2016 International Conference on Smart Green Technology in Electrical and Information Systems (ICSGTEIS)

CONFERENCE PROCEEDINGS
Advancing Smart and Green Technology to Build Smart Society

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Organized by
Department of Electrical and Computer Engineering
Postgraduate Study in Electrical and Computer Engineering
Udayana University

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WELCOME MESSAGE

It is my privilege and pleasure to welcome to the beautiful island of Bali all the distinguished participants to the International Conference on Smart-Green Technology in Electrical and Information Systems (ICSGTEIS 2016) which is held on 6 – 8 October 2016, in Sanur, Bali. The ICSGTEIS 2016 is organized by Department of Electrical and Computer Engineering together with Magister of Electrical and Computer Engineering, Udayana University, for international researchers, experts, students to share, exchange ideas, innovation, experience and the latest research in the field of Smart-Green Technologies. The conference is conducted in conjunction with 54th Anniversary of Udayana University and 51st Anniversary of Faculty of Engineering.

The conference includes a wide range of topics, that is not limited to Energy and Power Engineering, Electronic Devices and Systems, Multimedia Telecommunications, and Software Engineering and Information Systems. The conference has received 95 submissions. All submissions then have been reviewed through peer reviewing process. There are 38 selected papers for presentation.

Additionaly, the conference run three programs that are international workshop on ‘e-Government toward Smart City Implementation’, Udayana University IEEE Student Branch Workshop with topic of ‘Internet of Thing for Smart City’, International Student Conference conducted by Udayana University IEEE Student Branch, and social events. Totally eight keynote speakers are pleased to present and share their latest research in the plenary sessions and in the workshops.

For this good opportunity, I would like to express my great gratitude to all keynote speakers for their kind support to make this conference a great success. I would like to thank the IEEE Indonesia Section for their continuous support. My high appreciation goes to the President of Udayana University and Dean of Engineering Faculty of Udayana University for their encouragement and funding. Many thanks go to Primakara, PT. Telkom, and all technical sponsors for their kind assistance. In addition, I am grateful for great support of all technical program and organizing committees for their hard work for more than one year. Finally many thanks go to all participants. With all of your supports, the conference could be run now.

I wish you all have a successful conference and pleasant experience of Bali.

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ICSGTEIS 2016 General Chair
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INVITED TALKS
Inkjet-/3D-/4D- Printed Paper/Polymer-Based "Green" mmW Modules: The Final Step to Bridge Cognitive Intelligence, Nanotechnology and RF for IoT and 5G Applications

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Abstract. In this talk, inkjet-/3D-printed flexible antennas, RF electronics and sensors fabricated on paper and other polymer (e.g. LCP) substrates are introduced as a system-level solution for ultra-low-cost mass production of Millimeter-Wave Modules for Communication, Energy Harvesting and Sensing applications. Prof. Tentzeris will briefly touch up the state-of-the-art area of fully-integrated wireless sensor modules on paper or flexible LCP and show the first ever 2D sensor integration with an RFID tag module on paper, as well as numerous 3D and 4D multilayer paper-based and LCP-based RF/microwave structures, that could potentially set the foundation for the truly convergent wireless sensor ad-hoc networks of the future with enhanced cognitive intelligence and "rugged" packaging. Prof. Tentzeris will discuss issues concerning the power sources of "near-perpetual" RF modules, including flexible miniaturized batteries as well as power-scavenging approaches involving thermal, EM, vibration and solar energy forms. The final step of the presentation will involve examples from mmW wearable (e.g. biomonitoring) antennas and RF modules, as well as the first examples of the integration of inkjet-printed nanotechnology-based (e.g. CNT) sensors on paper and organic substrates for Internet of Things (IoT), 5G and autonomous vehicles applications. It has to be noted that the talk will review and present challenges for inkjet-printed organic active and nonlinear devices as well as future directions in the area of environmentally-friendly ("green") RF electronics and 'smart-skin' conformal sensors.
Learning Design and Digital Resources for STEM Education

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Abstract. STEM (curriculum integration of Science, Technology, Engineering and Mathematics) is being strongly recognized as critical for development of contemporary societies in the atmosphere of increasing economic, scientific and technological globalization. STEM related reforms emphasize that the teaching practices must (a) focus across the curriculum of the STEM disciplines, (b) be inquiry-, problem- and activity-based, and (c) incorporate digital literacies. In this paper we explore learning design framework and suitable digital resources for development of concept knowledge in STEM education. Further attention in this paper is given to an appropriate curriculum design that can serve needs and requirements of STEM education. Such curriculum must clearly emphasize importance of concept learning in STEM, in addition to that, promote knowledge uses and development of digital literacies.
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Performance Comparison of MC-SS MIMO and OFDM MIMO Systems on Selective Fading Channel

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Abstract—The combination of spread spectrum, OFDM (Orthogonal Frequency Division Multiplexing), and MIMO (Multiple Input Multiple Output) is expected to reduce the bit error rate and the fading effects so that enhancing the reliability of wireless communication. This research is aimed to assess the performance of Multi Carrier-Spread Spectrum MIMO (MC-SS MIMO) and OFDM MIMO systems in term of bit error rate versus energy bit per power noise (BER vs. Eb/No) over AWGN, flat fading, and selective fading channels. MC-SS MIMO and OFDM MIMO systems are modeled and simulated. The results have showed MC-SS MIMO system has given better performances compared to MIMO OFDM system. This condition applies on all channel models.

Keywords—MC-SS, MIMO, OFDM, BER, fading

I. INTRODUCTION

The combination system of the wireless telecommunication network aims to increase the data rate and decrease fading effects of the channel. The existing combination system that used in 4G is OFDM MIMO system. It combines OFDM technique with MIMO technique. The combination of spread spectrum, OFDM, and MIMO is expected to reduce the bit error rate and the fading effects so that enhancing the reliability of wireless communication.

In the spread spectrum technique each user is distinguished by providing a different spreading code, which code length is determined by the value of the spreading factor (SF) so that are not susceptible to distortion and multi-path interference [1].

OFDM (Orthogonal Frequency Division Multiplexing) is a transmission technique that uses multiple frequencies (multicarrier), which is the high-speed serial data stream divided into perpendicular subcarrier and add cyclic prefix to widen the duration of a symbol, to keep from Inter Symbol Interference (ISI) of multipath fading and interference due to noise [2].

Multipath fading in the wireless channel can be solved by MIMO (Multiple Input Multiple Output) system. MIMO system uses multiple transmitter and receiver antennas, which aims to make the reflected signal as the main signal amplifier so that amplifies each other [3].

Based on the advantages of OFDM, spread spectrum, and MIMO techniques, the combination of those techniques are modelled and analysed in this paper. This research is aimed to compare the performance of MC-SS MIMO system and OFDM MIMO system over AWGN, flat fading, and selective fading channel in term of BER vs. Eb/No.

This paper is organized as follows: Chapter I shows the background of the problem, Chapter II describes the transmission techniques in wireless communication, MIMO system is presented in Chapter III, System model is presented in Chapter IV, Chapter V shows results and discussion, finally, Chapter VI demonstrates conclusions.

II. TRANSMISSION TECHNIQUES

A. OFDM

OFDM is a special form of multicarrier modulation that divides high speed data flow into a number of low-speed data and then sent it through multiple subcarriers. In OFDM, the input data is supplied to several orthogonal parallel subcarriers with lower data rate. Subcarrier is not placed based on bandwidth, but arranged for overlapping each other and arranged to have a distance between subcarrier to build an orthogonal properties [4],[6],[8]. Simple OFDM system block diagram is showed in Fig. 1.

Fig. 1. OFDM Diagram Block
B. Spread Spectrum

The process of direct sequence spread spectrum (DSSS) is presented in the Fig. 2.

![Fig. 2. Block Diagram of Direct Sequence Spread Spectrum (DSSS)](image)

The description of DSSS system in Fig. 2 is as follows:

1) Input: Binary data $d_i$ with symbol rate $R_s = 1/T_s$ (bitrate $R_b$ for BPSK). *Pseudo-noise code $p_n$ with chip rate $R_c = 1/T_c$* [5].

2) Spreading: Transmitter ($t_0$), binary data ($d_i$) (for BPSK, I and Q for QPSK) directly multiple with PN sequence ($p_n$) which is separate from baseband binary data, to produce baseband signals transmitted $t_0$ [5]. The multiplication process refers to (1).

$$t_0 = d_i \cdot p_n \quad (1)$$

The effects of the $d_i$ multiplication by the PN sequence is to spread *baseband bandwidth $R_b$* from $d_i$ to *baseband bandwidth $R_c$* [5].

3) Despreading: *Spread Spectrum* signal cannot be detected with conventional narrowband receiver. At the receiver, baseband signal $r_0$ multiplied by PN sequence $p_n$ [5].

If $p_n = p_n$ synchronized to the PN sequence in the data received, then the binary data is restored produced on $d_i$ due to the multiplication of the spread spectrum signal $r_0$ with the PN sequence $p_n$ used in the transmitter is to disspread bandwidth $r_0$ to $R_b$ [5].

If $p_n \neq p_n$, then despread does not occur. A $d_i$ signal has *spread spectrum*. Receiver does not know PN sequence from transmitter so it cannot reproduce the data that has been sent [5].

III. MULTIPLE INPUT MULTIPLE OUTPUT

The principle of MIMO is to multiply the signal transmitted information to improve communication skills and reduce errors that can occur as a result of the transmission channel [4][9][10]. The MIMO antenna scheme can be seen in Fig. 3.

![Fig. 3. MIMO Antenna Scheme](image)

![A MIMO system][4][9][10], is presented in Equation 2.

$$y = h \cdot x + n \quad (2)$$

where $y$ is the received signal vector, $h$ is the channel impulse response matrix of $N$ number of transmitter antenna and $M$ number of receiver antenna ($N \times M$), $x$ stated transmitted signal vector, and $n$ states AWGN noise vector [4][9].

A. *Space Time Block Code (STBC)*

STBC system will send two different symbols simultaneously. At the moment of time $t$, the first antenna (Tx1) sends a signal $S_0$ and a second antenna (Tx2) transmit signals $S_1$. It is assumed that $S_0$ and $S_1$ is a symbol that has been modulated. Then at time $t + T$, the symbols of each transmitter antenna conjugated so that the first antenna (Tx0) will send a signal - and the antenna (Tx1) transmit signal + [4] as shown in Fig. 4.

![Fig. 4. MIMO STBC 2x2 Scheme](image)

In MIMO systems, the received signal at the receiver is the sum of the received signal from each antenna. The signals received in two adjacent intervals with the notation symbols which are shown as Tables 1 and 2 [4].

<table>
<thead>
<tr>
<th>Table 1 Channel notation on receiver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rx Antenna 1</td>
</tr>
<tr>
<td>Tx Antenna 1</td>
</tr>
<tr>
<td>Tx Antenna 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2 Signal notation on receiver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rx Antenna 1</td>
</tr>
<tr>
<td>t time</td>
</tr>
<tr>
<td>$t + T$ time</td>
</tr>
</tbody>
</table>

Equation 3 is the relationship between channel notation ($h$), signal notation ($r$), [4].

$$\begin{align*}
th_0 &= h_0s_0 + h_2s_1 + n_0 \\
h_1 &= -h_0s_1 + h_2s_1 + n_2 \\
h_2 &= h_0s_2 + h_2s_2 + n_2 \\
h_3 &= -h_0s_2 + h_2s_2 + n_2
\end{align*}$$
Where \( n \) is a complex random variable that shows the thermal noise and interference receiver [4].

1) Signal Combiner: Combiner made following the two signals are then sent to the Maximum likelihood Detector. Rules of combiner refer to Equation (4) and (5) [4].

\[
\begin{align*}
S_2 &= h_2 n_2 + h_2 n_1^2 + h_2 n_2^2 + h_1 n_2^2 \\
S_1 &= h_1 n_1 - h_0 n_1 + h_2 n_2 - h_2 n_1^2
\end{align*}
\]  

(4) 

(5) 

By substituting Equation (3), (4) and (5) appropriately then obtained Equation (6) and (7) [4]:

\[
\begin{align*}
S_2 &= (\omega_0^2 + \omega_1^2 + \omega_2^2 + \omega_3^2) n_0 + h_2 n_0 \xi_0 + h_2 n_2 n_0 - h_2 n_2 n_1^2 - h_2 n_1 + h_2 n_0 n_2 + h_2 n_2 + h_2 n_1^2 - h_2 n_1^2 - h_2 n_2^2 - h_2 n_2^2 - h_2 n_2^2 - h_2 n_2^2
\end{align*}
\]  

(6) 

(7) 

2) Maximum Likelihood Detector: Maximum Likelihood (ML) decoder will operate in accordance with Equation (8) and Equation (9). So signal is used for decision criteria, which refers to Equation (8) [4].

\[
\begin{align*}
(a_1 + a_2 + a_3 + a_4 - 1)|s|^2 + d^2(s_2, s_3) &\leq (a_1 + a_2 + a_3 + a_4 - 1)|s|^2 + d^2(s_2, s_3) \\
(a_1 + a_2 + a_3 + a_4 - 1)|s|^2 + d^2(s_2, s_3) &\leq (a_1 + a_2 + a_3 + a_4 - 1)|s|^2 + d^2(s_2, s_3)
\end{align*}
\]  

(8) 

For signal \( S_1 \), which refers to Equation (9) [4].

\[
\begin{align*}
(a_1 + a_2 + a_3 + a_4 - 1)|s|^2 + d^2(s_2, s_3) &\leq (a_1 + a_2 + a_3 + a_4 - 1)|s|^2 + d^2(s_2, s_3) \\
(a_1 + a_2 + a_3 + a_4 - 1)|s|^2 + d^2(s_2, s_3) &\leq (a_1 + a_2 + a_3 + a_4 - 1)|s|^2 + d^2(s_2, s_3)
\end{align*}
\]  

(9) 

IV. SYSTEM MODEL

A. Channel Model

Fading channel model has impulse responses \( h(t) \) as shown in Equation (10) [11][17][18][19].

\[
h_{\text{imp}}(t) = \sum_{k=1}^{6} h_k^{15} \delta(t - t_k)
\]  

(10) 

In fading channel model, power delay profile (PDP) that used is PDP outdoor or Typical Urban without Doppler. PDP for Typical Urban Channel can be seen in Table 3 [1].

<table>
<thead>
<tr>
<th>Path, ( k )</th>
<th>Path delay, ( t_k ) [μs]</th>
<th>( p(t_k) ) [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>-3.0</td>
</tr>
<tr>
<td>2</td>
<td>0.199</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>0.502</td>
<td>-2.0</td>
</tr>
<tr>
<td>4</td>
<td>1.606</td>
<td>-6.0</td>
</tr>
<tr>
<td>5</td>
<td>2.307</td>
<td>-8.0</td>
</tr>
<tr>
<td>6</td>
<td>5.017</td>
<td>-10.0</td>
</tr>
</tbody>
</table>

Table 3. PDP for typical urban channel

In fading channel model, the parameter is delay spread. Parameter delay spread is often written in the form of root mean square (rms), given in Equation (11) [11][17][18][19].

\[
\sigma_r = \sqrt{\frac{\tau^2}{\overline{\tau^2}}}
\]  

(11) 

where \( \overline{\tau} \) is mean excess delay expressed by Equation (12) and (13).

\[
\overline{\tau} = \frac{\sum_{k} P(\tau_k) \tau_k}{\sum_{k} P(\tau_k)}
\]  

(12) 

and

\[
\overline{\tau^2} = \frac{\sum_{k} P(\tau_k) \tau_k^2}{\sum_{k} P(\tau_k)}
\]  

(13) 

Flat fading channel has a flat spectral characteristic, while in frequency selective fading channel has fluctuates spectral characteristic. Flat fading channel characteristics in terms of rms delay spread \( \sigma_r \), symbol period \( T_s \), bandwidth channel \( B_c \), and bandwidth signal \( B_s \) which shown in Equation (14) and (15) [4][11].

\[
B_s << B_c \quad \text{and} \quad T_s >> \sigma_r
\]  

(14) 

(15) 

while the characteristics of frequency selective fading channel shown in Equation (16) and (17) [4][11].

\[
B_s > B_c \quad \text{and} \quad T_s < \sigma_r
\]  

(16) 

(17) 

B. MS-SS MIMO and OFDM MIMO Model

The MC-SS MIMO system over AWGN, flat and selective fading model can be seen in Fig. 5. In spreading process, spreading code and spreading factor are contributed the process. The data is formed from spreading modulation, it experiences number of lines changes where the number of lines spreading results to adjusting the value of the variable spreading factor [6][13]. Notation \( A \) denotes the multiplication of \( N \) and length of spreading factor variable. \( d \) denotes number of bits transmitted. \( N \) denotes number of symbols.

In OFDM-MIMO system, there is no spreading process [4]. Symbol modulated is converted from serial to parallel to form the subcarriers. OFDM MIMO system model over AWGN, flat and selective fading can be seen in Fig. 6. Before entering into MIMO, OFDM symbol has formed from parallel to serial and then split into two parts according to the number of MIMO antenna.
Fig. 5. Block Diagram of MC-SS MIMO System Model

Fig. 6. Block Diagram of OFDM MIMO System Model
V. RESULTS AND DISCUSSION

A. Comparison of MC-SS MIMO and OFDM MIMO System

Parameters are used in the simulation is presented in Table 4.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFDM Symbol length</td>
<td>64</td>
</tr>
<tr>
<td>Number of subcarrier</td>
<td>52</td>
</tr>
<tr>
<td>Number of FFT symbol</td>
<td>64</td>
</tr>
<tr>
<td>Modulation type</td>
<td>QPSK</td>
</tr>
<tr>
<td>Zero Padding length</td>
<td>14</td>
</tr>
<tr>
<td>Guard interval type</td>
<td>Cyclic prefix</td>
</tr>
<tr>
<td>Cyclic prefix length</td>
<td>16</td>
</tr>
<tr>
<td>Spreading code type</td>
<td>Walsh-Hadamard</td>
</tr>
<tr>
<td>Variable spreading factor</td>
<td>16</td>
</tr>
<tr>
<td>Spread spectrum type</td>
<td>Direct sequence spread</td>
</tr>
<tr>
<td>User type</td>
<td>Single user</td>
</tr>
<tr>
<td>MIMO type</td>
<td>STBC 2x2</td>
</tr>
<tr>
<td>Eb/No</td>
<td>-10 dB to 10 dB</td>
</tr>
<tr>
<td>Number of bit</td>
<td>100,000 bit (random)</td>
</tr>
</tbody>
</table>

The simulation showed a performance comparison of MIMO OFDM and MC-SS MIMO over AWGN channel, flat fading and frequency selective fading. It can be seen in Fig. 7, 8, and 9, respectively.

Fig. 7, 8, and 9 depicted that MC-SS MIMO system has better performance compared to OFDM MIMO system for all channel conditions. This is due to spreading process to the transmitted symbol. Referring to [12], the best spreading code method is Walsh-Hadamard where it is used in the simulation. One transmitted symbol spreads throughout the value of the variable spreading factor [14][15].

Fig. 8. BER Comparison of MC-SS MIMO and OFDM MIMO Systems over Flat Fading Channel

Fig. 9. BER Comparison of MC-SS MIMO and OFDM MIMO Systems over Frequency Selective Fading Channel

Using Walsh-Hadamard code, symbols are reserved at any time if an error occurs. The reserve of other symbols can be detected by receiver. Due to its advantage, there are not whole symbols destroyed. In the MIMO OFDM system, symbols are transmitted without reverse. When an error occurs, it will affect the whole symbols. The receiver cannot detect the symbol that was sent. The condition is illustrated in Table 5.

B. Comparison of Channel Models on MC-SS MIMO and OFDM MIMO Systems

The performance comparison of MC-SS MIMO and OFDM MIMO over AWGN, flat fading and selective fading channels can be seen in Fig. 10 and Fig. 11, respectively. From Fig. 10 and Fig. 11, it can be seen that the performance of MC-SS MIMO and OFDM MIMO systems over AWGN channel experiences the best performance compared to the systems over flat and frequency selective fading channels.
Table 5. Illustration of Spread Spectrum and OFDM Technique

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Spread Spectrum</th>
<th>OFDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit (8 bit)</td>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td></td>
<td>0 1</td>
<td>0 1</td>
</tr>
<tr>
<td></td>
<td>1 0</td>
<td>1 0</td>
</tr>
<tr>
<td></td>
<td>1 1</td>
<td>1 1</td>
</tr>
<tr>
<td>Symbol Data</td>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td></td>
<td>1 0</td>
<td>0 1</td>
</tr>
<tr>
<td></td>
<td>2 0</td>
<td>1 0</td>
</tr>
<tr>
<td></td>
<td>3 0</td>
<td>1 1</td>
</tr>
<tr>
<td>SF</td>
<td>16</td>
<td>None</td>
</tr>
<tr>
<td>Chips</td>
<td>1 -1 1 -1 1 -1 1 -1 1 -1 1 -1 -1</td>
<td>None</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spreading Process</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Assume the number of error for Eb/No = 0 on frequency selective fading channel is 2 symbol</td>
<td>(0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 -0 / 16</td>
<td>0 0</td>
</tr>
<tr>
<td></td>
<td>(1 -1 1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 / 16</td>
<td>1 0</td>
</tr>
<tr>
<td></td>
<td>(3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 -3 / 16</td>
<td>3 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Despreading Process</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Assume the number of error for Eb/No = 0 on frequency selective fading channel is 2 symbol</td>
<td>(0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 / 16</td>
<td>0 0</td>
</tr>
<tr>
<td></td>
<td>(1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 / 16</td>
<td>1 0</td>
</tr>
<tr>
<td></td>
<td>(2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 / 16</td>
<td>2 0</td>
</tr>
<tr>
<td></td>
<td>(3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 / 16</td>
<td>3 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol Mapping to Integer Value based on Despreading result under condition:</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 = 0 - 0.749</td>
<td>None</td>
</tr>
<tr>
<td>1 = 0.75 - 1.5</td>
<td>None</td>
</tr>
<tr>
<td>2 = 1.51 - 2.249</td>
<td>None</td>
</tr>
<tr>
<td>3 = 2.25 - 3</td>
<td>None</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol Received</th>
<th>0 0</th>
<th>0 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit Error Rate</td>
<td>0 0</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Fig. 12 showed the relation between BER and normalization delay. Normalization delay is the value of normalization of the \( \text{rms} \) delay spread. Referring to the [7], which is normalized delay of 0.1 to 0.6. The relation of delay normalization, \( \text{rms} \) delay spread and symbol period defined by Equation (18).

\[
\text{Symbol Period (Ts)} = \frac{\text{rms delay spread (\text{2f})}}{\text{delay normalization}}
\]  

(18)

From equation (18), it can be seen that the increasing normalized \( \text{rms} \) delay spread at the same delay spread, it causes symbol period getting smaller. From Fig. 12, it can be seen that the smaller symbol period, the BER has increased.

VI. CONCLUSION

The performances of MC-SS MIMO and OFDM MIMO systems over AWGN, flat fading and frequency selective fading channels have discussed. The MC-SS MIMO and OFDM MIMO systems over frequency selective fading channel experiences the worst performances compared to the systems over other channels. It occurs because symbol period lower than \( \text{rms} \) delay spread. So the systems are more susceptible to Inter Symbol Interference (ISI). The MC-SS MIMO system gives better performance compared to OFDM MIMO systems. This is due to spreading process to the transmitted symbol. One transmitted symbol will spread throughout the spreading factor.

REFERENCES