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Effects of Channel Coding with Spatial Diversity on BER for 5G Mobile Communications

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***Abstract*—Now a days the life of people without wireless devices are unimaginable. People use wireless mobile phones not only for communication purposes but also for all their personal needs such as internet banking, health monitoring, online shopping, educational purposes and much more. This makes the researchers to work over the continuous improvement towards wireless communication in order to satisfy the needs of people. In order to support all the technical needs of future wireless communication, various research has been developed. In this paper, a brief study on equalization technique, coding technique and diversity technique has been made. From this it is noted that diversity can be provided by using Orthogonal Time Frequency Space modulation technique.**

Keywords—Equalization technique, Coding technique, Diversity technique, Orthogonal Time Frequency Space (OTFS) modulation.

I. INTRODUCTION

General structure of a wireless communication system has been depicted in "Fig. 1". The performance of the wireless communication system can be deteriorated by both inter-symbol interference & fading. Frequency selective fading results in Inter-Symbol Interference (ISI) [1]. Inter-symbol interference occurs when one symbol intrudes with other ensuing symbols due to channel distortion. This makes the communication uncomfortable to the user. These results in loss of signal power by degrading signal to noise power ratio and even sometimes implies to temporary failure of the communication systems when there is severe drop in signal to noise ratio. This makes the system more liable to the errors due to synchronization.

When the transmitted signal gets affected by means of time, frequency or position, the variation in the signal is called fading. Fading in wireless communication is considered as major problem while considering a wireless link [2]. The communication channel which suffers from fading is known as fading channel.

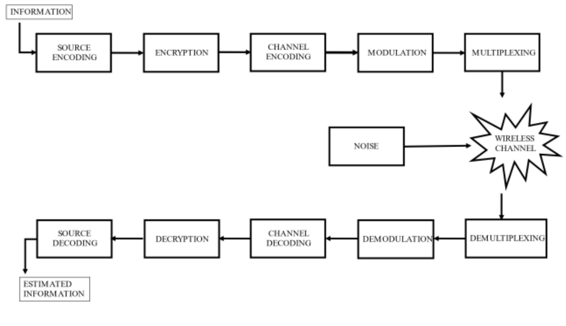

Fig. 1. General Structure of a wireless communication system

The fading can be caused due to multipath propagation or wave propagation i.e., due to atmospheric changes (such as rainfall, thunder, lightning) and obstacles present in the environment depicted in the "Fig. 2". There are two different types of fading which have been listed in the "Fig. 3", according to [1]. Hence there arises research to work towards these fading environment and certain mitigation techniques have been noticed to combat these fading environments and that have been denoted in "Fig. 4".

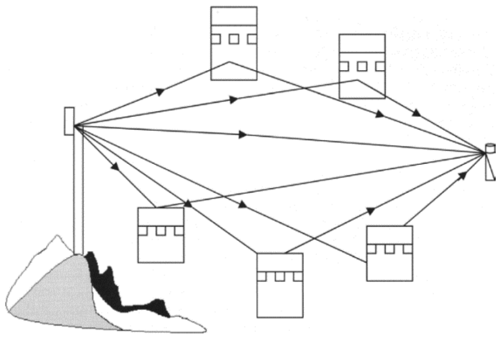

Fig. 2. Multipath Propagation

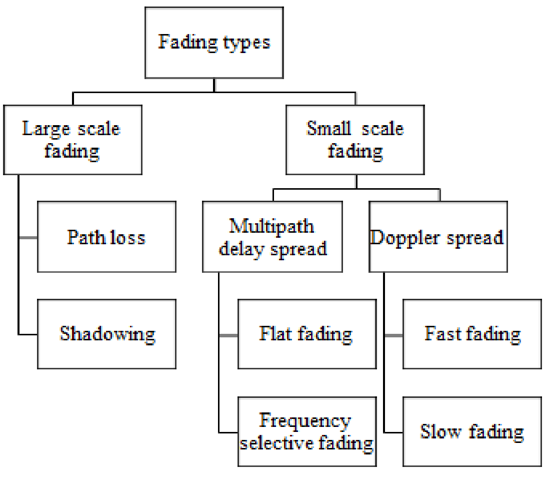

Fig. 3.Types of Fading

II. EQUALIZATION TECHNIQUE

Equalization is the signal processing technique that is usually implemented to combat the problem of inter-symbol interferences. In order to achieve perfect data transmission through a wireless channel, it is necessary to design an equalizer at the receiver side.

The different classifications of equalizers have been listed in the "Fig. 5". The device used to function the above process is called an Equalizer. The main objective of the equalizer is to force the Inter-symbol Interference to zero.In general,

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Equalizers were usually designed to compensate the channel effect, which deteriorates the system performance.

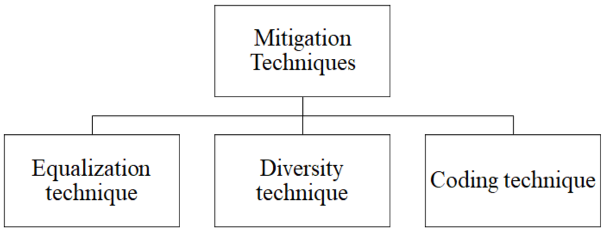

Fig. 4. Mitigation Techniques

Zero forcing Equalizers eliminates the inter-symbol interference at the slicer input whereas the Minimum mean square error equalizers trade-off between minimizing the inter-symbol interference and minimizing noise at the slicer input. The Zero forcing Equalizers found to achieve maximum diversity with minimum complexity [3].The Decision feedback equalizers (DFE) outperforms the zero forcing equalizer when the channel has severe amplitude distortion. Also, a non-linear DFE achieves higher data rate rather than conventional DFE [4]. In Minimum mean square error equalizers, the mean square error has been reduced by incorporating prediction filter.Fractionally spaced equalizers are based on Nyquist-rate sampling, usually 2 x symbol-rate sampling, avoids synchronization problems associated with matched filter front end.All the above equalizers perform with known channel state information. When the channel state information is unknown at the receiver an adaptive equalizer is opted.

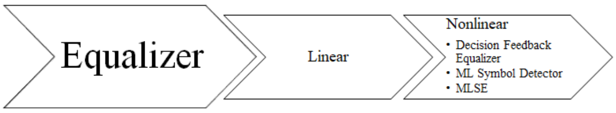

Fig. 5. Types of Equalizers

The adaptive equalizer tracks the time varying characteristics of the channel and thus known as adaptive equalizers. This equalizer significantly improves the system performance in presence of fading channel with raise in SNR value [5]. Adaptive Equalizers works on two operating modes, decision directed mode and training mode. Among the two operating modes, the training mode is mostly preferred. In the training mode, the transmitter can generate data symbol which is known to the receiver. So that, the receiver uses the known training signal at the slicer output. Once a certain time has been elapsed, then the slicer output is utilized and the corresponding data transmission begins. In Blind equalizer the transmitted signal is equalized based on the information of transmitted signal alone. It employs using Interleaving/Deinterleaving, advanced coding and ML criterion.

III. Diversity Technique

The effective technique to mitigate fast fading problem in wireless communication is the diversity technique [6]. Different types of diversity schemes have been listed in the "Fig. 6". Diversity can be achieved by transmitting multiple copies of information signal via N number of different channels. The main objective of diversity technique is that if some of the signal may undergoes fading and others may not. The various types of diversity include Temporal diversity, Frequency diversity, Spatial diversity and Polarization diversity.

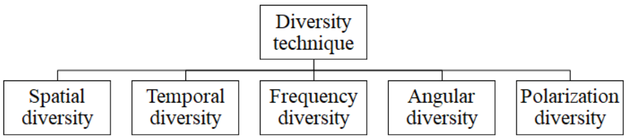

Fig. 6. Classification of Diversity technique

TABLE 1. Different Methodology of Diversity

S.No	Diversity	Methodology
1	Spatial	M number of transmit antennas & N number of receive antennas
2	Temporal	Different time slots
3	Frequency	Different frequency slots
4	Polarization	Receiver antenna with different polarization

A. *Space Time Block Codes*

The technique in which multiple copies of information source is transmitted through M number of transmitting antennas and received by N number of receiving antennas in order to enhance the performance of communication systems in table 1. The several copies of information source were generated by a space time encoder, which encodes the single information source. Then it sends the several copies of information source in the form of blocks using all M number of transmitting antennas at different time slots. Hence named as Space Time Block Codes [7]. A sample space diversity model has been depicted in the "Fig. 7". When the information regarding the channel is known to the receiver, then the system can able to achieve full diversity. However, it is little difficult that all the information about channel is known to the receiver. The channel state information can be predicted by sending some training signals to the transmitter and by this making the receiver to estimate the channel state information. In the communication system with two transmit antennas and M receive antennas were constructed. At the receiver a combiner combines all the received signal and pass through the Maximum Likelihood Detector. Here the transmit diversity technique with Maximum Likelihood Detector outperforms the Maximal Ratio Receiver Combining.

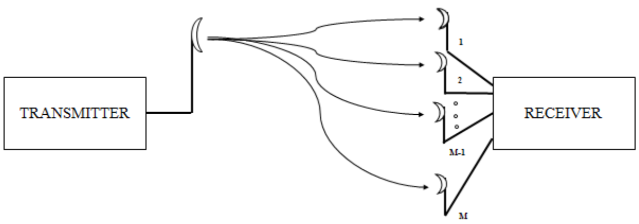

Fig. 7. Space Diversity

The comparison made between MIMO - Space Time Block Codes (STBC - MIMO) and MIMO - Spatial Multiplexing (SM - MIMO) schemes has been tabulated in

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the table 2. Both the STBC-MIMO and SM-MIMO were used to improve the performance of the wireless communication systems by means of coding gain and diversity gain by supporting multiple number of users at the same time. Sometimes, the SM-MIMO outperforms the STBC-MIMO system in table 2.

TABLE 2.COMPARISON OF STBC-MIMO AND SPATIAL MULTIPLEXING-MIMO (SM-MIMO)

Parameter	STBC-MIMO	SM-MIMO
Input	Single stream (single information split into many).	Multiple streams (different information source).
Receive antenna	Single or many.	Same as or more than the number of transmitting antenna but not less than that.
Channel estimation	Least square method is used.	Least square method is used.
Channel equalization	Maximum Likelihood decoding or Maximal Ratio Combining is used.	Zero forcing or Minimum Mean Square Error Equalizer or Maximum Likelihood decoding is used.

IV. LOW DENSITY PARITY CHECK CODES

The error correcting codes along with diversity technique will enhance the performance of a communication systems [8]. Here we discuss the linear error correcting code called Low Density Parity Check Codes (LDPC), which is best opted for error correction of information with high block size. It is also named as linear block code with sparse parity check matrix. In which sparse means there are many more zeros than ones. As it has very low ones, it is named as low-density parity check codes. Robert Gallager invented the LDPC codes in 1963. In 1981, R.M Tanner gave the pictorial representation of the parity check matrix called the Tanner graph.For example, consider a parity check matrix equation(1),

$$H = \begin{bmatrix} 1 & 0 & 11 & 0 & 10 \\ 0 & 1 & 01 & 1 & 01 \\ 1 & 1 & 00 & 1 & 10 \end{bmatrix} \quad (1)$$

"Fig. 8" depicts every column is denoted as bit node in circle representation and every row is denoted as check node in square representation. The edges correspond to 1's in the parity check matrix (H).Check node 2 denotes the row 2 of the parity check matrix(H). for LDPC $HC^T=0$. For the above matrix,

$$H = \begin{bmatrix} 1 & 0 & 11 & 0 & 10 \\ 0 & 1 & 01 & 1 & 01 \\ 1 & 1 & 00 & 1 & 10 \end{bmatrix} \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \\ c_6 \\ c_7 \end{bmatrix} \quad (2)$$

$$C_2 + C_4 + C_5 + C_7 = 0 \quad (3)$$

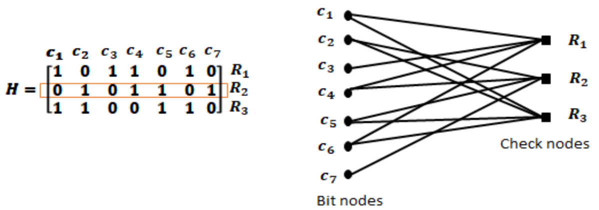

Fig. 8. Tanner Graph

In this equation (2) & equation (3) denotes that C_2, C_4, C_5, C_7 belongs to single parity check code (SPC). Every check node in the tanner graph enforces a SPC. Each SPC is named as local constraints. By using this we can easily decode.Tanner graph is a proper solution for decoding the LDPC codes. By simple decoding of each single parity check codes, we easily decode any large size matrix and thus it is well opted for 5G wireless communication systems as error correction codes.

"Fig. 9" is noted that the MIMO system with LDPC codes will provide excellent performance improvement in terms of BER [9]. On comparing turbo codes and other higher order codes, the non-binary LDPC provides improvement in the system performance by means of Bit Error Rate (BER) corresponding to Signal to Noise Ratio (SNR) [10].Error correcting codes can be combined with diversity technique to further improve the fading channel impairments, also a non-linear detector outperforms other linear combiners [11]. LDPC along with optimum combiner results in very good BER performance [12].

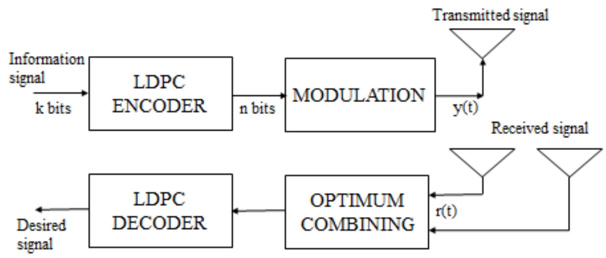

Fig. 9. LDPC System Model

V. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

In the emerging development in the wireless communication, a very high data-rate is craving in many applications. But we know that along with the raise in data rate there arises a big issue in case of symbol duration [13]. Here arises the problem called Inter-Symbol Interference (ISI), which needs complex equalization technique. An OFDM system splits the entire channel into more numbers of subchannels through which high-bit-rate data can be transmitted parallelly, so that the OFDM system does not suffer from the problem of ISI. In [14-16], full space and frequency diversity can be achieved by Combining Bit Interleaved coded modulation (BCIM) along with Space time block codes (STBC) and orthogonal frequency division multiplexing (OFDM).

However, OFDM technique suffers from synchronization error and it is found difficult to equalize multiple dopplers [17-18]. It results in unequal subchannel

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gain, which degrades the system performance. A new modulation technique has been found to outperform the OFDM technique named as Orthogonal Time Frequency Space (OTFS) Modulation [19].

VI. ORTHOGONAL TIME FREQUENCY SPACE MODULATION (OTFS)

From [22], OTFS modulation takes place by use of two transforms at both the transmitter and receiver shown in "Fig. 10". The importance of OTFS has been known from the literature survey summarized in Table 3. The two-dimensional information symbols from the QAM modulator in delay doppler domain is converted into a two-dimensional complex number sequence which is in Time-Frequency (TF) domain [20-22]. This can be made happened by using Inverse Symplectic Finite Fourier Transform (ISFFT) and Heisenberg Transform (HT).

HT converts the TF modulated symbols to time domain signal and makes it suitable for transmission via channel. On the receiver section the vice versa of the transmitter has been processed by using Symplectic Finite Fourier Transform (SFFT) and Wigner Transform (WT). This scheme provides promising solution for high-speed vehicular communication.

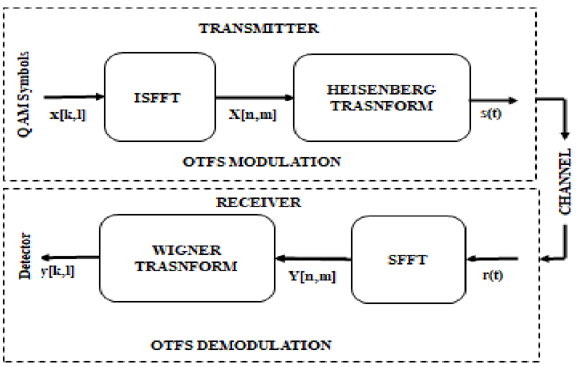

Fig. 10. OTFS Modulation and Demodulation

TABLE 3. LITERATURE SURVEY

Author	Year of Publication	Findings
Xiang Wang [14]	2020	Frequency Division Complementary Coded Code Division Multiple Access (FD-CC-CDMA) provides High diversity gain compared to OFDM-DS-CDMA.
Tadashi Ebihara [17]	2020	Doppler-resilient orthogonal signal division multiplexing (D-OSDM) along with MIMO achieves reliable error rate compared with normal OFDM system.
Zuwei Chen [19]	2020	A Discrete-Cosine-Spreading (DCS) aided M-ary DCSK scheme provides high data rate with minimum BER under multipath fading channel.
Huan Ma [21]	2022	TD-DCSK is compared with STBC-DCSK, OMC-MIMO-DCSK, and conventional DCSK system and proven that TD-DCSK provides high data rate.
Farah Arabian [15]	2022	Diversity alone cannot provide reliable communication link. There is also some error control coding is required.
Qi-Yue Yu [20]	2022	Space time domain parity check transmit diversity provides better BER performance compared to classical space time block codes in case of both the frequency selective and frequency non selective fading channels.
Jaewha Kim [18]	2022	A new method of Gamma Evolution has been used to derive upper bound on BER, to analyse the performance of LDPC for higher data rate
HuiyangQu [16]	2022	An Enhanced Data Detection scheme has been developed in order to cancel the interference and also to provide spatial and multipath diversities.
S.M. Alamouti [6]	1998	Error control codes can provide better diversity by incorporating of time diversity.
M. Kalaivani [7]	2014	Using STBC-OFDM, Full diversity can be achieved in case of known channel state information.
DAN FENG [10]	2018	Compared to turbo codes and other higher order codes LDPC can provide better improvement in system performance in terms of BER.
Zhen Mei [11]	2017	Error control coding technique along with diversity technique can further improve the system performance.
Beng Soon Tan [9]	2011	MIMO system along with LDPC support improving the efficiency in terms of BER.
EnisAkay [13]	2006	When the Bit Interleaved coded modulation technique combined with STBC-OFDM system, then frequency as well as space diversity can be achieved.
Sharma [12]	2009	An optimum combiner has been developed to support LDPC to improve the system performance.

VII. RESULTS & DISCUSSIONS

In order to support all the technical needs of future wireless communication, various research has been developed. It is clear that full diversity can be achieved by employing Parity check transmit diversity scheme [20]. Also, by employing enhanced data detection along with proper equalization technique, BER performance can be improved in consideration with higher order modulation technique for MIMO OTFS systems [16]. From this article, it is clear that the performance of a communication system can be improved by using the new modulation technique OTFS, along with suitable equalization technique.

VIII. CONCLUSION & FUTURE WORK

From the study, it is noted that the new 2D modulation technique, Orthogonal Time Frequency Space (OTFS) modulation provide improved latency when compared with Orthogonal Frequency Division Multiplexing (OFDM) technique for an high speed vehicular communication. Also, the future work can be proceeded by combining low density parity check codes along with STBC-OTFS in order to support future mobile communication with high mobility.

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