Hybrid RF-FSO System Cascaded with UWOC Link

Sanya Anees, Smriti Rekha Baruah, Pallab Sarma

Abstract - This work presents outage analysis of a hybrid communication system, where radio frequency (RF) and free space optical (FSO) communication links transmit in parallel to the then cascaded underwater wireless optical communication (UWOC) link forming a RF/FSO-UWOC cooperative system. Optical wireless communication (OWC) is being used as a viable communication technology by researchers due to its advantages such as fast speed, cost effectiveness, and highly secure transmission. The proposed architecture connects the terrestrial and the underwater regions to form an end-to-end cooperative system. This hybrid RF/FSO back-haul link makes the system more reliable as the optical link is highly susceptible to weather conditions. The channel models considered are Nakagami-m distributed fading, Double Generalized Gamma (DGG) distributed atmospheric turbulence along with Rayleigh distributed misalignment losses and mixture of Exponential Generalized Gamma (EGG) distributed oceanic turbulence for RF, FSO, and UWOC links, respectively. Results show that outage performance is severely affected due to RF fading, DGG distributed irradiance, air bubble concentration, temperature gradient, and saltiness of water source.

Index Terms-Double Generalized Gamma, Decode-and-forward, free space optical, optical wireless communication, radio-frequency, Nakagami-m distribution, underwater optical communication.

I. INTRODUCTION

Terrestrial optical wireless communication (OWC), in general called free space optical (FSO) communication has various assets over other contemporary technologies. It provides fast speed information transfer, immunity to electromagnetic interference, power efficiency, cost effectiveness, and license-free spectrum for communication [1] - [3]. But FSO link's performance gets hampered because of weather conditions, irradiance, and misalignment losses. Hybrid RF and FSO system performs simultaneous transmissions, where same information is transmitted in parallel through both the links, relay based FSO communication system or MIMO (multiple-input-multiple-output) FSO systems are possible solutions for making OWC systems reliable and better performing. The performance analysis of asymmetric cascaded RF-FSO cooperative system using amplifying-and-forwarding (AF) or decoding- and-forwarding (DF) schemes by the relay present between source and destination are studied in [6], [9], respectively.

Revised Manuscript Received on August 05, 2019.
Sanya Anees, Department of Electronics and Communication Engineering, Indian Institute of Information Technology Guwahati, Assam, India.
Smriti Rekha Baruah, Department of Electronics and Communication Engineering, Indian Institute of Information Technology Guwahati, Assam, India.
Pallab Sarmah, Department of Electronics and Communication Engineering, Indian Institute of Information Technology Guwahati, Assam, India.

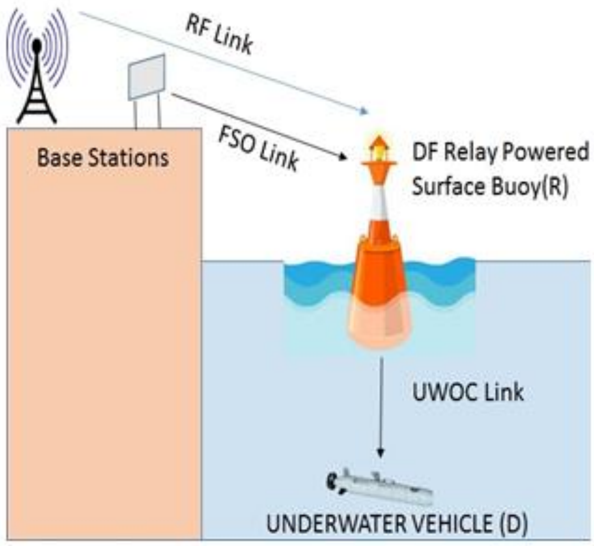

Fig.1. Hybrid RF/FSO system model cascaded with UWOC link using DF relay.

Similarly, underwater optical communication (UWOC) has been studied for deep-sea explorations for oil, monitoring of climate change, disaster management, underwater supervision, [7], [8] so as to be used an alternative to underwater acoustic communication providing high data rate and high security. Optical signals transmitted using UWOC links get degraded by scattering of light, absorption of photons, and underwater optical turbulence (UOT) [10]. In [11], bit-error-rate (BER) analysis of an UWOC link is carried out for basic on-off keying (OOK) modulation scheme and for studying the paths of photons, Monte Carlo simulation method is used. The performance for MIMO-UWOC links, where optical signals are amplified before transmission and space-time diversity used for transmission is presented in [12]. Both FSO and UWOC system can use any of the digital modulation technique using subcarrier intensity modulation (SIM). All the previously discussed UWOC systems modeled the UOT using Log-Normal distribution, as same distribution is used to characterize weak-to-moderate atmospheric scintillations in FSO systems. But [14] presents a new model using mixture of Exponential distribution and Generalized Gamma distribution (EGG) for modeling UOT. For this characterization, impact of thermal fluctuations, air bubble concentration, and saltiness or brininess of the underwater are taken into consideration. Using this EGG model for the UWOC link, BER performance for cascaded RF and UWOC system are studied in [15], in which the effects of fading and UOT on system's performance is investigated.

This work presents outage analysis of the DF based relayed communication system where a dual-hop RF-FSO system is cascaded with an UWOC link. Such RF/FSO-UWOC model can connect underwater transceivers with terrestrial core network as depicted in Fig.1. The RF link works in parallel with an FSO link for hybrid system. The source-relay back-haul link consists of radio and optical atmospheric links which experience Nakagami-*m* distributed fading, Double Generalized Gamma (DGG) distributed scintillations, respectively, followed by relay-destination UWOC link, which is characterized using EGG distributed UOT. This analysis is done by deriving analytical expressions for outage probability of the proposed system using statistical properties of the end-to-end SNR of the proposed system. The expressions are obtained in terms of Meijer-G function, which is in-built in softwares like MATLAB and MATHEMATICA. After analytical calculations, outage analysis is performed for either direct detection or heterodyne detection schemes for atmospheric fading condition parameters, underwater optical turbulence (UOT), brininess, temperature gradient, and bubble level concentration of the water source.

II. SYSTEM MODEL

This section presents a hybrid RF/FSO system cascaded with UWOC link using a DF Relay (R) placed at surface buoy on the water surface. Hybrid RF/FSO link connects terrestrial source (S) to R located at the surface of water source. The relay decodes the received signal and then re-encodes it to transmit it to the underwater vehicle using UWOC link at destination (D). The radio link, terrestrial optical link, and underwater optical link are characterized by Nakagami-*m* distributed fading, DGG distributed scintillations and misalignment losses, and EGG distributed irradiance, respectively. The signals from the hybrid RF/FSO system are analyzed at R using selection combining technique (SC), where the signal having higher SNR is selected. In DF relay at the surface buoy, the obtained signal is first decoded, then re-encoded and then converted into its optical equivalent using SIM scheme. Converted optical signal at R is then transmitted to the destination using UWOC link.

RF link has SNR expressed as $\gamma_{rf} = |h_1|^2\bar{\gamma}_{rf}$, in which $\bar{\gamma}_{rf} = E_1/\sigma^2$ denotes average SNR for the considered channel and E1 denotes the transmit signal power. Instantaneous SNR for terrestrial optical link is expressed as $\gamma_{fso} = I_{fso}^2\mu_{fso}$, where average optical SNR is $\bar{\gamma}_{fso} = \frac{E[I^f]}{E[I]^f}\mu_{fso}$, where 'p' denotes detection technique, which taken as 1 for heterodyne detection and 2 for direct detection. Average electrical SNR which is the average SNR of the electrical signal produced by the photo detector is given by $\mu_{fso} = (\eta E[I])^f/\sigma_d^2$. For analyzing multiple signals from hybrid links, selection combining (SC) technique is used. In this technique, the link whose received SNR is maximum is selected. The instantaneous SNR for the first hop can be written as

$$\gamma_r = \max\,(\gamma_{rf}, \gamma_{fso}) \tag{1}$$

III. CHANNEL MODEL

RF link, the FSO link, and the UWOC link channel models considered in the proposed system are discussed in this section.

A. RF Link

If the fading of RF link is taken as Nakagami-m distribution, the SNR of the link will be Gamma distributed whose PDF can be written as [5]

$$f_{\gamma_{rf}}(\gamma) = \frac{\gamma^{m-1}m^m}{\bar{\gamma}_{rf}^m\,\Gamma(m)}\,exp\left(-\frac{m\,\gamma}{\bar{\gamma}_{rf}}\right), \tag{2}$$

Where, *m* represents the degree of fading in Nakagami-*m* distribution. The CDF of the SNR of the radio link is given by [5]

$$F_{\gamma_{rf}}(\gamma) = \frac{1}{\Gamma(m)}\gamma\left(m, \frac{m,\gamma}{\bar{\gamma}_{rf}}\right) \tag{3}$$

where $\gamma(a, x)$ and $\Gamma(a)$ represent incomplete Gamma function and Gamma function, respectively .

B. FSO Link

FSO link characterized by atmospheric perturbations and misalignment losses which is modeled using DGG fading and Rayleigh distributed misalignment losses. The PDF can be given by [16]

$$f_{\gamma_{fso}}(\gamma) = \frac{A_1}{f\gamma}G_{1,\lambda+\sigma+1}^{\lambda+\sigma+1,0}\left(A_2h^{\alpha_2\lambda}\left(\frac{\gamma}{\mu_{fso}}\right)^{\frac{\alpha_2\lambda}{f}}\middle|\begin{matrix}\breve{k}_2\\ \breve{k}_1\end{matrix}\right) \tag{4}$$

where $A_1 = \frac{\epsilon^2\sigma^{\beta_1-0.5}\lambda^{\beta_2-0.5}(2\pi)^{1-\frac{(\lambda+\sigma)}{2}}}{\Gamma(\beta_1)\Gamma(\beta_2)}, A_2 = \frac{\beta_1^{\sigma},\beta_2^{\lambda}}{\lambda^{\lambda}\sigma^{\sigma}\Omega_1^{\sigma}\Omega^{\lambda}}$, in which $\frac{\lambda}{\sigma} = \frac{\alpha_1}{\alpha_2}$, $\widetilde{k}_1 = \frac{\epsilon^2}{\alpha_2\lambda}, \Delta(\lambda\colon\beta_1), \Delta(\sigma\colon\beta_2\,), \tilde{k}_2 = \frac{\alpha_2\lambda+\epsilon^2}{\alpha_2+\lambda}$, and $h = \frac{A_1+B_1}{(1+\epsilon^2)A_2^{\frac{1}{\alpha_2\lambda}}}, B_1 = \prod_{i=1}^{\sigma+\lambda}\Gamma(\frac{1}{\alpha_2\lambda} + \tilde{k}_{0,i})\,, \tilde{k}_{u,v}$ is

$$F_{\gamma_{fso}}(\gamma) = \frac{}{\Gamma(a)\Gamma(b)} \times\; G_{f+1,u+1}^{u,1}\left(c\left(\frac{\gamma}{\mu_{fso}}\right)^{\alpha_2\lambda}\middle|\begin{matrix}1, k_3\\ k_4, 0\end{matrix}\right) \tag{5}$$

in which $u = f(\lambda + \sigma + 1)$, $k_3 = \Delta(f\colon k_2), k_4 = \Delta(f\colon k_1), \quad and\ c = \left(\frac{A_2h^{\sigma_2\lambda}}{f^{\lambda+\sigma}}\right)^f$.

C. UWOC Link

The UWOC link is characterized by UOT which is modeled by EGG distribution written as [15]

$$f_{\gamma_d}(\gamma) = \frac{\omega}{f\gamma}G_{0,1}^{1,0}\left(\frac{1}{\nu}\left(\frac{\gamma}{\mu_{uwoc}}\right)^{\frac{1}{f}}\middle|\begin{matrix}-\\ 1\end{matrix}\right)\frac{c(1-\omega)}{f\gamma\Gamma(a)}\,G_{0,1}^{1,0}\left(\frac{1}{b^c}\left(\frac{\gamma}{\mu_{uwoc}}\right)^{\frac{c}{f}}\middle|\begin{matrix}-\\ a\end{matrix}\right) \tag{6}$$

In (6), ω represents the weight of the each distributions in the mixture distribution, such that it value ranges from 0 to 1. Other parameters line a, b, c denote fading level in Generalized Gamma distribution parameters and ν denotes Exponential distribution fading level. If c is set as 1, then the mixture PDF gets simplified to Exponential

Gamma (EG) distribution which models brininess and bubble concentration for constant temperature [14]. The SNR for UWOC link is given by $\gamma_d = \frac{(\eta_d I_d)^f}{\sigma_d^2}$. From instantaneous SNR, the average electrical SNR is computed as, $\mu_{uwoc} = (\eta E[I])^f/\sigma_d^2$. Although average electrical SNR is used for computation and analysis the average SNR of the received optical signal can also be calculated using $\bar{\gamma}_d = (\mu_{uwoc} E[I^f])/E[I]^f$. Distribution function for γ_d can be given by [15]

$$F_{\gamma_d}(\gamma) = \omega G_{1,2}^{1,1}\left(\frac{1}{\nu}\left(\frac{\gamma_d}{\mu_{uwoc}}\right)^{\frac{1}{f}} \middle| \begin{matrix} 1 \\ 1,0 \end{matrix}\right) + \frac{(1-\omega)}{\Gamma(a)} G_{1,2}^{1,1}\left(\frac{1}{b^c}\left(\frac{\gamma_d}{\mu_{uwoc}}\right)^{\frac{c}{f}} \middle| \begin{matrix} 1 \\ a,0 \end{matrix}\right) \quad (7)$$

IV. STATISTICAL PROPERTIES OF THE SYSTEM SNR

This section explains the statistical properties for instantaneous system SNR of hybrid RF/FSO communication system cascaded with UWOC link using a DF relay. From (1), for SC combining technique, CDF of the SNR for the first hop, i.e., hybrid RF/FSO link is given by

$$F_{\gamma_r} = F_{\gamma_{fso}} F_{\gamma_{rf}}. \quad (8)$$

Substituting (3) and (5) in (1), final expression of CDF can be given by

$$F_{\gamma_r}(\gamma) = A_1 G_{f+1,u+1}^{u,1}\left(c\left(\frac{\gamma}{\mu_{fso}}\right)^{\alpha_2\lambda} \middle| \begin{matrix} 1, k_3 \\ k_1, 0 \end{matrix}\right) \gamma\left(m, \frac{m,\ \gamma}{\bar{\gamma}_{rf}}\right), \quad (9)$$

where

$$A_1 = \frac{\epsilon^2 \sigma^{\beta_1 - 0.5} \lambda^{\beta_2 - 0.5} (2\pi)^{1-\frac{f(\lambda+\sigma)}{2}} f^{\beta_1+\beta_2-2}}{\alpha_2 \lambda \Gamma(\beta_1)\Gamma(\beta_2)}$$

Using (9), i.e., CDF of the SNR of the first hop, the end-to-end system SNR can be expressed as

$$\gamma_{eq} = \min(\gamma_r, \gamma_d) \quad (10)$$

Using (10), the CDF for system SNR is written as

$$F_{\gamma_{eq}} = 1 - \left(1 - F_{\gamma_r}\right)\left(1 - F_{\gamma_d}\right) \quad (11)$$

Substituting (9) and (7) in (11), CDF for SNR of the complete two-hop system S can be obtained as

TABLE I:
DGG Distribution Parameters representing variation in Strong and Moderate Irradiance System[16]

Turbulence	α₁	α₂	λ	β₁	β₂	σ	ω₂	ω₁
Strong	1.8621	1	17	0.5	1.8	9	1.5074	1
Moderate	2.1690	1	28	0.55	13	2.35	1.5793	1

$$F_{\gamma_{eq}} = 1 - \left[1 - A_1 G_{f+1,u+1}^{u,1}\left(c\left(\frac{\gamma}{\mu_{fso}}\right)^{\alpha_2\lambda} \middle| \begin{matrix} 1, k_3 \\ k_4, 0 \end{matrix}\right) \gamma\left(m, \frac{m,\ \gamma}{\bar{\gamma}_{rf}}\right)\right] \times \left[\omega G_{1,2}^{1,1}\left(\frac{1}{\nu}\left(\frac{\gamma}{\mu_{uwoc}}\right)^{\frac{1}{f}} \middle| \begin{matrix} 1 \\ 1,0 \end{matrix}\right) + \frac{1-\omega}{\Gamma(a)\Gamma} G_{1,2}^{1,1}\left(\frac{1}{b^c}\left(\frac{\gamma}{\mu_{uwoc}}\right)^{\frac{c}{f}} \middle| \begin{matrix} 1 \\ a, 0 \end{matrix}\right)\right] \quad (12)$$

From (11), the PDF of the entire system is given as

$$f_{\gamma_{eq}} = f_{\gamma_{rf}}(\gamma) F_{\gamma_{fso}}(\gamma) + f_{\gamma_{fso}}(\gamma) F_{\gamma_{rf}}(\gamma) + f_{\gamma_d}(\gamma) - F_{\gamma_{fso}}(\gamma) + f_{\gamma_{fso}}(\gamma) F_{\gamma_{rf}}(\gamma) + F_{\gamma_{rf}}(\gamma) F_{\gamma_{fso}}(\gamma) f_{\gamma_d}(\gamma) \quad (13)$$

By substituting (2), (3), (4), (5), (6), and (7) in (13), PDF of the full two-hop system SNR can be expressed.

V. PERFORMANCE ANALYSIS

Analytical expression for outage analysis of decode-and-forward based RF/FSO-UWOC cascaded system is presented. For a predetermined threshold value represented by γth, probability of outage can be written as

$$P_{out}(\gamma_{th}) = \Pr[\gamma_{eq} < \gamma_{th}] = F_{\gamma_{eq}}(\gamma_{th}), \quad (14)$$

Using (12), the P_{out} for γ_{th} can be given by

$$P_{out}(\gamma_{th}) = 1 - \left[1 - A_1 G_{f+1,u+1}^{u,1}\left(c\left(\frac{\gamma_{th}}{\mu_{fso}}\right)^{\alpha_2\lambda} \middle| \begin{matrix} 1, k_3 \\ k_4, 0 \end{matrix}\right) \gamma\left(m, \frac{m,\ \gamma_{th}}{\bar{\gamma}_{rf}}\right)\right] \times \left[\omega G_{1,2}^{1,1}\left(\frac{1}{\nu}\left(\frac{\gamma_{th}}{\mu_{uwoc}}\right)^{\frac{1}{f}} \middle| \begin{matrix} 1 \\ 1,0 \end{matrix}\right) + \frac{1-\omega}{\Gamma(a)\Gamma} G_{1,2}^{1,1}\left(\frac{1}{b^c}\left(\frac{\gamma_{th}}{\mu_{uwoc}}\right)^{\frac{c}{f}} \middle| \begin{matrix} 1 \\ a, 0 \end{matrix}\right)\right]. \quad (15)$$

TABLE II:
EGG Distribution Parameters for various Air Bubbles Concentration (L/MIN), Thermal Fluctuations (◦C/cm) and Irradiance Index σ^2_I for UWOC link [12]

BL	ΔT	σ_I^2	a	ω	b	λ	c
2.4	0.05	0.1484	1.4299	0.2130	1.1817	0.3291	17.1984
4.7	0.05	0.4201	1.0421	0.4589	1.57768	0.3449	35.9501
2.4	0.10	0.1659	0.6020	0.2108	1.2795	0.2694	21.1211
4.7	0.15	0.4769	0.3008	0.4539	1.7053	0.2744	54.1422

TABLE III:
EGG Distribution Parameters for various Air Bubbles Concentration and Different Salinity in UWOC Link [12]

Salinity	BL	σ_I^2	ω	λ	a	b	c
Salty	2.4	0.101	0.177	0.469	0.774	1.137	49.177
Fresh	2.4	0.109	0.195	0.527	3.729	1.072	30.321
Salty	4.7	0.131	0.206	0.395	0.531	1.215	35.737
Fresh	4.7	0.123	0.211	0.460	1.253	1.150	41.326

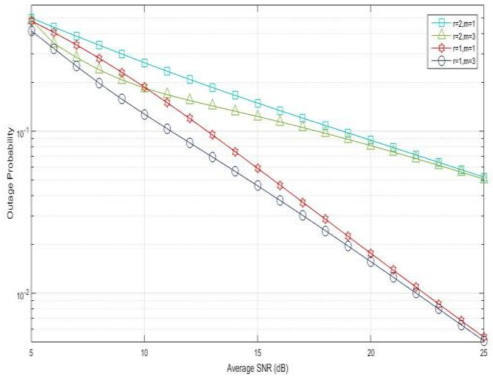

Fig. 2. Outage Probability versus SNR for proposed system using both detection techniques for various RF fading scenarios.

VI. RESULTS

Here numerical results of probability of outage for RF/FSOUWOC system are presented. Results are obtained for various channel parameters of FSO, RF, and UWOC links. Terrestrial optical link DGG distribution parameters taken for system simulation are enlisted in Table I.EGG distribution parameters for UWOC link are given in Table II and Table III.

Fig. 2. presents outage analysis for the considered DF based system, for different Nakagami-*m* fading parameter, *m* = 1 and 3 and for direct detection and heterodyne detection techniques. From the figure it is seen that stronger the fading, higher is the outage probability. Also the proposed system performs better where heterodyne detection is used as compared to when direct detection and heterodyne detection techniques.

From Fig. 3. outage analysis for different DGG distributed fading parameters for terrestrial optical link is presented. The misalignment loss is kept constant, i.e., ε = 1.2. Using parameters given in Table I, the graph shows that lower the irradiance, lower is the outage probability, thus resulting in better outage performance.

In Fig. 4. outage analysis is performed for various bubble level concentration and brininess. Using parameters in Table III we can see that for strong fading conditions, outage probability is very high and vice versa. This is due to

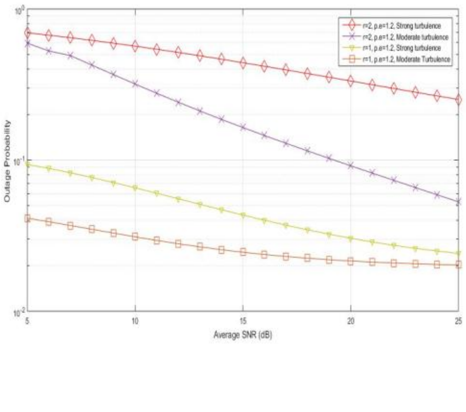

Fig.3. Outage analysis of proposed system for misalignment losses ε = 1.2 and different irradiance values.

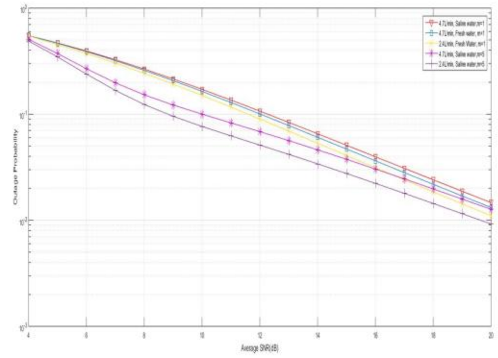

Fig.4. Outage Probability versus SNR for proposed system considering various bubble levels and saltiness.

the fact that increase in air bubbles concentration in water increases the UOT which in turn increases the outage probability. It can also be inferred from the figure that higher the brininess of the water source, higher will be the outage probability of the system. Fig.5 shows the outage probability under heterodyne detection techniques under varying temperature gradients and fading parameters listed in Table II. Figure shows that system provides lesser outage at lesser temperature gradients and vice versa.

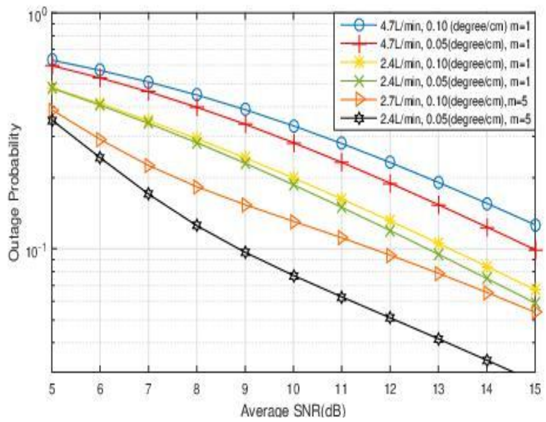

Fig. 5. Outage Probability of proposed system for different temperature gradient and fading.

VII. CONCLUSION

In this paper, hybrid RF/FSO-UWOC cascaded system is presented, using decoding and then forwarding relay, authors have got expressions of (i) statistical characteristics of ratio of signal to noise for the first hop, i.e., hybrid RF/FSO link (ii) statistical characteristics of ratio of signal to noise for complete system (iii) Outage probability. A detailed outage analysis for various channel parameters is performed, which shows that outage probability is severely affected from RF fading parameter, DGG irradiance parameters, and bubble level concentration, temperature gradient and brininess under water.

Retrieval Number J93300881019/2019©BEIESP
DOI: 10.35940/ijitee.J9330.0881019

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

REFERENCES

1. L. Andrews, R. Phillips, and C. Hopen, Laser Beam Scintillation with Applications. New York, USA: SPIE Press, 2001.

2. D. Kedar and S. Arnon, Urban optical wireless communication networks: The main challenges and possible solutions, *IEEE Commun. Mag*., vol. 42, no. 5, pp. S2S7, Jan. 2004.
3. M. A. Khalighi and M. Uysal, Survey on free space optical communication: A communication theory perspective, *IEEE Commun. Surveys & Tutorials*, vol. 16, no. 4, pp. 22312258, Fourth quarter 2014.
4. Mohammad Ali Amirabadi " Performance Analysis of a Novel Hybrid FSO/RF Communication System arXiv:1802.07160[eess.SP]
5. S. Anees and M. R. Bhatnagar, Performance of an amplify-and-forward dual-hop asymmetric RF-FSO communication system, *IEEE J. Opt. Commun. Netw*., vol. 7, no. 2, pp. 124135, Feb. 2015.
6. S. Anees and M. R. Bhatnagar, Performance evaluation of decode-andforward dual-hop asymmetric RF-FSO system, *IET Optoelectronics*, vol. 9, no. 5, pp. 232240, June 2015.
7. Hemani Kaushal and Georges Kaddoum, "Underwater Optical Wireless Communication," *IEEE Access*, April vol.4, pp. 1518-1547, 2016
8. Z. Zeng, H. Zhang,Y. Dong and J.Cheng, "A survey of underwater optical wireless Communication,"*IEEE Communications Surveys Tutorial*s, vol.19, no. 1, pp. 204-238, 2017
9. Mohammad Ali Amirabadi, "Performance Analysis of a Novel Hybrid FSO/RF Communication System,"arXiv:1802.07160 [eess.SP]
10. R. J Hill, "Optical propagation in turbulent water", *Journal of Optical Society of America*, vol. 68, no.8, pp 1067-1072, Aug. 1978
11. C. Gabriel, M. Ali Khalighi, Salah Bourennane, Pierre Leon and Vincent Rigaud, "Monte-Carlo-based channel characterization for underwater optical communication systems", IEEE/OSA *Journal of Optical Communications and Networking*, vol. 5, no.1, pp. 1-12, January 2013.
12. A. C. Boucouvalas, K. P. Peppas, K. Yiannopoulos and Z. Ghassemlooy, "Underwater Optical Wireless Communications With Optical Amplification and Spatial Diversity", *IEEE Photonics Technology Letters*, vol. 28, no. 22, November 15, 2016.
13. W. O. Popoola and Z. Ghassemlooy,"Sub-Carrier Intensity Modulated Free-Space Optical Communications in irradiance", *Journal of Light Wave Technology*, vol. 27, no. 8, April 15, 2009
14. E. Zedini, H. M Oubei, A. Kammoun, M. Hamdi, B.S Ooi and M. S Alouini "Unified Statistical Channel Model for Turbulence-induced fading in underwater wireless optical communications systems", *IEEE Transactions on Communications*, 2017.
15. S. Anees and R. Deka, "On the Performance of DF Based Dual-Hop Mixed RF/UWOC System", *IEEE Vehicular Technology Conference*, 2019.
16. H. AlQuwaiee, I. S. Ansari and M.-S. Alouini, "On the Performance of Free space Optical Communication Systems over Double Generalised Gamma Channel", *IEEE Journal on Selected Area in Communications*, vol. 33, no.9, September, 2015.

AUTHORS PROFILE

Sanya Anees (M'16) received Masters (W/D) in Communication Engineering from the University of Manchester, U.K., in 2011 and received Ph.D. from the Indian Institute of Teaching Delhi, in 2016. Her research interests include optical wireless communications, MIMO systems, and cooperative communications. Currently, she is working as an Assistant Professor in the Department of Electronics and Communication Engineering, Indian Institute of Information Technology Guwahati, Assam, India. She is reviewer of IEEE Transactions on Communications, IEEE Transactions on Wireless Communications, IEEE Transactions on Aerospace and Electronic Systems, IEEE Access, IET Communications, and has reviewed various IEEE conference papers such as, ICC, Globecom, VTC, and WCNC. She has also served as TPC Member of IEEE NCC-2018, IEEE ICSC-2018, and IEEE CICT-2017. Recently she was awarded Early Career Research Award by SERB, DST. In her Graduation, she has been awarded University Gold medal-2010 for being University Topper in Electronics & Communication Engg. Branch, Shri Rawatpura Sarkar Gold medal-2010 for being University Topper amongst students from Electronics & Communication Engineering, Computer Science, and Information Technology, and Prof. S. T. Chakravati Gold medal-2010 for being University Topper amongst students from Electronics & Communication Engineering, Electrical Engineering, Mechanical Engineering, and Civil Engineering.

Smriti Rekha Baruah received Bachelor of Technology (Hons.) in Electronics and Communication Engineering from Assam Science and Technology University in 2017. Currently, she is pursuing her Masters of Technology from Indian Institute of Information Technology, Guwahati, India in the field of Communication and Signal Processing Engineering. Her topics of interest include Internet of Things (IoT), Biomedical Signal Processing, Underwater Optical Communication and Underwater Acoustic Communication.

Pallab Sarma received his Diploma and Bachelor of Technology from Central Institute of Technology, Kokrajhar and Assam Science and Technology University, in 2013 and 2017, respectively, in Electronics and Communication Engineering. Currently , he is pursuing Masters specialized in Communication and Signal Processing from Indian Institute of Information Technology, Guwahati, India. His research areas are Underwater Optical Communication, Internet of Things (IoT), Free-Space Optical Communication and Health-care Engineering.