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EFFICIENT CELLULAR TRANSMISSION IN SOFTWARE DEFINED RADIO

G. Savitha and S. Karthikeyan
Faculty of Electronics and Communication Engineering, Sathyabama University, Chennai, India
E-Mail: savipaul@gmail.com

ABSTRACT

In this paper, we focus on efficient cellular transmission in Software Defined Radio (SDR) using Orthogonal Frequency Division Multiplexing (OFDM). SDR is an emerging technology for the radio communication system where some or all the physical layer functions are software defined. In this work, the QAM modulation is enhanced by using Linear Minimum Mean Squared Error (LMMSE) Equalizer. Subsequently, the Inter Carrier Interference (ICI) in the OFDM system leading to frequency offset is overcome by Maximum Ratio Combining (MRC) technique. Then the water filling algorithm is developed to improve the capacity of the SDR-OFDM network.

Keywords: software defined radio (SDR), OFDM, inter carrier interference (ICI), maximum ratio combining (MRC), linear minimum mean square error (LMMSE) equalizer.

1. INTRODUCTION

Software defined radios clubs together a broad realm of intricate radio techniques in a single device. SDR is a platform that solves incompatible wireless network issues by implementing radio functionalities as software modules running on generic hardware objectives. The radio operative incorporates the modulation and coding technique which can be changed without changing the hardware [2]. The main advantage of SDR-OFDM transmission is its robustness to frequency-selective fading characteristics of a mobile radio channel. SDR-OFDM system provides good resistance to frequency selectivity of the channel by dividing the entire spectrum into narrow banded subcarriers for the wideband data transmission.

The gain for the operator is the reconfigurable access network that allows them to dynamically alter the network configuration depending on the actual load situation and eventually, it will allow the exchange of the air interface without need to change the base station hardware. Additionally, if regulation would permit, a small operator could use their reconfigurable equipment to implement short and medium term spectrum sharing with other services [3]. Traditional hardware based radio devices have limitations in cross-functionality and can only be modified physically. This results in greater complex structure, higher production costs and reduced flexibility in supporting multiple waveform standards [1]. By contrast, software defined radio technology furnish a productive and comparatively inexpensive solution to this problem that allows reconfigurable, reliable, multimode and multi-functional wireless devices that can be enhanced using software upgrades.

Recently, Software Defined Radio-Orthogonal frequency division multiplexing (SDR-OFDM) systems have gained rapid significance and attention. SDR-OFDM is used in the European digital broadcast radio system and is being investigated for broadband indoor wireless communications. HIPERLAN2 (High Performance Local Area Network) and IEEE 802.11a standards provide some quality of service (QOS) support and emerges to support IP-based services. Such systems are based on SDR-OFDM and are designed to operate in the 5 GHz band. OFDM is a Frequency-Division multiplexing (FDM) scheme used as digital multi-carrier modulation method. A substantial figure of closely spaced orthogonal subcarrier signals are used to carry data on various parallel data streams or channels. Every single subcarrier is modulated with the mainstream modulation scheme at a low symbol rate, maintaining total data rates homogeneous to conventional single carrier modulation schemes in the same bandwidth. This paper is categorised as follows:

Section 2 characterizes the material and methods used in the system. Section 3 presents the SDR-OFDM Simulink implementation and gives the simulation results of the proposed model. Section 4 finalizes the paper.

2. MATERIALS AND METHODS USED IN SDR-OFDM

In the proposed SDR-OFDM system, the we observe the performance of techniques used in the system by generating random input to the OFDM transmitter through MATLAB. The proposed system has three modules of execution as follows:

a) Enhancing the performance of the QAM modulation by using LMMSE equalizer
b) Then the Inter Carrier Interference (ICI) caused by the frequency offset is detected and corrected by using Maximum Ratio Combining (MRC) technique.
c) Finally, Water Filling Algorithm is employed for the power allocation and capacity maximization

The block diagram of the proposed system is given below:

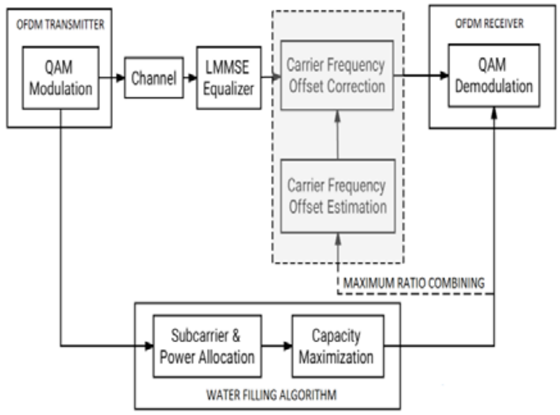

Figure-1.

2.1 Enhanced QAM using LMSSE equalizer

Digital modulation of individual carriers is customarily performed using BPSK, QPSK or QAM. The QPSK-SDR and 16QAM-SDR systems are operated on transmission paths characterized by severe disturbances such as those found in mobile communications where automobiles and other objects have their impact. The QAM modulation technique has the better performance than BPSK and QPSK. The performance of QAM can be further enhanced by using LMMSE equaliser.

The LMMSE equalizer performs channel estimation and avoids the channel distortion caused due to the noise and the multipath propagation. Channel estimation concepts comprise of duplet steps, one or both of which use the correlation of the channel. Initially, the attenuations at the pilot positions are evaluated and conceivably smoothed using the channel correlation. These measurements then serve to estimate (interpolate) the complex-valued attenuations of the data symbols in the second step. This second step uses the channel correlation properties either with FIR filters or with a decision-directed scheme [15].

First a matrix formulation is adopted and the channel attenuations of one SDR-OFDM symbol (the Fourier transform of h(t) evaluated at the frequencies f_k in the vector h) are collected. The observed symbols after the receiver FFT become

$$Y=Xh + n \tag{1}$$

where, the diagonal matrix X contains the transmitted symbols on its diagonal (either known pilot symbols or receiver decisions of information symbols), and the vector Y contains the observed outputs. In this matrix notation the least-squares (LS) channel estimate (minimizing for $||Y\text{-}X\hat{h}||^2$all possible $\hat{h}$) becomes

$$\hat{h}_{LS=X}{}^{-1}Y \tag{2}$$

This estimator simply divides the received symbol on each subcarrier by the transmitted symbol to obtain an estimate of the channel attenuation.

The frequency correlation can now be used to smooth and improve the LS channel estimate. Various strategies can be adopted to use the frequency correlation. The optimal linear minimum mean-squared error (LMMSE) estimate of h (minimizing $E\{||\hat{h}\text{-}h||^2\}$ for all possible linear estimators $\hat{h}$) becomes

$$\hat{h}_{MMSE\,=}\,A\hat{h}_{LS} \tag{3}$$

$$\text{where } A = R_{hh}(R_{hh}+\sigma^2(XX^H)^{-1})^{-1} \tag{4}$$

and

$R_{hh\,=}\,E(hh^H)$ is the channel autocorrelation

matrix, that is, the matrix is the subcarriers that includes correlations of the channel attenuations. The LMMSE estimator (or any other high-performance and complex estimator) can be used as a basis for the design of more feasible estimators. In generic low-complexity approximations are developed. Their performances can be made very close to that of the optimal LMMSE estimator. They are generic in the sense that they use assumed (fixed) channel correlation and SNR for the design of A. The LMMSE estimator is low-complexity and requires significantly fewer than N multiplications per estimated attenuation.

2.2 ICI elimination using MRC algorithm

A familiar complication of such a multi-carrier modulation technique is its vulnerability to frequency-offset errors triggered by oscillator inaccuracies and the Doppler shift. In such situations, the orthogonality of the carriers is no longer maintained and it results in inter carrier interference (ICI). Depending on the Doppler spread in the channel and the block length opted for transmission, ICI can influence a severe deterioration of QOS in SDR-OFDM systems.

The effect of ICI in SDR-OFDM systems can be observed as statistically estimating the frequency offset and cancelling this offset at the receiver. In this technique, a stream of *N* symbols are replicated such that the duplicate symbols are *N* positions apart. These symbols are then modulated using a 2*N*-point inverse Fast Fourier transforms (IFFT). Using a N-point Fast Fourier transform (FFT) the first set of *N* symbols are demodulated at the receiver, to yield the sequence Y_{1k}, and the second set is demodulated with another N-point FFT to yield the sequence Y_{2k}[16]. The frequency offset is the phase difference between Y_{1k} and Y_{2k}, that is, $Y_{2k} = Y_{1k}e^{j2\pi\varepsilon}$.

The MRC estimate of the normalized frequency offset is given by

$$\hat{\varepsilon}=(1/2\pi)\tan^{-1}\{(\sum_{k=-K}^{K}\mathrm{Im}[Y_{2k}Y_{1k}^{*}])/(\sum_{k=-K}^{K}\mathrm{Re}[Y_{2k}Y_{1k}^{*}])\} \tag{5}$$

This MRC estimate is a conditionally indifferent estimate of the frequency offset and will be computed by the received data. Once the frequency offset is known, the

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ICI distortion in the data symbols can be minimized by multiplying received symbols with a complex conjugate of the frequency shift. A mean squared error (MSE) metric is calculated between the estimated offset and the actual offset for different values of the frequency offset to test the accuracy of the estimate. Through an algorithmic iteration procedure, an estimate of the frequency offset can be obtained. It is observed that the SDR-OFDM technique offers fast convergence. The ICI distortion in the data symbols can be lessened by multiplying the received signal with a complex conjugate of the estimated frequency offset.

2.3 Water filling algorithm for the capacity improvement

2.3.1 Power allocation

The process of water filling algorithm is similar to streaming the water in the vessel. As water finds its level when filled in one part of a vessel with multiple openings, the receivers amplify each channel up to the required power level compensating for the channel impairments. The total amount of water filled (power allocated) is proportional to the carrier to noise ratio (CNR) of channel. Power allocated by individual channel is given by Equation (6),

$$P_i = \frac{Pt + \sum \frac{1}{Hi}}{\sum channel}(1/-Hi) \qquad (6)$$

Where, Pt is the allocated power budget of MIMO system among the different channels and H is the channel matrix of system [7], [11].

2.3.2 Capacity maximization

The algebraic sum of the capacities of all channels is the capacity of a MIMO and given by the formula below [7], [11].

$$\text{Capacity} = \Sigma \log_2 (1 + PowerAllocated * H) ni \qquad (7)$$

The total number of bits to be transported is to be increased. As per the scheme the ensuing steps are implemented in the water filling algorithm:

a) Avail the inverse of the channel gain.
b) Owing to the inverse of the channel gain water filling has non-uniform step structure.
c) Initially take the sum of the total power Pt and the reverse of the channel gain. It gives the complete region in the water filling process and inverse power gain.
d) Mark the initial water level by taking the average power allocated.
e) The power values of individual sub channel are quantified by subtracting the inverse channel gain.

3. RESULTS AND DISCUSSIONS

3.1 SDR-OFDM implementation in simulink

The IF and baseband sections of the transceiver have been designed and simulated using the MATLAB SIMULINK blocks, to facilitate the analysis of the proposed model's performance under channel noise is viewed in Figure-2. In the first step, the transmitter part consists of 16-QAM modulation and up-sampling. The receiver part comprises of down-sampling and 16-QAM demodulation, which have been designed and simulated.

Generally, up sampling or interpolation is useful to modify the effective speed of an existing sampled signal. By performing interpolation, the sample rate of a signal is increased. Conceptually, interpolation comprises the generation of a continuous varying curve passing through previous samples, followed by sampling the curve to obtain the interpolation sequence at the new sample rate.

The eye diagram and the scatter plot are observed for the aimed system, the 16-QAM baseband signal is up-sampled by a factor of 16 to produce a new sample rate. The eye diagram is comprehensible and appropriate tools for studying the effects of inter symbol interference (ISI) and the alternate channel deteriorations in the digital transmission [17]. When this block set constructs an eye diagram, the received signal is devised against time on a fixed interval axis. At the end of the fixed interval, it encloses around to the beginning of the time axis. Thus the diagram consists of many imbricating curves. One way to use an eye diagram is to track down the place where the "eye" is most widely opened or spread out, and use that point as the decision point when demapping the demodulated signal to recover a digital message. A scatter plot of a signal plots the signal's value at its determined points. In the best case, the decision points should be at times when the signal's eye diagram is widely exposed [18].

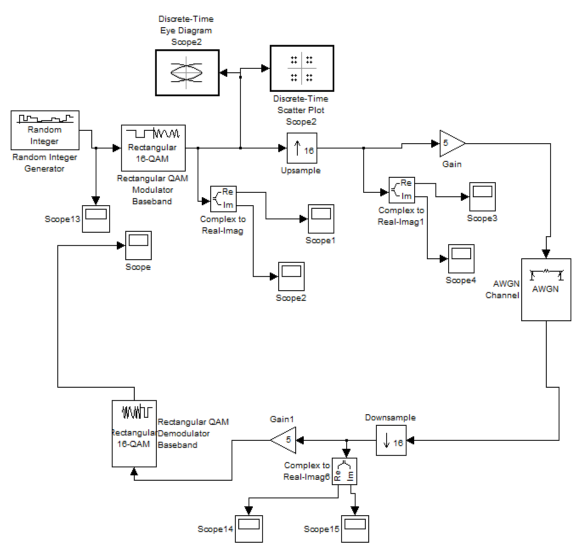

Figure-2. SDR-OFDM Simulink diagram.

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3.2 Simulation results

The SNR vs BER comparison output reveals the performance of three modulation techniques. Figure-3 shows that QAM is better than QPSK. But QAM and BPSK are seen to have the same performance. QAM is preferred to BPSK for the better performance because it is more bandwidth efficient and has high data rate than that of BPSK.

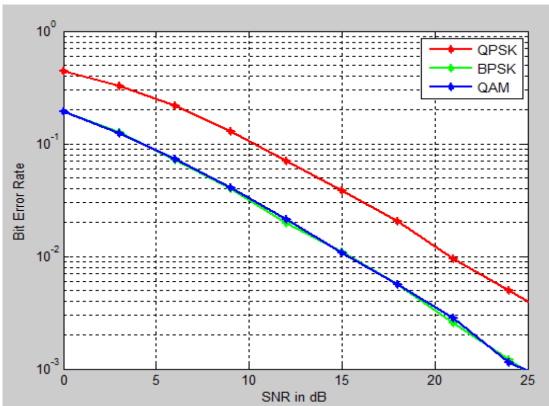

Figure-3. Comparison of modulation techniques.

Further, the performance of QAM modulation technique can be enhanced by using LMMSE Equalizer.

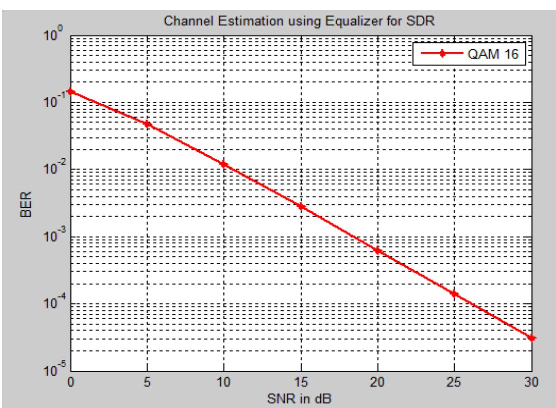

Figure-4. Enhanced SNR vs BER QAM performance using LMMSE Equalizer.

By using Maximum Ratio Combining (MRC) technique, the errors that occur due to the Inter Carrier Interference (ICI) are detected and minimised. The graph (Figure-5) demonstrates that the MSE is reduced exponentially along with the increase in the SNR. Then Figure-6 depicts a linear increase of the SNR gain with the transmission rate of the system.

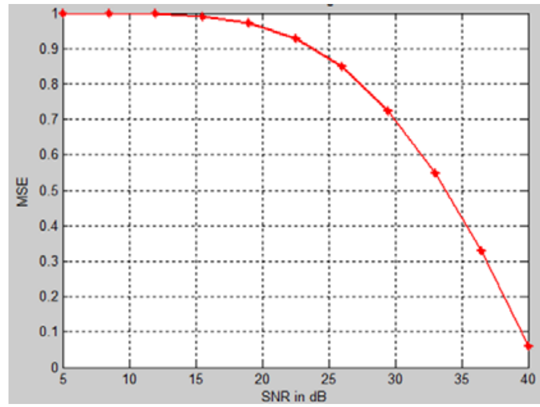

Figure-5. ICI reduction using MRC.

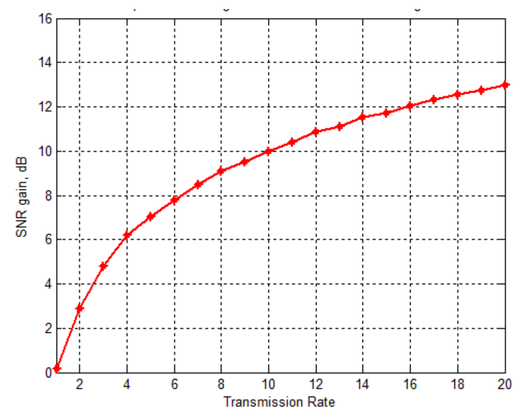

Figure-6. SNR gain improvement using MRC technique.

Water filling algorithm performs power allocation for each sub channel depending on the inverse of carrier to noise ratio. The amount of power allocated to each sub channel can be displayed in Figure-7 given below. Then the performance on capacity is done for different channels like Rician, Rayleigh and AWGN. Figure-8 shows that AWGN has the better capacity performance than the other channels.

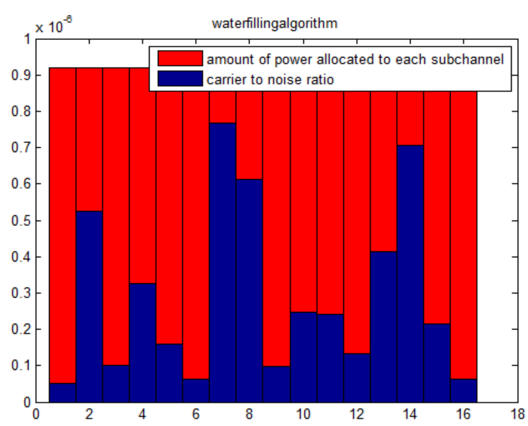

Figure-7. Power Allocation to each sub-channel.

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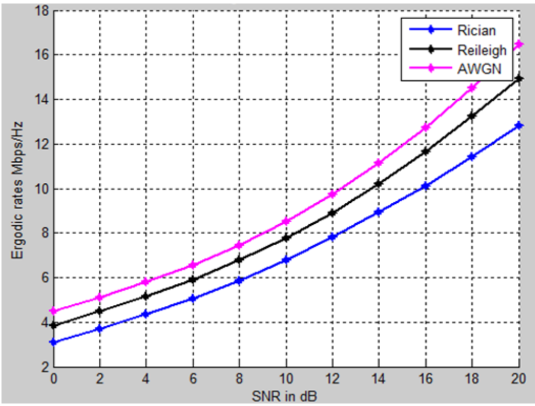

Figure-8. SNR vs Capacity performance using water filling algorithm.

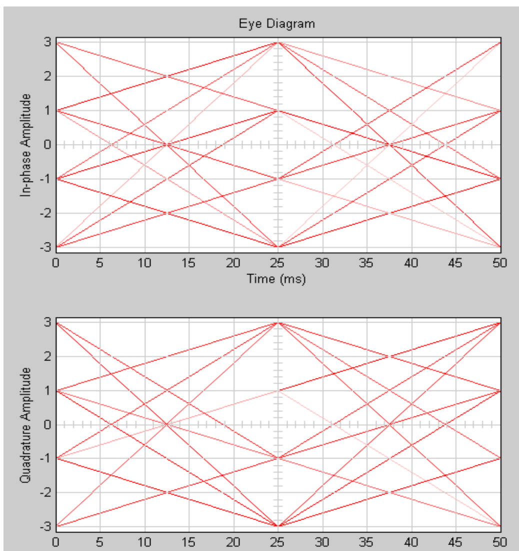

Figure-9. Eye diagram of the SDR-OFDM Simulink model.

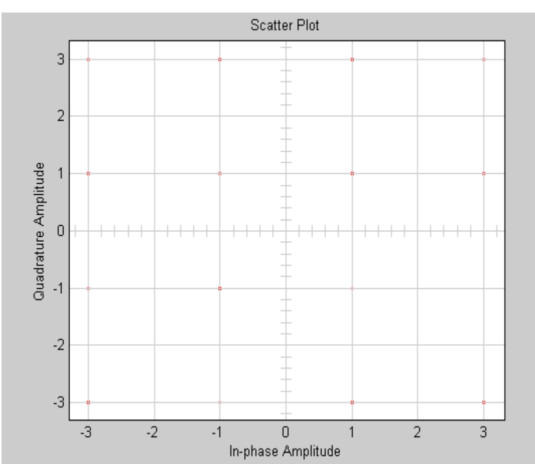

Figure-10. Scatter plot of the Simulink model.

4. CONCLUSIONS

This paper has sought to show that the main drawback of SDR-OFDM can be overcome by using MRC technique and by water filling algorithm that substantiates the capacity maximisation. LMMSE equaliser has been utilized to enhance the performance of QAM modulation in the SDR-OFDM system and it provides efficient cellular transmission. Software Defined Radio (SDR) system is a useful and adaptable future proof solution to cover both the existing and the emerging standards. SDR has given promising solution to multifunctional wireless communication devices in a single platform. The better returns on the investment can provide beneficial wireless communication systems for the next generation.

REFERENCES

[1] http://www.sdrforum.org/pages/documentLibrary/documents/SDRF-06-R-0011-V1_0_0].

[2] http://www.internationaljournalssrg.org.

[3] Evaluation of SDR Technology atstaholders.ofcom.org.uk>eval.pdf.

[4] Hen GeulYeh, Paul Ingerson. 2010. Software defined radio for OFDM transceivers. IEEE. 5(7).

[5] Mohammed AboudKadhim, Widad Ismail. 2010. Implementation of Wimax IEEE802.16d Baseband Transceiver Based Wavelet OFDM on Multi-Core Software-Defined Radio Platform. European Journal of Scientific Research.

[6] Abirami M, Gandhiraj R. 2013. Performance Analysis of Real Time OFDM Based Communication System Using GNU Radio and USRP. International Journal of Advanced Research in Computer Science and Software Engineering. 3(6).

[7] http://www.ijettjournal.org.

[8] Pedro and Nuno, “Multi-Mode Receiver for Software Defined Radio”, Institute of Telecommunication – University of Aveiro – Portugal, online available: http://www.anacom.pt/render.jsp?contentId=761239, 2008.

[9] Software defined radio, www.wikipedia.com.

[10] http://www.sdrforum.org/- Dec 2005.

[11] HemangiDeshmukh, Harsh Goud Capacity analusis of MIMO OFDM at ijarcet.org>wp-content>uplpads.

[12] Lee B W, Cho S H. 2005. An implementation of the SDR baseband platform for OFDM communication

VOL. 11, NO. 21, NOVEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

system. SDR technical conference, Orange County, California, USA.

[13] J. Mitola, III. 1999. Software radio architecture: A mathematical perspective. IEEE J. Select. Areas Commun. 17(4): 514-538.

[14] B. Kelley. 2009. Software Defined Radio for Broadband OFDM Protocols. Proc. IEEE Intern. Conf. Systems, Man, Cybernetics, San Antoniou, TX. pp. 2309-2314.

[15] Muhammad Islam, M. A. Hannan, S. A. Samad, A. Hussain. Modulation Technique for Software Defined Radio Application. 3rd WSEAS Int. Conf. on Circuits, Systems, Signal and Telecommunications (CISST'09). ISSN: 1790-5117.

[16] Vivek K. Dwivedi and G. Singh. 2008. An Efficient BER Analysis of OFDM Systems with ICI Cancellation Method, PIERS Proceedings, Cambridge, USA.

[17] www.rohan.sdsu.edu.

[18] https://books.google.co.in>books.

[19] www.radio-electronics.com.

[20] Software defined radio using MATLAB & Simulink-MathWorks in www.mathworks.com.

[21] www.desktopsdr.com.