Exploration of Main Effects for Radiosonde Systems Used in Civilian Weather Balloon Radar Systems

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ABSTRACT

A Radiosonde is a balloon-born instrument platform device which has many sensors and a transmitter (Tx) with a powerful battery pack for the use in weather balloons that measure various atmospheric parameters such as temperature, humidity, and atmospheric pressure at certain heights of the atmosphere and transmit them to a fixed receiver (Rx) located at the ground observation station. Radiosonde may operate at a nominal radio frequency of 403 MHz or 1680 MHz and both types may be adjusted slightly higher or lower as required. This research is focused on the effects or disturbances which are made by the commercial broadcast networks such as Radio, Television, Cellular services, the Geographical parameters, Environmental parameters such as Refractivity, Polarization, Permittivity, Conductivity, Climate and to provide alternatives after identifying the effects or disturbances due to above parameters to ensure the optimal working conditions for Radiosonde system which is used in Radar and Radiosonde Division of the Department of Meteorology, Sri Lanka.

KEYWORDS: Longley-Rice Model, Propagation Model, Radiosonde, Radio Frequency, Weather Radar

INTRODUCTION

The Radiosonde is a balloon-borne *instrument platform device* with radio transmitting capabilities. Originally named a radio-meteorograph, the instrument is now referred to as a Radiosonde, a name apparently derived by H. Hergesell from a combination of the words "radio" for the onboard radio transmitter and "sonde", which is messenger from old English.

The *Radiosonde* contains instruments capable of making direct *in-situ* measurements of atmospheric temperature, humidity and pressure with height, typically to altitudes of approximately 30 km.

These observed data are transmitted immediately to the ground station by a radio transmitter located within the instrument package.

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The ascent of a Radiosonde provides an indirect measure of the wind speed and direction at variouslevels throughout the troposphere. Ground based radio direction finding antenna equipment track the motion of the Radiosonde during its ascent through the air. The recorded elevation and azimuth information are converted to wind speed and direction at various levels by triangulation techniques.

Radiosonde is the most widely used and more economical solution for collecting upper air or atmospheric weather data in the world. The Radiosonde system used in Radar and Radiosonde division of Department of Meteorology is operating at a nominal radio frequency of 403 MHz was established in 1993 which is under malfunction due to many effects from its birth. This would be a great problem to the department to collect upper air weather data in daily routine. When interferences occur the transmission between transmitter of Radiosonde and receiver of ground station will be lost. Then the weather data for that particular occurrence will be lost because the Radiosonde would not contain any data logger or memory that is because it is not a reusable device. Loss of upper air weather data may directly impact to the weather observations and forecasts. The weather data collected by Department of Meteorology is so much important to naval, aviation, defense and disaster management systems all around the world. So each and every single weather datum is important. Malfunction of Radiosonde system causes major problems to all the naval, aviation, defense and other activities where the weather is an important factor.

RESEARCH OBJECTIVES

The purpose of the study was partially to find out effects which lead the Radiosonde Systems to malfunction which are used in civilian weather balloon radar system by the Radar and Radiosonde division of Department of Meteorology, Sri Lanka. Identifying the real problems which lead such an important system to malfunction may be a great support to the Department of Meteorology as well as to the other related organizations.

LITERATURE REVIEW

Technical and operational characteristics of Weather Radiosondes in Europe, illustrates a comprehensive response to the recommendations in DSI phase II that affect the radiofrequency spectrum available for weather Radiosondes in Europe. (ERC, 1996)

Monitoring quality and performance of the Radiosondes stations in Meteo-Francea research publication illustrates number of factors to be considered when establishing and operating a Radiosonde station. These factors are to be considered with this research boundaries. (Maridet, et al., 2002)

Analysis of possible interference between Radiosonde transmitters operating in the band of 1670-1675 MHz and space station receivers operating in the Mobile Satellite Service (MSS) discussed about several factors effects to the communication links between Radiosonde transmitter and receiver also space station receivers operating in same band. These factors are also to be considered and yet to be analyzed weather it matches the 400 MHz – 405 MHz band. (David, 2002)

A research paper on topic Identification of ducts using wind profiler radar, clarifying the ability of wind profilers to detect ducting conditions in the lower troposphere, which can cause interference on communication links, illustrates many factors to be considered for propagation losses. Height profiles of structure function parameter, of the refractive index, n, were retrieved from signal to noise ratio data from three wind profilers (915 MHz profiler at Aberystwyth, 915 MHz profiler at Camborne and 1290 MHz profiler at Dunkeswell). Intensive coincident Radiosonde measurements would provide a larger database which can be used to establish that wind profilers can identify ducts in the lower troposphere which can cause interference on terrestrial and satellite links. This would illustrate the effects to radiò frequency links between satellite systems and Radiosonde systems used in weather monitoring systems due to ducts. (Sengupta, et al., 2000)

Longley-Rice Propagation Model

The Longley-Rice model predicts long-term median transmission loss over irregular terrain relative to free-space transmission loss. The model was designed for frequencies between 20 MHz and 40 GHz and for path lengths between 1 km and 2000 km. This model was the main concern for the analysis process of this study.

DATA COLLECTION & ANALYSIS

Data analysis is can divide in to two groups as analysis for noises and analysis for path loses. The reason is to find out root causes of the problem which are the factors that effect to the Radiosonde system malfunction is necessary to consider all the factors which are relate based on the way that they affected.

Analysis for Noises

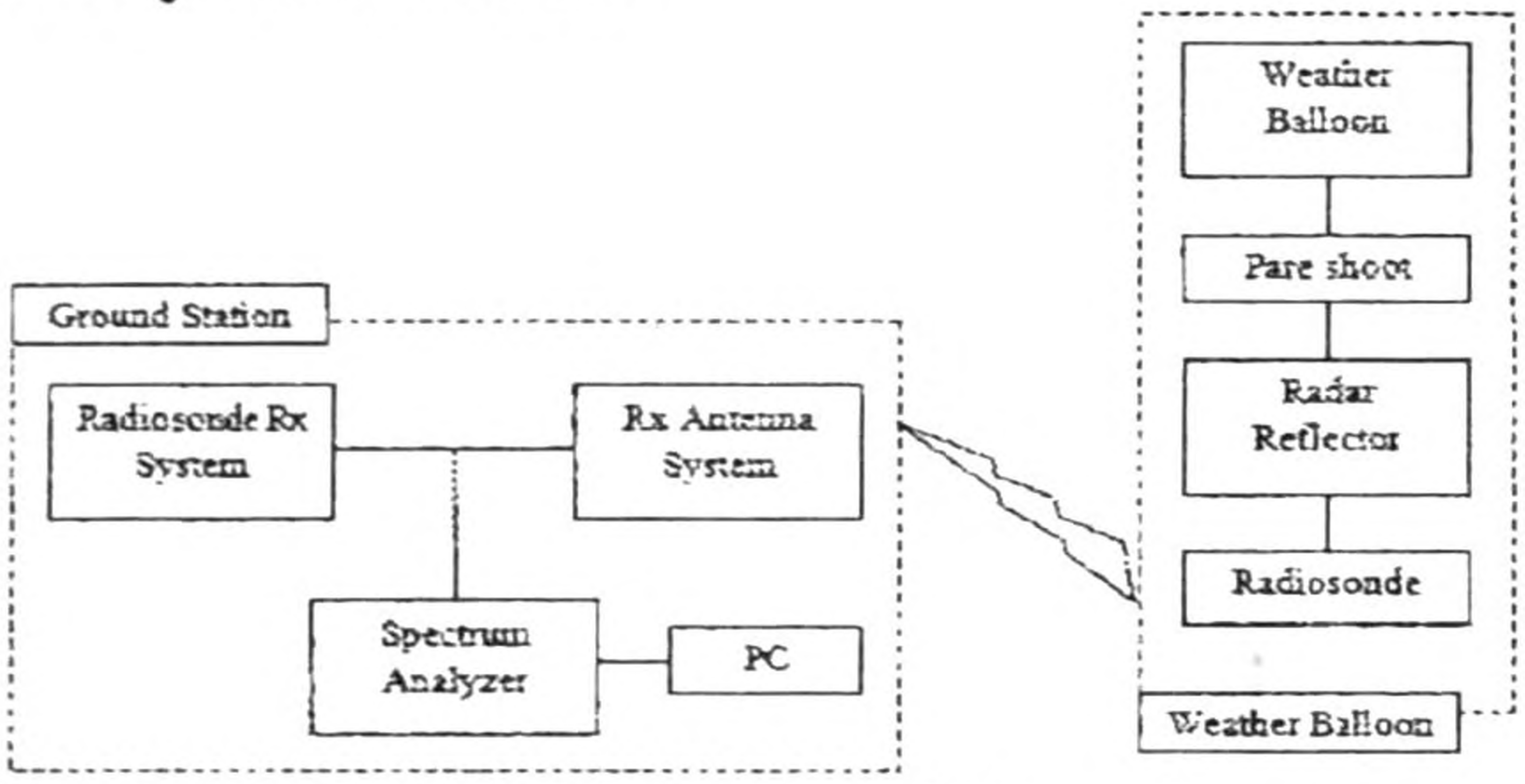


Figure 1. Block Diagram of Experiment Setup

After considering all the data gathered from the experimental setup showed in Figure 1 and the system parameters of the Radiosonde receiver system the analysis is done to identify the factors that may affect to the system functionality to malfunction.

From the specifications of the receiver system the Signal to Noise Ratio (SNR) and Noise Figure (NF) of the receiver system were identified. The temperatures were isolated to a fixed standard value of 20°C at the control room. Then the temperature related noises were calculated. The thermal, burst, flicker noise, shot noise, Johnson–Nyquist noise, white noise, electronic noise, electromagnetic noise were given approximate levels according to the system specifications of the system.

All the parameters of the transmitter of the Radiosonde were taken in to the account and equivalent isotropically radiated power (EIRP) and effective radiated power (ERP) was calculated.

For noises measurements were taken at 30 minutes intervals starting from 1100 hours to 1230 hours and 1600 hours to 1730 hours. Following graphs were illustrates a sample collection of noises during a day.

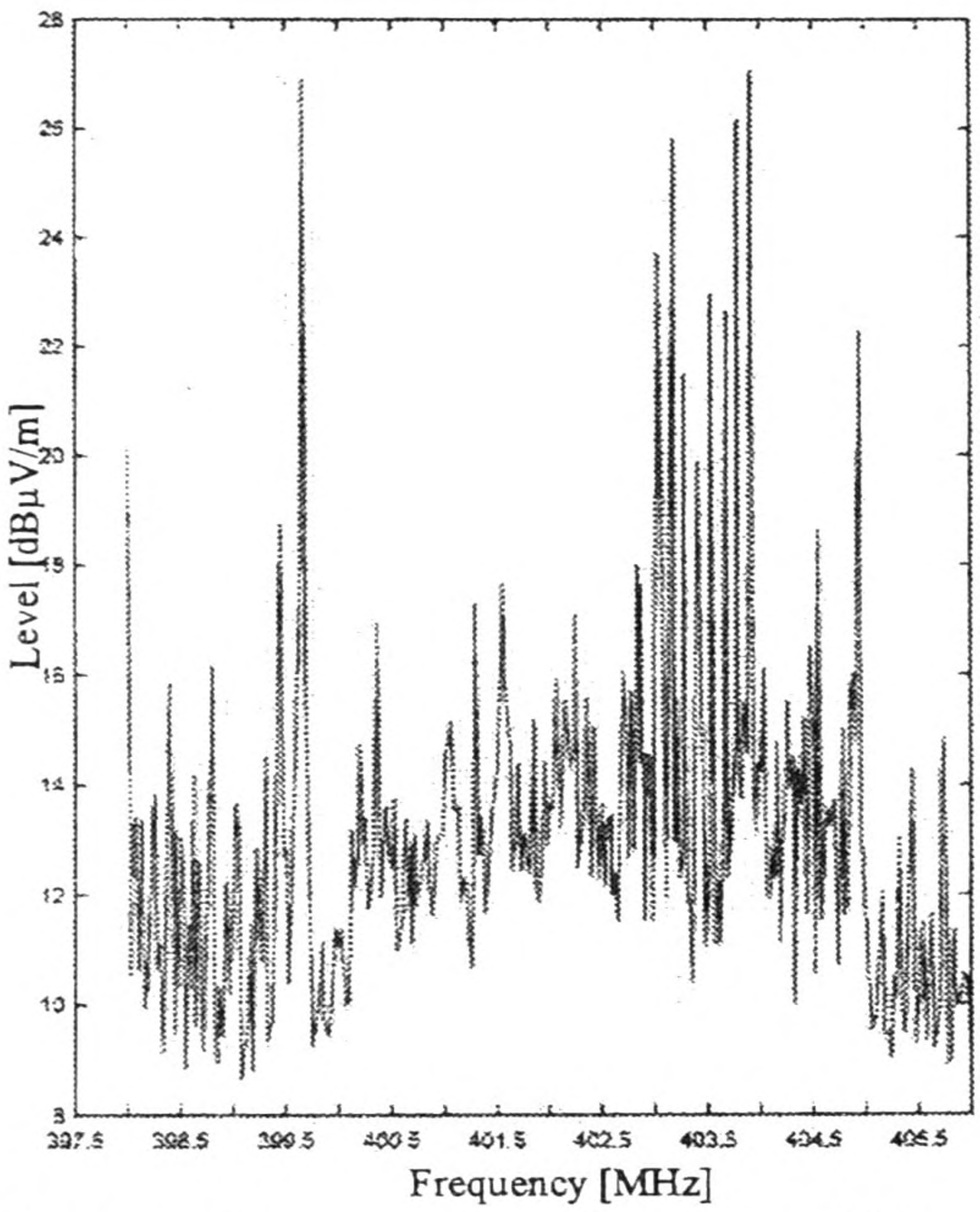


Figure 2. Spectrum Analysis Data 1200 Hours

Figure 2 shows the filtered data of received signal Noise which gathered using the experimental setup shows in Figure 1. From here we can clearly see there is considerable level of noise is included in the receiver signal.

Analysis for Path losses

For the analysis of path losses the Longley-Rice model also known as the ITM model was used. The original algorithm of Longley-Rice model was developed in FORTRAN. There are two popular Microsoft Windows Platform based software known as SPLAT® and Radio Mobile®. For the analysis of path loses Radio Mobile version 10.2.9 was used.

As shown in figure 5.4 and Figure 5.5 the Longley-Rice parameters and general parameters were given to Radio Mobile® for calculations.

RESULTS

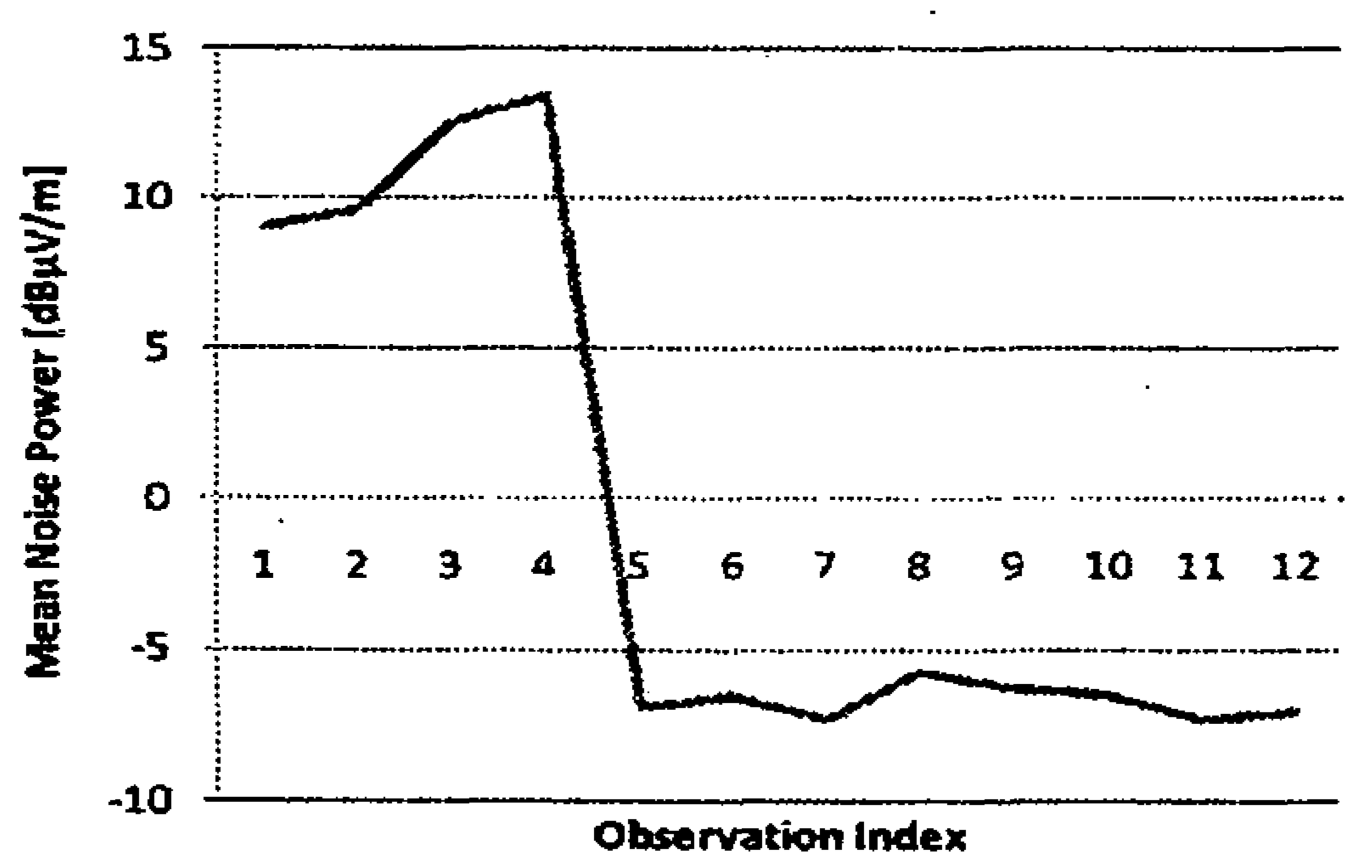
According to observations the receiver system have following characteristics,

- Center frequency (F_0) = 404.5 MHz
- Input Matched Impedance = 50Ω
- Absolute Gain of the system = 2.15 dBi
- Preamplifier Gain = 30 dB with Built in band-pass filter
- Best frequency response band = 403.5 MHz – 405.5 MHz
- Modulation Technique Used = AM
- Signal Bandwidth = 30 kHz

According to Observations the transmitter system have following characteristics,

- Battery Voltage = 9.8V – 12.5V
- Modulation Technique Used = AM
- Best frequency Transmitted band = 400.5 MHz – 405.5 MHz
- Antenna Gain = 1.2dBi
- transmitter Power = 200mW
- Antenna type Matched: 400MHz Telescopic Antenna
- Signal Bandwidth = 30 kHz

Figure 3 shows the daily variation of mean noise power with observation index. From observation 1 to 4 has curved increment and from observation 5 to 12 have very low level of noise level.



After series of analysis following parameters were found as factors which are affects to the receiver data stream of Radiosonde system which causes it to malfunction.

Internal Factors:

- Noises such as Thermal Noise, Electronic Noise and Shot noise

External Factors:

- Diagonal variation of Temperature
- Refractivity of the Environment
- Permittivity of the Environment
- Ground Conductivity
- Leakage Signals from nearby commercial broadcast networks

According to the results from the research there are two main categories of factors which are affecting to the Radiosonde system can be identified as external factors to the system and internal factors to the system itself. External factors are mainly from other broadcast networks, weather factors and other obstacles and environmental factors. Internal factors are the factors which are generated or affected while the system is in operation by it. The resulted factors are again can be subdivide in to two groups as changeable factors and unchangeable factors. The resulting factors are divided as shown in the table 6.1.

Table 1. Changeable/Unchangeable Factors

Changeable Factors	Unchangeable Factors
Electronic Noise	Diagonal variation of Temperature
Thermal Noise/ Johnson–Nyquist noise	Refractivity of the Environment
Shot noise	Permittivity of the Environment
	Leakage Signals from nearby Commercial Broadcast Networks

Thermal noise is the electronic noise generated by the thermal agitation of the charge carriers (usually the electrons) inside an electrical conductor at equilibrium, which happens regardless of any applied voltage. So it can be generated at any circuit which uses high frequencies.

Electronic noise is a characteristic of all electronic circuits. Depending on the circuit, the noise generated by electronic devices can vary greatly. Noise can be produced by several different effects. Thermal noise and shot noise are inherent to all devices. The other types depend mostly on manufacturing quality and semiconductor defects.

Most recent researches show that the Temperature of the atmosphere is varying in sinusoidal form along the day. The atmospheric temperature is directly affected in higher frequency propagations which is a founding in early 1990s.

Refractivity and permittivity are environmental factors which are based on humidity, solar radiation and water vapor level. Most high frequency signals are affected by these factors during long range transmissions.

Most Importantly the Radiosonde ground observation receiver system is placed in an area with large number of commercial and non commercial broadcast service providers and governmental service stations around. The leakages from those broadcasts due to many reasons may transmit streams in Meteorological aid band which appears as the noise to the Radiosonde transmission.

LIMITATIONS OF STUDY

There are few restrictions and limitations in this study. They are listed below with rationale.

Research could not be conducted for 1.7GHz band for Feasibility studies and Comparisons.

Research is only done for 400MHz band due to lack of instruments. E.g. 1.7GHz Radiosonde receiver and transmitter system for comparison. Unidentified factors can be affected because the one and only system is to be considered for the situation.

Research could not be conducted for different parameters such as General factors and Longley-Rice factors. The Radiosonde system is not a portable system for move to check for different parameters such as general parameters and Longley-Rice parameters used in Longley-Rice Model. So the fixed parameters for considered system operational area are considered for the research.

Research could not be conduct for different Radiosonde models for comparisons. Department of Meteorology only owns single 400MHz band Radiosonde system for Sri Lanka. So comparisons could not be performed within different Radiosonde systems for identify the root causes for the issue.

Receiver and transmitter parameters are fixed and could not change for comparison. Only single model is available for Radiosonde receiver system. Different models and their effects were not studied for the research.

Environmental effects were not fixed along the duration, so have to make an assumption for the research. The atmospheric conditions, ground conditions were changed during the research period. An assumption has made to fix the situation.

DISCUSSION AND RECOMMENDATIONS

Throughout the preceding chapters, this study has presented some necessary solutions for the main effects which are affect to the Radiosonde systems used in civilian weather balloon radar system of Department of Meteorology to experiment and if found favorable, adopt them in order to gain the maximum usage from the Radiosonde system of the Radar and Radiosonde division of Department of Meteorology.

It is recommended to upgrade and maintain standard environmental conditions to reduce the effects to an average level. Move the Radiosonde receiver system to a suitable ground which has recommended conditions in above is highly recommended.

CONCLUSION

It can be concluded that the interpreted research results of analyzing and observing the main effects which are affected to the Radiosonde systems used in civilian weather balloon radar system of Department of Meteorology under certain limitations and assumptions stated above. Following the recommendations listed can be improving the usage of Radiosonde system by reducing the effects to a minimum level.

- Radiosonde systems operating in the 400 MHz - 406 MHz band should be moved gradually to the 1.7 GHz band.
- The Radiosonde system should change the modulation technique to FM from AM.
- Transmitter of the Radiosonde should increase the transmitting power.
- The receiver should move to a ground which there are no heavy loads of transmission nearby.
- Use digitalized transmitter and receiver with the Radiosonde system.
- Use updated systems for Radiosonde receiver system.
- Maintaining environmental (Room) temperature where the ground receiver is placed to industry standard.
- Move the Radiosonde system to a ground where the environmental factors are effecting minimally.
- Use Radiosonde systems to collect weather data in different places around the country.
- Informing Telecommunication Regularity Commission which is the govern body of frequency allocation in Sri Lanka to analyze the spectrum and get necessary actions to free the meteorological aid band from unauthorized use.
- Inform all the network broadcasters to maintain their equipments to keep the meteorological band noise free from leakages and interferences from their signal streams.

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