ISSN 2047-3338

Comparative Analysis of Signal Propagation through Optical Fiber and Microwave Links

Y.O. Olasoji[1], M.O. Kolawole[2] and S.T. Ayoola[3]
[1,2,3]Department of Electrical and Electronics Engineering, Federal University of Technology, Akure, Nigeria
[1]yoolasoji@yahoo.com, [2]kolawolm@yahoo.com, [3]semite4u2@yahoo.com

***Abstract*– This study examines the degree of attenuation offered to the signal propagated through each of the optical fiber and microwave radio links. Measurements were taken at strategic locations of an operational telecommunication network that utilized both the optical-fiber and microwave radio links. Normalizing the effects contributing to signal attenuation, the range of attenuation per length of each link was estimated which can be used for network planning.**

***Index Terms*– Attenuation, Absorption Loss, Net Path Loss, Optical Fibre Link, Microwave Radio Link and Network Planning**

I. INTRODUCTION

COMMUNICATION was once confined to narrowband voice signals. Increasing demands for high quality visual, audio and data context have warranted development of long distance high demand, high capacity networks. Increasingly too, long distance high capacity networks optical fiber links have become ubiquitous. Some high capacity networks are still supplemented with microwave radio links. A transmission link is one of the major units or backbones that forms a network's primary path for transporting traffic between network segments, and to link core network to the subscribers' access points, for examples, base transceiver station (BTS) in GSM system [1]. Therefore, there is need for appropriate selection of transmission link for effective, efficient and speedy data and voice transmission within acceptable attenuation regime.

As in Nigeria telecommunication networks, optical fiber and microwave radio links are used extensively as the high-speed carrier forming a major pathway within the telecommunication link. Whether optical fiber or microwave radio link, the propagation signal attenuates along the transmission link. Each link has different primary sources of attenuation. For the optical fiber, the sources are absorption (due to intrinsic fibre material by core dopants) bending losses (connection losses at splices and joints), and Rayleigh scattering (wavelength dependent) [4]. Rayleigh scattering appears very much like absorption, but it absorbs and re-directs the light so quickly that it is considered scattering [3]. Unlike the optical-fiber link, microwave radio is always stationary, and every effort is made to ensure the antennas are line-of-sight, thus limiting impairment to that caused by free-space and atmospheric absorption and that associated with termination effects (i.e., coaxial cable used). This study does not quantify each of these causes of impairments; instead it examines total loss along each of the links.

II. BACKGROUND THEORY

The total loss between ports X and Y of an optical-fiber link, as represented by Fig. 1, can be expressed as the difference in the average power at port X (say β_X, in dB) and actual receive power at port Y (say β_Y, in dB). Consequently, the attenuation per link-length L is expressed as:

$$\alpha_{fib}\big|_L = \frac{1}{L}\left(\beta_Y - \beta_X\right) \qquad \text{(dB/m)} \qquad (1)$$

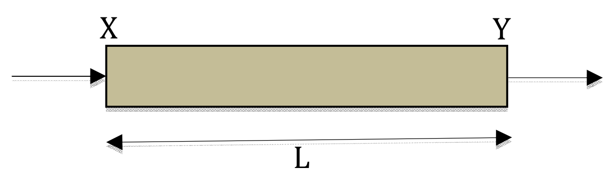

Fig. 1: An optical-fiber sector XY of length L

In the case of a microwave radio link, which operates a line-of-sight technique, the total loss α_μ is expressed as a sum of three losses, namely: free-space loss α_{FSL}, atmospheric absorption loss α_{abs}, and termination loss α_{coax}. Specifically

$$\alpha_\mu = \alpha_{FSL} + \alpha_{coax} + \alpha_{abs} \qquad \text{(dB)} \qquad (2)$$

where

(i) α_{FSL}; the free-space loss is defined as [2]

$$\alpha_{FSL} = 20\left[1.83 + \log f + \log L\right] \qquad \text{(dB)} \qquad (3)$$

L and *f* are link distance away from the receiver (measured in km, which is zero at the receiver) and radio link frequency (measured in GHz).

(ii) α_{abs} is the atmospheric absorption loss resulting from various climatic conditions including rain, fogs etc. There are many empirical models avaialble to quantifying elements of the absorption loss, which this study does not consider.

(iii) α_{coax} represents the attenuation offered due to termination effect i.e. that introduced by the coaxial cables connection between *radio indoor unit* (IDU) and the *radio outdoor unit* (ODU). Usually α_{coax} is taken as 1dB each for both the transmitting side and the receive side [2].

In this study, the total loss a_m is measured as the *net path loss* by subtracting the actual receive power P_R at one site (main switch station) from the transmitting power P_T at the other site (main switch station) forming a link. Hence, the attenuation per path length $\alpha_{\mu T}\big|_L$ equals measured total loss divided by path-length between main switch stations or sites, i.e.

$$\alpha_{\mu T}\big|_L = \frac{1}{L}\left(P_T - P_R\right) \quad \text{dB/km} \qquad (4)$$

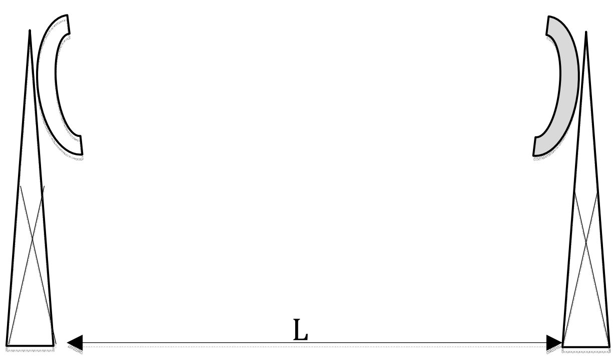

Fig. 2: A line-of-sight microwave radio link

III. MEASUREMENTS

Measurements were carried out on two transmission links (optical-fiber link and microwave radio link) between Lagos and Ibadan in Nigeria, a distance of 200km. A link is the distance between repeater stations. We observed in the course of the research that an optical fibre link is up to 200km while the longest-distance radio link is just about 48.27km but the links used in this reseach are approximately 30km. The optical-fiber link between Lagos and Ibadan is a tight-buffered fiber, consisting of 48 cores (or 24 channels each for uplink and downlink), terminated on the optical batch panel. An OTDR (*optical time domain reflectometer,* shown in Figure 3) was used to measure net loss (attenuation) and link distance on optical-fiber transmission link.

Fig. 3: Optical Time Domain Reflectometer (OTDR)

The OTDR was connected to each core on patch panel; one after the other and the attenuation for each port and link length were taken and recorded. Ten (10) ports were measured at 6GHz frequency. The pathlength between ports is calculated to be relatively similar, i.e. 143.14±2.6 km.

For the microwave link, measurements were taken on Harris microwave Radio which has 6 channels with data capacity of 155.52Mbits/s (STM-1) on each channel. Although this capacity (STM-1) can be multiplexed on some other microwave Radio facilities to have higher capacities of up to 311Mbits/s (STM-2) and 622Mbits/s (STM-4). We were restricted to transmit at the lower capacity of 2.048Mbits/s (E-1) on microwave radio link to different BTS stations. The telecommunication provider's facilities we used for these measurements operate the microwave links on all the above named capacities, but 155.52Mbits/s link, which is the only available synchronous digital heirarchy (SDH) transmission link in Nigeria, was examined in this research.

IV. RESULT AND DISCUSSION

From the attenuation data acquired for both optical fibre and microwave radio links, it can be deduced that optical fibre has lower and very uniform attenuation/km (which ranges between 0.1343dB/km and 0.1783dB/km) over a wide frequency range than microwave radio link attenuation/km (which ranges between 1.9433dB/km and 2.4800dB/km) for 6 GHz. This is also clearly shown on Fig. 4. The cummulative value of these losses is nominal compared with microwave radio attenuation link.

We further varied the frequency of measurements for the microwave link between 6GHz and 15GHz and observed the non-uniform variation in attenuation, as demonstrated in Fig. 5. A polynomial fit to the attenuation-frequency variation, of Fig. 5, gives the expression:

$$\alpha_{\mu T}\big|_{L/f} = 1.3368 - 0.05f - 0.0549f^2 \quad \text{dB/km/f} \qquad (5)$$

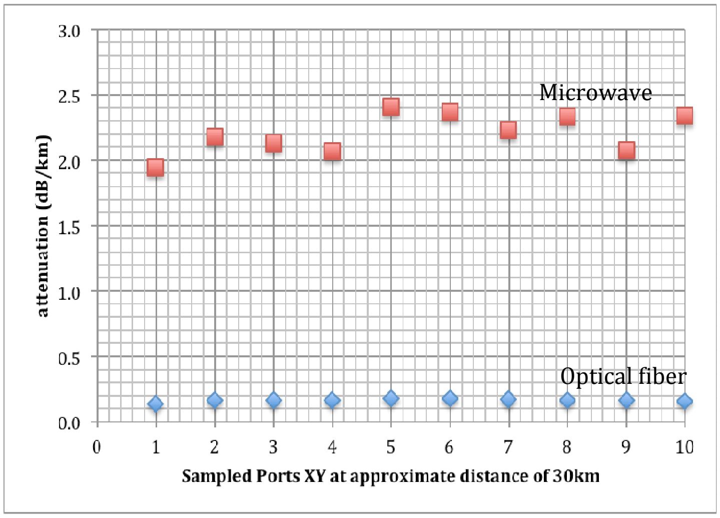

Fig. 4: Attenuation profile of optical-fiber and microwave radio links

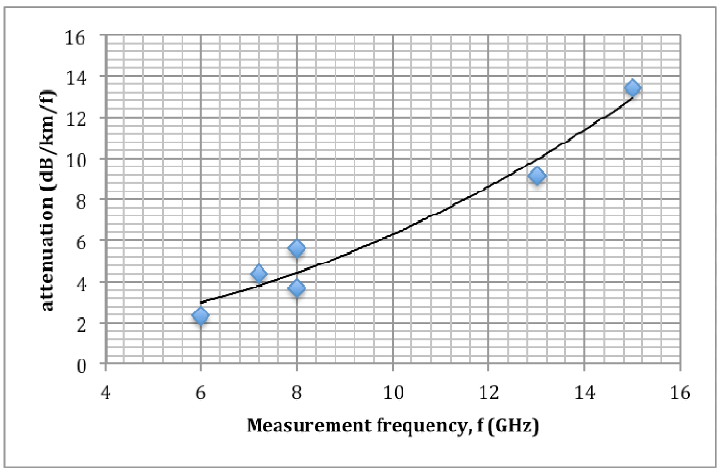

Fig. 5: Attenuation variation with frequency for Microwave radio link

with high correlation rate (R-squared value) of 0.0958 (i.e., $R^2 = 0.958$), where the frequency, *f*, unit in (6) is in GHz. The very high and non-uniform attenuation recorded on different microwave radio links is due to various environmental and climatic factors, as well as electromagnetic noise associated with other radio devices, motors or other nearby radio links. All these factors have no effect on optical fibre transmission links leading to very low and uniform attenuation.

V. CONCLUSION

Our study has shown the losses associated with the signal propagation on optical fibre and microwave radio transmission links. We demonstrated that considerable non-uniform propagation losses occur in the microwave rado link compared with the optical fibre link of lower and uniform attenuation. We deduce that optical fibre link would have excellent signal propagation performance when compared with microwave radio link.

REFERENCES

[1] S.T. Ayoola, *"Comparative analysis on signal propagation through optical fibre and microwave radio transmission links in GSM system,"* Postgraduate Diploma of Engineering Thesis, the Federal University of Technology, Akure, Nigeria, 2010.

[2] R.E. Bruce, *"The Satellite Communication Application Handbook,"* Boston: Artech House, 2004.

[3] J. Hecht, *"Absorption and scattering determine fiber attenuation,"* Laser Focus World, pp. 111-118, 2000.

[4] M.O. Kolawole, *"A course in telecommunication engineering,"* New Delhi: S Chand, 2009.