THE IMPACT OF ATMOSPHERIC TEMPERATURE AND WIND SPEED ON SATELLITE SIGNAL AT KU BAND

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ABSTRACT

The signal strength of ASTRA1R Satellite at 15.2^{0}E transmitting at KU band (11.7-12.7Ghz) was measured using a system developed by the research group. The signal strength measurement was done concurrently with atmospheric vagaries using Davis Automatic Weather Station collocated in the Department of Industrial Physics, Enugu State University of Technology (ESUT), longitude 7.54˚ and latitude 6.31˚. Signal strength data was analysed for any dependence on the weather vagaries variation. The effect of temperature variation and wind speed on signal strength was specifically studied. Results shows a strong inverse relationship between the temperature and the received signal strength. Same pattern of relationship was observed between wind speed and signal strength.

Key words. Metrological components, Atmospheric temperature, Radio Signal, Signal strength, Ultra High Frequency (UHF).

1.Introduction

The KU band is the portion of the electromagnetic spectrum in the microwave range of frequencies from 10 to 18 gigahertz (GHz). KU band is primarily used for satellite communications, most notably for fixed and broadcast services, and for specific applications such as NASA's Tracking Data Relay Satellite used for both space shuttle and International Space Station(ISS) communications. KU band satellites are also used for backhauls and particularly for satellite from remote locations back to a television network's studio for editing and broadcasting. The band is split by the International Telecommunication Union (ITU) into multiple segments that vary by geographical region(1).

Satellite earth station operating in KU band requires more accurate position control due to its much narrower focus beam compared to C band. However, increasing the frequency range brings conflicts along with benefits. Radio signal quality experienced increasing degradation with frequency due to rain, snow, atmospheric gases etc (2, 13). Among the major cause of signal degradation in the atmosphere is temperature and wind speed. It is imperative to note that when designing satellite communication system; signal degradation due to atmospheric vagaries should be taken into consideration (3, 14). The knowledge of atmospheric characteristics are important factors for system reliability in satellite networks. International Telecommunication Union Radio Communications (ITUR) maintains a database for atmospheric characteristics around the world that is used to estimate weather attenuations and other parameters. This attenuation is based on the concept of deriving the effective length of path through different weather conditions.

Recent studies have shown that the transmitted radio signals may go through spatial and temporal changes due to variations in the atmospheric conditions as well as environmental factors (4,15). These variations take place in the troposphere and it is due to refractivity changes in this region that causes these changes. The influence of atmospheric refraction in the propagation of electromagnetic waves has been studied from the beginning of radio wave technology. It has been proved that the path bending of electromagnetic waves due to inhomogeneous spatial distribution of the refractive index of air causes adverse effects such as diffraction on the terrain obstacles or the so called radio holes (5). Atmospheric refractivity is dependent on physical parameters of air such as temperature, pressure, relative humidity, wind and precipitation. It is observed that at the region of the troposphere, temperature decreases rapidly with altitude at a rate approximately 10 degrees Celsius per kilometer (6,7). Wind is observed in troposphere when there is a resultant change in the atmospheric pressure which results in the movement of air from a lower to a higher region causing winds of various speeds. Thus in order to improve and upgrade network so as to minimize the occurrence of dropped calls, access failures and to know the amount of fading expected at a given period of time in this environment, weather parameter measurements must taken into consideration.

This research evaluates the relationship between satellite signal strength at KU band and wind speed and temperature using the data obtained from the Automatic Weather Station and Signal Strength Meter in Enugu State University of Science and Technology (ESUT) for a period of five months.

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2.0 Materials And Method

The data used for this work is from Automatic Weather Station and Signal Strength Meter (AWSSSM) in the Department of Industrial Physics ESUT. The external module of the experimental set up is as depicted in Figure 2.0

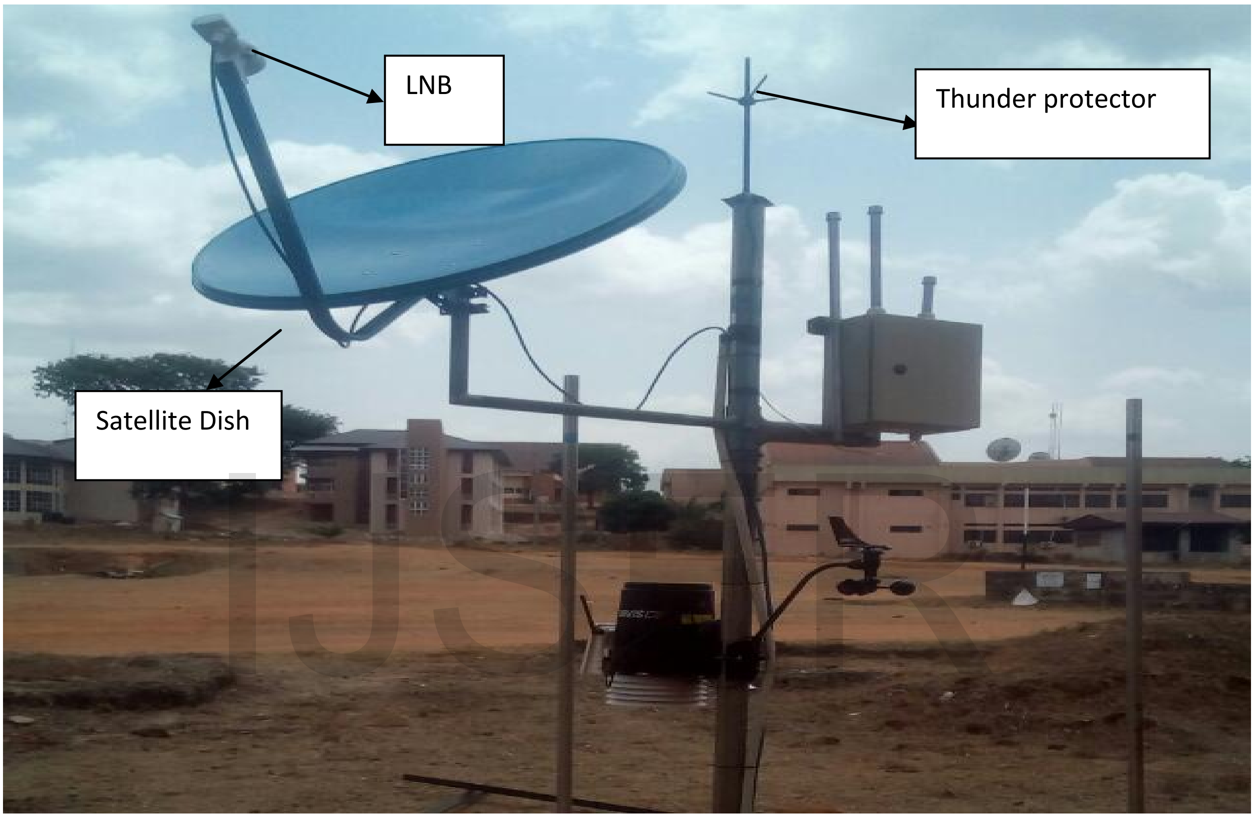

Figure 2.0: showing the pictorial representation of the AWSSSM

The satellite dish is focused on ASTRA1R at angle 15.2^0E. The dish concentrates the signal through Low Noise Block (LNB). The LNB is a universal type receiving 10.7 GHz – 12.6GHz (Ku Band). The signal is then converted through the LNB to signal between 950 MHZ – 2150MHz. The major Reason for the conversion is that the 10.7GHz – 12.6GHz signal cannot be transmitted through coaxial cable (because of attenuation) as shown in Figure 2.1.

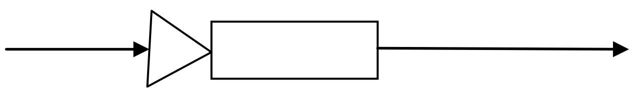

Figure 2.1

The indoor system consists of

1. Power supply to the LNB. The LNB is an amplifier and needs power to operate, the power is sent to it from the indoor system via the coaxial cable. It also sends its own signal to the indoor unit via the same cable.
2. RF power detector to detect the power of the signal coming to the LNB in dBm.
3. Processor connects with the power detector and sends the detected power to the PC.

The logger software on the PC was written with visual studio 12.0 and it accepts connection from the two instrumentation system displays them as graphs.

3 Methods

The experiment was carried using the AWSSSM and the main purpose was to determine the effect of atmospheric parameter (temperature and wind speed) on signal strength. This is done by using a high gain KU band signal of 11.7- 12.7GZ spectrum analyzer collocated with automatic weather station.. The measurement was taken for a period of 5 months starting from the month of April to August 2017. The signal strength and the meteorological components (temperature and wind speed) were measured and recorded every two seconds. The signal strength is in Decibel meter (dBm).

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4.0 Results And Discussion

The result from the experiment was analyzed to determine the effect of atmospheric temperature and wind speed on KU band signal. Figures 1 to 9 is scatter diagram for temperature and signal strength and Temperature and signal strength. The scatter diagram is used to determine the correlation coefficient between the parameters..

Table 1a and 1b showed the correlation coefficient for temperature and wind with signal strength for each month considered in the study area. The correlation with temperature (Table 1a) was obtained as -0.63717, -0.17281, -0.22749, -0.34193 and -0.40345 for the months of April, May, June, July and August respectively. This result shows there is inverse relationship between temperature and signal strength at Ku band in the study area. The effect is stronger for the months of April and August. The reason for this will be studied further in future work and with larger data.

Table 1b presents the correlation between wind speed and signal strength. The correlation coefficient with wind speed was obtained as -0.54793, -0.79445, -0.2263, -0.4505 and -0.13603 for the months of April, May, June, July and August respectively. This result also confirms a strong inverse relationship between wind speed and signal strength at KU band.

Results obtained from this study shows that temperature and wind speed were have effect on the signal strength in contrast to some past research which said there is none. In a similar study, Holland et al.,(8), concludes that temperature has no impact on received signals. This view is also shared by Anastasi et al. (9), who do not observe a change in packet receptions over different distances during varying environmental conditions. Their findings were however contradicted by Boano et al. (10), and Bannister et al. (11), who specifically show how higher temperature can reduce received signal strength on a sensor node and the result is in agreement with this study. They argued that change in temperature affects crystal accuracy which induces frequency shifts and thermal transceiver noise that may degrade performance. Recent research by Joseph Amajama (12) also agree that signal decreases with a slight rise in temperature and he concluded that signal strength is inversely proportional to temperature. Some researchers like Joseph Amajama (12) also argued that wind has a marked effect on radio signal. This research also observed that wind speed affects the signal strength and that the relationship between the two parameters is inverse.

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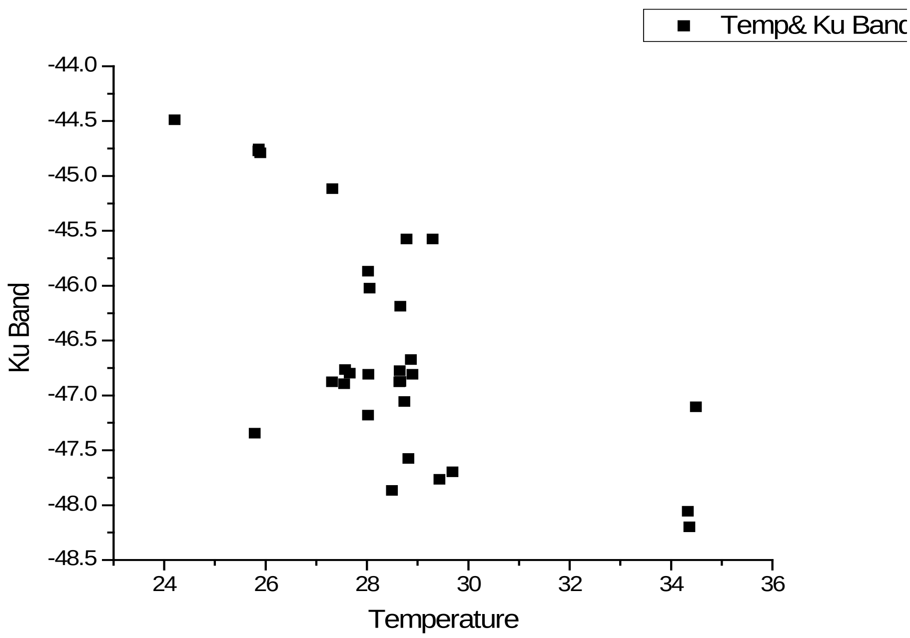

Fig 1.Temperature and Ku Band for April

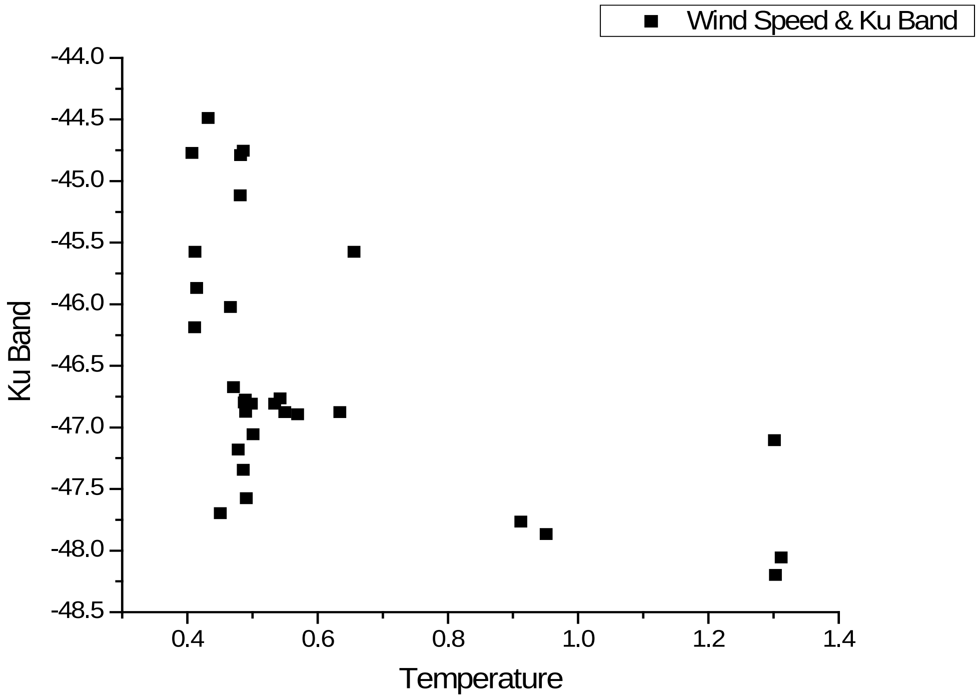

Fig 2 Wind Speed and Ku Band for April

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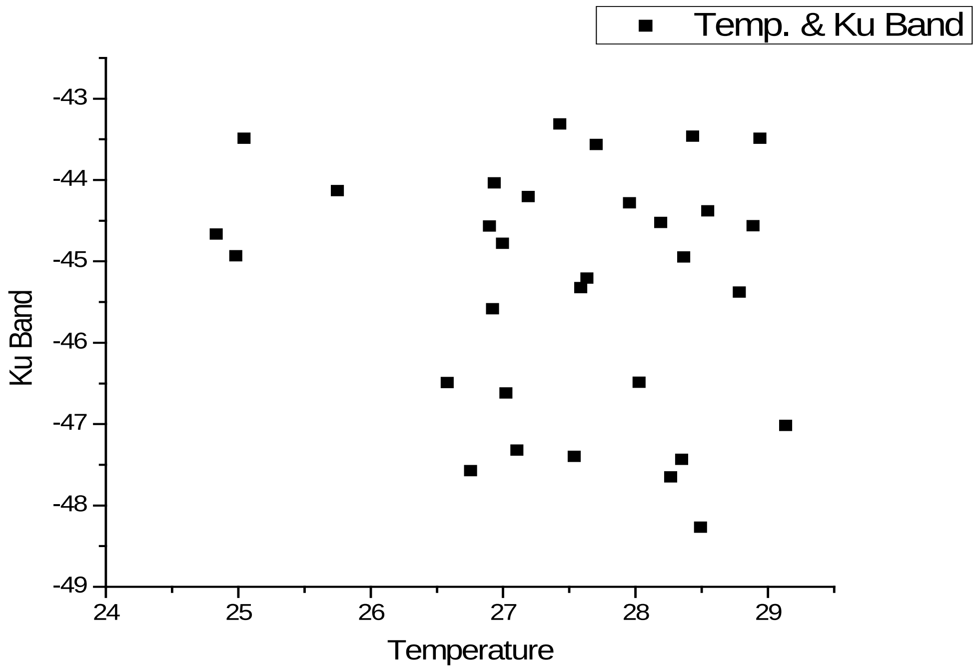

Fig.3 Temperature and Ku Band for May

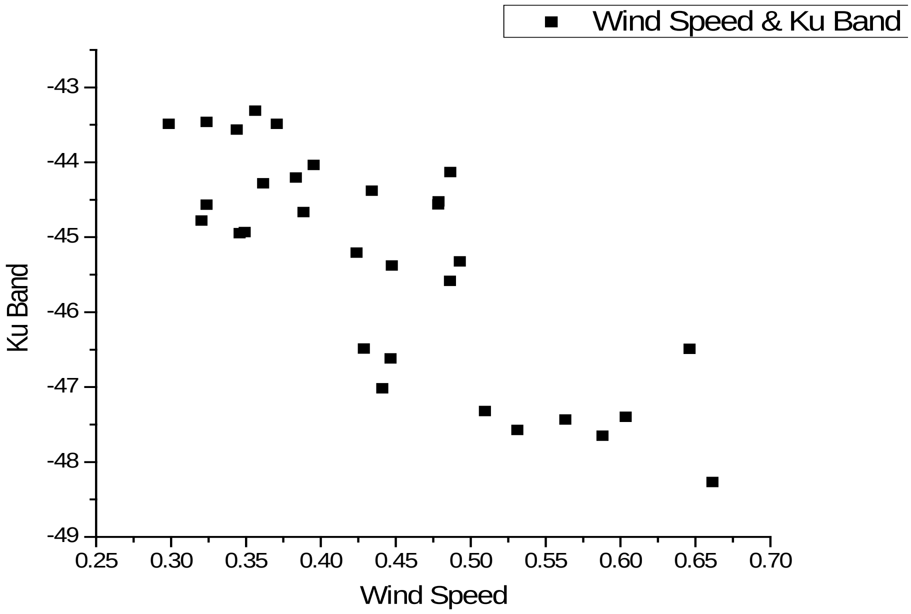

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Fig.4 Wind Speed and Ku Band for May

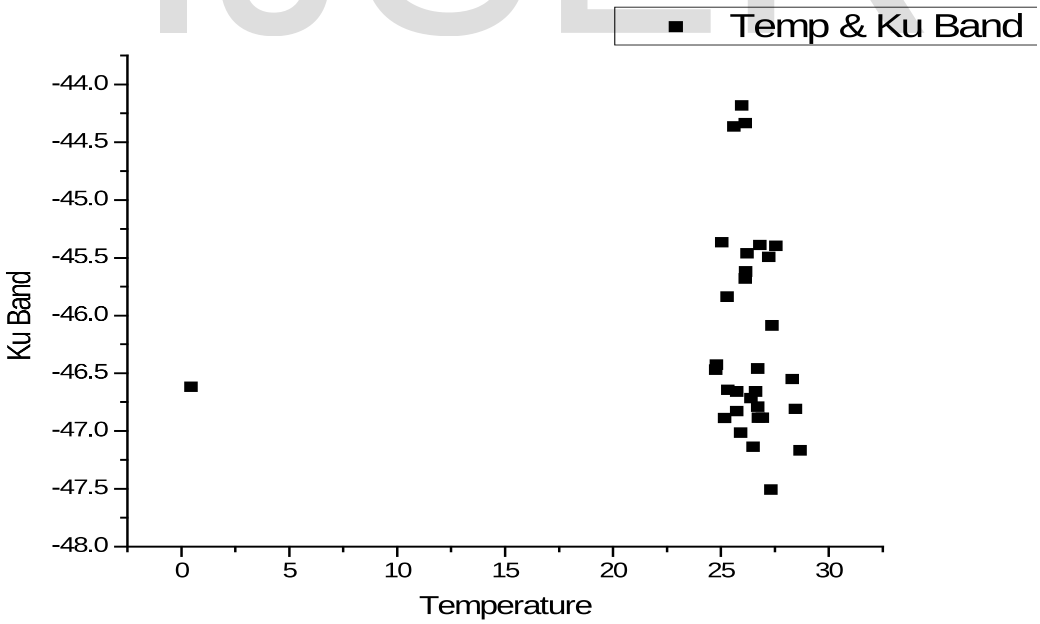

Fig.5 Temperature and Ku Band for June

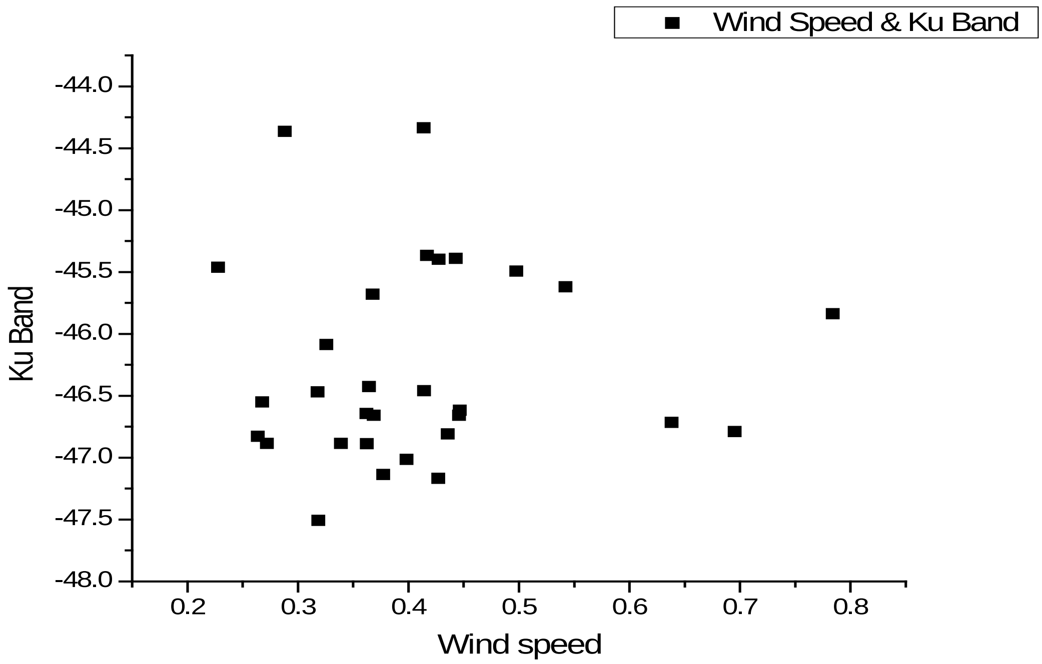

Fig.6 Wind Speed and Ku Band for June

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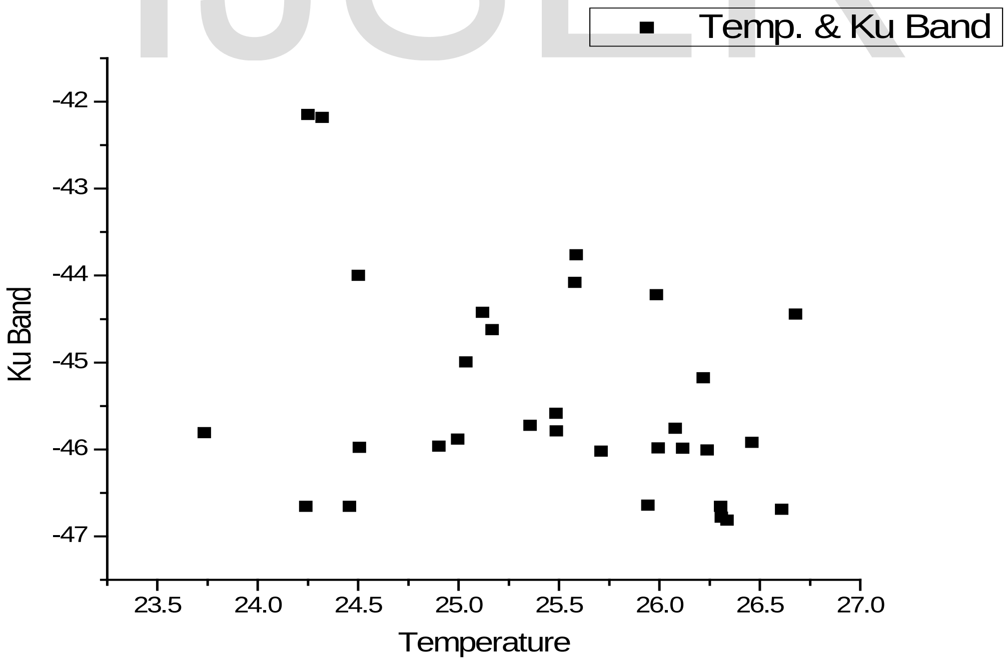

Fig.7 Temperature and Ku Band for July

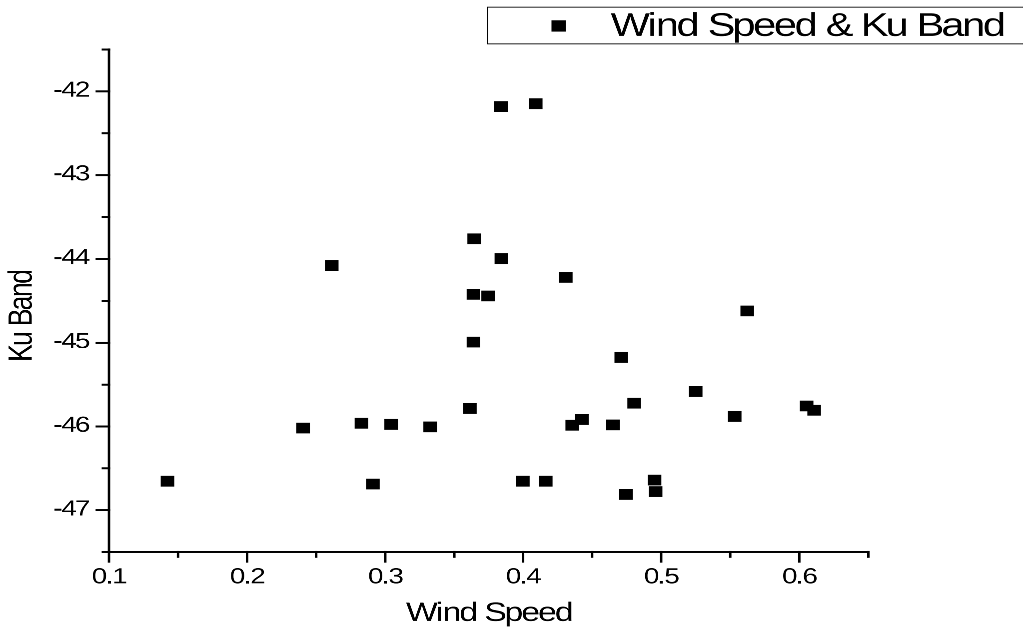

Fig.8 Temperature and Ku Band for August

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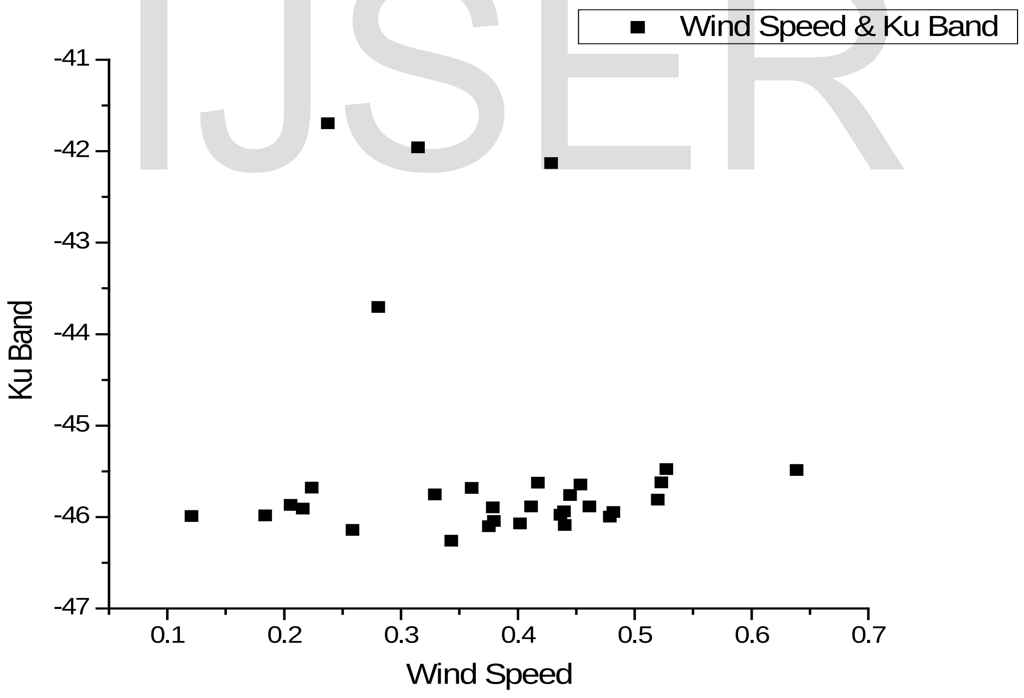

Figure 9. Wind Speed and Ku band for August

4.1a Correlation Coefficient of Temperature and Ku band for the five months

MONTHS	CORRELATION COEFFICIENT
April	-0.63717
May	-0.17281
June	-0.22749
July	-0.34193
August	-0.40345

4.1b Correlation Coefficient of Wind Speed and Ku Band for the five months

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MONTHS	CORRELATION COEFFICIENT
April	-0.54793
May	-0.79445
June	-0.2263
July	-0.4505
August	-0.13603

5.0 Conclusion

The effects of temperature and wind speed on satellite signal at KU Band was studied in this work using five months data. Result obtained showed that both temperature and wind speed have inverse relation with radio signal at this band. The effect of both weather vagaries studied on signal strength varies from month to month and no identified pattern was established in this study.

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