International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 1468-1479 www.ijaem.net ISSN: 2395-5252

Simulation and Analysis of Point-to-Point RoF System

[1]Y. A. Sumaila [2]A. Liman, [3]A. Hassan B/Kudu, [4]Hauwa-Kulu Shuaib, [5]A. Abdulkadir, [6]A. B. Magaji, and [7]A. Masanawa

[1,2](Physics Department, Kano University of Science And Technology Wudil, P. M. B. 3244, Nigeria,
[3]Computer And Information Technology, Federal University, Dutse Nigeria,
[4] Physics Department, Nigerian Defense Academy Kaduna Nigeria,
[5,6,7] Physics Department, Umaru Musa Yar-adua University, Katsina Nigeria.

Date of Submission: 20-03-2023 Date of Acceptance: 30-03-2023

ABSTRACT
Wireless coverage of the end-user domain, either at the outdoors or indoors, has become an essential part of broadband communication networks especially now that the whole world is going digital and cashless transaction era is the norm. Unified communication requires that the broadband service is transported effectively wirelessly and everywhere. The objective is to make people more productive. People spend much time trying to communicate with others, either at work, in the market or at home. Transporting their communication signal quicker and efficiently is what matters. Radio over fibre (RoF) is a technology for transporting radio signals (3G, 4G, 5G, Wi-Fi and MiFi etc) and the transmission of cable television signals (CATV) to the radio frequency (RF) signals. Our study is aimed to improve the quality of the RoF not only at network level but also at link level. We found out that the result in this work can assist to improve the throughput performance in the realistic of Wi-Fi or broadband by using a commercially available software simulation technique. Simulation results using HERALD (HElp for RAdio Link Design) software are presented in this paper.

KEYWORDS;- Radio Over Fibre (RoF), RF, Broadband Communication, Unified Communication, 5G

Acknowledgement: The Authors would like to thank the Institution Based Research (**IBR**) Unit of the Tertiary Institution Trust Fund (**TETFund**) Nigeria, for sponsoring this work in whole at KUST Wudil, Nigeria. Thanks to the Luigio Morino for his tremendous achievement in developing the clever software utilized in this work.

I. INTRODUCTION

Radio over fibre (RoF) system is a form of an analogue optically modulated RF signals transmitted using an optical fibre from the central station (CS) to a base station (BS) or remote access units (RAUs), [1]. It is a technology of the future currently receiving serious attention due to its ability to provide simple antenna front ends, increased capacity, and wireless access coverage. RoF technique has been considered a cost effective and reliable solution for the distribution of the future wireless access networks by using optical fibre with vast transmission bandwidth capacity, [2], RoF link is used in remote antenna applications to distribute signals for smaller BS or remote sub-BS, [3-5].

New revolution in fifth-generation wireless system, called the (5G) is promising in enhancing the data transfer rate of mobile networks [1-2], this is in terms of its scalability, connectivity range, and the energy efficiency of the new network [4 & 6]. In 2021, in excess of 50 billion devices were assumed to be connected to the global IP network by 2020, [7].

Transport networks will be very important part for the development of 5G networks. It would be constructed using a set of existing technologies, radio-over-fiber (RoF) transmission [8-11] and millimeter wave (MMW) technologies [12-14]. Optical fibre-based wireless systems can, however, transport long distance with high fidelity but at a disadvantage of high cost on the uplink transmitters and needs a lot of optical fibres. Cost is the paramount issue for the wide deployment of this technology.

Typical optical fibre-based transmission system is shown in figure 1 below.

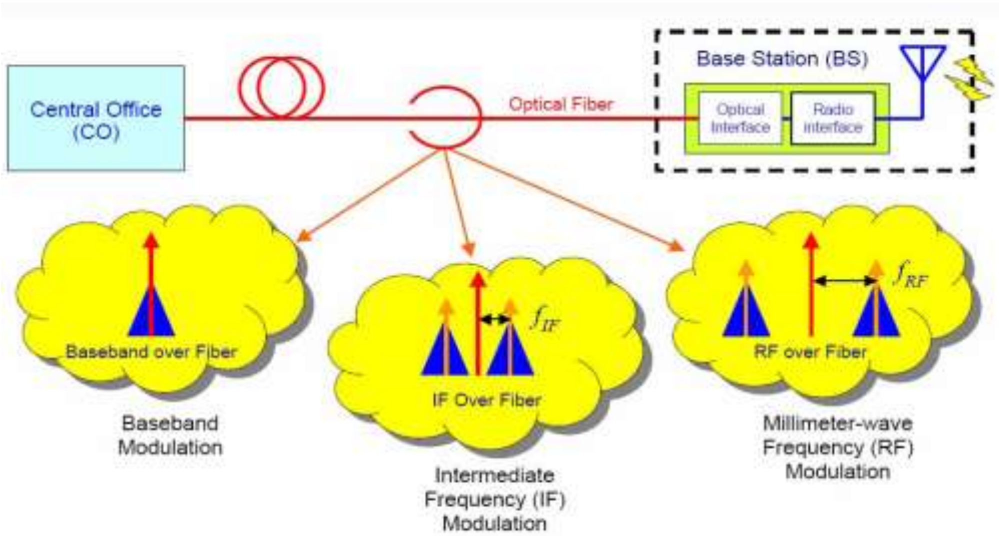


Figure 1: A typical optical fibre-based transmission system, [16].

A Point-to-Point radio-relay link enables communication between two fixed points, by means of radiowave transmission and reception. The link between two terminal radio sites may include a number of intermediate radio sites. The direct connection between two (terminal or intermediate) radio sites is usually referred as a "Radio Hop". A transmission Performance of Analog Radio-over-Fiber Fronthaul for 5G Mobile Networks was reported [2]. They investigated the effects of fiber transmission link like, dispersion, attenuation, launch power, transmission distance, number of aggregated channels, channel bandwidth, and type of modulation. They [2] also, have however, not taken into consideration any rain attenuation in their report. But this paper has considered the rain attenuation.

The demand to have broadband capacity wirelessly has put pressure on wireless communication system to increase both their transmission capacity as well as the coverage. High bandwidth signals over long distances encounter losses while the demand for the long distance transmission is ever increasing. Therefore, require a network on RoF technology as an immediate solution.

This paper presents analysis into the investigations for the transmission performance of poinit -to-point RoF-based for 5G mobile network. Results are presented for KUST Wudil, Kano Nigeria as the test Radio site.

II. MODEL DESCRIPTION

In this work, a typical RoF system is simulated and analyzed using HERALD Software by Luigio Moreno [18].

HERALD (HElp for RAdio Link Design) is a PC program for Windows that assists the radio engineer in the design of point-to-point (multi-hop) microwave links and networks, working in the frequency range from 0.4 to 58 GHz and can be extended to a far higher frequency range.

The HERALD design process is based on well-established design guidelines. Starting from basic hop configuration and link budget, reliable propagation models are applied to deal with the anomalous propagation events of rain, multipath, obstructions, and reflections. Close reference is made to recommendations of the ITU-R, the Radio branch of the International Telecommunications Union, formerly the CCIR.

User-defined antenna and radio equipment libraries allow us to select the items useful to configure the radio hop terminals.

The aim of this study is to analyse and Design a Radio over Fibre (RoF) System for Higher Speed Optical and Data Communication Interconnection Networks using commercial software (HERALD 3.0). A point-to-point radio over fibre architecture is deployed.

The Study Area

The Study Area is Wudil is located Latitude and longitude coordinates are: **11.794242, 8.839032**.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 1468-1479 www.ijaem.net ISSN: 2395-5252

Wudil is a small city in northern Nigeria, with the population close to 180,000 people. It is the capital city of a small district, Wudil district, and a small transportation knot near the Highway A237. Since the city is situated near Hadejia River, it is also an agricultural spot, with numerous small farms and cattle companies operating in the city. There is a large university in Wudil, the University of Science and Technology [18].

III. RESULT VIEW

The HERALD design process is based on well-established design guidelines. Starting from basic hop configuration and link budget, reliable propagation models are applied to deal with the anomalous propagation events of rain, multipath, obstructions, and reflections. Close reference is made to recommendations of the ITU-R, the Radio branch of the International Telecommunications Union, formerly the CCIR.

User-defined antenna and radio equipment libraries allow us to select the items useful to configure the radio hop terminals.

(a). Site and Hop Parameters

(i). Path Profile Report (Alpha-Beta)

Table 1 gives the data for the two particular radio sites, Alpha and Beta, chosen with geographical coordinates. The path profile is specified as a set of points (distance from first site, ground elevation above sea level, and obstruction above ground level if any). Table 2 shows the computed path profile and clearance analysis. The clearance is required to be free from any obstruction.

Table 1: RoF design parameters and characteristics values; Frequency 11GHz, Length: 34.820Km range, also applicable up to 60GHz.

RADIO SITES:	
ALPHA	**BETA**
Elevation : 381m	Elevation: 238 m
Antenna Height: 30.0m	Antenna Height: 5.0m

(ii). **Table 2:** Profile Point And Clearance Analysis

Distance(Km)	Elevation(m)	Obstacle(m)	Fresnel Radius(m)	K=Kstd=1.33		K=Kmin=0.71	
				Norm Clearance	Margin(m) (100F1%)	Norm Clearance	Margin(m) (0F1%)
0.031	381		0.9	32.41	28.9	32.35	29.7
0.124	382		1.8	15.33	26.3	15.21	27.9
0.310	375		2.9	11.70	31.0	11.51	33.3
0.403	375		3.3	10.08	29.9	9.87	32.5
0.589	374		4.0	8.30	29.0	8.04	31.9
0.868	370		4.8	7.30	30.3	6.98	33.6
0.961	370		5.0	6.82	29.4	6.49	32.8
1.333	363		5.9	6.59	33.0	6.20	36.6
1.426	363		6.1	6.27	32.2	5.87	35.9
1.612	359		6.5	6.34	34.6	5.92	38.3
1.705	359		6.7	6.08	33.8	5.64	37.5
2.078	351		7.3	6.30	38.7	5.82	42.5
2.171	351		7.5	6.09	37.9	5.60	41.7
2.357	349		7.7	5.96	38.4	5.45	42.2
2.450	347		7.9	6.03	39.6	5.51	43.4
2.543	347		8.0	5.85	38.9	5.32	42.7
2.729	345		8.3	5.76	39.4	5.21	43.2
3.287	337		9.0	5.77	43.0	5.18	46.7
3.380	337		9.1	5.64	42.3	5.04	46.0
3.566	336		9.3	5.48	41.9	4.87	45.5
4.031	327		9.9	5.81	47.4	5.16	50.8
4.124	327		10.0	5.69	46.7	5.03	50.1

4.217	328		10.1	5.48	45.0	4.81	48.4
4.682	321		10.5	5.62	48.6	4.93	51.8
4.868	318		10.7	5.70	50.2	5.00	53.4
5.054	318		10.9	5.50	48.9	4.79	52.0
5.426	311		11.2	5.66	53.2	5.03	56.2
5.519	311		11.3	5.67	52.6	4.93	55.5
5.705	309		11.4	5.67	53.3	4.92	56.1
5.798	310		11.5	5.50	51.6	4.74	54.4
5.984	305		11.6	5.76	55.3	5.00	58.1
6.170	305		11.8	5.59	54.0	4.82	56.7
6.624	304		11.8	5.60	54.4	4.82	57.0

(ii). **Hop Report**:
A radio hop is described in terms of;
a). Topographical data and terrain description :
b). Radio equipment, antennas and ancillary sub-systems installed at each radio site
c).Specific aspects on equipment installation and operation, like the Antenna positioning, Frequency used and Use of passive repeaters.
d). Climatic and environmental parameters.
Figure 2 below gives the configuration for the hop report between the 2 sites at the given coordinates.

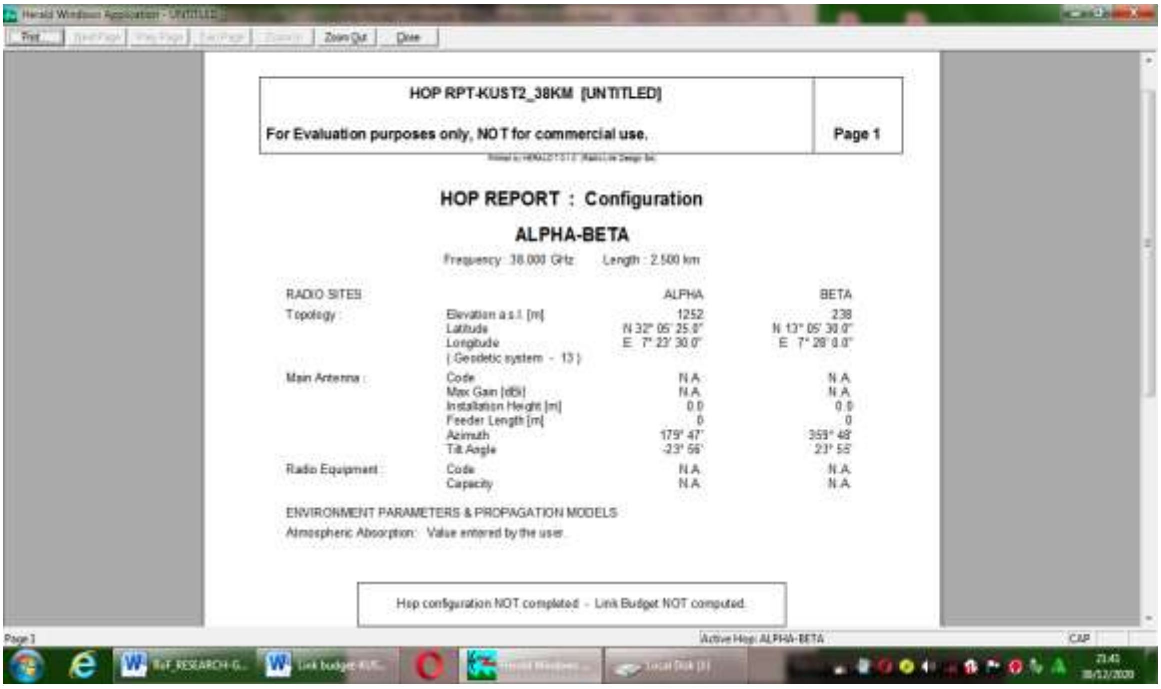


Figure 2: Hop configuration report for sites ALPHA (32’ 05’’N, 7’ 23’’E); BETA (13’ 05’’N, 7’ 28’’E) at 38GHz,2.5 Km.

(iii). Clearance Analysis: The path profile view is completed with a table below, fig. 3, where results on normalized clearance and margins are displayed; indication about compliance with clearance criteria and estimate of obstruction loss are all reported in the figure 3 .

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 1468-1479 www.ijaem.net ISSN: 2395-5252

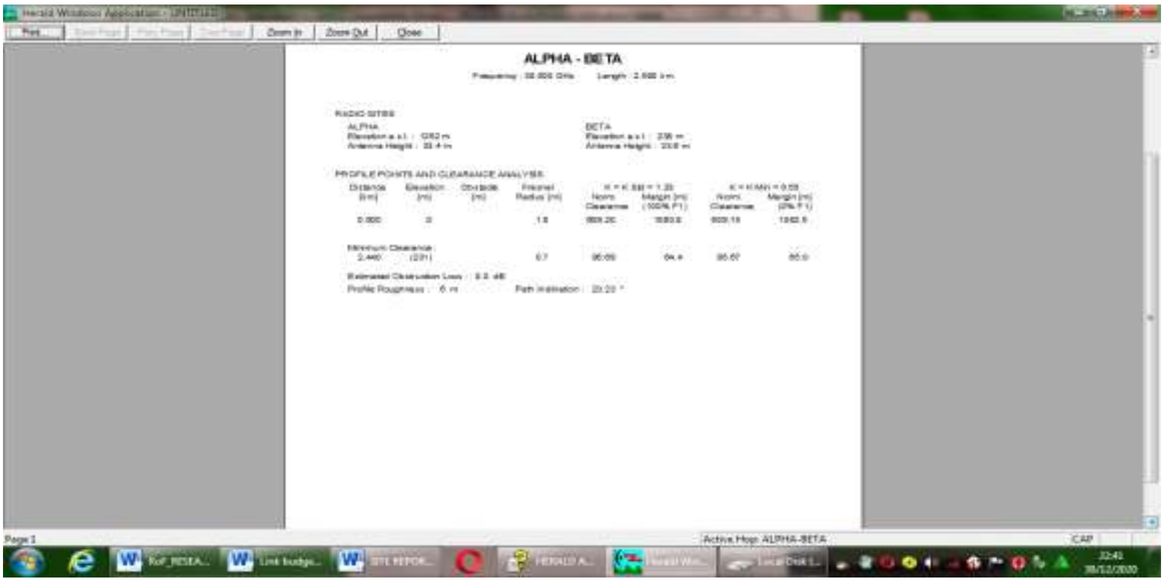


Figure 3: Path profile and clearance analysis, 38GHz, 2.5Km for radio sites ALPHA (32’ 05’’N, 7’ 23’’E); BETA (13’ 5’’N, 7’ 28’’E)

Figures 4 and 5 shows the Network report table and the site report for the radio sites.

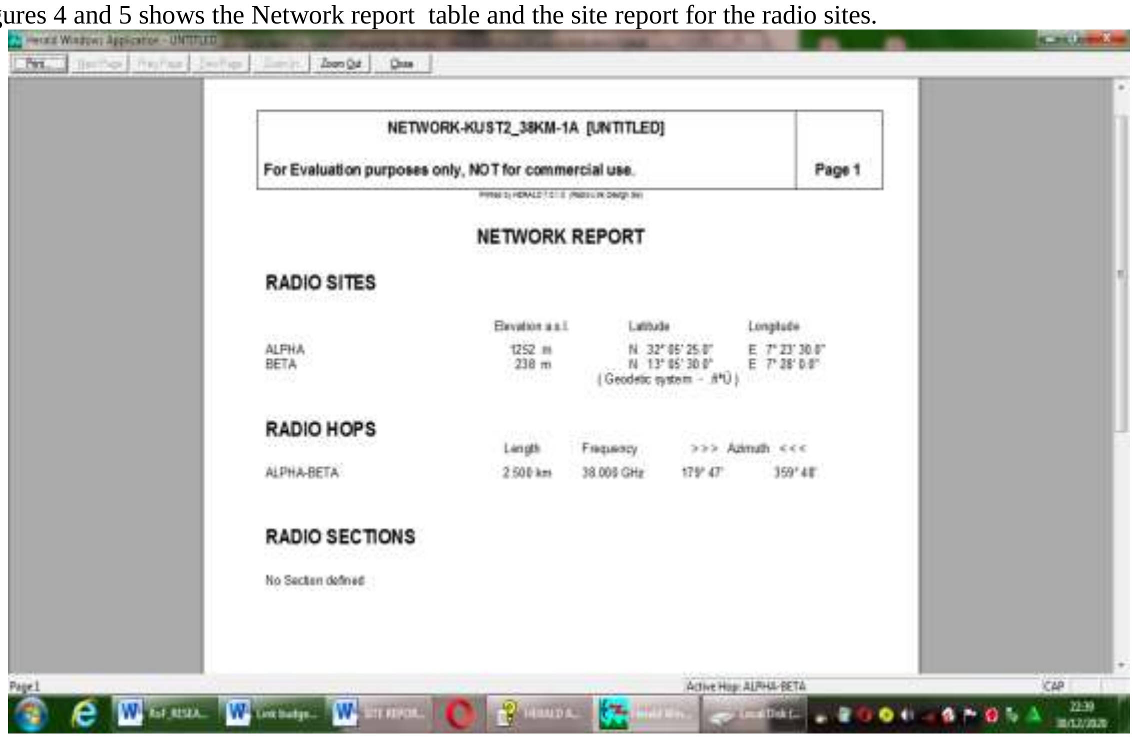


Figure 4: Network report for radio sites ALPHA (32’05’’,7’23’’); BETA (13’ 05’’N, 7’ 28’’E at 38GHz,2.5Km range.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 1468-1479 www.ijaem.net ISSN: 2395-5252

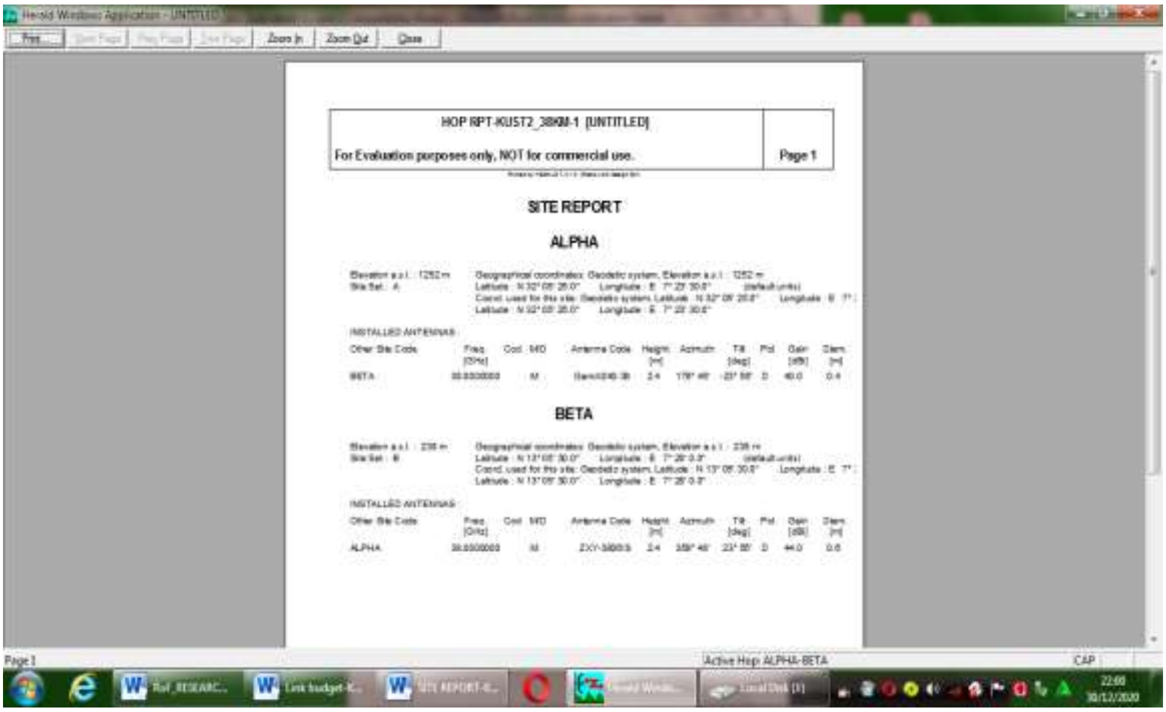


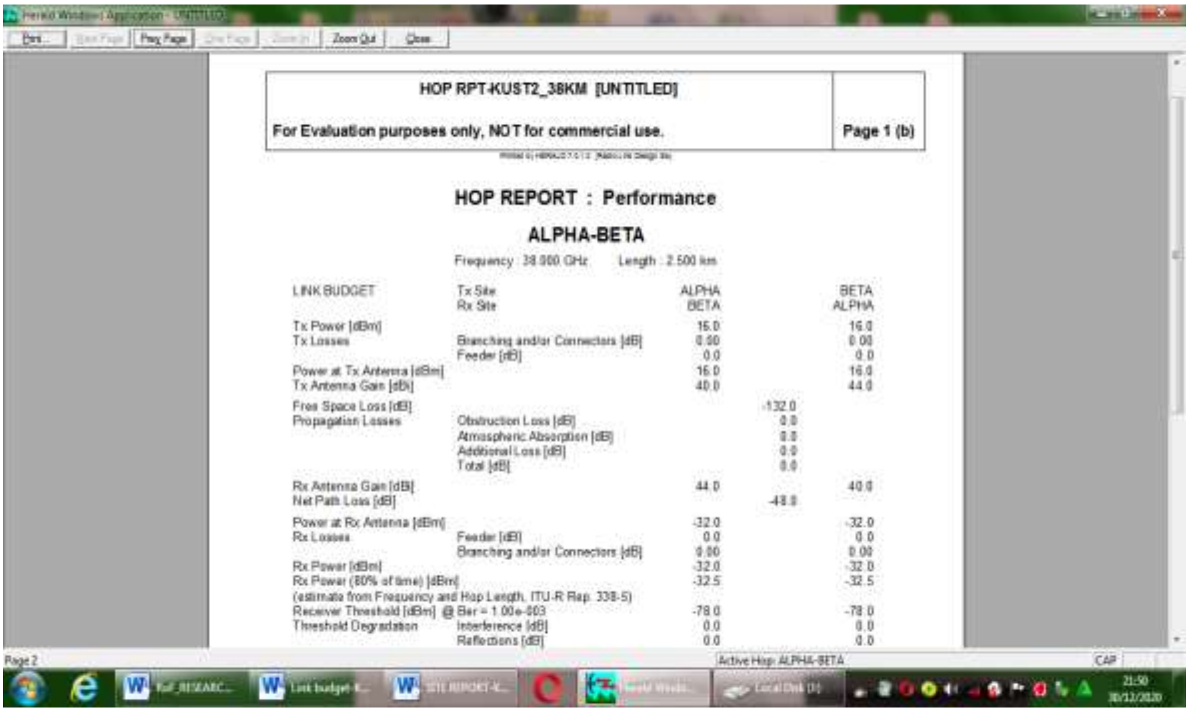
Figure 5: Site report for Geodetic system of ALPHA (32’ 05’’N,7’ 23’’E); BETA (13’ 05’’N, 7’ 28’’E

(**iv**). **Antenna radiation pattern:**Point-to-point radio hops usually make use of high-gain directive antennas, which offer several advantages:

a) both Transmission and Reception : the antenna gain is maximized in the desired direction.

b) Transmission : the emitted radio energy is focused toward the receiver, thus reducing the emission of interfering radio energy in other directions;

c) Reception: the receiver sensitivity to interfering signals coming from other directions is reduced.



International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 1468-1479 www.ijaem.net ISSN: 2395-5252

Figure 6; Hop performance report for ALPHA (32' 05''N, 7' 23''E); BETA (13' 05''N, 7' 28''E)

Figure 6 is the hop report performance for the chosen site and fig. 7 shows the corressponding link profile at 38GHz tranmitted for 2.5 Km without any reflection. Transmission with reflection signal curve is shown in fig. 8.

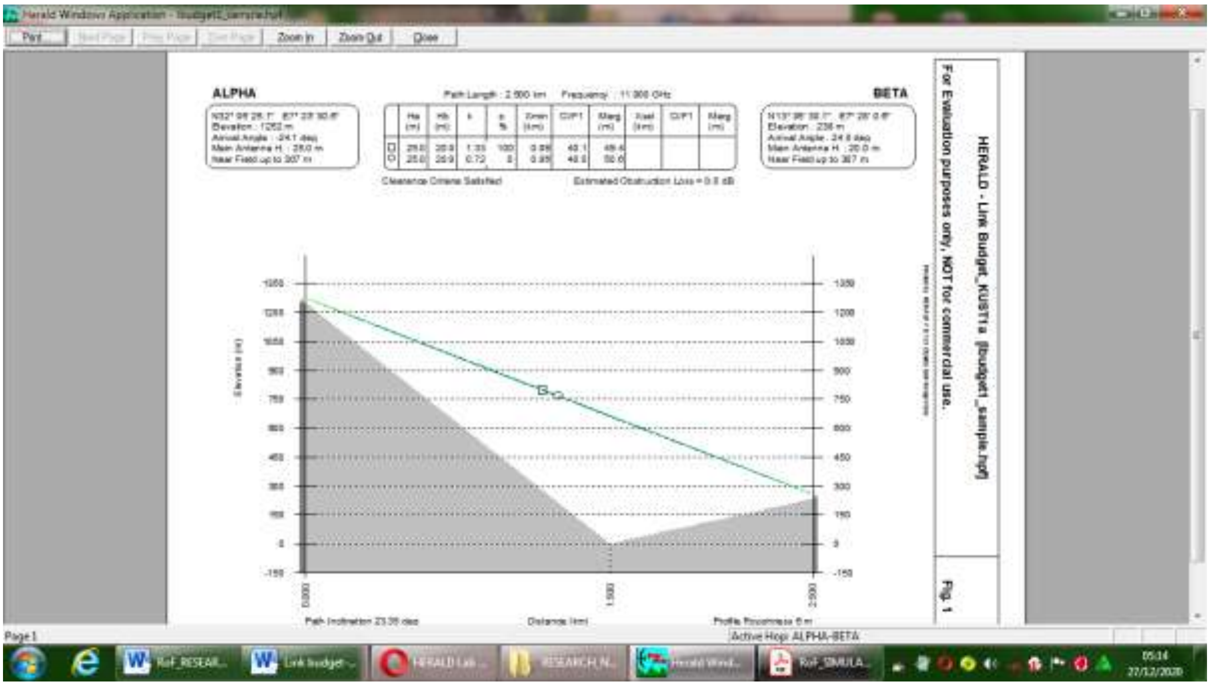


Figure 7: Path profile graph at 38GHz, 2.5Km without reflections; ALPHA (32' 05''N, 7' 23''E); BETA (13' 05''N, 7' 28''E).

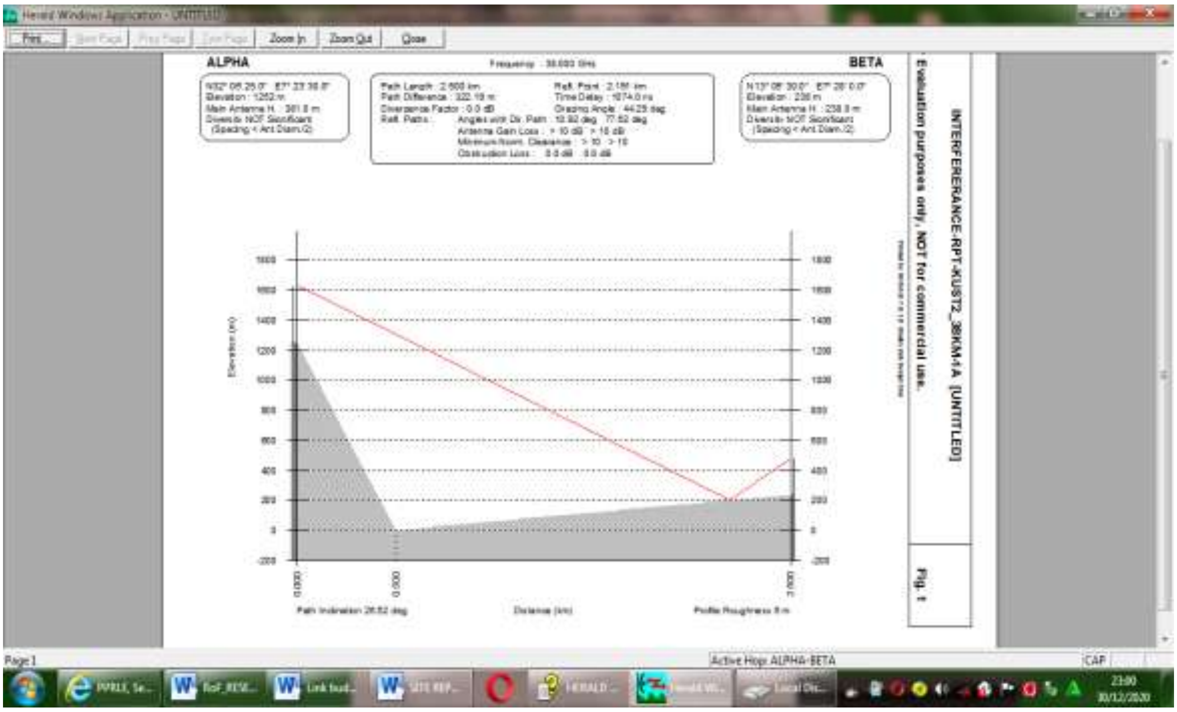


Figure 8: Path **with** reflections @ 38GHz, 2.5 Km, ALPHA (32' 05''N, 7' 23''E); BETA (13' 05''N, 7' 28''E).

The Simulation results for the rain availability/unavailability for the 2 radio site is as in fig. 9 below.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 1468-1479 www.ijaem.net ISSN: 2395-5252

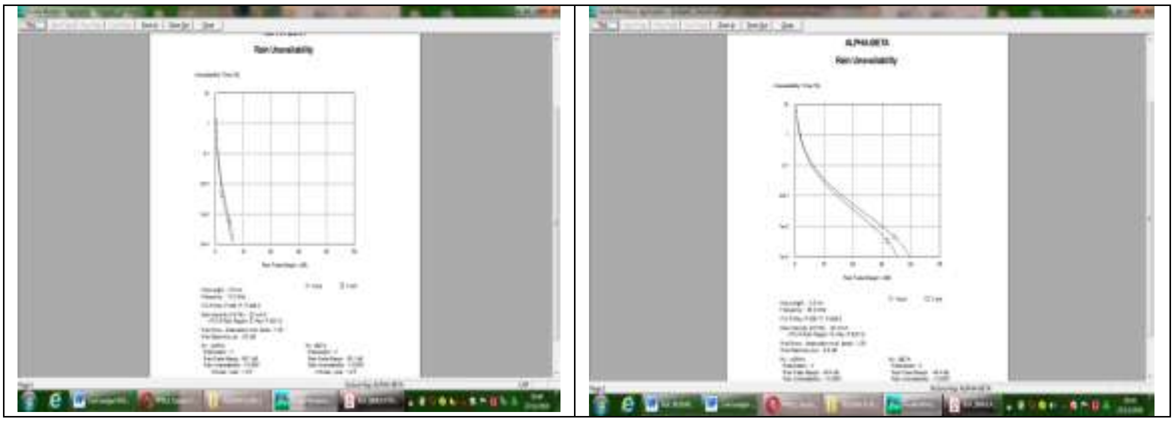


Figure 9: Simulation results for the rain availability/unavailability at 11GHz and 38GHz, 2.5 Km, respectively with ALPHA (32’ 05’’N, 7’ 23’’E); BETA (13’05’’N, 7’ 28’’E).

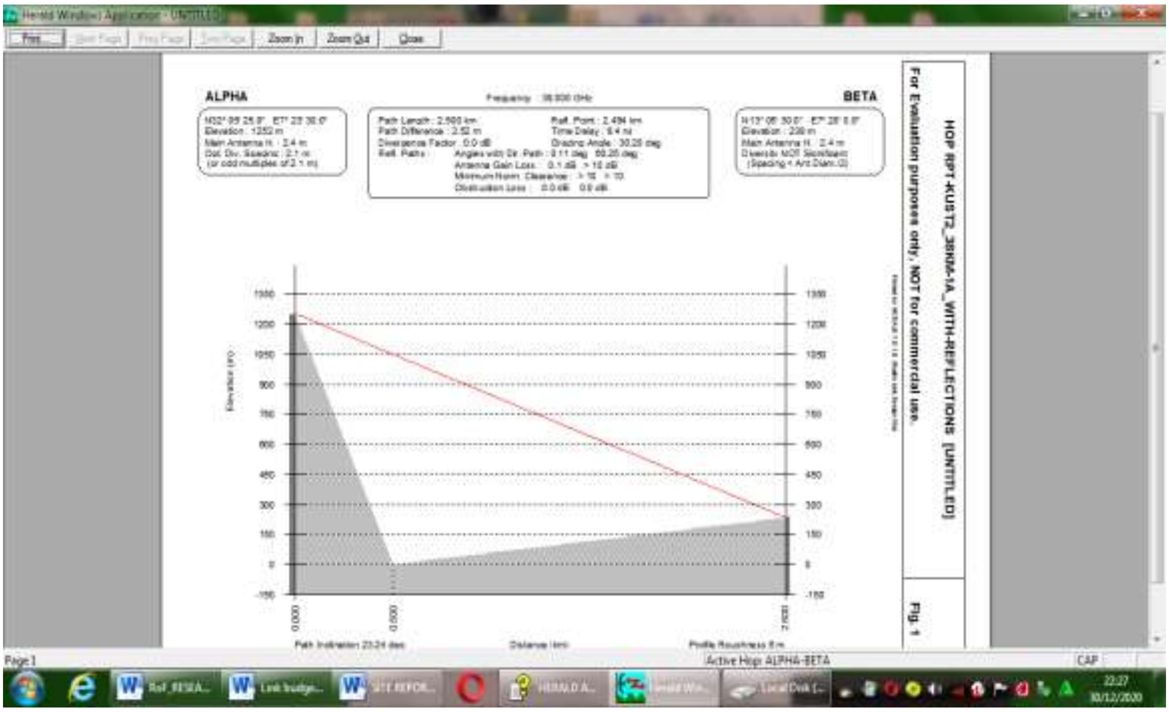


Figure 10; Transmission link showing clearance at 38GHz, 2.5 Km, ALPHA (32’ 05’’N, 7’ 23’’E); BETA (13’ 05’’N, 7’ 28’’E).

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 3 March 2023, pp: 1468-1479 www.ijaem.net ISSN: 2395-5252

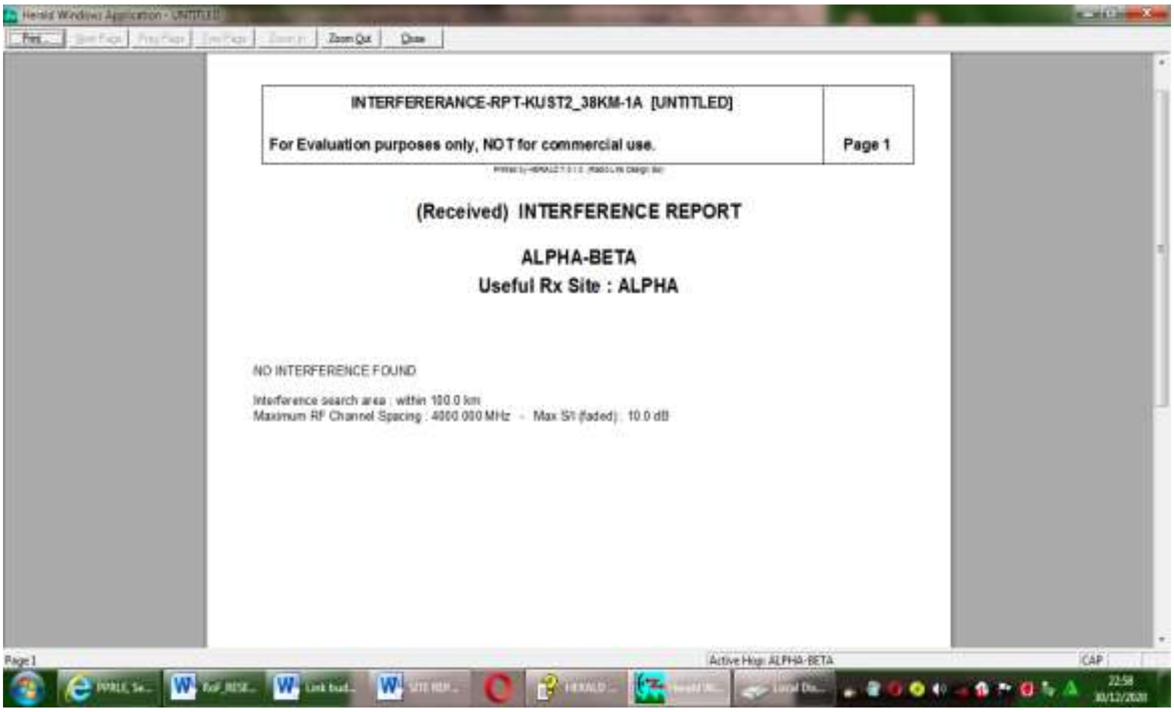


Figure 11: Interference report for 38GHz, 2.5 Km, ALPHA (32' 05''N, 7' 23''E); BETA (13' 05''N, 7' 28''E).

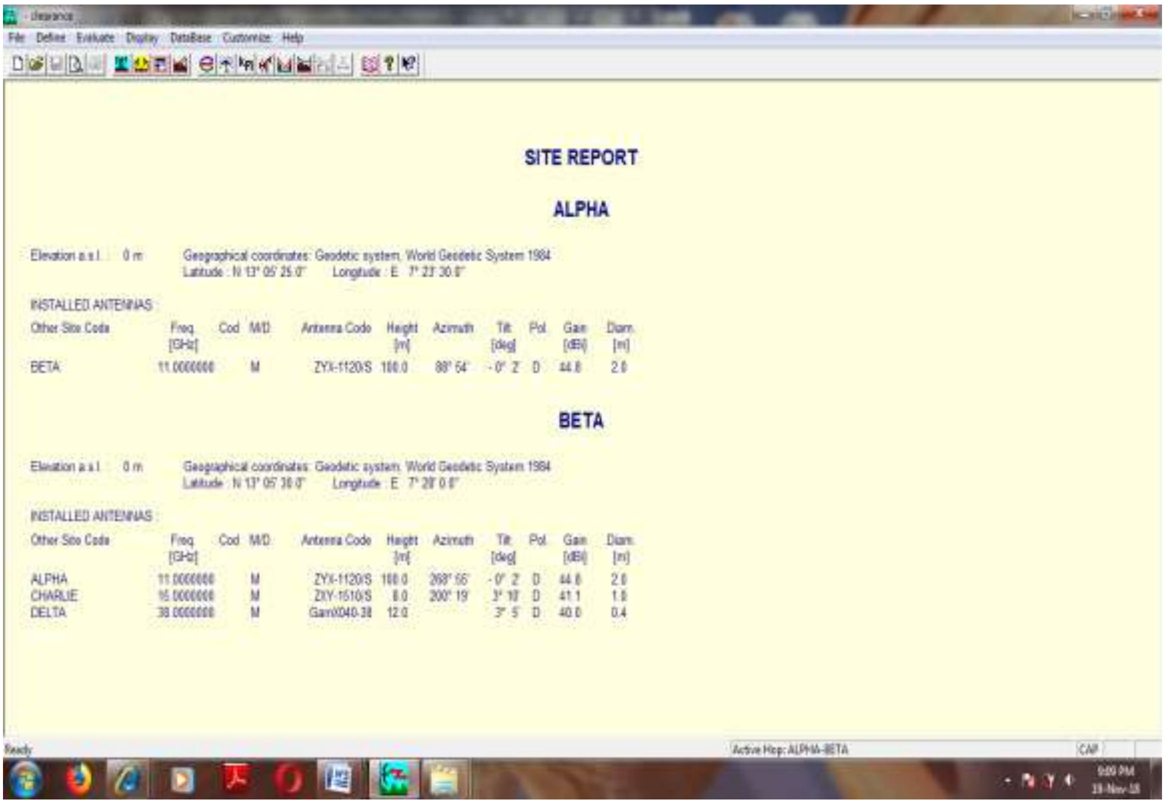


Figure 12: Site report data for Geographical sites at varied frequencies, 2.5 Km, ALPHA (13' 05''N, 7' 23''E); BETA (13' 05''N, 7'28''E).

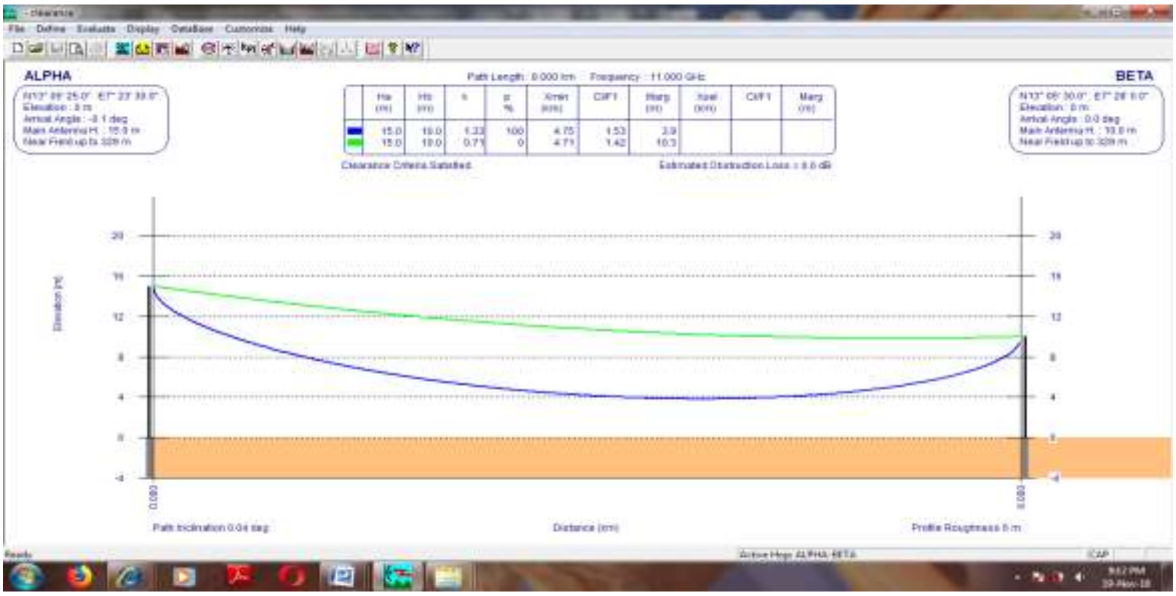


Figure 13: Transmission link for 11GHz, 8 Km, ALPHA (32’ 05’’N, 7’ 23’’E); BETA (13’ 05’’N, 7’ 28’’E), antenna placed on the ground, no reflection.

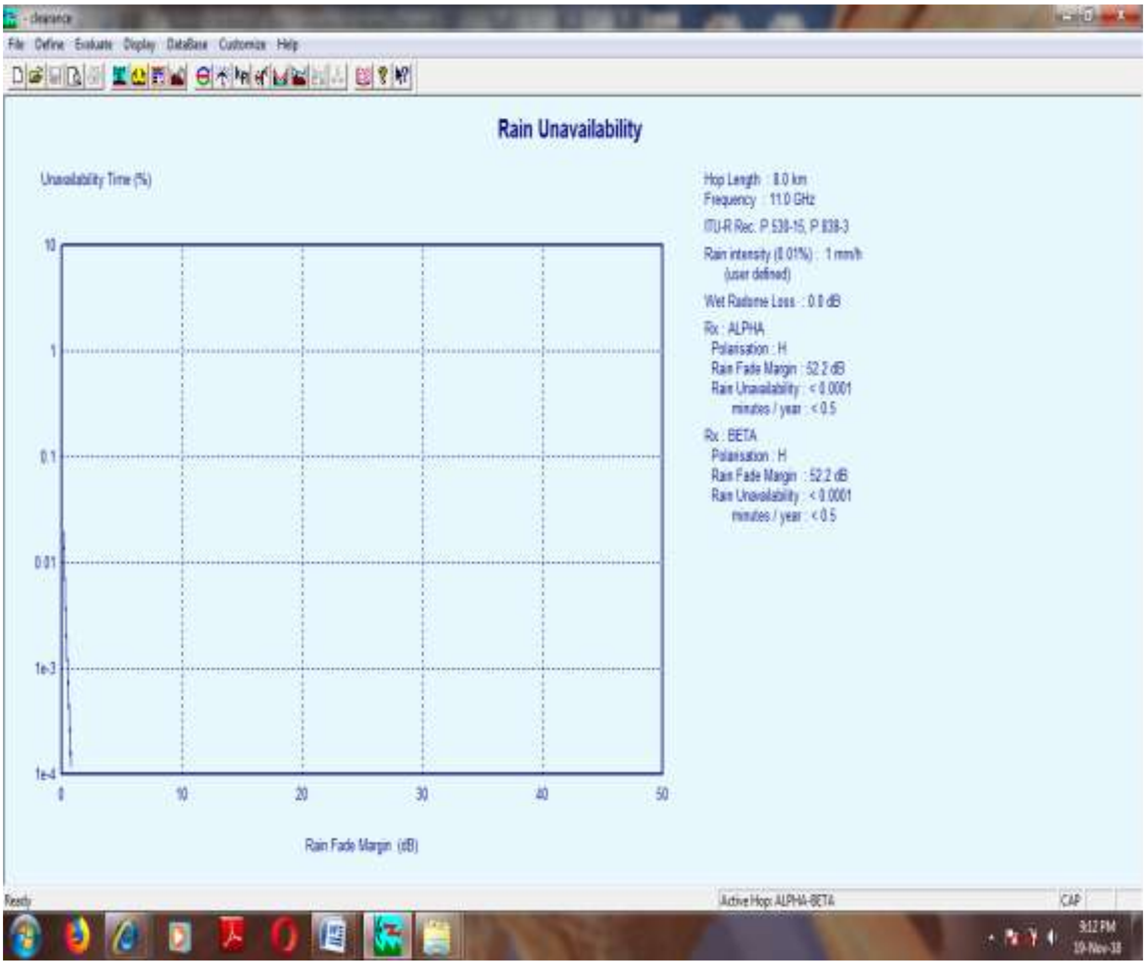


Figure 14: Rain unavailability report for 11GHz, 8 Km, ALPHA (32’ 05’’N, 7’ 23’’E); BETA (13’ 05’’N, 7’ 28’’E).

IV. CONCLUSION

Simulation and analysis of a poin-to-point RoF system is presented. In this paper, HERald software is used to evaluate the performance of a point-to-point system. The RoF so proposed is so simple that it reduces the system installation and hence, the cost. The path profile and the transmission clearance as shown in the figures 8, 10 and 13, indicates obstacle free propagation of the broadband wireless radio signals at up to 2.5KM.

Using the HERald Simulation, the performance of transmitting a radio communication signal through a point-to-point link was investigated. This was attained by using the antenna and radio equipment libraries which allow us to select the items useful to configure the radio hop terminals.

REFERENCE

[1]. Vandana Yadav, A.K. Jaiswal and Mukesh Kumar, ‘‘Radio over Fiber Technology’’. IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 9, Issue 3, Ver. I (May - Jun. 2014), PP 83-87 www.iosrjournals.org.

[2]. Sara S. Jawad, Raad S. Fyath, ‘‘Transmission Performance of Analog Radio-over-Fiber Fronthaul for 5G Mobile Networks’’, International Journal of Networks and Communications, 2018, 8(3): 81-96. DOI: 10,.5923/j.ijnc.20180803.0

[3]. R. Karthikeyan and Dr. S. Prakasam, “A Survey on Radio over Fiber (RoF) for Wireless Broadband Access Technologies”, International Journal of Computer Applications (IJCA) (0975-8887), Volume 64, No. 12, February (2013).

[4]. R. Karthikeyan and Dr. S. Prakasam, A Review – OFDM RoF (Radio over Fiber) System for Wireless Network, International Journal of Research in Computer and Communication Technology, Vol 3, Issue 3, March-(2014).

[5]. Ajay Kumar Vyas, Dr. Navneet Agrawal, “Radio over Fiber: Future Technology of Communication,” International Journal of Emerging Trends & Technology in Computer Science (IJETTCS), vol. 1, Issue 2, July – August 2012. ISSN: 2278-6856.

[6]. Zhang S., Wu Q., Xu S., and Li G. Y., "Fundamental green tradeoffs: progresses, challenges, and impacts on 5G networks," IEEE Communications Surveys and Tutorials, vol. 19, pp. 33-56, (2017).

[7]. Hasan N. U., Ejaz W., Ejaz N., Kim H. S., Anpalagan A. and Jo M., "Network selection and channel allocation for spectrum sharing in 5G heterogeneous networks", IEEE Access, vol. 4, pp. 980-992, (2016)..

[8]. Ranaweera C., Wong E., Nirmalathas A., Jayasundara C. and Lim C., "5G C-RAN With Optical Fronthaul: An Analysis From a Deployment Perspective", IEEE Journal of Lightwave Technology, vol. 36, no. 11, pp. 2059-2068, (2018).

[9]. Akyildiz I. F., Lin S. C., and Wang P., "Wireless software-defined networks (W-SDNs) and network function virtualization (NFV) for 5G cellular systems: An overview and qualitative evaluation," Computer Networks, vol. 93, no. 1, p. 66–79, December, (2015).

[10]. Ataee M. and Mohammadi A., "Energy-efficient resource allocation for adaptive modulated MIMO–OFDM heterogeneous cloud radio access networks", Wireless Personal Communications, vol. 95, no. 4, pp. 4847-4866, August, (2017).

[11]. Iezekiel S., "Radio-over-fiber technology and devices for 5G: an overview", Broadband Access Communication Technologies, vol. 9772, 2016.

[12]. Rashed A. N. and. Tabbour M. S, "Suitable optical fiber communication channel for optical nonlinearity signal processing in high optical data rate systems", Wireless Personal Communications, vol. 97, no. 1, pp. 397–416, November, (2017).

[13]. A. Ichkov, V. Atanasovski, and L. Gavrilovska, "Potentials for application of millimeter wave communications in cellular networks", Wireless Personal Communications, vol. 92, no. 1, pp. 279–295, January 2017.

[14]. S. A. Haider, M. J. Zhao, and I. Ngebani, "MIMO beamforming architecture in millimeter wave communication systems", Wireless Personal Communications, vol. 97, no.2, pp. 2597–2616, November 2017.

[15]. Y. Niu, Y. Li, D. Jin, Su, and A. V. Vasilakos, "A survey of millimeter wave communications (mmWave) for 5G: opportunities and challenges", Wireless

Networks, vol. 21, no. 8, pp. 2657-2676, November 2015.
[16]. M. Tesanovic and M. Nekovee, "mmWave-based mobile access for 5G: key challenges and projected standards and regulatory roadmap", Global Communications Conference (GLOBECOM), California, USA, (2015).
[17]. https://www.openstreetmap.org, accessed 9th February, 2021.
[18]. Luigio Moreno, www.radioengineering.org. Accessed 15th November, 2017.