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PERFORMANCE ENHANCEMENT OF LAND MOBILE SATELLITE SYSTEM

R. Nandhini[1], J.Zarina Yasmin[2], C. Arunachalaperumal[3]

[1,2] *PG Scholar, Department of PG Studies, S.A.Engineering College, Chennai -77*

[3]*Assistant Professor, Department of PG Studies, S.A.Engineering College, Chennai -77*

nandhu_raksana@yahoo.com[1], zarinayasminjafar@gmail.com[2], che_siva@yahoo.com[3]

Abstract

The Quality of Service (QoS) and spectral efficiency in land mobile satellite (LMS) communications drops drastically in the presence of shadowing and multipath fading. The method for increasing QoS and spectral efficiency, is done by without any increasing in total transmit power, antenna gain or bandwidth by using multiple-input multiple-output (MIMO) techniques. In order to carry out the performance assessment this paper addresses related MIMO satellite propagation channel modelling issues which lead to a new mathematical model to accommodate the multi-satellite transmission. The omni directional antenna's two RHCP and two LHCP used for complete analysis.

***Keywords*-- MIMO, Satellite Services, Alamouti Scheme, polarization diversity, Maximum Ratio Combining.**

I. INTRODUCTION

MIMO is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. Land Mobile Satellite Systems(LMSS) will have the option to use simultaneous transmission via two or more satellite as diversity. The two characteristic cases of satellite systems, which nowadays driving the commercial development of Satellite Communication are:

1) *fixed satellite* (fs) systems operating over gso orbits at frequency bands above 10 GHz (e.g. ku, ka) serving *fixed satellite terminals* (fsts) in an unobstructed propagation environment.
2) *mobile satellite* (ms) systems operating over gso orbits at frequency bands well below 10 GHz (e.g. l, s) serving *mobile satellite terminals* (msts) in propagation environments suffering from different degrees of obstruction (urban, suburban, rural). It have the potential application of MIMO over satellite as LMSS.

Three crucial factors in land mobile satellite (LMS) communication systems are the quality of service (QoS), spectral efficiency and cost. The QoS in a LMS system often suffers due to high link path loss due to the vast distances covered, signal shadowing and blockage, and a high link delay. Spectral efficiency can also be fairly low in LMS systems due to small received signal to noise ratios disabling the adoption of high order modulation techniques.

II. SYSTEM MODEL

A. Satellite MIMO Channel Model

To achieve a satellite diversity scheme that adaptively selects the best line of sight satellite seems promising for LEO/MEO satellites systems. This paper presumes a flat-fading channel model, only taking into account the LOS signal path as the dominating wave propagation mechanism. This is a reasonable assumption because in Satellite Communication, multipath signals play a secondary role. The power of the LOS signal component out values the power of reflections and scattered waves. Denoting the carrier frequency by fc, the frequency-flat MIMO channel is described by its channel transfer matrix $\boldsymbol{H}(fc) = \boldsymbol{H} \in CM\times N$ for a MIMO system consisting of N transmit and M receive antennae. The element $[\boldsymbol{H}]mn$ of the channel transfer matrix at the position mn in equivalent baseband notation is described by the mechanism of free-space propagation according to,

$$H_{mn} = a_{mn}\, exp\left\{-j\,\frac{2\pi f_c}{c_0} r_{mn}\right\} \qquad (1)$$

where, rmn is the distance between the m-th transmitter (Tx) antenna and the n-th receiver (Rx) antenna. $c0$ is the speed of light in free space. amn is the complex envelope that is calculated by:

$$a_{mn} = c_0 e^{jv_0} / (4\pi f_c r_m) \qquad (2)$$

With v_0 marking the carrier phase angle at the time of observation. Observing the channel path gain for all $M \times N$ pairs of Tx-Rx antenna combinations, they are found to be approximately identical due to the large distance between Tx and Rx.

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B. LMS channel

In order to investigate the transmission via multiple satellites it is indispensable to know the properties of the LMS channel. Shadowing is a major problem of mobile satellite communication. Due to low elevation angles of LEO systems, obstacles like buildings or trees prevent from a permanent line-of sight (LOS) connection between the mobile user and the satellite. Also, in contrast to geostationary satellite systems, multipath propagation is not negligible. In figure 1 it is shown that the signal *s(t)*is affected by a fading component *h(t)* and a noise component *n(t)*. The noise is assumed to be white and Gaussian distributed (Additive White Gaussian Noise, AWGN).

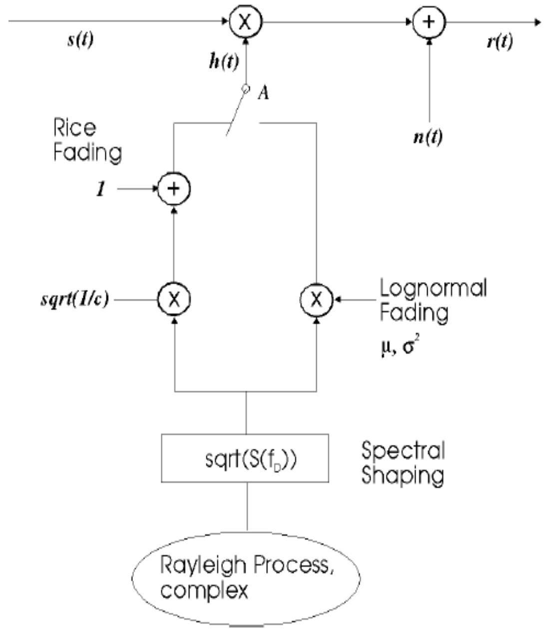

Fig. 1 Narrowband model of a LMS channel.

The fading is primarily determined by shadowing. In order to take into account this fact, a two state model is adopted. One distinguishes between a good state, which means LOS transmission between satellite and user terminal and a bad state with no-line-of-sight (NLOS) connection. The switching between these two states is generated by a two state Markov process.

C. Satellite Diversity Model

In order to increase the resilience against the LMS channel impairments, the following sources of diversity can be used: polarization diversity, satellite (or path) diversity, and terminal cooperation diversity.

In this paper, polarization diversity is the starting point to generate a MIMO transmission. In satellite communications, its utilization is widespread as densely scattered distributions around transmitters and receivers can be obtained by using dual-polarized antennas at both ends of the link. Therefore, polarization diversity becomes a definitely space and cost efficient solution. Polarization diversity combines pairs of antennas with orthogonal polarizations (i.e. horizontal/vertical, ± slant 45°, Left-hand/Right-hand CP etc.). Reflected signals can undergo polarization changes depending on the medium through which they are travelling. A polarisation difference of 90° will result in an attenuation factor of up to 34dB in signal strength. By pairing two complementary polarizations, this scheme can immunize a system from polarization mismatches that would otherwise cause signal fade. Additionally, such diversity has proven valuable at radio and mobile communication base stations since it is less susceptible to the near random orientations of transmitting antennas.

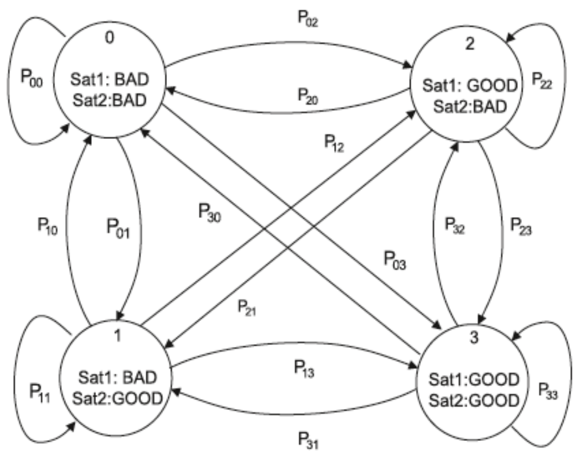

Fig. 2. 4-state Markov model for two correlated LMS channels.

Bearing these assumptions in mind and considering 2 dual-polarized satellites and up to 2 dual-polarized antennas at the terminal, the most general scenario results in a 4 x 4 MIMO channel,

$$\mathbf{H} = \begin{bmatrix} h_{11}^{11} & h_{12}^{11} & h_{11}^{12} & h_{12}^{12} \\ h_{21}^{11} & h_{22}^{11} & h_{21}^{12} & h_{22}^{12} \\ h_{11}^{21} & h_{12}^{21} & h_{11}^{22} & h_{12}^{22} \\ h_{21}^{21} & h_{22}^{21} & h_{21}^{22} & h_{22}^{22} \end{bmatrix}$$

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Where, h_{ij}^{kl} denotes the channel gain between the i th polarization of the k th receiver antenna and the polarization of the l th satellite antenna.

D. The MIMO-Satellite Diversity Channel

In this paper we are proposing an application for high data rate transmissions using a system employing multiple satellites.

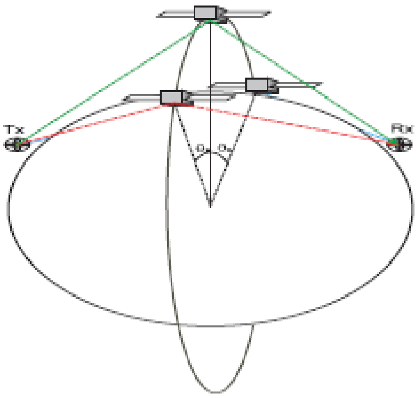

Figure 3. The MIMO-SAT diversity system with three satellites and the channel paths from the transmitter to the receiver.

This system consists of virtually created MIMO channels using satellite diversity in combination with the polarization and pattern diversity of a special type of MIMO antenna arrangements and also through using the spatial modulation technique. Fig. 3 shows the diversity setup for the case of three satellites separated by the angles $\theta_{a,b}$ and $\theta_{a,c}$. Each transmit and receive antenna of the system consists of a special compact MIMO antenna array. These compact antenna arrays can be of different complexity and design.

E. SPATIAL MODULATION

SM is also a spatial multiplexing MIMO technology. It has *Nt* transmit antennas and *Nr* receive antennas, and the modulation order is *M* . Input data is converted into $\log_2 MNT$ layers, then the transmit signal vector in one time slot, which is denoted by $x = [x1, x2, \ldots, xN]T$, can be obtained through SM mapping, and $E\{x^H x\} = 1$.

In the receiver, SM detection includes 2 steps, the first is estimation of the index of transmit antenna, the second is symbol demodulation for this antenna. The system diagram is shown in Fig.4

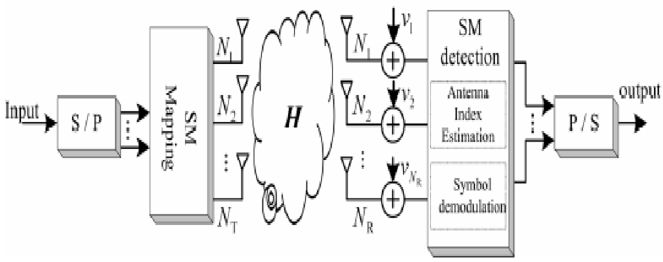

Fig 4. SM system model

Then received signal y=[y1,y2,...yNr]T for Nr receiver antennas at one time slot can be denoted by

$$y = Hx + v \qquad (3)$$

Suppose the *t* th element of ***x*** is *q x* . *q x* is nonzero and it is the *q* th symbol of conventional constellation of *M* order modulation, then ***x*** can be denoted by *tq q t* ***x*** = *x* ***e*** . Here *k* ***e*** is element vector of T *N* ×1 dimension , which denotes the *k* th element of the vector is 1, and the others are zero. So the received vector can be denoted by

$$y = Hx + v = h\, x + v \qquad (4)$$

F. Maximum Ratio Combining

Maximum ratio combining is a linear combining method. In a general linear combining process, various signal inputs are individually weighted and added together to get an output signal. The weighting factors can be chosen in several ways. A block diagram of a maximum ratio combining diversity is shown in Fig. 5. The output signal is a linear combination of a weighted replica of all of the received signals. It is given by

$$r = \sum_{i=0}^{n_R} \alpha_i . r_i$$

Where ri is received signal hantenna i,and ai is the weighting factor for receive antenna i. In maximum ratio combining, the weighting factor of each receive antenna is chosen to be in proportion to its own signal voltage to noise power ratio.

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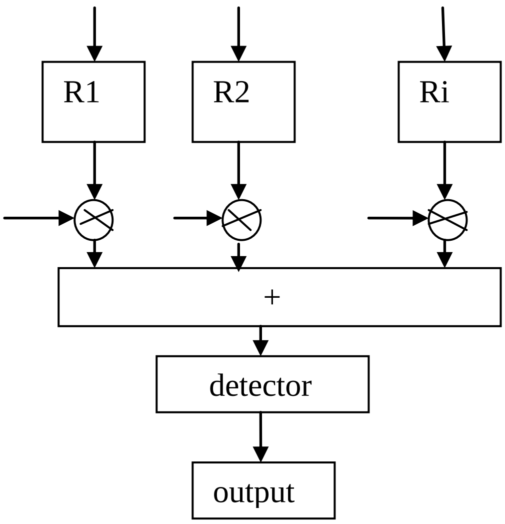

Fig 5 block diagram of MRC

III. RESULT AND CONCLUSION

In this work, MATLAB is used to test the channel performance using diversity technique based on QAM modulation scheme. By applying Alamouti's diversity and/or Maximum ratio combining technique, it is possible to make channel response from Rayleigh fading channel to AWGN channel.

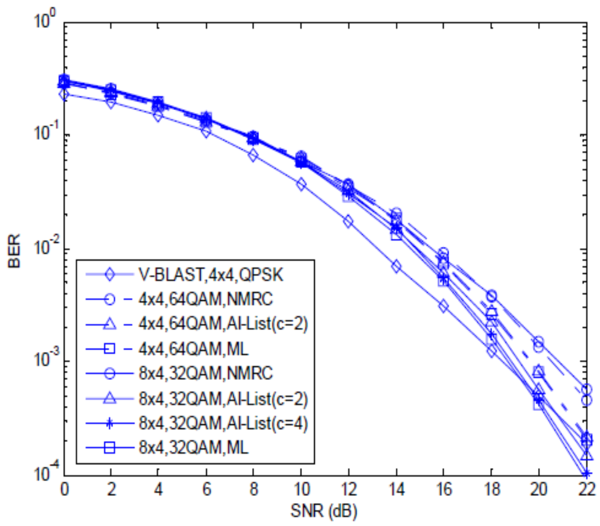

Fig 6 BER performance of SM system for the case of 8 bits/s/hz.

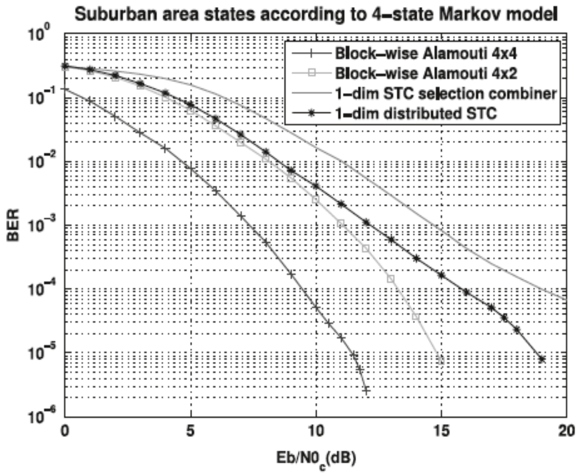

Fig 7. BER vs. Eb=N0c . Comparison of different techniques in dual satellite scenario.

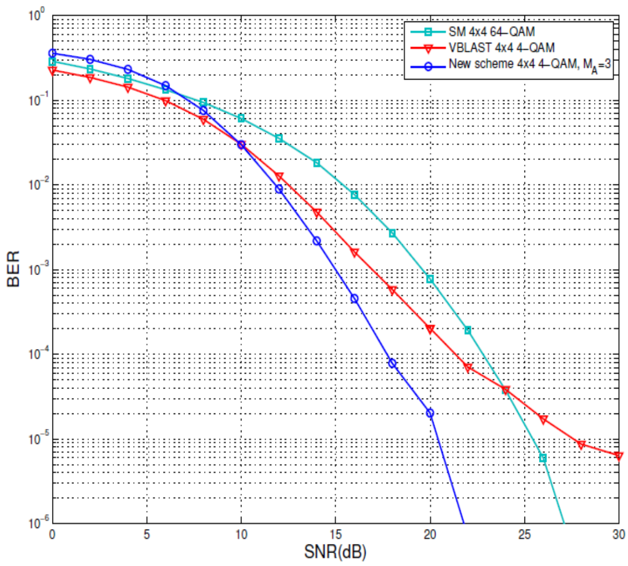

Fig 8. BER performance for 8 bits/s/Hz.

IV. CONCLUSION

In this paper the performance of availability and the capacity of a LMS system has been presented.

The proposed channel model for the evaluation of the system performance is a multi state Markov chain statistical modeling approach. From the results it is shown that using the transmission diversity with the combination of a combining technique, we can improve the availability to capacity ratio.

The results shows that the channel capacities are dependent on the elevation angle under a given satellite A technical method for increasing the system's capacity and QoS, without the increase of available bandwidth, is the use of multiple beam coverage. It is worth noting that the EGC is recommended for application in LEO LMS systems because it introduces less complexity, less cost and better percentage of time for which the CNR > CNRmin than the MRC.

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