Smart Antennas Cluster Year 2000 Report

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Abstract: This paper contains the common work of the three project involved in the adaptive antenna cluster, namely METRA, SATURN and ASILUM. The 2000 work was devoted to propagation methodology issues w.r.t multichannel characterization.

Introduction

Three IST projects are concerned by one or several of these aspects of smart antennas, namely **SATURN** (Smart Antenna Technology in Universal bRoadband wireless Networks), **METRA** (Multi-Element Transmit and Receive Antennas) and **ASILUM** (Advanced Signal processing schemes for Link capacity increase in UMTS). More specifically, SATURN considers beamsteering and diversity for UMTS TDD, beamsteering and MIMO for HIPERLAN II. METRA is concerned by MIMO for UMTS FDD and TDD. ASILUM considers beamsteering and interference rejection for UMTS TDD and FDD, and has some activity on MIMO. Hence, one major common topic among various projects is MIMO. In 2000 these 3 projects common work was propagation methodology, which was thus the topic of the cluster.

It has been now widely recognized [1],[2] that the capacity of a MIMO system depends on the multichannel correlation properties, which itself depends upon geometrical characteristics such as angular spreading at both the transmitter and the receiver side. Several measurements campaigns have been conducted in the various projects in order to study these issues.

Section 1 explains the goal of the measurements campaign, the main principles of the various solutions to reach this goal, and the difficulties encountered.

Section 2 describes the 5 solutions used respectively by University of Bristol, France Telecom R&D, KTH (Sweden), University of Aalborg (CPK) and IMST (Germany).

I Description of the various MIMO measurements methodologies

All contributors use a channel sounder, with various bandwidths, thus the channel impulse response is analyzed with variable precision.

All contributors use some multi sensor reception and some multisensor transmission. Multi sensor transmission/reception may be

- Synthetized
- Implemented with array antennas and parallel transmission/reception
- Implemented with array antennas and a fast switch between various transmissions and/or receptions.The switch should be both fast enough, in order to make sure that the channel stays fixed during the measurement, and without too much power loss. These two characteristics are very difficult (and very expensive) to obtain. Therefore, it may happen that the measurements are restricted to short range such as microcells or picocells, due to the loss in the switching process.

Some partners use linear array antennas (real or synthetized), some partners use circular or planar (synthetized) antennas. According to the antenna type (and also inter-element spacing) an analysis of matrix H and/or an angle of arrival analysis will be performed that can be 2D (azimuth) or 3D (elevation and azimuth).

II Detailed description of each contributor experimental set up. Exploitation plan

II.1 IMST for ASILUM

IMST equipment (Fig 1) is based on a RUSK sounder, having a bandwidth between 30 MHz and 120MHz. The centre frequency is 1.8GHz. The transmitter is a vertical polarized mechanical steerable directional array antenna with accompanying stepper motor and control unit (Fig.2). The receiver is a circular array antenna, together with a central element, all vertically polarized. This array is mounted on a rail, with a linear positioning system. A fast PIN diode switches between the 8 elements of the circular array.

Advantages of the set-up are

- the high transmit power capability.due to the absence of switch at the transmitter
- the gain of the transmitting antenna.(19dB) Considering wideband channel sounding up to 120 MHz, an omnidirectional transmitting antenna, and a transmit power of 20 W still limits the covering range at a center frequency of 1.8 GHz to 130 m, and 2 km, in suburban areas with NLOS wave propagation, and in open areas, respectively. To extend the coverage range a directional transmitting antenna is required.
- the increased measurement speed. This is due to the fast switching capability of the microwave PIN-diode switch at the receiver site.
- the 8 circular elements, together with the linear rail allow double directional analysis (both at the transmitter AND receiver sides).

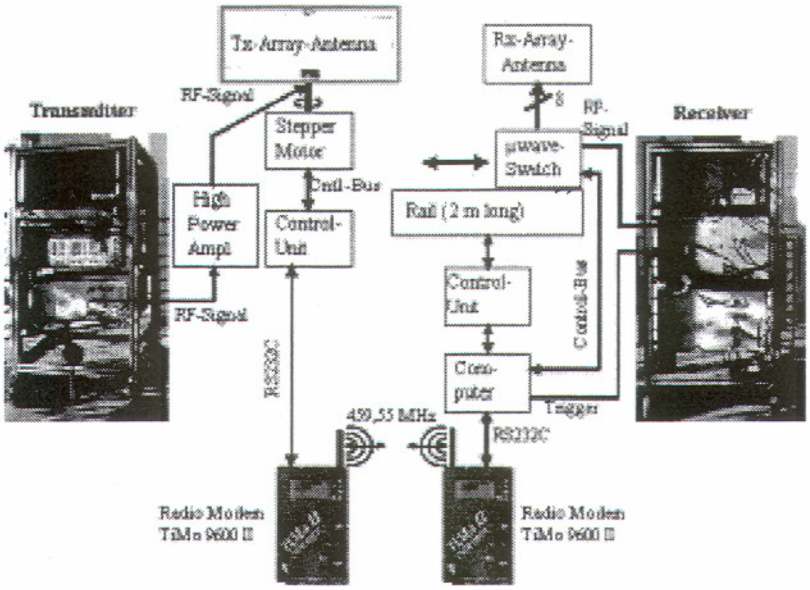


Figure 1 Experimental set-up extracted from ASILUM D2.1 [3]

Measurement Environments:

a micro and a macro cellular one. With a 30MHz bandwidth, the range was 600m in both cases.

Exploitation of the data:

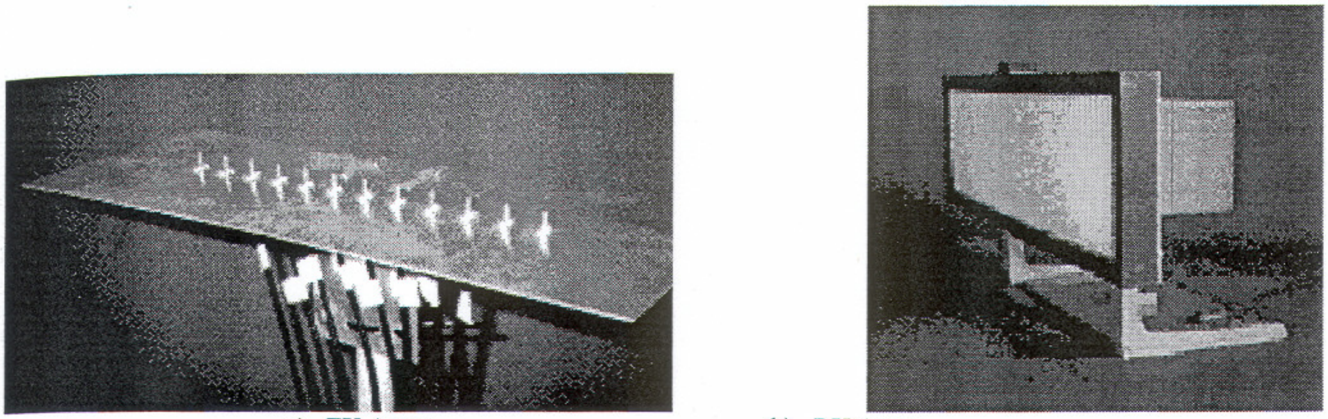
Type 1 measurements: long and short term fluctuations using a single element of the receive antenna.

Type 2 measurements: Doubly directional investigations (transmitter and receiver). The goal of the experiment is to check the validity of a propagation model based on geometrical considerations and coined Wideband Directional Channel Theoretical Model (described in [3]). Comparisons include delay and azimuth average/RMS spread.

Figure 2 (left)Transmitter directional antenna and rotating positioning system (right) Receiver circular array and linear positioning system

II.2 University of Bristol for SATURN

University of Bristol (UOB) also uses a RUSK BRI sounder from the Medav company, using a periodic multi-tone signal with a maximum 120 MHz bandwidth. The centre frequency is 5.2 GHz,. The **transmitter** is a uniform linear array and associated switching control and synchronisation circuitry. Decorrelation at small antenna element displacements can then be evaluated, which is significant for MIMO performances. The **receiver** is an 8 element uniform linear array. Each element is dipole-like (Figure 3 b). A fast multiplexing system is used to switch the receiver between each of these elements in turn in order to take a full 'vector snapshot' of the channel. Measurement accuracy is assured through the use of Rubidium referenced clocks, with an optical fibre providing synchronisation and absolute phase stability between the transmitter and receiver.



a) TX Array b) RX Array

Figure 3: Antenna arrays employed at the transmitter and receiver (5.2GHz deployment) extracted from [4]

Measurement Environments:

The indoor environment is represented by the Merchant Venture's Building (MVB) at University of Bristol. The receiver array will be set at three different locations, two in the entrance hall, one inside a laboratory room. Both LOS and NLOS cases will be available.

Exploitation of the data

One purpose is to study variations of the multi channel for receiver/transmitter in a fixed position. Time variations are caused by people moving in the environment. Long term statistics will also be obtained leaving the equipment by itself during the night (fixed environment). Data sets will also be analysed by KTH in order to obtain channel models and a capacity benefit analysis based on real channel data.

II.3 France Telecom R&D for SATURN

France Telecom R&D uses a new wideband-sounder, developed internally. The bandwidth is 250 MHz in indoor environment and 62.5 MHz in outdoor environment (because of permissions). The centre frequency will be 5.2GHz. The wideband radio channel experimental characterisation is a 3D analysis for each radio link end. Two virtual planar antenna arrays will be used to investigate spatial energy distribution at both transmitter and receiver:

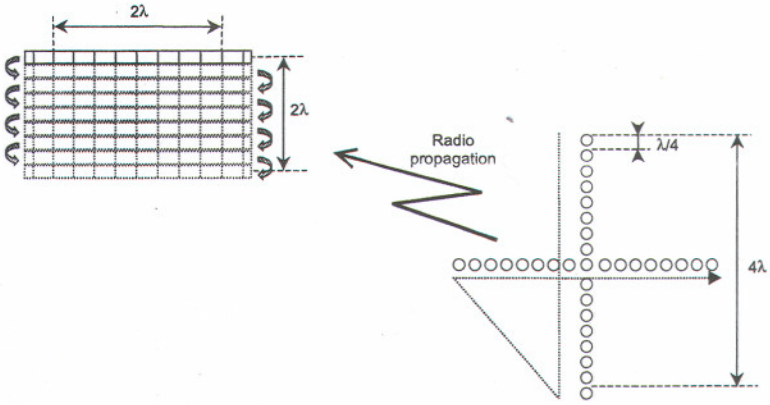


Figure 4 Measurement configuration for FTR&D MIMO experimentation

The **receiver** antenna (Fig 5a) is a 9-sensors linear array antenna plus two dummy elements. Elements are dipoles, made by FTR&D. The inter element spacing is λ/4. An additional fixed omni directional antenna is used as a phase reference at the receiver. The array antenna is moved along a micrometric track with a λ/4 step. Thus, using different position, this can be seen as a virtual planar antenna array. The receiver location is chosen as representative of a RLAN Access Point (AP) site, and will be placed vertically.

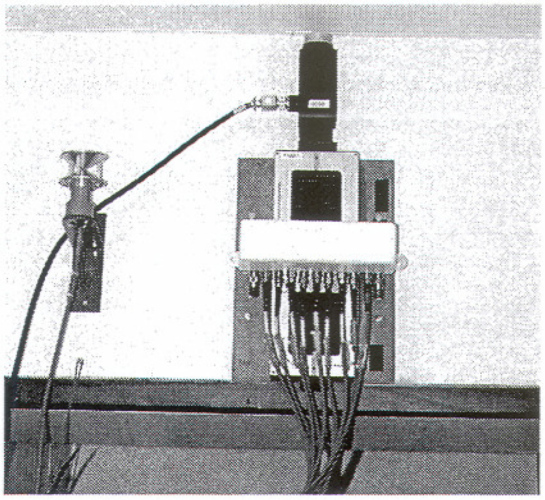
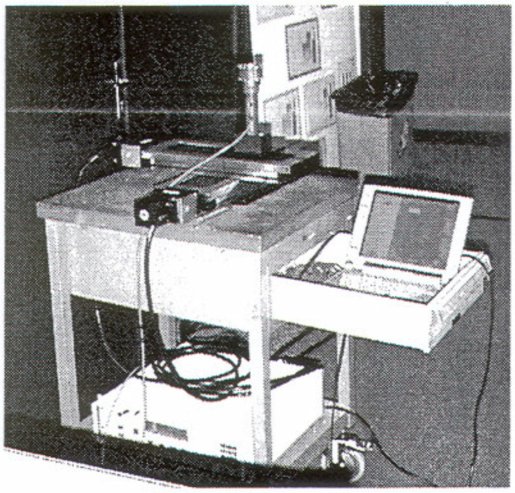



Figure 5a (left): Receiver antennas (linear array and omni directional antenna Figure 5b(right): Transmitter omni directional antenna on the XY micrometric track

The **transmitter** (Fig 5b) is an omni directional antenna. It is moved along a micrometric track with a λ/4 step. CIR (Channel Impulse Response) is measured at each spatial step. 17 steps corresponding to 4λ distance are used. The track is used in two perpendicular directions. The transmitter location is chosen as representative of Mobile Terminal position. Actually, it will be placed on the ground.

Measurement Environments:

Measurements campaigns were performed in two different environments. The first one is a typical campus-like environment. It is characterised by buildings separated by large space (from 50 m up to 200 m). The second one is an office building.

For each environment, several receiver locations were selected. For each of them, about 10 transmitter locations were chosen. In the campus-like environment, some outdoor to indoor measurements were performed. All of these locations were chosen to study influences on the MIMO radio channel characteristics of TX-RX distance, LOS/NLOS situation, angle between receiver array antenna and transmitter position, TX location (office, large room, corridor, ...),

Exploitation of data

FTR&D will carry out an analysis of the angular and temporal radio channel selectivity. Of the data. This experimentation will particularly allow investigating 2D and 3D spatial energy distributions respectively at the AP and at the Mobile Terminal in RadioLAN. Spatial correlation between elements of the virtual array antennas, will also be evaluated. Last, a spatial wideband channel model will be proposed for SIMO and MIMO transmission simulations. It will be based on a geometry-based modelling approach (references about this modelling concept can be found in [5]). Its relevant parameters will be extracted from the analysis of the above mentioned campaign. Comparisons on selectivity parameters between simulations and measurements, will also be shown.

II.4 KTH (Royal Institute of Technology, Stockholm, Sweden) for SATURN

In the context of SATURN, KTH will exploit data from experimentations led by University of Bristol and FTR&D, above described.

KTH performed a MIMO experimentation in conjunction with Telia, independently from SATURN. This experiment used a wideband sounder of 400 MHz bandwidth. The sounding sends a pseudo-noise sequence. The centre frequency is 5.8 GHz. The receive and transmit antenna are both of monopole type. The multi element case is synthetized by moving the receiver monopole between 21 positions, spaced 1/4 wavelength. The transmitter antenna is moved between 3 positions spaced 6 wavelengths.

Measurement Scenario

Indoor office buildings. The transmitter is positioned in an office, while the receiver is located in an open area. This is a typical NLOS scenario. Measurements have been performed during stationary conditions at night.

Exploitation of data

KTH concentrates on statistical models where the MIMO (and SIMO) channel is described by the second order statistics of the channel coefficients without direct reference to any geometrical parameters of the propagation. Such a model is useful both to generate new random channels in simulated systems studies, but also in the development and analysis of different signal processing algorithms for the transmitter and receiver. In many scenarios, it is reasonable to assume "spatial stationarity" meaning that the signal correlation between two antenna elements only depends on the element distance, thus fewer parameters are needed to describe the channel statistics. One such model was recently proposed by the METRA partner at Aalborg University [6]. This and other models are subject to validation against the UoB and FTR&D measurements. The KTH above described experiment led to a very good agreement between the independent identically distributed assumption for the elements of the channel matrix H and the measured capacity results.

II.5 METRA testbed developed by the University of Aalborg (Denmark)

The METRA measurement testbed (Figure 6) consists of 9 parallel receiving channels. In practice, a uniform linear array with 4 elements and a spacing of 1.5 λ is employed. The other 4 ports are connected to 2 dual polarized patches. The last port is used for reference signalling. Channel sounding measurements are performed every 20 ms at a carrier frequency of 2.05 GHz (UMTS band) and a chip rate of 4.096 Mcps. A more thorough description of the testbed is given in [7]. The TX uses a 1-to-4 switch with a switch time of 50 μs between each element of the antenna array, implementing a pseudo parallel transmission. A high power fast switch is not available which would be useful when investigating large microcell or macrocell scenario.

Measurement scenarios

- For METRA macrocell investigation, this is not a problem since data from a previous SIMO (Single Input Multiple Output) measurement campaign will be used. Synthesised array analysis will be undertaken to provide MIMO (Multiple Input Multiple Output) analysis.
- For METRA microcell investigation, the switch issue is not a problem. The distance between the base station (BS), outdoor, and the mobile station (MS), indoor, will be selected such that the propagation link budget is within the operating range of the measurement testbed.
- For METRA picocell scenario, the dimension of the cell is such that the power received is strong enough without using a high power fast switch.

Exploitation of results

One of the goals of the measurement campaign is to evaluate the spatial correlation that exists between several elements of a same antenna array for different cell scenarios.

Another aim of the measurements is to derive realistic parameters of the MIMO radio channel and to feed them into the COSSAP® implementation [6] of the stochastic channel model described in [8] in order to validate it.

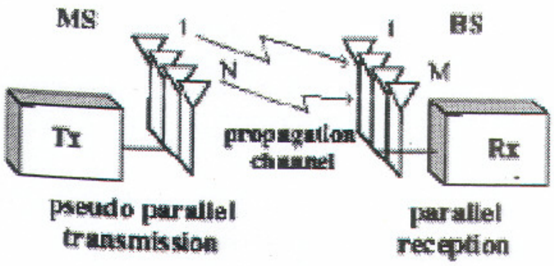


Fig 6 Configuration set-up for parallel channel sounding measurements, extracted from [9]

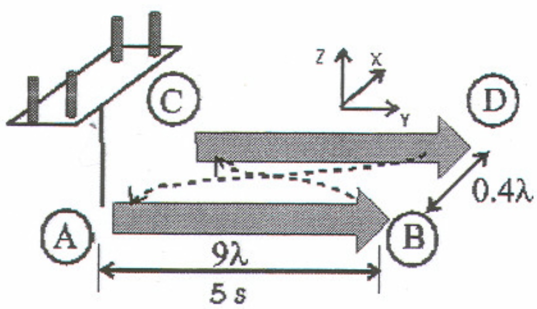


Figure 7 Measurement procedure at the mobile station, extracted from [9]

The specific array used at the mobile station, together with the specific motion they have (figure 7 and 8) allow some direction of arrival measurements at the mobile station. Indeed, the array first moves forward from A to B, and in a second set of measurements backward from D to C. Due to the specific distance between these two parallel displacements, namely 0.4 λ, a post processing analysis creates a virtual 4 elements array with interspace distance of 0.4 λ (figure 8).

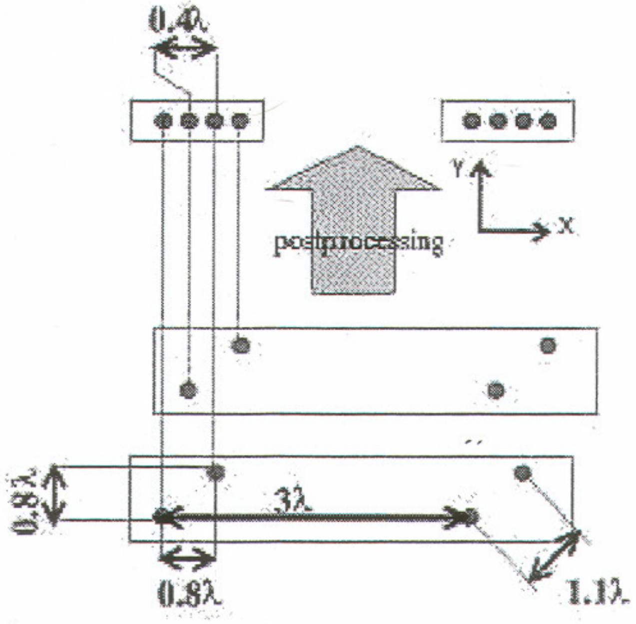


Figure 8 Top view drawing of the antenna array used during the measurement and the postprocessed linear antenna array at the mobile station, extracted from [9]

II.6 Conclusion

Future work in this cluster will include more about exploitation of data, algorithmic work, and MIMO performances

REFERENCES

[1] G.J.FOSCHINI, M.J.GANS "On Limits of Wireless Communications in a Fading Environment when Using Multiple Antennas" Wireless Personal Communications 6: pp. 311-335, 1998

[2] J.SALZ, J.H. WINTERS "Effect of Fading Correlation on Adaptive Arrays in Digital Mobile Radio" IEEE Trans on Vehicular Technology Vol 43, N°4, Nov 1994

[3] "Wideband Directional Channel Model and Measurement Campaign Public" Deliverable D2.1 of the ASILUM project

[4] M.A.BEACH, D.P.McNAMARA, P.KARLSSON " Development of a Channel Measurement System for Multiple-Input Multiple Output (MIMO) Applications" In Proc. IST Mobile Communications Summit , pages 497-501, Ireland, Oct. 2000

[5] P. LASPOUGEAS, P. PAJUSCO, J.C. BIC, "Radio Propagation in Urban Small Cells Environment at 2 GHz: Experimental Spatio-temporal Characterization and Spatial Wideband Channel Model". In Proc. IEEE Vehicular Technology Conference (VTC'2000), Boston, September 2000

[6] L. SCHUMACHER, K. I. PEDERSEN, J. P. KERMOAL, and P. MOGENSEN. "A link-level MIMO radio channel simulator for evaluation of combined transmit/receive diversity concepts" within the METRA project. In Proc. IST Mobile Summit 2000, pages 515-520, Galway, Ireland, Oct. 2000

[7] F. FREDERIKSEN, P. MOGENSEN, K.I. PEDERSEN and P. LETH-ESPENSEN, "A "Software" Testbed for Performance Evaluation of Adaptive Antennas in FH GSM and Wideband-CDMA", Conference Proceeding of the 3rd ACTS Mobile Communication Summit, Rhodes, Greece, vol. 2, pp 430-435, June 8-11 1998.

[8] K.I. P PEDERSEN, J.B. ANDERSEN, J.P. KERMOAL, and P.E. MOGENSEN, "A Stochastic Multiple-Input-Multiple-Output Radio Channel Model for Evaluation of Space-Time Coding Algorithms", IEEE Vehicular Technology Conference VTC 2000 Fall, Boston, USA, vol.2, pp. 893-897, September 2000

[9] J.P. KERMOAL, L. SCHUMACHER, P. MOGENSEN, K.I. PEDERSEN, F. FREDERIKSEN "METRA: Experimental Investigation of MIMO Radio Channels for Indoor Picocell Scenarios", In Proc. of IST Mobile Summit 2000, pp. 509-514, Galway, Ireland, October 2000