On the Uplink Velocity Estimation in WCDMA

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Abstract

A correlation-based velocity estimator is proposed for uplink WCDMA. The maximum Doppler frequency is measured and the effects of frequency offset are suppressed. A curve shifter is introduced to improve the low-velocity performance and the multiple-branch structure is adopted to extend the range of measurements.

Keywords: Velocity Estimation, Doppler Frequency, Correlation Coefficient, Curve Shifter, Transfer Region

1. Introduction

The WCDMA has been selected as part of IMT-2000 radio technology. According to Annex B in [1], the system is required to operate in different fading environment with velocity ranging from 3km/hr to 250km/hr. The velocity estimation is required to improve the channel estimations[3] and handoff decisions[5]. In this paper we propose a method based on the correlation coefficients[4][6][8]. The maximum Doppler frequency, which is proportional to the vehicle velocity, is measured. The effects of frequency offset caused by local oscillator are also suppressed.

In our currently integrated system, the channel estimator[3] requires the velocity information to choose the corresponding parameter sets, as shown in Fig. 1. Instead of the interpolator output for maximal ratio combining, we employ the simple averaging (SA) results for velocity estimation to avoid feedback control.

2. Doppler Frequency Estimater

The proposed estimator is shown in Fig. 2. The simple averaging block provides the rough impulse response *h'(t)* of the multipath channel. *h'(t)* further low-passed to reduce out-of-band noise and square-summed to produce the power envelope $|h(t)|^2$.

Fig. 3 shows the performance of a traditional correlation-based estimator using channel model Fading3[1] and varying the velocity from 1 to 250km/hr. The BLER is specified at E_b/N_0=7.2dB in the test cases. Therefore we test this method under Eb/N0=4.2, 7.2 and 50.0dB. The curve should be the square of $J_0(w_d t)$[8]. $J_0(x)$ is the 0^{th}-order Bessel function of the first kind. However it bends down around 15Hz if the AWGN is in the practical range. This makes the selections of the coefficient sets difficult in channel estimation.

A straightforward approach is to avoid the use of the curve at low velocity. The estimator measures the maximum Doppler frequency. If we shift the spectrum to the higher-frequency region, the low-velocity conditions will never occurs. The modulator is one of the simple methods to shift the spectrum,

$$y(t) = x(t)\cos(2pf_S)x(t)$$

where f_S is the shifted frequency. The correlation coefficient *r(t)* is calculated according to the shifted, or modulated, spectrum.

$$r_Y = \frac{\langle y(t)y(t-t)\rangle - m_y^2}{\langle y^2(t)\rangle - m_y^2}$$

where m_y is the mean of *y(t)*.

The modulation reduces the bias, but the bias still exists. As shown in [6], the bias is larger when the Doppler frequency is smaller, and the bias increases as the SNR decreases. The bandwidth of the low-passed filter has to be adopted to reduce the bias. Instead of changing the bandwidths of the filters, we adopt a structure shown in Fig. 5. We introduce several pre-filters with different cut-off frequencies for different ranges of vehicle velocity. A *region selector* is also introduced to choose the appropriate results. Only one pre-filter-velocity-estimator pair is choused.

A notion of *transfer region* is induced in the pre-filter design to increase the reliability of the region selector, as shown in Fig. 6. The curve (a) is applicable for high velocity region, and curve (b) is for medium velocity. The two curves are both available in a common region, and the correlation coefficient of the upper bound of curve (b) is smaller then the value of the minimum of curve (a). The region selector has to switch to curve (b) in this transfer region and we can guarantee no ambiguity occurs. The same process continues to extend the lower bound of the proportional region. With sufficient low cut-off frequency of the pre-filter, the curve with the knee at sufficient low velocity, like curve (c), can be achieved.

The curve in each proportional region is further 2nd-order curve fitted individually. We can figure out the velocity by solving the 2nd-order equation for each region. The region selector compares the solution with a threshold within the transfer region. The solution is selected if it is larger then the threshold. If the solution is smaller then the threshold, the selector chooses next proportional region for lower velocity and compare with the threshold of it again. Applying curve shifter increases the transfer region and therefore reduces the number of pre-filters required.

3. Simulation Results

In the simulations we employ slot format #0[2] which is suitable for 12.2Kb voice service. There are 6 pilot bits in each slot. The chip rate is 3.84MHz, and the DPCCH symbol rate is 15KHz. We follow the number of paths and the respective relative delay and average power specified [1]. We assume the directional scattering is uniform and there is no line of sight. The correlation coefficient is reduced to $r(t)=J_0^2(w_D t)$[8]. Assume b_0 is a constant and $J_0(x)|_{x=b0}=0$. The sampling period of the velocity estimator is T_s=1/1500, which is of the same length as one slot. The time difference t should be a multiple of T_s. With some manipulations we have

$$t = \frac{b_0 c}{2pf_c v_0}$$

where f_c is the carrier frequency 2GHz, c is the light speed 3×10^8m/s and v_0 is the upper bound of the velocity 250km/hr. Therefore we let t equal to 1/1500 sec.

As shown in Fig. 7, we define the metric $m_V=m_1/m_2$ to measure the performance of different approaches in low-velocity condition with E_b/N_0 equal to the requirements for BLER testing.

Fig. 8 shows the performance under different offset frequency f_S. Both the means and standard deviations are shown. We let f_S equals to 15Hz to get the optimal performance in our environment as shown in Tab. 1. The system is equivalent to the traditional one if f_S is equal to zero.

Tab. 1, Metric m_V for different modulation frequency f_S

f_S	m_V (%)
0 (without CS)	46.17
2	22.15
4	20.27
8	20.73
15	12.23
30	13.56
60	12.88
120	12.61
200	12.95
250	16.46
300	8.44
400	N/A

Fig. 9 shows the performance in different fading channels. The normalized standard deviation is less then 5%.

We further extend the velocity estimator to the multiple branch structure. Fig. 10 shows the performance in different channel models. *Op* stands for the operation point of E_b/N_0 in [1]. *Op-3* stands for the condition in which the E_b/N_0 is 3dB below the operation point, and *superior* stands for superior E_b/N_0 environment which is 50dB in this case. We can see that the proportional region ranges from 3km/hr to 250km/hr and the normalized standard deviation is less than 0.1 in most cases. In the extremely low-velocity environments, the standard deviation is still less then 0.5 when the E_b/N_0 is at the operation point.

4. Summary

A correlation-based maximum Doppler frequency estimator is proposed. The roughly estimated channel response is first low-passed and square-summed to produce the power envelope. A small time difference for cross-correlation calculation is figured out assuming uniform directional scattering without line of sight. A curve shifter is introduced to improve low-velocity performance. The estimator are further extended to a multiple branch structure to widen the measurement range. The simulation results show that the normalized standard deviation is less then 0.5.

5. Reference

[1] 3GPP TS 25.104 V3.9.0: "UTRA (BS) FDD; Radio transmission and Reception."

[2] 3GPP TS 25.211 V3.9.0: "Physical channel and mapping of transport channels onto physical channels (FDD)."

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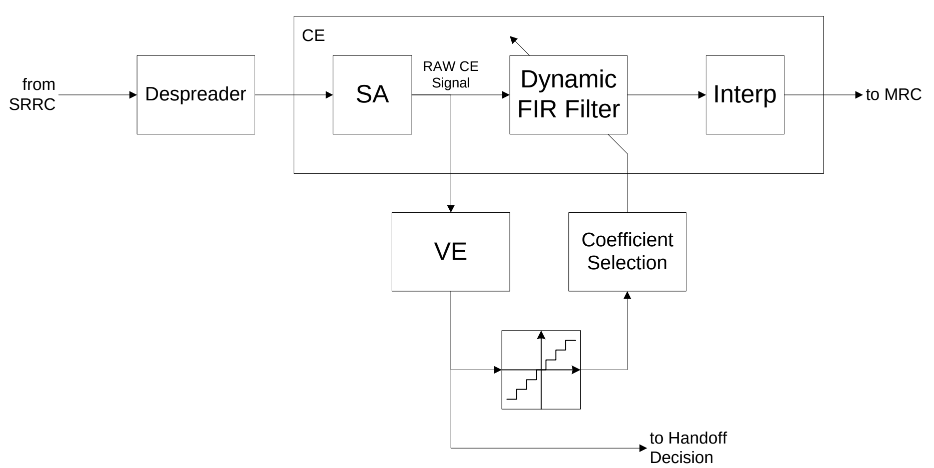

Fig. 1, Application of velocity estimation

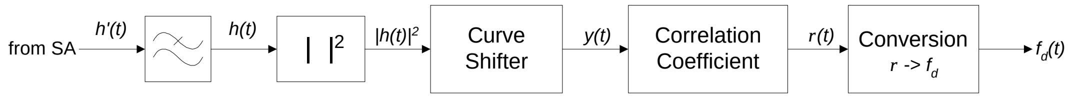

Fig. 2, Block diagram of velocity estimation

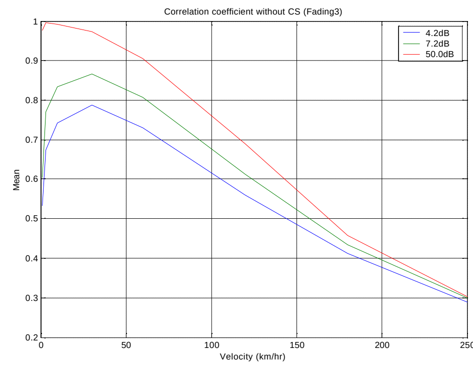

Fig. 3, Performance of traditional correlation-based estimator under Fading3

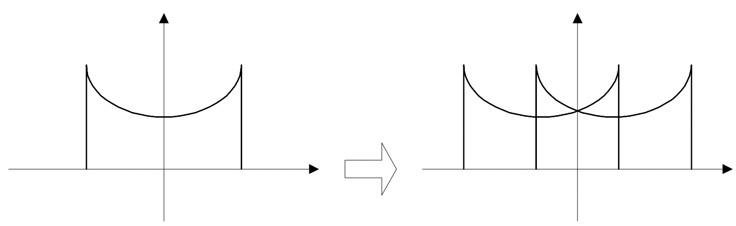

Fig. 4, Modulated spectrum of the power envelope of channel impulse response

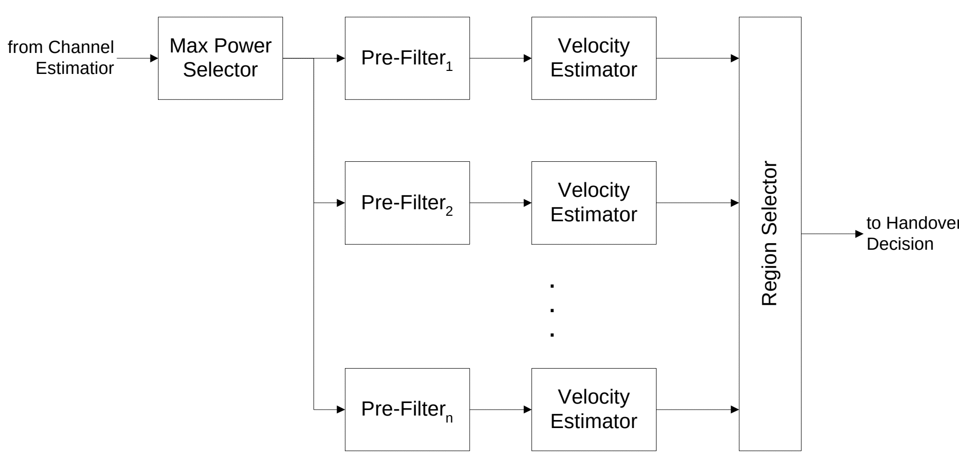

Fig. 5, Multi-branch structure

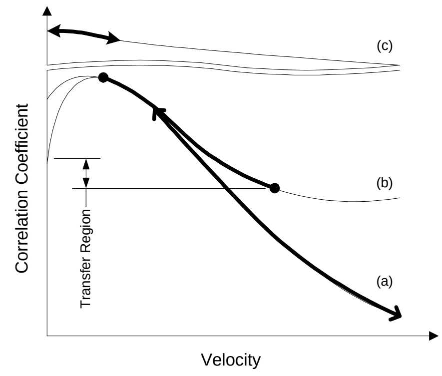

Fig. 6, Transfer region

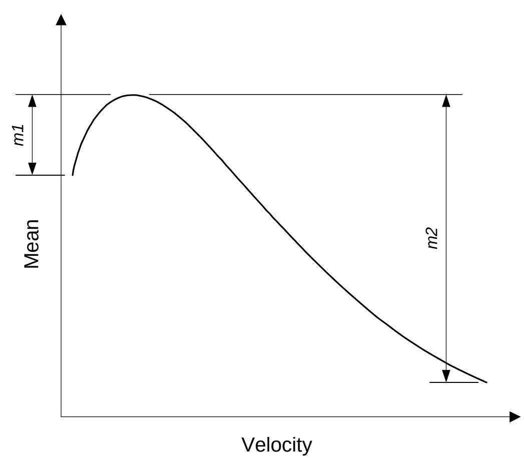

Fig. 7, Definition of low-velocity metric m_v and AWGN degradation metric m_{N3}

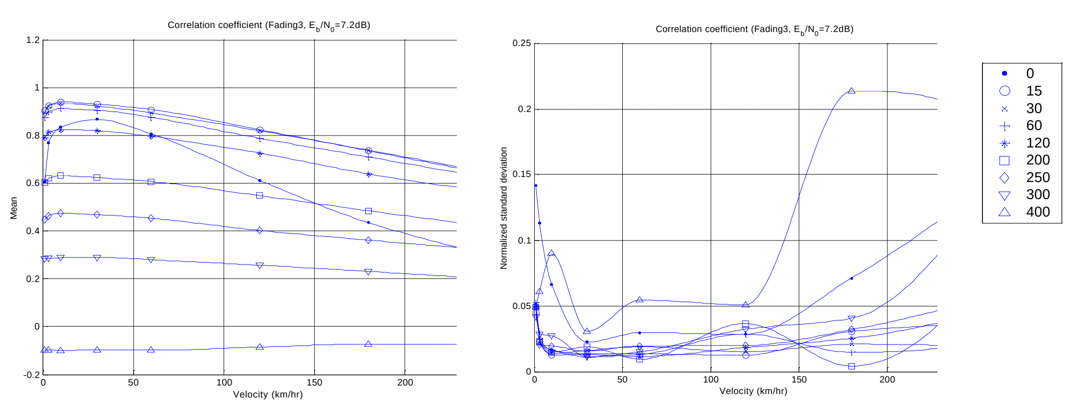

Fig. 8, Performance under different offset frequency f_S

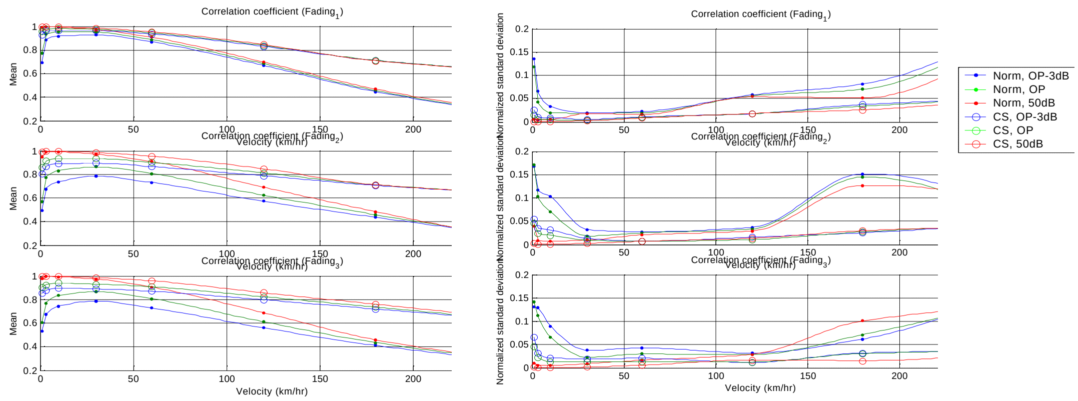

Fig. 9, Performance in different fading channels

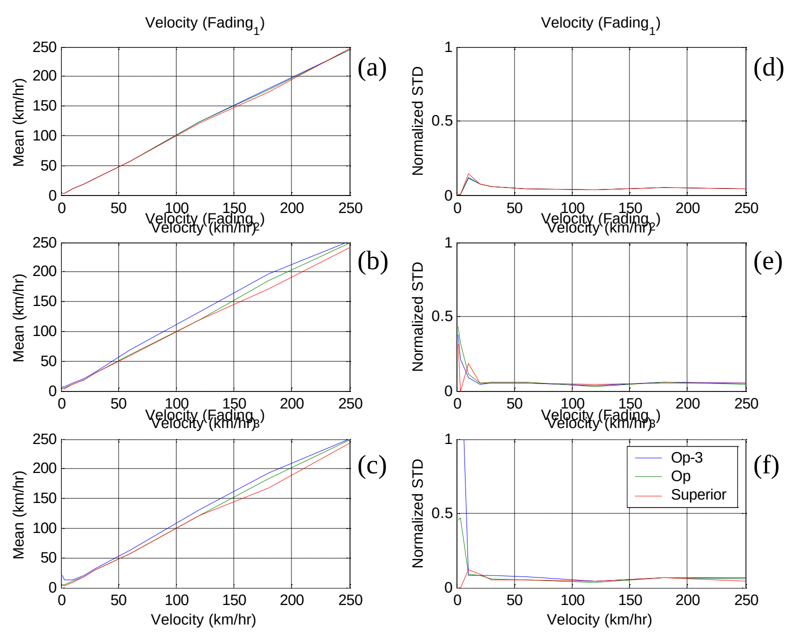

Fig. 10, Simulation results under differential channel model, a) mean of Fading_1; b) mean of Fading_2; c) mean of Fading_3; d) normalized standard deviation of Fading_1; e) normalized standard deviation of Fading_2; f) normalized standard deviation of Fading_3