1. INTRODUCTION

Modern wireless communication systems usually require accurate estimate of SNR without knowledge of the transmitted symbols. For instance, SNR estimation is required in order to perform efficient signal detection, power control, and adaptive modulation (Wiesel, Goldberg, & Messer, 2002; Das, 2008; Boujelben, Affes, & Stephenne, 2010). SNR estimators may be divided into two main categories; Data Aided (DA) SNR estimation when a prior knowledge about the transmitted data is available, and Non Data Aided (NDA) SNR estimation where we have no prior information about the transmitted data. In this paper, we consider the NDA SNR estimation.

Since the Cramer-Rao Lower Bounds (CRLB) gives the minimum variance of any unbiased estimator (Kay, 1993), it is used to assess the performance of the proposed NDA SNR estimator. Various SNR estimation techniques have been reported in the past for the conventional Single Input Single Output (SISO) NDA SNR estimation. In this paper, we consider the NDA SNR estimation over Single Input Multiple Output (SIMO) channels.

ABSTRACT

This paper discusses the problem of Non Data Aided (NDA) Signal to Noise Ratio (SNR) estimation of Binary Phase Shift keying (BPSK) modulated signals using the Expectation Maximization (EM) Algorithm. In addition, the Cramer-Rao Lower Bounds (CRLB) for the estimation of Data Aided (DA) and Non Data Aided (NDA) Signal to Noise Ratio (SNR) estimation is derived. Multiple Input Single Output (MISO) channels with Space Time Block Codes (STBC) is used. The EM algorithm is a method that finds the Maximum Likelihood (ML) solution iteratively when there are unobserved (hidden or missing) data. Extension of the proposed approach to other types of linearly modulated signals in estimating SNR is straightforward. The performance of the estimator is assessed using the NDA CRLBs. Alamouti coding technique is used in this paper with two transmit antennas and one receive antenna. The authors’ assumption is that the received signal is corrupted by additive white Gaussian noise (AWGN) with unknown variance, and scaled by fixed unknown complex channel gain. Monte Carlo simulations are used to show that the proposed estimator offers a substantial improvement over the conventional Single Input Single Output (SISO) NDA SNR estimator due to the use of the statistical dependences in space and time. Moreover, the proposed NDA SNR estimator works close to the NDA SNR estimator over Single Input Multiple Output (SIMO) channels.

Keywords: Binary Phase Shift Keying (BPSK) Signals, Cramer-Rao Lower Bounds (CRLB), Data Aided (DA), Multiple Input Single Output (MISO), Non-Data Aided (NDA) Estimation, Signal to Noise Ratio (SNR) Estimation, Space Time Block Codes (STBC) Channels, Transmit Diversity
tional Single input Single Output (SISO), and Single Input Multiple Output (SIMO) channels (Wiesel, Goldberg, & Messer, 2002; Das, 2008; Das & Miller, 2007; Boujelben, Bellili, Affes, & Stephenne, 2009, 2010). The CRLBs of both the DA and NDA SNR estimates for BPSK and QPSK modulated signals over SISO channels was first derived by Alagha (2001), he proved that for lower SNR values, the CRLB’s of SNR estimates for NDA estimators are significantly higher than those for DA estimators. In addition, Bellili, Affes, and Stephenne (2009, 2010) derived the CRLB for the DA and NDA SNR estimates of different M-QAM modulated signals over SISO channels. Soon after that, the CRLB of the DA and NDA SNR estimation for BPSK and QPSK modulated signals over SIMO channels was derived by Caiyao, Hongyi, and Tianzhong (2010). However, even though SIMO channels led to a remarkable improvement over SISO channels, it might not be practical to have a receive diversity (SIMO) especially when working with Mobile cell phones. The main problem with using the receive diversity (SIMO) systems with multiple antennas at the receiver then performing combining or selection and switching in order to improve the quality of the received signal is the cost, size, and power consumptions by the remote units (Alamouti, 1998). This is the main reason why we resort to the transmit diversity (MISO) systems instead. In this paper, considering the BPSK constellation system, we introduce a new EM based NDA SNR estimation method over MISO and STBC channel with AWGN. Also, the DA and NDA CRLBs for SNR estimation with STBC is derived. Theoretical results show that there is a remarkable improvement in the SNR estimation when making use of the mutual information offered by the transmit diversity technique especially at low values of SNR. The base station usually serves hundreds to thousands of remote units which is the sole reason of using transmit diversity at it instead of using the diversity at every remote unit covered by the base station. It is more economical in this case to add equipment to the base station instead of the remote units (Alamouti, 1998). Alamouti used a simple transmit diversity technique and assumed in his paper that the receiver has perfect knowledge of the channel. However, this assumption he said may seem highly unrealistic. One of our contributions in this paper would be solving this problem, as well as estimating the noise variance which would be used in estimating the SNR. Alamouti used two transmit antennas and one receive antenna. Two signals are simultaneously sent from the two antennas. Denoting the signal sent by antenna one by $S_1$ and the signal sent by antenna two by $S_2$. Then we repeat sending $-S_2^*$ from the first antenna, then $S_1^*$ from the second antenna, this ordering will be done to all our data. This is called space and time coding. Alamouti proved that this would have the same diversity order as the Maximal Ratio Receiver Combining (MRRC) with one transmit antenna and two receive antennas. The proposed NDA SNR estimator is compared to the NDA SNR estimators for SISO and SIMO channels in Wiesel, Goldberg, and Messer (2002), Das (2008), Das and Miller (2007), and Boujelben, Bellili, Affes, and Stephenne (2009, 2010).

The structure of the rest of the paper is as follows. Section 2, introduces the system model which then will be used in this paper. In Section 3, a review from the literature for the previously reported SISO NDA CRLBs for SNR estimators of the BPSK modulated signals. In Section 4, previously published SISO NDA SNR estimators for BPSK signals. Derivation of the proposed CRLBs for the DA and NDA SNR estimation with STBC channels with two transmit antennas and one receive antenna which is derived in Section 5 to measure the performance of our NDA SNR estimator. Section 6, the proposed EM based NDA SNR estimator is derived for our model. Performance analysis will be discussed in Section 7. Concluding remarks will then be drawn and discussed in Section 8.

## 2. SYSTEM MODEL

We initially assume that the received BPSK signal has been ideally filtered and sampled at the optimal sampling instant. The channels are assumed to be fixed with complex gain coef-

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