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Performance Analysis of Cooperative MIMO Schemes in HF (*High Frequency*) Communication Systems

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Abstract

Indonesia is the largest maritime and archipelagic country in the world that has more than 10,000 large and small islands extending from Sabang to Merauke and scattered around the equator. Most of these islands experience obstacles in daily lives, such as the difficulty of finding information, the difficulty of getting proper health and education services. It causes the majority of these islands experiencing isolation compared to other islands, so that the concept and planning needed in the development of undeveloped island group areas. Such conditions require Indonesia to build a long-distance and affordable communication system for many users to communicate from one island to another island.

It becomes the background to the creation of an idea to create a communication system that can transmit information over long distances, has a low complexity with low costs, that is the HF (High Frequency) communication system. This communication system utilizes the ionosphere as a transmission medium using a 3-30 MHz frequency. By choosing Jakarta as a source, Makassar as a relay and Jayapura as a destination, the HF communication system was created using cooperative diversity techniques. The use of cooperative diversity techniques is intended to reduce the effects that arise during the transmission process (such as fading and so on). By using Maximum Ratio Combining on the receiver (Jayapura), it is known that this communication system can be applied in everyday life.

The results of data processing that have been shown indicate a variation in the SN value both on the Jakarta-Jayapura, Jakarta-Makassar and Makassar-Jayapura tracks at certain times (00:00, 06:00, 12:00, 18:00). This is due to the behavior of the ionosphere at a certain time which results in the quality of the changing of received signal.

Keywords: HF (*High Frequency*) communication, Cooperative MIMO

I. INTRODUCTION

Radio communication HF (High Frequency) is a radio wave that works at a frequency of 3-30 MHz. It is usually used for long distance radio communications because of the nature of the wave that can be reflected by the ionosphere. Ionosphere itself has layers which each layer has different height.

During the day, the ionosphere has at least 4 layers: D, E, F1, and F2. But at night only the layer F is left. At night, in normal conditions, it tends to be better than during the day. This is because during the day the additional ionosphere layer (layer D) is ionized which is less perfectly ionized and thus inhibits reflection [2].

There are three components that determine the success of communication with the skywave emitted, namely frequency, elevation angle and emittance [2]. The frequency that can be used at any time depends on the electron density in the layers of the ionosphere which functions as a reflection of HF radio waves.

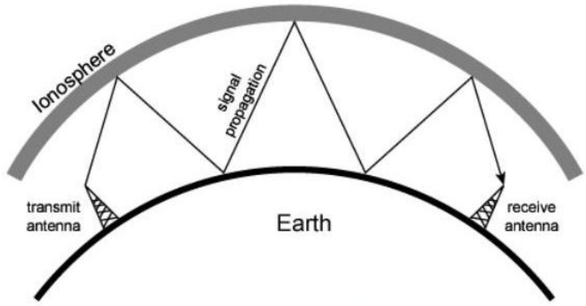

Fig 1. HF Radio Wave Propagation

In terms of increasing data throughput to support the continuity of HF communication, MIMO technique is considered appropriate to be applied. MIMO technique itself is a technique which puts multiple antennas on the transmitter and receiver so as to increase the data throughput using parallel data flow created by multipath signal propagation [4,5]. Unlike conventional antenna system which is highly susceptible to multipath, MIMO system works best in multipath conditions. This makes the MIMO system very appropriate to be applied to HF communication [8].

Michael A. Jensen and Jon W.Wallace [8] have simulated MIMO technique to increase capacity significantly. The simulation is the use of some antenna configurations to be applied to MIMO techniques to obtain the appropriate configuration for application. However, the application of the acquired configuration cannot be directly applied to the HF channel model, so further research is needed on MIMO system configuration adjustments to be applied to HF communication [8].

In addition, Ndao tried to exploit the 2×2 MIMO communication system which was tested on 280 km distance communication based on the polarization diversity of the transmitting antenna. In this case, it utilized two propagation modes of the ionosphere layer generated from the magneto-ion parameters in the ionosphere, known as ordinary (O) and extraordinary (X). These parameters are marked with two different set of parameters, such as attenuation or group delay. By utilizing this propagation mode, we will get a low correlation value that can be used as the implementation of MIMO communication system. These two propagation modes are generated from the electron density model, expressed as a function of altitude, while modeling of propagation mode has been done by Appleton-Hartree[1]. However, in this study, there is no discussion to obtain the impulse response combination of the two propagation modes O and X, ho and hx for each transmitter antenna [6,7].

Cooperative communication system serves to eliminate the influence of fading on the wireless channel, so as to improve system performance. Cooperative communication is a method that utilizes antenna from the other user with transmit diversity principle to get a plural virtual antenna by using different path in sending data. Thus, a distribution of many antennas are formed and serves to obtain additional information that can help the process of information translation on the receiving side.

This paper analyzed HF MIMO cooperative communication system over Jakarta-Makassar-Jayapura links by using ray tracing method. The simulation will be obtained using ray tracing simulation by PropLab 3.1. The next discussion is discussed in the next chapter. Chapter III describes the simulation results of cooperative MIMO communication system.

II. RESEARCH METHOD

Canal Generation with a Simple Ray-Tracing Method

In the first step, canal generation is performed using a simple Ray-tracing method with the aim of verification data from the canal that has been generated by the ray-tracing method. The first input parameter that must be obtained for generating canals with a simple ray-tracing method is the ionosonde virtual height parameter for each propagation track. After obtaining virtual height for each track, the distance between the link and the reflection coefficient for each propagation mode can be calculated and then generated by the MIMO channel matrix.

The first method proposed is processing the Ionospheric layer parameter data, especially at layer F. The parameter data is obtained by measuring using a tool named *Ionosonde*.

HF Link Communication System

The HF link communication system starts from transmitters in Jakarta, relays located in Makassar, and receivers in Jayapura. Based on the simulations performed, the specification of the data was:

Date	:	28 December 2011
Time (WIB (West Indonesia Time))	:	00.00 ; 06.00 ; 12.00 ; 18.00
Link	:	Jakarta - Jayapura, Jakarta - Makassar, Makassar – Jayapura
Observation Point	:	Jakarta (Lon : -6.175414, Lat : 106.827121) Makassar (Lon : -5.143587, Lat : 119.407544) Jayapura (Lon : -2.605059, Lat : 140.657367)

The *link* is the track that will be used in the simulation. Jakarta acts as a *source*, Makassar as a *relay*, and Jayapura as a *destination*. *Longitude* and *latitude* values are obtained from *Google Earth* at each observation point. After obtaining the appropriate parameters, find the $\frac{S}{N}$.

III. RESULTS

Comparison of $\frac{S}{N}$ Calculation Results With and Without Using the Analysis of MRC Cooperative Diversity

The following is the comparison curve of $\frac{S}{N}$ calculation results by using diversity techniques with *maximal ratio combining (MRC)* method and without using diversity techniques with *maximal ratio combining (MRC)* method. From the four curves (frequencies of 3 MHz, 7 MHz, 14 MHz, and 21 MHz) below, it can be concluded that the use of diversity techniques with the *maximum ratio combining* method has much better $\frac{S}{N}$ value than without using diversity techniques with *maximum ratio combining* method.

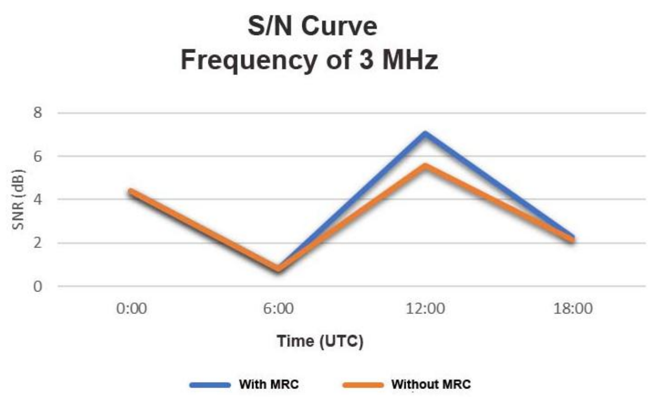

Fig 2. Curve of $\frac{S}{N}$ 3 MHz Frequency Calculation

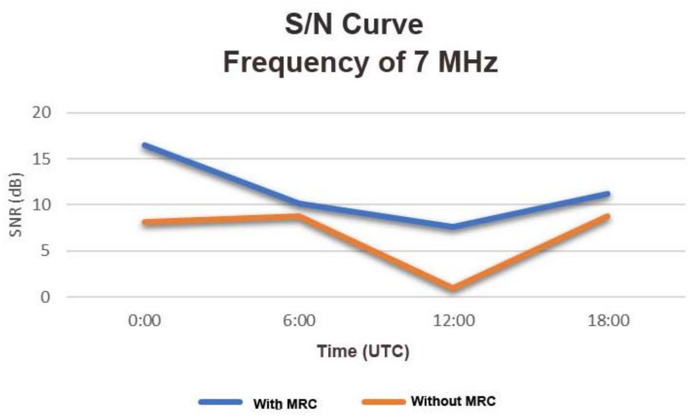

Fig 3. Curve of $\frac{S}{N}$ 7 MHz Frequency Calculation

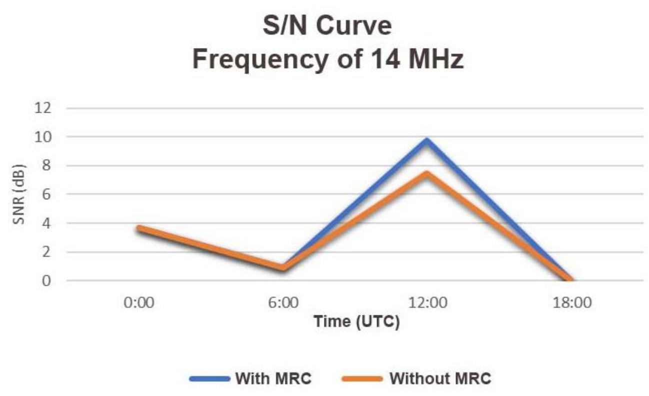

Fig 4. Curve of $\frac{S}{N}$ 14 MHz Frequency Calculation

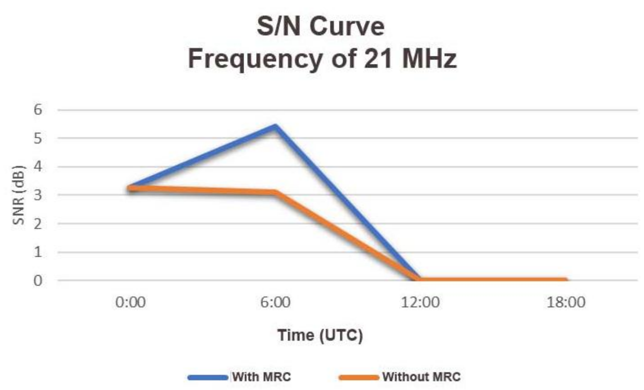

Fig 5. Curve of $\frac{S}{N}$ 21 MHz Frequency Calculation

IV. CONCLUSION

The ray tracing simulation of 3 links are presented. The calculation of MIMO capacity improved three times more than SISO capacity by using λ/2 transmitter and receiver antenna spacing. Frequency used in simulations were 3 MHz, 7 MHz, 14 MHz and 21 MHz. Meanwhile, cooperative communication system can increase SNR 3 times compared without direct signal transmission. The magnitude of cooperative MIMO capacity in HF communication system is related by link spacing. The longer the distance, the smaller the capacity. The result of data processing that has been infected by variation either on track Jakarta-Jayapura, Jakarta-Makassar and Makassar-Jayapura at certain times (00:00, 06:00, 12:00, and 18:00). This is the case of ionosphere behavior at any given time.

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