

PERFORMANCE ANALYSIS OF POWER ALLOCATION TECHNIQUES IN FM-OFDM SYSTEMS UNDER FREQUENCY-DEPENDENT NOISE

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Abstract

Unlike conventional OFDM, FM-OFDM provides enhanced resilience against non-linear distortions, making it a better choice for high-power transmission environments[6][7][19]. Although the presence of frequency-dependent noise across subcarriers introduces challenges in maintaining steady performance [20]. This paper presents a comparative analysis of different power allocation techniques, including Equal Power Allocation, Emphasis Filter Equivalent (EFE), and Modified Waterfilling (MWF), in FM-OFDM systems . The system performance is analyzed in terms of BER and bandwidth efficiency against fluctuating SNR [6]. Simulation results demonstrate that each method exhibits distinct advantages depending on the operating region, highlighting the need for adaptive strategies in practical systems [18][20].

I. INTRODUCTION

The evolution of wireless communication systems has led to the adoption of multicarrier modulation techniques capable of supporting high data rates and reliable transmission [6][7]. Orthogonal Frequency Division Multiplexing (OFDM) has been widely used due to its robustness against multipath fading and efficient utilization of bandwidth[2] [3][4]. However, a major drawback of OFDM is its high Peak-to-Average Power Ratio (PAPR), which reduces power efficiency and complicates transmitter design [5]. Several resource allocation methods have been proposed in literature [9]-[14][17][18], but they do not adapt to dynamic channel conditions.

To address this issue, Frequency-Modulated OFDM (FM-OFDM) has been proposed as a modified waveform that offers constant envelope transmission [19]. This characteristic improves performance in systems affected by nonlinear amplification and high mobility. Despite these advantages, FM-OFDM introduces a unique challenge in the form of frequency-dependent noise, where the noise power varies across subcarriers [20].

This variation necessitates the use of efficient power allocation techniques to optimize system performance. Several approaches have been proposed in the literature, including Equal Power Allocation, Emphasis Filter Equivalent (EFE), and Modified Waterfilling (MWF) [20]. Each of these methods aims to improve performance under specific conditions; however, their effectiveness varies depending on the operating SNR.

This paper presents a detailed comparative analysis of these power allocation techniques to evaluate their performance under different channel conditions and identify their strengths and limitations.

Keywords:- OFDM, FM-OFDM, Emphasis Filter Equivalent, Modified Waterfilling ,Equal Power Allocation, SNR,BER, Peak-to-Average Power Ratio

II. SYSTEM MODEL

Consider an FM-OFDM system with N_{total} subcarriers, of which N_s are actively used for data transmission. The input data symbols are modulated using QPSK [5][7] and processed through FM modulation [19] before transmission over the channel.



Fig. 1.

Block diagram of FM-OFDM system with adaptive power allocation.

At the receiver, after demodulation and signal processing, the received signal for the k^{th} subcarrier can be expressed as:

$$Y[k] = \sqrt{p[k]}X[k] + n[k]$$

where:

$X[k]$ represents the transmitted symbol

$p[k]$ is the power allocated to the subcarrier

$n[k]$ is the noise component

In FM-OFDM systems, the noise is not uniformly distributed and depends on the subcarrier index as 20:

$$N[k] \propto (1 - \cos(2\pi k/N))$$

This results in varying SNR across subcarriers, given by:

$$\gamma[k] = \frac{C \cdot p[k]}{1 - \cos(2\pi k/N)}$$

III. POWER ALLOCATION TECHNIQUES

1) Equal Power Allocation

In this method, the available transmit power is distributed uniformly across all subcarriers [9][13]. Although simple to implement, this approach does not efficiently utilize system resources in the presence of frequency-dependent noise.

2) Emphasis Filter Equivalent (EFE)

The EFE technique allocates power in accordance with the noise distribution across subcarriers [20]. Subcarriers affected by higher noise levels are assigned more power to compensate for degradation. This leads to a more uniform SNR profile, which improves error performance, particularly at higher SNR levels.

3) Modified Waterfilling (MWF)

The MWF approach is designed to maximize spectral efficiency by allocating more power to subcarriers with favorable conditions [1][6][10][14][20]. It reduces or eliminates power allocation to subcarriers with poor channel quality, thereby improving overall data rate performance. However, this approach may not always minimize error rates, especially at high SNR.

IV. SIMULATION RESULTS AND ANALYSIS

The performance of the above techniques is evaluated through simulations conducted in MATLAB under AWGN and Rayleigh fading channels. The system parameters include:

Number of subcarriers: 128

Active subcarriers: 64

Modulation scheme: QPSK 5

Channel models: AWGN and Rayleigh fading 8

SNR range: 0 dB to 20 dB

1) BER Performance

The BER performance of the three techniques is analyzed across different SNR values. At low SNR, MWF performs better by avoiding inefficient subcarriers [17][18][20].

At moderate SNR, MWF maintains good performance due to efficient power utilization.

At high SNR, EFE provides improved performance by equalizing SNR across subcarriers [20].

Equal Power Allocation shows comparatively poorer performance across all SNR levels. Adaptive method gives the lowest BER across all SNR values.

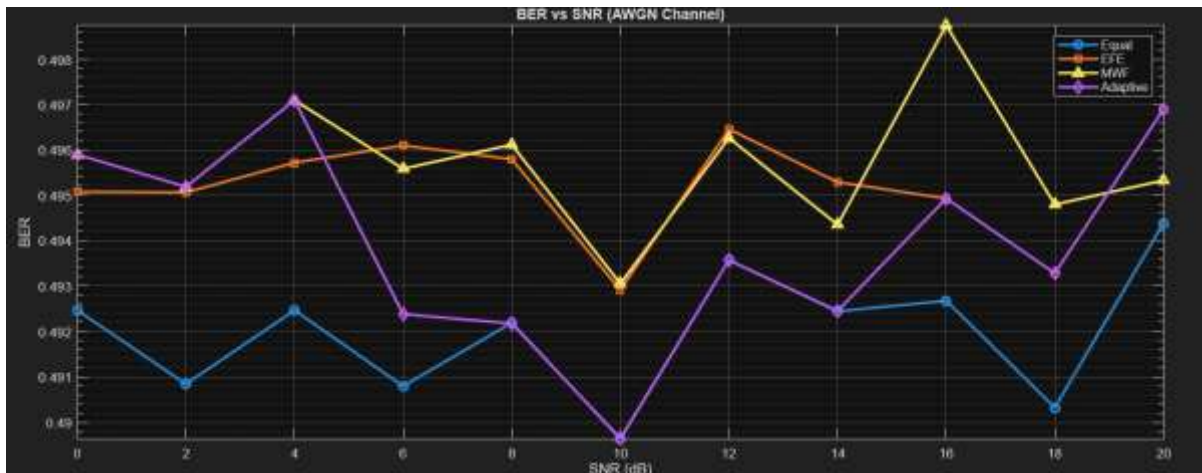


Fig. 2. BER vs SNR (AWGN Channel)

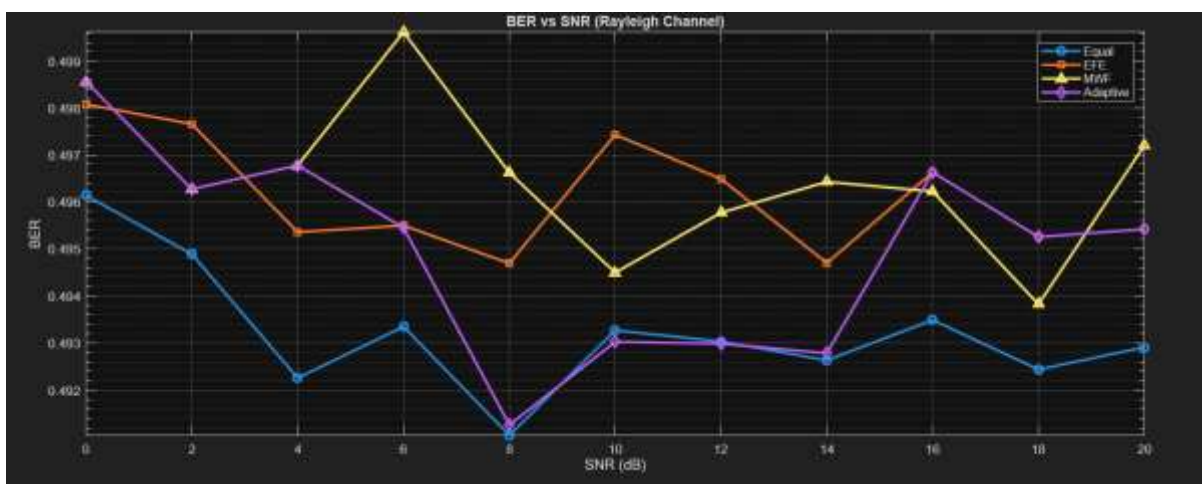


Fig. 3. BER vs SNR (RayleighChannel)

2) Spectral Efficiency

The spectral efficiency results indicate that MWF achieves the highest data rates due to its optimization strategy [1]. EFE provides moderate performance, while Equal Power Allocation remains the least efficient. Adaptive achieves near-optimal spectral efficiency (close to MWF)

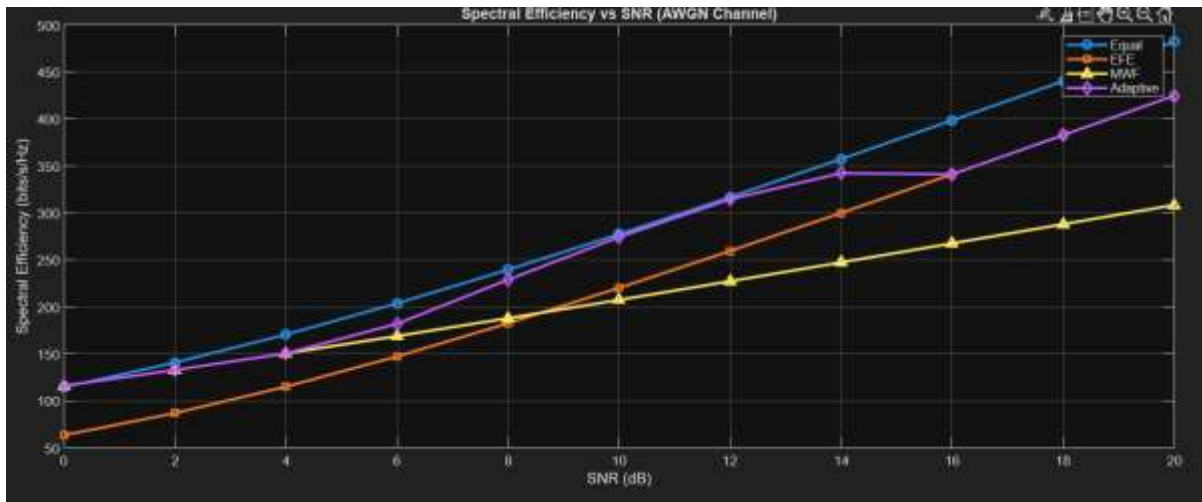


Fig. 5. Spectral Efficiency vs SNR (AWGN Channel)

3) SNR Distribution Analysis

The distribution of SNR across subcarriers highlights the behavior of each technique [20]:

Equal allocation results in uneven SNR distribution. EFE produces a nearly uniform SNR profile. MWF results in selective enhancement of specific subcarriers. Adaptive produces a balanced SNR distribution

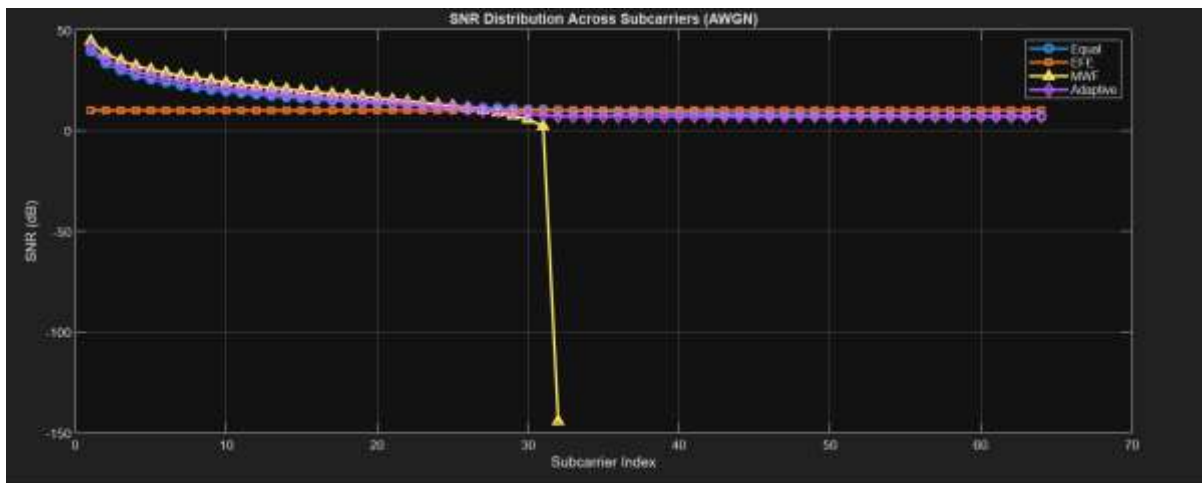


Fig. SNR Distribution Across subcarriers (AWGN Channel)

V. DISCUSSION

The analysis reveals that each power allocation technique has its own strengths and limitations. EFE is more suitable for minimizing error rates, particularly at high SNR, while MWF is effective in maximizing spectral efficiency at moderate SNR levels [20]. Equal Power Allocation, although simple, does not provide optimal performance in FM-OFDM systems with frequency-dependent noise.

The absence of a single optimal technique across all conditions indicates the importance of adaptive methods for practical implementation [6].

VI.CONCLUSION

This paper presented a comparative analysis of power allocation techniques in FM-OFDM systems [19][20]. The study demonstrated that the performance of each method varies with SNR conditions and system requirements. While EFE and MWF offer improvements over Equal Power Allocation, their static nature limits their effectiveness across all scenarios [18][20]. The findings highlight the need for adaptive approaches to achieve optimal performance in dynamic wireless environments [6][7].

References

- [1] C. E. Shannon, "Communication in the presence of noise," Proceedings of the IRE, vol. 37, no. 1, pp. 10–21, Jan. 1949.
- [2] R. W. Chang, "Synthesis of band-limited orthogonal signals for multichannel data transmission," Bell System Technical Journal, vol. 45, no. 10, pp. 1775–1796, Dec. 1966.
- [3] S. B. Weinstein and P. M. Ebert, "Data transmission by frequency-division multiplexing using the discrete Fourier transform," IEEE Transactions on Communication Technology, vol. 19, no. 5, pp. 628–634, Oct. 1971.
- [4] L. J. Cimini Jr., "Analysis and simulation of a digital mobile channel using orthogonal frequency division multiplexing," IEEE Transactions on Communications, vol. 33, no. 7, pp. 665–675, July 1985.
- [5] J. G. Proakis and M. Salehi, Digital Communications, 5th ed. New York, USA: McGraw-Hill, 2008.
- [6] D. Tse and P. Viswanath, Fundamentals of Wireless Communication. Cambridge, U.K.: Cambridge University Press, 2005.
- [7] S. Haykin, Communication Systems, 5th ed. New York, USA: Wiley, 2009.
- [8] Z. Wang and G. B. Giannakis, "A simple and general parameterization quantifying performance in fading channels," IEEE Transactions on Communications, vol. 51, no. 8, pp. 1389–1398, Aug. 2003.
- [9] L. Vandendorpe, J. Louveaux, O. Oguz, and A. Zaidi, "Rate-optimized power allocation for DF-relayed OFDM transmission under sum and individual power constraints," EURASIP Journal on Wireless Communications and Networking, vol. 2009, Article ID 814278, 2009.
- [10] M. Tao, Y.-C. Liang, and F. Zhang, "Resource allocation for delay differentiated traffic in multiuser OFDM systems," IEEE Transactions on Wireless Communications, vol. 7, no. 6, pp. 2190–2201, June 2008.
- [11] X. He, Y. Wu, and T. Ng, "Power allocation for wireless relay networks with multiple antennas," IEEE Transactions on Wireless Communications, vol. 10, no. 9, pp. 2983–2993, Sept. 2011.
- [12] D. Gacanin and F. Adachi, "Broadband analog and digital signal transmission over fading channels using MMSE-FDE," EURASIP Journal on Wireless Communications and Networking, 2011. [13] V.

Gunaseelan, K. P. Soman, and S. K. Mitra, "Efficient resource allocation algorithm for multiuser OFDM systems," Journal of the Institution of Engineers (India), 2008.

[14] G. Song and Y. Li, "Cross-layer optimization for OFDM wireless networks—Part I: Theoretical framework," IEEE Transactions on Wireless Communications, vol. 4, no. 2, pp. 614–624, March 2005.

[15] M. Dalela and Parul, "MIMO-OFDM: A review," International Journal of Engineering Research & Technology (IJERT), vol. 2, no. 10, 2013. [16] S. Du and F. R. Yu, "Joint power allocation in MIMO-OFDM systems with energy harvesting," SpringerPlus, vol. 5, no. 1, 2016.

[17] M. Bayam, A. J. Al-Dweik, and M. M. Al-Jarrah, "Power allocation for OFDM-based relay systems," Procedia Computer Science, vol. 94, pp. 371–378, 2016.

[18] Y. Gu, "A review of power allocation algorithms in OFDM systems," Highlights in Science, Engineering and Technology, 2023.

[19] J. Lorca and A. García Armada, "Frequency-modulated OFDM: A new waveform for high-mobility wireless communications," IEEE Transactions on Communications, 2023.

[20] K. Son, H. Kim, and Y. H. Lee, "Power allocation for frequency-modulated OFDM wireless systems," IEEE Communications Letters, 2023.