SELF-INTERFERENCE CANCELLATION USING THE WEIBULL DISTRIBUTION UNDER ESTIMATED CHANNEL GAINS FOR TWO-WAY SATELLITE RELAYING

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Abstract: In this study, we look at the two-antenna base station (BS) two-way satellite relaying (TWSR) system. The utilised satellite is a bend-pipe satellite that broadcasts signals with some transponder gain after receiving signals over the uplink. Self interference occurs while the signal is being transmitted, but it can be avoided by having complete knowledge of the uplink and downlink Earth Stations [ESs]. However, due to reciprocity issues and transmit power restrictions, it is difficult to produce this knowledge about the uplink and downlink ESs. We therefore use Weibull Distribution to analyse the Channel State of Information (CSI) and discover that, when CSI estimate is used in practise, the training protocol for two-way satellite relaying is designed correctly. Furthermore, we discovered that both ESs transmit orthogonal training sequences, which are essential for CSI's function in self-interference cancellation. We achieve a decreased bit error rate and average capacity of the scheme with the aid of the analytically proved impact of CSI estimation with Weibull Distribution over the functionality of the TWSR system.

Keywords: component: channel state of information, weibull distribution,two way satellite relaying,

I. INTRODUCTION

Wide band transmission capabilities, extensive coverage, and navigation are all features of satellite communications. For disaster recovery, satellites provide ubiquitous internet service across a vast area of thousands of square kilometres. [1]- [3] A One of these is signal latency, which is the interval of time between a data request and a response. Latency in one-way communication is the interval between the time a signal is transmitted and the moment it is actually received at its destination. The amount of latency depends on the distance travelled and the speed of light. Terrestrial networks have very little signal latency, however there is a problem with signal latency in satellite communications. Due to the signal's lengthy journey to the satellite orbit and return to Earth (35,786 km for a geostationary earth orbit (GEO) satellite), satellite communications have an extremely high latency [35]. The satellite communication system is likely the oldest wireless cooperative relaying communication system still in use today. The satellites serve as a relaying node in all satellite communications, and they are all located in free space, thousands of miles from the earth. Through the uplink channel, the satellite receives signals from the earth station and transmits them to the target earth station [4]–[8]. The bent-pipe satellites are most frequently employed in satellite communications. These satellites are more compact, lighter, and less expensive. The Bent pipe satellite receives signals via the uplink at a high frequency and down-converts them to the downlink at a lower frequency after boosting the baseband signal using transponder gain.

This kind of operation is comparable to the amplify-and-forward (AF) protocol used in terrestrial cooperative networks [9], [10]. The decode-and-forward relaying protocol based satellites require complex circuitry and are larger in weight as compared to the amplify and forward based satellites, which are employed more frequently since they function as repeaters. When thinking about satellite systems, computational complexity and simple circuitry are crucial since more processing at the satellite's terminal demands a lot of power, yet as transponder sizes grow, the weight and price of the satellite system also rise. Although non-regenerative satellite systems are typically utilised, the Decode and Forward protocol has a de-noising aspect that makes on-board processing satellites appealing [21]. Only a small number of applications, including the military and emergency services, use regenerative satellites, which decode and send protocol-based satellites [3]. Rain, fog, snow, a poor angle of inclination, lack of line-of-sight (LOS), and reduced power transmission due to masking between the satellite and a terrestrial user all limit the satellite's coverage region. The impact of masking is felt by indoor users. Data is exchanged between two earth stations via a single antenna amplify-and-forward (AF) satellite in a two-way satellite relay. [12]-[15]. In two-way AF relaying, two terrestrial users can exchange signals in two orthogonal time-slots or phases through a terrestrial relaying node. Two-way amplify and forward relaying is advantageous in satellite communication systems because it uses just half as many time slots as one-way relaying, which minimises the latency associated in the transfer of the data between two earth stations [16]. There are two stages to this process. The relay is simultaneously accessed by both users in the first phase, also known as the multiple access phase. The relay transmits whatever it has received during the first phase to both users during the subsequentphase.

$$\hat{s}_j = \arg \min_{s_j} |y_i - aG_i s_i - aG_{i,j} s_j|^2$$

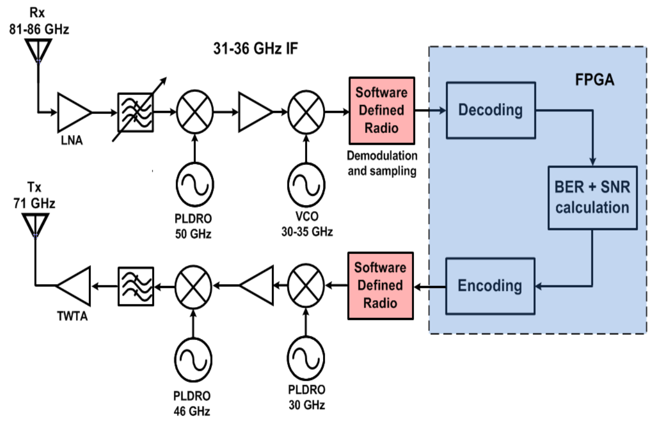
in the receiver on the ground for two-way satellite relaying. Each earth station is expected to have exact knowledge of the channel gains needed to cancel self-interference and decode the data sent by the other earth station. Since satellite links vary more quickly than terrestrial links due to atmospheric changes, it is challenging to precisely track the uplink channels in the earth station due to high signal latency. A differential modulation based Two Way Satellite Relaying technique is presented to eliminate the issue of channel state information (CSI) estimate for self-interference cancellation and symbol detection. The error performance of the two-way relaying satellite technique can be enhanced if the exact channel state information estimate is available in the earth station. Studying the Two Way Satellite Relaying with Approximated Channel State Information is hence essential. It is also desirable to suggest a training scheme design for the two-way satellite relaying systems since channel state information estimation is a significant issue in satellite systems. Here, we go into further detail about two-way amplify and forward satellite communication. Based on the maximum-likelihood (ML) decoder of the two-way relayed data in ESs, a training protocol appropriate for the practical satellite presuppositions is proposed.

The peak-to-average power ratio (PAPR) ideal training sequences for both earth stations and the mean square error (MSE) in the Channel State Information estimation are calculated. The initial frame that each earth station will transmit contains the training symbols. The key benefit of the proposed two-way satellite relaying approach is that it does not require any modification to the current satellite nodes because it does not depend on the satellite providing feedback on its estimates of the uplink channel state information. Additionally, the average bit error rate (BER) and average capacity of the suggested system over the Closed-form deductions of shadowed Rician fading linkages are made. The practical behaviour of the scheme with a wide range of parameters, such as training duration and Shadowed-Rician (SR) fading scenarios, is better understood thanks to these analytical expressions. The remainder of the essay is structured as follows. In Section II, the Weibull distribution and performance analysis with system model self-interference cancellation are examined. In Section III, we apply the formula to determine the numerical performance. Results in graphical form are covered in Section IV. An examination of the average capacity and bit error rate is done in Section V's tables for comparison work. Later in this Section, we go over the description of Table VI, and Section draws some helpful conclusions for the work that has been provided.

II. PERFORMANCE ANALYSIS:

A. SYSTEM MODEL:

A transponder satellite receives the signal from one ground station across a range of uplink frequencies, amplifies it, then sends it to the other ground station or earth station through several ranges of downlink frequencies [27]. Together, the satellite's electrical parts produce an RF communication channel with a defined bandwidth, such as 36MHz [28]. In the Ku band, we were active on our project. In the microwave frequency range, the Kuband region of the electromagnetic spectrum is between 12 and 18 GHz. A Ku band has a 14GHz and 12GHz uplink and downlink frequency, respectively.



It is expected that the system functions for Ku-band. Two more assumptions must be true for this to work flawlessly. First, at any one time, only one of the two earth stations is transmitting a signal. Second, it is believed that all signals move at a single frequency even when two separate signal frequencies are used. The satellite antenna receives the signal once it is broadcast via the uplink frequency. The LNA (Low Noise Amplifier) receives the signal once it has been received. The signal goes through two phases of down conversion after being transmitted via a filter. To lower the signal frequency to a specific range, the signal is first sent via a 50GHz Phase-Locked Dielectric Resonant Oscillator (PLDRO). The initial downconverted signal is run via a voltage control oscillator (VCO) in the second step to increase its frequency to the 1GHz range. Analog to digital conversion and downconversion of the signal are both done using software defined radio. The resulting digital data can be utilised for demultiplexing, encoding, decoding, and BER-SNR calculations. The decoded signal from the FPGA is subjected to BER calculation and re-encoded (decoding via forward error calculation (FEC)). The software defined radio is then used to decode the signal once more and turn it into an analogue signal. The frequency of this analogue signal is subsequently increased by passing it through two stages of PLDRO and VCO. Due to its ability to produce large output powers, travelling wave tube amplifiers are used to further process this upconverted signal rather than a solid state device. Then, using a satellite transmitting antenna, this signal is sent to the earth station. [28]

B. SELF INTERFERENCE CANCELLATION:

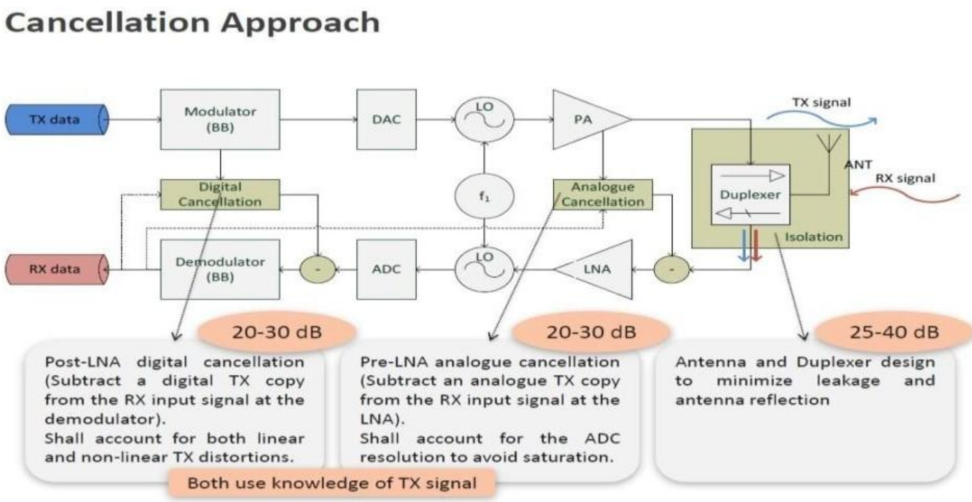
The required signal is extracted from the composite signal at the receiver along with some noise after a broadcast signal from the source is cancelled there. The advantage of the innovation is that the user is aware of the precise structure of the source broadcast signal beforehand [22]. The bandwidth of the residual self-interference channel is often reduced by self-interference suppression. A frequency-selective self-interference signal will therefore be handled by adding an active self interference cancellation. [23]. When channel gain is increased in an amplify-and-forward protocol with self interference cancellation, performance deterioration can be minimised. [38].

Fig. 1 shows the transmission protocol for the AF two-path relaying scheme over two consecutive time slots. Let yrj I and yd I stand for the signal received at relay j (j = 1, 2) and the signal received at D (D = I respectively. x (1) is transmitted from S in time slot 1. Hence, at R1 and D,

$yr1\ (1) = \sqrt{\rho}\ hs, r1x\ (1) + nr1\ (1),$ (1)
$yd\ (1) = \sqrt{\rho}\ hs, dx\ (1) + nd\ (1),$ (2)

Where, hs, d and hs, rj are the average transmit power and the channel coefficients from S to D and S to the j-th relay, respectively. The additive white Gaussian noise (AWGN) at the j-th relay is represented by the values of nrj I and nd I at CN (0, 2), respectively [29].

Due to their relatively lower processing complexity and HW needs compared to alternative two-hop techniques and their short forwarding latency, repeaters in particular could be a desirable solution for future wireless networks [25]. We consider imperfect
self-interference cancellation at both sources that exchange information through multiple relays, in contrast to the existing literature, which assumes perfect self-interference cancellation. Then, maximal-ratio combining is used to improve the decision statistics under imperfect signal detection. [26].



C. WEIBULL DISTRIBUTION:

A continuous probability distribution is the Weibull distribution. It is currently the most widely used technique in reliability engineering and the analysis of failure data worldwide. In comparison to other distributions, it has a lower probability error. The Weibull distribution's probability density function is given by:

(3) $$p_X(X) = \frac{v}{w} x^{v-1} e^{\frac{-x^v}{w}}, x > 0$$

CI. NUMERICAL CALCULATIONS

(4) $$y_s = \sum_{i=1}^{2} h_i s_i + w_s$$

(5) $$y_i = a g_i y_s + w_i$$

Where si is the symbol of ES-i from M-PSK constellation with Es energy; marks the uplink channel coefficient of ES-i; and ws represents the additive white Gaussian noise (AWGN) at the satellite, which contains zero mean complex Gaussian noise elements with 2s variance.

(6) $$snr1 = 10.\,^\wedge(snr/10)$$

All channel gains are modeled as SR fading channels. The Probability distribution function (PDF) of |gi |2 is given by [26]

$$f_{|g_i|^2}(x) = \alpha_i e^{-\beta_i x} 1F1(m_i; 1; \delta_i x), x > 0 \quad (7)$$

Where I = 0, 1, I = 0.5(2bimi / (2bimi + I mi/bi, I = (0.5/bi), I = 0.5 i/ (2b2 I mi + bi i), the parameter I is the average power of the LOS component, 2bi is the average power of the multipath component, and 0 mi is the Nakagami parameter; for mi = 0

$$y_i = ag_i h_i s_i + ag_i h_j s_j + ag_i w_s + w_i \quad (8)$$

Since w_i and w_s, the Conditional pdf is given by, the decision metric of the symbol s_j is given by the ML detector mentioned above

$$\hat{s}_j = arg\ min\, |y_i - aG_i s_i - aG_{i,j} s_j|^2 \quad (9)$$

The signals received in the ES-i during the training period (k = 1, L) can be written by using

$$z_i^{(k)} = aG_i p_k + aG_{i,j} q_k + ag_i w_s + w_i \quad (10)$$

$$y_i^{(n)} = aG_i s_i^{(n)} + aG_{i,j} s_j^{(n)} + ag_i w_s^{(n)} + w_i^{(n)}$$

The Moment Generating Function [MGF] based approach is used to derive the average capacity. For the considered earth station ES-i, the average capacity using MGF approach is given as

$$C_i = \frac{B}{ln2} \sum_{n=1}^{N} v_n U_1(s_n) \left\{ \frac{\delta}{\delta s} M_{\gamma i}(s) \Big| s \to s_n \right\} \quad (11)$$

Here B represents bandwidth

The expression for and is used in the above equation

$$s_n = \tan\left(\frac{\pi}{4}\cos\left(\frac{2n-1}{2N}\pi\right) + \frac{\pi}{4}\right)$$

$$v_n = \frac{\pi^2 \sin\left(\frac{2n-1}{2N}\pi\right)}{4N\cos^2\left(\frac{\pi}{4}\cos\left(\frac{2n-1}{2N}\pi\right) + \frac{\pi}{4}\right)} \quad (12)$$

$U_1(s_n)$ is represented in the form of Meijer-G function

$$U_1(s_n) = -G_{2,1}^{0,2}\left(\frac{1}{s_n}\middle|\begin{matrix}1,1\\0\end{matrix}\right)$$

$$\times\frac{-\vartheta_{j,k}^{-1}\bar{\gamma}}{\left(1+\frac{2E_s}{a^2S}\right)\left(\beta_j-\delta_j\right)c}\times G_{34}^{23}\left(\frac{\beta_i-\delta_i}{\vartheta_{j,k}}\middle|\begin{matrix}0,1+l_j+m-l_i,1\\l_j+m+d_i-l_i,1+l_i+m,1\end{matrix}\right)$$

The conditional MGF is given by

$$M_{\gamma_i|\gamma}(s) = \tilde{\alpha}_j\sum_{l_j=0}^{\tilde{c}_j}\binom{\tilde{c}_j}{l_j}\tilde{\beta}_j^{\tilde{c}_j-l_j}\times$$

$$\left(\begin{matrix}\Phi^{-(\tilde{d}_j-l_j)}(s,y)\left(1+\left(\tilde{\beta}_j-\tilde{\delta}_j\right)\Phi^{-1}(s,y)\right)^{-\tilde{d}_j}+\\ \tilde{\epsilon}_j\tilde{\delta}_j\times\Phi^{-(\tilde{d}_j-l_j-1)}(s,y)\left(1+\left(\tilde{\beta}_j-\tilde{\delta}_j\right)\Phi^{-1}(s,y)\right)^{-(\tilde{d}_j+1)}\end{matrix}\right)$$

Where $\Phi(s,y)$ is given by,

$$\Phi(s,y) = \frac{y\tilde{\gamma}s}{(y+c)\left(1+\frac{2E_s}{a^2s}\right)} \quad (13)$$

The conditional MGF is averaged, where the γ_i MGF of is derived and it is given by equation (14)

$$M_{\gamma_i}(s) \cong \frac{\alpha_i\tilde{\alpha}_j}{(\tilde{\beta}_j-\tilde{\delta}_j)^{\tilde{d}_j}}\sum_{l_j=0}^{\tilde{c}_j}\binom{\tilde{c}_j}{l_j}\tilde{\beta}_j^{\tilde{c}_j-l_j}\sum_{l_i=0}^{c_i}\binom{c_i}{l_i}\beta_i^{c_i-l_i}\times \left(\frac{s\bar{\gamma}}{\left(1+\frac{2E_s}{a^2S}\right)}\right)^{l_j}\Big(\mathcal{I}(l_i,d_i,l_j,\tilde{d}_j,\vartheta_{j,k})+\epsilon_i\delta_i\times\mathcal{I}(l_i,d_i+1,l_j,\tilde{d}_j,\vartheta_{j,k})+\frac{\tilde{\epsilon}_j\tilde{\delta}_j}{\tilde{\beta}_j-\tilde{\delta}_j}\times\mathcal{I}(l_i,d_i,l_j,\tilde{d}_j+1,\vartheta_{j,k})+\frac{\epsilon_i\delta_i\tilde{\epsilon}_j\tilde{\delta}_j}{\tilde{\beta}_j-\tilde{\delta}_j}\mathcal{I}(l_i,d_i+1,l_j,\tilde{d}_j+1,\vartheta_{j,k})\Big)$$

In this $\mathcal{I}(l_i,d_i,l_j,\tilde{d}_j,\vartheta_{j,k})$ is given by equation (15)

$$\mathcal{I}(l_i,d_i,l_j,\tilde{d}_j,\vartheta_{j,k}) = \sum_{m=0}^{\tilde{d}_j-l_j}\binom{\tilde{d}_j-l_j}{m}\frac{\vartheta_{j,k}^{-(l_j+m+d_i-l_i)}}{\Gamma(d_i)\Gamma(\tilde{d}_j)c^{l_j+m}}\times G_{23}^{22}\left(\frac{\beta_i-\delta_i}{\vartheta_{j,k}}\middle|\begin{matrix}1-\tilde{d}_j,1-(l_j+m+d_i-l_i)\\0,\tilde{d}_j-l_j-m-d_i+l_i,1-d_i+l_i\end{matrix}\right)$$

And

$$\vartheta_{j,k} = \frac{s\bar{\gamma}+\left(1+\frac{2E_s}{a^2S}\right)(\tilde{\beta}_j-\tilde{\delta}_j)}{\left(1+\frac{2E_s}{a^2S}\right)(\tilde{\beta}_j-\tilde{\delta}_j)c} \quad (16)$$

Then the derivative of first order of $\mathcal{I}(l_i,d_i,l_j,\tilde{d}_j,\vartheta_{j,k})$ can be given as equation (17)

$$\hat{\mathcal{I}}(l_i,d_i,l_j,\tilde{d}_j,\vartheta_{j,k}) = \frac{\delta}{\delta s}\mathcal{I}(l_i,d_i,l_j,\tilde{d}_j,\vartheta_{j,k}) = \sum_{m=0}^{\tilde{d}_j-l_j}\binom{\tilde{d}_j-l_j}{m}\frac{(\beta_i-\delta_i)^{-(l_j+m+d_i-l_i)}}{\Gamma(d_i)\Gamma(\tilde{d}_j)c^{l_j+m}}$$

(17)

The first order derivative of MGF is given as

$$\frac{\delta}{\delta s}M_{\gamma_i}(s) = \frac{\alpha_i\tilde{\alpha}_j}{(\tilde{\beta}_j-\tilde{\delta}_j)^{\tilde{d}_j}}\sum_{l_j=0}^{\tilde{c}_j}\binom{\tilde{c}_j}{l_j}\tilde{\beta}_j^{\tilde{c}_j-l_j}\sum_{l_i=0}^{c_i}\binom{c_i}{l_i}\beta_i^{c_i-l_i}\times$$

$$l_j s^{l_j-1}\left(\frac{\overline{\gamma}}{\left(1+\frac{2E_S}{a^2S}\right)}\right)^{l_j}\begin{pmatrix}\mathcal{I}\left(l_i,d_i,l_j,\tilde{d}_j,\vartheta_{j,k}\right)+\epsilon_i\delta_i\times\\ \mathcal{I}\left(l_i,d_i+1,l_j,\tilde{d}_j,\vartheta_{j,k}\right)+\\ \frac{\tilde{\epsilon}_j\tilde{\delta}_j}{\tilde{\beta}_j-\tilde{\delta}_j}\times\mathcal{I}\left(l_i,d_i,l_j,\tilde{d}_j+1,\vartheta_{j,k}\right)+\\ \frac{\epsilon_i\delta_i\tilde{\epsilon}_j\tilde{\delta}_j}{\tilde{\beta}_j-\tilde{\delta}_j}\mathcal{I}\left(l_i,d_i+1,l_j,\tilde{d}_j+1,\vartheta_{j,k}\right)\end{pmatrix}$$

$$+\frac{\alpha_i\tilde{\alpha}_j}{(\tilde{\beta}_j-\tilde{\delta}_j)^{\tilde{d}_j}}\sum_{l_j=0}^{\tilde{c}_j}\binom{\tilde{c}_j}{l_j}\tilde{\beta}_j^{\tilde{c}_j-l_j}\sum_{l_i=0}^{c_i}\binom{c_i}{l_i}\beta_i^{c_i-l_i}\times\left(\frac{s\overline{\gamma}}{\left(1+\frac{2E_S}{a^2S}\right)}\right)^{l_j}\begin{pmatrix}\mathcal{I}\left(l_i,d_i,l_j,\tilde{d}_j,\vartheta_{j,k}\right)+\epsilon_i\delta_i\times\\ \mathcal{I}\left(l_i,d_i+1,l_j,\tilde{d}_j,\vartheta_{j,k}\right)+\\ \frac{\tilde{\epsilon}_j\tilde{\delta}_j}{\tilde{\beta}_j-\tilde{\delta}_j}\mathcal{I}\left(l_i,d_i,l_j,\tilde{d}_j+1,\vartheta_{j,k}\right)+\\ \frac{\epsilon_i\delta_i\tilde{\epsilon}_j\tilde{\delta}_j}{\tilde{\beta}_j-\tilde{\delta}_j}\mathcal{I}\left(l_i,d_i+1,l_j,\tilde{d}_j+1,\vartheta_{j,k}\right)\end{pmatrix} \quad (18)$$

The satellite's transmission bandwidth is estimated to be 36 MHz, which falls into the L, C, Ku, and Ka bands within the listed bandwidth, in order to compute the average capacity. Equations 1 and 2 are used to obtain the analytical estimates of capacity in bits per second (bits/sec) for a range of SNR values. Here, the training duration L ranges in steps of 2 from 2 to 10. The analytical expression for the TWSR system's average capacity is quite precise. The TWSR scheme's capability is negatively impacted by the short training duration. When compared to training length L=2, the capacity loss can be further decreased by employing training length L=10. With L=2, the investigated scheme has a capacity loss of around 46 percent; however, when L=10 is used, the capacity loss is further decreased to about 14 percent. SNR . This training-based TWSR method may obtain a very high value of capacity of 7.4 Megabits per second at 12 dB SNR under the FHS/FHS fading scenario.

GRAPHICAL RESULTS

0 Future with Weibull distribution and MIMO antenna beam-forming scehme 10
_______________ILS/ILS, analysis, QPSK
Weibull ,MIMO antenna using optimal beam-forming
-1
10

-2

10

-3 BER
10

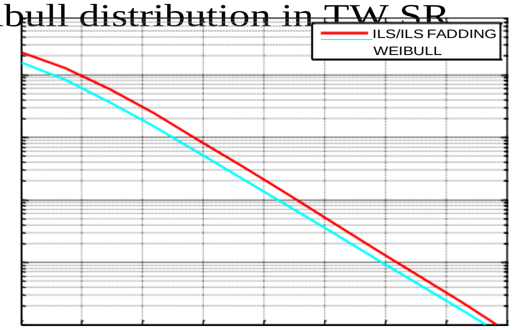
-4
10

-5
10

-6
10
0 10 20 30 40 50
SNR[DB]

Fig1 *shows the graph of weibulldistribution in beam forming*

Weibull distribution in TW SR



-1
10

-2
10
BER

-3
10

-4
10

-5
10
0 5 10 15 20 25 30 35 40
SNR[DB]

Fig2 *shows the graph of weibull in TWSR and it lower BER*

V. TABLE – RESULTS OF THE PAPERS COMPARISON

SIMULATION RESULTS	TWSR	WEIBULL
BER vs SNR	0.1573	0.09
BER vs SNR	0.22	0.155
AVERAGE CAPACITY vs SNR	0.5853	0.8651

V. DESCRIPTION OF TABLE

The comparison of the two-way satellite relaying system with the estimated information channel state is shown in the above table. The findings from earlier articles were found to support the theoretical findings. When weibull distribution was applied to the data, we were able to create results that were more precise and close to the ideal values. The statistics in the tabulation demonstrate that the average channel capacity has grown, allowing it to transmit more parallel data with a lower error rate.

VII. CONCLUSION

We have looked at the issues that arise both during transmission and receipt of the signal from the ESs. A training process has been established to address issues and estimate CSI that is not ideal. When the weibull distribution was applied, the self interference effect was lessened, and the results were found to be better and more in line with ideal theoretical values. Based on the theoretical findings, analytical expressions for BER and SNR have been discovered. As a result, we can demonstrate from this work that the average channel capacity is enhanced for training symbols for L=8 and L=10 in the QPSK constellation.

VIII. REFERENCES

[1] T. Pratt, C. Bostian, and J. Allnutt, Satellite Communications, 2nd ed. New York, NY, USA: Wiley, 2003.

[2] G. Maral, M. Bousquet, and Z. Sun, Satellite Communications Systems: Systems, Techniques and Technology, 5th ed. New York, NY, USA: Wiley, 2009.

[3] K. Y. Jo, Satellite Communications Network Design and Analysis. Norwood, MA, USA: Artech House, 2011.

[4] Arti M. K. and M. R. Bhatnagar, “Beamforming and combining in hybrid satellite-terrestrial cooperative systems,” IEEE Commun. Lett., vol. 18, no. 3, pp.
6
.

[5] Arti M. K., “Channel estimation and detection in hybrid satelliteterrestrial communication systems,” IEEE Trans. Veh. Technol., to be published, doi: 10.1109/TVT.2015.2456433.

[6] Arti M. K., “A novel beamforming and combining scheme for two-way AF satellite systems,” IEEE Trans. Veh. Technol., to be published, doi:10.1109/TVT.2016.2557352.

[7] A. Nosratinia, T. E. Hunter, and A. Hedayat, “Cooperative communication in wireless networks,” IEEE Commun. Mag., vol. 42, no. 10, pp. 74–80, Oct. 2004.

[8] Arti M. K., R. K. Mallik, and R. Schober, “Performance analysis of OSTBC relaying in AF MIMO relay systems with imperfect CSI,” IEEE Trans. Veh. Technol., vol. 64, no. 7, pp. 3291–3298, Jul. 2015.

[9] M. R. Bhatnagar, “Performance evaluation of decode- and-forward satellite relaying,” IEEE Trans. Veh. Technol., vol. 64, no. 10, pp. 4827–4833, Oct. 2015.

[10] B. Rankov and A. Wittneben, “Achievable rate regions for the two-way relay channel,” in Proc. IEEE Int. Symp. Inf. Theory (ISIT), Seattle, WA, USA, Jul. 2006, pp. 1668–1672.

[11] Arti M. K. and M. R. Bhatnagar, “Performance analysis of two-way AF MIMO relaying of

OSTBCs with imperfect channel gains," IEEE Trans. Veh. Technol., vol. 63, no. 8, pp. 4118–4124, Oct. 2014.

[12] Arti M. K., R. K. Mallik, and R. Schober, "Beamforming and combining in two-way AF MIMO relay networks," IEEE Commun. Lett. vol. 17, no. 7, pp. 1400–1403, Jul. 2013.

[13] Arti M. K. and M. R. Bhatnagar, "Imperfect CSI based two-way AF MIMO relaying of OSTBC," in Proc. IEEE Int. Conf. Commun. (ICC), Sydney, NSW, Australia, Jun. 2014, pp. 4430–4435.

[14] F. Gao, R. Zhang, and Y.-C. Liang, "Optimal channel estimation and training design for two-way relay networks," IEEE Trans. Commun., vol. 57, no. 10, pp. 3024–3033, Oct. 2009.

[15] S. Abdallah and I. N. Psaromiligkos, "Exact Cramer– Rao bounds for semiblind channel estimation in amplify-and-forward two-way relay networks employing square QAM," IEEE Trans. Wireless Commun., vol. 13, no. 12, pp. 6955–6967, Dec. 2014.

[16] C. Couvreur, "The EM algorithm: A guided tour," in Proc. 2nd IEEE Eur. Workshop Comput. Intensive Methods Control Signal Process., Prague, Czech Republic, Aug. 1996, pp 1–6.

[17] Arti M. K., "Channel estimation and detection in satellite communication systems," IEEE Trans. Veh. Technol., to be published, doi: 10.1109/TVT.2016.2529661.

[18] Arti M K., "Performance evaluation of maximal ratio combining in Shadowed–Rician fading land mobile satellite channels with estimated channel gains," IET Commun., vol. 9, no. 16, pp. 2013–2022, Nov. 2015.

[19] Arti M. K., Member, IEEE, Two-Way Satellite Relaying With Estimated Channel gains IEEE transactions on communications, vol. 64, no. 7, july 2016.

[20] Self interference cancellation for two-party relayed communication Inventors: Mark D. Dankberg, Encinitas; Mark J. Miller, Vista, both of Calif.; Michael
G. Mulligan, Westford, Mass.)

[21] (Passive Self-Interference Suppression for Full- Duplex Infrastructure Nodes Evan Everett, Achaleshwar Sahai, and Ashutosh Sabharwal cs.IT 17 dec 2013)

[22] (AF Two-Path Half Duplex Relaying with Inter-Relay Self Interference Cancellation: Diversity Analysis and its Improvement H. Wicaksana, Student Member, IEEE, S. H. Ting, Member, IEEE, C. K. Ho, Member, IEEE, W. H. Chin, Member, IEEE, and Y. L. Guan, Member, IEEE, ieee transactions on wireless communications, vol. 8, no. 9, september 2009)

[23] (Impact of Channel Estimation Error on the Performance of Amplify-and-Forward Two-Way Relaying Chenyuan Wang ; Ted C.-K. Liu ; Xiaodai Dong IEEE Transactions on Vehicular Technology (Volume: 61, Issue: 3, March 2012)

[24] MIMO On-Frequency Repeater with Self-Interference Cancellation and Mitigation Peter Larsson, Mikael Prytz Ericsson Research, Sweden

[25] www.jsati.com/why-satellite-how-Spacesegment4.asp

[26] en.wikipedia.org/wiki/Transponder

