Understanding Linearization and Its Recent Developments

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ABSTRACT

Linearization has become of enormous importance because of the need to efficiently send greater and greater amounts of information over a limited spectrum. It is of special value at frequencies below 1 GHz because of the limited bandwidth available at these lower frequencies and that information rate/Hz is dependent on the level of distortion. This talk will review the basics of linearization; a systematic procedure for reducing an amplifier's distortion [1], [2]. It will discuss the linearization of high power amplifiers (HPAs), particularly those at HF through UHF and the considerations/trades associated with its application. It will set limits on the performance that can be achieved. In all cases the end goal is an HPA with a constant gain and phase at all power levels up to maximum power. This concept can be used to define an ideal HPA that sets a performance bound on the linearity of a *real* HPA and provides a reference for HPA comparison.

The links between linearity and efficiency will be considered. Of the three most common forms of linearization; feedback, feedforward and predistortion, predistortion linearization (PDL) is by far the most popular form used at RF and microwave frequencies. PDL is widely used because of its 1) lower overhead (potential to increase both HPA linearity and efficiency), 2) lower complexity (potential to lower HPA cost, size and weight), and 3) ability to provide wider bandwidth (BW) than competitive forms of linearization. PDL techniques will be the focus of this presentation. However, for applications requiring narrow BW, < several MHz, feedback linearization should be considered. Advances in solid-state technology, such as GaN devices has changed the HPA business sector. Solid state HPAs with BW (from HF to > several GHz) and higher efficiencies than considered possible a few years ago are now a reality. Novel circuit topologies combined with device higher voltage capabilities and PDL are allowing HPAs to achieve both linearity and record high efficiency over multi-octave BWs with power added efficiencies (PAEs) of > 60%. These new devices are generally more nonlinear and benefit more from linearization.

Both analog and digital techniques will be included and are used at RF and microwave frequencies. If the input signal to a digital PDL (digital signal processing) is in a digital form, the decision to use digital linearization is not difficult. However, if the input is an analog signal, it is not as clear since the RF signal must be down converted and processed at baseband, which adds significantly to the complexity and cost. If several signals are present the situation is even more complicated. For high performance (distortion reduction > 15 dB), the DPL must be able to process over a BW $\geq$ 5~7 times the signal BW. As BW increases, the cost of digital linearization rises sharply, making digital PDL impractical for wideband applications.

Memory effects (MEs) will also be discussed. MEs are the dependence of gain and phase transfer characteristics on factors besides the level of the input signal. Many GaN devices have MEs due to the trapping of charge. A problem for RF HPAs is MEs due to *bias modulation* (signal envelope induced in variation of the drain (and gate) voltage. These bias induced products can add or subtract from the regular distortion products. The decision to use linearization is primarily economic. The higher the linearity of a HPA, the less is the advantage of linearization. The higher the power of a PA, the easier it is to justify linearization. There are other factors that impact the decision to linearize. The improved efficiency when an HPA is operated closer to its maximum power level, can often be the deciding factor.

[1] A. Katz, R. Gray and R. Dorval, “Truly wideband linearization,” IEEE Microwave Magazine, Vol. 10, Issue 7, Part Supplement, pp. 20-27, Dec. 2009.
[2] A. Katz, “Linearization: Reducing Distortion in Power Amplifiers,” IEEE Microwave Magazine, pp. 37-49, Dec. 2001