RF Self-Interference Channel Characterization For Full-Duplex MIMO Transceivers

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Introduction

- The purpose of this research is to implement Full-Duplex 2x2 MIMO communication for the 5G mobile standard.
- Full-Duplex (FD) communication is the transmission and reception of radio signal simultaneously on the same frequency band.
- This increases data throughput and spectral efficiency.
- Simultaneous transmission and reception results in strong self - interference between the radio's local transmitter and the signal received from a distant source. This interference must be cancelled.
- RF Self-Interference Cancellation (SIC) enables simultaneous reception of a very weak signal while transmitting a very strong signal from the same base station.
- The SI channels must be characterized in order to be able to design efficient canceller circuit.

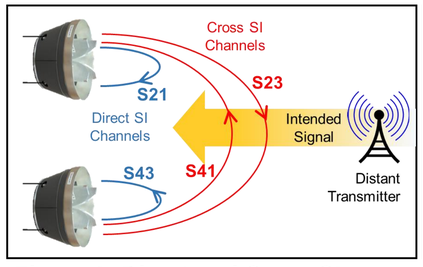

Figure 1: Direct and Cross SI Channels in 2x2 Full Duplex MIMO System

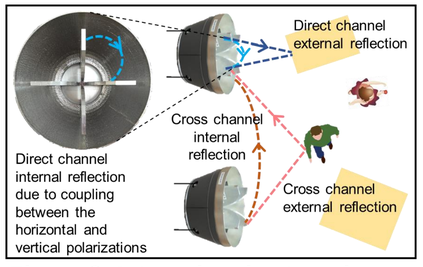

Figure 2: Internal and external reflection in 2x2 Full Duplex MIMO System

Background

RF SIC Stages:
Stage 0: Antenna Tx/Rx Isolation
Stage 1 (S1): RF/ Analog **Passive** Cancellation
Stage 2 (S2): RF/ Analog **Active** Cancellation
Stage 3 (S3): BB Digital Cancellati-on. Since the power of the intended signal is relatively low compared to the self-interference, we need several stages of cancellation. Without the RF Cancellation stage, the LNA will generate many non-linearity elements which may saturate the receiver.

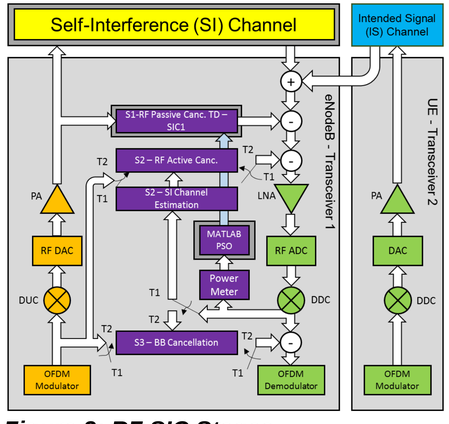

Figure 3: RF SIC Stages

Methodology

VNA channel sounding technique was used for characterization of the SI channel.

Advantages:

1. Co-located setup simplicity & minimum data post-processing required
2. Can sweep over wide frequency range of 500 MHz for increased time resolution without the need for high sampling rate needed in other sliding correlator channel sounding techniques

Disadvantages:

1. Requires static environment when sweeping over wide frequency range to prevent variations of channel during the acquisition time. A time-varying channel may give erroneous data
2. Relatively slow measurement time compared to other Chirp & PN Channel sounding techniques
3. Practical only for co-located Tx\Rx channels with low external interference

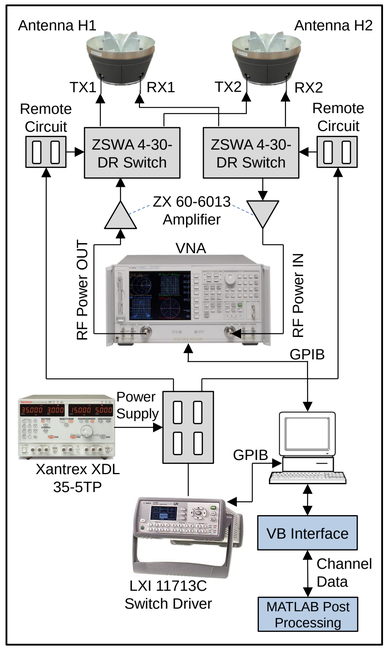

Figure 4: Setup for carrying out channel measurement using the VNA technique

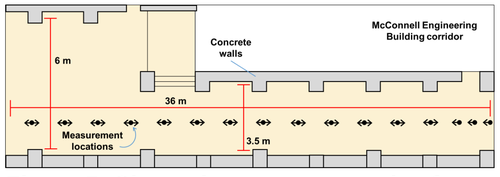

Figure 5: Channel measurement plan for static environment in corridor

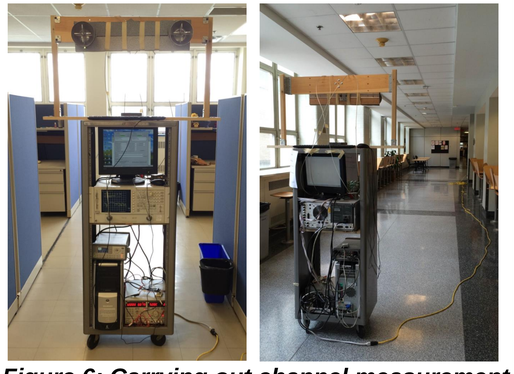

Figure 6: Carrying out channel measurement for static environment in corridor

Measurement environment and procedure:

1. Calibrate measurement equipment on the cart
2. Plan sufficient number of measurement locations in chosen environment, each location approximately 1 m apart from each other
3. Fix equipment in cart and move to different location for each measurement.
4. For 500 MHz bandwidth keep environment static to avoid variations in channel during the acquisition time. Center frequency at 2.49 GHz & 1601 sweep points

Results

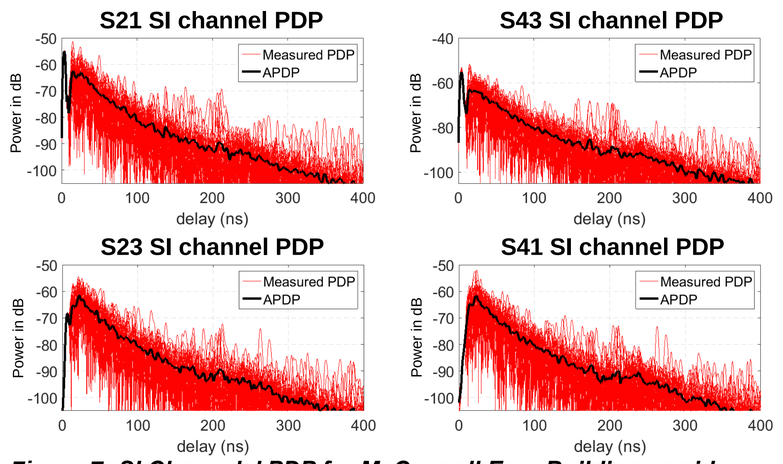

Figure 7: SI Channels' PDP for McConnell Eng. Building corridor

The graphs generated from the channel data show that the power delay profiles (PDP) are mainly composed of two parts:

1. The antenna reflection part which is due to internal reflection in the antenna caused by coupling between the V & H polarization. This < 10ns delay part is independent of the environment, and Tap Delay Stage 1 Passive RF/ Analog SI Canceller can be used for this very slowly changing SI part.
2. The second part > 10ns delay is due to the external reflections. Presence of reflecting objects cause multipath propagation of the same Tx signal, creating small-scale fading effects of the signal at the receiver. This space multipath highly depends on the environment. More dynamic Stage 2 & 3 SIC is used for this part.

Conclusion

16 different locations with at total of 62 measurements were performed to obtain various statistical results for a typical SI channel in office space indoor environment.

Direct & Cross SI due to antenna internal structure and near objects, is static, and may need only 1-2 tap delays Stage 1 canceller with low rate tuning, but with passive high input power linearity.

SI due to external objects reflections has Ricean distribution and requires digital S2 & S3 cancelation techniques.

Acknowledgements

Thanks to Professor Tho Le Ngoc and my supervisors Fei Chen and Robert Morawski for their assistance and support.