WIRELESS MULTIMEDIA CONTINUOUS PACKET CONNECTIVITY (CPC), POWER AMPLIFIER (PA) BACK-OFF AND THE CUBIC METRIC (CM)

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Abstract: With the every-increasing complexity of (e.g. multi media) signal waveforms generated by transmitters of modern digital communications systems, there comes a corresponding demand for transmitters to continue to operate efficiently (e.g. from a cost per bit and power output point of view) and to produce minimum distortion, within specified limits. This paper looks at how a particular CPC scheme (for efficient resource usage) might be devised and what the resulting impact is on the CM measure. The work uses, as a basis for simulations, mainly the Uplink of the third generation (3G) Wideband Code Division Multiple Access (WCDMA) Release six (R6) system.

1 INTRODUCTION

When looking at services which require high user bit rates, wireless communication systems have tended to lag behind wired systems due to problems caused by the less benign radio transmission environment. To the end user however, service is all important. The current perception is that users would like to have the same service offered over a wireless link as they would be able to obtain over a wired one. This has led to the design of cellular wireless systems which are capable of working with relatively high data rates, in particular over the wireless link.

2 CONTINUOUS PACKET CONNECTIVITY (CPC)

The increase in data rate that allows for the delivery of enhanced user services needs to be complimented by the "efficient" delivery of that service, that is to say, resources should not be needlessly wasted. Optimisation of system resource is a necessary task in order to drive down the cost per bit to the end user. Multi-media (e.g. internet) service users require relatively high data rates combined with low data access delays. Internet sessions tend to be bursty in nature, with defined periods of activity and inactivity. Users require that they stay in a CPC mode during periods of inactivity, i.e. they should stay continuously connected. To ensure efficient resource usage, users should be assigned only the minimum resources which would allow them to remain connected during these inactive times.

The CPC scheme given in Section 5 is thus aimed at reducing the power level of the Uplink (UL) Dedicated Physical Control Channel (DPCCH) when there is no data to be transmitted on the UL Enhanced Dedicated Physical Data Channel (E-DPDCH).

3 CUBIC METRIC

HSDPA and HSUPA/E-DCH involve the deployment of an increased number of channels and associated channel configurations. The way these channels are configured, and their subsequent processing by the PA, has an impact on PA distortion. In the past (i.e. with second generation, 2G, systems) the calculation of a signal's PAPR has been sufficient to determine what the PA back-off should be. However, recent literature e.g. (3GPP TSG RAN WG4#31, 2004), (3GPP TSG RAN WG4#33, 2004), (3GPP TSG RAN WG4#38, 2006), (Rohde & Schwarz, see ref) has suggested that the PAPR measure is not sufficiently accurate when working with the, increasingly, complex signals that occur with enhanced 3G systems. Reference (3GPP

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TSG RAN WG4#31, 2004) indicates that the CM has the required accuracy for determining what the PA back-off should be for any given channel format and combination for current, modern, cellular systems, such as WCDMA.

4 CM DERIVATION

Modulator output can be represented as a complex stream of N samples, $\{v_t\}$, as indicated in Figure 1;

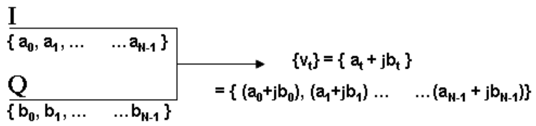

Figure 1: Modulation Output.

From the literature, e.g. (3GPP TS 25.101 v6.12.0, see ref), the CM is given by;

$$CM = CEIL([\ 20*\log10(\ (v\_norm^3)_{rms}\ ) - 20*\log10(\ (v\_norm\_ref^3)_{rms}\ )\ ]\ /\ k) \quad (1)$$

Where,

v_norm is the normalised voltage waveform of the input signal

- v_norm_ref is the normalised voltage waveform of the reference signal (12.2kbps AMR Speech) and 20*log10((v_norm_ref3)rms = 1.52dB
- k is 1.85 for signals where all channelisation codes meet the following criteria CSF,N where N < SF/2
- k is 1.56 for signals whe
- re any channelisation codes meet the following criteria CSF,N where N > SF/2
- CEIL{x,0.5} means rounding upwards to the nearest 0.5dB, i.e. CM ∈ [0,0.5,1.0,1.5,2.0,2.5,3.0,3.5

A more explicit form of the CM can be derived;

$$CM = CEIL([20*\log10(c_{rms}) - 20*\log10({}_{ref}c_{rms})]/\ k) \quad (2)$$

where,

$$c_{rms} = N.\ (\ (P_{cubed})/(P_{total}{}^3)\ )^{(1/2)} \quad (3)$$

5 CPC CONCEPT

HSUPA/E-DCH defines a new radio interface for the uplink communication, with the main overall goal of improving coverage and throughput as well as reducing the delay of the uplink dedicated transport channels.

The key technical capabilities introduced with HSUPA/E-DCH are;

1) A new, dedicated Transport Channel, the uplink E-DCH which maps onto a group of new Physical Channels for both signalling and traffic.
2) Introduction of Hybrid Auto Repeat ReQuest (H-ARQ) - including Chase and Incremental Redundancy (IR) combining.
3) Fast Node B Scheduling to control the Set of Transport Formats, within set Radio Network Controller (RNC) limits, from which each User Equipment (UE) may choose – enabling improvement in coverage and capacity in the uplink.
4) Fast Retransmissions based on a H-ARQ Protocol for error recovery at the Physical layer.

From item (1), the introduction of a new dedicated Transport Channel (and the resulting increase in the number of uplink Physical channels) has the knock-on effect of increasing the PAPR and puts higher requirements on accurately specifying the required back off of the UE Power Amplifier.

During Multimedia (e.g. internet) sessions UE's should be assigned minimum resources during inactive periods. During an inactive period a user may be, for example, reading recent information obtained as a result of a request sent to an appropriate website, before responding – and thereby moving into an active period of the session. In particular it may not be necessary for inactive UEs to continue communications using a relatively high power level for control signalling when lower power levels may be sufficient. If control signalling power is reduced, the level of cell interference is correspondingly reduced and more users are able to be catered for in a cell (and in this way the system becomes more efficient).

One way in which this could be carried out is to use a concept referred to as SIR_target reduction, i.e. Layer 1 signalling (3GPP TR 25.903 v0.4.0, see ref), which is applied by the Node B when inactivity of some UE on the E-DCH is detected. This detection might in fact be done looking at the corresponding Medium Access Control (MAC) packet activity. The Layer 1 signalling amounts to the Node B reducing the Uplink (UL) SIR target to a predetermined value (the Radio Network Controller, RNC, is not involved in the immediate process and thus relatively long delays associated with Radio Resource Control, RRC, are avoided and the user stays in the cell dedicated channel, CELL_DCH, state). The predetermined value is set to a level which ensures reliable transmit power control (TPC) detection. WCDMA inner loop power control then converges to this, reduced target, value, thus reducing the transmit power of the UL Dedicated Physical Control Channel (DPCCH) and thereby also reducing overall cell noise/interference.

As an example, the above, SIR_target reduction scheme might use the following UL channels during its application;

1) Dedicated Physical Control Channel (DPCCH) which consists of;
   a. Two Transmit Power Control, TPC, bits, and,
   b. Eight Pilot Bits.
2) High Speed Dedicated Physical Control Channel (HS-DPCCH) which consists of;
   a. Channel Quality Indication (CQI) bits
   b. Acknowledgement/Negative Acknowledgement (ACK/NACK) bits

Having reduced the power usage (and hence interference) during periods of inactivity, a method is then required to ensure that signals (on the HS-DPCCH) are transmitted at their correct levels when UEs are then active (e.g. when new data arrives in the UL MAC-enhanced dedicated channel, MAC-e, buffer). This is achieved through β boosting (3GPP TR 25.903 v0.4.0, see ref). SIR_target reduction together with β boosting allows UEs to operate in CPC fashion. Figure 2 and Figure 3 show a simplistic view of waveforms during active and inactive periods.

In order to obtain any gain during the active periods the total transmit power of the DPCCH and the HS-DPCCH after SIR_target reduction and boosting should be less than the total transmit power that occurs when using normal SIR target operation. It is noted that the two methods of operation may not result in the same performance results since there may be a penalty associated with knock-on effects of channel estimation under (possibly) worse conditions (3GPP TR 25.903 v0.4.0, see ref).

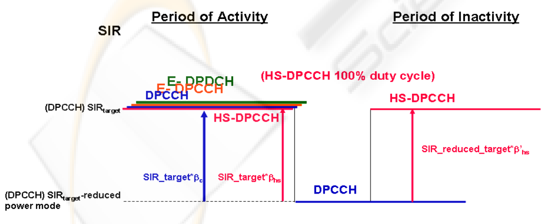

Figure 2: Signal to Interference Ratio (SIR)/Power of Waveforms during periods of activity and inactivity, for a 100% HS-DPCCH duty cycle.

It is noted that the 3GPP standard of ref (3GPP TS 25.213 v6.5.0, see ref) indicates how to set the β (gain) values of appropriate signals. Of particular interest is the β_{hs} value, as derived from a quantized amplitude ratio, A_{hs}, which is translated from Δ_{ACK} , Δ_{NACK} and Δ_{CQI} signalling coming from higher layers. Δ_{ACK} , Δ_{NACK} and Δ_{CQI} are carried by the HS-DPCCH channel and are associated with acknowledgment, negative acknowledgement and channel quality indication respectively.

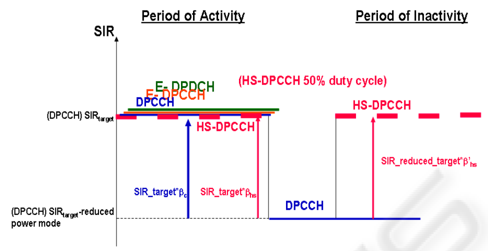

Figure 3: Signal to Interference Ratio (SIR)/Power of Waveforms during periods of activity and inactivity, for a 50% HS-DPCCH duty cycle – indicated by equally spaced dashed lines.

6 SIGNAL GENERATION & RESULTS

In order to estimate whether the proposed CPC scheme, is likely to lead to distortion effects due to incorrect PA back-off setting (through determination of the CM), representative signals are simulated and the CM calculation is performed. Comparison of calculated CMs of other 3G WCDMA R6 signals is then undertaken (with and without the inclusion of the proposed CPC scheme). Using the empirical results from ref (3GPP TSG RAN WG4#31, 2004), in the form of a graph, the calculated CM values can be mapped onto the required PA power back-off values. From these simulations, comparisons, and mapping a conclusion might then be reached as to whether such a scheme would significantly add distortion when such CPC signals are processed and transmitted by the PA. decibels (dBs) above the DPCCH.

Table shows some of the various signals considered – Signal A is the reference signal (3GPP TSG RAN WG4#31, 2004), (3GPP TSG RAN WG4#33, 2004), (3GPP TS 25.101 v6.12.0, see ref This signal can be used to verify the "raw CM" value of 0.0. Values obtained are in agreement with the previous literature. Signals B to I are those which might occur when the CPC scheme is implemented, i.e. they reflect various power offsets during an inactive period and which might be the result of boosting the β_{hs} value so that the HS-DPCCH is a certain number of decibels (dBs) above the DPCCH.

Table 1: Considered Signals.

	DPCCH				DPDCH				E-DPDCH				HS-DPCCH				E-DPCCH				raw_CM (dB)	CM (dB)	CM	DPCCH (dB)	HSDPCCH (linear)	Power Step Difference (dB)	Duty Cycle (%)
	Br	βc	SF	C	Br	βd	SF	C	Br	βed	SF	C	Br	βhs	SF	C	Br	βec	SF	C							
A	Q	8	256	0	I	15	64	16	-	–	-	-	-	–	-	-	-	–	-	-	0	0	0	ref	-	ref	-
100% HS-DPCCH Duty Cycle																											
B	Q	15	256	0	-	-	-	-	-	-	-	-	Q	30	256	33	-	-	-	-	3.74409	2.5	2.024	0	3.981	6	100
C	Q	15	256	0	-	-	-	-	-	-	-	-	Q	42.25	256	33	-	-	-	-	2.66214	1.5	1.439	0	7.943	9	100
D	Q	15	256	0	-	-	-	-	-	-	-	-	Q	59.76	256	33	-	-	-	-	1.68645	1	0.912	0	15.849	12	100
E	Q	15	256	0	-	-	-	-	-	-	-	-	Q	84.43	256	33	-	-	-	-	0.97419	1	0.527	0	31.623	15	100
50% HS-DPCCH Duty Cycle																											
F	Q	15	256	0	-	-	-	-	-	-	-	-	Q	30	256	33	-	-	-	-	3.7457	2.5	2.025	0	3.981	6	50
G	Q	15	256	0	-	-	-	-	-	-	-	-	Q	42.25	256	33	-	-	-	-	3.42432	2	1.851	0	7.943	9	50
H	Q	15	256	0	-	-	-	-	-	-	-	-	Q	59.76	256	33	-	-	-	-	3.03883	2	1.643	0	15.849	12	50
I	Q	15	256	0	-	-	-	-	-	-	-	-	Q	84.43	256	33	-	-	-	-	2.71976	1.5	1.47	0	31.623	15	50

Note: the raw_CM value does not include normalization by the factor K of ref (3GPP TS 25.101 v6.12.0, see ref), and does not include the quantization indicated by the "CEIL" (rounding up to the nearest 0.5dB) function found in the same reference. The column headed CM(dB) does take this into account and values are seen to stay within the 0 to 3dB range (consistent with the requirement of ref (3GPP TS 25.101 v6.12.0, see ref)).

Values for β_{hs} of 42.25, 59.76 and 84.43 correspond to power offsets, $20\log_{10}(\beta_{hs}/\beta_c)$, of $20\log_{10}(42.25/15)$,$20\log_{10}(59.76/15)$,$20\log_{10}(84.43/15)$, i.e. 9dB, 12dB and 15dB respectively.

It is noted that the relationship of PAPR or the CM to amplifier back-off are derived empirically, e.g. (3GPP TSG RAN WG4#31, 2004), (3GPP TSG RAN WG4#33, 2004) using a limited number of amplifiers, with curves fitted to experimentally obtained data. Using these references and the resulting empirical result, the raw_CM values of decibels (dBs) above the DPCCH.

Table are mapped onto the corresponding power back-off value. The resulting graph can be seen in Figure 4.

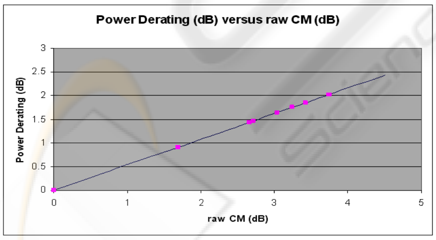

Figure 4: PA De-rating/Back-off versus raw_CM (dB). The points on the graph are the simulation results mapped onto the PA back-off value.

7 CONCLUSION

The PAPR or CM relationship with amplifier back-off is dependent on the complexity of modulated signals. For current systems, the PAPR/CM versus PA back-off relationship can be determined empirically through the generation of appropriate Uplink Modulated Waveforms. The CM is a value which can be determined through simulation (as in this paper).

Through comparison of appropriately modulated waveforms that comprise the CPC scheme given in this report, it has been seen that such a scheme produces CM values close to those of similar non CPC waveforms, laying in the same 0 to 3dB range (3GPP TSG RAN WG4#31, 2004), (3GPP TSG RAN WG4#33, 2004), (3GPP TSG RAN WG4#38, 2006).

It can therefore be concluded that the impact of the reported CPC scheme on the CM and the subsequent PA amplifier back-off is no worse than that which currently exists, i.e. when no such CPC scheme is implemented. Indeed, if an issue had been found, or is ever found, it would undermined the CMs usage suitability, in terms of its ability to be used with any channel combination and format and any system concept.

Implementation of any CPC scheme that alters the gain value of the HS-DPCCH requires that the appropriate standard, e.g. ref (3GPP TS 25.213 v6.5.0, see ref), or future standards are modified to reflect the change in relationship between the HS-DPCCH and the DPCCH.

Finally, a different (more explicit) procedure from that of (3GPP TS 25.101 v6.12.0, see ref) has been derived in this paper.

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