Design of NOMA Employing F-Domain Equalization And Recursive Detection For Noisy Channels

Vijay Bisen
Assistant Professor, Dept of Electronics & Communication
VITM, Indore, MP

Abstract- *Due to the limitations on the available bandwidth, it is becoming difficult to manage the available bandwidth and share them among different users. Hence it becomes mandatory to design multiplexing techniques which would utilize the available bandwidth effectively. The most common multiplexing techniques used thus far have been frequency division multiplexing (FDM), time division multiplexing (TDM) and orthogonal frequency division multiplexing (OFDM). Off late, OFDM has been the go to multiplexing technique and has been used in several wireless technologies. Still, the search for more efficient multiplexing techniques has been an ongoing process. One of the strongest contenders for the same which could cater to the needs of future generation communication systems is non-orthogonal multiple access (NOMA). The proposed work presents a non-orthogonal multiple access technique for wireless communications under noisy channel conditions employing frequency domain equalization and recursive detection. The results indicate that the proposed system attains much better Quality of Service (QoS) due to the fact that the BER reduces to a much lesser value thereby rendering more reliability to the proposed system.It also has higher noise immunity since the noise doesn't override the signal even at lesser values of SNR.*

Keywords- Non orthogonal multiple access (NOMA), Additive White Gaussian Nosie (AWGN), Noisy Channel, Recursive Detection, Bit Error Rate

I. INTRODUCTION

The present scenario in wireless communication is seeing a rapid increase in the number of users and also the data size due to multimedia applications. This necessitates the use of high data rates for communication. Moreover, the spectral efficiency needs to be enhanced so as to incorporate more users in the available bandwidth. Non-orthogonal multiple access often termed as NOMA is an extremely effective alternate multiple access technique which scores over conventional multiple access schemes such as FDM and even OFDM. The comparative spectra of FDM, OFDM and NOMA are depicted in the figure below. It can be seen that the NOMA scheme utilizes the bandwidth most frugally rendering high spectral efficiency.

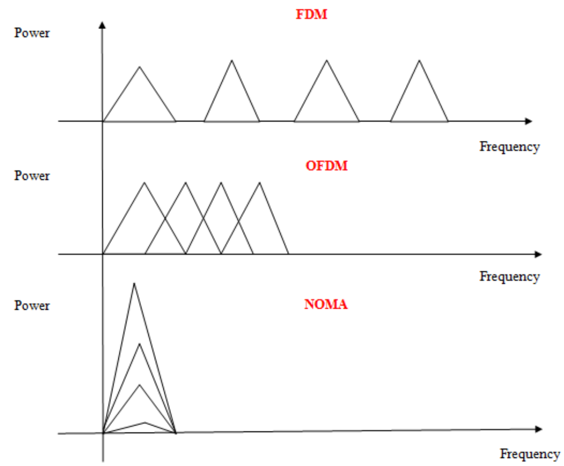

Figure.1 Comparative Spectra of FDM, OFDM and NOMA.

The primary concept of NOMA lies in the fact that NOMA separates the signals from multiple users in the power domain as compared to the frequency or time domain separation in the cases of FDM and TDM respectively. This however has serious limitations and critical repercussions in noisy channel conditions typically in additive White Gaussian Noise (AWGN) conditions wherein all spectral bands are equally affected by noise effects.

II. THE NOISY CHANNEL CONDITION FOR NOMA

The typical noisy channel can be mathematically represented as:

$$N(f) = \frac{N_0}{2} \forall f \qquad (1)$$

Here,

N(f) is the frequency dependent noise psd
f is the frequency metric
N_0 is the constant psd strength

The same can be graphically depicted as:

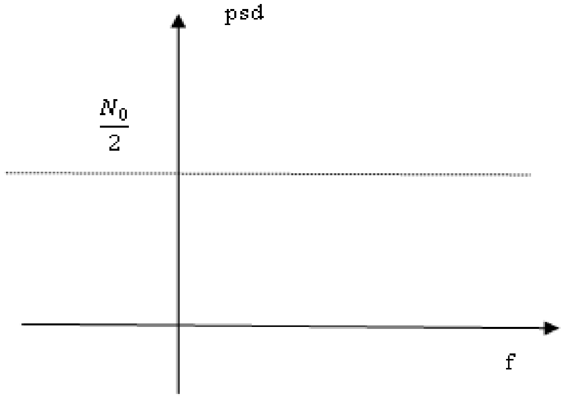

Figure.2 AWGN Conditions in Noisy Channels

The figure above indicates that irrespective of the frequency range used for data transfer, the signals will get affected by noise. This leads to a situation which hinders the reception of the composite NOMA signal.

This results in the waxing and weaning of the different multi path components of the received NOMA signal with variable path gains.

a) Individual signal strength of each MPC be given by:

$$S_i = g_i\sqrt{P_i} \qquad (3)$$

Where S represents i[th] MPC power,

'g' represents gain of the i[th] path
P represents the power of the i[th] MPC
The multipath model is depicted below as a tapped delay line model:

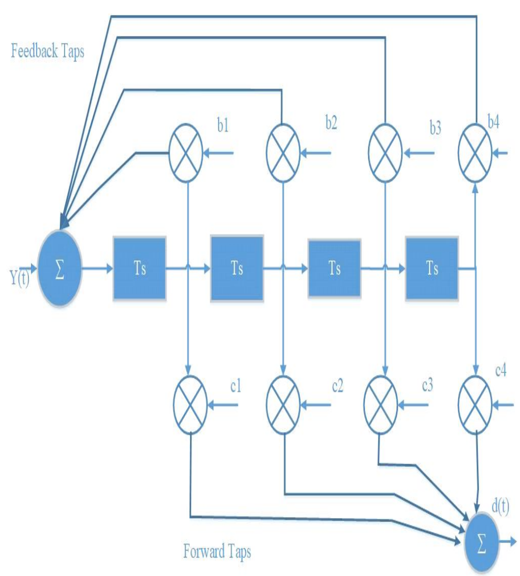

Figure.3 Tapped Delay Line Model for NOMA

As the noise and interference effects the power level separation of NOMA signals, there is a mandatory requirement for frequency domain equalization for the NOMA signal which is explained in the subsequent section.

III. FREQUENCY DOMAIN EQUALIZATION AND RECURSIVE DETECTION

The proposed system is explained as a sequence of the following steps:

1) Estimate and equalize channel.
2) Employ recursive detection.
3) Use the errors in channel estimates to update feedback weights of the mechanism
4) Compute the BER of the system using the relation:

$$BER = \frac{\text{Number of bits containing errors at receiver}}{\text{Total number of bits transmitted}} \qquad (2)$$

5) Estimating the channel with high accuracy using weight updating and computing the received signal strength at receiver

$$P(d) = P_t - L(d), d > d_o \qquad (3)$$

Here,

P_t =Transmitted Power
P(d)=average receiver power in dBm
L(d)= distance is the path loss in dB
d=certain distance
d_0 stands for the distance from which the proposed channel model can be used.

$$Find: \max(Sn)\, to\ evaluate\ x1 = max1 \qquad (4)$$

Here,

x1 is the strongest in search of iteration 1.
The iteration is carried out till the last of the composite MUD signal is not decoded.
The composite signal at a distance d can be statistically expressed as:

$$\bar{L}(d) = \bar{L}(d_o) + 10n\log_{10}\left(\frac{d}{d_o}\right) \qquad (5)$$

d_o=reference distance

n= constant value which is 2for LOS link but mostly uses higher than 2 for Multi path channel in both area cities and urban area

$$L(d) = \bar{L}(d_0) + 10n\log_{10}\left(\frac{d}{d_0}\right) + X_\sigma \quad (6)$$

Where

X_σ=zero-mean Gaussian random variable (in dB)

σ=Standard deviation

For reception of the signal, evaluate the following:

$$S_i = sign\{real[S_{composite}(t)]\} \quad (7)$$

$$S_q = sign\{real[S_{composite}(t)]\} \quad (8)$$

Here,

I represents the in-phase component
Q represents the quadrature component

Step12. Compute the system load given by:

$$\beta = \frac{N_b K}{N_b N_s - (N_b - 1) N_0} \quad (9)$$

Here,

$N_b$is the number of users

$N_s$is the sub-carrier spacing
K is the number of data nodes
Computation of composite BER:

$$BER_i = 1 - \sum(s_i - s_i')/nN_0 \quad (10)$$

$$BER_q = 1 - \sum(s_q - s_q')/nN_0 \quad (11)$$

Here,

I represents the in phase component and Q represents the quadrature component.
N is the number of bits
N_0 is the oversampling ratio
Thus the overall average BER can be computed as:

$$BER = \frac{K[BER_i + BER_q]}{2} \quad (12)$$

IV. SIMULATION RESULTS

The simulations are carried out on Matlab (Matrix Laboratory) and are shown below.

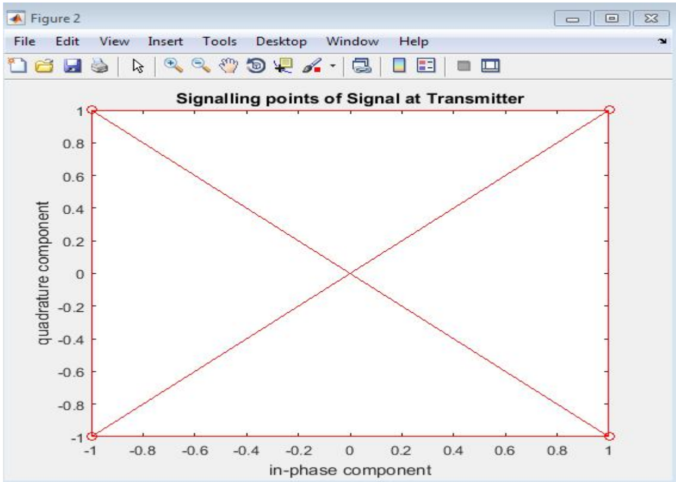

Figure.4. Signalling Points

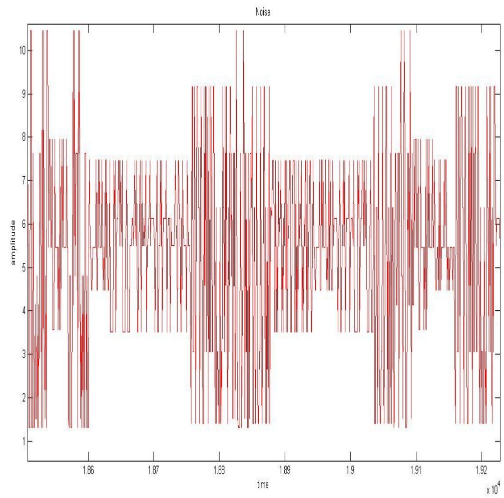

Figure.5 Noise Addition in the AWGN Channel

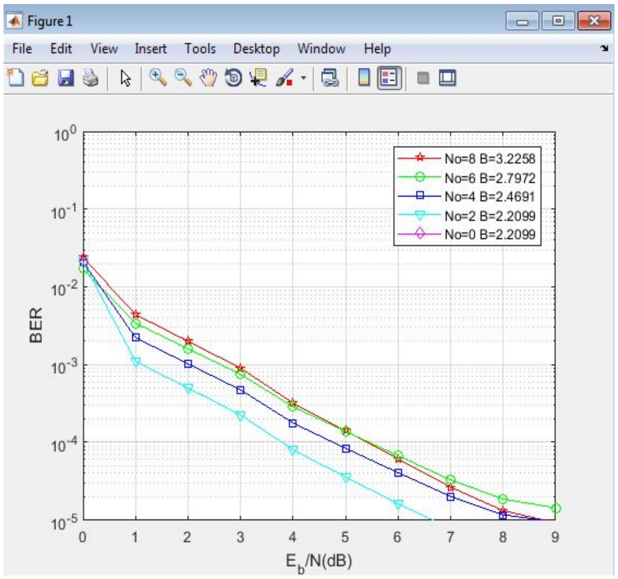

Figure.6 BERwith k=40

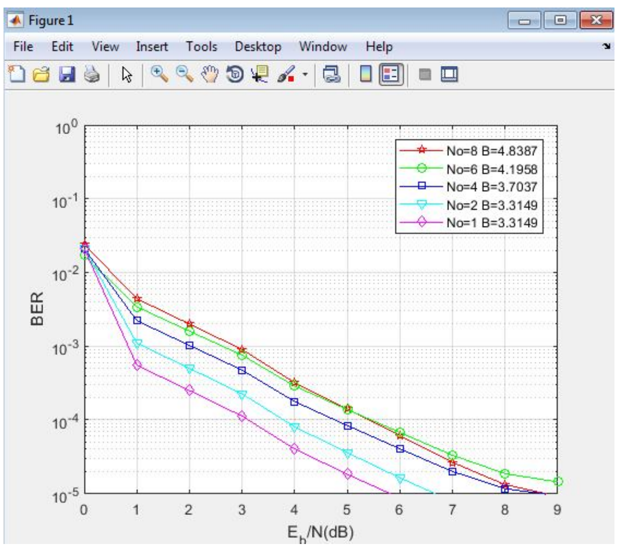

Figure.7 BER with k=60

V. CONCLUSION

In this paper, it has been shown that through f-domain equalization and recursive detection, it is possible to detect the NOMA signal which is separated in the power domain. Moreover, its worth mentioning that channel equalization is employed so as to mitigate the variable channel gain effects dependent on the different transmitter to receiver path lengths. This ensures that the different power levels corresponding to different path lengths can be recovered at the receiving end with equal probability of error. The results clearly indicate low error probability for the proposed system.

REFERENCES

[1] YunlongCai, ZhijinQin ,Fangyu Cui, Geoffrey Ye Li, Julie A. McCann, "Modulation and Multiple Access for 5G Networks", IEEE 2018

[2] B Wang, L Dai, Y Zhang, T Mir, "Dynamic compressive sensing-based multi-user detection for uplink grant-free NOMA", Vol-20, Issue-11, IEEE 2016

[3] J Choi, J Mo, RW Heath, "Near maximum-likelihood detector and channel estimator for uplink multiuser massive MIMO systems with one-bit ADCs", Vol-64, Issue-5, IEEE Xplore- 2016

[4] MahaAlodeh ; SymeonChatzinotas ; BjörnOttersten, "Energy-Efficient Symbol-Level Precoding in Multiuser MISO Based on Relaxed Detection Region", Vol-15, Issue-5, IEEE Xplore- 2016

[5] Fabian Monsees ; Matthias Woltering ; Carsten Bockelmann ; Armin Dekorsy, "Compressive Sensing Multi-User Detection for Multicarrier Systems in Sporadic Machine Type Communication", IEEE 2015

[6] BichaiWang ;Linglong Dai ; Yifei Yuan ; Zhaocheng Wang, "Compressive Sensing Based Multi-User Detection for Uplink Grant-Free Non-Orthogonal Multiple Access", IEEE-Xplore 2015

[7] S Wang, Y Li, J Wang, "Multiuser detection in massive spatial modulation MIMO with low-resolution ADCs", IEEE Transactions on Wireless Communication, Vol-14, Issue-4,available at IEEE Xplore, IEEE 2015

[8] S Narayanan, MJ Chaudhry, A Stavridis, "Multi-user spatial modulation MIMO", Proceedings of Wireless Communications and Networking Conference (WCNC), available at IEEE Xplore, IEEE 2014

[9] P Botsinis, D Alanis, SX Ng, LLCSO Hanzo, "Quantum-Assisted Multi-User Detection for Direct-Sequence Spreading and Slow Subcarrier-Hopping Aided SDMA-OFDM Systems", IEEE 2014

[10] A Mukherjee, SAA Fakoorian, J Huang, "Principles of physical layer security in multiuser wireless networks: A survey", Vol-16, Issue-3, IEEE 2014

[11] Rui Bai, Samuel Palermo, Patrick Yin Chiang, "A 0.25pJ/b 0.7V 16Gb/s 3-Tap Decision-Feedback Equalizer in 65nm CMOS", IEEE 2014

[12] Rodrigo C. de Lamare, "Adaptive and Iterative Multi-Branch MMSE Decision Feedback Detection Algorithms for Multi-Antenna Systems", IEEE 2013.

[13] ShayanShahramian, HemeshYasothara, and Anthony Chan Carusone, "Decision Feedback Equalizer Architectures With Multiple Continuous-Time Infinite Impulse Response Filters", IEEE 2012.