Erciyes Üniversitesi
Fen Bilimleri Enstitüsü Dergisi
Cilt 37, Sayı 1 , 2021

Erciyes University
Journal of Institue Of Science and Technology
Volume 37, Issue 1, 2021

An Investigation of Large Intelligent Surfaces over Different Fading Channels

Furkan Arslan[*1], **Ömer Adıgüzel**[2], **İbrahim Develi**[3]

[*1] Erciyes Üniversitesi Mühendislik Fakültesi Elektrik-Elektronik Mühendisliği, KAYSERİ
[2] Erciyes Üniversitesi Mühendislik Fakültesi Elektrik-Elektronik Mühendisliği, KAYSERİ
[3] Erciyes Üniversitesi Mühendislik Fakültesi Elektrik-Elektronik Mühendisliği, KAYSERİ

(Alınış / Received: 10.02.2021, Kabul / Accepted: 22.03.2021, Online Yayınlanma / Published Online: 28.04.2021)

Keywords
5G,
Large Intelligent Surfaces,
MIMO,
Rician Channel,
Weibull Channel

Abstract: With the developments of communication technology, the number of wireless devices is increasing day by day. Fifth generation (5G) has an important place in the communication of these devices. Different technologies have been proposed to fulfill the requirements of 5G standards. Among these technologies, Large Intelligent Surfaces (LIS) promise the future for the realization of 5G technology. LIS are the communication technology whose name has been heard recently. In this paper, the topic of LIS has been discussed with considering some scenarios different fading channels. Furthermore, performance analysis has been performed over Rician and Weibull fading channels by considering the computer programmed application of LIS. A comparison of dual-hop (DH) and access point (AP) types, which are LIS types, was realized. The results were interpreted and new solution proposals were discussed.

Geniş Akıllı Yüzeylerin Farklı Sönümlü Kanallarda İncelenmesi

Anahtar Kelimeler
5G,
Geniş Akıllı Yüzeyler,
MIMO,
Rician kanalı,
Weibull kanalı

Özet: İletişim teknolojisindeki gelişmelerle birlikte kablosuz cihaz sayısı her geçen gün artmaktadır. Bu cihazların iletişiminde beşinci nesil (5G) önemli bir yere sahiptir. 5G'nin gereksinimlerini karşılamak için farklı teknolojiler önerilmiştir. Bu teknolojiler arasında, Geniş Akıllı Yüzeyler (LIS), 5G teknolojisinin gerçekleştirilmesi için gelecek vaat etmektedir. LIS, son zamanlarda adı duyulan iletişim teknolojisidir. Bu makalede LIS teknolojisi, bazı senaryolar ve farklı sönümlü kanallar dikkate alınarak tartışılmıştır. Ayrıca LIS'in bilgisayar programlı uygulaması dikkate alınarak Rician ve Weibull sönümlü kanallar üzerinden performans analizi yapılmıştır. LIS türleri olan iki atlamalı (DH) ve erişim noktası (AP) türlerinin karşılaştırması yapılmıştır. Sonuçlar yorumlanmış ve yeni çözüm önerileri sunulmuştur.

***İlgili Yazar:** furkan.arslan@erciyes.edu.tr

1. Introduction

The role of communication in our lives is great importance day by day. Wireless communication technology has made great progress with recent studies. While first generation (1G) was used in the first mobile phone models, Second generation (2G) entered our lives with digital mobile phone technologies. Mobile communication gained speed with third generation (3G) in the early 2000s. The most distinctive difference between 3G technology to 2G technology is that it attaches importance to data transmission. Fourth generation (4G) and 4.5G refer to the mobile data network currently used in mobile phones. With the increase in the number of mobile users, ensuring uninterrupted communication is one of the most serious issues that operators work on. As a result of the research, it has been said that the number of mobile users has reached enormous numbers in the coming years. Besides, it is obvious that with the development of technology, life has become easier and technology is used in every field. New mobile communication technology is needed to fulfill all these needs. Fifth generation (5G) technology will play a crucial role in wireless communication and internet technology. The widespread use of 5G communication technology enables the communication between humans and machines. 5G communication technology provides faster data transfer compared to previous technologies [1].

In the literature, the author in [2] has performed Bit Error Rate (BER) analysis large intelligent surfaces (LIS) over Rayleigh channel. Huang et al. have worked on energy efficiency in LIS systems [3]. While Dardari has worked on modeling [4], Hu et al. have worked on data transmission in LIS technology [5]. The authors have shown that the array gain and spatial resolution of the LIS architecture are proportional to the surface area and radius [6]. Thirumavalavan et al. demonstrated the BER analysis of the reconfigurable intelligent surface (RIS) supported NOMA system [7]. Alghamdi et al. has shown that the performance analysis of the LIS systems [8]. In [9], the analysis of the difference between the Rician and Rayleigh channels in the LIS systems has made. In this study, performance analysis is discussed by examining different fading channels on LIS.

The rest of the article is organized as follows. In section 2, system model on LIS based communication system is given. In section 3, the simulation results are shown. Finally, conclusions are given in section 4.

2. Material and Method

In order to fulfill the requirements of 5G technology, firstly multiple input multiple output (MIMO) technology has been proposed. MIMO can be defined as a wireless network where data transmission and reception take place over a radio channel. Generally there are two main MIMO types: standard MIMO and massive MIMO. While standard MIMO uses two or four antennas, Massive MIMO has a larger number of antennas. While the standard MIMO have been already used in 4G systems, massive MIMO is expected to come into play with the widespread use of 5G systems. Massive MIMO is expected to be an essential component of 5G. Since LIS technology has been introduced the number of wireless devices is increased with the spread of 5G technology in the coming years. As a continuation of massive MIMO, the LIS system has been suggested in [5] using all adjacent surfaces for the transmitter and receiver.

LIS are the smart devices that ensure the quality of the signal and enable the region to work more efficiently [12]. LIS differs from MIMO as aspect of transfer, backscatter and amplification models [2]. These surfaces are made by humans and provide the advantage of wireless charging, more efficient operation at remote distances and high-speed data transmission. [5]. Further, the LIS has small editable characteristics and consists of passive reflective elements. Because the elements in LIS are cheap and editable; there is no need for an additional power supply to understand the incoming code and to transmit [3]. With the widespread use of LIS, we are able to see it in all areas of our lives, for instance, the clothing industry, construction industry, electronic device covers [11]. LIS includes non-polarized film capacitors and materials obtained using materials such as plastic metal. The concept of LIS was proposed in [12] by using frequency selective surfaces to control the signal field.

2.1. System Model

In this part, the system model of LIS-based applications is discussed. In Figure 1, h_i and g_i represent the fading channel between the source – LIS, LIS – user respectively. LIS Dual Hop (DH) system is used to maximize the SNR value.

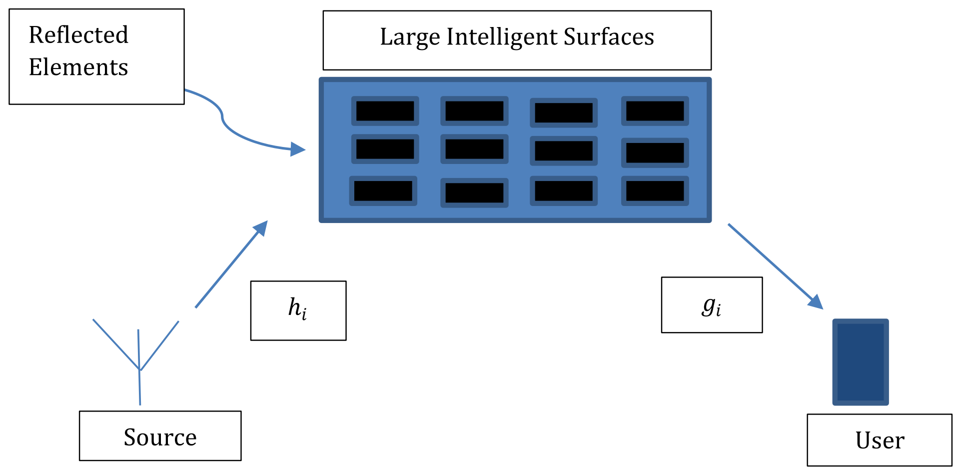


Figure 1. LIS DH system [2]

The expression h_i, $g_i \sim CN(0,1)$ and $CN(0, \sigma^2)$ denotes the complex Gaussian distribution with zero mean and variance σ^2. It is said that the LIS contains N reconfigurable reflective elements. Received baseband signal of the LIS with N reflective passive elements is as follows [2]:

$$y = \left[\sum_{i=1}^{N} h_i e^{j\vartheta_i} g_i\right] s + n \tag{1}$$

where ϑ_i refers to regulable phase, s represents the data symbol, n represents $CN(0, N_0)$ Additive white Gaussian noise (AWGN). $h_i = c_i e^{-j\theta i}$ and $g_i = d_i e^{-j\varphi i}$ and c_i, d_i represent the channel amplitudes, θ_i, φ_i represent the phases. The received baseband signal in (1) can be expressed as [13]:

$$y = g^T \vartheta\, hs + n \tag{2}$$

where $g = [g_1 g_2 g_3 \ldots g_N.]^T$ and $h = [h_1 h_2 h_3 \ldots h_N]^T$ refer to vectors between terminals and LIS. ϑ is diagonal matrix. The instantaneous signal to noise ratio (SNR) value at $\vartheta = diag([e^{j\vartheta_1} e^{j\vartheta_2} e^{j\vartheta_3} \ldots e^{j\vartheta_N}]$ the user side is follows as [13]:

$$\rho = \left(\left|\sum_{i=1}^{N} c_i d_i e^{j(\vartheta_i - \theta_i - \varphi_i)}\right|^2 E_s\right) / N_0 \tag{3}$$

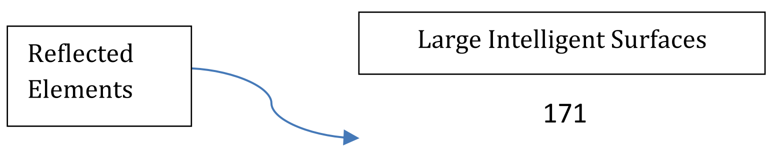
where E_S indicates the transmitted energy. It is possible to simplify the instantaneous SNR expression with the help of LIS element. Using $\vartheta_i = \theta_i + \varphi_i$ i = 1. . ., after arranging up to N, the following expression is obtained [13]:

$$\left|\sum_{i=1}^{N} f_i e^{j\tau_i}\right|^2 = \sum_{i=1}^{N} f_i^2 + 2\sum_{i=1}^{N} \sum_{k=i+1}^{N} f_i f_k \cos(\tau_i - \tau_k) \tag{4}$$

where $\tau_i = \tau$ is maximized for all i values and the instantaneous SNR value is given by [2]:

$$\rho = \left(\left|\sum_{i=1}^{N} c_i d_i\right|^2 E_s\right) / N_0 \tag{5}$$

Here, LIS itself is used as an access point (AP). In AP, reflectors are used both as signal power amplifiers and for transmitting information. When the AP is used for LIS systems in Figure 2, the channel g_i can be expressed as $g_i = d_i e^{-j\varphi i}$. In the AP system, on the source side, the LIS is powered by the RF or unmodulated carrier signal. Carrier signal is a cos $2\pi f_c t$ and carrier frequency f_c [2].



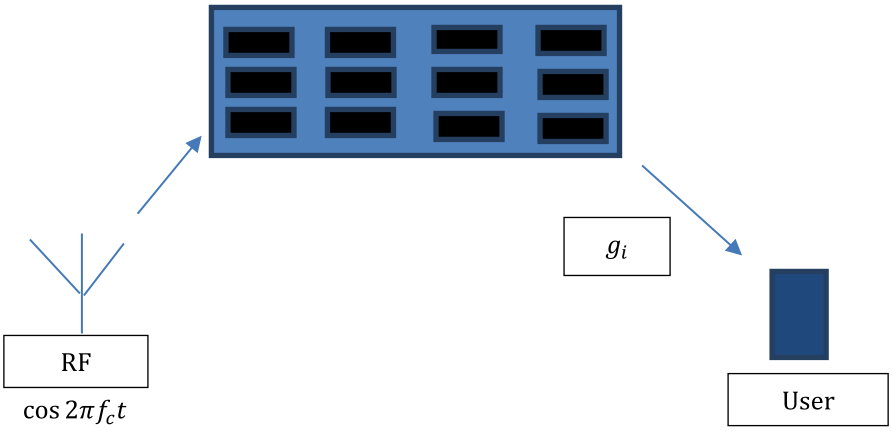


Figure 2. LIS AP system [2]

The received baseband signal expression for LIS AP system is follows as [2]:

$$y = \sqrt{E_s}\left[\sum_{i=1}^{N} e^{j\vartheta_i} g_i\right] + n \quad (6)$$

where E_S indicates the transmitted energy. ϑ_i is the phase stimulated by the ith reflector. The $\log_2 M$ bit is considered to be transmitted. $\vartheta_i = \omega_m + \varphi_i$, ω_m m ϵ (1,2,3,4, ... ,M) is prompted by LIS to send the mth message. Then, the signal received in the AP system is rewritten as [2]:

$$y = \sqrt{E_s} B e^{j\omega_m} + n \quad (7)$$

where B refers to the gain. The proximity of this signal indicates that there is a phase shift keying (PSK) modulated signal transmitted on a channel with gain B. For m = 1,2,3, ..., M values, $\omega m = 2\pi(m-1)\ M$ is expressed and the instantaneous SNR value is obtained as [2]:

$$\rho = (E_s B^2)/N_0 \quad (8)$$

LIS is a promising technology for next generation communication technologies. Finally, the advantages of the LIS system over MIMO can be summarized as:

1) Higher energy efficiency is achieved in LIS systems [14].
2) While a base station is needed in MIMO systems, transmission is made without the need for a base station in LIS systems. Higher data rates are achieved in LIS systems.
3) Thus, higher data rates are achieved.
4) Estimation and sending back information is easier in LIS systems [15].

2.2 Channel Model

2.2.1. Rician Channel

Rician channel is used in situations where there is a line of sight path (LOS). Rician distribution occurs when here is a strong path in addition to low level dispersed paths [16]. Rician channel is also called Nakagami-n fading channel. The expression of the probability density function of the Rician channel follows as:

$$p(r) = \frac{2(1+n^2)e^{-n^2}}{\Omega} \exp\left(-\frac{(1+n^2)r^2}{\Omega}\right) \mathrm{I}_0\left(2nr\sqrt{\frac{1+r^2}{\Omega}}\right) \quad (9)$$

The I_0 parameter specifies the Bessel function. In the Rician distribution, Rayleigh fading is obtained in the condition that $n = 0$, but it is stated that there is no fading when $n = \infty$ [17].

2.2.2. Weibull Channel

The Weibull distribution is the type of distribution used for modeling multipath fading channels in both indoor and outdoor environments. The expression of the Weibull probability density function follows as:

$$p(r) = \frac{cr^{c-1}}{\beta} exp\left(-\frac{r^c}{\beta}\right) \tag{10}$$

The c expression being used is the Weibull fading parameter. β is a positive scale parameter. The expression c must take a value between 0 and ∞. If $c = 1$, the Weibull distribution becomes an exponential distribution, while in the case of $c = 2$, the Weibull distribution becomes the Rayleigh distribution [18].

3. Results

In this section, Figures 3 and 4 are presented systems for the LIS over Rician fading channel.We set as K=1 dB and K=3 dB for Figures 3 and 4, respectively. Binary phase shift keying (BPSK) modulation is used as the modulation type. From these results, it is observed that as the K factor increases, a lower BER is achieved. BPSK modulation is used as the modulation type. With the doubling of N value, an improvement of approximately 8 dB is observed in SNR values.

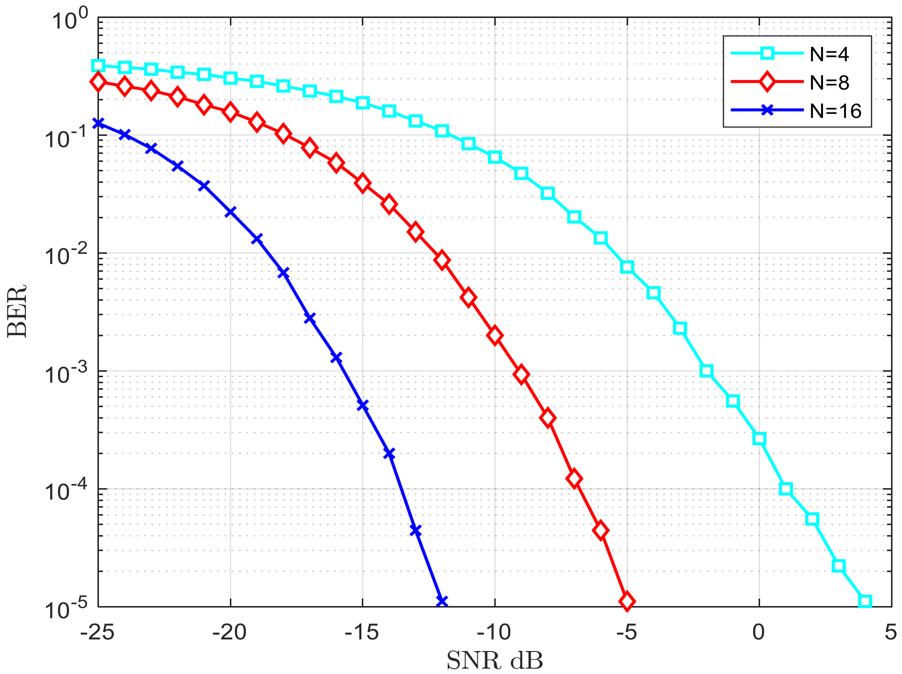


Figure 3. LIS BER analysis for the LIS AP over Rician fading channels (K=1 dB)

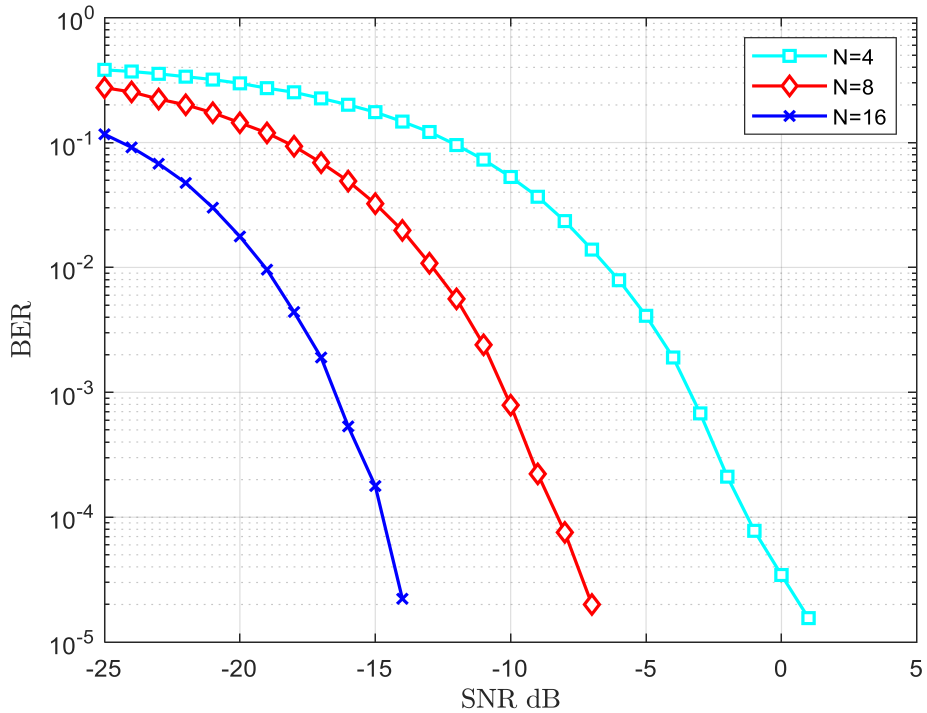


Figure 4. LIS BER analysis for the LIS AP over Rician fading channels (K=3 dB)

The symbol error rate (SER) analysis using different *M* (signal order) values over the Rician channel is shown in Figure 5. *K* values are taken as 1 dB. *M* values are taken by taking 2 and 4. *N* value is taken as 4. LIS-AP system has better error performance than LIS-DH system, and LIS-AP system is less affected than LIS-DH system by the change of *M*. It is observed that the use of the LIS AP system provides approximately 1 dB improvement compared to the LIS DH system.

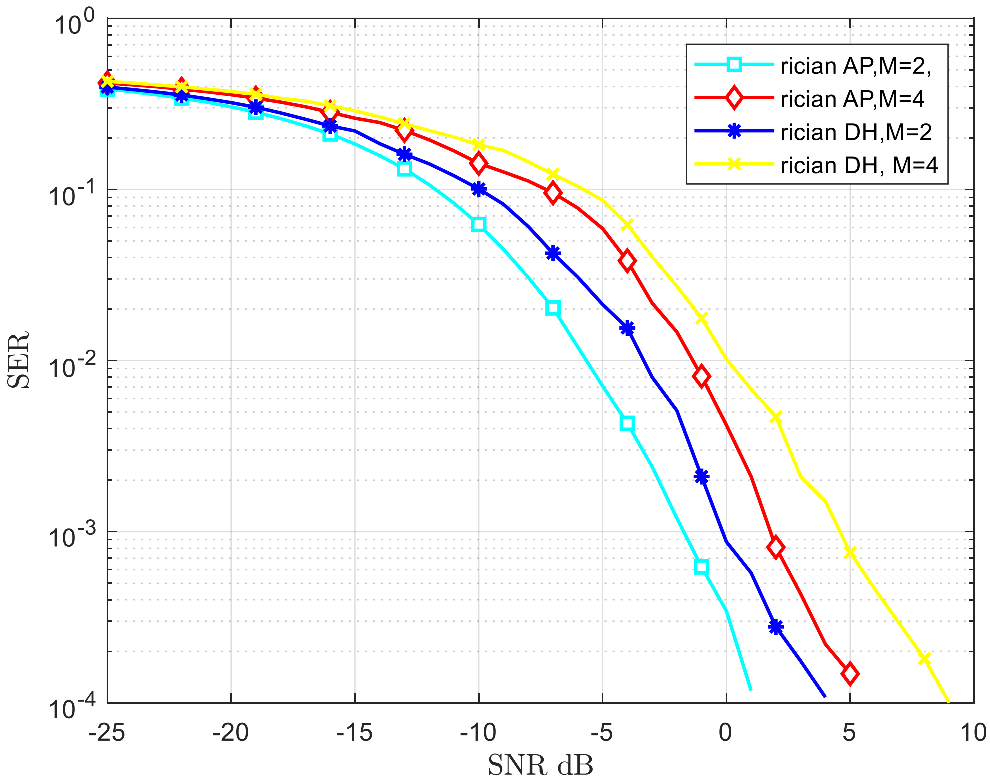


Figure 5. LIS SER analysis , different M values

AP and DH systems performance analyzes are in compared Figure 6. While PSK modulation is used in the AP system, QAM modulation is used in the DH system. When the results are examined, the AP system provides more reliable communication over the Rician channel and it is observed that the Access Point system has a better error performance than the DH system. When the results are compared the N values in the same number, it can be seen that the LIS AP system provided almost 3 dB improvement compared to the LIS DH system.

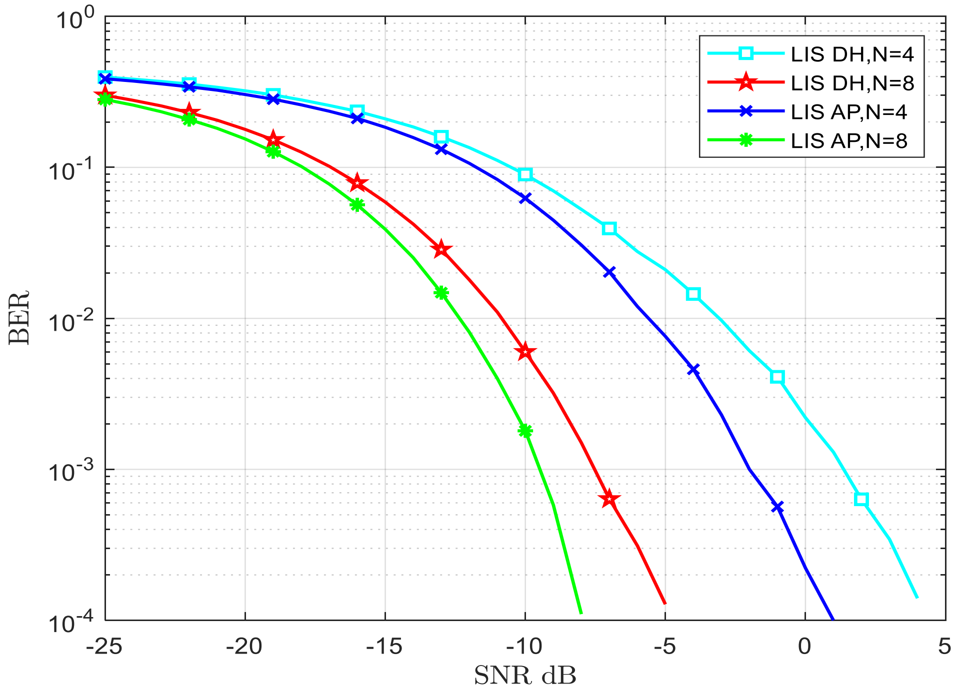


Figure 6. BER comparison for LIS-AP and LIS-DH systems

BER performance analysis for the considered system model over the Weibull channel is discussed in Figure 7. BPSK modulation is used as the modulation type. The Weibull fading parameter and scaling parameter are 2. As seen in Figure 7, it is understood that the BER improves with the increase of the *N* value as expected. *M* values are taken as 2. With the doubling of *N* value, an improvement of approximately 8 dB is observed in SNR values.

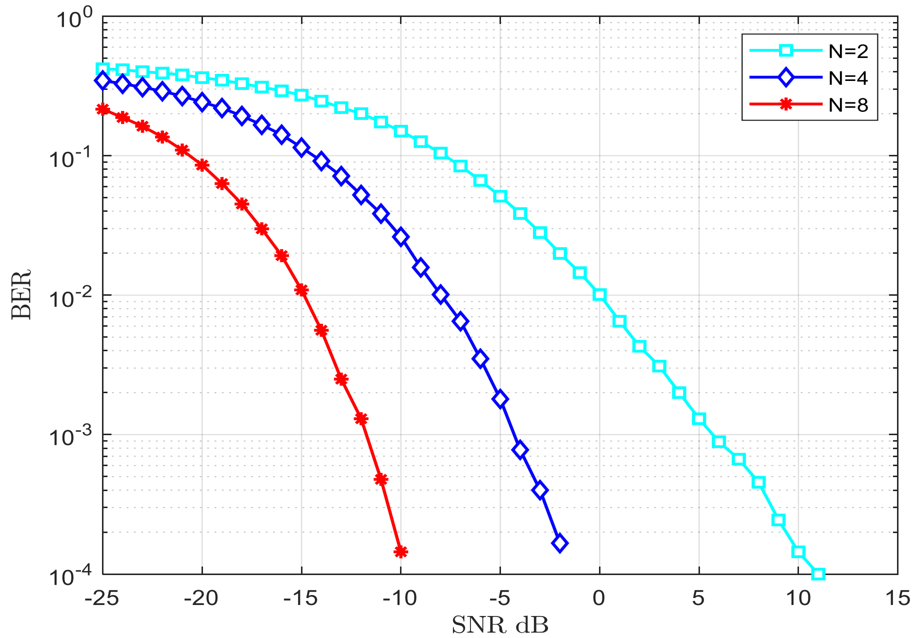


Figure 7. Weibull BER analysis for fading and scaling parameter are taken as 2.

BER performance analysis for the considered system model over the Weibull channel is discussed in Figure 8. In Figure 8 the fading parameter and scaling parameter are 4. It can be seen that an improvement is observed in the error performance, with the increase in parameter values. With the doubling of the fading and scaling parameters, an improvement of roughly 4 dB is observed. *M* values are taken as 2.

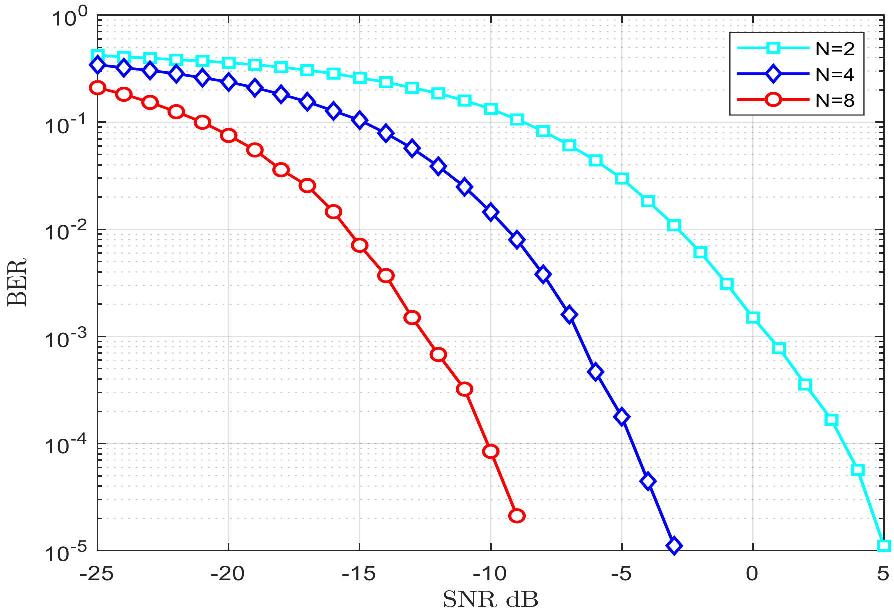


Figure 8. Weibull BER analysis for fading and scaling parameter are taken as 4.

The symbol error rate (SER) analysis using different *M* (signal order) values over the Weibull channel is shown in Figure 9. *M* values are taken by taking 2 and 4. *N* value is taken as 2. It is observed that the LIS DH system is more successful with a low SNR value, but the LIS AP system is more successful as it passes to a high SNR value. Further, It is observed that the use of the LIS AP system provides approximately 12 dB improvement compared to the LIS DH system.

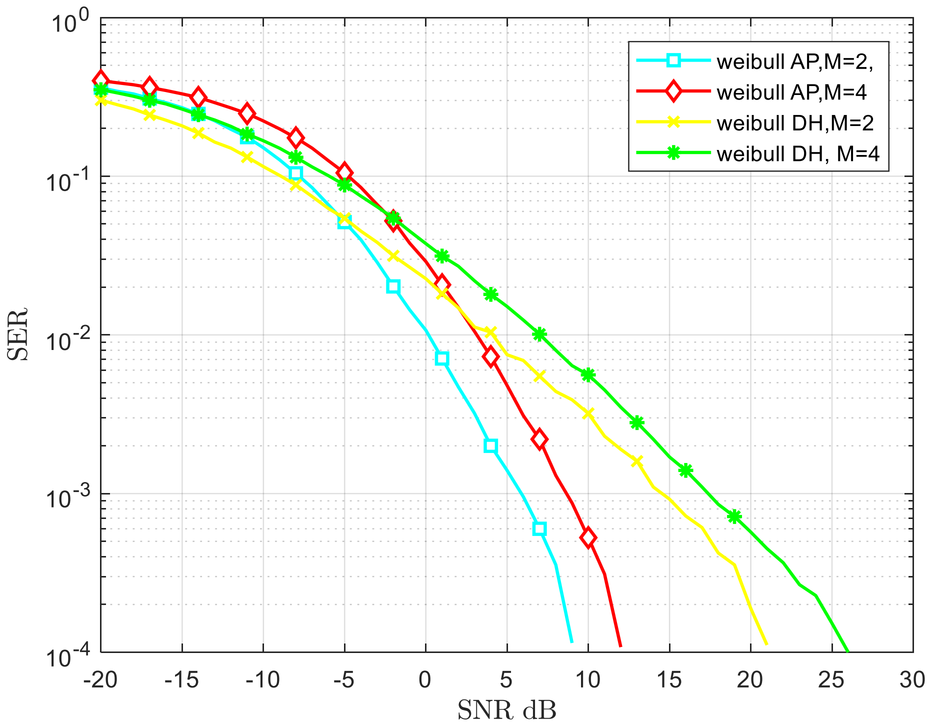


Figure 9. Weibull SER analysis, different M values

4. Discussion and Conclusion

In this paper, the error performance of the LIS systems has been analyzed through computer simulations in different fading channels. It can be understood that, there is an improvement in the error performance ratio with the increase of the fading factor for Rician channel. Further, when LIS AP and LIS DH systems were compared with different M values, it was observed that the LIS AP system was more successful. It has been observed that the change of the M value affects the LIS DH system more than LIS AP system. It is also observed that the LIS itself is simple transceiver AP system, where an unmodulated carrier is reflected by the LIS, therefore the AP system over the Rician channel has better performance than the DH system. For the Weibull channel, it is observed that with the increase of the fading and scaling parameter, the error performance improves. LIS AP and LIS DH systems were compared for different M values over the Weibull channel. The LIS AP system has also been found to be more successful in the Weibull channel on high SNR values. With the widespread use of the LIS system, it has been understood that the demand for MIMO systems is eliminated. To contribute to future research, LIS provides better performance with the increase in the number of reflective element and we have stated that this is a promising research topic for data transfer in wireless communication beyond MIMO.

References

[1] R. Mesleh and A. Alhassi, Space Modulation Techniques. New Jersey: John Wiley & Sons, ch. 1, pp. 1-2, 2018.

[2] E. Basar, “Transmission Through Large Intelligent Surfaces: A New Frontier in Wireless Communications” 2019 European Conference on Networks and Communications (EuCNC),ArXiv:1902.08463,Apr.2019.

[3] C. Huang, A. Zappone, G. C. Alexandropoulos, M. Debbah, and C. Yuen, "Reconfigurable intelligent surfaces for energy efficiency in wireless communication," IEEE Transactions on Wireless Communications, vol. 18, no. 8, pp. 4157–4170, August 2019.

[4] D. Dardari, “Communication with large intelligent surfaces: Fundamental limits and models,” CoRR, vol. abs/1912.01719, 2019.

[5] S. Hu, F. Rusek, and O. Edfors, "Beyond Massive MIMO: The Potential of Data transmission with Large Intelligent Surfaces," IEEE Transactions Signal Process., vol. 66, no. 10, pp. 2746-2758, May 15, 2018.

[6] J. Yuan, H. Q. Ngo, and M. Matthaiou, “Large intelligent surface (LIS)-based communications: New features and system layouts,” in Proc. IEEE, July 27, 2020

[7] V. C. Thirumavalavan and T. S. Jayaraman, “BER analysis of reconfigurable intelligent surface assisted downlink power domain NOMA system,” in proc. IEEE International Conference on Communication Systems & Networks (COMSNETS), Jan. 2020, pp. 519–522.

[8] R. Alghamdi et al., “Intelligent surfaces for 6G wireless networks: A survey of optimization and performance analysis techniques,” arXiv preprint arXiv:2006.06541, 2020.

[9] F. Arslan, İ. Develi, “Kablosuz Haberleşme İçin Geniş Akıllı Yüzeylerin Kullanımının İncelenmesi”, 4th Engineers of Future International Student Symposium (EFIS), vol.4, pp.144, May 2020.

[10] C. Liaskos, S. Nie, A. Tsioliaridou, A. Pitsillides, S. Ioannidis, and I. Akyildiz, “A new wireless communication paradigm through software controlled metasurfaces,” IEEE Communications Magazine, vol. 56, no. 9, pp. 162– 169, Sept. 2018

[11] C. Huang, G.C., Alexandropoulos, A. Zappone, M. Debbah., C. Yuen, “Energy Efficient Multi-User MISO Communication using Low Resolution Large Intelligent Surfaces”, IEEE Globecom Workshops (GC Wkshps), pp.1-6, 14 Sep 2018.

[12] L. Subrt and P. Pechac, “Controlling propagation environments using intelligent walls,” in Proc. 2012 6th European Conference on Antennas and Propagation (EUCAP), Prague, Czech Republic, Mar. 2012, pp. 1–5.

[13] E. Basar, M. Di Renzo, J. De Rosny, M. Debbah, M. Alouini, and R. Zhang, “Wireless communications through reconfigurable intelligent surfaces,” IEEE Access, vol. 7, pp. 116753-116773, Aug. 2019.

[14] Q.-U.-A. Nadeem, A. Kammoun, A. Chaaban, M. Debbah, and M.-S. Alouini, “Asymptotic max-min SINR analysis of reconfigurable intelligent surface assisted MISO systems,” IEEE Transactions Wireless Commun., 2020.

[15] M. Jung, W. Saad, "Performance Analysis of Large Intelligence Surfaces (LISs): Asymptotic Data Rate and Channel Hardening Effects", IEEE Transactions on Wireless Communications, vol.19, pp.2052-2065, March 2020.

[16] H. Hashemi, "The indoor radio propagation channel", Proceedings of the IEEE, vol.81, pp.943-968, July 1993.

[17] Simon, M. K., Alouini, M-S., 2005. Digital Communication over Fading Channels. John Wiley & Sons, New Jersey, 900 pp.

[18] J. Cheng, C. Tellambura, N.C. Beaulieu, "Performance of digital linear modulations on Weibull slow-fading channels", IEEE Transactions on Communications, vol.52, pp.1265-1268, August 2004.