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An Analog Pre-Distortion Linearizer for the Correction of the Non-Linear Distortion in Shallow and Deep Class-AB Power Amplifiers

University Investigators

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Background and Unmet Need

Analog pre-distortion (APD) can reduce the overall complexity and power consumption of a communications system as it doesn't require supplementary digital processing resources. As the demand for more efficient, simple, and robust radio frequency (RF) systems increases (lower SWAP-C), analog pre-distortion could provide a vital solution for optimizing the performance and power efficiency of power amplifiers (PAs), particularly in applications that are sensitive to latency and real-time processing.

Analog pre-distortion has been a traditional technique for linearizing tube amplifiers and is now finding application in modern mmWave solid-state broadband amplifiers. The benefit of analog pre-distortion lies in its fundamental simplicity, allowing the nonlinear effects to be directly incorporated into the RF chain, whether as a hybrid circuit or within a microwave monolithic integrated circuit (MMIC). Current state-of-the-art analog linearizers do not have sufficient tunability to cover various biasing of class-AB power amplifiers. If the analog linearizer correction is not properly matched to the amplifier, it will lead to a degradation in linearity.

Digital pre-distortion (DPD) is a widely used technique that enhances the linearity of radio frequency power amplifiers by applying an inverse distortion mechanism in the digital domain. DPD, however, relies on a digital signal processor (DSP) (either a field-programmable gate array (FPGA) or DSP) that may not be available in the transmitter, and it can introduce latency. This presents challenges in real-time applications where immediate response is crucial. The use of DPD is also prohibitive for low-cost, low-power and low-weight devices where the introduction of a digital signal processor, digital-to-analog and analog-to-digital converter will significantly increase the costs. Thus, there is a need for more efficient modalities.

Opportunity

Dr. Cappello's High-Performance RF Lab has developed an electronic circuit that can correct the gain and phase nonlinear distortion of a typical class-AB power amplifier at different biases, from shallow to deep class-AB. In particular, this linearizer is also capable of correcting the gain "hump" that high-efficiency PAs tend to exhibit and causes significant distortion and instability in communication systems. This novel circuit combines two correction paths using a branch-line coupler, producing a composite signal designed to cancel both the AM/AM and AM/PM nonlinearities of the downstream power amplifier. The circuit is designed to operate in L-/S-band and utilizes dual-branch architecture and dual-transistor nonlinearity. The linearizer can also operate at mmWave frequencies or in repeat applications, for which DPD systems are not practical. Advantages of this system include power savings. For example, ~0.018W vs. ~12.6W of a DPD system significantly reduced energy and manufacturing costs and provided significant footprint reductions within integrated systems when compared to DPD systems.

Compared to state-of-the-art APD systems, the Cappello design possesses several advantages, including substantially lower power consumption and superior performance at significantly wider

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bandwidth.[1] Further, this technology is in compliance with 3rd Generation Partnership Project (3GPP) standards for 5G telecommunications, having achieved an Adjacent Channel Leakage Ratio (ACLR) of -46.1/46.6 dBc over a 400 MHz bandwidth (1.8-2.2 GHz). Of particular note, Dr. Cappello's technology achieved this performance while also maintaining extremely low power consumption of 18mW, and without requiring any extra component.

Compared to DPD solutions, this APD system employs simple and low-cost circuitry, significantly simplifying the transmitter layout. As a Plug-and-Play system, the technology can be easily integrated into existing communication systems and used to improve the linearity of RF power amplifiers for communication and radar applications.

Unique Attributes

- Dual-branch dual-transistor APD design that mirrors the inverse nonlinearity of a Class-AB PA for a multitude of bias points.
- Designed as a Plug and play" model for easy integration into existing systems/infrastructure.
- milliWatt level power consumption, low-noise, and with 10-dB of gain.
- Possibility to correct both small-signal gain drop and large-signal gain compression.
- Very wide bandwidth (tested with 100MHz signal, 20% relative bandwidth).

Applications

The Cappello APD can be used in any wireless communication system that utilizes RF transmitters, including base stations, smartphones, and other mobile handsets, as well as satellite communications, radar, and defense applications.

Stage of Development

Technology Readiness Level 3, Experimental Proof of Concept.

Intellectual Property

US Provisional Patent filed June 2025.

Publications

Borno, M. S. I., & Cappello, T. A. (2025). A digitally controlled analog predistortion linearizer for the correction of deep and shallow Class-AB RF power amplifiers. IEEE Transactions on Microwave Theory and Techniques. September 12, 2025.

Licensing and Collaboration Opportunity

Villanova is seeking a licensee or collaborator to commercialize the invention.

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[1] Borno, M. S. I., & Cappello, T. A. (2025)