Agenda item: **Ad hoc 1**

Source: **Siemens AG**

Title: **Comments on Joint Predistortion**

Document for: **Discussion**

Introduction

Joint Predistortion (JP) has been proposed to be included in UTRA [1][4][7][8][9]. However there were some objections by several companies to use JP in the TDD mode. In this document we want to summarise our comments to the use of JP.

Discussion

The purpose of Joint Predistortion (JP) is to shift baseband complexity from the UE to the NodeB in order to reduce the power consumption in the UE and, hereby, to enlarge the mobility time. Before DL transmission JP applies a linear matrix to all spread and scrambled data signals in such a way that an easy receiver structure (code matched filter) can be used in the UE. JP is strongly based on DL/UL reciprocity, since the DL channel equalisation is based on a proper UL channel estimation. This implies that JP can only be used in case of slow changing channel conditions, limited user velocity and a restricted delay between UL and DL transmission. As proposed in [6], JP shall be an option in both UE and NodeB that is switched on only, if the channel conditions and the user speed are favourable.

Regarding the use of Joint Predistortion there are at least the following open items relating to signalling, testing, feasibility, performance and power consumption benefits:

1. Signalling

In the case of higher velocity or fast changing channel characteristic, the JP mode needs to be switched off. In the current scheme, there has to be a (higher Layer) signalling mechanism to signal to the UE, whether JP is applied or not.

1.1. The signalling has to be done for all users in a time slot in which JP is applied. Acknowledgement messages must be sent by the UE to the NodeB before JP can be switched off. This leads to a signalling overhead due to JP that depends on the switching rate. Therefore, JP can be used only in very stable environments, where no such often change is expected.

1.2. Switching off JP must be signalled to the UE early in advance, since the ACK/NAK signalling mechanism takes some time. This means that channel fluctuations or the change of the user speed must be foreseen somehow. It’s quite unclear how the possible use of JP can be predicted reliably.

1.3. If higher layer signalling cannot be detected by the UE because of wrong predistortion, the UE will never detect the change and this will lead to an unpredictable, unstable situation.

2. Testing

Since the JP algorithm itself will not be specified, the output signal of the NodeB is unpredictable. This raises problems in testing the performance, since this depends on the implementation in both

NodeB and UE. What is the ‘standard’ NodeB to be used for testing the UE? What is the standard UE to be used for testing the NodeB?

3. General Feasibility

3.1. There will be mismatches between transmit and receive filters at both NodeB and UE. At least a ripple in passband up to 1dB should be taken into account, therefore differences in channel estimation could be up to 2dB. Since JP strongly relies on the UL/DL reciprocity this unavoidable mismatch may make the use of JP impossible.

3.2. For 2Mbps the benefits in terms of battery saving are biggest. However, it is unlikely that the 2Mbps data rate is applicable for JP at all, since this seems to be the worst case for UL/DL channel estimation because of the delay between UL and DL slots.

3.3. With reduced E_b/N_0 the BER tends to 0.5. With respect to the sensitivity of JP to channel estimation a major degradation of the DL transmission can be expected, when errors in UL channel estimation occurs or DL/UL channel reciprocity no longer holds.

3.4. In order to avoid the major degradation of the DL transmission, a reliable estimate of the UE’s speed has to be performed in the NodeB. For other features that were introduced in UTRA TDD and that are affected by the user speed (e.g. closed loop Tx diversity), the performance does not depend in such a degree on the UL/DL reciprocity or the user speed.

3.5. In the optimum case, if JP is applied to the data parts of the TDD burst, the chain of the JP matrix and the DL channel is seen by the UE as a single path AWGN channel. However, up to now there is no definition how to derive the timing of the resulting 'virtual' AWGN channel at the UE. The channel estimator of the UE provides the estimation of the actual mobile channel and is therefore not immediately suited as a time reference to the virtual AWGN channel. Thus a particular rule to derive the position of the predistorted data signal from the channel estimate has to be defined. This definition will lead to an additional uncertainty in the JP process, in particular if the reference timing is set relative to the first or highest channel impulse. There exist no figures showing how this will affect the resulting BER/FER.

4. Performance

4.1. The impact of realistic indoor channel characteristics like moving persons and opening doors has not been taken into account yet.

4.2. JP implies perfect fast power control, however this was not assumed for JD. The real BER curves for JD will therefore be different to the presented curves if fast PC is also applied for JD.

4.3. There might occur a degradation of users in neighbouring cells, using no JP in the same timeslot at the same frequency, because the codes are optimised in whiteness and this cannot be guaranteed in case of a predistorted signal. The higher PAR ([3] up to ±1dB) could lead to degradation of other cells.

5. Power Consumption Benefits

The aspect of battery saving seems to be the most important effect when using JP. However, there are still some doubts that this benefit is as high as assumed in [1].

5.1. In Tdoc [1] the power consumption of JP is compared to that of JD. For the RF part, a value of 163 mW [2] is assumed, common for all data rates. It is more likely, that RF consumption in the simulations will be a function of the data rate, since reception and decoding are also dependent on the number of active timeslots (e.g. A/D-Converter); furthermore depending on development

of new techniques for semiconductor devices, the percentage of power consumption in base band calculation will generally go down in the future in contrast to RF part power consumption.

5.2. The calculation effort of JD can dramatically be decreased if static channel conditions and indoor channels are assumed, while saving some expensive matrix operations and assuming shorter channel impulse responses (indoor) and therefore do the estimation for only a few (W in the range of 10) channel parameters (instead of W=57).

5.3. Since JP shows the largest benefit for high data rates and since signalling overhead will increase with multiple users in one time slot, it seems reasonable that JP will be applied only to time slots which are allocated to a single user. In this case JD can be switched off at all, when the channel estimate indicates that there is a single path channel.

5.4. Additional complexity results for the case of multicode in DL should be provided, since all the former simulations assume variable spreading (SF=2) in DL.

Conclusion

Joint Predistortion (JP) was proposed to be used optional at both NodeB and UE in UTRA TDD. This contribution lists a lot of still open questions and general concerns related to the use of JP that can be used as basis for further discussion.

Because of these problems JP is not seen as an valuable and feasible option and it is therefore proposed not to be included in the release ’99 of UTRA TDD.

References

[1] Tdoc R1-99917 “Battery Savings using Joint Predistortion”
[2] Tdoc SMG2 270/97, “Concept Group Alpha – Wideband Direct-Sequence CDMA, evaluation document / Draft 1.0), Part 2”, 10-1997
[3] Document “Simulation results on the effects of Joint Predistortion on the transmitted signal spectrum”, Bosch
[4] Tdoc TSG-RAN WG#8 R1-99f17 “Impact on transceiver chain phase imbalances on Joint Predistortion”
[5] Tdoc SMG2 UMTS-L1 553/98 “Joint Predistortion Complexity”
[6] Tdoc R1-99156 „Summary of Joint Predistortion“
[7] Tdoc R1-99918 „Tx Diversity with Joint Predistortion“
[8] Tdoc R1-99g20 „TDD transmit diversity with joint predistortion - further simulation results“
[9] Tdoc R1-99g37 „Joint predistortion text proposal“