IMPLEMENTATION OF OPTIC FIBRE TRANSMISSION SYSTEM FOR DIGITAL INTEROPERABILITY OF RADIO WAVE IN NIGERIAN RADIO TELECOMMUNICATION INDUSTRIES

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Abstract: This paper presents the implementation of fibre optic transmission system for digital interoperability of radio frequency signal in the Nigerian Radio telecommunication industry. The main aim of this work is to present a novel approach of real time digital transmission of information communication from the Base radio stations to other receiver stations all across Nigeria using optic fibre network. It is possible for someone in Lagos to tune in and listen to dream Fm radio station broadcast from Enugu with a simple transistor radio. This paper presents the possibility with the employment of dark fibre (already installed and reserved by some Nigeria mobile telecommunication companies for the system implementation) using time division multiplexing. This will highly reduce the cost of installation and enable most of our radio stations to pipeline their plans into this technology.

Keywords: Optic fibre, transmission, Communication, interoperability, Information technology.

I. INTRODUCTION

Today talking about information communication technology industries, the average mindset is the internet, space satellite and mobile communication industries and lots more. Radio and television industries was less recognized of which however, is the fore runner of other modern means of digital communication. The growing need for fast broadband telecommunication in the Nigerian society and the economy requires a reliable, affordable, and scalable state-of-the-art communications infrastructure network [1]. To accommodate this, considerable investments are needed to expand and upgrade today’s telecommunication infrastructural network. In the last decade lots of upgrade has been done in the mobile and internet angle of information technology, employing even the proposed system (fiber optic) and satellite for broadband transmission and as a result huge success has been recorded so far based on the quality and speed of data streaming. However, despite the success so far little research contribution has been published to help improve and upgrade the radio station industry. This paper presents a technique that will enable national broadcast and real time transmission of radio signal from one state to another at the speed of light (optic fiber) from the host radio station base. The well known advantages of optical fiber as a transmission medium such as low loss, light weight, large bandwidth characteristics, small size and low cable cost made it the ideal and most flexible solution for efficiently transporting radio signals to remotely located antenna sites in a wireless network [2]. In addition to its transmission properties, the insensitivity of fiber optic cables to electromagnetic radiation is a key benefit in their implementation as the backbone of a wireless transmission.

This paper is organized as follows: statement of the problem, then a brief history of radio station and radio broadcasting in Nigeria was reviewed. Radio communication system is overviewed stating the current challenges of radio transmitting signals before the system proposal is stated. Section 5 discussed optic fiber communication system and fiber loss was not waved aside, Guass laws of electromagnetism were reviewed while section 7 and 8 discuss multiplexing and transmission mode.
of the system, the network architecture was also buttressed with the system implementation and finally the conclusion.

1.1 Statement of the problem
It is a standard procedure that when calling a radio station in view of a particular subject or broadcasting program, the names and locations are expected to be mentioned. It is always interesting listening to callers from some neighboring states like Ebonyi and Abia (both in south eastern Nigeria) contributing to the favorite radio program (Political platform, Dream FM).

II. RADIO BROADCASTING IN NIGERIA
Nigeria was introduced to radio broadcasting 85 years ago with the presentation of the first Radio Distribution System (RDS) in Nigeria, transmitting signal from BBC to Lagos. It took 6 years to increase the number of receivers to approximately two thousand. The number of RDS receivers reached about a thousand people in 1939, however, it grew to 74 thousand by 1960 [10]. After the Nigerian independence celebration in 1960, the Voice of Nigeria was launched in 1961 followed by the creation of the Federal Radio Corporation (shortly known as FRCN) in 1978. Ray Power FM was established in 1994 as the first privately owned radio station in Nigeria. The first international transmission (to the whole world) was possible in 1996, but the masses could get this service beginning from 2007 [10]. Today the Modern Nigeria has more than 60 stations of different ownership by private, state and federal government.

III. CHALLENGES OF RADIO SIGNAL TRANSMISSION
The successful interoperability of radio signal has been impaired by many factors which include:

i. Electromagnetic Interference
ii. Copper cable problems
iii. Distance
iv. Attenuation
v. Latency
vi. High cost
vii. Radio interference
viii. Antenna problems
ix. Weather attack
x. Limited broadband

From the aforementioned challenges above, the most common issues are interference, cable problems, antenna problems [5] and limited broadband transmission. One will wonder why radio signals from the western part of Nigeria cannot be received here in the eastern part of the country. This is simply because of the broadband transmission medium employed (coaxial cable) for radio signal modulation.

IV. SYSTEM PROPOSED
Optical signal transmission and detection offers immunity from fading and security at the physical level where the optical signal is typically contained within the indoor communication environment [2]. The proposed system still employs the same communication equipment and procedure in the conventional radio wave generating process (see section 3) for distribution which is already implemented within the Nigerian Radio base stations. But for transmission (long distance or interstate operability), this paper presents a time division multiplexing (TDM) of the generated carrier signal and the use of optic fiber (designed to counter signal losses) instead of the conventional coaxial cable for haul transmission at the approximate speed of light regardless of the distance. The diagram below portrays the fiber transmission channel with multiplexing and tools to compensate for signal losses and amplification.
V. OPTIC FIBER COMMUNICATION
Since its invention around Five decades now, the use of and demand for optical fiber have grown tremendously. The applications of optical fiber today are quite numerous. With the explosion of information traffic due to the Internet, electronic commerce, computer networks, multimedia, voice, data, and video, the need for a transmission medium with the bandwidth capabilities for handling such vast amounts of information is paramount [3]. Fiber optics, with its comparatively infinite bandwidth, has proven to be the answer.

Fiber optics is a medium for transmitting information from one point to another in the form of photons. Unlike the copper cable form of transmission, fiber optics is not electrical in nature. A basic fiber optic system consists of a transmitting device that converts an electrical signal into a light signal, an optical fiber cable that carries the light, and a receiver that accepts the light signal and converts it back into an electrical signal [3]. The figure 2: below portrays the basic sections of optic fiber communication system

![Basic optic fiber communication structure](image)

Figure 2: Basic optic fiber communication structure

1.2 Technical Issues of Optic Fiber
Huge benefits has been recorded for optic fiber transmission which include long distance, low power loss, faster speed, better system reliability, low cost among others. However, the characteristics of optic fiber communication link still have to be discussed. Noise figure, gain and dynamic range of optic fiber link cannot be neglected. There are various noise originators such as the laser phase noise, photo diode shot noise and the thermal noise also the length of the cable may be limited as a result of phase decorrelation and chromatic dispersion. As in all analogue transmission systems the impedance matching is required at the transmitting and receiving end to attain maximum power transfer. Handling these technical issues requires additional circuits control within the system as shown in figure 3.

VI. ELECTROMAGNETIC MODE THEORY FOR OPTICAL TRANSMISSION
In order to obtain an improved model for the propagation of light in an optical fiber, electromagnetic wave theory must be considered [7]. The basis for the study of electromagnetic wave propagation is provided by Maxwell’s equations. For a medium with zero conductivity these vector relationships
may be written in terms of the electric field $E$, magnetic field $H$, electric flux density $D$ and magnetic flux density $B$ as the curl equations

\[\nabla \times E = -\frac{d B}{dt}\]  
\[\nabla \times H = \frac{d D}{dt}\]  
And the divergence conditions:
\[\nabla \cdot D = 0 \quad \text{(no free charge)}\]  
\[\nabla \cdot D = 0 \quad \text{(no free poles)}\]

2. Multiplexing
In order to increase the information transfer over an optical fiber communication link it is necessary to multiplex several signals into a single fiber. It is possible to convey these multichannel signals by multiplexing in the frequency domain or electrical time, as with conventional electrical line or radio communication, prior to intensity modulation of the optical source. Hence, digital pulse modulation schemes may be extended to multichannel operation by time division multiplexing (TDM) narrow pulses from multiple modulators under the control of a common clock. Pulses from the individual channels are interleaved and transmitted sequentially, thus enhancing the bandwidth utilization of a single-fiber link.

VII. TRANSMISSION MODES FOR OPTIC FIBER PROPAGATION
Fiber optic cable is available in single-mode and multi-mode types. Multi-mode cable has a larger core diameter (50um or 62.5um) than single-mode fiber (9um core diameter). When light travels down multi-mode fiber it is reflected at different angles as it propagates down the transmission path. These multiple reflections cause the light to spread out in time as it propagates down the fiber, making it more difficult for the receiver to recover the data. Single-mode fiber on the other path being much narrower, confines the optical signal to a straighter path with fewer reflections. As a result, optical signal dispersion is significantly reduced which translates into a cleaner signal. Longer transmission lengths can therefore be achieved with single mode cable. It is also a bonus that single-mode fiber can now be purchased for the same or less than multi-mode fiber.

2.1 Optic Fiber Transmission Network Architecture
The network architecture of the proposed system varies according to the planned service application. The conventional transmitting system within a metropolitan area network is already in place for existing radio stations of which ring, star or mesh network topology can be adopted. Basically the network system consists of a Host Base station and a remote site (BS1) connected with a optic fiber network as shown in figure 4: Due to the political instabilities and terror challenges (combating our beloved Country Nigeria) there is need and demand for increase capacity and range of radio station broadcasting by stake holders for effective information communication and hence security. Tree network topology is proposed for the transmission network of the optic fiber system, this is considered as a topology of choice based on the dynamics and base station location in different states. This is a set of star network topologies subordinated to a central base station thereby distributing the signal to other base stations (BS1 and BS2).
2.2 Fiber Optic Loss Calculations
The transmission loss of optical fibers has proved to be one of the most important factors in bringing about their wide acceptance in telecommunications. As channel attenuation largely determined the maximum transmission distance prior to signal restoration, optical fiber communications became especially attractive when the transmission losses of fibers were reduced below those of the competing metallic conductors (less than 5 dB km$^{-1}$) [11]. Signal attenuation within optical fibers, as with metallic conductors, is usually expressed in the logarithmic unit of the decibel. The decibel, which is used for comparing two power levels, may be defined for a particular optical wavelength as the ratio of the input (transmitted) optical power $P_i$ into a fiber to the output (received) optical power $P_o$ from the fiber as:

$$\text{Number of decibels (dB)} = 10 \log_{10} \frac{P_i}{P_o}$$

This logarithmic unit has the advantage that the operations of multiplication and division reduce to addition and subtraction, while powers and roots reduce to multiplication and division [11]. However, addition and subtraction require a conversion to numerical values which may be obtained using the relationship:

$$\frac{P_i}{P_o}$$

In optical fiber communications the attenuation is usually expressed in decibels per unit length (i.e. dB km$^{-1}$) following:

$$\alpha_{dB}L = 10 \log_{10} \frac{P_i}{P_o}$$

where $\alpha_{dB}$ is the signal attenuation per unit length in decibels which is also referred to as the fiber loss parameter and $L$ is the fiber length.
The ratio of the signal power to noise power at varying length is determined and buttressed using the table 2. Showing how the Q. factor decreases when the distance increases in kilometers as show and modeled below using the eye analyzer.

VIII. SYSTEM MODELING

OptiSystem offers optical transmission system design and planning from component to system level and present the analysis and scenarios visually [9]. It is employed to test, simulate various multiplexing network, dispersion map design, transmitter, receiver and amplifier design and others. Optisystem is a based on realistic optical fiber product that does not depend on other simulation design and modeling as a communication system. There are hundreds of official components in Optisystem component library.

In this paper, the simulation model analyzer of the optical transmission system in optical fiber has been discussed by analyzing the effect of the components in data receiver by using different parameters setting.(see table 1)

The fiber network topology was modeled employing the optisystem simulation software. The results of the analysis were detailed in (table 2) and analyzed in the graphs below using different values of Q factor, Eye height threshold and at varying fiber cable length (km).

| Simulation parameters |
|-----------------------|
| C/W Input power       | 5dBm                        |
| C.W laser Frequency   | 193                         |
| Frequency of transmitter | 1550nm                     |
| Fiber length          | 40km                        |
| Attenuation of cable section | 0.2Db/km                  |

Model of the eye diagrams with varying distance with optisystem software tool

![Eye Diagram Analyzer](image)

**Figure 5: Eye diagram analyzer at 10km**
Figure 6: Eye diagram analyzer at 20km

Figure 7: Eye diagram analyzer at 30km
Figure 8: Eye diagram analyzer at 40km

Table 2: output reading of the optic transmission model with optisystem at different distance in km

| Fiber length (km) | Threshold | Eye Height | Maximum Q Factor | Minimum Bit Error Rate |
|-------------------|-----------|------------|------------------|------------------------|
| 10                | 0.0896305 | 0.133059   | 23.8289          | 7.90673e-126           |
| 20                | 0.0827148 | 0.123112   | 19.819           | 9.56138e-088           |
| 30                | 0.0764782 | 0.111393   | 12.788           | 8.74496e-038           |
| 40                | 0.0739315 | 0.0944921  | 8.66328          | 2.096622e-018          |

From the figure 9a: above, the value of Q factor is observed at different distance based on the values generated from the table 2. It was observed that as the transmission distance (km) increase the Q factor decreases.
From the eye diagram in the model framework (see table 2) it was observed that at increase distance (km) the eye height decreases as shown above in figure 9b.

![Figure 9c: Threshold at varying distance](image)

From the figure 9c: above the value of threshold is observed at different distance IN (km) based on the values generated from the table 2. It was observed that as the transmission distance (km) increase the eye height decreases.

**IX. SYSTEM IMPLEMENTATION**

This process defines how the system should be built, ensuring that information system is operational and meet quality standards. The new system is explained using the diagram below in figure 10: the diagram begins with the basic mode for generating radio signal in a radio communication system (see section 3). The signal generated is distributed within the metropolitan area, employing transmitting antennas. But for long distance transmission as proposed (see section 4) the radio signal generated is converted to light using converter such as global Radio Frequency-over-fiber transceiver, AJA converters etc before transmission. Radio-over-fiber (ROF) is an analog transmission process that employs RF signals to modulate light which is transmitted over a fiber optic cable [2]. The optical link provides speed, high bandwidth, low loss communication link to transport RF energy at optical frequency then a time division multiplexing is used to multiplex the signal and transmit using the base band radio over fiber technique, employing remote heterodyne detection method as proposed by [7]. This technique is adopted as a candidate for the realization of conversion between optical and high frequency radio signals using a radio over fiber (ROF) converter from the base station to other radio access unit in different locations at the rate of 768Mbps. The TDM is employed as channel access medium networks to allow multiple users to share the same network at the receiving end simultaneously at different time slot for shared network regenerators are employed to help overcome loss due to attenuation of the optical fiber, while the amplifier is used to boost the signal along the path of transmission. The base band signal is recovered back to radio signal at the end point using a converter and receiver antenna which further boast the signal and distribute.
X. CONCLUSION

The implementation of optic fiber for digital transmission of radio signal will go a long way to improve information technology in the Nigerian radio station industry. The radio over fiber transmission technology has huge benefits including the ability for multiple service interoperability and standards with realization of future proof architecture compared to the conventional method. Furthermore, the implementation cost will be limited if already installed dark fiber within our metropolis is employed for transmission. It provides a cost effective approach for remotely located antennas by limiting system complexity with a centralized based station closer to the customer. Furthermore, the system was modeled and analyzed as shown in table 2 affirming that the Q factor and other related factors (threshold ad eye height) decreases as the transmission distance increases.

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