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A Study Ofaudio Satellite Communication System Analysis in Akure South West, Nigeria

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Abstract: Communication system analysis is important for the prediction of the performance of communication links. A receiving earth station set up at Akure (lat. 7.28°N, long. 5.2°E) for this study accessed eight space stations and a 40 Mhz oscilloscope measured the audio components of the signals received. The propagation losses incurred, the figures of merit of the space transmitter and the receiver are estimated. The results show that in clear weather conditions, the path loss capability exceeds the actual path loss for each channel. The actual path loss is mainly due to free space path loss. Satellite audio signals can conveniently be transmitted from Atlantic ocean region, Indian ocean region and Pacific ocean region and received intelligent output at any part of Akure with a parabolic dish antenna of 0.5 efficiency.

Key words: Effective receiver sensitivity, effective isotropic radiated power and path loss capability

INTRODUCTION

A basic communication system consists of a transmitter and a receiver, each with its associated antenna, the two being separated by the path to be covered. In order to generate an intelligible output, the receiver requires a certain minimum signal called the static threshold, which is to be collected by its antenna and presented to its input socket. Radio wave communication between any particular transmitter and receiver depends primarily on the transmitter power, sensitivity of the receiver and the loss associated with the path between them (Radio Society of Great Britain, 1994).

Usually, the transmitter generates a much stronger signal than the minimum required by the receiver, hence a large loss of signal may be tolerated. For many path of interest, the actual path loss may be larger and communication may therefore become impossible. An added complication is that, the variation in path loss over a given path for a period of time can be large. If communication is to be maintained for a high proportion of time, a relatively powerful equipment will be required in order to cope with poor propagation conditions.

The objective of communication system analysis is to quantify these factors so that the performance of a communication link can be predicted. The result of the system analysis can be used to determine the initial design of equipment for a link, to determine the suitability of existing equipment to communicate over a given path and, if the way in which the path loss varied with time is known then the percentage of total time that communication is practicable can be predicted. In the latter case, the analysis will also indicate by how much the potency of the equipment must be increased to produce acceptable level of communication.

MATERIALS AND METHODS

Dishes up to about a metre in diameter are usually made from solid materials. Aluminum is usually used because of its light weight and durability. Unplated materials such as iron and steel are likely to corrode and thereby result in deformation of the dish surface. Fibre material is preferable because it prevents corrosion. Obviously windage problem increase with dish size. Mesh wire presents an advantage over solid materials in this regard but the wire-to-hole ratio must be high else much signal will be lost. It is obvious that a solid material reflect better than a surface full of holes but if the size of the hole is kept to a small fraction of the wavelength that is being reflected, the hole will cause a moderate reduction in efficiency.

Fibre material is the major material used for this casting. It is made up of alkaline free glass know as E-glass. This material has an outstanding electric insulating properties and chemical stability. It is in the form of tin strands and has the following properties that make it useful in the casting of parabolic reflector antenna.

- The glass fibre has the ability to prevent energy loss. It is useful to enhance reflection of signal to the focal point.

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- It react very well with resin thus producing a nearly perfect paraboloid.
- It has resistance against moderately high temperature.
- It does not shrink with age nor promote bacterial or fungal growth.
- It has resistance against rusting, chemical attack and weathering.

The antenna for the present study was constructed by the method of moulding. A 3.0 m dish was constructed using a concrete mould. After washing the mould surface with a mixture of water and detergent and allowing to dry, a cake of soap dipped in water was rubbed on it leaving the surface with dispersed soap leather. After about ten minutes, resin solution (phenol-formaldehyde) was applied to the surface with the aid of a medium size painting brush. Layers of aluminum foil were neatly laid on the mould followed by layers of fiberglass. The resin held the foil to the mould throughout the period of the construction while the soap leather provided easy removal of the dish from the mould after construction. More resin solution was now spread on the fiberglass. The parabolic dish metal frame was placed on the mould, followed by other layers of fiberglass before the addition of resin solution to ensure firm grip between the fibre, aluminum foil and the metal frame. After 5 h, the dish was sufficiently dried and ready for use. After removal the edge was trimmed to shape. The front painted white while the back was painted gray. The mould was again washed as well as the brush. Relevant percautional measure taken was the washing of hands each time the resin solution came in contact with them.

The parabolic dish was used to access eight space stations; the audio signals of the stations were measured with the aid of a 40 MHz oscilloscope.

Path loss: The maximum path loss that a particular equipment can tolerate is called the path loss capability and is the different between the figure of merit of the transmitter and the receiver. If the actual path loss is greater than the path loss capability then communication is not possible. The figure of merit of a transmitter is called the effective isotropic radiated power (eirp) and is the power required to be radiated from an isotropic source to produce the same signal at the receiver input as the actual transmitter-receiver combination (Radio Society of Great Britain, 1994). The minimum power a receiving antenna must collect in order that the receiver can generate an intelligible output is the effective receiver sensitivity (ers).

Microwave propagation between space and earth station is through line of sight mode; the radiation intensity decreases as the square of the distance from the transmitting antenna. According to Timothy and Charles (1986), the loss incurred in a given path length r_A in the ionosphere is

$$L_A = 20\log\left(\frac{4\pi r_A}{\lambda}\right) \tag{1}$$

When a linearly polarized wave enters the ionosphere it splits into two characteristic waves, the ordinary and the extraordinary waves and each has its own polarization and propagation constant. The complex refractive index, n, at angular frequency w is given as (Hall and Barcley, 1991).

$$n^2 = 1 - \frac{X}{1 - iZ - \left[\frac{Y_T^2}{2(1-X-iZ)}\right] \pm \left[\frac{Y_T^4}{4(1-X-jZ)^2} + Y_L^2\right]^{\frac{1}{2}}} \tag{2}$$

Two special cases of this equation are possible namely the quasi-longitudinal and the quasi-transverse approximations and in each case the collision term Z = 0. the dimensionless quantities X, Yand Z are defined as follow

$$X = \frac{Ne^2}{\Sigma_o m w^2} \tag{3}$$

$$Y_T = \frac{eB\sin\vartheta}{mw} \tag{4}$$

$$Y_L = \frac{eB\cos\vartheta}{mw} \tag{5}$$

$$Z = \frac{v}{w} \tag{6}$$

θ is the angle between the propagation direction and the geomagnetic field, v is the electron collision frequency, N is the electron concentration, e and m are the electron charge and mass respectively and Σ_0 is the permittivity of free space and w is the angular wave frequency. For quasi-transverse propagation, The Appleton-Hartree equation reduces to the following forms for the upper and lower signs, respectively.

$$n^2_{upper} = 1 - X \tag{7}$$

$$n^2_{lower} = 1 - \frac{X(1-X)}{1-X-Y_T^2} \tag{8}$$

For quasi-longitudinal propagation, The Appleton-Hartree equation reduces to

$$n^2 = 1 - \frac{X}{1 \pm Y} \qquad (9)$$

The complex refractive index can also be written as

$$n = \mu - i\chi \qquad (10)$$

where μ is the actual wave refractive index and χ is responsible for wave absorption in the ionosphere. The decay in amplitude for a path length r_1 in the ionosphere is

$$L_I = kr_I\,\chi \qquad (11)$$

where k is the propagation constant in the ionosphere.

The two characteristic waves have different phase velocities so that their phase difference changes as they travel. At their exit from the ionosphere the two waves combine but because of the phase difference Ψ, theresulting polarization is not the original polarization. The resulting mismatch loss, according to Maral and Bousquet (1998), is written as

$$L_P = -20 \log \cos \Psi \qquad (12)$$

Figure of merit of earth station: The figure of merit of a receiver and its associated antenna is the effective receiver sensitivity (ers) and is the minimum power the antenna must receive in order that the receiver can generate an intelligible output and in term of antenna gain G and system noise temperature T_{sys} is written as (Radio Society of Great Britian, 1994; UNESCO, 1996).

$$ers = \frac{G}{T_{sys}}(dB) \qquad (13)$$

The system noise temperature is the sum of the noise temperature of LNB and dish. Carrier to noise spectral density can be written in terms of down link eirp of the transmitting and ers of the receiving systems (UNESCO, 1994).

$$\frac{C}{N_0} = eirp + \frac{G}{T_{sys}} - L_f - L_A - k \qquad (14)$$

The antenna noise temperature is a function of the direction in which it is pointing, its radiation pattern and the state of the surrounding environment (ITU, 2000).

$$T_A = T_m\left(1 - 10^{-(L/10)}\right) \qquad (15)$$

L is path attenuation, T_m is the average medium temperature (K) and it can be determined empirically by

$$T_m = 1.12T_g - 50 \qquad (16)$$

T_g is ground temperature (K).

Measurements and calculations: Eight different international television channels were received at Akure (latitude 7.28°N, longitude 5.2°E) with the aid of a 3.0 m parabolic reflector and a 40MHz oscilloscope measured the amplitude of the channels' audio signal of frequency 22 KHz. Unlike video signal, the audio signals are sinusoidal unstable signals and therefore the audio waveform of each television channel was photographed repeatedly (randomly) and the average of the waveform amplitude is taken to be the signal level in voltage for the channel.

Some of the channels accessed on the Intelsat satellites are

- Independent Television, Madagascar (ITV) on Intelsat 804
- TV Afrique channel 5 (TV5) on Intelsat 803
- Cable Network News (CNN) on Common Feed on Intelsat 803
- Portuguese Television (AF AFL) on Intelsat 605
- Metro (MET) on Intelsat 605
- East Africa Television (EATV) on Intelsat 804
- Dutch Television (DWTV) on Intelsat 704 and
- CFITV on Intelsat 803

The decibel equivalent of the signal level is deduced using signal level (Table 1)

$$(dB) = 20\log\left(\frac{V}{V_0}\right) \qquad (17)$$

where V is the signal level in volt and $V_0 = 1$ mV, is the reference voltage

The waves of all the channels received are plane polarized, though some are vertically polarized while the others are horizontally polarized. Table 2 contains the channel parameters. L_A was calculated using Eq. 1. The absorption indexes χ for the ordinary and extraordinary waves are 409.229 and 404.350, respectively. L_I and L_P were determined using Eq. 11 and 12, respectively. The total loss is denoted as L. Neglecting signal loss in the coaxial cable used to transport signal to the indoor receiver, the LNB output is the sum of LNB gain and the signal level input into the LNB (Table 3)

$$\begin{aligned} LNB_O &= LNB_G + LNB_I \\ LNB_G &= 55dB \end{aligned} \qquad (18)$$

Table 1: Signal levels at earth station

Channel	AFAFL	MET	ITV	EATV	CNN	CFITV	TV5	DWTV
LNB_O (dB)	35.269	38.062	30.630	25.437	30.103	34.151	34.648	32.041
LNB_I (dB)	-19.731	-16.938	-24.370	-29.563	-24.897	-20.849	-20.352	-22.959
A_S (dB)	46.489	49.282	41.850	36.657	41.323	45.371	45.868	43.261
eirp (dB)	110.002	110.002	110.466	110.466	101.667	101.667	101.667	93.864
C/N	230.914	230.914	231.304	231.304	232.304	232.304	232.304	230.985
plc	110.224	110.224	110.688	110.688	101.889	101.889	101.889	94.086

Table 2: Channel parameters

Channel	AFAFL	MET	ITV	EATV	CNN	CFITV	TV5	DWTV
Signal level (V)	0.580	0.800	0.340	0.187	0.320	0.510	0.540	0.400
Signal level (dB)	35.269	38.062	30.630	25.437	30.103	34.151	34.645	32.041
Polarization	V	H	H	V	H	V	V	V
Satellite position	60.0°E	60.0°E	64.0°E	64.0°E	338.5°W	338.5°W	338.5°W	359.0°W
Video Frequency (Ghz)	3.644	4.131	3.644	3.644	3.931	3.650	3.650	3.915

Table 3: Atmospheric losses

Channel	AFAFL	MET	ITV	EATV	CNN	CFITV	TV5	DWTV
$r_A \times 10^4$ (Km)	3.888	3.888	3.928	3.928	3.615	3.615	3.615	3.587
L_A (Db)	91.086	91.086	91.175	91.175	90.454	90.454	90.454	90.386
r_I (Km)	1161.857	1161.857	1360.516	1360.516	567.430	567.430	567.430	537.993
L_I (dB)	16.147	16.147	18.906	18.906	7.885	7.885	7.885	7.477
Ψ	81.115	81.115	81.506	81.506	65.527	65.527	65.527	29.826
L_P (Db)	16.220	16.220	16.620	16.620	7.650	7.650	7.650	1.240
L (dB)	107.446	107.446	107.984	107.984	98.183	98.183	98.183	91.701

The LNB_I is the sum of receiving antenna gain and the signal level received on the dish surface from space.

$$LNB_I = G + A \qquad (19)$$

$$G = 10\log\left(\frac{\pi D_A}{\lambda}\right)^2 \eta = -66.22\text{dB} \qquad (20)$$

where D_A =3.0 m, f =22KHz and η = 0.5 (ITU, 2000) .

The approximate figure of merit of each channel can be calculated from

$$\text{eirp} = A_S + L \qquad (21)$$

The antenna brightness temperature using Eq. 15 is 280K

T_m = 280 K for cloud or 260 K for rain (ITU, 2000).

The noise temperature of the $_{\text{LNB}}$ =17 K, therefore,

$$T_{sys} = T_A + T_{LNB} = 280+17 = 297\text{ K} \qquad (22)$$

The figure of merit of the TVRO then is

$$\text{ers} = \frac{G}{T_{sys}} = \frac{-66.22}{297} = 0.222\,\text{dB}/\text{K} \qquad (23)$$

The carrier to noise ratio of each of the channel can be calculated using Eq. 14. The path loss capability, plc, is then given as

$$\text{plc} = \text{eirp-ers} \qquad (24)$$

RESULTS AND DISCUSSION

In this study, the propagation path length in free space is large for each of the channels and therefore major signal loss occurred in free space. Losses due to absorption in the ionosphere and polarization mismatch are roughly equal and relatively minimal because the propagation path length in ionosphere for each channel is relatively short. The graphs reveal that increase in path length increases the signal loss in any of the media. Fig. 1 and 2 show a linear relationship between the loss and distance. The dependence of polarization loss on wave rotation show in Fig. 3 is not completely linear. The losses on channels in east are more because the lower the elevation angle, the more the path length and consequently the greater the loss. The paths with short path length have greater signal level on the dish surface. The efficiency of the receiver is relatively low being audio signal and therefore the effective receiver sensitivity too. The gain of the LNB is large compared to that of the reflecting surface and therefore substantially increase the signal level t the dish surface. The carrier to noise ratio of the channels is almost equal and substantially high, this is because the noise temperature of the receiving system

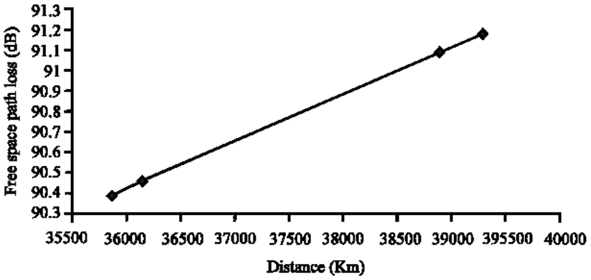

Fig. 1: Free space path loss as function of distance

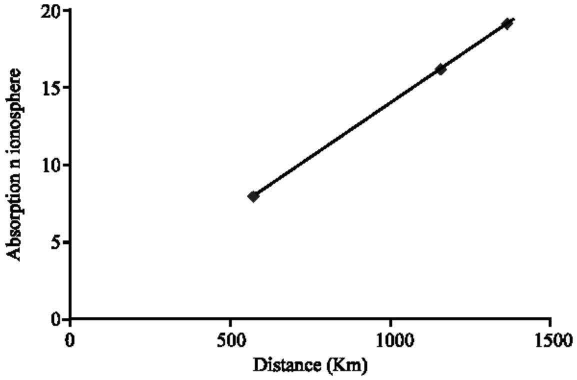

Fig. 2: Ionospheric absorption variation with distance

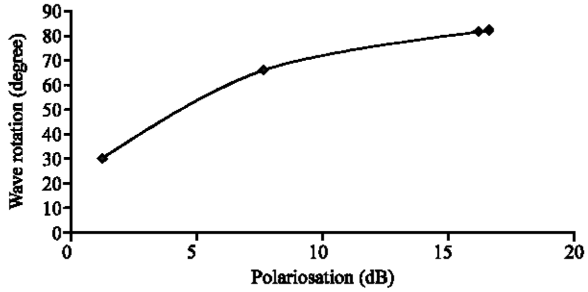

Fig. 3: Dependence of polarisation loss on wave rotation

is relatively low. The effective isotropic radiated power of the channels is almost equal, showing the channels transmit with the same power. The path loss capability exceeds the actual path loss in all the channels and therefore intelligent output were received in all the channels.

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