Diversity technique evaluation for LTE high mobility user based on high altitude platform

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Abstract. HAPS (High Altitude Platform Station) is an alternative technology of communication system that utilizes terrestrial and satellite systems. HAPS technology is located in the stratosphere layer with the height of 17-22 km above the earth's surface. HAPS has some advantages, which are wide range area, communication ability on line of sight (LOS), and low propagation delay. In this paper we present the comparison between single HAPS system and two HAPS diversity technique. From simulation result, it is evident that using two HAPS as a diversity technique gives better performance than the single HAPS system, it is shown by how the two HAPS diversity technique requires less SNR than the single HAPS system, typically 3 dB less of SNR.

1. Introduction

Recently, the need of getting data access service is very large, this is triggered by the development of technology mobile devices that are very fast in which requires data access services to cover all its needs. The existing data access services are still lacking, given the uneven distribution of data access caused by the lack of infrastructure capable of meet all user needs. One of the obstacles is the scope of the data spreading area is quite narrow cause not all regions can get adequate access services. High Altitude Platforms Station (HAPS) comes as one solution to solve the problem and complement existing infrastructure. HAPS is a technology built in the hope of obtaining a wide range of data access such as satellites but at a cheaper cost, in addition to that, the placement of HAPS is at a distance of 17-22 km making the communication time shorter than satellites, making it will be more suitable in this content this technology no need expected to have wide coverage and better response of data access.

There are many methods used to improve the performance of HAPS, one of which is the use of Multiple Input Multiple Output (MIMO) as an additional diversity technique, namely spatial diversity to reduce fading. This is done by sending information to each antenna. By using this MIMO diversity technique the probability loss of information will decrease exponentially.

In a recent study Nevie and Iskandar [1] and Iskandar and Albaz [2] the researcher performed a comparison of HAPS performance using MIMO or SISO, to analyze the effect of the technique on the capacity and BER performance in single HAPS. In another study Celcer et all. the writer uses the MIMO Virtual technique by utilizing multiple HAPS that generate a constellation point that resembles the MIMO form [3]. In our case, the study is focused on discussing the space diversity technique by applying...
multiple HAPS techniques [3], on MIMO antenna to improve the performance (BER) of HAPS. In Figure 1, we can see balloon HAPS as one of the telecommunication system. This platform is designed to be able to work either as a stand alone network or as an interconnection network [4].

![Figure 1. HAPS as one of telecommunication system.](image)

### 2. Diversity model

Diversity is a technique for dealing with multiplying fading by using two or more statistically independent signals (in time, frequency, spatial, or polarization) between each other in a wireless system. The basic principle of diversity is to send multiple signals that carry the same information through multiple channels with independent fading, this is done to provide a possibility of one or more signals not being exposed to deep fade, thus sending sufficient signals to the receiver. Diversity techniques in general consists of 3 types which are time diversity (diversity of time), frequency diversity (frequency diversity) and space diversity. In this research the diversity technique used is space diversity.

Space diversity is also called antenna diversity; the signal results is obtained from coming signals carrying the same information which are obtained from different receiver antennas in which then the signals are combined. The separation distance from one antenna with another antenna must exceed the distance of the channel. These two signals coming from the two transmit antennas are then combined at the receiving side. Some combining techniques commonly used in communication system are equal gain combing (EGC), maximum ratio combining (MRC), and interference rejection combining.

The other application of the method of space diversity is the MIMO antenna which is short for Multiple Input and Multiple Output. In radio waves, MIMO is a method to double the capacity by using multiple antennas to transmit and receive data. MIMO becomes a very important thing in wireless communication.

#### 2.1. Equal gain combining

EGC, the outputs of different diversity branches are first co-phased and weighted equally before being summed to give the resultant output. After that the resultant output signal is connected to the demodulator. The weights are all set to one with the requirement that the channel gains are approximately constant and this is usually achieved by using an automatic gain controller (AGC) in the system.

#### 2.2. MIMO

MIMO uses multiple antenna transmitters and receivers to improve system performance. MIMO is a technology that uses multiple antennas to coherently break down more information rather than using a single antenna. Two important advantages given to MIMO are spatial antenna and multiplexed diversity. MIMO technology relies on signals from various directions. These signals from various directions are
reflections from arriving signals at the receiving antenna after the transmission of the main signal Line of sight (LOS) [5]. On non MIMO networks, these signals from various directions are accepted as interference only reduces the recipient's ability to collect information present in the signal while in MIMO it uses signals coming from various directions to increase receiver's ability to parse low signal.

2.3. Space Time Block Code (STBC) Alamouty
STBC technique is used to transmit multiple copies of the data stream through multiple antennas and receive various data to improve the reliability of data Transmission. One type of STC is Space Time Block Code (STBC) Alamouty. STBC is the simplest form of STC introduced by Siavash M Alamouty in 1998 whose application is limited to systems with two antenna transmitters. In STBC Alamouty the same data stream is transmitted through both transmitters. However, before transmitted, the data flow leading to each antenna undergoes several treatments in every two symbols will still be sent in two periods of symbols but on the second antenna the sequence of symbols is reversed, conjugated and one of them negated with the aim to facilitate the separation of both n symbols in the receiver. STBC Alamouty can be stated as follows [2].

\[
\begin{align*}
    r_0 &= h_0s_0 + h_1s_1 + n_0 \\
    r_1 &= -h_0s_1^* + h_1s_0^* + n_1 \\
    r_2 &= h_2s_0 + h_3s_1 + n_2 \\
    r_1 &= -h_2s_1^* + h_3s_0^* + n_3
\end{align*}
\] (1)

Table 1. Coding and transmission sequence for two antenna.

| Antenna 0 | Antenna 1 |
|-----------|-----------|
| Time t    | S_0       |
| Time t + T| -S_1^*    |

Table 2. The value of elevation angle and k factor.

| Elevation Angle | 10° | 20° | 30° | 40° | 50° |
|-----------------|-----|-----|-----|-----|-----|
| K Factor (dB)   | 1.4 | 2.0 | 2.3 | 2.7 | 4.6 |
| Elevation Angle | 60° | 70° | 80° | 90° |     |
| K Factor (dB)   | 6.4 | 9.2 | 12.2| 16.8|     |

The combination of these receiver signals produces a new formula, which can be written as follows.

\[
\begin{align*}
    \hat{s}_0 &= h_0^*r_0 + h_1^*r_1^* + h_2^*r_2 + h_3^*r_3^* \\
    \hat{s}_0 &= h_0^*r_0 + h_1^*r_1^* + h_2^*r_2 + h_3^*r_3^*
\end{align*}
\] (2)

2.4. HAPS channel
The study of the characteristics of a communication channel is very important. The ideal communication channel has several properties that have unlimited bandwidth and a flat frequency response. Whereas the communication channel found in the field situation has the characteristics of selective frequencies. Since HAPS is positioned highly above the ground, there are two components signals that are received by the receiver. First component is line of sight (LOS), the direct signal from the transmitter to the receiver. And the other one is multipath scattered signal (contribution of Rayleigh Channel). For the channel model, we used the channel that is most suitable with the characteristic of this platform. HAPS follows Rician distribution because of its dominant LOS component. In this paper, the channel is assumed to be a single ray, because the using of HAPS mostly in rural areas. For this paper, rician model has been normalized and can be expressed in equation:
\[ H_{ric} = \sqrt{\frac{K}{K + 1}} H_{LOS} + \frac{1}{\sqrt{K + 1}} H_{Ray} \]  

(3)

where \( K \) is the ratio of LOS component power and NLOS component. The value of \( K \) factor with nine elevation angles is showed in table II [6].

3. System model

Figure 2 shows the system model that is simulated in this paper. In this model, two HAPS will be used. Each platform is placed at an altitude of 20 km, separated at 148.07 km from its centre with this configuration, when the user is at the elevation angle of 30° on one platform. It will be at 100 elevation angle on the other platform.

![Figure 2. Two HAPS diversity technique model.](image)

### Table 3. System’s parameters.

| Parameter              | Parameter Value                  |
|------------------------|----------------------------------|
| Bandwidth              | 10 MHz                           |
| Number of Subcarrier   | 600                              |
| Number of IFFT         | 1024                             |
| Length of CP           | 80                               |
| Frequency Spacing      | 15 kHz                           |
| Duration of Slot       | 0.5 ms                           |
| Modulation             | QPSK                             |
| Velocity               | 60 km/h ; 350 km/h               |
| Frequency of sampling  | 15.36 MHz                        |
| Duration time symbol   | 66.67 μs                         |
| Duration guard time    | 5.21 μs and 4.69 μs              |
| HAPS altitude          | 20 km                            |
| HAPS coverage (radius) | 113.43 km                        |
| HAPS separation        | 148.07 km                        |
| Combiner               | EGC                              |

In this simulation, the users of interest are the ones in the overlapping region of the two HAPS (the grayed area in Figure 2, those are the users at the elevation angle from 0° up to 30°. The standard used in this model are LTE, with parameters given in table III. The communication system in each HAPS are exactly the same as the one in Nevi and Iskandar where a LS estimation technique is used to enhance the system’s performance [1]. We consider two cases where the users’ mobility is 60 km/h and 350 km/h.
4. Simulation result
This simulation compares two cases where a single HAPS and two HAPS are used as a diversity technique for users at the elevation angle less than 30o. The comparison of performance is in a form of BER archived by the system at a certain SNR. Fig. 3 shows the simulation result for user with velocity of 60 km/h. We can see that, using two HAPS as diversity gives better performance in the system. In this case, the two HAPS diversity technique require less SNR, typically 3 dB, than the single HAPS system to archive the same BER value.

Just as the previous case, when the velocity is equal to 350 km/h, the two HAPS diversity technique require an average 3 dB less SNR than the single HAPS system. It is evident that the two HAPS diversity technique scheme gives a better performance than the single HAPS scheme, especially for user at the edge of the HAPS coverage.

![Figure 3](image1.png)

**Figure 3.** Comparison of BER to SNR between single HAPS and Two HAPS diversity technique, velocity = 60 Kmph.

![Figure 4](image2.png)

**Figure 4.** Comparison of BER to SNR between single HAPS and two HAPS diversity technique, velocity = 350 Kmph.
5. Conclusion

In this paper we present the comparison between single HAPS system and two HAPS diversity technique. The two HAPS diversity technique gives better performance than the single HAPS system. In this case, it requires less SNR than the single HAPS system. Typically, the two HAPS diversity technique requires 3 dB less of SNR. This enhanced performance is achieved by taking advantage of space diversity between two HAPS. This space diversity between two HAPS gives the system capability to serve users at the edge of the HAPS coverage with better quality.

References

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