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# Performance Analysis of OFDM Signal Using Maximum Likelihood Estimation Technique

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**ABSTRACT:-** The OFDM based wireless communication system design includes the design of OFDM transmitter, and OFDM receiver. Maximum likelihood Estimation method is used for the prediction of timing and frequency offsets introduced by channel. It has been shown that ML estimation method improves the performance of the system very effectively. There are several other techniques also for prediction of timing and frequency offsets of an OFDM system., but in this paper ML is main area of consideration.

**KEYWORDS:-** OFDM, ML Estimation.

**INTRODUCTION:-** In a basic communication system, the data are modulated onto a single carrier frequency. The available bandwidth is then totally occupied by each symbol. This kind of system can lead to inter-symbol-interference (ISI) in case of frequency selective channel. The basic idea of OFDM is to divide the available spectrum into several orthogonal sub channels so that each narrowband sub channel experiences almost flat fading. Orthogonal frequency division multiplexing (OFDM) is becoming the chosen modulation technique for wireless communications. OFDM can provide large data rates with sufficient robustness to radio channel impairments. The attraction of OFDM is mainly because of its way of handling the multipath interference at the receiver. Multipath phenomenon generates two effects

(a) Frequency selective fading and

(b) Intersymbol interference (ISI).

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# OFDM AND ML ESTIMATION:-

**Orthogonal Frequency Division Multiplexing (OFDM)**

**Modulation** - A mapping of the information on changes in the carrier phase, frequency or Amplitude or combination.

**Multiplexing** - Method of sharing a bandwidth with other independent data channels.

OFDM is a combination of modulation and multiplexing. Multiplexing generally refers to Independent signals, those produced by different sources. In OFDM the question of multiplexing is applied to independent signals but these independent signals are a sub-set of the one main signal. In OFDM the signal itself is first split into independent channels, modulated by data and then re-multiplexed to create the OFDM carrier.

**Maximum Likelihood Estimation of Timing and Frequency Offset in OFDM.**

**1. The OFDM system model**

The diagram below shows the basic data flow chart of an OFDM system

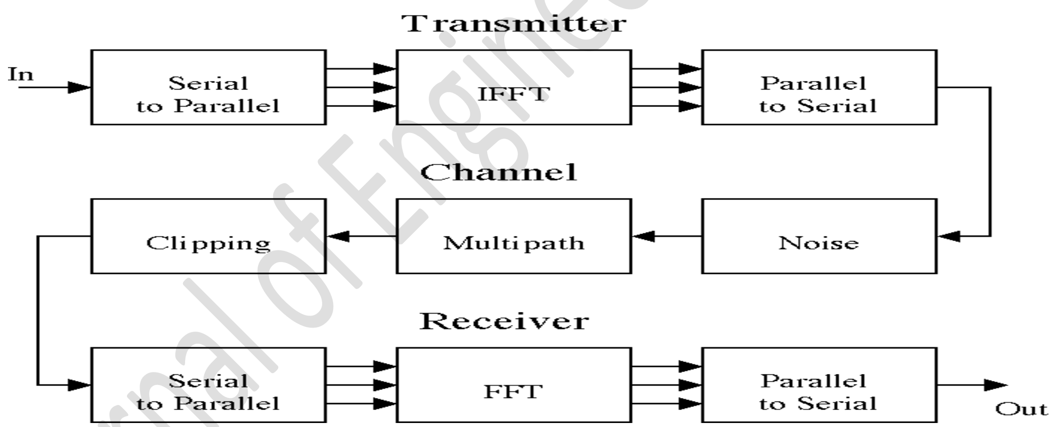


**Fig1. OFDM model**

Fig. 1 illustrates the baseband, discrete-time OFDM system model we investigate. The complex data symbols are modulated by means of an *inverse discrete Fourier transform* (IDFT) on N parallel subcarriers. The resulting OFDM symbol is serially transmitted over a discrete-time channel, whose impulse response we assume is shorter than L samples. At the receiver, the data are retrieved by means of a discrete Fourier transform (DFT).An accepted means of avoiding

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intersymbol interference (ISI).

**2. ML estimation:-**

Assume that we observe consecutive samples of, cf. Fig.4.9, and that these samples contain one complete-sample OFDM symbol. The position of this symbol within the observed block of samples, however, is unknown because the channel delay is unknown to the receiver. Definite index sets.

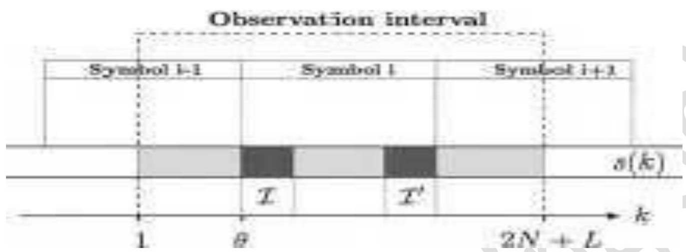


**Fig. 2.1 Structure of OFDM signal with cyclically extended symbols *s(k)*: The set I contains the cyclic prefix, i.e., the copies of the L data samples in I'**

$$\mathcal{I} \triangleq \{\theta, \cdots, \theta + L - 1\} \quad \text{and}$$
$$\mathcal{I}' \triangleq \{\theta + N, \cdots, \theta + N + L - 1\}$$

The set I' thus contains the indices of data samples that are copied into the cyclic prefix ,and the set I contains the indices of the prefix. collect the observed samples in the (2N+L)*1-vector r\[r(1)………r(2N+1)]T . Notice that the samples in the cyclic prefix and their copies r(k),k € I*U* I' are pair wise correlated, i.e.

$$\forall k \in \mathcal{I}: \quad E\{r(k)r^*(k+m)\} = \begin{cases} \sigma_s^2 + \sigma_n^2 & m = 0 \\ \sigma_s^2 e^{-j2\pi\varepsilon} & m = N \\ 0 & \text{otherwise} \end{cases}$$

While the remaining samples r(k), k ¢ IU I are mutually uncorrelated. The log-likelihood function for θ and $\varepsilon$ , Λ(θ ,ε ) is the logarithm of the probability density function *F*(r/θ,ε) of the 2N+L observed samples in **r** given the arrival time θ and the carrier frequency offset $\varepsilon$ . In the following, we will drop all additive and positive multiplicative constants that show up in the expression of the log-likelihood function since they do not affect the maximizing argument.

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Moreover, we drop the conditioning on (θ, $\varepsilon$ ) for notational clarity. Using the correlation properties of the observations **r** , the log-likelihood function can be written as.

$$\begin{aligned}\Lambda(\theta,\varepsilon) &= \log f(\boldsymbol{r}|\theta,\varepsilon)\\ &= \log\left(\prod_{k\in\mathcal{I}} f(r(k),r(k+N)) \prod_{k\notin\mathcal{I}\cup\mathcal{I}'} f(r(k))\right)\\ &= \log\left(\prod_{k\in\mathcal{I}} \frac{f(r(k),r(k+N))}{f(r(k))f(r(k+N))} \prod_{k} f(r)k))\right)\end{aligned} \quad \ldots\ldots\ldots(1)$$

where $f(.)$ denotes the probability density function of the variables in its argument. Notice that it is used for both one- and two-dimensional (1-D and 2-D) distributions. The product in (1) is Independent of θ (since the product is over all $k$ ) and $\varepsilon$ (since the density $f(r(k))$is rotationally invariant). Since the ML estimation of θ and $\varepsilon$ is the argument maximizing Λ(θ ,ε ) , we may omit this factor. Under the assumption that **r** is a jointly Gaussian vector, (1) is shown in the Appendix to be

$$\Lambda(\theta,\varepsilon)=|\gamma(\theta)|\cos(2\pi\varepsilon+\angle\gamma(\theta))-\rho\phi(\theta) \quad \ldots\ldots\ldots(2)$$

where ∠ denotes the argument of a complex number.

$$\gamma(m) \triangleq \sum_{k=m}^{m+L-1} r(k)r^*(k+N),$$
$$\Phi(m) \triangleq \tfrac{1}{2}\sum_{k=m}^{m+L-1} |r(k)|^2+|r(k+N)|^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots(3,4)$$

And

$$\rho \cong \left|\frac{E\{r(k)r^*(k+N)\}}{\sqrt{E\{|r(k)|^2 E\{|r(k+N)|^2}}\right| = \frac{\sigma_s^2}{\sigma_s^2+\sigma_n^2} = \frac{SNR}{SNR+1} \quad \ldots\ldots\ldots(5)$$

Is the magnitude of the correlation coefficient between ***r(k)***and ***r(k+N).***The first term in (2) is the weighted magnitude of γ ($m$) , which is a sum of L consecutive correlations between pairs of samples spaced N samples apart. The weighting factor depends on the frequency offset. The term ϕ ($m$) is an energy term, independent of the frequency offset $\varepsilon$ .Notice that its contribution depends on the SNR (by the weighting-factor ρ ).

The maximization of the log-likelihood function can be performed in two steps:

$$\max_{(\theta,\varepsilon)} \Lambda(\theta,\varepsilon) = \max_{\theta} \max_{\varepsilon} \Lambda(\theta,\varepsilon) = \max_{\theta} \Lambda(\theta,\hat{\varepsilon}_{\mathrm{ML}}(\theta)).$$

The maximum with respect to the frequency offset $\varepsilon$ is obtained when the cosine term in (2)equals one. This yields the ML estimation of $\varepsilon$

$$\hat{\varepsilon}_{\mathrm{ML}}(\theta) = -\frac{1}{2\pi}\angle\gamma(\theta) + n$$

where *n* is an integer. A similar frequency offset estimator has been derived in equation under different assumptions. Notice that by the periodicity of the cosine function, several maxima are found. We assume that an acquisition, or rough estimate, of the frequency offset has been performed and that $|\varepsilon| \leq 1/2$; thus $n=0$, Since $\cos(2\pi\varepsilon + \angle\gamma(\theta)) = 1$, the log-likelihood function of θ (which is the compressed log-likelihood function with respect to $\varepsilon$ ) becomes

$$\Lambda(\theta,\hat{\varepsilon}_{\mathrm{ML}}(\theta)) = |\gamma(\theta)| - \rho\Phi(\theta)$$

and the joint ML estimation of θ and $\varepsilon$ becomes

$$\hat{\theta}_{ML} = \arg\max_{\theta}\{|\gamma(\theta)| - \rho\phi(\theta)\}$$

$$\hat{\varepsilon}_{ML} = -\frac{1}{2\pi}\angle\gamma(\hat{\theta}_{ML})$$

Notice that only two quantities affect the log-likelihood function (and thus the performance of the estimator): the number of samples in the cyclic prefix L and the correlation coefficient ρ given by the SNR. The former is known at the receiver, and the latter can be fixed. Basically, the quantity $\gamma(m)$ provides the estimates of θ and $\varepsilon$ . Its magnitude, which is compensated by an energy term, peaks at time instant $\theta^{\wedge}_{ML.}$ while its phase at this time instant is proportional to $\varepsilon^{\wedge}_{ML}$. If is a prior known to be zero, the loglikelihood function for becomes $\Lambda(\theta) = \mathrm{re}\{\gamma(\theta)\} - \rho\,\phi(\theta)$ ,

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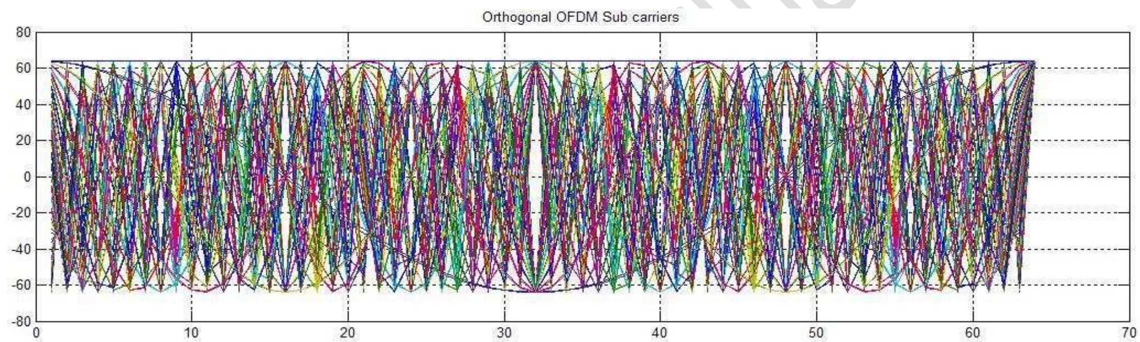
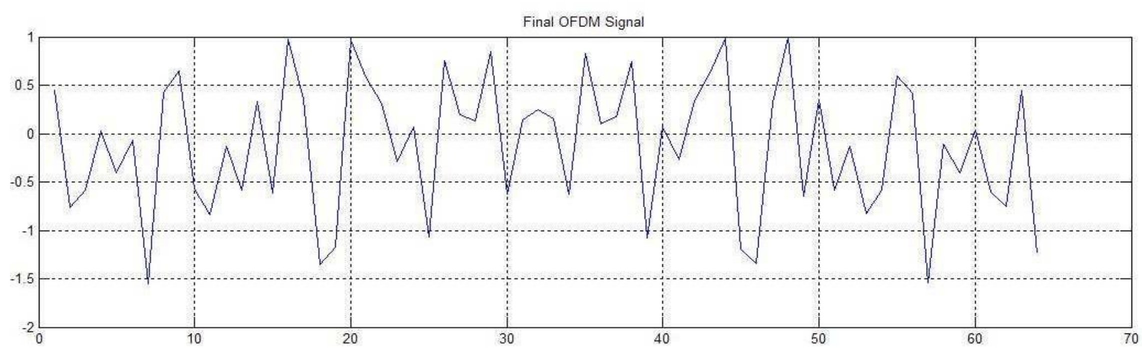
and $\theta^{\wedge}_{ML}$ is its maximizing argument. This estimator and a low-complexity variant are analyzed in equation.

In an OFDM receiver, the quantity $\gamma(\theta)$ , which is defined in(3), is calculated on-line, The Signals $\wedge(\theta,\varepsilon^{\wedge}_{ML}\ \theta)$ (whose maximizing arguments are the time estimates $\theta^{\wedge}_{ML}$ and (whose values at the time instants yield the frequency estimates). Notice that some equations describe an open-loop structure. Closed-loop implementations based in (5) and (11) may also be considered. In such structures, the signal $\wedge(\theta,\varepsilon^{\wedge}_{ML}(\theta))$ is typically fed back in a phase-locked loop (PLL). If we can assume that $\theta$ is constant over a certain period, the integration in the PLL can significantly improve the performance of the estimators.

## Simulation results:

1. OFDM with 64 sub channels, simple OFDM symbol




## CONCLUSION

- Maximum likelihood estimation method was implemented for the calculation of timing and frequency offsets ..

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- These frequency offsets are found to disturb the orthogonality of the OFDM symbols.

It was observed that using this ML estimation method we can improve the performance of any OFDM system.

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