



**HAL**  
open science

## First Demonstration and Visualization of Receive Spatial Modulation Using the "Radio Wave Display"

Dinhthuy Phan-Huy, Yvan Kokar, Jean Rioult, Nadine Malhouroux-Gaffet, Jean-Christophe Prevotet, Philippe Ratajczak, Maryline H elard, Abdelwaheb Ourir, Kammel Rachedi, Christian Leray, et al.

### ► To cite this version:

Dinhthuy Phan-Huy, Yvan Kokar, Jean Rioult, Nadine Malhouroux-Gaffet, Jean-Christophe Prevotet, et al.. First Demonstration and Visualization of Receive Spatial Modulation Using the "Radio Wave Display". 21st International ITG Workshop on Smart Antennas (WSA 2017), Mar 2017, Berlin, Germany. 1p. hal-01489004

**HAL Id: hal-01489004**

**<https://hal.science/hal-01489004v1>**

Submitted on 14 Mar 2017

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destin ee au d ep ot et  a la diffusion de documents scientifiques de niveau recherche, publi es ou non,  emanant des  tablissements d'enseignement et de recherche fran ais ou  trangers, des laboratoires publics ou priv es.

# First Demonstration and Visualization of Receive Spatial Modulation Using the “Radio Wave Display”

D.-T. Phan-Huy<sup>1</sup>, Y. Kokar<sup>2</sup>, J. Rioult<sup>3\*</sup>, N. Malhouroux-Gaffet<sup>1</sup>, J.-C. Prévotet<sup>2</sup>, P. Ratajczak<sup>1</sup>, M. H elard<sup>2</sup>, A. Ourir<sup>5</sup>, K. Rachedi<sup>5</sup>, C. Leray<sup>6</sup>, J. de Rosny<sup>5</sup>, Le Cornec<sup>1</sup>, A. Gati<sup>1</sup>, T. Sarrebourse<sup>1</sup>, P. Pajusco<sup>4</sup>, M. H elard<sup>2</sup>, M. Di Renzo<sup>7</sup>  
<sup>1</sup>Orange Labs, <sup>2</sup>INSA-Rennes, <sup>3</sup>Ifsttar, Luxondes<sup>\*</sup>, <sup>4</sup>Telecom Bretagne, <sup>5</sup>ESPCI, <sup>6</sup>ATOS, <sup>7</sup>Centrale-Sup elec, France  
 {dinhthuy.phanhuy, nadine.malhouroux, alain.lecornec, azeddine.gati, thierry.sarrebourse}@orange.com, jean.rioult@ifsttar.fr, {yvan.kokar, Jean-Christophe.Prevotet, maryline.helard}@insa-rennes.fr, patrice.pajusco@telecom-bretagne.eu, {a.ourir, kammel.rachedi, julien.derosny}@espci.fr, christian.leray@atos.net, marco.direnzo@lss.supelec.fr

**Abstract**— In this paper, a demonstration of new single processing candidate techniques for the future fifth generation of mobile networks and the internet of things, called Transmit Spatial Modulation and Receive Spatial Modulation, is described. These techniques exploit multiple antennas to boost the spectral efficiency of the wireless link. However, compared to multiple-antenna systems, they use less Radio-Frequency modules, and are expected to be lower in cost, size and energy consumption. They are thus promising to provide high data rate to/from small connected objects. In Transmit Spatial Modulation, the receiver, (a base station for instance), additionally to conventional demodulation, detects “where, in space, the signal comes from” to get additional data bits. In Receive Spatial Modulation, the receiver (a connected object for instance), additionally to conventional demodulation, detects “where, in space, the signal is arriving at” to get additional bits. Thanks to a new device called the Radio Waves Display and our spatial modulation test bed, for the first time, we visualize, in real time, the spatial repartition of the signal around and on the receiver. This enables even the general public to perform a spatial de-modulation, in a visual manner, and understand intuitively, the concept.

**Keywords**—Green, 5G, massive MIMO, green, visualization, RF, propagation, spatial modulation, internet of things

## I. INTRODUCTION

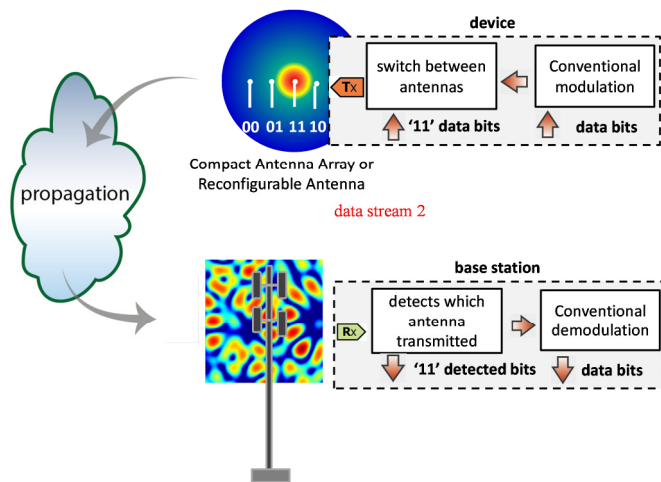


Fig. 1. Principle of Transmit spatial modulation with four transmit antenna elements or ports: the device is transmitting with only one antenna at a time, the base station has previously estimated the channel between the device and itself and is able to detect which of the four antennas of the device is currently

transmitting. The index of each antenna of the device is coded in binary. By transmitting with one particular antenna, the device indicates the bits being sent. The base station recovers the bits by detecting which antenna is the current active antenna. Note that the RF signal bears a conventional modulation (in phase and amplitude).

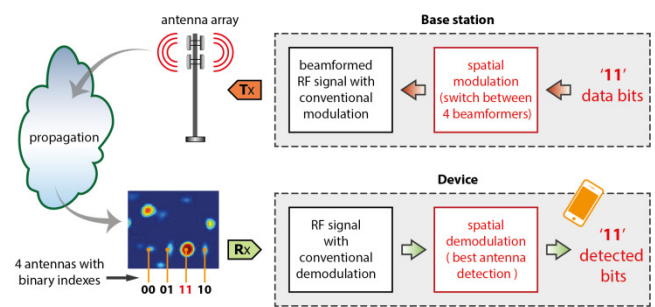


Fig. 2. Principle of Receive spatial modulation with four receive antenna elements: the base station has a set of beamformers (previously determined thanks to a channel estimation phase), and is able to focus towards any of the four antennas of the device. The index of each antenna of the device is coded in binary. By focusing onto a particular antenna, the base station indicates the bits being sent. The device recovers the bits by detecting which antenna is the current focusing target. Note that the RF signal bears a conventional modulation (in phase and amplitude).

Fig. 3. THE SPATIAL MODULATION TEST-BED CHARACTERISTICS

Parameter	Value
Carrier frequency	2.4 GHz
Bandwidth	40 MHz
FFT/IFFT size	256
CP length	64
Num. of pilot symb. (UL)	$5N_R$
Num of pilot symb. (DL)	$N_R$
Num. of OFDM symb (DL)	819
Carrier frequency	2.4 GHz
Bandwidth	40 MHz
FFT/IFFT size	256
CP length	64
Num. of pilot symb. (UL)	$5N_R$

Fig. 4. THE RADIO WAVES DISPLAY CHARACTERISTICS

Parameter	Value
Technology	Digital
Panel area	1m <sup>2</sup>
Number of sensors	400 (20x20)
Sensitivity	-60 dBm to 0 dBm (or max

	dynamic)
Minimal dynamic range	3dB
Bandwidth	50 MHz to 3 GHz
Number of displayed colors	1024
Sensitivity adjustment	Min and max threshold
Frequency of display	1 second or Instantaneous MaxHold
Number of color bars	4
Separate color for saturation (pink)	On or Off
Weight	30 Kg

The Luxondes Radio Waves Display converts radiofrequency signals (between 50 MHz and 3 GHz) into light and directly displays the strength of the Electro-Magnetic-field of a wave which is passing through it. This device is represented in Fig. 6. The 1m x 1m display unit uses 400 (20x20) autonomous identical sensors working as elementary visualization pixels.

#### ACKNOWLEDGMENT

This work is partially supported by the French project SpatialModulation (<https://spatmodulation.cms.orange-labs.fr/>) under grant number ANR-15-CE25-0016 and the French project TRIMARAN. We would like to thank N. Demassieux who asked us to build a demo allowing the general public to visualize the focusing performed by the prototype of the TRIMARAN project, and funded the realization of the first Radio Wave Display presented in this paper.

#### REFERENCES

- [1] 22th Conference of the Parties (COP22). <http://cop22.ma/en/>.
- [2] "5G White Paper" issued by the Next Generation Mobile Networks (NGMN) Alliance, 17 Feb 2015, available at: [https://www.ngmn.org/uploads/media/NGMN\\_5G\\_White\\_Paper\\_V1\\_0.pdf](https://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0.pdf).
- [3] Yang, H.; Marzetta, T. L. "Performance of conjugate and zero-forcing beamforming in large-scale antenna systems," *IEEE J. Select. Areas Commun.*, vol. 31, no. 2, pp. 172–179, Feb. 2013.
- [4] Jungnickel, V.; Manolakis, K.; Zirwas, W.; Panzner, B.; Braun, V.; Lossow, M.; Sternad, M.; Apelfrojd, R. and Svensson, T. "The role of small cells, coordinated multipoint, and massive MIMO in 5G," *IEEE Communications Magazine*, vol. 52, pp. 44–51, May 2014.
- [5] Yang, H.; Marzetta, T. L. "Energy Efficient Design of Massive MIMO: How Many Antennas?," in *Proc. 2015 IEEE 81st Vehicular Technology Conference (VTC Spring)*, Glasgow, 2015, pp. 1-5.
- [6] [http://www.luxondes.com/pdf/luxondes\\_plaquette\\_dalle\\_an.pdf](http://www.luxondes.com/pdf/luxondes_plaquette_dalle_an.pdf)
- [7] Rioult, J.; Heddebaut, M.; Deniau, V.; Kone, L.; Copin, G. "Visualisation optique directe de ph\_enom\_enes de propagation en chambre réverbérante à brassage de mode," in *Proc. 18 ème Colloque International et Exposition sur la Compatibilité Electro-Magnétique (CEM 2016)*, July 2016, Rennes, France, 4p, 2016. Available at: <https://hal.archives-ouvertes.fr/hal-01374211/document>
- [8] Malhouroux-Gaffet, N.; Pajusco, P.; Burghlelea, R.; Leray, C., "Capacity Gain of MIMO Systems with Microstructured Antenna Arrays," *European Conference on Antennas and Propagation (EUCAP) 2014*, 6-11 april 2014, The Hague – The Netherlands.
- [9] Prévotet, J.-C.; Kokar, Y.; Hélar, M.; Crussièr, M. "Implementation of a Time-Reversal MISO OFDM Test-Bed," *European Workshop on Testbed based wireless research (ETW)*, Stockholm, Sweden, 19 november 2014.
- [10] Prévotet, J.-C.; Kokar, Y.; Hélar, M.; Crussièr, M. « Implementation of a Time-Reversal MISO OFDM Test-Bed », *Wireless World Research Forum (WWRF) 2014*, Guildford, UK, 26-28 september 2014.
- [11] Lerosey, G.; De Rosny, J.; Tourin, A.; Derode, A.; Montaldo, G.; Fink, M. "Time reversal of electromagnetic waves," *Phys. Rev. Lett.*, vol. 92, no. 19, May 2004.
- [12] Dubois, T.; Hélar, M.; Crussièr, M.; Maaz, I. "Time reversal applied to large MISO-OFDM systems," in *Proc. 2013 IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, London, 2013, pp. 896-901.
- [13] C. Balanis, *Antenna Theory: Analysis and Design*, 2nd ed. New York: Wiley, 1997.
- [14] Derode, A.; Tourin, A.; De Rosny, J.; Tanter, M.; Yon, S.; Fink, M. "Taking Advantage of Multiple Scattering to Communicate with Time-Reversal Antennas," *Phys. Rev. Lett.* 90, 014301

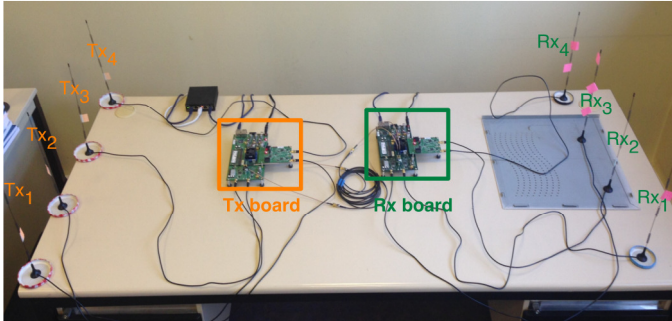


Fig. 5. Experimental set-up.

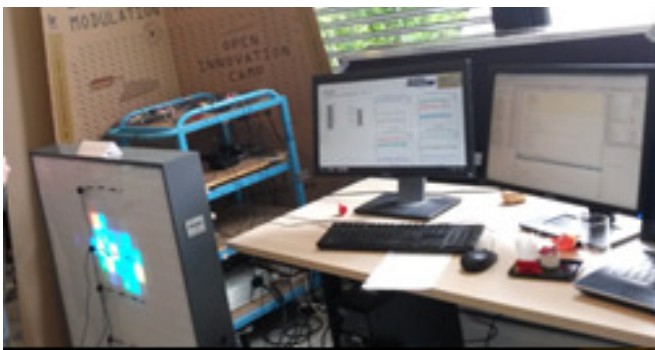


Fig. 6. Receive spatial modulation setup, with 4 receive antennas scotched on the front of the Radio Waves Display and the transmitter around 1 meter behind, focusing alternatively towards one of the 4 antennas.

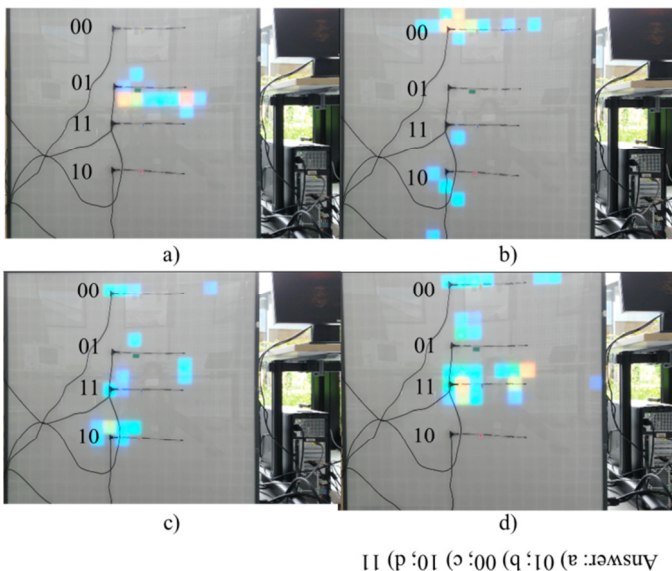


Fig. 7. Receive spatial modulation game: perform spatial demodulation by finding visually the detected bits for the four presented configurations

- [15] Renzo, M. D.; Haas, H.; Ghayeb, A.; Sugiura, S.; Hanzo, L. "Spatial modulation for generalized MIMO: Challenges, opportunities, and implementation," in *Proc. of the IEEE*, vol. 102, pp. 56–103, Jan. 2014.
- [16] Phan-Huy, D. T.; H elard, M. "Receive antenna shift keying for time reversal wireless communications," in *Proc. IEEE Int. Conf. Communications (ICC)*, pp. 4852–4856, June 2012.
- [17] Kokar, Y; Pr evotet, J.-C.; H elard, M. "Receive antenna shift keying modulation tesbed for wireless communication systems," *IEEE Globecom 2016*, Washington D.C., Dec. 2016, accepted.