High Linearity Power Amplifier Design

Some Distortion Mechanisms
Distortion Mechanisms

Power Supply

Device

Circuit

Thermal

Drive

Load
Where do IM Products Come From?

\[ s(t) = a \cos(2\pi f_1 t) + a \cos(2\pi f_2 t) \text{ volts} \]

amplitude of each tone

Math: nth order Intermod Product:

\[ a_{\text{in}} = [s(t)]^n \]

Homework: calculate for \( n = 2 \) and \( n = 3 \)
Math doesn’t show the physical mechanisms

Four Classic Envelope Distortion Mechanisms

1. Modulation by the Envelope
Dominates at peak of waveform

Cure: Back-Off
Stiffen DC supply at envelope frequency
2. gain (operating point) modulation

Dominates at minima of envelope waveform

increase quiescent current and stiffen bias at envelope frequency
\[ s_i(t) = a(t) \cos\left(2\pi f_0 t + \phi(t)\right) \text{ volts} \]

\[ s_o(t) = g(t) a(t) \cos\left(2\pi f_0 t + \phi(t)\right) \text{ volts} \]

\[ g(t) = f\{a(t) \cos\left(2\pi f_0 t + \phi(t)\right)\} \]

small signal gain
\[ g = g_m R_L \]
\[ g_m \sim 38 \text{ } I_0 \]
3. Device Swing into Cutoff and/or Saturation

Use Bigger Device to control more current

Decrease Rload--less voltage swing for same power output
4. High Frequency IM products interacting

Use big shunt C networks at device and load
What are implications of more than one distortion mechanism:

1. Math is flawed

2. Fixing one may not make a big improvement, or may make something else worse
For Example: Two-Tone signal with 4 equal, in phase 3rd order IM products:

1.000 volt each tone
0.01 volt each IM product = 0.04 volts

3rd order IM -28 dBc

eliminate one 0.01 volt source of distortion: = 0.03 volts

3rd order IM -30.5 dBc
For Example: Two-Tone signal with 4 equal, random phase 3rd order IM products:

1.000 volt each tone
-40 dBc each individual IM product

total 3rd order IM -34 dBc

eliminate one -40 dBc distortion product

3rd order IM 35.2 dBc
Eliminating a distortion mechanism can be very expensive, and often takes DC power

For 1.2 dB improvement--it might be better to just raise the quiescent current.

...or back off the output power by 0.4 dB
Others:

Interaction between driver and output stage in interstage network

thermal effects if envelope variations are slow relative to thermal time constants

Operating near the edge of a narrow output filter or diplexer

and some interesting new ones you will discover on your next project!
Distortion Mechanisms generally Interact

Next: some tools to study distortion