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| RESEARCH ARTICLE

Block Diagonalization in the 5G SA Network

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| ABSTRACT

In this paper, we did programming regarding the Block diagonalization technology in the 5G standalone SA network, in this program, we have created a 5G site with 16 antennas(minimum of Massive MIMO) and 4 active users equipped of 4 antennas, this system is called Multi Users Massive MIMO system, the link that was chosen is the downlink,we have calculated the maximum throughput in the 5G downlink where we have obained a value of 1673864 b/ms, this value is divided by the number of Massive MIMO layers which worth 16 to get a transport block size of 104616 b/ms (no Cyclic redundancy check CRC). The Block Error rate BLER is null (no detection of errors in reception) because we are in the case of no crc and no channel coding (uncoded transmission), the signal of each user among 4 to be transmitted consists of 4 vectors, each vector has a length of 52308 that corresponds to the number of symbols which are the outputs of Quadrature Phase Shift Keying QPSK Mapping Operation. The received signal at each user equipment UE has a form which can be represented by the multiplication of preconding matrix of this UE with the channel matrix between this UE and the 5G site plus the noise received at the antennas of this UE. the results show that the product of channel gain between UE and the 5G site(known in emission) with the precoding matrix of the other UE gives a matrix which composes of imaginary elements each of which has a real part and imaginary part which both tend to zero(the inter users interferences IUI is canceled). The results show also that when the Signal to Noise Ratio SNR increases(several transmissions) the Bit Error Rate decreases.

| KEYWORDS

5G, NR, QPSK, TBS, CRC, BLER, BD, MASSIVE MIMO, IUI, Broadcast Channel, ZF Equalizer

| ARTICLE INFORMATION

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1. Introduction

The Block diagonalization BD is a technology which allows to cancel the inter user interferences in emission. The eNB (4G site) can transmit the physical downlink shared channel PDSCH with the code rate (MCS) that can successfully decoded by UE (i.e, causing no CRC/no BLER) [Sharetechnote, n.d]. In recent years,researchers have been based on the study of MIMO system. Recently,researchers will study Massive MIMO where the number of antennas increases at the transmitter level or at the receiver level compared to the number of antennas at the transmitter or receiver known in MIMO system. In this article entitled BLOCK DIAGONALIZATION PRECODING FOR MULTIUSER-MIMO DOWNLINK CHANNEL [Nur Asniffah, 2016], they have worked with a number of transmitting antennas which varies between 4 up to 10 and with a number of receiving antennas between 2 up to 5. In our article we have worked with 16 transmitting antennas (minimum of Massive MIMO) and 4 receiving antennas at each receiver. Even,the radio parameters such as bandwidth, spectrum and throughput are increased by respecting the standards of 5G. The problem we want to solve is to find algorithms that can cancel the interference between users at the transmitter level in 5G SA network that consist of the 5G core network and a NR Massive MIMO site equipped with 16 transmitting antennas that operates in a high frequency range in GHZ(higher-band Radio Access Network RAN 3.5, 28 GHZ) with a bandwidth of 100 MHZ and 4 active users positionned in the cell covered by the 5G site (each UE is equipped with 4 receiving antennas). The solution is to create using MATLAB software a *Hudltilde* matrix such that the product of this matrix by another user precoding matrix is null. In this technology of BD,the received signal at each user equipment UE has a form of the product of the channel gain between this user equipment UE and the 5G site with his precoding matrix plus the received noise at the antennas of this user,an ZF equalizer is neccessary in reception for the signal detection of this user equipement UE (i.e, the multiplication of this ZF equalizer by the received signal at UE). With this type of transmission (uncoded transmission), there is no errors detection and errors correction,so the BER is calculated only to compare the binary message in emission (before QPSK mapping) and the binary message in receptions (after QPSK demapping). The rest of this paper consists of: an section on 5G New Radio (NR) Throughput,an section on 5G SA Network and The BD algorithms in the 5G SA Network,an section on the results and discussion of our program execution and an conclusion.

2. Literature Review

The book entitled MIMO-OFDM WIRELESS COMMUNICATIONS WITH MATLAB contributed to my research by making me understand the technology of block diagonalization in MIMO system.

3. Methodology

According to 3GPP TS 38.306, the approximate maximum data transfer rate in 5G downlink is calculated in Mbps using the following equation [3].

$$T = 10^{-6} \times \sum_{j=1}^{J} \left\{ \begin{matrix} \left(v_{Layers}^{(j)} \times Q_m^{(j)} \times f^{(j)} \times R_{maxim} \right) \\ \times \left(\frac{N_{PRB}^{BW(j),u} \times 12}{T_s^u} \times \left(1 - OH^{(j)}\right) \right) \end{matrix} \right\} \quad (1)$$

This equation has different parameters and the details of each one are as below: J is the number of aggregated components carriers in a band or band combination, in 5G NR, the maximum number of CC is 16 components carriers, $v_L^{(j)}$ represents the maximum number of MIMO layers. In MIMO, the number of layers is very similar to the term stream and also the number of the layer can't be more than the antennas number. $v_L^{(j)}$ (maximum value) = 8 per user in DL and 4 in UL, $f^{(j)}$ Scaling factor, is used for Medium and High mobility and should be configured per Carriers. It can take the following values 0.4, 0.75, 0.8 and 1, $N_{PRB}^{BW(j),u}$ represents the number of resource block pairs allocated PRBs per bandwidth per subcarrier spacing SCS, the maximum number of allocated PRBs per BW per SCS is specified in the table1:

TABLE 1
MAXIMUM TRANSMISSION BANDWIDTH CONFIGURATION

SCS, KHZ	5 MHZ	20 MHZ	25 MHZ	80 MHZ	100 MHZ
15	25	106	133	N/A	N/A
30	11	51	65	217	273
60	N/A	24	31	107	135

$Q_m^{(j)}$represents the maximum modulation order per Modulation Coding Scheme MCS. 5G supports different modulation types QPSK(2 bits per symbol), 16 Quadrature Amplitude Modulation QAM(4 bits per symbol), 64QAM(6 bits per symbol) and 256QAM(8 bits per symbol), R_{maxim} Value depends on the type of coding and for LDPC code maximum number is 948/1024 = 0.92578128(from 3GPP MCS index table), T_s^u represents the average Orthogonal Frequency Division Multiplexing (OFDM) symbol duration in a subframe for u(i) value for normal cyclic prefix, $u(i) = 0,1,2,3,4,5$. $OH^{(j)}$ represents the overhead for control channels. It can take the following values: Its value is 0.14 for FR1(FR1) for downlink, Its value is 0.18 for FR2(FR2) for downlink, Its value is 0.08 for FR1(FR1) for uplink, Its value is 0.10 for FR2(FR2) for uplink.

Let's assume that a network operator does have 100 MHz of spectrum for 5G NR. In this case, the DL maximum throughput FDD will be calculated as below: $j = 1$ as we have here one carrier component, $v_L^{(j)} = 16$ assuming 16 layer in DL, according to 38.214-Table 5.1.3.1-1, $MCS = 9$, $Q_m^{(j)} = 2$, $R_{maxim} = 0.6630859375$, $f^{(j)} = 1$ for FDD, BW: 100MHz FR1, $u = 1$ for subcarrier spacing 30 KHz, $N_{PRB}^{BW(j),u} = 273$, $T_s^u = \frac{10^{-3}}{14\times 2^u}$, $OH^{(j)} = 0.14$ for FR1 DL. DL Data Rate is equal to 1673864 b/ms.

5G in standalone mode, or SA, is a 5G that works all alone without relying on the existing 4G infrastructure[4]. So it involves : A 5G site uses 3.5GHZ to 28 GHZ spectrum. A core network 5G who receives data from the internet network (data sources). 5G smartphones compatible with SA. The figure 1 show the 5G SA architecture.

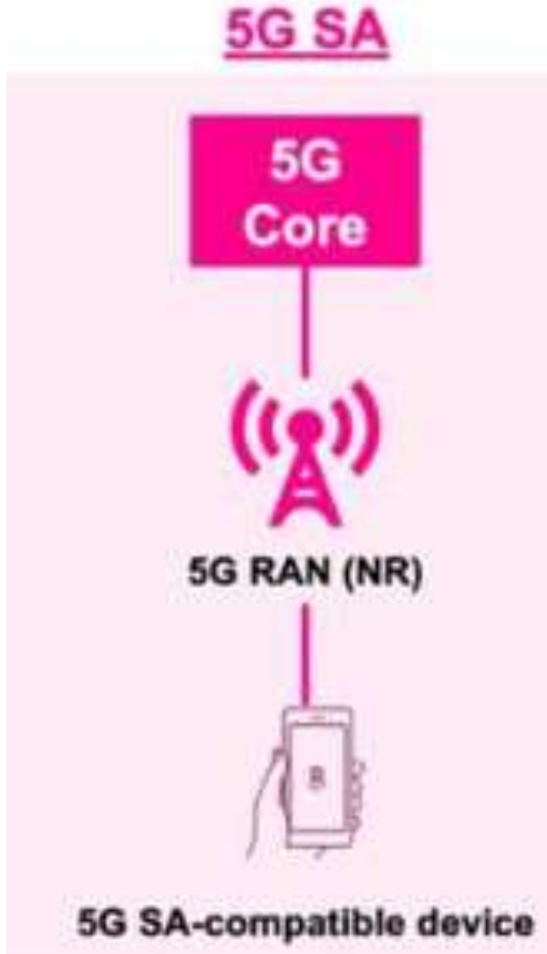

Fig. 1. 5G SA architecture, [5]

The block diagonalization Algorithms in the 5G DL can be represented by the following equations:

The number of transmitting antennas NT and the number of receiving antennas NR can be represented as follows:

$$NT = 16; \quad (2)$$

$$NR = 4; \quad (3)$$

The channel matrix between the UE1 and the 5G site H1 ∈ $C^{4\times16}$ (Broadcast Channel) can be represented[6] :

$$\left\{ \begin{matrix} H1 = (randn(NR, NT) + \\ 1i * randn(NR, NT))/sqrt(2); \end{matrix} \right\} \quad (4)$$

The channel matrix between the UE2 and the 5G site H2 ∈ $C^{4\times16}$ (Broadcast Channel) can be represented :

$$\left\{ \begin{matrix} H2 = (randn(NR, NT) + \\ 1i * randn(NR, NT))/sqrt(2); \end{matrix} \right\} \quad (5)$$

The channel matrix between the UE3 and the 5G site H3 ∈ $C^{4\times16}$ (Broadcast Channel) can be represented :

$$\left\{ \begin{matrix} H3 = (randn(NR, NT) + \\ 1i * randn(NR, NT))/sqrt(2); \end{matrix} \right\} \quad (6)$$

The channel matrix between the UE4 and the 5G site H4 ∈ $C^{4\times16}$ (Broadcast Channel) can be represented :

$$\left\{ \begin{matrix} H4 = (randn(NR, NT) + \\ 1i * randn(NR, NT))/sqrt(2); \end{matrix} \right\} \quad (7)$$

Let us build the following H1dltilde channel matrix that contains the channel gains of all users in exception for user 1 :

A = conj(H2); (8)

B = transpose(A); (9)

C = conj(H3); (10)

D = transpose(C); (11)

E = conj(H4); (12)

F = transpose(E); (13)

G = [B D F]; (14)

H = conj(G); (15)

MATRIX1 = transpose(H); (16)

H1dltilde = MATRIX1; (17)

Let us build the following H2dltilde channel matrix that contains the channel gains of all users in exception for user 2 :

K = conj(H1); (18)

L = transpose(K); (19)

M = conj(H3); (20)

N = transpose(M); (21)

O = conj(H4); (22)

P = transpose(O); (23)

Q = [L N P]; (24)

R = conj(Q); (25)

S = transpose(R); (26)

H2dltilde = S; (27)

Let us build the following H3dltilde channel matrix that contains the channel gains of all users in exception for user 3 :

T = conj(H1); (28)

U = transpose(T); (29)

V = conj(H2); (30)

W = transpose(V); (31)

X = conj(H4); (32)

Y = transpose(X); (33)

Z = [U W Y]; (34)

AA = conj(Z); (35)

BB = transpose(AA); (36)

H3dltilde = BB; (37)

Let us build the following H4dltilde channel matrix that contains the channel gains of all users in exception for user 4 :

CC = conj(H1); (38)

DD = transpose(CC); (39)

EE = conj(H2); (40)

FF = transpose(EE); (41)

GG = conj(H3); (42)

HH = transpose(GG); (43)

MATRIX2 = [DD FF HH]; (44)

JJ = conj(MATRIX2); (45)

KK = transpose(JJ); (46)

H4dltilde = KK; (47)

The Singular value decomposition (SVD) of H1dltilde is given as:

[U1,S1,V 1] = svd(H1dltilde); (48)

The precoding matrix for user 1,W1 ∈ $C^{16\times4}$ is written as :

W1 = V 1(:,13 : 16); (49)

The Singular value decomposition (SVD) of H2dltilde is given as :

[U2,S2,V 2] = svd(H2dltilde); (50)

The precoding matrix for user 2,W2 ∈ $C^{16\times4}$ is written as :

W2 = V 2(:,13 : 16); (51)

The The Singular value decomposition (SVD) of H3dltilde is given as :

[U3,S3,V 3] = svd(H3dltilde); (52)

The precoding matrix for user 3,W3 ∈ $C^{16\times4}$ is written as :

W3 = V 3(:,13 : 16); (53)

The Singular value decomposition (SVD) of H4dltilde is given as :

[U4,S4,V 4] = svd(H4dltilde); (54)

The precoding matrix for user 4,W4 ∈ $C^{16\times4}$ is written as :

W4 = V 4(:,13 : 16); (55)

We will create a Quadrature phase shift keying QPSK modulator as follows :

QPSKmod = comm.QPSKModulator(ʹBitInputʹ,true); (56)

Then,we program the users signals xutilde ∈ $C^{4\times52308}$,u = 1,2,3,4. For user 1,the signal to be transmitted is written as follows :

x1 = randi([0 1],N2,1); (57)
symbols1 = step(QPSKmod,x1); (58)

symbolsoneone = transpose(symbols1); (59)

x2 = randi([0 1],N2,1); (60)

symbols2 = step(QPSKmod,x2); (61)

symbols22 = transpose(symbols2); (62)

x3 = randi([0 1],N2,1); (63)

symbols3 = step(QPSKmod,x3); (64)

symbols33 = transpose(symbols3); (65)

x4 = randi([0 1],N2,1); (66)

symbols4 = step(QPSKmod,x4); (67)

symbols44 = transpose(symbols4); (68)

For user 2,the signal to be transmitted is written as follows :

x5 = randi([0 1],N2,1); (69)

symbols5 = step(QPSKmod,x5); (70)

symbols55 = transpose(symbols5); (71)

x6 = randi([0 1],N2,1); (72)

symbols6 = step(QPSKmod,x6); (73)

symbols66 = transpose(symbols6); (74)

x7 = randi([0 1],N2,1); (75)

symbols7 = step(QPSKmod,x7); (76)

symbols77 = transpose(symbols7); (77)

x8 = randi([0 1],N2,1); (78)

symbols8 = step(QPSKmod,x8); (79)

symbols88 = transpose(symbols8); (80)

For user 3,the signal to be transmitted is written as follows :

x9 = randi([0 1],N2,1); (81)

symbols9 = step(QPSKmod,x9); (82)

symbols99 = transpose(symbols9); (83)

x10 = randi([0 1],N2,1); (84)

symbols10 = step(QPSKmod,x10); (85)

symbols1010 = transpose(symbols10); (86)

x11 = randi([0 1],N2,1); (87)

symbols11 = step(QPSKmod,x11); (88)

symbols1111 = transpose(symbols11); (89)

x12 = randi([0 1],N2,1); (90)

symbols12 = step(QPSKmod,x12); (91)

symbols1212 = transpose(symbols12); (92)

For user 4,the signal to be transmitted is written as follows :

x13 = randi([0 1],N2,1); (93)

symbols13 = step(QPSKmod,x13); (94)

symbols1313 = transpose(symbols13); (95)

x14 = randi([0 1],N2,1); (96)

symbols14 = step(QPSKmod,x14); (97)

symbols1414 = transpose(symbols14); (98)

x15 = randi([0 1],N2,1); (99)

symbols15 = step(QPSKmod,x15); (100)

symbols1515 = transpose(symbols15); (101)

x16 = randi([0 1],N2,1); (102)

symbols16 = step(QPSKmod,x16); (103)

symbols1616 = transpose(symbols16); (104)

We insert the power of 50 dBm in Watts in our program :

pt = 100; (105)

sqpt = sqrt(pt); (106)

We will create the matrix MATRICEX which represented the transmitted signal by the 5G site and TxData which represented the sum of products of precoding matrix for UE u with the user signal xutilde :

$$\text{MATRICEX} = [\text{symbolsoneone}; \text{symbols } 22; \text{symbols } 33; \text{symbols } 44; \text{symbols } 55; \text{symbols } 66; \text{symbols } 77; \text{symbols } 88; \text{symbols } 99; \text{symbols } 1010; \text{symbols } 1111; \text{symbols } 1212; \text{symbols } 1313; \text{symbols } 1414; \text{symbols } 1515; \text{symbols } 1616]; \quad (107)$$

$$\text{TxData} = \text{W1} * \text{sqpt} * \text{MATRICEX}(1:4,:) + \text{W2} * \text{sqpt} * \text{MATRICEX}(5:8,:) + \text{W3} * \text{sqpt} * \text{MATRICEX}(9:12,:) + \text{W4} * \text{sqpt} * \text{MATRICEX}(13:16,:); \quad (108)$$

Then, we will create the loop in MATLAB as follows: the signal to noise ratio *SNRdBs* takes several values as follows:

SNRdBs = 0 : 2 : 30; (109)

For iSNR takes several values from 1 up to length(SNRdBs)

SNRdB = SNRdBs(iSNR); (110)

$Z_u \in C^{4\times52308}$. The variance sigma2 of noise received at user u antenna is given by the following equation:

$$\text{sigma2} = \text{NT} * \text{pt} * 0.5 * 10^{-\text{SNRdB}/10}; \quad (111)$$

Sigma = sqrt(sigma2); (112)

The received signal by user 1, $Rx1 \in C^{4\times52308}$ is given by the following equation:

$$\left\{ \begin{matrix} Rx1 = H1 * TxData + sigma * \\ (randn(4, N2/2) + 1i * randn(4, N2/2)); \end{matrix} \right\} \quad (113)$$

The received signal by user 2, $Rx2 \in C^{4\times52308}$ is given by the following equation:

$$\left\{ \begin{matrix} Rx2 = H2 * TxData + sigma * \\ (randn(4, N2/2) + 1i * randn(4, N2/2)); \end{matrix} \right\} \quad (114)$$

The received signal by user 3, $Rx3 \in C^{4\times52308}$ is given by the following equation:

$$\left\{ \begin{matrix} Rx3 = H3 * TxData + sigma * \\ (randn(4, N2/2) + 1i * randn(4, N2/2)); \end{matrix} \right\} \quad (115)$$

The received signal by user 4, $Rx4 \in C^{4\times52308}$ is given by the following equation:

$$\left\{ \begin{matrix} Rx4 = H4 * TxData + sigma * \\ (randn(4, N2/2) + 1i * randn(4, N2/2)); \end{matrix} \right\} \quad (116)$$

We will create an zero forcing ZF equalizer for each user u,$EQu \in C^{4\times4}$:

W1H1 = H1 ∗ W1; (117)

W2H2 = H2 ∗ W2; (118)

W3H3 = H3 ∗ W3; (119)

W4H4 = H4 ∗ W4; (120)

$$EQ1 = W1H1 * inv(W1H1 * W1H1); \quad (121)$$

$$EQ2 = W2H2 * inv(W2H2 * W2H2); \quad (122)$$

$$EQ3 = W3H3 * inv(W3H3 * W3H3); \quad (123)$$

$$EQ4 = W4H4 * inv(W4H4 * W4H4); \quad (124)$$

$$y = [EQ1*Rx1;EQ2*Rx2;EQ3*Rx3;EQ4*Rx4]; \quad (125)$$

Such that $y \in C^{16\times52308}$. We will create a QPSK Demodulator as follows :

$$\text{QPSKdemod} = \text{comm.QPSKDemodulator('BitOutput', true)}; \quad (126)$$

we will now create a vector *symbhat* $\in C^{836928\times1}$ as follows :

$$yy = 52308; \quad (127)$$

$$symbhat = reshape(MATRICEX,NT * yy,1); \quad (128)$$

We did the next QPSK demapping operation only to retrieve the message.

$$demapped1 = step(QPSKdemod,symbhat); \quad (129)$$

After, we will create also other vector *symbohat* $\in C^{836928\times1}$ as follows :

$$symbohat = reshape(y,NT * yy,1); \quad (130)$$

$$symbosliced = QPSKslicer(symbohat); \quad (131)$$

$$trsymbolsliced = transpose(symbosliced); \quad (132)$$

$$demapped2 = step(QPSKdemod,trsymbolsliced); \quad (133)$$

$$N3 = 1673856; \quad (134)$$

The Bit Error rate BER is calculated for each value of iSNR as follows :

$$BER(iSNR) = biterr(demapped2, demapped1)/N3; \quad (135)$$

When we finish with the loop we write end. We trace the graph of SNRdBs according to BER by applying these program lines : semilogy(SNRdBs,BER,' −o'),gridon xlabel('SNRdBs'); ylabel('BER');title('BitErrorRate') We will open a new document,then we save the document in MATLAB as QPSKslicer.m, then we write the program of the QPSKslicer(x) function as follows :

$$\text{function[xsliced]} = \text{QPSKslicer(x)} \quad (136)$$

$$sq05 = 1/sqrt(2); \quad (137)$$

$$jsq05 = 1i * sq05; \quad (138)$$

For i equal to 1 up to length(x) if imag(x(i))>real (x(i)) if imag(x(i))>-real(x(i)),

$$xsliced(i) = jsq05; \quad (139)$$

else

$$xsliced = -sq05; \quad (140)$$

end
else
if imag(x(i))>-real(x(i)),

$$xsliced = sq05; \quad (141)$$

else

$$xsliced = -jsq05; \quad (142)$$

end

end
end

4. Results and Discussion

The result of the product of the *H1dltilde* ∈ $C^{12\times16}$ matrix by *W*1 ∈ $C^{16\times4}$(the first three columns) is represented in table 2. The result of the product of the *H1dltilde* ∈ $C^{12\times16}$ matrix by *W*1 ∈ $C^{16\times4}$(the fourth column) is represented in table 3. The result of the product of the *H2dltilde* ∈ $C^{12\times16}$ matrix by *W*2 ∈ $C^{16\times4}$(the first three columns) is represented in table 4. The result of the product of the *H2dltilde* ∈ $C^{12\times16}$ matrix by *W*2 ∈ $C^{16\times4}$(the fourth column) is represented in table 5. The result of the product of the *H*3*dltilde* ∈ $C^{12\times16}$ matrix by *W*3 ∈ $C^{16\times4}$(the first three columns) is represented in table 6. The result of the product of the *H*3*dltilde* ∈ $C^{12\times16}$ matrix by *W*3 ∈ $C^{16\times4}$(the fourth column) is represented in table 7. The result of the product of the *H4dltilde* ∈ $C^{12\times16}$ matrix by *W*4 ∈ $C^{16\times4}$(the first three columns) is represented in table 8. The result of the product of the *H4dltilde* ∈ $C^{12\times16}$ matrix by *W*4 ∈ $C^{16\times4}$(the fourth column) is represented in table 9.

Table 2
The Results of The Product of H1dltilde By W1 (The First Three Columns)

column1	column 2	column 3
0	0e+00-5.55e-17i	5.55e-17+1.11e-16i
2.22e-16+3.19e-16i	2.5e-16	-3.33e-16-1.67e-16i
0e+00-1.11e-16i	-6.94e-17-5.55e-17i	-5.55e-17-1.11e-16i
0e+00-2.22e-16i	0e+00-3.89e-16i	-1.67e-16-5.27e-16i
4.02e-16+1.11e-16i	1.11e-16	-1.11e-16-4.72e-16i
-3.33e-16+9.71e-17i	-2.5e-16-2.43e-17i	-7.29e-17+3.89e-16i
2.95e-17+6.94e-17i	-7.08e-16+1.93e-16i	3.33e-16-1.18e-16i
1.11e-16+4.16e-16i	-1.18e-16-7.5e-16i	5.55e-17-1.39e-17i
-1.39e-16-4.93e-16i	1.67e-16-1.67e-16i	-1.39e-17-2.22e-16i
-8.33e-17+2.78e-17i	-4.16e-16	4.44e-16+1.67e-16i
1.11e-16-2.22e-16i	2.84e-16+1.01e-16i	3.19e-16-2.19e-16i
-1.25e-16+8.33e-17i	-2.5e-16+5.55e-17i	-2.22e-16-3.89e-16i

Table 3
The Results of the Product of H1dltilde by W1 (The Fourth Column)

column 4
1.11e-16-1.11e-16i
-2.78e-16-3.54e-16i
3.05e-16+6.77e-17i
-5.55e-17-1.67e-16i

-3.89e-16-4.44e-16i
-2.78e-17+1.11e-16i
-3.89e-16
-8.33e-17-2.22e-16i
5.55e-16+3.33e-16i
3.61e-16+2.22e-16i
-3.12e-16+3.33e-16i
2.22e-16-3.33e-16i

Table 4
The Result Of The Product Of H2dltilde By W2 (The First Three Columns)

column 1	column 2	column 3
0e+00+1.39e-16i	0e+00-2.17e-16i	4.44e-16-3.33e-16i
-6.66e-16-5.55e-17i	0e+00+1.11e-16i	2.43e-16+3.33e-16i
3.33e-16-1.11e-16i	2.22e-16+5.55e-17i	2.22e-16-1.67e-16i
8.60e-16-7.22e-16i	-2.78e-17-8.33e-17i	1.11e-16+1.11e-16i
-3.61e-16-1.11e-16i	2.26e-17-2.08e-16i	-1.11e-16-3.33e-16i
3.33e-16-3.33e-16i	-1.39e-16-2.22e-16i	-1.11e-16+8.33e-17i
5.55e-17+2.15e-16i	1.39e-17+1.39e-16i	-1.94e-16-1.49e-16i
8.33e-17-3.54e-16i	-5e-16+3.33e-16i	2.78e-16 + 2.36e-16i
3.61e-16+3.33e-16i	0e+00+1.04e-16i	2.78e-16+5.01e-16i
-5.55e-17+2.78e-16i	-1.67e-16-2.78e-16i	-1.11e-16-3.33e-16i
-8.33e-17-1.67e-16i	-4.86e-16-9.71e-17i	4.16e-17-5.55e-17i
-1.05e-16 + 5.55e-17i	-4.15e-16-7.63e-16i	5.55e-17-4.44e-16i

Table 5
The Result Of The Product Of H2dltilde By W2 (The Fourth Column)

column 4
2.22e-16-4.16e-17i
5.27e-16+5e-16i

-2.78e-17-3.89e-16i
-1.39e-16+2.22e-16i
3.75e-16-2.22e-16i
0e+00-1.11e-16i
1.39e-17-5.55e-16i
-3.89e-16
2.78e-17+5.55e-17i
8.33e-16+2.78e-16i
-3.89e-16-5.55e-17i
6.66e-16+1.11e-16i

Table 6
The Result Of The Product Of H3dltilde By W3 (The First Three Columns)

column1	column 2	column 3
2.78e-17-2.78e-16i	-2.43e-16+5.55e-17i	1.11e-16-1.67e-16i
1.11e-16-1.21e-17i	-2.22e-16-2.08e-16i	1.11e-16-2.22e-16i
4.54e-16+3.89-16i	2.5e-16 + 2.78e-17i	1.25e-16+5e-16i
4.44e-16+5.24e-16i	6.80e-16+4.44e-16i	4.72e-16-5.83e-16i
0e+00+2.22e-16i	0e+00-7.22e-16i	3.89e-16-2.39e-16i
6.66e-16+1.11e-16i	-3.89e-16-1.63e-16i	1.11e-16+4.44e-16i
1.25e-16-1.39e-17i	5.31e-16-3.33e-16i	-5.55e-16-5.55e-17i
-2.78e-16-5e-16i	-5.55e-16+1.94e-16i	-1.25e-16-8.33e-17i
6.51e-17+1.11e-16i	-5.55e-17-4.86e-16i	5.55e-17+5.55e-16i
1.67e-16+3.33e-16i	-3.33e-16+3.33e-16i	1.67e-16+2.22e-16i
-3.89e-16 -4.02e-16i	1.67e-16+4.16e-17i	-6.66e-16-3.33e-16i
2.22e-16-1.46e-16i	-5.55e-17-5.55e-17i	5.27e-16+1.39e-16i

Table 7
The Result Of The Product Of H3dltilde By W3 (The Fourth Column)

column 4
1.67e-16-1.11e-16i
2.08e-17
-2.22e-16-5.55e-16i
3.61e-16+1.56e-16i
8.33e-17+2.5e-16i
-2.22e-16+2.78e-16i
0e+00+1.67e-16i
-4.44e-16-1.67e-16i
1.67e-16+4.72e-16i
1.39e-17-1.11e-16i
-1.46e-16-2.22e-16i
2.22e-16-5.55e-17i

Table 8
The Result Of The Product Of H3dltilde By W4 (The First Three Columns)

column 1	column 2	column 3
-2.22e-16+6.94e-17i	1.11e-16-1.11e-16i	3.05e-16-3.33e-16i
-4.16e-16+6.66e-16i	-3.33e-16+4.44e-16i	-5e-16-1.39e-16i
-1.11e-16+1.67e-16i	8.33e-17-1.11e-16i	-8.33e-17+5.18e-16i
-3.33e-16+5.55e-17i	3.82e-16+3.89e-16i	-1.94e-16+2.22e-16i
-6.66e-16-5e-16i	-3.61e-16-5.55e-17i	2.22e-16-2.22e-16i
3.89e-16+1.67e-16i	2.781e-16+5e-16i	3.89e-16+3.05e-16i
-1.11e-16+5.55e-17i	-1.11e-16+5.658e-17i	-2.22e-16-6.94e-17i
1.80e-16+8.33e-17i	3.47e-17+1e-16i	2.22e-16
6.38e-16-1.11e-16i	-2.78e-17-2.22e-16i	-1.11e-16-2.78e-17i
1.67e-16+2.04e-16i	-1.11e-16	-2.78e-17-5.55e-17i

-8.33e-17	4.44e-16-1.39e-16i	5.55e-17-7.5e-16i
3.82e-17-3.75e-16i	2.36e-16	-9.71e-17-1.67e-16i

Table 9
The Result Of The Product Of H3dltilde By W4 (The Fourth Column)

column 4
3.33e-16-2.78e-17i
5e-16+8.33e-17i
-5e-16-7.63e-17i
1.67e-16+1.67e-16i
6.11e-16
2.78e-16+2.22e-16i
3.33e-16+2.78e-16i
-1.11e-16 + 3.61e-16i
2.5e-16-2.22e-16i
3.33e-16+1.67e-16i
1.11e-16-2.91e-16i
-6.11e-16-8.5e-17i

The results show that the product of *H*1*dltilde* with *W*1 is a matrix with imaginary elements such that each element of the matrix has an imaginary part and an real part which tend to zero. The results show that the product of *H2dltilde* with *W*2 is a matrix with imaginary elements such that each element of the matrix has an imaginary part and an real part which tend to zero. The results show that the product of *H3dltilde* with *W*3 is a matrix with imaginary elements such that each element of the matrix has an imaginary part and an real part which tend to zero. The results show that the product of *H4dltilde* with *W*4 is a matrix with imaginary elements such that each element of the matrix has an imaginary part and an real part which tend to zero. So the inter users interferences IUI are canceled in emission TX at user equipment UE1, user equipment UE2, user equipment UE3 and user equipment UE4 and each user UE among four users (4 UEs) receives its desired signal plus noise matrix $Z_u \in C^{4\times 52308}$ at these antennas (4 receiving antennas).

The figure 2 shows the graph of signal to noise ratio in decibels SNRdB according to the Bit Error Rate BER. For differents values of signal to noise ratio in decibels SNRdBs and the variances sigma2 (Several transmissions). The value of Bit Error Rate BER decreases when the value of signal to noise ratio in decibels SNRdBs increases. With this type of transmission (uncoded transmission) where the Cyclique Redundancy Check CRC is negligible and the Block Error rate BLER is null,there is no errors detection and errors correction,so the Bit Error Rate BER is calculated only to compare the binary message in emission (before Quadrature Phase Shift Keying QPSK mapping) and the binary message in receptions at UE1,at UE2,at UE3 and at UE4.

Fig. 2. Bit Error rate

For a Multi user Massive MIMO system composed of an 5G site equipped of 16 transmitting antennas and of eight 5G UEs,each one of these UEs is equipped of 4 antennas. By using the block diagonalization method, the received signal by user *u* noted *yu* is given as follows :

$$y1 = H1 \times W1 \times x1tilde + Z_1 \quad (143)$$

$$y2 = H2 \times W2 \times x2tilde + Z_2 \quad (144)$$

$$y3 = H3 \times W3 \times x3tilde + Z_3 \quad (145)$$

$$y4 = H4 \times W4 \times x4tilde + Z_4 \quad (146)$$

$$y5 = H5 \times W5 \times x5tilde + Z_5 \quad (147)$$

$$y6 = H6 \times W6 \times x6tilde + Z_6 \quad (148)$$

$$y7 = H7 \times W7 \times x7tilde + Z_7 \quad (149)$$

$$y8 = H8 \times W8 \times x8tilde + Z_8 \quad (150)$$

The value of TBS is 104616 b/ms. We have the following dimensions : $Hu \in C^{4\times16}$, $Wu \in C^{16\times4}$, $xutilde \in C^{4\times52308}$, $Zu \in C^{4\times52308}$, $yu \in C^{4\times52308}$ and $Wu \times xutilde \in C^{16\times52308}$.

5. Conclusion

Block diagonalization technology allows to eliminates inter user interferences. The results that have been obtained show that the inter user interference are canceled and each user has received his desired signal. So it’s important to use this technology of Block diagonalization to facilitate the cancellation of interferences in 5G standalone SA network.

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References

[1] 3GPP TS 38.306 version 15.3.0 Release 15, 5G; NR; User Equipment (UE) radio access capabilities, pp. 6-7, Octobre 2018.

[2] Cho, Y.S., KIM, J., Yang, W.Y., and Kang, C.G. (2010). MIMO-OFDM WIRELESS COMMUNICATIONS WITH MATLAB,1-457.

[3] Corp.mobile.rakuten. (n.d). https://corp.mobile.rakuten.co.jp/english/news/press/2021/0712 01/

[4] Ericsson. (n.d). https://www.ericsson.com/fr/blog/3/2022/5/5g-sa-et-5g-nsa-quellesdeferrences-

[5] Nur Asniffah, Z., Nur Idora, I and Mohd Syarhan, I. (2016). BLOCK DIAGONALIZATION PRECODING FOR MULTIUSER -MIMO DOWNLINK CHANNEL, *Jurnal Teknologi*. 1-6.

[6] Sharetechnote (n.d). https://www.sharetechnote.com/html/handbook lte cqi.html