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Agenda item: **Ad hoc 1**

Source: **Bosch**

Title: **Answers to Tdoc TSGR1#9(99)i06**

Document for: **Discussion**

Introduction

Joint Predistortion (JP) was extensively discussed at RAN1 meeting #8. No decision could be reached. To come to a conclusion, companies were asked to summarise remaining concerns. [1] is such a list of concerns and comments on JP. Here we try to give answers to those comments.

Answers and Comments

Below the comments of [1] are listed, each followed by our comments.

1. Signalling

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.

Comments:
Not all users in the same JP slot must be switched altogether to joint detection (JD). Signalling is required only for users which have to be switched from JP to JD or vice versa. Only one additional signalling bit per user is required. For avoiding high switching rates see below, 1.2.

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.

Comments:
A simple switching rule based on velocity prediction is the following: switch JP user to JD slot if $v_{predict} = v_{last} + (v_{last} - v_{lastbutone}) > v_{crit.JD}$. Switch to JP if $v_{predict} = v_{last} + (v_{last} - v_{lastbutone}) < v_{crit.JP}$. Multiple switching back and forth at critical velocities will be prevented by choosing $v_{crit.JP} < v_{crit.JD}$ (Hysteresis).
During acceleration there will be enough time for switching: even when accelerating from 0 to 100km/h in 10s, velocity will increase by 1km/h only during 10 frames. 10 frames should be enough for switching.

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.

Comments:
JP signalling, like other control information, will be strongly protected by channel coding. Errors will be quite rare. Remaining errors can be detected by measuring the physical channel BER. If the BER of a JP physical channel exceeds a critical value, the UE should cause the NodeB to reconfigure to a JD channel.

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?

Comments:
Since JP algorithms will not be specified, the NodeB's DL performance must be tested. This can be done by using a standard UE defined by a code matched filter for detection. Different from JD systems, the JP UE's detector performance must not be tested, since the detection algorithm is prescribed.

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.

Comments:
We will provide simulation results taking into account a passband ripple at forthcoming meetings.

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.

Comments:
According to [2], 2Mbps will be mapped onto 11 DL slots. In principle, this mapping allows for using the remaining 4 slots in the UL. When using multiple switching points, this corresponds to frame structure 2 of [3]. It allows to use JP up to about 25km/h. In the worst case, only 1 UL slot per frame will be available. Then the 2Mbps service may be mapped onto 8 JP slots and 3 JD slots. This mapping corresponds to frame structure 1 of [3] and will work up to about 10km/h. Even using this mixed mapping will result in about 2.5 times lower detection complexity compared to a pure JD mapping (assuming complexity savings of JP detection compared to JD by the factor of 5.4 given below in sec.5.4.).

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.

Comments:

See 3.1.

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.

Comments:
Correct.

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.

Comments:
The same synchronisation mechanisms as without JP should be used. This means that synchronisation should be based on the SCH and on midambles. Synchronisation tracking based on midambles may be done by determining the largest channel estimation component. No corresponding simulation results are available yet.
Other synchronisation mechanisms may be possible which do not require any midamble (then freeing the midamble portion for additional data transmission). Corresponding ideas exist, but have not been worked out in detail so far.

4. Performance

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

Comments:
Currently there is not yet any channel model taking into account opening doors. JP as well as JD and Rake performance will degrade in indoor environments with quickly appearing and disappearing paths.

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.

Comments:
For a comparison of JP and JD with fast PC simulation results see [3].

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 ([...] up to ±1dB) could lead to degradation of other cells.

Comments:
Inter cell interference is most severe at cell borders. Furthermore JP signals are generated only at NodeBs. Therefore it can be expected that interference at cell borders by JP signals will be much lower than interference by JD signals from neighbouring UEs (within neighbouring cells).
More exact interference values will be provided later by means of simulations.
Higher PAR values will not lead to a degradation of other cells. Though JP leads to higher PAR values compared to TDD spreading without JP, the values are similar to those of the FDD mode. So, out of band emissions will be sufficiently low when using power amplifiers meeting the requirements of FDD power amplifiers. Meeting these requirements should be ensured by conformance testing.

5. Power Consumption Benefits

5.1. In Tdoc [4] the power consumption of JP is compared to that of JD. For the RF part, a value of 163 mW [...] 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.

Comments:
Of course RF power consumption will depend on the data transmission rate. The values given in [4] can be seen as an upper bound for the following reasons: Due to lack of specific TDD RF power consumption information, in [4] RF power consumption estimates for the FDD mode have been used. Since FDD UEs do transmit and receive in all slots, the given values are best compared to TDD values with equal numbers of transmission and reception slots and all slots in use. This corresponds to similar and high data rates in up and down link of the TDD mode. In most realistic cases more slots will be used in the DL than in the UL. Then RF power consumption in the UE will be reduced compared to the given values. This results in even higher battery savings with JP.
In a more recent TDD specific analysis we arrived at slightly higher values: TDD RF will consume about 15mW per slot for reception and for transmission when neglecting power amplifier consumption. Assuming UE power class 4, the power amplifier will require about 0.5mW additional consumption per transmit slot in indoor environments. Assuming a 2Mbps service in the DL and a 144kbps service in the UL, this will result in about 180mW overall RF power consumption (compared to 163mW assumed in [4]).
Regarding power consumption in future implementations, it might be true that base band consumption per MIPS will decrease faster than RF consumption per output power. On the other hand more and more functionalities accomplished nowadays by RF will be transferred to base band processing in the future. Therefore base band complexity will stay important.
Finally it must be clear, that power consumption always depends on implementation. That is why any power consumption estimation must be inexact to a certain degree. [4] tries to give coarse estimates only.

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).

Comments:
The figures given in [4] already take into account lowered JD complexity when dealing with short channels. For multicode complexities see below, 5.4.

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.

Comments:
Since TDD uses orthogonal spreading codes, JD can be switched off in single path environments even in DL time slots with multiple users. The question is, whether a channel is really single path. All UMTS channel models are multipath channels, even in indoor environments. Simulation results show that JD is required in these cases (compare [5]).

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.

Comments:
The following figures compare JP and approximate JD detection complexities when using multiple codes. Since there are no approximate JD complexities available for the mappings of [2], we use multicode JD complexities taken from [6] for alternative mappings. JP detection complexities are calculated for the same mappings.

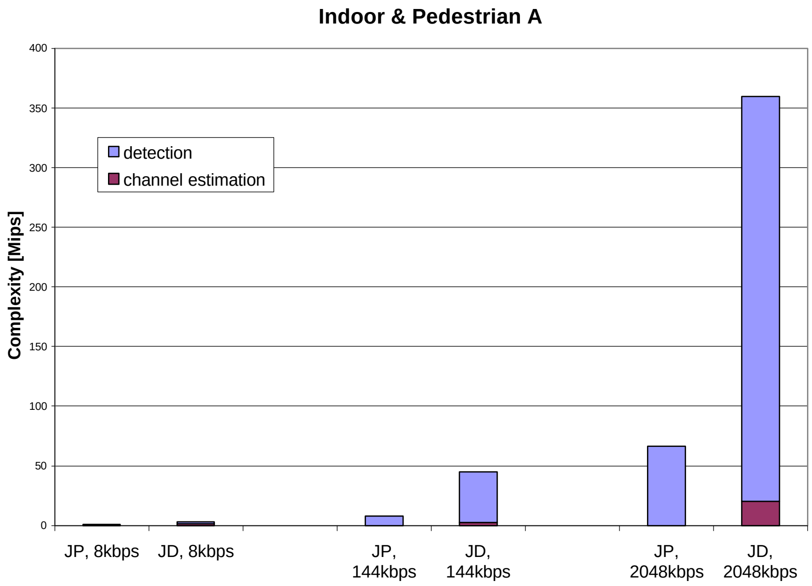

Fig.1: Mips requirements (real multiplications) of JP and JD in the indoor and pedestrian A environment.

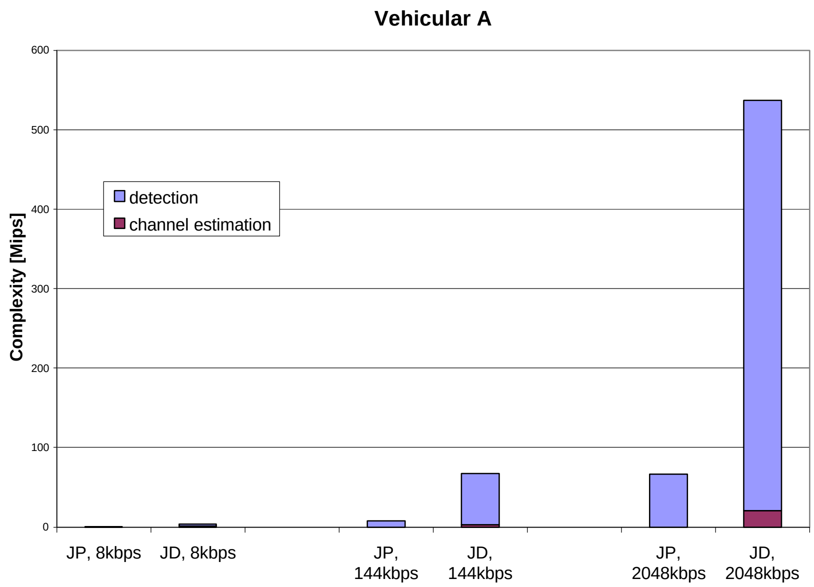

Fig.2: Mips requirements (real multiplications) of JP and JD in the vehicular A environment.

When using multiple codes, JP saves complexity by a factor of at least 5.4 at high data rates.

Summary and Conclusions

In this paper we tried to give answers to remaining concerns on JP. Most of the questions could be answered. Nevertheless some questions could not yet be answered in detail. Therefore, we propose not to include JP in release ’99, but to continue the discussion in 2000. To give the basis for a final decision, we will provide lacking information at forthcoming meetings.

References

[1] Tdoc R1-99i06, “Comments on Joint Predistortion“, source: Siemens, Dec. 1999.

[2] Tdoc R1-99d28, “Inclusion of a Clause for Detailed Channel Coding – REVISED“, source: Siemens, Aug. 1999.

[3] Tdoc R1-99j48, “TDD transmit diversity with Joint Predistortion – further simulation results (2)”, source: Bosch, Dec. 1999.

[4] Tdoc R1-99917, “Battery Savings using Joint Predistortion“, source: Bosch, July 1999.

[5] Tdoc R1-99a82, “TDD downlink performance in indoor environments”, source: Bosch, Aug. 1999.

[6] Tdoc SMG2 UMTS-L1 301/98, “Receiver complexity with variable spreading option (TDD part)”, source: Alcatel, Sept. 1998.