Multi-User Ranging Code Detection in OFDMA System Using MMLD Algorithm for Improving Detection Performance

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Abstract— Successive user detection algorithm is used to observe the multi user ranging signals and calculate there corresponding parameters. Using IEEE 802.16 specification in Orthogonal Frequency Division Multiple Access (OFDMA), initial ranging method designed an algorithm called Moment Maximum Likelihood Detection (MMLD) to detect the codes assigned and predicting offset timing. The objective function which is derived from the Expectation Maximization (EM) algorithm is used in the MMLD to cancel the channel estimation errors and Multiple Access Interference (MAI). To reduce the MAI over the iteration, the Maximum Likelihood Estimation (MLE) algorithm is designed in the MMLD. The experimental results indicate that the system is highly accurate.

Keywords— *IEEE 802.16e, OFDMA System, Initial Ranging, MMLD, Timing Offset.*

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I. INTRODUCTION

Initial ranging is performed on the OFDMA system. In initial ranging process, to avoid the MAI and Inter Carrier Interference (ICI), the Subcarriers arrive at the Base Station (BS) with the local timing and frequency references. The BS is required to detect the ranging code which are divided by the multi user ranging signals, and it is used to extract their corresponding timing offsets and power levels for data transmission. To establish uplink synchronization for the radio nodes, a large number of subcarrier stations and user terminals are used. All of these are used to develop the Internet of Things (IOT) [1] which indicates the increase in detection performance and the capacity of the IR process. To find out the different ranging signals that are in contention in the same ranging channel, Single User Detection (SUD) algorithm is presented. These algorithms are used to detect the multi user ranging signal and calculate their parameters to show the orthogonality of the codes. The phase shift suffers from the ranging signals from the Ranging Subcarrier Station (RSS), sensitivity to frequency in the wireless channels, the orthogonality is misaligned. As a result the performance of these algorithms decreases drastically.

The solution to the MAI is provided in [2]-[5] where in dividing the wide band ranging channels into narrow band sub channels, there is possibility to assign ranging sub channels to different Ranging Subscriber Stations (RSS) and these channels will support few RSS signals, so the reduction in the subcarrier will reduce the performance.

The other solution to estimate the MAI is Successive Interference Cancellation (SIC) based algorithms provided in [6]-[8] and these algorithms are based on the detected signals estimated and interference cancellation. One of the SIC based algorithm is Successive Multi User Detection (SMUD). The received signal over the number of iterations detects and cancels from strong to weak points in the active channel paths using SMUD algorithm, it then estimates parameters of the strongest path.

Another SIC algorithm proposed in [7] and [8] is Generalized Likelihood Ratio Test (GLRT) to detect the possible ranging codes. By using the MLE the GLRT predicts the Channel Impulse Response (CIR) attained by every detected code, where the derived single code is used for reconstructing the corrupted codes and signals employing SIC algorithm.

The SIC based algorithms [6]-[8] analyses a problem whether the operation of SIC is done directly in the received signal. After each code SIC process the channel estimation errors by applying the GLRT technique that are accumulated into the received signal and the remaining undetected channel codes or paths cannot be mitigated when it has large number of RSSs that impairs the performance of the algorithms. The three parameters which are required to design the simulation results are GLRT, Constant False Alarm Rate (CFAR) detection and RSSs.

II. MOMENT MAXIMIZATION LIKELIHOOD DETECTION

The MMLD algorithm is derived in the form of EM algorithm and the objective function where the possible active channel paths are derived from the conditional log likelihood function in the Expectation (E-step) and the Maximization (M-step) which is used to achieve the MLE algorithm. The BS does not know the number of active paths. The MMLD algorithm is designed to check and detect the validity of the each channel path and present the results of detection over the performed iterations. The proposed MMLD algorithm produces better detection performance and better Intial Ranging capacity by comparing with existing algorithms.

The MMLD algorithm process is as shown in the Figure 1 where the first step is to update the objective function which will then be projected to all the possible paths for the first code. If the strongest path is found there is estimation of channel and timing offset otherwise channel estimation will be set to zero and the process repeats until the strongest path is found and until the code is detected.

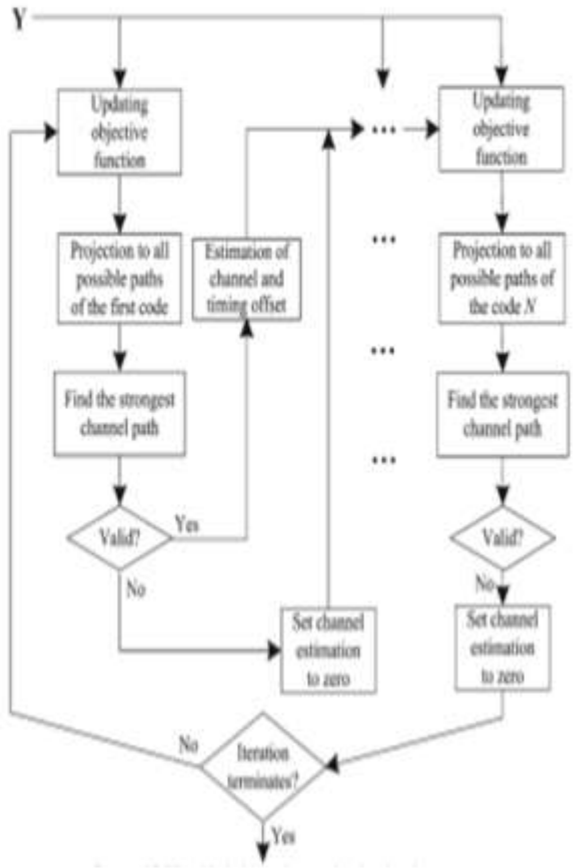

Fig 1: Block Diagram of MMLD algorithm

A. SIGNAL MODEL

Let **s**= $\{s[n]\}_{n=1}^{N}$ denote the transmitted discrete time baseband signal vector. If we assume an Additive White Gaussian Noise (AWGN) channel, the observed baseband signal has the following form

$$y[n]=\begin{cases} s[n]+w[n], \\ w[n] \end{cases} \qquad n=1,\ldots, N \quad \begin{matrix} H_1 \\ H_0 \end{matrix} \qquad (1)$$

Where w[n] and s[n] are the noise signals and transmitted signals and the noise signal is assumed as $\{w[n]\}_{n=1}^{N}$.

B. PRELIMINARY

The kth moment of the random variable X is given as

$$M_k = E\,\{X^k\} = \begin{cases} \Sigma_x x^k p(x), & \text{For discrete X} \\ \int_{-\infty}^{\infty} x^k p(x)dx, & \text{For continuous X} \end{cases} \qquad (2)$$

Where E {.} and p {.} define expectation and probability density function.

The kth moment thus given by

$$M_k = \frac{b^k(-1)^k}{p(p-1)^k} \sum_{i=0}^{p-1} (p-2i-1)^k \qquad (3)$$

For continuous uniform random variable $X \sim u[-b, b]$ applying (2) gives

$$M_k = \begin{cases} \frac{b^k}{k+1} & \text{For even k} \\ 0, & \text{For odd k} \end{cases} \qquad (4)$$

For a continuous Gaussian random variable $X \sim N(0, \sigma^2)$, applying (2) gives

$$M_k = \begin{cases} 1 \text{ x } 3 \text{ x} \ldots \text{x } (k-1)\sigma^k & \text{For even k} \\ \int_{-\infty}^{\infty} x^k p(x)dx & \text{For odd k} \end{cases} \qquad (5)$$

C. ABSOLUTE MOMENT BASED DETECTOR

The kth absolute moment of random variable X is given by the equation $M_k = E\,\{X^k\}$ where the following 2nd and 4th absolute moment equations are obtained by using equations given in (3) and (5) as shown in equation (6)

$$\begin{aligned}
M_{ay2} &= E\{|y[n]|^2\} \\
&= 2\sigma^2(\beta+1), && \text{Any s[n]} \\
M_{ay4} &= E\{|y[n]|^4\} && (6) \\
&= 2\sigma^4(4\beta^2+16\beta+8), && \text{s[n] = BPSK, QPSK} \\
&= 2\sigma^4\left(\frac{132}{25}\beta^2+16\beta+8\right), && \text{s[n] = 16 QAM (p=4)} \\
&= 2\sigma^4\left(\frac{116}{21}\beta^2+16\beta+8\right), && \text{s[n] = 64 QAM (p=8)} \\
&= \sigma^4\left(\frac{28}{5}\beta^2+16\beta+8\right), && \text{s[n] = CU}
\end{aligned}$$

Where $\beta = \frac{E\{|s[n]|^2\}}{E\{|w[n]|^2\}}$ is the SNR (Signal-to-Noise Ratio) and CU stands for continuous uniform random variable.

The gap between the m-ary and CU of the 4th moment decreases and M increases.

The ratio T ≜ $-\frac{M_{ay4}}{M_{ay2}}$ is calculated as

$$T = -\frac{M_{ay4}}{M_{ay2}} \tag{7}$$

$$= -2, \qquad \text{Noise only}$$

$$= -2+\left(\frac{\beta}{\beta+1}\right)^2, \qquad s[n] = \text{BPSK, QPSK}$$

$$= -2+\frac{17}{25}\left(\frac{\beta}{\beta+1}\right)^2, \qquad s[n] = 16\ \text{QAM}$$

$$= -2+\frac{13}{21}\left(\frac{\beta}{\beta+1}\right)^2, \qquad s[n] = 64\ \text{QAM}$$

$$= -2+\frac{3}{5}\left(\frac{\beta}{\beta+1}\right)^2, \qquad s[n] = \text{CU}$$

The estimated value of M_{ay2} and M_{ay4} are calculated as

$$\widehat{M}_{ayk} = \frac{1}{N}\sum_{n=1}^{N} |y[n]|^k, \qquad k = 2,4. \tag{8}$$

The T becomes

$$\widehat{T} = -\frac{\widehat{M}_{ay4}}{\widehat{M}^2{}_{ay2}} \tag{9}$$

Thus, the binary hypothesis test of equation (1) examines whether $\widehat{T}$ = -2 or $\widehat{T}$> -2. To get the original P_d and P_f.

We use the following theorems.

Theorem 1: Given the real value function

$$\widehat{T} = -\frac{\widehat{M}_{ay4}}{\widehat{M}^2{}_{ay2}}$$

The asymptotic distribution of $\sqrt{N}(\widehat{T} - T)$ is

$$\sqrt{N}(\widehat{T} - T) \sim N(0, \sigma^{-2}) \tag{10}$$

Where$\sigma^{-2} = v\Phi v^T$,

$$V = \left[\frac{\partial \widehat{T}}{\partial \widehat{M}_{ay2}}, \quad \frac{\partial \widehat{T}}{\partial \widehat{M}_{ay4}}\right]_{\widehat{M}_{ay2}=M_{ay2},\widehat{M}_{ay4}=M_{ay4}}$$

$$=\left[2\frac{M_{ay4}}{M^3{}_{ay2}}, \quad -\frac{1}{M^2{}_{ay2}}\right] \tag{11}$$

And Φ is the asymptotic covariance matrix of a multivariate random variable.

$$\sqrt{N}\left(\left[\widehat{M}_{a2},\widehat{M}_{a4}\right]^T - \left[\widehat{M}_{a2},\widehat{M}_{a4}\right]^T\right) \sim N(0, \Phi)$$

By applying multivariate central limit theorem, it gives that

$$\Phi_{(1,1)} = M_{ay4} - M^2{}_{ay2}, \ \Phi_{(1,2)} = \Phi_{(2,1)} = M_{ay6}\ M_{ay2}\, M_{ay4}\ and\ \Phi_{(1,1)} = M_{ay8} - M^2{}_{ay4}.$$

Substituting Φ in equation (10) gives

$$\sigma^{-2} = \frac{4M^2{}_{ay4}\,\Phi_{(1,1)} - 4M_{ay4}M_{ay2}\ \Phi_{(1,2)} + M^2{}_{ay2}\,\Phi_{(2,2)}}{M^6{}_{ay2}} \tag{12}$$

$$= \frac{4M^3{}_{ay4} + M^2{}_{ay2}\,M_{ay8} - 4M_{ay2}M_{ay4}M_{ay6} - M^2{}_{ay2}\,M^2{}_{ay4}}{M^6{}_{ay2}}$$

The steps can get the following vacancies

$$\sigma^{-2} = 4, \tag{13}$$

$$= \frac{8\beta^4+32\beta^3+40\beta^2+k}{(\beta+1)^6},$$

$$= \frac{0.234\beta^6+2.765\beta^5+17.114\beta^4+42.24\beta^3+46.4\beta^2+k}{(\beta+1)^6},$$

$$= \frac{0.26\beta^6+3.51\beta^5+19.49\beta^4+44.8\beta^3+47.62\beta^2+k}{(\beta+1)^6},$$

$$= \frac{0.325\beta^6+3.977\beta^5+20.503\beta^4+45.715\beta^3+48\beta^2+k}{(\beta+1)^6},$$

Where $k = 24\beta+4$ and 1st, 2nd, 3rd, 4th, and 5th iterations are for the noise.

Thus T=-2 in Ho hypothesis, we use the below test statics

$$T_8 = \sqrt{N}\left(\hat{T} + 2\right) \tag{14}$$

By using the equation (14), we decide $\{y[n]\}_{n=1}^{N}$ of (1) as H_0 if$T_8 < \lambda$ and as H_1 as $T_8 \geq \lambda$ where λ is threshold value. λ is selected for constant P_d or P_f.

The $P_f(\lambda)$ is expressed as

$$P_f(\lambda) = P_r\{T_8 > \lambda | H_0\} \tag{15}$$

Under Ho hypothesis, as $T_s \sim N(0,4)$ equation (15) becomes

$$P_f = \int_\lambda^\infty \frac{1}{\sqrt{2x\sigma^{-2}}} exp^{-\frac{x^2}{2\sigma^{-2}}} dx = Q\left(\frac{\lambda}{\sqrt{\sigma^{-2}}}\right) = Q\left(\frac{\lambda}{2}\right) \tag{16}$$

Where the Q function is given as

$$Q(\lambda) = \frac{1}{\sqrt{2\pi}} \int_\lambda^\infty exp^{-\frac{x^2}{2}} dx$$

The $P_d(\lambda)$ is expressed as

$$P_d(\lambda) = P_r\{T_8 > \lambda | H_1\} \tag{17}$$

Under H1 hypothesis, $T_8 \sim N(\mu, \sigma^{-2})$, where $\mu = \sqrt{N}(T+2)$

The $P_d(\lambda)$ is expressed as

$$P_d(\lambda) = \int_\lambda^\infty \frac{1}{\sqrt{2x\sigma^{-2}}} exp^{-\frac{(x-\mu)^2}{2\sigma^{-2}}} dx = Q\left(\frac{\lambda-\mu}{\sqrt{\sigma^{-2}}}\right) \tag{18}$$

III. RESULTS AND PERFORMANCE ANALYSIS

A. Simulation Parameters

The considerations are taken in acceptance with the IEEE 802.16m family. The size of Fast Fourier Transform (FFT) is 1024 and Cyclic Prefix (CP) is taken as 128 samples, sampling frequency is 11.2MHz and the bandwidth of the system is 10 MHz and carrier frequency is taken as 2.3 GHz, radius of the cell is given as 1Km. The cell border is 114 samples, both the sides of the guard bands has taken 80 subcarriers. For Initial ranging data transmission 864 subcarriers are used. These subcarriers are grouped as tile sand then each tile consists of 4 adjacent sub-carriers. The 6 non-consecutive tiles are included in each sub channel where the 6 sub channels indicate the total ranging subcarriers, which means it includes 144 ranging subcarriers. The IR includes 40 ranging codes where the subcarrier spacing is more than 2% of the Carrier Frequency Offset (CFO). The estimation probability of FA (False Alarm) is kept within 1x10^{-3} and the channel model is set to be the ITUM.1225 Vehicle –A channel with mobile speed of 60Km/h.

B. Simulation Results

1) Choice of most quantity of Iterations: Fig.2 shows the graph for detection probability vs the maximum number of iterations. For the Signal to Noise Ratio (SNR) values from 0 dB to 20 dB the RSSs range is taken from 6 to 10 and when the maximum number of iterations exceeds the detection probability the performance is better for RSS 6 with the assumption that he threshold value is not utilized here.

2) Selection of Early Terminating Threshold: Figure 3 shows the miss-detection-probability vs the number of iterations with respect to the early terminating threshold λ, where "Lambda" stands for λ and is show in the Figure 3 and 4 . As we see from the graph with the increase in λ , the detection performance also increases. To develop the overall detection extra stages are used and this allows for the improvement in performance. This shows that 0.01 is low sufficient to be a trademark for the MMLD to dissolve in advance, that may gain an ultimate performance while maximizing the volume with reduced the difficulty and hence the name MMLD.

3) MSE of Channel Estimation: Figure 5 shows the graph of the MSE Vs number of iterations and from the figure seen as the number of iterations increases the mean square error estimation will reduces which indicates that there is increase in performance. From the figure the MSE of the channele estimation for different codes becomes constant from 6th iteration onwards which indicates there is no further improvement.

4) Probability Detection: Figure 6 and 7 shows the detection probability of detection (PD) for MMLD vs the SNR values. The probability of detection (PD) values is plotted for different values of SNR and for different SNR values the miss detection probability is '0'. As SNR increases the performance of MMLD algorithm improves when compared to other existing algorithms and the perfromance remains constant after certain value of SNR.

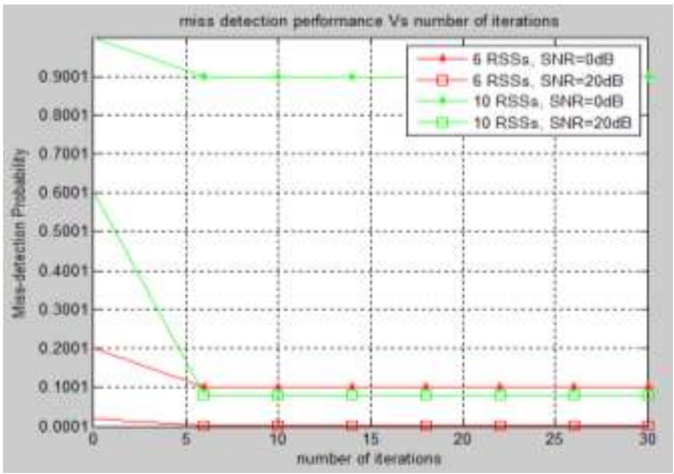

Fig 2: Miss Detection Performance Vs Number of Iterations

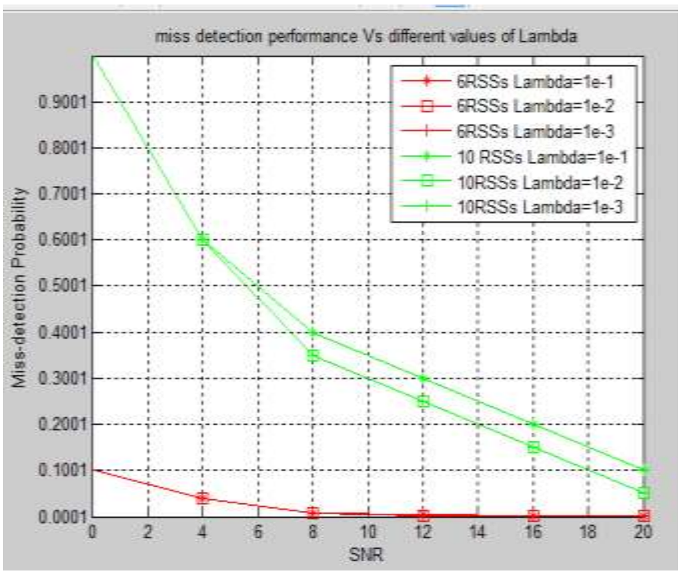

Fig 3: Miss Detection Performance Vs Different values of Lambda

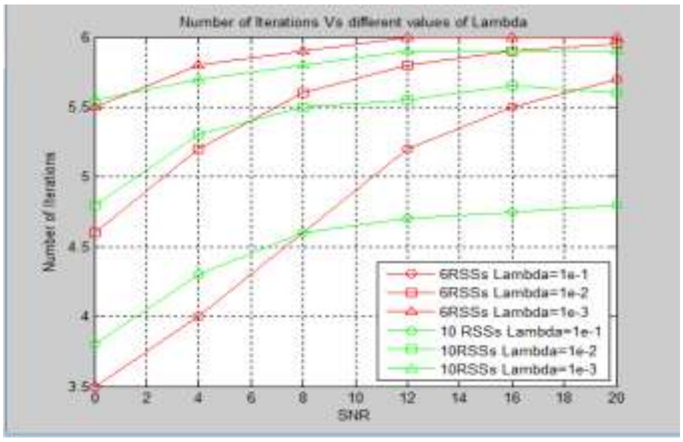

Fig 4: Number of iterations Vs Different values of Lambda

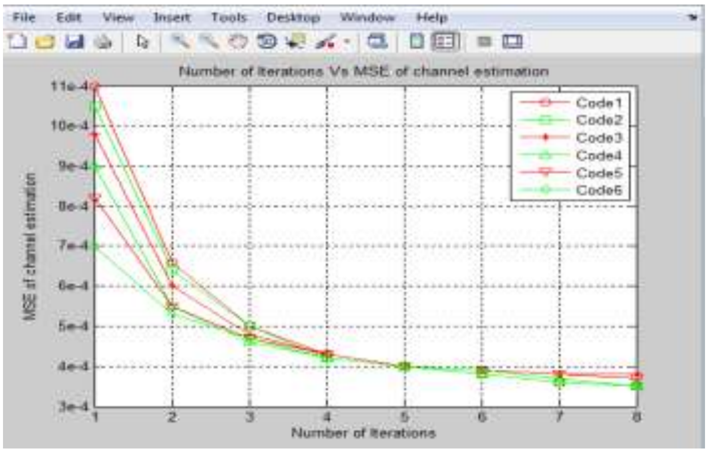

Fig 5: MSE of channel estimation

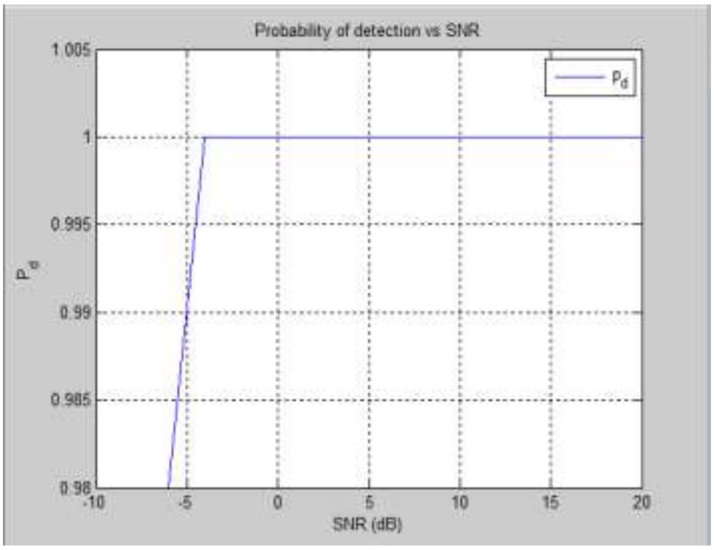

Fig 6: PD Vs SNR

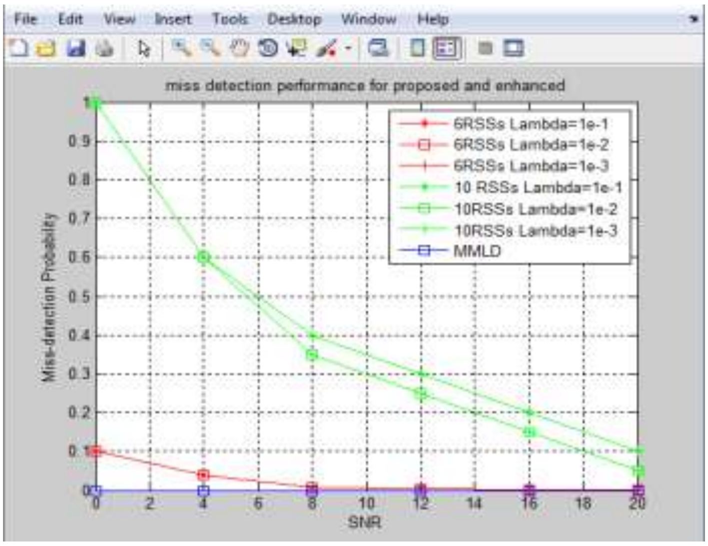

Fig 7: Comparison of MMLD

IV. CONCLUSION

Aim of this algorithm is to obtain better channel capacity and better performance in the OFDMA system using MMLD algorithm that employs EM algorithm where it performs the MLE for each channel. MMLD algorithm accomplishes initialization, code detection and timing estimation providing better miss detection probability compared to other existing algorithms.

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