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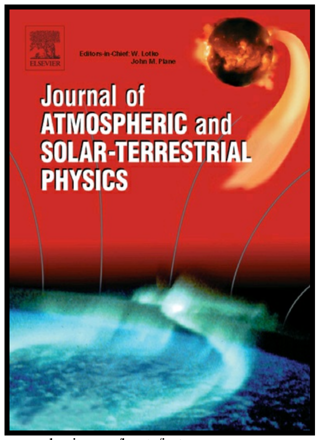

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Phase synchronization between tropospheric radio refractivity and rainfall amount in a tropical region

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Abstract

This study investigated linear and nonlinear relationship between the amount of rainfall and radio refractivity in a tropical country, Nigeria using forty seven locations scattered across the country. Correlation and Phase synchronization measures were used for the linear and nonlinear relationship respectively. Weak correlation and phase synchronization was observed between seasonal mean rainfall amount and radio refractivity while strong phase synchronization was found for the detrended data suggesting similar underlying dynamics between rainfall amount and radio refractivity. Causation between rainfall and radio refractivity in a tropical location was studied using Granger causality test. In most of the Southern locations, rainfall was found to Granger cause radio refractivity. Furthermore, it was observed that there is strong correlation between mean rainfall amount and the phase synchronization index over Nigeria. Coupling between rainfall and radio refractivity has been found to be due to water vapour in the atmosphere. Frequency planning and budgeting for microwave propagation during periods of high rainfall should take into consideration this nonlinear relationship.

Keywords: phase synchronization, radio refractivity, precipitation, recurrence plot, RQA, climate

1. Introduction

Exponential growth in radio communication needs has necessitated the demand for more bandwidths for communication (Adedayo et al., 2013). Possibilities of high and low frequencies are being investigated to meet the growing demands. Satellite communications systems are designed with several factors such as fading, noise, cross polarization etc in mind. Several factors such as soil parameters (Adedayo et al., 2013), cloud, and rainfall affect signal propagation in communication systems. Liquid Water Content (LWC) of clouds has been reported to contribute about 0.8% to the total refractivity in the troposphere (Yang and Zou, 2012). The contributions of hydrometeors, water vapour, dry air and other particulate to propagation have been reported by Solheim et al. (1999). The path delay (ZD) can be computed using the expression $ZD(mm) = \int_0^\infty N dz$, where N is the refractivity and z is the vertical signal path in kilometers (Solheim et al., 1999; Hogg et al., 1981). To account for the effect of rainrate (R) on attenuation (A) of radio signals in the troposphere, Olsen et al. (1978) proposed a relationship of the form $A = aR^b$ where a and b are functions of transmitting frequency and rain temperature. However, propagation of electromagnetic waves in the troposphere (about 10km) altitude above the earth surface) is affected by two key factors: precipitation and variations in refractivity.

Rainfall is very important to the existence of man. It plays important role in determining the economy of a location. Excessive rainfall causes ecological disasters while insufficient rainfall makes a location unsuitable for existence. Rainfall has been described as one of the most complex and difficult components of the hydrological cycle to model (Maity, 2012). Rainfall interferes or attenuates communication signals, making it an important factor to be considered in frequency planning. The attenuation of signals due to rain becomes very significant at frequencies

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