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Increasing Data Throughput Over HF links

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Traditional HF Radio

- Analog voice & 50,75…bps

New Trends on HF

- Digital voice, Noise reduction…
- High Data Rate …19200…bps➔QAM

➔ High linearity, SNR ,Efficiency

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Requirements from the New HF Radio
For HDR performance

-Linearity - ISI	-High efficiency
-High dyn. range	-Small size.
-Low ACI & IBN	-High MTBF.
-High Power TX.	-feasible.

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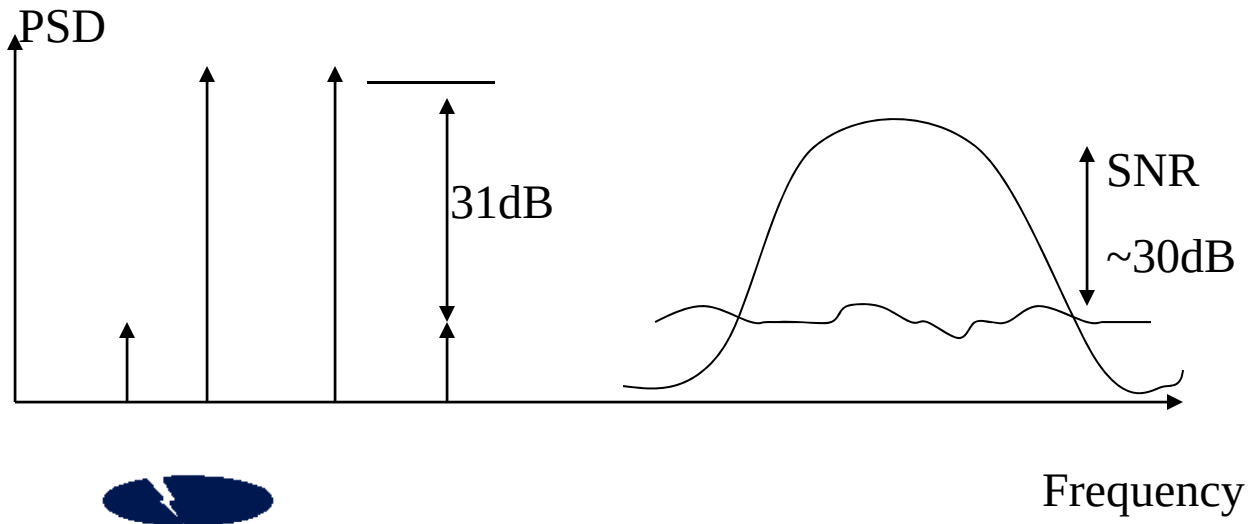
HPA and High Data Rate (HDR)

TX Inter-Mod : 31dB

HDR RX SNR Requirements : >33 dB



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micom Radio &HPA Solution

Linearized Power Amplifier :

	micom	Current Spec.	
TX PWR	125/175W…	125W	Availability !
Inter-Mod	>42 dB	30-32dB	Data Rate !
Efficiency	>45%	30%	Energy !
PWR con.	280 /390W	416W	Size !

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micom HDR-ISB System Solution

micom – 2*ISB Radio 125/175W

ready for 500-4000 W

micom – MD-9600/19200

STD-5066 email gateway

JITC @ Q1-Q2 2005

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Technical session on
Linearized techniques & Achievements on
micom – radio

Mr. Yehuda Eder

Thank you , have a productive day

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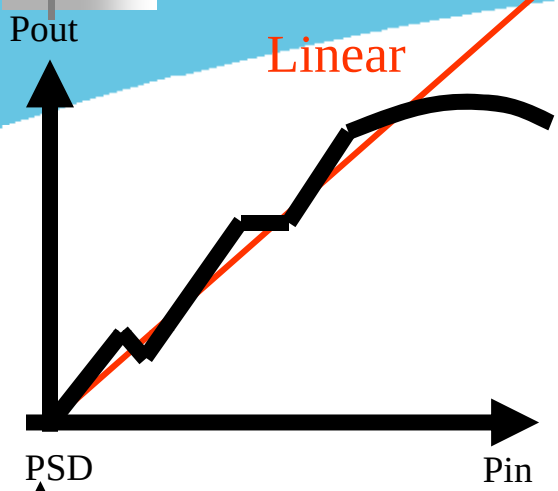
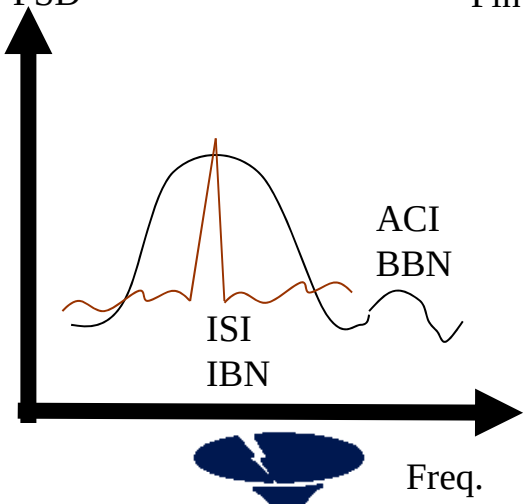
Problem description





Non Linearity caused by:

- PA/transmitter linearization
- RGC – Receiver Gain Control
- TGC/ALC – Transmitter Gain Control
- D/A-A/D – Resolutions
- Local Oscillators phase noise
- Receiver/Transmitter BW
- Group Delay Variation

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Available Solutions

Linear Power Transceiver :

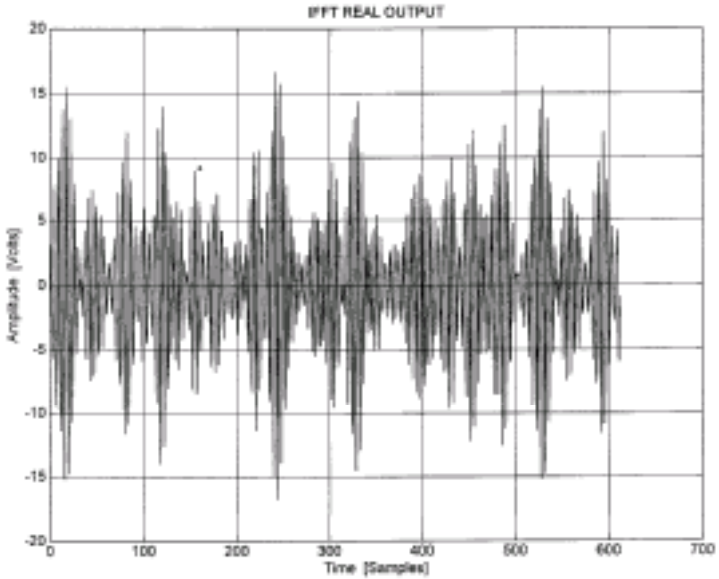
Linear Power Amplifier, Class-A or A/B with large backoff :
Low efficiency, high cost

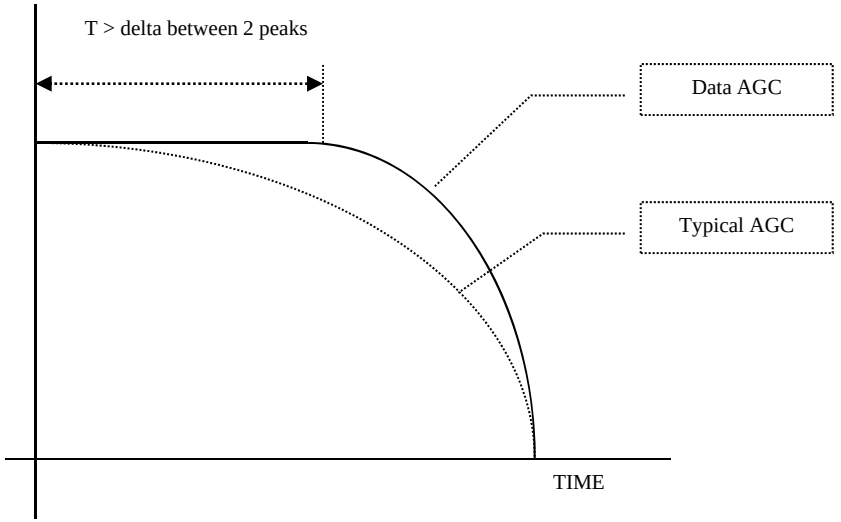
AGC, TGC,ALC : HELD (Input regulation based on average signal level should be held)
HF channel receive signal variations may cause problems to the receiver performance and the linearity.

Linearized Power Amplifier
High Efficiency and IMD

RGC – Receiver Gain Control
TGC/ALC–Transmitter Gain Control

Special techniques for attack-release of GAIN CONTROL must be used.



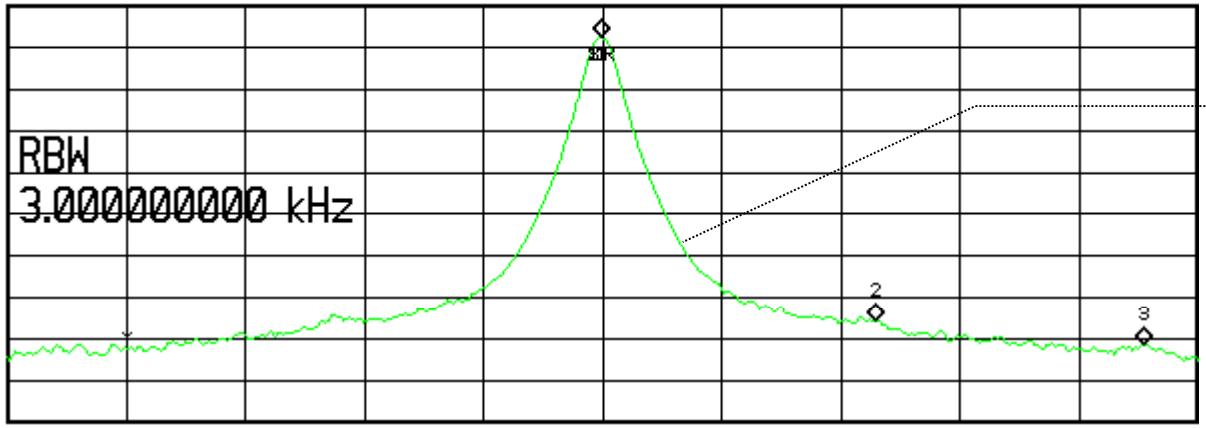


Distortion & Noise in CODECs

- Integral non-linearity
- Differential non-linearity.
- Total Harmonic Distortion (THD).
- Total Harmonic Distortion Plus Noise (THD+N)
- Signal to Noise and Distortion Ratio (SINAD, or S/N+D).
- Effective Number Of Bits (ENOB).
- Signal to Noise Ratio (SNR).
- Analog Bandwidth (Full Power, Small Signal)
- Spurious Free Dynamic Range (SFDR).
- Two Tone Inter-modulation Distortion.
- Noise Power Ratio (NPR).

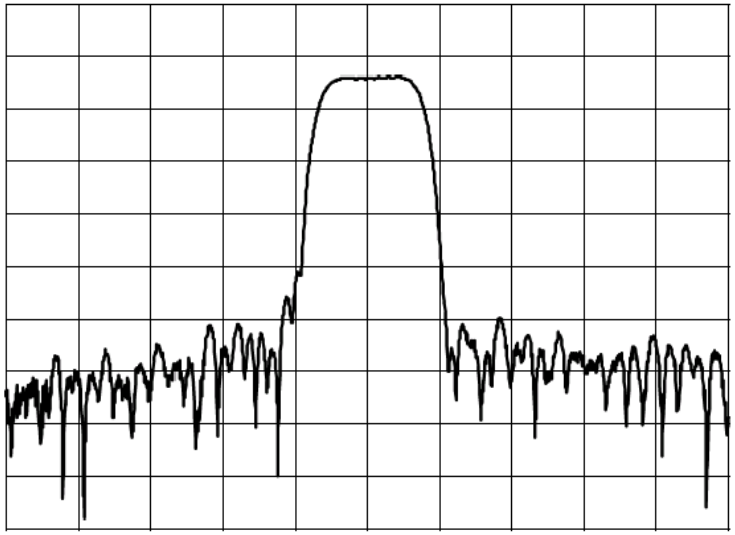
Local/Synthesizer Oscillators phase noise

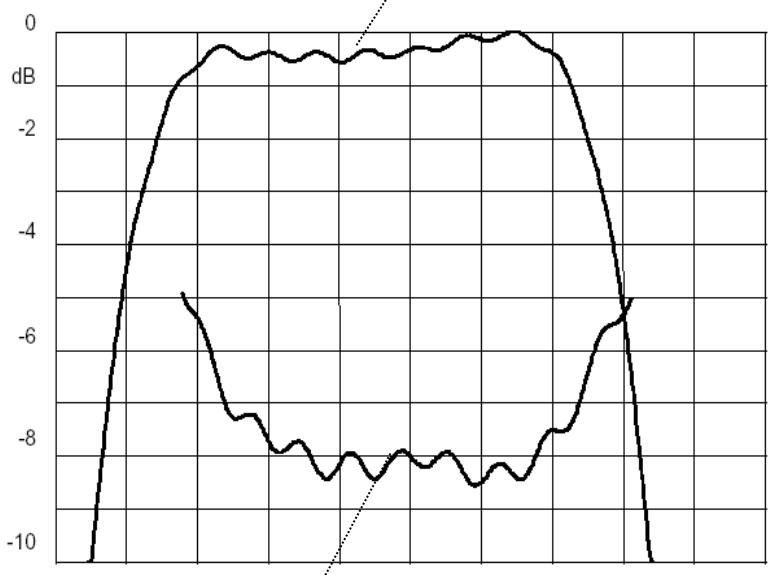
The synthesizer is the source of:
IBN
BBN



High noise near the carrier = SNR degradation

Receiver/Transmitter BW





In band ripple

Group delay variances

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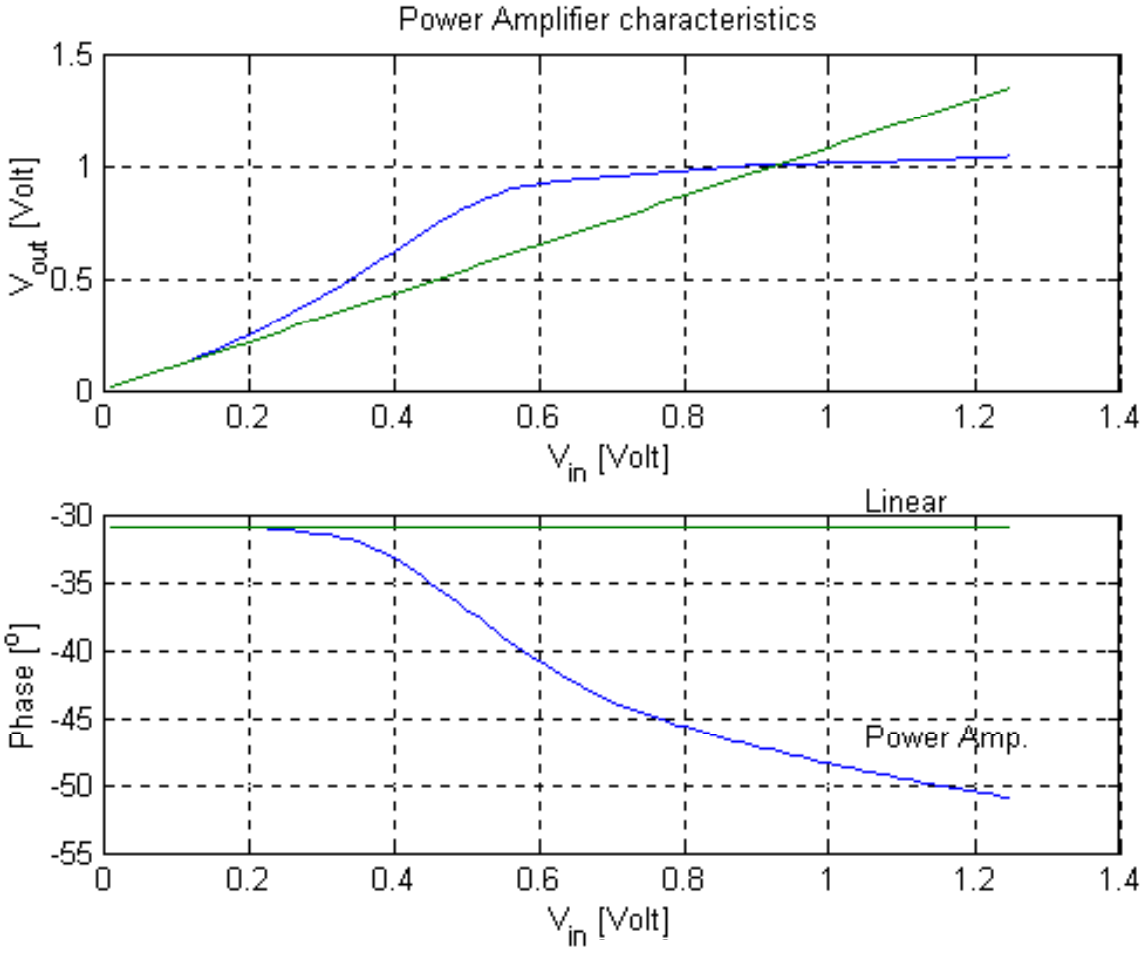
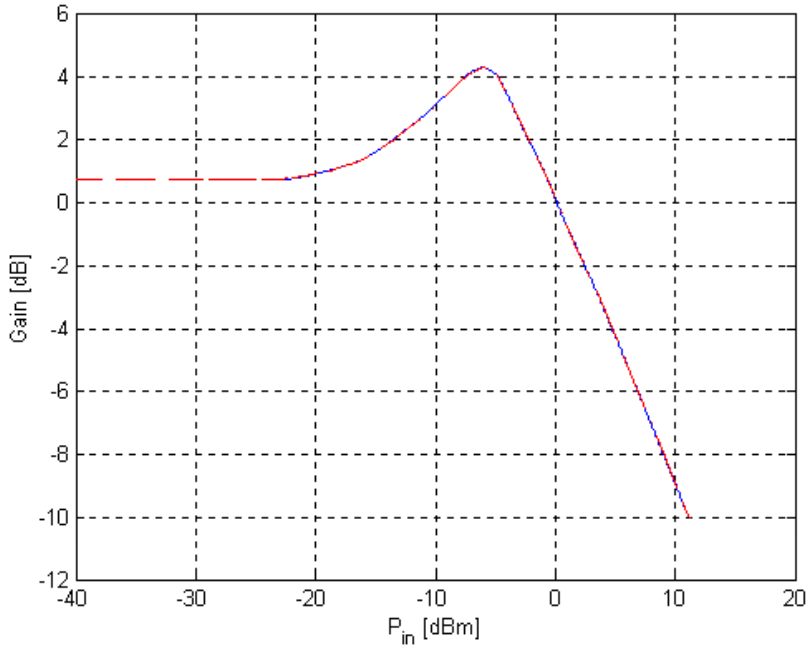
PA characteristics - linear scale

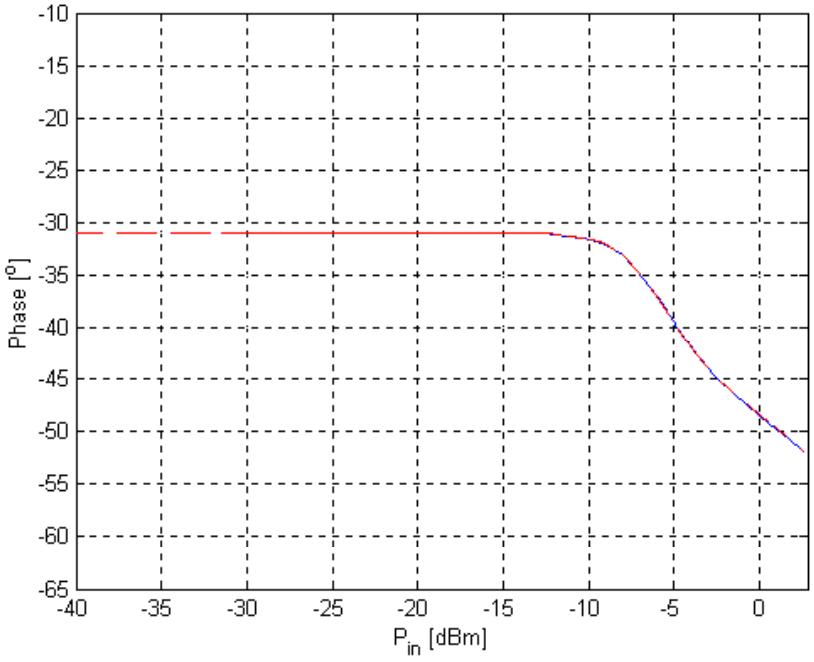


“Typical” class AB PA characteristics (measurements)

Power Gain



Phase Transfer Function



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PA linearity vs. SNR

MIL-STD188-141B Requirement:
Intermodulation distortion (IMD).
The IMD products of HF transmitters produced by any two equal-level signals within the 3 dB bandwidth shall be at least 30 dB below either tone for fixed station application, and 24 dB below either tone for tactical application.

The 24/30dB limits the SNR performance.

Summary Performance tests results:

IMD (below tone)	SNR
45	34
39	33
33	31
30	28
24	24
20	19
19	18

the IMD should be improved for better SNR

PA Linearization Techniques

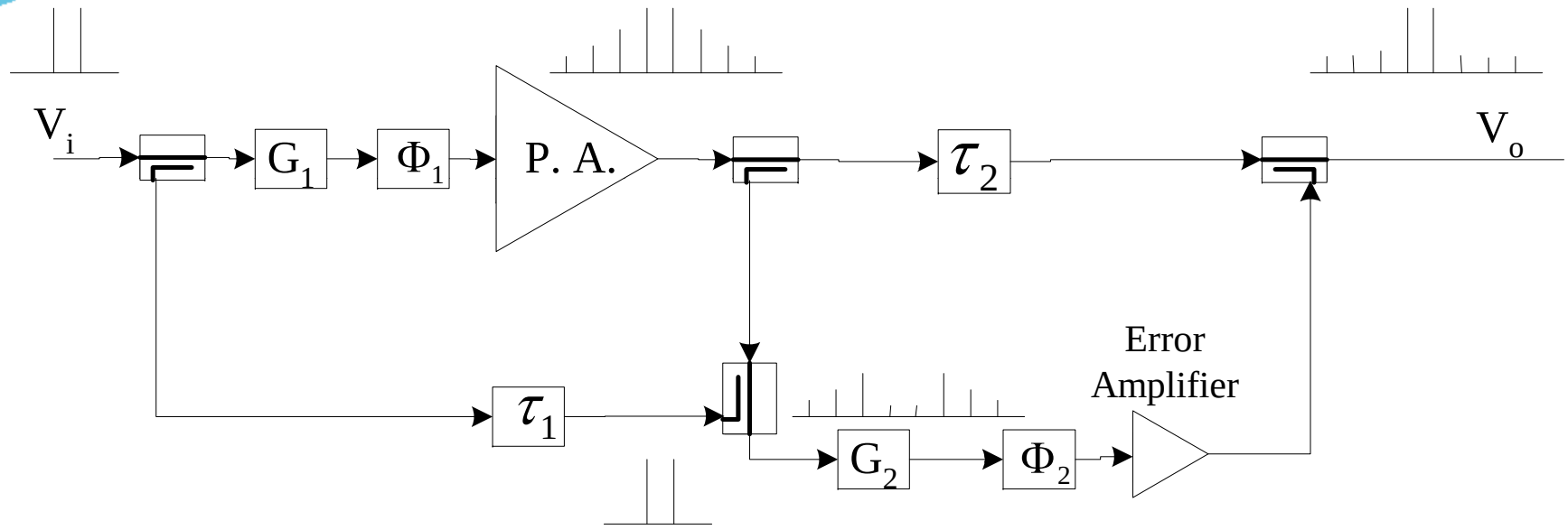
Power Amplifier Linearization Techniques:

- Feed Forward
- Pre-Distortion
- EER – Envelope Elimination Restoration
- Cartesian Feedback

Our approach:
High Efficiency Class-AB amplifier with Cartesian Feedback & EER to achieve high linearity and high efficiency.

Linearization Techniques

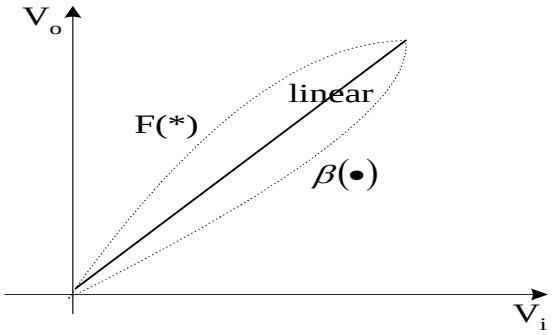
Feed-forward

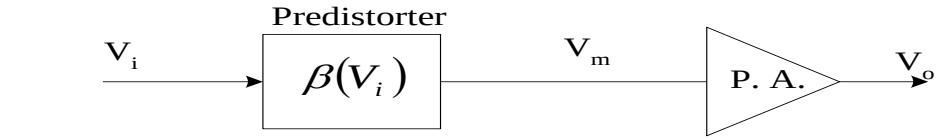


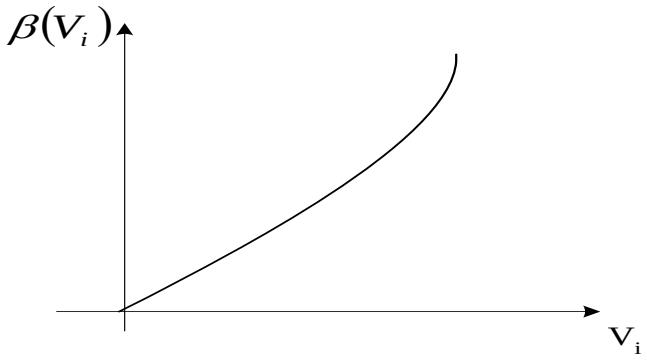
High complexity, Wide BW @ low freq. Range

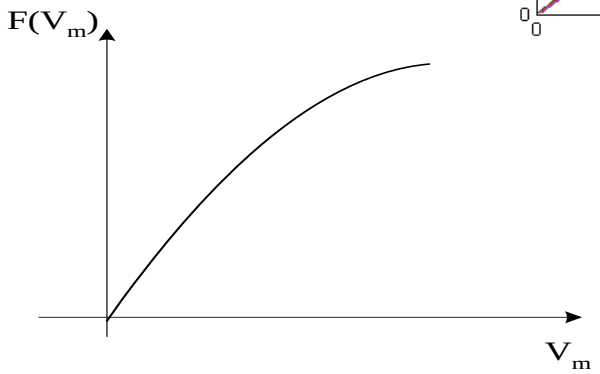
Linearization Techniques

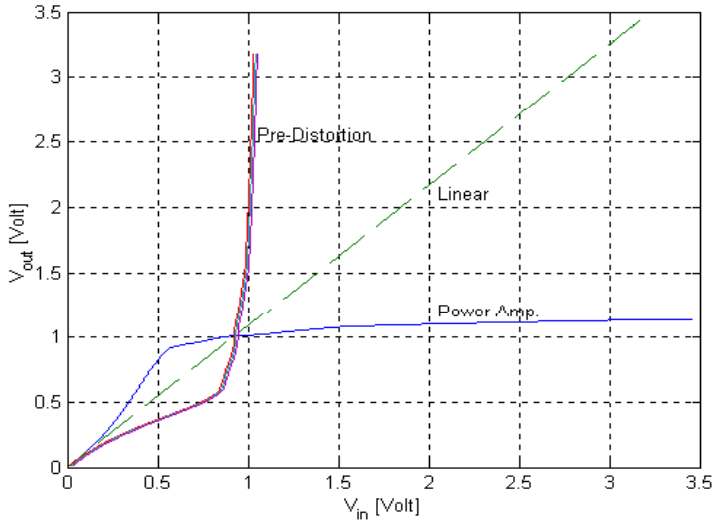
pre-distortion







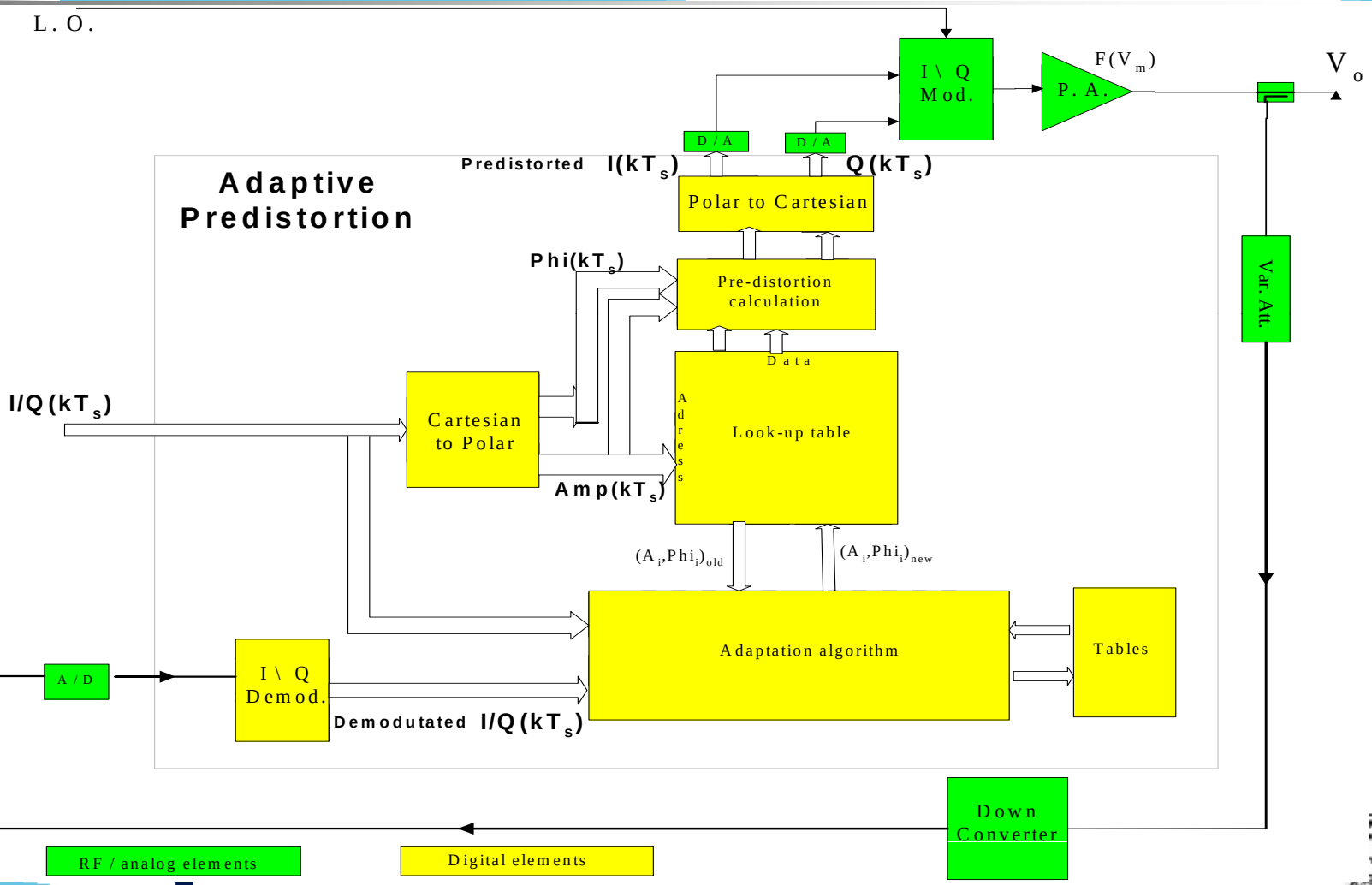




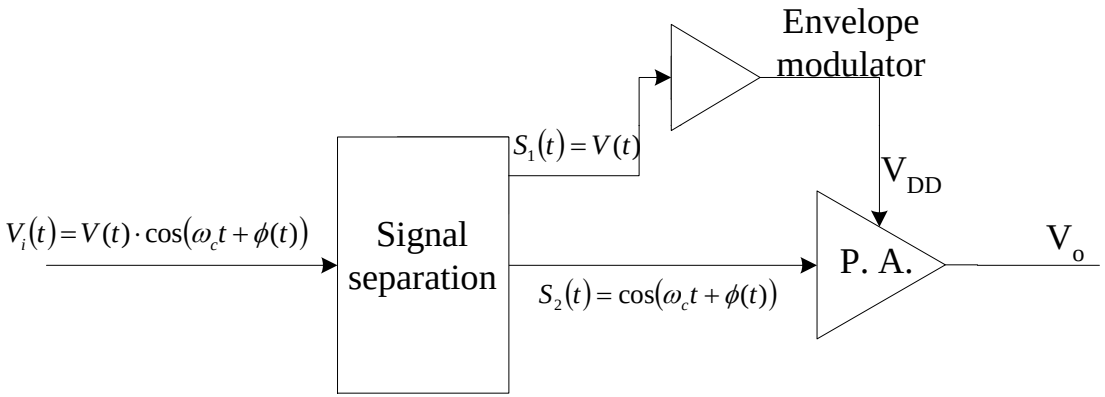
High complexity, Wide BW @ low freq. Range

Linearization Technique

Digital adaptive pre-distortion

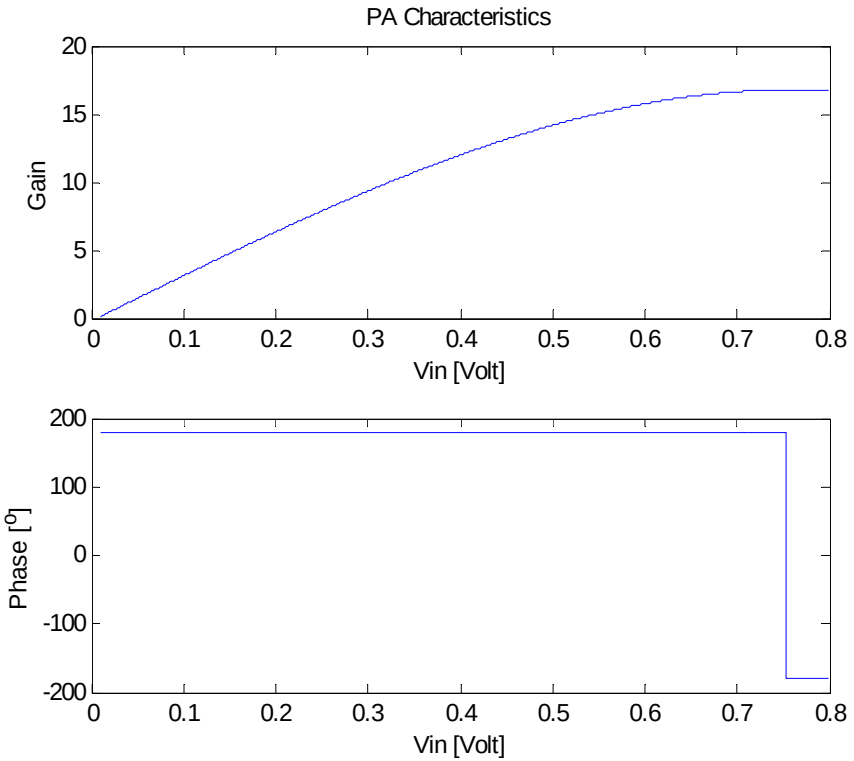


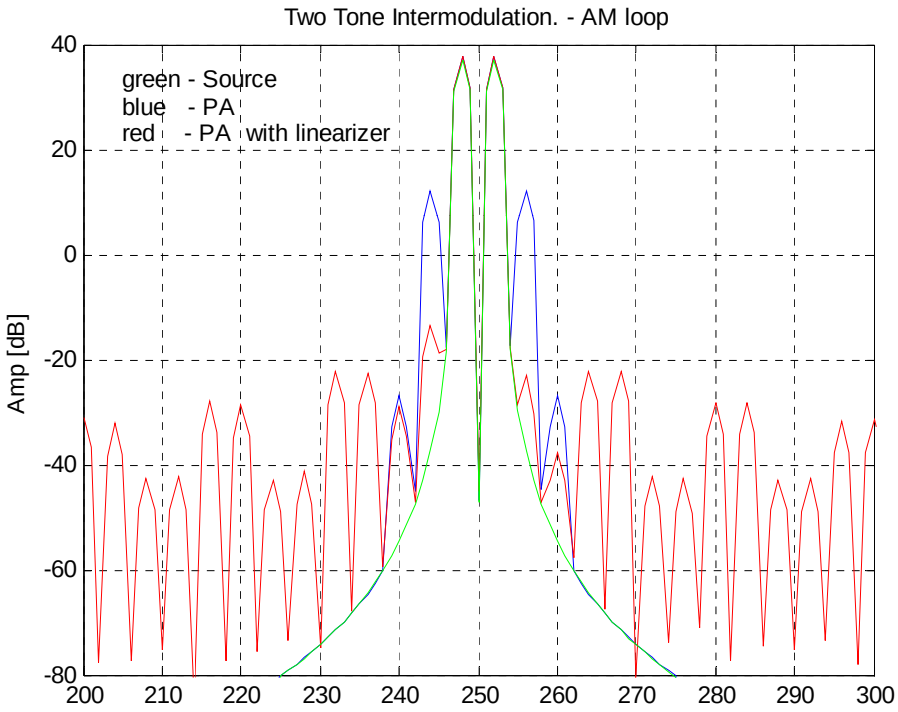
EER (Envelope Elimination and Restoration)



AM loop –**PA without AM-to-PM**

I_{pol}=[-95 0 87 0] ; Q_{pol}=0



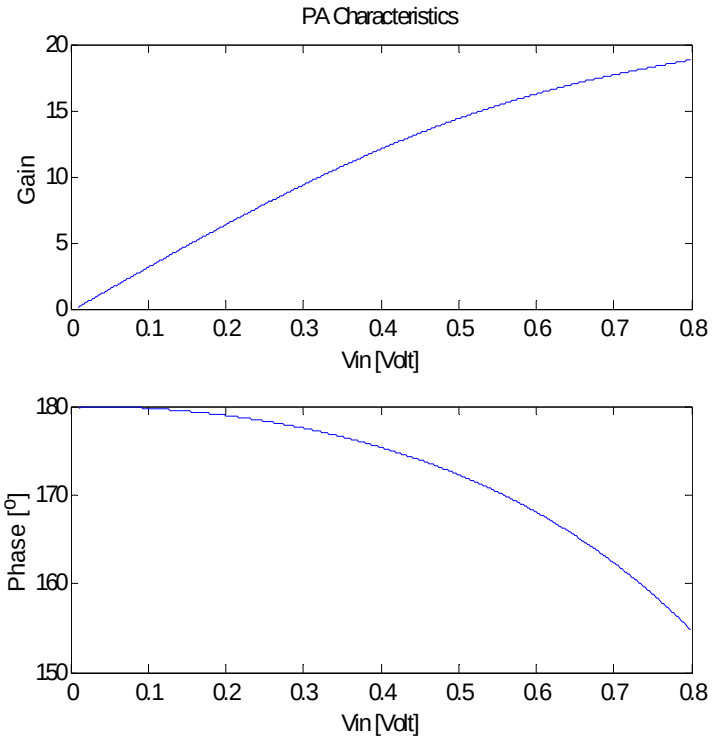


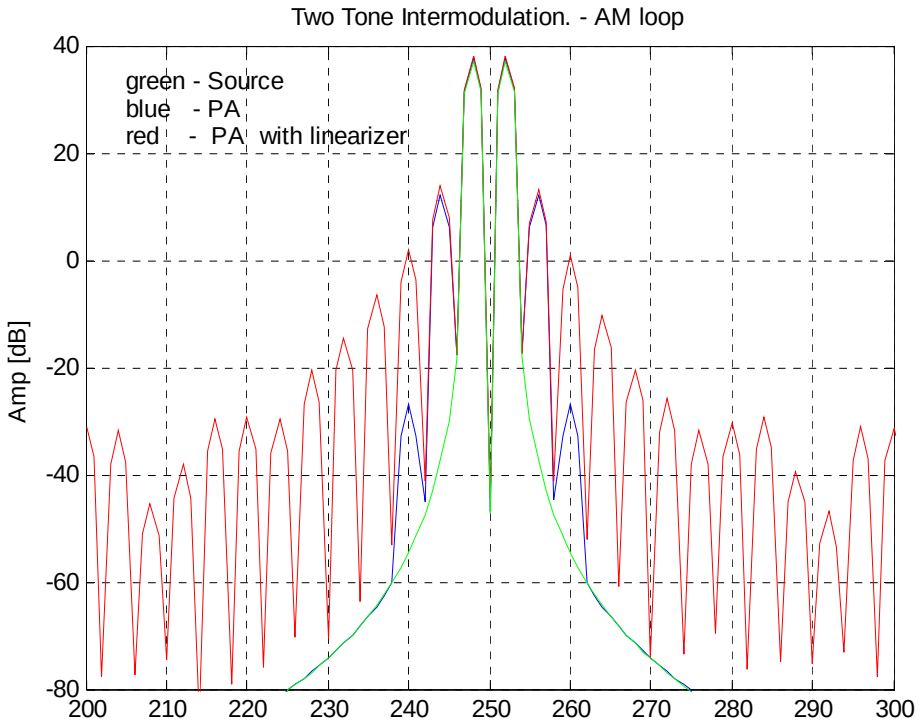
IM3 = 25 dBc

AM loop improvement > 20 dB

PA with AM-to-PM (0 ÷ 25°) – AM loop

I_{pol}=[-95 0 87 0] ; Q_{pol}=[-75 0 0 0]





IM3 = 25 dBc

AM loop improvement 0 = dB

For QAM modulation EER is not efficient

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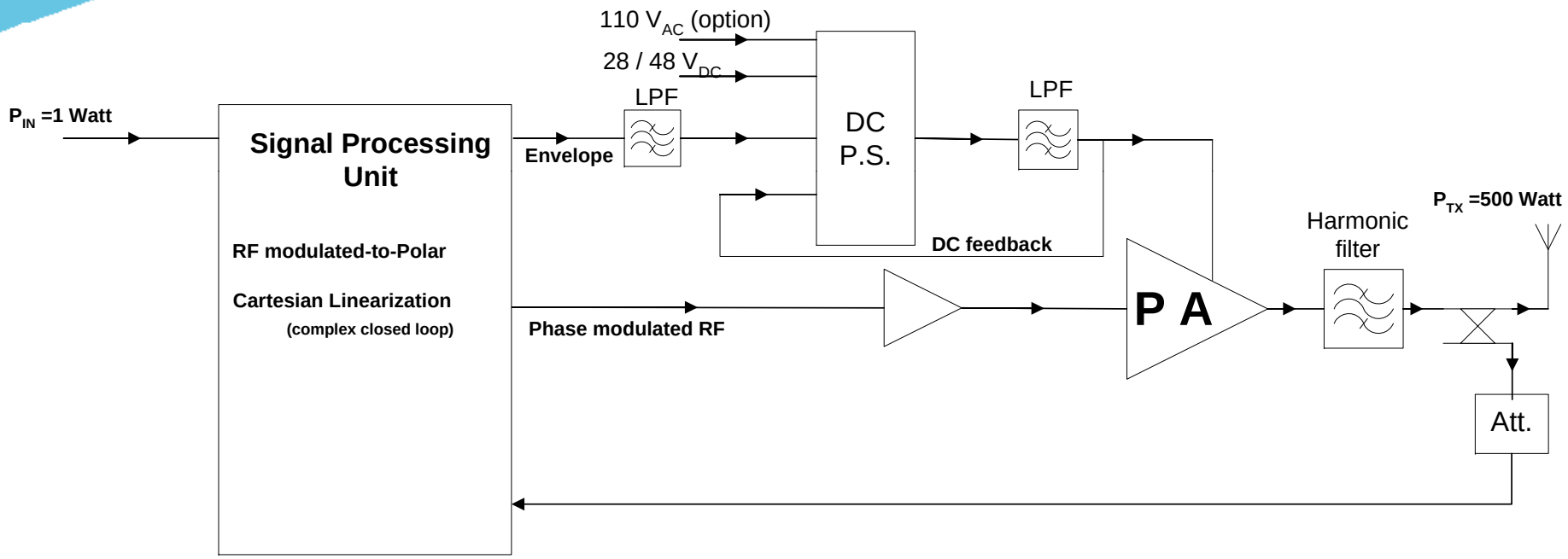
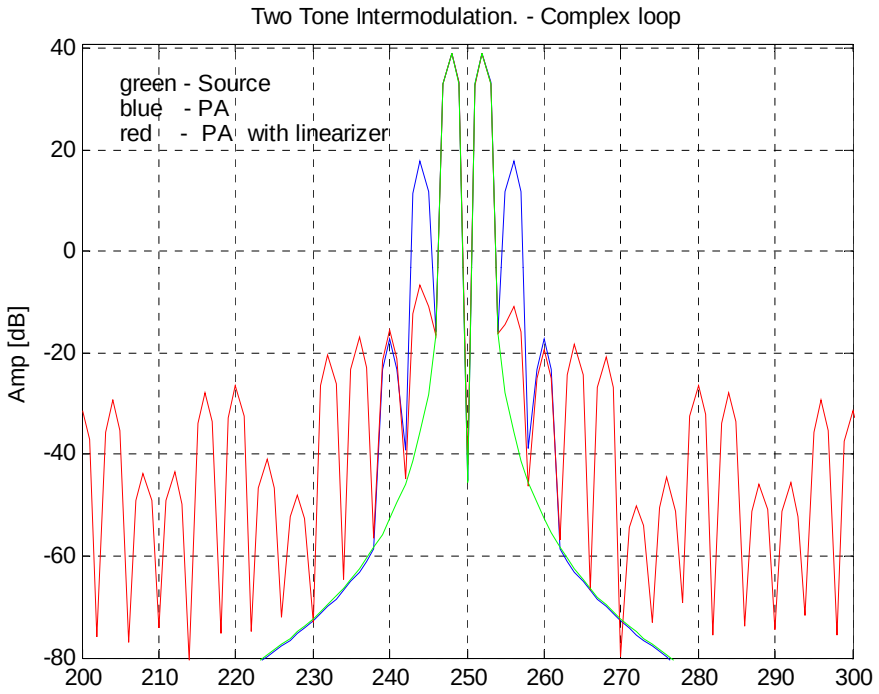
Micom Linearization solution
EER & Cartesian loop



Micom simulation results

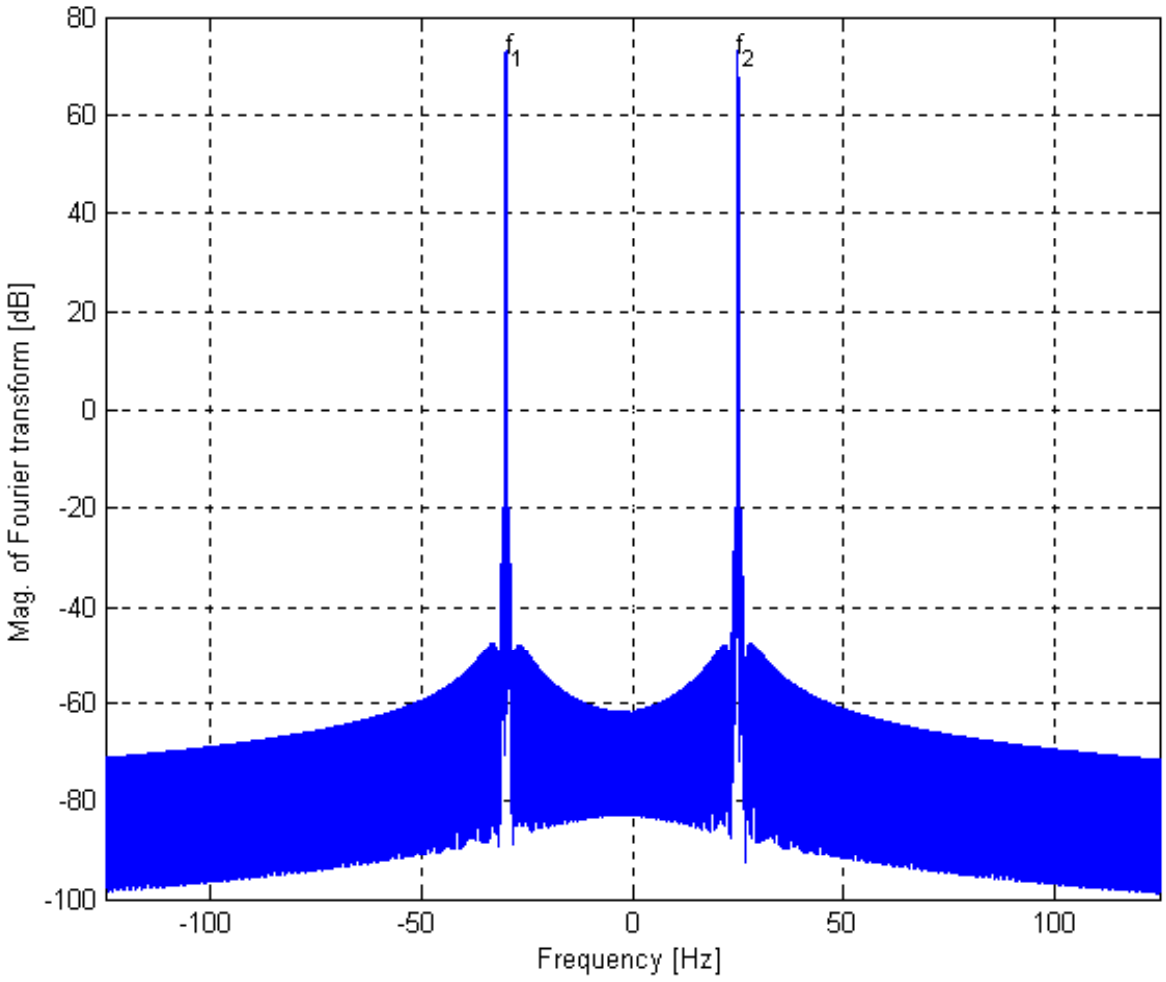


IM3 = 20 dBc

Complex loop improvement ~ 25 dB

Two complex tones - baseband spectrum

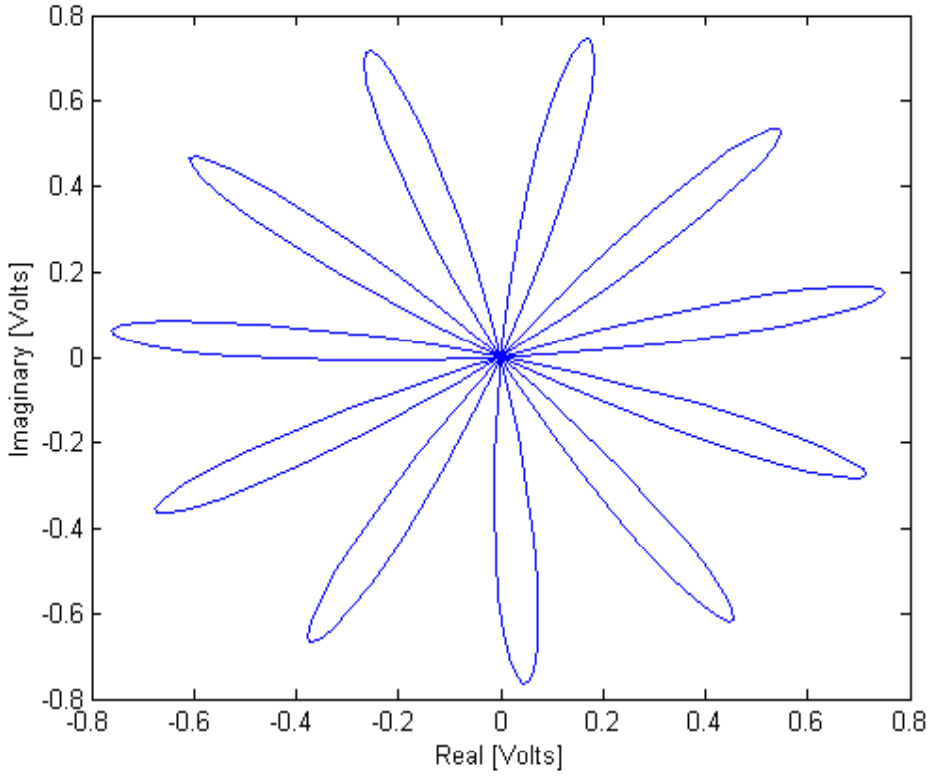
$f_1 = -30$ Hz, $f_2 = 25$ Hz



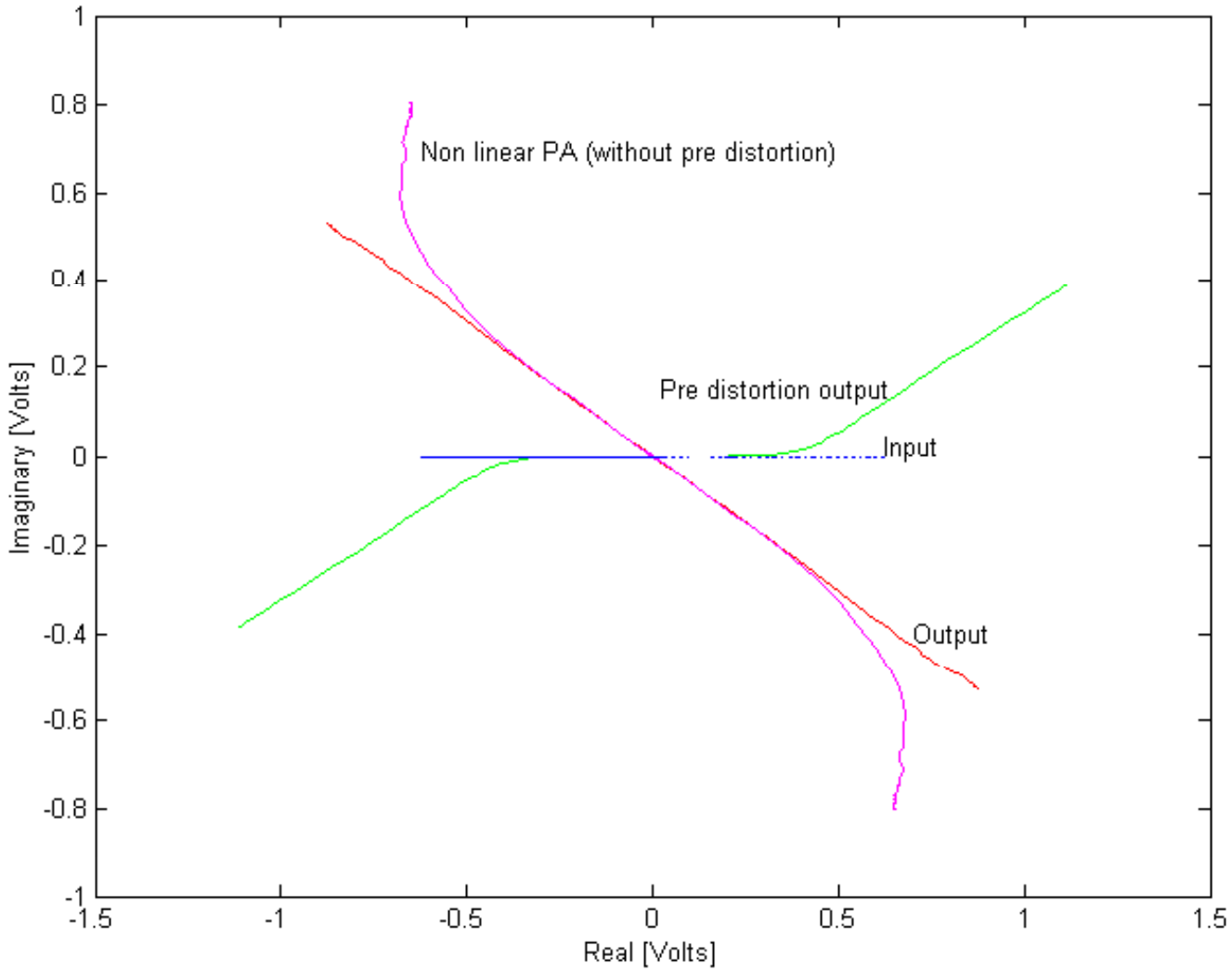
Two complex tones - I/Q plot

$$I(t) = a\sin(2\pi f_1 t) + a\sin(2\pi f_2 t + \pi)$$

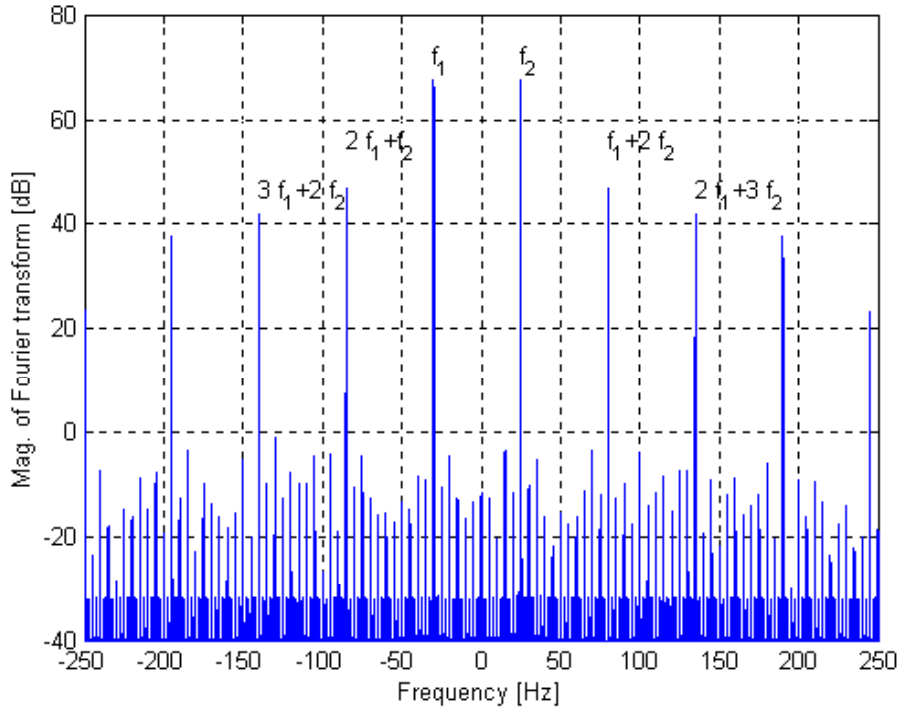
$$Q(t) = a\sin(2\pi f_1 t + \pi/2) + a\sin(2\pi f_2 t + \pi/2)$$

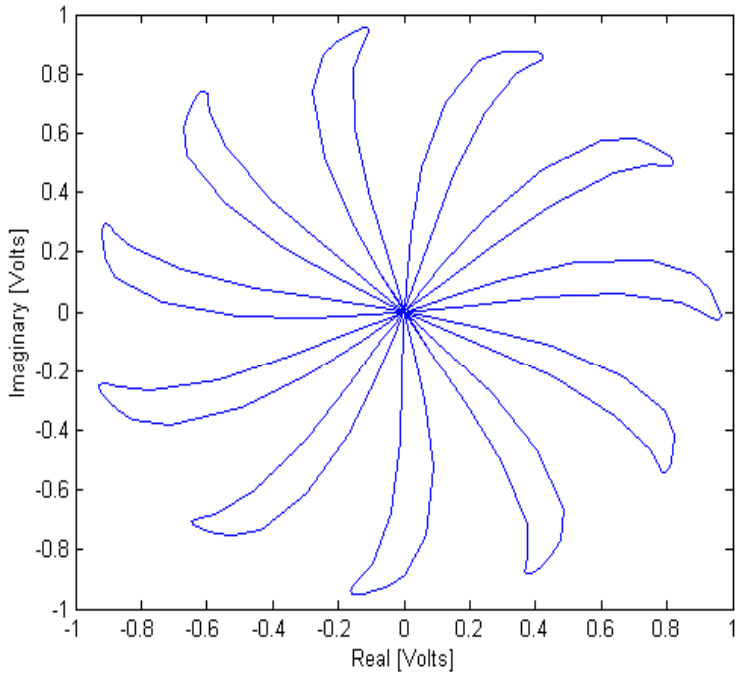


Single tone (modulating signal) I/Q plot

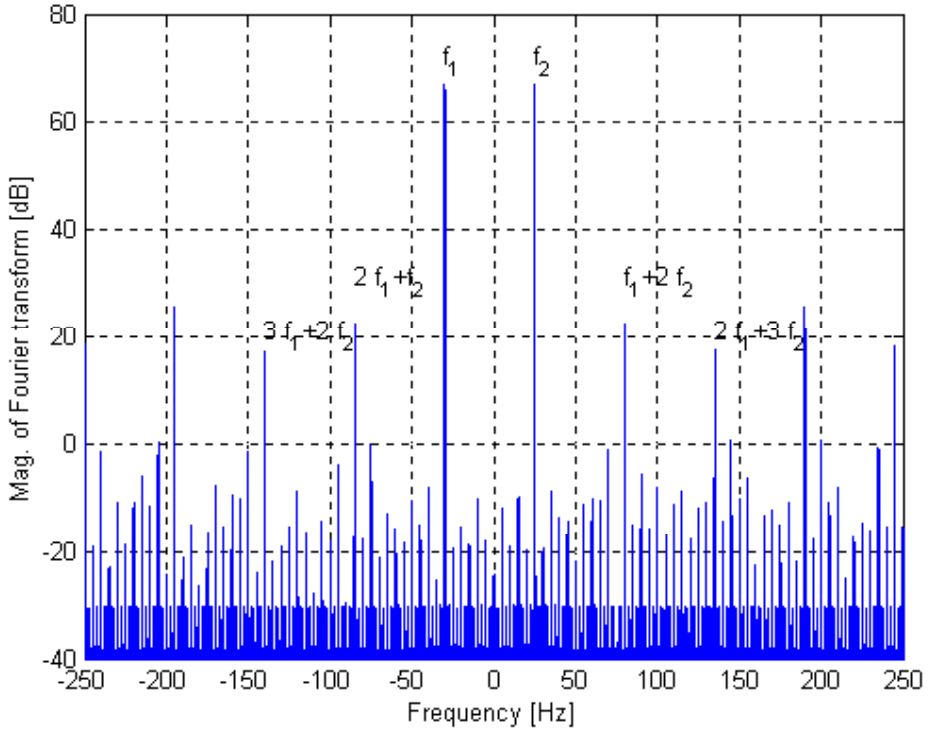


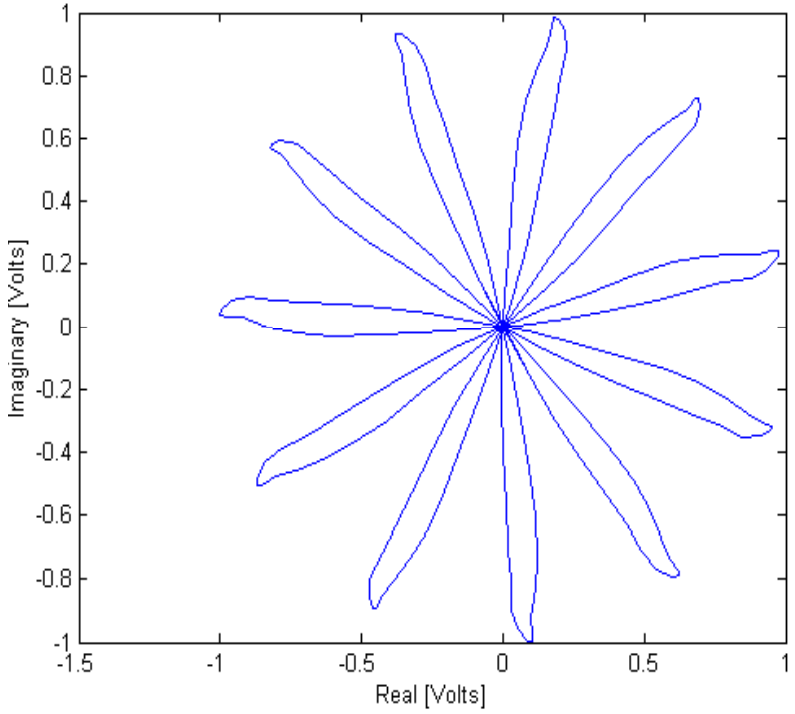
Non-Linear PA



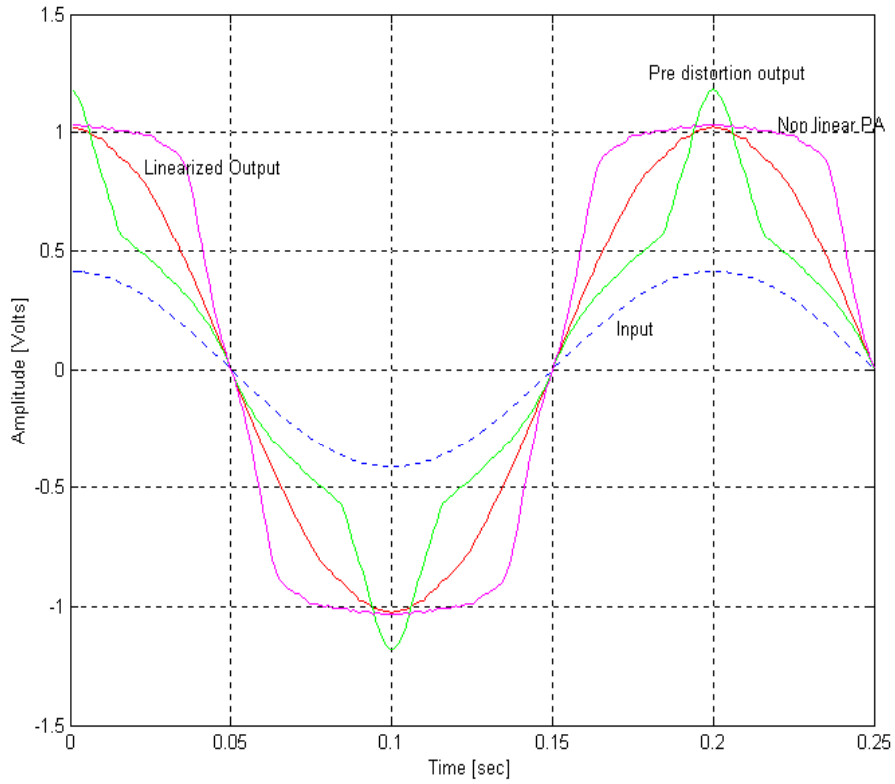


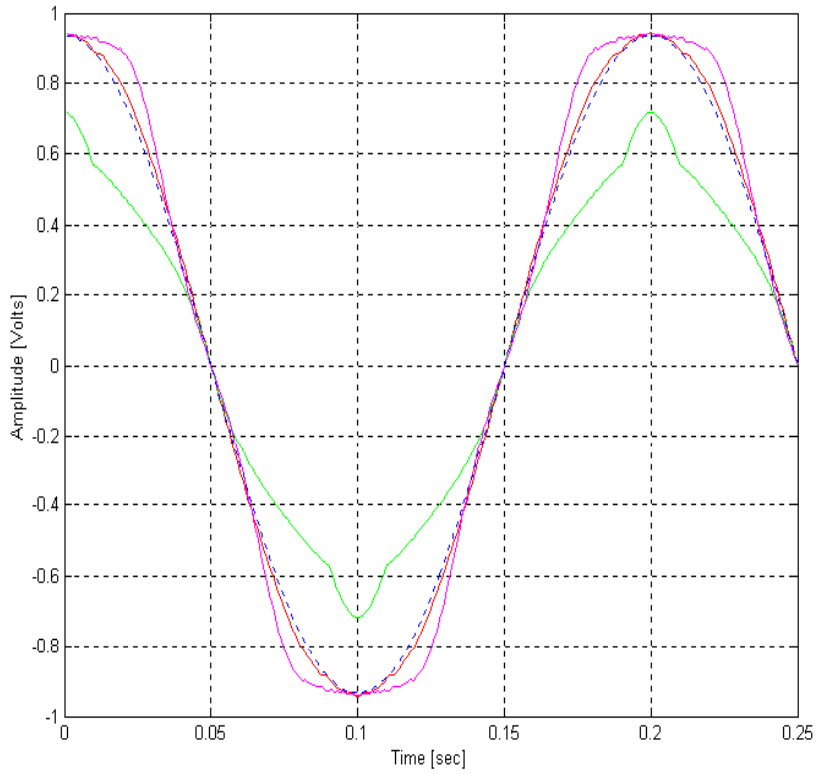
Linearized PA





Single tone time waveforms (RF or modulating signal)





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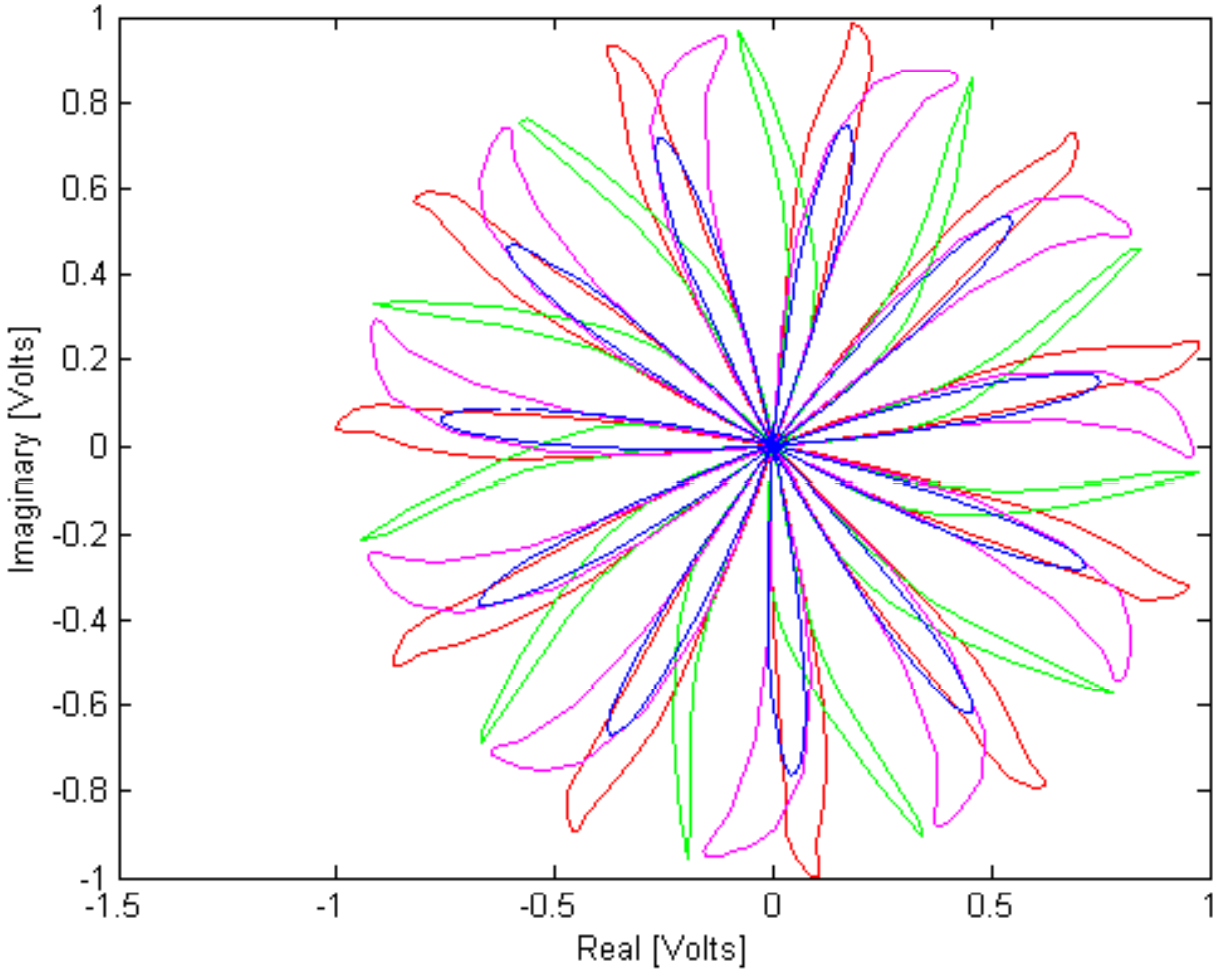
I/Q plot


Imaginary [Volts]
Real [Volts]
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.5
-1
-0.5
0
0.5
1

Thank you