



Bandwidth Channel Efficient MIMO Based OQAM-modulated FBMC Using Hadamard and Space-Time Transmission Schemes

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Abstract

*There is need for the optimal utilization of the available radio spectrum and the proper and efficient assignment of the time-frequency resource for the present and next generation wireless communication systems. Researches have been carried out to use the combined advantages of Offset Quadrature Amplitude Modulated Filter Bank Multicarrier (FBMC-OQAM) data symbols alongside MIMO systems but have suffered some limitations in the results due to choices in tools, approaches and techniques adopted. The primary limitation is that the researchers did not optimally use the collective advantages of the efficient bandwidth channel capacity of MIMO and the spectral efficiency of OQAM-modulated FBMC. This research work however, exploits the attributes of both systems for the MIMO transmission of OQAM-modulated data symbols over up to 8×8 antennas. OQAM modulation disorients orthogonality in the imaginary domain of the data symbol was restored using Hadamard coding scheme. The imaginary intrinsic interference at the receiver side was cancelled using space-time transmission scheme (STTC). The evaluated bandwidth channel capacity of the system when compared with that of the work of Nissel *et al.*, (2017), presented an enhanced channel capacity of 22.7%. The analysis and simulations were carried out in MATLAB R2018a.*

Keywords: FBMC, FBMC-OQAM, FFT, Hadamard scheme, IFFT, MIMO, PHYDYAS filter, STTS.

1.0 Introduction

There is need for an efficient transmission and reception of data in wireless communication systems in order to efficiently utilize the available radio spectrum in the sub-six Giga Hertz, with the aim of achieving bandwidth channel efficient wireless transmission. This would be achieved by optimally utilizing the real and also the imaginary parts of a complex data symbols (Abdoli *et al.*, 2015). Offset Quadrature Amplitude Modulated Filter Bank Multicarrier (FBMC-OQAM) has a better spectral efficiency and data rate due to its marginal out of bound emissions (OOBE) (Nissel, Blumenstein, *et al.*, 2017). The OQAM modulation comes about by the offset modulation of the FBMC data symbol at one-half the period between imaginary and real parts of the data symbols (Siohan *et al.*, 2002). With such a modulation technique, channel capacity is gained while maintaining the available radio spectrum in the operational frequency band (Farhang *et al.*, 2014). Also, OQAM modulation of FBMC data symbols offers considerable degree of immunity to multipath fading (Moles-Cases *et al.*, 2017). These advantageous functionalities of OQAM on FBMC however come with disorienting the orthogonality of the imaginary components (Nissel, Blumenstein, *et al.*, 2017) rendering the complex data symbols orthogonal in the real field only. Bi-orthogonality was however restored using Hadamard scheme (Halmi *et al.*, 2015).

These superior advantages among others, make FBMC-OQAM suitable in the wireless communication systems of present times and beyond (Chaudhary & Patil, 2012). The sensitivity of FBMC-OQAM to imaginary intrinsic interference is as the result of the intersection of the filter response immediately positioned sub-channels (Ja'afar *et al.*, 2019), and as such, FBMC-OQAM is less harmonic with MIMO (Nissel & Rupp, 2016). In the process of restoring bi-orthogonality of the complex data symbols using Hadamard scheme, spreading the data symbols in time-frequency domain in the operational band of sub-six Giga Hertz reduced the imaginary intrinsic interference (Ja'afar



et al., 2019). The symphony of FBMC-OQAM with conventional MIMO systems of 2×2 antennas for an efficient transmission was enhanced using Space-Time Block Coding (STBC). For a MIMO system having larger number of antennas up to a massive MIMO, Space-Time Transmission Scheme (STTC) was used. Thus, Space-Time transmission Scheme (STTS) specifically meant for MIMO was used to obtain a desired quality of service in terms of bandwidth channel capacity with low decoding complexity (Arti, 2018). Transmitting OQAM-modulated FBMC data symbols over a MIMO system improves the performance of the system and throughput (Harbi & Burr, 2018). This research used Hadamard scheme and STTS to enhance the bandwidth channel capacity of a MIMO based FBMC-OQAM system.

2.0 Related Works

Zakaria & Le-Ruyet, (2012) mitigated the intrinsic interference in FBMC scheme which eased its applicability to conventional MIMO system by means of extending onto FBMC the advantages of spatial diversity transmission schemes for MIMO based OFDM. This was achieved by developing a novel FFT-FBMC scheme, a scheme established on the concept of FFT. The developed system was however spectrally deficient due to interferences caused by the cyclic prefix inserted between adjacent subcarriers.

Farhang *et al.*, (2014) reviewed on the compatibility of FBMC on MIMO with respect to bandwidth and capacity of a multiuser network. The review established the spectral superiority of MIMO based FBMC over OFDM with respect to computational simplicity, bandwidth efficiency, and system latency. This however is simply a review and was specifically for FBMC and not FBMC-OQAM and imaginary intrinsic interference was left out.

By designing a transceiver with properly localized prototype filters in time and frequency, **Zakaria, (2014)** provided a way for annulling interference and OOB in MIMO based FBMC system. Spectral efficiency of the system was enhanced significantly but at the detriment of orthogonality

Meng *et al.*, (2015) developed STBC for the omnidirectional broadcasting of the common information in a MIMO downlink via simplified computations. The research eased coverage of information at any time in a MIMO system omnidirectionally. The high demand of STBCs for huge coherence time made the developed STBC unsuitable for effective transmission over MIMO system and spatial diversity was attained partially.

Chaudhary *et al.*, (2016) looked into MIMO with respect capacitive functionality of multicarrier modulation techniques purposely to improve the functionality of the system. The multicarrier data symbols were efficaciously transmitted over a conventional MIMO channel. The research was however bounded to conventional MIMO and was not specific on the type of multicarrier modulation techniques.

Daniel *et al.*, (2017) investigated on improving the performance of wireless MIMO in terms of data rate, spectral efficiency, bandwidth channel capacity and signal coverage using STBC. The STBC was employed using Alamouti scheme for conventional MIMO system to obtain full diversity. The research however was not applicable to higher number of antennas and it left out the issue of orthogonality.

Nissel *et al.*, (2017) used Hadamard scheme to ease the computation involved in restoring bi-orthogonality and to annul intrinsic imaginary interference in conventional MIMO based FBMC-OQAM. Due to the huge channel coherence time requirement of STBC, the adopted approach was unsuitable for MIMO with higher number of antennas. The approach also tainted the system with inter-channel interference. As such, the need for further signal processing made the system computationally complex.

Arti, (2018) developed an STTS to suit MIMO systems for combat the deficiency posed by STBC. Through a low complexity decoding, the developed scheme improved the compatibility of MIMO with FBMC thereby enabling the



transmission of huge amount of data. However, the research was specifically for the development of the scheme leaving out issues such as orthogonality.

The reviewed literatures have presented interesting results relevant to this research. Shortcomings of the researches are one or more of computational complexity and bandwidth underutilization. This research however in the best way possible, optimally utilized the advantages of MIMO and FBMC-OAQM in order to obtain a bandwidth channel efficient system that addresses these two limitations.

2.1 Multicarrier Schemes

Multicarrier modulation is one which the data signal is divided into a number of parts in order to convey on distinct carrier-signals that have narrow bandwidth (Malla & Joshi, 2014). Multicarrier modulation is resistive of fading due to multipath, interference from neighboring symbols (Inter Symbol Interference, ISI), and noise to some extent (Malla & Joshi, 2014). The time continuous multicarrier signal is mathematically represented (Nissel, Zochmann, *et al.*, 2017) as follows:

$$x(t) = \sum_{k=1}^K \sum_{l=1}^L g_{l,k}(t) x_{l,k} \quad (1)$$

Where, $g_{l,k}(t)$ is the transmit basis pulse and $x_{l,k}$ is the data symbol at subcarrier position l and time position k .

There are numerous multicarrier modulation schemes but FBMC-OQAM is of better spectral efficiency and performances with respect to how dense are the symbols, localizing the time and the frequency, and orthogonality in both real and imaginary domains (Ja'afar *et al.*, 2020).

2.1.1 FBMC-OQAM

There are numerous multicarrier modulation schemes but FBMC-OQAM is more spectrally efficient for its use of prototype filter to annul interferences from neighboring carriers and symbols, and also to ease localization of frequency and time (Ja'afar *et al.*, 2020). When the subcarriers of the complex FBMC data symbols are modulated at an offset which is a shift of one-half the period of the symbol in-between the real and imaginary parts, the FBMC data symbol is said to be OQAM-modulated, thus the FBMC-OQAM (Siohan *et al.*, 2002).

The transmit signal of OQAM-modulated FBMC is mathematically given (Rottenberg, 2018) as:

$$s(t) = \sum_{l=0}^{2L+1} \sum_{k=0}^{\infty} d_{l,k} p_{l,k}(t) \quad (2)$$

with,

$$p_{l,k}(t) = j^{l+k} p(t-kT) / 2 e^{j2\pi f \frac{1}{T}} \quad (3)$$

where,

$p_{l,k}(t)$ is the modulated prototype pulse of the OQAM symbol and $d_{l,k}$ is the complex OQAM data symbol at a position l of the subcarrier and at a position k of the multicarrier.

2.1.2 Hadamard Scheme

Hadamard coding scheme is one in which the code-words are made up by the rows of a Hadamard matrix (Cheraghchi *et al.*, 2013). A Hadamard matrix is an $n \times n$ matrix whose elements are only -1's and 1's, with every row of the rows



different from the other row in exactly $n/2$ places, making all the rows to have exactly $n/2$ 1's and $n/2$ -1's, except for one of the rows that is composed of completely -1's (Dostert, 2001). A Hadamard matrix has all its rows and columns mutually orthogonal. Hadamard matrix of size $n \times n$ is presented as (Malek, 2015):

$$\mathbf{H}\mathbf{H}^* = n\mathbf{I}_n \quad (4)$$

where \mathbf{I}_n is a size n identity matrix and \mathbf{H}^* is the conjugate complex of \mathbf{H} .

Length of a Hadamard matrix represents the code length. Orthogonality in Hadamard matrix is perfected by the independency of the codes. A simple 4×4 Hadamard matrix is as follows (Ja'afar *et al.*, 2019):

$$\mathbf{H}_4 = \begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{pmatrix} \quad (5)$$

2.1.3 The System Model of MIMO

A MIMO system having (n_T) transmission antennas and (n_R) reception antennas during every symbol time slot, T_s , has its transmit signal given by $n_T \times 1$ column vector, \mathbf{X} . The vector coefficients of \mathbf{X} are x_i defined at $i = 1, \dots, n_T$, and is also the signal conveyed at the i^{th} transmit antenna within one symbol time slot. Likewise, the received signal is denoted by $n_R \times 1$ column vector of \mathbf{y} with a vector coefficient y_j defined at $j = 1, \dots, n_R$, received at the j^{th} receive antenna. The vector \mathbf{X} of the signal, the vector \mathbf{n} of the noise and the matrix \mathbf{H} of the channel are decoded by the receiver. Such a MIMO has a system model as (Shubhangi & Ashwini, 2015):

$$\mathbf{Y} = \mathbf{H}\mathbf{x} + \mathbf{n} \quad (6)$$

where the received component vector is \mathbf{Y} , matrix of the channel is denoted by \mathbf{H} , vector of the transmit component is given by \mathbf{X} , while \mathbf{n} represent vector of the noise.

\mathbf{H} which is the matrix of the channel, has members, h_{ij} which are named channel coefficients between the j^{th} receive antenna and the i^{th} transmit antenna. At the receiver side, noise is represented by $n_R \times 1$ column vector, and having the same variance power, σ^2 . In a situation whereby the mean of the entire receive power by each antenna (P_{rj}) at the receiver side equals that of the antennas at the transmitter side n_T , then SINR (ρ) for each of the antennas at the receiver side is given as (Shubhangi & Ashwini, 2015):

$$\rho = \frac{P}{\sigma^2} \quad (7)$$

where, P is a summative power of the conveyed signals within the time slot T_s , and the variance power is denoted by σ^2 which is equal to $[\mathbf{H}^H \mathbf{H}]^{-1}$.

MIMO Channel Capacity:



Channel capacity according to Shannon is the mean of the uttermost common data taken over every channel state. A MIMO system has it's channel capacity as follows (Loyka, 2001) :

$$C = B \log_2[\det(\mathbf{I} + \frac{\rho}{n} \mathbf{H}\mathbf{H}^*)] \quad (8)$$

where ρ is the SNR , B is the bandwidth, \mathbf{I} is identity matrix of size n and \mathbf{H}^* is the conjugate transpose of \mathbf{H} .

2.1.4 Space Time Transmission Scheme for MIMO (STTS)

The transmission scheme for MIMO (STTS) is matrix based scheme that detects and corrects error just like STBC such that reliability is attained through the transmission of multiple copies of a signal (Sandhu *et al.*, 2003). Unlike STBC in which columns of the matrix represent the data transmission within a time slot while the time slot is represented by rows of the matrix (SD & Sujatha, 2012), the notation is however reserved in STTS (Arti, 2018).

For a MIMO system of equation (6), in a situation where the MIMO is having a huge antenna count N such that N_t denotes the number of transmit antenna while N_r denotes the receive antennas, the number of time slots required to convey the N complex data symbols is $\frac{N}{2}$. The vector of the transmit data, $X \in \mathbb{C}^{N \times N/2}$ of the STTS (with C as a set of complex numbers) so that a data of each antenna is conveyed with its sign flipped in the second time frame excluding the data symbols of the two former sequentially positioned antennas as follows (Arti, 2018):

$$x = \begin{pmatrix} x_1 & x_1 & -x_1 & \cdots & \pm x_1 \\ x_2 & x_2 & -x_2 & \cdots & \pm x_2 \\ x_3 & -x_3 & -x_3 & \cdots & \pm x_3 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_N & -x_N & x_N & \cdots & \mp x_N \end{pmatrix} \quad (9)$$

The transmit antennas are represented by rows of the matrix while the time interval is represented by the columns. The vector, Y of the receive components, the matrix of the channel, H , and the vector of the noise, n of the transmission model are interpreted viz (Arti, 2018):

$$Y = [y_k] \quad (10)$$

with, $y \in \mathbb{C}^{1 \times N/2}$, for $k \in (1, \dots, N/2..$

$$H = [h_i] \quad (11)$$

with, $h \in \mathbb{C}^{1 \times N}$, for $i \in (1, \dots, N)$.

$$\mathbf{n} = [n_j] \quad (12)$$

with, $n \in \mathbb{C}^{1 \times N/2}$, for $j \in (1, \dots, N/2)$.



3.0 Materials and Methods

This section presents the methods adopted, and an explicit analytical and computational processes employed in achieving the set objectives. The objectives involve the employment of Hadamard scheme to restore orthogonality in the imaginary field of OQAM-modulated FBMC symbols, using SSTC to annul imaginary intrinsic interference and transmitting the data symbols over a MIMO system of 8×8 antennas, and finally evaluating the performance of the developed system with respect to the work of Nissel *et al.*, (2017) in terms of bandwidth channel capacity.

The methodology adopted in actualizing the set objectives is as follows:

- Restoring (Bi)-Orthogonality of OQAM-modulated FBMC using Hadamard scheme.
- Employing STTS to cancel the imaginary intrinsic interference of the FBMC-OQAM system and for transmission over a MIMO system.
- Evaluating the channel capacity of the developed system using the Shannon Formula and comparing with the work of Nissel *et al.*, (2017).

3.1 Restoring (Bi)-Orthogonality of OQAM-modulated FBMC using Hadamard scheme.

With the set up parameters of Table 1, (Nissel *et al.*, 2017) in a Raleigh fading channel infected with a Gaussian Noise (AWGN), and using a PHYDYAS filter, and in the presence of, a multicarrier signal source of equation (13) (Ja'afar *et al.*, 2020) was used to develop an FBMC-OQAM data model in matrix form of equation (14).

Table 1: Setup Parameters for restoring Bi-orthogonality in FBMC-OQAM (Nissel *et al.*, 2017)

S/ N	Parameter	Numerical Value	Comment
1	Subcarriers (L)	24	Number of subcarriers for each symbol in FBMC
2	Symbols (K)	2	From 2 symbols up to a limit of 8 symbols for the conventional MIMO
3	Simulation Iteration	200	Any number of iteration will do
4	Subcarrier Spacing (F)	15e3 (Hz)	LTE subcarrier spacing
5	Sampling Rate	15e3*L*14 (S/s)	Over sampled by 14 which corresponds to CP length of OFDM

$$y(t) = \sum_{n=0}^{N-1} \rho_n e^{j\phi_n} x(t - \tau_n) \quad (13)$$

with, $e^{j\phi_n}$ as the amplitude complex exponential factor, ρ_n as the differential amplitude, τ_n is the n^{th} differential time.

$$y = Q^H H P_{D+n} \quad (14)$$

with n as a Gaussian distributed noise, D is the stack of complex transmit symbols, P is a stack of the modulated prototype pulse, H is time-variant convolution matrix of the signal impulse response h , Q^H is the Hermitian of Q , whose conjugate of its complex entries is equal to the transpose of its complex conjugate.



In an AWGN channel, the impulse response H of the system is an identity matrix I_n (Ja'afar *et al.*, 2020) whereby bi-orthogonality was restored by Hadamard coding scheme of the transmit signal of equation (14). Equation (14) then transforms into the following (Ja'afar *et al.*, 2020):

$$y = Q^H P D + n \quad (15)$$

The complex valued transmit-data symbols were pre-coded with a Hadamard matrix C written as a pulse vector $C_{l,k} \in \mathbb{C}^{1 \times LK}$ which was stacked as follows:

$$C = (c_{1,1} \dots c_{N,1} \ , \ c_{1,LK} \dots c_{N,LK}) \quad (16)$$

The stack of the coded complex transmits symbols D of equation (14) transformed into the following:

$$D = C D^c \quad (17)$$

By projecting H onto the received symbols y , and With P equals Q in AWGN channel, the received coded symbol $y^c \in \mathbb{C}^{1 \times LK}$, was obtained.

$$y^c = C^H Q^H Q C D^c + n \quad (18)$$

The terms $C^H Q^H Q C$ is an identity matrix which ascertains the orthogonality of the system as established in equation (8) (Malek, 2015). Diagonality between the subcarrier position and the multicarrier position when plotted against each other confirms orthogonality of the data symbols. The plot is given in figure 1 (Ja'afar *et al.*, 2020).

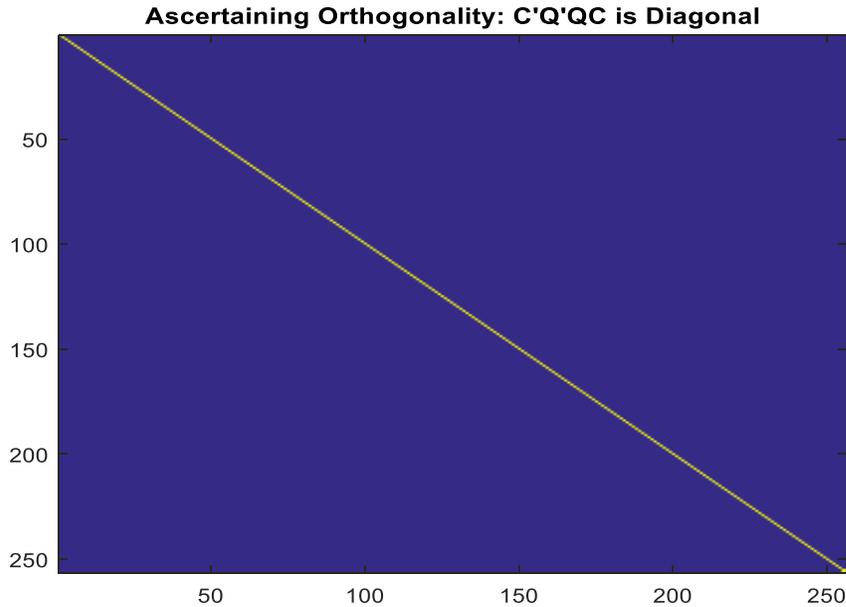


Figure 1: Restored Orthogonality Ascertained by diagonal $C^H Q^H Q C$ (Ja'afar *et al.*, 2020)



3.2 Employing STTS to cancel the imaginary interference and for transmission over a MIMO system.

For a MIMO of $N \times N$ antennas expected to transmit N symbols, $\frac{N}{2}$ time-slots are required. The matrix representation of the STTS was given in equation (9) where x_i is a complex symbol with $i \in \{1, 2, \dots, 64\}$. In the presence of Gaussian distributed noise, n , all over the channel, a stack of the noise $\mathbf{n}_{1 \times N/2} \in \mathbb{C}^{1 \times N/2}$ and channel coefficients $\mathbf{h}_{1 \times N} \in \mathbb{C}^{1 \times N}$ are as follows:

$$\mathbf{N} = (n_1 \quad n_2 \quad \dots \quad n_{N/2}) \quad (19)$$

$$\mathbf{H} = (h_1 \quad h_2 \quad \dots \quad h_N) \quad (20)$$

Thus, a stack of the received coded symbols of equation (18) is as follows:

$$\mathbf{Y} = \mathbf{H}\mathbf{X} + \mathbf{N} \quad (21)$$

such that \mathbf{Y} is a stack of received coded symbols $\mathbf{y}_k \in \mathbb{C}^{N \times 1}$ with $k \in \{1, 2, \dots, N/2\}$, thus:

$$\mathbf{Y} = (y_1 \quad y_2 \quad \dots \quad y_{N/2}) \quad (22)$$

Whose coefficients y_k are as follows:

$$y_k = \sum_{i=1}^k h_i x_i - \sum_{i=k+1}^N h_i x_i + n_k \quad (23)$$

where $k \in \{1, 2, \dots, N/2\}$ with The highest entry of coefficient y_k as $N/2$.

$$y_{N/2} = \sum_{i=1}^{N/2} h_i x_i - \sum_{i=N/2+1}^N h_i x_i + n_{N/2} \quad (24)$$

$$y_{N/2-1} = \sum_{i=1}^{N/2-1} h_i x_i - \sum_{i=N/2+1}^N h_i x_i + n_{N/2-1} \quad (25)$$

By collecting equations (24) and (25), the following was obtained:

$$\frac{y_{N/2-1} + y_{N/2}}{2} = h_{N/2-1} x_{N/2-1} + h_{N/2} x_{N/2} + \frac{n_{N/2} + n_{N/2-1}}{2} \quad (26)$$

$x_{N/2-1}$ was obtained by annulling $x_{N/2}$ and vice versa through multiplication with the left null of the h components which are Hermitian matrices as follows:

$$B_i = (\text{null}(h_i^H))^H \quad (27)$$



where the B components are the left nulls of the h components such that:

$$B_i h_i = 0 \quad (28)$$

Thus, equation (26) transformed into the following:

$$\frac{y_{i-1} + y_i}{2} = h_i x_i + w \quad (29)$$

The received component Y which is a stack of y_i for $i \in \{1, 2, \dots, N/2\}$ becomes the following:

$$\mathbf{Y} = 2\mathbf{H}\mathbf{x} + \mathbf{w} \quad (30)$$

where w is the Gaussian distributed noise which have a null mean with a variance of unity.

3.3 Evaluating the channel capacity of the developed system using the Shannon Formula and comparing with the work of Nissel *et al.*, (2017).

The capacity in bandwidth of the developed system's channel was determined using the Shannon formula of equation (8). The developed system of equation (30) whose Gaussian distributed noise is having a null mean and a variance of unity, rendered the SINR of equation (7) to be absolutely the transmit power P . Hence channel capacity of the developed system is as follows:

$$C = B \log_2[\det(\mathbf{I} + 2\mathbf{P}\mathbf{H}\mathbf{H}^*)] \quad (31)$$

where, B is the bandwidth, I is the $n \times n$ identity matrix and H^* is the transpose conjugate of H .

The multiplicative operation of a square matrix with its transpose conjugate is an identity matrix I . Hence,

$$C = B \log_2(1 + 2P) \quad (32)$$

A plot of the channel capacity of the developed system of equation (32) is presented in Figure 2.

For the work of Nissel *et al.*, (2017), the number of data symbols $g_i(kK)$ injected into the IFFT using a Hermit filter is equal to the number of multicarrier symbols and Hadamard scheme was employed to equation (14) to restore (Bi)-Orthogonality whereby the component $\mathbf{C}^H \mathbf{Q}^H \mathbf{Q} \mathbf{C}$ of equation (18) is an identity matrix of size 2×2 . STBC was employed to equation (14) for the transmission of the data symbols to obtain the received component of equation (6). This was done by transmitting x_i over the conventional MIMO system. The system has a Gaussian distributed noise which has a null mean and a variance of unity. Hence, by using the Shannon formula of equation (8), the capacity of the channel bandwidth is as follows:

$$C = B \log_2(1 + P) \quad (33)$$

A plot of the channel capacity of the work of Nissel *et al.*, (2017) as presented in equation 33 is presented in Figure 3.

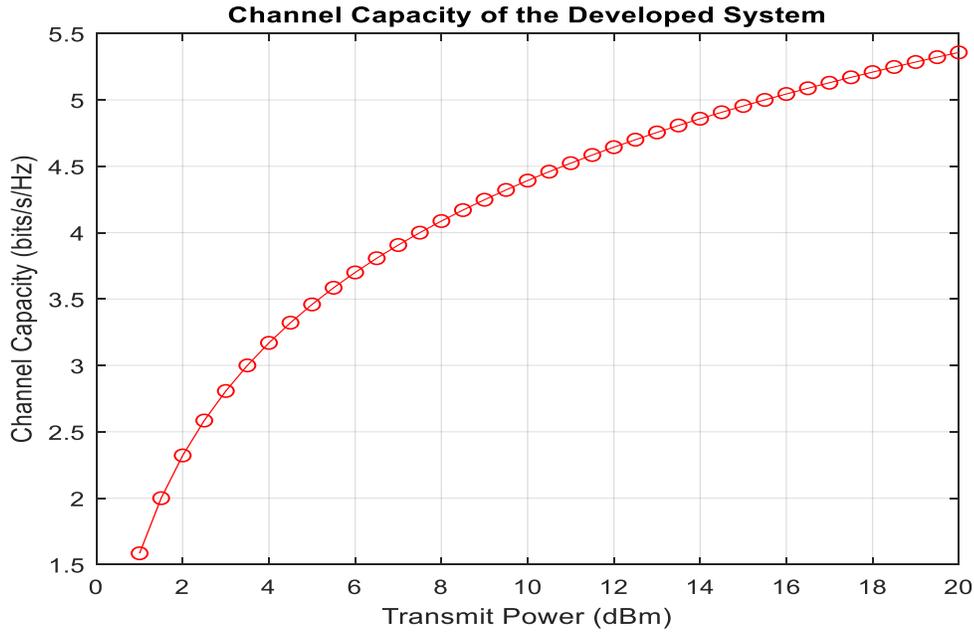


Figure 2: Channel Capacity of the Developed System.

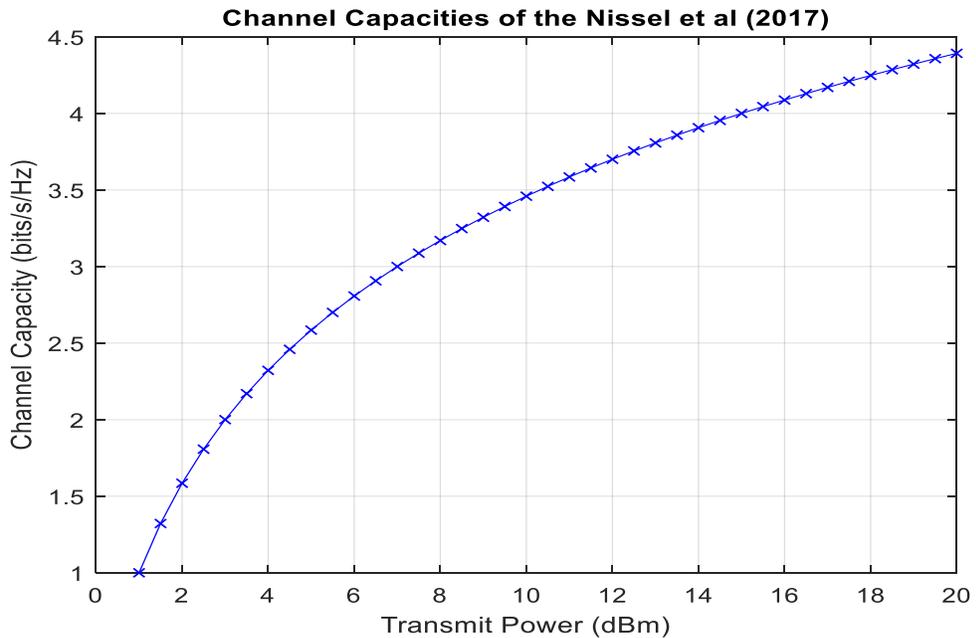


Figure 3: Channel Capacity of the Work of Nissel *et al.* (2017).

4.0 Results and Discussion

The bandwidth channel capacity of the developed system was compared with the system of Nissel *et al.*, (2017) for the purpose of validation. A comparative plot of both works was plotted and presented in Figure 4.

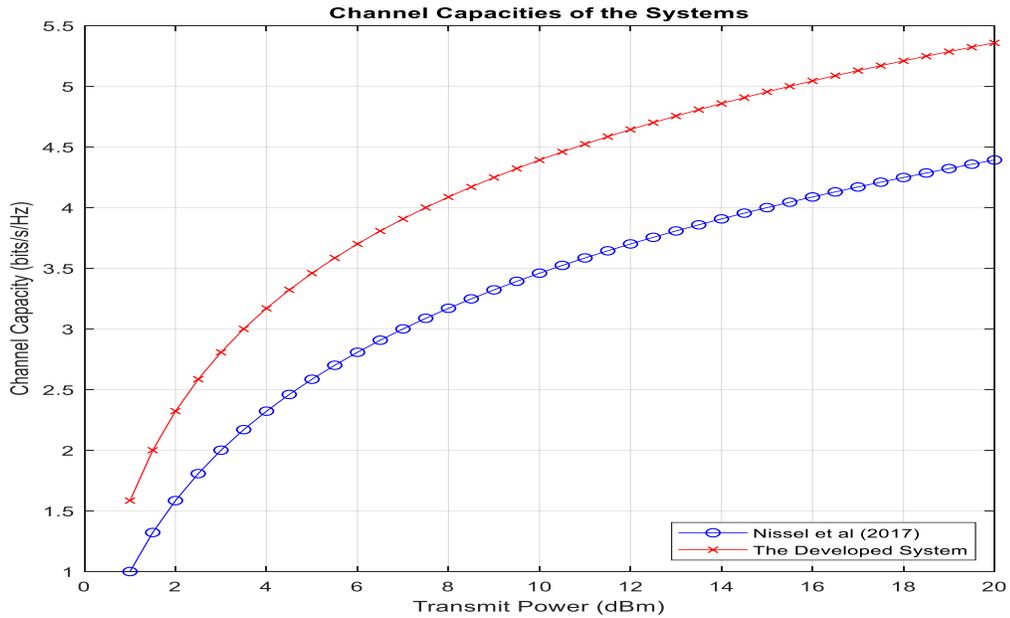


Figure 4: A Comparative plot of the Channel Capacity of the Developed system and that of Nissel *et al.*, (2017)

For a constant bandwidth, it could be seen from Figure 4 how the channel capacities at 20dBm transmit power of the developed system and the system of Nissel *et al.* (2017) are 5.4b/s/Hz and 4.4b/s/Hz respectively. This indicates 1.0b/s/Hz or 22.7% increment in the channel capacity of the developed system as compared with the system of Nissel *et al.* (2017). If the work of Nissel *et al.*, (2017) is set to have 100% bandwidth channel efficiency, then the developed system having an improvement of 22.7% will relatively be having 122.7%. The result obtained as compared with the system of Nissel *et al.* (2017) is summarized in table 2.

Table 2: Summary of the Result

Performance Metric	Developed System	Nissel <i>et al.</i> (2017)	Percentage Improvement
Channel Capacity	122.7%	100%	22.7%

5.0 Conclusion

Several researches have been carried out to mitigate error and interference and also to enhance spectral efficiency and channel capacity in the transmission of OQAM-modulated FBMC data symbols over MIMO. The primary difference of this research with previous researches, especially the work of Nissel *et al.*, (2017) is the choice of filter and the choice of MIMO transmission scheme. The transmission scheme adopted by the previous researches which is STBC, requires massive channel coherence time and thus, impractical for a number of antennas beyond the conventional. The choice of filter for this research (PHYDYAS filter) was informed by how dense energy is in the time domain, how efficient is the mitigation of inter carrier interference with respect to the speed of decay is in the frequency domain, and lastly how flexible the pliable the filter is to overlapping factor. With these choices, this research was able to come up with an efficient MIMO based filter bank multicarrier using Hadamard and space-time transmission schemes. The significant result improvement offered by this research work when compared with the work of Nissel *et al.*, (2017) is a 22.7% improvement in the bandwidth channel capacity.



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