Frequently Asked Questions

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⇒ Q: Why most of discussion and reported implementation is based on using separate transmit and receive antennas?

⇒ A: The sole reason has been to reduce complexity of hardware implementation based on the available platform, which supports multiple antennas. There are some results for single antenna case as well.

⇒ Q: Why presentation is based on using corrective beam-forming (which requires two transmit antennas) rather than signal injection?

⇒ A: Again, the reason has been to reduce complexity of hardware implementation, and also make it possible to study various signals involved in cancellation. It should be obvious to a person skilled in the area that similar results would be obtained using signal injection. There are some results for signal injection using a single antenna as well.

⇒ Q: What is the size of A/D and D/A used in the implementation?

⇒ A: A/D and D/A were limited to what is in the hardware of Lyrtech platform (14 bits A/D and 12 bits D/A). We did not have any indication that A/D or D/A would act as performance bottleneck even if the number of bits is significantly lower. Also, A/D and D/A of a decent size are readily available at sampling rates required in typical wireless applications. Requirement on D/A accuracy is less than A/D, as inaccuracies in D/A do not contradict linearity and will be subsequently canceled in the final stage in the base-band.

⇒ Q: What would be an immediate application of full-duplex nodes?

⇒ A: The primary benefit of full-duplex is in networking applications where a central node can transmit, while listening to new clients who want to join the network. This can be achieved by having full-duplex data links (using OFDMA) and half duplex superimposed control signaling. Also, the clients do not need to support full-duplex and central node can transmit data to one and receive data from another. This feature can be added to many of current OFDMA networks with small modifications.

⇒ Q: How is the degradation in SNR (Residual self-Interference plus Noise divided by Noise, RINR) measured?

⇒ A: Power of residual self-interference+noise is measured in non-zero OFDM tones. Power of noise is measured in both OFDM zero tones as well as when transmitter is off (no significant difference was observed). In the reported tests, AGC was disabled (LNA gain was once manually set) to have a better framework to compare different schemes in terms of RINR (AGC saves some A/D bits). Tests were performed over 802.11 channel 13 which is not used in North America (to reduce interference from neighboring nodes). RINR is averaged over several thousands OFDM frames. Measurements were also performed to measure the equivalent of RINR is a half-duplex link. This accounts for the degradation in SNR due to various mismatches which can be quite significant in half-duplex connection between distant nodes, while these are avoided in a full-duplex system due to having access to the same clock/carrier/timing in cancellation of self-interference. Results show that the degradation is generally higher than what is observed for RINR, and consequently the observed RINR due to adding the full duplex feature is even less significant. These results are not reported due to space limitations as well as the fact that the results would depend on the specific implementation (in our case, we have followed the conventional methods used in typical 802.11 receivers for carrier/time recovery and signal detection).

⇒ Q: What is the setup for channel measurement in self-interference cancellation?

⇒ A: We examined sending 3 consecutive pilots (long training sequence used in 802.11) with averaging to improve the channel measurement of the first phase, but the result was similar to the case of using a single pilot. In general, the system is very robust to such errors as the effect does not violate linearity and consequently subsequent stage of cancellation in base-band will account for such errors. For the second phase, number of pilots (again long training sequence of 802.11) used for averaging is adaptively adjusted depending on the conditions (to make sure second stage is always useful). The more effective is the first stage of active cancellation, the higher should be the accuracy of channel estimation in the second phase and two complementary adaptation rules are used to select the number of training sequences used in the second phase.

⇒ Q: What are the issues with backward compatibility, is there a need to change the entire network structure to use full-duplex?

⇒ A: We can have half-duplex legacy nodes that are serviced by a smart full-duplex access point, but in long term it make sense to have full duplex capability in all nodes. Various mechanisms for control signaling, resource allocation, scheduling, even carrier sense multiple access strategy, can remain the same, but relying on full-duplex nodes, they will act more efficiently with less delay.

⇒ Q: In this presentation suggesting changing in the PHY/MAC?

⇒ It is not a different PHY. It is similar to equalization, and it does require additional training to measure the channel for the self-interference (interference between transmit and receive in a given node), but that is it. It is not using a different MAC, although it will be meaningful to have a more efficient MAC to exploit two-way capability, but not the other way around. In general, issues such as scheduling, resource allocation, handoff, etc., will be simplified as nodes can transmit (or receive) control signals, while receiving (or transmitting) data. For example, issues of CSMA will be essentially solved.

⇒ Q: Why everything is based on OFDM and OFDMA?

⇒ A: In theory, it should work with any legacy mechanism used for signal separation, e.g., TDMA or CDMA. We tried TDMA with adaptive filtering in time domain for interference removal in the baseband (instead of subtraction in the OFDM domain) and it was essentially functional. Some mild issues were observed which appeared to occur when the self-interference channel was very frequency selective. We did not spend too much to optimize the performance for TDMA system, as the 802.11 PHY (for OFDM) was readily available, and hardware tools were available. In addition OFDM is used in many new wireless standards.

⇒ Q: Are the tests performed over any other bands? What about interference in the ISM band? Can the reported results for degradation in SINR be biased due to the interference in the ISM band (in the sense that the additional noise due to self-interference is not significant in comparison with the multi-user interference.)?

⇒ A: Testes were performed in 2.4 and 5Ghz ISM bands on UW campus. Channel 13 of the 2.4Ghz band is not used in Canada, and we performed our tests mostly over this channel to have less interference. UW campus does use the 5Ghz band, and we tested the system over this band as well with similar results. There is no evidence that results will be any different if tested in an ideal environment in which additive Gaussian noise is the dominant factor (no multi-user interference). In general, even in cellular systems, multi-user interference is usually the dominant factor.