

Benefits of Increased Mobile Transmit Power for HSDPA through qBoost™ Envelope Tracking technology

I. Discussion of the Problem

A new era of higher downlink data rates was ushered in with the addition of HSDPA (Release 5) to the 3Gpp specifications. However, the limitations of the mobile's *uplink* transmit power capabilities may limit the coverage of these higher data rates.

In 3Gpp Release 99, the mobile transmits a combination of two channels- DPDCH (data and voice) and DPCCH (control). With HSDPA, an additional control channel is added to each user's uplink signal. This is the HS-DPCCH channel, and it provides acknowledgement (ACK/NACK) and channel quality information (CQI) to the base station regarding the high speed downlink data received by the mobile, as part of the system HARQ (hybrid ARQ) error control scheme.

Adding the HS-DPCCH channel to the uplink does, however, come with a significant drawback. The issue is a "double penalty" to cell coverage, and is shown in Figure 1.

First, the HS-DPCCH channel, when transmitted, adds to the total uplink power already defined by DPDCH (data) and DPCCH (control). The mobile is limited to +24dBm maximum total uplink power, so if the DPDCH and DPCCH channels already combine to meet the +24dBm limit, the addition of the HS-DPCCH channel requires a corresponding drop in the power of the other channels to ensure the +24dBm limit is not exceeded.

Second, the HS-DPCCH channel introduces a high PAR (peak-to-average ratio) modulation in the uplink. Ordinary 3Gpp mobile power amplifiers are strained to meet ACPR (adjacent channel power rejection) requirements while operating under these higher PAR conditions. Thus the decision was made by the 3Gpp working groups 1 and 4 made to allow a reduction in UE maximum output power when HS-DPCCH is transmitted. In other words, when the mobile should be transmitting *more* power to retain DPDCH and DPCCH power under HS-DPCCH operation, the specifications specify *less* power.

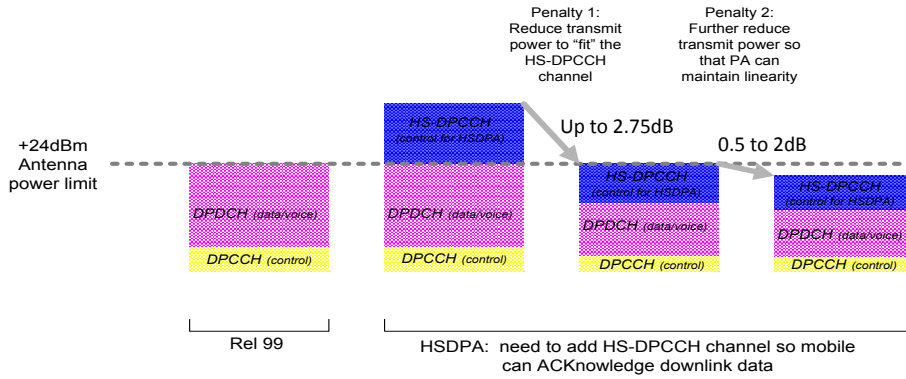
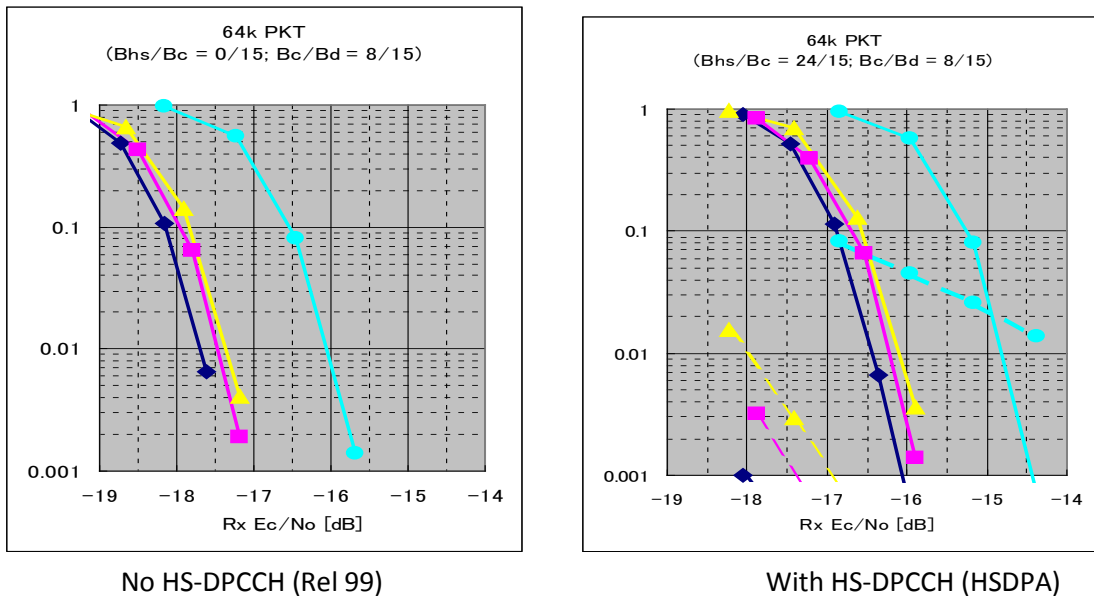
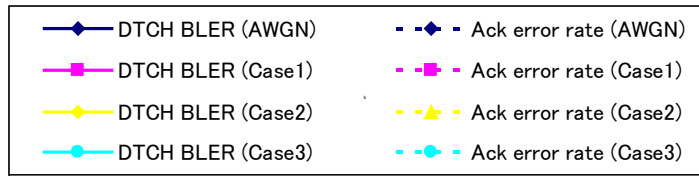


Figure 1. Double-penalty when the mobile is transmitting at maximum power (+24dBm) near the cell edge.

The reduction in power in the DPDCH, DPCCH and HS-DPCCH channels when the mobile is at maximum uplink power level (at the cell edge) is clearly visible from Figure 1. The power reduction directly affects the uplink power budget and coverage, especially for networks originally dimensioned for Release 99 coverage.

To quantify the coverage reduction, simulations were performed by NTT DoCoMo in a submission to 3Gpp* to determine the additional E_c/N_0 required to demodulate the data (DTCH) in the mobile uplink, in the case where the HS-DPCCH channel is added to the mobile uplink when DPDCH and DPCCH channels already combine to meet the +24dBm limit. A 64kbps uplink bearer was used in the simulation, while a 2Mbps downlink was assumed, with ACK and CQI transmitted every frame. In this scenario, HS-DPCCH is transmitted with sufficient power to limit the error rate of the ACK burst ($\beta=24/15$, meaning HS-DPCCH is transmitted 2.6x the DPCCH power level).





Source: DoCoMo TSG-RAN WG1 and WG4 report TSGR 1040108

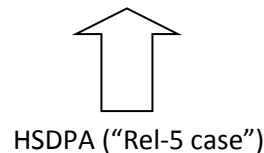
Figure 2. Block Error Rates simulated with/without HS-DPCCH, at maximum mobile power

Required E_c/N_0 for 5% DTCH BLER (AWGN)

Rel-99 case	Rel-5 case
64kbps DTCH	64kbps DTCH
-18.0 dB	-16.7 dB (1.3 dB increase)

Table 4 – Uplink cell radius shrinkage of a 64kbps bearer

w/o HS-DPCCH UE max Tx pow = 24 dBm	w/ HS-DPCCH UE max Tx pow = 24 dBm	w/ HS-DPCCH UE max Tx pow = 23 dBm	w/ HS-DPCCH UE max Tx pow = 22 dBm
100.0%	91.7%	85.7%	80.2%



*Source: DoCoMo TSG-RAN WG1 and WG4 report TSGR 1040108

Figure 3. Link budget and coverage reduction.

The simulations show a reduction to 91.7% of the original cell radius, corresponding to a 16% loss in coverage area. Cell radius shrinkage is based on 3Gpp macro cell propagation model where path loss exponent is 3.43, so that each dB loss is equivalent to approximately 6.5% cell radius reduction, multiplicative, corresponding to a 12.6% loss in coverage.

The coverage loss was calculated for a 5% BLER in AWGN, but the figures are close for other path models. Note that even with no backoff (UE maxTXpow= 24dBm), there is still a loss of coverage. The coverage loss may well affect the high speed downlink service as well. To quote DoCoMo: “To achieve a

high downlink throughput at the TCP level, an appropriate uplink data rate must be provided. For example, to support a 2Mbps throughput in the downlink, an uplink data rate of 64kbps is required typically.

Therefore, if the UE max Tx power is reduced during HS-DPCCH transmission, the service areas of high data rate uplink bearers such as 64kbps and 384kbps shrink as in the above results, which in turn shrinks the area where users can enjoy high downlink data rates.”

II. The Power Amplifier Dilemma

The simple solution to the problem is to increase, not decrease, the mobile maximum transmit power when needed. That is, when the mobile is transmitting close to +24dBm with DPCCH and DPDCH, and the HS-DPCCH channel is turned on (to acknowledge the downlink HSDPA transmission), the mobile transmitter power should be allowed to increase beyond the +24dBm limit to accommodate the additional power of the HS-DPCCH. Certainly, the mobile power should not be *decreased*!

The chief limitation, since the advent of amplitude-modulated signaling, has been the ability of the power amplifier in the mobile to provide power at these higher levels, while maintaining reasonable efficiency. When roaming away from the basestation, the power amplifier is often the most power hungry component in the cell phone or data card, and therefore great care is taken to ensure the PAs in 3Gpp mobiles are designed to run efficiently to maximize talk-time during normal Release 99 operation.

Hypothetically, the PA can be redesigned to increase its maximum output power and reduce HSDPA backoff (by forcing a change to the PA matching network and an increase the PA devices size); this however forces the PA to operate with substantially worse efficiency at lower powers. In other words, a PA designed to handle the HSDPA conditions will result in poor voice talk time.

Thus, in 2004, 3Gpp working groups 1 and 4 decided to allow a reduction in mobile maximum output power when HS-DPCCH is transmitted, and thus permit the use of typical Release 99 PA's without redesign. Thus, talk time benefited, while HSDPA coverage was allowed to suffer.

Table 3: Operating Ranges

PARAMETER	MIN	TYP	MAX	UNIT	COMMENTS
Operating Frequency (f)	1920	-	1980	MHz	
Supply Voltage (V _{CC})	+3.2	+3.4	+4.2	V	P _{OUT} ≤ +28.5 dBm
Enable Voltage (V _{ENABLE})	+2.15 0	+2.4 -	+3.1 +0.5	V	PA "on" PA "shut down"
Mode Control Voltage (V _{MODE1} , V _{MODE2})	+2.15 0	+2.4 -	+3.1 +0.5	V	Low Bias Mode High Bias Mode
RF Output Power (P _{OUT}) 3GPP HSDPA Case A HSDPA Case B HSDPA Case C	+28.0 ⁽¹⁾ +27.0 ⁽¹⁾ +26.0 ⁽¹⁾ +25.5 ⁽¹⁾	+28.5 +27.5 +26.5 +26.0	- - - -	dBm	1/15 ≤ β _e /β _d ≤ 12/15 13/15 ≤ β _e /β _d ≤ 15/8 15/7 ≤ β _e /β _d ≤ 15/0
Case Temperature (T _c)	-10	-	+90	°C	

The device may be operated safely over these conditions; however, parametric performance is guaranteed only over the conditions defined in the electrical specifications.

Notes:

(1) For operation at V_{CC} = +3.2 V, P_{OUT} is derated by 0.5 dB.

Source: Anadigics

Figure 4. Typical PA datasheet showing back-off of RF Output Power numbers under HSDPA cases (note that absolute numbers are power level before duplexer and other RF losses)

III. The Quantance Solution

Quantance has developed a breakthrough technology which fundamentally eliminates the tradeoff between talk time and HSDPA power described in the previous section. This technology is provided for commercial use in the Quantance Q1000 PA controller, a small IC designed to work in conjunction with a standard WCDMA PA. The Q1000 offers a new approach to regulating the operation of the PA by providing the optimal modulated supply voltage to the PA, while correcting the PA distortion in a closed loop. Using the Q1000 has minimal impact to the radio architecture, and subsumes other components in the wireless transmit circuit of mobile devices.

The Q1000 offers an immediate reduction in battery current drain compared with existing PA's. Given the differentiating importance of talk time, this feature alone can motivate a mobile designer to design in this IC. These current savings are even greater when the technology is compared to a PA capable of transmitting the HS-DPCCH bursts without the back-off normally required. A typical PA scaled this way sacrifices efficiency across a wide operating range. By comparison, a system using Quantance technology does not suffer this penalty.

Measured data illustrating this comparison is available by contacting Quantance at info@quantance.com, referring to this white paper, and asking for the comparison performance data.

Given the +1/-3dB power tolerance of the mobile for any given class, the additional power beyond +24dBm is legal only to +1dB additional (to +25dBm); therefore to take advantage of the benefit, the mobile could be classified as a higher power class (to +27dBm). To meet SAR compliance, the mobile could be configured to increase power beyond +24dBm for HS-DPCCH bursts only, while operating in the lower class mode during voice operation. This way, the HSDPA coverage footprint can be maintained (as described earlier).

Operators and network engineers, accustomed to the power amplifier dilemma, may now rethink this tradeoff and consider the benefits of increased mobile uplink power, improving the experience of high ARPU generating data customers, without the usual sacrifice to talk time.

Please visit www.quantance.com for more information about the Q1000 and Quantance technology.