USC Viterbi School of Engineering

Seminar

Ming Hsieh Department of Electrical and Computer Engineering

Zak-OTFS – The Waveform for Next Generation Communication Systems

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Abstract: In this talk we present our work based on signal representation in the delay-Doppler (DD) domain which gives rise to pulsones. The DD domain representation of any time-domain/frequency-domain signal is given by its Zak transform. Pulsones are simply quasi-periodic pulses in the DD domain whose interaction with a doubly-spread channel is stationary and non-fading when the pulse period along the delay axis is greater than the channel delay spread and the pulse period along the Doppler axis is greater than the channel Doppler spread, a condition we refer to as the crystallization condition. In Zak-OTFS modulation, information is carried by pulses in the DD domain. Due to the stationary input-output (I/O) relation of Zak-OTFS modulation, the effective DD domain channel can be acquired/estimated with negligible overhead, and the performance is robust to channel delay and Doppler spread.

Zak-OTFS modulation is therefore ideally suited for ubiquitous communication (e.g., satellite communication, aircraft communication, high speed train, where we encounter high Doppler spread). Machine learning (ML) can revolutionize wireless communication only if the interaction of the carrier waveforms with the channel varies very slowly in both time and frequency. Since Zak-OTFS renders a stationary I/O relation, it enables learning algorithms to achieve better resource allocation/precoding etc. Zak-OTFS waveforms are also suited for radar sensing. Appropriate DD domain signal processing allows for co-existence of communication and sensing signals with little cross-interference, i.e., integrated sensing and communication.

Our pioneering work on this new waveform is a paradigm shift in the way communication systems are designed and is expected to play a decisive role in the future of wireless communication. This work is presented in detail in our book titled “OTFS Modulation: Theory and Applications”, Wiley and IEEE Press, Nov. 2024.

Bio: Saif Khan Mohammed is a Professor with the Department of Electrical Engineering, Indian Institute of Technology Delhi (IIT Delhi). He currently holds the Jai Gupta Chair at IIT Delhi. He received the B.Tech. degree in Computer Science and Engineering from IIT Delhi, New Delhi, India, in 1998, and the Ph.D. degree from the Electrical Communication Engineering Department, Indian Institute of Science, Bangalore, India, in 2010. From 2010 to 2011, he was a Post-Doctoral Researcher at the Communication Systems Division (Commsys), Electrical Engineering Department (ISY), Linkoping University, Sweden. He was an Assistant Professor at Commsys, from September 2011 to February 2013. His main research interests include waveforms for sixth generation (6G) communication systems, wireless communication using large antenna arrays, coding and signal processing for wireless communication systems, information theory, and statistical signal processing.

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