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OFDM Based Radio Link of Transmitter and Receiver under RF Impairments

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ABSTRACT: *OFDM and other multicarrier waveforms are extremely delicate to RF non- impairments, for example, phase noise and IQ imbalance, of transmitting and receving devices. The execution of OFDM radio link under such RF impairments are measured regarding detection error rate and generally focusing on one impedance at once. In any case, there is just exceptionally constrained deal with expository examinations of shared data and rate misfortune statements, as capacities of RF impairment levels. In this article, we determine two shut structure common data outflows, in the form of infinite series representation, for a discretionary subcarrier of a general OFDM radio link disabled with transceiver phase noise and IQ imbalance in frequency-selective Rayleigh disseminated block fading radio channel, coating both uncorrelated and also completely corresponded mirror subcarrier scenarios. We additionally indicate that mutual information saturates to a limited esteem because of the inherent RF impairments even in the case that the symbol-to-noise ratio approaches infinity. Broad examinations with outcomes acquired from full OFDM radio link recreations are additionally given to outline and check the precise match between analytical and simulated mutual informationbehavior.*

KEYWORDS: *:Mutual information, IQ imbalance ,phase noise, frequency-selective channel*

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I. INTRODUCTION

ORTHOGONAL Frequency Division Multiplexing (OFDM) has gained significant popularity in the air interface design of existing and emerging radio communication systems, DVB-T/H/T2/NGH,3GPPLTE/LTE−Advanced, WiMAX, and IEEE 802.11x series. This is particularly stemming, from fairly simple equalization structures and ability to do adaptive modulation and coding as well as multi-antenna (spatial) processing at subcarrier level. On the downside, however, OFDM waveforms are found very sensitive to certain imperfections in the radio frequency (RF) electronics, such as oscillator phase noise (PN), carrier frequency offset (CFO)and IQ imbalance . Some recent works have investigated the performance degradation of OFDM systems under these RF impairments ,the performance metrics in these works are concentrated on bit error rate (BER) and symbol error rate (SER) or average signal-to-interference-plus-noise ratio (SINR) and not on mutual information analysis. Most of the existing works provide analysis of mutual information considering only one impairment at a time i.e. either IQ imbalance or PN, respectively .Recently, the joint effect of IQ imbalance and CFO is considered in where a lower bound on capacity is derived. This yields novel closed-form expressions for characterizing the performance loss at subcarrier level due to RF imperfections alone, which can then be used, e.g., in dimensioning the allowable RF impairmentlevels.

1.1. Phase Noise

Phase noise is the frequency domain representation of rapid, short-term, random fluctuations in the phase of a waveform, caused by time domain instabilities ("jitter").There have been two conflicting yet widely used definitions for phase noise. It define phase noise to be the spectral density of a signal's phase only, while the other definition refers to the phase spectrum resulting from the spectral estimation of the signal itself. Both definitions yield the same result at offset frequencies well removed from the carrier. At close-in offsets however, the two definitions differ. An ideal oscillator would generate a pure sine wave. In the frequency domain, this would be represented as a single pair of Dirac delta functions (positive and negative conjugates) at the oscillator's frequency, i.e., all the signal's power is at a single frequency. All real oscillators have phase modulated noise components. The phase noise components spread the power of a signal to adjacent frequencies, resulting in noise sidebands. Oscillator phase noise often includes low frequency flicker noise and may include white noise. Phase noise is a type of stationary noise and is closely related to jitter. A particularly important type of phase noise is that produced byoscillators.

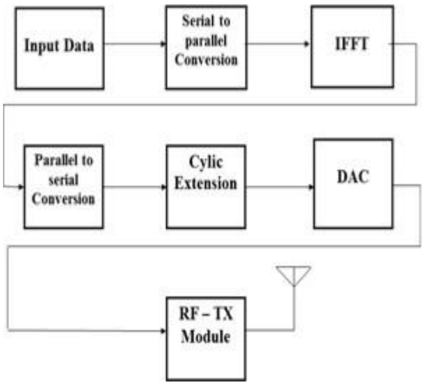

Fig 1.1 Block Diagram of OFDM Transmitter

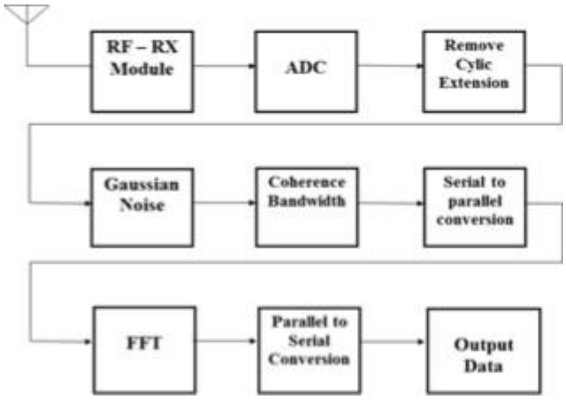

Fig 1.2 Block Diagram of OFDM Receiver

Phase noise is inherently present in oscillators, and its effect is equivalent to a random phase modulation of the carrier. In general, phase noise is present at both the transmitter and the receiver, and has to be described as two multiplicative distortions together with the convolution by the channel impulse response However, for a small phase-noise bandwidth (relative to the subcarrier spacing, i.e., small total phase increment during one OFDM symbol), the resulting effect approximately equals that from the phase-noise process with a total bandwidth that is the sum of both the processes. We, therefore, restrict our discussion to the case with phase noise at the receiver only.

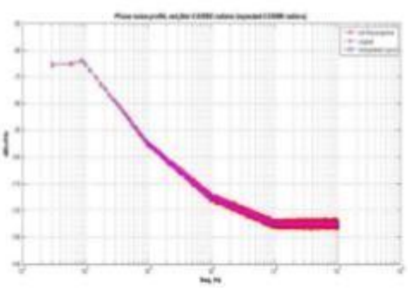

Fig 1.3 Phase noise

1.2 Iq Imbalance

IQ imbalance is the amplitude and phase mismatch of the oscillator signals used for mixing the in-phase and quadrature components of the input signal. These arise due to limitations in the accuracy of the hardware used in the

generation of these signals. Any typical real transmitted signal would have its spectrum centered around the carrier frequency. In the absence of IQ imbalance, at the receiver side, during the conversion from RF to baseband, the spectrum of the transmitted signal is translated to baseband with the spectrum now being symmetric around the origin. However, in the presence of a mismatch, the spectrum above and below the carrier frequency of the transmitted signal overlap with each other after down conversion. In the case of OFDM because of the two overlapping spectra (from the positive and negative side , each subcarrier experiences interference from its symmetric counterpart. The origin of IQ imbalance has to do with image rejection architectures proposed for heterodynereceivers.

Heterodyne receivers are highly prone to image frequencies especially when employing multiple intermediate frequency (IF) stages in the RF chain.

Image rejection architectures basically consist of splitting the input path into an in-phase and quadrature phase paths and in the ideal case of no mismatch, the image signal is removed.

However, most transceivers today are of the direct- conversion type, i.e., no IF stage is employed and direct conversion from RF to baseband is done. For these type of receivers, i.e., no IF stage, the image signal does not arise.

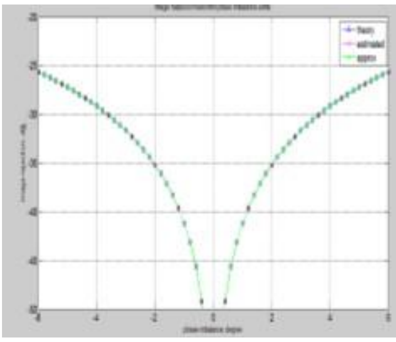

Fig 1.4 IQ Imbalance

In OFDM systems, virtual carriers mean the unmodulated (or zero modulated) subcarriers in the guard band. In a virtual carrier based CFO estimation algorithm is proposed without considering the I/Q imbalance effect[6]. In the following of the section, will examine whether it is feasible to extend this CFO estimation algorithm to the situation with I/Q imbalance in OFDM receivers. The basic idea of the virtual carrier based CFO estimation algorithm is that the total energy in the virtual carrier space should be zero, ignoring the noise component for the moment, if no CFO presents. If there is CFO in the receiver, the total energy in the virtual carrier space will be non-zero due to the ICI introduced by CFO to the virtual carrier space. In the proposed CFO estimation algorithm, to estimate the CFO the received signal should be corrected by an estimated CFO first. Then the energy in the virtual carrier space is calculated. The optimal CFO estimation will be theone resulting in the minimum energy in virtual carrier space. When there are CFO and I/Q imbalance presenting in the OFDM receiver, the CFO in the received signal described cannot be completely corrected simply by complex multiplication.

II. LITERATURE REVIEW

2.1 OFDM Link Performance Analysis Under Various ReceiverImpairments

Krondorf .M and Fettweis.G proposed a methodology about an OFDM analysis in RF impairments

A methodology for OFDM link capacity and bit error rate calculation that jointly captures the aggregate effects of various real life receiver imperfections such as carrier frequency offset, channel estimation error, outdated channel state information due to time selective channel properties and flat receiver I/Q imbalance. The probability density function of the frequency domain received signal subject to the mentioned impairments is derived. Furthermore, this PDF is verified by means of bit error rate calculation. It can be used to exactly evaluate uncoded bit error rates when a- prior knowledge of the mobile channel power delay profile, the image rejection ratio and receiver CFO is used.

2.2 Effects Of Phase Noise On OFDM Systems With And Without PLL Characterization And Compensation

Petrovic.D, Rave.WandFettweis.G represents the phase noise on OFDM systems with and without Phase locked loop systems. It approximates the phase-noise waveform by using a Fourier series approximation for the current phase- noise realization. Thereby, it cancels the effects of the phase noise beyond the standard common phase error correction used in contemporary OFDM standards. The algorithm requires that the correlation properties of the inter carrier interference are known.For estimating the DFT coefficients of the realizations of the segmented phase process ejφ(t) in OFDM transmission. The central idea is the approximation of the phase-noise realization by a DFT series. It can simplify this approximation by using only the lower order coefficients that dominate theseries.

2.3 BER Sensitivity Of OFDM Systems To Carrier Frequency Offset And Wiener PhaseNoise

Pollet.T,Bladel.M.V and Moeneclaey.M proposed the strategy of BER sensitivity to wiener phase noise. The communication between the transmitter and receiver blocks consists of two stages. In the block- type pilot symbols are transmitted and the channel coefficients are jointly estimated with the phase noise in the time domain. In the comb-type OFDM symbols are transmitted such that the receiver can jointly estimate the data symbols and the phase noise.One limitation of OFDM systems is that theyare
highly sensitive to the phase noise introduced by local oscillators.

III. RESULT AND TABULATION

The channel coefficients are randomly drawn from a zero mean complex Gaussian distribution where the variance of nth tap is calculated from the exponentially-decaying power delay profile of the form with the sampling frequency being and to control the correlation coefficient (ϕ) of the subcarrier responses, TX and RX PN sequences, are modelled as mutually independent discrete Wiener processes.

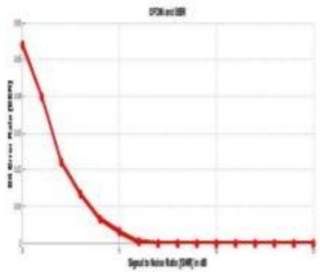

Fig 3.1 System output for signal to noise ratio (SNR) in dB

In fig 3.1, it shows the output for the average mutual information with built-in PN and IQ imbalance parameters, under both uncorrelated and fully correlated responses of the channel for mirror subcarriers. ISINR versus symbol-to- noise ratio (σ2s/σ2w) for indicated phase imbalance values (φTX, φRX) and example subcarrierk=100.

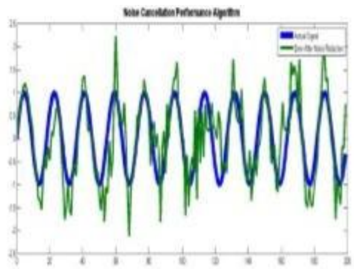

Fig 3.2 IQ Imbalance using noise cancellation algorithm

The simulated results for Phase Noise and IQ Imbalance can be shown in the above Fig 3.2. In this, the actual signal will be generated along with the error. After the noise reduction, the original signal will be generated separately. Evidently, the mutual information saturates despite increasing symbol- to-noise ratio, even for small IQ imbalance and PN values, opposed to the corresponding monotonic increase in the reference case where these RF impairments areabsent.

IV. CONCLUSION

In RF impairments, we reduced the noises such as Phase noise,IQ imbalance in terms of detection error rate .By reducing the noise level,bit error rate and symbol error rate values are also efficiently improved.Here, we found the mutual information analysis of a general OFDM radio link from an arbitrary subcarrier perspective when the transmission is impaired by moderate frequency-selective block fading Rayleigh channel, transceiver (TX and RX) IQ imbalances and phase noise. We have shown that for given channel response and PN realizations, the useful and interference parts of the received signal at arbitrary subcarrier are complex Gaussians and essentially mutually independent of each other. Hence, the well known mutual information law applies for the instantaneous mutualinformationwhich is conditioned on the channel response and PN realizations. The main contribution of this paper is then the derived series representation for the average mutual information with built-in PN and IQ imbalance parameters, under both uncorrelated and fully correlated responses of the channel for mirror subcarriers. We have also shown analytically that the average mutual information under RF impairments is upper bounded by impairment-free mutual information law, and that at large SNR (channel additive noise level approaching zero), the mutual information under RF impairments saturates to a finitevalue.

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