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REFRACTIVITY AND HUMIDITY PROFILING USING MICROWAVE RADIOMETER OBSERVATION AND INTERFERENCE OF RADIO DUCTS

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ABSTRACT

Refractivity and humidity profile change with time has visible effect on signal to noise ratio (SNR). Such effects can be stretching, shifting of pattern with time or over elevation angle. This study was aimed at using microwave radiometer observation and interference of radio ducts to analyze the effects of refractivity and humidity profiling, by considering the SNR. Indeed, this effect can be roughly quantified via an additional phase shift between carriers of the direct and reflected waves which would lead to a shift in the phase of the modulation pattern. The method used for implementing this research work involved getting radiometer data from the National space research and development agency (NASRDA). At varying altitude ranges, the humidity profile in millimetre (mm) was 378.0, 368.58, 357.57, 374.0, 329.0, 293.0 and 780.0 which corresponded to the radio ducts 0.21522, 0.13255, 0.16339, 0.15879, 0.12795, 0.11549 and 0.18045 in metre (m).

1. INTRODUCTION

Radio frequency interference (RFI) can adversely impact the performance of microwave radiometers operating outside protected portions of the frequency spectrum. (Johnson *et al.*, 2004). For L-band systems, 27 MHz is protected from 1400-1427 MHz, but bandwidths on the order of 100 MHz are desirable to improve sensitivity in applications such as refractivity and humidity profiling. No protected spectrum is available at C-band, and results from the C-band channel of the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR) sensor on the aqua satellite is showing significant RFI induced corruption of data (Lobi, 2001). Aqua is a National Aeronautics and Space Administration (NASA) earth

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science satellite mission responsible for collecting a large amount of information about the earth's water cycle, including evaporation from the oceans, water vapour in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice and snow cover on the land and ice. (Parkinson, 2013). Additional variables also being measured by aqua include radiative energy fluxes, aerosols, vegetation cover on the land, phytoplankton and dissolved organic matter in the oceans, and air, land, and water temperatures. Because much of the RFI at L-band is from radars with pulse lengths on the order of microseconds, traditional radiometers (i.e., those which directly measure total power or power spectral density integrated over time scales of milliseconds or greater) are poorly-suited to this task. This motivates the design and development of radiometers capable of coherent sampling and adaptive, real time mitigation of interference (Anandan, 2001).

Balsley (2005) recently showed that the effect of multipath interference of radio duct signals can be used to infer information about humidity profile in the vicinity of the radio antenna. This effect of multipath interference causes the signal to undulate with time while the radio satellite ascends or descends at relatively low elevation angles. An electrodynamics model of radio multipath was built that has a bare-humidity model as the input and the total radio received power as the output. This model treats humidity as a continuously stratified medium with a specific composition of material ingredients having complex dielectric permittivity. It was demonstrated that radio receivers installed for geophysical and geodetic applications can be used to estimate variations in near surface humidity moisture (Lowry, 2002).

2. MATERIALS AND METHODS

2.1. Materials

A microwave radiometer was used, with two sidebands on either side of the oscillator that are mixed down to the band pass filter. The power detector converts the band limited white noise signal at the output of the band pass filter to a voltage proportional to the total noise power (Roettger, 1989).

2.2. Data Collection

Interference and observation on radio ducts data was collected from NASRDA. Microsoft excel was used for plotting of the graphs.

2.3. Development of Radiometer Algorithm

Step 1: Before refractivity retrievals can be made, a reference map of phase and refractivity must be obtained.

Step 2: the first sets of phase measurements was taken and are called the reference phase, made at time t_0.

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Step 3: The reference phase measurements was made when the refractivity field is nearly uniform and is not changing with time. Thus, when the refractivity field is constant, the ground clutter target's phase should also be constant if the target's phase is only changing due to refractivity.

Step 4: A reference refractivity map, N-ref was produced at the same time, t_0. After the reference maps have been produced, a phase measurement was made at scan time t_1.

Step 5: A phase difference was calculated between the measured phase at t_1 and the reference phase at t_0.

Step 6: The reliability index was calculated for the reference phase measurements and was based on the variations of the target's phase with time (over an hour). When the refractivity field is nearly constant, a quality clutter target's phase should exhibit minimal temporal variations. Thus, the quality clutter targets will have a high Reliability Index (RI). Finally, based on set threshold values of the Quality Index (QI) and RI, any phase measurement with a QI or RI below the threshold value was censored.

Step 7: The final step in the algorithm was calculating the range derivative of the smoothed phase difference field to obtain the refractivity difference, N. By adding the refractivity difference to the reference refractivity measurement, N-ref, an absolute refractivity field was be obtained. In addition to absolute refractivity fields, scan-to scan refractivity change fields (hereafter called scan-to scan refractivity) was produced by substituting the phase measurements from the preceding volume scan for the reference phase measurements. Given the uncertainty of the reference refractivity field, scan-to-scan refractivity measurements are more accurate than absolute refractivity measurements because the reference scan was eliminated.

3. RESULTS AND DISCUSSION

Table 1 presents each profile region, altitude range, humidity profile and their ducting values. The humidity profile can be seen to rise and fall steadily from profile range 1 to 6, while at profile range 7 it is very high. The ducting value was also observed to be high at altitude above 15 km. The higher the humidity profile, the more the effect of the radio ducting on electromagnetic interactions with the atmosphere, in terms of bending away from the source to the destination.

Table 1: Humidity profiles with altitude ranges

Profile Region	Altitude range (km)	Humidity profile (mm)	Radio ducts (m)
1	0.0 to 0.3048	378.0	0.21522
2	0.3048 to 0.6096	368.58	0.13255
3	0.6096 to 0.9144	357.57	0.16339
4	0.9144 to 4.1453	374.0	0.15879
5	4.1453 to 8.9916	329.0	0.12795
6	8.9916 to 15.0266	293.0	0.11549
7	Above 15.0266	780.0	0.18045

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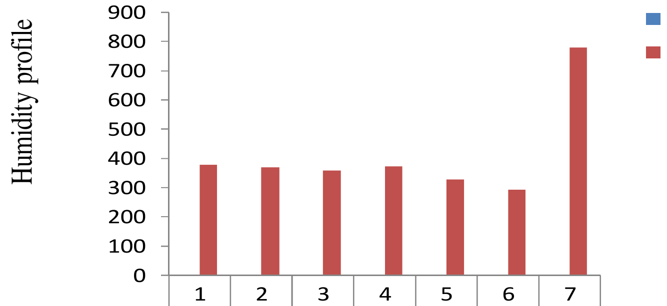
In addition, electromagnetic (EM) waves propagate along curved paths through the atmosphere due to spatial variations in humidity. The vertical gradients of these properties are especially strong near the earth's surface, which can lead to highly anomalous propagation conditions. For example, the rapid decrease of humidity with height normally occurring just above the ocean surface often results in refractive conditions that cause radio frequency waves to bend downward toward the earth's surface at 400 mm of humidity and to become channelled within a thin layer. The electromagnetic signals make the radio wave to undergo refractivity. It can be inferred that the higher the radio ducts, the higher the humidity profiling.



	1	2	3	4	5	6	7
Radio ducts	0.215	0.132	0.163	0.158	0.128	0.115	0.180
Humidity profile	378	368.5	357.5	374	329	293	780

Figure 1: Effect of radio ducts on humidity profiling

The effect of the humidity is more pronounced at around 780 mm. The ducting condition here can also be seen to open up the interference effects for radio wave propagation to be continually possible. The reduced refractive index due to lower densities at the higher altitudes in the Earth's atmosphere bends the signals back toward the earth. Signals in a higher refractive index layer, i.e., duct, tend to remain in that layer because of the reflection and refraction encountered at the boundary with a lower refractive index material. In some weather conditions, such as inversion layers, density changes so rapidly that waves are guided around the curvature of the earth at constant altitude (Thomas, 2006).

From Figure 2, humidity profiling decreases with increase in altitude up to an altitude 5.6 km. Above an altitude of 5.6 km, humidity profiling was observed to increases. This indicates that interference had little effect on altitude. Humidity profiling is highest at around 790 mm at an altitude of 7.2 km.

Figure 3 shows the trend of radio ducts with respect to the altitude. Radio ducts decreased with increase in altitude between 0 and 2 km after which there was a slight increase in radio duct between 2 and 3 km, which is due to atmospheric interference by air molecules.

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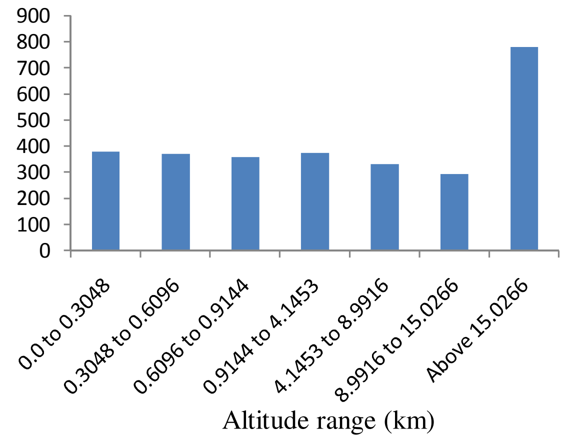

Figure 2: Effect of altitude on humidity profiling

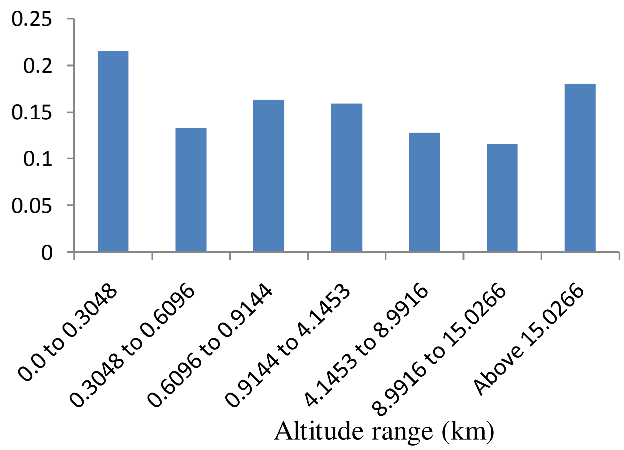

Figure 3: Effect of altitude on radio ducts

4. CONCLUSION

Microwave radiometer data has been collected and used for refractivity and humidity profiling on observation of radio ducts. The extraction of humidity profiles in the lower troposphere using combined radiosonde and radiometer data was also carried out. Future work should refine the algorithm, in particular improving accuracy by editing the spectral data to remove any contamination such as ground clutter. The interference effects at varying altitude can be seen in the various Figures and the degree of ducting conditions that can have an effect on electromagnetic propagation at any frequency band.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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