Modified Entropy based Least Square Channel Estimation for OFDM and UFMC 5G Systems

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Abstract:

The 5G network is anticipated to enable a sizable volume of wireless connections and mobile data traffic. A demand for several wireless communication is to attain greater spectrum, energy-efficiency, as well as quality of service (QoS) in terms of delay, dependability, and security. A developing technology for 5G wireless communication systems is massive multiple-input multiple-output (MMIMO). In MMIMO technology the main criteria for the transfer of information are multi carrier modulation (MCM) techniques for better spectral efficacy. It acts as a main part in the design of physical layer. In recent years orthogonal frequency division multiplexing (OFDM) MCM technique has played a vital role for the transmission of the information. But the main disadvantage of the OFDM system is the cyclic prefix that is added at the end of information. Because of this CP the symbol length also increases. To overcome the problem universal filtered multicarrier (UFMC) MCM technique is used. The other main criteria for the transmission of information are channel estimation (CE). 5G MMIMO systems require efficient CE technique to improve the performance of the system. For 5G MMIMO-UFMC systems, this research provides a modified entropy-based least square (MELS) CE approach. This research work is evaluated using MATLAB software. The performance analysis of UFMC and OFDM systems are done for MELS CE technique. The parameters such as bit error rate (BER) and mean square error (MSE) are analyzed for UFMC and OFDM systems. The results also prove that the proposed MELS CE technique performs better for UFMC 5G MMIMO system compared to OFDM 5G MMIMO system.

Keyword: *5G, Universal filtered multi carrier, Orthogonal frequency division multiplexing, Modified entropy-based LS.*

1. Introduction:

Currently, the design of the architecture for 5G wireless communication systems is growing more dependent on MMIMO [1] technology. LTE and LTE-A wireless communication industries are where it has mainly found success. The delivery of high data rate services to wireless users has been adjusted for LTE and LTE-A. A base station with multiple antennas supports numerous users in MMIMO [2]. Numerous antennas are provided by MMIMO at the base station [3-4]. The growth of networks has raised user demand for high-speed information, particularly for internet use; as a result, there has been a surge in interest in network dynamic spectrum access [5]. The common frequency spectrum has been used by the wireless system with numerous nodes. One of the most common approaches in a multicarrier system (MCS) for spreading subsets of subcarriers in nodes is orthogonal for set of subcarriers in OFDM [6]. Because of the strict timing and synchronisation requirements, OFDM has been deemed difficult. The shortcomings of the OFDM MCS would be rectified by a MCS such as UFMC, which Saltzberg proposed. When analogy to the OFDM, the MCS will improve spectral shape of the subcarrier. The design of the prototype filter (PF) achieves the aforementioned criterion, bridging the absence of CP leading [7] the approach also offers effective spectrum utilisation via the reduction of ISI. The UFMC system utilises OQAM to attain full transmission BW capacity [8]. The major goal of this study will be to evaluate the multicarrier in OFDM and UFMC systems, particularly as they apply to 5G wireless networks. To compare the two methodologies, an evaluation will be conducted using MATLAB. Future mobile systems are expected to be very diverse, with a broader range of applications including improved eMTC, eMBB, vehicle communication and URLLC [9].

These technological innovations necessitate effective assistance that allocates time-frequency resources to meet the different needs of the innovations. The 3GPP network has kept the usage of 5G OFDM, although with minor changes to ensure backward compatibleness. The incorporation of OQAM technology into UFMC scheme will improve its spectral efficacy (SE).

2. OFDM System:

It is a kind of MCM in which data is sent over numerous lesser rates of subcarriers. OFDM's is resistant against channel dispersion and simplicity of phase and CE in time-varying context are of its primary advantages. OFDM is a modulation technology [10] that is utilised in a variety of applications such as 3GLTE, WiMAX, digital audio radio, undersea connectivity, wireless LANs and modulation of optical light. OFDM mixes many signals running at the same time and at the different frequencies. Subcarriers or tones are the names given to these frequencies OFDM has bit rate R_b, maps n-bit words to M = 2n symbols, divides the resulting symbol stream into N parallel streams, and modulates each stream onto one of N different carriers. The carriers' N frequencies are selected so that they are jointly orthogonal throughout one OFDM symbol duration, permitting separate retrieval of every parallel information stream. The spectrum of a number of consecutive OFDM carriers is shown in Figure 1.

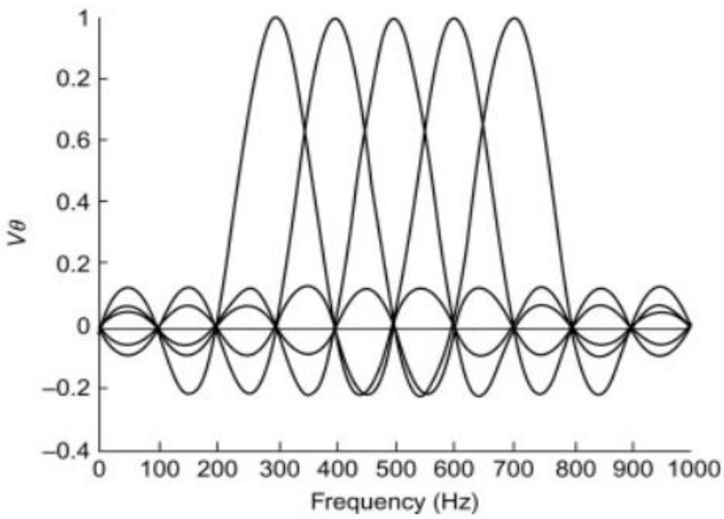

Figure 1: Spectrum unmodulated OFDM Carriers.

Figure 2 depicts the technique of imprinting a parallel stream of symbols it onto carriers that are orthogonal. The primary benefits of OFDM are that its rate of symbol is N times lesser than that of the initial stream of symbols.

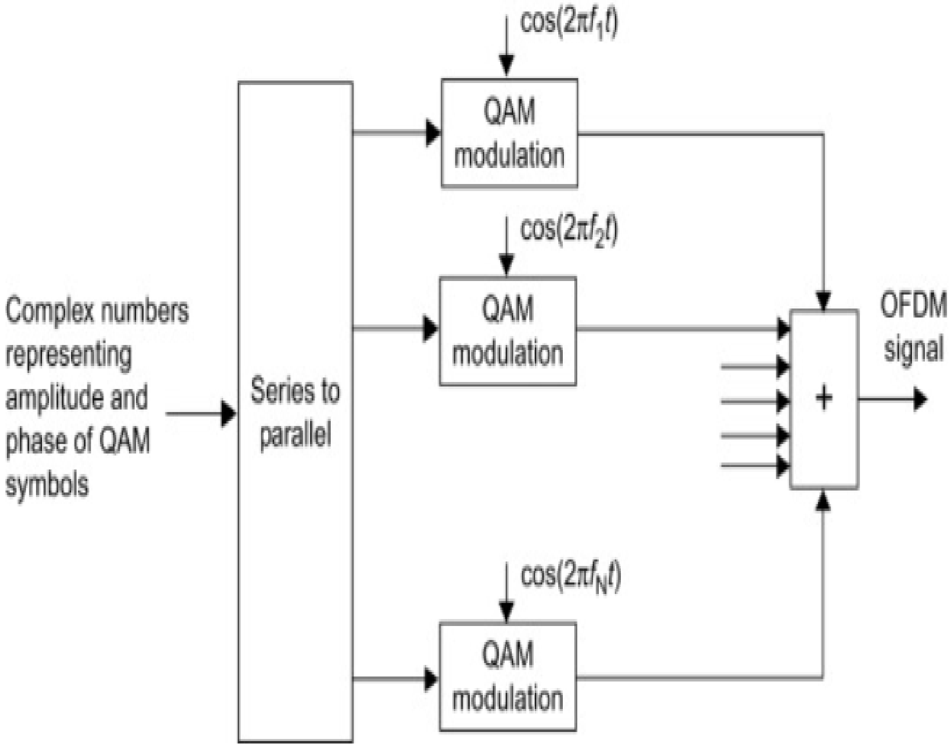

Figure 2: Basic process of computing OFDM signal.

Dispersion of time in the radio network causes echoes of previous symbols to overlap with later symbols, causing ISI. Minimizing the symbol rate on each orthogonal channel minimises the degree of overlap, reducing the deteriorating effects of ISI on BER significantly. In reality, the multipath channel compromises the rigorous orthogonality of OFDM carriers. Orthogonality can be restored by adding a CP to lengthen the lifetime of each OFDM symbol. The prefix is a duplicate of the last component of an OFDM symbol placed in front the OFDM symbol. To be completely effective, the CP must last at least as long as the longest lagged multipath echo. The CP consideration expands the time arrangement [11]. The OFDM conspire has the associated flaws. Because of the rectangular windowing, there is a lot of loss in SE. When CP is used, SE is reduced [12]. Inside the neighbouring groups, there is an impedance in the unsynchronized manner. The figure 3 depicts transceiver of CP-OFDM system.

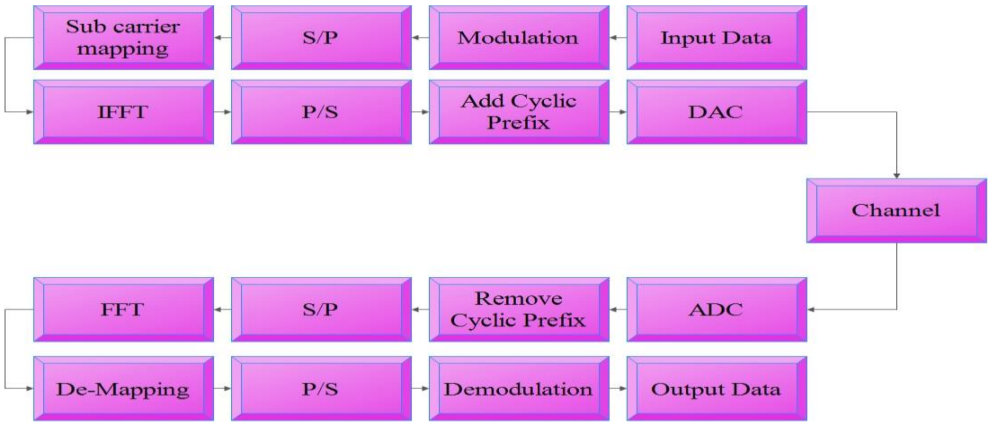

Figure 3: Transmitter and Receiver of CP-OFDM.

3. UFMC System:

The UFMC is an evolved variation of the OFDM, the modulators for these approaches are identical, with the main change being the substitution of the OFDM with a MCM constructed using the scheme of filter bank, which is replaced by the synthesis filter bank (SFB). The UFMC approach has overcome the limitations of OFDM by using generalised pulse shaping filters that ensure confined subchannels in the time and frequency domains [13]. The UFMC system includes a spectrum confinement signal, which allows for more efficient use of radio resources and eliminates the need for CP [14]. The UFMC features filter banks, with the synthesize filter bank located on the transmitter side. When the filter bank exits the synthesis bank, it is changed to serial. The serial to parallel converter will convert the signal to parallel form before transferring it all to the analyzing filter bank [15]. After exiting this bank, the parallel to serial converter will convert it to serial. Figure 4 depicts a novel UFMC transceiver.

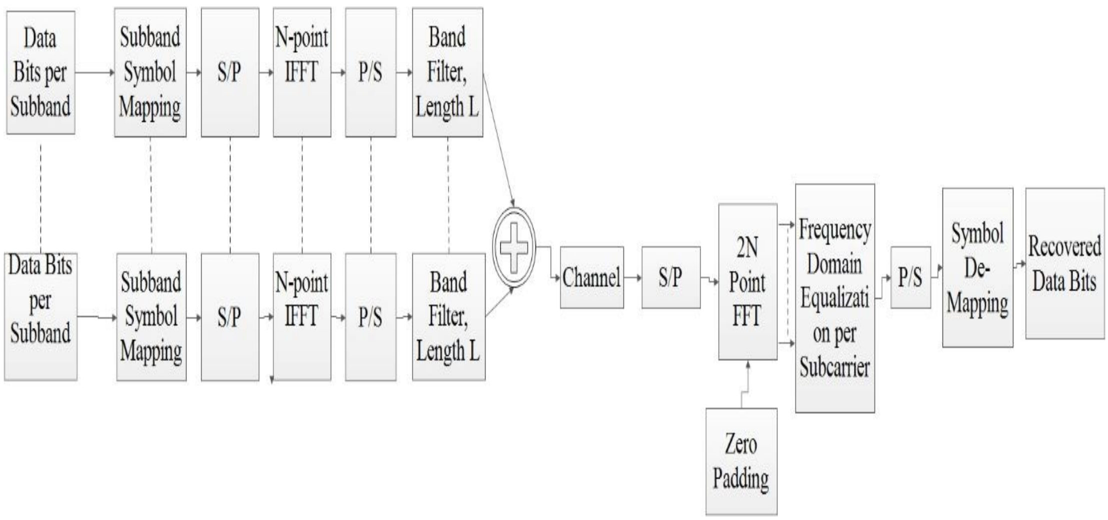

Figure 4: Transceiver of UFMC system.

The time-domain broadcast vector of a specific multi-carrier symbol of user k is a superposition of sub-band-wise filtered components having L filter length and length of FFT N. The IDFT-matrix V_i transforms the n_i complicated QAM symbols to time-domain for every B subbands, numbered i. V_i contains the necessary columns of the IFFT matrix based on the location of the corresponding sub-band within the overall accessible frequency range. F_i is a Toeplitz matrix that contains the filter impulse response and linear convolution is performed. There is no temporal overlap between the following symbols of UFMC. Block-wise filtering adds flexibility and can be used to overcome the primary FBMC shortcomings. Filtering per subcarrier block produces filters that are spectrally wider in pass-band than FBMC as well as consequently shorter in time. This reduced time can be utilized to reduce the length of filter, for example, in the sequence of the OFDM CP. Short bursts, as well as operating in fractured bands, will be adequately supported. Side-lobe suppression now applies between resource blocks rather than subcarriers. The UFMC is orthogonal to the complicated plain. Thus, complicated modulation symbols can be employed, and the issues mentioned above are not present. The time domain filter ramp-up and ramp-down gives a symbol shape with intrinsic soft protection against ISI, as well as resilience for supporting various access users that are not exactly time-aligned. UFMC is more spectrally efficient than OFDM due to the ability to minimize guard bands and avoid utilizing a CP that is discarded later in the receiver. The frequency-domain FFT-based receiver analysis can still be used: After appending zeros to the next power of two to the receive time frame, an FFT is performed, with each subsequent frequency value corresponding to a subcarrier main lobe. Single-tap per-subcarrier frequency domain equalizers, similar to OFDM, can be used to equalize the combined influence of the radio channel and the associated subband filter. This results in a complexity order that is comparable to that of OFDM. Prior to the translation to frequency domain, domain pre-processing might be used. UFMC is more resistant to multi-user interference, has higher SE [16], outperforms OFDM in coordinated multipoint transmission, and is best suited to fragmented spectrum. UFMC outperforms OFDM in rapid burst/low latency transmission circumstances and may give sophisticated orthogonality while avoiding several traps. As UFMC provides high spectral efficiency by overcoming the problem of CP which is present in OFDM system.

4. Modified Entropy-based LS CE:

CE aims to characterize the effect of input sequence in physical medium [17-18]. The entropy-based method assesses antennas based on the data they communicate to and receive from other antennas. So, for MMIMO-UFMC, the MELS CE algorithm with modified entropy is suggested. With N transmitter antennas and M reception antennas, let P serve as the transmitter node and T serve as the receiving node. The received signal is represented as since node P has N antennas

$$Y_p = S_p h_1 + S_t h_2 + F\widetilde{n_p} \quad (1)$$

Where $S_p and\ S_t$ = pilot matrix that are known at the receiver end.

h_1, h_2=channel matrices estimate.

Therefore, the received signal equation is rewritten and is given as

$$Y_p = Sh + F\widetilde{n_p} \quad (2)$$

The MELS procedure is shown in picture 5

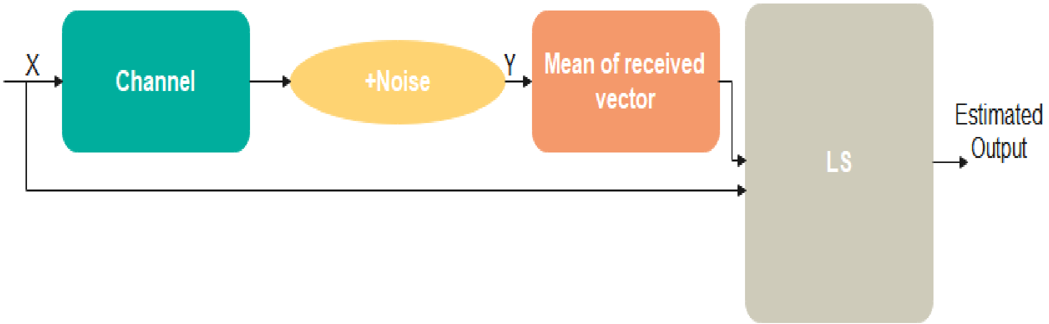

Figure 5: MELS block diagram.

The MMIMO-UFMC system with MELS is displayed in the figure 6.

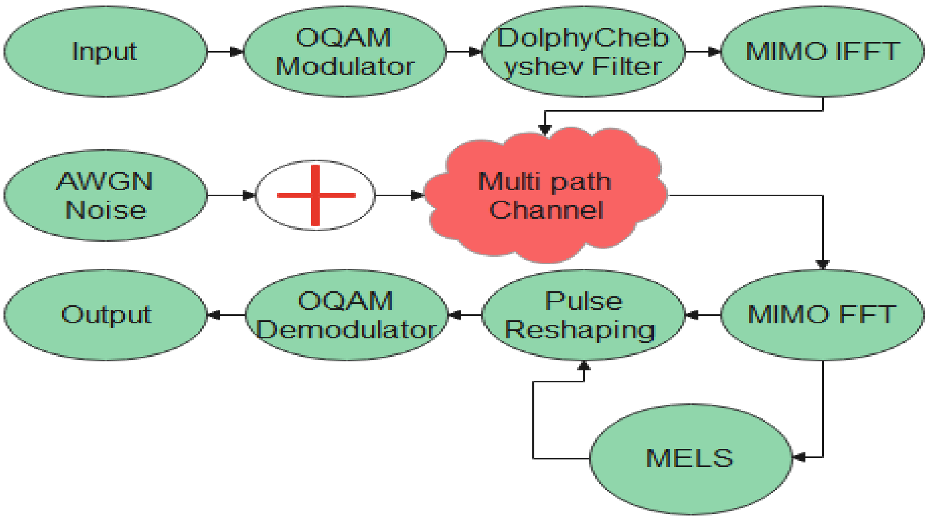

Figure 6: MMIMO-UFMC system with MELS.

It is necessary to calculate the total of all incoming inputs in modified entropy first. Later, the mean is computed using the signal's modulation order. The modified entropy is represented as

$$S^{\theta} = \frac{X_1+X_2+\cdots\ldots+X_p}{M} \quad (3)$$

Where M= Modulation order

$X_1 + X_2 + \cdots \ldots + X_p$= Summation of the received inputs at the receiver.

Finally, the LS estimate after the modified entropy $S^{\theta}$of the received signal is given as

$$\hat{h} = S^{\theta}(X^{-1}Y_p) \quad (4)$$

Where S^{θ}= modified entropy of the S.

5. Simulation Results & Discussion:

The study compared UFMC modulation to OFDM and its general versions. The results demonstrated that the UFMC provided a way to overcome the constraints of OFDM. The advantages of UFMC modulation have resulted in its use in developing communications technology such as LTE and 5G communications. The power spectrum for the UFMC transmitted signal was examined in order to achieve reduced out-of-band leakage [19]. The UFMC system has high spectral efficacy compared to OFDM is shown in the figure 7. The UFMC has a fewer lobed side, as seen in figure 8. The feature enables enhanced use of the assigned spectrum, hence enhancing spectral efficiency. When compared with subcarrier filtering, OFDM has a longer filter delay, necessitating QAM processing. When compared OFDM MCM studied in the investigation, the UFMC-QAM provides a superior channel. The results are implemented using MATALB software.

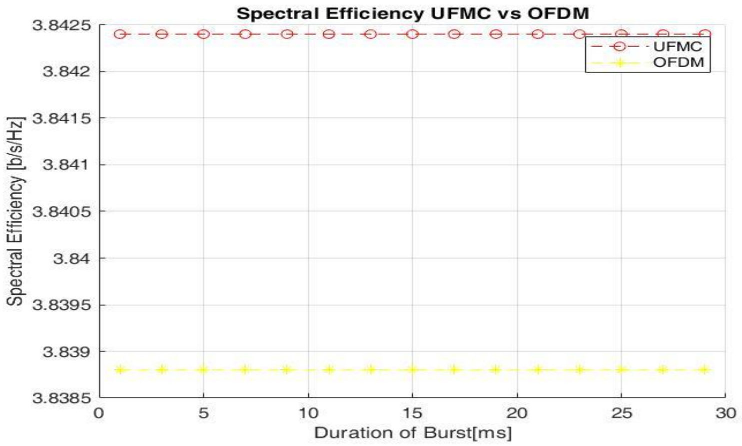

Figure 7: Spectral efficacy UFMC vs OFDM.

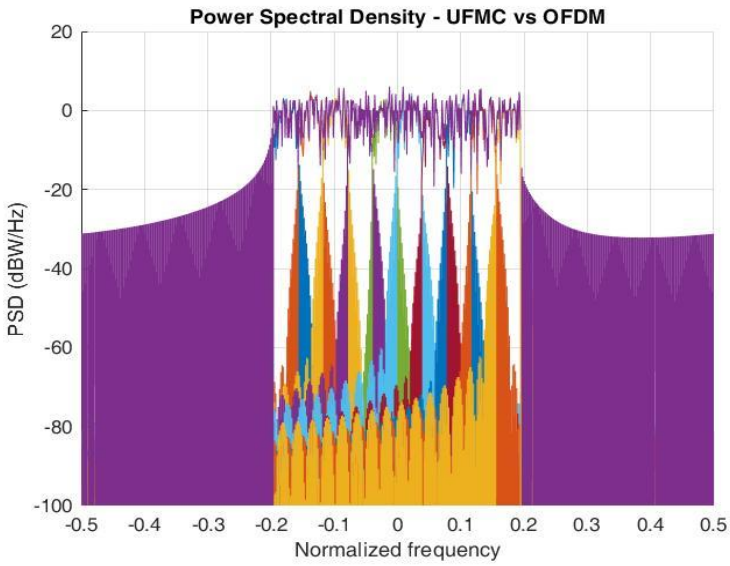

Figure 8: PSD UFMC Vs OFDM.

Table 1: Comparison of OFDM & UFMC (High-H, Medium-M, Low-L)

S.No	Parameters	OFDM	UFMC
1	OOB Emission	H	L
2	Spectral efficiency	L	H
3	Computational complexity	L	H
4	Latency	M	H
5	PAPR	H	H
6	Robustness to CFO	L	H
7	Flexibility	H	M

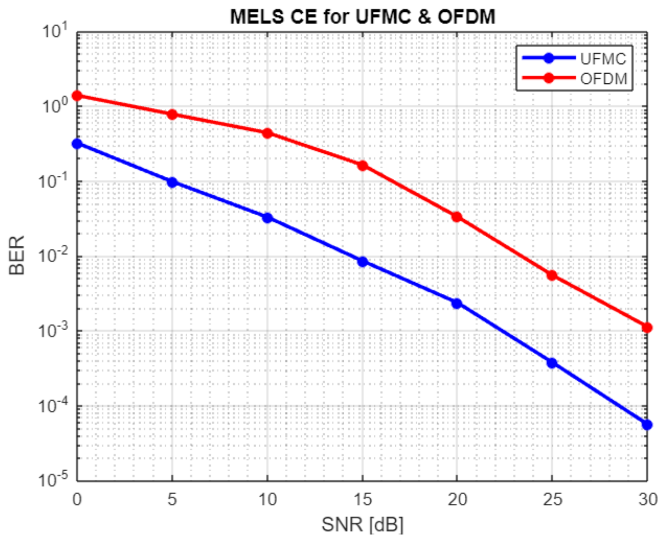

Figure 9: BER of MELS CE for UFMC & OFDM.

Compared to OFDM, figure 9 demonstrates that the proposed CE method performs better with the UFMC system. BER is less for MELS CE UFMC system compared to MELS CE OFDM system.

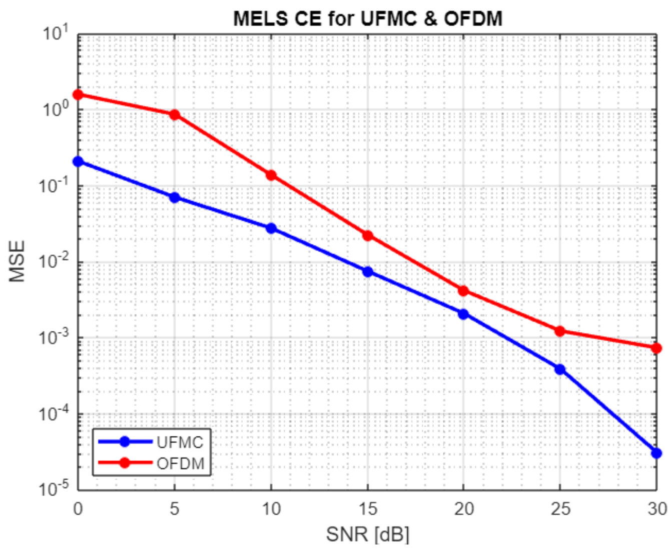

Figure 10: BER of MELS CE for UFMC & OFDM.

Compared to OFDM, figure 10 demonstrates that the suggested channel estimate method performs better with the UFMC system. MSE is less for MELS CE UFMC system compared to MELS CE OFDM system. The simulation parameters that are used for proposed MELS CE is illustrated in table 2.

Table 2: Simulation parameters of proposed channel estimation technique

S.No	Simulation Parameters	Numbers
1	Bits per subcarrier	8
2	Subcarriers	1024
3	Modulation Order	256
4	Modulation	OQAM
5	SNR (dB)	15
6	Number of Taps	3
7	Number of iterations	15

6. Conclusion:

Many emerging characteristics of 5G MMIMO communications necessitate a complete rethink of the physical layer. While OFDM is a move in the right direction, it is still not ideal because several complications arise when practical system parameters are applied. Though there are several recommendations for dealing with challenges by addressing the symptoms rather than the source, there is still a penalty to pay. As a result, we rethought the filtered multicarrier paradigm and created UFMC. With UFMC, we may get the benefits of OFDM while avoiding the downsides. UFMC, like OFDM, is more resistant to multi-user interference, has higher SE, performs better in coordinated multipoint transmission, and is more suited to fragmented bandwidth than OFDM. UFMC outperforms OFDM in small burst/low latency transmission circumstances and may give sophisticated orthogonality while avoiding several traps. This paper also discusses the MELS CE technique for OFDM and UFMC system. The proposed CE method outperforms for UFMC 5G systems compared to OFDM 5G system. The parameters that are analyzed in this paper are BER and MSE. As the SNR increases the BER and MSE of the MMIO-UFMC system reduces compared to MMIO-OFDM systems. The results are executed using the MATLAB software. The computational complexity of the proposed CE is its biggest drawback. As the number of iterations rises, the system becomes increasingly complicated. As a result, efforts must be made to reduce computing complexity.

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