

# Omar El Ayach

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## CONTACT INFORMATION

Wireless Networking and Communications Group  
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## EDUCATION

### **The University of Texas at Austin, Austin, TX**

Ph.D., Electrical and Computer Engineering (expected May 2013)

- Total GPA: 3.79 (Graduate Courses GPA: 3.87)
- Thesis Title: *Interference Alignment from Theory to Practice*
- Advisor: Professor Robert W. Heath, Jr.

M.Sc. in Engineering, Electrical and Computer Engineering, May 2010

- Total GPA: 3.77 (Graduate Courses GPA: 3.85)
- Thesis Title: *Interference Alignment in Real World Environments*
- Advisor: Professor Robert W. Heath, Jr.

### **The American University of Beirut, Beirut, Lebanon**

B.E., Computer and Communication Engineering, June 2008 (with High Distinction)

- GPA: 91.2/100 (4.00)
- Senior Design Project: Indoor Wireless Localization for the AUB Medical Center

## EXPERIENCE

### **Samsung Electronics, Richardson, TX**

*Engineering R&D Intern*

**May '12 - August '12**

- Developed multimode precoding algorithm for millimeter wave MIMO systems with a special focus on the hardware constraints of practical millimeter wave transceivers.
- Developed open-loop MIMO transmission strategies based on combined RF and baseband precoder cycling for millimeter wave MIMO systems.

*Engineering R&D Intern*

**May '11 - July '11**

- Analyzed the performance of various precoding strategies in millimeter wave single and multi-user networks with large antenna arrays in realistic fading channels.
- Developed novel low-complexity precoding strategies for the millimeter wave single user channel. The proposed algorithms build on concepts in MIMO signal processing, multi-objective optimization, and sparse signal recovery.

### **The University of Texas at Austin, Austin, TX**

*Graduate Research Assistant*

**September '08 - Present**

- Implementing a multi-user software-defined MIMO OFDM testbed. The system consists of three two-by-two MIMO links to test the applicability of MIMO concepts such as interference alignment in realistic propagation environments.
- Developing low-overhead feedback strategies for MIMO interference networks based on both limited and analog feedback. Examining the practical limits physical layer cooperation in wireless systems with a focus on mobility, signaling overhead, and modern network infrastructure, e.g., distributed antenna systems.

*Teaching Assistant (Wireless Communication Lab)*

**Fall '08 and '09**

- Supervisor: Prof. Robert W. Heath Jr.
- Instructed lab sessions, corrected assignments, corrected exams, and held office hours. The lab aims at implementing a full wireless communication link using LabView and software defined radio hardware from National Instruments.

**The University of California at Berkeley, Berkeley, CA**

*Research Intern*

**June '07 - September '07**

- Supervised by: California Center for Innovative Transportation
- Implemented a WiMax network interface to be used in deploying and testing the research center's new WiMax network at the Berkeley Highway Lab.
- Conducted a feasibility study on implementing a new transportation networking protocol (NTCIP) on embedded systems. Finally, implemented several protocols to ensure backward compatibility of new hardware with existing equipment that can not be phased out.

**American University of Beirut, Beirut, Lebanon**

*Teaching Assistant (Introduction to Computer Programming)*

**Fall '05**

- Instructed lab sessions, corrected assignments, and corrected exams. The class introduces first year engineering students to computer programming using C++.

SELECTED  
COURSEWORK

Communication Systems, Digital Communication, Signal and Systems, Advanced Wireless Communication, Wireless Communication Lab, Information Theory, Computer Networks, Queueing Theory, Network Science (Graph Theory), Introduction to Systems Theory, Control Systems, Probability and Stochastic Processes, Convex Optimization, Markov Decision Processes, Internet Security, Electronics, Computer Architecture, Operating Systems, Data Structures and Algorithms, Electromagnetics.

PUBLICATIONS

### **Books**

- (B1) R. W. Heath, Jr., et al., "MIMO Communications," Cambridge University Press, in preparation

### **Journal Papers**

- (J2) S. Akoum, O. El Ayach, and R.W. Heath, Jr., "Capacity & Coverage in mmWave MIMO Cellular Systems" *in preparation, to be submitted to IEEE Transactions on Wireless Communications*, May 2013
- (J3) O. El Ayach, S. Rajagopal, S. Abu-Surra, Z. Pi, and R.W. Heath, Jr., "Spatially Sparse Precoding in Millimeter Wave MIMO Systems," *submitted to IEEE Transactions on Wireless Communications*, May 2013
- (J4) J. Starr, O. El Ayach and R.W. Heath, Jr., "Interference Alignment in Distributed Antenna Systems," *submitted to IEEE Transactions on Wireless Communications*, April 2013
- (J5) O. El Ayach, S.W. Peters and R.W. Heath, Jr., "The Practical Challenges of Interference Alignment," *IEEE Wireless Communications Magazine*, vol. 20, no. 1, pp. 35-42, February 2012
- (J6) O. El Ayach, A. Lozano and R.W. Heath, Jr., "On The Overhead of Interference Alignment: Training, Feedback, and Cooperation," *IEEE Transactions on Wireless Communications*, vol. 11, no. 11, pp. 4192-4203, November 2012

- (J7) O. El Ayach and R.W. Heath, Jr., “Grassmannian Differential Limited Feedback for Interference Alignment,” *IEEE Transactions on Signal Processing*, vol. 60, no. 12, pp. 6481-6494, December 2012
- (J8) M. Watfa, T. Nsouli, M. El Ayach, and O. El Ayach, “Reactive Localization in Underwater Wireless Sensor Networks with Self Healing,” *International Journal of Intelligent Systems Technologies and Applications (IJISTA)*, vol. 1, no. 3, pp. 1-11, August, 2012
- (J9) O. El Ayach and R.W. Heath, Jr., “Interference Alignment with Analog Channel State Feedback,” *IEEE Transactions on Wireless Communications*, vol. 11, no. 2, pp. 626-636, February 2012
- (J10) O. El Ayach, S.W. Peters, and R.W. Heath, Jr., “The Feasibility of Interference Alignment Over Measured MIMO-OFDM Channels,” *IEEE Transactions on Vehicular Technology*, vol. 59, no. 9, pp. 4309-4321, November 2010

### Conference Papers

- (C11) O. El Ayach, R.W. Heath, Jr., S. Rajagopal, and Z. Pi, “Multimode Precoding for Millimeter Wave MIMO Systems with Multiple Antenna Sub-Arrays,” *submitted to IEEE Global Telecommunications Conference*, Atlanta, GA, March 2013
- (C12) S. Rajagopal and O. El Ayach, “Open Loop Transmission Strategies of Millimeter Wave MIMO Systems,” *submitted to IEEE Global Telecommunications Conference*, Atlanta, GA, March 2013
- (C13) A. AlKhateeb, O. El Ayach, G. Leus, and R.W. Heath, Jr., “Hybrid Precoding for Millimeter Wave Cellular Systems with Partial Channel Knowledge,” *in Proceedings of Information Theory and Applications Workshop (ITA)*, San Diego, CA, February 2013
- (C14) O. El Ayach and R.W. Heath, Jr., “Interference Alignment – Recent Progress, and Future Directions,” *in Proceedings of IEEE Radio Wireless Symposium (RWS)* pp. 205-207, Austin, TX, January 2013
- (C15) S. Akoum, O. El Ayach, and R.W. Heath, Jr., “Capacity & Coverage in mmWave Cellular Systems” *in Proceedings of Asilomar Conference on Signals, Systems and Computers*, pp. 688-692 Pacific Grove, CA, November 2012
- (C16) O. El Ayach, R.W. Heath, Jr., S. Abu-Surra, S. Rajagopal, and Z. Pi, “The Capacity Optimality of Beam Steering in Large Millimeter Wave MIMO Systems,” *in Proceedings of IEEE Int. Workshop on Signal Processing Advances in Wireless Communications (SPAWC)*, pp. 100-104, Cesme, Turkey, June 2012
- (C17) O. El Ayach, R.W. Heath, Jr., S. Abu-Surra, S. Rajagopal, and Z. Pi, “Low Complexity Precoding for Large Millimeter Wave MIMO Systems,” *in Proceedings of IEEE International Conference on Communications (ICC)*, pp. 3724-3729, Ottawa, Canada, June 2012
- (C18) O. El Ayach, A. Lozano and R.W. Heath, Jr., “Interference Alignment – Is Multiplexing Gain Worth the Overhead?,” *in Proceedings of IEEE Communication Theory Workshop (CTW)*, Maui, HI, May 2012 (Note: 2 page extended abstract, no published proceedings)

- (C19) O. El Ayach, A. Lozano and R.W. Heath, Jr., “Optimizing Training and Feedback for MIMO Interference Alignment,” in *Proceedings of Asilomar Conference on Signals, Systems and Computers*, pp. 1717-1721, Pacific Grove, CA, November 2011
- (C20) O. El Ayach and R.W. Heath, Jr., “Grassmannian Differential Limited Feedback for Interference Alignment,” in *Proceedings of the 19th European Signal Processing Conference (EUSIPCO)*, pp. 1075-1079, Barcelona, Spain, August 2011
- (C21) J. Starr, O. El Ayach and R.W. Heath, Jr., “Interference Alignment with Per-Antenna Power Constraints,” in *Proceedings of IEEE International Symposium on Information Theory (ISIT)*, pp. 2746-2750, St. Petersburg, Russia, August 2011
- (C22) O. El Ayach and R.W. Heath, Jr., “Interference Alignment with Analog CSI Feedback,” in *Proceedings of IEEE Military Communications Conference (MILCOM)*, pp. 1644-1648, San Jose, CA, November 2010
- (C23) M. Watfa, T. Nsouli, M. El Ayach, and O. El Ayach, “Reactive Localization in Underwater Wireless Sensor Networks,” in *Proceedings of IEEE International Conference on Computer and Network Technology*, pp. 244-248, Bangkok, Thailand, April 2010
- (C24) O. El Ayach, S.W. Peters, and R.W. Heath, Jr., “Real World Feasibility of Interference Alignment Using MIMO-OFDM Channel Measurements,” in *Proceedings of IEEE Military Communications Conference (MILCOM)*, Boston, MA, October 2009

PATENTS

- (P1) Z. Pi, O. El Ayach, S. Rajagopal, and S. Abu-Surra, “Multiple Antenna Transmission with Per-Antenna Power Constraints,” United States Patent Application US 2013/0051486 (WO 2013/032294), February 28, 2013
- (P2) O. El Ayach, S. Rajagopal, S. Abu-Surra, and Z. Pi, “Combining Baseband Processing and Radio Frequency Beam Steering in Wireless Communication Systems,” United States Patent Application US 2013/0028341 (WO 2013/015664), January 31, 2013
- (P3) O. El Ayach, S. Rajagopal, and Z. Pi, “Multimode Precoding Using Hybrid RF/Baseband Processing,” Provisional Patent Application, filed August 2012.
- (P4) S. Rajagopal, O. El Ayach, and Z. Pi, “Open Loop MIMO Transmission Scheme for Communication Systems with Large Number of Antennas,” Provisional Patent Application, filed August 2012.
- (P5) S. Rajagopal, R.S. Gallacher, O. El Ayach, and K. Josiam, “Closed Loop Single User and Multiuser Beamforming for Millimeter Wave Communication Systems with a Single Digital Chain,” Provisional Patent Application, filed June 2012.

ORAL PRESENTATIONS

- (O1) “Interference Alignment – From Information Theory to Engineering Practice”, UT in Silicon Valley, Santa Clara, CA, March 2013
- (O2) “Interference Alignment – Is Multiplexing Gain Worth the Overhead?”, Texas Wireless Summit, Austin, TX, October 26, 2012
- (O3) “Multimode Precoding in Millimeter Wave MIMO Systems”, Samsung Electronics, Richardson, TX, August 3, 2012

- (O4) “The Capacity Optimality of Beam Steering in Large Millimeter Wave MIMO Systems,” IEEE Int. Workshop on Signal Processing Advances in Wireless Communications (SPAWC), Cesme, Turkey, June 2012
- (O5) “Interference Alignment – Is Multiplexing Gain Worth the Overhead?”, IEEE Communication Theory Workshop (CTW) 2012, Maui, HI, May, 2012
- (O6) “Grassmannian Differential Limited Feedback for Interference Alignment”, Texas Wireless Summit, Austin, TX, November 2011
- (O7) “Optimizing Training and Feedback for MIMO Interference Alignment”, Asilomar 2011, Pacific Grove, CA, November, 2011
- (O8) “Low Complexity MIMO Precoding Strategies for the Millimeter Wave Point-to-Point and Broadcast Channels”, Samsung Electronics, Richardson, TX, July 25, 2011
- (O9) “Grassmannian Differential Feedback for Interference Alignment”, 2011 IEEE Winter School of Information Theory, Barcelona, Spain, March 14, 2011
- (O10) “Low Overhead Feedback Strategies for the Interference Channel”, Texas Wireless Summit, Austin, TX, November 15, 2010
- (O11) “Interference Alignment with Analog CSI Feedback”, MILCOM 2010, San Jose, CA, November, 2010
- (O12) “A Practical Network View of Interference Alignment”, Workshop on Frontiers of Controls, Games, and Network Science with Civilian and Military Applications, Austin, TX, February, 2010
- (O13) “Interference Alignment: Feasibility and Overhead”, Texas Wireless Summit, Austin, TX, November 5, 2009
- (O14) “Real World Feasibility of Interference Alignment Using MIMO-OFDM Channel Measurements”, MILCOM 2009, Boston, MA, October, 2009
- (O15) “Real World Feasibility of Interference Alignment Using MIMO-OFDM Channel Measurements”, The Winedale Workshop, Round Top, TX, October, 2009
- (O16) “Interference Alignment Over Measured MIMO-OFDM Channels”, DARPA IT-MANET Workshop, Cambridge, MA, September 14, 2009

#### AWARDS

Recipient of WNCG Student Leadership Award, 2012

Recipient of IEEE Communications Society Student Travel Grant, 2010

Dean’s Honor List in the Faculty of Engineering and Architecture at A.U.B. (Fall ’04 - Spring ’08)

#### REFEREE SERVICE

- *IEEE Transactions on Communications*
- *IEEE Transactions on Information Theory*
- *IEEE Transactions on Signal Processing*
- *IEEE Transactions on Vehicular Technology*
- *IEEE Transactions on Wireless Communications*
- *IEEE Communications Letters*
- *IEEE Wireless Communications Letters*
- *EURASIP Journal on Wireless Communications and Networking*

- *IEEE Global Communications Conference (GLOBECOM) 2010, 2011, 2012*
- *IEEE Int. Conf. on Acoustics, Speech, and Signal Processing (ICASSP), 2011*
- *IEEE International Symposium on Information Theory (ISIT), 2011, 2012*
- *IEEE Vehicular Technology Conference (VTC), 2011, 2012, 2013*
- *IEEE Int. Conf. on Computing, Networking and Communications (ICNC) 2011*
- *IEEE Int. Conf. on Communications (ICC) 2012*
- *IEEE Wireless Communications and Networking Conference (WCNC), 2012*
- *IEEE Int. Symposium on Wireless Communication Systems (ISWCS), 2012*
- *IEEE Int. Symposium on Information Theory and its Applications (ISITA), 2012*
- *IEEE Int. Workshop on Signal Processing Advances in Wireless Communications (SPAWC), 2013*

PROFESSIONAL  
ACTIVITIES

Publicity chair for the 2013 IEEE Radio and Wireless Symposium, Austin, Texas, January 2013.

Publicity chair for the 2012 IEEE Radio and Wireless Symposium, Santa Clara, California, January 2012.

Publicity chair for the 2011 IEEE Radio and Wireless Symposium, Phoenix, Arizona, January 2011.

Volunteer for the IEEE International Symposium on Information Theory (ISIT), 2010.

SKILLS

Engineering Software: MATLAB, LabVIEW, Mathematica, NS2

Programming Languages: C, C++, Java, Perl, Python, UNIX shell script, Microsoft SQL, Tcl/Tk, VHDL