# *Receiving diversity measurements in indoor scenario*

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## Abstract

In this paper, the results of narrowband indoor multiple-input multiple-output (MIMO) measurements in the C band at 4.5 GHz are presented. Multi channel I-Q radio receiver, was used to measure the indoor channel for LOS and NLOS scenario. A single transmitter employing quarter wavelenght dipole was at an indoor position of  the building where two different type of MIMO receiver antenna with 3 elements was moving. The hardware implementation is presented and results for path loss and MIMO capacity.

## Introduction

In the case of a MIMO wireless communication system there are used transmitting as well as receiving end  multiple antenna elements. The core idea in MIMO systems based on space-time signal processing in which time is complemented with the spatial dimension inherent in the use of multiple spatially distributed antennas. The ideal stochastic scattering models give very promising capacity increase for the MIMO systems, compared to the single channel capacity, but the further investigations show that in real environment this capacity increase can not be realise because of the real physical propagation conditions. Based on these facts the necessity of system measurement is still remains.

In this paper multi channel I-Q radio receivers are used to deploy the channel characterization.

## Measurement setup

The measurements setup is part of an existing receiver beamforming array, which has the main characteristics of  operation in C band, 16 parallel I-Q receiver channel, -102dBm receiver sensitivity for 3dB SNR, 12 bits ADC, real time sampling on every channel simultaneously, fast in-built  DSP for embedded signal processing ( 380 MIPS). The system control is on USB interface using LabView control and processing software. The architecture of the single channel with high frequency front end can be seen on Fig. 1.

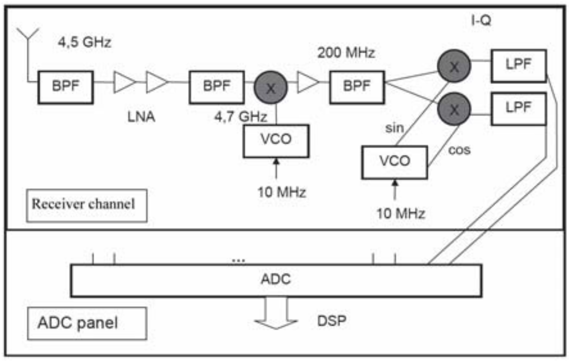


Fig. 1. The I-Q receiver and signal processing part

Our measurement system contains three major parts. The receiver blocks, the DSP unit and the measuring software running on a laptop computer. The four receiver units with overall 16 input channels operate at 4.5GHz center frequency, after double conversion baseband I-Q signals are sampled and converted to 12bit data. The DSP can provide sampling numbers the powers of 2 (1, 2, 4,…,256). The receiver antennas are the newly developed MIMO antennas. For our measuring setup only three channel receiver was used from the existing 16 because of the partly finished MIMO antenna which has now only 3 outputs.

## Diversity (MIMO) antennas

Two MIMO antenna has been analized and realized for the comparison and optimization of especially the mutual coupling between the antenna elements. The first structure realized prototype is a part of a MIMO cube with slot dipole on the edges (Fig. 2.)

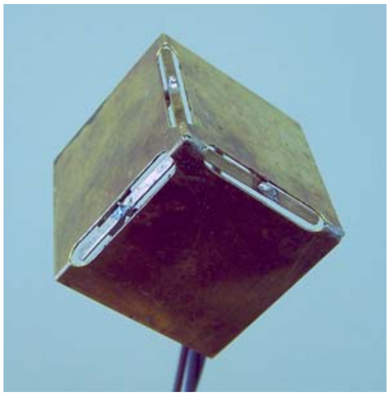


Fig. 2. MIMO cube with slot dipoles on edges (Antenna 2)

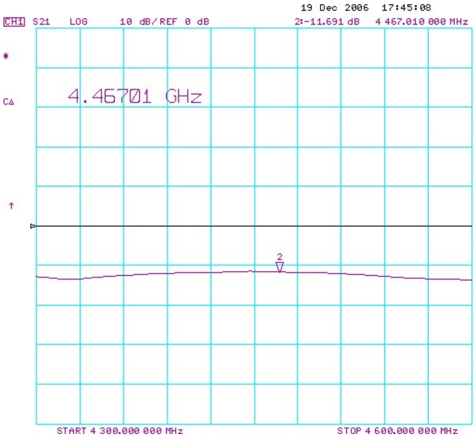
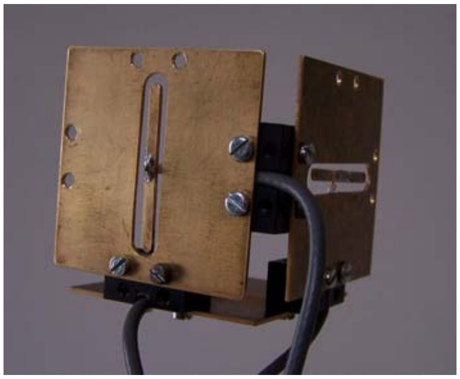


Fig. 3. Slot dipoles on edges measured coupling (S21 in dB)

The mutual coupling for the first type of MIMO antenna between the dipoles are slightly below -10 dB which would be desired much this level below for MIMO application without capacity degradation.



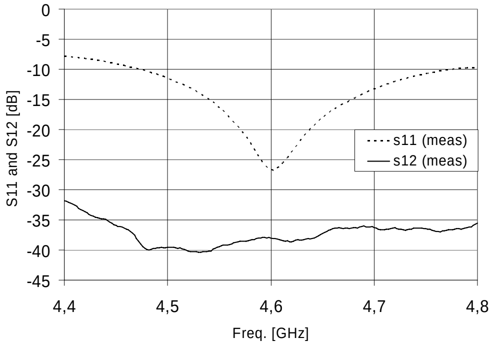


Fig. 4. MIMO cube with slot dipoles on separated planes (Antenna 1)

Fig. 5. Measured MIMO antenna input reflection and coupling (S11 and S21 in dB) for dipoles on separated planes

For the second prototype antenna also the input reflection and also the S-parameter isolation between ports guaranties a MIMO applicability without capacity degradation.

The measurements are performed and evaluated for the two receiver antenna structure so the 1x3 receiver diversity case was investigated.

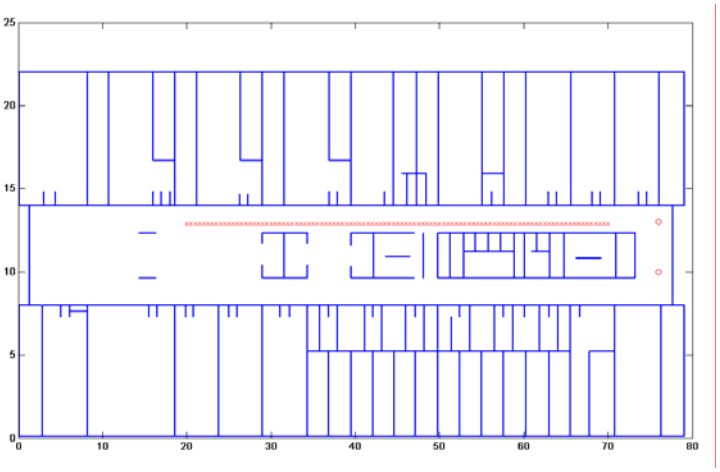


Fig. 6. Measurement scenario with o Tx and x Rx positions

The receiver with antennas (Fig. 15.) and data storage computer was located on moveable cart and also LOS and NLOS measurements were performed. The transmitter generated a narrowband CW signal at 4.5 GHz and to the two localization the transmitter antennas have been placed.

Fig. 7. MIMO antenna with 4 channel receiver

## Results

First the **H** transmission matrix measured and stored than the singular value decomposition and capacity of the system is expressed using the eq. (1).

$$C = \log_2\left[\det\left(\mathbf{I}_M + \frac{\rho}{N}\mathbf{H}\cdot\mathbf{H}^*\right)\right]$$

$$C = \sum_{i=1}^{m}\log_2\left(1+\frac{\rho}{N}\lambda_i\right) b/s/Hz \qquad (1)$$

where

$\mathbf{I}_M$ is the identity $MxM$ matrix

* is conjugate transpose

**H** is the $MxN$ channel matrix

$\rho$ is the SNR at each receiver antenna

$\lambda_1\ \lambda_2\ \ldots\ \lambda_m$ are the nonzero eigenvalues of $\mathbf{H}\cdot\mathbf{H}^*$ matrix

$m=min(M,N)$

The from measured transmission matrix calculated mean capacities and for comparison purposes exponential trendline to the mean capacity values are presented.

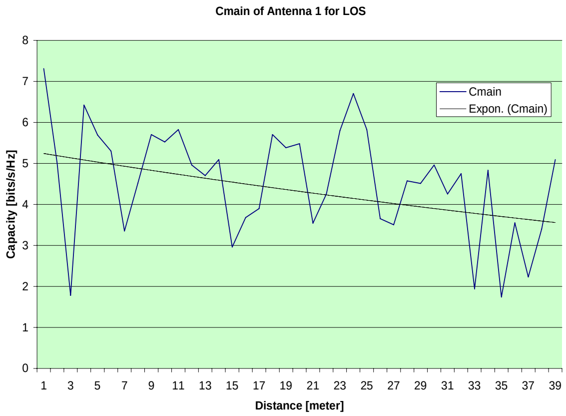


Fig. 8. LOS measurement using dipoles on edges (Antenna 1)

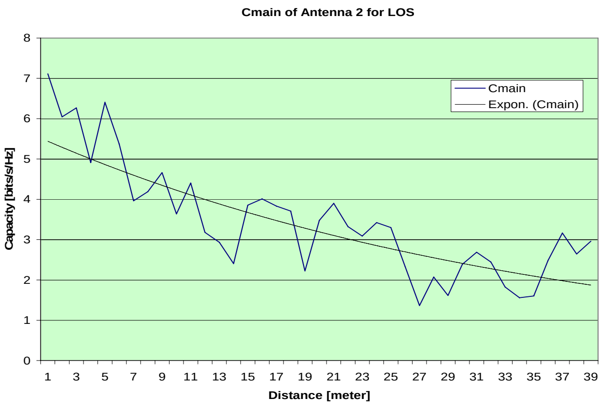


Fig. 9. LOS measurement using dipoles on edges (Antenna 2)

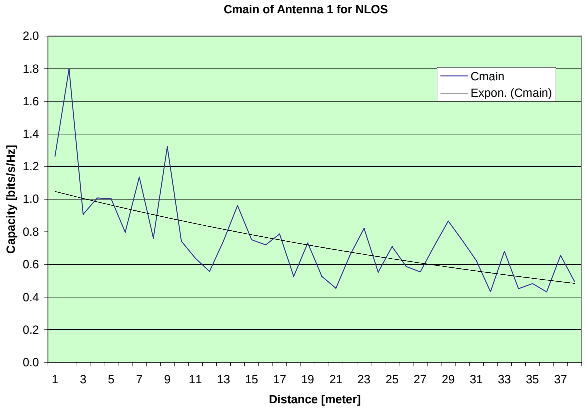


Fig. 10. NLOS measurement using dipoles on edges (Antenna 1)

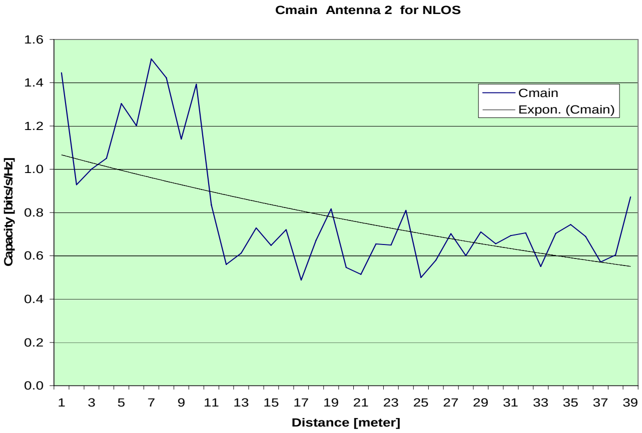


Fig. 11. NLOS measurement using dipoles on edges (Antenna 2)

## Conclusion

We have performed 1x3 receiver diversity measurement for this investigation direction later extending toward MIMO measurements for the C band. Determined capacity for LOS and NLOS cases for the two types of MIMO antennas using a multiple channel receiver and narrowband single transmitter. We have justified the difference between the two receiver antennas, especially for the LOS case. The capacity decrease behavior is much better for the antenna 1 with the smaller coupling between antennas. For NLOS case the difference is not characteristic.

## Acknowledgment

This work was carried out in the framework of Mobile Innovation Center, Hungary (Mobil Innovációs Központ).

## References

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