Power Amplifiers for Wireless Handsets PAE vs Linearity and Talk Time

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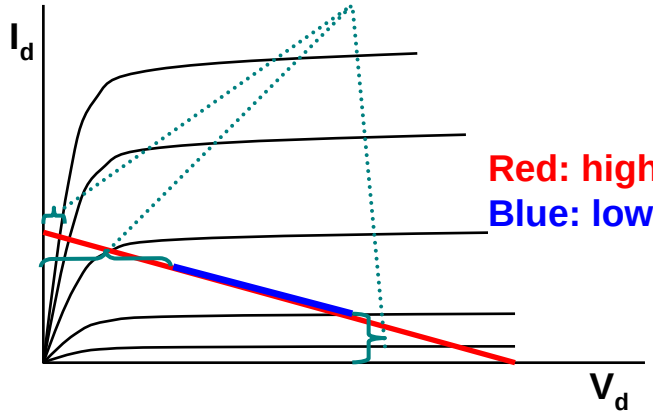
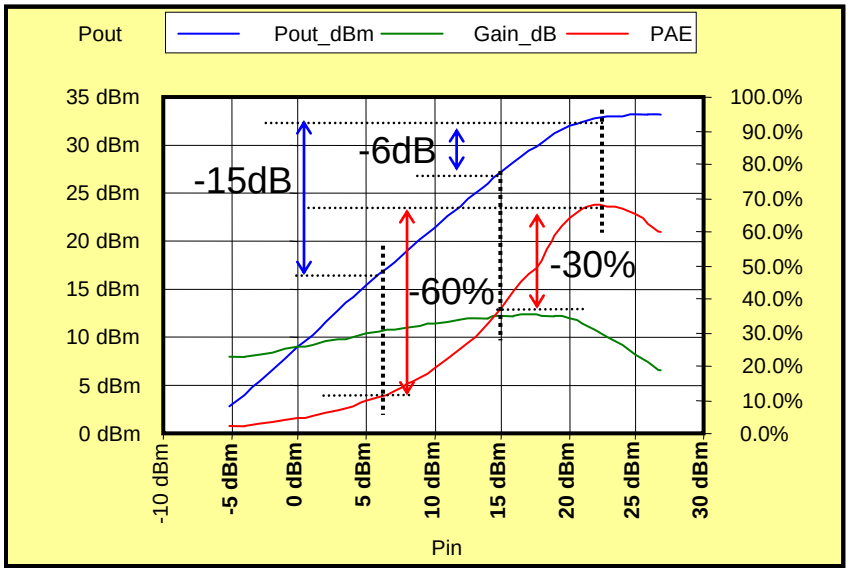
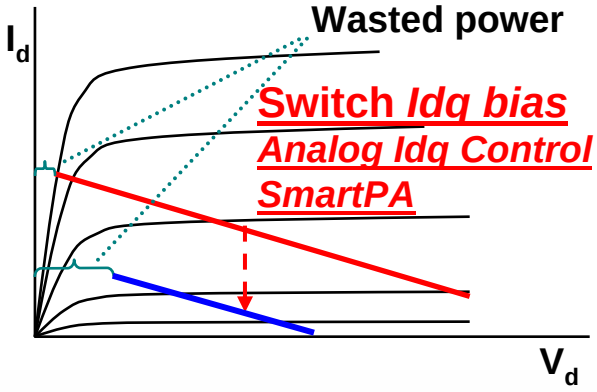
Conventional Options - To Improve PAE at Mid and Low Power Levels

Wasted power at Smaller Signal Swing

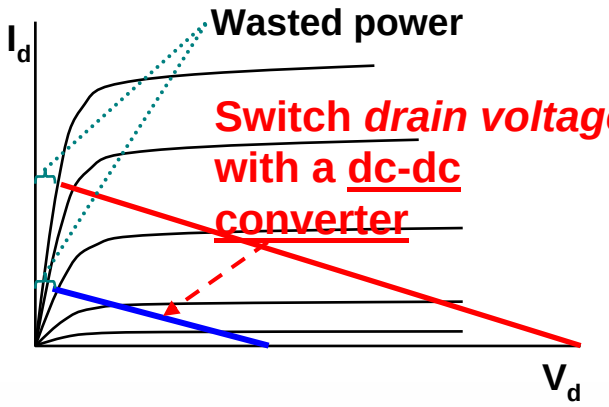




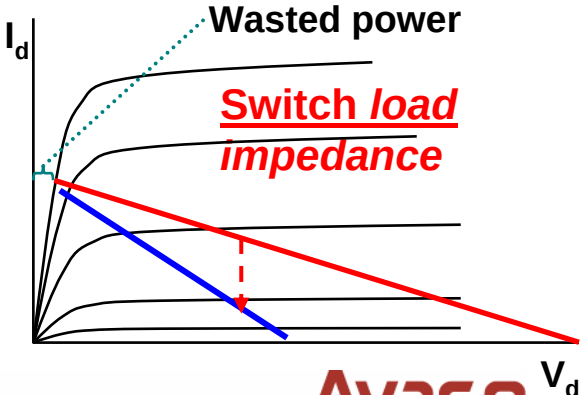
Option-I: Constant Vdd and Load Impedance, Change Idd



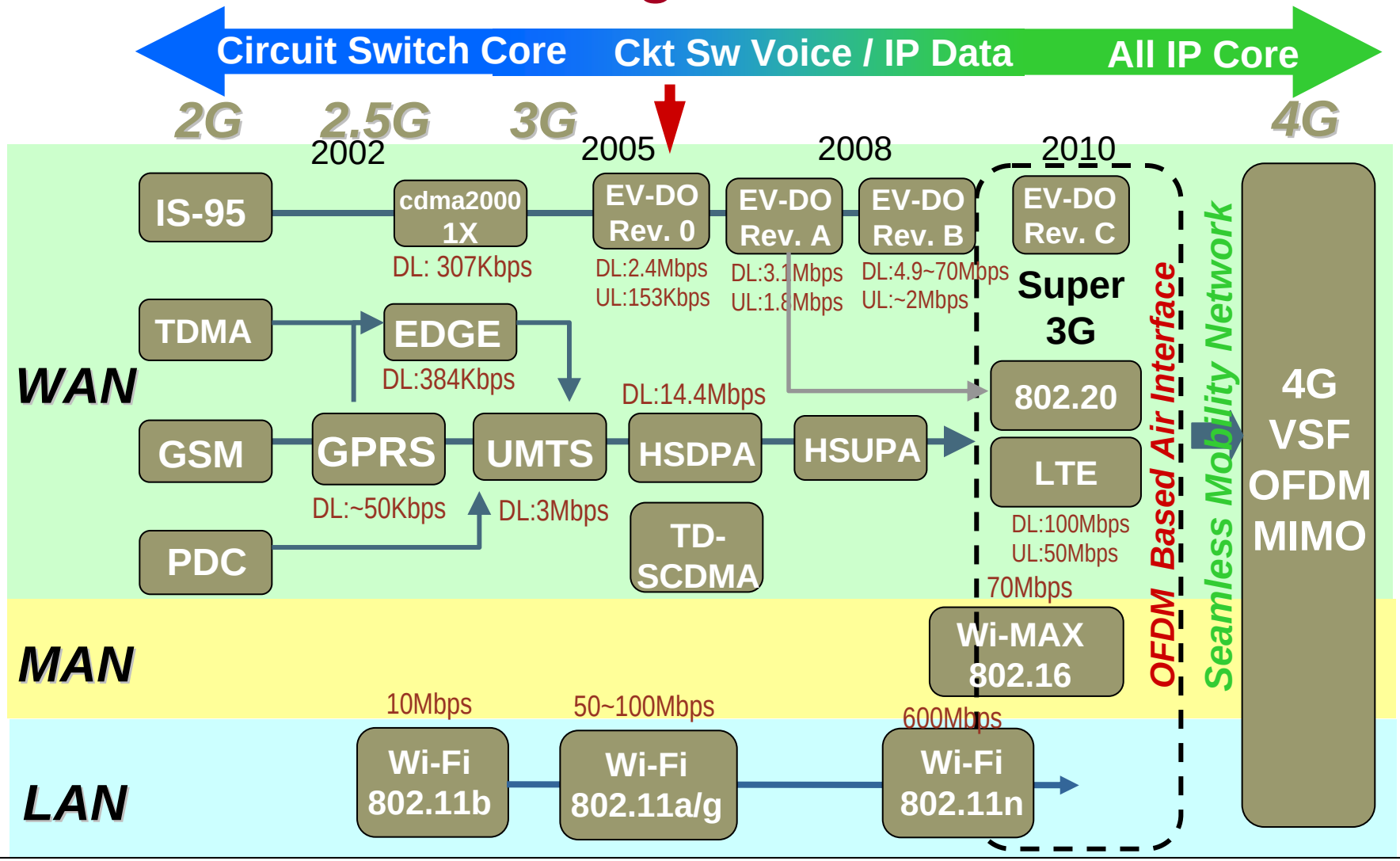
Option-II: Constant Load Impedance, Change Vdd



Option-III: Constant Vdd, Change Load Impedance



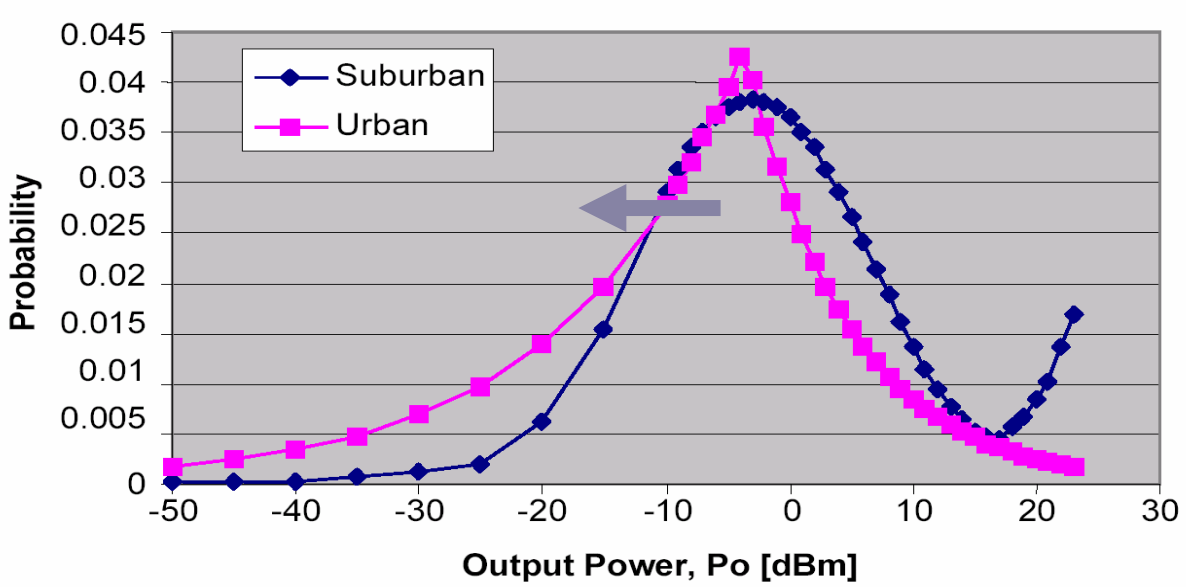
Wireless Standard Migration Path



PA Back Off	1.5~2dB	~3dB	3~4dB	>5dB	8~9dB
PAE (%)	55~60%	40~45%	35~40%	20~30%	<15%

CDMA Power Usage Pattern

Handset Output Power Statistical Usage Model: CDG Stage-4 PDF Model



- *Most Transmit Power Usage : -10 to 10 dBm*
- But, PA is optimized for full power (27~28 dBm)
- Poor efficiency at lower power levels, which are in the mostly used power region
- More than enough linearity in the low power region

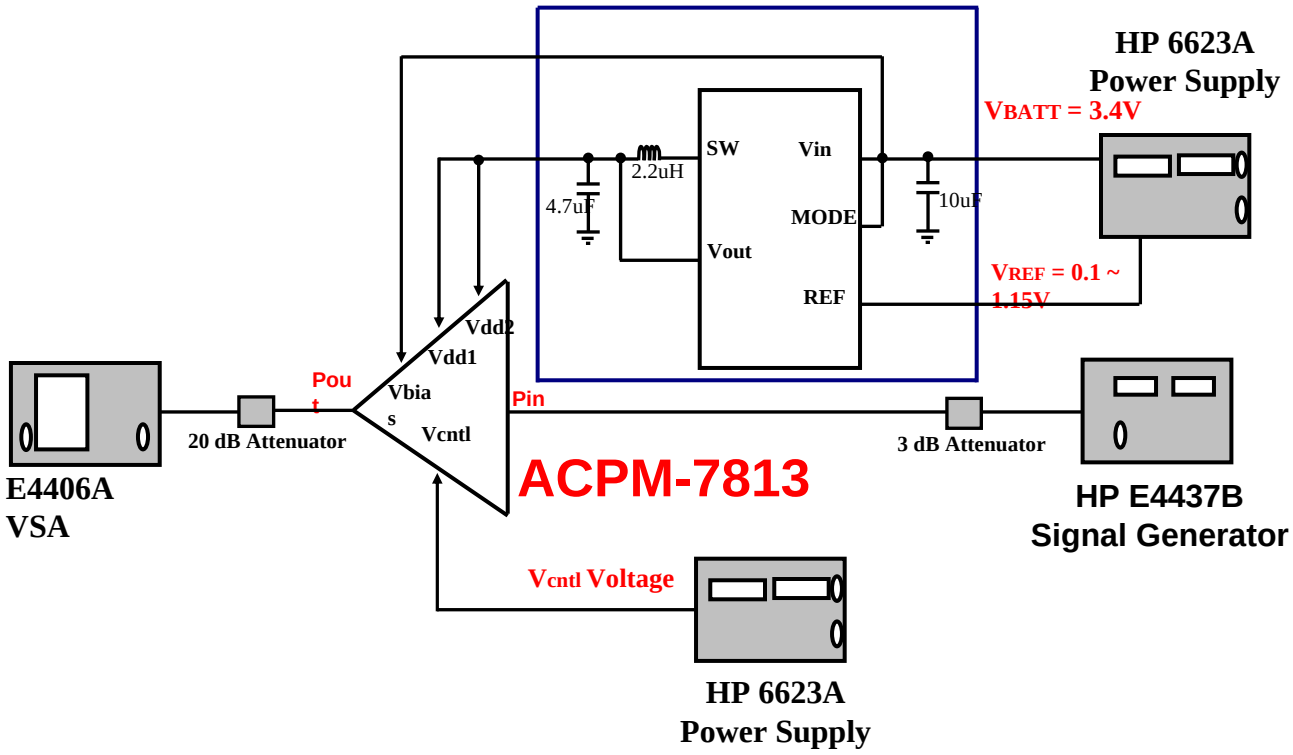
$$Talk\ \ Time\ \propto 1/P_{DCmean}$$

$$P_{DCmean} = \int_{P_{Min}}^{P_{Max}} P_{DC}(P_{OUT}) \times pdf\ (P_{OUT})\, dP_{OUT}$$

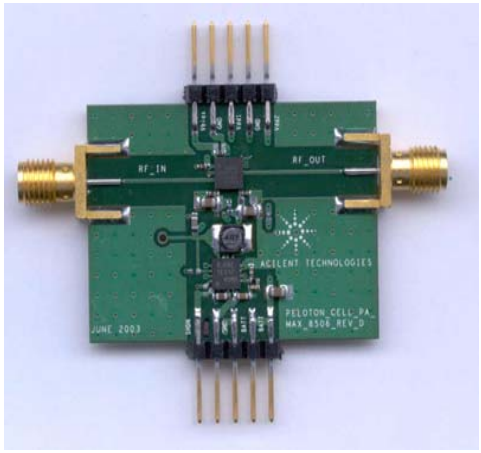
To maximize Talk Time, $P_{DC\ mean}$ need to be minimized.

IMPROVE MID and LOW POWER EFFICIENCY !

E-pHEMT PA (CDMA) with DC-DC Step-Down Converter



ACPM-7813



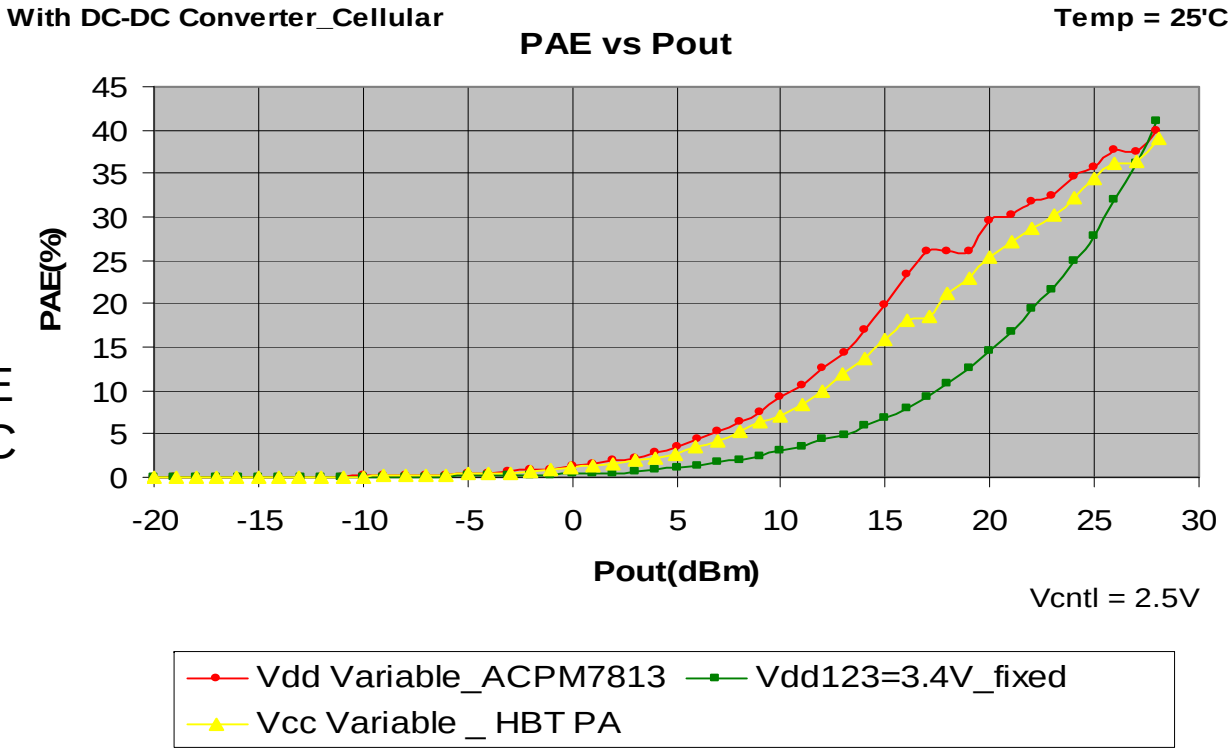
Note: Continuously adjust Vdd to get the best PAE, while meeting ACPR requirements

E-pHEMT PA (CDMA) with DC-DC Step-Down Converter

ACPM-7813 is 850MHz Band CDMA Power Amplifier based on E-pHEMT Technology.

ACPM-7813 shows excellent Mid-Power PAE improvement with DC-DC Step-Down Converter.

3~5% better PAE in 16~18dBm Pout range than a typical GaAs HBT PA .

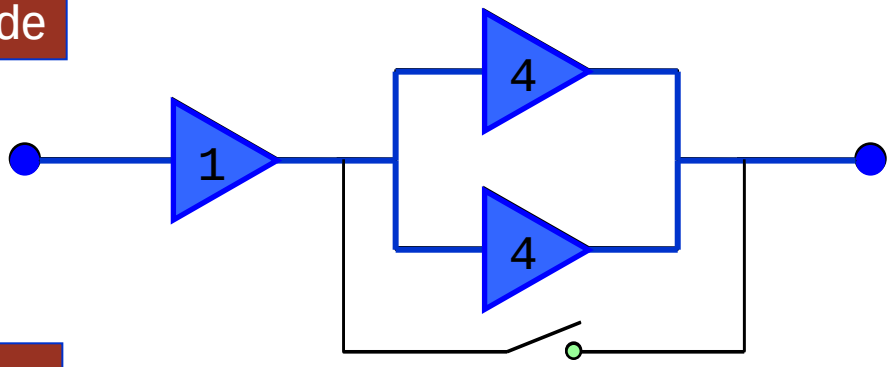


Band	PA	PAE(%)	Gain(dB)	ACPR1(dBc)	ACPR2(dBc)	Bias Condition	Pout(dBm)
Cellular	ACPM-7813	23.36	24.25	-51.42	-64.97	Vdd1=Vdd2=1.0V	16
	HBT PA	18.13	24.81	-48.20	-56.96	Vcc2=1.0V	16
PCS	ACPM-7833	22.43	18.67	-51.68	-60.43	Vdd1=Vdd2=1.0V	16
	HBT PA	14.31	19.24	-46.82	-69.02	Vcc2=1.0V	16
	Table 1.	Comparison table of the PA performance with DC-DC Converter					

New Circuit Techniques → *Cool* PAM

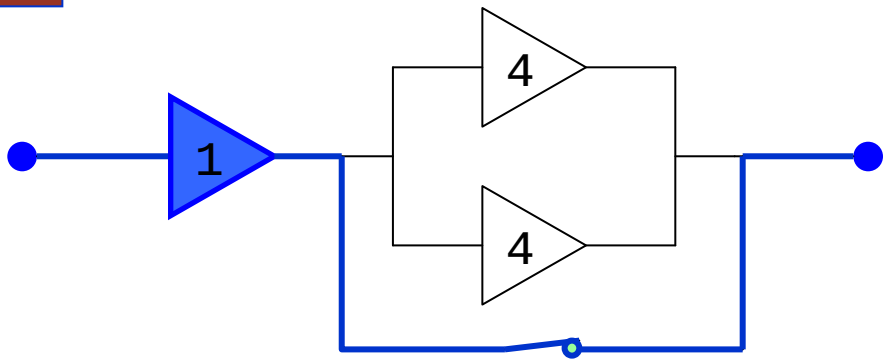
Alternative way to improve Mid Power PAE WITHOUT using DC-DC Converter.

High-power mode



Pout > 16dBm

Low-power mode

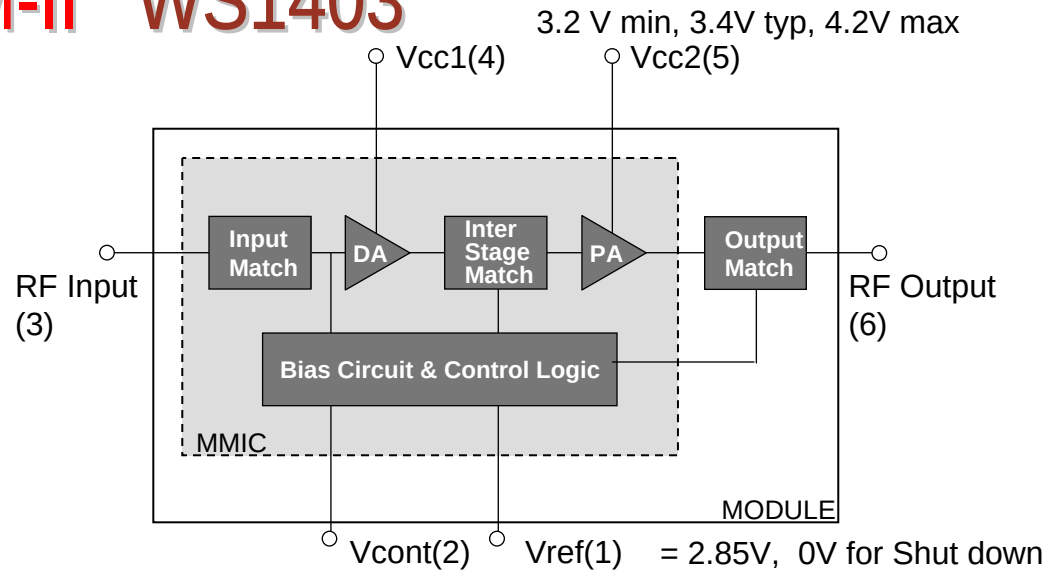


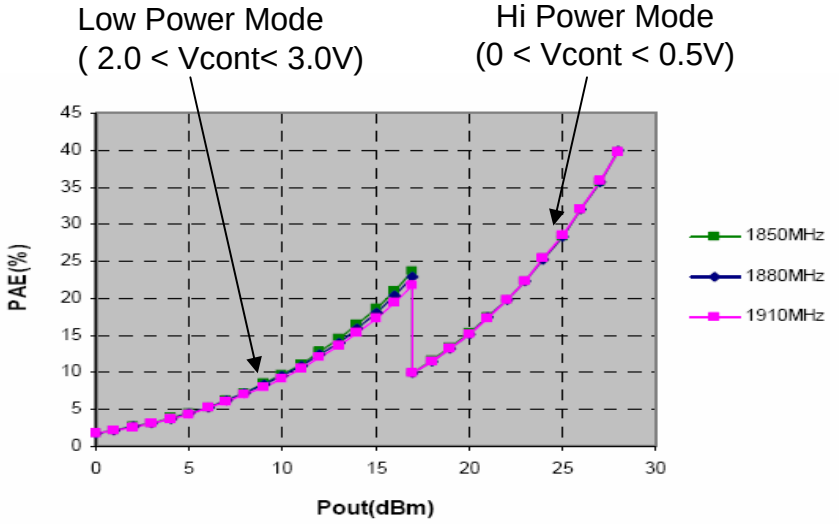
Pout < 16dBm

3mm x 3mm 1900MHz InGaP HBT Power Amplifier

CoolPAM-II WS1403

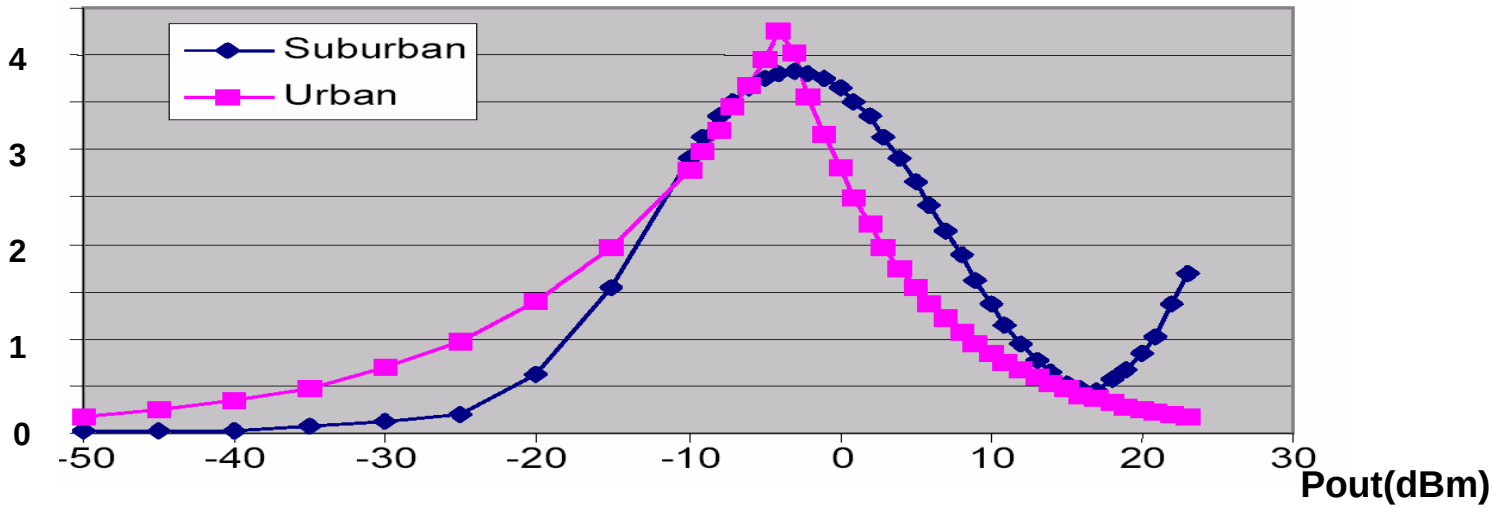
- **Features**
  - InGaP HBT Technology
  - Good Linearity
  - High Efficiency
    - 40% at 28dBm
    - 23% at 17dBm
  - Low Quiescent Current
    - 14mA for Low Power Mode
  - 8-pin Surface Mounting
  - Package (3mmx3mmx1.1mm)
  - Low power-state control
  - 50ohm Input and Output Matching
  - CDMA 95A/B, CDMA 2000-1X / EVDO
- **Schedule**
  - MP: Apr '07
  - **IMT2000 Band version is ACPM-1403**





The Technology

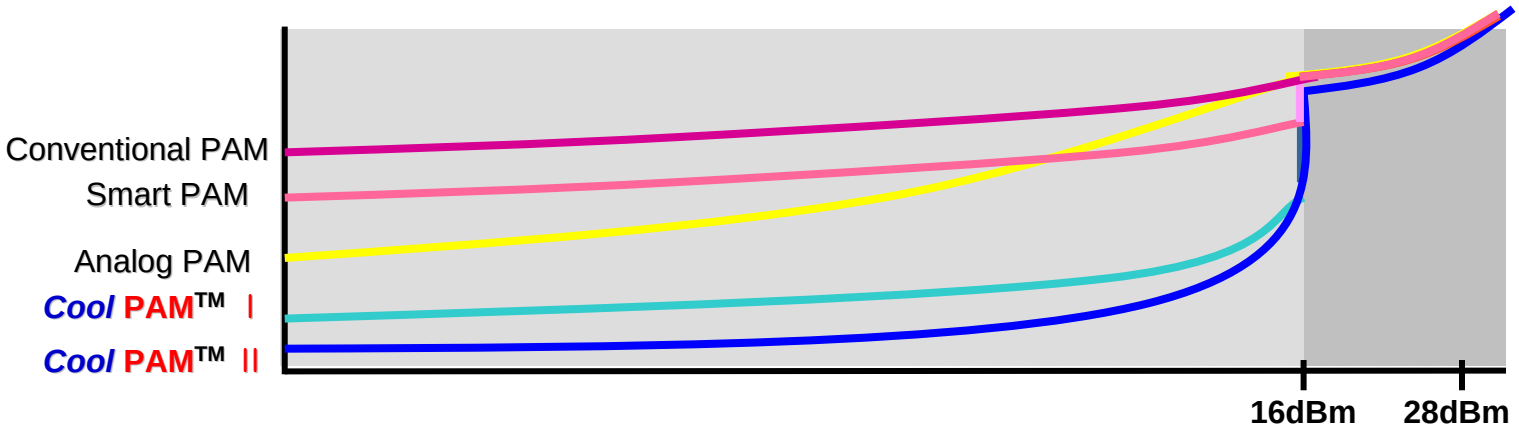
Probability of Usage(%)



Low Power Region

High Power Region

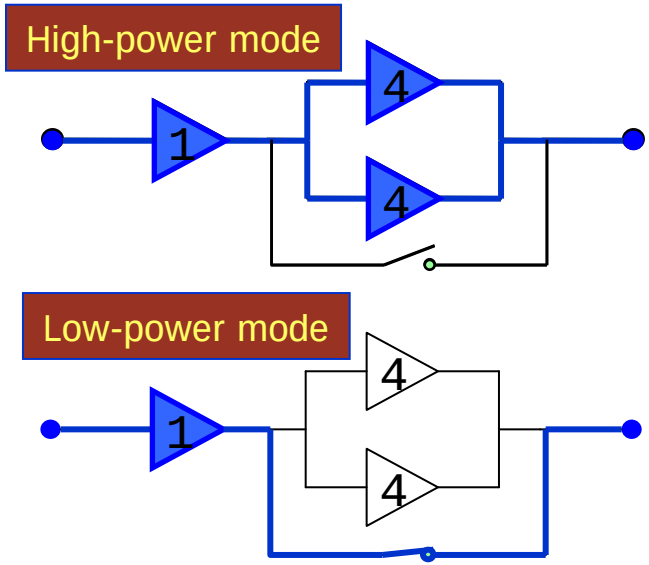
Current Consumption



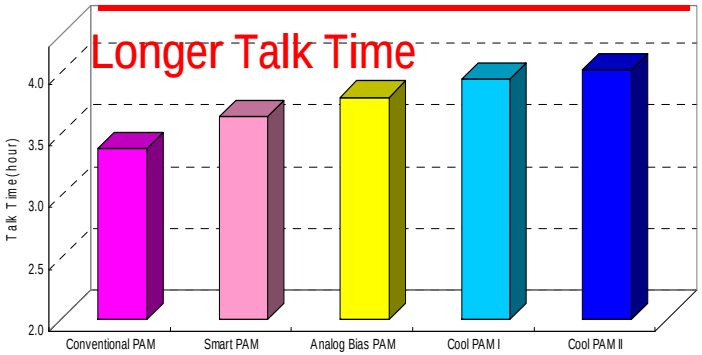
Note) Smart PA: 2-Step Idq change by digital control, Analog PAM: Continuous Idq Control

The Values to Customers by *Cool* PAM

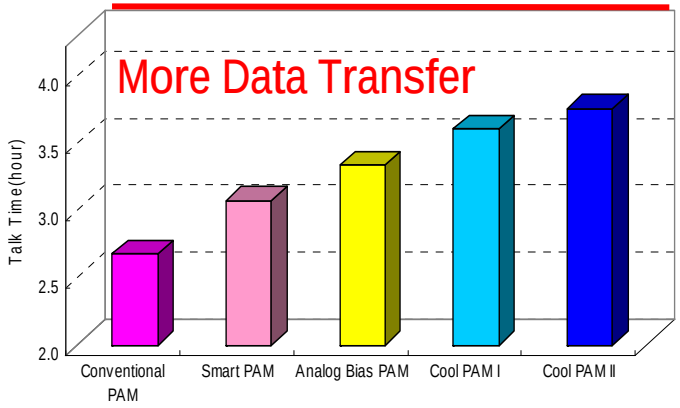
Power Amplifier IP to Provide Excellent Efficiency at Low and Mid Power Without Use of DC-DC Converter.



Projected Talk Times (Hrs)



Projected Packet Data Transfer Times (Hrs)



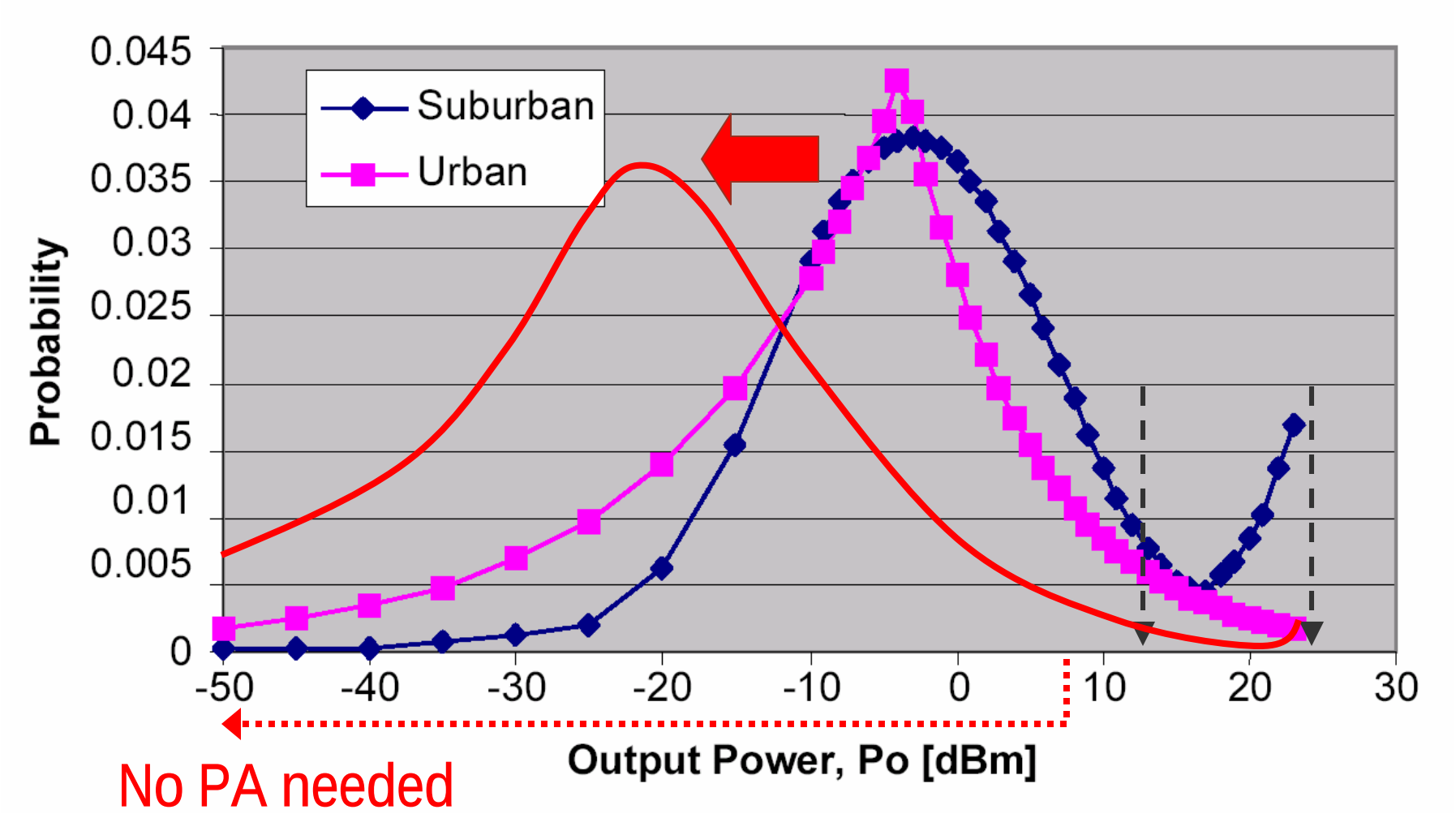
: physical limit

Measured Talk Time (minutes)

Output Power	Competitor's PAM	Avago *Cool* PAM I	Avago *Cool* PAM II
10dBm	205	232	**237**
13dBm	190	**221**	**226**

Battery Capacity : 850mA·h
Tested with actual phone board for Verizon CDMA handsets

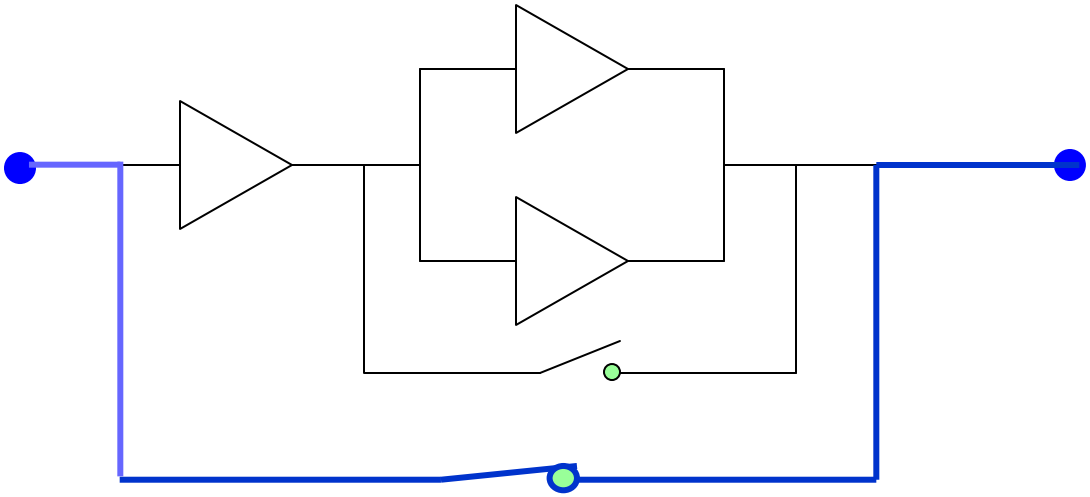
Recent Power Usage Pattern & Talk Time



Different PA architecture and measures needed

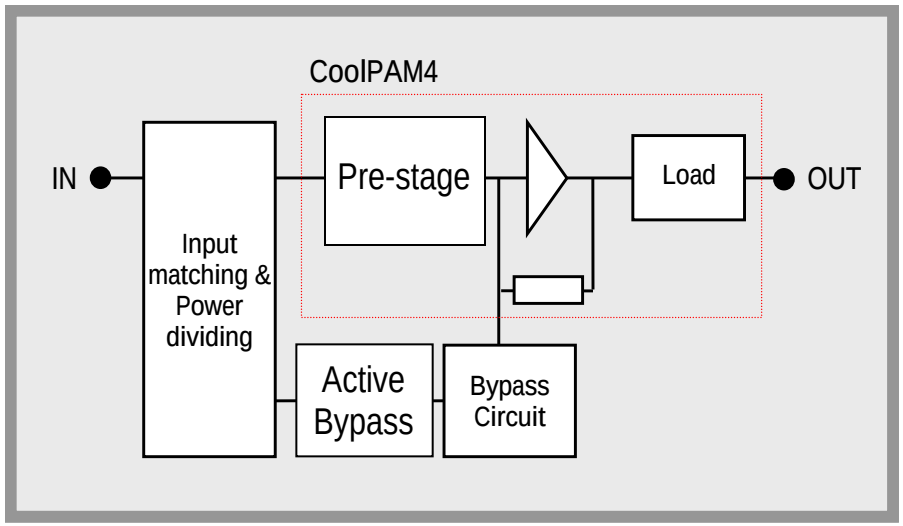
CoolPAM-V Operation

Digital Control Using Series Switching

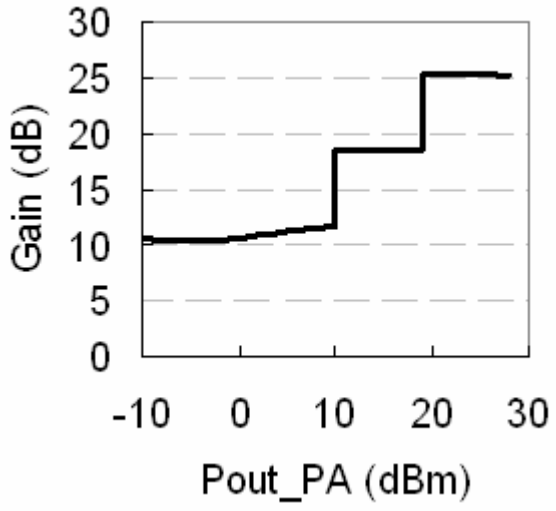


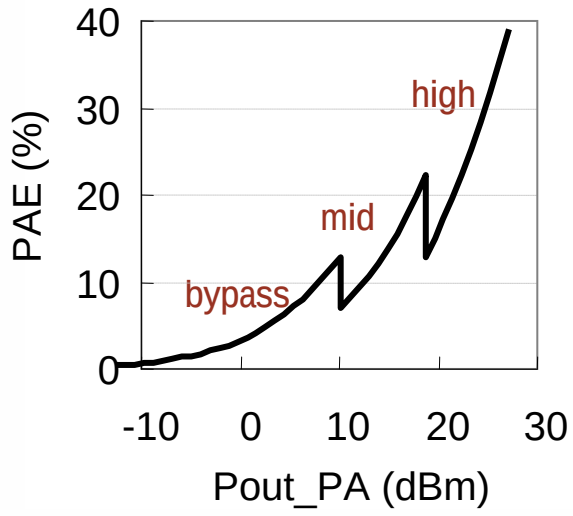
- A complete stage bypass results in the largest power savings in the low-power mode, However, for proper operation, it requires multiple switches ➲ hard to miniaturize and commercialize.

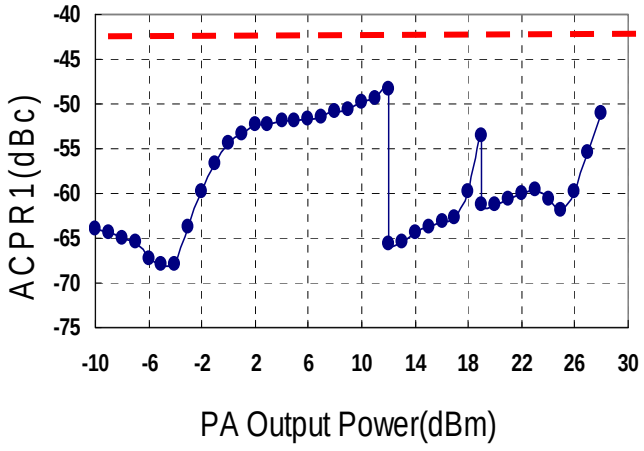
Prototype Demonstration



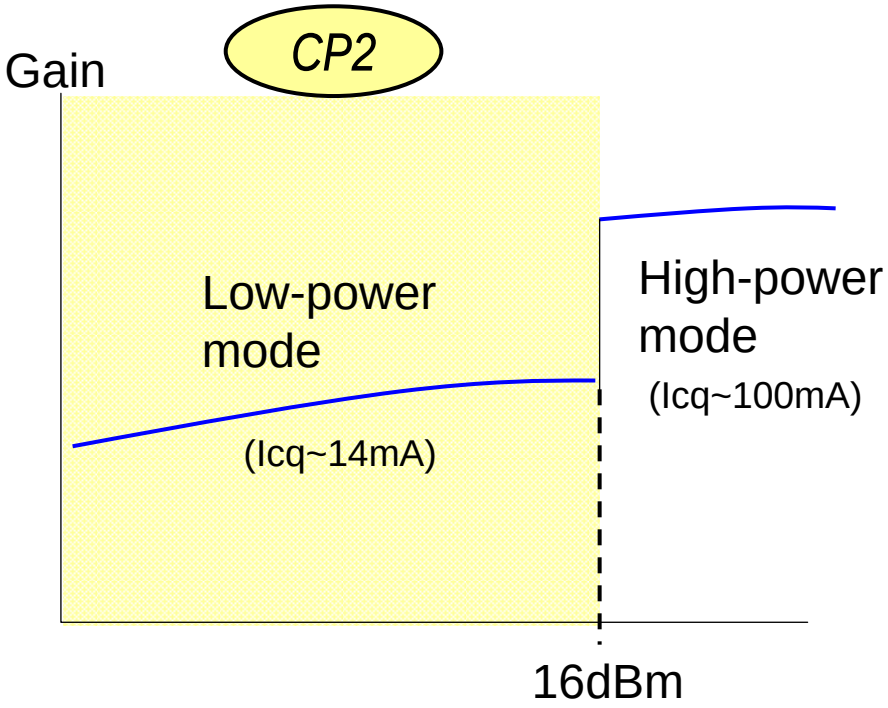
- Note
  - → *measurement data*
  - → Idle current ~ 3 mA
  - → Switching points : 11/18dBm
  - → Demonstrated at 3GSM



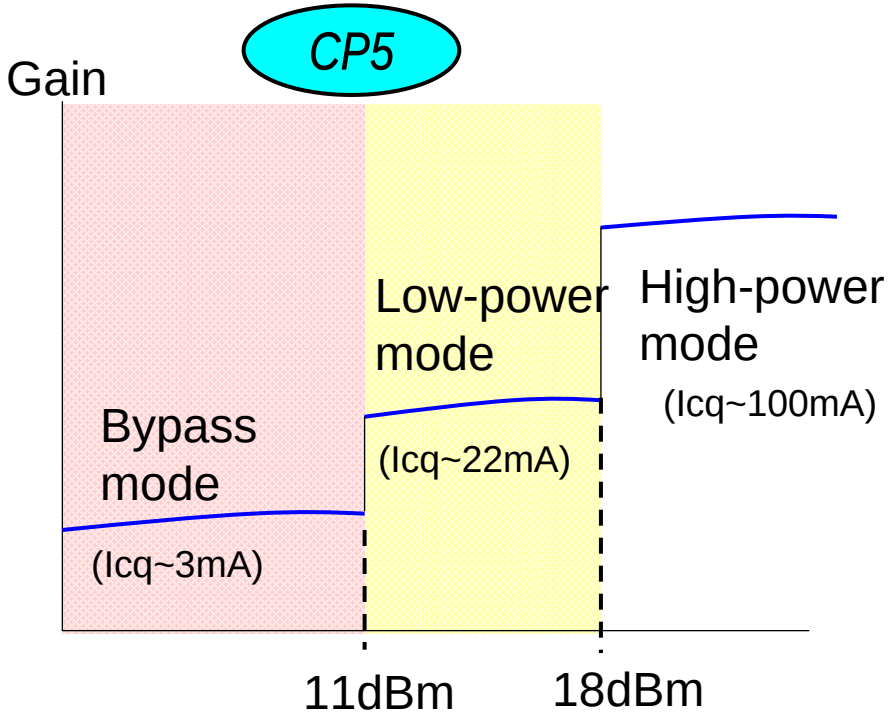




Modes of Operation

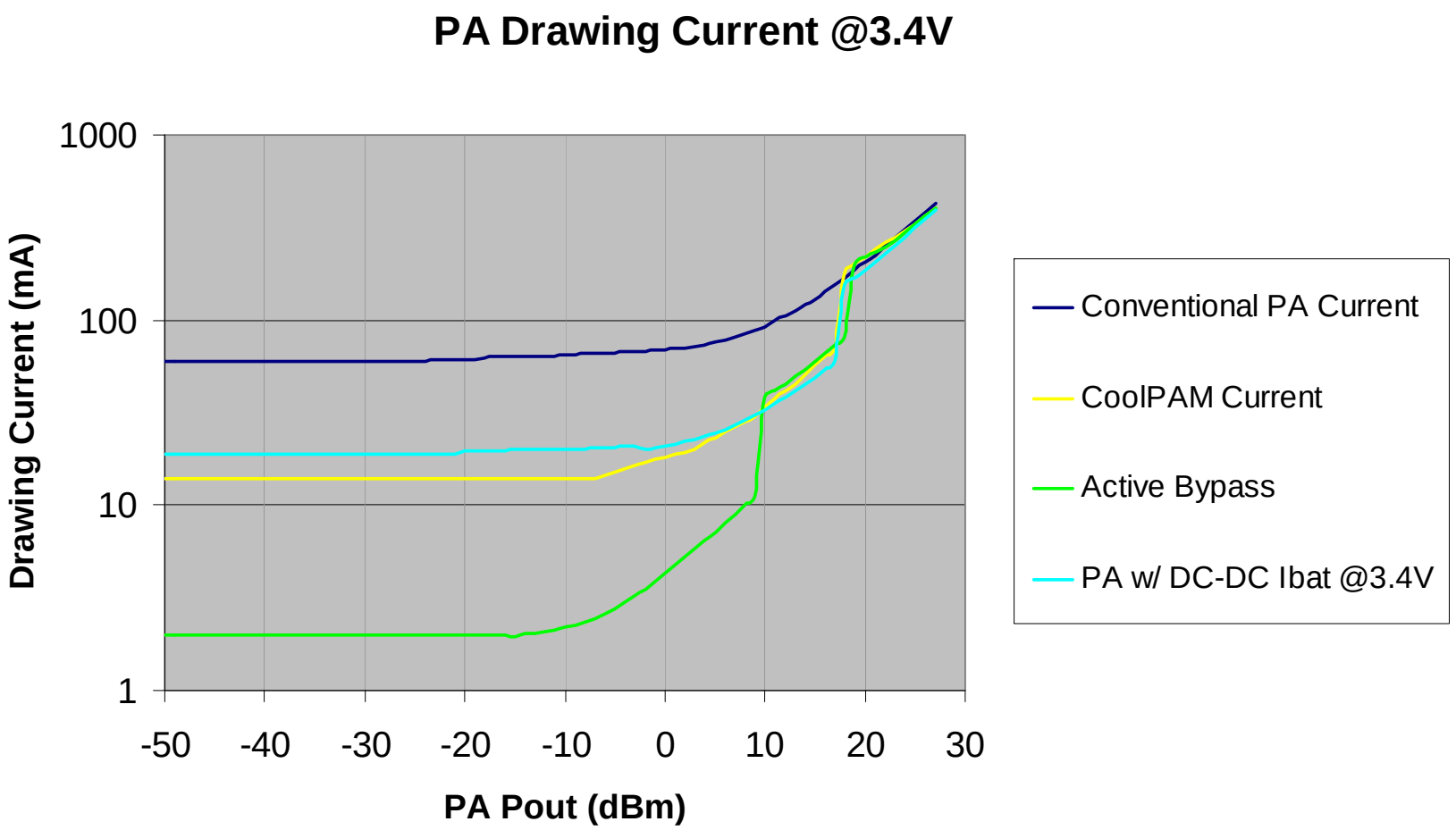


CoolPAM 2 (Stage-bypass PA)



CoolPAM 5 (Active bypass PA)
→Extended power saving region

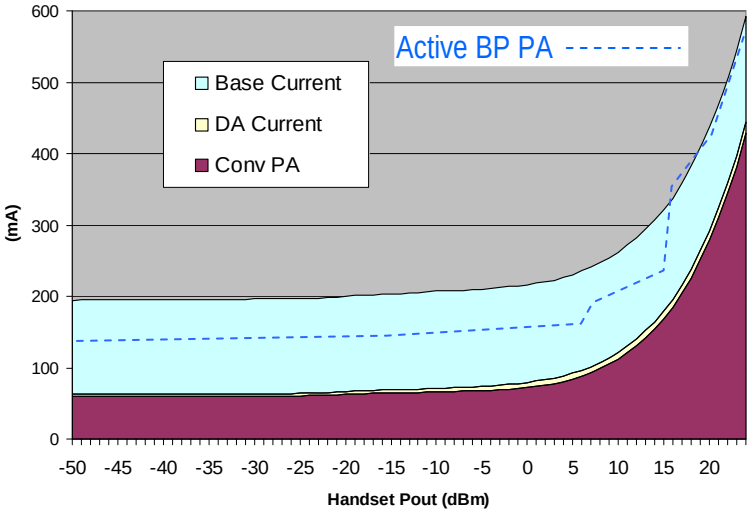
Various PA Type Drawing Current Comparison



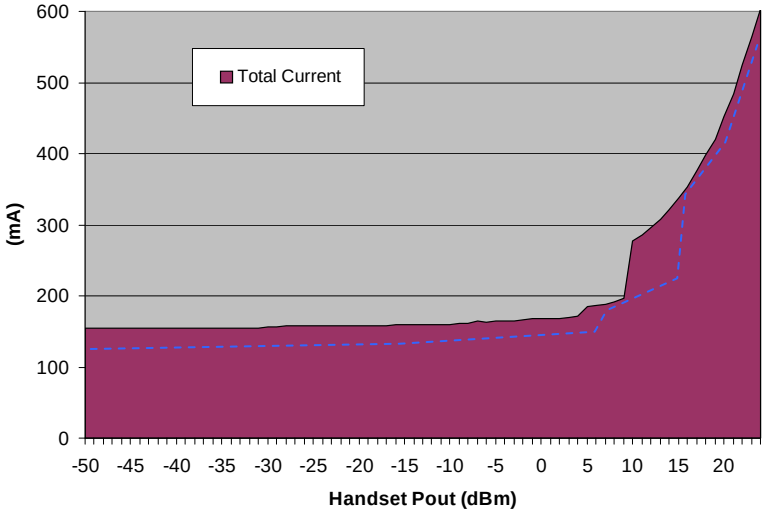
Quiescence Current is major contributor to extend the talk tme.

Handset Total Current Profile Comparison

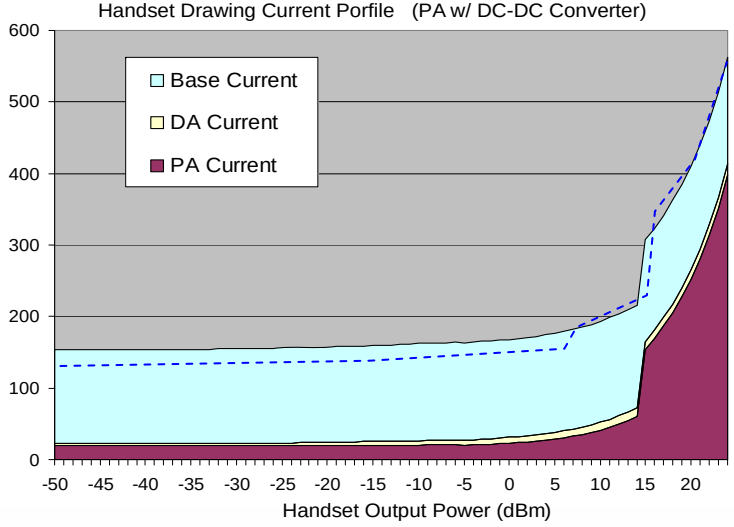
Handset Drawing Current (Conventional PA)



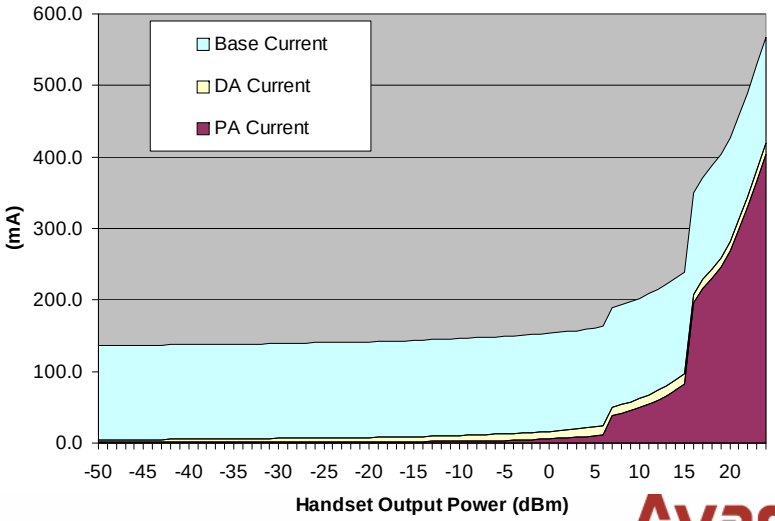
A Comercial US CDMA Handset Total Current (using DC-DC)



Handset Drawing Current Porfile (PA w/ DC-DC Converter)

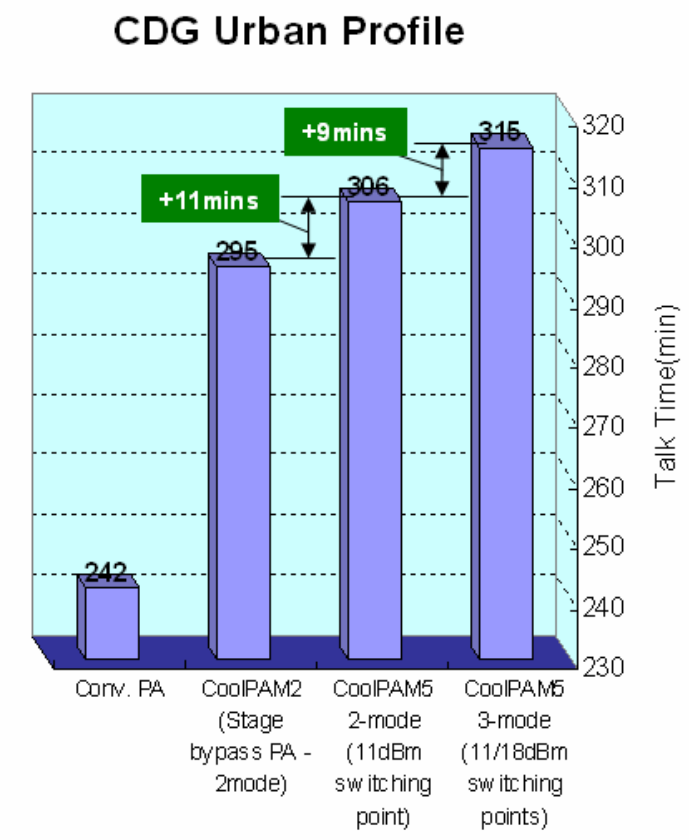


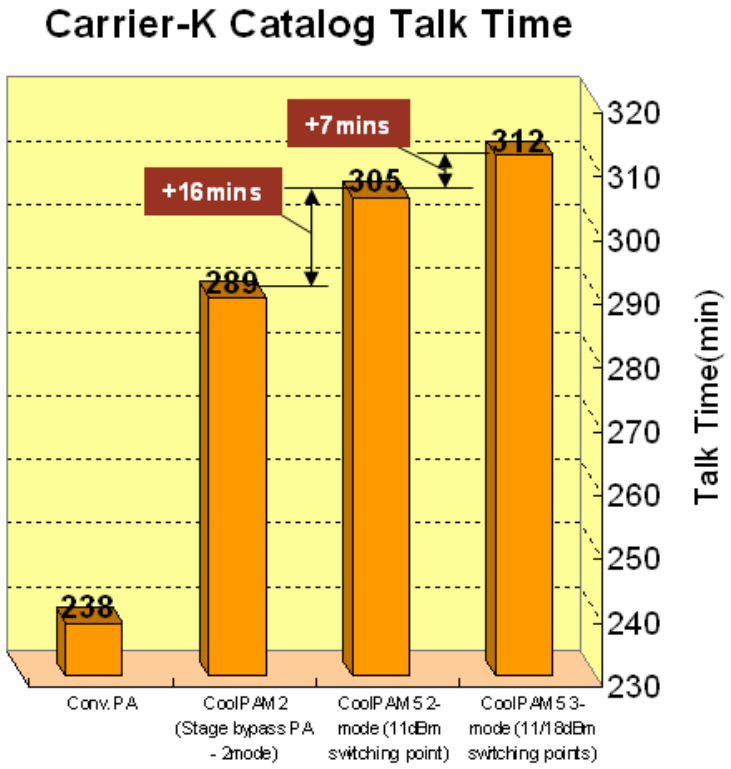
Handset Drwaing Current (Active Bypass PA)



Talk Time Comparison – CDG Profile & Carrier-K Metric

- Measurement data with CP5 Engineering Sample





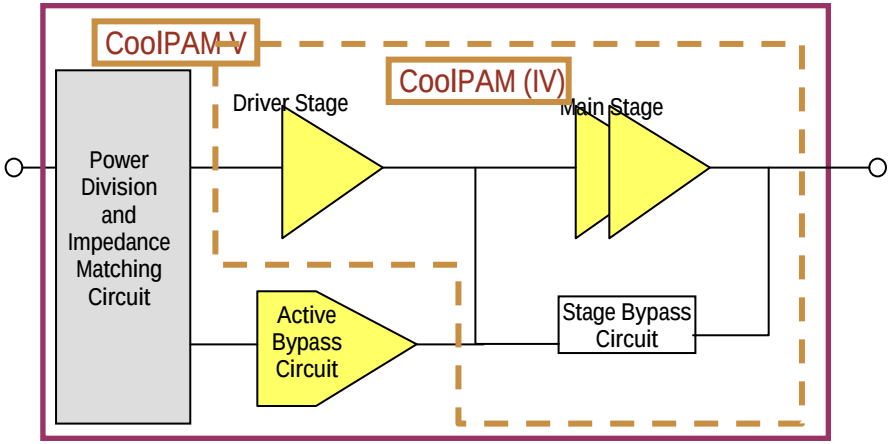
Battery: 850mAH

CoolPAM Evolution

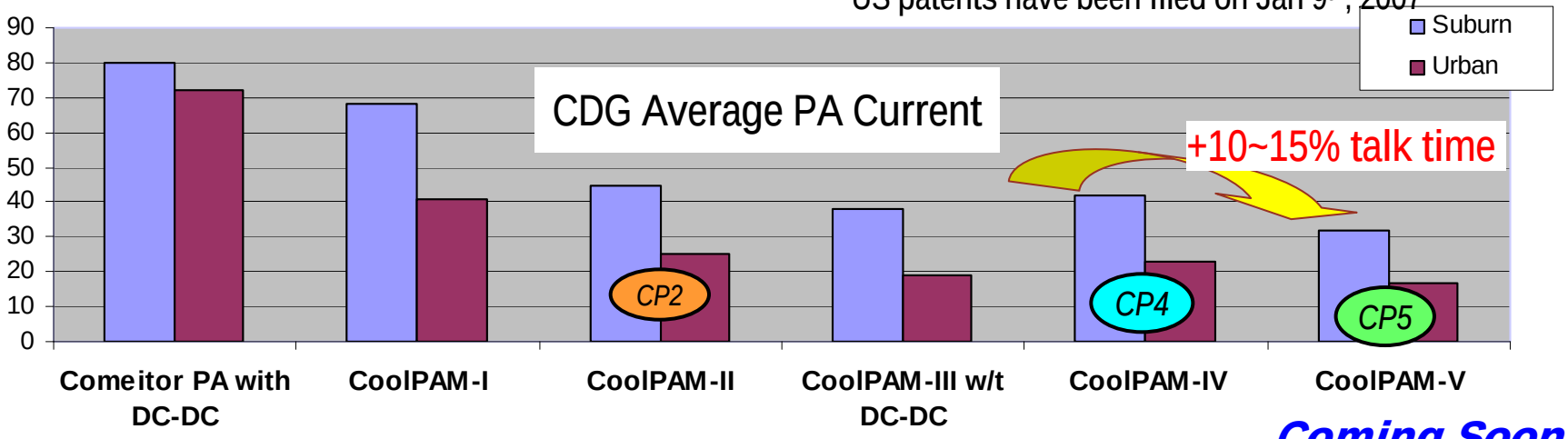
CoolPAM is evolutional PA technology to enhance mid power and low power efficiency, which improves effective talk time of CDMA and UMTS handsets.

Using CoolPAM as the core PA engine, Avago offers for various bands of Standalone PA and By-Band FEM

Active Bypass Architecture



*US patents have been filed on Jan 9th, 2007



Coming Soon!

CDMA		**Cell, KPCS PCS**	**Cell, PCS JCDMA, IMT2000**			**Cell, PCS JCDMA, IMT2000**
UMTS				**B1, B2 B5**	**B1, B2, B3/4, B5/6, B8, B9**	**B1, B2, B3/4, B5/6, B8, B9**