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Improved Channel Estimation and Removal of Fading for MIMO-OFDM Systems

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ABSTRACT

Many inference algorithms develop the time-domain connection of the direct by employ a Kalman filter base on a first-order (or sometimes second-order) estimate of the time-varying channel amid a norm based on link toning (CM), or on the Minimization of Asymptotic Variance (MAV). To decrease the complexity of the high-dimensional RW-KF for combined opinion of the multi-path multifaceted amplitudes, we suggest using an inferior dimensional RW-KF that estimate the compound amplitude of each path separately. We demonstrate that this amounts to a simplification of the joint multi-path Kalman increase formulation through the Woodbury's identities. Hence, this innovative algorithm consists of a superposition of self-determining single-path single-carrier KFs, which be optimized in our earlier studies. This examination allow us to settle in the optimization to the authentic multi-path multi-carrier scenario, to afford logical formulas for the mean-square error presentation and the best tuning of the future estimator in a straight line as a function of the physical parameter of the canal (Doppler frequency, signal-to-noise-ratio, power delay profile). These logical formula are known for the first-, second-, and third-order RW models used in the KF. The future per-path KF is exposed to be as well-organized as the accurate KF (i.e., the joint multi-path KF), and outperforms the autoregressive-model-based KFs future in the literature.

Keywords: OFDM; Kalman filter; Random walk model.

1. Introduction

Orthogonal frequency-division multiplexing (OFDM) is a process of training digital facts on many carrier frequencies. OFDM has developed keen on a well-liked system for wideband digital communication, whether wireless or over copper wires, second-hand in applications such as digital television and audio broadcasting, DSL Internet access, wireless networks, power line networks, and 4G mobile infrastructure [1]-[3]. OFDM is a frequency-division multiplexing (FDM) system used as a digital multi-carrier modulation technique. A big number of intimately spaced orthogonal sub-carrier signals are second-hand to bring data on a number of parallel data stream or channel. Every one sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintain total data rates alike to conservative single-carrier lilt schemes in the similar bandwidth [4],[5]. Figure 1 shows the multi-hop OFDM system.

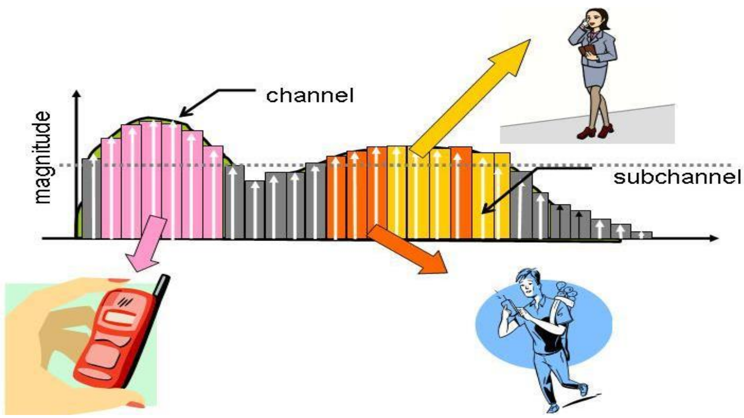

Figure 1. Multi-hop OFDM

The main lead of OFDM over single-carrier scheme is its facility to survive among severe channel situation (for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath) with no compound equalization filter. Channel equalization is cut down since OFDM may be view as by means of many slowly modulate narrowband signal fairly than one fast modulate wideband signal. The low sign rate make the employ of a guard interval flanked by symbols reasonably priced, making it likely to get rid of inter symbol interference (ISI) and use echo and time-spreading (on analogue TV these are visible as ghosting and blurring, respectively) to reach a diversity gain, i.e. a signal-to-noise ratio development. This device also facilitate the plan of single frequency networks (SFNs), where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system [6]-[9].

1.1. Channel Estimation in OFDM

The majority of the conservative method works in a symbol-by-symbol system by the association of the channel only in the frequency-domain (FD), i.e. the association among sub channel. Generally, they consist in estimate the direct at the pilot subcarrier situation and at that time interpolating it over the whole incidence network. The channel judgment at the pilot frequencies can be based on the Least-Squares (LS) criterion, or, for superior concert, on the Linea Minimum Mean-Square-Error (LMMSE) criterion. In Low-Pass Interpolation (LPI) has been exposed to perform better than all interpolation techniques second-hand in channel estimation. Though the conventional method can work with time-varying channel, the in order of the time-domain connection is not exploited. Still, the channel belief method can be supposedly seriously enhanced by the previous OFDM symbols, according to the on-line Bayesian Cramer-Rao Bound (BCRB) analyzed. Thus, Chen and Zhang proposed a structure to track the complex gains of each sub channel by using one Kalman filter (KF) per sub-channel. In practice, only a subset of pilot-subcarriers is used to perform the per-sub channel KF, and the global frequency rejoinder of the feed is motionless obtain by LPI exclamation.

2. Related Work

The channel is modeled as a first-order Gauss-Markov process and trellis-based methods are used with either forward backward or fixed lag MAP processing. Fitting a realistic time varying channel into this framework generally requires the use of approximations which degrade performance and/or limit the range of applicability (e.g., to slowly varying channels). The soft non-coherent equalizer they propose for DD channels builds on recent ideas from the multiple-input multiple-output (MIMO) literature such as the use of suboptimal tree search to find the dominant contributions to a non-coherent metric. Our principal contribution is the derivation of a fast algorithm for the sequential update of the BEM-based non-coherent metric. In particular, the proposed algorithm yields a complexity that scales linearly in the block length and quadratic ally in the number of BEM parameters [10],[11]. The explicit formulae of the optimum parameter and the asymptotic MSE of the RW3-KF they're given, assuming the knowledge of the channel statistics. A connection between the steady-state RW3- KF and the typical third-order DPLL was established. They also conclude that, for KF based estimators; the they'll-tuned third-order random walk model is more adequate compared with the first-order AR model in the low-variation context, with the resulting estimator performance very close to the BCRB. Possible future directions are to extend this work to the vectorial case for multi-path channel and/or multi-carrier modulation scenarios. Also, MSE performance of the other components of the RW3 model could be investigated [12].

Channel estimation is a fundamental task for a wireless communication receiver and Kalman filter (KF) has been mostly used in the past years, concerning a large and various ranges of systems from MIMO to OFDM systems. This algorithm is quasi-optimal for high mobility case. But, for most conventional Doppler frequencies, where channel variation within one symbol duration can be neglected, the performance of this estimator is relatively poor compared to less complex algorithms and is far from the Bayesian Cramer-Rao Bound. On the other hand, other adaptive algorithms can be obtained in using constant coefficients if an a priori model of the dynamic of time-varying parameters is available. All these methods require a priori knowledge of the statistics of the channel, at least in their optimized versions. The goal of this paper is to address the aforementioned issues [13].

A new algorithm which jointly estimates path Complex Gains (CG) and Carrier Frequency Offset (CFO) in the presence of very high mobility has been presented. The algorithm is based on the EM algorithm. Within one OFDM symbol, each time-varying CG is approximated by a Basis Expansion Model (BEM) representation. The dynamics of the BEM coefficients are modeled by first-order auto-regressive processes. The algorithm operates in two steps, an acquisition step (pilot OFDM symbols) and a tracking step. Moreover, they have derived a closed-form exact Hybrid Cramer-Rao Bound (HCRB) for joint CFO and CG estimation in the presence of very high mobility.

Long Term Evolution (LTE) represents the wireless technology that will lead the growth of mobile broadband services in the next years. In this scenario characterized by a growing proliferation of mobile devices and applications, LTE is very appealing for network providers in order to support a wide range of multicast services, expected to be massively accessed by mobile users for commercial and other purposes. Although the Multimedia Broadcast Multicast Service (MBMS) improves the LTE capability of supporting multicast services, it is well known that the radio resource management (RRM) on a per-group basis is challenging and limited in performance due to the presence of cell-edge users which experience poor channel conditions [14].

3. Narrow Down of the Article

Per-path RW-KF is predictable to stand self-governing learn of every solitary path, which allow the optimization penalty find in the single-carrier single-path framework to be practical openly. KFs could do among a linear recursive state-space illustration of the channel [15],[16]. However, the firm Clarke model does not own up such an illustration. A rough computation frequently second-hand in the text consists of future the vanishing course as auto-regressive. Hence, an extensively second-hand waterway estimate is based on a first-order Auto-Regressive model (AR1), as optional by combined with an association- identical (CM) criterion to attach the AR1 coefficient. The KF channel estimator that consequences beginning this choice, in future called AR1-KF, has be used in more than a few studies concerning a variety of systems, such as in multiple-input-multiple- output systems , and in OFDM system.

The AR1-KF appear to be opportune for the incredibly towering mobility case, which lead to quasi-optimal channel belief show compare to poorer limits, as see, for instance, in (in these studies, the AR1-KF is actually second-hand to track the basis extension model coefficients of the high-speed channel). However, here they consider restrained normalize Doppler frequency ethics; i.e., this corresponds to low mobility (km/h) with the actual systems such as Worldwide Interoperability for Microwave Access (WiMAX) mobiles. However, with the development of the cognitive radio, inferior transporter frequencies are investigated for future systems. For instance, VHF/UHF television broadcast bands from 54 MHz to 862 MHz and aeronautical bands from 960 MHz to 1215 MHz are planned to be deployed. For a given, as the speed is inversely relative to the delivery service incidence, values approximately can write to a relative high mobility with such systems (hundreds of km/h).

This prompt the want for a broad study of guide assessment for On the other hand, it has been shown recently that the MSE performance of a KF can still be improved by switching from the AR1 model to an integrated RW model (also called the integrated Brownian model) for the approximation model. A second-order RW model and a third-order RW model have been respectively considered. They take into account that the exact path CA continues in a given direction during several symbols for low, and shows a strong trend behavior.

The Kalman estimators based on these second-order and third order models are here called the RW2 KF and RW3-KF estimators, respectively. The RW-KF estimators of the previously cited studies were designed for single-path channel estimation in single-carrier systems. In the present study, we consider multi-path channel estimation in multi-carrier systems (i.e., OFDM systems). In this context, we are interested in devising simplified methods compared to the high-dimensional KFs that perform joint estimation of the path CAs.

4. System Model

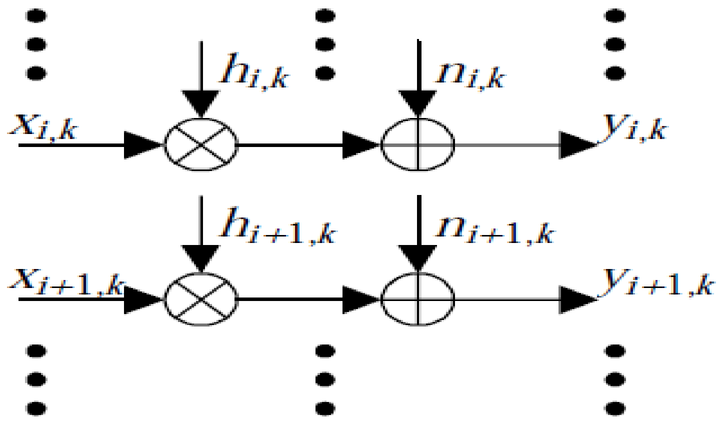

Figure 2. OFDM Communication

Pilot Pattern: Figure 2 represents the OFDM communication model. The optimal 2-D pilot pattern so as to minimize the MSE of the estimated CIR assuming the use of a conventional interpolator. The authors first analytically verify the optimum pilot shape that was suggested by computer simulation. For a given pilot density, the authors derive the optimal pilot spacing in terms of the moments of the Doppler spectrum and power delay profile representing the channel characteristics in the time and frequency domain, respectively. The use of pilot patterns with a regular structure since the use of equi-spaced and equi-powered patterns has been shown to provide better performance in addition to the simplicity of implementation. Fig depicts various kinds of pilot patterns on a 2-D time–frequency grid in OFDM systems. Figure 3 represents the block diagram of channel estimation based random walk model. Figure 4 shows the pilot arrangements of the proposed system.

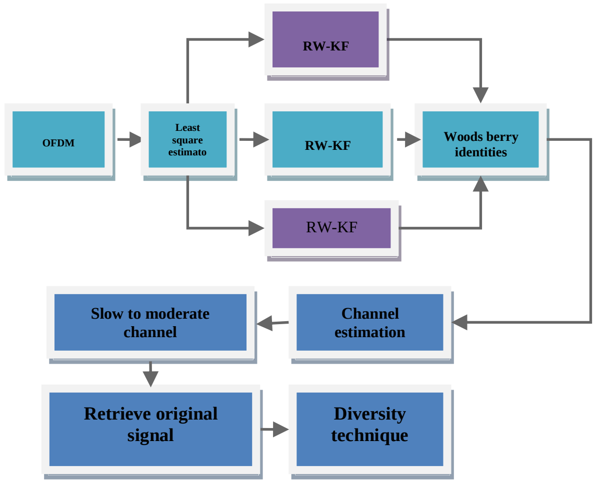

Figure 3. Channel estimation based Random walk Model

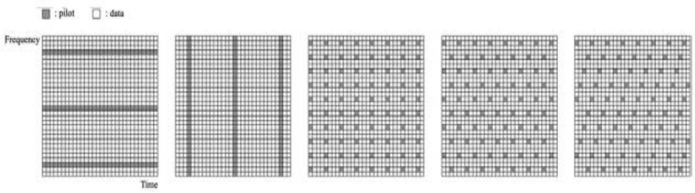

Figure 4. Pilot Arrangement

Bayesian Cramer-RAO: In estimation theory and statistics, the Cramér–Rao bound (CRB) or Cramér–Rao lower bound (CRLB), named in honor of Harald Cramér and Calyampudi Radhakrishna Rao who were among the first to derive it, expresses a lower bound on the variance of estimators of a deterministic parameter. The bound is also known as the Cramér– Rao inequality or the information inequality. In its simplest form, the bound states that the variance of any unbiased estimator is at least as high as the inverse of the Fisher information. An unbiased estimator which achieves this lower bound is said to be (fully) efficient. Such a solution achieves the lowest possible mean squared error among all unbiased methods, and is therefore the minimum variance unbiased (MVU) estimator. However, in some cases, no unbiased technique exists which achieves the bound. This may occur even when an MVU estimator exists.

Kalman Filter: Kalman filtering, also known as linear quadratic estimation is an algorithm that uses a series of measurements observed over time, containing noise and other inaccuracies, and produces estimates of unknown variables that tend to be more precise than those based on a single measurement alone. More formally, the Kalman filter operates recursively on streams of noisy input data to produce a statistically optimal estimate of the underlying system state. The filter is named for Rudolf E. Kalman, one of the primary developers of its theory.

5. Conclusion

Our solution is a two-step solution: first, an error signal for each channel path is calculated with the LS criterion. Secondly, based on this error signal, a KF is applied to each path independently. This per path KF solution explores the time-domain correlation of the channel, while the LS step exploits the frequency-domain correlation of the channel. We have shown how to apply the previous results we obtained for a single-path single-carrier to the multi-path multi-carrier context. This has allowed us to provide tables with the optimal RW parameters, together with the theoretical formulae of the variance of the estimation error. Furthermore, we have demonstrated that our per-path KF solution can be interpreted as a simplified version of the more complex joint multi-path KF. This has been done through the Woodbury's identities. The simulation results show that the performance of this low-dimensional solution is comparable to that of the joint multi-path KF. A possible way to extend this work could be by applying it to MIMO-OFDM systems.

Declarations

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Competing Interests Statement

The authors declare no competing financial, professional, or personal interests.

Consent for publication

The authors declare that they consented to the publication of this research work.

References

[1] Y. Zhao and A. Huang (1997). A novel channel estimation method for OFDM mobile communication systems based on pilot signals and transform domain processing. In Proc. IEEE 47th Veh. Technol. Conf., 3: 2089–2093.

[2] M.-H. Hsieh and C.-H. Wei (1998). Channel estimation for OFDM systems based on comb-type pilot arrangement in frequency selective fading channels. IEEE Trans. Consum. Electron., 44(1): 217–225.

[3] S. Coleri, M. Ergen, A. Puri, and A. Bahai (2002). Channel estimation techniques based on pilot arrangement in OFDM systems. IEEE Trans. Broadcast., 48(3): 223–229.

[4] C. Komninakis, C. Fragouli, A. Sayed, and R. Wesel (2002). Multi-input multi-output fading channel tracking and equalization using Kalman estimation. IEEE Trans. Signal Process., 50(5): 1065–1076.

[5] D. Nathangashree, L. Ramachandran, S. Senthilkumar & R. Lakshmirekha (2016). PLC based smart monitoring system for photovoltaic panel using GSM technology. International Journal of Advanced Research in Electronics and Communication Engineering, 5(2): 251–255.

[6] S. Suganya, R. Sinduja, T. Sowmiya & S. Senthilkumar (2014). Street Light Glow on Detecting Vehicle Movement Using Sensor. International J. for Advance Research in Engineering and Technology, ICIRET–2014.

[7] W. Chen and R. Zhang (2004). Kalman-filter channel estimator for OFDM systems in time and frequency-selective fading environment. In Proc. IEEE Int. Conf. Acoust., Speech, Signal Process. (ICASSP), May 2004, 4: 377–380.

[8] A. Asuvaran & S. Senthilkumar (2014). Low delay error correction codes to correct stuck-at defects and soft errors. 2014 International Conference on Advances in Engineering and Technology (ICAET). doi: 10.1109/icaet.2014.7105257.

[9] T. Al-Naffouri (2007). An EM-based forward-backward Kalman filter for the estimation of time-variant channels in OFDM. IEEE Trans. Signal Process., 55(7): 3924–3930.

[10] H. Hijazi and L. Ros (2010). Joint data QR-detection and Kalman estimation for OFDM time-varying Rayleigh channel complex gains. IEEE Trans. Commun., 58(1): 170–178.

[11] E. P. Simon, L. Ros, H. Hijazi, and M. Ghogho (2012). Joint carrier frequency offset and channel estimation for OFDM systems via the EM algorithm in the presence of very high mobility. IEEE Trans. Signal Process., 60(2): 754–765.

[12] S. Hwang, J. Um, M. Song, C. Kim, H. Park, and Y. Kim (2008). Design and verification of IEEE 802.22 WRAN physical layer. In Int. Conf. Cognit. Radio Oriented Wireless Netw Commun., Singapore.

[13] S. Senthilkumar, L. Ramachandran, R. S. Aarthi (2014). Pick and place of Robotic Vehicle by using an Arm based Solar tracking system. International Journal of Advanced Engineering Research and Science, 1(7): 39–43.

[14] M. Sohail and T. Al-Naffouri (2010). An EM based frequency domain channel estimation algorithm for multi-access OFDM systems. Elsevier Signal Process., 90(5): 1562–1572.

[15] Akbar Ali, R. Harish Kumar, R. Dheenathalayan, N. Prasanth, V. Parthasaradi, S. Senthilkumar, T. Senthil Kumar (2023). Audio Streaming Using Li-FI Communication. Irish Interdisciplinary Journal of Science & Research, 7(1): 1–7. doi: https://doi.org/10.46759/IIJSR.2023.7101.

[16] Senthilkumar Selvaraj (2013). Semi-Analytical Solution for Soliton Propagation in Colloidal Suspension. International Journal of Engineering and Technology, 5(2), Apr–May 2013.