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Comparative Analysis of the Effect of Distance on Signal Strength using Selected Communication Media

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ABSTRACT

This paper presents an investigation of the effect of distance on communication via optical fibre single mode and multimode structure. It also gives a comparative analysis of transmission over radio wave and fibre optic links. First, data were collected at different distances in the multimode and single mode optic fibre link, recorded and analyzed. Secondly, data was taken and compared to multimode fibre optic and microwave (18GHz) links. It was observed that communication through multimode optic fibre link degraded noticeably with the increase in distance in comparison with the single mode optic fibre link. In comparison with the 18GHhz microwave link, the multimode fibre optic link performed better as a communication medium. This information is especially useful for making critical decisions for the deployment of future communication infrastructure.

Key Words: *Microwave, Fibre Optics, Base Station, Links, Multimode, Single mode.*

1. INTRODUCTION

The utilization of fibre optics in broadcast communications has been basic for quite a long time. Generally, fibre optics has turned out to be dynamically transcendent in modern information communication systems. High data rate capabilities, noise rejection and electrical detachment are only a couple of the imperative attributes that makes fibre optic technology a great choice for communication in modern business systems [l].

In digital communication, fibre optic technology is frequently utilized for point-point connections. Fibre optic connections are also being utilized to expand the separation impediments of RS-232; RS-422/4 systems while ensuring high information rates and diminishing electrical obstruction. Typical electrical information signals are changed into a modulated light beam, brought into the fibre and carried through a little measurement glass or plastic fibre to a recipient that changes the light once again into electrical signals. Fibre's capacity to transport the light signal with minuscule losses depends on some central material science related with the refraction and reflection of light [2]. With the development of hyper-scale Data centres (DC); single-mode transmission is used to address the issue of distant system reach. In recent data centres (DC), multimode fibres and single-mode fibres are used with VCSEL-based multimode handsets and single mode handsets. Enterprise data centres majorly use OM3/OM4 multimode fibre for data transmission as most channel lengths are less than l00 m, and the trend looks to continue since multimode (MM) transmission remains a cost effective solution covering large transmission distances [3]. In extensive scale data centres, a part of the optical transmission has short distances, less than ten meters, where multimode transmission is more financially savvy than single-mode transmission. Single-mode connectivity is used in data centres both at short distances, like the multimode fibre, and at longer distances, above l00m. In the telecommunication industry, single-mode is widely used. The reasons for this are its high system bandwidth and distant transmission capability [4]. For very short distances in enterprise data Centre's, single-mode fibre is for the carrier interface to provide linkage to the router and fibre connection mainframe for storage applications [5]. For very long distances (several hundred meters) both MM and SM transmission co-exist, considering the data rate and the type of data centres.

The world is fast becoming a global village and as such the most important tool to make the world become a global smart city is telecommunications. Growth in population fuels growth in the demand for high speed internet. The primary driver to achieve a very high speed and limitless internet service the most reliable way is the fibre network. Fibre is the proven solution for giving broadband service for example video on request, internet gaming, HD TV and voice over the internet protocol (VOIP). Since the l970s when fibre optics was invented, the demand and use of fibre optics has grown tremendously. The use of fibre optics has become uncountable and the users have found it more reliable than any other means of data transmission.

With the high demand of data activity because of the web, electronic trade, PC systems, multimedia, voice, data, and video, there comes a high requirement for transmission medium with the transfer speed capacities for conveying such measures of data. Fibre optics, with its similarly limitless data transfer capacity, has proven to be the solution [6]. Fibre optics has been widely adopted by almost all the telecommunication industries in the world with Nigeria inclusive, some of the front runners in this aspect are as follows; AT & T, MCI and U.S. Sprint. While in Nigeria, we have the like of SWIFT Networks, MTN Nigeria, Global Communications, Main-one cable etc., these companies have used and are still using fibre optics to provide the following value added services such as voice over internet protocol, local telephone services with internet services inclusive from their central office switches to various locations and enterprise offices. Fibre optics have become the most adopted means of transmitting data from internet service providers' office or BTS to any organization such as banks, universities, malls and to other privately owned firms who need their services. The protection characteristic in fibre systems could be a major advantage. Cable TV or Community Antenna TV (CATV) corporations have discovered that fibre optics is valuable for video services. The high data conveying capacity or transmission capacity of fibre settles on it, the ideal decision for transmitting signals to subscribers. But in this research, we shall discuss and focus more on the following [7];

- Multimode fibre which is the second type of fibre and it is often used in short distance communication such as metro fibre deployment
- Single mode fibre optics as a means of long distance communication
- We shall also compare the data collected when using multimode fibre with and without optical amplifier
- We will also compare this data collected in point 3 above with the transmission using single mode fibre optics as a means of communication.
- We will also compare data collected from communication system using microwave as a channel with multimode fibre optics transmission with and without optical amplifier.

2. LITERATURE REVIEW

The utilization of light for communication goes back to antiquated circumstances in the event that we decipher optical interchanges in wide sense [8]. The vast majority has utilized mirrors, fire reference points or smoke signs to pass on a solitary snippet of data (for example triumph in war). Basically a similar thought was utilized around the end of the eighteenth century through signaling lamps, banners, and alternative semaphore gadgets. The thought was expanded further, after a proposal of Claude Chappe in l792, to transmit automatically coded messages over long distances (l00km) by the utilization of middle of the road hand-off stations [9], going about as regenerators or repeaters in the cutting edge dialect. The opto-mechanical communication systems of the nineteenth century were innately moderate. In current day wording, the powerful bit rate of those systems was under l bit per second.

A communication system transmits data starting with one place then unto the next, regardless of whether they are isolated by a couple of kilometres or by a body of water. Data is regularly conveyed by associate magnetic force radio radiation whose frequency can vary from a few mega-hertz to several hundred terahertz. Optical communication systems utilize high carrier frequencies in the visible or near-infrared region of the electromagnetic spectrum [10]. They are generally known as light-wave systems to differentiate them from microwave systems, whose carrier frequency is usually smaller by 5 orders of magnitude (lGHz). Fibre-optic communication systems are light-wave systems that utilize optical strands for data transmission. Such systems have been conveyed worldwide since l980 and have surely reformed the technology behind broadcast communications. In reality, the light-wave technology, along with microelectronics, is accepted to be a central point in the information age.

The introduction of telegraphy in the l830s supplanted the utilization of light by electricity and started the period of electrical interchanges [11]. The Bit rate B could be expanded to l0 b/s by the use of new coding methods, for example, Morse code. The utilization of delegate hand-off statins permitted communication over long distances (l000km). Surely, the principal effective intercontinental transmit link went into activity in l866. Telegraphy utilized basically an advanced plan through two electrical beats of various lengths. The presentation of phone in l876 acquired a noteworthy change as much as electric signals were transmitted in simple form through a constantly fluctuating electric current [12].

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The examination period of optical fire communication systems began around l975. The huge advance acknowledged more than 25-year time span stretching out from l975 to 2000 can be separated into a few particular ages. The first generation of light-wave systems worked almost 0.8µm and utilized Gallium Arsenide (GaAs) semiconductor lasers. After different endeavours amid the time of l977-l979, such systems became available commercially in l980 [13]. They worked at a bit rate of 45 Mb/s and allowed repeater dividing of up to l0km.

Cloud computing and web administrations keep on driving expanded transmission capacity request, pushing information communications rates [14]. These higher rates may lead system designers to trust that single-mode optical fibre enjoys increasing advantage over multimode optical fibre in field applications. Regardless, higher LAN speeds do not thus infer that single-mode optical fibre is the right alternative. Albeit single-mode optical fibre holds favourable circumstances as far as transmission capacity and reach for extended distances, multimode optical fibre effectively bolsters most distances needed for big business and information centre networks, at cost fundamentally not as much as single-mode. In big business local Area Networks and shorter field runs, OFS' laser Wave FlEX 300 (OM3) and laser Wave FlEX 550 (OM4) Multimode Optical Fibres can without much of a stretch help come to up to five hundred to six hundred metres and for the l0 Gb/s maximum speeds normally needed today. looking to conceivable future desires of 40 and even l00 Gb/s transmission speeds, OFS' laser Wave Flex multimode fibre will bolster these same achievements once combined with accessible (40G) or destined to be accessible (l00G) expanded reach multimode transceivers.

For progressively differing necessities of the present wide assortment of data centres, laser Wave Flex OM3 and OM4 optical fibres bolster run of l00 – l50 metre maximum distances are found in several applications except the biggest data centres. The biggest stockroom scale data centres contain thousands of shorter server-to-server, server-to-top-of-rack or end-of-row associations [15].

As information rates increase within the information centre, a brand new multimode fibre referred to as wide band fibre will allow utilization of Short Wavelength Division Multiplexing (SWDM) innovation to transmit numerous signals on one fibre, expanding the transfer speed of a single fibre. This lessens the quantity of fibres needed to achieve more noteworthy speeds, and jam the monetary advantage of utilizing multimode optical fibre. As SWDM applications are developed and institutionalized, multimode optical fibre will bolster lengthy distances than OM4 fibre. Completely OM4 perfect, laser Wave FlEX band multimode fibre can be introduced now to help the present OM4 applications, and be prepared for future SWDM applications. Multimode fibre keeps on being the less expensive alternative over single-mode fibre for shorter distance applications. Whereas the genuine price of the multimode interface is larger than single-mode fibre optic link [15]. On the average, single mode transceivers keep on costing from l.5 to five times over multimode transceivers, contingent upon rate. As quicker optoelectronic technology develops and volume increase, costs descend for each, and therefore the price gap amongst multimode and single-mode diminishes. In any case, single-mode optics has dependably been costlier than their identical multimode partner. This reality is upheld by the distinction in multimode versus single-mode l0G optics, a typical local area network speed utilized these days. Multimode transceivers likewise expend less power than single-mode transceivers, an imperative that is very significant. In vast centres with lots of connections, a multimode arrangement will provide considerable better price assets, from both a transceiver and power/cooling viewpoint. The manner by which these two fibre types transmit light in the long run prompted their totally different names. Typically designed for systems of moderate to long distance, single-mode fibres have a little core size that licenses the transmission of just a single mode or beam of light. This little core requires exactness in arrangement to infuse light from the transceiver into the core, essentially driving up transceiver costs. By correlation, multimode fibres have bigger cores that guide numerous modes instantaneously. The bigger core makes it considerably easier to catch light from a transceiver, allowing supply expenses to be controlled. Correspondingly, multi-mode connectors price not as much as single-mode connectors thanks to the lot of demanding arrangement stipulations of single-mode fibre. Single-mode connections need more prominent care and expertise to terminate, which is the reason segments area unit are oftentimes pre-terminated at the processing plant. Then again, multimode connections can without much of a stretch be performed in the field, offering establishment adaptability, cost reserve funds and genuine feelings of serenity. Thus, multimode optical fibre systems keep on being the savviest fibre choice for big business and data centre applications up to 500 – 600 metre range [12-14]. Past the compass of multimode fibres, it ends up important to utilize single-mode fibre. Be that as it may, while evaluating single-mode fibres, confirm to think about additional current selections. A bend-insensitive, full-spectrum single-mode fibre provides a lot of transceiver choices, more noteworthy transmission capacity and a smaller sensitivity to treatment of cables and patch cords than in standard single-mode glass fibre [12-15].

3. METHODOLOGY

Figure 1: Fibre backhaul connection [12]

Figure 1 shows the schematic diagram of a fibre backhaul link between two locations which are the BTS and the client end as indicated in the diagram. There are four hand holes (junction boxes) between the base station and the client location which is about 5000m from the BTS. Single mode fibre and multimode fibre were used in this study to check the variance in the signal strength with increase in distance. The purpose of the four hand holes between the client location and the BTS is to drop some fibre cores at each hand hole so as to create room for future clients within the area. This saves cost for the telecommunication company and the clients since the fibre can be taken from the nearest hand hole to the client instead of going a long distance from the BTS. Single mode fibre and multimode fibre of length 5000m were used from the base station to the client end. Transmission speeds of l00, 200, 300, 400, 500, 600, 700, 800 and 900 all in mega bit per second were used to move information from the BTS. For each transmission speed, the signal strength was collected at intervals of l00, 200, 300, 400, 500, 600, 700, 800, 900, l000 all in meters. At 300 meters when the signal’s strength noticeably starts to reduce, an optical amplifier was introduced to strengthen the signal and at 700 meters another optical fibre amplifier was also introduced. Finally, multimode fibre optics was also compared with microwave communication by collecting data using both media. In this case a microwave of 18GHz was used.

Figure 2 shows the network room diagram of a particular client, the diagram shows the schematic representation of the internal network diagram of the client. The symbols represented are explained as follows;

l: This is the router at the network room where the information coming from the BTS is terminated, this router also carries same configuration with the one at the BTS.

2: This is the cisco switch where the data from router 2 is re-distributed to the number of offices requested by the client. Each port on the switch is configured on different VLANs and these VLANs are linked to the IP addresses as assigned to each office in the router configuration.

3: This is the Ethernet patch panel. This is to make a proper arrangement of the UTP cabling during the installation of the network and it also makes troubleshooting easy whenever there is fault.

4: This is the media converter chassis where the fibre optic coming from the BTS is terminated before transferring it to router l in the network room. This conversion is necessary because electrical signals transmitted in the form of light need to be converted back to electrical signals.

5: The fibre patch panel; fibre optic cable from each office are spliced at this point and linked with patch cord to the media converter chassis in order to supply internet services to the client’s office.

6: This represent the router at the base station where the link configurations are carried out by the internet service provider, the bandwidth, the VLANS and the IP address are all configured and assigned to the client for internet access.

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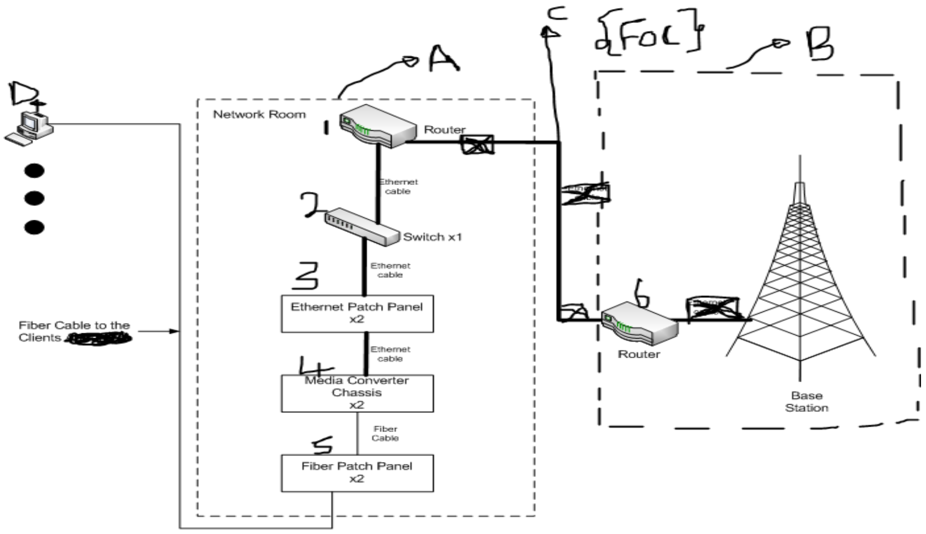

Figure 2: Diagrammatic Representation of a Typical Network Room [12]

4. RESULTS AND DISSCUSSION

4.1 The Effect of Distance on Multimode and Single Mode Fibre Optics Communication

Table 1: Signal Strength without Optical Amplifier in Multimode Fibre

S/N	DIS(m)	Bandwidth TX (Mbps) at the BTS	Bandwidth RX for Single Mode Fibre (Mbps)	Bandwidth RX for Multimode Fibre (Mbps)
1	100	100	98.5	98.4
2	200	150	149.0	148.5
3	300	200	199.3	197.4
4	400	250	249.4	246.7
5	500	300	298.9	295.9
6	600	350	349.0	309.1
7	700	400	399.0	347.5
8	800	450	449.5	330.8
9	900	500	498.9	380.0
10	1000	550	548.9	440.9

Table 2: Signal Strength with Optical Amplifier in Multimode Fibre

S/N	DIS(m)	Bandwidth TX (Mbps) at the BTS	Bandwidth RX for Single Mode Fibre (Mbps)	Bandwidth RX for Multimode Fibre (Mbps)
1	100	100	98.5	98.5
2	200	150	149.0	149.0
3	300	200	199.3	199.3
4	400	250	249.4	249.4
5	500	300	298.9	298.9
6	600	350	349.0	349.0
7	700	400	399.0	399.0
8	800	450	449.5	449.5
9	900	500	498.9	498.9
10	1000	550	548.9	548.9

4.2. The Effect of Distance on 18GHz Microwave Radio and Multimode Fibre Optics Communication

Table 3: From January 3rd to l3th 20l7 and Time: 9am to 11am daily

Days	DIS(m)	Bandwidth TX (Mbps) at the BTS	Bandwidth RX for Microwave Link(Mbps)	Bandwidth RX for Multimode Fibre (Mbps)
l	l00	l00	95.0	98.5
2	200	l50	l37.l	l49.0
3	300	200	l9l.0	l99.3
4	400	250	245.0	249.4
5	500	300	292.0	298.9
6	600	350	340.9	349.0
7	700	400	389.8	399.0
8	800	450	440.6	449.5
9	900	500	49l.0	498.9
l0	l000	550	548.5	548.9

Table 4: From January 3rd to l3th 20l7 and Time: l2noon to 2pm daily

Days	DIS(m)	Bandwidth TX (Mbps) at the BTS	Bandwidth RX for Microwave Link(Mbps)	Bandwidth RX for Multimode Fibre (Mbps)
l	l00	l00	98.l	98.5
2	200	l50	l48.5	l49.0
3	300	200	l98.0	l99.3
4	400	250	245.9	249.4
5	500	300	289.5	298.9
6	600	350	340.0	349.0
7	700	400	389.9	399.0
8	800	450	400.7	449.5
9	900	500	48l.9	498.9
l0	l000	550	535.8	548.9

Table 5: From March 3rd to l3th 20l8 and Time: 9am to 11am daily

Days	DIS(m)	Bandwidth TX (Mbps) at the BTS	Bandwidth RX for Microwave Link(Mbps)	Bandwidth RX for Multimode Fiber (Mbps)
l	l00	l00	90.0	98.5
2	200	l50	l3l.5	l49.0
3	300	200	l83.0	l99.3
4	400	250	238.6	249.4
5	500	300	280.0	298.9
6	600	350	330.9	349.0
7	700	400	370.8	399.0
8	800	450	434.6	449.5
9	900	500	489.0	498.9
l0	l000	550	527.5	548.9

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Table 5: From March 3rd to l3th 20l8 and Time: l2noon to 2pm daily

Days	DIS(m)	Bandwidth TX (Mbps) at the BTS	Bandwidth RX for Microwave Link(Mbps)	Bandwidth RX for Multimode Fibre (Mbps)
l	l00	l00	95.5	98.5
2	200	l50	l36.0	l49.0
3	300	200	l90.0	l99.3
4	400	250	240.8	249.4
5	500	300	285.5	298.9
6	600	350	338.0	349.0
7	700	400	380.9	399.0
8	800	450	344.5	449.5
9	900	500	492.6	498.9
l0	l000	550	5l9.5	548.9

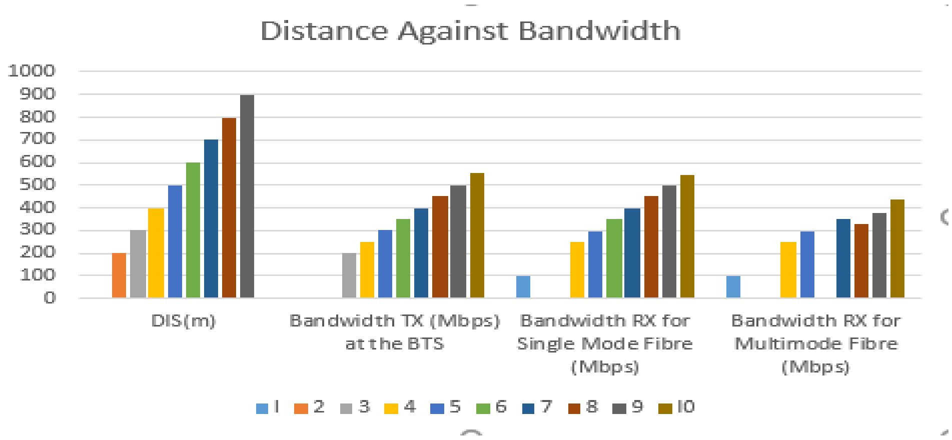

Figure 3: Bandwidth against Signal Strength without Optical Amplifier in Multimode Fibre

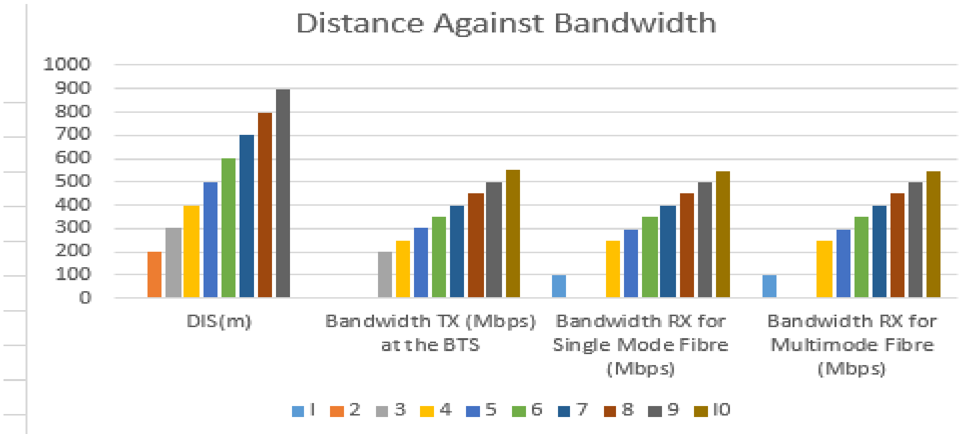

Figure 4: Bandwidth against Signal Strength with Optical Amplifier in Multimode Fibre

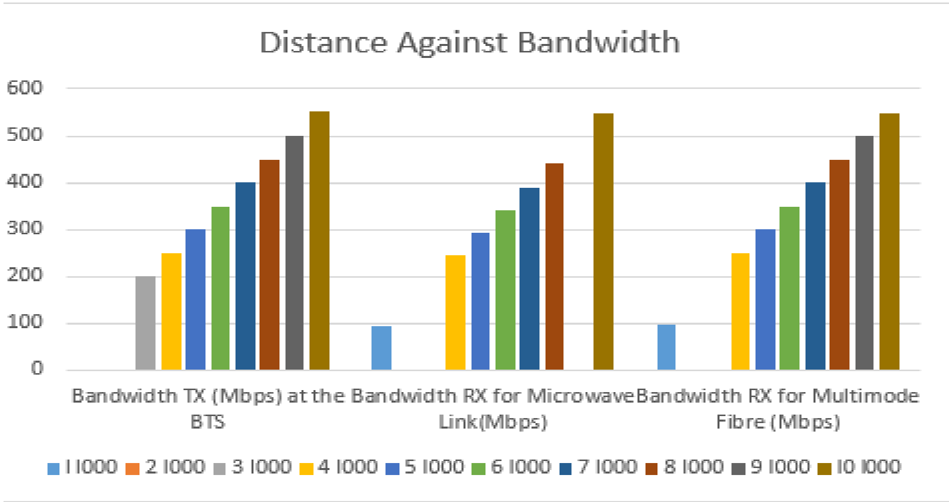

Figure 5: Bandwidth against Distance for 18GHz Microwave Radio and Multimode Fibre Optic Communication from January 3rd to 13th 2017 and Time: 9am to 11am daily

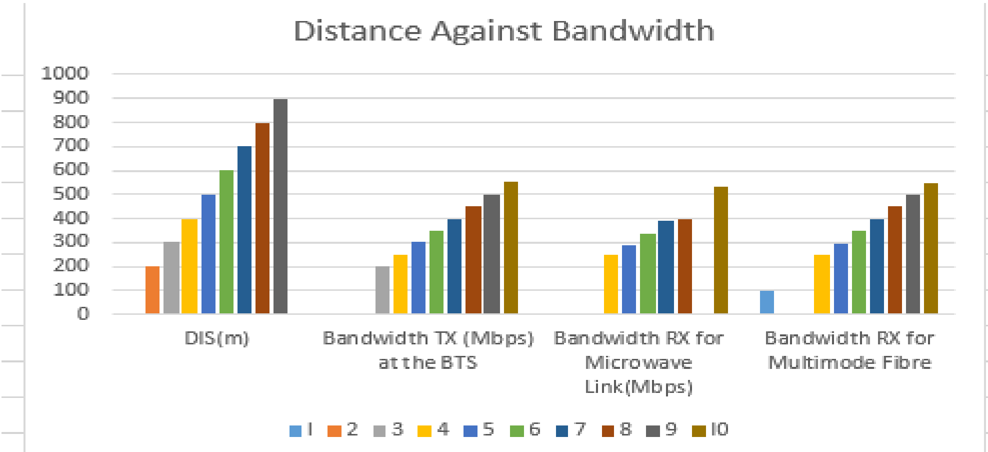

Figure 6: Bandwidth against Distance for 18GHz Microwave Radio and Multimode Fibre Optic Communication from January 3rd to 13th 2017 and Time: 12noon to 2pm daily

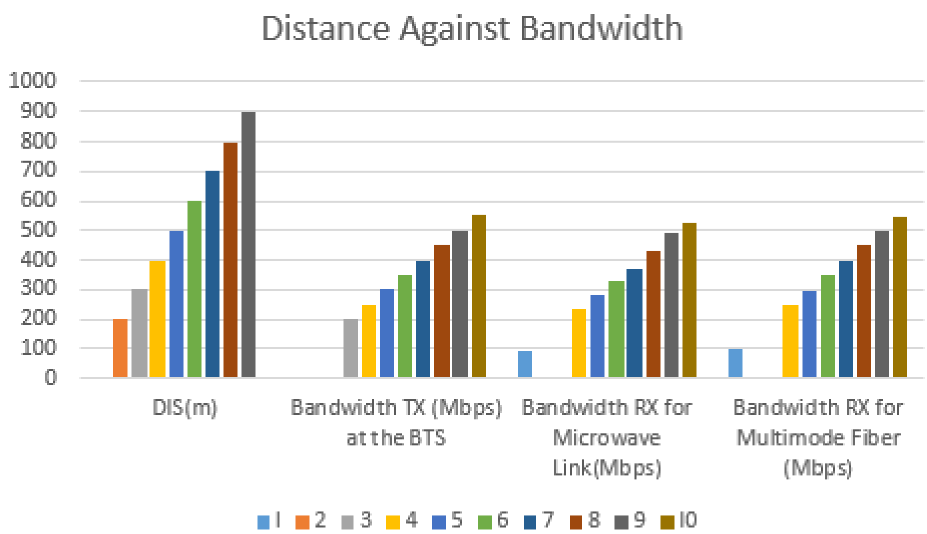

Figure 7: Bandwidth against Distance for 18GHz Microwave Radio and Multimode Fibre Optic Communication from March 3rd to 13th 2018 and Time: 9am to 11am Daily

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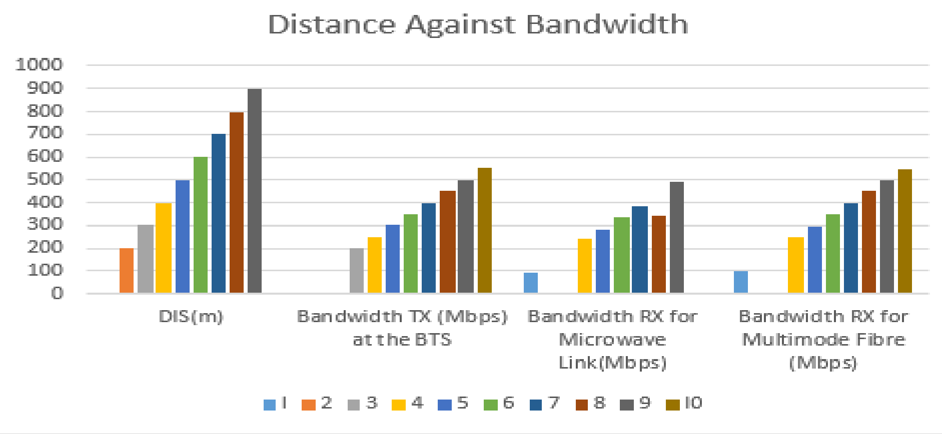

Figure 8: Bandwidth against Distance for 18GHz Microwave Radio and Multimode Fibre Optic Communication from March 3rd to l3th 20l8 and Time: l2noon to 2pm Daily

Tables 1 and 2 present the data on signal strength at different distances. It was observed that there were no changes in the signal strength using single mode with or without an optical amplifier but in the case of multimode without optical amplifier; there was a drastic reduction in signal strength. The change in signal strength with increase in distance was insignificant for the multimode with optical amplifier. This is shown more clearly in Figure 3 and Figure 4. While Tables 3 to 6 present the data collected when comparing microwave of 18GHz to a multimode at different times of the day. It was observed that the 18GHz microwave performs on the same capacity with the multimode but with variations at different times of the day. There were more losses in the morning between 9am to 11am but the loss dropped between the hours of 12noon to 2pm. Figures 5 to 8 buttresses this fact. The losses noticed between the hours of 9am to 11am could be as a result of the weather condition (clouds or moist air due to dew in the morning before the sunshine). The losses continue to reduce as the weather becomes clearer later in the day. This can be deduced from Tables 3 to 6 for January and March 2018. The speed of the radio was calculated using the website fast.com.

5. CONCLUSION

Signal strength generally diminishes with increase in distance. The single mode fibre optic had the longest recorded range before a tangible drop in signal strength was detected. The signal strength of the 18GHz microwave was the most affected by distance. It was also discovered that the strength of the microwave varies even at different times of the same day probably due to weather conditions.

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