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INVESTIGATION OF TRANSMISSION IMPAIRMENTS ON BAUCHI FM BROADCAST THROUGH FIELD STRENGTH MEASUREMENTS

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Abstract. Measurements of relative field strength were carried out on the FM Broadcasting frequency of 94.57 MHz of a 20kW transmitter of the Bauchi Radio Corporation. Measurements were taken at regular intervals up to a distance of 70 km along five different routes starting from Bauchi (10.25°N, 9.75°E) in each case. There was a rapid deterioration of the field strength with distance owing to factors such as shadowing or diffraction and meteorological conditions in the lower atmosphere. Coverage gaps existed in shadowed valleys. Fill-in stations are required in regions of poor service to provide limited local coverage. Even when the transmitting antenna has adequate terrain clearance listeners can help improve their own reception by sitting their antenna to minimise local shadowing losses.

1. INTRODUCTION

Communication services in low frequency (LF) and medium frequency (MF) bands rely mainly on the ground wave. In the high frequency (HF) band, the sky wave is employed by taking advantage of the reflecting properties of the ionosphere. In the very high frequency (VHF) and ultra high frequency (UHF) bands, the lower parts of the atmosphere is used as the propagation medium and the mechanism is usually described as tropospheric propagation.

The troposphere can be regarded as the region of the atmosphere extending from the earth's surface up to about 16 km near the equator. Freeman [1] described two theories explaining over-the-horizon communication by tropospheric scatter. One theory postulates that atmospheric turbulence, irregularities in the refractive index, or similar homogeneous discontinuities are capable of diverting a small fraction of the transmitted radio energy toward a receiving station. The other theory is that the air is stratified into discrete layers of varying thickness in the troposphere. The boundary between these layers become partially reflecting surfaces for radio waves and thereby scatters the waves downward over the horizon. In this region, the free-space conditions are modified by: 1) the earth's terrain and 2) meteorological condition in the earth's atmosphere.

Measurements of relative field strength were carried out on Bauchi Frequency Modulation (FM) Broadcast in order to investigate the causes of impairments on that service.

2. MODE OF PROPAGATION

Consider propagation over flat ground, as in Fig.1, with a transmitting antenna at height h_t and a receiving antenna at a height h_r, the spacing d is taken to be large compared with h_t and h_r.

The path of the direct wave is TR and that of the reflected wave is TPR. The field at R is then the vector sum of the two components, which are approximately equal in magnitude. The components would be in phase opposition but for the fact that the path lengths TR and (TP + PR) are different. When d is large compared with h_t and h_r, this path difference is given [2] as

$$\text{Path difference} = \frac{2 h_t h_r}{d} \tag{1}$$

and the corresponding phase difference is

$$\text{Phase difference} = \frac{4\pi h_t h_r}{\lambda d} \tag{2}$$

We thus have two components, each of amplitude $\frac{E_0}{d}$ (where E_0 is the field strength at unit distance from the transmitting antenna) and the phase difference being as given above. The resultant is therefore

$$E_r = \frac{2E_0}{d}\sin\frac{2\pi h_t h_r}{\lambda d^2} \tag{3}$$

When λd is large compared with h_t and h_r, equation (3) becomes

$$E_r = E_0\frac{4\pi h_t h_r}{\lambda d^2} \tag{4}$$

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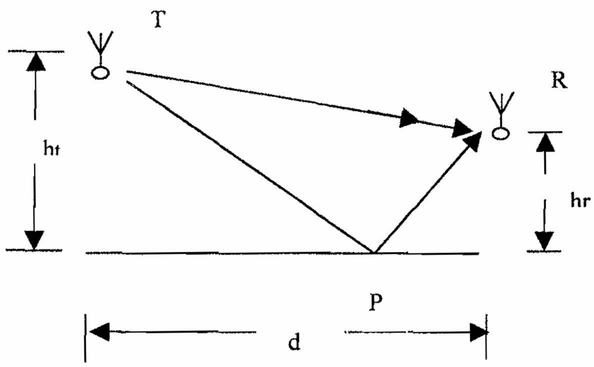

Figure 1: Propagation over flat ground

This gives the field strength received at distance d from the transmitter.

According to Roddy and Coolen (1990), E_0 is given by

$$E_0 = \sqrt{30 P_t G_t} \quad (5)$$

where P_t = average power of the transmitter and G_t = maximum directivity gain of the transmitting antenna

According to [1] we can think of the decrease of the field strength with distance as arising from a $\frac{1}{d}$ factor for the signal radiated by the source into empty space and a further $\frac{1}{d}$ factor because as d increase we, are sliding down the flank of the main beam. The results of the field strength, calculated for various distances from the transmitter, are presented in Table 1.

3. MEASUREMENT OF FIELD STRENGTH

Measurement of relative field strength were carried out on the FM Radio Broadcasting frequency of 94.57 MHz of a 20 kW transmitter of the Bauchi Radio Corporation (BRC), situated in Yelwa, Bauchi. The investigation, carried out in March 1995, covered a radius of 70 km at intervals of 10 km (using car distance meter) in five different directions from Bauchi (10.25°N, 9.75°E). The five routes from Bauchi are Alkaleri, Tafawa Balewa ,Toro, Kafin Madaki and Darazo as can be seen from Bauchi map in Fig.2.

4.1 *Equipment for Measuring Field Strength*

Fig.3 shows the layout for the measurement of the field strength using a field Strength Meter. The set up consists of a Field Strength Meter, a half-wave dipole antenna and a coaxial transmission line (feeder). The field strength meter is essentially a radio receiver equipped with attenuators (RF and IF stages) and incorporates the generator (noise generator) of comparison signal serving as reference when measuring the level. The comparison signal generates noise at constant level regardless of frequency. For measurement, this output is first received and then the attenuator is set taking it as the reference level. Then, the wave to be measured is received and the attenuator is adjusted so that the reading becomes identical with that of the reference level. The level under measurement is obtained from the attenuator reading at that time.

4.2 Procedure for Measurement of Field Strength

The procedure for obtaining readings using the field strength meter is follows:

i) Prior to measurement, the level calibration is first performed using the procedure outlined in instruction manual.

ii) Field strength is found by measuring RF voltage V induced at the measuring antenna placed within unknown field, E and converting the voltage thus obtained using the conversion factor as follows:

Table 1: Values of calculated field strength at various distances from the transmitter

Distance from Transmitter (km)	1	10	20	30	40	50	60	70
Field Strength [dB(μ V/m)]	101.78	61.79	49.75	42.70	37.70	33.83	30.66	27.98

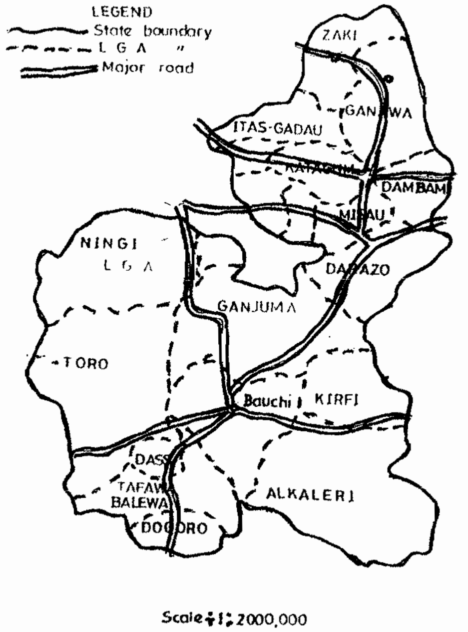

Fig.2: Administrative map of Bauchi State

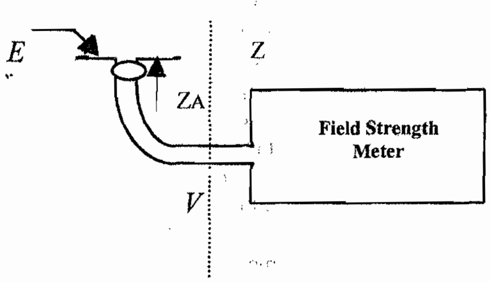

Fig.3: Layout for measurement of field strength

$$E = V - K\,E \quad (dB(\mu V m^{-1}) \qquad (6)$$

where K is the voltage-field conversion factor. The voltage and field strengths are expressed as follows:

Voltage = RF attenuation reading + IF attenuation reading (conversion factor not included) + meter reading (7)

Field Strength = RF attenuation reading + IF attenuation reading (conversion factor included) + meter reading (8)

The field is kept from being disturbed to the extent possible by separating the antenna far from an obstacle as much as possible while taking the measurements.

4. RESULTS AND DISCUSSION

The values of field strengths measured at 10 km intervals starting from the transmitter along the five routes are given in Table 2. Fig.2 is the administrative map of Bauchi State showing the site of the transmitter and the various routes along which the investigations were carried out. Fig.4 depicts plots of field strength versus distance for the five routes as well as a comparison between calculated and measured values. It shows a rapid deterioration of field strength with distance along the various routes similar to theoretical prediction except that Toro route shows less fading until towards the far end. In the computations, consideration was given to the fact that the FM station was broadcasting at half power (10 kW).

The transmitting antenna of the FM station of height 100m has adequate terrain clearance. As can be seen from the road profiles (Figs. 4-9), it is placed on a high point of 2050m above mean sea level.

Along Toro route the highest point is 2400m above the datum while the lowest point is the same as the height reference. This explains the high field strength values observed along this route. However, many hilly areas can be observed along this route. All the other routes have contours that are lower than the reference point.

Table 2: Field strength measured along five different routes from Bauchi

Distance from Transmitter (km)	Field strength [$dB(\mu Vm^{-1})$] Darazo Route	Tafawa Balewa Route	Alkaleri Route	Toro Route	K/Madaki Route
1	76	74	80	86	88
10	65	66	62	62	51
20	49	59	50	58	44
30	38	44	42	48	32
40	26	39	31	39	28
50	22	34	26	28	25
60	17	24	19	22	15
70	8	19	16	11	10

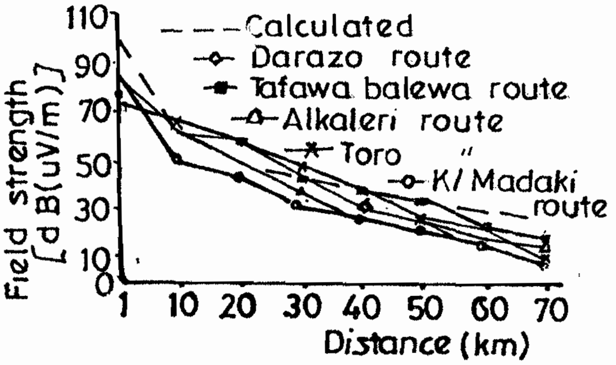

Fig.4: Field Strength versus distance for FM (94.57 MHz) Bauchi

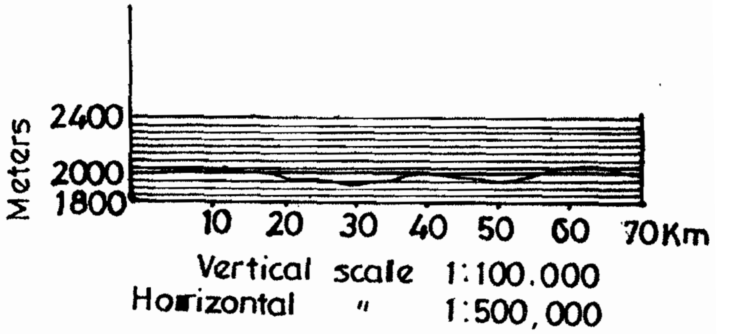

Fig.6: Profile of Bauchi-Kafin Madaki route

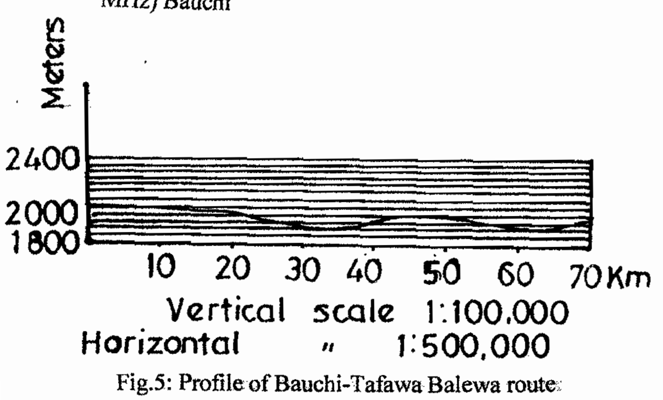

Fig.5: Profile of Bauchi-Tafawa Balewa route

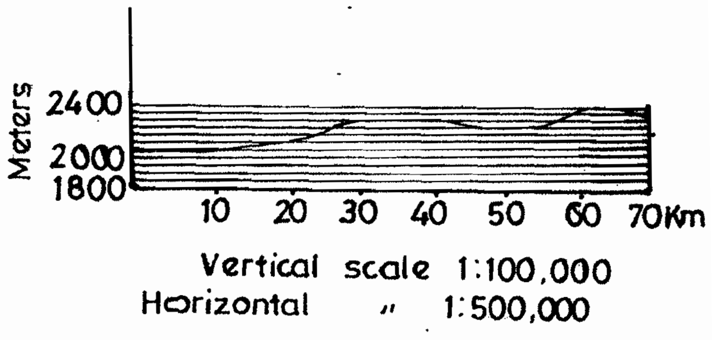

Fig.7: Profile of Bauchi-Toro route

Coverage gaps existed in shadowed valleys. For example, Karfin Madaki, Darazo and Alkaleri route suffer from these phenomena. Such places need to be served by "fill-in" stations providing limited local coverage. Listeners can help to improve their own reception conditions by first considering the direction from which the signal arrives and then citing the antenna to minimise local shadowing losses. Hills, tall buildings, trees and similar obstacles cause radio shadows similar to optical shadows. The higher the frequency the more the shadowing loss of a given obstacle becomes.

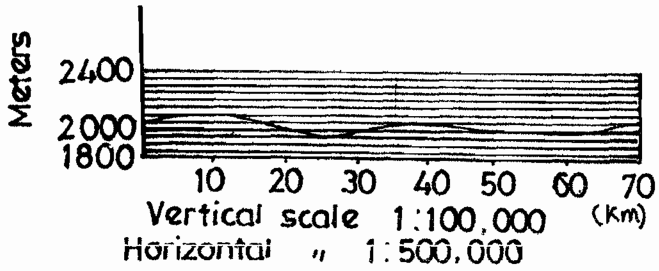

Fig.8: Profile of Bauchi-Darazo route

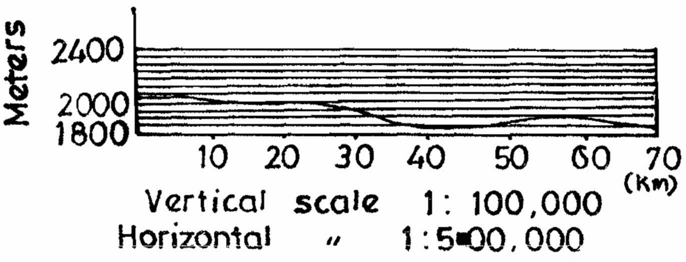

Fig.9: Profile of Bauchi-Alkaleri route

In practice, the troposphere is not homogeneous. The temperature, pressure and humidity vary from point to point and also with time, so that there are consequent variations in the refractive index, which although small, scatter the incident radiation to some extent. The meteorological conditions responsible for such variations and their influence on radio-wave propagation have been described by [2,3,4]. Under conditions with strong vertical humidity and temperature gradient in the atmospheric layers of large horizontal extension, radio waves may be trapped, resulting in enhanced field strengths far beyond the radio horizon [5]. Ajayi [6] gave evidence of transhorizon propagation between Lagos and Ile-Ife at the FM Broadcasting Service of the Federal Radio Corporation of Nigeria (FRCN). He attributed the observed anomaly to partial reflection and scattering in the lower atmosphere.

5. CONCLUSION

In the VHF and UHF bands we use space waves without the advantage of a reflecting layer but the use of the available radiation is then very insufficient. The space wave is equivalent to a main beam radiated upwards whereas the antennas of our receivers are necessarily very close to the ground. We are therefore working on the flank rather than on the maximum of the main beam in addition to other interferences. Since it is not possible to eliminate such interferences completely, services should be protected from interferences for a given percentage of time, usually 95 percent.

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