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PERFORMANCE ANALYSIS OF COOPERATIVE COMMUNICATION SYSTEMS USING WIRELESS OPEN ACCESS RESEARCH PLATFORM FOR INDOOR AND OUTDOOR ENVIRONMENT

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ABSTRACT

Effect of multipath fading can decrease the performance of wireless communication systems. The multi-input multi-output (MIMO) technique, which uses multiple antennas, often used to overcome multipath fading. This technique is one of the diversity techniques. Some wireless devices have limitation about the size, cost, and hardware complexity, so there can not implement a multiple antenna. Then, new technique has been developed to overcome these limitations, there was called cooperative communication systems. Although the cooperative communication system has been widely studied, but it was not much researcher already implemented this system. Therefore, this study will be conducted a simulation and implementation of cooperative communication system on Wireless Open Access Research Platform (WARP) module using Demodulate and Forward relaying techniques with Maximum Ratio Combining (MRC) and Selection Combining (SC). In this research will compare the performance of cooperative communication system with non-cooperative communication system, i.e. Single Input Single Ouput (SISO) and multi-hop to evaluate the BER performance as function of the transmit power and distance variation. At the first scheme of BER measurement, the distance between the source and the destination was fixed as 6 meters, relay was right in the middle, and the transmit power be varied from -39.67 dBm to -11.47 dBm. In the second scheme, the transmit power was be adjusted -39.67 dBm, the distance between the source and destination in a variation of 1 meter to 6 meters. The results of measurement showed that cooperative communication system with MRC better than SISO communication systems, multi-hop communication and cooperative communication system with SC for indoor or outdoor environment.

Keywords: *Cooperative Communication System, Relay, Demodulate And Forward, MRC, SC, WARP*

1. INTRODUCTION

Currently, the development of communication technology is very rapidly. Many communications equipment that uses wireless media has many advantages, i.e. a simple and a high mobility. In implementation of wireless communication system has many challenges, such as a signal is transmitted over wireless communication, a signal will have a lot of interference that can degrade system performance. Channel conditions will decline so that channel capacity and reliability of the transmitted data is also decreased. Multipath fading is the most dominant effect in the wireless communication system.

To overcome multipath fading, diversity techniques are used. Spatial diversity is one technique that uses multiple antennas (MIMO). Some wireless devices have limited the size, cost, and complexity of the hardware so that we can not implement multiple antennas [1]. Then there was developed other techniques to overcome these limitations that it was called cooperative communication systems. By using cooperative communication systems, can be generated virtual antenna that supports diversity techniques [2].

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Cooperative communication system is a mechanism that uses the resources of the nodes are distributed to improve the overall performance of wireless networks [3]. In the cooperative communication systems, source (S) sends information broadcast to destination (D) and to relay (R) which is another user nearby. Therefore the signal received by R will be processed and then sent to D. The signals are received from the source or relay will undergo a process of combining on the destination side [4].

Research on cooperative communication system was widely studied [1-2] [5-6]. On the paper provides a very good overview of the theory of cooperative communication systems. Although the cooperative communication system has been widely studied, little research that implements the system. Thus, the problems associated with implementation are still not well understood.

There are a wide range of platforms used to implement cooperative communication systems. In [7] the authors use software-define-radio platform that is used for the design of physical layer (PHY). There is still a shortage if you use that platform, i.e. the software implementation of the physical layer does not work in real time. As for the other platforms that can be used is the GNU Radio project. The project provides a flexible platform for wireless development, which includes open-source framework from wireless algorithms are implemented in software. With most of the processing is executed the PC host, the GNU Radio system can not achieve the high-throughput communications and wide-band communication [8]

One platform that can improve the deficiencies of the previous platform was WARP. Wireless Open-Access Research Platform (WARP), a FPGA module that has been prepared to implement advanced wireless algorithms. This platform has many advantages, WARP is made with special hardware design, integrate resources FPGA-based processing with real radio interface. Moreover this platform is supported by a special module that allows users of various processing hardware and peripheral resources. The platform also supports the modules used to build a variety of research applications, including real-time implementation of the physical layer and MAC layer [9-11]. Therefore, in this study the authors will implement cooperative communication system in the Wireless Open Access Research Platform (WARP). This research demonstrated the performance of cooperative communication systems in indoor and outdoor environments. Indoor measurements will be performed in Building B303 and outdoor measurements performed in the parking lecturer of the Department of Electrical Engineering Institute of Technology - Surabaya.

The paper begins with a brief description of research background in introduction section. Section II describes research methode. Section III explains implementation results and analysis. Finally, a summary is given in the last section.

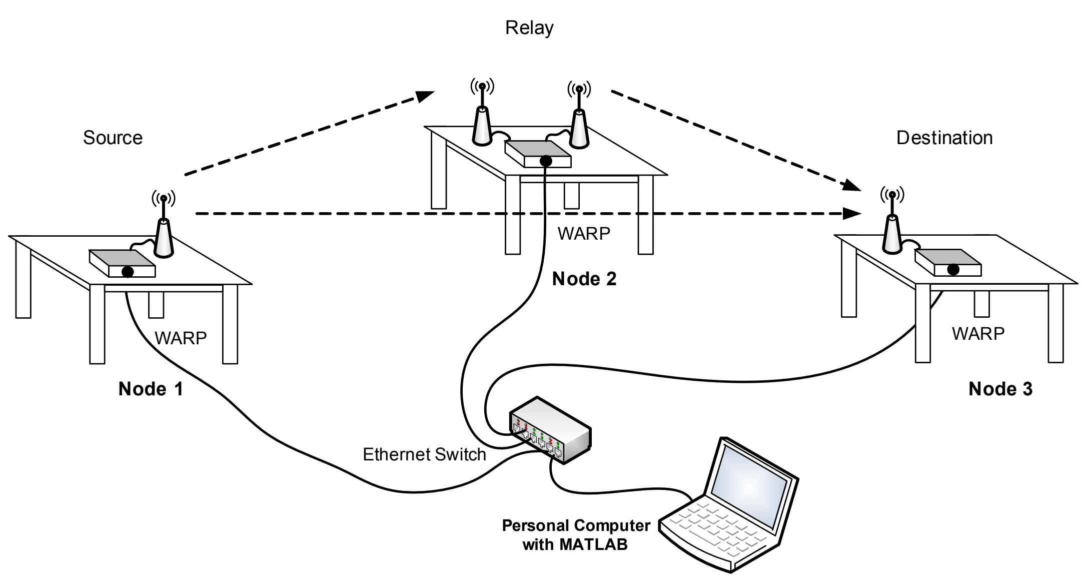

Figure 1: Cooperative Communications System Configuration on WARP

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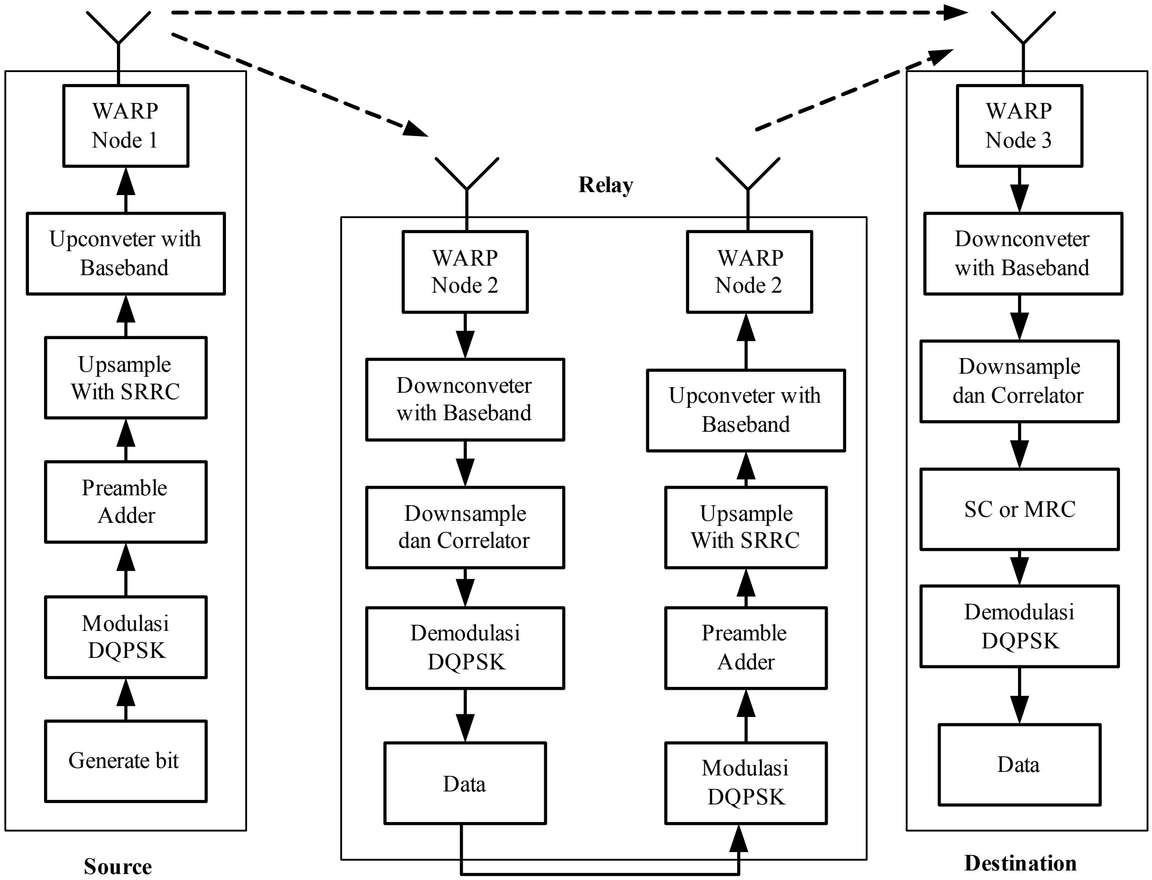

Figure 2: Cooperative Communications System Block in WARP

2. SYSTEM MODEL AND RESEARCH METHODE

In the cooperative communication systems, source (S) relay that information broadcast to destination (D) and to relay (R) which is the other users in the area are close by. Then the signal received by R will be processed first and then sent to D. The signals received from the sender or from the relay will experience the process of combining in the receiver [4]. Implementation of the WARP cooperative communication system will be described as shown in Figure 1.

Cooperative communication systems operating under the protocol Time Division Multiplexing (TDM) in which the source transmits data during the first slot and the relay transmits during the second. The data which is transmitted during the first time slot is received by the relay and the destination node. In this study the type of relay used is demodulate and forward.

This implementation is performed on the module WARP is an FPGA module that has been prepared to implement advanced wireless algorithms. The communication system described in this paper using such a PC-based version of WARP MATLAB called WARPLAB. WARP-based cooperative communication system is designed to use a modulation technique Differential Quadrature Phase Shift Keying (DQPSK). By using DQPSK modulation, does not require phase synchronization at the receiver because DQPSK is a non-coherent modulation technique. Figure 2 is a block diagram design to the implementation of cooperative communication system in WARP.

Based on Figure 2 can be seen that WARP (node1) as a source, WARP (node2) as a relay, and WARP (node3) as a destination. Data is raised a bit stream along 2^{11}, then carried the DQPSK modulation, added preamble, through up-sampling process with Squared Root Raised Cosine (SRRC) and the up-converter and the baseband signal is

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ready to be delivered through the WARP node 1 to the relay and the destination.

In the relay (node 2), the signal undergo the reverse process from the source (node 1) is down converter, down sample, and demodulation. Furthermore, the signal is transmitted to the destination (node 3). At the destination (node 3) receives two signals, the signals are from the source and the signal from the relay. Both of these signals will undergo a process of combining. The combining technique used is Selection Combining (SC) and Maximum Ratio Combining (MRC).

At techniques Selection Combining (SC), there was selected the best signal from all of the received signal in destination. This selection was based on the value of the Receive Signal Strength Indicator (RSSI) which is the biggest in accordance with equation (1)

$$y_d[n] = \begin{Bmatrix} y_{S,} & if\, RSSI_S > RSSI_R \\ y_{R,} & others \end{Bmatrix} \quad (1)$$

As for the technique Maximum Ratio Combining (MRC), the both signal was summed as Equation (2):

$$y_d[n] = \frac{RSSI_S}{RSSI_S + RSSI_R} y_s[n] + \frac{RSSI_R}{RSSI_S + RSSI_R} y_R[n] \quad (2)$$

where :

$y_d[n]$: MRC output signal in destination
$RSSI_S$: RSSI of received signal from *source*
$RSSI_R$: RSSI of received signal from *relay*
$y_s[n]$: received signal from *source*
$y_R[n]$: received signal from *relay*

After combining process, the receiver will do the reverse process of that performed by the transmitter. As these stages are down converter, filters Squared Root Raised Cosine (SRRC) at the receiver and down sampling. To detect the location of the preamble, correlation process is carried out with reference matrix that has been generated on the receiver. After that, on the end stage, it demodulates the DQPSK signal to obtain estimates of the received signal. Furthermore, the received signal compared to the signal sent to count the value of the bit-error-rate of system.

3. IMPLEMENTATION RESULTS AND ANALYSIS

In the Chapter III contains the results of simulation and analysis, which includes the cooperative communication system on module WARP, with reference to the parameters in Table 1.

Table:1 Simulation Parameter

No.	Parameter	Specification
1.	Number of bit	2^{11}
2.	Modulation scheme	DQPSK
3.	Filter type	SRRC
4.	Number of *preamble*	13
5.	Number of *sample*	8
6.	Sample Frequency	40 MHz
8.	*Carrier Channel*	12 [0-14]
9.	*Transmitter baseband gain*	0 [0-3]
10.	*Transmitter RF gain*	0-63
11.	*Receiver baseband gain*	0 [0-31]
12.	*Receiver RF gain*	[1-3]

3.1 Implementation Results of Cooperative Communication System on WARP Module

In this implementation of cooperative communication systems, relay is used to the demodulation process, then it forwards signal to destination. In Figure 3 will be shown in the signal forms sent from the source and received.

Based on the WARP specifications that signal input at the transmitter buffer must be between the amplitude of -1 and 1. As explained earlier that the cooperative communication system is two paths, the direct path (source - destination) and the path through the relay (source - relay - destination). Figure 3 shows the signal to be transmitted by the source with the amplitude level between -1 and 1. It also shows the signal received by the relay. Based on these images can be seen that the signals arriving at the relay delayed and decreased amplitude.

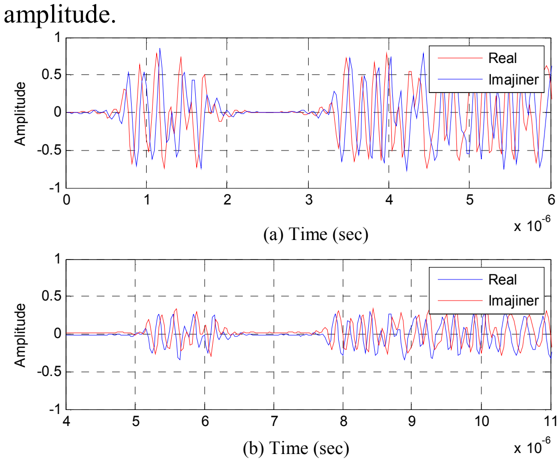

Figure 3: (a) Baseband Signal from Source, (b) Received Baseband Signal in Relay

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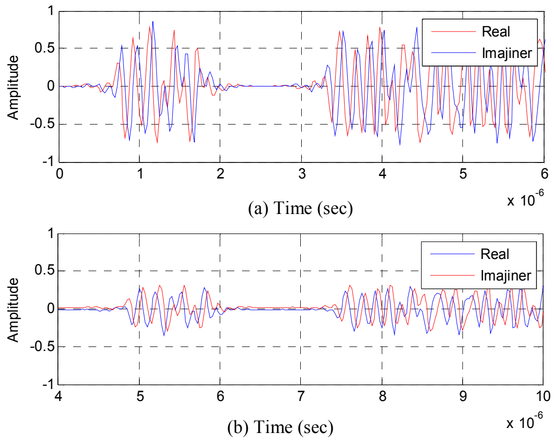

Figure 4: (a) the Baseband Signal Sending by Relay, (b) Baseband Signal Received by Destination

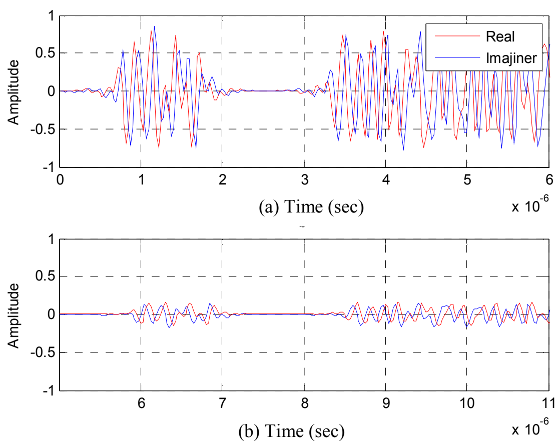

Figure 5: (a) Baseband Signal Sent by Source, (b) Baseband Signal Received by Destination (direct link)

Because the relay is used Demodulate and Forward, then the relay undergo demodulation process before hand. After the demodulated signal is modulated so that the signals sent back by the relay resembles the signal transmitted by the source, then the signal will be sent to the destination. The image signal sent by the relay and received by the destination shown in Figure 4.

Figure 4 shows that the signals sent by the relay resemble the signal sent by the source because in the relay has demodulation and modulation processes. Not only that the signal received by the destination even resemble the signal received by the relay. In direct path (source - destination), distance between the source to destination twice the distance of the source to relay or relay to destination. The signal form is sent by the source to the destination with a direct path or no relay is shown in Figure 5.

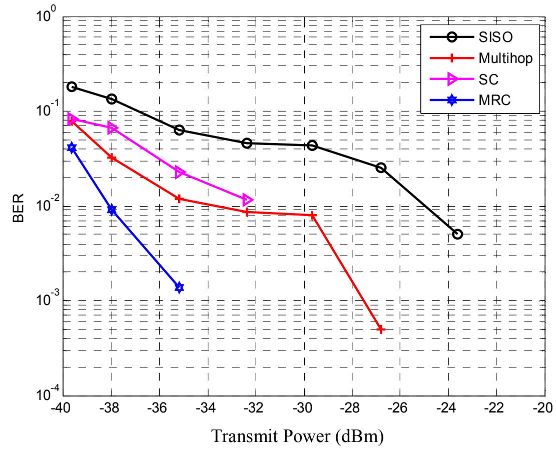

Figure 6: Performance of Cooperative Communication System for various Taransmit Power in Indoor Environment

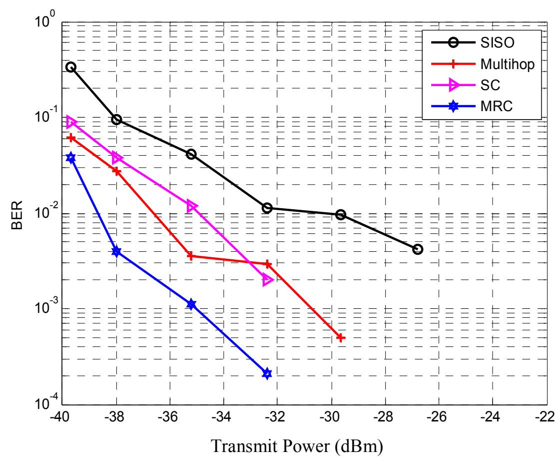

Figure 7: Performance of Cooperative Communication System for various Taransmit Power in Outdoor Environment

Based on Figure 5, it can be seen that received signal by the destination was smaller and the delay was greater in the direct path than if through a relay. Based on the signal form, the use of the relay is more profitable than a direct path.

3.2 Analysis of Implementation Results on WARP for Various Transmit Power

In this section, it compared to the three systems that have been implemented i.e. SISO communication system, multi-hop and cooperative communication system. The cooperative communication system will be evaluated to use two combining techniques, by using Selection Combining (SC) and Maximum Ratio Combining (MRC). Performance of system will be evaluated

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that bit error rate as function of the transmit power. The distance between souece and destination is 6 meters, and relay is right down the middle. This measurement is performed in indoor and outdoor environments.

Based on Figure 6, it can be seen that the cooperative communication system using Maximum Ratio Combining (MRC) is better than non-cooperative communication systems (SISO), multi-hop communications system or a cooperative communication system using Selection Combining (SC). For example, Indoor environment, the transmit power of -35.19 dBm, the SISO communication system has Bit Error Rate (BER) at 6.25 x 10^{-2}. In the multi-hop communication system and the system of cooperative communication system using Selection Combining (SC), its value is almost the same BER is1.2 x 10^{-2} and2.27 x 10^{-2} dBm, while the value of BER in cooperative communication system using Maximum Ratio Combining (MRC) is 1.4 x 10^{-3}. Only by using the transmit power of -32.39 dBm in cooperative communication system using Maximum Ratio Combining (MRC) have been achieved BER value of 0, in other words all the data received there were no errors. As for the multi-hop and SISO communication system get BER is equal to 0 at the transmit power -20.3395 dBm and -23.5975 dBm.

Performance of multi-hop communication system is similar to the cooperative communication system using a type Selection Combining (SC). The cooperative communication system with Selection Combining (SC) selects one of the signals that have the greatest SNR between direct path with via relay (multi-hop). It is assumed that nodes are not moving. Signal on direct channel is worse than the multi-hop. A cooperative communication system using Selection Combining (SC) always chooses the signal from multi-hop channel so that the performance of cooperative communication system using Selection Combining (SC) is almost the same as multi-hop communication system. If seen the results of the implementation of the BER values of communication system using Selection Combining (SC) is not much different to the multi-hop communication system. For example the transmit power of -39 672 dBm, BER value at multi-hop communication amounted to 7.87 x10^{-2} while cooperative communication system using Selection Combining (SC) is 8.35 x 10^{-2}. Based on Figure 3, power transmit values also affect the value of BER where for the transmit power increases, so BER value of system decrease. In addition to the analysis conducted in the indoor environment, the analysis is also done outdoor environment shown in Figure 7.

In general, it can be seen that performance of the SISO, multi-hop and cooperative communication system in outdoor environments showed a similar pattern to the indoor environment in which the cooperative communication system using Maximum Ratio Combining (MRC) is better than SISO, multi-hop and cooperative communication system using Selection Combining (SC).

3.3 Analysis of Implementation Results on WARP for Various Distance

In this section, the system performance is evaluated for the condition of transmit power remains while the distance between the source and destination are made varies. The result can be seen in Figure 8 and 9. In the figure can be seen that the distance between the source and destination affects BER values. For example in the cooperative communication system using Maximum Ratio Combining (MRC), at a distance of 1 meter BER its value at 0, while at a distance of 3 meters BER value for 2.58 x 10^{-3}. Thus the greater the distance between the source and destination, the BER values are also getting bigger. At figure 8, there is a comparison curve between SISO communication systems, multi-hop and cooperative in indoor environments and figure 9 is in outdoor environments.

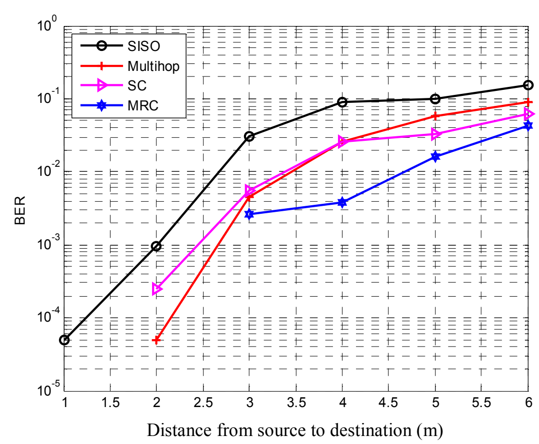

Figure 8: Performance of Cooperative Communication System for various distances in Indoor Environment

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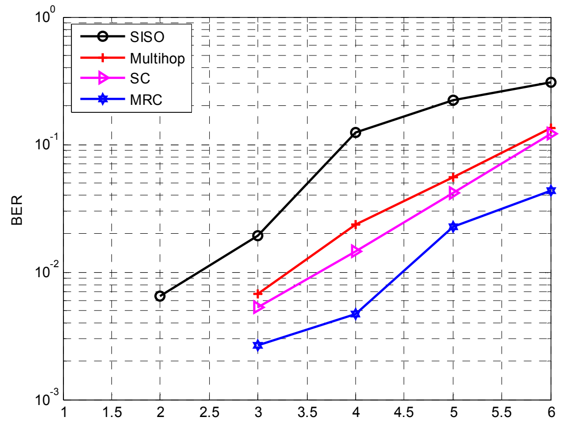

Figure 9: Performance of Cooperative Communication System for various distances in Outdoor Environment

4. CONCLUSION

Implementation of SISO communication systems, multi-hop and cooperative communication systems on WARP with relay Demodulate and Forward and techniques Selection Combining (SC) and Maximum Ratio Combining (MRC) is done using the framework WarpLab that integrate between Matlab and WARP modules. In this paper used three modules WARP as the source, relay and destination. In this implementation was analyzed the performance of each system to see the value of BER as a function of the transmit power and distance.

Based on measurement results, cooperative communication system using MRC is better than SISO communication system, multi-hop and cooperative communication system using SC. For example the transmit power of -35.19 dBm, the BER value of SISO communication system of 6.25×10^{-2}. In the multi-hop communication system and cooperative communication system using SC are almost the same of BER 1.2×10^{-2} and 2.7×10^{-2}, while the value of BER in cooperative communication system using Maximum Ratio Combining with MRC is 1.34×10^{-3}. Only by using the transmit power of -32.39 dBm, cooperative communication system with MRC has achieved BER value of 0. As for multi-hop communication system and SISO have achieved BER value equal to 0 at power transmit -20.3395 dBm and -23.5975 dBm.

These measurements were not only indoor but also outdoor area. Cooperative communication system using MRC at -35.19 dBm transmit power in the indoor area had BER value 1.34×10^{-3}, where as in the outdoor of 1.1×10^{-3}. BER value is also influenced by the value of transmit power and the distance between the source and destination. The greater the value of the transmit power, the value of BER gets smaller while the greater the distance between the source and destination, the greater its value BER.

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6.

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