TSG-RAN Working Group1 meeting #9 **_TSGR1#8(99)j02_**
Dresden, Germany, 30 November – 3 December 1999

**Agenda Item:**
**Source:** **Nokia**
**Title:** **Soft symbol reliability for uplink PC in soft handover (Rev.)**
**Document for:** **Decision**

## 1. CONTENTS OF THE CONTRIBUTION

The contribution is divided into two main parts. Although these parts are separable from an operation point of view, they are however dealt with together for convenience. These two contribution parts include:

- The use of the TPC command Soft Symbols for estimating the reliability of the TPC command instead of a separate SIR measurement. Although these two variables are closely related, as demonstrated in the following Section, the use of the Soft Symbols directly does provide advantages over the use of a separate SIR measurement.

- The use of various TPC algorithm blocks (two or more) in parallel in order to enhance the probability of a correct TPC decision. The basic idea of the parallel use is illustrated in Figure 1. Out of the individual TPC block outputs, the minimum output is selected as the final output for each TPC round. The enhanced reliability introduced with the parallel algorithm use leads to lower transmitted power levels of the system, as demonstrated by the results. While discussing the various algorithms that could be employed by the parallel system, a new Integrating algorithm is introduced, with its benefits clearly demonstrated. There are several alternatives for the parallel TPC blocks introduced and discussed in the contribution, and it is proposed that all of the alternatives could be used, and the basic idea of parallel use is included in the standard.

- An integrating algorithm is introduced, making use of the information of past TPC commans. This integrating algorithm is employed as a block of the parallel system, and cannot be applied by itself without other component. Adding the integrating block, however, enhances the overall performance of the TPC parallel algorithm.

It is recommended that the standard text should include the following components/demands:

1. Use of soft symbol TPC command for reliability estimation.

2. Use of algorithm blocks (two or more) in parallel for maximum performance. Of these parallel outputs, a minimum is selected (0 or 1). The algorithms to include may vary, with the following exception:

3. One of the parallel blocks must be the integrating algorithm block.

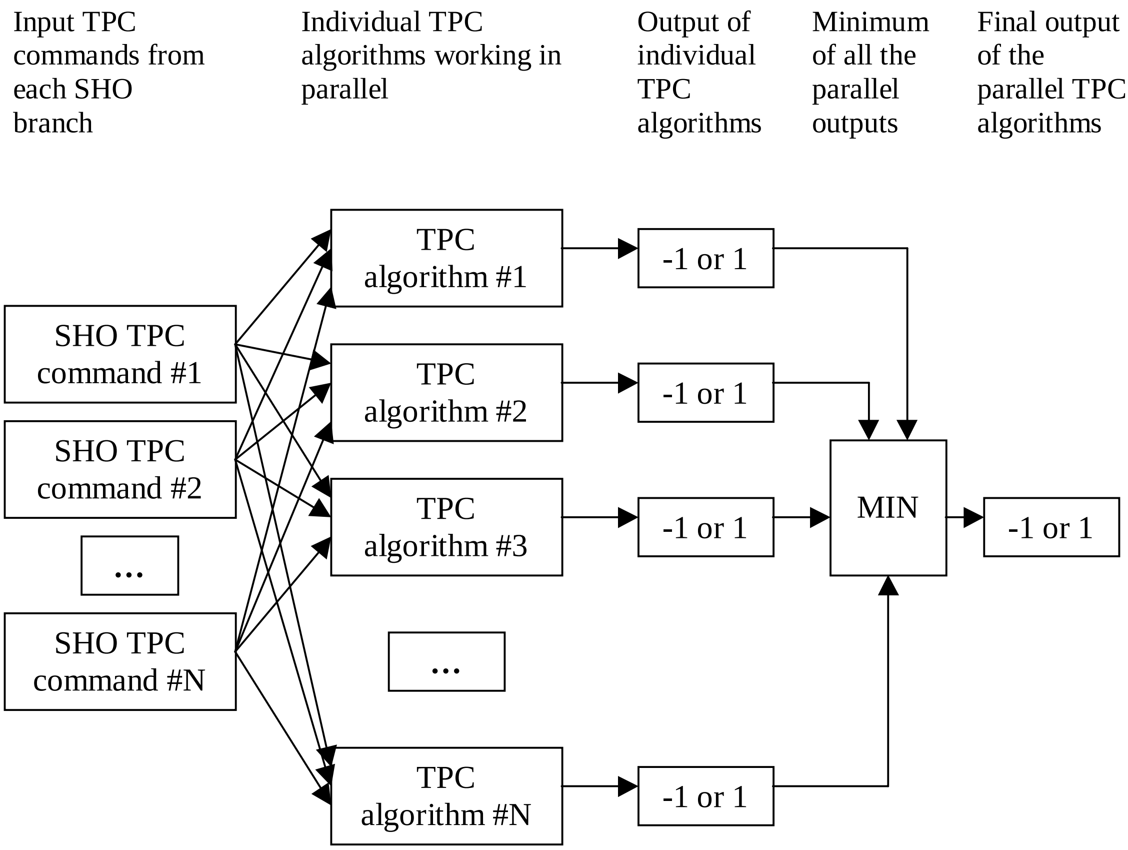


**Figure 1. Parallel use of several TPC algorithms. Each block treats the TPC commands in SHO individually, yielding a TPC command. Out of these commands, the minimum is selected. There are several TPC algorithm block combinations discussed in this contribution.**

## 2. TECHNICAL DETAILS

### 2.1. Soft Symbol reliability estimation

The Soft Symbol in this text refers to the TPC command that has traveled through the channel and has been decoded. The original transmitted symbol (or bit) has changed from –1 or +1 to something else, due to the channels effects such as noise. It is argued that the use of the Soft Symbols directly, with a threshold other than 0, will provide an equal or better (0.5 dB decrease in Ptx levels as shown by the results) when compared to the SIR-based scheme. There is no separate algorithm block that would estimate the reliability based on the Soft Symbols. Instead, the use of a variable Soft Symbol threshold is responsible for selecting an optimum (=reliable) TPC command.

Therefore, the use of Soft Symbols instead of SIR for reliability estimation has the following advantages:

1. Ptx levels decrease by as much as 0.5 dB when compared to the SIR-based scheme, as demonstrated by the provided simulation results.

2. No separate SIR measurement needed by the TPC algorithm

3. No separate received TPC command reliability estimation block needed by the algorithm, as the Soft Symbol reliability estimation is carried out by using a variable threshold for determining the TPC command (up/down)

The values of the soft symbol TPC command used in the simulations shown in this contribution are only valid for a system where background noise has been assumed to be normalized, i.e. equal to 1. In order to be able to use the soft symbol threshold in a real-world system, a normalization procedure has to be applied.

This procedure for the soft-symbol (*SS*) can be defined as follows:

$$SS_{normalized} = \frac{SS_{not\ normalized}}{N_0}, \qquad (1)$$

where $N_0$ is the wideband interference in a WCDMA system. The Soft Symbol (SS) itself can be expressed as a complex variable:

$$SS_{general} = x + yj \qquad (2)$$

**It must therefore be noted that all Soft Symbol numeric values presented in the contribution text refer to a system with normalized background noise, and should only be regarded as relative indicators. This applies to the example algorithms sequences shown in Section 3, and in the X-axis labels in all of the graphs shown.**

The Soft Symbol (SS) parameter was used as a variable decision threshold by all of the algorithms investigated, except the current algorithm, where a SIR-based threshold was used. In addition, all algorithm components with an MRC block used a constant threshold of 0 for that block. The algorithms are described in more detail below.

## 3. ALGORITHMS

The algorithm development and testing was based on the idea of combining few of the developed TPC blocks and running them in parallel. Of these parallel outputs the minimum was selected as the final output of the overlay TPC block. The studied algorithms (main blocks and their combinations) are shown in Table 1. The main blocks are briefly introduced in the following sub sections.

**Table 1. Main TPC blocks and their combinations, forming parallel TPC outputs, out of which a minimum is selected.**

| Algorithm acronym | SIR based reliability (current algorithm)<br><br>SIR | Soft Symbol based reliability<br><br>SS | Maximal Ratio Combining<br><br>MRC | Soft symbol integration<br><br>INT |
|---|---|---|---|---|
| Current SIR based | ● | | | |
| SS | | ● | | |
| SS + MRC | | ● | ● | |
| SS + INT | | ● | | ● |
| MRC + INT | | | ● | ● |
| SS + MRC + INT | | ● | ● | ● |

### 3.1. Current TPC algorithm with SIR based reliability

SIR reliability estimation is the algorithm currently regarded as the "standard" algorithm, and has been thoroughly discussed in the introductory Section. The SIR reliability threshold was varied from 0.0 to 0.4 with a step size of 0.05, while an optimum detection (minimum Ptx levels) was obtained with SIR threshold values between 0.2 and 0.3 (in a noise normalized system).

Example sequence: (values apply to a noise normalized system)

SIR reliability threshold = 0.2, TPC detection threshold = 0.

| | | | | | |
|---|---|---|---|---|---|
| SS1: | -0.2 | -0.3 | 0.1 | -0.3 | -0.6 |
| SIR1: | 0.3 | 0.4 | 0.5 | 0.1 | 0.2 |
| | | | | | |
| SS2: | 0.6 | 0.3 | 0.4 | 0.2 | -0.1 |
| SIR2: | 0.3 | 0.1 | 0.3 | 0.4 | 0.3 |
| | | | | | |
| Output TPC: | 0 | 0 | 1 | 1 | 0 |

SS = Soft Symbol TPC command

### 3.2. TPC algorithm with Soft Symbol (SS) based reliability

The received TPC command includes information on the quality of the command, information which is lost during binary detection. Therefore an approach where the soft symbol itself, instead SIR, is used to determined the reliability of the TPC command. The threshold for the soft symbol detection was varied from –0.6 to 0.0 with a step size of 0.05, while optimum detection (minimum Ptx levels) was obtained with Soft Symbol threshold values between –0.4 and –0.2 (in a noise normalized system).

Example sequence: (values apply to a noise normalized system)

SS reliability threshold = –0.25

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TPC, SS1: | -0.2 | -0.3 | 0.1 | -0.3 | -0.6 | ⇒ | 1 | 0 | 1 | 0 | 0 |
| TPC, SS2: | 0.6 | 0.3 | 0.4 | 0.2 | -0.1 | ⇒ | 1 | 1 | 1 | 1 | 1 |
| Output TPC: | min(TPC1,TPC2) | | | | | ⇒ | 1 | 0 | 1 | 0 | 0 |

## 3.3. Maximum Ration Combining (MRC)

In the MRC approach the TPC soft symbols are combined by simple addition, since there is no phase in the signal. A threshold of 0 has been used for determining whether an up- or down-command is selected as output.

Example sequence: (values apply to a noise normalized system)

| | | | | | |
|---|---|---|---|---|---|
| TPC, SS1: | -0.2 | -0.3 | 0.1 | -0.3 | -0.6 |
| TPC, SS2: | 0.6 | 0.3 | 0.4 | 0.2 | -0.1 |
| MRC | 0.4 | 0 | 0.5 | -0.1 | -0.7 |
| Output TPC: | 1 | 1 | 1 | 0 | 0 |

## 3.4. Soft Symbol Integration with (INT)

In this approach, the minimum input soft symbols (in SHO) are integrated and a separate soft symbol thresholding for this integrated sum is conducted. After each TPC round, the minimum soft symbol value of that round is added to the integrated sum. If the integrated sum is below a predetermined threshold, a power-down command is issued, even if the individual soft symbols from that particular TPC round do not imply a power-down command.

If a power-down command is issued, based on the integrated sum crossing the threshold value or due to the individual soft symbols, the integrated sum for the next TPC round is again set to zero. A flow chart of the algorithm operation is shown in Figure 2.

The main benefit of this approach is that it adds "memory" to the system, as not only the TPC command of the current PC round affect the decision making.

Summary of the algorithm logic:

As the integrator must be used along with another TPC block in the parallel system, the following summary and the example sequency applies to a case where the one of two parallel blocks is the integrator (INT) and the other is the SS algorithm. From each TPC round in a SHO case, the minimum TPC command is integrated and thus kept in storage for later use:

- If any of the reliable SHO TPC commands are "down", the output is naturally "down"
- If all of the SHO TPC commands are "up", the output is "up", but in addition, the minimum of the SHO "up" commands of that TPC round is added to the integrated sum
- If the integrated sum exceeds a predetermined threshold, a "down" command is issued, even if all the SHO TPC commands are "up"
- The integrated sum is reset after every "down" command

The INT algorithm is ideal for cases where there are a lot of almost "down" commands, leading to a forced "down" every now and then.

Example sequence: (values apply to a noise normalized system)

Threshold applying for Soft Symbols and the integrated sum: -0.6

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| TPC, SS1: | -0.2 | -0.1 | -0.05 | 0.1 | -0.3 | -0.2 | 0.1 |
| TPC, SS2: | 0.1 | -0.3 | 0.0 | 0.2 | -0.1 | 0.3 | -0.7 |
| Integrated sum: | -0.2 | -0.5 | -0.55 | -0.45 | -0.75 | 0 | -0.7 |
| Output TPC: | 1 | 1 | 1 | 1 | 0 | 1 | 0 |

The integrated sum is responsible for the first down ('0') command ,whereas both the integrated sum and the individual TPC command is responsible for the second down command in the example sequence.

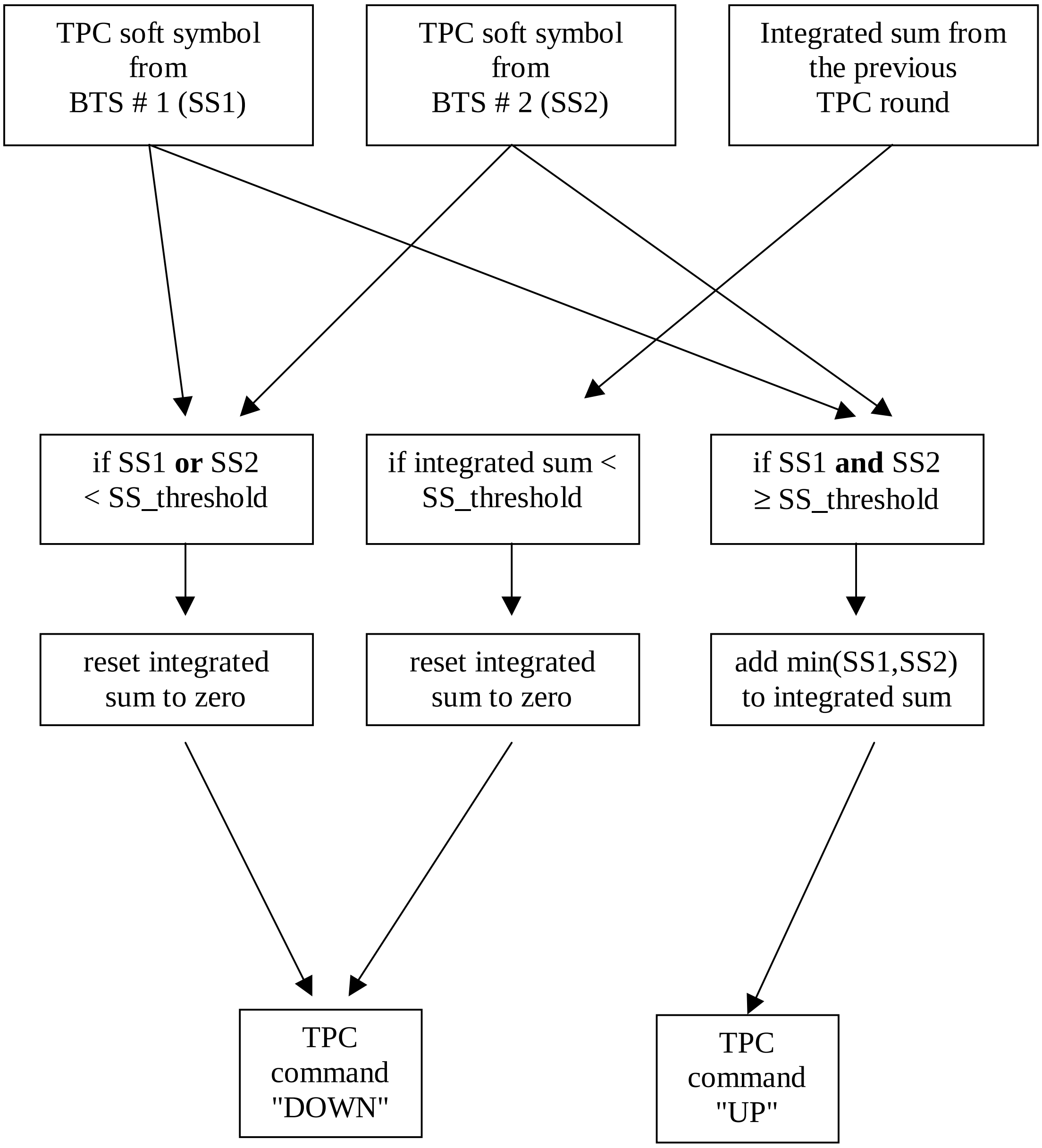


**Figure 2. Flowchart of the INT algorithm operation, in a case where the INT is used in parallel with SS algorithm. The INT algorithm cannot be employed unless parallel to another algorithm block.**

## 4. SIMULATION CASES AND PARAMETERS

All TPC algorithms were simulated with the COSSAP stream-driven simulator, employing a previously constructed two-BTS model. This model also included the outer-loop power control adjusting the reference SIR levels during simulations.

The following cases were considered in the simulations:

- Service: speech 8 kbit/s
- Channel: Pedestrian A (taps 0.2 dB, -12.3 dB)

- MS speed: 3 km/h, 20 km/h, 50 km/h and 120 km/h
- FER (UL and DL): 1% and 1%, 10% and 10%, 10% and 1%
- Simulation length: 8000 frames

The parameters and their values used in the simulations are listed in Table 2.

**Table 2. Simulation parameters and values used in the COSSAP simulations [4].**

| | |
|---|---|
| Frequency | UL: 1920 MHz, DL: 2150 MHz |
| Chip rate | 4096 kchips/s |
| Spreading factor | 128/256 (data/control) |
| Channel coding | UL in both UL and DL |
| Power control | Slot-by-slop (0.625 ms) with a slot delay |
| Power control step | 1 dB, both in UL and DL |
| Interference modeling | Gaussian noise |
| RX-antenna diversity | UL: yes, DL: no |
| SHO combining | Maximum ratio combining in downlink, frame selection in uplink |
| Channel estimation | Only from pilot symbols, interpolation over three slots for data (weights: 0.4, 1.0 and 0.4) |
| Power/SIR estimation | The SIR estimation is done by first coherently averaging the pilot symbols for each tap. Then the sum of the squares of these values is used as the S estimate. The noise value is constant (equal to 1) and is assumed to be known. |
| Number of RAKE fingers | 2 |
| Receiver/transmitter filters | Not used, 1 sample per chip |

## 5. SIMULATION RESULTS WITH A PILOT AND TPC POWER OFFSET

All the results presented in this Section have been obtained **by employing a pilot and TPC power offset of 3 dB** compared to the data channel in the COSSAP model.

### 5.1. SIR algorithm vs. SS algorithm

As a start, the behavior of the algorithm with soft symbol based reliability as compared to the SIR based reliability of the standard approach is first demonstrated. The average level difference between BTSs was 0 dB in the simulations.

The reliability thresholds were varied for both the SIR reliability and the SS reliability simulations. In the SIR algorithm, the SIR threshold determining whether a TPC command was reliable or not was varied from 0.0 to 0.4, with a step size of 0.05. In the SS algorithm simulations, the Soft Symbol threshold was varied from –0.6 to 0.0, with a step size of 0.05 (values apply to a noise normalized system).

The results with four different speeds (3, 20, 50 and 120 km/h) are shown in Figure 3 to Figure 6. The results are shown as the transmitted power in uplink as function of the reliability thresholds employed (either soft symbol or SIR, depending on algorithm). For each of the speeds, three FER cases FER are shown: 1% FER in UL and DL, 10% FER in UL and DL, and a case where we have different FER for UL and DL, i.e. 10% and 1%, respectively.

The results show that in case of 1% FER, the minimum Ptx with the SS algorithm is roughly 0.5 dB less than with the SIR algorithm, when the speeds are 3 and 20 km/h. For higher speeds the difference is less, roughly 0.2-0.3 dB. As expected, the Ptx levels decrease from the 1% FER cases with roughly than 1.2-1.4 dB when the FER is set as 10%. This decrease is observed in all speeds. If the DL FER is kept at 1% while the DL FER is 10%, the Ptx levels decrease even further, by roughly 0.2-0.3 dB. With this last configuration, the probability of erroneously received TPC commands in the MS is reduced by a low FER target, while the Ptx levels are reduced as in the UL/DL 10% FER case.

It must be noted that the Ptx discussed here and elsewhere in the text are in fact the energy-per-symbol ($E_s$), and by adding 6 dB to these levels we would get the energy-per-bit ($E_b$).

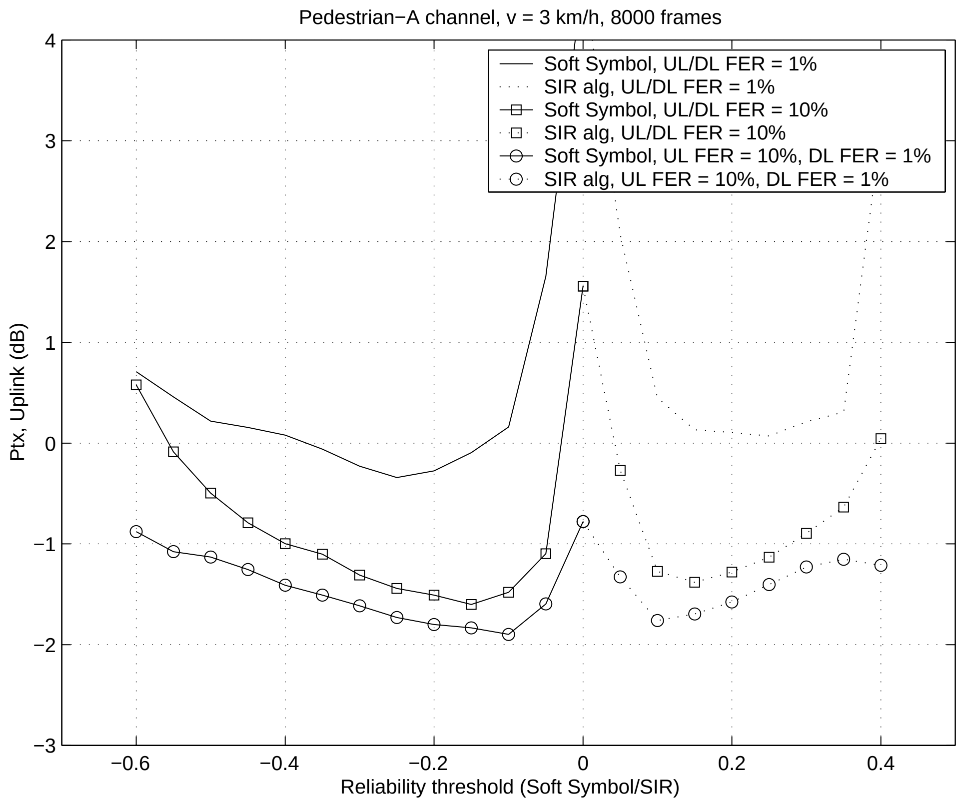


**Figure 3. Comparison of UL Ptx of SS and SIR algorithms. Mobile speed is 3 km/h and three FER cases are considered (a) UL/DL FER = 1%, (b) UL/DL FER = 10% and (c) UL FER = 10%, DL FER 1%.**

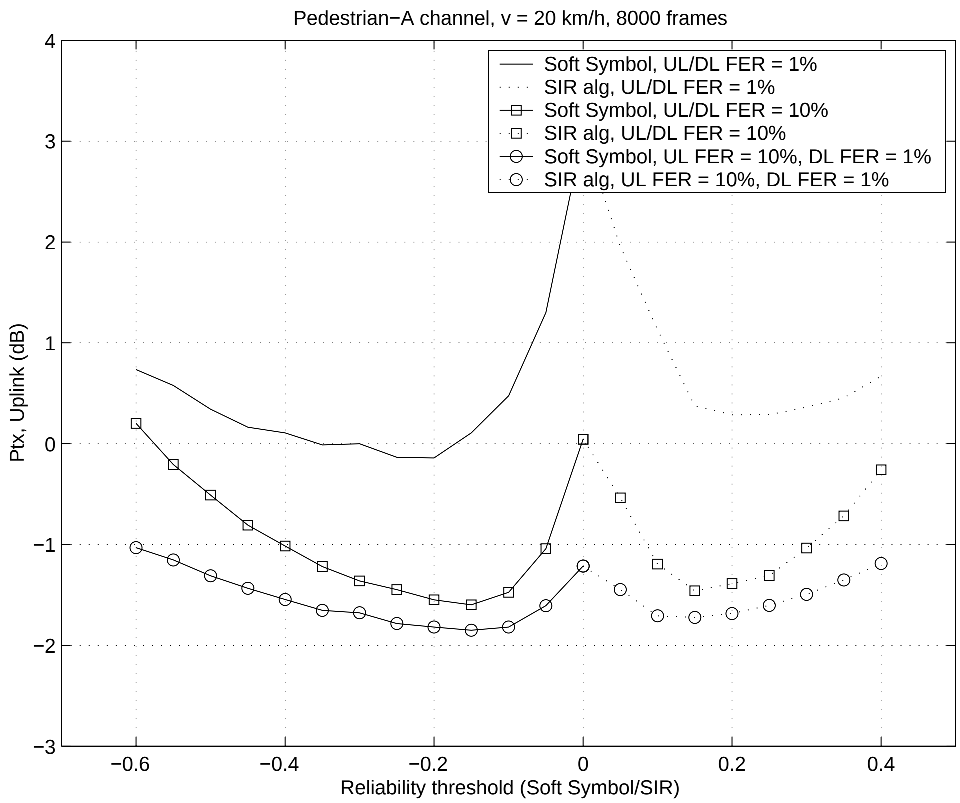


**Figure 4. Comparison of UL Ptx of SS and SIR algorithms. Mobile speed is 20 km/h and three FER cases are considered (a) UL/DL FER = 1%, (b) UL/DL FER = 10% and (c) UL FER = 10%, DL FER 1%.**

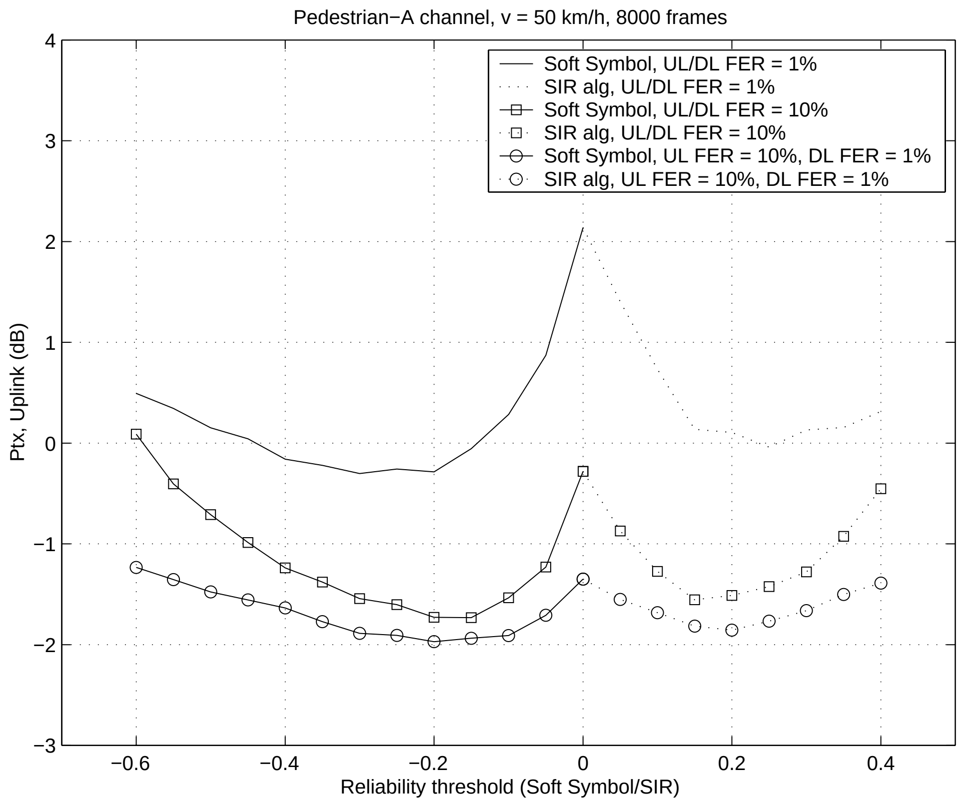


**Figure 5. Comparison of UL Ptx of SS and SIR algorithms. Mobile speed is 50 km/h and three FER cases are considered (a) UL/DL FER = 1%, (b) UL/DL FER = 10% and (c) UL FER = 10%, DL FER 1%.**

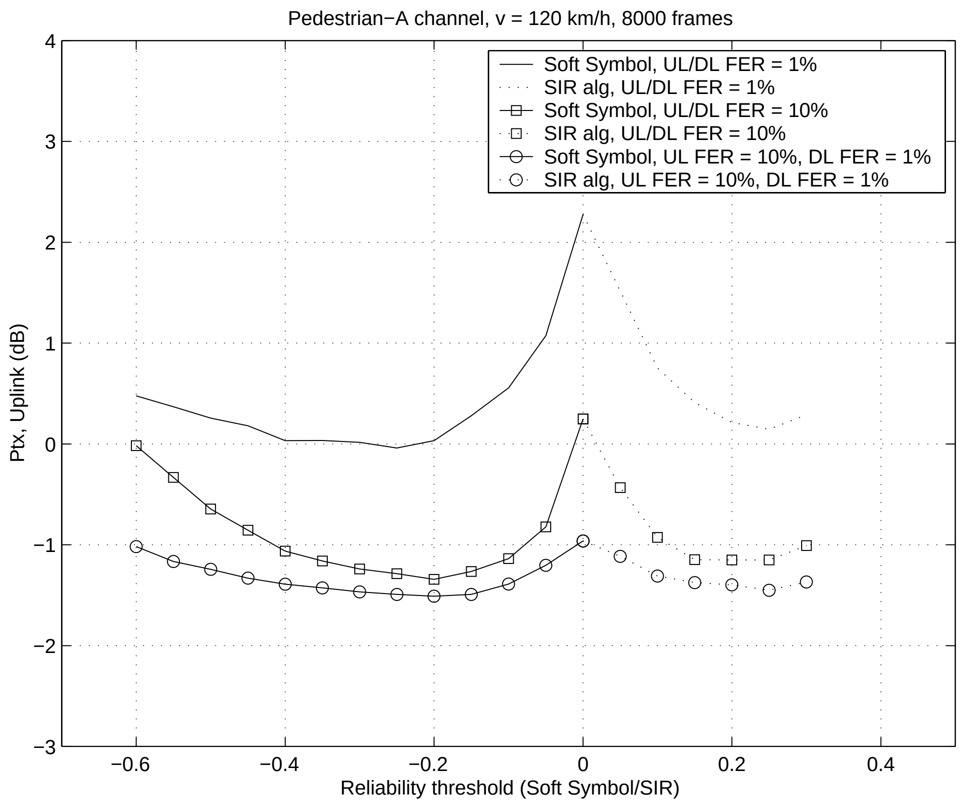


**Figure 6. Comparison of UL Ptx of SS and SIR algorithms. Mobile speed is 120 km/h and three FER cases are considered (a) UL/DL FER = 1%, (b) UL/DL FER = 10% and (c) UL FER = 10%, DL FER 1%.**

## 5.2. Comparison of PARALLEL TPC algorithms with reference to SS algorithm

The following sub-Sections will discuss the performance of the SS algorithm as compared to the proposed algorithms and their combinations listed in Table 1. In order to categorize the results in some reasonable way, they have been divided into subgroups according to the mobile speed, i.e. 3, 20, 50 and 120 km/h.

### 5.2.1. Mobile speed 3 km/h

The three FER cases (1% UL/DL, 10 % UL/DL, and 1% DL 10% UL) are shown in Figure 7 to Figure 9. As the algorithms presented only use the soft symbol (SS) reliability, the horizontal axis is different from the results shown in Figure 3 to Figure 6. The vertical axis, however, is the same in all figures for easier reference. As the results show, the differences between the algorithms are small, and the relations between the various FER cases is the same as in the results shown for the SS and SIR comparison.

All of the algorithms simulated show lower Ptx levels than the SS algorithm. It must be noted that in the previous Section it was already shown that the SS algorithm performed better than the current SIR based algorithm. The lowest overall (as a function of reliability threshold) Ptx levels are achieved with the MRC+INT algorithm. However, differences to the other combination algorithms are small, as the Ptx levels are within a roughly 0.2 dB margin for all of the algorithms. The parameter sensitivity (i.e. reliability threshold) is also lower when compared to SS algorithm.

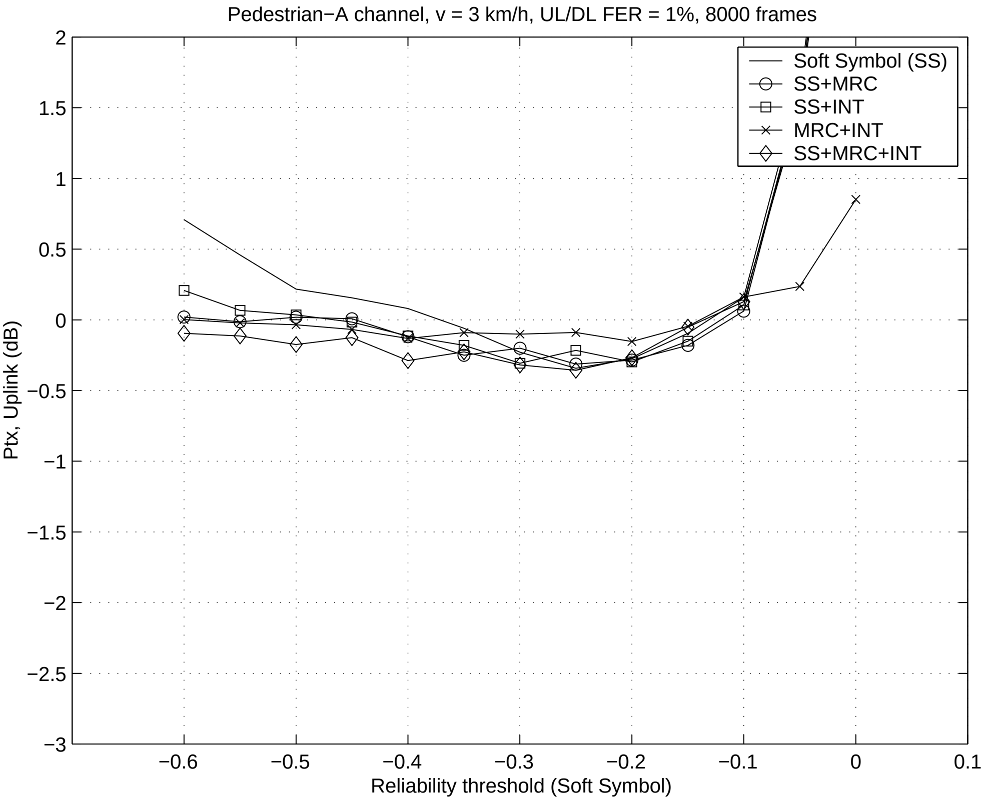


**Figure 7. Comparison of TPC algorithms listed in Table 1. Mobile speed is 3 km/h, UL/DL FER is 1%.**

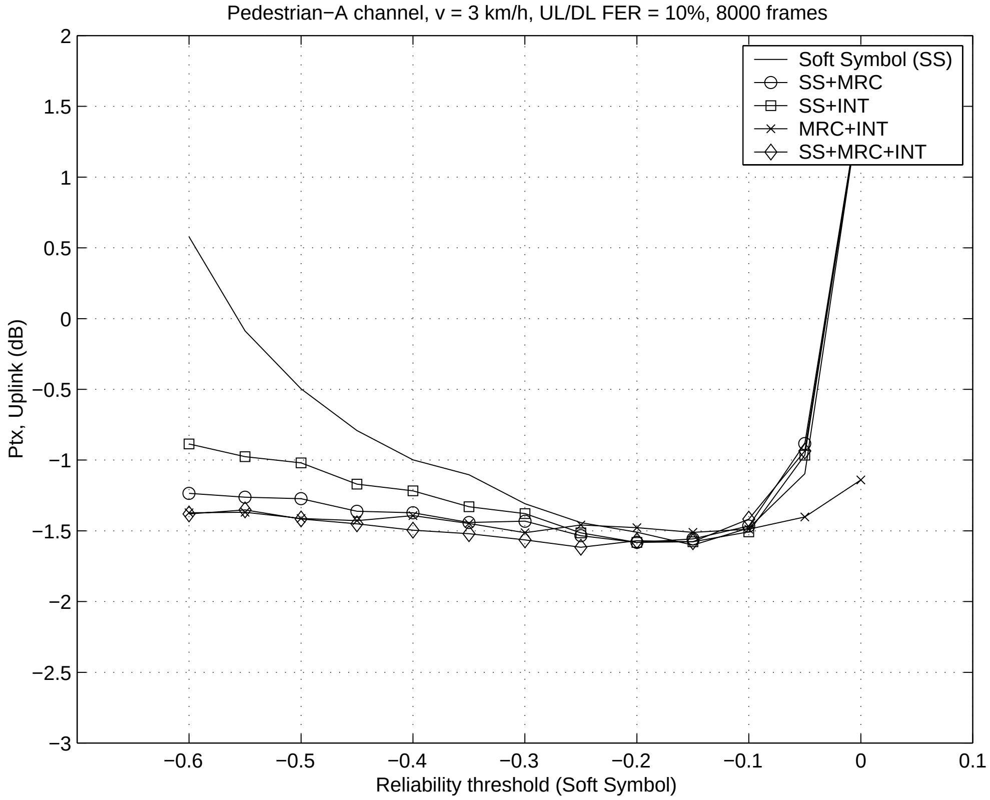


**Figure 8. Comparison of TPC algorithms listed in Table 1. Mobile speed is 3 km/h, UL/DL FER is 10%.**

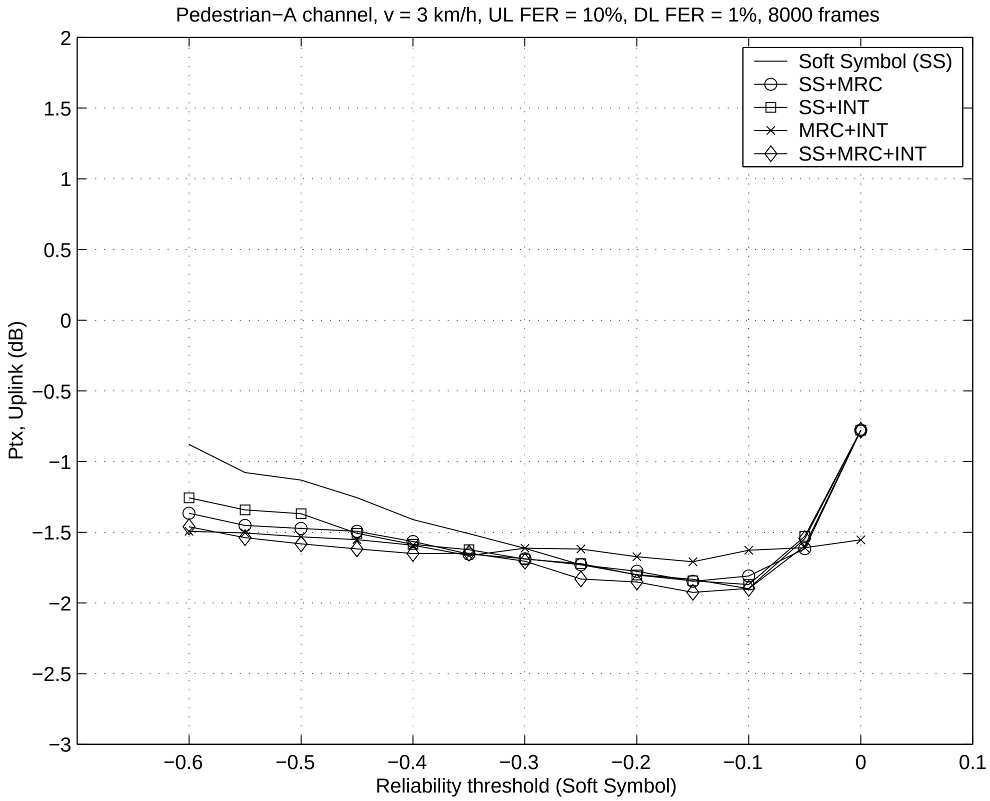


**Figure 9. Comparison of TPC algorithms listed in Table 1. Mobile speed is 3 km/h, UL FER is 10% and DL FER is 1%.**

### 5.2.2. Mobile speed 20 km/h

The three FER cases (1% UL/DL, 10 % UL/DL, and 1% DL 10% UL) are shown in Figure 10 to Figure 12. In general, the results are very similar to those with a MS speed of 3 km/h. In fact, all of the algorithms are so closely grouped that any individual differences are hard to point out. The minimum Ptx levels are also reached by more than one parallel algorithm.

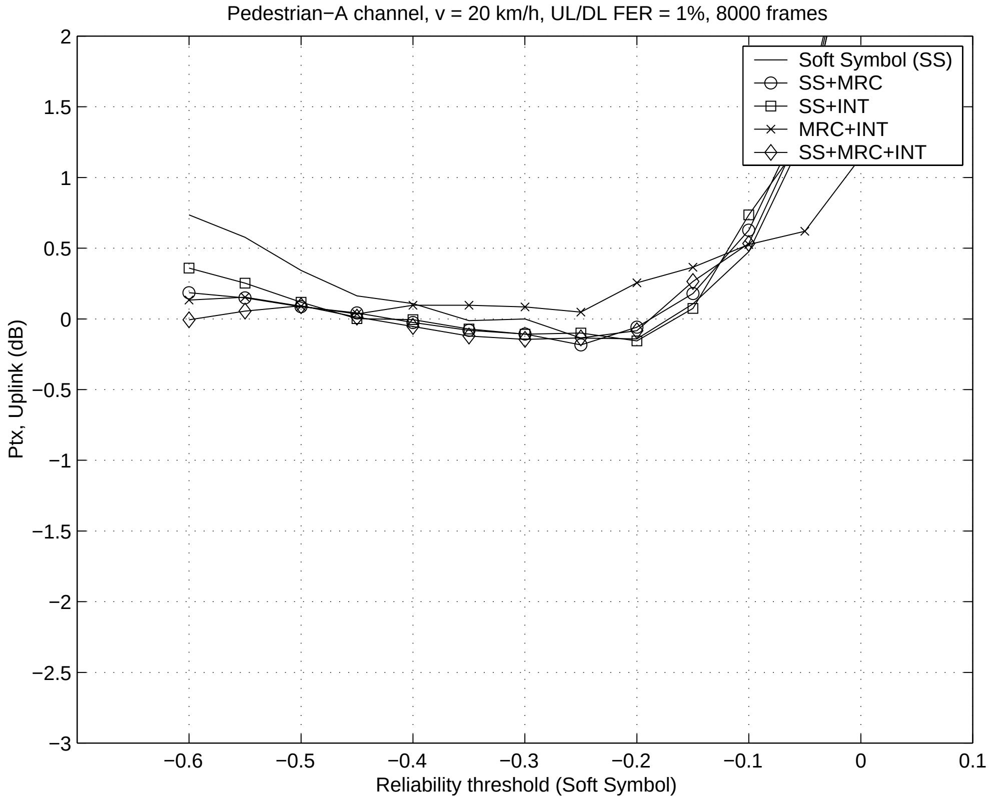


**Figure 10. Comparison of TPC algorithms listed in Table 1. Mobile speed is 20 km/h, UL/DL FER is 1%.**

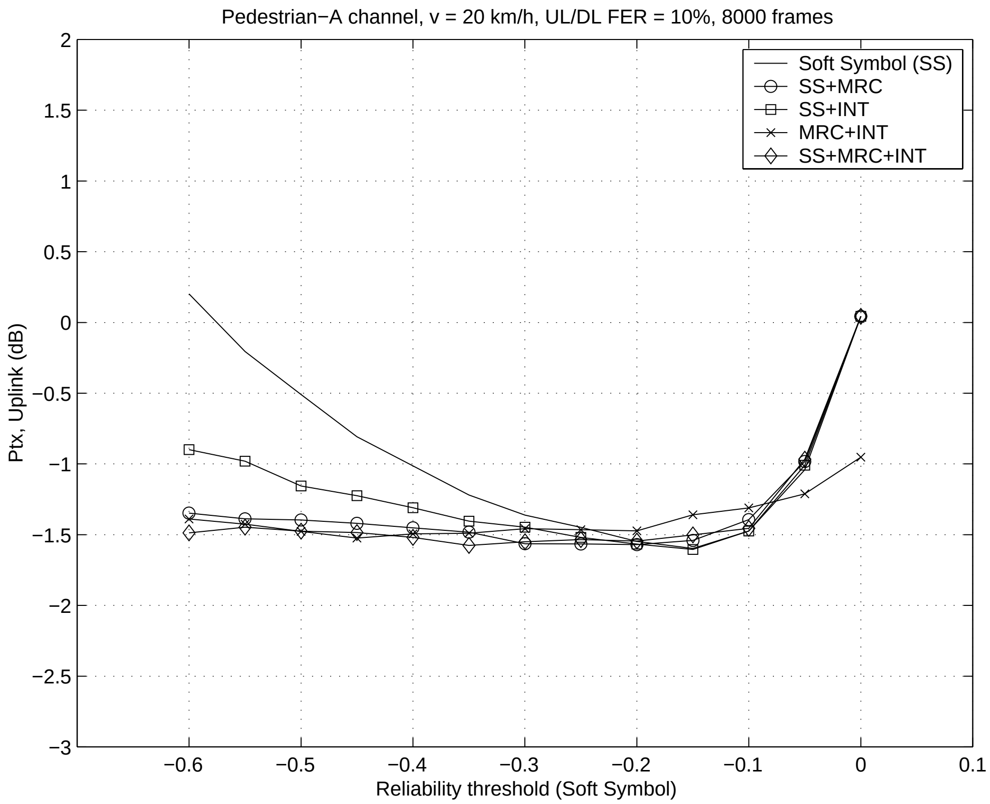


**Figure 11. Comparison of TPC algorithms listed in Table 1. Mobile speed is 20 km/h, UL/DL FER is 10%.**

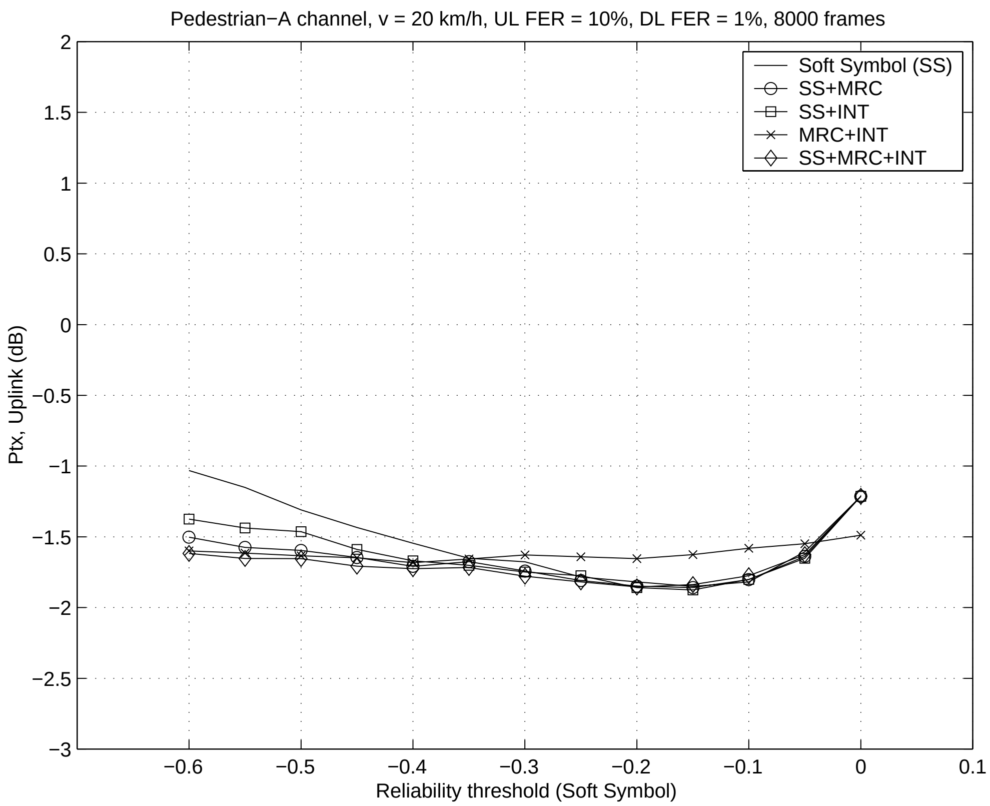


**Figure 12. Comparison of TPC algorithms listed in Table 1. Mobile speed is 20 km/h, UL FER is 10% and DL FER is 1%.**

### 5.2.3. Mobile speed 50 km/h

The three FER cases (1% UL/DL, 10 % UL/DL, and 1% DL 10% UL) are shown in Figure 13 to Figure 15. What was discussed in the case of 20 km/h also applies to 50 km/h, i.e. the differences are small and none of the new algorithms clearly outperform the others.

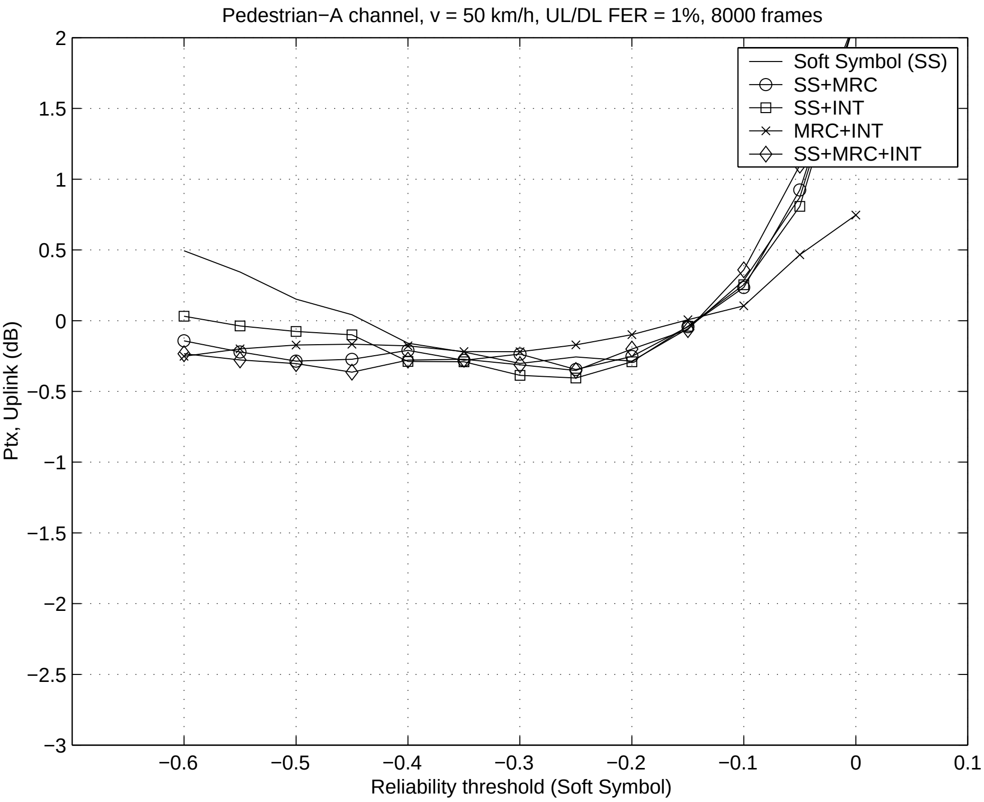


**Figure 13. Comparison of TPC algorithms listed in Table 1. Mobile speed is 50 km/h, UL/DL FER is 1%.**

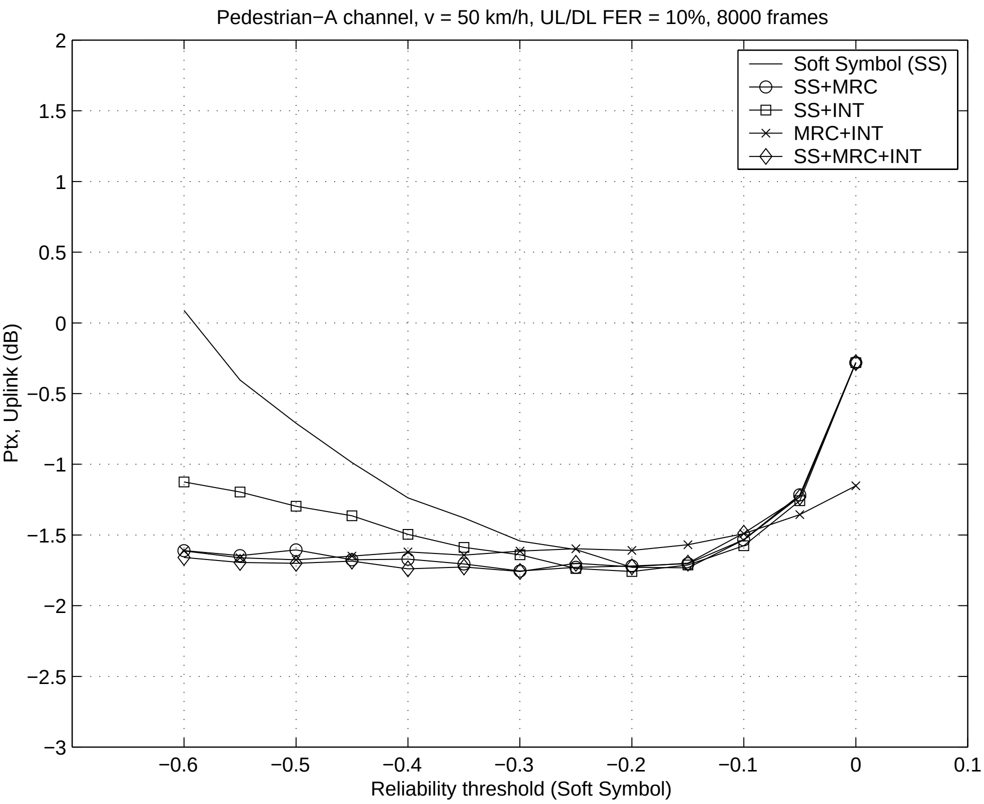

**Figure 14. Comparison of TPC algorithms listed in Table 1. Mobile speed is 50 km/h, UL/DL FER is 10%.**

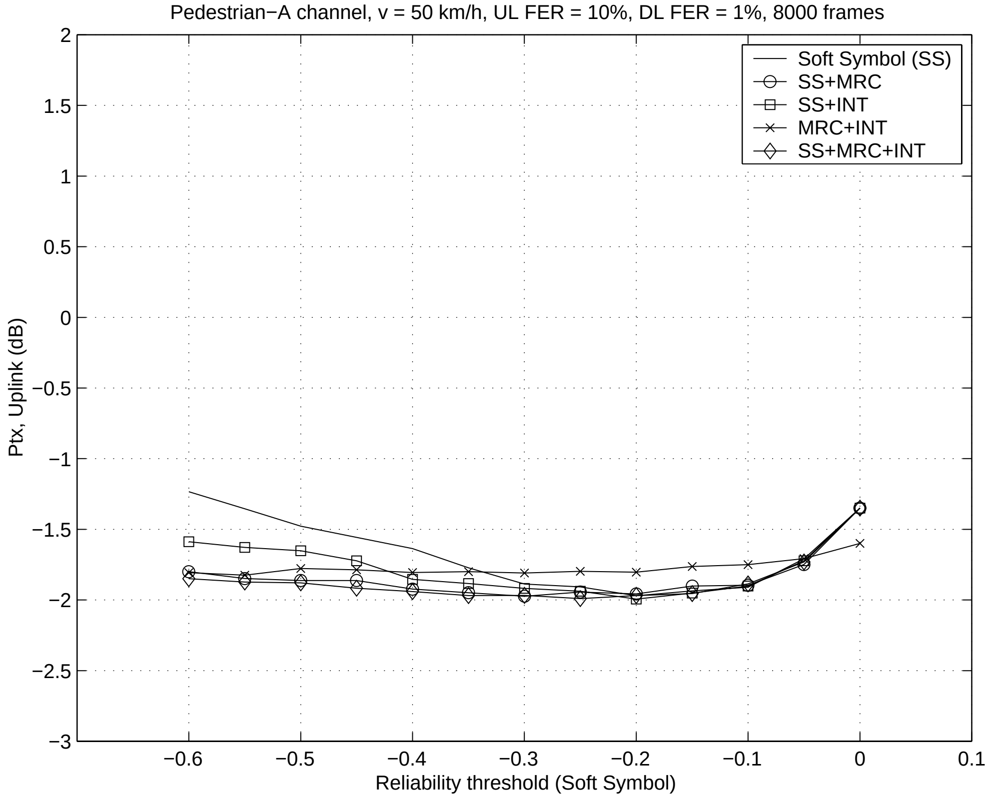


**Figure 15. Comparison of TPC algorithms listed in Table 1. Mobile speed is 50 km/h, UL FER is 10% and DL FER is 1%.**

### 5.2.4. Mobile speed 120 km/h

The three FER cases (1% UL/DL, 10 % UL/DL, and 1% DL 10% UL) are shown in Figure 16 to Figure 18. The results are again similar to other speeds. As in the previous results, the sensitivity of the new algorithms to the reliability threshold (and the differences in Ptx levels) are almost negligible in the UL FER 10% and DL FER 1% case.

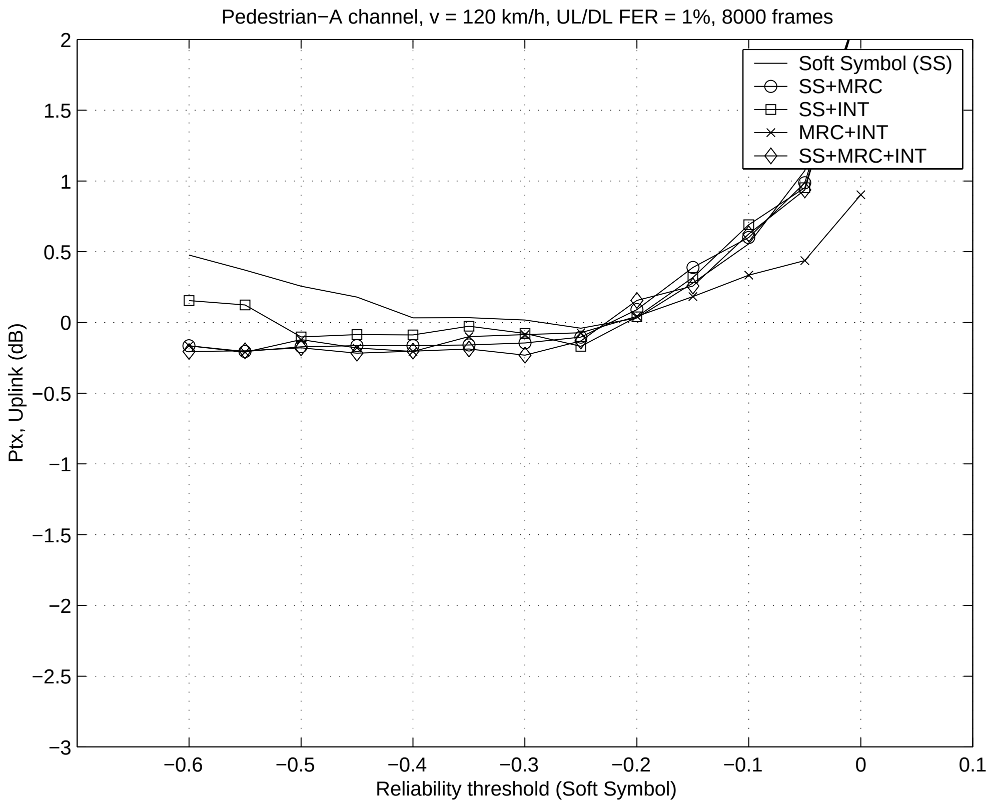


**Figure 16. Comparison of TPC algorithms listed in Table 1. Mobile speed is 120 km/h, UL/DL FER is 1%.**

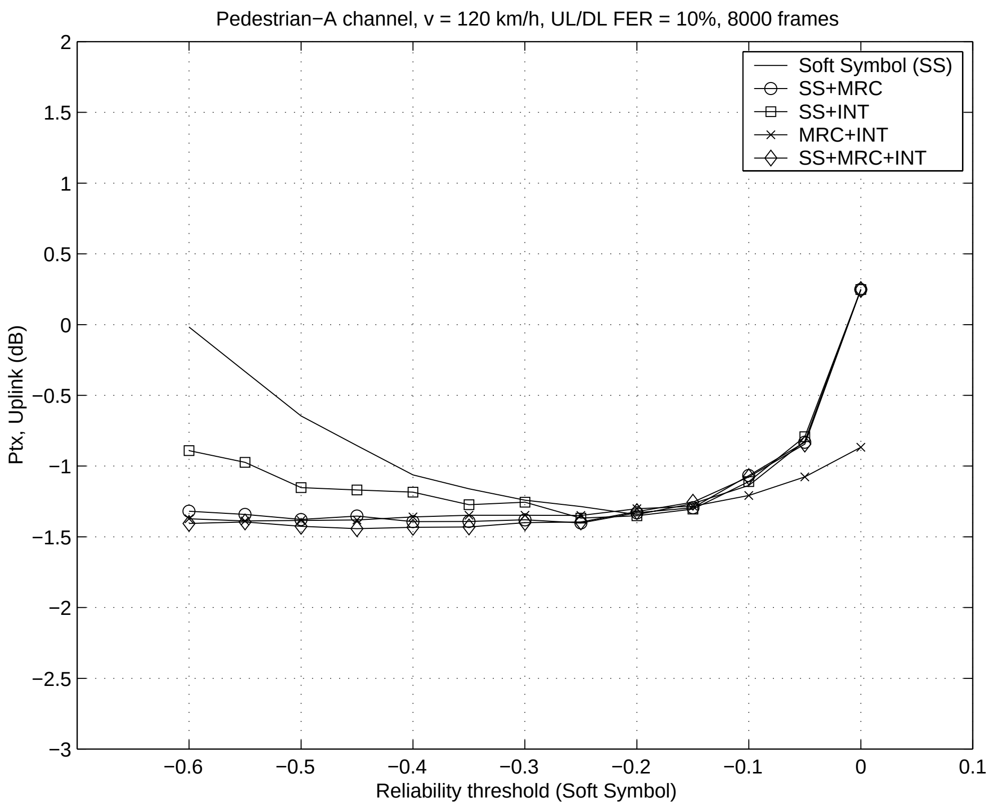


**Figure 17. Comparison of TPC algorithms listed in Table 1. Mobile speed is 120 km/h, UL/DL FER is 10%.**

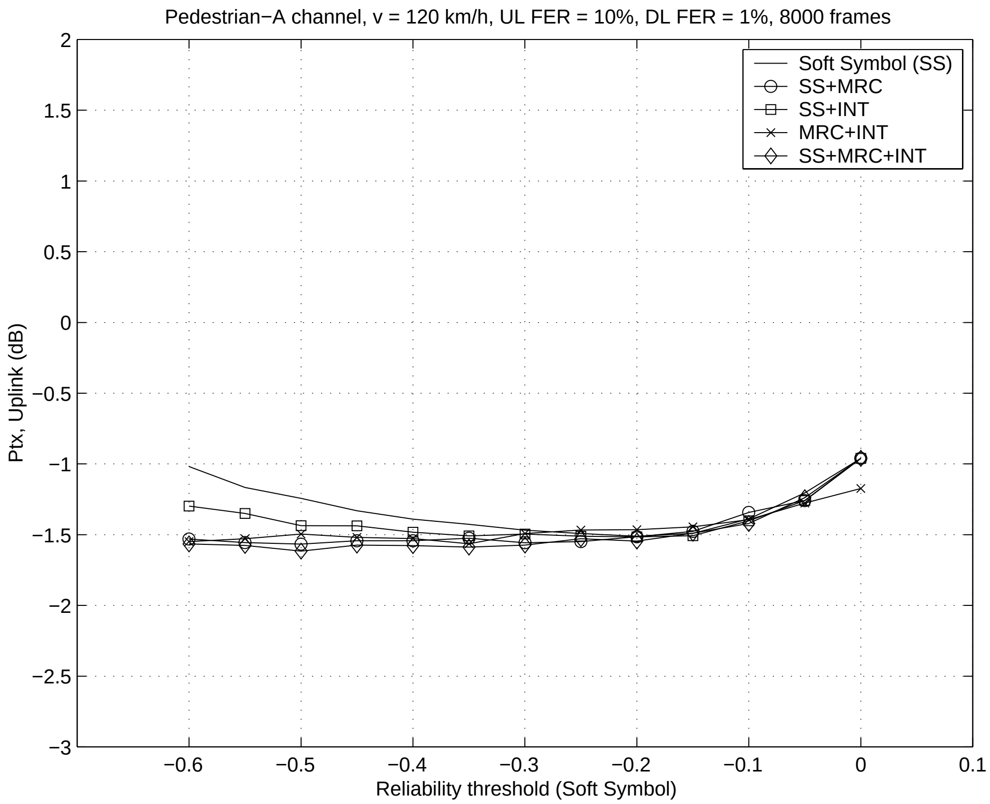


**Figure 18. Comparison of TPC algorithms listed in Table 1. Mobile speed is 120 km/h, UL FER is 10% and DL FER is 1%.**

# 6. TEXT PROPOSAL FOR TS25.214

## 5.1.2.2.2 Algorithm 1 for processing TPC commands

### 5.1.2.2.2.1 Derivation of TPC_cmd when only one TPC command is received in each slot

When a UE is not in soft handover, only one TPC command will be received in each slot. In this case, the value of TPC_cmd is derived as follows:

- If the received TPC command is equal to 0 then TPC_cmd for that slot is –1.
- If the received TPC command is equal to 1, then TPC_cmd for that slot is 1.

### 5.1.2.2.2.2 Combining of TPC commands known to be the same

When a UE is in soft handover, multiple TPC commands may be received in each slot from different cells in the active set. In some cases, the UE has the knowledge that some of the transmitted TPC commands in a slot are the same. This is the case e.g. with receiver diversity or so called softer handover when the UTRAN transmits the same command in all the serving cells the UE is in softer handover with. For these cases, the TPC commands known to be the same are combined into one TPC command, to be further combined with other TPC commands as described in subclause 5.1.2.2.2.3.

### 5.1.2.2.2.3 Combining of TPC commands not known to be the same

In general in case of soft handover, the TPC commands transmitted in the different cells may be different.
This subclause describes the general scheme for combination of the TPC commands known to be different and then provides an example of such scheme. It is to be further decided what should be subject to detailed standardisation, depending on final requirements. The example might be considered as the scheme from which minimum requirement will be derived or may become the mandatory algorithm.

5.1.2.2.2.3.1 General scheme

First, the UE shall conduct the soft symbol decision on each of the power control command TPCi, where i = 1, 2, …, N and N is the number of TPC commands not known to be the same, that may be the results of a first phase of combination according to subclause 5.1.2.2.3.
Then the sensitivity of the soft symbol reliability threshold is improved by Maximum Ratio Combining (MRC) and integrating component. These are run in parallel with soft symbol reliability estimation and the minimum individual output determines the final output.
In this approach, the minimum input soft symbols are integrated and a separate soft symbol thresholding for this integrated sum is conducted. After each TPC round, the minimum soft symbol value of that round is added to the integrated sum. If the integrated sum exceeds a predetermined threshold, a power-down command is issued, even if the individual soft symbols from that particular TPC round do not imply a power-down command.
If a power-down command is issued, based on the integrated sum exceeding its threshold value or the individual soft symbols, the integrated sum for the next TPC round is again set to zero.

~~First, the UE shall estimate the signal-to-interference ratio $PC\_SIR_i$ on each of the power control commands $TPC_i$, where i = 1, 2, …, N and N is the number of TPC commands not known to be the same, that may be the result of a first phase of combination according to subclause 5.1.2.2.2.2.~~
~~Then the UE assigns to each of the $TPC_i$ command a reliability figure $W_i$, where $W_i$ is a function β of $PC\_SIR_i$, $W_i = \beta(PC\_SIR_i)$. Finally, the UE derives a combined TPC command, TPC_cmd, as a function γ of all the N power control commands $TPC_i$ and reliability estimates $W_i$:~~
~~$TPC\_cmd = \gamma (W_1, W_2, \ldots W_N, TPC_1, TPC_2, \ldots, TPC_N)$, where TPC_cmd can take the values 1 or -1.~~
~~5.1.2.2.2.3.2 Example of the scheme~~
~~A particular example of the scheme is obtained when using the following definition of the functions β and γ:~~
~~**For β:** the reliability figure $W_i$ is set to 0 if $PC\_SIR_i < PC\_thr$, otherwise $W_i$ is set to 1. This means that the power control command is assumed unreliable if the signal-to-interference ratio of the TPC commands is lower than a minimum value PC_thr.~~
~~**For γ:** if there is at least one $TPC_i$ command, for which $W_i = 1$ and $TPC_i = 0$, or if $W_i = 0$ and $TPC_i = 0$ for all N $TPC_i$ commands, then TPC_cmd is set to 1, otherwise TPC_cmd is set to 1. Such a function γ means that the power is decreased if at least one cell for which the reliability criterion is satisfied asks for a power decrease.~~

## 7. CONCLUSIONS

Based on the comparison of various TPC algorithms and their combinations, the following conclusion can be made:

- The use of the soft symbol reliability instead of SIR based reliability was better in that the Ptx levels in almost all cased dropped up to 0.5 dB, and the sensitivity to the selected reliability threshold was less critical,

- Using various TPC algorithm components, such as maximum ratio combining and/or soft symbol integration in parallel will increase the reliability of the overall TPC algorithm, as demonstrated by decreasing Ptx levels and less critical reliability threshold selections. Of all the algorithms, the SS+MRC+INT can, with reservations, be regarded as the best approach.