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# A Design of Adaptive Space Time Frequency MIMO-OFDM with Nanotechnology

**Sabeenian Royappan Savarimuthu**[1*], **Angel Daniel**[1] **and Manjunathan Alagarsamy**[2]

*[1]Department of Electronics and Communication Engineering, Sona College of Technology, Salem, Tamil Nadu, India*
*[2]Department of Electronics and Communication Engineering, K. Ramakrishnan College of Technology, Trichy, Tamil Nadu, India*

**[*]Correspondence to:**
Sabeenian Royappan Savarimuthu
Department of Electronics and
Communication Engineering,
Sona College of Technology,
Salem, Tamil Nadu, India.
**E-mail:** sabeenian@sonatech.ac.in

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## Abstract

MIMO (Multiple-Input Multiple-Output) networks could be created for one of two functional purposes: either to reduce bit error rate (BER) or to enhance capability without using more bandwidth or power. In order to reduce inter-carrier interference (ICI) and enable dynamic switching among these two modalities in wireless fading channels, MIMO space-time-frequency (STF) conjugated two-path transmitting orthogonal frequency division multiplexing (OFDM) networks with precoders have been proposed in this study. A 2x1 STF-OFDM network will be first constructed using the STF paradigm. Secondly, to create a new 2x1 STFCC-OFDM network, a conjugate cancellation (CC) two-way transmitting method is combined with the STF-OFDM network. Contrasting this approach to the CC method, it increases BER without increasing bandwidth or power. Finally, to create the 2x1 WHSTFCC-OFDM network, the Walsh-Hadamard (WH) transform has been used as the precoder. Moreover, a 2x2 WHSTFCC-OFDM structure is then developed. When more capacity is required, it can be utilized to boost BER or swap to dual 2x1 WHSTFCC-OFDM networks. According to calculations, the 2x1 WHSTFCC-OFDM network does have the lowest BER, followed by the STFCC-OFDM network and the STF-OFDM network. Corresponding to this, the 2x2 STFCC-OFDM system comes in second place behind the 2x1WHSTFCC-OFDM in terms of BER performance. Such WHSTFCC- and STFCC-OFDM methods have all been straightforward and outward-compatible with the current OFDM network. For the 4th generation and upcoming 5th generation MIMO networks, they might be used as core building components in OFDM transmitters and may dynamically transition between 2x2 and 2x1 designs as necessary.

## Keywords

Multiple-input multiple-output, Space-time-frequency, Orthogonal frequency division multiplexing, Conjugate cancellation, Walsh-Hadamard

## Introduction

Among the most difficult issues in current wireless communication networks is how to achieve high data transfer rates while maintaining good quality-of-service, which can satisfy the constantly increasing consumer and application demands. Due to the constrained bandwidth and channels fading brought on by multipath elements in the wireless link, this is a difficult subject. Combining the ideas of MIMO with OFDM has been suggested as one viable approach to solving this issue [1, 2]. As a result, novel MIMO-OFDM wireless communication networks have emerged. Data transmission speeds are greatly increased by MIMO technology that presupposes the employment of numerous antennas at the wireless link's sender and recipient sides [3]. In order to offer a greater data transfer rate with minimal error and sufficient reliability to radio channel difficulties, OFDM assumes a multicarrier transceiver and FDM, in which a solitary data stream has been transferred over numerous reduced rate subcarriers that are placed orthogonally to one another. Realistically, the multi-path latency endurance and susceptibility to MIMO's frequency specific channel fading, along with the OFDM's higher data transfer rate, enhance the MIMO-OFDM system's transmitted signals [4]. Moreover, wireless communication networks must offer a comprehensive secured and end-to-end solution in order to deliver voice, information, and visual to consumers whenever and wherever they demand it. They also need to be able to meet the demand for ever-enhancing greater data rates. However, because of the multipath channels of the broadcast signal, the broadband channel primarily experiences bandwidth selective fading, making it challenging for the receiver portion to identify the sent signal without being given a signal's less affected copy.

The most widely used air interfaces protocol for 5G and 4G wireless communications was MIMO-OFDM. It integrates MIMO and OFDM technology. OFDM splits the bandwidth into a significant number of tightly separated subcarriers to offer multipath dispersion at high velocities, while MIMOs multiply radio bandwidth by delivering various signals through numerous antennas. MIMO-OFDM offers the largest capability and signal throughput since it seems to have the largest spectral efficiency. Thus, this serves as the basis for the majority of Wireless LAN and mobile internet network protocols. That example, distinct data streams might be delivered over various pathways by utilizing precoding the signals and numerous antennas. According to Raleigh's research, OFDM might be the most effective processing method for the increased data rates needed by MIMO. Due to the fact that OFDM splits a single higher-speed data flow into numerous parallel channels with lesser speeds. In addition, by splitting user statistics among a number of sparsely spaced, spectral subcarriers, OFDM offers reliable broadband connection. Inter-Symbol Interference (ISI), the major problem to reliable broadband connections, may be detached appreciations to this strategy. ISI occurs when two signals that have been closely spaced in time have a sizable degree of overlapping. Increased data rates sometimes require smaller length signals, increasing the risk of ISI. OFDM certificates extended endurance symbols by breaking up a higher-rate data channel into multiple lower-rate data channels. By utilizing a CP (cyclic prefix), it's indeed feasible to construct a buffer period that entirely disallows ISI. There won't be any overlap among consecutive symbols and, as a result, no ISI, if the buffer interval has been bigger than the latency blowout, or the variation in deferrals that symbols encounter as they are sent across the channel [5]. Moreover, the primary benefit of OFDM seems to be the ability to broadcast many signals simultaneously while retaining a higher spectral efficacy. Channel coding methods are used in the OFDM scheme, wherein errors have been experienced at particular sub-bands in the spectral domain, to ensure resilience towards frequency-selective fading. With this method, high bandwidth for wireless technology may be attained affordably. The block diagram of MIMO-OFDM system is indicated in figure 1.

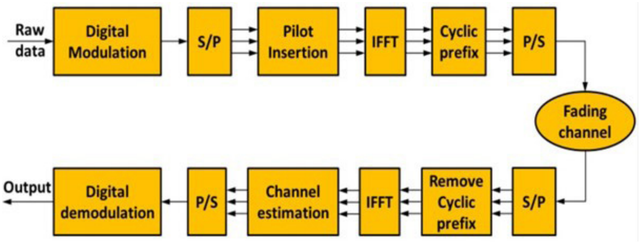

**Figure 1:** MIMO-OFDM block diagram.

Diversity refers to the transmission of a copy of the original communication signal. Adding channel variety to the network is a proven strategy to lessen the impacts of signal fading [6]. The idea underlying channel diversity seems to be to send the recipient many copies of the desired signal via separately fading channels. By doing this, the likelihood that all of the signal's elements would fade concurrently is greatly decreased. Several spatially dispersed antennas decrease the likelihood of signal loss; integrate antenna signals to boost collected mean power and use IFFT to accomplish OFDM encoding [7]. Many sources of variety are available through wireless communications systems. Diversities must be effectively tapped into through a transmitting and coding method. Temporal, spatial diversity, and frequency, have been the three primary diversity methods. Several antennas and space-time coding are used to achieve spatial variety. An effective way to get a sender diversity benefit in a MIMO network that is close to ideal is by using space-time block coding (STBC). The Alamouti method has been extended in STBC [8]. The essential elements of both plans are the same. These codes may accomplish the full broadcast diversity determined by the amount of send antennas since they are bidirectional. In other terms, STBCs are a more complicated variant of Alamouti's STC, with identical decoding and encoding algorithms on the sender and recipient ends of the communication channel. The amount of send antennas is represented by the numbers of rows in the data structure, and the quantity of time slots is represented by the variety of columns in the data structure. Signals have been initially mixed at the recipient side before being transferred to the maximum probability detector, in which the decision criteria have been put into use. The goal of STBCs was to maximize diversity pattern for a certain amount of broadcast and receiver antennas while adhering to the requirement of a straightforward linear decoding method [9]. Due to this, STBCs have become the most popular and commonly utilized system. When channel estimation has been required for coherent identification, STBCs and numerous other space-time algorithms, like STTCs, have been intended for the job.

The term "SF coding" refers to this technique, which uses OFDM sub-channels as well as coding over antennas. Simply spreading the Alamouti codes across two sub-carriers in single OFDM block seems to be an easy technique to implement SF coding for dual transmits antennas. The greatest diversity benefit in frequency selecting MIMO channels could be achieved, but the SF coding strategy could only attain spatial diversity benefit. An SF code formulation strategy has been developed by multiplying the original information streams with a portion of the Discrete Fourier Transform matrices in order to fully use the variety in MIMO multipath fade channels [10]. Full variety can be achieved by the resultant SF codes, albeit at a significant cost in bandwidth effectiveness. As wireless communications need a lot of bandwidth, network designers must maximize spectrum utilization and use cutting-edge modulation methods to achieve the maximum data speeds. MIMO method and PAPR mitigation approaches are a few of the main variables among many that help to improve spectral efficiency [11]. Hence, the future generation of wireless communication networks requires a more sophisticated amendment mechanism and the transfer of structural information. Multimedia applications that are driven by anticipated future wireless networks and call for high data rates and fast movement rates. The MIMO-OFDM system's output seems to be the combination of many subcarriers, and as a result, the outcome signal strength may be beyond the power amplifier's straight operating range. Among the most significant issues that must be solved when developing a MIMO-OFDM technology has high PAPR. Power amplifiers having a continuous range ranging across a significant spectrum of input power have been necessary to transfer signals with higher PAPR without interference. The layout of such amplifiers is highly pricey. Regardless, how big the power amplifier's straight range was, every time a signal enters or exits it, non-linear deformation occurs, which degrades performance [12, 13].

Moreover, partial transmit sequence (PTS) seems to be a probabilistic-predicated PAPR mitigation strategy [14]. The fundamental idea underlying the PTS method seems to be the splitting of data blocks into non-overlapping subblocks, all of which are phase-shifted using a substantially unbiased rotational factor to lower PAPR. This method for OFDM network PAPR mitigation is adaptable and effective. According to reports, it involves a revised Selective Mapping (SLM) system. PTS performs superior to its SLM equivalent. The chief gain of this tactic over SLM was that no extra data has to be sent to the receivers to indicate when divergent modulation is being employed throughout all subblocks. It must be emphasized that although the benefits MIMO-OFDM system offers, it still experiences significant signal variations known as the PAPR. This research employed the Walsh-Hadamard transform as precoding and PTS to mitigate the MIMO-OFDM system's PAPR in an attempt to solve this issue. Moreover, the main objective of this research is described as follows:

- Implementing STF with CC to prevent signal crossing.
- To enhance the spectral efficiency and decrease the PAPR by PTS technique.
- PTS technique includes Walsh-Hadamard transform.

## MIMO-OFDM

When using MIMO-OFDM technology, the transmitted signal's PAPR and ICI have been regarded as bottlenecks since they significantly reduced performance. Therefore, Youssef et al. [15] found that Residue Numbers (RN) as a coding method is hindered in MIMO-OFDM technology. The PAPR result have been analyzed and contrasted to non-RN System (RNS) coding processes, and the ICI stages have been determined and assessed in regard to traditional ICI reduction methods as self-cancellation, pulse shaping, and windowing methods implemented in MIMO-OFDM technology. For the MIMO-OFDM technology with the ICI defects, BER, RNS coding, and Complementary Cumulative Distribution-Function have been analyzed and assessed. The outcomes showed that the transmitting model performed better than the network without RNS deployment. However, the computational time is high.

Yeh and Zhou [16] suggested to integrate 4x1 ST-OFDM network with PC for creating a 4x1 STPC-OFDM network. The two-path blocks coding strategy used in the 4x1 STPC-OFDM network's PC strategy reduces ICI in the wireless channels. Additionally, numerous receiver antennas could be included into a generic STPC system. More variety and improved BER performance are offered. To further improve the BER, diagonal transforms like the WHT and Zadoff-Chu transform could be used as precoders. Simulations showed that 4x1-STPC-OFDM entire rate methods have been more resistant to frequency-selective streams and possess a good BER results compared to a 1/2 rate ST-OFDM network that has comparable bandwidth efficiency, even though STPC-OFDM networks call for two-path transfer. Furthermore, while utilizing higher modulation indices, it reclaims bandwidth effectiveness and yet offers an improved BER for acceptable data rate while compared to 4x1 ST-OFDM. However, the design complexity is high.

In particular, in quickly fluctuating mobile networks with impulsive noise (IN), a resilient communication network with an enhanced BER is preferred. Yeh and Zhou [17] therefore present a 2x2 STCC two-path transferring technique coupled with interleaved OFDM (IOFDM) network. The interleaving in IOFDM has been used to increase variability without coding. Owing to STCC in frequency-selective wireless fading systems, the STCC-IOFDM system offers good ICI reduction, and the interleave mechanism adds both temporal and frequency variety to efficiently defeat IN. The suggested STCC-IOFDM networks have proven to be resilient to a variety of frequency-selective settings, particularly whenever the IN was present in subpar urban wireless channels, according to tests. In both IN and wireless fading channels, the STCC-IOFDM and STCC-OFDM technologies outperform the ST-IOFDM and ST-OFDM networks in terms of robustness and BER outcomes. Unfortunately, the redundancies in transmitting reduce the bandwidth efficacy.

Solyman et al. [18] evaluated and then contrasted 3 novel frameworks for mobile sensor connections relying on Alamouti-decoding: the Alamouti STBC MIMO/multiple-input single-output (MISO) multicarrier-modulation (MCM) structure, the elongated orthogonal STBC-MISO-MCM model, and the MIMO technology. Additionally, the suggested scheme applies MIMO systems instead of the traditional single-antenna orthogonal chirp DM (OCDM) networks, predicated on the distinct fractional-cosine transform OCDM framework to reduce the impact of time-varying and frequency-selective channels, utilizing low-complexity limiters, particularly by disregarding the ICI bringing from distant sub-channels and employing the LSMR repetition method to reduce the equalization intricacies, primarily with extended OCDM. The proposed networks' block schematics have been supplied to make the theoretical assessment more comprehensible and straightforward. The suggested MISO and MIMO-OCDM systems function better than the traditional MISO and MIMO-OFDM systems, according to simulation findings. Last but not least, the findings demonstrate that OCDM had a superior channel energy pattern than traditional OFDM, enhancing system efficiency and enabling the system to reduce the equalization complication. However, the processing time of the method is high.

Subcarrier orthogonality is necessary for OFDM networks. However, there are situations that produce ICI and worsen BER efficiency, like residual carrier frequency offset, temporal changes brought on by phase noise, or Doppler shift. Yeh and Yildiz [19] introduce STCC networks, which integrate CC to reduce the OFDM network's ICI with 4x1 and 2x1-ST coding. Even though there isn't an entire orthogonal transmission matrix, STCC-OFDM networks with four transceiver antennas offer a greater transfer rate than entire orthogonal with 0.5 transmissions coding rate under the similar antenna construction, and also greatly enhance the BER of transmission matrices non-orthogonality. Additionally, compared to conventional ST, 4x1 ST-OFDM, and CC with 0.5 coding rate, the erroneous floor offered by 4x1-STCC-OFDM networks with 1as coding rate has been much lower. Without bandwidth, adding power, or computing burden, this STCC-OFDM network may perform the necessary 5G MIMO-OFDM network functions. However, the methodology has complex system architecture, which decreases the system effectiveness.

The integration of MIMO-OFDM has significantly advanced wireless communication networks during the past ten years. It has drawn a lot of interest as an outstanding service option for the coming generation. Yet one of OFDM's key drawbacks is its greater PAPR, which increases disturbance and reduces the High-Power Amplifiers (HPA) power efficiency. Although PTS seems to be a prominent and promising technique, it has a high computational overhead due to its thorough searching for phase variables, which effectively reduces the PAPR of OFDM signals. Thus, Lahcen et al. [20] conducted a study to provide a unique PTS-based strategy for enhancing PAPR effectiveness. The research uses one stage to maximize the block with the highest PAPR in the suggested technique, which uses a phase weighted procedure with minimal computer cost. The simulation outcomes demonstrated that the suggested technique not only greatly lowers PAPR but also minimizes computational burden. However, the model has higher processing time.

Excessive PAPR is seen as a serious problem in contemporary MIMO-OFDM technology. The PTS approach can be used to get around this fundamental problem. Due to the thorough search for phase components to best decrease PAPR, the computational complexity using this approach is relatively significant. In order to address the issue of greater search difficulty, the PTS method incorporates the Enhanced Switching Differential method, which was presented by Rakshit et al. [21]. In the study, a wavelet transform approach predicated on Adaptive Update Lifting has been developed. This technique increases operational versatility and susceptibility to frequency and time synchronization whereas improving system efficiency by reducing upper end lobes. Last but not least, an enhancement in the mitigation of BER, computational complexity, and PAPR in an Adaptive Update Lifting-based MIMO-OFDM network has been described using an integration of Enhanced Switching Differential-based PTS and turbo coding technique. Error rectification and phase component searches may both be done effectively using a turbo decoder. With the aid of the necessary formulae, the recommended scheme's hypothetical performance has been examined. Also, comparisons with the currently used procedures are offered here. Results from MATLAB simulations show that the proposed hybrid methodology may minimize PAPR and enhance BER significantly with less search computational burden than competing methods. However, the design process takes more time.

The wireless communication system's effectiveness and capability are enhanced by MIMO-OFDM. Because of its outstanding spectral efficacy and resistance to frequency-selective fade channels, OFDM seems to be an effective and attractive modulation technology for wireless communication. Its PAPR, which represents a major drawback, is present. Among the most popular methods for MIMO-OFDM systems that perform well at PAPR mitigation referred as PTS. Unfortunately, the standard PTS approach has a very high computational cost. Wang [22] suggests a less-complexity mixed subblock-segmentation PTS Method for PAPR mitigation in MIMO-OFDM systems. For analytical reasons, the study derives computational intricacy utterances for the suggested segmentation technique and compares its computational intricacy relative to the arbitrary segmentation technique—which does have the best PAPR reduction performance—in order to determine which segmentation technique is more computationally complex. As per the simulation outcomes, the PAPR reduction method performs just marginally worse than random segmentation. However, the hybridization process takes more time.

Due to its potential to provide higher data rates, resilience to fading networks, and consistent communication, MIMO systems in combination with OFDM have attracted significant interest in future generation bandwidth multimedia technologies. While employing OFDM has numerous benefits over ISI, such as resilience and excellent spectrum efficiency, there are also some drawbacks. High PAPR seems to be the main problem that arises with OFDM setups. Several techniques, such as tone reservation (TR), filtering and clipping, PTS, dynamic constellation framework, interleaving, and SLM are available for reducing PAPR. By resolving the present problems, the primary purpose of the work is to lower the PAPR in MIMO-OFDM network. To lower the PAPR, Vijayalakshmi and Reddy [23] presented a unique strategy integrating the Gaussian pulse-predicated TR and PTS methods. The fundamental concept behind the TR approach is the calculation of an additional time-domain signal, that lowers the OFDM system's power efficiency by increasing mean power while decreasing the real transmit signal's PAPR. In order to decrease the mean power, the technique uses an adaptable optimization process (i.e., fusion of artificial bee colony and gray wolf optimization). In an attempt to lower the PAPR, the PTS method is also applied to the resultant signal. The outcome showed that the PTS strategy significantly lowers the PAPR by choosing the ideal phase sequence integration. However, the computational complexity is high.

In order to solve the issue of PAPR inside a reconfigurable high-speed MIMO-OFDM (RHS-MIMO-OFDM) system and efficiently decrease PAPR in OFDM, Shivaji et al. [24] suggested an efficient hybrid PTS (EHPTS). Nevertheless, the PTS approach must analyze every possible element affecting phase rotation that makes the statistical model's computing complexity rise linear with the numeral of subcarriers and sub-blocks. The research provides an approach that is mostly performed on choosing the optimal phase parameters to lower the higher PAPR in order to lessen the analysis' intricacy. The unique local analytic procedures that are created and conducted to investigate the ideal phase factors were added into the suggested RHS-MIMO-OFDM network. The simulation's findings demonstrated that, as contrasted to traditional PTS approaches, the suggested EHPTS approach minimized PAPR impacts on OFDM systems. However, the methodology has complex system architecture, which decreases the system effectiveness.

A viable approach for boosting the wireless communication network's capability and thwarting multipath occurrences seems to be the coupling of MIMO with multicarrier modulation methods like OFDM. Modern multimedia systems can use MIMO-OFDM as a powerful technology that can be included into many wireless communication protocols. The greatest issue with multicarrier modulation, meanwhile, is the MIMO-OFDM network's significant PAPR. As a result, PAPR reduction using probabilistic approaches and novel optimization techniques was given and examined by Lahcen et al. [25]. These methods were created to find a sent signal that satisfies the demands of modern communication networks by having a minimal computational burden and a minimal PAPR out. The efficiency of the suggested technique in scenarios of SISO-OFDM and afterwards MIMO-OFDM was proven by simulation outcomes. However, the design complexity is high.

In MIMO-OFDM technology, PAPR has been discovered to play a substantial role. Among the most effective ways to lower the PAPR in OFDM transfers is PTS. Finding the ideal phase component in a PTS system is seen to be a big problem. Kumutha and Amutha [26] employed the orthogonal activation approach to determine the starting density for the upgraded Artificial Bee Colony (ABC) technique in attempt to get around this issue. Also, the PTS methodology employs a thorough search strategy to identify the best possible amalgamation of phase parameters. Moreover, the network's computational burden would rise as a result. The improved ABC method also employs a slightly suboptimal technique to address this problem. In order to lower the BER and PAPR, the study coupled the STBC with the PTS-based upgraded ABC method. The PAPR and BER in the OFDM network are significantly mitigated by the diagonal initialization approach and sub-optimal technique in the ABC technique. However, due to utilization of hybrid schemes, the processing time is higher.

For wireless communication networks, the transmitter combining technologies of OFDM with MIMO offers a workable substitute for improving quality-of-services while also achieving excellent spectral efficacy and data rates. Yet the fundamental issue with the MIMO-OFDM network that needs to be considered into account is the significant PAPR. PTSs seems to be a potential technique and simple approach that can effectively reduce PAPR, but finding the best phase factors necessitates a thorough search, adding to the difficulty of the calculation as the number of subblocks increases. Amhaimar et al. [27] suggest a PTS method with a lower computational overhead that is predicated on a brand-new swarm intelligence algorithm termed the fireworks algorithm. The suggested method's ability to effectively decrease computing burden while maintaining excellent PAPR mitigation was proven by simulation outcomes. The results also show that the PTS scheme-predicated fireworks algorithm definitely surpasses the most popular and significant evolutionary method. However, the computational time is high.

### MIMO-OFDM with nanotechnology

MIMO-OFDM technology has been the backbone of high-speed wireless communication systems for quite some time. However, to improve its performance and address the challenges posed by the increasing demand for higher data rates and the scarcity of radio spectrum, researchers have turned to nanotechnology. The integration of nanomaterials in MIMO-OFDM systems has the potential to enhance the efficiency and reliability of wireless communication systems. By incorporating nanoscale devices and materials, such as carbon nanotubes and graphene, the communication channel can be improved, leading to better signal quality, reduced noise, and higher data rates. Furthermore, the use of nanotechnology can also help reduce power consumption and make wireless communication systems more energy efficient. Overall, the integration of nanotechnology in MIMO-OFDM systems is a promising area of research that has the potential to revolutionize the way we communicate wirelessly.

## Methodology

### STCCC

On a per-OFDM symbol base, the ST-OFDM employs the ST transmission diversity approach. In [2x1] architecture, the transmitter forms the input data matrices as 2 lengths $n$ successive blocks as shown below.

$$d_1 = \left[ d_1 d_2 \ldots\ldots d_{n-2} d_{n-1} \right]^T \quad (1)$$

$$d_2 = \left[ d_n d_{n+1} \ldots\ldots d_{2n-2} d_{2n-1} \right]^T \quad (2)$$

At times $t$ and $t + T$, $d_1$ and $d_2$, as well as $-d*_2$ and $d*_1$, have been transferred to two concurrent IFFTs and, using transceiver antennas Tx1 and Tx2, correspondingly, are transferred with CP. CPR has been started at the recipient initially. After FFT, the dual acquired signal matrices at times $t$ and $t + T$ become:

$$y_1 = H_1 d_1 + H_2 d_2 \tag{3}$$

$$y_2 = -H_1 d_{*2} + H_2 d_{*1} \tag{4}$$

The network at time $t$ can be represented by the transmit antennas Tx1 and Tx2 as $h_1$ and $h_2$, respectively. The decision parameters have been computed as below in the remaining sections of this work, presuming that fading has been constant over two successive symbols.

$$\hat{d}_1 = H_{*1} y_1 + H_2 y_{*2} = \left(\left|H_1\right|^2 + \left|H_2\right|^2\right) d_1 \tag{5}$$

$$\hat{d}_2 = H_{*2} y_1 + H_1 y_{*2} = \left(\left|H_1\right|^2 + \left|H_2\right|^2\right) d_2 \tag{6}$$

Where $h_1$ and $h_2$ were dual diagonal vectors, and $H_1$ and $H_2$ represent their diagonal components, respectively, of their corresponding channel impulse responses. The presented ST-OFDM transceiver is shown in figure 2.

As ST-OFDM as well as CC both operate on a per-OFDM-symbol base, their integration is logical. The STCC-OFDM transmitter's streamlined block diagram is shown in figure 3. Two length $n$ consecutive blocks have been produced as input data matrices at the transmissions in the manner described below.

$$d_e = \left[d_0 d_2 \ldots\ldots d_{2n-4} d_{2n-2}\right]^T \tag{7}$$

$$d_0 = \left[d_1 d_3 \ldots\ldots d_{2n-3} d_{2n-1}\right]^T \tag{8}$$

The even and odd parts of data symbols during the 2n interval were $d_e$ and $d_0$, respectively. To perform the upper IFFT and lower IFFT as well as the conjugate operation ()*, correspondingly, at time $t$ and $t + T$, $d_e$ and $d_0$, and $-d*_0$ and $d*_e$ are passed to dual parallel branches. The bottom branch uses a conjugate operator first followed by an FFT to demodulate the acquired signal from Tx2, whereas the upper branch uses an FFT to demodulate the signals from Tx1 at the recipient baseband. Keep in mind that the receiver must carry out activities, such as:

$$y_{1e} = H_1 d_e \tag{9}$$

$$y_{20} = \bar{H}_2 d_0 \tag{10}$$

$$= FFT\left[h_{*2}\right] d_0 = \bar{H}_2 d_0 \tag{11}$$

The conjugate's channel impulse responses n-point FFTs $h_2$ have been present wherein $H_2$ seems to be a diagonal component. The acquired signal $r_2$'s conjugate procedure's FFT findings at the bottom branch are:

$$y_{20} = FFT\left[\left(r_2\right)^*\right]$$

$$= FFT\left\{\left[h_2 \otimes \left(IFFT\left(d_0\right)\right)^*\right]^*\right\}$$

In conclusion, if the STCC system is implemented as a consecutive one-branch or two-branch, the overall computing demand is exactly the same as for the ST method without adding complexity.

## PAPR

Since the sent signal in OFDM networks is indeed the culmination of a number of modulated signals, its peak power could be significantly higher than its mean power. Even though they only happen seldom, such big peaks often have deleterious impact on the network as a whole. For RF propagation, the HPA, for example, must possess a broad linear spectrum, which would be utilized inefficiently. Furthermore, out-of-band emission and in-band deformation are brought due to the HPA's non-linearities. In-band interference causes a rise in BER. Yet, the signal sent in the nearby frequency ranges may be significantly hampered by the out-of-band interference. The proportion of the transferred signal's transient power to the mean power is known as signal's PAR.

$$PAR_{x_c(t)} \triangleq \max\left|x_c(t)\right|^2 \Big/ E\left\{\left|x_c(t)\right|^2\right\}, 0 \le t \le T \tag{12}$$

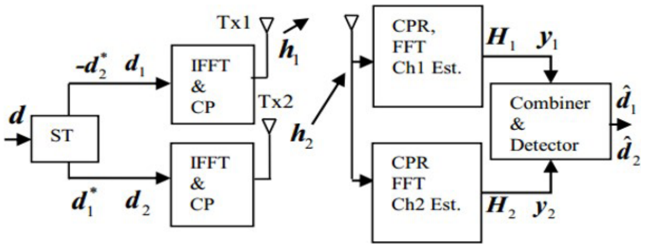

**Figure 2:** ST-OFDM transceiver.

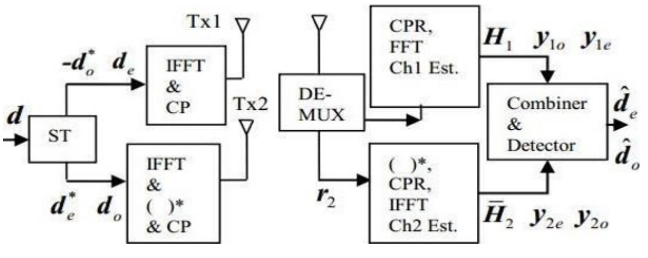

**Figure 3:** Regular STFCC-OFDM transceiver.

Here, the average value of (.) is represented by $E\{.\}$. On the other side, the baseband comparable signal x may also be used to evaluate the PAR issue $x(t)$, considering that max$|x_c(t)|$ ≈ max |x(t)|.

$$E\left\{\left|x_c(t)\right|^2\right\} \approx \frac{1}{2} E\left\{\left|x(t)\right|^2\right\} \tag{13}$$

PAR$|x_c(t)|$ ≈ 2PAR |x(t)|is the result. The continuous-time PAR is another name for the PAR described above. In real-world scenarios, the resampled baseband equivalent signal $x_n$ was typically used to compute the PAR. Thus, Nyquist sampling (J = 1) might not be able to catch all peaks of x(t). This PAR distribution has been named as discrete-time PAR in this research. Consequently, employing the discrete-time PAPR, oversampling has been needed to approach the continuous-time PAR; for a good estimate, the resampling factor *J* must be J ≥ 4.

$$E\left\{\left|x_n\right|^2\right\} = \frac{1}{N} \sum_k \left|X_k\right|^2 \tag{14}$$

The OFDM network's PAPR becomes al = N if $X_k$ were impartial, equally dispersed ($i.i.d$) random elements. As a result, PAPR's statistical interpretation has been more widely applied in practice. If an OFDM signal peaks at with likelihood Pc, it is referred to as a peak.

$$Pr\left[PAR(X) \le \_\right] = Pc \tag{15}$$

The PAPR's Complementary-Cumulative Distribution-Function (CCDF), also known as clip probability, has been described as $P(\_) = Pr[PAPR(X) > \_] = 1 - Pc$; i.e., there has been a 1 percent chance that PAPR will exceed. As an illustration, the PAPR probability for various oversampling parameters and for various demonstrate that J = 4 could offer a reliable estimation to the constant period PAPR dispersion.

## PAPR reduction methods

In the related works section, a number of PAPR reduction methods have been suggested. There are two groups created from these procedures. These are methods for scrambling and distorting signals, respectively. The methods commonly employed for PAPR reduction are described as follows: Signal Scrambling Techniques, Block Coding Techniques, SLM, PTS, and Interleaving Technique. However, the present research uses PTS strategy for PAPR mitigation; the PTS method includes Walsh-Hadamard transform method. The architecture of PTS is illustrated in figure 4.

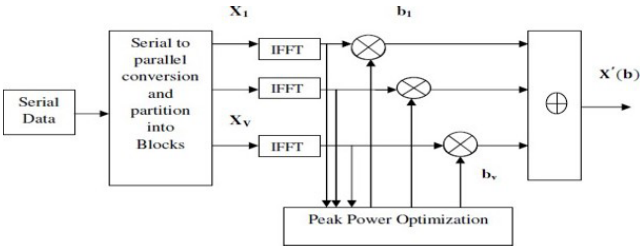

**Figure 4:** PTS architecture.

A signal becomes broken down into a collection of basis values using the non-sinusoidal, diagonal transformation method known as the Walsh-Hadamard transform. Walsh features, which have been square or rectangular waves with coefficients of +1 or -1, represent these basis capabilities. Walsh or Walsh-Fourier transforms might be other names for Walsh-Hadamard transforms. Sequence values are produced using the Walsh-Hadamard transform. About ½ of the zero-crossings/unit of time's typical quantity has been referred to as a sequence, which seems to be a broader concept of frequency. There is a distinct sequence value for each Walsh function. It may be employed to determine the original transmission's signal harmonics. Walsh functions have been stored using the Hadamard, sequence, and dyadic sorting methods. The Walsh functions are arranged in the manner seen in the picture above according to sequence sorting, which has been employed in signal processing tasks. In control purposes, the Hadamard scheduling puts them in the following order: 0, 4, 6, 2, 3, 7, 5, 1. In a mathematical arrangement known as a gray code or dyadic sequencing, they are arranged as 0, 1, 3, 2, 6, 7, and 5.

Uses for the Walsh-Hadamard transform include screening, power spectrum assessment, voice processing, and image processing. Spread-spectrum assessment and bandwidth retention needs can be significantly reduced thanks to it. The Walsh-Hadamard transform does have a faster variant called the fast WH transform (FWHT), just like the FFT. Moreover, the FWHT seems to be quicker to compute and consumes less storage area than the FFT since it only utilizes actual subtractions and additions, whereas the FFT employs complicated values. Compared to the FFT, the FWHT can more correctly describe signals with severe discontinuities while utilizing less coefficients. As the FWHT and the reverse FWHT have been symmetric, they both employ the same mathematical procedures. Thus, this research employed Walsh-Hadamard transform for reducing PAPR. Moreover, table 1 shows the returns-sequence values of Walsh-Hadamard transform.

Wherein WAL (n, i) is a Walsh function and i = 0, 1,..., N - 1. The N components are split into two groups of N/2 components, as in the Cooley-Tukey method for the FFT, then joined employing a butterfly architecture to create the FWHT. The FWHT coefficients have been determined for images, in which the input has been generally a 2D signal, by first

**Table 1:** Walsh-Hadamard transform returns-sequence values.

| Order | Sequencing |
|---|---|
| 0 | 1 1 1 1 1 1 1 1 |
| 1 | 1 1 1 1 -1 -1-1-1 |
| 2 | 1 1 -1-1-1-1 1 1 |
| 3 | 1 1 -1-1 1 1 -1-1 |
| 4 | 1 -1-1 1 1-1-1 1 |
| 5 | 1-1 -1 1 -1 1 1 -1 |
| 6 | 1 -1 1 -1 -1 1 -1 1 |
| 7 | 1 -1 1 -1 1 -1 1 -1 |

assessing across the rows and then assessing down the columns. The ensuing FWHT for the subsequent straightforward signal reveals that x was produced employing Walsh functions with 0, 1, 3, and 6 sequence values, that represent the non-zero indexes of the modified x. The initial signal is recreated via the inverse FWHT.

x = [4 2 2 0 0 2 -2 0];

y = fwht(x);

⇒ x = 4 2 2 0 0 2 -2 0

⇒ y = 1 1 0 1 0 0 1 0

x1 = ifwht(y); x1 =4 2 2 0 0 2 -2 0

## Results and Discussion

For developing all the above programs, a higher configuration PC/laptop support with higher random-access memory and support of higher graphical processing unit with a central processing unit is required. For effective development, the OS processor must support data transmission speeds of 64 bits per second. Scientists and engineers may use the programming environment MATLAB® to evaluate, create, and test systems and technologies that will change the world. The proprietary multi-paradigm programming languages and computing environment called MATLAB were developed by The MathWorks Corporation. Using MATLAB, it's indeed able to manipulate matrices, visualize functions and data, execute algorithms, construct user interfaces, and link to other computer languages. The MATLAB system, a matrix-based dialect that enables the most intuitive representation of computer mathematics, seems to be the core of MATLAB.

The quantity of bit defects in a digital broadcast seems to be the quantity of bits, which were modified as an outcome of noise, disturbance, deformation, or bit synchronization issues that were received as part of a data movement over a communication network. The amount of bit errors split by the overall number of bits transported throughout the course of an investigation is known as the BER. A unit less quantity was BER. It seems to be a crucial variable for describing the performance of data channels. While transferring information via a wireless radio/link or cable telecommunication connection from one spot to another, faults in crucial variables can be seen at the receiver side. BER is computed by equation 16.

$$BER = N_B(E) \Big/ T_N(TB) \tag{16}$$

Where, $T_N(TB)$ indicates total no. of transferred bits and $N_B(E)$ indicates no. of bits in error. The attained PAPR with STFCC and without STFCC is shown in figure 5.

By using STFCC the above X axis (PAPR) and Y axis (BER) have been plotted and results obtained successfully. In output, there exist sudden decreases of PAPR when we apply STF with conjugate cancellation whereas, without conjugate cancellation STF, original PAPR is higher. The Obtained original PAPR is 0.5856 decibels, STFCC PAPR is 0.3861 decibels and Efficiency is 34.0723 in bits/s/Hz. Moreover, the attained PAPR distribution at when N = 128 is shown in figure 6.

## Conclusion

The development and comparison of the 2x1 networks SF-OFDM, STF-OFDM, STFCC-OFDM, and WHSTFCC-OFDM have been presented in this study. Whenever the standardized Doppler frequency $E_d$, more precisely while the OFDM block length n, was short, the STF-OFDM network performs greater in terms of BER compared to SF-OFDM network in the TU region. The pre-coded 2x1-WH-STFCC-OFDM does have the lowest BER, followed in order by the STF-OFDM and the STFCC-OFDM. Also, the designs and comparisons of 2x2-STFCC-OFDM and WH-STFCC-OFDM have been made. In the frequency-selective fading network, notably in the tiny $E_d$ and high $E_b/N_o$, the novel pre-coded 2x2- and 2x1-WHSTFCC-OFDM networks significantly outperform the 2x2 and 2x1 STFCC-OFDM strategies in terms of BER efficiency. This was because, inside the OFDM blocks, WHT offers significant

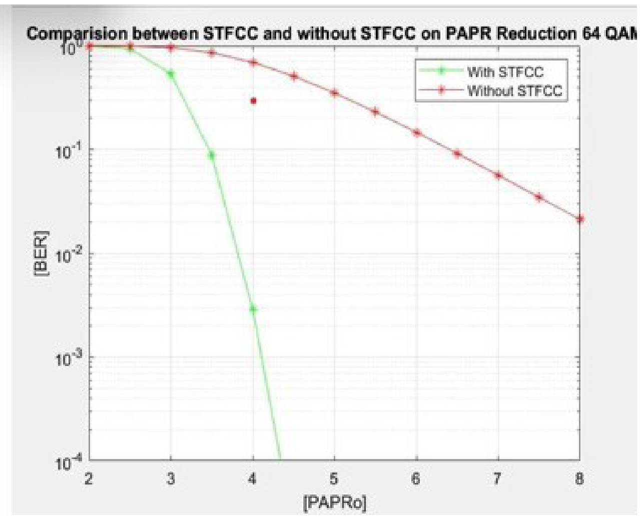

**Figure 5:** PAPR with STFCC and without STFCC.

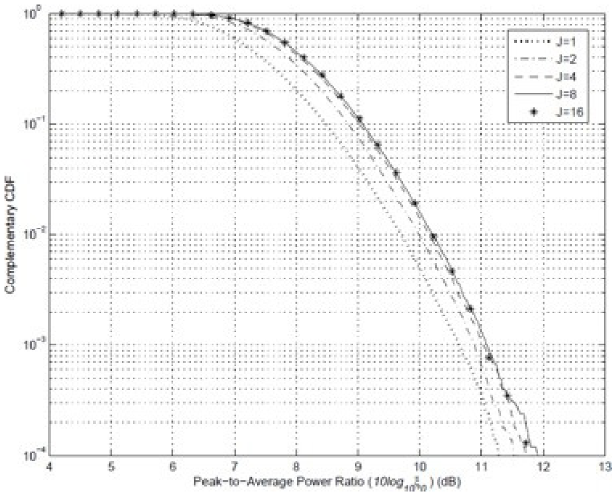

**Figure 6:** PAPR distribution for different oversampling factors, N = 128.

subcarrier variety whereas CC method offers ICI cancellation. As a result, the frequency-selected fading network achieves a substantially greater SNR and variety benefit. However, this research implemented the STFCC in 64-QAM and reduces the bit error rate and PAPR and increases the Spectral efficiency. Further, the aim is to develop a 128-QAM in the STF architecture with CC.

The use of nanotechnology in MIMO-OFDM technology has been gaining attention in recent years. The integration of nanotechnology with MIMO-OFDM can lead to the development of compact and highly efficient wireless communication systems. One of the potential applications of nano MIMO-OFDM technology is in the development of small-sized wireless communication devices that can operate in environments with high interference and limited bandwidth. This technology can enable the development of devices with multiple antennas, which can significantly improve the data rates and reliability of wireless communication systems. Another potential application of nano MIMO-OFDM technology is in the development of high-performance sensor networks. By using multiple antennas and advanced signal processing techniques, this technology can enable the development of highly efficient sensor networks that can operate in harsh environments and provide real-time data transmission and analysis. The use of nanomaterials in MIMO-OFDM technology can also lead to the development of highly efficient and low-cost devices.

Also, this aims to increase spectral efficiency furthermore and to decrease the original PAPR. In Future even when the data generations transition from 4G to 5G, 5G to 6G….so on. There is a need to make the signal better. In summary, the integration of nanotechnology with MIMO-OFDM technology has the potential to revolutionize the wireless communication industry by enabling the development of highly efficient and compact devices that can operate in challenging environments.

## Acknowledgements

None.

## Conflict of Interest

None.

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