Overview of Power Estimation Methods in Mobile Communications

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Abstract: This is a survey paper. In this paper various methods used for power estimation in wireless communications have been discussed. Wireless communications has become an inseparable part of our life. Power consumption is one of the major factors that decide the communication system quality. Accurate power estimation has an important role for power control and handoff decisions in mobile communications. Window based weighed sample average power estimators are commonly used due to their simplicity. In practice, the performances of these estimators degrade severely when the estimators are used in the presence of correlated samples. In this paper performances of the local mean power estimators namely, sample average, optimum unbiased and maximum likelihood estimators and Kalman Filter are analyzed in the presence of correlated samples. The variance of the estimators is used as performance measures.

Keywords: *Power estimation, sample average estimator, Local mean power estimation, shadowing, maximum likelihood estimator, Kalman Filter.*

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I. INTRODUCTION

In today's scenario wireless communication technology has been increasing at a faster rate and people are more attracted towards mobile devices since they are handy and easy to use and also well good to maintain. The quality of these devices is also far better than the wired devices. Power consumption is the major factor that decides the communication system quality. Accurate power estimation is very necessary. The reasons behind it are:-

1. **Channel Access: -** The Channel Access methods are multiplexing methods that help multiple users to simultaneously use the communication services in a single bandwidth in a wired or wireless medium. Communication Channels are very expensive. Both wireless medium or cable connections. Communication Service providers must accommodate multiple users over a limited channel to make profit. Access methods allow multiple users to share these limited channels and increase the productivity. There are five basic channel accesses or multiplexing methods, Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Orthogonal Frequency Division Multiple Access (OFDMA), and Spatial Division Multiple Access (SDMA). The choice of these channel access methods depends on how much power each system is consuming and the system where the channel access methods are being used.
2. **Handover**: - Handover in mobile communication is the term defined for the transfer of control information of ongoing call from one base station to another without breaking the call. In telecommunications there may be different reasons why a handover might be conducted:
   - When the phone is moving away from the coverage region of one BTS and entering the coverage region of another BTS the call is transferred to the second BTS in order to avoid call termination.
   - When the capacity of one cell for connecting new calls is used up, the call is transferred to the nearby cell in order to get some free capacity.
   - In Non-CDMA networks when two adjacent frequencies are being used then the new call request is transferred to the new cell so as to prevent interference.
   - In CDMA networks handover is induced to eliminate the near-far effect, even when the p[hone still has an excellent connection to the current call.
3. **Power Control: -** For a good communication system it is important that it should consume minimum power. For this it is necessary to control the power consumption. So it becomes a matter of extreme importance that the power consumed should be estimated accurately.
4. **Optimal Tuning: -** For perfect tuning transmitter and receiver should be synchronized with each other. This can be done by maintaining the transmitted and received power at a specific ratio.

Various power estimation techniques have been implemented over years with some advantages and disadvantages. In this

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paper performances of all these estimators has been discussed and compared.

Mockford, Turkmani and Parsons (1990) analysed local mean signal variability in rural areas. The local mean of the signal envelope was described by a lognormal distribution. The power spectral density of the local mean signal was estimated along rural routes. Goldsmith, Greenstein and Foschini (1994) studied the error statistics of real time power measurements in cellular channels with multipath and shadowing. The authors considered two measurement methods (filtering the squared envelop, and filtering the logarithm of the squared envelop) and two filter types (integrate-and-dump and RC). Accurate measurements were obtained by filtering either the logarithm of the detected power or the power itself [11].

Valenzuela, Landon and Jacobs (1997) explored techniques for the measurement of local mean signal strength at 900 MHz and 2 GHz. Linear averaging technique was used to estimate the local mean and ray tracing propagation model was used to evaluate different methods of calculating the local mean signal strength for indoor environment[11].

Manohar Das and Cooprider (1997) introduced new techniques for detection of changes in the local mean of a signal. The first one utilized a discrete cosine transform (DCT) based data compression principle, and the second one was based on a robust piecewise linear approximation (PLA) of the given signal. The results of experimental studies were compared with the performance of the two methods with the existing filtered derivative method. Wong and Cox (1999) derived the optimal local mean signal level estimator for the Rayleigh fading environment and compared with the sample average estimator. Variance of the two estimators were estimated and compared with the Cramer-Rao Lower bound. The 5th and 95th percentiles of the estimators were obtained by computer simulation. Antilog Rayleigh (ALR) distribution was used to estimate the signal variation in a Rayleigh fading environment[11].

Young-Chai Ko and Mohamed-Slim Alouini (2001) presented two local mean power estimation techniques over Nakagami fading channels. Chai Ko and Mohamed-Slim Alouini presented maximum likelihood as well as minimum variance unbiased estimators for the local mean signal power estimation. De Jong and Herben (2001) presented new method for the computation of local mean power from individual multipath signals predicted by two-dimensional ray tracing based on an expression for the spatial average of the received power, which takes into account the spatial correlation between signals. The presented method is based on the spatial average of the received power over each pixel area[11].

Avidor and Mukherjee (2001) investigated the possibility of obtaining better estimates or prediction of the path loss between a mobile and the surrounding base station by processing more measurements, including older measurements of received power that are not used by current deployed algorithm. The current or near future value of the local mean received power including the shadow loss was estimated by using the algorithm[11].

Tepedelenlioglu, Sidiropoulos and Giannakis (2001) derived the maximum likelihood and median filtering for power estimation in mobile communication system. Linear filtering techniques for power estimation was compared with the maximum likelihood (ML) estimator and the median filtering techniques for power estimation was compared with the linear filtering, maximum likelihood (ML) estimator and uniformly minimum variance unbiased (UMUV) estimator. Jiang, Sidiropoulos and Giannakis (2003) proposed a scalar Kalman-Filter-based approach for improved local mean power estimation [11].

The performance of the Kalman filter (KF) was compared with the window based estimators, like the sample average estimator of (Goldsmith, Greenstein & Foschini, 1994) the uniformly minimum variance unbiased (UMVU) estimator of (Wong & Cox, 1999) and the maximum likelihood (ML) estimator of (Tepedelenlioglu, Sidiropoulos and Giannakis, 2001) [11].

II. LOCAL POWER ESTIMATORS

In this section each power estimator has been discussed separately:-

1. ***Sample Average Estimator:-***
   This is the earliest used methods and is the simplest one for power estimation. Due to the rapid changing characteristics of the Rayleigh fading process, an estimate of local mean power is obtained by averaging the samples X [11]. The average of the received samples as follows,
   $$E_{SA} = \frac{1}{N}\sum_{j=1}^{N} X_j$$
   Where N is the window size,
   X_j is the received power measurement.
2. ***Optimum Unbiased Estimator:-***

The optimum unbiased estimator was derived in 1999, as follows [11]

$$E_{OU} = 10\left[\log T - \frac{H_{N-1}}{\ln 10}\right]$$

Where

$$T = \sum_{j=1}^{N} 10^{X_j/10}$$

And

$$H_N = 1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \cdots\cdots\cdots\cdots + \frac{1}{N}$$

For N=1, 2, 3…… H_N is known as the N^{th} harmonic number.

3. Maximum Likelihood Estimator:-

In 2001, the maximum likelihood estimator for local mean power estimation was derived as follows [11]:-

$$E_{ML} = 10[\log(T) - \log(N)]$$

Where,

$$T = \sum_{j=1}^{N} 10^{X_j/10}$$

4. ***Median Filter:-*** Motivated by the impulsive character of the multipath process, median filtering technique was proposed. Median filtering is widely used in signal and image processing and is known to outperform linear filtering alternatives in the presence of heavily tailed noise. Median filtering can be derived as [8]:-

$$S_{MD}[n] = median(P[n-M], \cdots P[n+M]) - \beta$$

Where the *median* operator orders the sample within the bracket, and selects the middle value, N=2M+1 is the window length of the running median filter, and β~ -1.5920 is a correction term that satisfies

$$\int_{\beta}^{\infty} f_H(x)\,dx = \int_{-\infty}^{\beta} f_H(x)\,dx = 0.5$$

And should be included since H(t), as a random variable, has a nonzero median value given by β

5. ***Kalman Filter:-*** Based on the autoregressive model for the shadow process the Kalman filter based approach has been proposed. The Kalman Filter can be regarded as a sequential minimum mean square error (MMSE) estimator of a signal corrupted by white Gaussian noise, where the signal is characterized by an AutoRegressive dynamic model with white gaussian driving noise. The scalar/static Kalman Filter can be summarized in table below [1]:-

$$\hat{S}(n/n-1) = a\hat{S}(n-1/n-1)$$

$$M(n/n-1) = E\left[\left(S(n) - \hat{S}(n/n-1)\right)^2\right] = a^2 M(n-1/n-1) + \sigma_\phi^2$$

$$K(n) = \frac{M(n/n-1)}{\sigma_H^2 + M(n/n-1)}$$

$$\hat{S}(n/n) = \hat{S}(n/n-1) + K(n)\left(P(n) - \hat{S}(n/n-1)\right)$$

$$M(n/n) = E\left[\left(S(n) - \hat{S}(n/n)\right)^2\right] = \left(1 - K(n)\right)M(n/n-1)$$

Where, $\hat{S}(n|n-1)$ is the apriori estimate of the filtered signal,

$\hat{S}(n-1|n-1)$ is the aposteriori estimate of the previous signal,

$M(n|n-1)$ is the apriori estimation error,

$M(n|n)$ is the minimum mean square estimation error,

K(n) is the Kalman Gain,

$\sigma_\emptyset^2 = (1-a^2)\sigma_S^2$ is the variance of the noise included in the first order autoregressive model of the shadowing process, and

σ_S^2 is the variance of shadowing,

σ_H^2 is the variance of the fast fading,

a is the correlation coefficient.

III. PERFORMANCE COMPARISION OF POWER ESTIMATORS

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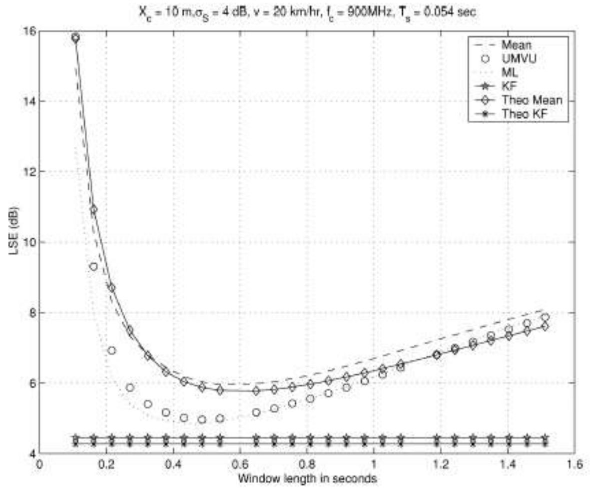

Fig.1: Comparison in urban areas with large T_s

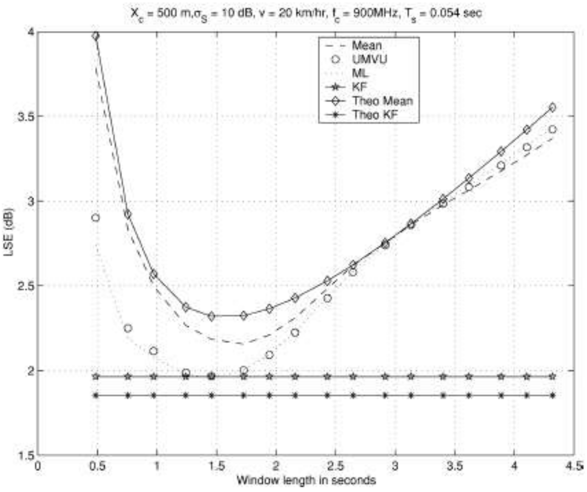

Fig.2: Comparison in suburban areas with large T_s

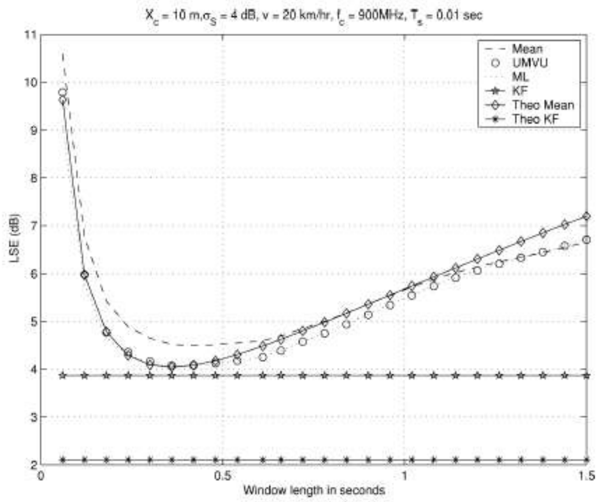

Fig.3: Comparision in urban areas with small T_s

IV. CONCLUSION

In this paper the performances of all the various power estimators has been analysed. The comparison was made between the sample average estimator, optimum unbiased estimator, maximum likelihood estimator, median filter and kalman filter. The results of our comparison show that Kalman filter approach for power estimation is far better technique than other estimators as it uses a series of measurements for the same value. Also the use of kalman filter has proved to be a convinient method for processing in real time environment. As we see that other estimators those work under the assumption that the shadow process ans fading are constant throughout the averaging duration. Kalman filtering implements a window free approach that is optimal in the Linear Minimum Mean Square Error (LMMSE) sense when the multipath is white, with very modest computational complexity.

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References

[1] Tao Jiang., Sidiropoulos, N. D., & Giannakis B. Giannakis. (2003). Kalman Filtering for Power Estimation in Mobile Communications. *IEEE Trans. On Wireless Communications, Vol.2, No-1, pp.151-161.*

[2] Mockford, S., Turkmani, A. M. D., & Parsons, J. D. (1990). Local Mean Signal Variability in Rural Areas at 900 MHz *in Proc. 40th vehicular Technology Conf,. pp. 610-615.*

[3] Valenzuela, R. A., Landon, O., & Jacobs, D. L. (1997). Estimating Local Mean Signal Strength of Indoor Multipath Propagation. *IEEE Trans. On Veh. Technol., Vol.46, No 1.*

[4] Wong, D., & Cox, D. C. (1999). Estimating Local Mean Signal Power Level in a Rayleigh Fading Environment. *IEEE Trans. on Veh. Technol., Vol-48, No-3, pp.956-959.*

[5] Goldsmith, A. J., Greenstein, L. J., & Foschini, G. J. (1994). Error Statistics of Real-Time Power Measurements in Cellular Channels with Multipath and Shadowing. *IEEE Trans on Veh. Technology*, Vol.43, No.3, pp.439-446.

[6] Manohar Das., & Cooprider, A. (1997). New Technologies for Detection of Changes in the Local Mean of a Signal. *In proc. of the 40th Midwest Symbosium on circuit and systems*, Vol.2, 3-6, pp.849-852. Manohar Das., & Cooprider, A. (1997). New Technologies for Detection of Changes in the Local Mean of a Signal. *In proc. of the 40th Midwest Symbosium on circuit and systems*, Vol.2, 3-6, pp.849-852.

[7] Young Chai Ko., & Mohamed Slim Alouini. (2001). Estimation of the Local Mean Power over Nakagami Fading Channels. *12th IEEE International Symposium on personal, Indoor and Mobile Radio Communications*, Vol.1, pp c-107-c-112.

[8] Tepedelenlioglu, Sidiropoulos, N.D., Giannakis B. Giannakis. (2001). Median Filtering for Power Estimation in

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Mobile Communication systems. *in Proc. 3rd IEEE Signal Processing workshop on Signal Processing Advances in Wireless Communications*, Taiwan, pp.229-231.

[9] Avidor, D., & Mukherjee, S. (2001). Estimation and Prediction of the Local Mean Signal Power in Mobile System. *Veh. Technol. Conference, VTC 2001 Spring. IEEE VTS 53rd*, Vol.4, 6-9 pp.2751-2755.

[10] M. Ali and M. Zohdy, "Interactive Kalman Filtering for Differential and Gaussian Frequency Shift Keying Modulation with Application in Bluetooth," Journal of Signal and Information Processing, Vol. 3 No. 1, 2012.

[11] Lenin Gopal, Ashutosh Kumar Singh and Veeramani Shanmugam, "Power estimation in mobile communication Systems", Computer and information science journal, Vol.1, No 3, 2008.

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