Some Comments on Peaky Signal Power Amplifiers

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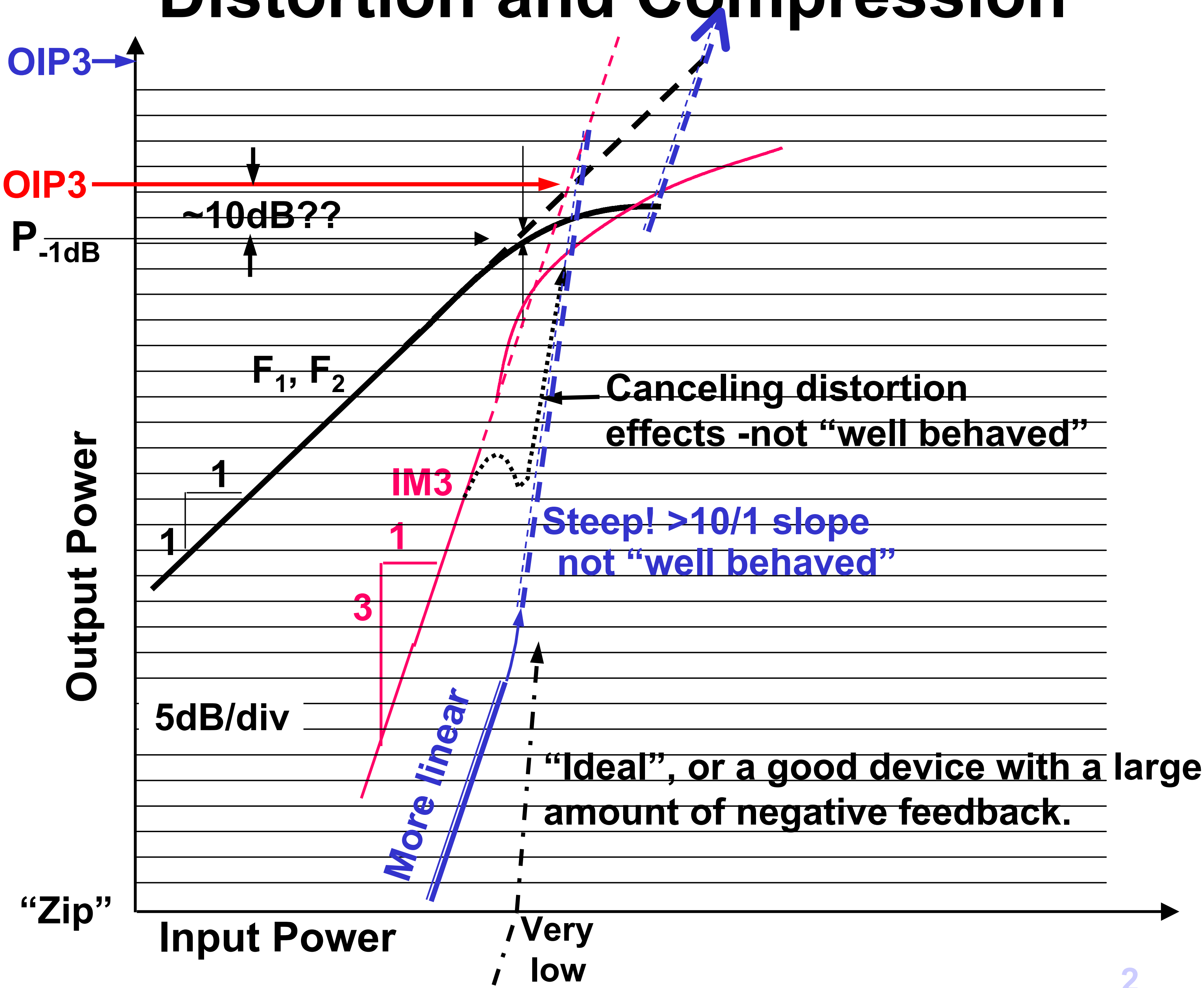
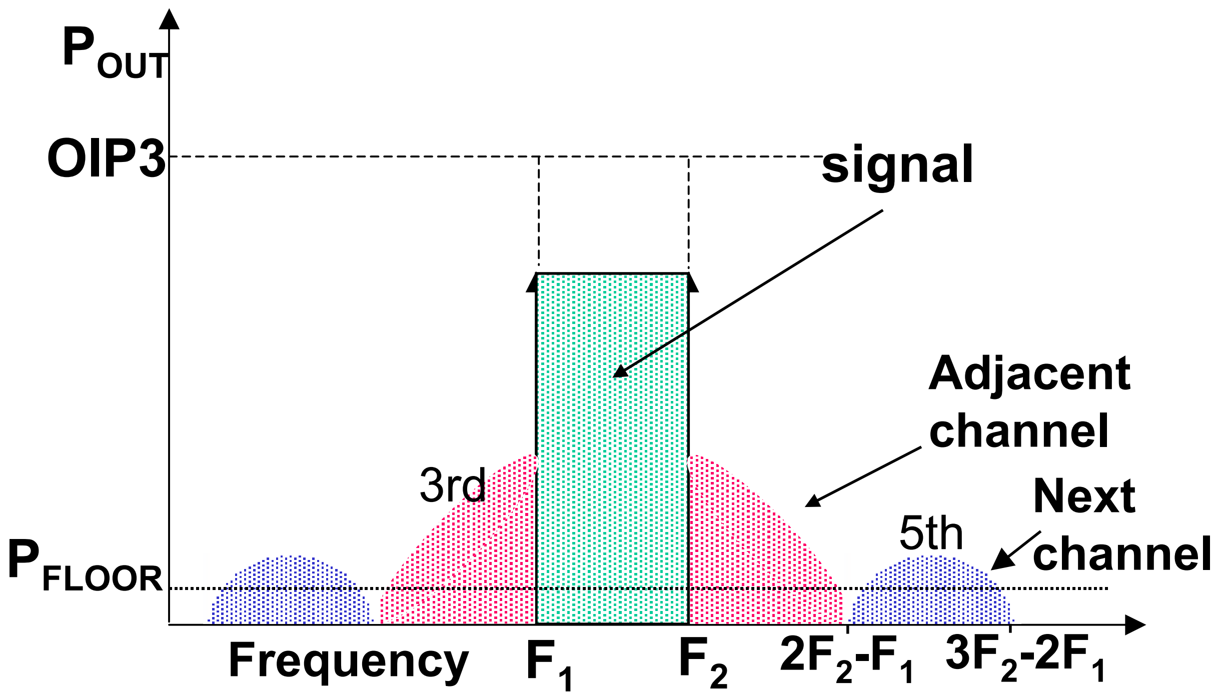
The selected topics for comment:

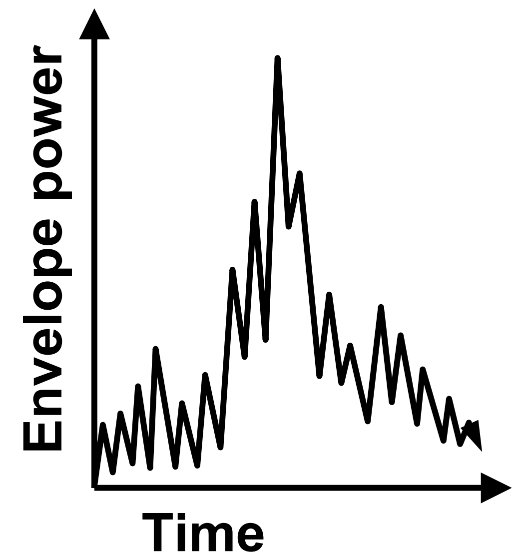
- Third order distortion and compression
- The effect of second harmonic loading on the third order distortion of an HBT, or anything with finite μ
- Third order distortion reduction-
  second harmonic feed forward- a form of predistortion
- Predistortion techniques- a new kink
- Distortion reduction-feed forward
- Feed forward cancellation
- Other methods for third order distortion reduction- remodulate

Distortion and Compression



Multi-Carrier Signals -ACP





The n signals making up the channel can add up at times to a peak power level as large as n times the total average power. Although this is only occasional, the limiting that occurs generates higher order distortion. Thus, the OIP3 performance can be overshadowed by the peak power performance of the amplifier.

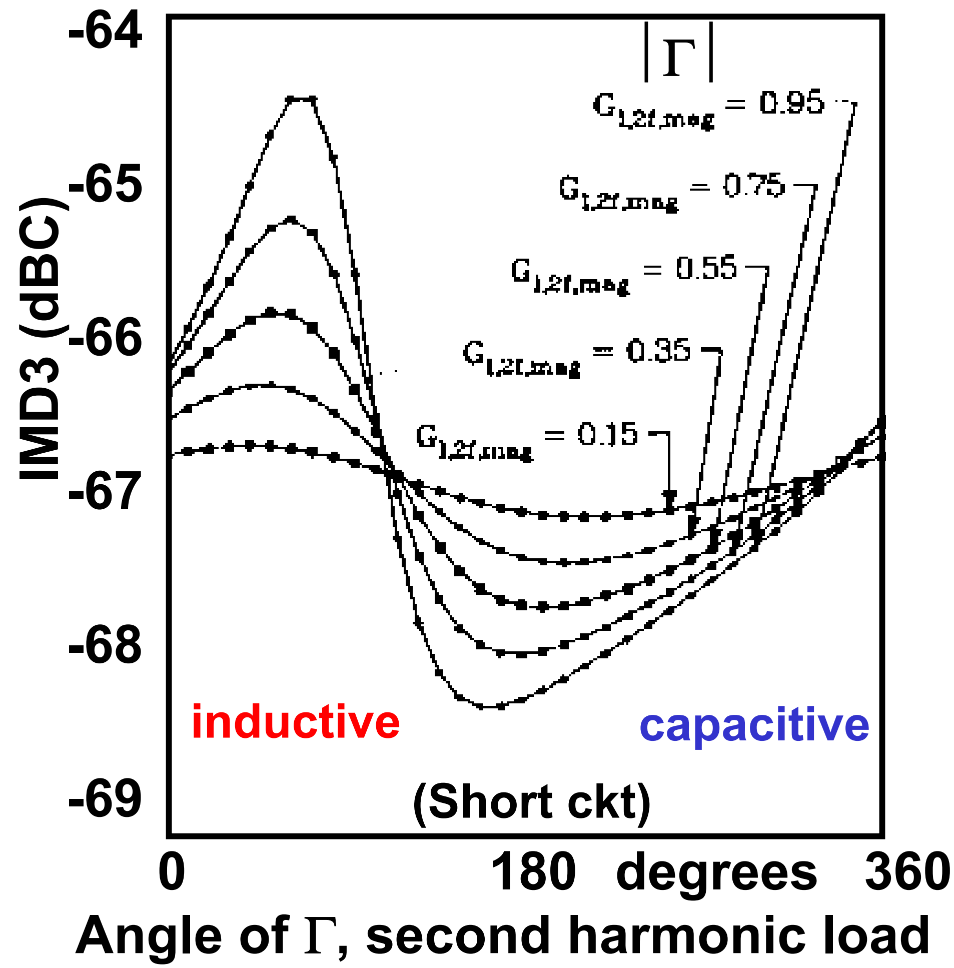
The slope of the adjacent channel interference is due to the probability of the third order IM products falling at that frequency.

The Effect of Second Harmonic Loading on the Third Order Distortion of an HBT

HBTs and HEMT amplifiers can have exceptional OIP3-Pdc. However, they are susceptible to the effect of second harmonic mixing to generate third order intermodulation distortion.

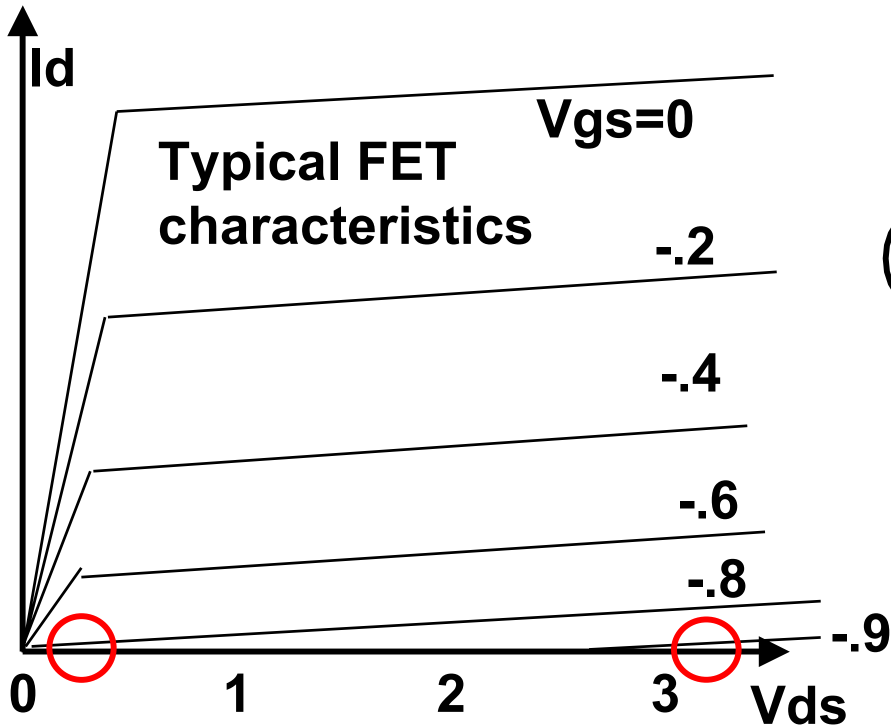
- variations of +/- 3dB in IMD3 output levels can be observed when varying the second-harmonic load reflection coefficient

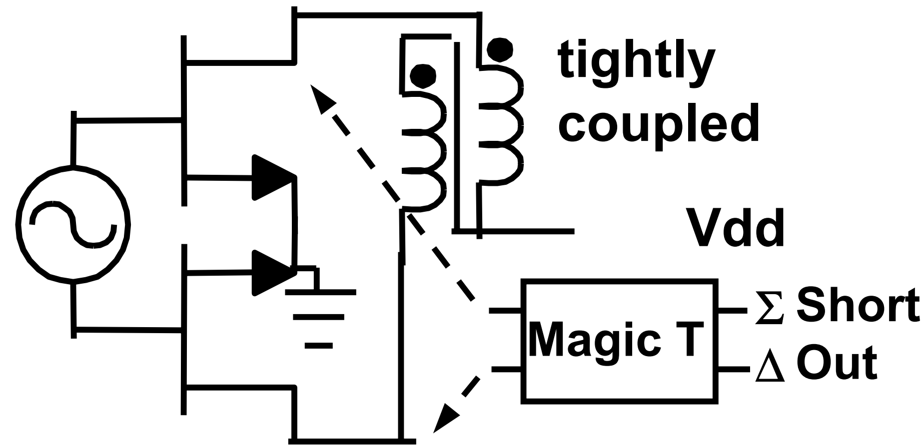
- lowest IMD3 occurs for a short circuit at the second harmonic as seen at the collector of the HBT



*Ref:: Samelis et al., IEEE Trans. On MTT, Vol 40, No 12 December 1992 pp 2374-2380

Third order distortion reduction- second harmonic load





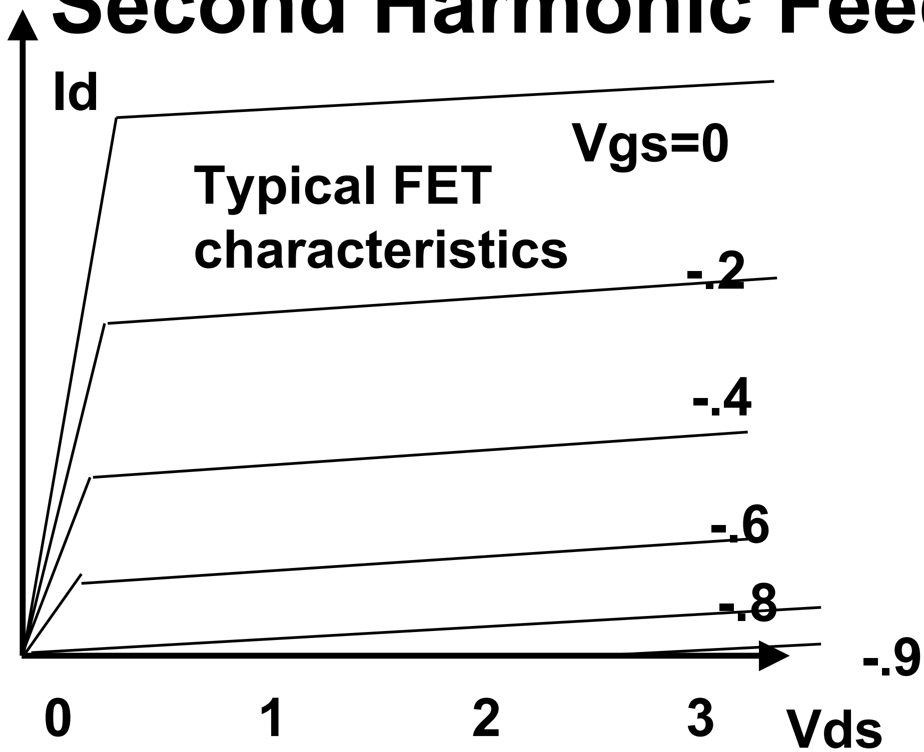
Second harmonic shorted by symmetry, tight coupling. OR use a filter that appears as a second harmonic short circuit.

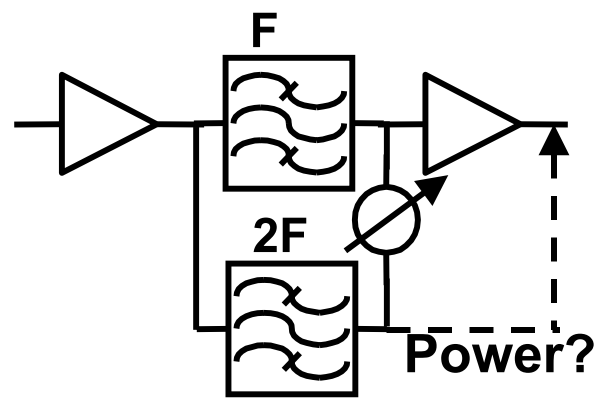
Note the VPO shift with VDS, this effectively adds in the output voltage.

It is important to eliminate second harmonic at the FET output. For wideband (> octave), a symmetric short is imperative!

If zero second harmonic voltage is better than allowing that generated by the transistor current, how about adding extra second harmonic of the opposite phase?

Third Order Distortion Reduction-Second Harmonic Feed Forward-Predistortion



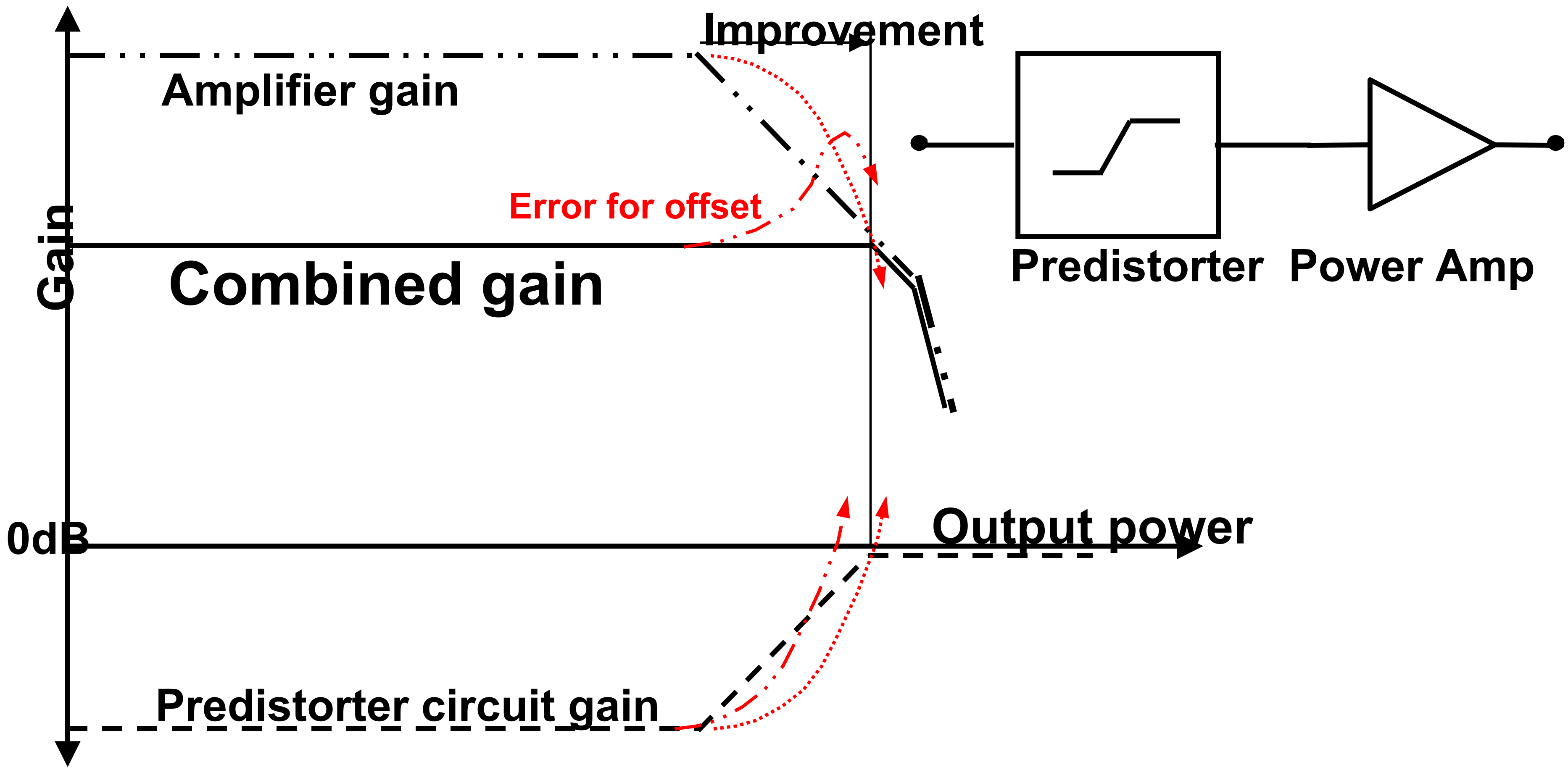


How to guarantee the right level of second harmonic?

The second harmonic at the output of the first stage is fed forward into the second with the correct phase and amplitude to cancel the third order distortion. This approach is sensitive to the last stage gain, relationship of second and third order distortion in the output stage, and the second order characteristics of the driver being well controlled. Note that the load on the driver is a highly tuned circuit that will cause manufacturing sensitivity. Feeding second harmonic into the output at a higher power level looks even more difficult. Maybe common mode into a differential bipolar (beware of FET Rout) amplifier would be ok. (back)

Distortion Reduction- Predistortion

•Predistort the RF input to the amplifier…..15dB distortion improvement



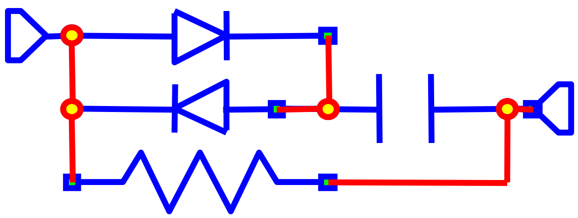
•Cancellation of 2 unrelated distortion signals by careful adjustment

Temperature and manufacturing problems-gain sensitive

Requires a constant load impedance on the amplifier

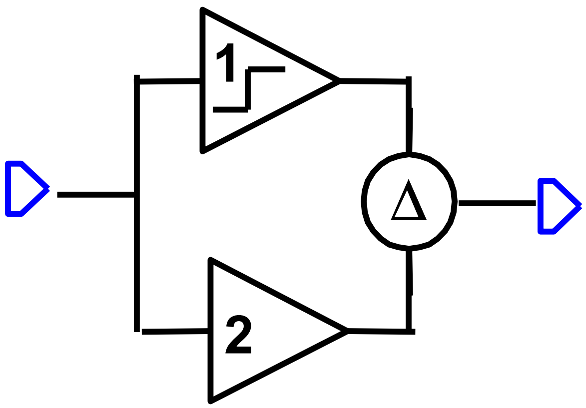
Very difficult when the amplifier begins to compress rapidly

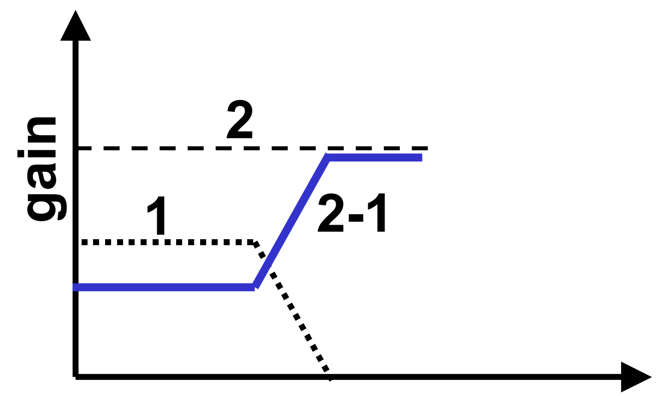
Predistortion Techniques

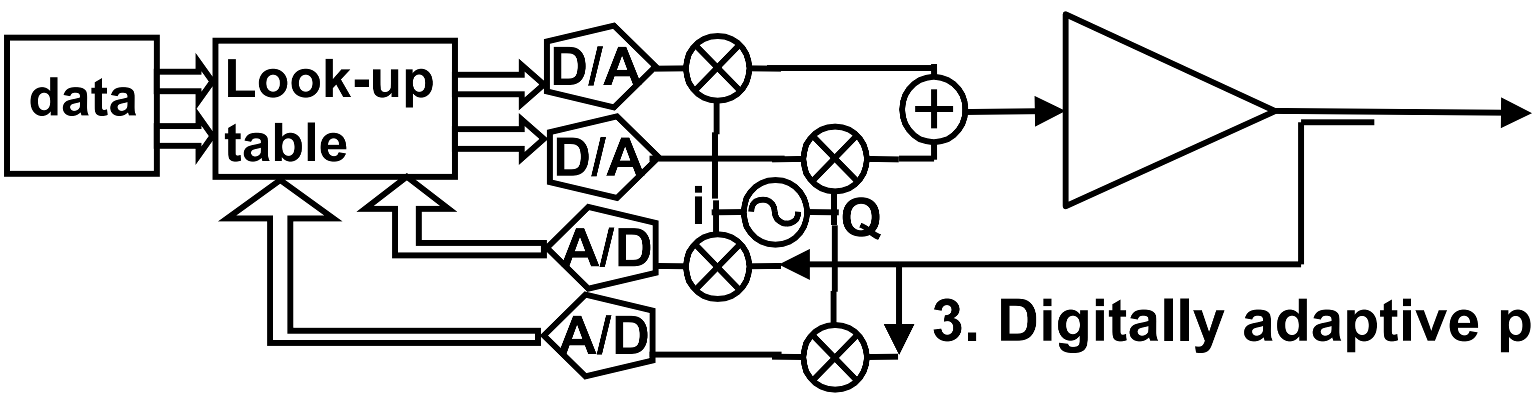


1. Padded back to back diodes. Temp sensitive, but more diodes easily added.

2. Limiting amplifier







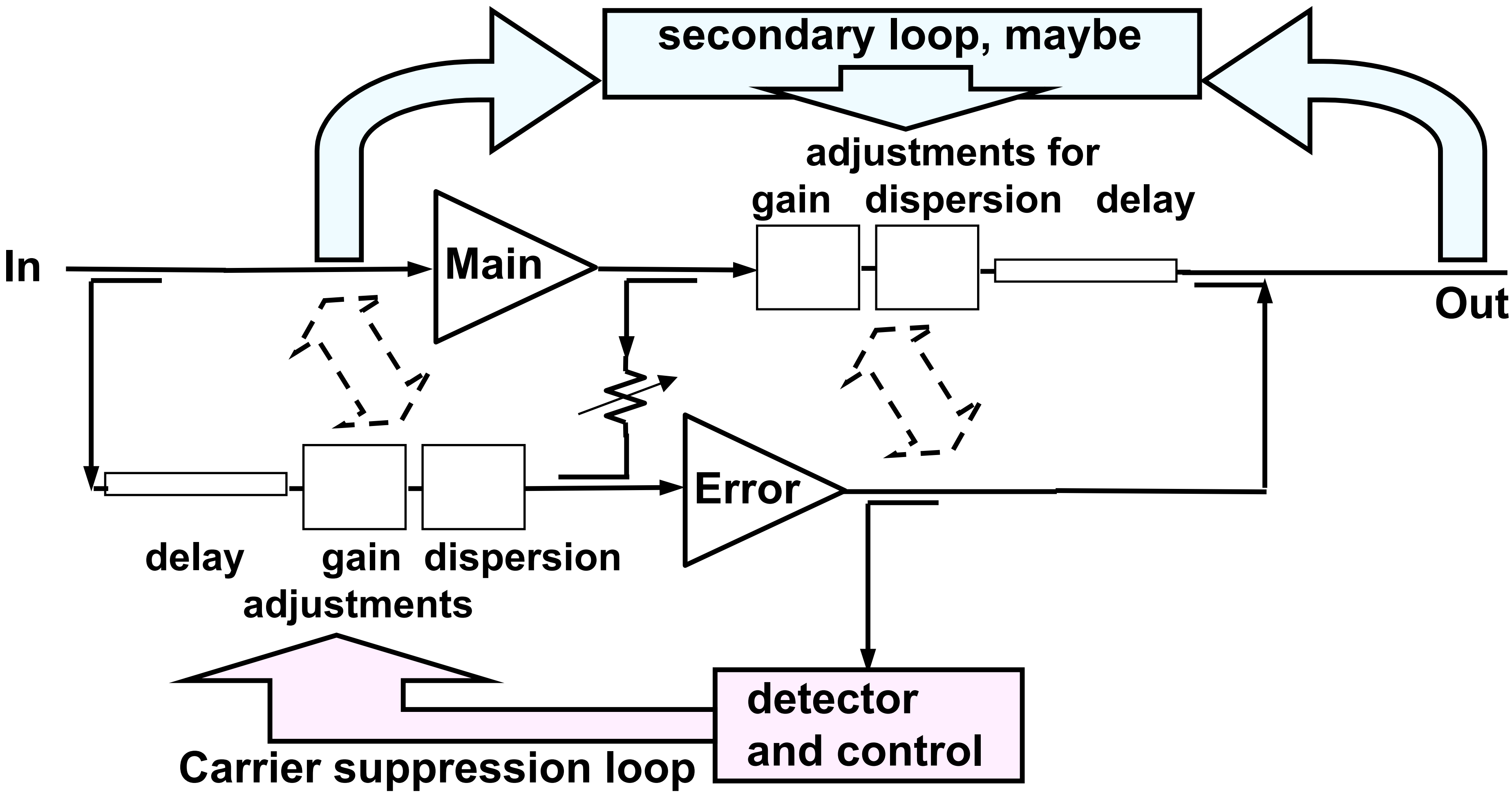
3. Digitally adaptive predistortion

Distortion Reduction-Feed forward

- **Feed-forward cancellation……30dB ： Subtract a sample of the output signal from a pure sample of the input signal to leave only the distortion.**
  - Phase and gain equalize distortion signal
  - Subtract out distortion signal from output

Very complex for good performance, difficult to integrate
Both amplifiers must be high power, even the drivers.
Need multiple stages of low distortion gain, which makes the cancellation more difficult, temperature dependent, etc. Thus, the complexity of all stages is raised.

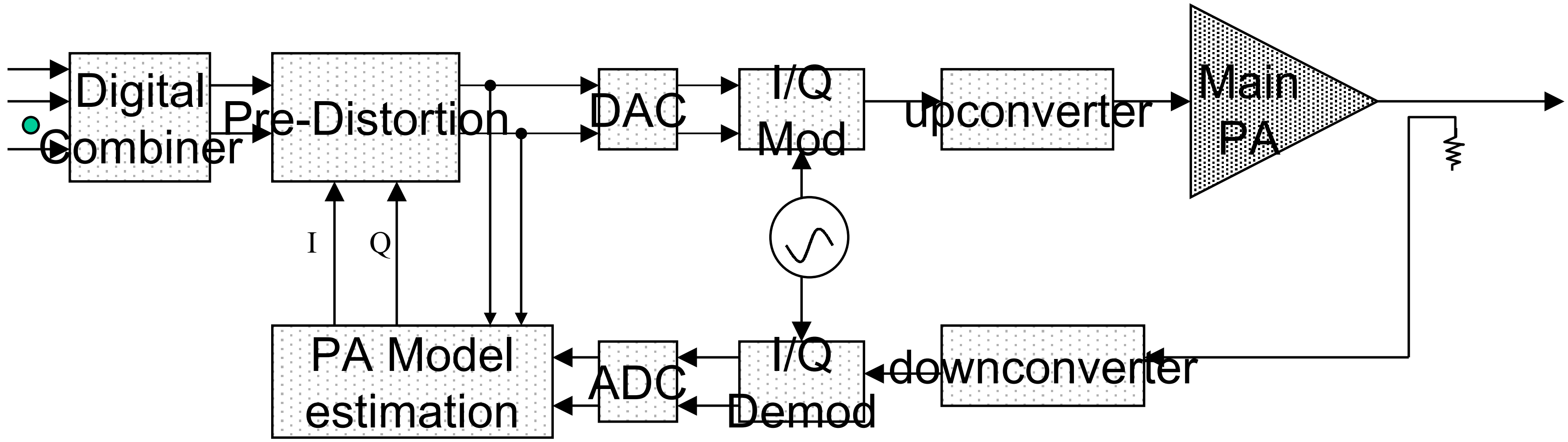
Feed Forward Cancellation



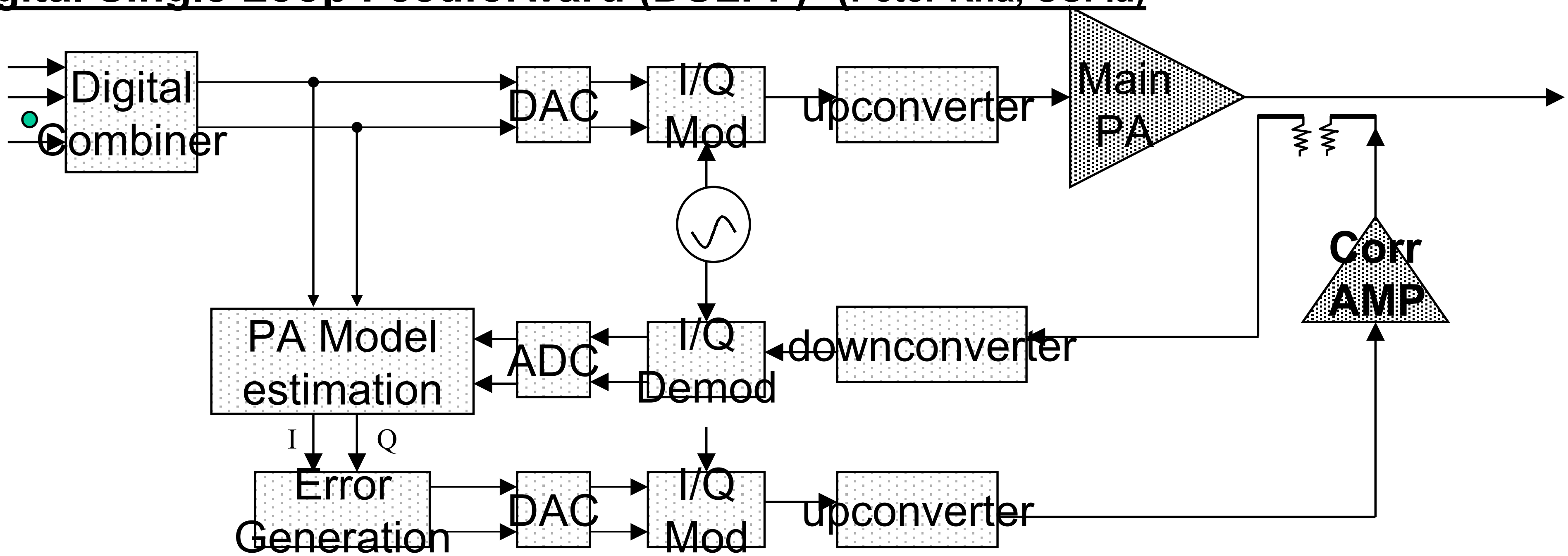
The main amplifier operates with the input signal's peak-to-average ratio. The error amplifier handles a much higher peak-to-average ratio signal, idling much of the time. If predistortion is used in the main amplifier, the error amplifier has an even more peaky signal to amplify, nearly impulses. Therefore, the frequency response of the error amplifier must be super.

DSLFF in comparison to predistortion

Digital Predistortion



Digital Single Loop Feedforward (DSLFF)- (Peter Rha, USFla)



Comparisons

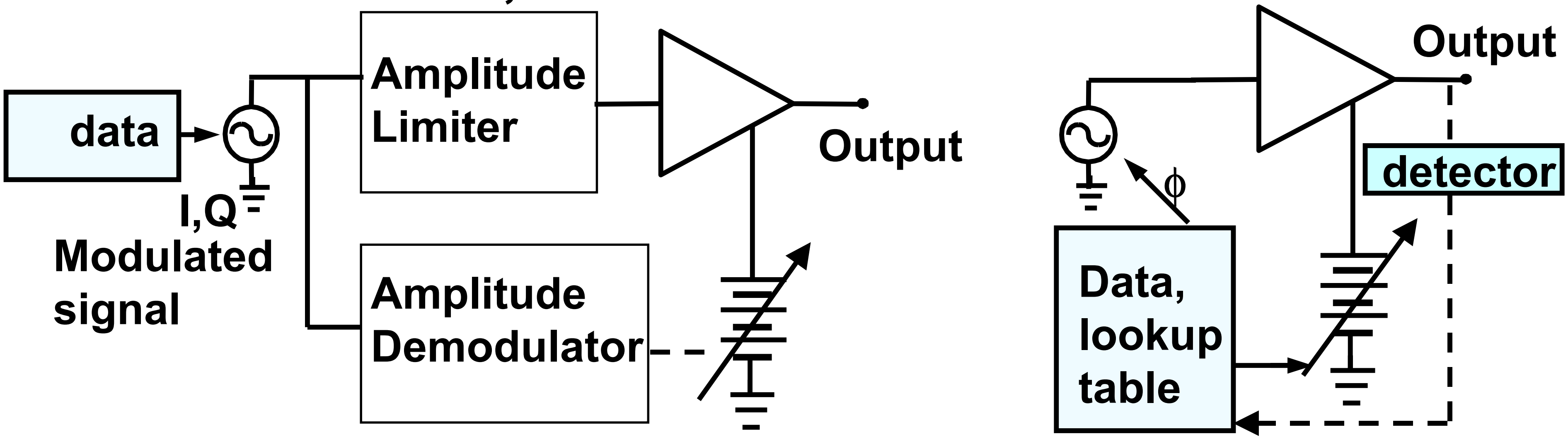
Compared to conventional two-loop feedforward

1. Linearization circuitry is simplified – elimination of one loop.
2. Elimination of the coupler and the delay line at the output of main PA results in less power loss after amplification.
3. Not as accurate as feedforward.

Compared to predistortion

1. PA can operate with less backoff, at a higher peak power level and a higher efficiency. (advantage)
2. PA nonlinearity models with memory effects used for predistortion are equally applicable. (same)
3. Addition signal path for feeding correction signal is needed. (disadvantage)

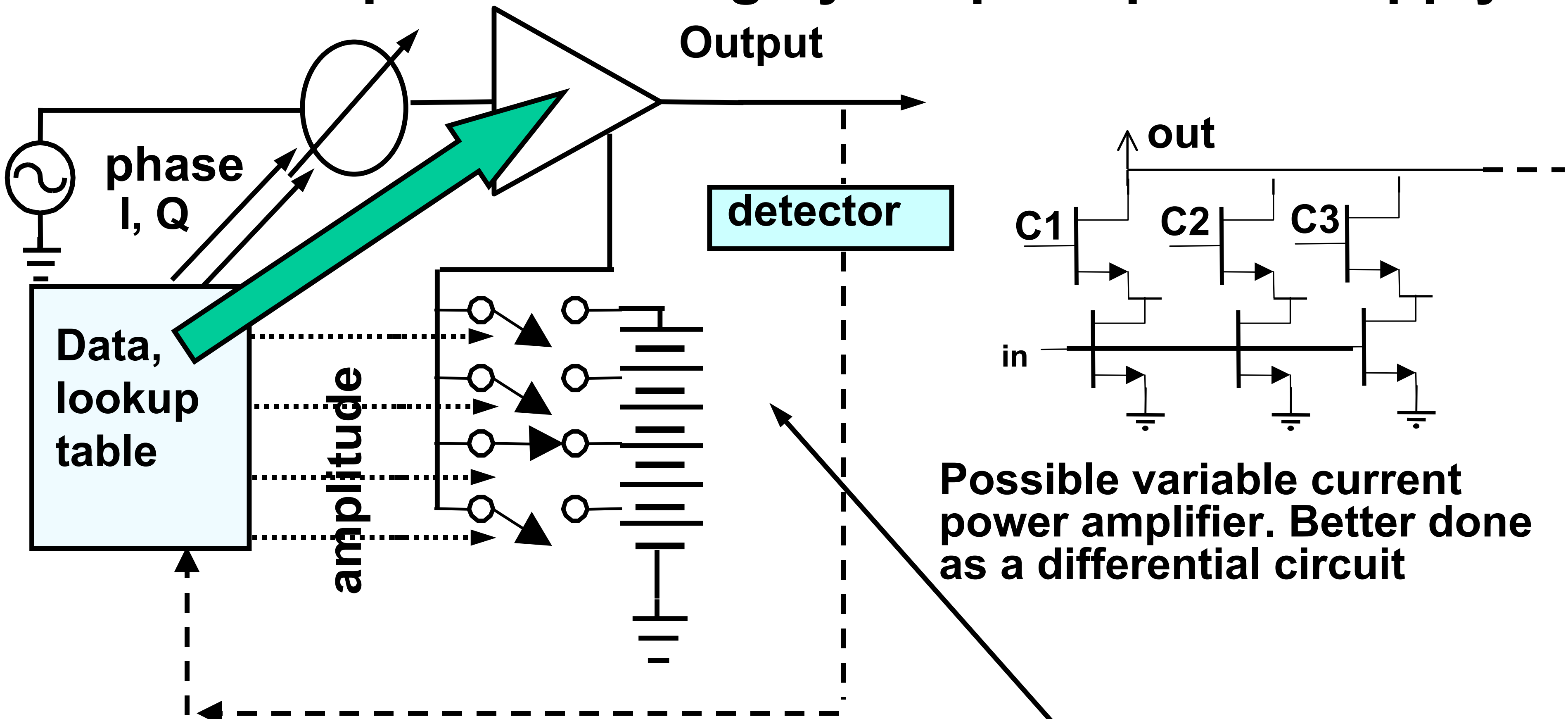
Other methods for third order distortion reduction- demodulate, remodulate……vs……modulate



- Very efficient approach, limited by the load impedance variation and voltage breakdown
- Needs a linear amplitude demodulator, a problem for small signals
- Performance is limited by the speed of the power converter, <1MHz
- May have AM-PM due to the supply voltage variation affecting capacitances

- If you are going to do all this, why not feed the modulation data to the power supply, and directly phase modulate the source? For cleanup, use a lookup-table based feedback loop.
- Detector linearity a problem? Use 2 detectors for high and low level, have the microprocessor choose the best one

Other Methods for Third Order Distortion Reduction-Class B amplifier with highly adaptive power supply



Possible variable current power amplifier. Better done as a differential circuit

Just before the moment a larger supply voltage is needed for linearity, the supply voltage switches. Note that the dc-dc converter does not need to follow the modulation.

Even the amplifier can be switched; Push-pull dual gate or cascode amplifiers can be switched in and out as needed, thus varying the operating current and peak current on demand, along with the supply voltage. Maybe the power amplifier *is* the modulator.

Summary

Bad behavior may be good for you.

Second harmonic can help or harm OIP3 by a large amount.

Modern microprocessor technology and lookup tables can eliminate tweaking, and enable manufacturability. Even memory effects can be added in, with some computation.

As power supply switching frequencies increase, the bandwidth of the very high efficiency variable voltage amplifiers will benefit. Particularly if the supply doesn't determine the output level, but provides the correct voltage for the amplifier.

The extremely non-linear waveforms handled by distortion amplifiers have higher peak-to-average ratios than the main amplifiers, and might demand a different approach entirely from the main amp.
Maybe…design for peak power, don't worry about dissipation and thermal resistance, use tightly packed cells to get more watts/area.