WMC (IMS) Monday 08:00 – 17:00 BCEC Room 153AB

Power Amplifier Linearization: From Advanced Analog and Digital Techniques to Practical Real-Time Implementations

Full-day workshop reviewed by MTT-5, MTT-17, MTT-20

Organizer(s):

John Wood, Freescale Semiconductor, Tempe, AZ USA; IMS TPC.
Slim Boumaiza, University of Waterloo, Ontario, Canada.

In RF transmitters, the power amplifier is usually the limiting factor in terms of both the efficiency of the system and the overall linearity. In recent years, as the spectral efficiency of the modulation methods required for communications standards such as WiMAX, LTE, etc. has increased, improvements in the PA efficiency have been wrought by better device technology and circuit & system architectures. While the linearity and efficiency must be traded-off against each other, the communications standards also specify limits of acceptable nonlinearity in terms or error vector and spectral spreading, for instance. The PA or system designer must then include some form of linearizer to meet these specifications. In this workshop we shall present some background for the sources and effects of nonlinear behaviour in RF power amplifiers, including memory effects. A number of approaches for improving the linear performance of the PA when deployed in a transmitter system will be described, including analog linearization methods such as feedforward, feedback and harmonic injection, and various implementations of digital pre-distortion schemes. Peak-to-Average Power Reduction (Crest Factor Reduction) schemes will also be described. Base station and handset PA linearizing techniques will be presented, and both academic and industry approaches will be covered. This will be an advanced workshop, for academics and industry professionals active in RF PA design, and in linearization & DPD development.

Speakers:

1. John Wood, Freescale Semiconductor
"Nonlinear Behaviour & Linearizability of RF Power Amplifiers"

In this presentation, we will begin by describing the nonlinear behaviour and sources of memory effects in RF high-power amplifiers that are designed for high efficiency operation with modern wireless communications signals. The PA nonlinear behaviour can be analyzed using system identification techniques to yield structured models that can be used as the basis of linearization methods. An outline modeling approach in the time-domain will be described, as a method of determining the linearizability of the PA in terms of its degree of nonlinearity and fading memory behaviour. Some practical pre-distortion approaches will also be presented.

2. Jose Carlos Pedro, University of Aveiro
"Power Amplifier Behavioral Modeling and Linearizer Identification Methods"

Power amplifier (PA) linearization relies on finding an auxiliary circuit capable of generating a distortion that cancels the one originally created in the amplifier nonlinearities. Therefore, the success of PA linearization strongly depends on an accurate behavioral model of its nonlinear distortion. This is particularly important in digital predistortion, DPD, where the linearizer must be a very good approximation of the PA model pre-inverse. This Talk starts by identifying the main sources of PA nonlinearity and proceeds to derive general conditions for the PA behavioral model identification. The presentation will then address methods for the analytical inversion of this PA model to end up discussing methods of DPD identification. Application examples of these DPD techniques will be given for the traditional current mode amplifier based Cartesian Transmitters, and the new switched mode amplifier based Polar Transmitters.

3. Anding Zhu, University College, Dublin
"Volterra Series-Based Digital Predistorter Design and Vector Hole Punching for OFDM Signals"

In this presentation, we first propose an efficient open-loop wideband Volterra digital predistorter whose parameters can be characterized by using a simple off-line process, which dramatically reduces the system complexity and implementation cost. Secondly, we introduce a new decomposed piecewise Volterra model based on a vector threshold decomposition technique for linearizing envelope-tracking (ET) power amplifiers. Experimental results show that by using this decomposed DPD model, the distinct characteristics of the ET power amplifiers at different signal power levels can be accurately modeled, and thus the distortion caused by this nonlinear behavior can be effectively compensated. Finally, a vector-hole punching technique for OFDM signals is presented, which aims to remove low amplitude values occurred in drain-modulated polar transmitters and thereby improves their linearities.

4. Paul Draxler, Qualcomm, Inc. & University of California, San Diego
"Techniques for Envelope Tracking Linearization"

With communication systems driving for higher data rates, the requirement for higher efficiency is providing motivation to build innovative systems, such as envelope tracking power amplifiers. The linearity requirements for these systems are such that linearization is required component of the envelope tracking system. This presentation introduces an envelope tracking system, the linearization used on this system, how the signal is decomposed into memoryless, deterministic memory and random components, and finally how a piecewise Volterra series model is used to construct models for predistortion on a number of devices.

5. R. Neil Braithwaite, Powerwave Technologies
"Crest Factor Reduction (CFR) of Wideband Wireless Multi-Access Signals"

The fundamentals of crest factor reduction of wideband wireless multi-access signals such as multi-carrier CDMA, WCDMA, Wimax, and LTE are reviewed. Several CFR approaches are discussed including clip and filter, tone reservation, constellation extension, partial transmit sequence, and selective mapping. Each approach achieves a reduced crest factor by increasing error vector magnitude, increasing bit error rate, increasing power transmitted, or reducing payload data throughput due to the transmission of auxiliary or redundant information. However, CFR is of critical importance for maximizing the efficiency of many types of power amplifiers, for example Doherty structures, while avoiding increases in out-of-band distortion.

6. Slim Boumaiza, University of Waterloo
"Advanced Memory Polynomial Linearization Techniques"

This talk expounds on the reduction of the computation complexity of Memory-Polynomial behavioral model devised for mimicking and/or linearizing the dynamic nonlinear response of power amplifiers (PA). First, starting from the circuit topology of the PA, a closed-form expression will be derived and then used to reduce the number of coefficients of the Memory Polynomial. Second, the theoretical similarity between the Memory Polynomial and the Parallel Hammerstein schemes was used to develop an experimental approach for the reduction of the number of coefficients. This approach relies solely on the visualization of the Finite Impulse Responses filters of every order of nonlinearity to determine the optimal modeling structure. These two systematic approaches allowed for the reduction of the number of coefficients to almost one-third and the conditioning number by three orders of magnitude while maintaining the same linearization capability.

7. Roland Sperlich. Texas Instruments
" Digital Pre-distortion Systems and Tradeoffs in Commercial Deployments"

The presentation details the technical tradeoffs in designing commercial grade digital pre-distortion systems. Software, architecture/hardware tradeoffs and design considerations are described.

8. R. Neil Braithwaite, Powerwave Technologies
" Adaptive Feedforward Linearization of Power Amplifiers"

The fundamentals of feedforward linearization are reviewed including the use of cancellation loops to reduce distortion generated by an amplifier. The importance of aligning cancellation loops in terms of gain and delay is discussed as well as techniques for controlling and measuring loop alignment. Basic algorithms for tuning the loop control devices to minimize the measured misalignment are reviewed including the use of pilot signals for aiding the second loop alignment process. It is shown how these algorithms are modified to optimize the distortion cancellation in the presence of non-ideal components including nonlinear amplifiers, limited bandwidth in delay circuits, and coupling losses.

9. Gayle Collins, Freescale Semiconductor
"Linearization using Controlled Harmonic Injection"

Signals that pass through RF power amplifiers are distorted by the nonlinearities present in the amplifier running at saturation. The result is a greater number of frequency components in the output signal. In the case of a two stage amplifier, the injection of these components into the second stage can sometimes result in a greater overall linearity of the amplifier. The use of the interstage matching network to mitigate the inherent nonlinearies of the amplifier by the prudent choice of the interstage structure will be discussed as well as the impact of the harmonic impedances presented to the amplifier. The optimal interstage match is one that presents the appropriate load line to the driver stage as well as the most favorable source impedance to the second stage transistor. Techniques for achieving the optimal interstage match will be presented as well as the tradeoffs in performance.

10. Kelly Mekechuk, Pulsewave RF
"Direct Digital Predistortion at Radio Frequency via Real-Time Feedback"

This workshop discusses the use of non-linear real-time feedback techniques to linearize RF power amplifiers. The workshop begins with a review of basic linear control theory. This review sets the basis for the discussion of several design considerations when employing real-time linear feedback to linearize RF power amplifiers. The latter portion of the workshop describes non-linear real-time feedback techniques, with a focus on delta-sigma modulators and their use in linearizing RF power amplifiers. Several different architectures for realizing an RF power amplifier based upon non-linear feedback are described, along with laboratory results.