INTERNATIONAL JOURNAL OF INNOVATIVE TRENDS IN ENGINEERING (IJITE) ISSN: 2395-2946
ISSUE: 96, VOLUME 72, NUMBER 01, DECEMBER 2020

A Study on Multi Antenna and Spatial Diversity in Wireless Communication Based on OFDM

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Abstract- Wireless communications systems are widely deployed to provide various types of services including wireless mobile data services. High spectral efficiency and high transmission speed due to the applications of audio, video and internet services are the challenging requirements of future wireless broadband communications. The rising number of devices that require high data rates is placing increasing demands on bandwidth. The ever increasing demand for very high rate wireless data transmission calls for technologies that maximize spectral efficiency (bits per second per Hertz), robustness against multipath propagation, range of the communication system and minimizes power consumption as well as implementation complexity. One of the ways these challenges are being met is with the use of orthogonal frequency division multiplexing (OFDM). OFDM is not only spectrally efficient but resilient to the effects of the multipath wireless channel. Since the selection of modulation scheme and ultimate design of any communication depends on the characteristics of the channel, this work presents an extensive survey on characteristics of channels and modulation techniques for an OFDM wireless communication system.

Keywords- Wireless Communication System, M-QAM and M-PSK, STBC-FT, Digital modulation, Channel fading.

I. INTRODUCTION

The growing demand for services with high data rates and high spectral efficiency is the key to rapid technological evolution in the field of wireless communication. In the last two decades wireless communication has experienced a massive growth with a mission to provide new services with high data rates. Many new wireless systems have been gradually introduced which include 2nd, 3rd and 4th generation mobile systems as well as Wi-Fi.

The new techniques which are being developed are gradually being incorporated in commercial products and new wireless communications standards are being wishedford. Recently, Third generation (3G) and fourth generation (4G) mobile communication systems have been deployed commercially at many places to fulfil the need for packet-based services with high data rate. Moreover lot of advancements has been incorporated in 3G systems to improve the existing data rates. Some of these include- high speed downlink packet access (HSDPA) in wideband code division multiple access (WCDMA) systems, 1x evolution-data, 4G, MIMO-OFDM, MC-CDMA, etc.

Modern communication standards, offer high data rate for mobile devices. The relative motion of a receiver to the transmitter leads to Doppler Effect. This can be improved for communication systems that use MIMO-OFDM. Consequently, Wireless communication system is a system in which information is conveyed from one point to another by using a finite set of discrete symbols. This system has been the subject of numerous Workes over the past fifty years of its introduction. As such, during the last three decades, the development and use of wireless communication systems, has extensively increased and are still becoming more and more attractive due to the ever increase in demand for data communication, ease of regeneration of signals, high flexibility and availability of options for data processing in comparison to analogue transmission. Block diagram of a typical wireless communication system is shown in Figure 1.1

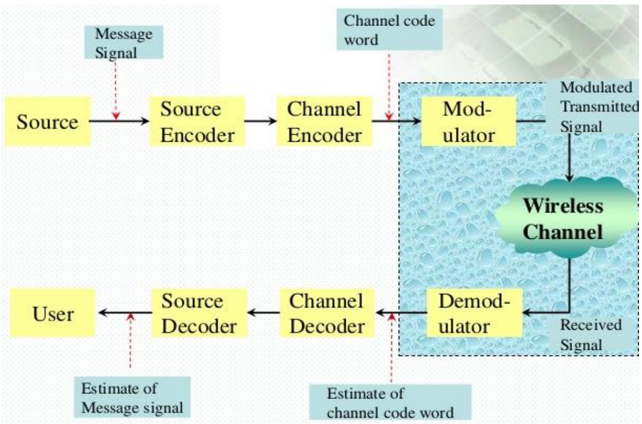

Figure 1.1 Block diagram of a typical wireless communication system

II. SYSTEM MODEL

Spatially modulated STBC (FT-STBC) has been introduced and is gaining some greater traction. FT-STBC was wishedford to exploit the combined advantages of FT and STBC. Since the transmitter side, such as base stations, can support more complex algorithm than the receiver side (e.g. mobile phone), FT-STBC can as well be extended to QO-STBC for improved system performance.

Since its inception, wireless communications technology has continued to evolve. Digital succeeded analog in wireless communications for reasons related to resource (e.g. bandwidth) economy, flexibility, cost, etc. For improved quality of service (QoS), such as throughput, data rate and bit-error ratio (BER), different channel coding and multiple access schemes have been investigated by Workers based on design merits.

Orthogonal Frequency Division Multiplexing (OFDM)

Orthogonal frequency division multiplexing (OFDM) is a multicarrier multiplexing technique that divides a wideband into many narrow-bands. The input data are divided into parallel streams, each narrow-band modulating a separate subcarrier. The narrow-band waveforms have overlapping sidebands, but are orthogonal to one another. Since the wideband is de-multiplexed into many narrow-bands, it enables the scheme to multiplex large amount of data to increase a system throughput.

A sum of these narrowband waveforms yields one OFDM symbol block. To guard these symbol blocks from interfering with one another over a channel, a cyclic prefix (CP) is used which must be of the order of the channel delay spread. The proportion of time occupied by the CP represents an overhead. Nevertheless the effective data rate of an OFDM system is high and OFDM has very good spectral efficiency.

Principle of OFDM Signalling:

Orthogonal waveforms of OFDM convey messages as binary data. The data are modulated onto subcarriers equally spaced in frequency across a band. Modulation of the subcarrier generates sinc-shaped side-lobes which are overlapping, but orthogonal as shown in Figure 1.2. It should be noted for this modulation scheme that each binary data occupies one frequency of the many FFT-generated waveforms for one OFDM block. During simulation, the messages are randomly generated input data.

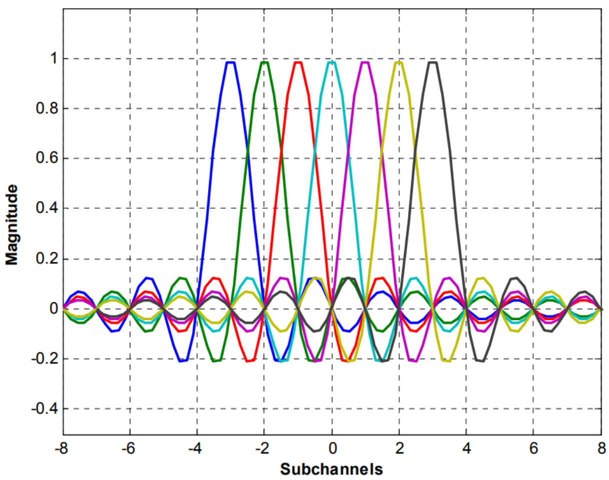

Figure 1.2: Orthogonal waveforms of OFDM showing sub-channels

Wireless Communications

The ever increasing demand for very high rate wireless data transmission calls for technologies that maximize spectral efficiency (bits per second per Hertz), robustness against multipath propagation, range of the communication system and minimizes power consumption as well as implementation complexity. The signal propagation in a wireless Environment, with Line of sight (LOS) and non Line of sight (NLOS) is shown in Fig. 1.3.

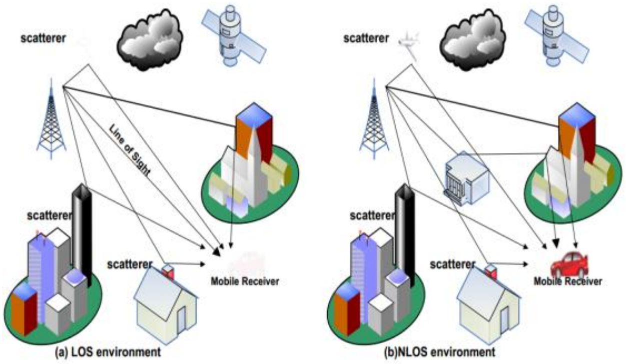

Fig. 1.3 Signal Propagation in a Wireless Environment, with and without LOS

There are two types of modulation in wireless communication, analog and digital. Analog modulation takes an analog message signal at baseband and moves the signal spectrum in the frequency domain. Digital modulation maps bits in the data stream to analog waveforms that can be transmitted

Wireless Channel Models:

The mobile communication environment exhibits a randomly time-varying multipath channel due to the relative radial motion between the transmitter and receiver in- cluding moving scatterers, and multipath propagation delays. The channel link is modeled as a length-L finite impulse response (FIR) filter, for which the continuous time impulse response is given by

$$h(t,\tau) = \sum_{\ell=0}^{L-1} \sqrt{P(\tau_\ell)} w_\ell(t)\,\delta(\tau - \tau_\ell)$$

where δ (t) denotes the Dirac delta function, τ_A is the propagation delay of the Ath

complex channel tap wA (t) of average power

$$P(\tau_\ell).\ \{P(\tau_\ell)\}_{\ell=0}^{L-1}\ 1$$

represent the channel power delay profile (PDP), normalized as

$$s\ \sum_{\ell=0}^{L-1} P(\tau_\ell) = 1.$$

The wide sense stationary uncorrelated scattering (WSSUS) model is commonly used for multipath wireless channels.

Since the selection of modulation scheme and ultimate design of any communication depends on the characteristics of the channel, we present the characteristics and modeling of flat and frequency selective fading channels which either remain constant or vary with time.

Channel fading:

In wireless communications, fading is variation or the attenuation of a signal with various variables. These variables include time, geographical position, and radio frequency. Fading is often modeled as a random process. A fading channel is a communication channel that experiences fading. In wireless systems, fading may either be due to multipath propagation, referred to as multipath induced fading, weather (particularly rain), or shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading. The diversity combining schemes have been extensively studied over some general fading distributions such as Rayleigh, Ricean, Nakagami-m, and Weibull etc. M. D. Yacoub has suggested κ-μ and η-μ fading channels to model the mobile radio environment more accurately. These fading distributions are used to model non-homogeneous fading environment.

Different types of Channel Fading modules are named below.

- Flat Fading Channel
- AWGN Channel
- Delay Spread
- Doppler Shift
- Rayleigh Fading
- Rician Fading Channel
- Frequency-Selective Fading Channel
- Time Flat and Time Selective Channels

Space-Time Block Codes:

This introduces space-time block codes. Space-time block coding (STBC) has emerged as one of the major techniques to exploit the MIMO benefit. Both spatial and temporal diversity are achieved in STBC. STBC also offers simple decoding with the use of maximum likelihood detection algorithm at the receiver. Other types of codes based on STBC have then emerged and are of most interest as both full rate and full diversity can be achieved contrary to the STBC where full rate cannot be achieved for more than two transmit antennas After some background information on wireless channel models, the simple Alamouti encoding using 2 transmit antennas and one receive antenna is presented. Space-time block codes for general MIMO systems are then described and tested for different number of transmit and receive antennas. Further, Quasi- orthogonal space-time block coding and differential space-time block coding techniques are discussed and their performance comparison with the original space-time block coding technique is also provided.

Digital Modulation

The process, in which digital symbols get transformed into signals or waveforms that are compatible with the channel characteristics, is known as the digital modulation. Two of the most common types of digital modulation are baseband modulation and bandpass modulation. In the baseband modulation, waveforms mostly take the form of shaped pulses whereas in the bandpass modulation the shaped pulses modulate a sinusoid called a carrier wave, or simply a carrier, out of which bandpass modulation are well known and often used for their important benefits in signal transmission.

Quadrature Amplitude Modulation(QAM):

Quadrature amplitude modulation (QAM) is a very popular modulation technique for digital communication systems primarily because of its spectral efficiency. In addition to the 3 basic types of modulation techniques, there are other modulation techniques that are created by combining these three basic techniques. One of the most important and popular types of these combinational techniques are Quadrature Amplitude Modulation (QAM). ASK is combined with PSK to create this hybrid system known as QAM, where both the amplitude and phase are changed at the same time. QAM modulation techniques are often employed in many radio communications, data delivering related or broadcast applications.

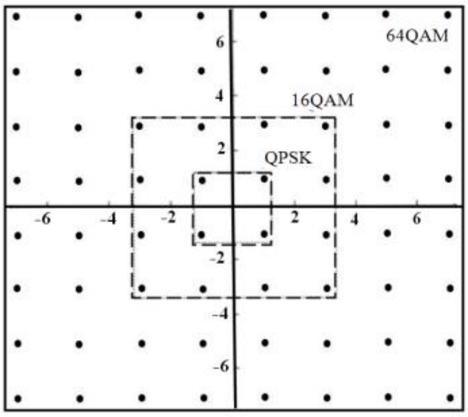

Figure 1.4 QPSK, 16-QAM and 64-QAM constellations

A method for implementing QAM modulation is through use of rectangular constellations, which can be divided into independent Pulse Amplitude Modulated (PAM) components, namely for both the In-phase and the Quadrature (I-Q) part. An example of rectangular constellations for Quadrature Phase Shift Keying (QPSK), 16QAM and 64QAM is illustrated in Figure 1.4

Like the above explained modulation techniques, in QAM, the phase and amplitude of the carrier signal (Figure 1.5) similarly changes in response to a change in state of the input signal. This change in the state of the input subsequently changes the amplitude and phase of the output signal, as shown in Figure 1.6.

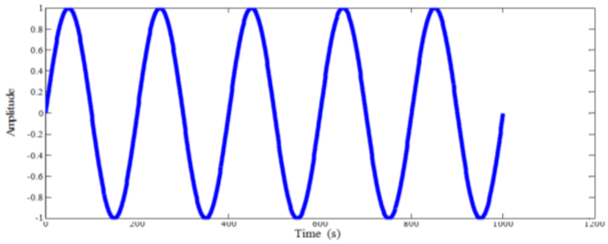

Figure 1.5. The carrier sine signal

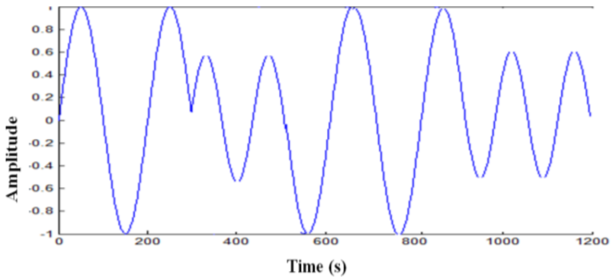

Figure 1.6. QAM – Both amplitude and phase have changed in response to a change in state of the input signal

Out of the above discussed modulation techniques, M-PSK and M-QAM are the most widely used techniques, and therefore this Work concentrates on using these two modulation schemes

Phase Shift Keying

Phase shift keying (PSK) is one of the main digital bandpass modulation techniques and was developed during the early periods of outer-space program. This modulation technique is now extensively used in many systems and applications such as military, commercial communication systems etc.

The generic mathematical expression for PSK is

$$S_i(t) = \sqrt{\frac{2E}{T}} \cos\,[\omega_i t + \varphi_i(t)] \qquad 0 \le t \le T \qquad i = 1, \ldots. M$$

Where:

- E: The symbol energy
- T: The symbol time duration ($0 \le t \le T$) The $\varphi_i(t)$ is the phase term and can be expressed as:

$$\varphi_i(t) = \frac{2\pi i}{M} \quad i = 1, \ldots. M$$

One of the most common examples of PSK modulation technique is the Binary PSK (BPSK) where M is 2. In a typical BPSK modulation techniques, the phase of the Si(t) waveform is shifted to one of the two states, zero (S1) or 180° (S2), following a change at the symbol transitions.

III. LITERATURE REVIEW

SR.NO.	TITLE	AUTHORS	YEAR	METHODOLOGY
1	Performance of Massive-MIMO OFDM system with M-QAM Modulation based on LS Channel Estimation	A. Riadi, M. Boulouird and M. M. Hassani	2019	ZF and MMSE detectors is evaluated with (Nt×Nr), (50 × 100) and (50 × 300) respectively antennas array, for various modulations techniques 16-QAM, 64-QAM, and 128-QAM, and for various OFDM sub-carriers 64, 256, 512 and 1024.
2	"Performance analysis of outage probability and error rate of square M-QAM in mobile wireless communication systems over generalized α-µ fading channels with non-Gaussian noise,"	F. S. Almehmadi and O. S. Badarneh	2018	A valid for integer and non-integer values of the fading parameters
3	, "On the Capacity of Wireless Powered Communication Systems Over Rician Fading Channels,"	F. Zhao, H. Lin, C. Zhong, Z. Hadzi-Velkov, G. K. Karagiannidis and Z. Zhang,	2018	A comprehensive analysis of the achievable ergodic capacity in two scenarios, depending on the availability of channel state information (CSI) at PB, namely, the absence of CSI and partial CSI

4	"Capacity of wireless powered communication systems over rician fading channels,"	F. Zhao, H. Lin, C. Zhong, Z. Hadzi-Velkov, G. K. Karagiannidis and Z. Zhang,	2017	The ergodic capacity of a multi-input multi-output (MIMO) wireless powered communication system with partial channel state information at the power beacon (PB).
5	"Unified Framework for the Effective Rate Analysis of Wireless Communication Systems Over MISO Fading Channels,"	M. You, H. Sun, J. Jiang and J. Zhang,	2017	A unified framework for the effective rate analysis over arbitrary correlated and not necessarily identical multiple-input single-output (MISO) fading channels,
6	"Optimization of Effective Area Spectral Efficiency for Wireless Communications Systems under Nakagami-m Fading Channels,"	A. Omri and M. O. Hasna,	2016	An optimization of the effective area spectral efficiency (EASE) metric for point-to-point transmission systems, and decode-and-forward (DF) relaying communications networks under Nakagami-m fading channels
7	"Optical MIMO DCO-OFDM wireless communication systems using STBC in diffuse fading channels,"	P. C. Thao, D. Le Khoa, N. T. Tu, L. H. Phuc and N. H. Phuong,	2016	The simulation of the optical wireless channel to analyze effects of dispersion multipath.
8	, "Cooperative Dual-Hop Wireless Communication Systems With Beamforming Over $eta-mu$ Fading Channels,"	O. S. Badarneh and R. Mesleh,	2016	The end-to-end performance of cooperative beamforming in dual-hop relaying systems operating over η - μ fading channels

A. Riadi, M. Boulouird and M. M. Hassani [1] A Least Squares Channel Estimation (LSCE) method is designated for a Massive MIMO system combined with Orthogonal Frequency Division Multiplexing (OFDM) and higher order modulation technique. The performance of ZF and MMSE detectors is evaluated with (Nt×Nr), (50 × 100) and (50 × 300) respectively antennas array, for various modulations techniques 16-QAM, 64-QAM, and 128-QAM, and for various OFDM sub-carriers 64, 256, 512 and 1024. The performance is determined in terms of Bit Error Rate (BER). Increasing the number of Bits/symbol provides an increase of BER both the ZF and MMSE detectors for an antennas array 50 × 100; Whereas increasing the number of OFDM sub-carriers provides a decreasing of BER. Combining 128-QAM modulation with 1024-sub-carriers and increase the receiver antennas array three times (i.e., 50 × 300), decreases more the BER both the ZF and MMSE detectors. Consequently the ZF and MMSE detectors provide a best BER so a best system performance.

F. S. Almehmadi and O. S. Badarneh [2] This Work derives new and exact closed-form expressions for the average symbol error rate (SER) of square M-ary quadrature amplitude modulation (M-QAM) in wireless communication systems over the α-μ fading channels subject to an additive non-Gaussian noise. The obtained expressions take into account static and mobile wireless receivers. In addition, a closed-form expression for the outage probability in mobile networks is obtained. Please note that all derived expressions in this Work a valid for integer and non-integer values of the fading parameters. Analytical results are presented to study the impact of noise shaping parameter, severity of fading, and mobility on the average SER. Monte-Carlo simulations results are also provided to validate the accuracy of the analytical results

F. Zhao, H. Lin, C. Zhong, Z. Hadzi-Velkov, G. K. Karagiannidis and Z. Zhang [3] In this Work, we consider a point-to-point multi-input multi-output wireless-powered communication system, where the source S is powered by a dedicated power beacon (PB) with multiple antennas. Employing the time splitting protocol, the energy constrained source S first harvests energy through the radio-frequency signals sent by the PB and then uses this energy to transmit information to the destination D. Unlike several prior works, we assume that the energy transfer link is subjected to Rician fading, which is a real fading environment, due to relatively short range power transfer distance and the existence of a strong line of sight path. We present a comprehensive analysis of the achievable ergodic capacity in two scenarios, depending on the availability of channel state information (CSI) at PB, namely, the absence of CSI and partial CSI. For the former case, equal power allocation is used, while for the later one, energy beamforming is used to enhance the energy transfer efficiency. For both the cases, closed-form expressions for the upper and lower bounds of the ergodic capacity are derived. Furthermore, the optimal time split is discussed, and the capacity in the low and high signal-to-noise ratio regimes is studied through simple closed-form expressions. Numerical results and simulations are provided to validate the theoretical analysis. The results show that the Rician factor K has a significant impact on the ergodic capacity performance, and this impact strongly depends on the availability of the CSI at the PB

F. Zhao, H. Lin, C. Zhong, Z. Hadzi-Velkov, G. K. Karagiannidis and Z. Zhang [4] This Work investigates the ergodic capacity of a multi-input multi-output (MIMO) wireless powered communication system with partial channel state information at the power beacon (PB). Employing time splitting protocol, the PB first transmit energy-bearing signals to the energy constrained source S through beamforming, and then S uses this energy to transmit information to the destination. Unlike several prior works, we assume that the energy harvesting link is subjected to Rician fading. Base on this, we present a comprehensive analysis of the system achievable ergodic capacity. Specifically, closed-form expressions for the ergodic capacity bounds are derived. Besides, we investigated the capacity performance in both high and low signal-to-noise ratio regimes and the optimal time split that maximizes the capacity performance. Numerical results and simulations are provided to validate the theoretical analysis. The results show that the Rician factor K has a significant impact on the ergodic capacity performance

M. You, H. Sun, J. Jiang and J. Zhang, [5] This Work wishedfors a unified framework for the effective rate analysis over arbitrary correlated and not necessarily identical multiple-input single-output (MISO) fading channels, which uses the moment generating function (MGF) based approach and H transform representation. The wishedford framework has the potential to simplify the cumbersome analysis procedure compared with the probability density function-based approach. Moreover, the effective rates over two specific fading scenarios are investigated, namely, independent but not necessarily identical distributed (i.n.i.d.) MISO hyper Fox's H fading channels and arbitrary correlated generalized K fading channels. The exact analytical representations for these two scenarios are also presented. By substituting corresponding parameters, the effective rates in various practical fading scenarios, such as Rayleigh, Nakagami-m, Weibull/Gamma, and generalized K fading channels, are readily available. In addition, asymptotic approximations are provided for the wishedford H transform and MGF-based approach as well as for the effective rate over i.n.i.d. MISO hyper Fox's H fading channels. Simulations under various fading scenarios are also presented, which support the validity of the wishedford method.

A. Omri and M. O. Hasna, [6] In this Work, we present an optimization of the effective area spectral efficiency (EASE) metric for point-to-point transmission systems, and decode-and-forward (DF) relaying communications networks under Nakagami-m fading channels. For each transmission mode, we derive a closed-form expression for the maximum transmission range and use it to derive the average affected area, and the average ergodic capacity. We then introduce the EASE expression to quantify the spatial spectral utilization efficiency. For DF relaying, the EASE metric is based on a newly introduced index, namely, useful relaying index (URndx), which is used to validate the communication possibility between a source and a relay for given transmission parameters in a given environment, and provides information about the necessity of using relaying communications. Based on the expression of EASE, we derive the optimal transmission powers that maximize the EASE for each mode. Through mathematical analysis and numerical examples, we show that the EASE metric provides a new perspective on the design of wireless transmissions, especially the transmission power optimization process.

P. C. Thao, D. Le Khoa, N. T. Tu, L. H. Phuc and N. H. Phuong, [7] Optical Wireless Communication (OWC) is superior to radio wireless communication in several technical applications. In order to study the characteristics of Optical Multiple Input Multiple Output (OMIMO) channels, first, this Work presents the simulation of the optical wireless channel to analyze effects of dispersion multipath. We use ray tracing method to calculate the impulse response as well as the frequency response of the channel limit the reflections within seconds. Afterwards, we firstly investigate the OMIMO DCO-OFDM using Space Time Block Code (STBC) of Alamouti in diffuse fading channels to analyze the bit error rate (BER) of the system. The simulation results of the channel, as well as the communication system, are calculated and evaluated specifically.

O. S. Badarneh and R. Mesleh, [8] The end-to-end performance of cooperative beamforming in dual-hop relaying systems operating over η - μ fading channels is investigated. In the analysis, the source-destination node pair is equipped with multiple antennas, whereas the fixedgain relay has a single antenna. The η - μ fading channel has Nakagami-m, Rayleigh, one-sided Gaussian, and Nakagami-q (Hoyt) channels as special cases. In this Work, novel statistical expressions for the generalized moments of the end-to-end signal- to-noise ratio (SNR), cumulative density function (cdf), probability density function (pdf), and moment-generating function (mgf) are derived and evaluated. Furthermore, the obtained results are used to derive new and simple expressions for the pdf, the outage probability, and the mgf of the end-to-end SNR over Nakagami-m fading channels. In addition, we show that the derived expression for parameter C over the Nakagami-m fading channel is incorrect, and hence, it leads to inaccurate results. Also, we study the impact of the fading parameters η and μ on the end-to-end system performance. Simulation results show that, in contrast to the fading parameter η, μ has a significant impact on the system performance.

IV. PROBLEM IDENTIFICATION

This work, therefore, focuses on the design and analysis of OFDM system for powerline based communication. Different techniques will accordingly be investigated for achieving better performance. This will be accomplished by initially investigating the performance of the designed system for different modulation type and order. the transmission of bits and following the comparative performance analysis studies of the OFDM modem different techniques and scenarios will be conducted in future. Although there have been number of works on employing the OFDM techniques in powerline communication, there still remains many unexplored areas and techniques to be discovered and improved.

V. CONCLUSION

This work provided principal and theoretical background to digital modulation, and different digital bandpass modulation techniques such as PSK, FSK, ASK and QAM. This work also contained the simulation results for the three main types of modulations technique and one of the most important and popular hybrid systems. Following the simulation results for the main types of modulation scheme, the principal and theoretical background to the main blocks of an STBC-FT, including basic principle of STBC-FT, a high-level technical computing language called MATLAB® was used in order to design and put into operation the outlined of a communication system. More specifically, A step by step simulation response for each block of the transmission part of the designed fundamental System modem, consisting of the most important blocks.

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