# High Altitude Platform Using Space-Time Block Coded Spatial modulation

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*Abstract* **- In this paper, MIMO STBC-SM emerged as a solution for wireless communications to improve capacity and decrease bit error rate. One of the MIMO variant, which is used in this paper, is STBC-SM(Space Time Block Code Spatial Modulation). It combines spatial modulation (SM) and space-time block coding (STBC) to take advantage of the benefits of both while avoiding their drawbacks. Here we show the MIMO STBC-SM $2\times 1$ and $2\times 2$ on HAPs channel with the assumption that the channel state condition is known at the receiver. HAPs channel characteristics are known to follow the Ricean distribution in which it depends on its K factor. Using Computer simulation in MATLAB, this paper analyzes HAPs channel performance using MIMO STBC-SM $2\times 1$ and $2\times 2$ are able to increase performance of HAPs channel including HAPs channel at low elevation angle.**

*Key words* **– MIMO Space-time block code spatial modulation, HAPs, Ricean Channel, K factor.**

## I.INTRODUCTION

The big three option in the use of telecommunication are by means of the terrestrial wire system (copper wire, coax and fiber optic cable), terrestrial wireless system and satellite communication system [4]. In last few years, a new set of option have been added in the form of high altitude platform stations (HAPs) [8]. High Altitude Platforms (HAPs) [9] is an object floating on a stratospheric layer bringing wireless communication equipment at approximately 17-22 km above the ground. HAPs is able to exploit much the advantages and at the same time overcome the drawback of the traditional systems in terms of propagation delay and path loss suffered by satellite system or a huge number of base station required by the terrestrial system.

In our previous research [8], HAPs channel characteristic which is experimentally measured in semi-urban environment, deteriorates at low elevation angle. In other word the performance of HAPs communication needs improvement for the users who are located at the edge coverage. Measurement result shows that for low elevation angle, i.e. lower than 40º, fading depth is observed to be approximately 25 dB or more. Such huge fading depth, of course, will limit HAPs service coverage to elevation angle only higher than 40º or about 50 km in diameter of service coverage. To overcome such problems MIMO STBC-SM is proposed in this work. In the STBCSM scheme, the transmitted information symbols are expanded not only to the space and time domains but also to the spatial (antenna) domain which corresponds to the on/off status of the transmit antennas available at the space domain, and therefore both core STBC and antenna indices carry information.

MIMO is simply defined as an use of more than one antenna at transmitter and/or receiver. There are two kinds of MIMO called Spatial Multiplexing (SM) and Space Time Block Code (STBC). On this paper, we use MIMO STBC-SM with 2 antennas transmitter with combination of 1 and 2 antennas at receiver. HAPS is then used as transmitter and both antennas is placed onboard the platform as depicted in Fig 1. The previous research [10] have shown that MIMO can be implemented on single HAPs with specific spacing between them depend on its frequency. For 2.4 GHz, both antennas must be separated about 12 meters. Simulation is then run by MATLAB R2008a. The variables that are used in the simulation is elevation angle from 10 – 90 degree which represent the K factor and operating frequency at 1.2 and 2.4 GHz.

The remaining part of this paper is outlined as follows. Section II presents channel model and propagation characteristic in a HAPs system. Section III reviews in detail a concept of MIMO STBC-SM. Simulation model and results are explained in Section IV. Section V shows concluding remark with conclusion.

## II.HAPs CHANNEL MODEL AND PROPAGATION CHARACTERISTIC

Generally, there are some propagation phenomena that can happen on HAPS channels as follow: Free space path loss, multipath fading, rain attenuation, gas absorption, and scintillation [9]. Most of them are frequency dependence. Rain attenuation, gas absorption, and scintillation are significant only on a high operating frequency, i.e. above 10 GHz. While this paper used freq 1.2 and 2.4 GHz, all of them will be ignored on the formulation and simulation.

In case of HAPs channel, Ricean fading is a general case of fading channel model that there are two components of signal arrive at the receiver. First component arrive at receiver through line of sight (LOS) path and the second component come from multipath scattered signal. In HAPs communications channel, it is possible to have both components because HAPs is highly positioned above the ground. Therefore, the channel characteristics in HAPs system can be represented by Ricean distribution which is expressed as follows,

$$x(t)=\sqrt{\frac{K\Omega}{K+1}}e^{j(2\text{®} f_c \cos(\text{¯})t+\text{¤})}+\sqrt{\frac{K}{K+1}}h(t) \quad (1)$$

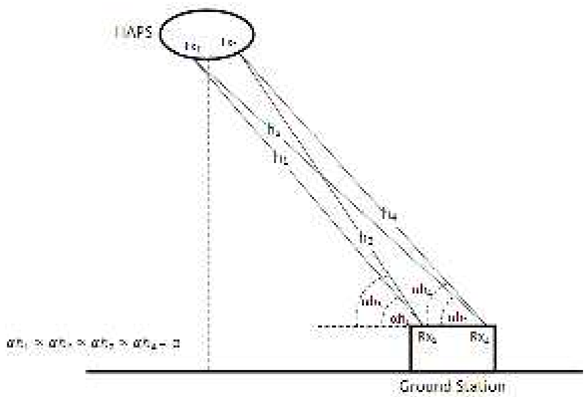


*Fig.1 MIMO STBC-SM in HAPs Channel*

Where K is a ricean factor,¯ and¤ are elevation angle, $f_D$ is Doppler frequency from receiver movement with velocity (v), and h(t) is a scattered component that can be expressed as

$$r_h(²) = E[h(t)h^*(t+²)] = \int_{-®}^{®} p_h(¯) e^{j2® f_D \cos(¯)²} d¯ \quad (2)$$

If $E\left[h^2(t)\right]$ is estimated to be one, then scattered signal power on the formula above become $\pm^2$. On the other hand, LOS signal power which is significant in HAPs channel, is denoted by $A^2$, and K is defined as $A^2/2\pm^2$. So, the total power is represented by

$$E\left[x^2(t)\right] = A^2 + 2\pm^2 \quad (3)$$

$E\left|x^2(t)\right|$ is local mean received power. Therefore it is to be said that Ricean signal is an addition of LOS and NLOS component with a weighting factor of K. Then the formula above can be written as follow

$$H = \sqrt{\frac{K}{K+1}} H_d + \sqrt{\frac{1}{K+1}} H_s \quad (4)$$

Where $H_d$ is LOS component, and $H_s$ is NLOS component.

## III. SPACE-TIME BLOCK CODED SPATIAL MODULATION (STBC-SM)

A new MIMO transmission scheme, called STBC-SM [11], is proposed, in which information is conveyed with an STBC [2] matrix that is transmitted from combinations of the transmit antennas of the corresponding MIMO system. The Alamouti code is chosen as the target STBC to exploit. As a source of information, we consider not only the two complex information symbols embedded in Alamouti's STBC, but also the indices (positions) of the two transmit antennas employed for the transmission of the Alamouti STBC[1].

A general technique is presented for constructing the STBC-SM scheme for any number of transmits antennas. Since our scheme relies on STBC, by considering the general STBC performance criteria proposed by Tarokh *etal*, diversity and coding gain analyses are performed for the STBC-SM scheme to benefit the second order transmit diversity advantage of the Alamouti code.

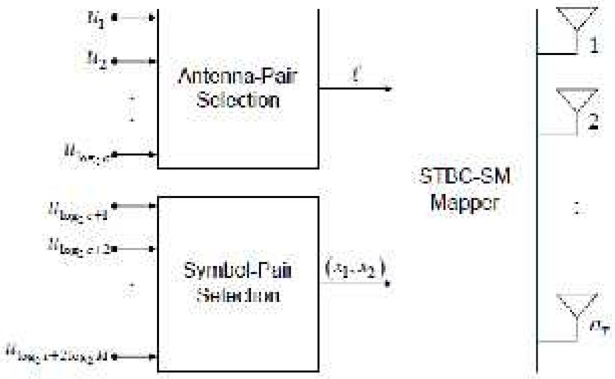


*Fig.2 Block Diagram Of The STBC-SM Transmitter*

The block diagram of the STBC-SM transmitter is shown in Fig. 1 [11]. A low complexity ML decoder is derived for the proposed STBC-SM system, to decide on the transmitted symbols as well as on the indices of the two transmit antennas that are used in the STBC transmission.

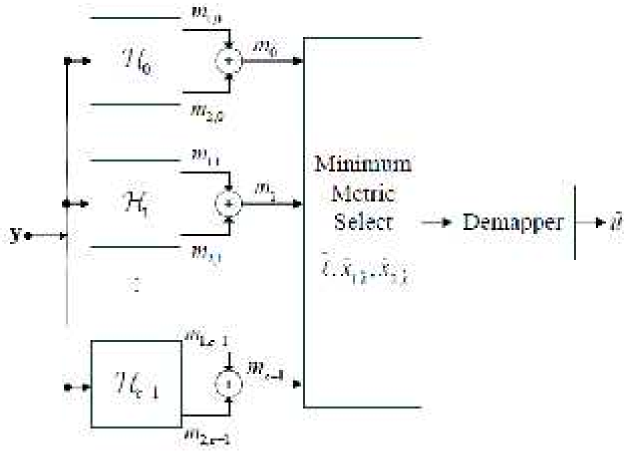


*Fig.3 Block Diagram Of The STBC-SM ML Receiver*

The block diagram of the STBC-SM transmitter is shown in Fig. 3 [11].

## IV. SIMULATION MODEL & RESULT

The simulation model is presented in fig.4. First we generate random data to make a symbol stream input that consist of approx. 1000 bits. Then the data is BPSK modulated and then its output is inserted to STBC-SM encoding block. The process that happens in this block is almost same as explained before. Bit stream into two parts and for the next time slot, Alamouti[6] conjugate data is sent on each antenna.

The next process is to send the data via MIMO antenna through Ricean HAPs Channel with its

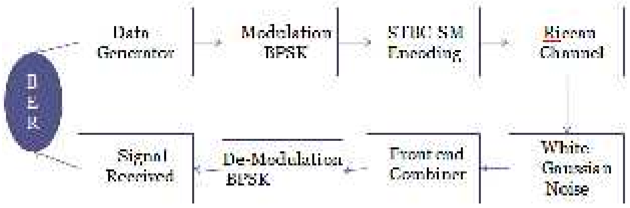


*Fig.4 MIMO STBC-SM on HAPs Model*

characteristics has been experimentally investigated in our previous work. K factor as a Ricean parameter for HAPs channel has been measured and we found that its value directly governed by an elevation angle of the user that look to the HAPs. Output data from STBC-SM encoder block in frequency domain are then multiply by this Ricean fading parameter and also Additive White Gaussian Noise at receiver. After that Front end combiner block processes the received data stream using channel information that in this work we assume perfect channel estimation. The extracted data from this block is then demodulated into received bit stream. This received bit stream finally compared by first bit stream sent before to get the bit error rate (BER) at specific signal to noise ratio value.

*Table I – Simulation Parameter*

| Frequency | 1.2 Ghz & 2.4 Ghz |
|---|---|
| **Amount of Bits** | 100000 |
| **Eb/No** | STBC-SM 2×1 = 0 ; 2 ; 4 ; 6 ; 8 ; 10 ; 12 ; 14 ; 16 ; 18 ;20<br>STBC-SM 2×2 = 0 ; 2 ; 4 ; 6 ;8 ; 10 ;12 |
| **Modulatio** | BPSK |
| **Frame Length** | 100 |
| **Number of Packet** | 1000 |
| **Antenna Tx** | 2 |
| **Antenna Rx** | STBC-SM 2×1 = 1<br>STBC-SM 2×2 = 2 |
| **K Factor** | Freq. 1.2 Ghz = 0.9; 1.5;2.2;4.1;8.9; 11.4; 13.5; 15.2; 18.6.<br>Freq. 2.4 Ghz = 0.9; 1.5;2.2;4.1;8.9; 11.4; 13.5; 15.2; 18.6. |

Table I shows the parameter that is used in the simulation. We used 100,000 bits which is separate into 1000 packet data, each of them consist of 100(frame length).

For the comparison of all method, SISO 1×1 HAPs system is simulated first. The result is shown in fig 5 and 6 for each operating frequency, 1.2 and 2.4 Ghz respectively.

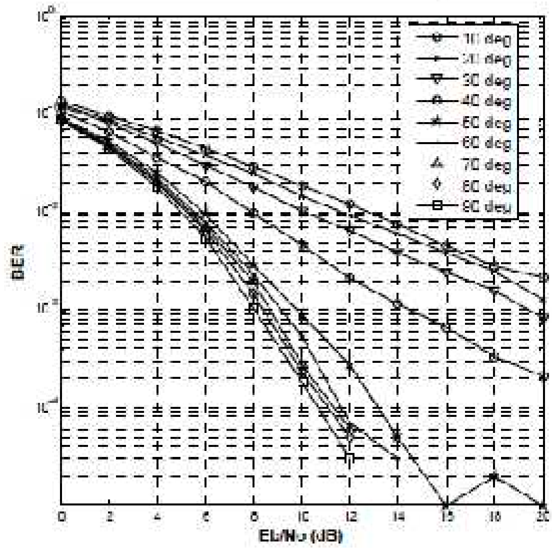


*Fig.5 Performance of SISO 1×1 (Frequency 1.2 GHz, elevation 0-90º)*

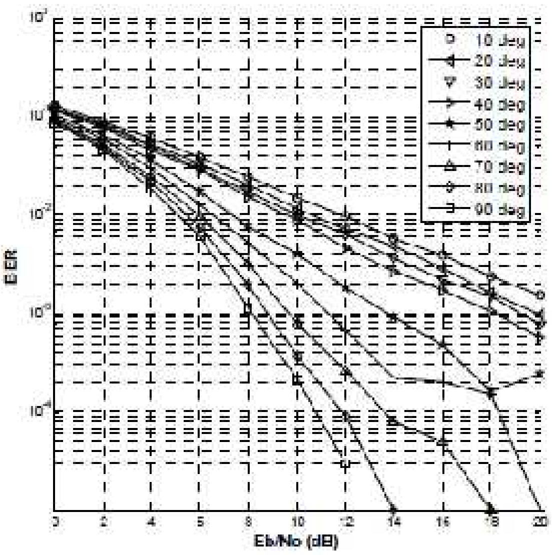


*Fig.6 Performance of SISO 1×1 (Frequency 2.4 GHz, elevation 0-90º)*

Then the configuration is changed by adding one or more antenna at transmitter creating MISO 2×1 HAPs system. Using STBC-SM encoding and decoding technique the simulation result is shown in fig 7. Simulatio shows the MISO can increase HAPs channel performance not only for low elevation angle but also for all of ground station positions. MISO is able to achieve better performance of about 1-11 dB for required BER $10^{-3}$ variously at 10º-90º.

By adding one more antenna in receiver the configuration is now change to MIMO STBC-SM 2×2. In fig 8 simulation shows that this model can make significant improvement better than the previous SISO or MISO 2×1. It has 4-17dB improvement compared to SISO and 3-6 dB compared to MISO 2×1 at BER value $10^{-3}$ for all elevation angles.

 

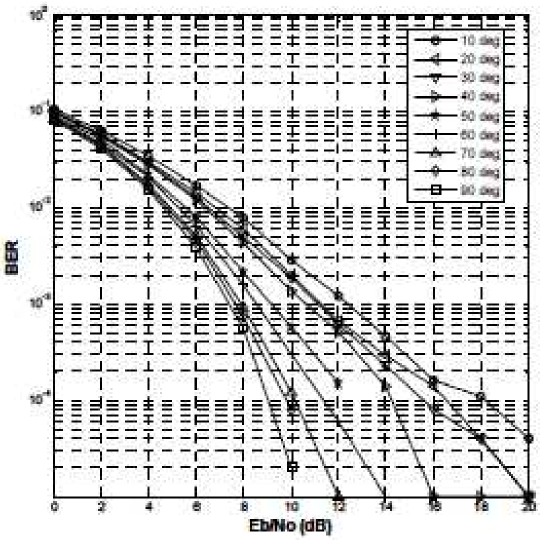


*Fig. 7 Performance of MISO STBC-SM 2×1 (freq 2.4 GHz, elevation 0-90º)*

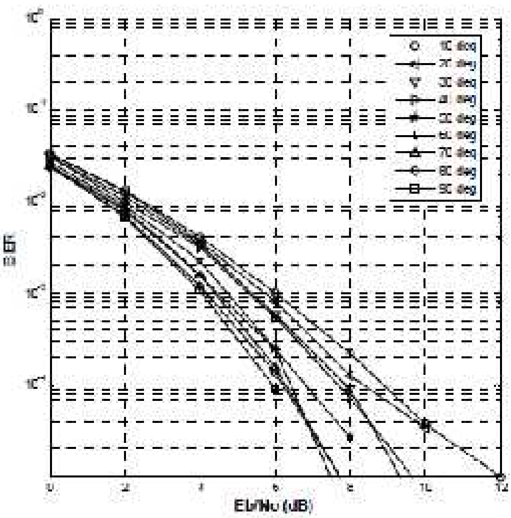


*Fig. 8 Performance of MISO STBC-SM 2×2 (freq 2.4 GHz, elevation 0-90º)*

## IV.CONCLUSION

Performance analysis of MIMO STBC-SM on HAPs has been proposed in this paper. Simulation result shows that STBC-SM 2×1 can improve BER performance from HAPs SISO 1×1 configuration (1-11dB on BER$10^{-3}$), while MIMO STBC-SM 2×2 even can improve more significant from SISO 4-17 dB on the same BER value for all elevation angles. By adding more antennas at receiver or transmitter may be able to improve better performances. For high elevation angles (50-90 deg), the use of MIMO STBC-SM 2×2 is much more significant than STBC-SM 2×1. All of this improvement can also increase the radius of HAPs coverage.

MIMO STBC-SM can really improve the BER performance of HAPs system, but not the capacity. Simulation result shows that MIMO STBC-SM have no improvement comparing to HAPs SISO configuration.

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