Characterization and digital mitigation of transmitter and receiver nonlinearities for achieving high dynamic range

Abstract:

Dynamic spectrum access radios, also known as cognitive radios, will benefit from the capability of transmitting and receiving communications waveforms across many disjoint frequency channels. However, the advantages of multi-channel operation come at the expense of stringent linearity requirements on the analog transmit and receive hardware. These requirements include tight spectral masks, low in-band distortion, and high dynamic range. Specifically, lower transmitter distortion is required to accommodate modern modulation techniques such as wideband multicarrier signaling. However, nonlinearities generated by the analog components of the transmitter, such as the power amplifier, make achieving a tight spectral mask with low distortion particularly difficult, especially while trying to simultaneously maintain high power efficiency. Additionally, the analog frontends of receivers are desired to operate over wide bands in environments where very strong out-of-band interference may be present, requiring the receiver to operate with high dynamic range. In this case, the nonlinearities of the analog and mixed signal components limit the dynamic range of the receiver, possibly preventing the detection and/or demodulation of the intended transmission.

In this tutorial, we describe how nonlinear digital signal processing can be used to invert the nonlinearities of transmitters and receivers that follow digital modulation and precede demodulation. We will first review the basics of polynomial signal processing, and then describe the differences in deriving a pre-distorter for the transmitter versus a post-distorter for the receiver. We will then survey a number of different methods for choosing polynomial basis functions that makeup pre- and post-distorter architectures. The tradeoff between computational complexity and linearization performance will be crisply formulated when deriving both pre- and post-distorter architectures. The advanced digital signal processing techniques to be presented will both model and mitigate nonlinear distortions generated by the analog and mixed signal components of transmitters and receivers, and thus extend dynamic range. This tutorial from NRL technical staff draws on over 10 years of direct research and development experience on DARPA, ONR, and NSA funded efforts.

This tutorial is classified as *intermediate*.

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Joel Goodman is a senior research engineer in the Tactical Electronic Warfare Division of the Naval Research Laboratory. Prior to this, Joel was a technical staff member at MIT Lincoln Laboratory (MIT LL), most recently serving on the Chief Technology Officer's technical advisory group that allocates MIT LL IR&D funding for advanced research. He has been involved in developing algorithms for data distribution in distributed sensor networks and algorithms for physical layer communications, and most recently developing nonlinear signal processing algorithms for communications, SIGINT, and radar applications. He was an invited lecturer for an IEEE advanced signal processing symposium on the topic of nonlinear signal processing in 2008, was a recipient of the Eastman technical achievement award for his work on magnetic imaging systems, was a recipient of the 2012 Alan Berman Research Publications award, and is currently serving as Vice-Chair of the IEEE Northern Virginia section. He has published a number of peer-reviewed papers on the topic of nonlinear signal processing, as well as over 60 papers, patents, and book chapters on the topics of communications and signal processing. Joel received his M.S. in electrical engineering from Boston University in 1989.

Kevin Lorenz received the PhD degree in Electrical Engineering from Purdue University in 2012. His thesis research focused on image registration and segmentation. He has additionally worked on projects sponsored by grants from the National Institutes of Health, National Science Foundation, and Department of Homeland Security involving image segmentation and registration, machine learning, object tracking, image classification, and mobile application development. Kevin has recently joined the Naval Research Laboratory in the Tactical Electronic Warfare Division as a recipient of the Jerome and Isabella Karle Distinguished Scholar Fellowship. His current research interests include linear and nonlinear signal processing, wired and wireless communications, and machine learning.