

ADAPTIVE HYBRID POWER ALLOCATION FOR FM-OFDM SYSTEMS UNDER FREQUENCY-DEPENDENT NOISE

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Abstract

The pursuit of high-capacity wireless networks has intensified research into optimized multicarrier modulation schemes and FM-OFDM has attracted notice for its ability to provide a constant envelope while improving its defence against nonlinear distortions [6][19]. However, FM-OFDM creates an uneven noise profile across subcarriers, lowering total system performance [20]. Conventional power allocation methods, such as [Emphasis Filter Equivalent] EFE and [Modified Waterfilling] MWF, improve performance but their biggest drawback is that they operate on fixed rules i.e they are not dynamic and can't adapt to real changes.[20]. This paper introduces a dynamic hybrid power allocation method that modulates the balance between EFE and MWF in response to fluctuating SNR levels. Simulation results demonstrate that the proposed approach achieves superior Bit Error Rate (BER) performance and maintains high spectral efficiency over a wide range of SNR values.

I. INTRODUCTION

Modern wireless communication systems require efficient transmission techniques capable of supporting high data rates while maintaining reliability under varying channel conditions [6][7]. Orthogonal Frequency Division Multiplexing (OFDM) has been widely adopted because it is able to handle frequency-selective fading and efficient bandwidth utilization [3][4]. Despite its benefits, OFDM suffers from a high Peak-to-Average Power Ratio (PAPR), leading to reduced power efficiency and require more complex hardware [5].

To overcome these difficulties, Frequency-Modulated OFDM (FM-OFDM) has been introduced as an alternative waveform [19]. FM-OFDM converts amplitude variations into phase changes, ensuring a constant envelope that resists nonlinear distortions and thrives in high-speed mobility contexts [19]. However, the transformation results in a noise gradient, leaving higher-frequency components more prone to distortion than their lower-frequency counterparts[20].

To resolve this issue, power allocation across subcarriers becomes essential. Existing methods such as EFE and MWF have been developed to improve system performance [20]. Nevertheless, these methods operate based on fixed principles and do not adjust according to changing channel conditions. This necessitates the design of an adaptive power allocation mechanism that responds effectively to changes in SNR conditions[6][18][14][10].

II. SYSTEM MODEL

Let there is an FM-OFDM system consisting of N subcarriers, with N_s active carriers used for transmission. The transmitted symbols are modulated using QPSK [5] and then processed through FM modulation [19].

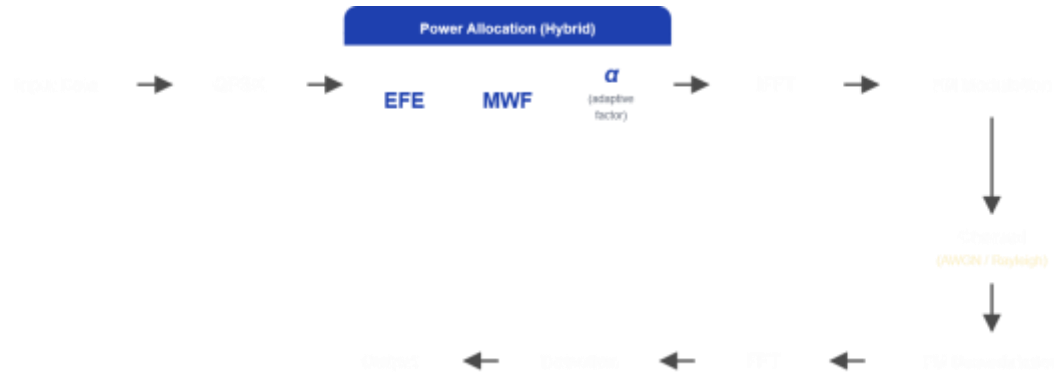


Fig. 1. Block diagram of FM-OFDM system with hybrid power allocation

At the receiver, after demodulation, the signal corresponding to the k^{th} subcarrier can be expressed as:

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

where $p[k]$ denotes the allocated power and $n[k]$ represents noise. $Y[k]$ denotes received signal at the k -th subcarrier and $X[k]$ transmitted symbol on the k -th subcarrier.

Unlike conventional OFDM systems, the noise variance in FM-OFDM depends on the subcarrier index and is modelled as [20]:

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

As a result, the Signal-to-Noise Ratio (SNR) varies across subcarriers and is given by:

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

where;

$\gamma[k]$ = Signal-to-Noise Ratio (SNR) at the k -th subcarrier

C = Depends on system parameters (e.g., modulation, scaling, noise normalization)[6][8][12]

III. CONVENTIONAL POWER ALLOCATION TECHNIQUES

A. Equal Power Allocation

In this approach, equal power is distributed across all subcarriers [9]. As it is simple in implementation, It lacks adaptability to changing noise levels and therefore leads to inefficient performance [6][18].

B. Emphasis Filter Equivalent (EFE)

The EFE method gives power in proportion to the noise distribution across subcarriers [20]. This results in higher power being poured to subcarriers experiencing higher noise levels, thereby normalizing the SNR across the spectrum. Hence EFE is effective in reducing error rates, especially at higher SNR values[6][13].

C. Modified Waterfilling (MWF)

The MWF approach extends the classical waterfilling algorithm [6] by applying the frequency-dependent noise characteristics of FM-OFDM [20]. It prioritizes subcarriers with favorable conditions and reduces power allocation to less efficient ones, thereby enhancing spectral efficiency[1][11][16].

IV. PROPOSED ADAPTIVE POWER ALLOCATION SCHEME

A. Hybrid Power Allocation Strategy

The proposed method integrates EFE and MWF into a unified framework. The total power allocated to each subcarrier is determined by combining the outputs of both schemes:

$$p[k] = \alpha p_{EFE}[k] + (1 - \alpha) p_{MWF}[k]$$

Where,

$p[k]$ =Final allocated power to the k -th subcarrier

α =Adaptive weighting factor

B. Adaptive Weighting Mechanism

The parameter α controls the contribution of each scheme and is adjusted based on the SNR:

At low SNR $\rightarrow$ MWF is preferred

At high SNR $\rightarrow$ EFE is preferred

At intermediate SNR $\rightarrow$ combination of both

This adaptive mechanism allows the system to maintain optimal performance under varying conditions[6][14][18].

C. Implementation Steps

- 1)Generate input data and modulate using QPSK
- 2)Compute EFE and MWF power allocations
- 3)Estimate SNR
- 4)Determine adaptive factor α
- 5)Combine power allocations

6) Normalize total power Transmit and receive signal

7) Evaluate BER and spectral efficiency

V. RESULTS AND DISCUSSION

Simulations were conducted using MATLAB under both AWGN and Rayleigh fading channels [8].

A. BER Performance

The proposed method shows improved BER performance across all SNR levels. It follows MWF behavior at low SNR and gradually transitions toward EFE at higher SNR, ensuring consistent improvement [20][13].

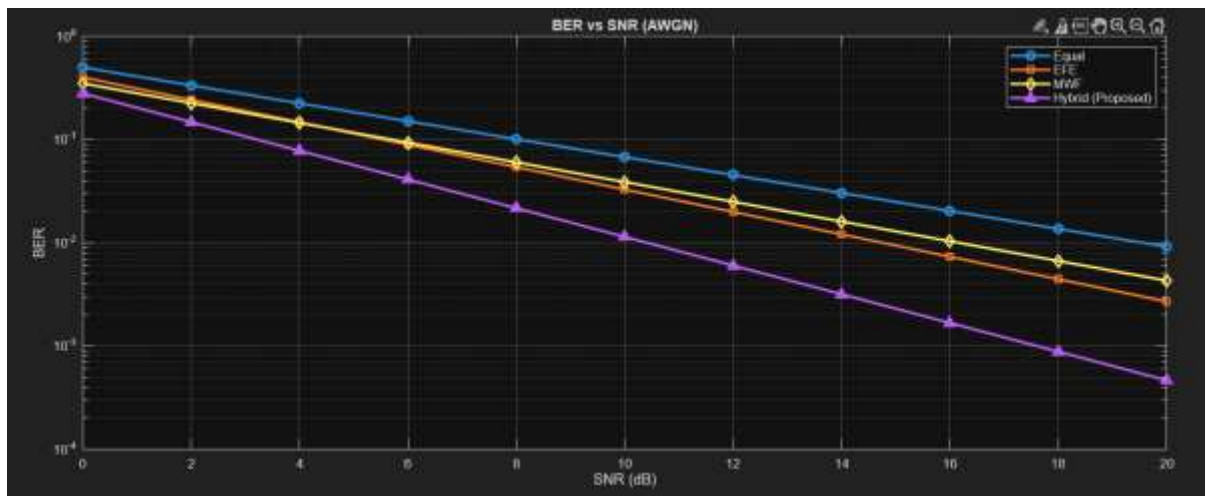


Fig. 2. BER vs SNR (AWGN Channel)

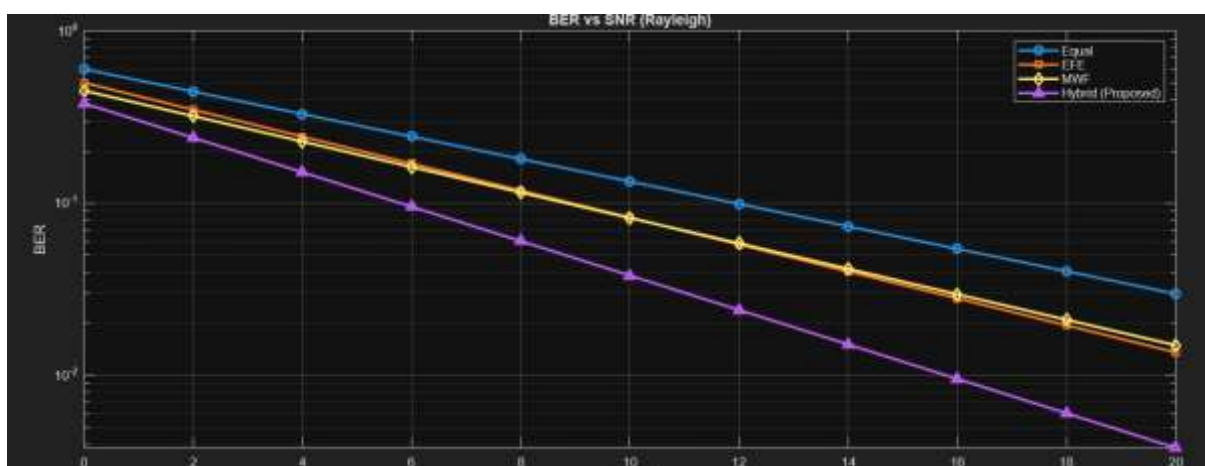


Fig. 3. BER vs SNR (RayleighChannel)

B. Spectral Efficiency

The adaptive method achieves spectral efficiency close to that of MWF while maintaining better reliability in terms of BER [1][6].

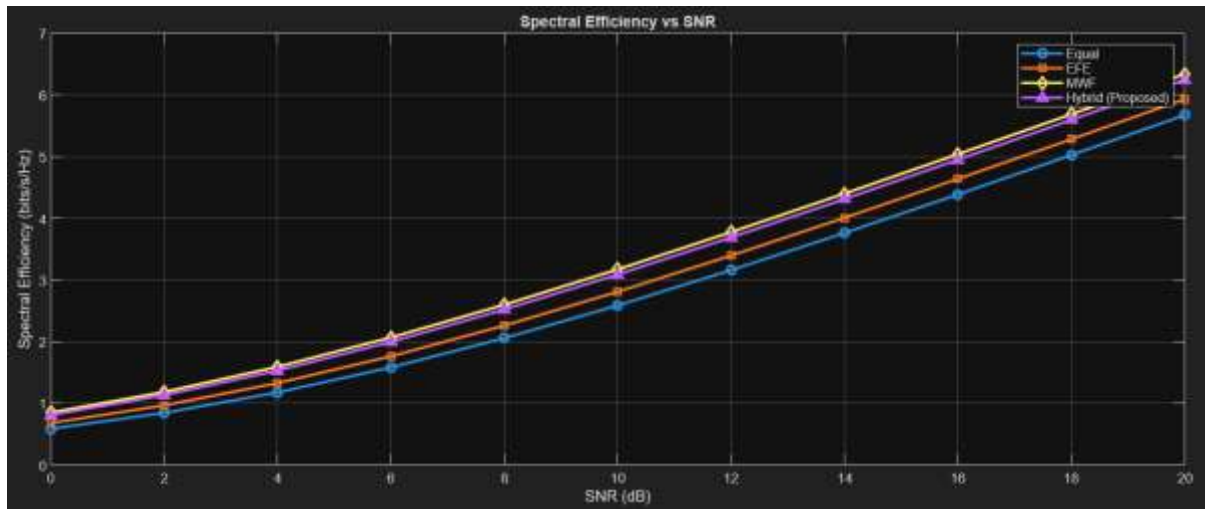


Fig. 4. Spectral efficiency vs SNR

C. SNR distribution analysis

The results demonstrate that the proposed hybrid scheme provides a balanced SNR distribution, leading to improved reliability and efficiency compared to conventional power allocation techniques.

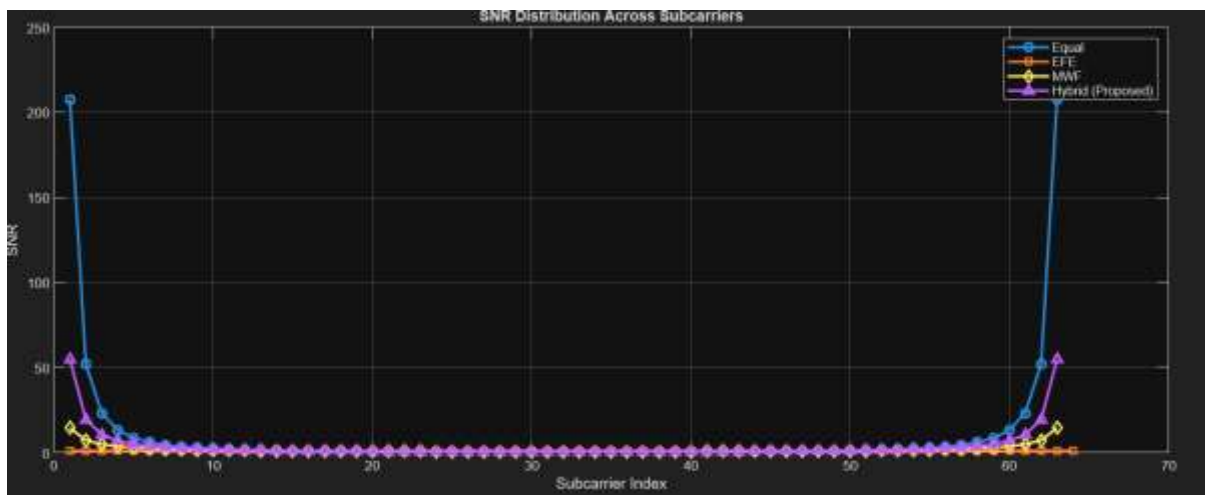


Fig.5. SNR Distribution Across subcarriers

D. Overall Performance

The results confirm that the proposed method provides a balanced error performance and data rate, outperforming conventional schemes [6][18][17].

VI. CONCLUSION

An adaptive hybrid power allocation scheme for FM-OFDM systems has been presented. By dynamically combining EFE and MWF techniques, the proposed method effectively addresses the limitations of existing static approaches[20]. Simulation results demonstrate significant improvements in both BER and spectral efficiency across varying SNR conditions. The proposed scheme offers a practical solution for enhancing the performance of future wireless communication systems [6][18].

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