IBFD Power Line Communication For Analog Interference Cancellation

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Abstract- *In this paper, we present an all-analog echo cancellation solution to achieve in-band full duplex (IBFD) operation in broadband power line communications (BB-PLC). The performance of active digital interference cancellation, as proposed previously for IBFD BB-PLC, is limited by distortion and quantization noise introduced by the analog-to-digital converter (ADC). Hence, we explore analog interference cancellation (AIC) solutions to reduce the power of the signal entering the ADC. We consider various AIC solutions for other communication media known from the literature, and show that a direct implementation of any of these solutions to a BB-PLC system renders an expensive and/or ineffective realization. Acknowledging the specific challenges encountered in BB-PLC, we propose an AIC mechanism that not only eliminates the effects of ADC distortion and quantization noise, but also provides sufficient echo cancellation gain (ECG) to function without an active digital interference cancellation module. We demonstrate through simulation results that our proposed solution provides over 80 dB of ECG,which is sufficient to reduce the echo power down to the minimum power line noise floor.*

Keywords- Analog cancellation, in-band full-duplex (IBFD), broadband), echo cancellation power line communication (BB-PLC)

I. INTRODUCTION

Alexios, et al Full-duplex wireless communication offers improved spectral efficiency, as well as more efficient relaying and medium access, but requires suppression of self-interference. In this paper we analyze the existing methods for active RF suppression and use the ”Rice architecture” for its low complexity and favorable scaling when applied to multi-antenna systems. We analyze the effects of the different sources of self-interference and quantify the potential for further suppression (genie aided suppression). Our single-chain implementation using a circulator achieves 48 dB of active RF suppression, but only 66 dB of total suppression in the analog domain. On the other hand, our single chain implementation using separate antennae reaches 85 dB of total analog suppression, thus reducing the self-interference to the noise floor. Extending these setups, we present a low complexity implementation of a 2_2 full-duplex MIMO node, which achieves even higher suppression than the single-chain counterparts .At both stages we reproduce the self-interference signal, and subtract it from the received signal. It is important to note that all the components of the self-interference signal are accessible to us (i.e., cancelable) at both stages.

Gautham, et al(2014) [2] We introduce in-band full duplexing (IBFD) for broadband power line communication (BB-PLC) systems. Inspired by the use of IBFD in digital subscriber lines, Ethernet, cable communication and recently in wireless communication we investigate the constraints and requirements for a successful IBFD implementation in BB-PLC. We propose a two stage IBFD structure consisting of an initial analog isolation using an active hybrid circuit, and a simplified mixed-domain digital echo cancellation procedure to suppress the self interference. Further, we enhance the digital cancellation filter to better adapt to linear periodically time-varying channel conditions, commonly encountered in PLC scenarios. We evaluate our solution under diverse power line channel and noise conditions to examine the overall data rate gains that can be achieved. Lastly, we extend IBFD to multiple-input multiple-output BB-PLC systems that enable faster and/or more robust data transmission.

Tsakalaki, et al (2013) [12] presents an antenna system with combinedfull-duplex and 2-order multiple-input-multiple-output (MIMO) functionalities, i.e., a system capable of spatially multiplexing and spatially de-multiplexing 2 data streams in the same frequency and in the same time. By exploiting symmetries in the construct and the feed, simple corrective beam forming weights can be applied at the transmitter (Tx) ports in orderto selectively cancel the Tx signal at the receiver (Rx) ports,thus guaranteeing a large amount of isolation necessary for full duplex (i.e., simultaneous and in-bandTx and Rx) operation. On the other hand, the 2 MIMO ports (either at the Tx or at the Rx) are sufficiently decoupled thanks to polarization diversity. The proposed antenna system exhibits a remarkable level of full duplex isolation over a wide bandwidth while maintaining low coupling between its MIMO ports and can serve as a concrete implementation of an antenna system equipped with both MIMO as well as full-duplex capabilities.

Andrea ,et al (2011) [28] We propose an efficient bottom-up power line communication (PLC) channel simulator that exploits transmission line theory concepts and that is able to generate statistically representative in-home channels. We first derive from norms and practices a statistical model of European in-home topologies. The model describes how outlets are arranged in a topology and are interconnected via intermediate nodes referred to as derivation boxes. Then, we present an efficient method to compute the channel transfer function (CTF) between any pair of outlets belonging to a topology realization. The method is based on a systematic remapping technique that leads to the subdivision of the network in elementary units, and on an efficient way to compute the unit transfer function referred to as voltage ratio approach. The difference from the more conventional and complex ABCD matrix approach is also discussed. We finally show that the simulator can be configured with a small set of parameters and that it offers a theoretical framework to study the statistical PLC channel properties as a function of the topology characteristics, which is discussed in Part II of this work.

Sahai, et al (2011) [13] In this paper we propose a frequency-domain broadbandchannel simulator for indoor power line communications (PLC). We follow a bottom-up approach by defining the topology in a fixed mode or in a random mode. The channel matrix coefficients are derived by using the well-known two-port ABCD line modelling. The channel simulator takes into account cable characteristics, effective lengths of branches, and also loads by selecting the load impedances from a predefined set. We will show how to use our bottom-up channel simulator to generate random PLC channels and to match measurement results with a predefined approximation.Power line communications (PLC) systems transmit dataover conductors designed and used for electric power transmission.In the beginning PLC systems have shown limitedapplications, since they only supported low data rate. However,it has recently been shown that PLC systems can be usedto provide high-speed data rate by using a bandwidth up to100 MHz as defined in the G.hn standard.

Kikkert , et al (2016) [15] In this paper, a channel model for broadband indoor Power Line Communications (PLC) is presented and discussed. The modelling approach is based on the physical structure of the electrical networks inside homes and small offices. The structure has been simplified to derive a parametric model that still preserves the essential behaviour of these channels in the HF band (up to 30 MHz). The model provides realistic channels by setting values to a reduced number of physical parameters. In addition, statistical distributions for such parameters that allow generating ensembles of random channels are suggested. The validity of the generated channels is assessed by comparing their behaviour to the one of channels measured at several indoor power networks. Hence, this model can be employed to estimate the performance of transmission techniques on PLC channels, to aid in the design of PLC systems or to make prototypes conformance tests.

Gautham ,et al (2016) [16] In this paper, we investigate the feasibility of In-Band Full-Duplexing (IBFD) for Broadband Power Line Communication (BB-PLC) systems, to potentially double the throughput and spectral efficiency. IBFD accomplishes this through simultaneous bidirectional communication over the same power line in the same frequency band, by applying echo cancellation (EC) to suppress the interference caused by the self-transmitted signal. In light of various EC schemes employed in Digital Subscriber Lines, Ethernet, co-axial cables and recently in wireless systems, we investigate the specific requirements and constraints in BB-PLC, and present solutions for an effective IBFD implementation for such systems. We then use our simulated EC gain values to examine the overall data rate gains obtained by IBFD under different channel attenuations and PLC noise conditions, to determine if we truly obtain a 100% increase in throughput at all conditions.

Lee, et al (2013) [20] In this paper, we present an experiment- and simulation-based study to evaluate the use of full duplex (FD) as a potential mode in practical IEEE 802.11 networks. To enable the study, we designed a 20-MHz multiantenna orthogonal frequency-division-multiplexing (OFDM) FD physical layer and an FD media access control (MAC) protocol, which is backward compatible with current 802.11. Our extensive over-the-air experiments, simulations, and analysis demonstrate the following two results. First, the use of multiple antennas at the physical layer leads to a higher ergodic throughput than its hardware-equivalent multiantenna half-duplex (HD) counterparts for SNRs above the median SNR encountered in practical WiFi deployments. Second, the proposed MAC translates the physical layer rate gain into near doubling of throughput for multimode single-AP networks. The two results allow us to conclude that there are potentially significant benefits gained from including an FD mode in future WiFi standards.

Evan et al (2014) [14] Recent research results have demonstrated the feasibility of full-duplex wireless communication for short-range links. Although the focus of the previous works has been active cancellation of the self-interference signal, a majority of the overall self-interference suppression is often due to passive suppression, i.e., isolation of the transmit and receive antennas. We present a measurement-based study of the capabilities and limitations of

three key mechanisms for passive self-interference suppression: directional isolation, absorptive shielding, and cross-polarization. The study demonstrates that more than 70 dB of passive suppression can be achieved in certain environments, but also establishes two results on the limitations of passive suppression: (1) environmental reflections limit the amount of passive suppression that can be achieved, and (2) passive suppression, in general, increases the frequency selectivity of the residual self-interference signal. These results suggest two design implications: (1) deployments of full-duplex infrastructure nodes should minimize near-antenna reflectors, and (2) active cancellation in concatenation with passive suppression should employ higher-order filters or per-subcarrier cancellation.

Ashutosh et al (2016) [9] In-band full-duplex (IBFD) operation has emerged as an attractive solution for increasing the throughput of wireless communication systems and networks. With IBFD, a wireless terminal is allowed to transmit and receive simultaneously in the same frequency band. This tutorial paper reviews the main concepts of IBFD wireless. One of the biggest practical impediments to IBFD operation is the presence of self-interference, i.e., the interference that the modem's transmitter causes to its own receiver. This tutorial surveys a wide range of IBFD self-interference mitigation techniques. Also discussed are numerous other research challenges and opportunitiesin the design and analysis of IBFD wireless systems.

II. CONCLUSION

In this paper, we have presented the first all-analog echo cancellation solution for full-duplex PLC. By performing active EC in the analog domain, we overcame the limitation of distortion and quantization noise introduced by the ADC. Considering the known AIC techniques available in IBFD and frequency division duplexed systems across different communication media, we proposed a digitally controlled analog cancellation solution tailored for BB-PLC scenarios. We showed through simulation results that the ECG values obtained by our solution is sufficient to function independently without an additional DIC module. Our numerical results also indicate that our all-analog cancellation solution provides greater echo cancellation gains and data rate gains compared to the state-of-the-art IBFD implementation. We remark that our active AIC solution is also easily scalable to multiple-input multiple-output BB-PLC transceivers.

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