Application Note AN-006: *Linearity trade-off in the HPA transmit path*

Introduction

A major element in any communication system is the transmit chain, primarily the final amplifier or high-power amplifier (HPA). The purpose of the HPA is to increase the input signal (waveform) to a level that meets the link budget of the system. The key is to maximize efficiency, the conversion of DC power to RF power. HPA efficiency increases and tends to peak at and into compression towards device saturation, unfortunately amplitude modulated waveforms and frequency division multiplexed (FDM) schemes are susceptible to linearity. Heat dissipation, compression curve, device bandwidth and frequency response of the HPA device must be considered as well, which is determined by device construction and primarily material process. This note will discuss theses trade-offs.

Linearity

Linearity is a measure of the fidelity of a signal (waveform) as it passes through an active chain of devices intended to increase the amplitude or power of this waveform. This desired increase in amplitude is referred to as gain and is typically represented as power gain $10*\log_{10}(Pout / Pin)$ i.e. if Pout is twice Pin, $10*\log_{10}(2/1) = 3dB$. In the real world nothing is ideal and amplifier systems will always introduce some form of non-linearity in either amplitude or phase of the desired waveform. Linearity is benchmarked in many ways, such as output power at one dB compression (P1dB), output 3rd order intercept point (OIP3) and intermodulation distortion (IMD).

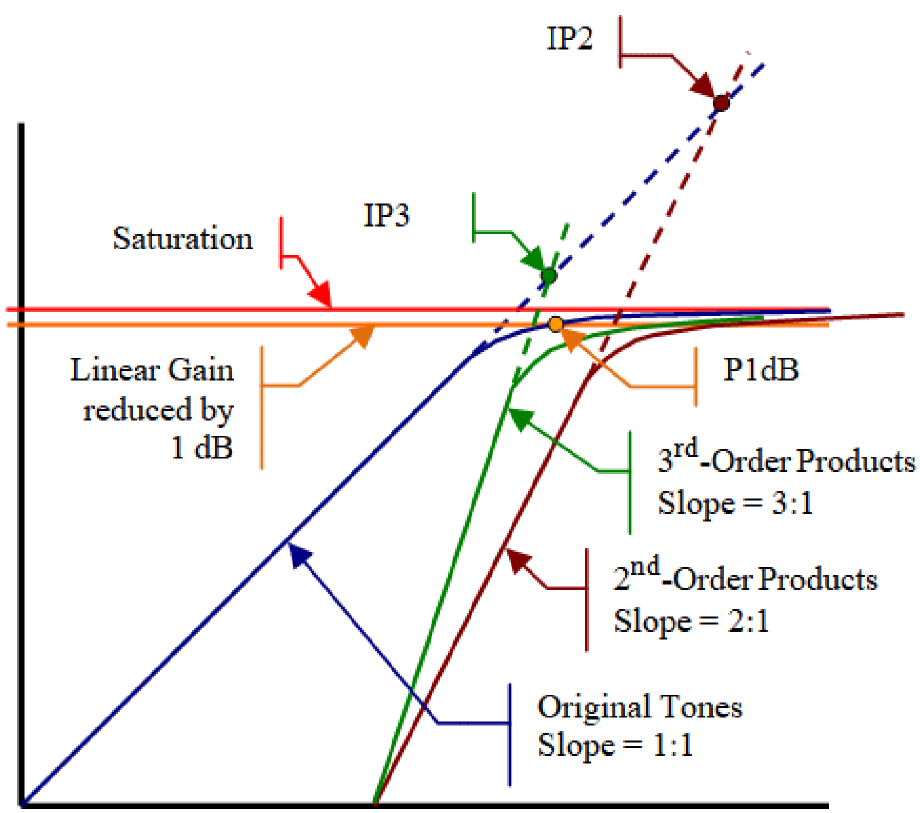

Figure 1: Amplifier compression curve

Power Amplifier Efficiency

Amplifier efficiency is the measure of the conversion of DC power to RF power and is represented as drain efficiency or what is more commonly accepted, power added efficiency (PAE); PAE considers the input power as well as output power. The PAE of the HPA is dependent on serval parameters, amplifier class, bias, input / output impedance matching. PAE increases with Pout and typically peaks at or near compression as seen in *Figure 2*.

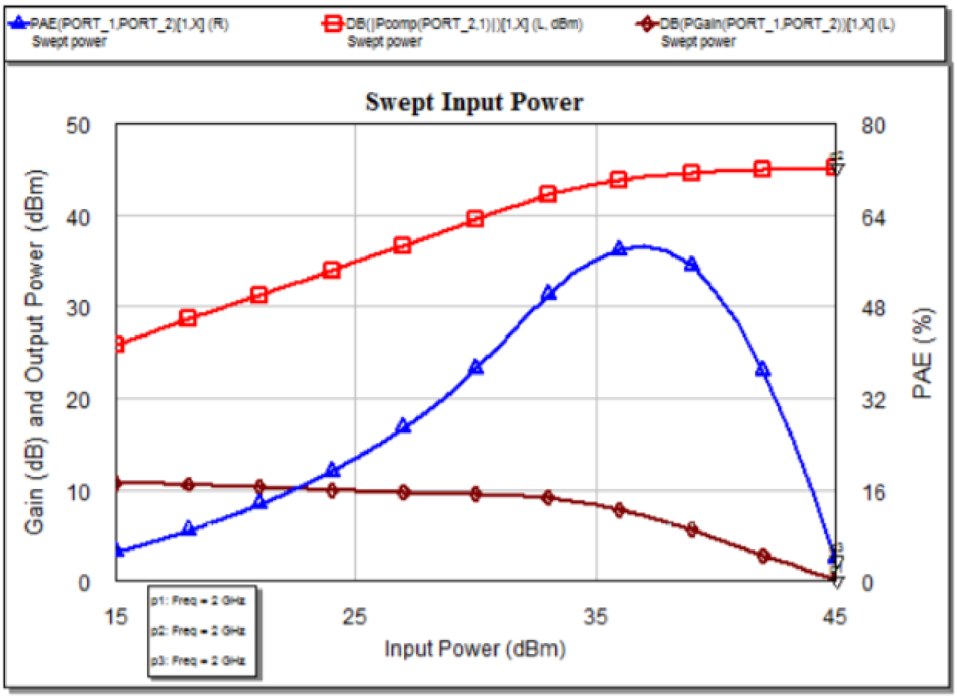

Figure 2: PAE, Pout and gain vs. Pin HPA

Modulation

In communication systems waveforms are modulated in various ways with information, some of these techniques are susceptible to amplitude non-linearities such as quadrature amplitude modulation (QAM) and others phase, such as quadrature phase shift keying (QPSK). These modulated signals are called carriers and historically represent single channels of transmitted data. Most modern systems incorporate multiplexed channel schemes where data (symbols) are divided and modulated into multiple carriers such as orthogonal frequency division multiplexing (OFDM). OFDM or FDM techniques have their advantages, lower individual carrier data rates (parallel data transmission), multipath, error correction etc., however a byproduct is a susceptibility to intermodulation distortion (IMD). The parameter defined by the OFDM system that is critical in determining the power requirement of the transmit chain is the peak to average power ratio (PAPR). PAPR increases with the number channels and sub-carriers, which in turn requires greater head room or output back-off (OBO) from compression. Typical PAPR is in the range of 10-12dB.

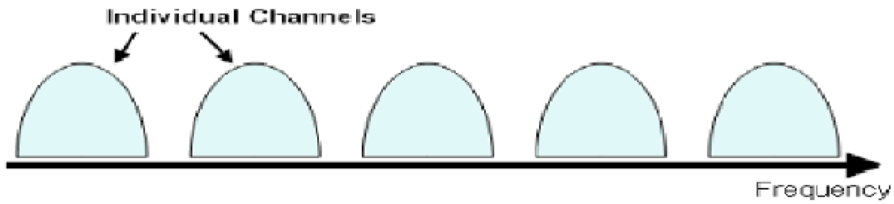

Figure 3: Single carrier modulation scheme

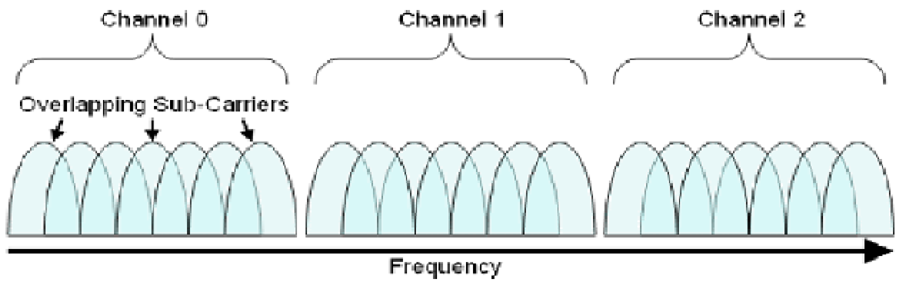

Figure 4: Multi carrier FDM modulation scheme

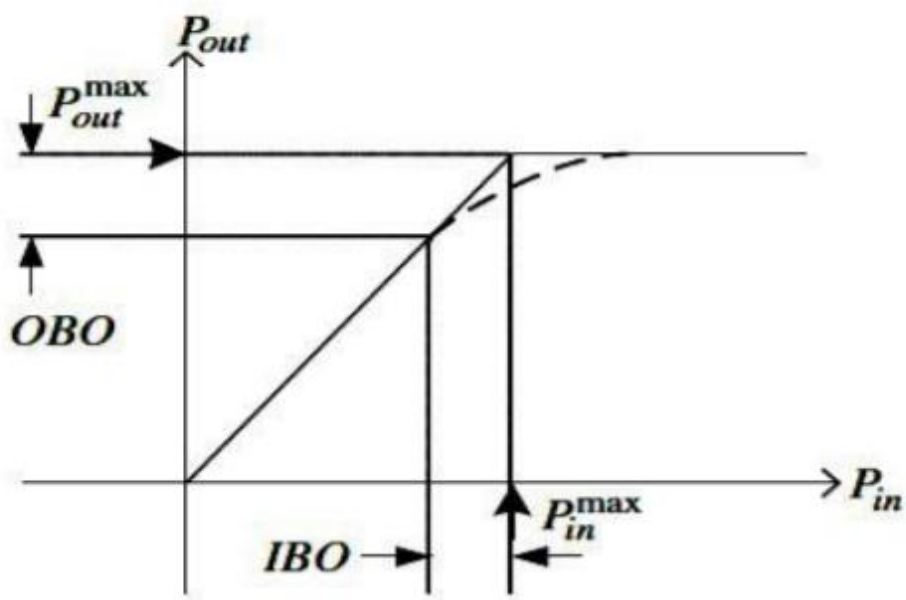

Figure 5: Compression curve depicting IBO / OBO

High Power Amplifier Devices

There are three dominate device technologies, LDMOS, GaAs and GaN. LDMOS is vary mature, high output power in the kW, very rugged, good efficiency and gain. The only real limitation with LDMOS is frequency. GaAs devices are prevalent in high frequency medium power applications however are being displaced by GaN. GaN can produce much higher output power at the same frequencies and increased bandwidth as GaAs. In addition, GaN can handle higher drain voltages, thus reducing current consumption, has a wide band gap structure, which translates to higher power density, operating temperatures, smaller die and PAE over GaAs.

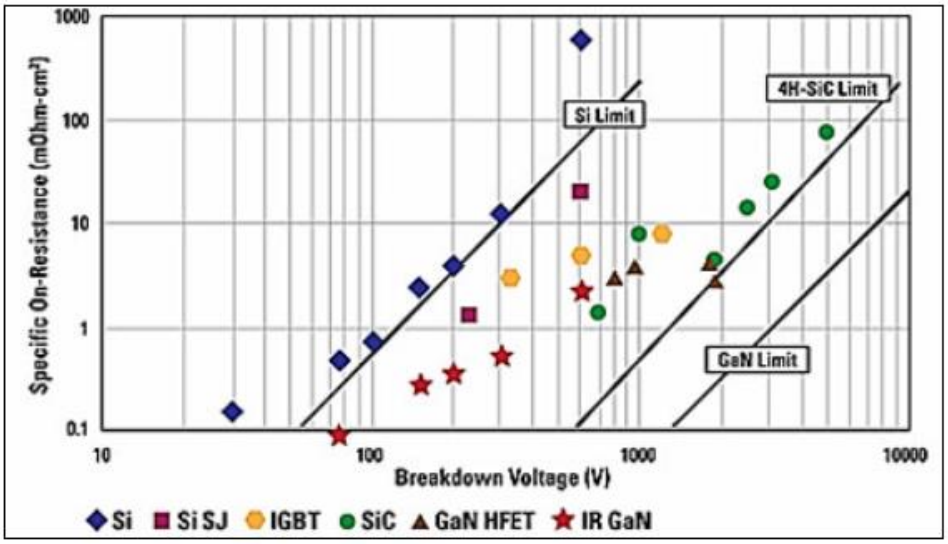

Figure 6: Breakdown voltages vs device process

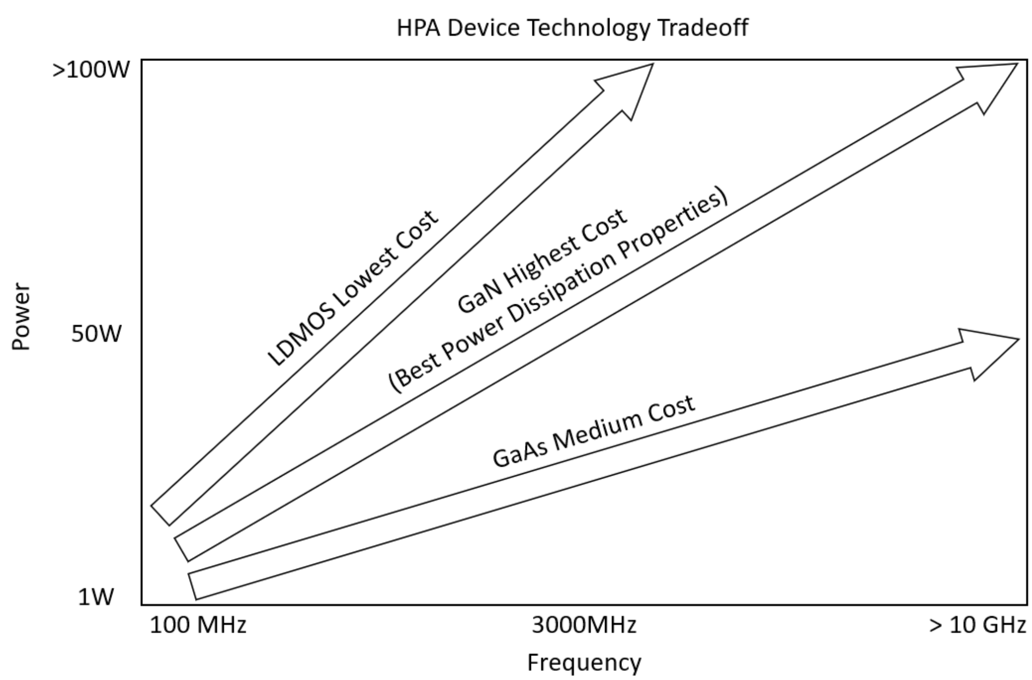

Figure 7: HPA device technology tradeoff

Summary

Device technology choice is dependent on many factors, cost, power dissipation, frequency range, bandwidth, output power, modulation scheme and size. Of the three major technologies LDMOS is the most robust and lowest cost however bandwidth and frequency limited. GaAs is robust but limited in power, where GaN is robust and delivers high output power like LDMOS, extended high frequency response like GaAs, with excellent bandwidth properties however at a higher component cost. Special care needs to be taken when considering Pout requirement when it comes to OBO. Modulation scheme needs to be considered FDM multiplexing and or amplitude modulated waveforms QAM. If the scheme is not known, or HPA will used in a software defined radio system (SDR), it would be best to consider an OBO of 10-12dB.

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