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High Performance Amplifier Solutions for LTE and Beyond

RAN Evolution Challenges, coverage and capacity

- High data rates in wireless networks will reach theoretical limits (Shannon Theorem)
  - Necessitates better interference management, more complex equipment
- MIMO
  - Increased demand of processing power
  - Increased antenna, antenna networks, site clutter (2X2, 4X4, Active Antenna)
- OFDM
  - Increased heat dissipation, High Peak/Average ratios
  - Higher frequencies (2.5, 3.5 GHz, etc…)
- In-building is extremely important (50% users are indoor)
  - 2X data rate = 50 % more Base stations!
  - Location of terminals determines BTS density
- Larger BWs of Operation
- Extreme pressure in both commercial and military communications for lower pricing, Lower OPEX

Markets for Communication Amplifiers

Military Market Drivers

- Military Communications
  - SDR Inter-operability, multi-standard, high BW
  - Portable and mobile platforms
  - Integrated Datalinks (voice/data/video)
  - COTS, lower cost

Military Comms Market Size: 15.2 Billion
(asdreports.com)

BTS Market Drivers

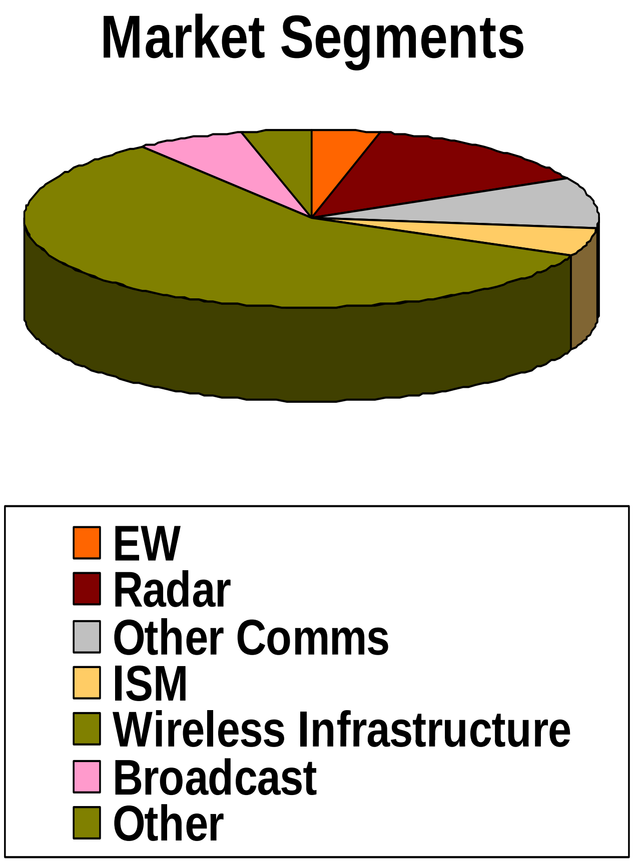
- Lower Cost, High Reliability
- Remote Radio Heads
  - eliminate Losses
  - DAS In/building systems
- Improved BTS efficiency
  - reduced OpEx costs

•**Mobile Telecom Market Size: 40 B** (reuters.com)

Amplifier Semiconductor Market Breakdown

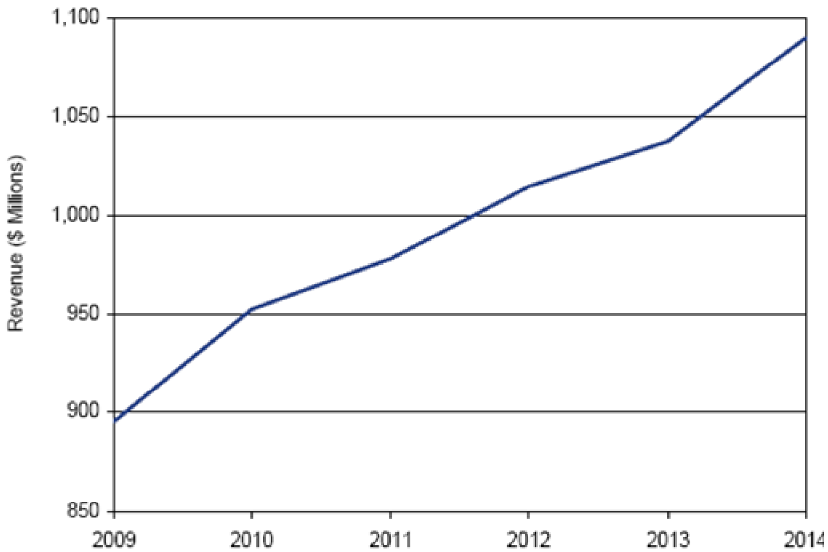
- Market Size by Revenue

- EW = $37M (4%)
- Radar = $130M (14%)
- Other Comms = $87M (9%)
- ISM = $50M (5%)
- Wireless Infrastructure = $550M (58%)
- Broadcast = $60M (6%)
- Other = $36M (4%)
-
- Total = $950M
  - Source: ABI

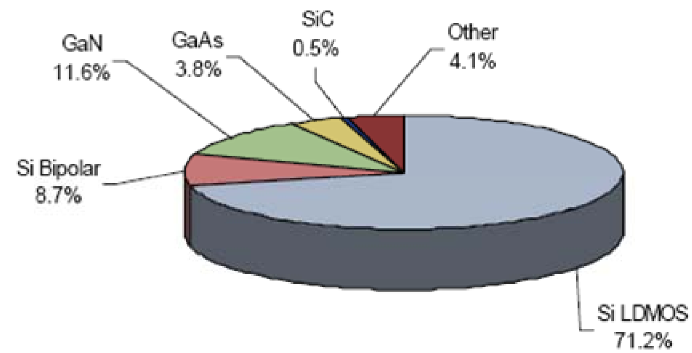


Power Transistor Market Analysis

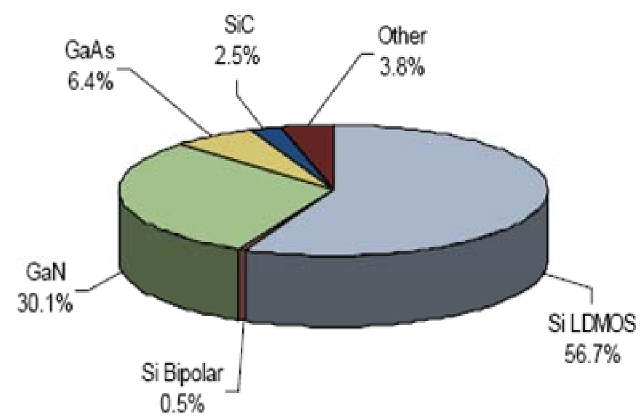
- Total RF Power Device Revenue



- Market Share by Technology - 2009

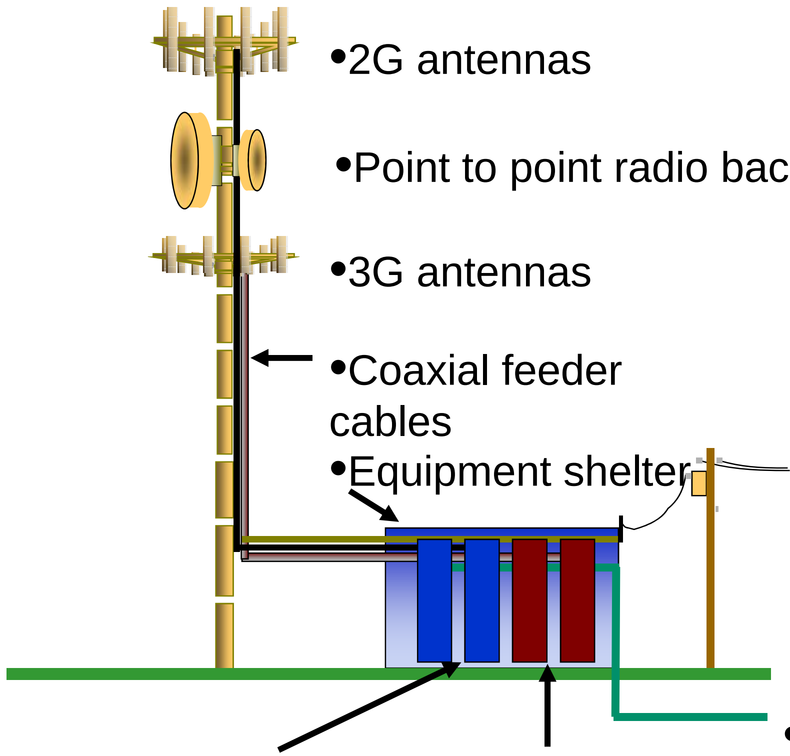


- Market Share by Technology - 2014



- Source: ABI Research

W-CDMA cell site efficiency



Cell site efficiency $= \dfrac{P_{RF}}{P_{DC}}$

~ 5%

- **Efficiencies**
- Transistor: 45- 50%
- PA : 30%
- Site : 5%

Need for Efficiency

•Operators target 50% reduction in their power consumption by 2020

•Increase overall base station efficiency

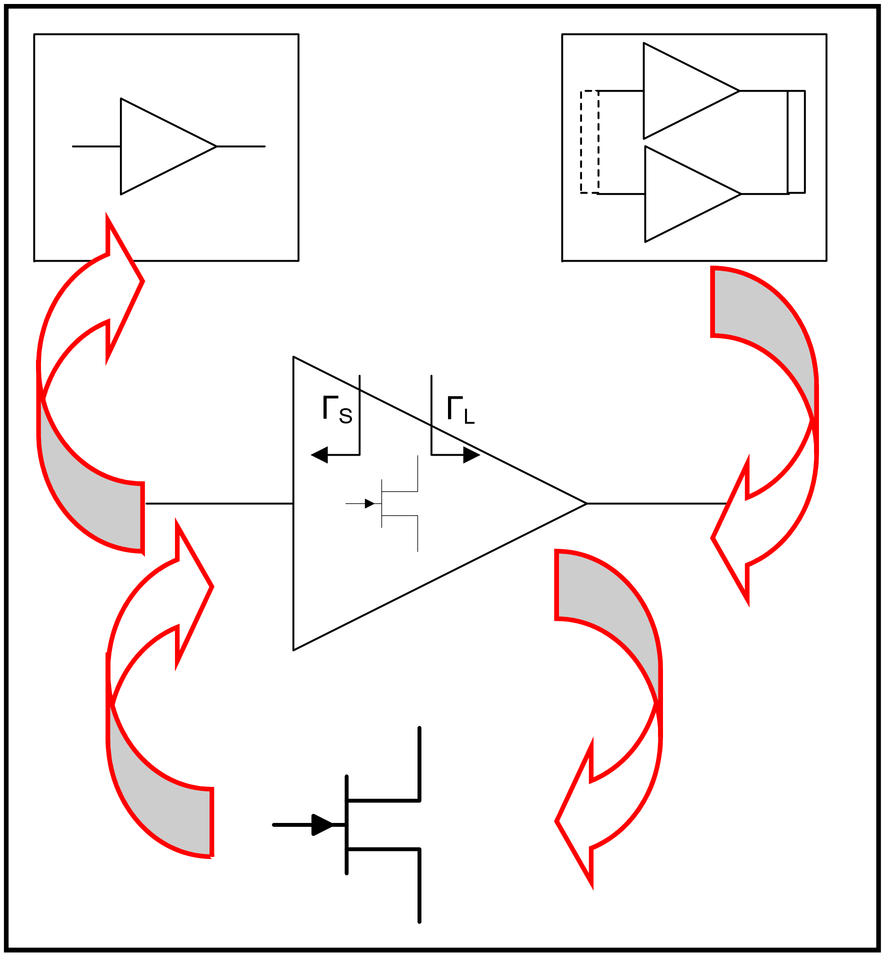
•Improving the
•QoS/RF power ratio

•Scaling of energy needs with traffic

•Increased PA efficiency
•will substantially contribute to power consumption reduction

•The remaining of the targeted 50% reduction

Design Approach



System level:

☞Single or multi-branch architectures: Doherty, drain modulation, predistortion

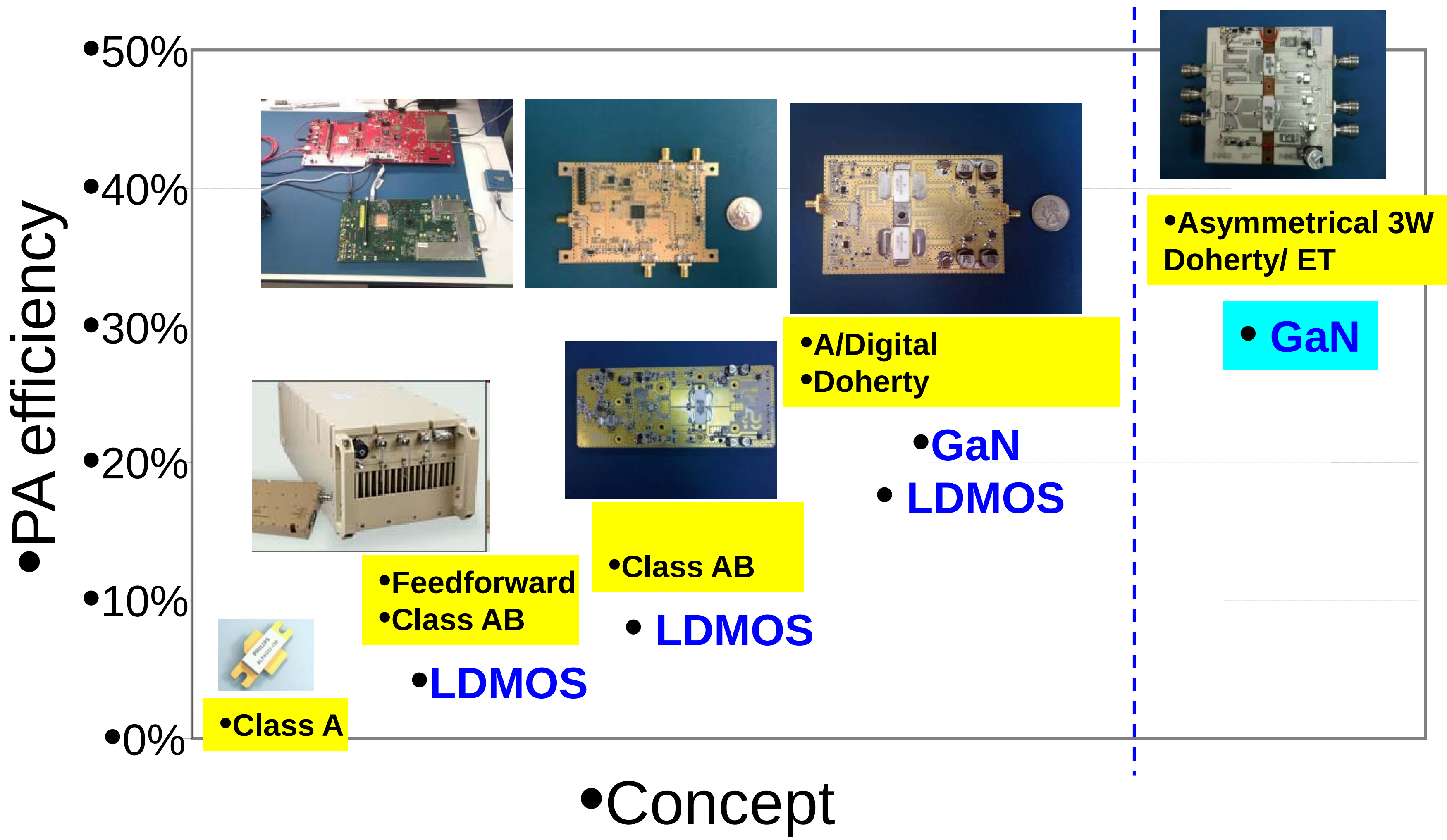
Circuit level:

☞PA class of operation: A, AB, B, C, F, E, S…

Device level:

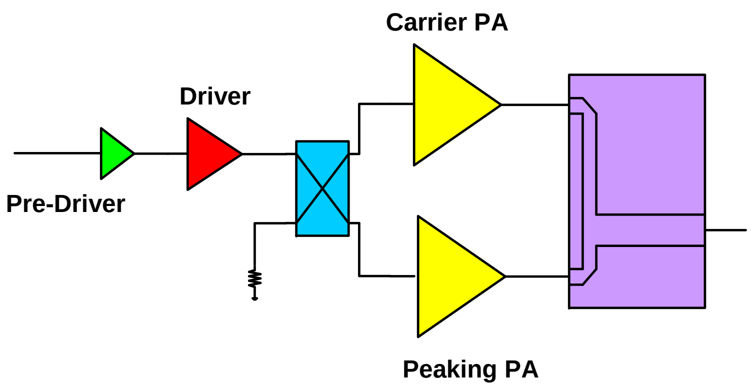
☞Transistor technology: GaN, LDMOS, HBT etc…

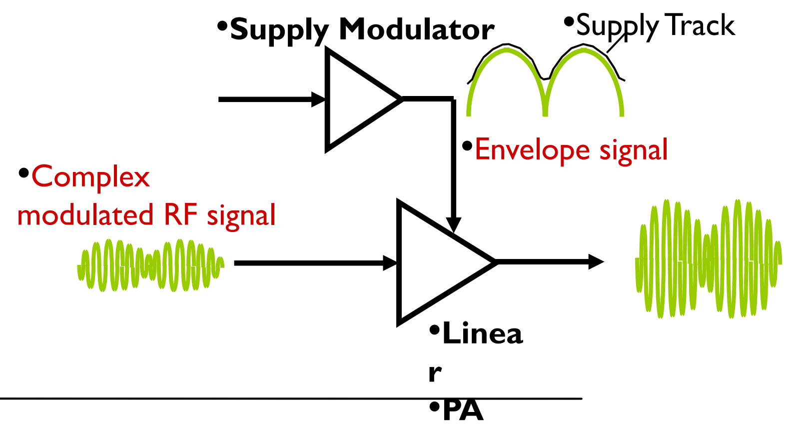
•Amplifier Architectural Roadmap

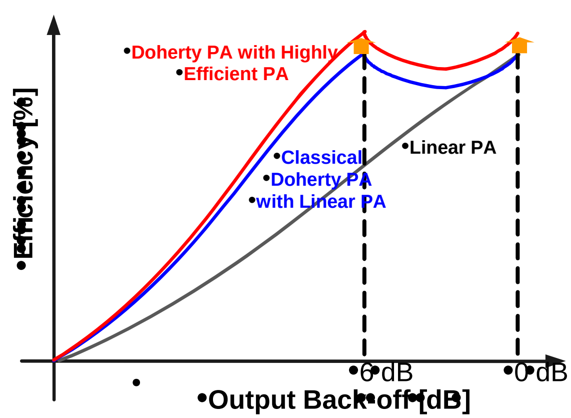


Highly Efficient Transmitters

- **Doherty PA**
- **Envelope Tracking**







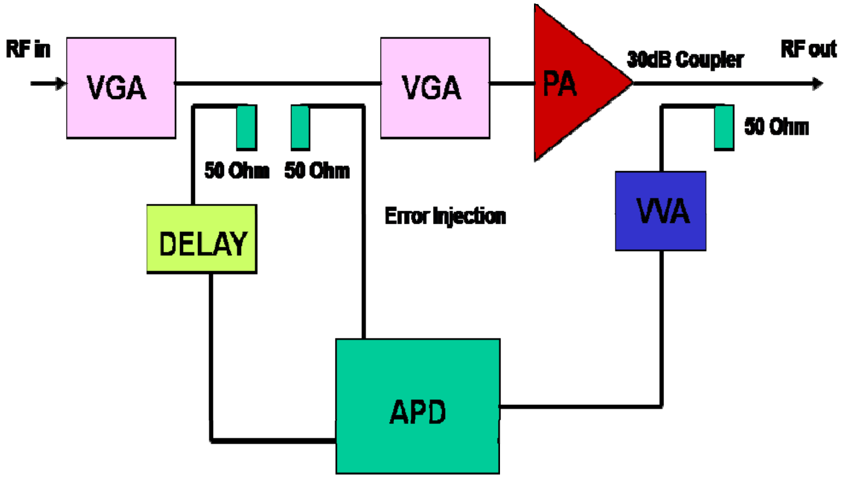
$$\eta_{EER/ET} = \eta_{SM} \times \eta_{PA}$$

η_{SM} : Efficiency of Supply Modulator

Analog Predistortion (APD)

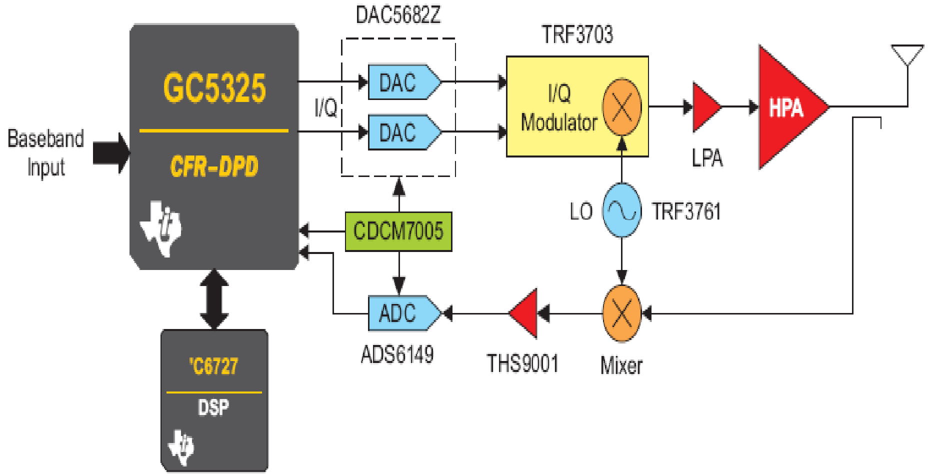
- Large input BW (60 MHz)
- RF in/out
- Large linearization BW (300 MHz)
- Low-Moderate distortion suppression (> 8-20 dB)
- Potential for high system efficiency (25-30%, or higher)
- Low cost
- Lower complexity than DPD
- A good choice for applications in which the PAM is not highly nonlinear and exhibits low memory effects
- Low Power consumption

•APD Basic Block Diagram



Digital Predistortion (DPD)

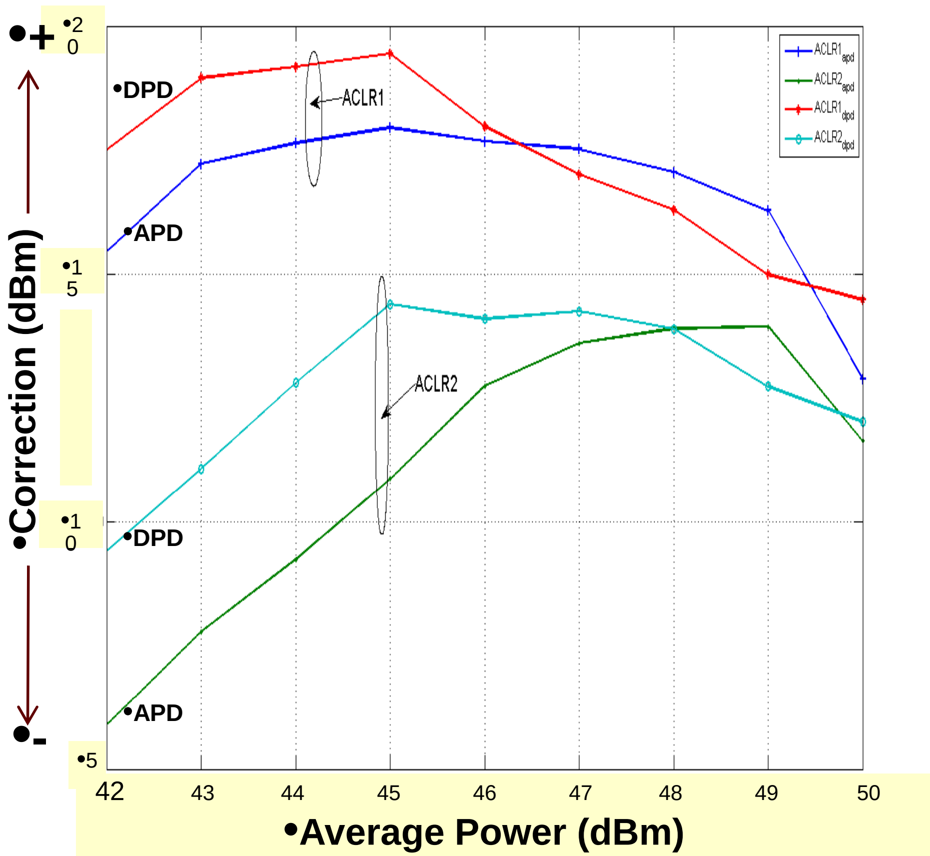
•DPD Basic Block Diagram



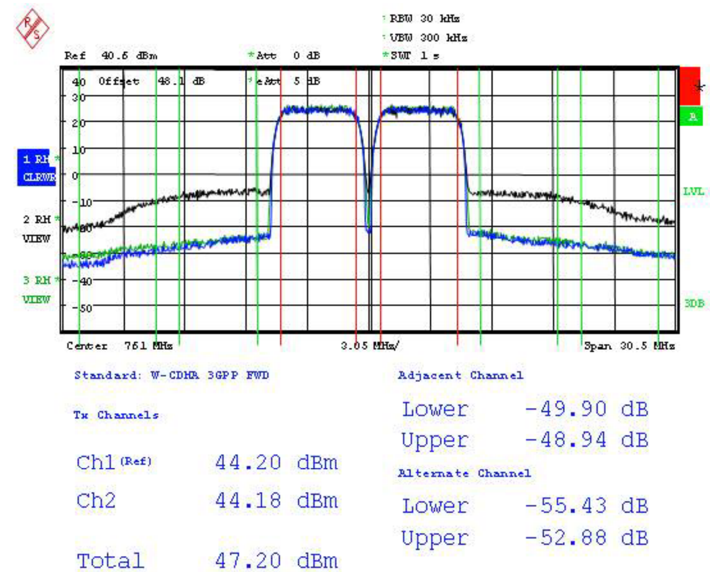
- Moderate input BW (20 MHz)
- Moderate linearization BW (100 MHz)
- Potential for large distortion suppression (> 25 dB)
- Potential for moderate system efficiency (20-25%)
- Better linearization performance at the expense of higher complexity and cost
- For some applications the only solution that combines adequate correction and signal BW

Performance comparison: APD vs. DPD correction

0110 WCDMA 8 dB PAR



• **50W Amplifier**



- Pout = 47 dBm. F = 761 MHz. PAM Efficiency = 46%
- APD and DPD IMD suppressions at this power were similar (about 1 dB difference)

Typical Radio Head Efficiency Budget

#TX/RX paths			RF drivers (W)	PA out rms (W)	PA isol etc. (dB)	filter (dB)	Out (W/path)
2			8	24.9	-0.35	-0.6	20
DC/DC efficiency (%)		Freq (MHz)	PAPR (dB)	Final stage PA eff (%)			RF out (W)
89%		2100	7.0	**50%**			40
General Interface control power (W)	linearization (W/path)	LNA/VSWR (W/path)				power consumed (W/path)	total power consumed (W)
15	12.5	2		49.8		81	179
						RH efficiency (%)	**22.3%**
						Power dissipated (W)	139

2TX/2RX RRH 20W per TX

Typical Radio Head Efficiency Budget

#TX/RX paths			RF drivers (W)	PA out rms (W)	PA isol etc. (dB)	filter (dB)	Out (W/path)
2			8	24.9	-0.35	-0.6	20
DC/DC efficiency (%)		Freq (MHz)	PAPR (dB)	Final stage PA eff (%)			RF out (W)
89%		2100	7.0	60%			40
General Interface control power (W)	linearization (W/path)	LNA/VSWR (W/path)				power consumed (W/path)	total power consumed (W)
15	12.5	2		41.5		72	161
						RH efficiency (%)	25%
						Power dissipated (W)	121

2TX/2RX RRH 20W per TX

- IMPROVED PA EFFICIENCY

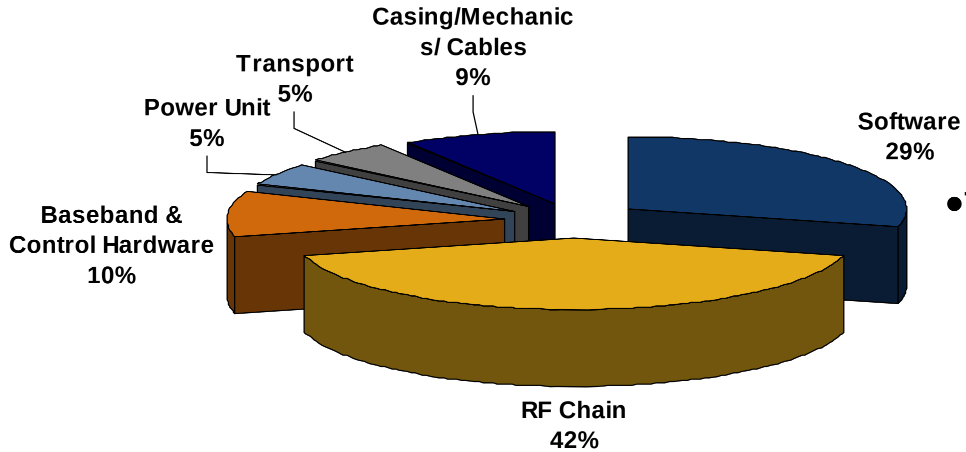
Typical Radio Head Efficiency Budget

#TX/RX paths			RF drivers (W)	PA out rms (W)	PA isol etc. (dB)	filter (dB)	Out (W/path)
2			8	24.9	-0.35	-0.4	20
DC/DC efficiency (%)		Freq (MHz)	PAPR (dB)	Final stage PA eff (%)			RF out (W)
89%		2100	7.0	50%			40
General Interface control power (W)	linearization (W/path)	LNA/VSWR (W/path)				power consumed (W/path)	total power consumed (W)
8	10	2		47.5		76	161
						RH efficiency (%)	25%
						Power dissipated (W)	121

2TX/2RX RRH 20W per TX

- **IMPROVED FILTER CONTROL AND DPD OR APD**

Efficiency is not everything

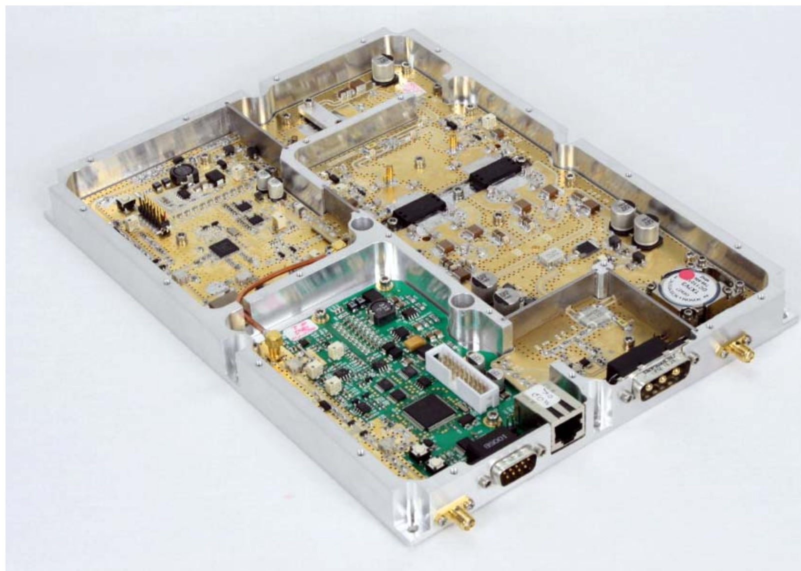


- Typical Comms system cost breakdown

- **Equipment cost is often biggest concern**
- **MTBF , ease of installation**
- **Remote maintenance and configuration**
- **Upgradeability**

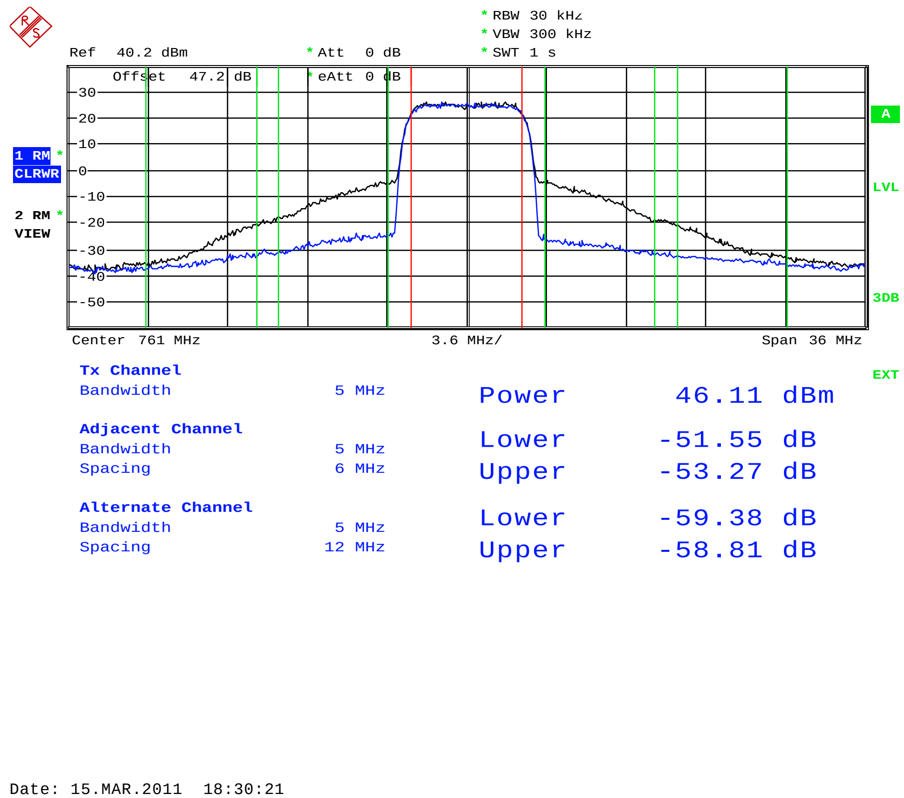
Showcase: 750 MHz LTE Amplifier

- **Reliable, Low Cost, High Performance**



Performance summary 700 MHz HE PA– LTE

Pout (dBm)	Signal	PAR (dB)	Correction (dB)	Eff (%)	Corrected Linearity (dBc) ACLR1/ACLR2
46	010 LTE **Fc = 761 MHz**	8	20	33	-51.55/ --58.81
47	010 LTE **Fc = 761 MHz**	8	22	37	-51.22/ -57.73
48	010 LTE **Fc = 761 MHz**	6.5	23	40	-52.11/ -58.15



Summary

- Cost, efficiency, reliability are key to both commercial and military communications markets
- Wide Bandwidths, multiple standards operation are driving more challenging designs
- Compact size and portability are key in tactical radios
- Advanced Spread Spectrum techniques will only make matters more difficult
- Amplifiers are moving to the antenna