Ameliorate of Cross-Polarization in 2×2 MIMO down link using C & Ku-Band

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Abstract—**An analytical approach is existing to evaluate the interference due to effect of cross-polarization diversity of 2×2 MIMO from satellite to ground is modeled using Rician k-factor. With the help of simulation, comparative analysis of BER vs SNR and power range evaluated for different environments like Open Area (OA), Suburban Area (SUA), Urban Area (UA) and Aeronautical/Marine Area (A/M A) for C-band as well as Ku-Band. Some other parameters also being highlighted like power range, S/N, how uplink and downlink S/N effects overall S/N. Also compares Ku vs C band in which data sustainability is higher in C band.**

Keywords-Satellite Communication, Cross-polarization, BER, SNR, 2×2 MIMO, Power Range, C-Band, Ku- Band.

I. INTRODUCTION

Satellite communication is a momentous part in the global telecommunications system. In SATCOM the applicability of the MIMO technology is subject to contentious discussions in the scientific community. The main reason can be found in the characteristics of the satellite channel. The satellite channel for Fixed Satellite Services (FSS) and Mobile Satellite Services (MSS) in frequency bands above 10 GHz is specified by a strong Line-of-Sight (LOS) signal with no or negligible multipath components (MPC). Since MPC are widely believed to be a prerequisite for high MIMO capacity gains, the applicability of spatial multiplexing to the SATCOM channel has been doubted in the past. Instead, polarization multiplexing has always been the preferred MIMO strategy for SATCOM [2] [4] [6].

Cross-polarization is an interference for satellite when antenna are placed asymmetric. If antennas are placed symmetric than the signal strength can be zero. MIMO satellite system consist of one or more satellite in the same orbit communicating with one or more fixed ground station. MIMO enables system capacity to be increased in proportion to the number of transmitting and receiving antennas, a result of which is improved spectrum efficiency MIMO are widely used in Ka and Ku band in satellite communication. However the transmission quality at higher frequency and shorter wavelength is importantly influenced by rain and gaseous. That will caused the signal attenuation and decreased link availability [1] [3] [5] [7].

In this paper analytical evaluation of Bit Error Rate (BER) considering effect of cross-polarization diversity of MIMO from satellite to ground is modeled using Rician k-factor and SNR. With the help of simulation, Comparative analysis of BER vs SNR and power range for 4 different areas such as Open Area (OA), Suburban Area (SUA), Urban Area (UA) and Aeronautical/Marine Area (A/M A) for C-band as well as Ku-Band.

II. MATHEMATICAL ANALYSIS OF RECEIVE SIGNAL

The receive signal for 2×2 MIMO system,

$$R = HA + V$$

Where,
R is the receive signal vector R= $[r_{11}, r_{12}, r_{21}, r_{22}]$
A is the transmitted signal vector A= $[a_{11}, a_{12}, a_{21}, r_{22}]$
V is the noise vector V= $[v_{11}, v_{12}, v_{21}, v_{22}]$
H is the channel matrix $H = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$

The channel matrix H is the combination of co-polar and cross-polar components. Here, h_{11}, h_{22} are co-polar components and h_{12}, $h_{21}$are cross-polar components. In this 2×2 MIMO system, a receive signal travel Line-of-sight (LOS) path. The receiver will receive with cross-polarization effect. For minimizing the cross-polarization effect the receive signal is detected with time varying envelope k-factors [1][7].

Polarizing scattering matrix for 2×2 MIMO system,

$$L = \begin{bmatrix} l_{11} & l_{12} \\ l_{21} & l_{22} \end{bmatrix}$$

The channel matrix can be written as

$$H = L \begin{bmatrix} A_{11} & 0 \\ 0 & A_{22} \end{bmatrix}$$

Where,

$$A_{11} = \sqrt{\frac{k_{11}}{k_{11} + k_{12} + 1}}$$

And

$$A_{22} = \sqrt{\frac{k_{12}}{k_{22} + k_{21} + 1}}$$

So, SNR equation is;

$$SNR = \frac{\frac{k_{11}(1-\beta)}{k_{11}+k_{12}+1}}{2S/N\left(\frac{k_{12}(1-\eta)+(1-\alpha)}{k_{11}+k_{12}+1}\right)+2}$$

This SNR equation puts into BER equation;

$$BER = 0.5\ erfc\sqrt{SNR} = 0.5erfc\sqrt{\frac{\frac{k_{11}(1-\beta)}{k_{11}+k_{12}+1}}{2S/N\left(\frac{k_{12}(1-\eta)+(1-\alpha)}{k_{11}+k_{12}+1}\right)+2}}$$

Table 1. Parameter of different ground link area

Name of Parameters	Value
K-factor (k_{11},k_{21}) : (OA)	100
K-factor (k_{12},k_{22}) : (OA)	0
K-factor (k_{11},k_{21}) : (SUA)	70
K-factor (k_{12},k_{22}): (SUA)	1
K-factor (k_{11},k_{21}) : (UA)	40
K-factor (k_{12},k_{22}): (UA)	5
K-factor (k_{11},k_{21}) : (MA)	90
K-factor (k_{12},k_{22}): (MA)	1
LOS signal coefficient (β)	0.005-0.9
Reflected signal coefficient (η)	0.3
Diffused signal coefficient (α)	0.4
SNR	2-50
BER	10^{-35}-10^{0}

III. MATHEMATICAL ANALYSIS ACCORDING TO BANDS AND RANGE

Consider first uplink Earth Station is transmitting noise free signal the receive signal at the satellite is

$$P_{ru} = \frac{Ptu*Gtu*Gru}{\left(\frac{4\pi Ru}{\lambda u}\right)^2}$$

The uplink noise at the input of the satellite is

$$Pnu = K * Tsat * Bn$$

Where, K=Boltzmann Constant, Tsat=Temperature, Bn= Bandwidth, Pru= Receive uplink power, Ptu= Transmitting uplink power, Gru= Receiving gain for uplink, Gtu= Transmitting gain for uplink

So, the uplink S/N ratio is given by,

$$\frac{1}{\left(\frac{S}{N}\right)_U} = \frac{\left(\frac{4\pi Ru}{\lambda u}\right)^2 * K * Tsat * Bn}{Ptu * Gtu * Gru}$$

Now, the satellite transmits in the downlink a noise free signal the received signal at the downlink Earth station is given by,

$$P_{rd} = \frac{Ptd*Gtd*Grd}{\left(\frac{4\pi Rd}{\lambda d}\right)^2}$$

The downlink noise at the input of the Earth station is given by

$$Pnd = K * Tes * Bn$$

Where, K=Boltzmann Constant, Tsat=Temperature, Bn= Bandwidth, Prd= Receive downlink power, Ptd= Transmitting downlink power, Grd= Receiving gain for downlink, Gtd= Transmitting gain for downlink.

So, the downlink S/N ratio is given by,

$$\frac{1}{\left(\frac{S}{N}\right)_D} = \frac{\left(\frac{4\pi Rd}{\lambda d}\right)^2 * K * Tes * Bn}{Ptd * Gtd * Grd}$$

Where, uplink frequency for C-Band fu=[5.925-6.425], downlink frequency for C-Band fd=[3.70-4.20], uplink frequency for Ku-Band fu=[14-14.50], downlink frequency for Ku-Band fd=[11.70-12.20]

The overall S/N ratio become

$$\left(\frac{S}{N}\right)_{OVERALL} = \frac{1}{\frac{1}{\left(\frac{S}{N}\right)_U} + \frac{1}{\left(\frac{S}{N}\right)_D}}$$

For Finding BER;

$$BER = 0.5\ erfc\sqrt{SNR_{OVERALL}}$$

Now, for receive power is given by,

$$Pr = SNR_{OVERALL} + GR + LOSS$$

IV. RESULT AND ANALYSIS

Here simulated analysis of 2×2 MIMO satellite to ground link. Comparative analysis of SNR and BER performance results for different link parameters in 4 separate areas such as open area, suburban area, urban area and aeronautical/marine area.

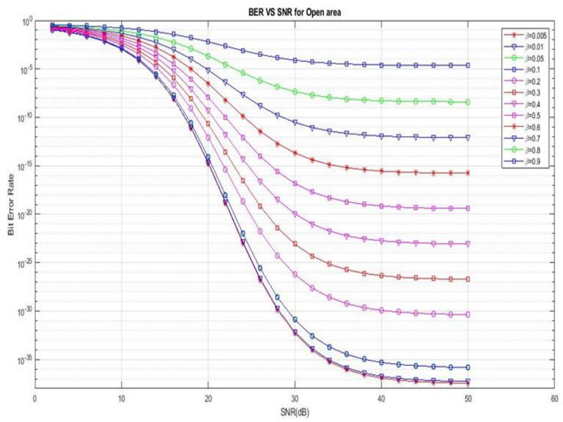

Fig.1. BER vs. SNR in Open Area for a satellite to ground link

The plot BER vs SINR (dB) for open area shown in Fig. 1 with the different values of the Cross-Polar Discrimination of the LOS components (β) and direct polarized channel components and specular channel components a satellite to ground link. It is observed that BER improve with the increase in SNR but degrades with the increment of cross-polarization coefficient. For the higher value of direct and cross-polarization parameters, BER curves are become floor as seen from the figure. It is also noticed that BER exhibits lower performance for the lower value of(β).

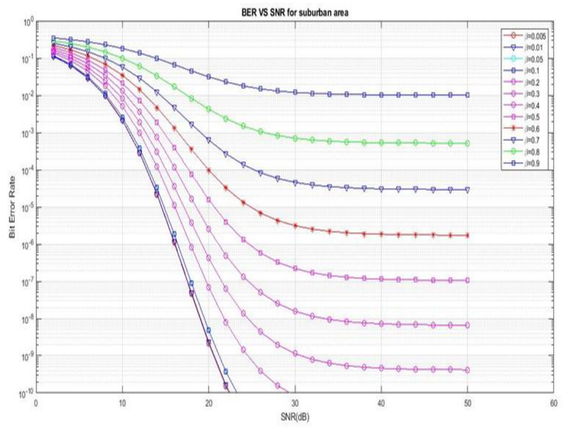

Fig. 2. BER vs. SNR in Suburban Area for a satellite to ground link

Fig. 2 describes the BER vs. SINR curve in sub-urban area, it is observed that the value of SNR is increasing with the value of β. The SNR value is found 24 dB and 50 dB for sub-urban area and open area respectively under $\beta=0.1$.

Fig.3 illustrates the BER vs. SINR outcome for the urban areas varying β. It is noticed that better SNR as well as BER performance has been achieved for higher value of β in compared to that previous OA and SA schemes. The figure also describes that SNR is remain fixed for the value of β less than 0.1.

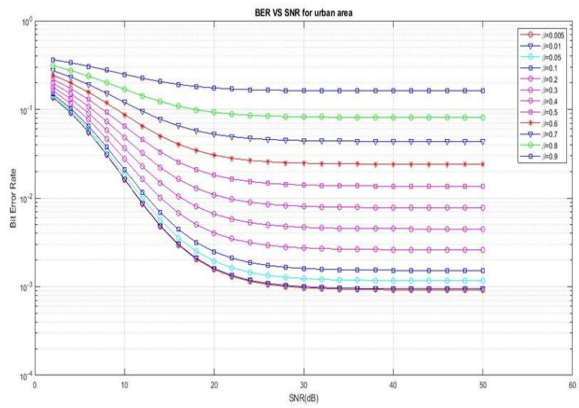

Fig.3. BER vs. SNR in Urban Area for a satellite to ground li

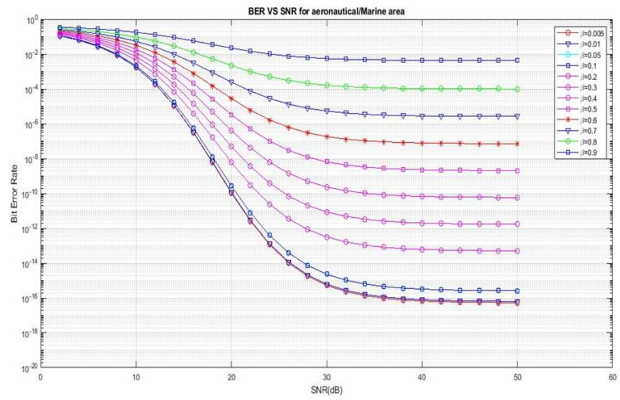

Fig.4. BER vs. SNR in Aeronautical/Marine Area for a satellite to ground link

Fig.4 indicates the Bit Error Rate Versus SNR curve, where for the similar value of Line-of-sight co efficient (β). This figure also attained superior BER results over the other policies as evident from the figure.

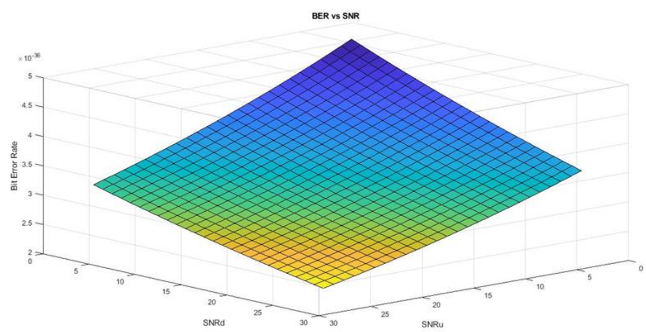

Fig.5.BER vs SNR for Ku Band

Fig.5 Illustrate for Ku band particular uplink 26 different results for downlink. And as different uplink-downlink ratio BER decreases according to graph up-to $10^{\wedge(-38)}$.

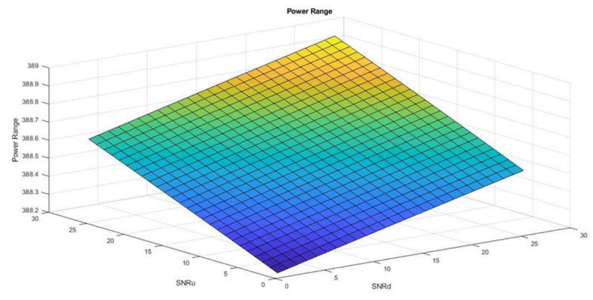

Fig.6. Power Range vs SNR for Ku Band

Fig.6 Illustrate for Ku band particular uplink 26 different results for downlink. And as different uplink-downlink ratio, Power Range increases for SNR_{u-d}.

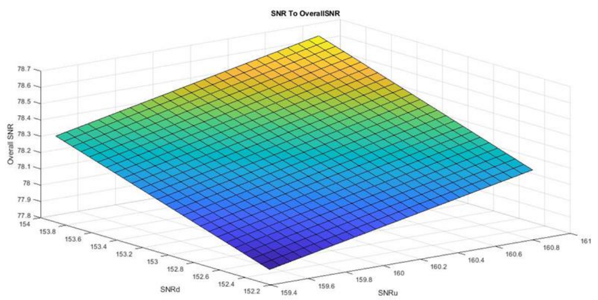

Fig.7. SNR uplink- downlink vs Overall SNR for Ku Band

Fig.7 shows for Ku band particular uplink 26 different result for downlink, overall SNR become increase.

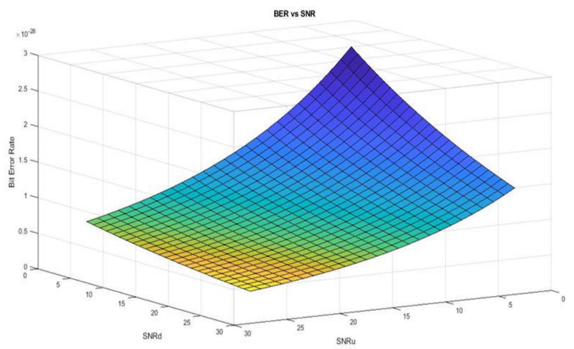

Fig.8. BER vs SNR for C Band

Fig.8 Illustrate for C Band, frequency range, for particular uplink 26 different results for downlink. And as different uplink-downlink ratio BER decreases according to graph up-to $10^{(-28)}$.

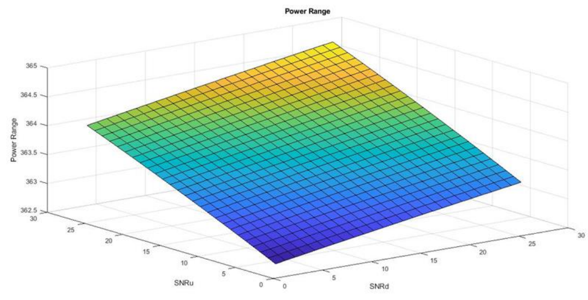

Fig.9. Power Range vs SNR for C Band

Fig.9 Illustrate for C band particular uplink 26 different results for downlink. And as different uplink-downlink ratio, Power Range increases for SNR_{u-d}.

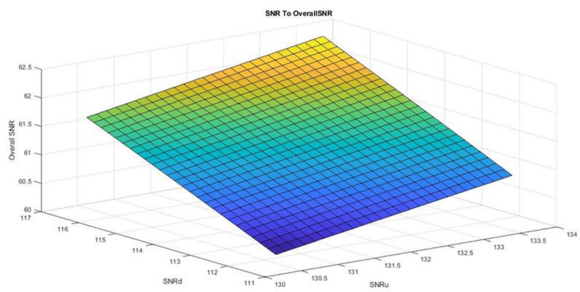

Fig.10. SNR uplink- downlink vs Overall SNR for C Band

Fig.10 Illustrate frequency range, for uplink is between 5.925-6.425 GHz [130-134 dB] and for downlink frequency is 3.70-4.20 GHz [111-117 dB]. For particular uplink 26 different results for downlink. And as different uplink-downlink ratio Over All increases according to graph up-to Over All SNR 60-62.5 dB

V. RESULT AND ANALYSIS

Under 2X2 MIMO with OFDM technique in satellite communication, change in direct and spectral components for different areas as a result author find various stability points with dependency of LOS signal coefficient (β). For taking increased value of β BER and SNR increased 250% and 127.27% respectively. Stability and Accuracy of SNR, BER and power range depends on frequency variation; in which C band has effective power range compare with Ku band. And Ku band is 30% less noisy compare with C band

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