Journal of the Nigerian Association of Mathematical Physics
***Volume* 23 (March, 2013), pp 503 – 510**
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Measurement of Soil Electrical Parameters For Planning AM and FM Radio Broadcast Stations In Southwestern Nigeria.

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Abstract

This research investigates the effect of soil electrical parameters affect radio wave propagation on communication. Davis 6345 vantage pro 2 wireless leaf and soil moisture/soil temperature measuring equipment capable of measuring soil moisture content and soil temperature were used.

The wireless soil moisture and temperature sensor interface module acts as a transmitter, transmitting soil moisture and soil temperature data at a fixed frequency of 928MHz to the console (receiver) of the vantage pro 2 equipped with a customized data logger to log the data at a predetermined time interval. Soil parameters were measured at seven different locations with reference to AM/FM radio broadcast stations that are available in those locations. Using the transmitting power of these radio stations and the soil parameters obtained, electric field strength values were estimated for each location via the use of Matlab ®2007b.

Investigation shows that radio stations with amplitude modulation (AM) for example Eko FM(Lagos), Kwara Radio (Ilorin) and Gateway Radio (Ogun) show more decrease in electric field strength with increase in distance compared to radio stations with frequency modulation (FM). Relative permittivity of the stations obtained are as follows: Lagos ranges from 6.40 – 9.86, Ilorin showed relative permittivity in the range 6.18 – 8.13, and Ado-Ekiti, 4.90 – 9.61. The ranges 4.62 – 6.70, 6.40 – 9.89, 7.00 – 9.80 and 8.20 – 9.50 were obtained for the stations Ibadan, Abeokuta, Akure and FUTA respectively.

1.0 Introduction

Radio wave propagation is essential to human existence. Some of the challenges affecting good propagation from a radio source include meteorological factors [1], extraterrestrial sources such as geomagnetic storms [2].

The two important electrical properties of the ground are therefore its conductivity and permittivity. The permittivity is often assumed constant for a particular soil and area. Therefore, it is the conductivity that is more important because it varies with the properties of the soil. Effective ground conductivity of the surface of the earth lies between 0.1 -30S/m, it is therefore very important to know the value around a transmitting mast so as improve its value if it too low [3-4].

An antenna is a structure usually made from a good conducting material that has been designed to have a shape and size such that it will radiate electromagnetic waves. Also, an antenna is a structure on which time- varying current can be excited with a relatively large means of a transmission line or waveguide [5].

The available literatures on this subject are replete with several models developed to estimate soil permittivity, but the Topp *et al*[6] model relates directly the volumetric moisture content (θ_v) with the permittivity (ε_a) and it is generally applicable to coarse grained /fine grained mineral soils[7]. It can be employed to estimate permittivity of relationship written as:

$$\varepsilon_a = 3.03 + 9.3\theta_v + 146\theta_v^{\,2} - 76.7\theta_v^{\,3} \qquad (1)$$

This model was adopted because it accommodates the various soil classifications and the moisture content values of all the locations visited. However, because the soil moisture content sensor used measured moisture content of the soil in centibar (cb), the values obtained from the Vantage Pro 2 instruments were converted to volumetric water content using the relationship

$$\theta_v = K + 0.09807 \times 10^{-2} m^3 m^{-3} \qquad (2)$$

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Volumetric Soil Moisture content can be defined as the ratio of the volume of water present in a soil sample to the total volume of the soil sample. That is

$$\theta_v = \frac{Volume\,of\ water\,in\,a\,soil\,sample\ (m^3)}{Total\ Volume\,of\ the\,soil\,sample\,(m^3)} \tag{3}$$

The field strength attained by radio transmitter at a given distance from the point of emission over homogenous terrain, that is with practically constant electrical values of the soil, is given by the relation[8]:

$$E(d) = \frac{9.487\sqrt{\mathrm{P}_E}\,\mathrm{A}(\rho)}{d} \tag{4}$$

where

E is the electrical field strength available in V/m at the receiving point to be reached (by transmitter).

P_E is the effective radiated power in watts

d is distance between n the transmitter and receiver in kilometer

$\mathrm{A}(\rho)$ is the flat-earth attenuation function that takes into account the ground losses.

For $P_{0\leq 4.5}$ and all b: $A = e^{-A3P_0 - 0.01P_0^2} - (\sqrt{P_0/2})(\sin\ b)e^{-5/8P_0}$ (5)

For $P_{0>4.5}$ and all b: $A = \frac{1}{2\mathrm{P}_0 - 3.7} - (\frac{\sqrt{\mathrm{P}_0}}{2})(\sin\ b)(e^{-5/8P_0})$ (6)

The attenuation factor A takes into consideration of the losses of the ground wave occurring in the earth. It depends on the frequency, the ground constants and the radio path length. Its exact calculation is time consuming, however, if simplifying assumptions are introduced the attenuation factor can be expressed in terms of numerical distance P_0 and the phase constant b. The accuracy of this calculation is perfectly adequate for the practical determination of equipment requirements.

For vertical polarization:

$$\mathrm{P}_0 = \frac{\pi R(km)\,f\,(MHz)^2\cos b}{(54\times 10^2)\sigma} \tag{7}$$

$$b = \tan^{-1}\frac{(\varepsilon_r + 1)\,f\,(MHz)}{18\times 10^3\sigma} \tag{8}$$

and for horizontal polarization:

∧

$$\mathrm{P}_0 = \frac{\pi R(km)6\times 10^4\sigma}{\cos b} \tag{9}$$

$$b = \tan^{-1}\frac{(\varepsilon_r - 1)\,f\,(MHz)}{18\times 10^3\sigma} \tag{10}$$

where

f is the frequency in MHz

σ is the conductivity of the earth in Siemens per meter

ε is the relative permittivity of the earth

2.0 Methodology

There are various techniques by which soil parameters can be measured. The suitability of each method depends on several issues like cost, accuracy, response time, installation, management and durability[9]. Some of the available methods include Cone Penetrometer, Time Reflectometry, frequency Domain Reflectometry, water content reflectometer and Telemetry method.

For the purpose of this work, the telemetry method was used with the Davis 6345 Vantage Pro 2 Wireless Leaf and Soil Moisture/Temperature measuring equipment capable of measuring soil moisture content and soil temperature. The error margins of the Davis Instrument used for temperature and soil moisture content are $\pm 0.5^0$C and ± 0.5 cb respectively.

The research was conducted over six (6) states of the country and considering six (6) Radio stations. The frequency and radiating power of the transmitter of radio stations from different locations are used as case study as shown in the table 1.

Table 1: Frequency and Radiating Power of Radio Stations under study.

LOCATION	FREQUENCY	RADIATING POWER (KW)
EKO FM (Lagos)	617kHz	50
KWARA RADIO (Ilorin)	612kHz	50
OLUYOLE FM (Ibadan)	98.5MHz	50
GATEWAY RADIO (Ogun)	94.5MHz	20
POSITIVE FM (Akure)	102.5MHz	8.1
EKTV (Ekiti)	631kHz	22
FUTA FM (Akure)	93.1MHz	1.0

RESULTS AND DISCUSSIONS

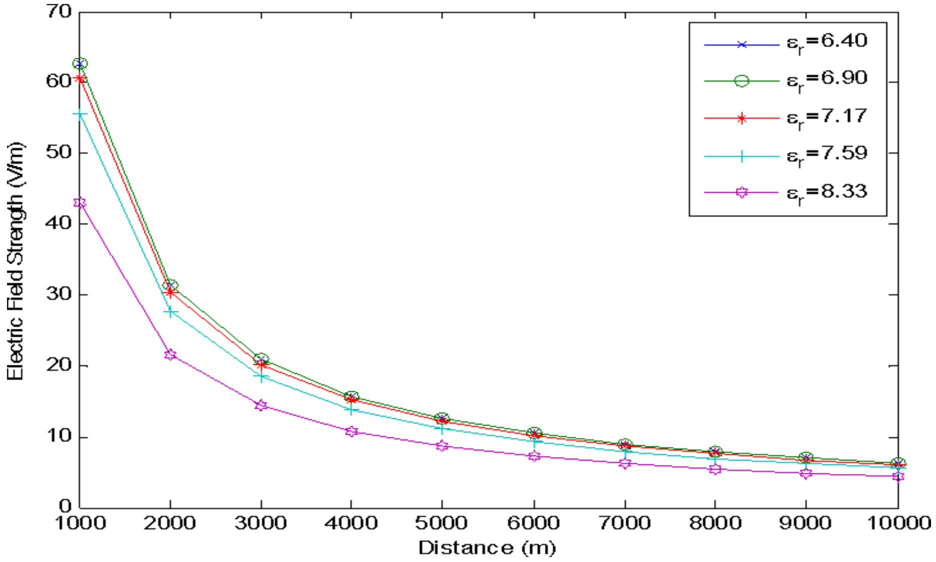


Fig 4.1: Graph of electric field strength (V/m) against distance (m) in Lagos.

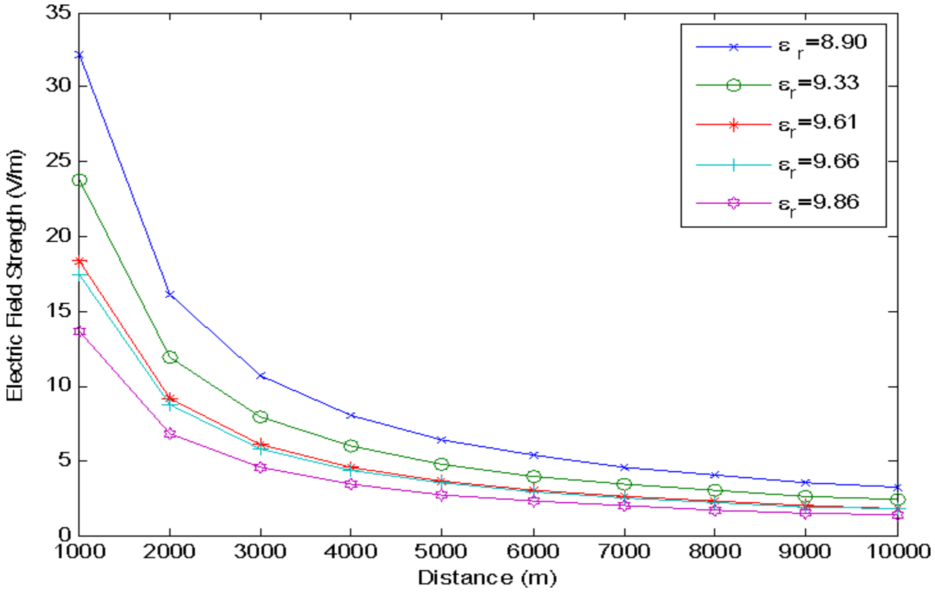


Fig 4.2: Graph of Electric field strength (V/m) against distance (m) Lagos.

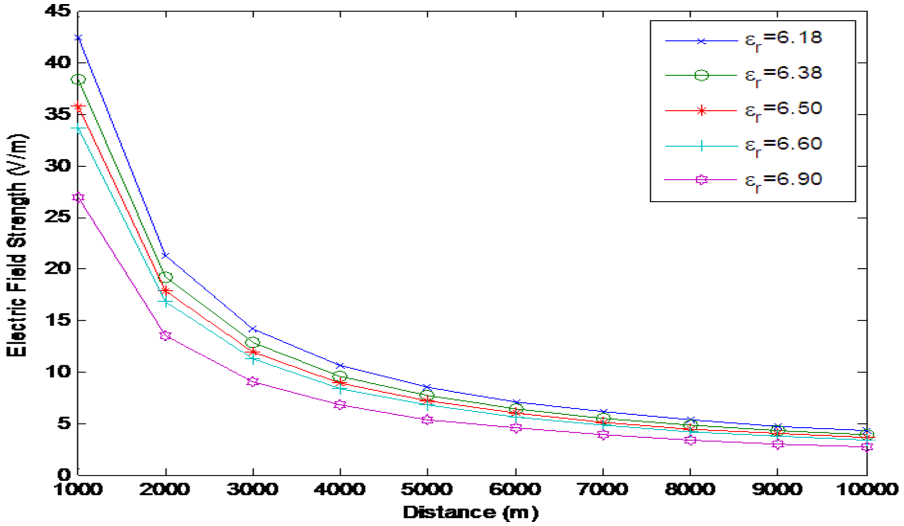


Fig 4.3: Graph of electric field strength (V/m) against distance in Ilorin.

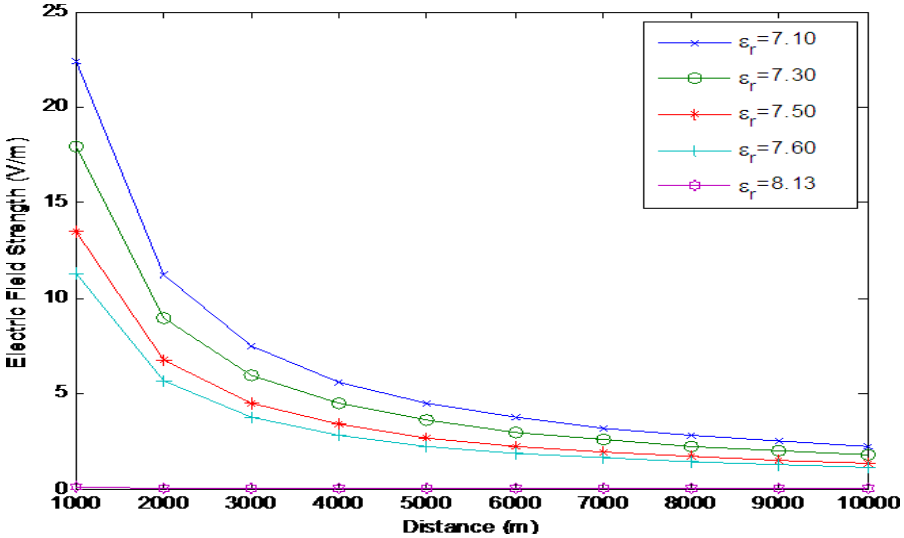


Fig 4.4: Graph of electric field strength (V/m) against distance (m) in Ilorin.

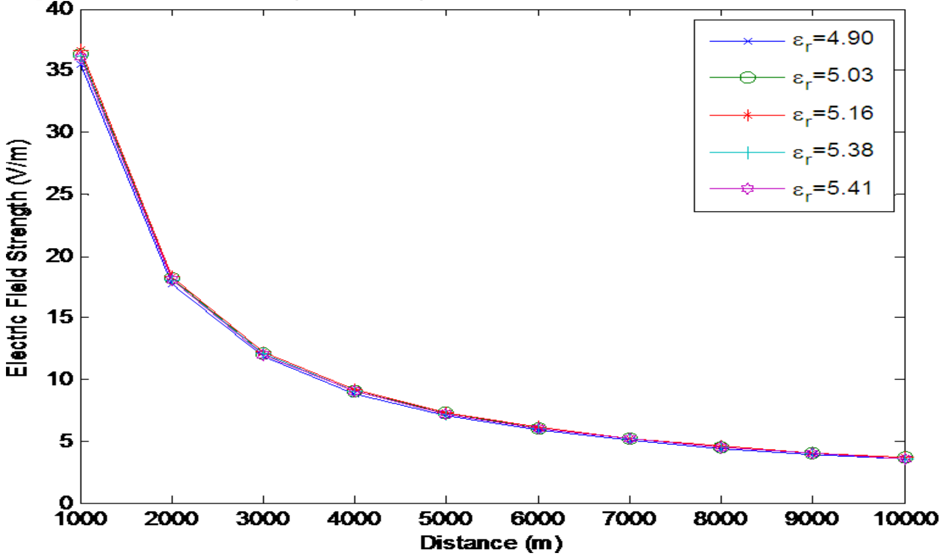


Fig 4.5: Graph of electric field strength (V/m) against distance (m) in Ado Ekiti.

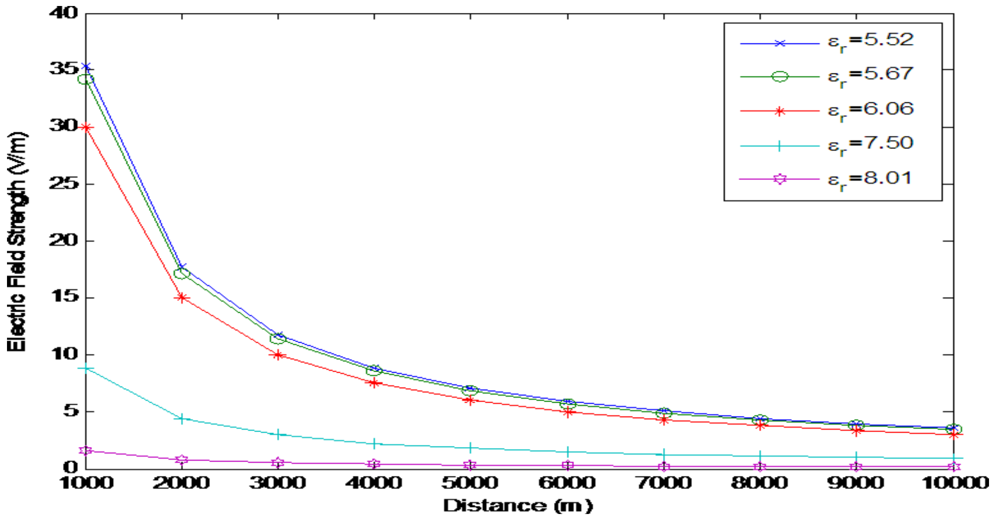


Fig 4.6: Graph of electric field strength (V/m) against distance (m) in Ado Ekiti.

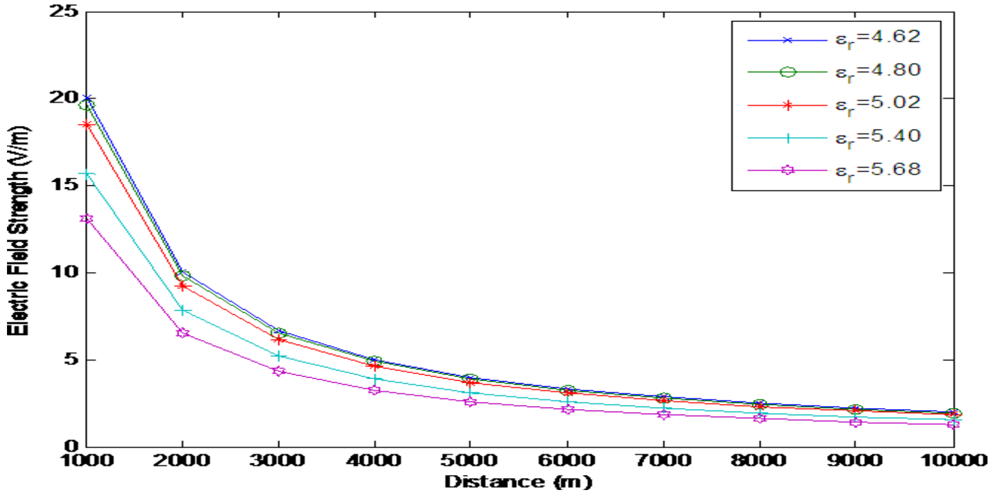
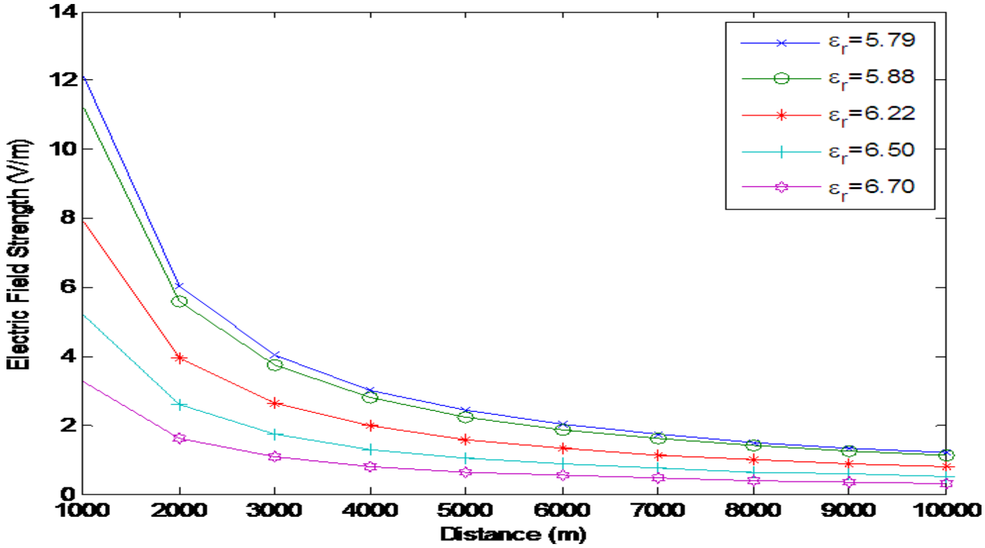


Fig 4.7: Electric field strength (V/m) against distance (m) in Ibadan.



4.8: Electric field strength (V/m) against distance (m) in Ibadan.

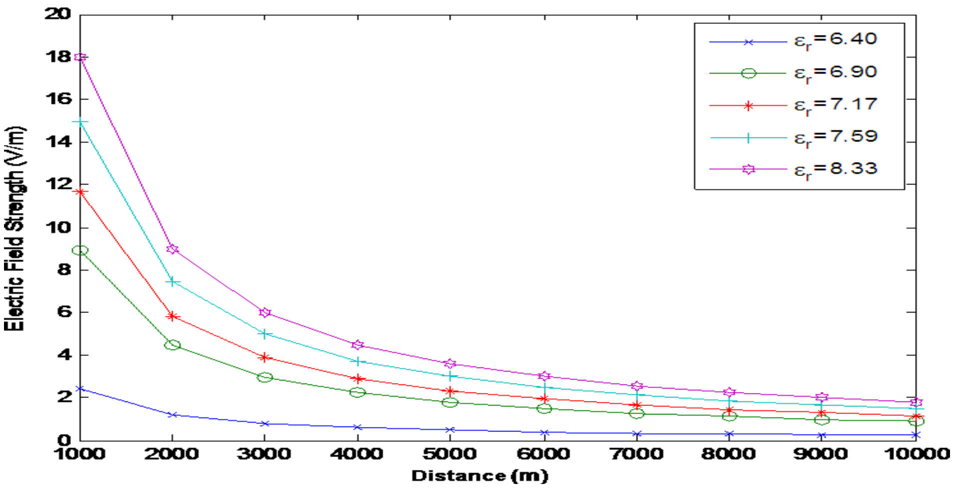


Fig 4.9: Electric field strength (V/m) against distance (m) in Ogun State.

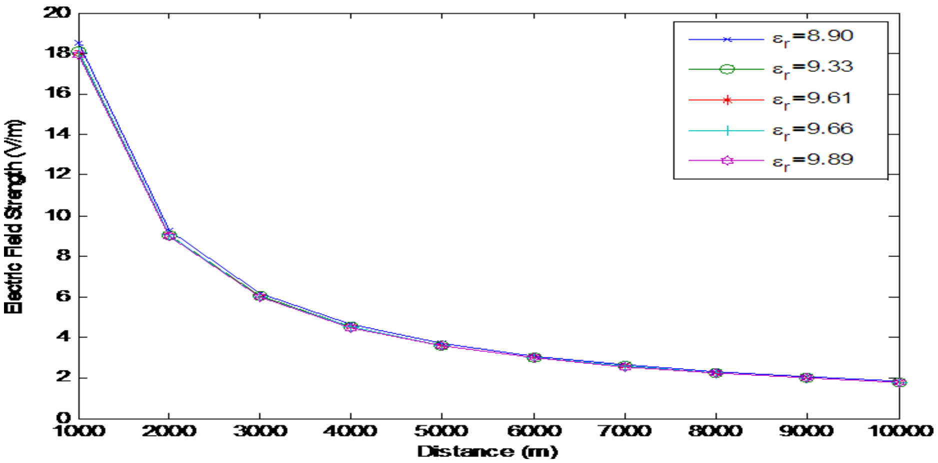


Fig 4.10: Electric field strength (V/m) against distance (m) in Ogun State.

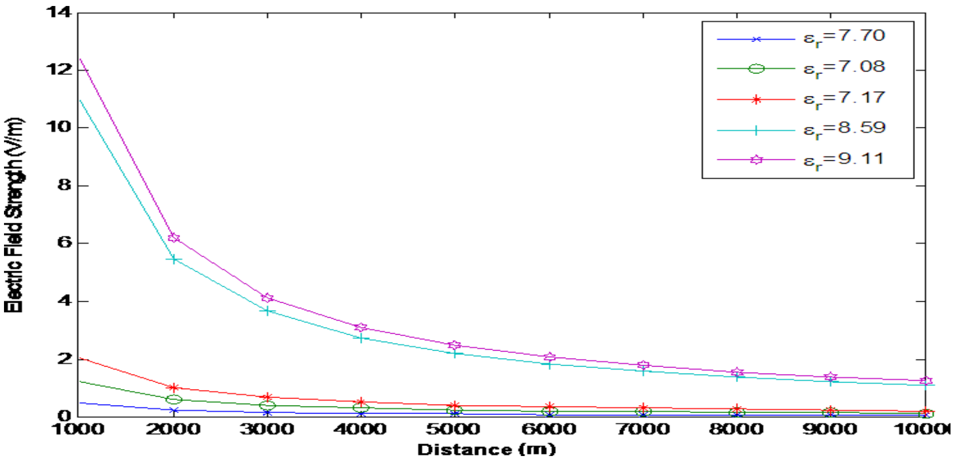


Fig 4.11: Electric field strength (V/m) against distance (m) in Akure.

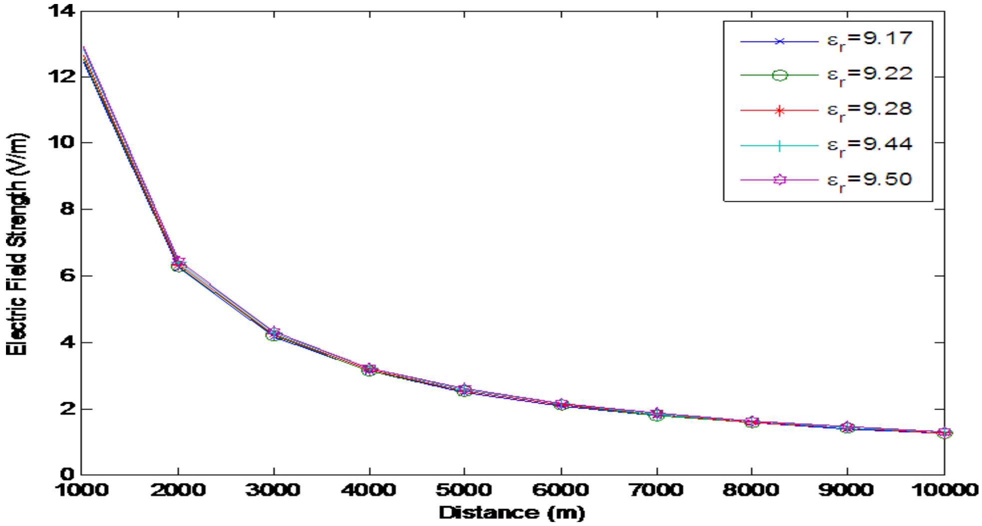


Fig 4.12: Electric field strength (V/m) against distance (m) in Akure

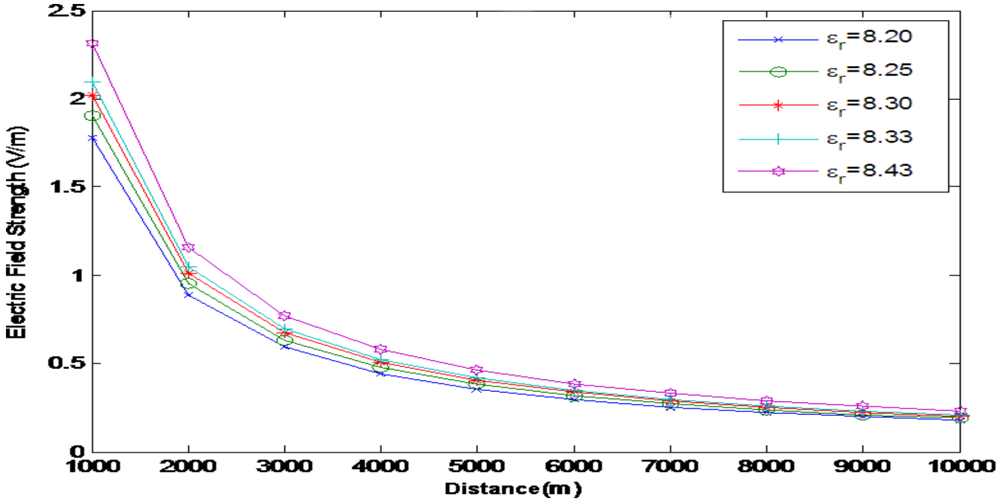


Fig 4.13: Electric field strength (V/m) against distance (m) from FUTA (Ondo State)

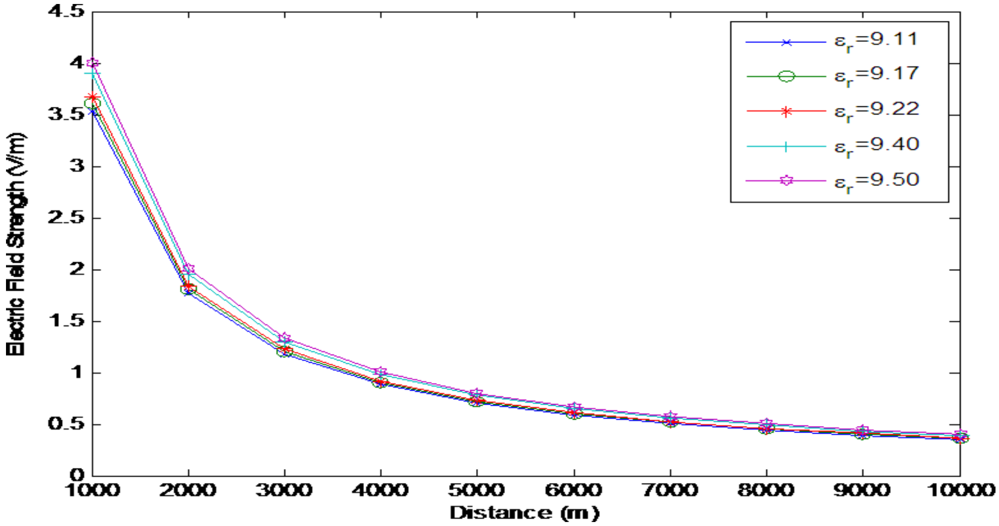


Fig 4.14: Electric field strength (V/m) against distance (m) in FUTA.

CONCLUSION

In this study, the relative permittivity has been measured around six states and seven radio stations (FM/AM) in Southwestern Nigeria. The results obtained shows that radio stations with amplitude modulation (AM) for example Eko FM(Lagos), Kwara Radio (Ilorin) and Gateway Radio (Ogun) show more decrease in electric field strength with increase in distance compared to radio stations with frequency modulation (FM). Relative permittivity of the stations obtained are as follows: Lagos ranges from 6.40 – 9.86, Ilorin showed relative permittivity in the range 6.18 – 8.13, and Ado-Ekiti, 4.90 – 9.61. The ranges 4.62 – 6.70, 6.40 – 9.89, 7.00 – 9.80 and 8.20 – 9.50 were obtained for the stations Ibadan, Abeokuta, Akure and FUTA respectively.

The variation of electric field strength of the radio stations with distance show a steady declined according to theoretical value of $(1/r^2)$, where r = distance from the station.

It is recommended that stations such at Ilorin, Ado-Ekiti and Ogun use artificial ground screen and boost their signals to improve reception at distances far away from the station.

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