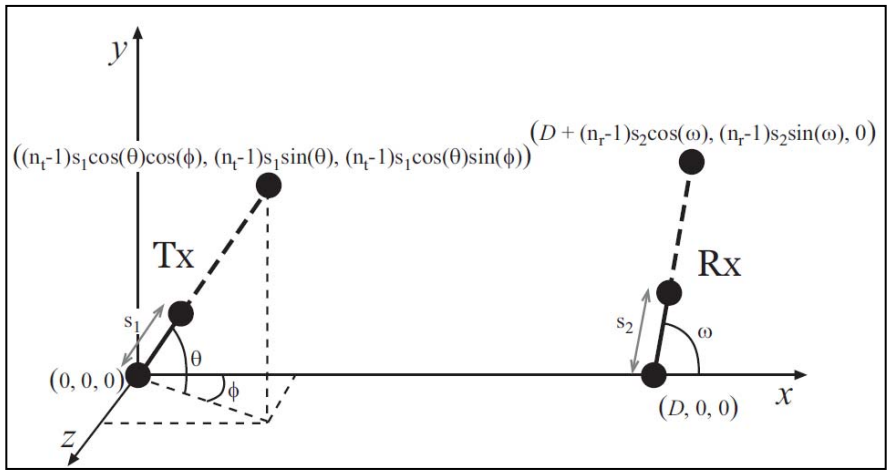




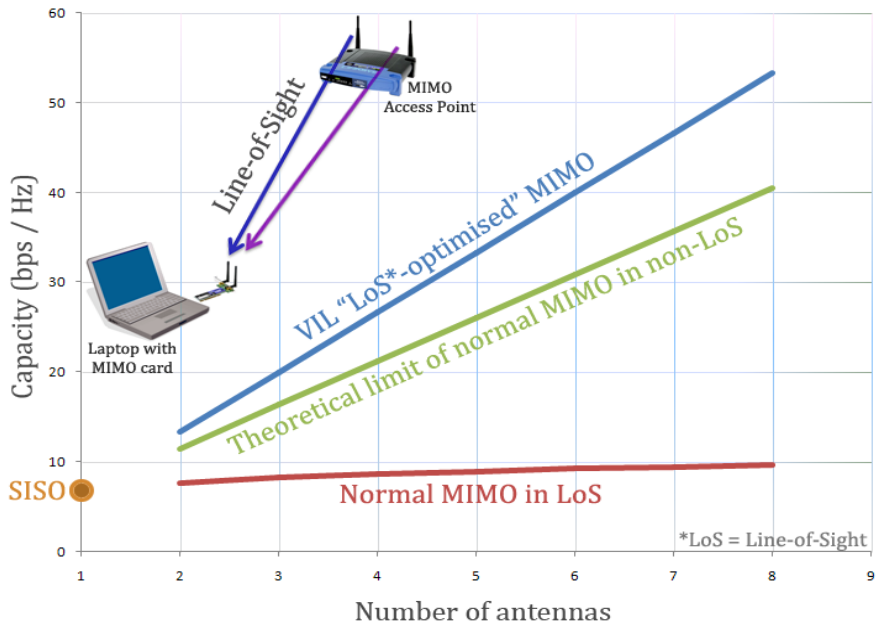
Maximum Capacity Criterion

- Using the capacity formula and assuming a free-space channel a simplified maximum capacity criterion for Uniform Linear Arrays was previously derived:

$$s_1 s_2 = \frac{\lambda D}{n_t \sin\omega \sin\theta}$$

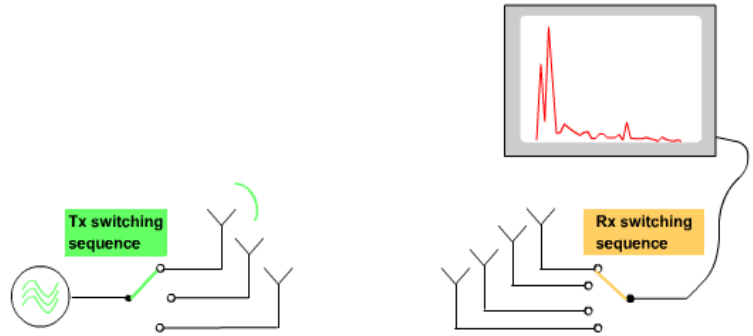


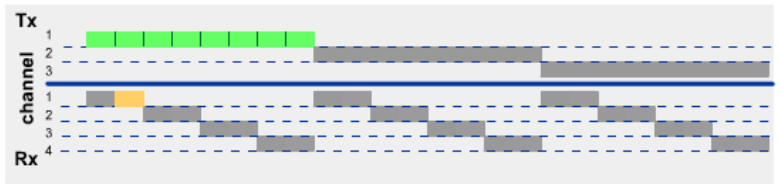
- This equation gives the required inter-element spacing to achieve the maximum capacity in a MIMO system in free-space as a function of the T-R distance (D) and the orientation of the arrays (θ, ω)



MIMO Measurement Setup

- A measurement campaign was conducted to investigate the LoS performance of MIMO systems in the home environment
- LoS-optimised and standard MIMO arrays were employed
- MIMO channel measurements were taken using a MEDAV MIMO channel sounder
- 4x8 channel responses were recorded for 36 locations and using dual-polarised patch antenna elements





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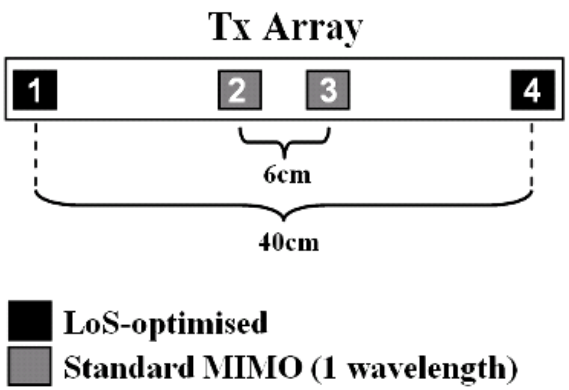
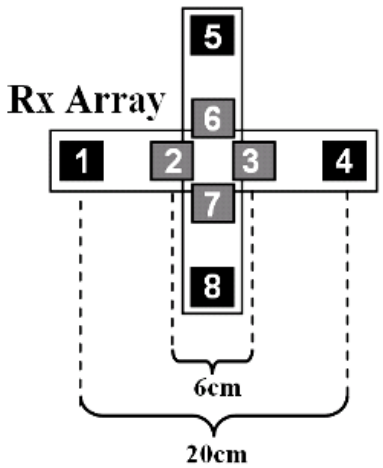
Antenna arrays

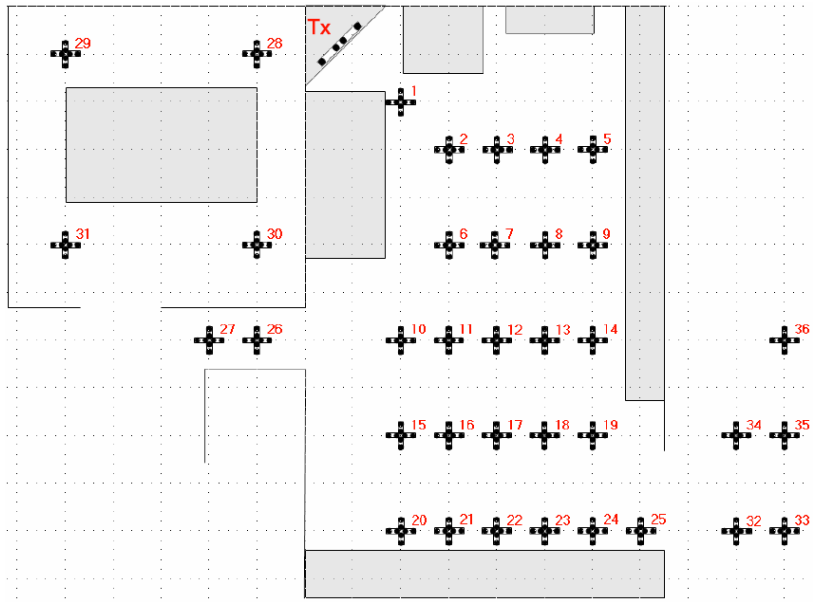
- A 4-element transmit antenna and an 8-element receive antenna were designed/constructed by the University of Bristol
- The antenna elements were identical dual-polarised patch antennas
- The following antenna spacings were calculated from the maximum capacity criterion and correspond to LoS-optimised and standard configurations





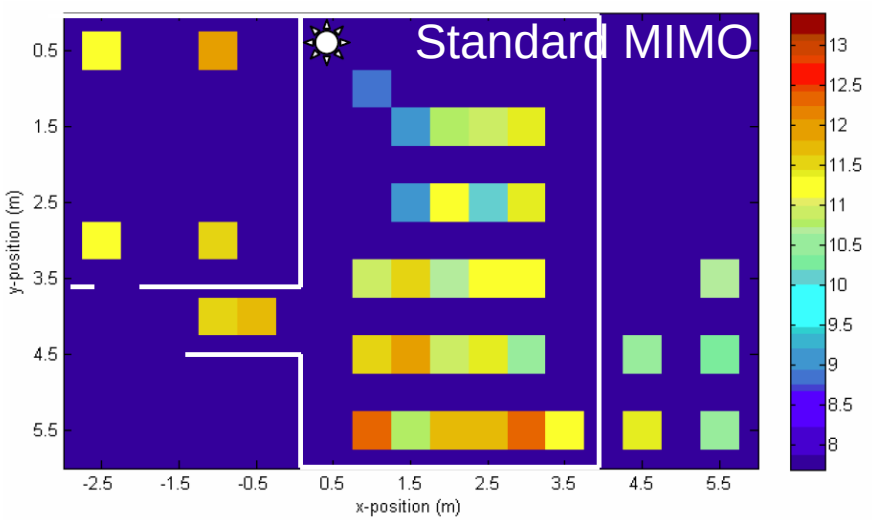
Measurement Environment

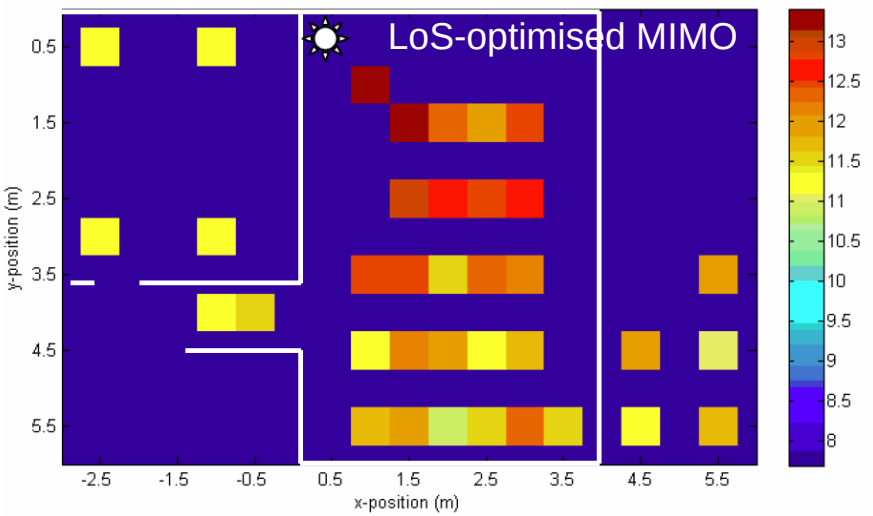
- The measurements were conducted in a 6.5m x 3.8m lounge area, an adjacent kitchen, a corridor and a patio area
- The Tx antenna was mounted on a cabinet at a height of 2.06m
- The Rx was mounted on a tripod at 88cm height
- The measurements were taken for 25 LoS and 11 non-LoS locations



Measurement Results I

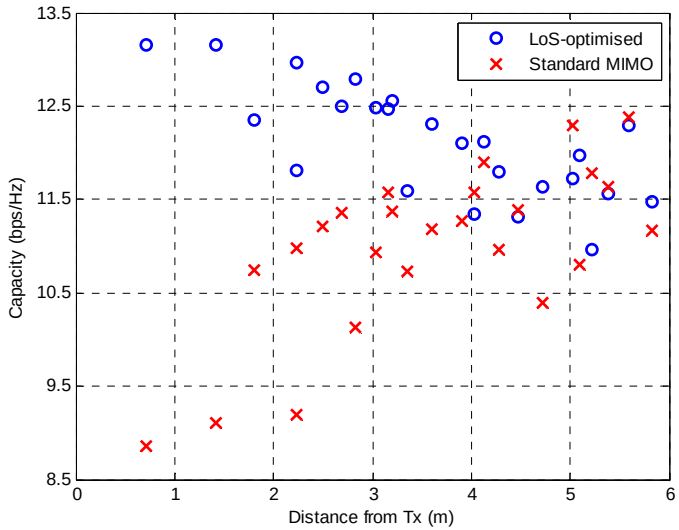
- The channel capacity was measured in LOS and non-LOS points
- ~48% improvement was observed near the transmitter
- ~32% improvement was observed in LOS locations further away from the transmitter
- At the corner of the room the capacities from both systems converged to i.i.d. Rayleigh

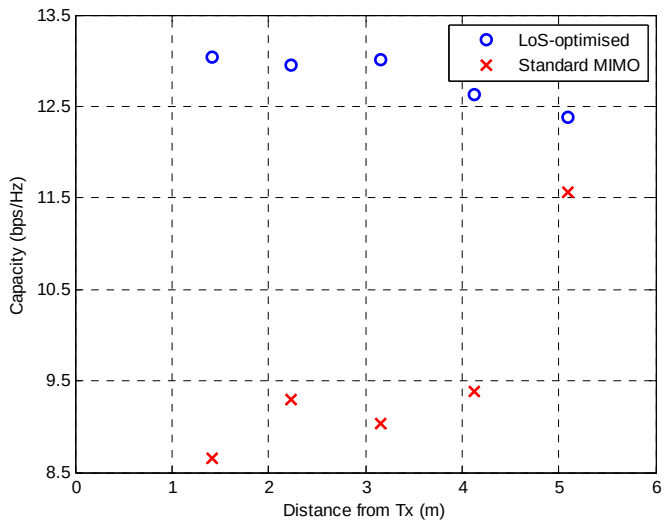




Measurement Results II

- The capacities were also plotted versus the transmitter-to-receiver distance
- Very similar behaviour to the theoretical study was observed
- To improve the K-factor a number of measurements was also taken on the vertical plane

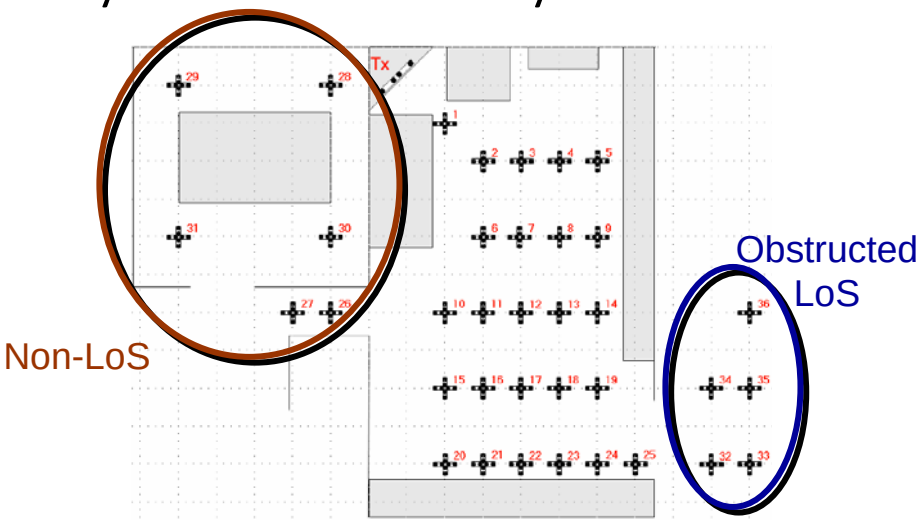


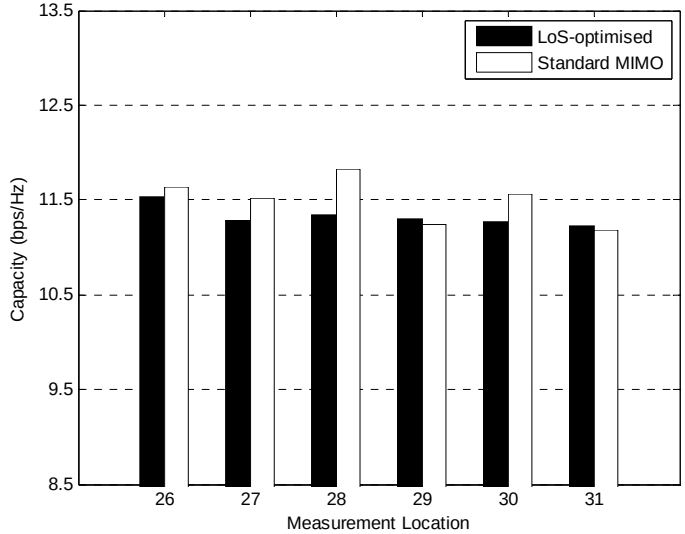


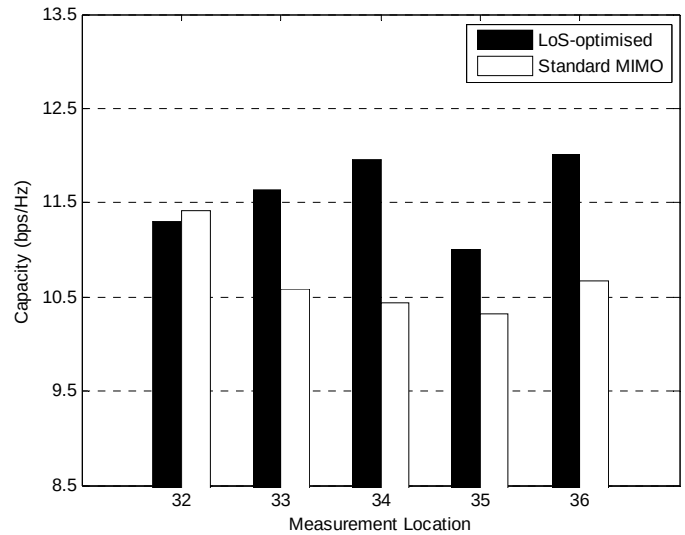
Measurement Results III

- As expected, the LoS-optimised and standard MIMO capacities converged to the i.i.d. Rayleigh capacity in non-LoS areas

- In obstructed LoS areas the LoS-optimised configuration has outperformed the standard MIMO system due to the keyhole effect

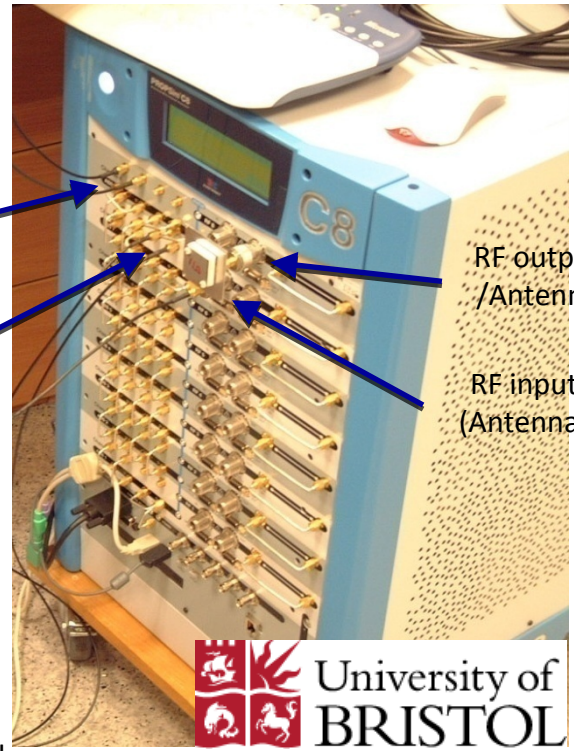






Ongoing/Further Work

- A MIMO platform is being built as part of the IST FP6 ASTRALS project
- This combines a software MIMO WiMAX transmitter/receiver Matlab software, an arbitrary waveform signal generator and appropriate RF up-down/converters
- Initial results have shown significant performance gains in terms of the received BER between LoS-optimised and standard MIMO systems



Conclusions

- The results from a measurement campaign in the home environment in the 5 GHz frequency band were presented
- The performances of standard (narrow-spaced) and LoS-optimised (wide spaced) antenna arrays were presented in terms of the MIMO capacity
- LoS-optimised antenna arrays have shown to outperform standard arrays especially in locations close to the transmitter
- At larger distances the performance of both configurations was found to converge to the i.i.d. Rayleigh capacity
- Ongoing and further work was presented involving the implementation of a software/hardware MIMO WiMAX platform

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thank you for your attention

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