

# TI Developer Conference

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## Use of Digital Radios for Cost and Size Reduction in Wireless Infrastructure

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Technology for Innovators™

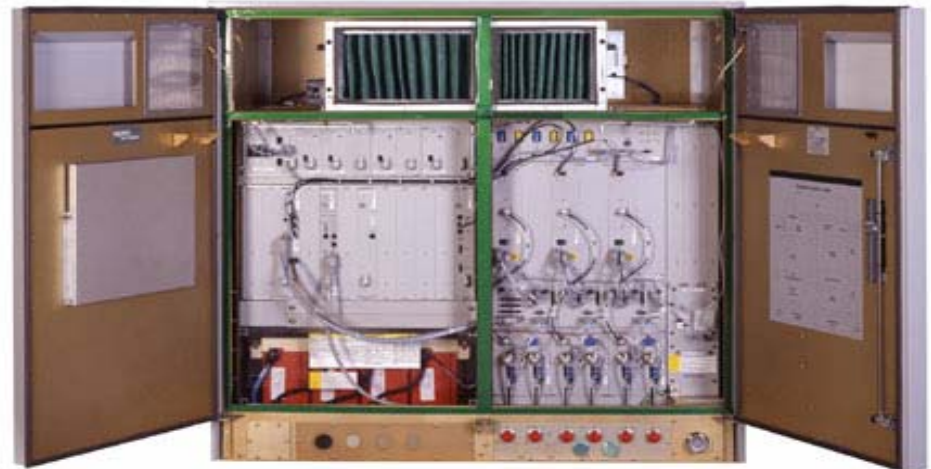
 **TEXAS INSTRUMENTS**

# Agenda

- ◆ Challenges for Wireless Operators
- ◆ Base Station Size Drivers
  - Heat
  - Peak to average
- ◆ Distributed Architectures
- ◆ High Efficiency Amplifiers
  - Common digital radio system
  - Doherty
  - Envelope tracking

# Operator Challenges

- ◆ Falling ARPU means that wireless operators continue to demand Opex and Capex reduction
- ◆ Leasing and electricity costs are significant
  - It takes 2 power stations run the wireless network in Germany
- ◆ The predominant costs (90%) in deploying any Base Station are civil works
  - site survey and negotiation
  - antenna systems and cables
  - power supply
  - permits
  - cost of towers
  - installation
  - housing cabinets
  - backhaul



Courtesy of Alcatel-Lucent

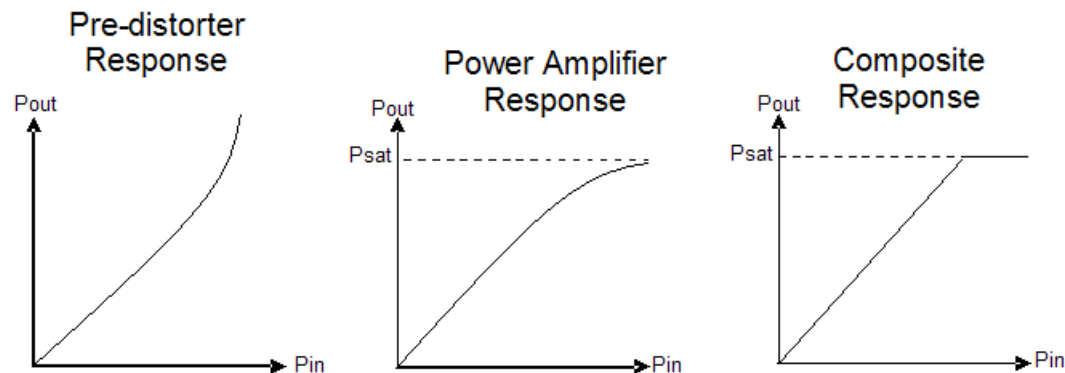
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# Why Are Base Stations So Large?

- ◆ Power amplifiers and heat
- ◆ Typical power efficiency of UMTS power amplifier is 10%
- ◆ 30 watts at output of power amplifier requires 300 watts of DC power
- ◆ In addition requires 100 watt air conditioning to keep cool
- ◆ Add in DC-DC converter efficiency – requires 500 watts per sector
- ◆ Cable loss, filters and TMAs reduce RF power by more than half
  - 500 watts consumed DC power per Amplifier Sector
  - 10 watts useful radiated power
- ◆ Could get worse with higher order modulation schemes
  - 64QAM has higher peak to average than QPSK
  - higher signal peak power means power amplifier operates in lower efficiency region

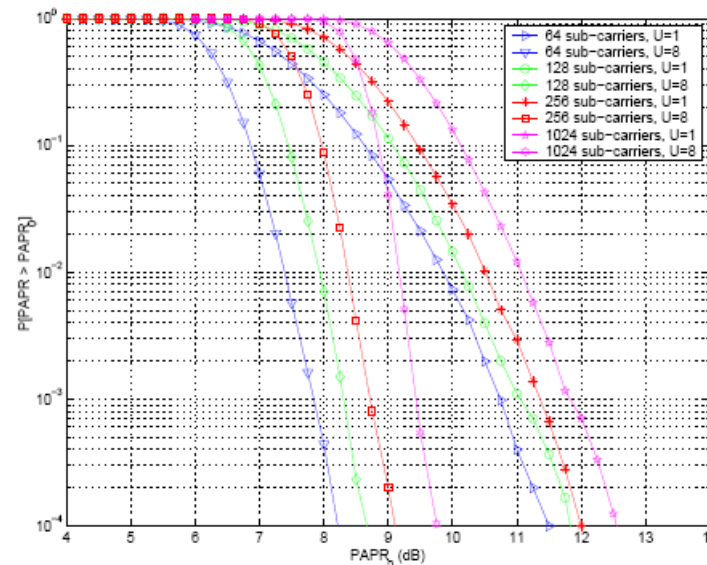
# Amplifier Efficiency

- ◆ Best PA efficiency is achieved as  $P_{sat}$  is approached
- ◆ Linearity degrades as waveform peaks approach  $P_{sat}$ . Poor linearity manifests in degraded EVM and increased spectral re-growth.
- ◆ Minimum EVM and spectral re-growth defined by regulatory bodies
- ◆ Pre-distortion applies a non-linear function prior to the PA which has the inverse response of the PA. The combination of the pre-distorter and power amplifier has a linear response.
- ◆ Pre-distortion allows the PA to operate closer to  $P_{sat}$  and therefore with better efficiency



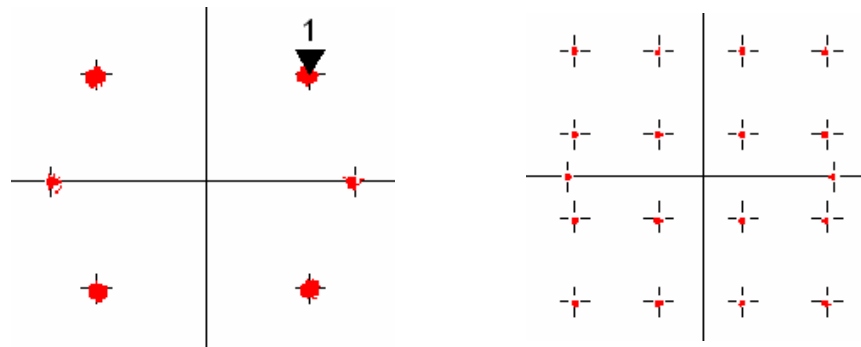
# Peak to Average For OFDM Signals

- ◆ In order to use frequency spectrum more efficiently, modulation schemes need to increase the use of the amplitude within the signal
- ◆ This increases the peak to average of the signal meaning that the power amplifier needs to operate significantly backed off from its optimal efficiency point



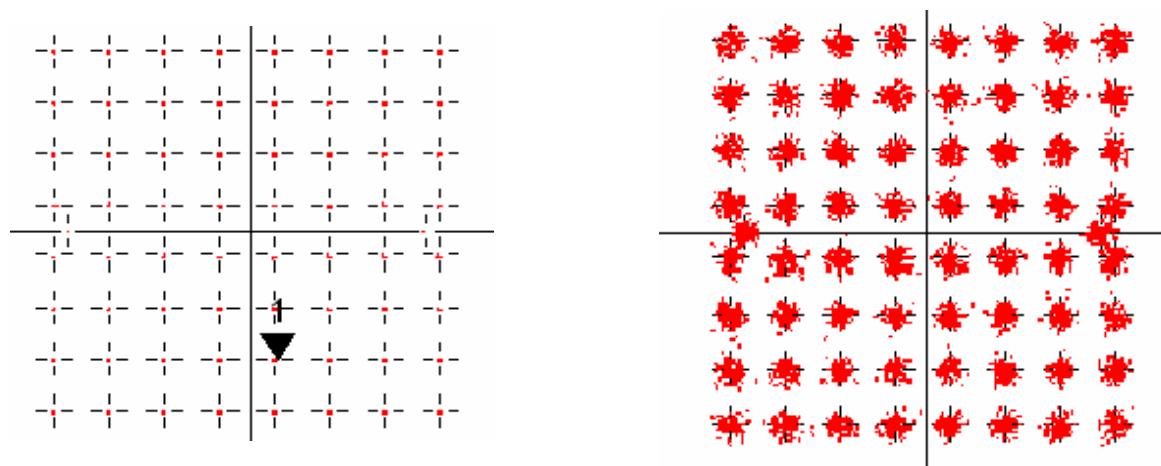
# Peak to Average Reduction

- ◆ The increased peak to average can be reduced by digital signal processing, either in the baseband or in the radio
- ◆ Reducing the peaks of a signal has an impact on the EVM
- ◆ The impact is acceptable for low order modulation schemes



# Peak to Average Reduction

- ◆ But not so acceptable for higher order schemes.....



- ◆ Hence QPSK can tolerate 17% EVM, whereas 64QAM can only tolerate 2%

# Signal Processing Can Help

- ◆ Higher modulation schemes require bigger amplifiers and more power
- ◆ Algorithms in the digital domain can reverse the trend
- ◆ Analog problem requiring a digital solution
- ◆ Use digital silicon to reduce analog silicon
- ◆ The prize is significant.....

# Distributed Basestation Architectures

- ◆ If the efficiency of amplifier can be increased then the radio and amplifier can be moved to the antenna
- ◆ This eliminates cable loss – requires amplifier to radiate only 10 watts directly into antenna
- ◆ With efficiencies of 30% the amplifier consumes only 30 watts
- ◆ It is possible to reliably convection cool this level of power in a heatsink weighing 30 lbs (one man installation)
  - Lightweight deployment (lower civil works costs)
  - Lower cost deployment (more leasing options)
  - Lower running costs (electricity consumption reduced 5 fold)

# How to Achieve High Efficiency

- ◆ Doherty amplifiers
  - Peaking amplifier
- ◆ Envelope tracking amplifiers
  - Dynamic adjustment of bias current
- ◆ Both techniques add non-linearities onto the signal
- ◆ Require digital predistortion to linearise signals
- ◆ When combined with crest factor reduction efficiencies of 30% can be achieved now
- ◆ Efficiency  $\propto$  Reliability  $\propto$  Power
  - Higher efficiency gives higher reliability or higher power

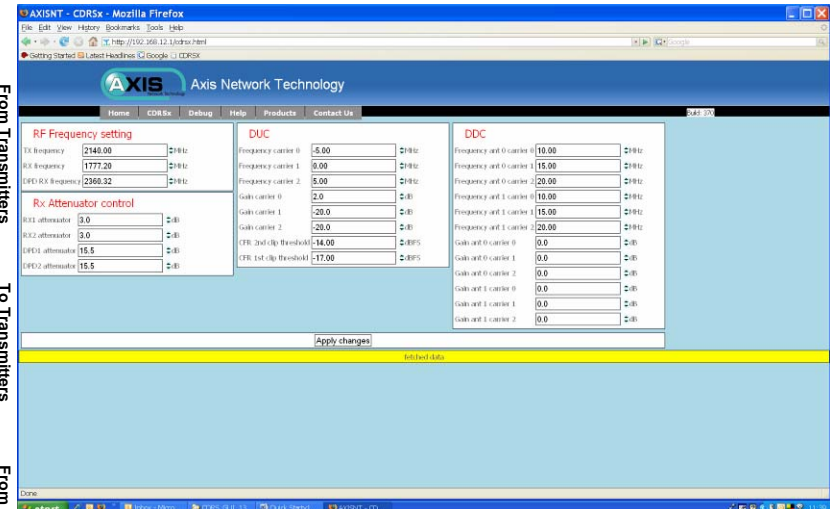
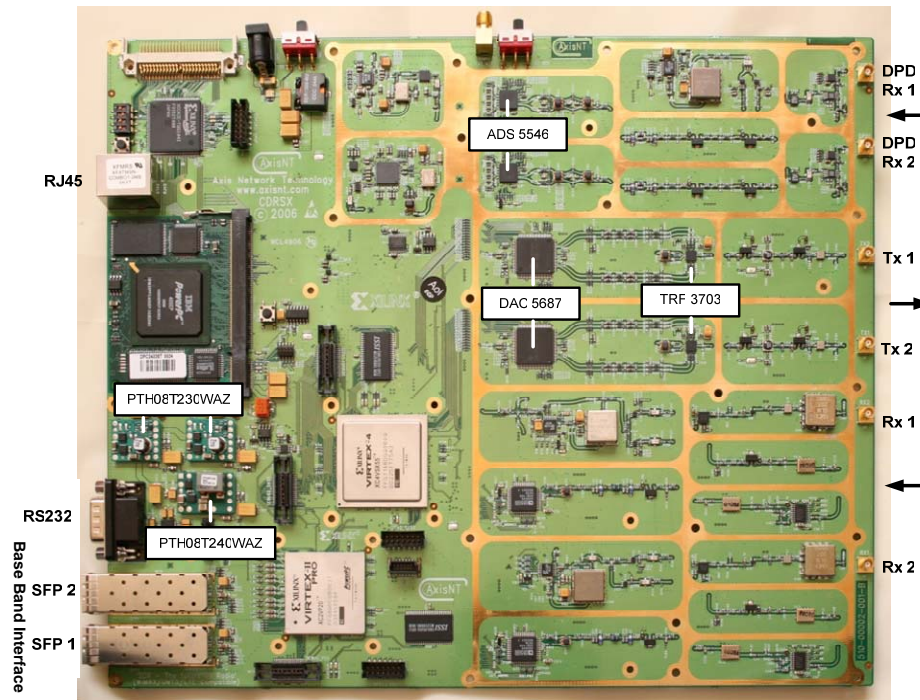
# Drive For Higher Efficiency

- ◆ Axis Network Technology have created a test and development board to allow the techniques to be trialled and optimised
- ◆ This development platform capitalizes on Texas Instruments complete portfolio of analog front end solutions, optimized for wireless infrastructure solutions
- ◆ The CDRS uses the latest 400MHz to 4GHz direct IQ modulator from TI, TRF3703. The modulator combined with the high performance DAC5687, enables direct up-conversion, supporting wide bandwidth transmitter frequency ranges without redesign
- ◆ In addition, the CDRS uses TI's ADS5545 14-bit 190 MSPS ADC as the digital pre-distortion receiver

# Common Digital Radio System

- ◆ CDRS (Common Digital Radio System) offers customers a sophisticated digital radio development environment with a comprehensive set of standards based interfaces and features. The product is focused on providing quick and simple solutions to customers needs for a development, prototyping and test platform as well as volume production solutions
- ◆ I/Q to RF - End to End Radio Solution
- ◆ CPRI & OBSAI Enabled
- ◆ Direct Base Band Integration option
- ◆ Wide Frequency 400 MHz to 4 GHz
- ◆ MIMO Enabled
  - ◆ -2 channel MIMO as standard
  - ◆ -4 channel MIMO capable
- ◆ Complete RF Module Management Capability
  - ◆ -Digital Pre Distortion
  - ◆ -Drain Modulation
  - ◆ -Crest Factor Reduction
- ◆ Complete Signal Processing Suite - UMTS / CDMA / WiMAX
- ◆ Easy to Access and control - Web & Matlab Interface

# Common Digital Radio System

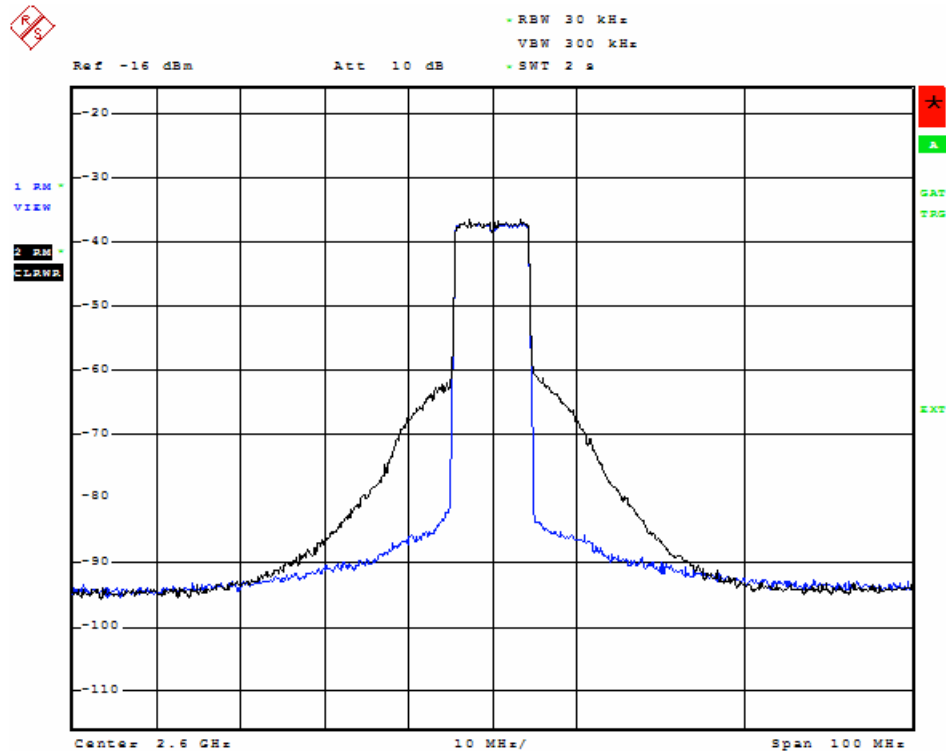


Packaged Product

# Doherty Power Amplifier (PA)

- ◆ Doherty PA Architecture desirable to improve efficiency
- ◆ Doherty provides up to approx. 10% efficiency improvement over AB architecture
- ◆ In general, Doherty configuration results in degraded linearity and 'softer' compression characteristic. Results in degraded EVM and ACLR performance compared to class AB.
- ◆ If main and peaking amplifiers in Doherty configuration are equally biased Doherty configuration reverts to class AB
- ◆ When combined with DPD and CFR the peak power (and cost) can be significantly reduced

# Doherty Power Amplifier



- ◆ 41.25 dBm Burst Power
- ◆ 45% Duty Cycle
- ◆ Final stage efficiency 30%
- ◆  $P_{in} = 31$  watts (including driver stage)

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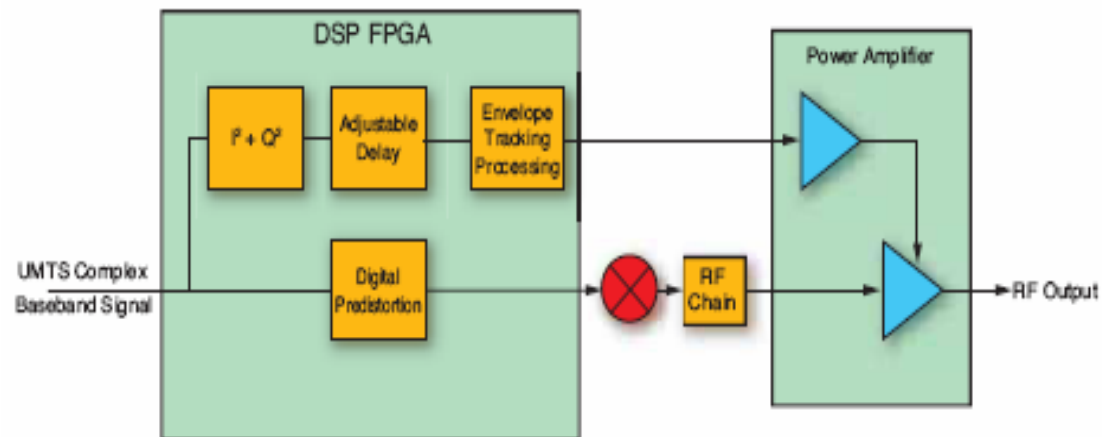
# Doherty versus AB Efficiency



- ◆ Doherty configuration provides 10% better efficiency than class AB.
- ◆ Doherty configuration provides 20% better efficiency than non-predistorted amplifiers
- ◆ 30% can be achieved with 10dB peak to average

# Envelope Tracking

- ◆ Envelope tracking amplifiers use a variable voltage power supply which is dynamically adjusted to track the envelope of the applied modulation. The amplifier always operates in mild compression, even at reduced output power, and this greatly improves the average efficiency.
- ◆ Nujira states they can support three WCDMA carriers while achieving power efficiencies approaching 50%



# Vision

- ◆ 10 watts at antenna is required for balanced links
- ◆ Transmit diversity is critical for OFDM-based systems
- ◆ 2 x 10 watt remote heads are ideal product
- ◆ With 50% efficiency remote head MTBF of >400,000 hours can be reached
- ◆ Capex and Opex reduction for operators of reliable remote heads is enormous
  - 80% reduction in electricity costs
  - 60% reduction in leasing costs
  - 50% reduction in civil engineering costs
  - 100% reduction in cable costs

# Conclusion

- ◆ Higher order modulation schemes require enhanced digital signal processing algorithms to minimize peak power requirement
- ◆ DPD is fundamental to enabling high efficient power amplifiers
- ◆ Increasing the efficiency of power amplifiers has multi-level pay back in both Capex and Opex
- ◆ With highly efficient amplifiers, convection cooled, one man lift, reliable remote heads can be deployed
- ◆ Significant development effort is required to increase efficiency
- ◆ TI based AXIS<sup>®</sup> digital radio is ideal platform for developing and enhancing high efficiency techniques
- ◆ TI based AXIS digital radio is being used for development of digital signal processing algorithms



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