TSG-RAN Working Group1 meeting #3
Stockholm 22-26, March 1999

TSGR1#3(99)138

Agenda Item:

Source: InterDigital Comm. Corp.

Title: Reissue of SMG2 L1 Documents on RACH Preamble Detection

Document for:

Summary:
This contribution includes SMG2 UMTS L1 Tdocs 620/98, 621/98, 009/99, 010/99 and 011/99 and is intended for historical background. on the subject of the impact of doppler on RACH preamble detection

Please observe the following.

a) The block diagram in Tdoc 620/98 for the Differential Detection is incorrect. A corrected version was included in Tdoc 011/99.
b) We originally considered multiple Doppler channel processing in Tdoc 620/98 , but now have the opinion that this is complex and undesirable.
c) We acknowledge that the more realistic Doppler shift is one way; i.e. f v/c, as opposed to original model 2f v/c. However, the issue still exists because speeds up to 500 km/hr are required. Future work will use the new assumption.
d) Document 621/98 is included for completeness but is not directly related to the Doppler issue.

ETSI SMG2 UMTS Layer 1 Experts Group Tdoc SMG2 UMTS L1 620/98
Helsinki, Finland
14-18 December, 1998

Title: Random Access Preamble Detection in Presence of Doppler

Source: InterDigital

Summary:

The objectives of this contribution are:

- To quantify the effects of Doppler on RACH Preamble Detection.
- Identify the level of sophistication and complexity needed to reduce losses
- Suggest an alternative, based on differential decoding, that is simple and robust.

The conclusions are:

- Straightforward processing in the presence of high Doppler is unacceptable.
- Asynchronous detection of Random Access Channel (RACH) packet preambles will require careful design to deal with Doppler shifts.
- More sophisticated processing will reduce Doppler losses but may introduce complexity.
- A modified preamble supporting differential decoding of the signature may be a prudent alternative to deal with high Doppler cases.

1 Introduction

This study was conducted in response to Tdoc 596/98 and xx.18, paragraph 6.1.1.2 which identified detection and false alarm performance as study items for the RACH.

- Document xx.05 defines the 16-character signature set currently proposed for the RACH.
- The WCDMA/NA proposal and Concept Group Alpha – Wideband Direct-Sequence CDMA Evaluation Document (Draft 1.0) system description suggest a notional circuit that supports detection of this signature set.
- For this study it is assumed that the RACH detection process should operate for ranges up to a round trip time of no more than 1/16 millisec; i.e. approximately 8 km. For ranges beyond that value, additional processing is needed to resolve ambiguity.

Assuming a Mobile User synchronizes its local frequency to the Base Station and transmits at that frequency, the Doppler shift in Hz is

$$\Delta f = 2(v/c)2 \times 10^{9}$$

The following Table illustrates the impact of speed on the Doppler. The third column represents the ΔfT product for T = 1 millisecond. It is apparent that this can become quite large for high-speed users.

Table 1- Impact of vehicle speed on Doppler

Speed(km/hr)	Doppler Shift(Hz)	ΔfT
50	185	.185
100	370	.37
120	440	.44
200	741	.74
300	1,110	1.11

2 Detection Performance Using Straightforward Processing

The Table 2 is a reprint from xx.05 and shows the current RACH preamble signature matrix.

Figure 1 shows a representative preamble detection circuit, obtained from the WCDMA/NA proposal and the Concept Group Alpha – Wideband Direct-Sequence CDMA Evaluation Document (Draft 1.0) system description.

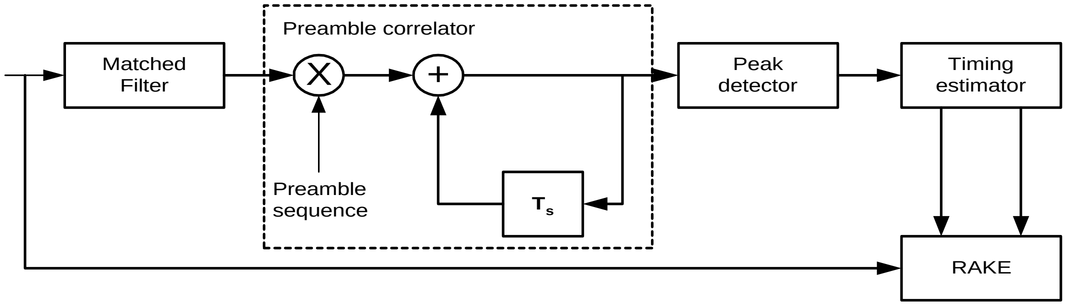

Figure 1 - Base-station Random-Access Receiver

Figure 2 shows the detection performance for a straightforward detection process, suggested by the circuit. For the curves shown it is assumed that;

- Signal is constant amplitude in noise
- Greatest of 16 signatures selected
- Probability of failure to detect energy is assumed negligible
- One-pass processing with no Doppler compensation
- Frequency error due only to Doppler

We see that, for high values of Doppler, there is a significant problem.

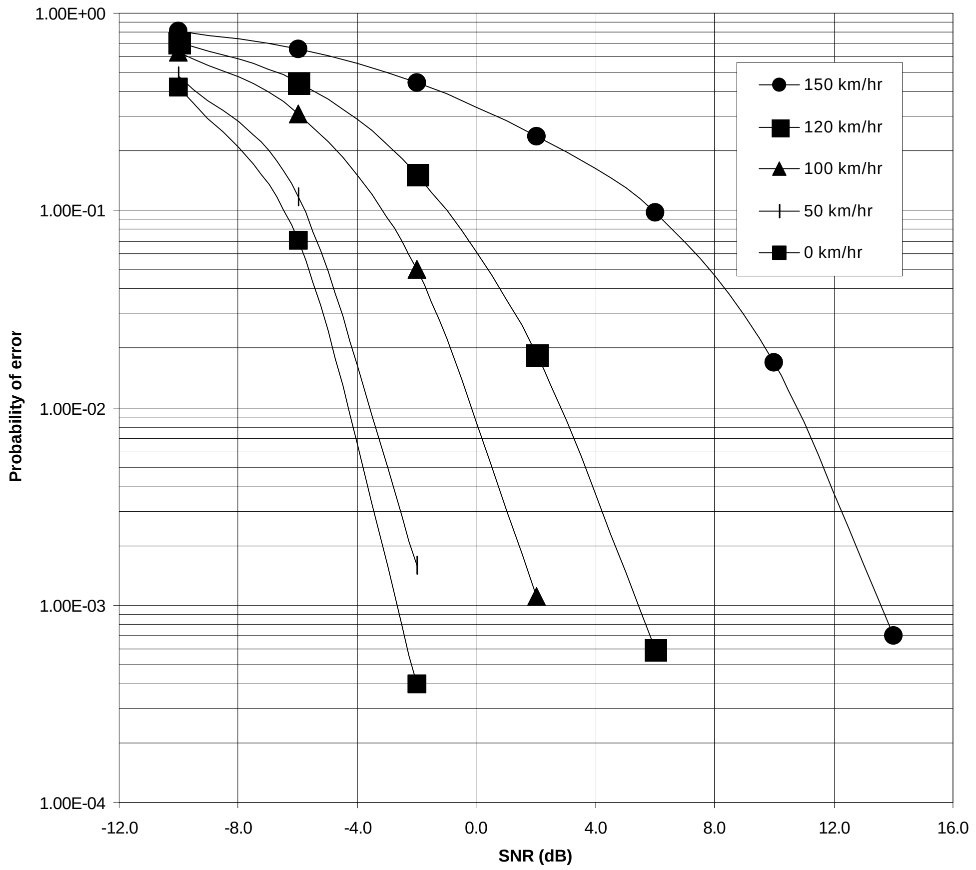

Figure 2 - Coherent Detection. No Range Ambiguity. Constant Amplitude Signal

Figure 3 shows similar results, assuming that the signal is subject to Rayleigh fading, assumed fixed over the 1 millisecond interval.

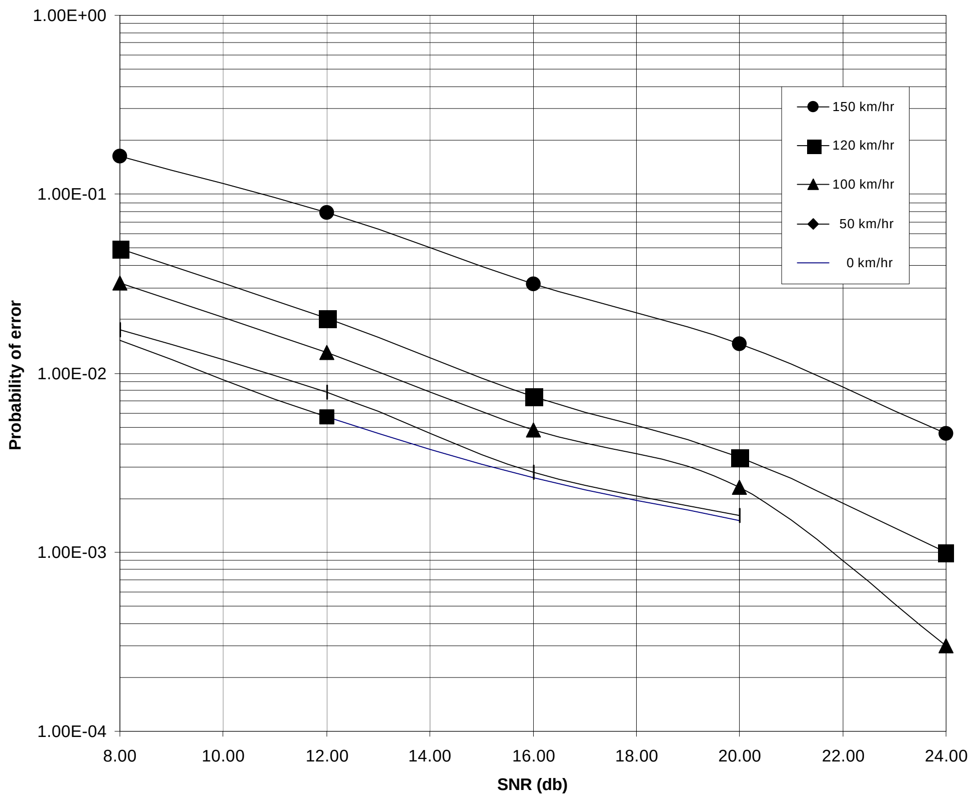

Figure 3 - Coherent Detection. No Ambiguity. With Rayleigh Fading

Table 2 – Preamble Signatures A = 1+j

	Preamble symbols															
Signature	P_0	P_A	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}
1	A	A	A	-A	-A	-A	A	-A	-A	A	A	-A	A	-A	A	A
2	-A	A	-A	-A	A	A	A	-A	A	A	A	-A	-A	A	-A	A
3	A	-A	A	A	A	-A	A	A	-A	A	A	A	-A	A	-A	A
4	-A	A	-A	A	-A	-A	-A	-A	-A	A	-A	A	-A	A	A	A
5	A	-A	-A	-A	-A	A	A	-A	-A	-A	-A	A	-A	-A	-A	A
6	-A	-A	A	-A	A	-A	A	-A	A	-A	-A	A	A	A	A	A
7	-A	A	A	A	-A	-A	A	A	A	-A	-A	-A	-A	-A	-A	A
8	A	A	-A	-A	-A	-A	-A	A	A	-A	A	A	A	A	-A	A
9	A	-A	A	-A	-A	A	-A	A	A	A	-A	-A	-A	A	A	A
10	-A	A	A	-A	A	A	-A	A	-A	-A	A	A	-A	-A	A	A
11	A	A	A	A	A	A	-A	-A	A	A	-A	A	A	-A	-A	A
12	A	A	-A	A	A	A	A	A	-A	-A	-A	-A	A	A	A	A
13	A	-A	-A	A	A	-A	-A	-A	A	-A	A	-A	-A	-A	A	A
14	-A	-A	-A	A	-A	A	A	A	A	A	A	A	A	-A	A	A
15	-A	-A	-A	-A	A	-A	-A	A	-A	A	-A	-A	A	-A	-A	A
16	-A	-A	A	A	-A	A	-A	-A	-A	-A	A	-A	A	A	-A	A

5 An alternative approach-Use differential detection for the RACH preamble

It is well known that Differential Phase Shift Keying (DPSK), while somewhat less efficient that coherent PSK under ideal conditions, is more robust in the presence of Doppler.

Figure 4 shows the performance of the two concepts, as well as performance of the original.

- Coherent Detection (80 hypotheses)
  - 16 signatures
  - 5 Doppler channels
- Differential Detection (16 hypotheses)
  - 16 signatures

It can be seen that, while the coherent detection with Doppler processing is better in performance than differential processing, the difference is on the order of 2 dB. However, there are complexity and potential implementation losses that may counterbalance this difference in performance.

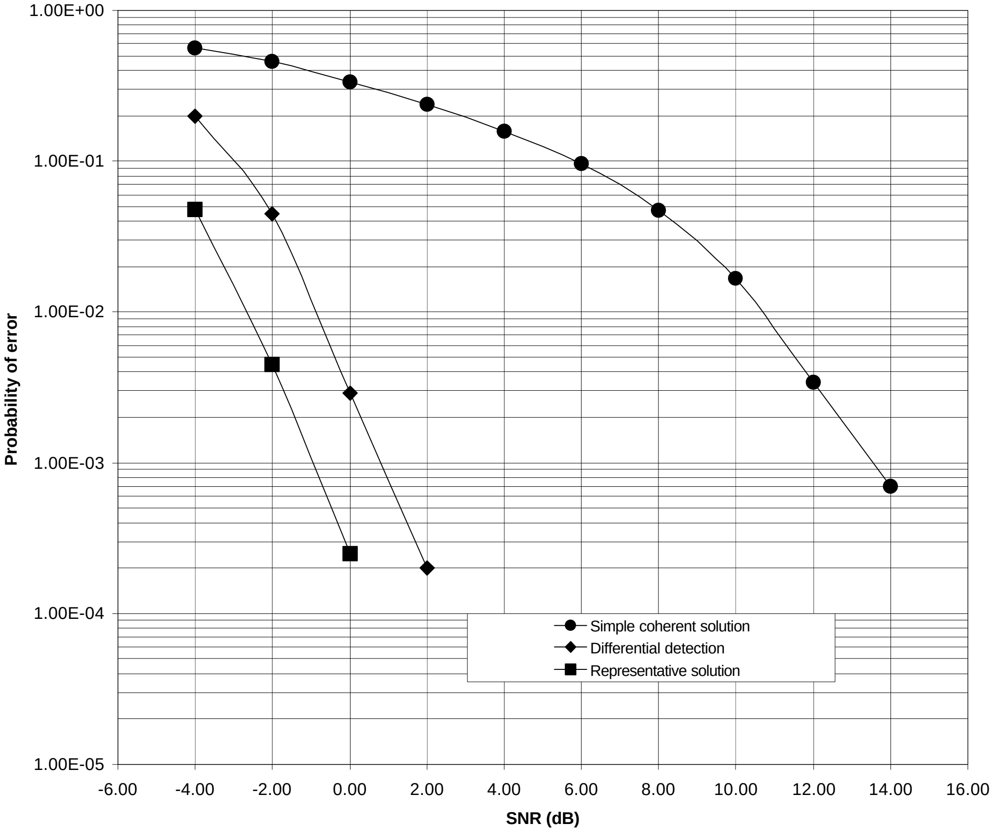

Figure 4 - Comparison of Simple Coherent Detection, Differential Detection and Representative Solution (150 km/hr)

Consider the notional block diagram in figure 5.

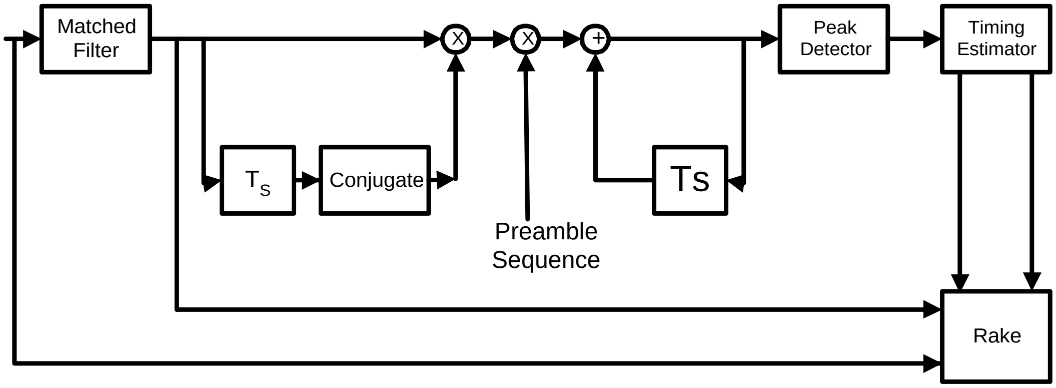

Figure 5 Modified Receiver

In order to support this detection concept, the original signature matrix would be modified according to the following rule:

Start all signatures with +A; this requires those rows in the original table be multiplied by -1

Now, referring to the modified matrix, which we will call the modified original matrix,

For all signatures after I=0, comparing the new value of the modified original with the previous value of the new signature:

Symbol = A if no change
Symbol = -A if change

The Matrix will then appear as in Table 3.

Table 3 – Preamble Signatures A = 1

	Preamble symbols															
Signature	P_0	P_A	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}
1	A	A	A	-A	A	-A	-A	A	-A	-A	-A	A	A	-A	-A	-A
2	A	-A	-A	-A	A	-A	A	A	-A	A	-A	-A	-A	A	A	-A
3	A	-A	-A	-A	-A	A	A	A	-A	-A	-A	-A	A	A	-A	-A
4	A	-A	-A	A	A	A	A	A	A	-A	-A	A	A	-A	A	-A
5	A	-A	A	-A	A	A	A	-A	A	-A	A	A	-A	A	-A	-A
6	A	A	-A	-A	A	A	-A	-A	A	A	A	-A	A	-A	A	-A
7	A	-A	A	-A	-A	-A	A	-A	A	A	A	A	A	A	A	-A
8	A	A	-A	A	-A	A	-A	-A	-A	A	A	A	A	A	-A	-A
9	A	-A	-A	A	-A	-A	A	A	A	A	-A	A	-A	-A	-A	-A
10	A	-A	A	A	-A	A	A	-A	-A	-A	A	-A	-A	-A	A	-A
11	A	A	A	A	A	A	-A	A	A	A	-A	-A	-A	A	-A	-A
12	A	A	-A	-A	-A	-A	-A	-A	A	-A	A	-A	-A	-A	-A	-A
13	A	-A	A	A	A	-A	A	-A	-A	A	A	-A	A	-A	-A	-A
14	A	A	A	-A	-A	A	-A	A	-A	A	-A	A	-A	-A	A	-A
15	A	A	A	A	-A	-A	-A	A	A	-A	-A	-A	A	A	A	-A
16	A	A	-A	A	A	-A	-A	-A	-A	-A	A	A	-A	A	A	-A

6 New signature matrix does not preclude coherent processing

The following simulation results illustrate that it is possible to use the proposed signature matrix and apply coherent processing. This would permit Base Station designers to select either strategy for implementation. Figure 6 shows that a coherent detection based on the proposed signatures would only have about 0.3 dB of loss relative to the current baseline.

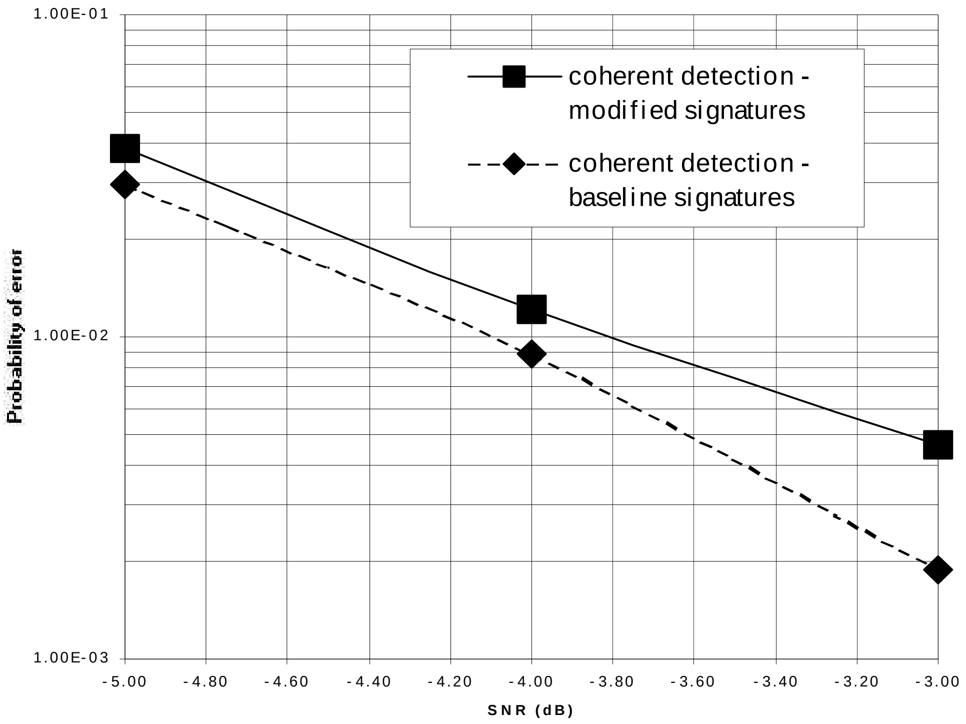

Figure 6 - Comparison of baseline and modified signatures

7 Conclusion

- Straightforward coherent processing of 16 symbol RACH preamble will suffer large losses at high Doppler.
- A sophisticated processor that compensates for Doppler is required
- Differential decoding will be far more robust over large ranges of Doppler
- Proposed signature does not preclude coherent processing
- It is recommended that the proposed approach be identified as an alternative and that further analysis be performed to quantify the complexity and implementation losses expected for each approach.

ETSI SMG2 UMTS Layer 1 Experts Group   Tdoc SMG2 UMTS L1 621/98
Helsinki, Finland
14-18 December, 1998

Title: Random Access Packet Power Adjustment for the Message Portion

Source: **InterDigital**

Summary:

The objectives of this contribution are:

- To quantify the effects of applying a power adjustment for the Message part of the RACH packet transmission.
  - To estimate the probable magnitude of this adjustment
  - To quantify the benefit of transmitting the magnitude of the adjustment as part of the Ack

1 Introduction

Several contributions have proposed that a RACH preamble be sent first, and repeated at increasingly higher power levels until the Base Station detects one and sends an acknowledgement (Ack) message. Then, after the Mobile Station receives the Ack, it sends the message at an appropriate power level.

This contribution attempts to quantify the following issues:
- What is the proper step size between preamble transmissions for power ramping?
- What is the size of the power adjustment between the message and the detected preamble?
- Is there a benefit for the Base Station to send a field of data that specifies the power change from preamble to message?

The analysis shows that
- There should be a nontrivial increase to the power relative to the detected preamble (on the order of 5.5 dB).
- There is a benefit to having the Base Station transmit its recommended value of the adjustment when the step size of the power ramp up is 2 dB or more. This feature enables reduction of the message power by avoiding the transmission of excess Signal Power. For 10% FER and 3 dB step size, the power reduction due to transmitting of the adjustment be on the order of 1 dB.

2 Simulation Model

The model assumes that the Mobile Station sends its first preamble at a weak level; e.g. -6 dB. It then increases the power level by x dB (x is a parameter to be varied; e.g 1dB, 2dB, 3dB) until the preamble is detected.

The detection process is simulated as 16 symbol samples; The transmitted signal is subject to Rayleigh fading and AWGN. The Rayleigh fading is constant within one preamble, and independent between consecutive transmissions.
Detection is assumed successful when the energy of 16 samples exceeds a threshold. (Threshold selected in advance to correspond to false alarm probability of 10^{-5}).

For each successful detection the simulation records the actual SNR and the estimated SNR of the detected preamble.

The message is then assumed to be transmitted at the actual SNR of the detected preamble plus the delta SNR.

The simulated message power level is combined with a predefined characteristic of Frame Error Rate versus Eb/No to compute the probability of Frame Error.
A frame corresponds to a Message. Figure 1 shows the assumed curve of FER versus Eb/No.

This simulation is performed for various cases.

- Case 1: Fixed delta; Power ramp up step size and size of the fixed delta are varied.
- Case 2: Variable delta; Power ramp up step size is varied. The base station estimates the preamble SNR to derive value of delta as follows:

$$\boxed{\Delta = \Delta_0 - S\hat{N}R}$$

3 Results

3.1 *Fixed Delta*

Figure 2 shows the Average power transmitted by the Mobile Station for the Message portion to ensure a given Frame Error Rate for different values of ramp up step size. Each curve corresponds to a fixed ramp up step size. Each point corresponds to a certain value of delta and represents the average transmitted power and the resulting average FER over 1000 experiments. Figure 3 shows, for each point, the delta SNR with respect to the SNR of the detected preamble and the resulting FER. Again, each curve corresponds to a fixed ramp up step size and each point corresponds to a certain value of delta. For example, if the desired FER is 10% and the ramp up step size is 1 dB, the power of the transmitted message should be higher by 5.6 dB than the preamble power. Note that the penalty of transmitting excess power increases with increasing uncertainty of the level of the transmitted power. We see that, to ensure a frame error rate of less than 10% the recommended delta with respect to the detected preamble power is:

- 7.6 dB for 1 dB ramp up step size
- 6.5 dB for 2 dB ramp up step size
- 5.6 dB for 3 dB ramp up step size

These values of delta corresponding to the following values of transmitted power:

- 8.6 dB for 1 dB ramp up step size
- 9.8 dB for 2 dB ramp up step size
- 10.5 dB for 3 dB ramp up step size

3.2 *Variable Delta*

Figures 4-4 show analogous results for the case where the base station estimates SNR and sends the value of the correction. For this case the required values of transmitted SNR are:

- 8.2 dB for 1 dB ramp up step size
- 9.2 dB for 2 dB ramp up step size
- 9.4 dB for 3 dB ramp up step size

4 Conclusions

- The message power should be increased significantly from the level of the preamble (For 10% FER the increase is on the order of 5.5 dB).
- The savings in message power level due to variable delta are small for 1 dB step size in the ramp up, and become more significant as the ramp up step size increases. For a 3 dB step size, the saving can be on the order of 1 dB.
- For 1 dB ramp-up step size we recommend the use of fixed delta. For larger step size, variable delta, controlled by the base station should be considered. Additional study is required to take in account the accuracy of the power adjustment information transmitted by the base station. Note that to cover a range of 4 dB with a resolution of 0.25 dB, the base station must transmit a 4-bit word for the power adjustment information.

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Figure 7: Assumed Curv

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Figure 8: Average Trans

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Figure 9: Average Delta

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Figure 10: Average Transmitted Power and Average FER for Estimated Delta

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Figure 11: Average Delt

ETSI SMG2 UMTS Layer 1 Experts Group Tdoc SMG2 UMTS L1 2X99-009
Helsinki, Finland
18-20 January, 1999

Title: Random Access Preamble Detection:
Relative Power of Preamble and Message Block

Source: InterDigital

Summary:

This paper explains differences between Tdocs 621/98 and 670/98 in regard to the relative power levels between PRACH preamble and message portion.

1 Introduction

In Tdoc SMG2 UMTS-L1 621/98, it was estimated that the PRACH preamble was typically detected at lower levels than those recommended for successful message processing.; on the order of 5.5 dB. This appeared to be in disagreement with other analyses; e.g. Tdoc SMG2 UMTS-L1 670/98, from Ericsson, which estimated that the power levels should be about the same value.

We have reviewed the assumptions of both of these documents and have reconciled the differences, as discussed below.

2 Analysis

The following differences were identified.

Message Data Rate Tdoc 621 assumed that the message was transmitted at 16 kbps, while Tdoc 670 assumed 8 kbps. This immediately accounts for 3 dB of the discrepancy. However, if the message is transmitted at 32 kbps, then add 6 dB to the message power, relative to 8 kbps or 3dB relative to 16 kbps.

Note that, if in the operational concept, the Mobile User has the freedom to select its transmit data rate, then it is recommended that it has the capability to set its output power accordingly.

Criterion for preamble detection Tdoc 621 assumed that the preamble was detected against the lowest threshold consistent with a small false alarm probability. Tdoc 670 required that the preamble be strong enough to provide a useful channel estimate for the message processing. Also, Tdoc 621 assumed that detection was based on energy summation while we assume that Tdoc 670 used signature detection. It is shown in 2X99-010 that energy summation is insensitive to Doppler while signature detection using the baseline, coherent approach, loses several dB in Doppler. These issues account for several dB of difference.

Model for Frame Error Rate Versus SNR Tdoc 670, figure 3, shows a characteristic which passes through 10 % BLER at C/I = 21.5 dB (Vehicular A, 120 km/h). At 8 kbps, adding 10 log(4Mcps/8kbps) this could be interpreted as +5.5 dB. Assume FER and BLER are synonymous. The corresponding model of Tdoc 621 passed through Eb/No=4.7 dB at 10% FER. This actually would add an additional dB of difference.

3 Conclusion

- The differences between Tdoc 621/98 and Tdoc 670/98 are explainable.

The primary issue of Tdoc 621 was the uncertainty in the power level rather than the absolute value. We believe that these observations are still valid

ETSI SMG2 UMTS Layer 1 Experts Group Tdoc SMG2 UMTS L1 2X99-010
Helsinki, Finland
18-20 January, 1999

Title: Random Access Preamble Detection in Doppler:
Detection Based on a Prespecified SNR

Source: InterDigital

Summary:
This contribution discusses preamble detection performance under the assumption that preambles are only declared when they are detected at a high threshold, consistent, e.g. with having sufficient energy to support channel estimation, rather than simply at the minimum detectable level, consistent with low false alarm probability.

1 Introduction

In Tdoc SMG2 UMTS-L1 620/98 and Tdoc SMG2 UMTS-L1 621/98 it was assumed that preamble detection occurred at the lowest possible level consistent with acceptable false alarm or false detection probabilities.

In associated discussions, as well as in Tdoc SMG2 UMTS-L1 670/98, it was pointed out that it may be desirable and integral to the system concept for PRACH preambles to be declared only if they exceed a prespecified value; e.g. 3 dB, or higher, to ensure sufficient energy to create a useful channel estimate.

Therefore, this contribution compares the performance of different detection schemes on the assumption that ACK is sent by the base station to the Mobile User only if the estimated SNR is a prespecified number.

Three detection schemes are considered:
- Coherent Detection for each of the 16 baseline signatures
- Differential Detection for each of the 16 signatues
- Energy-Sum of 16 energy samples at the specified symbol spacing.

In the third case, it is assumed that signature determination is an auxiliary function, considered only if the energy sample summation passes its threshold.

2 Model

For each of the three detection techniques, for a fixed amplitude signal in AWGN, the threshold was empirically determined to give 50% probability of detection at the specified level (e.g. 3dB).

For this analysis it is assumed that the range of operation is no more than about 8 km, consistent with round trip time less than 1/16 millisecond.

For each of these thresholds, we estimated the probability of false alarm in noise. For Coherent and Differential Detection, probability of false alarm is the probability that any of the 16 signatures is falsely detected (i.e. 16 x the probability that a specific signature is falsely detected). For power summation, probability of false alarm is independent of signature.

For a target SNR of 3 dB

- For Differential Detection Pfa = 10^{-8}
- For Coherent Detection Pfa = 5 x 10^{-9}
- For Envelope Summation Pfa = 2 x 10^{-8}

For a target SNR of 6 dB the values of Pfa are obviously orders of magnitude smaller.

3 Performance in the Ideal Channel

Figure 1 shows the probability of failed detection versus SNR for each of the three detection schemes using a target SNR of 3dB. It can be seen that there is little difference in performance.

Figure 2 shows the probability of failed detection versus SNR for Coherent Detection for the Doppler values corresponding to 30, 120 and 150 km/hr. We see significant impact due to the Doppler.

Figure 3 shows the probability of failed detection versus SNR for Differential Detection and for the same Doppler values; corresponding to 30, 120 and 150 km/hr

Figure 4.shows the probability of failed detection versus SNR for the same values, 3, 120, and 150 km/hr for energy summation. As one would expect, there is virtually no effect due to Doppler.

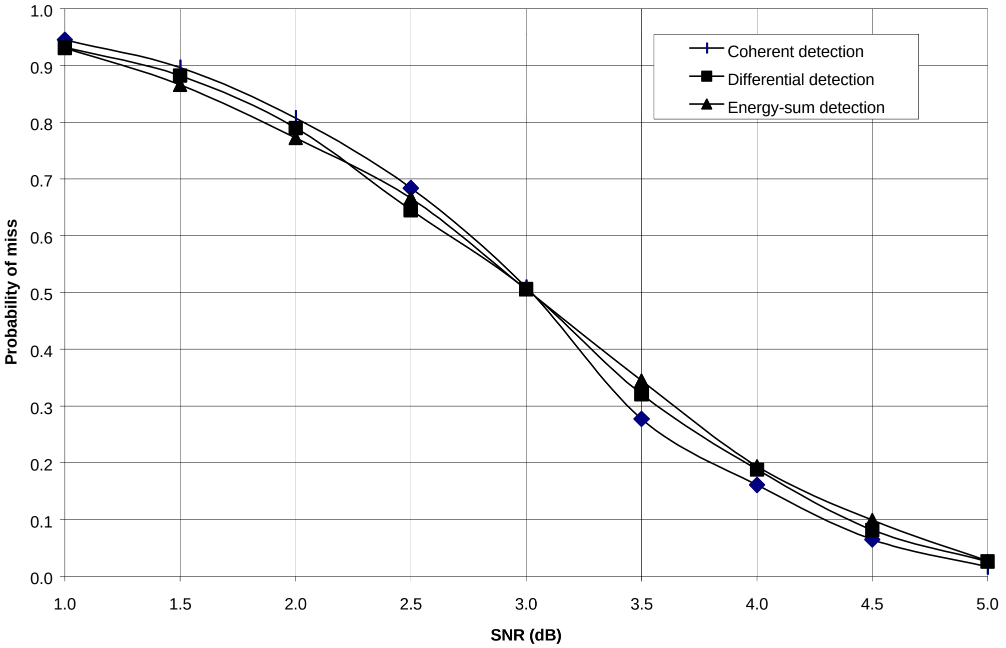

Figure 6 Probability of failed detection with zero Doppler

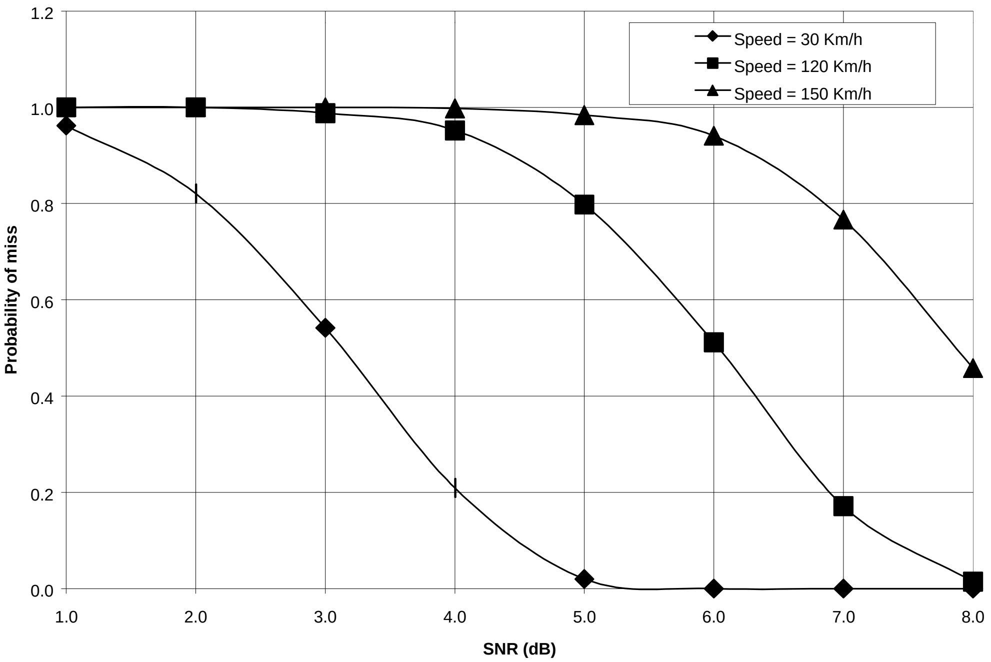

Figure 7 Probability of Failed Detection for Coherent Detection

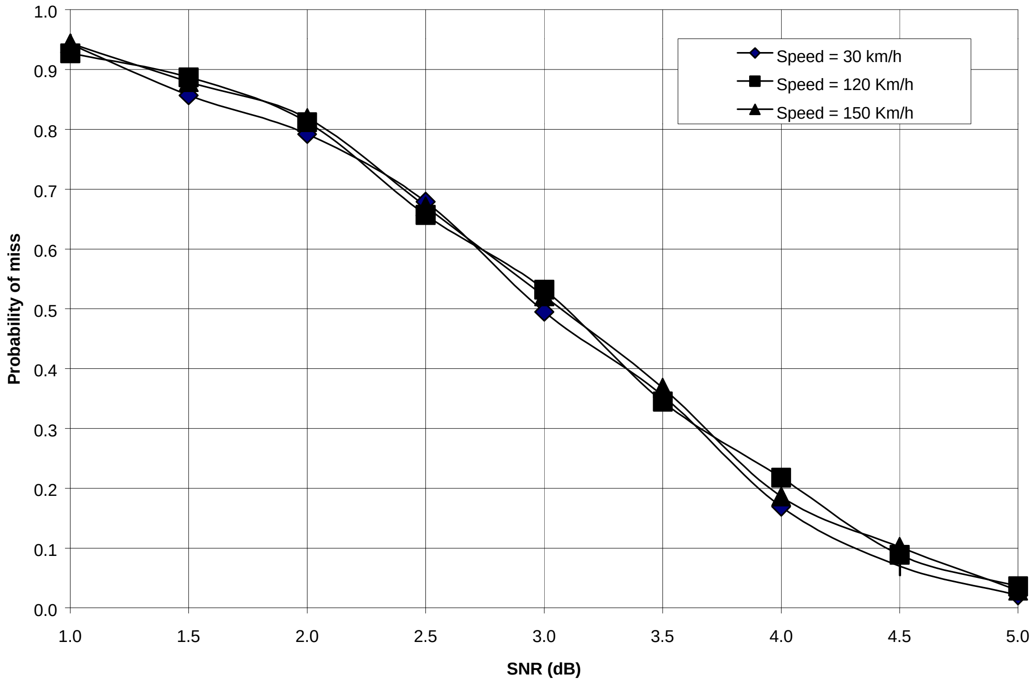

Figure 8 Probability of Failed Detection for Differential Detection

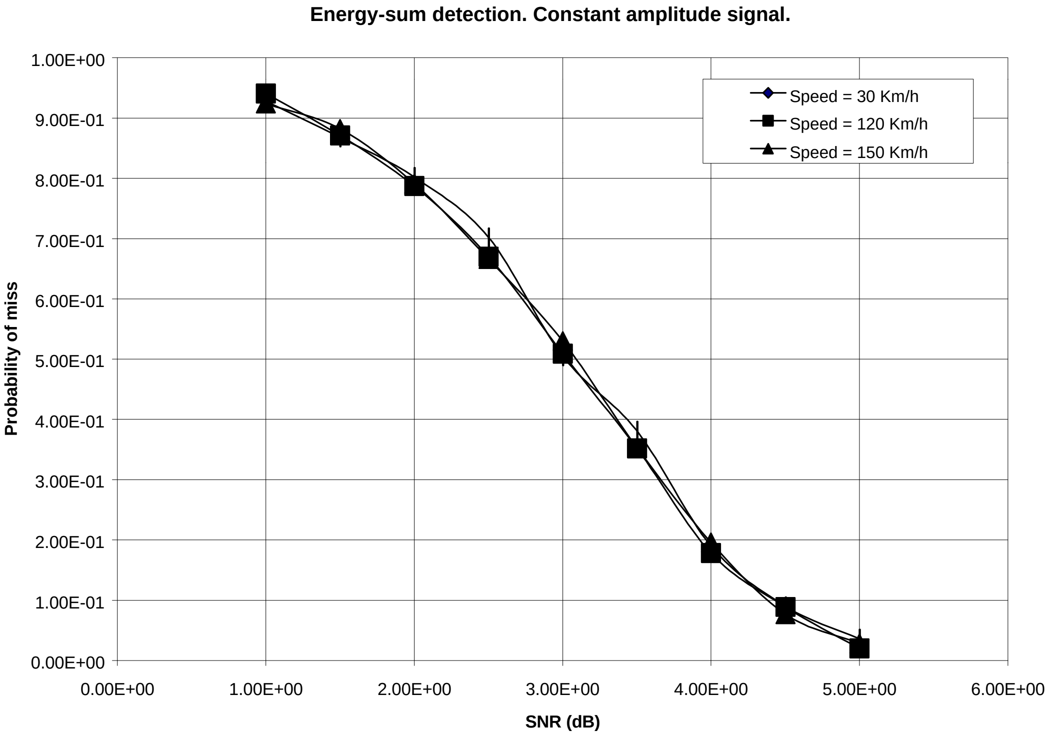

Figure 9 Probability of Failed Detection Using Energy Summation

4 Performance in the ITU Channel Model

Figures 5 through 8 illustrate performance as the sngals are passed through the ITU Channel Model. We see similar trends as shown in section 3. See Tdoc 2X99-011 for a description of the channel model.

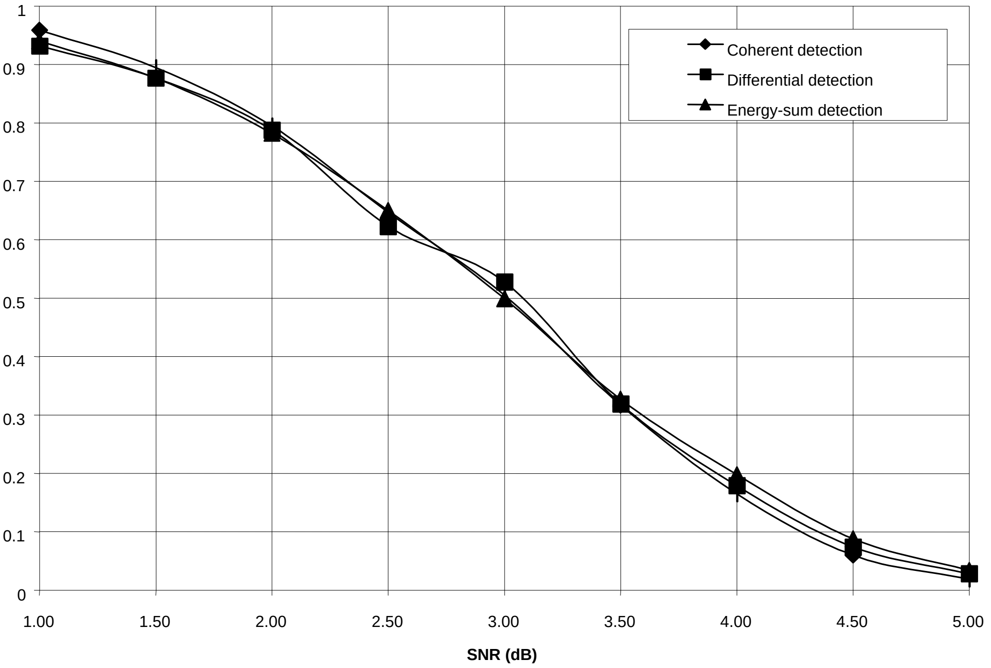

Figure 5 Probability of Failed Detection with ITU Channel Model

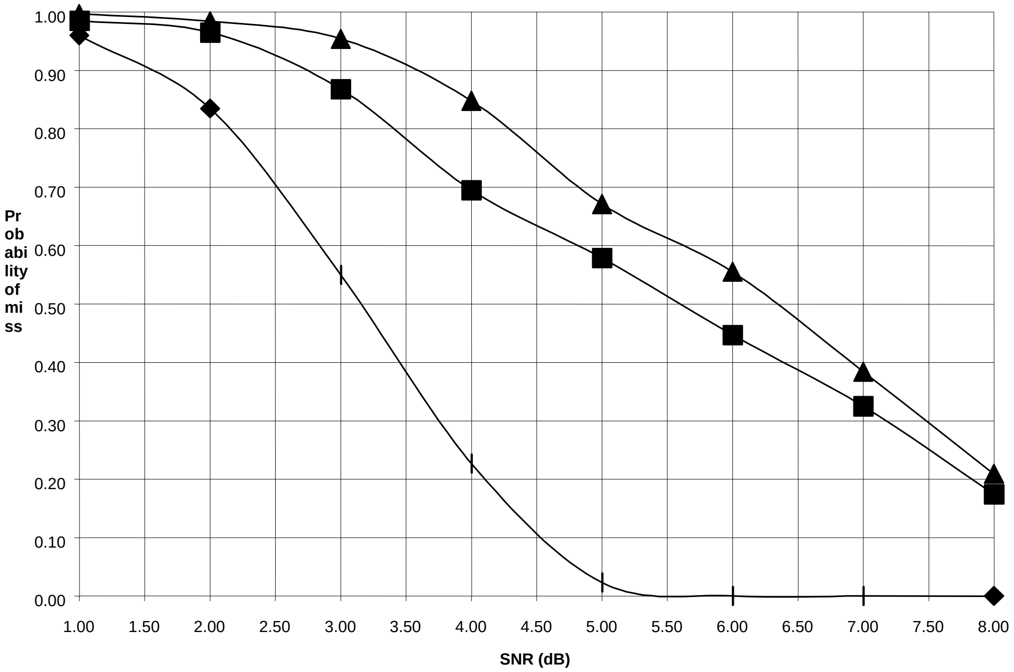

Figure 6 Probability of Failed Detection with ITU Channel Model

Coherent Detection

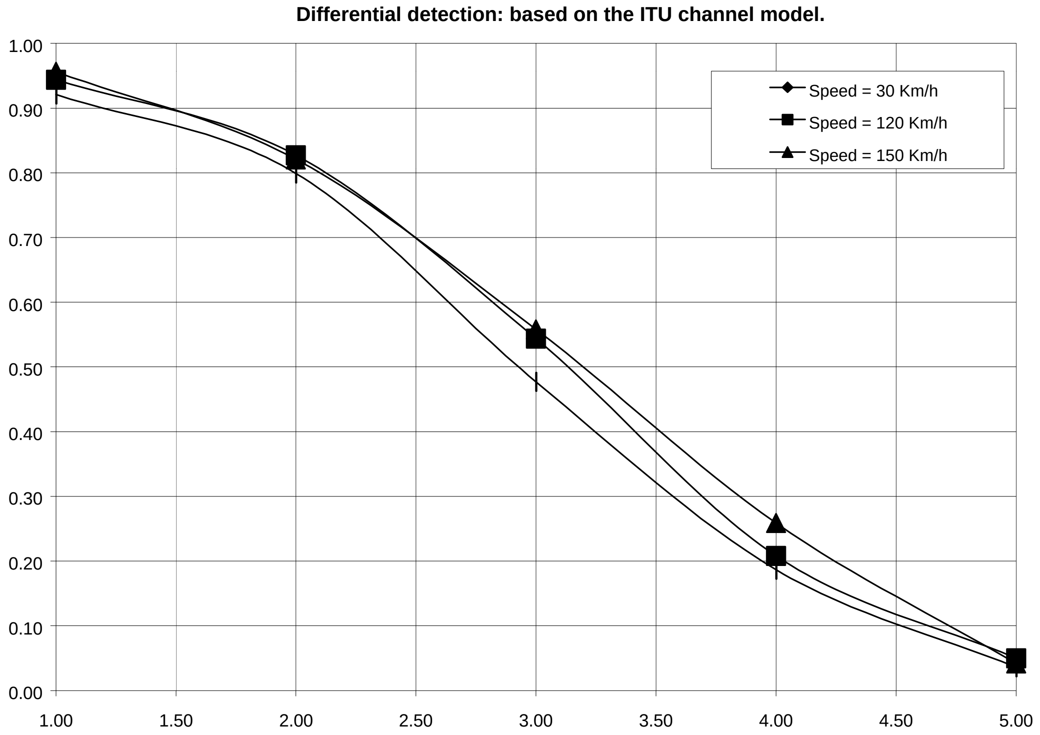

Figure 7 Probability of Failed Detection with ITU Channel Model
Differential Detection

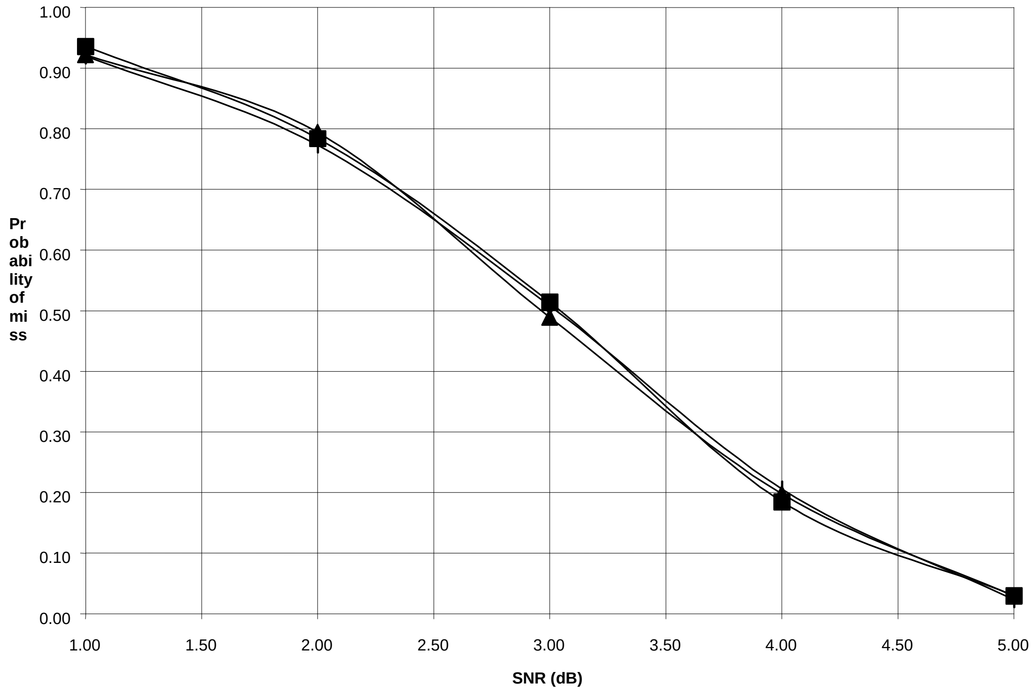

Figure 8 Probability of Failed Detection with ITU Channel Model
Energy Summation

5 Conclusions

It appears that, for Preamble presence,

- Envelope power summation is most reliable
- Differential Detection is next best
- Coherent Detection is least reliable

In the actual processor it may be advantagous to

- First detect presence, based on energy
- Then select the best of 16 signatures

The results of this contribution reenforce the conclusions of Tdoc 2X99-011, that Differential Preamble Detection is superior to Coherent Preamble Detection.

ETSI SMG2 UMTS Layer 1 Experts Group   Tdoc SMG2 UMTS L1 2X99-011
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Title: Random Access Preamble Detection in Doppler:
Performance in ITU Channel Model

Source: InterDigital

Summary:

This contribution expands on Tdoc SMG2 UMTS-L1 620/98, to show detection performance in the classic Doppler spectrum as defined in Appendix 1 to Annex 2 of Recommendation ITU-R M.1225.

The results continue to show the relative merit of differentially encoded signatures over the FDD baseline signatures.

This document also includes a corrected version of the notional block diagram for the differential detection process.

1 Introduction

In Tdoc SMG2 UMTS-L1 620/98 it was shown that the use of differentially encoded PRACH preamble signatures provide a performance advantage over the current FDD baseline for cases with high Doppler (e.g., above 120 km/h).

These results were shown for an ideal channel in noise, and for a simplified Rayleigh model. It was suggested that we repeat the analysis for a channel with Doppler spread.

The results follow.

2 The model

The simulation was performed at the symbol level.

For each trial, for each specified SNR, 16 complex samples were generated by passing the signal through the channel model. These outputs were then normalized so that, assuming noise with unity variance, the average of the 16 samples yielded a short term SNR at the specified value, while maintaining the phase relationship among the 16 samples. Then 16 complex random noise samples were drawn from a Gaussian model yielding unity noise power level. Then each of the two detection techniques was exercised and either passed or failed.

The channel model used by the simulation is a discrete Wide Sense Stationary Uncorrelated Scattering (WSSUS) channel model whose impulse response can be represented as follows:

$$h(\tau,t)=\sum_{n=1}^{6}\sqrt{p_n}\sum_{i=1}^{20}\alpha_n^i\exp\left(-j\cdot 2\pi\ f_d\,t\cdot\cos\theta_n^i\right)\delta\ (\tau-\tau_n) \qquad (1)$$

where p_n and t_n is the average power and delay for the *n*-th multipath, respectively and, a_n^i and q_n^i are the complex-valued attenuation factor and arrival angle for the *i*-th unresolvable sub-multipath in the *n*-th multipath, respectively.
Note that f_d is the round trip Doppler shift in Hz.
Note also, that this is the Vehicular Model Type B, as defined in ITU-R M.1225.

For this contribution we used only one path per simulation, and ran simulations for two of the six paths, namely path 1 and path 3. That is, when the transmitted sequence is $s(t)$, the received baseband signal without AWGN is

$$\begin{aligned} r(t) &= s(t) \otimes h(t_{sp}, t) \\ &= s(t - t_{sp}) \cdot \sqrt{p_{sp}} \sum_{i=1}^{20} a_{sp}^{i} \cdot \exp\left(- j \cdot 2p\, f_d t \cdot \cos q_{sp}^{i}\right) \end{aligned} \qquad (2)$$

where the notation, $\otimes$, denotes the convolution operation and the subscript, *sp*, represents the specific path.

In the simulations, we used the pre-generated parameters including a_n^i and q_n^i, summarized in Appendix 1. These were six of the seven paths provided by Nokia as part of the reference channel model for the Turbo Code evaluations. To meet the realistic mobile radio channel such as the randomness of amplitude and phase, we treat the propagation delay for the specific path as a random variable, h, so that the equation (2) can be written by

$$r(t) = s(t) \cdot \sqrt{p_{sp}} \sum_{i=1}^{20} a_{sp}^{i} \cdot \exp\left(- j \cdot 2p\, f_d (t + h) \cdot \cos q_{sp}^{i}\right) \qquad (3)$$

3 Differential Decoding Block Diagram

Tdoc 620/98 had an editorial error in the block diagram for Differential Detection process. As reported verbally at the December meeting, the error was only editorial, and the correct version, figure 1, shown below, was the basis for all performance analysis.

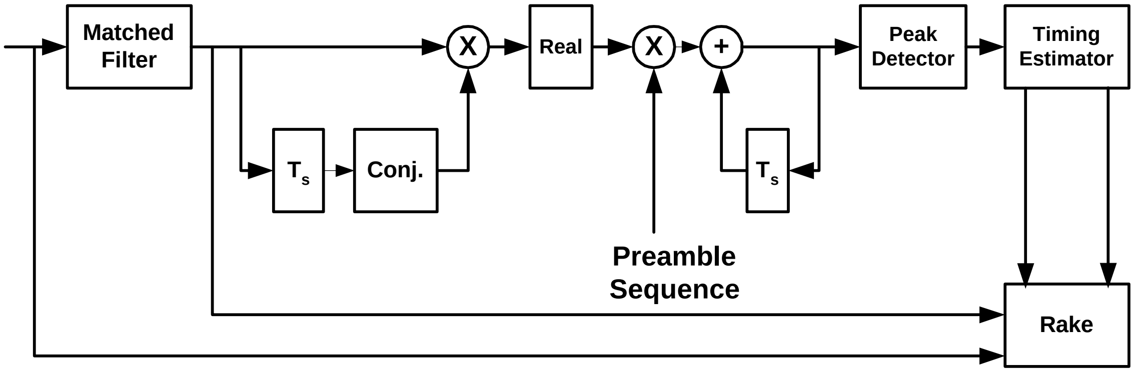

Figure 10 Differential Detection Block Diagram

4 Results

Figures 2 and 3 show probability of incorrect signature selection versus SNR for differential processing and coherent processing for 30 km/hr. 120 km/hr and 150 km/hr. Each of these figures corresponds to a different path of the channel model. We observe that the performance of differential decoding is consistent for both cases and in general agreement with performance predicted for an ideal channel in Tdoc 621. Performance of coherent processing is clearly degraded by Doppler. In one case, figure 2, the degradation is apparently catastrophic at 120 and 150 km/hr.

Figure 4 shows probability of incorrect signature versus SNR for 30 km/hr for coherent processing using either the baseline FDD signatures or the proposed new signatures. This demonstrates that, if a base station employs a coherent processor to optimize for low speed users, it will suffer negligible loss by using the proposed signature set versus the baseline signature set.

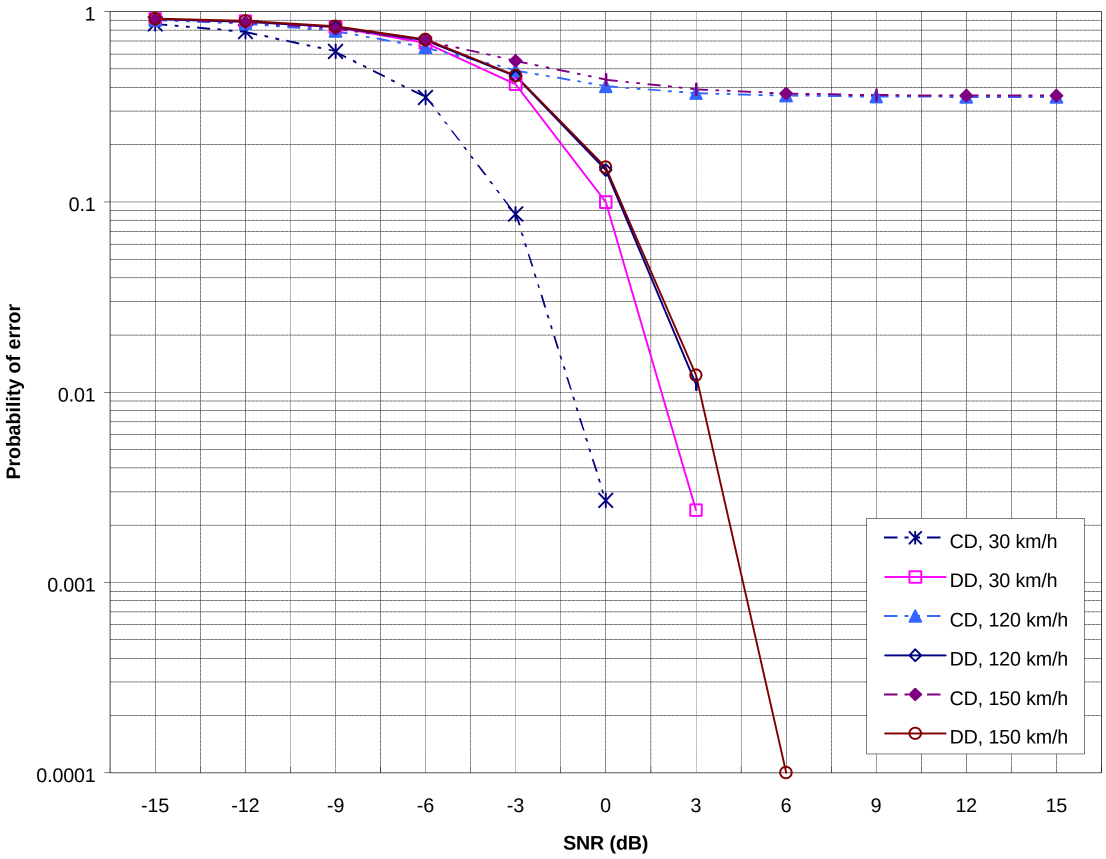

Figure 11 Performance in ITU Model Path 1

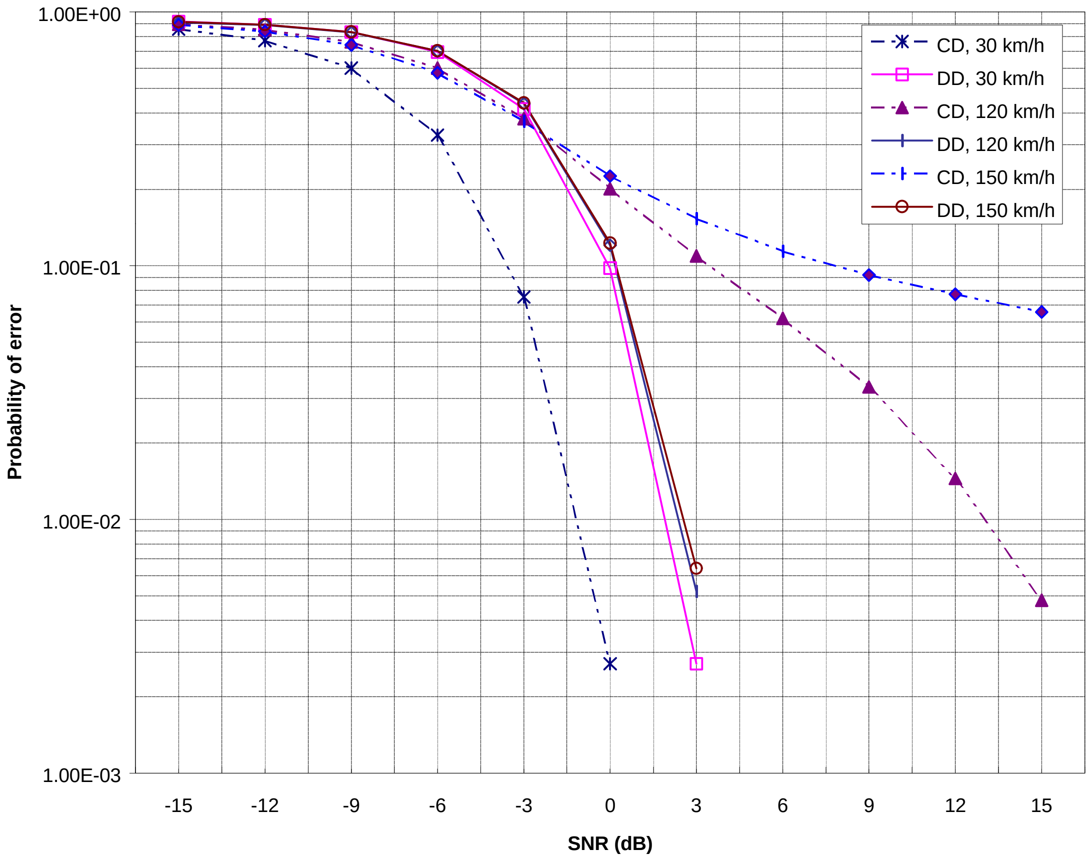

Figure 12 Performance in ITU Model Path 3

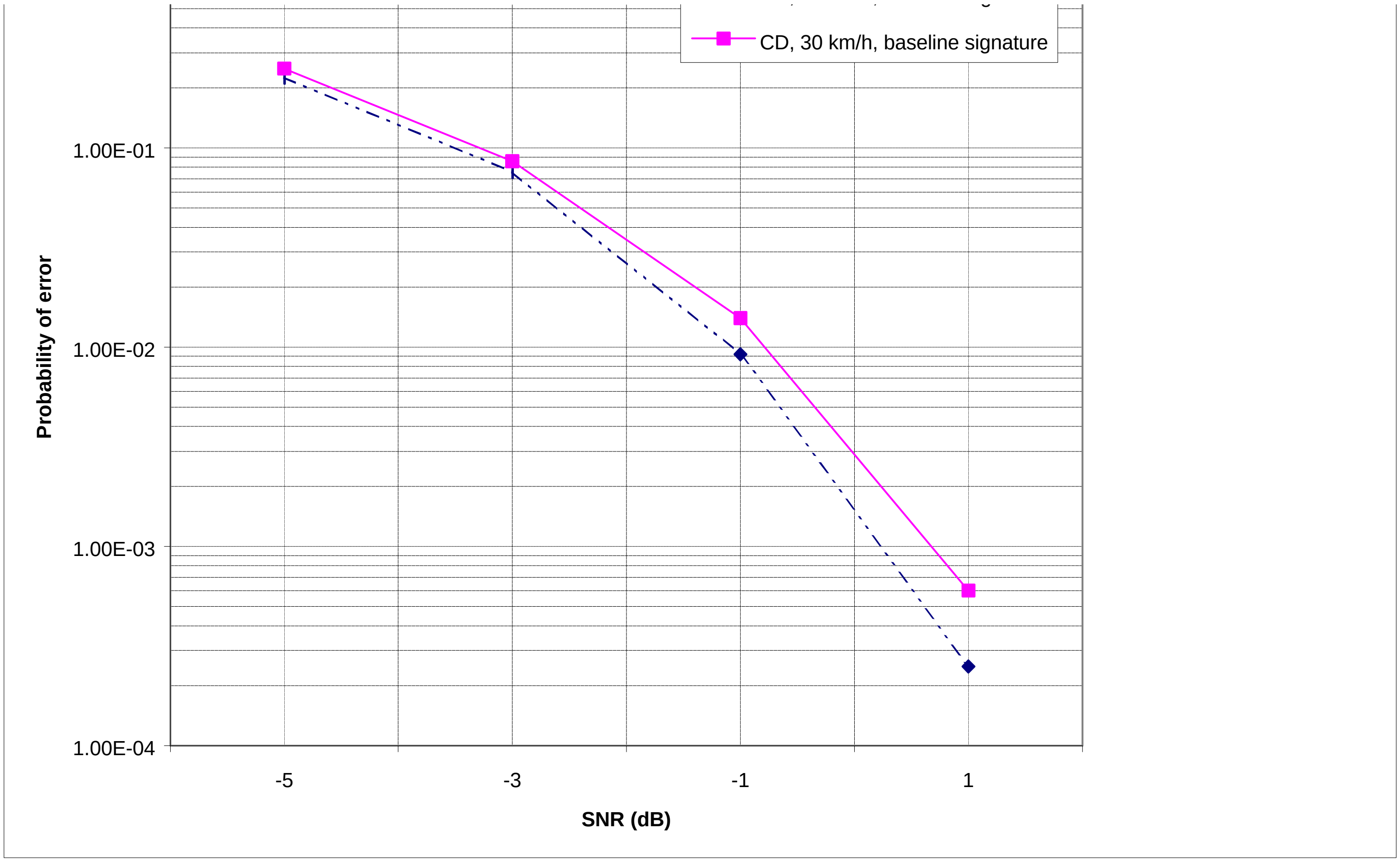

Figure 13: Performance Using Coherent Processing for Baseline and Proposed Signatures

5 Conclusion

The recommendations of Tdoc 620 are reconfirmed after using the ITU channel model. For the limited number of cases exercised, Differential Decoding performance appeared to be robust and predictable. Coherent processing suffered large losses for one case and virtually a complete failure for the other case.

6 Recommendation

The proposed signature set be adopted to permit base stations to use Differential Detection of PRACH signatures.

Appendix 1

Channel parameters

Real part of channel Coefficients

	Path 1	2	3	4	5	6
Sub-path 1	-0.548	-0.427	-0.853	-0.485	1.758	-0.494
2	0.543	0.004	-0.428	0.241	0.269	0.606
3	0.652	0.402	2.066	-1.049	-0.802	-0.884
4	-0.215	-0.457	0.315	0.121	-0.469	-1.933
5	-0.766	-1.946	-0.519	-1.519	-0.555	-0.109
6	0.223	-0.454	0.625	0.765	-0.326	2.105
7	-1.16	-0.277	-1.063	0.826	0.166	-0.22
8	0.032	0.306	1.691	-0.062	0.104	0.235
9	1.054	0.521	0.436	-0.107	-0.271	0.791
10	0.0005	1.172	0.434	1.523	0.678	1.386
11	-1.929	-1.484	0.899	-1.311	-0.645	1.348
12	0.814	0.49	-1.204	0.564	0.723	-0.314
13	-0.061	-0.83	1.747	0.192	1.069	0.495
14	2.349	0.501	0.573	1.567	-0.491	0.927
15	0.172	-0.373	-0.296	0.234	-1.124	0.15
16	-0.049	-1.998	-2.503	0.481	-3.007	0.554
17	0.241	-0.577	0.42	-0.445	0.554	0.379
18	-0.334	1.615	0.11	1.892	0.572	0.009
19	0.181	-1.04	1.342	1.782	-1.903	0.083
20	-2.178	0.713	-0.348	-0.208	-0.568	-0.809

Imag part of channel Coefficients

	Path 1	2	3	4	5	6
Sub-path 1	1.509	1.652	0.587	1.598	0.112	-0.686
2	-1.142	-0.946	1.511	1.265	0.266	-0.081
3	0.18	0.283	-0.943	0.122	0.36	-0.007
4	0.014	-0.129	2.563	-1.767	-0.863	-0.297
5	0.198	-0.169	-0.68	-0.683	0.212	1.395
6	-1.814	0.078	0.844	-0.239	0.675	0.085
7	0.367	-0.817	-0.986	0.193	0.835	0.236
8	-0.648	0.826	-0.193	0.072	1.392	1.896
9	0.822	-1.053	0.781	0.839	0.688	-1.179
10	-0.68	-1.074	1.116	0.913	-0.341	0.856
11	-2.173	0.84	-0.095	0.542	-1.1	2.357
12	1.568	-1.077	0.454	0.009	-0.731	-0.32
13	0.378	-0.622	-0.875	0.5	0.202	1.256
14	0.056	1.339	0.484	-0.183	-1.263	0.706
15	1.115	0.598	1.262	-2.339	0.662	0.121
16	-0.114	-0.436	0.743	-0.871	0.362	-1.324
17	1.164	1.503	1.408	1.755	0.953	1.042
18	-0.074	0.704	-0.29	-0.17	-0.806	1.104
19	1.802	-0.038	0.985	0.467	-2.014	-0.107
20	-0.579	-0.011	-1.354	0.457	-0.098	-0.321

Angle of channel (degrees)

	Path 1	2	3	4	5	6
Sub-path 1	0	0	0	0	0	0
2	18	18	18	18	18	18
3	36	36	36	36	36	36
4	54	54	54	54	54	54
5	72	72	72	72	72	72
6	90	90	90	90	90	90
7	108	108	108	108	108	108
8	126	126	126	126	126	126
9	144	144	144	144	144	144
10	162	162	162	162	162	162
11	180	180	180	180	180	180
12	162	162	162	162	162	162
13	144	144	144	144	144	144
14	126	126	126	126	126	126
15	108	108	108	108	108	108
16	90	90	90	90	90	90
17	72	72	72	72	72	72
18	54	54	54	54	54	54
19	36	36	36	36	36	36
20	18	18	18	18	18	18