Polar Modulation: An Alternative for Software Defined Radio

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Outline

- SDR Radio implementation issues
- Issues in meeting multi-mode requirements
- Polar Modulation as an Alternative approach
- Polar Multi-mode cellular performance
- Summary

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Introduction

- No single cellular standard is deployed worldwide
- Multimode operation is required for future terminals
  - Coverage is essential for economic success
  - 2G systems will remain online
- Low cost is an overriding requirement
  - GSM voice-only has set the economic standard
  - power consumption, ***if close***, is bendable
- Battery life, size, and weight cannot be sacrificed (much)
- SDR radio subsystems have proven difficult to realize

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Fundamental Signal Equations

- Basic Signal Equation

$$s(t) = A(t)\cos\left(\omega_c(t) + \phi(t)\right)$$

- Quadrature Equivalent

$$s(t) = I(t)\cos\left(\omega_c(t)\right) + Q(t)\sin\left(\omega_c(t)\right)$$

- In theory, this looks obvious and simple to realize…...

Key RF System Terms

- PAR - ratio of PEP to signal rms power
- PMR - ratio of PEP to MEP
- DR - Range of maximum to minimum signal rms power
- Duplex
  - full: simultaneous transmit and receive operation
  - half: alternating transmit and receive operation
- Signal Quality
  - EVM: difference of signal to desired complex envelope
  - rho: correlation between signal and desired complex env.
- BW - signal occupied bandwidth

… and *many* others, often system specific

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Uplink Signal Characteristics

Cellular signals' complexity evolution

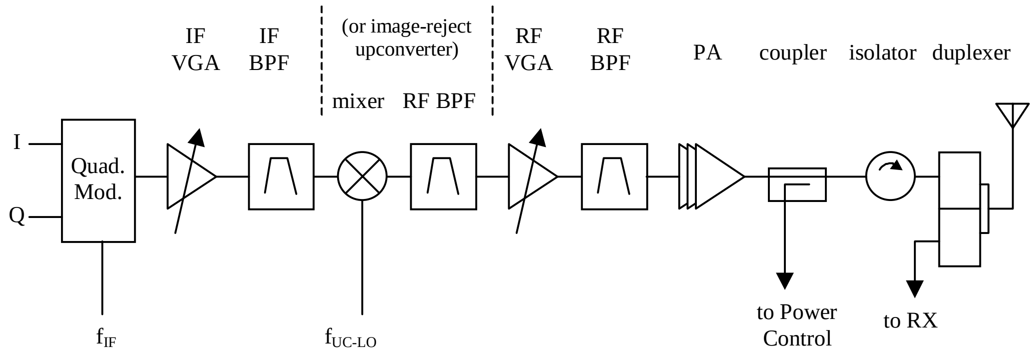
- Signal envelope peak-to-average ratios are increasing
  - average power influences coverage
  - peak power sets PA design
- Full duplex operation is returning
- Power control dynamic range is increasing

	System	PAR (dB)	PMR (dB)	Duplex	Power Control (dB)
voice	**1G**	0	0	full	25
voice	ANSI-136	3.5	19	half	35
voice	GSM	0	0	half	30
data	GPRS	0	0	half/full	30
data	EGPRS	3.2	17	half/full	30
voice & data	UWC136-I	3.2 & 5.5	10 & infinite	half	35
voice & data	UMTS	3.5-7	infinite	full	80
voice & data	IS-95B	5.5-12	26 - infinite	full	73
voice & data	cdma2000	4-9	infinite	full	80

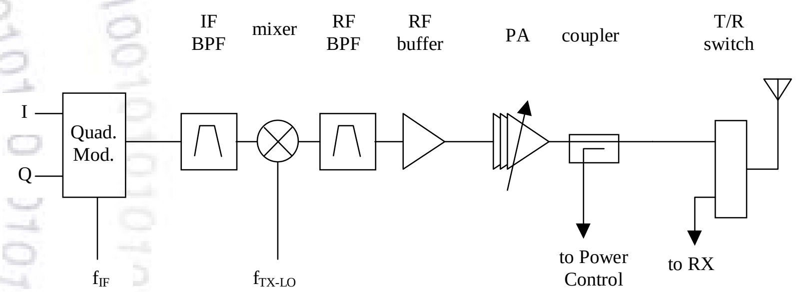
+ PMR

Independent Evolution Results

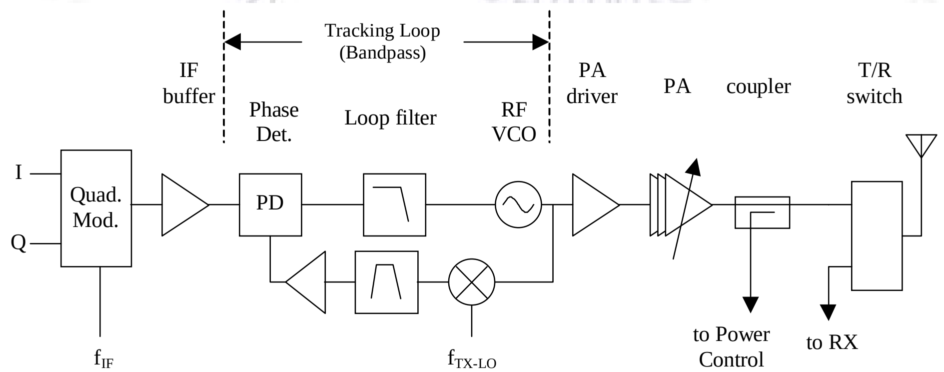
Conventional Uplink Transmitter Architectures



CDMA / WCDMA



NADC / EGPRS



GSM/GPRS

SDR COVERAGE

- CDMA design is a superset
- GSM design sets cost baseline

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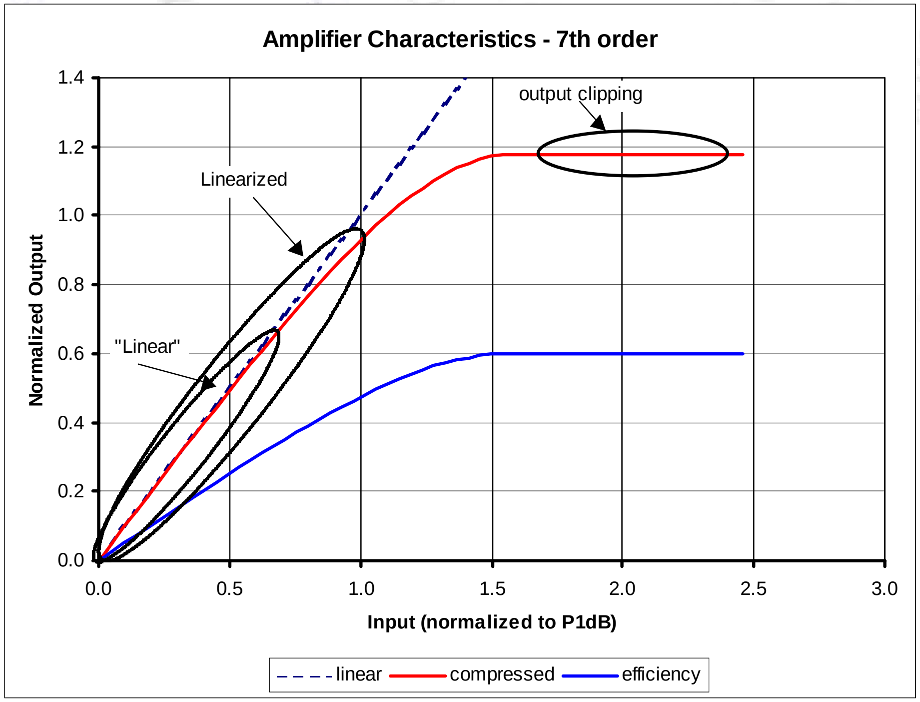
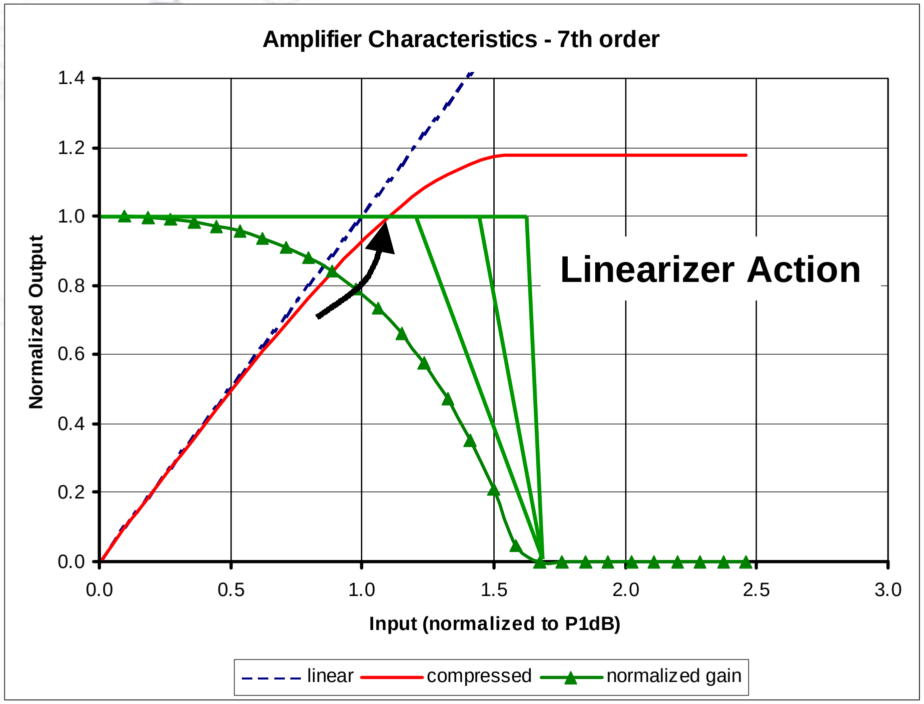
Linear Amplifier - Large Signal Distortion

- Standard tradeoff: linearity (low distortion), or efficiency
- Gain (slope) goes to zero at output clipping
- Linearizer cannot correct gain near or into clipping





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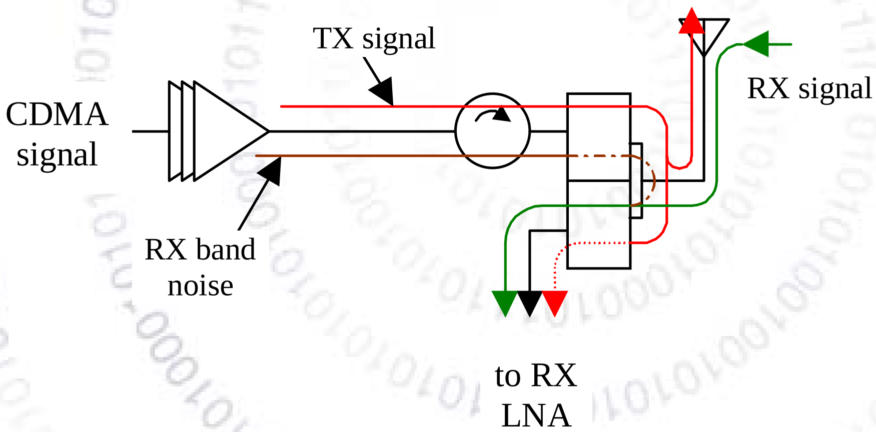
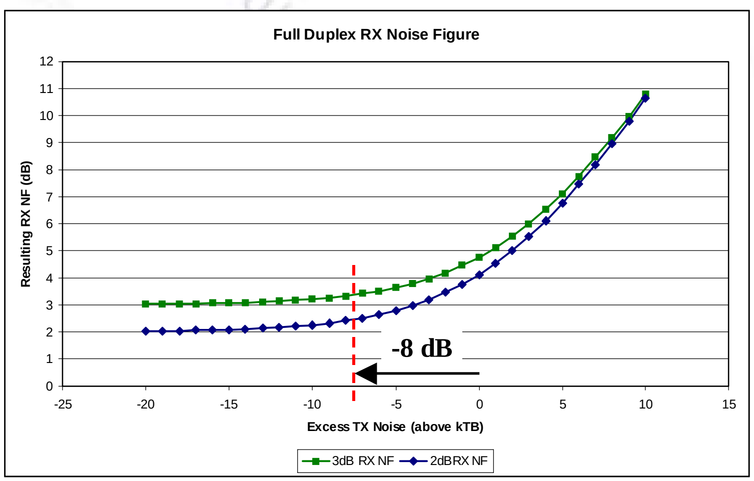
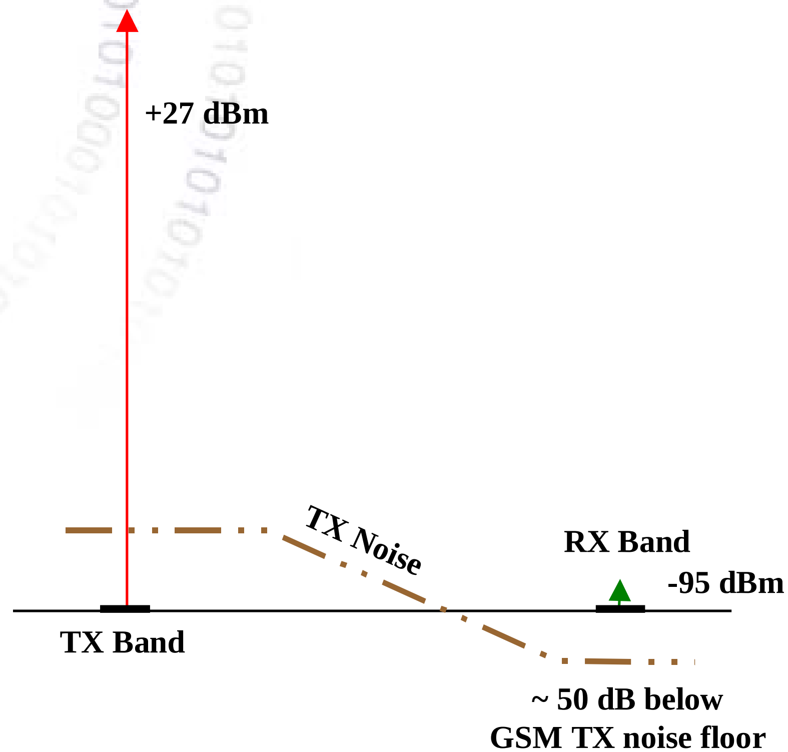
Full Duplex - The Ultimate in Near-Far Interference

- Transmitter is ON while receiving
- Filters are vital - TX & RX are ***physically connected***







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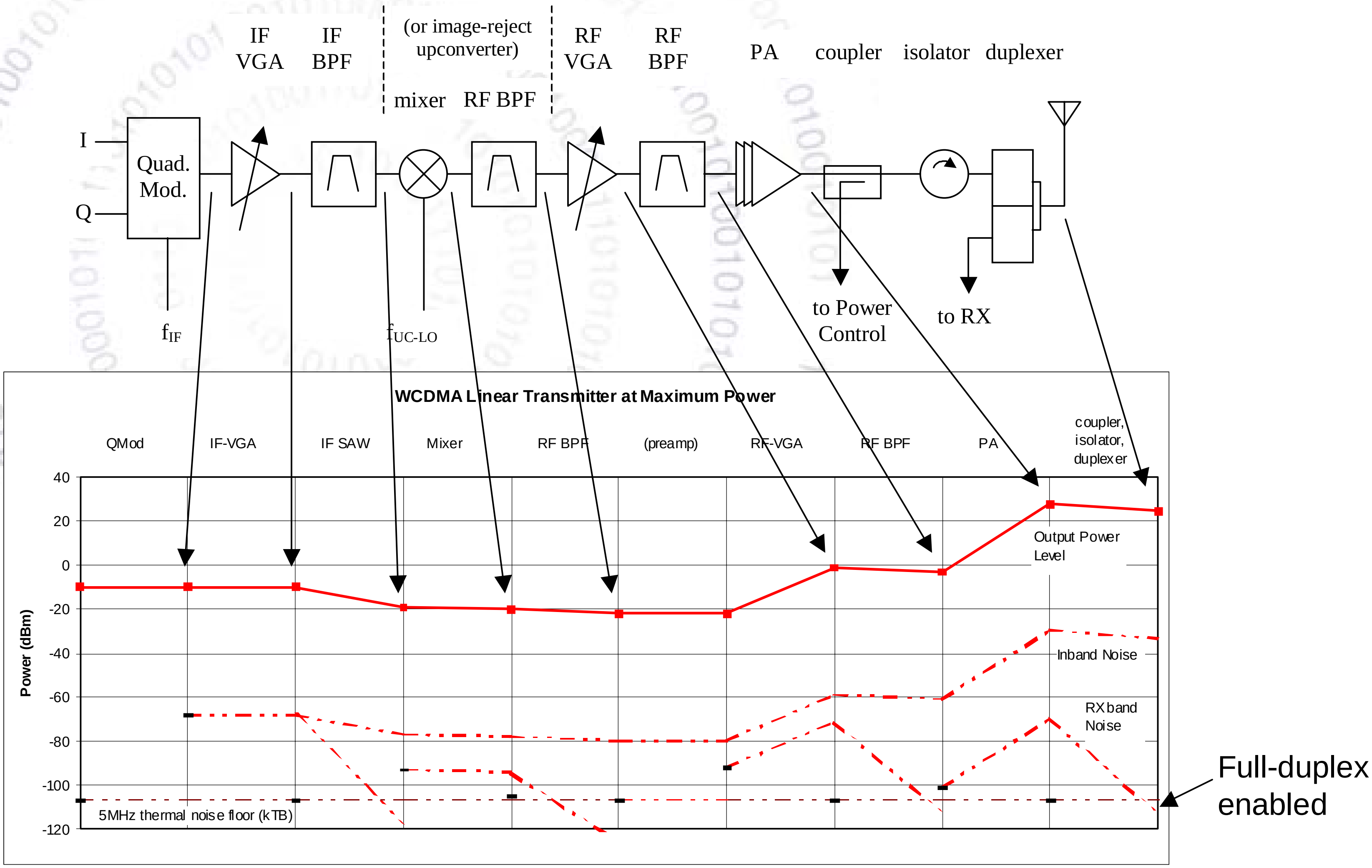
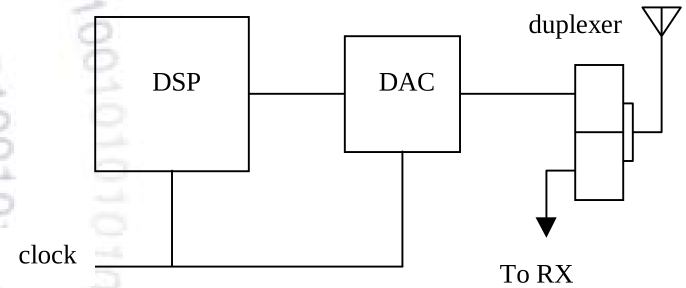
Noise Figure Effects



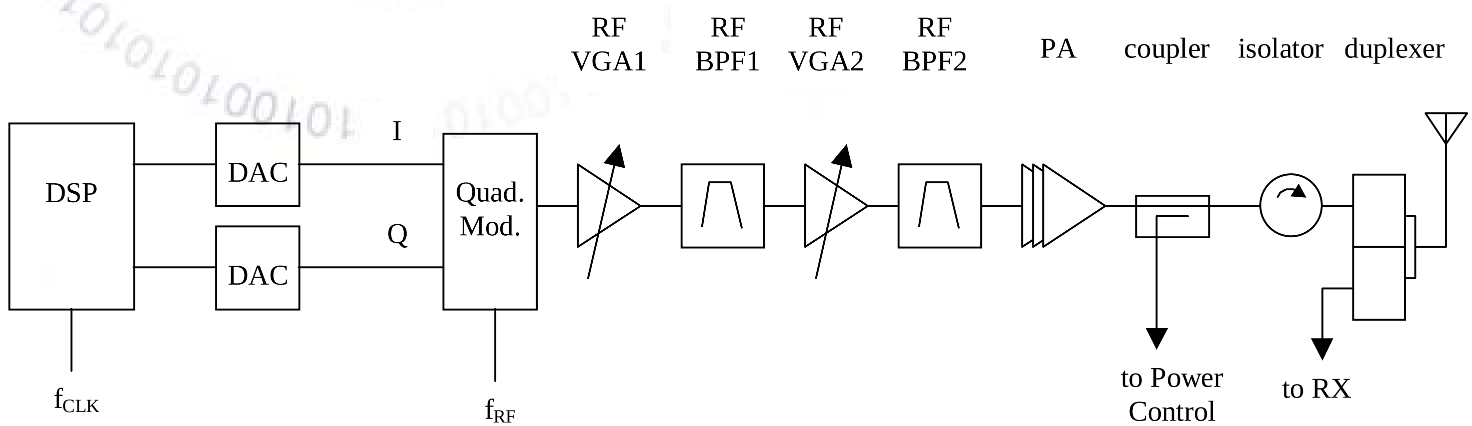
Full-duplex System Operation Drives CDMA Architecture

SDR

- Ideal
  - All signal characteristics defined by the DSP



- ‘practical’ proposals



Moore's Law Doesn't Necessarily Help

- Energy-based signal processing (CMOS)
  - (micro) Joules per operation

$$P_D = \alpha N \cdot CV^2 f$$

- RF is power-based signal processing
  - dBm, dBm/HzBW are the units of measure

$$P_D = V \cdot I$$

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Issues with Conventional Approaches

- Distortion for large signals
- Noise at the bottom end
- NFI for Full-Duplex systems

- There is room for an alternative approach

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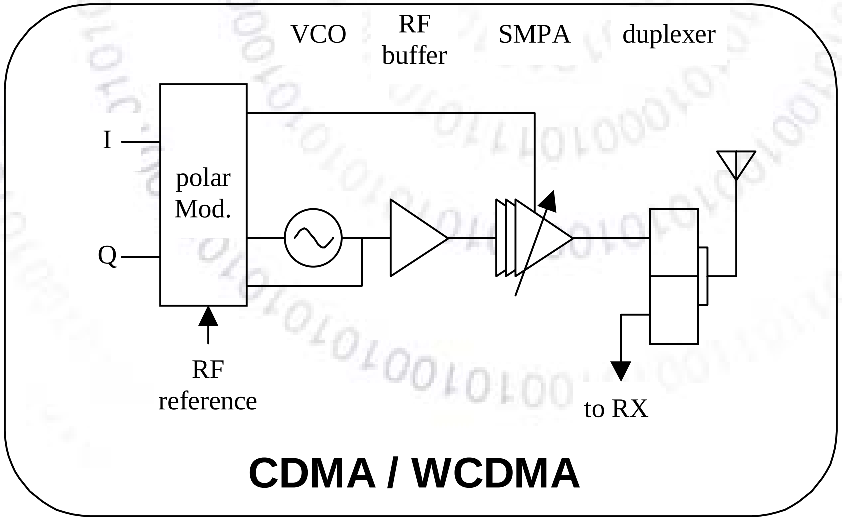
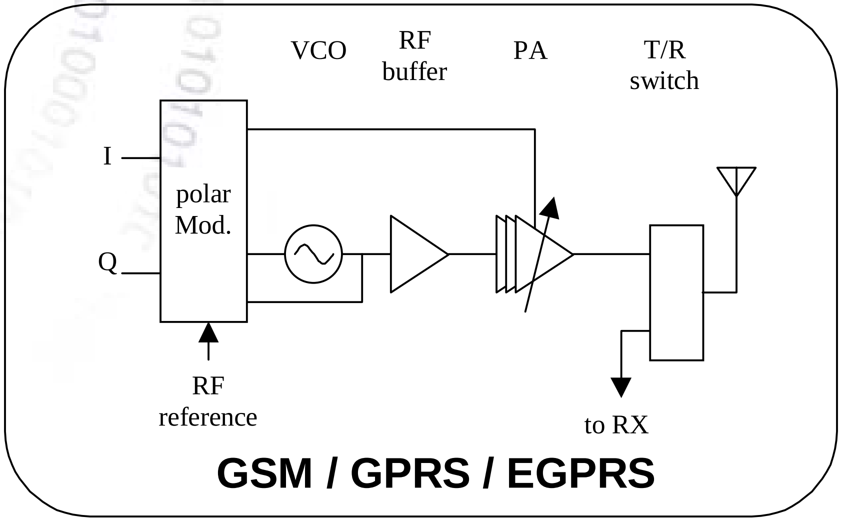
Alternative: Polar Signal Processing

- Reduce/eliminate circuit linearity requirement
- Change to polar coordinate signal processing
- DSP still defines the signal parameters





$$s(t) = A(t)\cos\left(\omega_c(t) + \phi(t)\right)$$

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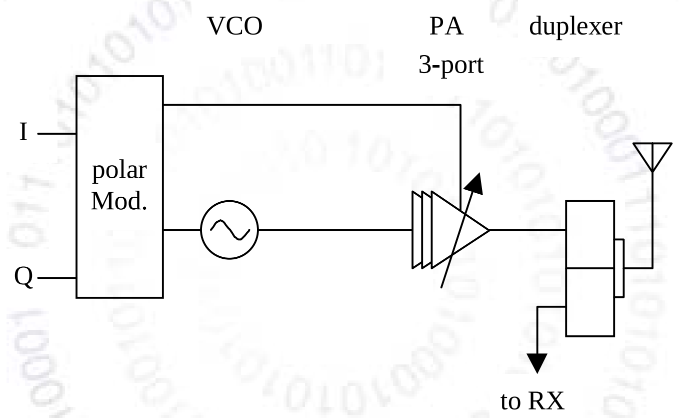
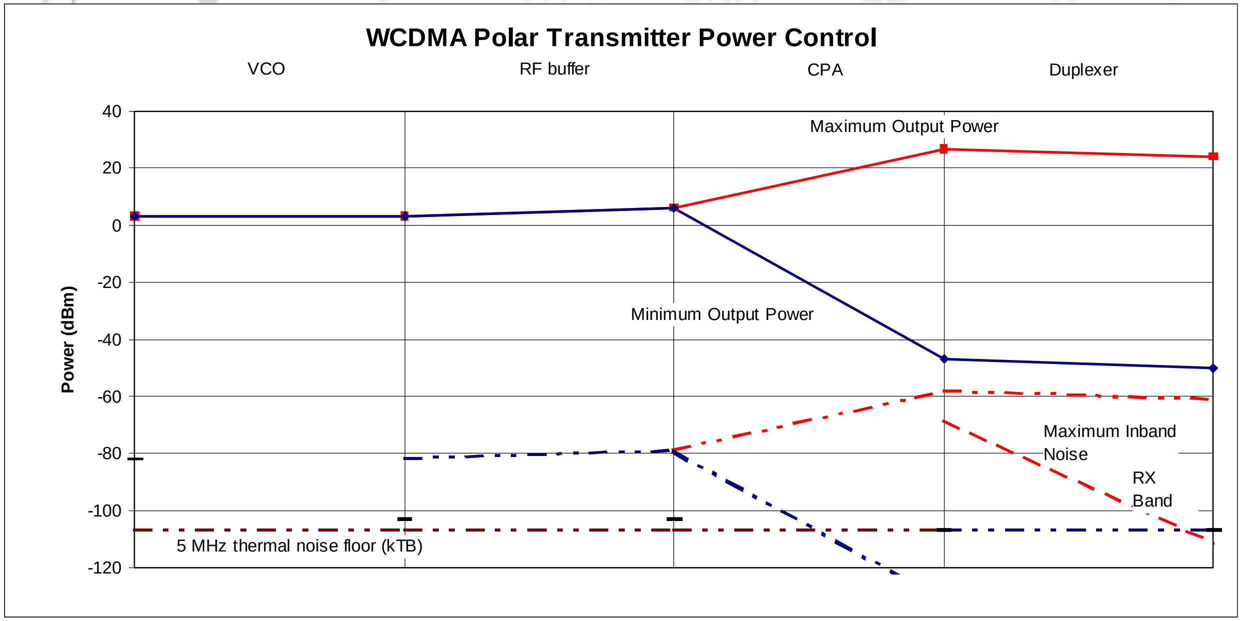
Polar CDMA (General Purpose) Transmitter





- Noise floor set by VCO phase noise
- PA 'gain' is varied
- No requirement for linear RF circuitry
- Duplexer only needed at highest powers for RX noise
- Lower cost potential compared to linear CDMA TX

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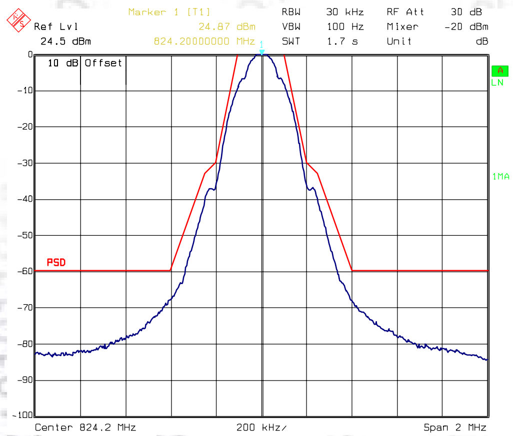
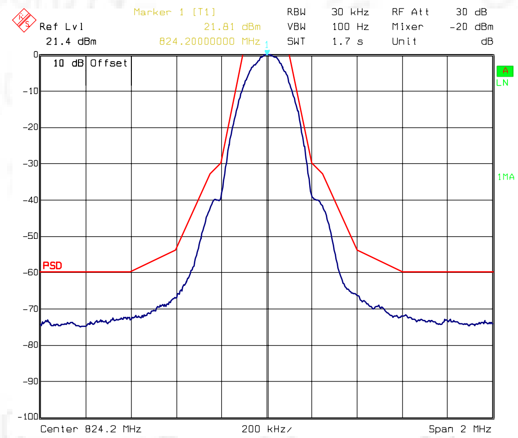
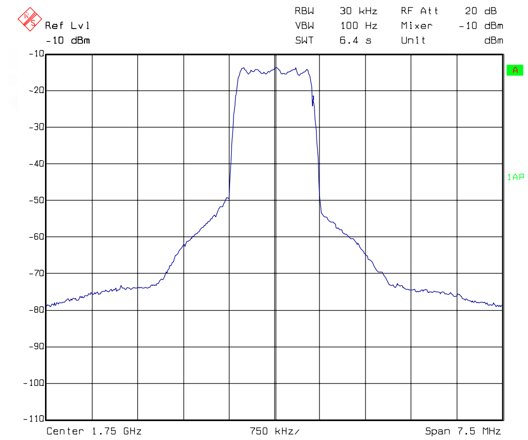
Polar Impact™ Multimode Performance



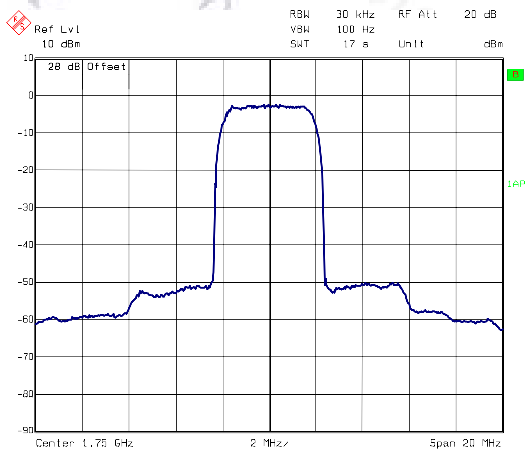
GSM/GPRS



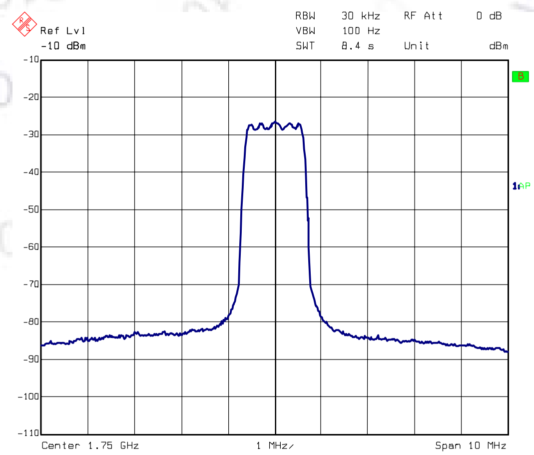
EDGE/EGPRS



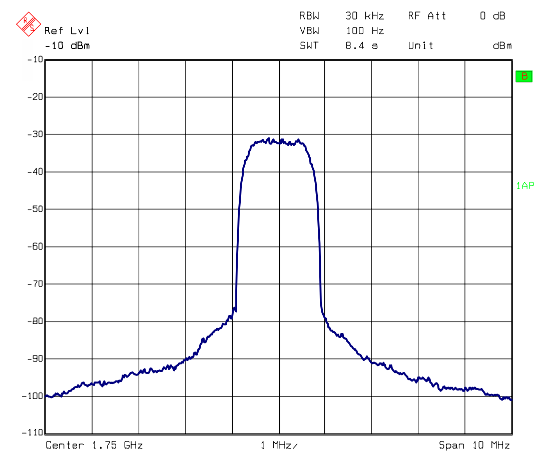
cdmaOne™



UMTS W-CDMA
IMT-2000-DS



cdma2000 1xRTT (RC3)
IMT-2000-MC



UWC-136
IMT-2000-SC

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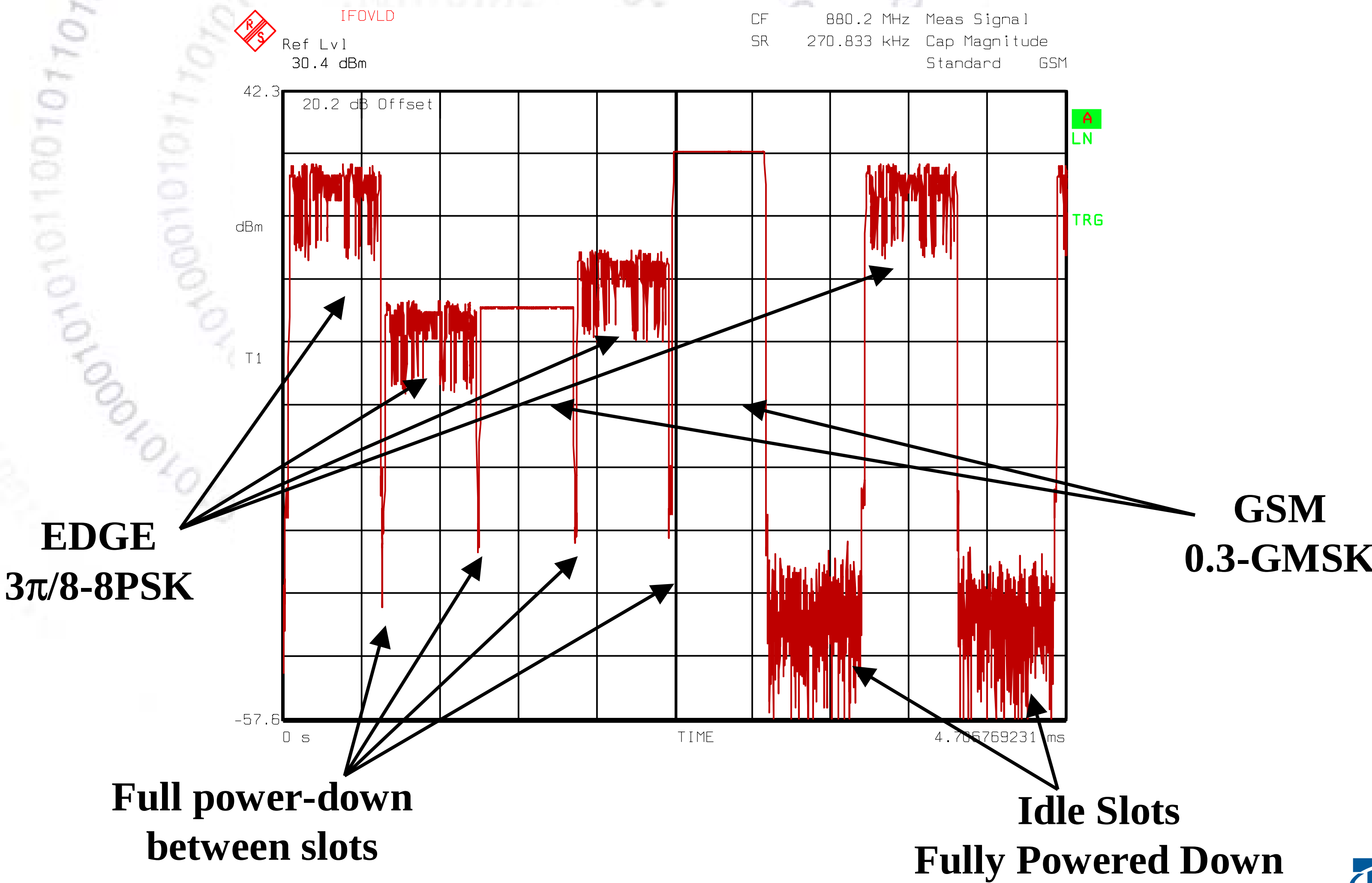
Dynamics - Modulation Agility

Slot-by slot agility between GSM/GMSK and GSM/EDGE



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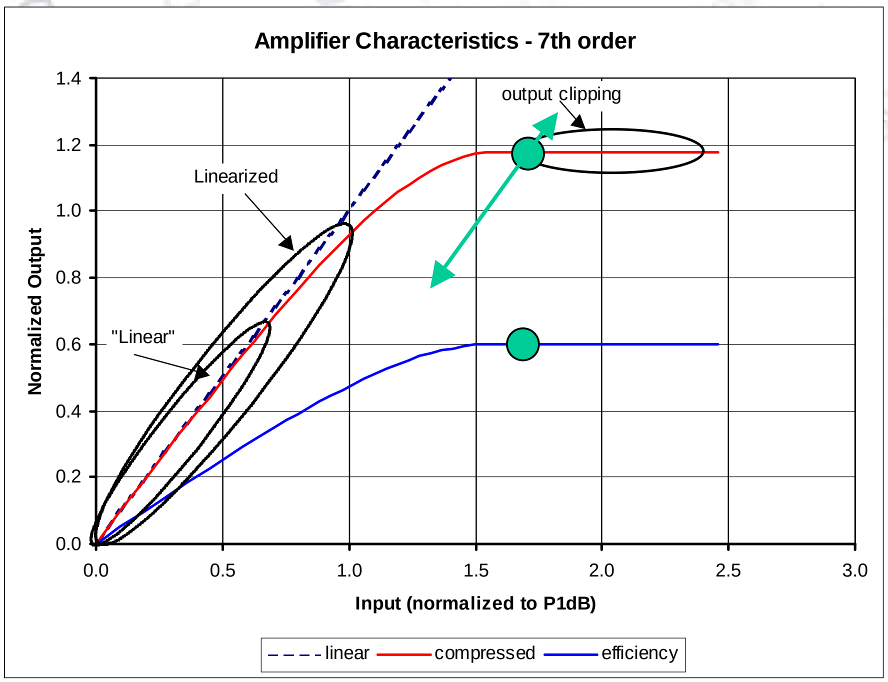
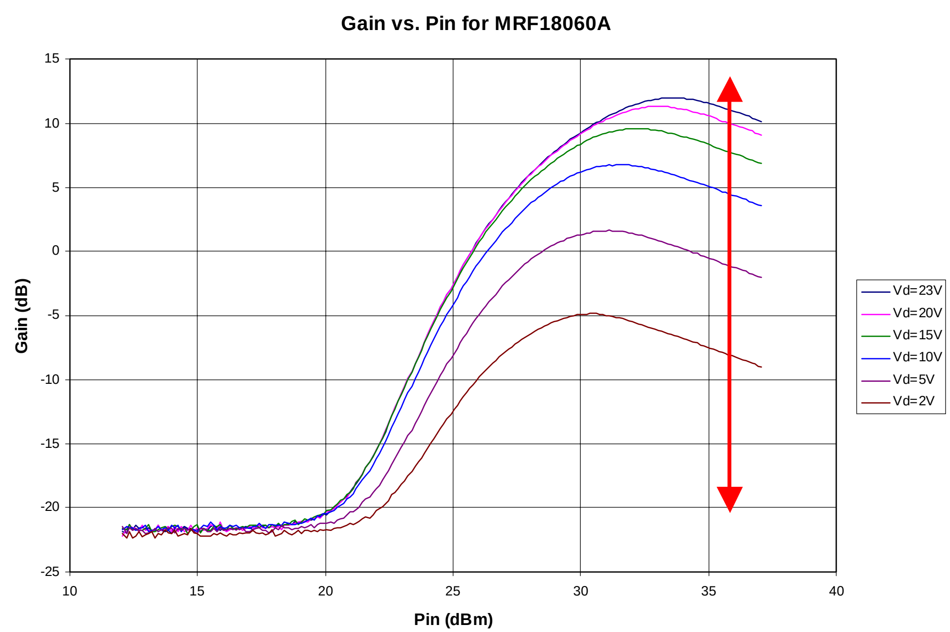
Why Polar Modulation is so different -

- Compressed operation runs RF device near maximum efficiency at all times
- Operates in the 'gain' domain, as a power VGA
- Is peak power limited





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Summary

- Ideal SDR remains impractical for mobile devices
- Linear system/circuit approaches are difficult
  - Large signal distortion
  - Noise on small signals
  - Full Duplex support
- Polar Modulation has some advantages
  - Much lower large signal distortion
  - VCO sets noise floor
- Polar technology readily supports multimode RF
  - GPRS / EGPRS / UMTS / IS-95 / cdma2000 / UWC136 shown on common hardware
  - cost difference from GSM is minimal

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