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Abstract

In this report we present an in-house built miniaturized Radiosonde Ground Receiver (mRGR) system along with a suitable portable Ground Plane (GP) (quarter wave) antenna for meteorological data telemetry from different aerial platforms such as balloons and Unmanned Aerial Vehicles (UAVs) / drones to ground station. The mRGR system consists of a portable Ground Plane (GP) antenna for receiving Ultrahigh Frequency (UHF) signals, portable receiver for processing radiosonde data and Windows GUI based software for telemetry decoding. The performance of mRGR system with GP antenna is assessed by processing the signals received from the radiosonde balloon. The telemetry data is compared with the standard Vaisala telemetry data and found a good correlation. Experiments were also conducted by integrating radiosonde (Vaisala RS-41) to an Unmanned Aerial platform or drone and the meteorological data is received at the ground through mRGR system. The data further processed for vertical profiles of temperature, relative humidity, pressure and winds. Thus, mRGR system is portable, cost effective and easily deployed for field experiments/campaigns at any remote locations.

Summary
Miniaturized Radiosonde Ground Receiver (mRGR) system along with a suitable portable Ground Plane (GP) antenna is in-house designed and developed for meteorological data telemetry from different aerial platforms such as balloons and UAVs / drones to ground station. It is a miniaturized low cost receiver system for high altitude data telemetry. The system consists of a portable GP antenna for receiving UHF signals, portable receiver for processing radiosonde data and Windows GUI based software for telemetry decoding. This system is easy to configure, portable and easy for deployment in field experiments/ campaigns in any remote location.

The mRGR system for radiosonde is experimented for both balloon and UAV (Drone) platforms. For balloon platform we compared our system data with standard Vaisala data and found a good correlation.

Few flights conducted with UAV-sonde depicted vertical profiling of meteorological parameters in the lower boundary layer. The high resolution data in the boundary layer reveal small scale features in the meteorological parameters as compared to Radiosonde balloon data. The same Radiosonde has been utilized multiple times on UAV. The benefit of UAV-Sonde profiling include different pre-determined paths which is not possible with weather balloon.

Contents

1. Introduction

Worldwide, radiosonde balloons are used for profiling of upper atmosphere for meteorological parameters. The radiosonde or meteorological balloons have been in use for decades and been proven to be reliable and accurate in vertical profiling of the atmosphere [1], [2]. Most of the radiosondes have the proprietary hardware receiver or Universal Software Radio Peripheral (USRP) for meteorological balloon telemetry to ground station. Most of these receivers are big in size, expensive and are suitable for bench-top applications only [3].

IITM initiated the utilization of Unmanned Aerial Vehicles (UAV) for atmospheric research purpose under the project '*Lower Atmospheric Research using Unmanned Aerial System facility (LARUS)*'. Under this project, field experiments/campaigns will be conducted at different remote locations using UAVs/drones and tethered balloons. To meet the field requirements, we designed and developed a portable cost effective miniaturized Radiosonde Ground Receiver (mRGR) system similar to the standard Radiosonde receiver system. The system is in-house designed and developed for easy field deployment. It broadly consists of three major components such as 1) a portable Ground Plane (GP) antenna for receiving Ultrahigh Frequency (UHF) signals, 2) portable receiver for processing radiosonde data and 3) Windows GUI based software for telemetry decoding. The portable receiver is connected to a laptop/computer using a USB interface. The mRGR system is a very simple and easy to operate and decode data. The aim of this report is to highlight in-house development of mRGR system for field experiments and compare the data with standard receiver system. Also discuss the results obtained using UAV-Sonde and mRGR.

2. Equipment design

The block diagram of mRGR system with various components is shown in Figure 1. The system is constructed by collecting various components available in the market and their source/online links are given at the end of this report. The mRGR system consists of (1) mini Telemetry System (mTS), (2) mini Sound Processing System (mSPS) and (3) mini Decoding Software System (mDSS) [3] [4]. Each of these components is described in detail in the subsequent sections.

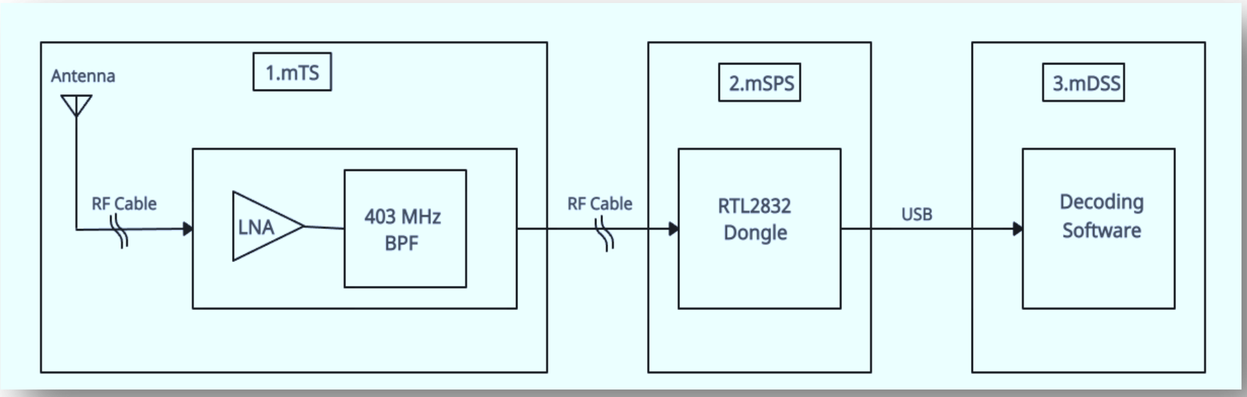

Figure 1: Block diagram of mRGR system with different stages.

Based on the above block diagram, the constructed mRGR system at IITM is shown in Figure2.

Figure 2: Photograph of mRGR system developed at IITM

2.1 mini Telemetry System (mTS):

The mTS consists of the following components.

2.1.1 Antenna:

Antenna is a device which converts electromagnetic (EM) wave signals into electrical signals. In mRGR system we designed a 400-406 MHz Ground Plane (GP) antenna, which is highly efficient for receiving radiosonde transmitted signals from higher altitudes.

A GP antenna is one type of Omni-directional antenna [4] [5] [6]. It has two main elements; one is the vertical monopole and the second one is radial. The monopole element of a GP antenna is always oriented vertically and connected to the centre of the conductor. Downside of monopole element radial measuring 1/4 wavelength is connected to the outer conductor or shield of line. GP antenna base should be 1/4 wavelength above the ground or other conducting surface, and the radial will act as a near-perfect ground system for the electromagnetic field.

The length of Antenna Element is calculated using the following standard equations.

Vertical Monopole Element A = [(λ*0.25) * vf],

Radial Element B = [(λ*0.28) *vf]

where λ = wavelength, and vf = velocity factor

Given that

a. Frequency(f): 403 MHz
b. Speed of light(c): 3×10^8 m/s.
c. Velocity Factor (vf): 0.95(or less).
d. Wavelength (λ=c/f): 74.4 cm

Hence, A = ((74.4 * 0.25) * 0.95) **= 17.67 cm**

and B = ((74.4 * 0.28) * 0.95) = **19.79 cm**

Based on the above calculation, the GP antenna is constructed. Its 2D diagram along with GP constructed Antenna is shown in Figure 3 and more details are given in Table 1.

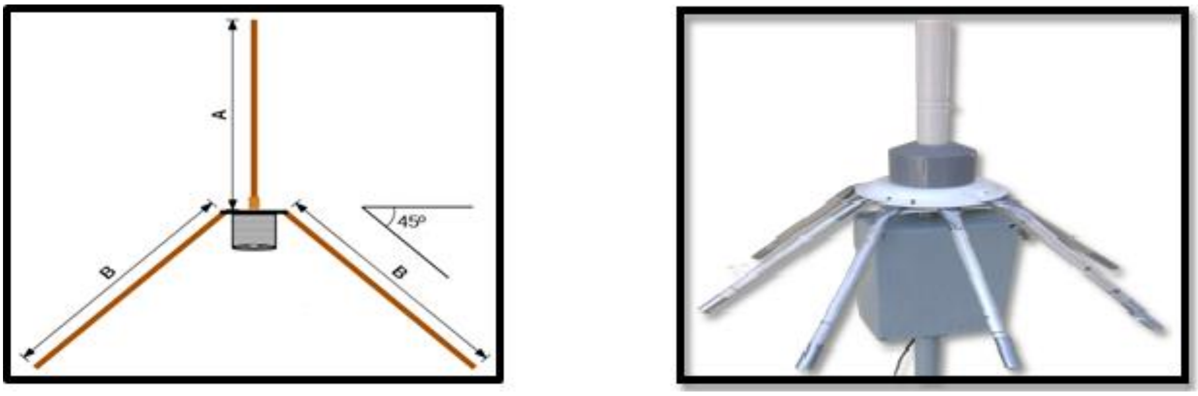

Figure 3: (a) Ground Plane (GP) 2D diagram of Antenna and (b) constructed antenna at IITM

Table.1: GP Antenna Details

Frequency Range	400-406 MHz
Radiation pattern	Omni-directional
Polarization near horizon	Vertical
Polarization at Zenith	Circular

2.1.2 403 MHz Filtered Preamplifier:

This is a small filter with preamp unit between a software defined radio receiver and an antenna. It has a Surface Acoustic Wave (SAW) bandpass filter and a Low Noise Amplifier (LNA), which stops out of band intermodulation while providing additional gain for increased sensitivity. 403 MHz Band Pass Filter (BPF) is specially designed to filter out band signal and reduce noise with performance optimization [9].

The LNA, which is situated before the SAW filter, is an electronic circuit that amplifies a very low-power signal without significantly degrading its signal-to-noise ratio. The amplifier will increase the power of both the signal and the noise present at its input, but the amplifier will also introduce some additional noise.

Radiosonde signals travel through free space and degrade the signal. The 403 MHz Filtered Preamplifier (Figure 4) is used here to amplify received weak signals and its technical details are given in Table-2.

Figure 4: Picture of 403 MHz Filtered Preamplifier

Table 2. 403 MHz Filtered Preamplifier technical details

Frequency	403 MHz
Gain	21dB
Noise Figure	0.75dB
Power Input	Bias Tee/5V USB-C
Insertion Loss	2.3 dB
Connectors	High Quality SMA

2.2 mini Sound Processing System (mSPS):

2.2.1 RTL2832 SDR V3 Dongle:

The sonde signal (Gaussian Frequency Shift Keying or GFSK) received by the mini telemetry unit is to be decoded into original signal. The mini Sound Processing System is the low cost and lightweight Upper-Air Sounding signal processing system. The mSPS makes wide use of Software Defined Radio (SDR) technology for receiving radiosonde signals (Figure 5).

Figure 5: RTL 2832 SDR/V3 Dongle

The SDR is a radio communication system where components that have been traditionally implemented in hardware(like mixers, filters, amplifiers, modulators/demodulators, detectors, etc.) are instead implemented by means of software on a personal computer or embedded system. The SDR technology is commonly used today in a wide range of products including cellular base stations, military communication systems and public safety radios.

In Analog RF Tuner (RF units) the entire 400-406 MHz meteorological frequency band is first translated to an Intermediate Frequency (IF) band. The IF signal is then sampled by a good-performance, 8-bit analog-to-digital converter. Down conversion of the digital signal to the baseband is done with an inbuilt Digital Down Converter (DDC) in the receiver processor unit. Further processing of the signal – demodulation, error detection/correction and telemetry analysis is done in a Digital Signal Processor (DSP) [7] [8].

The signal processor sends the baseband data to a decoding software system which takes care of data decoding & saves telemetry data. The RTL2832 SDR/V3 generalized block diagram is shown in Figure 6 and the technical details are given in Table-3.

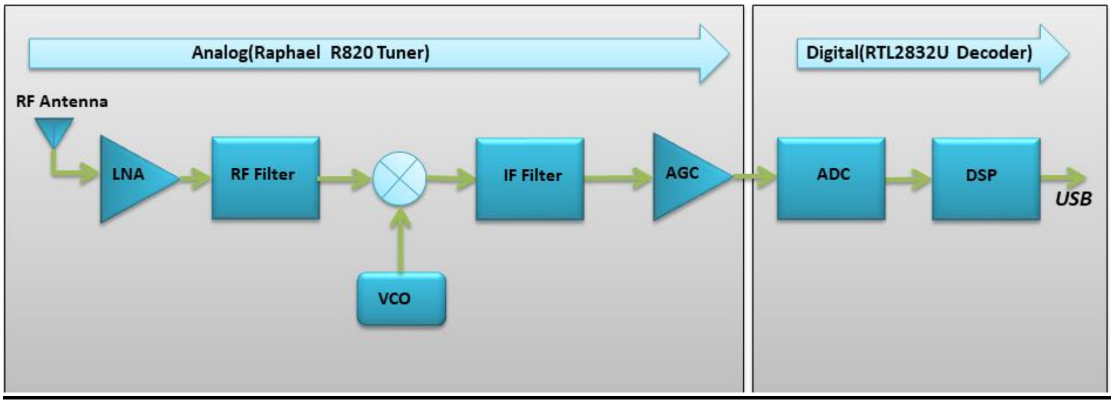

Figure 6: RTL 2832 SDR/V3 Dongle flow diagram

Table 3. RTL2832 SDR V/3 Dongle technical Details

General Specification:	
Dimension (L x W X H)	90 x 50 x 15 mm
Power Consumption	280mA
DC Power Connection	5V (USB Powered)
Weight	< 100 gm
Connectors	
UHF Coaxial	SMA-F
PC Interface	USB
Radio Receiver System:	
Modulation	GFSK
Frequency Range	0.5 - 1766 MHz
Frequency Accuracy	1 ppm
Input Impedance	50 ohms
ESD Protection	Improved BAV 99 Diode
Additional Details:	
ADC	8 bits
Host Interface	USB
Support	Windows, Linux, Mac
Environmental Condition:	
Operating Temperature	0° C to 45° C
Storage Temperature	-55° C to 70° C

2.3 mini Decoding Software System (mDSS):

The mini decoding software is the last block in mRGR system. It takes the sonde processed signal and decodes it to the original physical parameter [11]. Here we use free windows-based software to decode RS-41 radiosonde telemetry, used in conjunction with a FM radio receiver (mSPS) (Figure 7).

The mDSS allows operators to display radiosonde position on a Google map, the parameters like pressure, temperature, humidity, wind speed and direction, export telemetry data in CSV format and also balloon burst related information in real time.

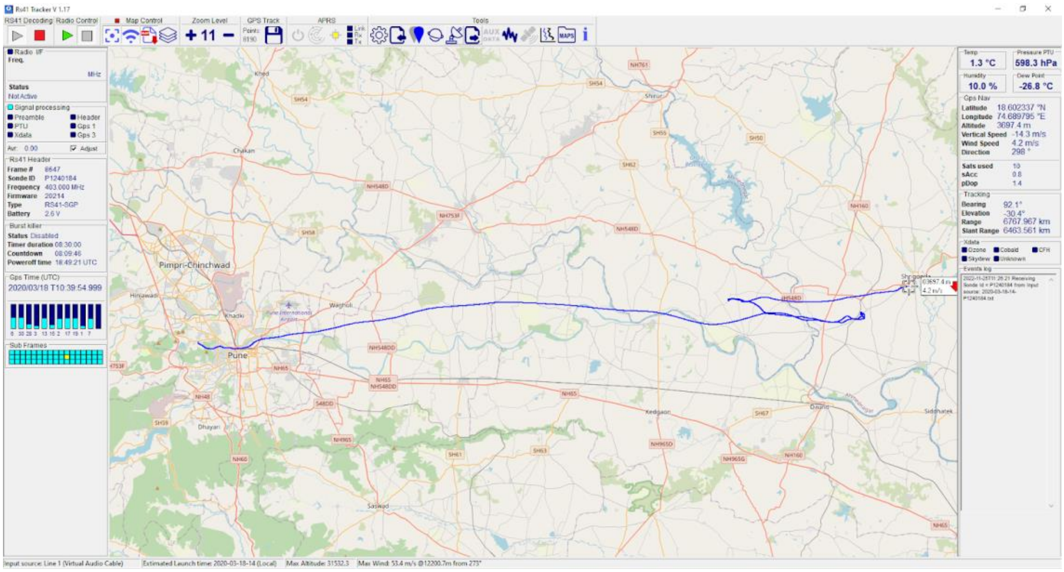

Figure 7: Decoding windows-based Software

The mDSS main features are as follows:

- Direct decoding of GFSK signal received by the mSPS unit.
- Real time radiosonde position on map (online/offline mode are available)
- Real time user position on map (connection to an external GPS required)
- Radiosonde RAW data save
- Post processing of RS41 RAW data file (flight replay).
- Radiosonde track can be saved in kml/gpx format.
- RS41 Telemetry export in csv format
- Skew-T Diagram.

- Tracking position (Elevation, bearing, Range, Slant Range). The parameters are calculated using the presented home position or current user location (see GPS IN).
- Support for KML ghost-track. Software is able to load a GPS track file in KML format. This feature real time comparison between the current radiosonde track and the forecast track.

3. Results & Discussion

3.1 Balloon-sonde

The Radiosonde balloon released at IITM, Pune on 18th March 2020 at 8:30 UTC is tracked by mRGR system along with a standard Vaisala Digi-Cora Sounding System. Comparison of the ground received radiosonde balloon data from Vaisala Sounding (VS) System and IITM mRGR system is shown in Figure 8 and the respective Skew-T plot is depicted in Figure 9.

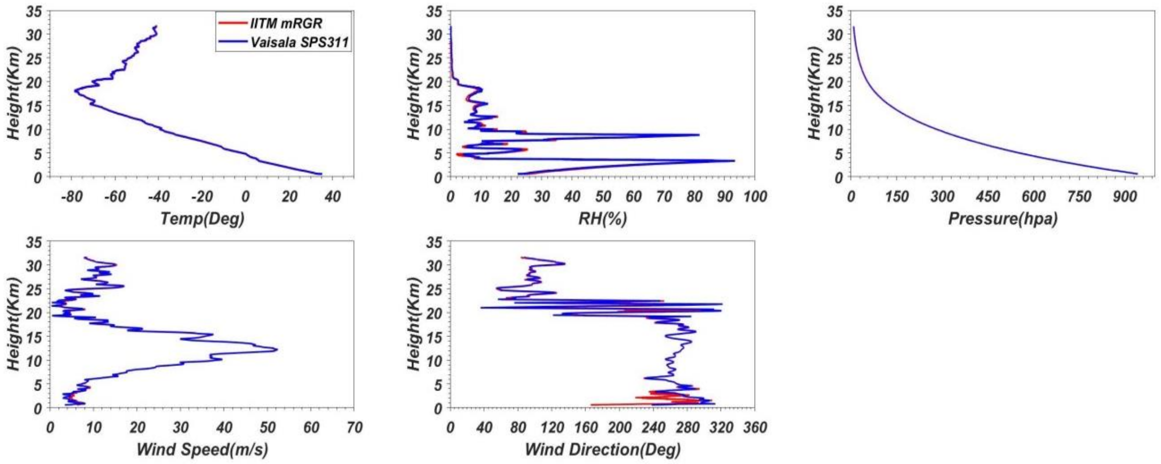

Figure 8: Comparison of vertical profiles of meteorological parameters received from a Radiosonde balloon

The Figure 8 depicts the comparison of the vertical profiles of the meteorological parameters such as temperature, relative humidity, pressure, wind speed and wind direction from two different receivers. A very good comparison is observed especially with pressure, temperature and wind speed. While, a small deviation is noticed with respect to wind direction especially in the lower altitudes which will be explored further.

The comparison statistics of different parameters are shown below in Table 4. A very good correlation is observed with all parameters.

Table 4: mRGR system comparison

Parameter	R Square	Slope	RMSE
Temperature (°C)	0.9999	0.9988	0.2944
Relative Humidity (%)	0.9978	1.023	0.915
Pressure (hpa)	1.000	1.000	0.5029
Wind Speed (m/s)	0.9976	0.983	0.6781
Wind Direction (deg)	0.9553	0.9572	16.18

For the same profile, the Skew-T plot in Figure 9 again depicts that the sensitivity of the mRGR system is close to the standard receiver system.

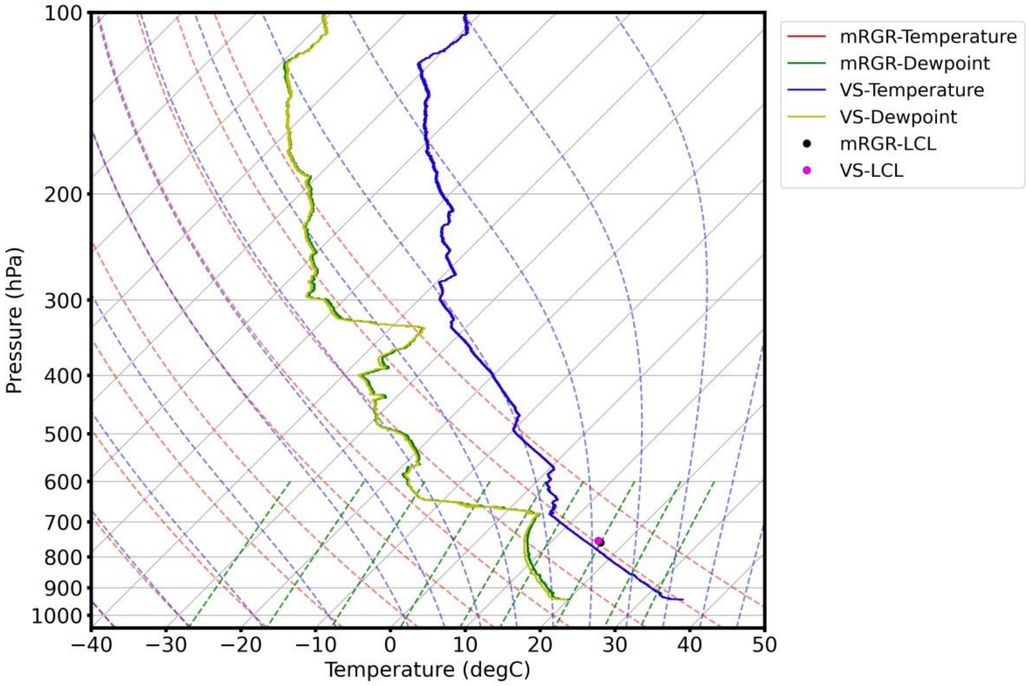

Figure 9: SKEW-T Profile

The balloon tracks of nearly 8 radiosonde flights from IITM pune (shown in figure 10) indicate the vertical as well as horizontal trajectories. The trajectories also represent the descent profile once the balloon is burst at some altitude. Hence, it also indicates that the mRGR system is capable of receiving horizontal profile up to 100-120 Km.

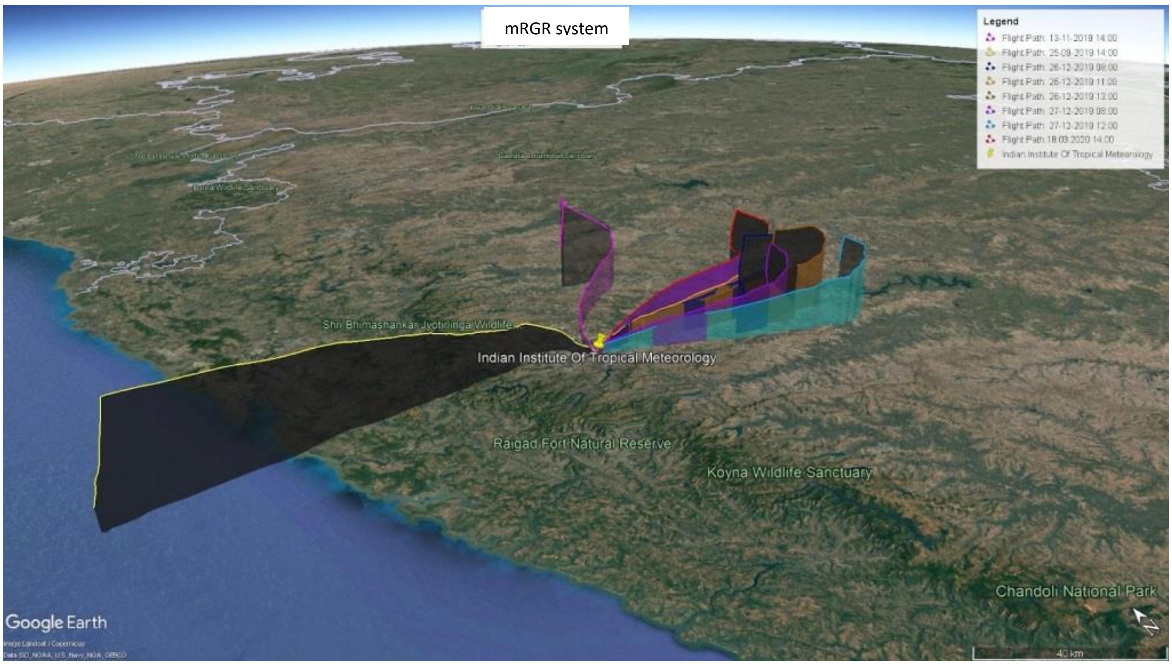

Figure 10: Balloon-Sonde Trajectories

3.2 UAV-Sonde:

Fixed wing Unmanned Aerial Vehicle (UAV) system is integrated with a Radiosonde RS-41. Flights were conducted at a remote location during a field campaign. The maximum height reached was approximately 538m above ground level (AGL), corresponding to 1191 m (AMSL).

Radiosonde RS-41 having telemetry transmits its data at 400-406 MHz frequency range using GFSK and it has a capability to transmit the signals up to a range of 350 Km. The range and resolution of the meteorological sensors are presented in Table 5, as given by Vaisala (2018) [10].

Table 5: Vaisala RS-41 Specification

Parameter	Sensor	Range	Resolution
TEMPERATURE SENSOR	PLATINUM RESISTOR	+60 °C to -90 °C	0.01 °C
HUMIDITY SENSOR	THIN-FILM CAPACITOR	0 to 100 % RH	0.1 %
PRESSURE	CALCULATED FROM GPS	From surface pressure to 3 hpa	0.01 hpa
WIND SPEED	CALCULATED FROM GPS	1 - 160 m/s	0.1 m/s
WIND DIRECTION	CALCULATED FROM GPS	0 to 360 deg	0.1 °C

The data from the UAV-Sonde is received by mRGR system and processed for further analysis. UAV-Sonde flight track covering the boundary layer above the ground is shown in Figure 11.

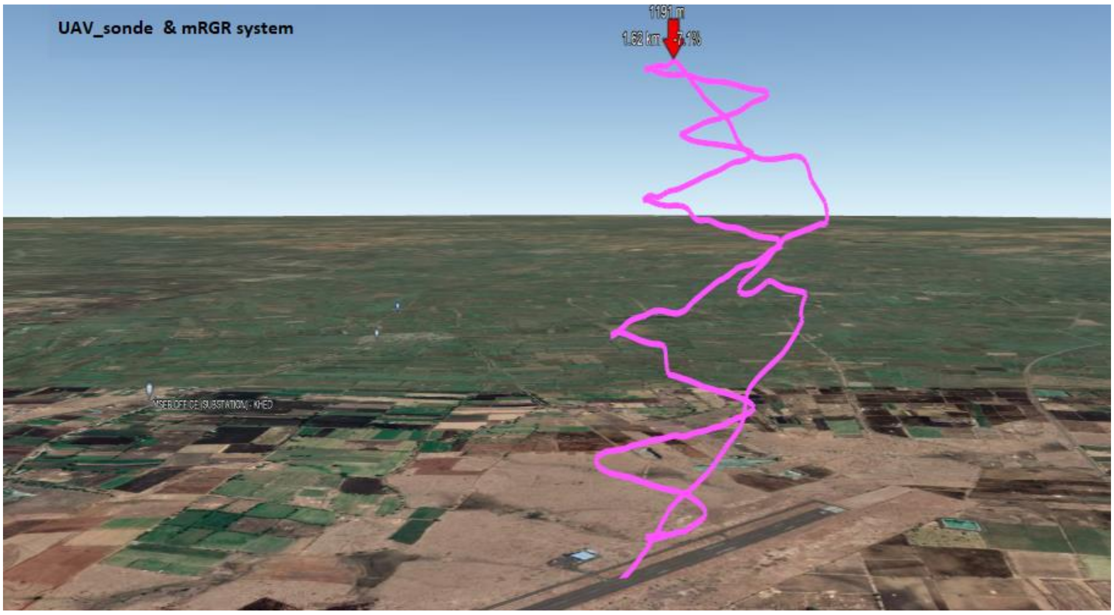

Figure 11: UAV-Sonde flight track (Ascent & Descent) on Google map

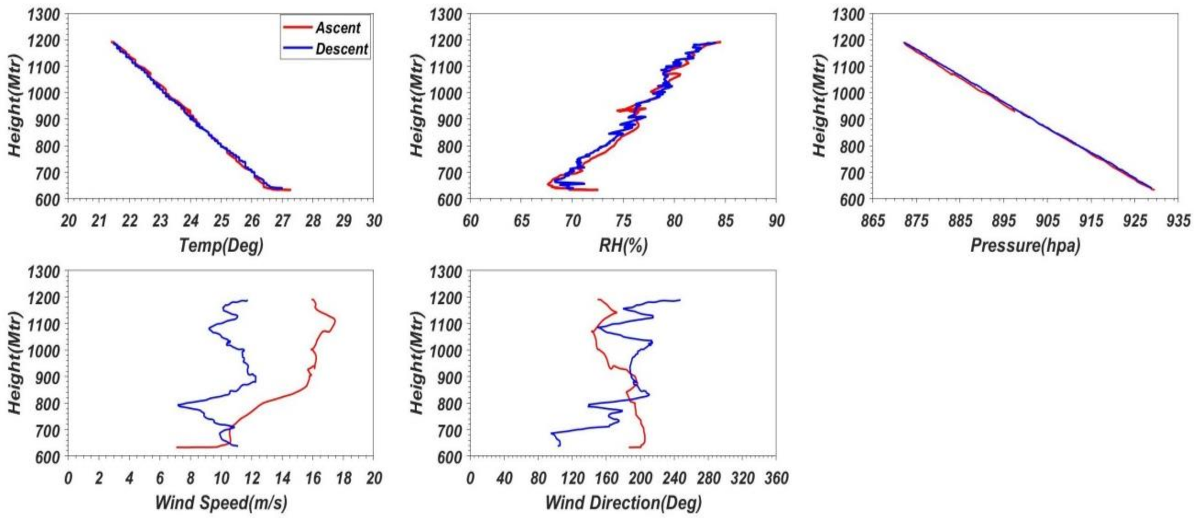

Figure 12: UAV-Sonde profiles for Ascent & Descent flight

The profiles of meteorological parameters such as Temperature, Relative Humidity, Pressure, Wind speed and Wind direction shown in Figure 12 depict the high frequency measurements in the boundary layer.

4. Summary

Miniaturized Radiosonde Ground Receiver (mRGR) system along with a suitable portable Ground Plane (GP) antenna is in-house designed and developed for meteorological data telemetry from different aerial platforms such as balloons and UAVs / drones to ground station. It is a miniaturized low cost receiver system for high altitude data telemetry. The system consists of a portable GP antenna for receiving UHF signals, portable receiver for processing radiosonde data and Windows GUI based software for telemetry decoding. This system is easy to configure, portable and easy for deployment in field experiments/campaigns in any remote location.

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5. Scope of Work

Here we presented a new portable mRGR system for radiosonde. However, there is still a scope for further improvement such as metallic enclosure for components, Ground GPS Antenna for more precise location tracking, improvements in antenna and low loss RF cable to make the receiver system robust and reliable. Further, it is possible to upgrade the software to track all types of radiosondes like GRAW, iMET, Vaisala RS-92 and mini-RS.

Acknowledgment

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