Spatial Channel Sounder for MU-MIMO Emulation

Mamadou Dialounké Baldé, Stéphane Avrillon, Christian Brousseau, Dominique Lemur, Bernard Uguen
IETR UMR CNRS 6164, University of Rennes 1, Rennes, France
Emails : {mamadou.balde, stephane.avrillon, christian.brousseau, dominique.lemur, bernard.uguen}@univ-rennes1.fr

***Abstract*—This paper presents a versatile spatial Vector Network Analyzer (VNA) channel sounder exploiting a four axis positioner and optical transposition devices which allows a large separation between Tx and Rx antennas. To illustrate its versatility, the channel sounder can be used over several frequency bands of interest for the development of future multi antenna systems. This channel sounder allows to acquire a large number of static channel matrices through a properly sampled region of space in order to retrieve the time-varying behavior of the MIMO and MU-MIMO channel. An indoor LOS 4×8 MIMO channel measurement data acquired in a small room along a $0.7m$ translation is presented to illustrate the capabilities of the sounder.**

I. Introduction

Multi Users MIMO (MU-MIMO) as well as Massive MIMO have risen in discussions since the beginning of the decade. Indeed the knowledge of the MIMO channels is becoming tremendously important in the context of 5G cellular network where the full potential of this twenty years old technique [1] is going to be exploited efficiently. [2] has reviewed the necessity to characterize and model the channel radio propagation and [3] introduced the Massive MIMO concept where key benefits of this technology are explored and how it becomes a serious candidate for future wireless technology like 5G and beyond. From there, understanding the time evolution of the spectral structure of the matrix MIMO $\mathbf{H}$, spatial focusing, human mobility effects become important. The VNA channel sounder exploits a four axis positioner, three translations and one rotation. Optical transposition devices allow a large separation between Tx and Rx antennas in order to extend the range involved in scenario of interest as small cells scenarios. This spatial channel sounder will allow answering questions regarding large MIMO and MU-MIMO channel matrix structure. Section II describes the channel sounder and the measurement setup and finally in section III we present a 4×8 MIMO measurement data obtained from this spatial channel sounder.

II. Description of the Channel Sounder and Measurement Setup

Table I provides the current main characteristics and Fig. 1 illustrates the overview of the presented spatial scanner channel sounder.

The transmitting array is an Uniform Linear Array (ULA) of 8 antennas matched between 1.8 and 2.2 GHz and separated by the half wavelength of $d = 7.5cm$ corresponding to the 2 GHz center frequency. Each antenna element consists of a

TABLE I
Parameters of the whole channel sounder

Parameters	Characteristics
Tx ULA	8 folded dipoles antennas
Rx ULA	4 folded dipoles antennas
VNA	E5072A(up to 8.5GHz) [1.8-2.2 GHz]
Scanner	4 axes (X, Y, Z, R)
Polarization	V
Switch $1-4$	100 ns
Switch $1-8$	50 ns
RF/opt&opt/RF	100m (up to 28GHz)

folded dipole designed in vertical polarization. This antenna configuration could evolve easily for addressing higher band scenarios until the upper 28GHz limitation brought by the RF optical transposition.

An Agilent E5072A VNA is used to measure the complex S_{21} parameter. Despite the longer time measurement, the VNA solution offers a wide band characterization in addition to a high measurement dynamics.

Fig. 1. Overview of the full equipment placed in the room of LOS experiments

An other drawback of the VNA is the centralization of the emission and reception which makes very difficult large antenna separations. To overcome this problem, optical transpositions which consists of two modules, optical to RF and RF to optical converters are used. Those devices can work up to 28 GHz and then make possible separation between receiver and transmitter antennas of up the length of the optic fibre, typically about $100m$ in our case.

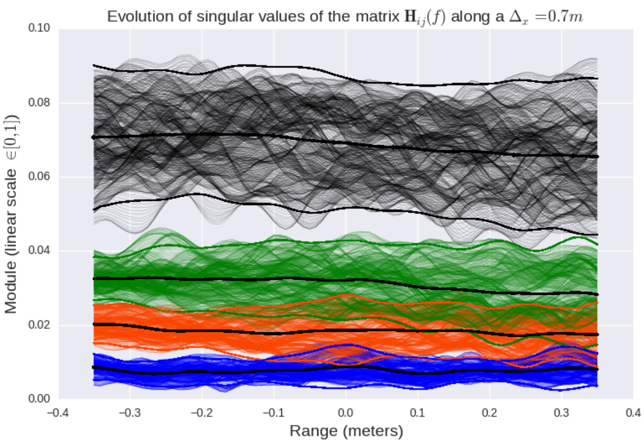

Fig. 2. Evolution of the 4 singular values of $\mathbf{H}_{ij}(f)$ w.r.t distance (801 frequency point realizations)

The spatial scanner is a four axis positioner. Axis are denoted X, Y, Z, R and each of them is equipped of a stepper motor connected to the stepper drives via cables of $10m$ length and has a sub-millimeter precision on the movements. Axis X is composed of one rail belt transmission and another rail without training for $1.62m$ of length. With $0.78m$ of length, axis Y has one rail ball screw transmission. Beside there are a axis Z which has a ball screw transmission that can stretch up to $0.4m$ and a axis R allows rotation over $360°$. Because we are using a VNA, the time variability of the channel should be emulated from large collections of spatial channel data. The VNA, the 4 axis scanner and switches are fully controlled on a single Linux control platform. The associated Python open source code is available on the Github repository [4] of the PyLayers platform [5].

It is imperative that the scanner remains static during the VNA data acquisition. This implies a handshaking protocol between the VNA and the scanner which is facilitated by having a fully centralized control over all devices. The full Python interface handling control between VNA and scanner, stores and processes data. Data are stored in *numpy* multidimensional array which offers a powerful data container for further MIMO post-processing. Calibration data are stored jointly with measurement data in `hdf5` file format.

III. Preliminary Measurements Results

This section presents a short analysis of the measurement dataset corresponding to the 4×8 single user MIMO system. The measurements were held inside a $17.68m^2$ room where the receiver is placed at $5.05m$ from the transmitter in a perfect LOS. Several wood furnitures (tables and chairs) were present inside the room and the data are obtained from a $70cm$ translation of this array along the radio-electric axis denoted x for 100 positions separated by $7mm$. Figure 2 presents the evolution of the 4 singular values of the $\mathbf{H}$ matrix with respect to range. The observed variability corresponds to the whole set of 801 frequency points. We observe that the first singular value exhibits a larger variation than the others which reflects the LOS situation. This observation is confirmed by the impulse response of the channel in Figure 3 where a strong path appears around $18.11ns$.

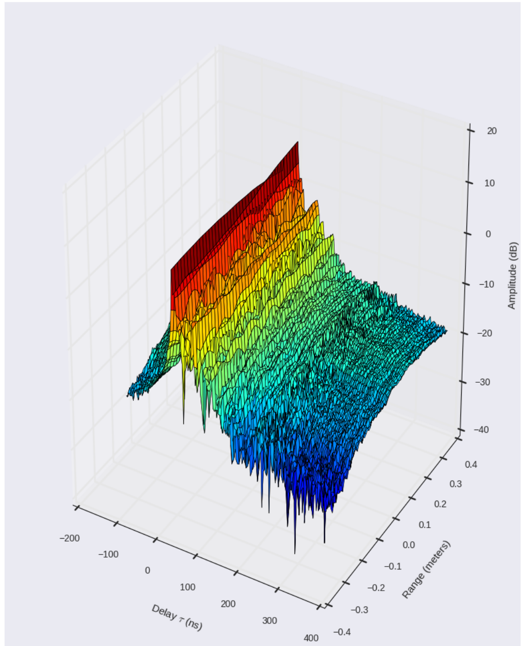

Fig. 3. Impulse response of the channel along a $\Delta_x = 0.7m$

IV. Conclusions and Future work

In this paper, a spatial VNA channel sounder exploiting a four axis positioner and optical transposition is presented. A 4×8 single user MIMO channel measurement data has been presented and demonstrates the full equipment capabilities. In particular the evolution of the spectral properties of the channel matrix can be investigated when the channel is modified by a a given motion. From this experience, we are planning a new campaign in order to investigate MU MIMO and massive MIMO channel propagation.

References

[1] I. Emre Telatar. Capacity of multi-antenna Gaussian channels. *European Transactions on Telecommunications*, 10:585–595, 1999.

[2] N. Czink, A. P. G. Ariza, K. Haneda, M. Jacob, J. Karedal, J. Medbo, J. Poutanen, J. Salmi, G. Steinbock, and K. Witrisal. Channel measurements. In *Pervasive Mobile and Ambient Wireless Communications*, pages 5–65, 2012.

[3] T.L. Marzetta. Noncooperative cellular wireless with unlimited numbers of base station antennas. *Wireless Communications, IEEE Transactions on*, 9(11):3590–3600, November 2010.

[4] https://github.com/pylayers/pylayers/tree/master/pylayers/measures

[5] N. Amiot, M. Laaraiedh, and B. Uguen. Pylayers: An open source dynamic simulator for indoor propagation and localization. In *Communications Workshops (ICC), 2013 IEEE International Conference on*, pages 84–88, June 2013.