Tutorial on Full-Duplex Techniques for 5G and Beyond

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In-band *full-duplex (FD)* technology, by which devices transmit and receive simultaneously on the same frequency band, has attracted a lot of research attention lately. Since FD radios can potentially double the spectral efficiency, they are a promising technology for 5G and future wireless networks. However, FD radios suffer from severe *self-interference (SI)*, as well as extra cross-directional coupling between simultaneous uplink and downlink operation which further degrades the overall network performance. To this end, many research groups around the world have proposed new transceiver designs, implemented advanced FD prototypes and have shown that SI can be mitigated almost down to the noise floor, or even below in some cases. All these accomplishments show the feasibility of FD and its applicability for future wireless networks. Despite these fundamental results and achievements, there are still many challenges and open problems to resolve about FD operation. In order to achieve the full potential of FD transmission, it is necessary to cope with the self-interference and develop new mechanisms and efficient protocols.

We invite you to join this tutorial session were we present the state-of-the art of FD transceiver design and applications and promote a general discussion on the common open questions and future challenges related to emerging wireless networks so that any engineer or scientist working on communications will find it interesting and inspiring. In particular, we divide the tutorial into two sections where we address the following topics:

1. Self-interference characterization (1:15h)
    - What is SI and how does it manifest itself in modern FD antenna/transceiver designs?
    - How to overcome SI? Introduction to advanced SI mitigation techniques: physical isolation, processing using analog electronics, time-domain digital cancellation and spatial-domain suppression
2. Full-duplex applications (1:15h)
    - Characterization of the residual SI from imperfect mitigation: hardware impairments, countermeasures and analytical modeling
    - Point-to-point links, relaying systems
    - Cellular/small-cells
    - Cognitive radios and physical-layer security

Biographies

Hirley Alves received the B.Sc. and M.Sc. degrees from Federal University of Technology - Paraná (UTFPR), Brazil, in 2010 and 2011, respectively, both in Electrical Engineering and a dual D.Sc. degree from University of Oulu and UTFPR in 2015. His D.Sc. thesis is closely related to the scope of this tutorial. Dr. Alves has been working at the Centre for Wireless Communications (CWC), University of Oulu, Finland, since 2011 where he is engaged in several national (Academy of Finland) and international projects such as BeFemto and DUPLO. He has acted as a Special Session chair in CAMAD'15, and Track Co-chair at STEMCOM'16, workshop chair at European Wireless 2016 and a has presented a tutorial on Full-Duplex (jointly with Taneli Riihonen) also at European Wireless 2016. His research interests are cooperative communications, full-duplex technologies, physical-layer security and ultra-reliable communication mechanisms for future wireless networks.

Taneli Riihonen received the D.Sc. degree in electrical engineering (with distinction) from Aalto University, Helsinki, Finland in August 2014. Related to the scope of this tutorial, his D.Sc. thesis "Design and Analysis of Duplexing Modes and Forwarding Protocols for OFDM(A) Relay Links" (`http://tinyurl.com/full-duplex`) was nominated as the best engineering dissertation of the year in Finland. Dr. Riihonen has held various research positions at the Department of Signal Processing and Acoustics, Aalto University School of Electrical Engineering since September 2005. He is serving as an Editor of IEEE Communications Letters since October 2014. Taneli has given a tutorial on Full-Duplex (jointly with Hirley Alves) at European Wireless 2016. His research activity is focused on physical-layer multicarrier, multiantenna, relaying and full-duplex wireless techniques with current interest in the evolution of 5G systems.