Spectral Analysis of Ku-Band Scintillation Dataset for Satellite Communication in a Tropical Location

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Ayodeji Gabriel Ashidi
Department of Physics
Federal University of Technology,
PMB 704
Akure, Nigeria
agashidi@futa.edu.ng

Joseph Babatunde Dada
Department of Physical sciences
Elizade University
Ilara-Mokin, Nigeria
babatunde.dada@elizadeuniversity.edu.ng

Yusuf Babatunde Lawal
Department of Physical Sciences
University of Africa
Toru-Orua, Nigeria
yusuf.lawal@uat.edu.ng

***Abstract*— This study undertakes the determination of suitable cutoff frequency for extracting scintillation amplitude dataset from radio propagation beacons on satellite link within Akure (7.17ºN, 5.18ºE), Southwest Nigeria. Attempt was also made towards evaluating the spectral characteristics of scintillation parameters through power spectra density (PSD) analysis. Concurrent measurement of satellite beacon signals and meteorological parameters was carried out on Earth-space path over the location for tropospheric amplitude scintillation studies. Tektronix Y400 NetTek Analyzer and Davis Vantage Vue weather station were used for beacon and weather parameters measurements at 1 second and 1 minute integration times respectively. Data spanning one (1) year of measurement were used for the investigation. Results show that extra contributions to signal distortions by non-scintillation mechanisms during extraction of scintillation dataset from satellite radio beacon series may be eliminated by using a cutoff frequency, f_c of 0.25 Hz for high pass filtering. Also, spectral slopes with lower magnitudes were found to occur more predominantly than those with higher magnitudes.**

Keywords*— Amplitude, scintillation, satellite communication, cutoff frequency, spectral slope

I. Introduction

The spectrum of a signal is fundamentally a description of the energy of that signal as a function of frequency. Spectral analysis therefore refers to the various methods deployed to determine the spectra of a given signal [1], [2], [3]. One of such methods is the power spectral density (PSD) estimation.

Spectral analysis of scintillation amplitude time series is significant for a couple of practical applications. Firstly, the magnitude of the PSD at any frequency indicates the level of distortions contributed to the totality of scintillation variance of the system per time at such frequency. Also, the area under the power spectral density curve gives the variance of the scintillation process. It is equally significant in determining suitable cutoff frequency for separating between fluctuations in satellite signal beacons due to amplitude scintillation and those due to other propagation impairing factors such as rain, fog, hay, clouds, etc [4], [5], [6], [7], [8], [9]. In scintillation studies, it is very important to ensure stationarity of link parameters (especially meteorological parameters) on the earth-space path. This is achieved by computing power spectral density (PSD) functions over short time intervals in which meteorological variables remain approximately constant. From previous studies [4], [5], [6], [7], [8], [9], [10], and the analysis of scintillation dependence on measurement interval, the time period is recommended to be below one hour as much as possible [1], [2], [3], [11], [12], [13].

For accurate determination of scintillation amplitude spectral characteristics, it must first be established that fluctuations in the received signal beacons due to scintillation have been carefully separated from those due to other propagation factors. Consequently, the extraction of scintillation amplitude dataset, computation of its power spectral density, determination of its spectral shape parameters (slope and cutoff frequency) and how these parameters relate to scintillation intensity are the crux of this study.

II. Synopsis of Scintillation Data Extraction and Power Spectral Density Estimation

A. Extraction of Scintillation Dataset

Extraction of amplitude scintillation dataset from the "pack" of propagation beacon distortions using the most accurate cutoff frequency is very important. It helps to ascertain that legitimate contributions from scintillation mechanism to the fast fluctuations in the signal amplitude are not filtered off; while ensuring also that fluctuations due to other propagation impairing factors such as rain, fog, hay, clouds, etc. are effectively prevented from "contaminating" the scintillation dataset. The standard practice of reading off the cutoff frequency as the frequency value at the intersection between the asymptotes to the flat and sloping portions of the spectrum having a low pass filter shape is commonly prescribed. But in reality, the spectral shape is not usually so well defined and it is sometimes hard to determine the exact point of intersection between the respective tangents [6], [11], [12], [14].

An alternative way of determining the suitable cutoff frequency for extracting scintillation amplitude parameters from beacon signals is to implement high pass filtering algorithm using a range of cutoff frequencies; evaluate the goodness of fit of the output of each to a Gaussian model; and then determine which one proffers best goodness of fit characteristics [14], [15]. This procedure was implemented in this study over a wide range of radio beacon data with cutoff frequency between 1 mHz and 1 Hz

B. Power Spectral Density Estimation

The PSD, $S\chi$ (f), of a random process describes the distribution of its power with frequency [1], [2], [3]. It is possible to simply compute $S\chi$ (f) as the periodogram of the segmented dataset. This translates to finding the magnitude-squared of the discrete-time Fourier transform of the χ variables estimated using a fast Fourier transform (FFT) technique. But, the method has been widely reported to return high values of variance $S^2\chi$ (f), which remains largely unchanged even with increasing sample size [5], [14], [15]. An approach to avoiding the large variance conundrum is to