



Radar Reflectivity of Micro Rain Radar (MRR2) At 16.44180N, 80.620E of India

Krishna Reddy Maddikera^{1*}, Sarat K Kotamraju², K. Ch. Sri Kavya³, Bala Gangadhar Tilak Gande⁴

¹Department of Electronics and Communication Engineering
Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur District-522502, A.P., INDIA

*Corresponding Author

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Abstract: To improve accurate standards of Radar Reflectivity Z, Rainfall Rates RR, and even to monitor small size precipitation particles Z-R relation is derived in this work with the help of Micro Rain Radar. Formerly, taking rain/precipitation data from ground-based rain gauges (Cylindrical, Optical, Weighing, Tipping Bucket Rain Gauges, Disdrometers, etc.,) currently, in this work using METEK MRR (Micro Rain Radar) of Frequency Modulated Continuous Wave System which reads the vertical structure of precipitation particles and hence named as vertical profile radar which operates at 24.2 GHz and height up to 6000m/6kms with an increment step size of 200m respectively to monitor the frozen hydrometeors. It is installed at (16.440 N, 80.620 E) K L University, 29 meters above the sea level (ASL) in CARE LAB. The METEK is manufacturer of micro rain radar, to know the Radar Reflectivity of precipitation, it is observing the amount of power received to the radar receiver after hitting the precipitation particles with respect to the transmitted power of the radar. This proposed work considered distinctive rain conditions at different heights ASL ranging from 200m 1200m 2200m, and derived Z-R relations respectively. This work has been provided significant natural disasters such as Geophysical, Hydrological, Climatological and Meteorological pre-intimation easily using METEK MRR.

Keywords: Radar, Micro Rain Radar, Rain Rate (Rr), Radar Reflectivity (Z), Vertical Profile Radar, Above The Sea Level (ASL), dBZ, hail

1. Introduction

Now a day's Satellite Communication usage is most important for Communication purposes from Space Links to Ground Links. But due to rain/precipitation, fading of information is seen largely which causes loss of data during uplink and downlink of channels. Huge attenuation of signals is of mainly due to Precipitation or Rain particles. For over nearly 40-45 Radars has been used for weather services which are mostly used by Construction Engineers, Meteorology departments for weather predictions to overcome floods and saving livelihood. Formerly rain gauges ground-based only such as Cylindrical, Optical, Weighing, Tipping Bucket Rain Gauges, Disdrometers. Here we are using the METEK Micro Rain Radar for measuring precipitation parameters such as rainfall rate RR, Radar Reflectivity Z, Melting Layer/Bright Band, Liquid Water Contents.

RADAR - Radio Detection and Ranging, is used to know the locations or tracing/aiming the targets with utmost accuracy by transmitting the EM waves as seen in below fig. 1.i. explains about After the EM waves transmission in to the atmosphere it reflects/backscatters after hitting the target/object with a certain distance from transceiver to object. As shown in fig.1.ii and iii. Simply, explains about the source original waves with some frequencies are reflected back (after hitting an object/target that is stationary/moving (doppler)) as echo said to be reflectivity which is a continuous.

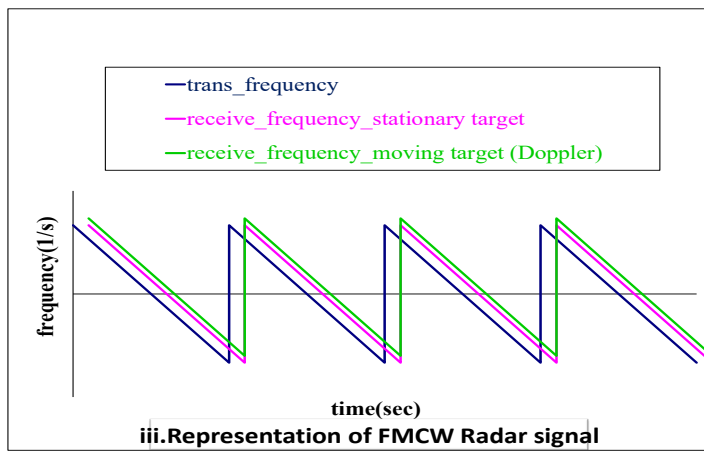
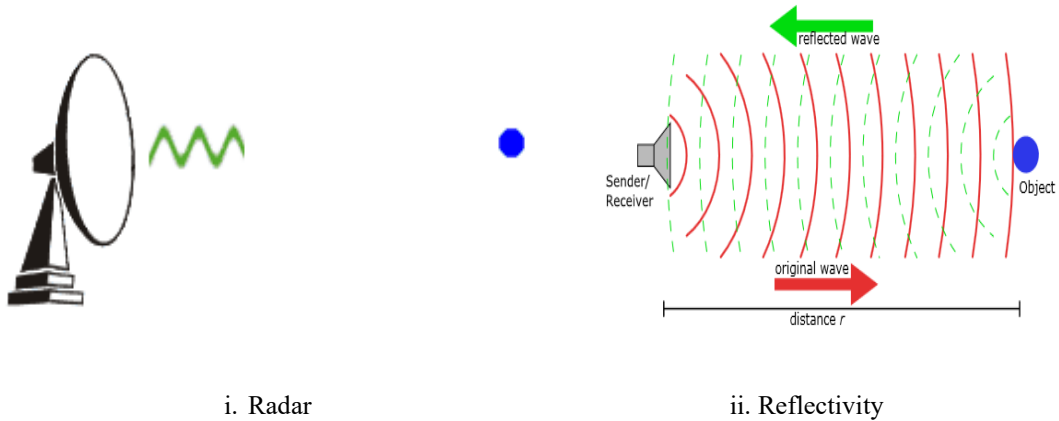


Fig. 1 - Schematics of i. Radar, ii. Reflectivity and iii. Frequency Modulated-Continuous Wave (FM-CW) Radar - Micro Rain Radar

The microwave rain radar, has been continually monitoring the radar signal, as well as transmitted waves are received from sender. The continuous wave frequency modulation can help out the MRR functioning so that, 0 GHz to 24GHz radar profile has been find 15 to 6000 meters signal on doppler hydrometer scale.

Before 1988, for precipitation measurements Ground Based Rain Gauges have been using. From the beginning of 1988 onwards these vertically pointing doppler scanning weather radars were deployed firstly by U S Defence for Weather Services [1]. Till now Globally 160+ Weather Surveillance Radars are installed for Rain Rate Measurements which is named as WSR-88D Radars which are dual polarised ones as shown in fig. 2. MRR is also a type of vertically pointing radar which is used/installed at KL college premises for weather prediction measurements of single polarized one [2]. The FMCW radar can provide accurate communication between transmitter and receiver and tracking MRR infomation. The spectral power parameters improve the backscatter intensity along with drop size and rain distribution.

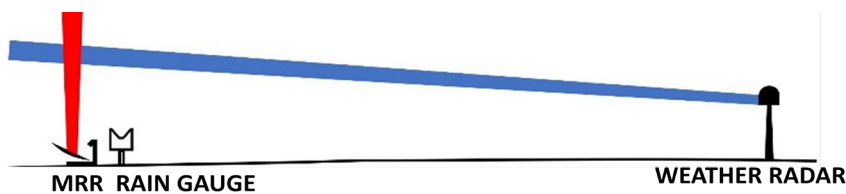


Fig. 2 - Precipitation measurement devices

The precipitation devise should be maintained typical principles like gauge-degree, drop-size and scattering density. The following elements has been improved with MRR with ASL 29m measurement.

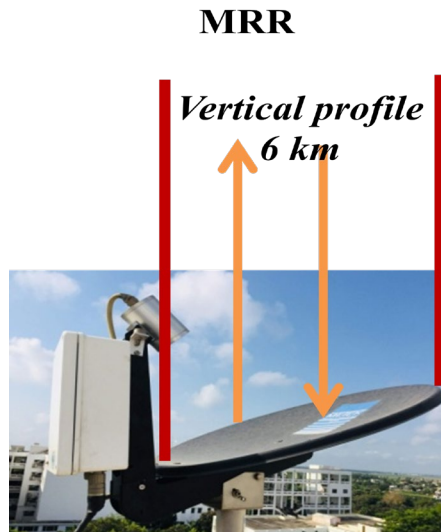


Fig. 3 - Micro Rain Radar, K L University (ASL 29m)

Radar Reflectivity is the amount of transmitted power received by the radar receiver after hitting the rain particles. The main need of Reflectivity is to predict the intensity (Reflectivity Intensities are given by US National Weather Service as green, yellow, red and magenta colors in dBZ) and based upon that ITU (International Telecommunication Union reviews electronic standards for every 4-5 years) prepares the enhanced standards for satellite communication with appropriate changes to it [3]. Radar Reflectivity depends upon Rain Rate (RR) and Drop Size Distribution (DSD) of rain drops [4].

$$Z = Z(RR, DSD)$$

The Radar Reflectivity Z is depended on raindrops and its diameter, thus it's very sensitive to raindrop size diameters, as it changes then the change in Z is also observed [5]. The precipitation measurement devices are noting but estimating rain as well as snow gauges, in this scenario, recording and non-recording classifications have been presented. The earlier meters like udometer, ombrometer and pluviometer are less accurate to measure rainfall assessment. The radiation of MRR radar bounces has been calculated from rain gauge scale, usually 12 to 24 inches diameter bucket is placed and dip the scale on it [6]. There are two types of rain gauges, non-recording type and recording type. Rain gauge is a type of instrument used by meteorologists and hydrologists to measure rainfall rate in a certain period of time [7]. Rain gauges are also known as udometer, pluviometer and ombrometer [8].

1.1. Reflectivity Intensity Scale

In the course of Micro Rain Radar (MRR) operation, the Reflectivity (dBZ) is determined with different echo intensities with distinct colours for each and every elevation scan as shown in fig.4, The values on the scale of dBZ represents the intensity of rainfall [9]. When the Light Rain (LR) occurs then dBZ value reaches to 20 (green colour) i.e., lower reflectivity (dBZ) is observed. Meanwhile if the dBZ is higher then, the occurrence of Moderate Rain is seen (yellow colour). For Sleet/Ice/Snow/Hail conditions a lot of energy is backscattered with very high dBZ values causing Heavy/Extremely High Rain which is seen as Red Colour which is incorporated in Table 1.



Fig. 4 - NWS precipitation scale

The reflectivity and precipitation scales are deciding the NWS parameters, in this Green, yellow, red and magenta colors are used to get RR activity range [10]. The MRR is a vertical pointing radar profiler, in these distributions of freezing and bright bandings are observed with 4 modes such as light rain, moderate rain, heavy rain and extremely heavy rain.

Table 1 - National Weather Service (NWS) precipitation scale

Colour	Reflectivity (dBZ)	RR (mm)	Precipitation mode
Green	20	<=5mm (1mm-5mm)	Light Rain
Yellow	35	>=6mm – 45mm (0.25in)	Moderate Rain
Red	50	>=50mm-350mm (2 in)	Heavy Rain
Magenta	65	>=400mm (16 in)	Extremely Heavy Rain

Here the main objective of this work is, we observed the Radar Reflectivity intensities are varied according with the volume of precipitation (Rainfall) of nine events collected from Micro Rain Radar during 2018 and 2019 of Monsoon Rainfall and Clear Sky condition which is installed at K L University, Vijayawada. About the Observational Location of Micro Rain Radar, its process and MRR observations are presented in Section 2. Section 3 presents the Outcomes and Observations of Micro Rain Radar with a step size height of 200m, 1200m and 2200m. Conclusions are summarized in Section 4.

2. Literature Survey

In this section a brief note on MRR rainfall radar models and its limitations are explained. The majority of nations throughout the globe are deeply concerned about the effects of global climate change on ecosystems. Climate change poses a threat to world and needed climate change studies. Temperature and precipitation patterns have been studied during the last 10 decades.

S.No	Technique	keynote	Limitations of study
1	Z_R relations-based raindrop estimation [11]	In this investigation an advanced Z-R relation-based raindrop assessment has been performed at pacific sea. In this study an advanced metrology techniques have been used to find the exact rainfall estimation in any location.	The Z-R relation-based rainfall estimation facing haze related issue in winter season so an advanced study is required
2	Empirical study of rainfall estimation using Z-R relation [12]	In this study correlating the theoretical as well as empirical study related to rainfall calculation.	This study mainly focusing summer season climatological changes according to sea level changes. Unable estimate rainfalls in monsoon seasons.
3	Z-R relation using Alor Setar radar [13]	In this research temporal matching method is used to find the earth and environmental changes.	The TMM is little bit mis-accurate rainfall assessment model when unstructured data is applied on it.
4	k-band and x-band based Radar rainfall model [14]	In this study ZR relation-based radar estimation is performed to analyses the rainfall assessment	This study limited the rain retrieval rate at monsoon seasons.
5	NOAA/ESRL based hilly area climatological estimation [20]	This research area covering hilly area and sea level climatological issues.	The NOAA/ESRL technology limited with unsupervised data.
6	STORMWATER NETWORK [21]	This Storm water based network can providing information about Rainfall estimation.	The storm water network limited with seasonal changes, so that an advanced MRR models are required.

The University of Delaware provided the high-resolution gridded data needed for this project. Researchers found that temperatures have been rising over the last 20 to 30 years, particularly during summer months when monthly average daily temperatures reach 35 oC. According to Mann-Kendall test results for January through February and October through November/December there is no statistically significant trend. Analysis of precipitation time series revealed that the greatest precipitation happened in the early 1910s and 1920s, that peak steadily fell, and the lowest precipitation occurred in the past 20 years when the precipitation rate was always below the 115-year mean value.

There is a statistically significant declining trend seen in the yearly precipitation time series when the Mann-Kendall test is used. Detailed information on the impact of global warming on global climate will be provided by this research [15].

Due to the climatical connection of residential network, urbanization and climate change are the primary causes of urban floods, which is accompanied by wastewater pollutants in certain places. In global Stormwater Management Model (SWMM) was utilized to assess the combined stormwater network performance. IDF curves for 2-hour storms with intervals of 15 minutes and return periods of 2, 5, 10, 25, and 50 years provided the rainfall data used in this study. Curve Numbers were employed to simulate infiltration processes, whereas Dynamic Waves were used to simulate flow routing. N-Manning, N-Imperv, D-Imperv, and D-Perv were shown to be the most sensitive to the model's parameters. For the rainfall return periods of 2, 5, 10, 25, and 50 years, the simulation results showed nodes inundated with ratios of 59% to 72% to 73% and 67% to 67%. Some areas of the network were unable to handle the varying rainfall intensity, resulting in surface flooding that was accompanied by unlawful residential wastewater pollution. Some network components might be redesigned, and a separate sewer network could be installed, according to this research. [16]

Numerical information is obtained from weather stations and several meteorological websites on air quality. Researchers are working to create a Data to Text (D2T) weather generator that would make it easier for consumers to interpret weather and air quality data. There are four main components to the development of D2T: signal analysis, data interpretation, document planning, and microplanning and realization. New features such as exponential smoothing for time series data prediction, a linear model with gradient descent for managing missing values, and statistical data summarization are all part of this study's contribution to signal analysis. Some of the accessible R packages were used in this investigation. Measures for readability, computation time, relevance and honesty, as well as comprehensibility and significance were utilized to verify the findings. Results showed that children between ages 13 and 15 can understand the system's readability, calculation time is short (round 2.64 s), and the system's relevance, veracity, comprehensibility and significance all received adequate marks. A text generation system for weather and air quality news is therefore possible with the suggested technology. [17]

Climate, one of the world's most important determinants of human well-being, has changed over time as a result of natural and man-made factors. Bangladesh, one of the world's most densely populated nations, is under danger from climate change brought on by human activity's overconsumption of natural resources. A statistical analysis of daily rainfall data from 1957 to 2006 was used in this work to examine the north-eastern section of Bangladesh, particularly the city of Sylhet, for changes in rainfall patterns and their related alterations. The monthly mean and daily maximum rainfall have been shown to have a strong association. Using a linear regression analysis, it is discovered that all months are significant. Several important statistical metrics, such as CV, RV, and PIV, have been examined and found to be out of whack, including the mean values. These variables are all related to the coefficient of variation. It's also important to examine the monthly, annual, and seasonal variance of rainy days to see if there are any noteworthy variations. [18]

Artificial Intelligence and deep learning approaches are now being used to propose crucial E-commerce apps. Offline and online items can't be understood by human computers, computer-aided designs. As a result, consumers are crucial in gaining knowledge about various items, including food, clothing, and health care. However, overcoming this human perception constraint is a huge challenge. An enhanced FCNN deep learning model with global thresholding is suggested in this study. Pre-processing and categorization of digital photos and internet photographs will be used in this project. Classification is accomplished using FCNN at the primary stage, and at the end stage, the performance metrics such as accuracy, sensitivity, and throughput have been attained and the results are challenging the current technology, which is based on segmentation [19].

The above all dissuasion has been provide limitations of earlier studies, by using existed technology suggestions proposed an MRR based rainfall estimation model. The empirical and theoretical study has been performed in below section with proper experimental setup.

3. Empirical Region and Method

In this section, a brief note on Z-score standardization and its realization concepts are explained. The MRR PC is maintained by researcher through the connection with master plan design. The MRR radar, India Map and MRR PC components are main factors to analysis the rainfall. The MRR-2 is an advanced doppler spectrum, which can originate at particular location via dropping size analysis. The simple setup can handle doppler velocities, attenuation and reflectivity functions. The raw data have been alternatively calculating, rain percentage and weather monitorization.

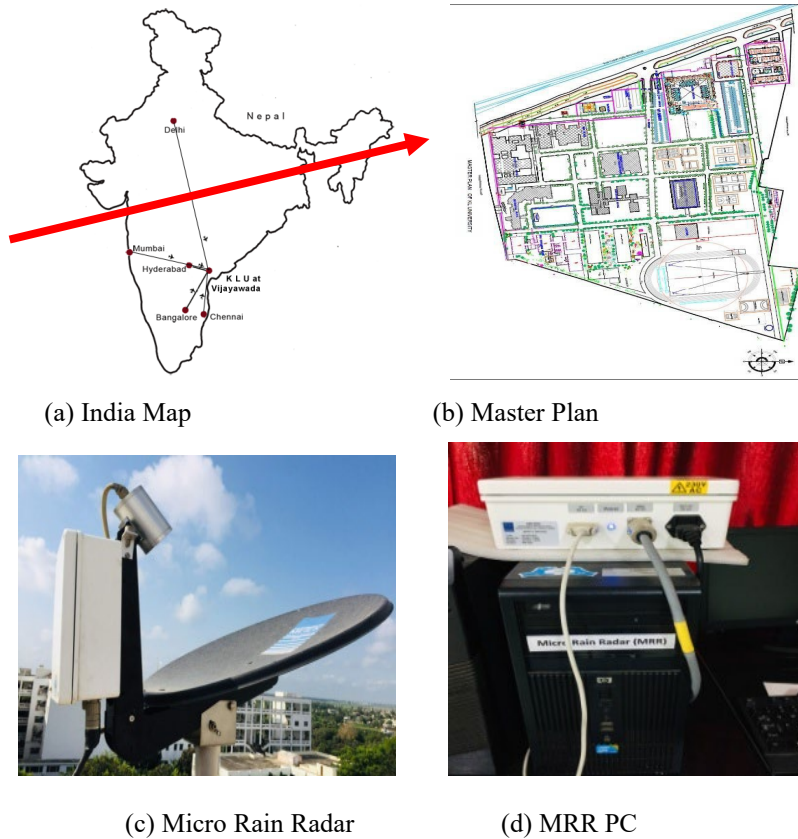


Fig. 5 - MRR installed location with PC at K L University in CARE LAB (16.4418oN, 80.62oE)

Here in this work, the real time data is collected from Micro Rain Radar MRR which is installed at K L University, 29 meters above the sea level (ASL=29m) with co-ordinates 16.440 N, 80.620 E, Vijayawada, India. It is a vertical Doppler radar which operates at 24.2GHz; these EM waves are transmitted from MRR and backscattered after hitting the precipitation particles. This MRR is a FMCW Radar with time resolution of 10s which consisting of Thirty range gates with 200m step size variation of vertical height up to 6 Kilometers. FMCW radar (Frequency-Modulated Continuous Wave radar = FMCW radar) is a form of radar sensor that emits continual transmit power, similar to a traditional continuous wave radar (CW-Radar). The CW radar, FMCW radar may modify its operational frequency during detection, which means the broadcast signal is multiplexed in frequency (or in phase). Radar measurements using runtime measurements are only physically feasible because of these frequency fluctuations (or phase). Simple continuous wave radar systems without modulated signal have the drawback of being unable to calculate target range because they lack the timing mark required to correctly clock the transmit and receive cycle and convert this to range. This kind of time references for measuring distances between stationary objects may be created by modulating the broadcast signal's frequency. In this procedure, a signal is sent that regularly rises or lowers in frequency. When an echo signal is received, the change in frequency is delayed by t (because to runtime shift), which is referred to as the pulse radar method. The lifetime must, however, be measured directly in pulse radar. Instead, changes in phase or frequency between the actually emitted and receiving signal are detected in FMCW radar.

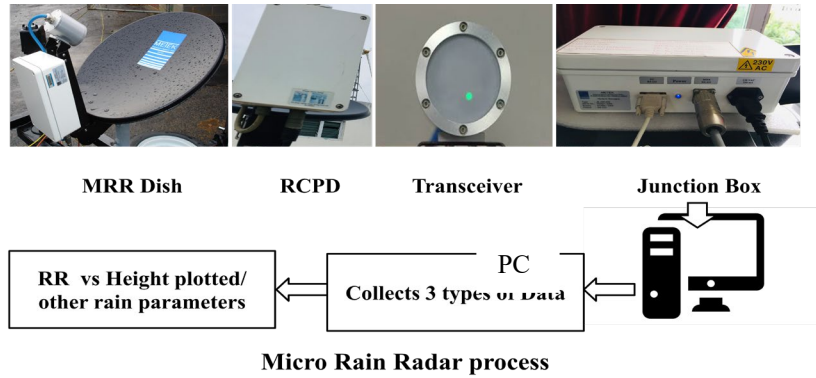


Fig. 6 - Micro Rain Radar (MRR) process

As shown in above Figure.6. MRR consists of Parabolic Dish offset antenna of 70cm diameter with 20 beam width for transmitting radar signals and receiving the backscattered signals, RCPD-RADAR Control and Processing Device for collecting and calculating the spectral data(raw, average and processed) and Transceiver transmits the signals (with 50mW of power and wavelength 12.4mm) into the atmosphere and receives the Doppler spectra, Junction Box a communicative box between RCPD and PC , PC – compact size Personal Computer with higher data storage (in TB), Latest OS(Operating System) and METEK Graphics Software should be installed to read the real time data. MRR collects three types of data as Raw Spectral, Averaged and Processed, where Averaged and Processed data is similar and we will take only the processed data for evaluation [METEK, Physical Basics].



Fig. 7 - MRR Micro Rain Radar observations

4. Radar Reflectivity Derivation

Reflectivity of Radar (Z) is derived from RADAR power equation [NEXRAD, WSR-88D]

$$Pr = (PtG^2H\pi^3K^2/1\phi^24 (\ln2) \lambda^2) * (Z/R^2) \quad \text{--- (1)}$$

From equation (1), Pr =Average Power,	Pt=Transmitted Power
G ² =Antenna Gain	θ^2 =Beam width
H=Pulse width	$\pi^3 = \pi * \pi * \pi$
K ² =Physical Constant	$\lambda^2 = \lambda * \lambda$
$1\phi^24 (\ln2)$ =Constant	Z=Reflectivity
R ² =Range*Range	

Here Z is the Reflectivity depends upon rainfall rate RR and drop size distribution DSD of rain drops [5] [6] [8],

$$Z = Z (RR, DSD) \quad \text{--- (2)}$$

Reflectivity is given as

$$Ze = \int_0^{Dmax} |K|^2 N0e^{-\Lambda D} D^6 dD \quad \text{--- (3)}$$

Precipitation/Rain rate is given as

$$R = \int_0^{Dmax} N0e^{-\Lambda D} (\pi D^3/6) v (D) dD \quad \text{--- (4)}$$

Where D is rain drop size mm, N0 is constant=8000/m³ which is a small rain drops concentration. Λ is mm⁻¹ presence of diameter of rain particles in a volume of air with inverse mean,

V is ms-1 presence of volume of rain particles per unit volume of air.

From above we have similar functions of Ze and R. Thus it gives the relation between two of them as Z-R relation as

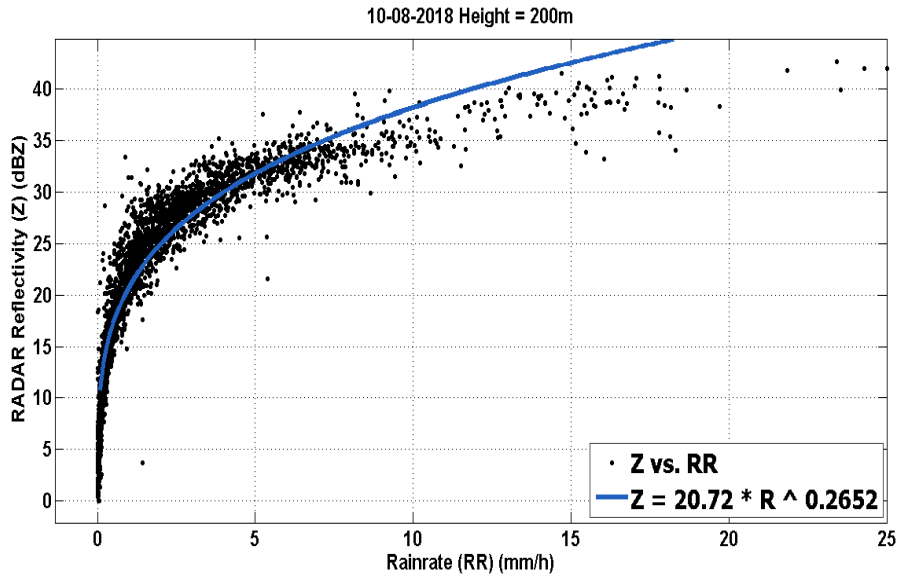
$$Z = A * R^b \quad \text{--- (5)}$$

Z → Reflectivity, Units → mm⁶ m⁻³ and

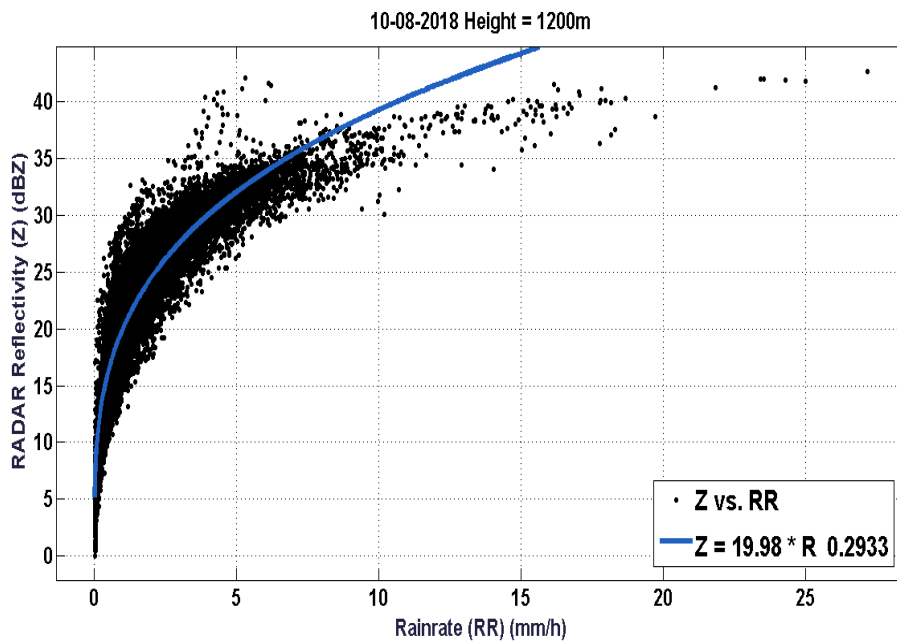
R → Rain Rate, Units → mmh⁻¹

Where A and b are radar parameters depends upon the precipitation particles such as snow, fog, rainfall (convective, stratiform), hails that has distinct K, Λ, N0, v and these values are varied in accordance with the conditions of physiographical, meteorological and climatic conditions of that observational/predicted region[5][6].

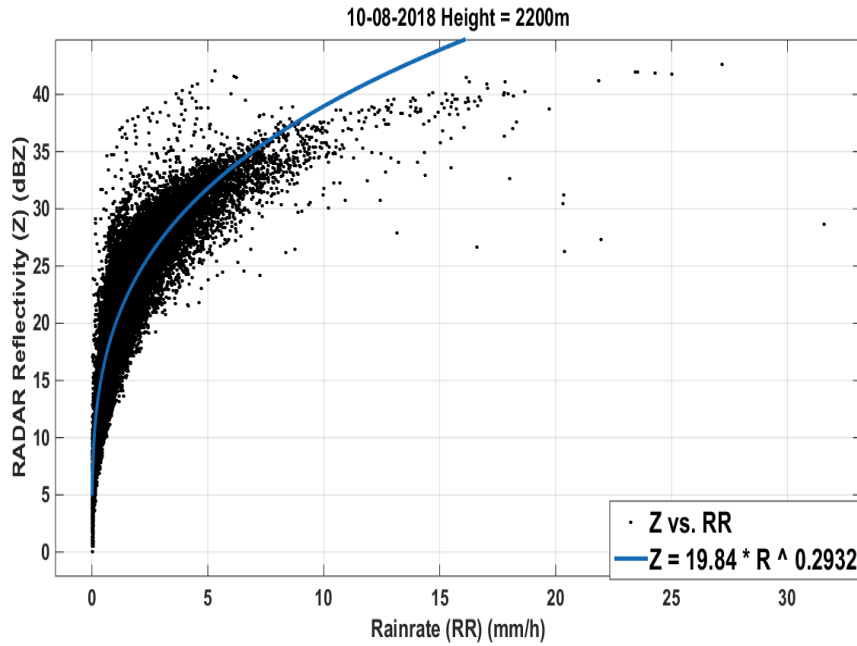
5. Outcomes and Considerations



i.



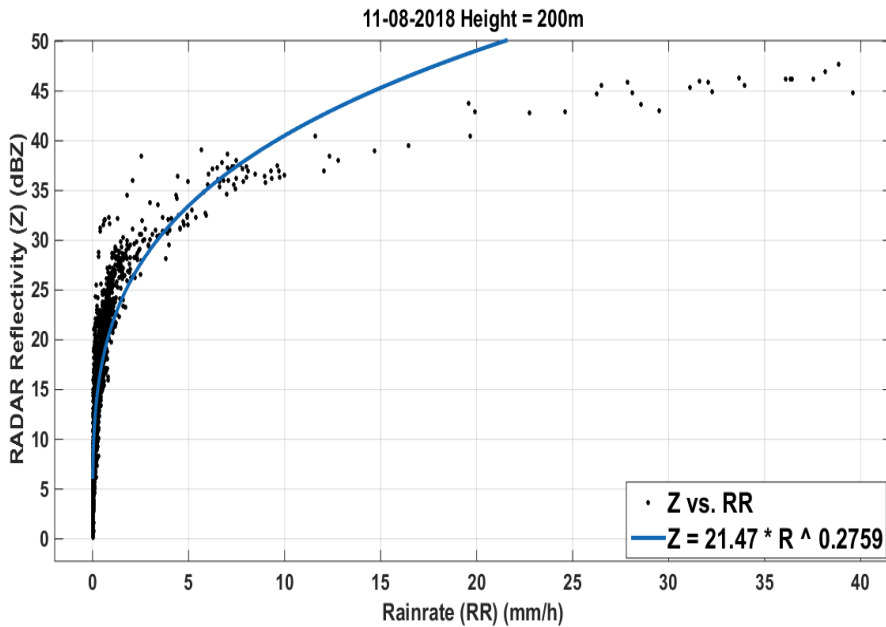
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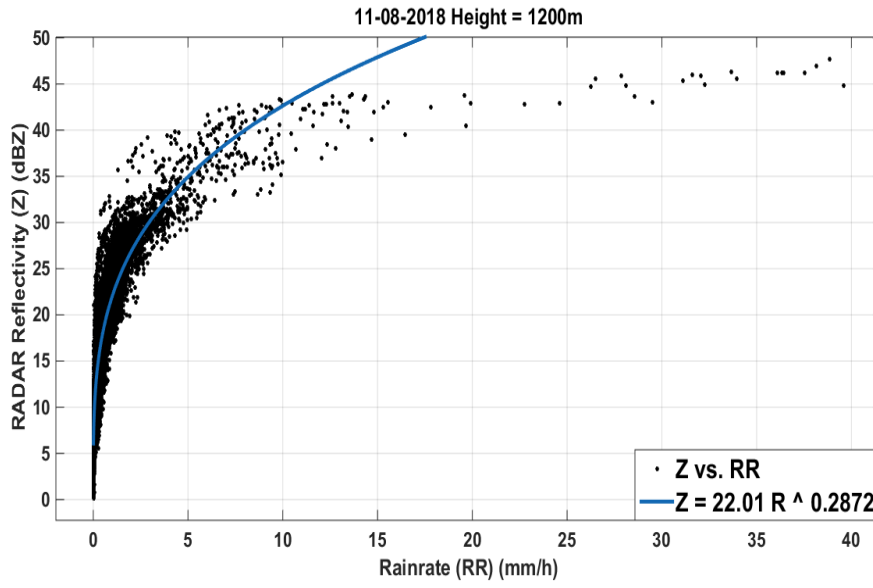
iii.

Fig. 8 - Z-R relation i. 200m, ii. 1200m and iii. 2200m
On 10-08-2018

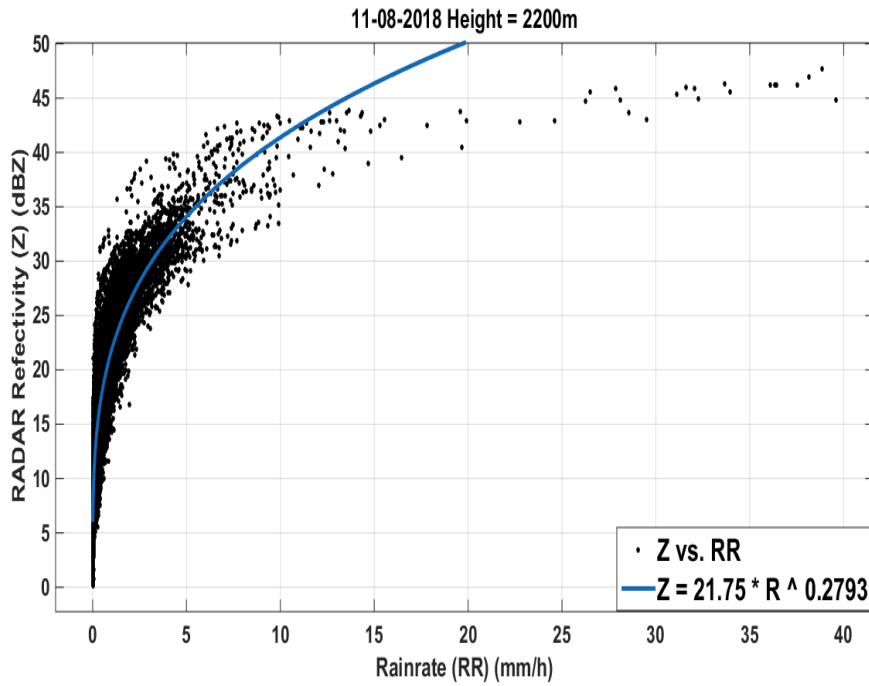
From the above fig.8, The Reflectivity of this Micro Rain Radar is 45 dBZ with moderate rainfall of 30mm and having colour on NWS Precipitation scale as Yellow + Orange shades. At the ground base height of 200m to 1km due to falling velocity of rain drops there is a chance of coalescence where smaller rain drops merges to a bigger rain drops causing high attenuation of signals at this stage and RR and Z is also observed as high. We have observed, for the rain rate of about 10 mm the Reflectivity is 35dBZ.



i.



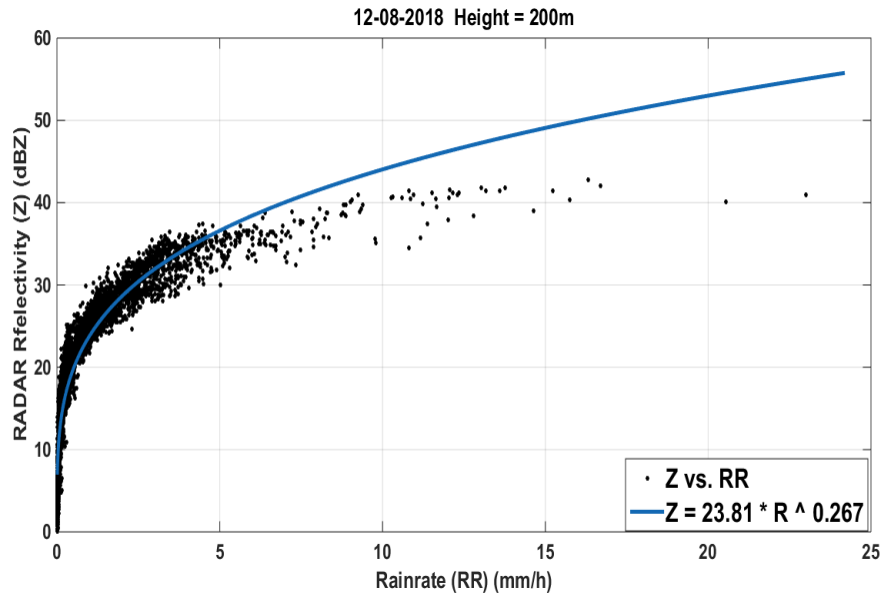
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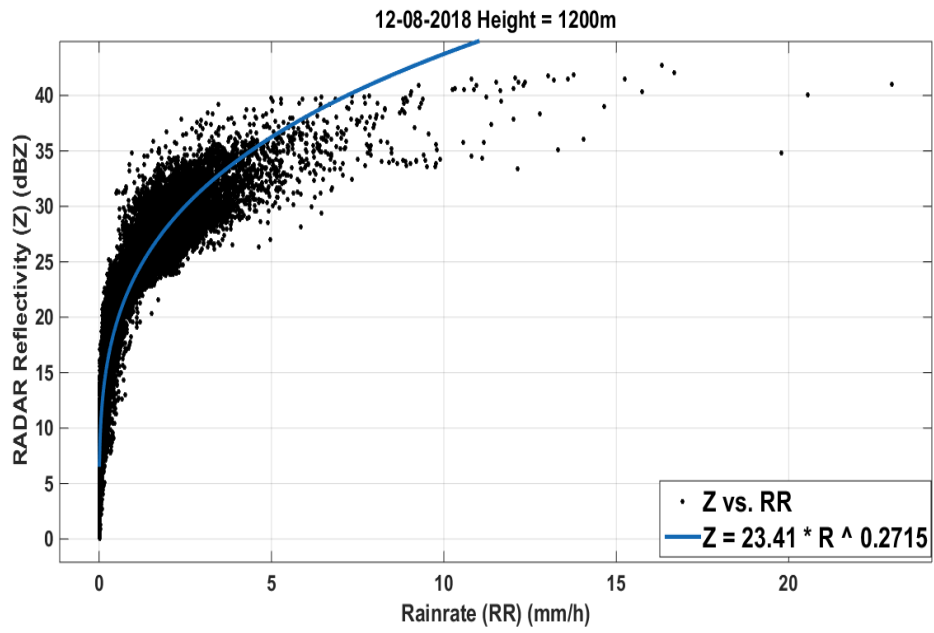
iii.

**Fig. 9 - Z-R relation i. 200m, ii. 1200m and iii. 2200m
On 11-08-2018**

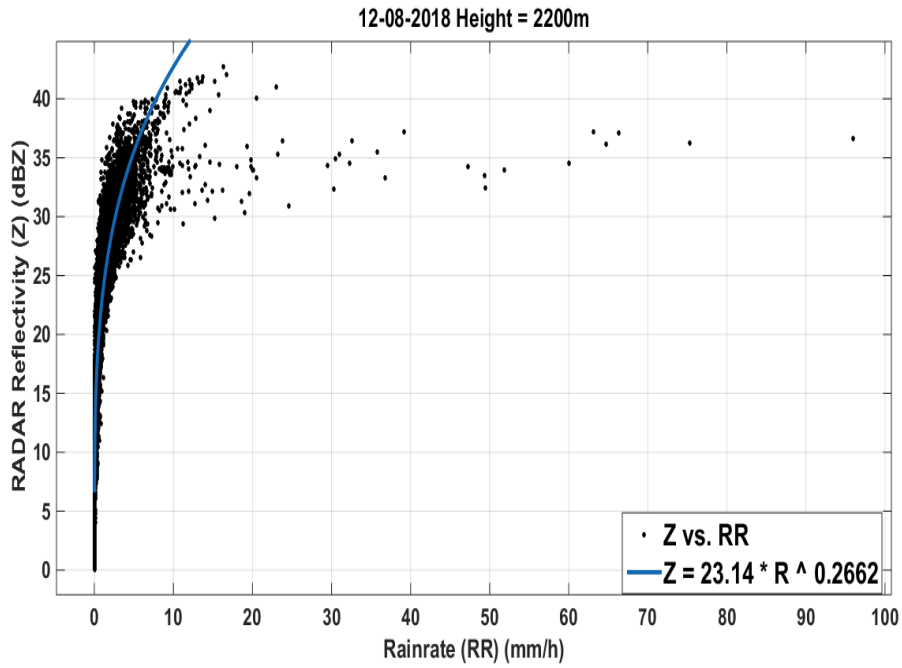
From the above fig. 9, The Radar Reflectivity (Z) is about 48 dBZ with Moderate Rainfall RR of 40mm and National Weather Service Precipitation scale is seen as Yellow + Orange shades. In this for a rain rate RR of 5mm the Reflectivity Z factor is about 30 dBZ.



i.



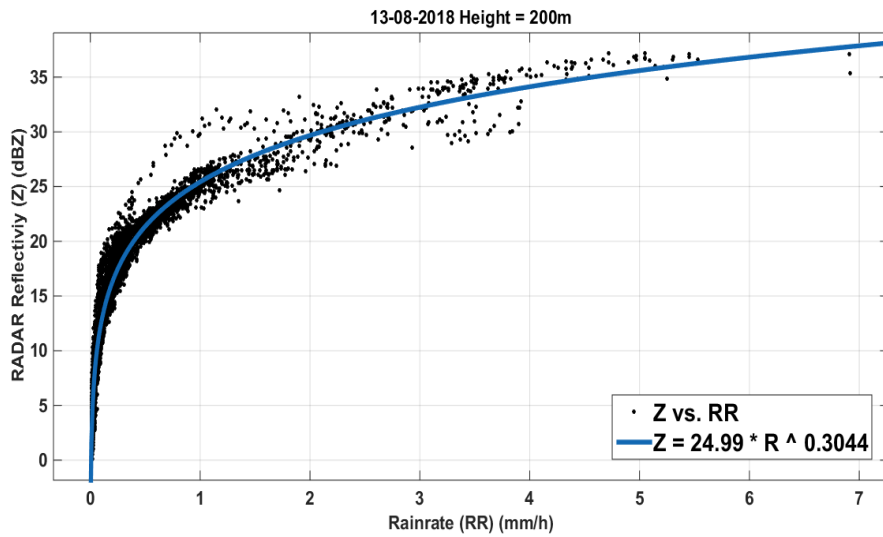
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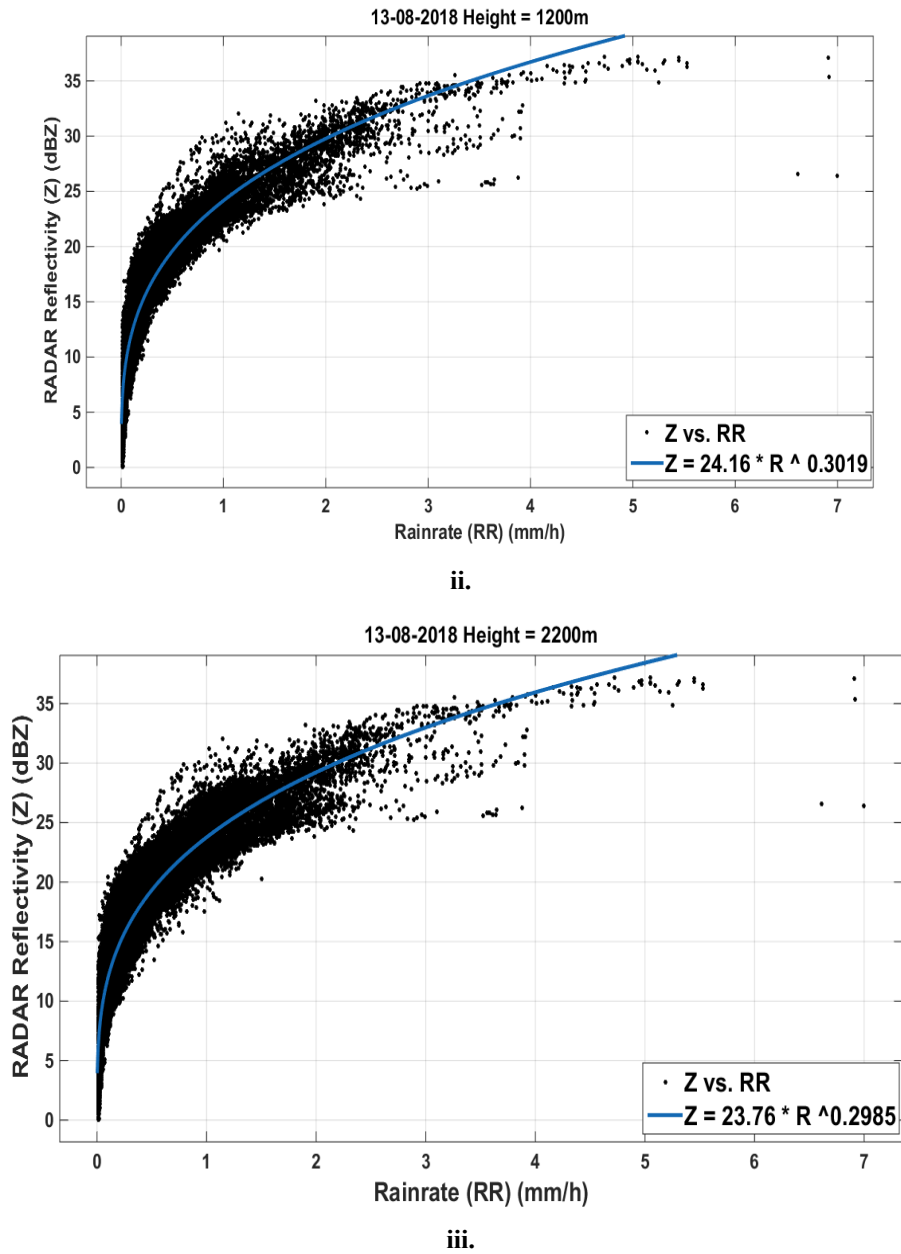
iii

Fig. 10 - Z-R relation i. 200m, ii. 1200m and iii. 2200m
On 12-08-2018

From the above fig. 10, Radar Reflectivity factor (Z) is 43 dBZ with Moderate Rainfall Rate of 28mm and the colour shades on NWS Scale is seen as Yellow + Orange shades. In this event during the rainfall of 5mm only, the Reflectivity Z is observed as very high as 35 dBZ.

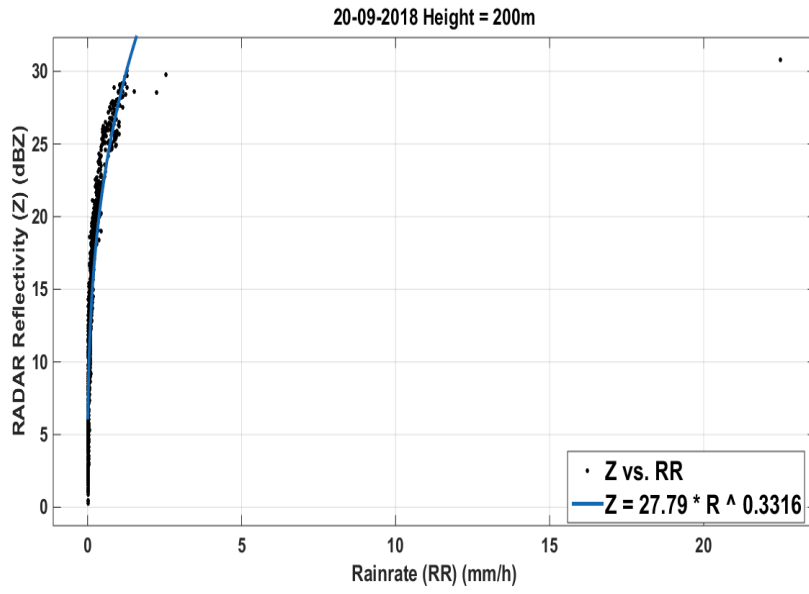


i.

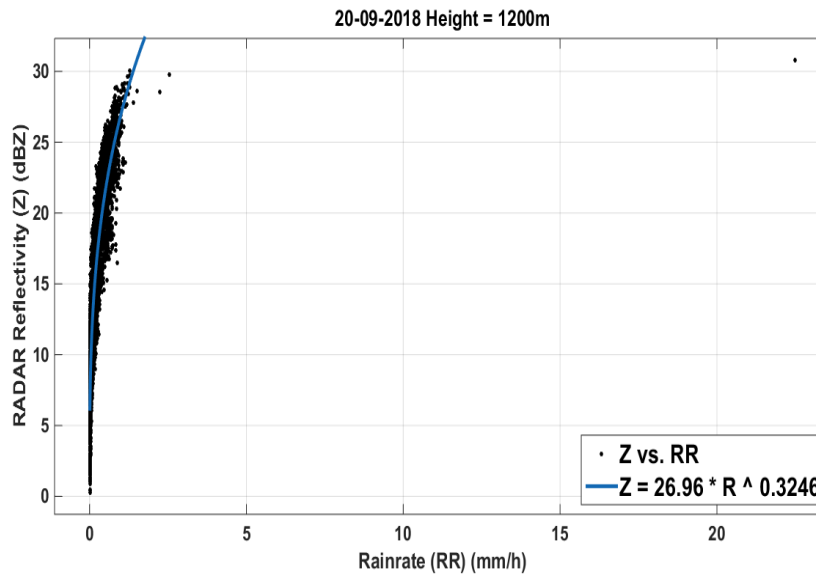


**Fig. 11 - Z-R relation i. 200m, ii. 1200m and iii. 2200m
On 13-08-2018**

From the above fig.11, The Reflectivity Z of Micro Rain Radar is about 40 dBZ having colour shades of Yellow + Orange on NWS Scale and rain rate RR is about 8mm. In this event we have observed at a rain rate of 2.5mm has maximum Reflectivity Z about 28 dBZ.



i.



ii.

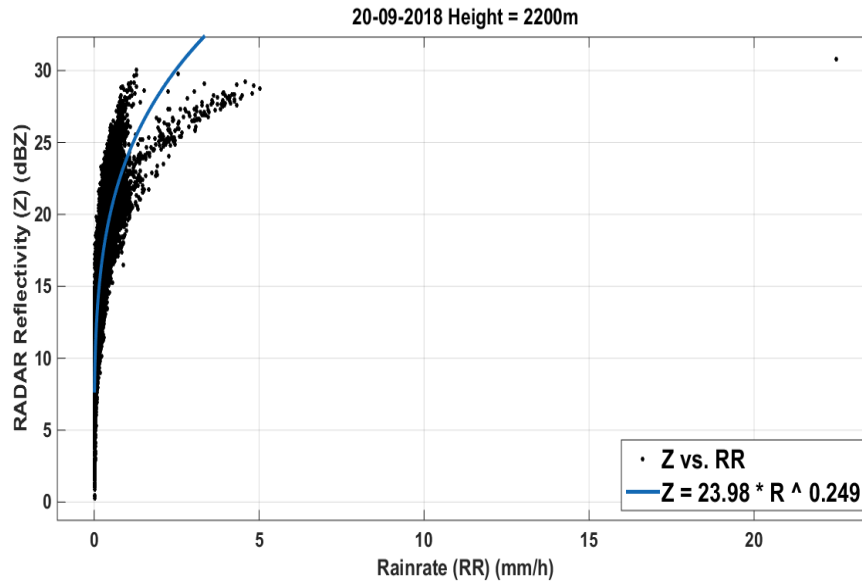
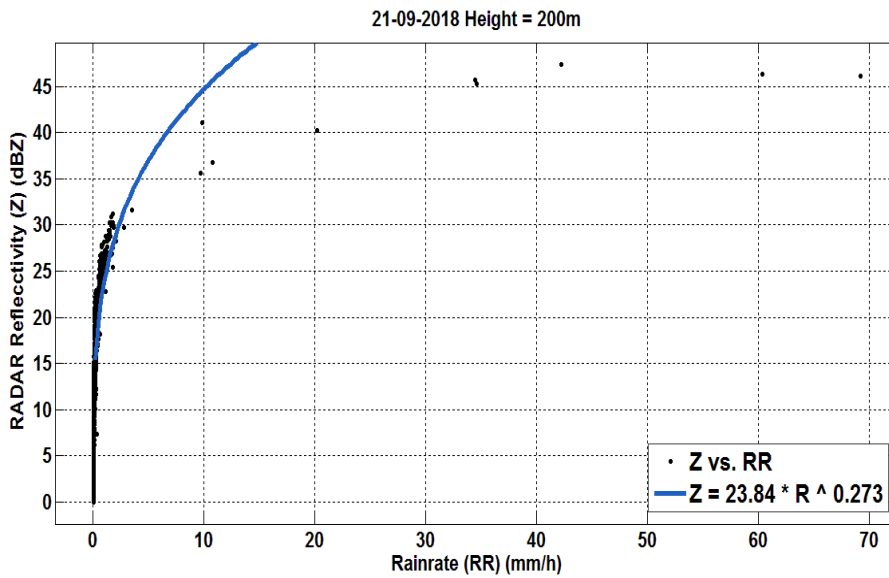
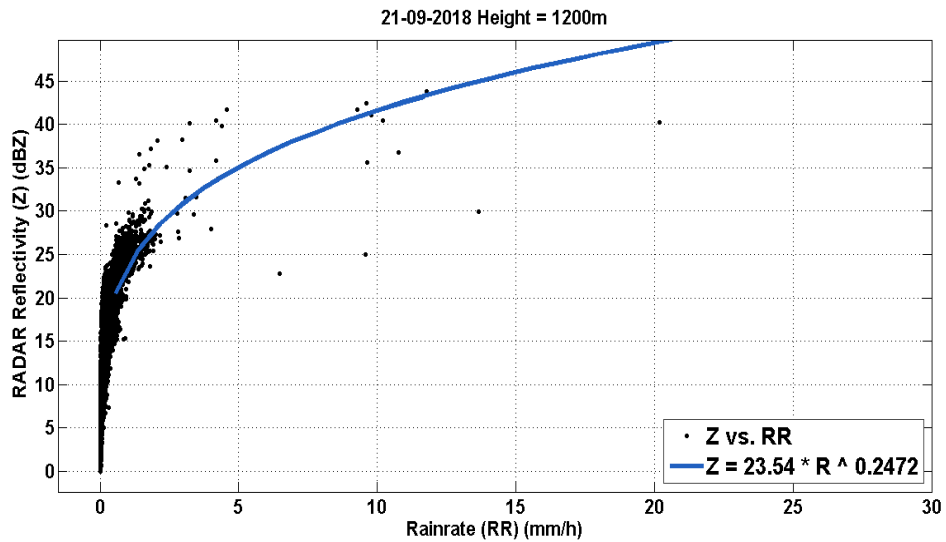


Fig. 12 - Z-R relation i. 200m, ii. 1200m and iii. 2200m
On 20-09-2018

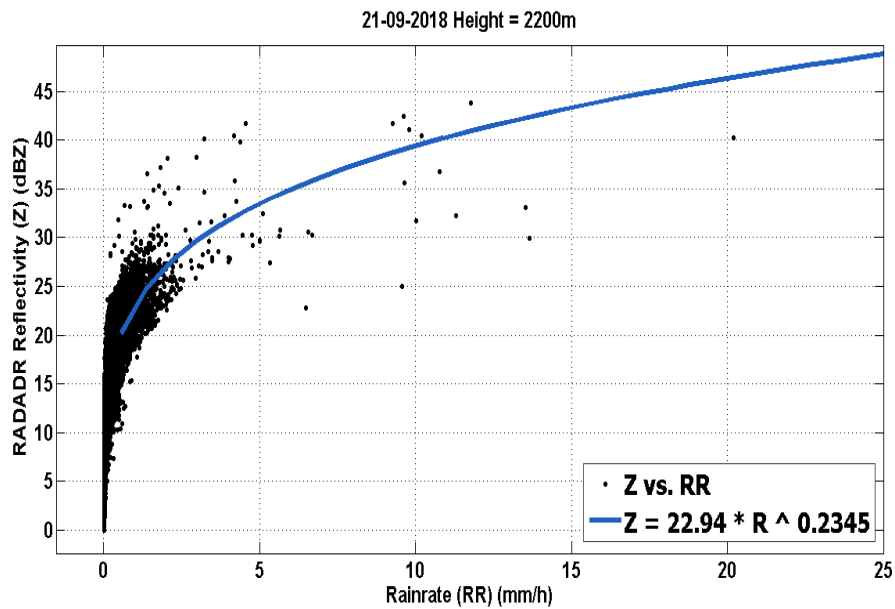
From the above fig.12, The Radar Reflectivity Z of MRR is 34 dBZ having RR 15mm of Moderate Rainfall rate and the shades of colours on NWS scale is seen as Yellow + Orange shades.



i.



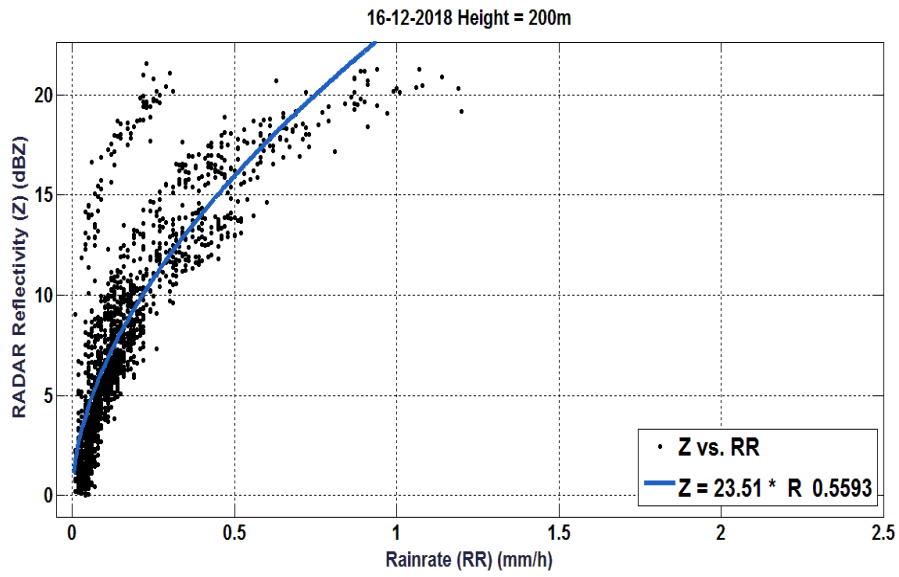
ii.



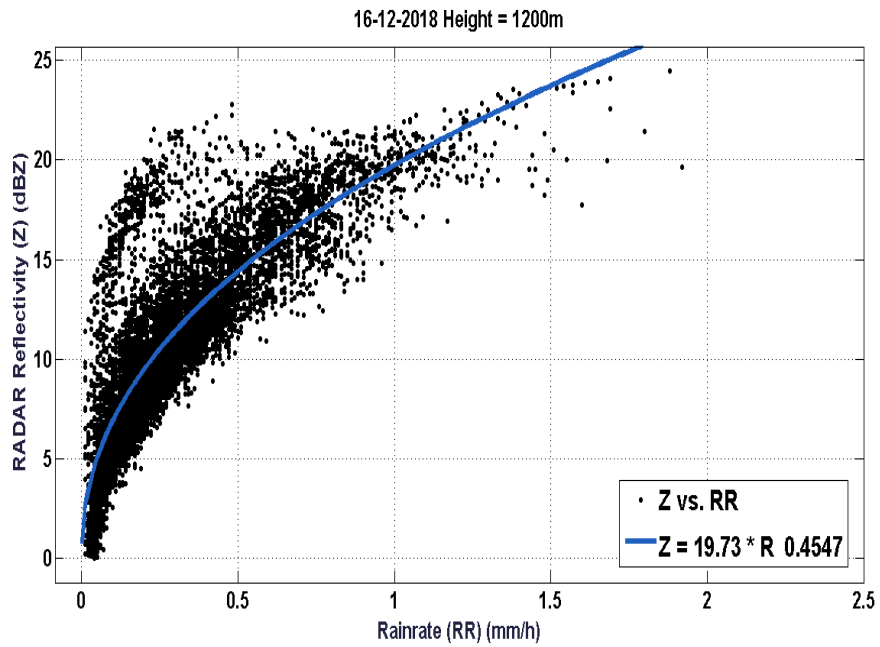
iii.

Fig. 13 - Z-R relation i. 200m, ii. 1200m and iii. 2200m
On 21-09-2018

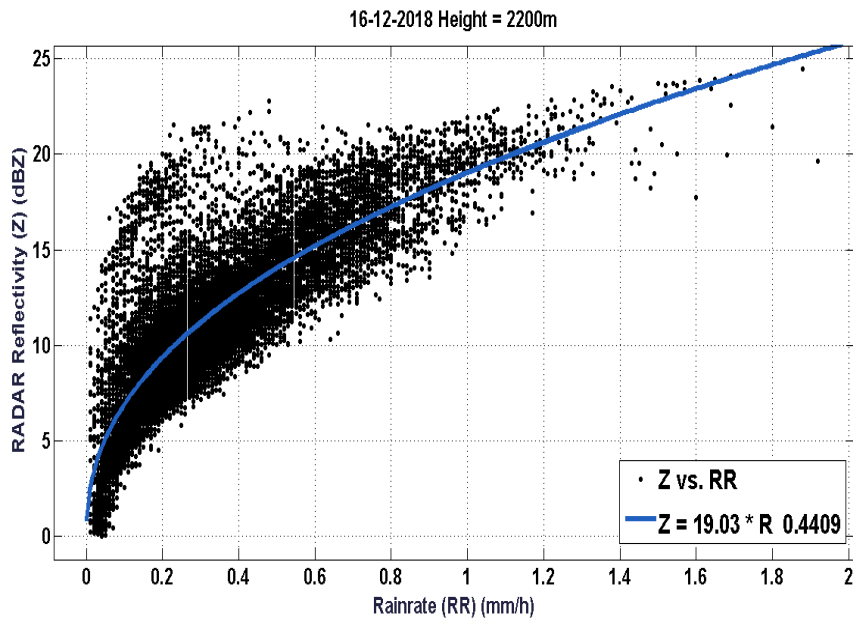
From the above fig.13, The Reflectivity of MRR (Z) is 48 dBZ with Moderate rain rate of about RR 35mm and NWS intensity scale shades are Yellow + Orange colours.



i.



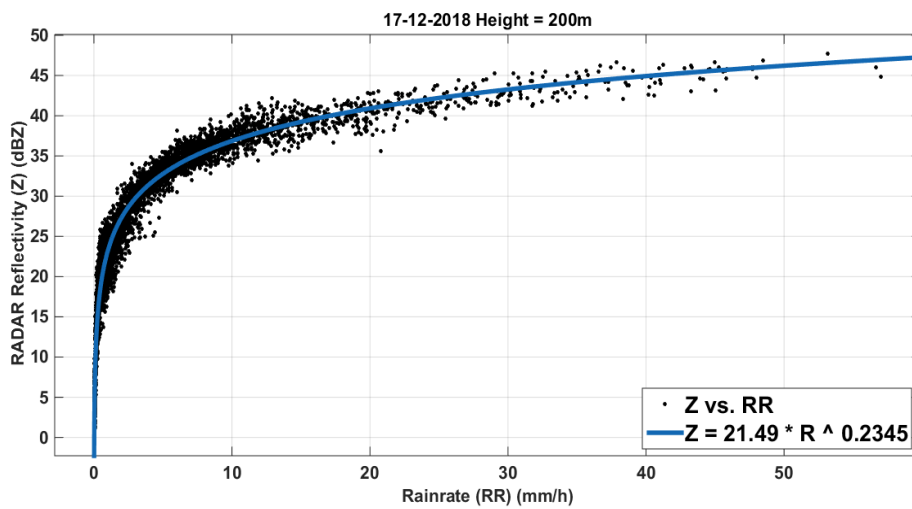
ii.



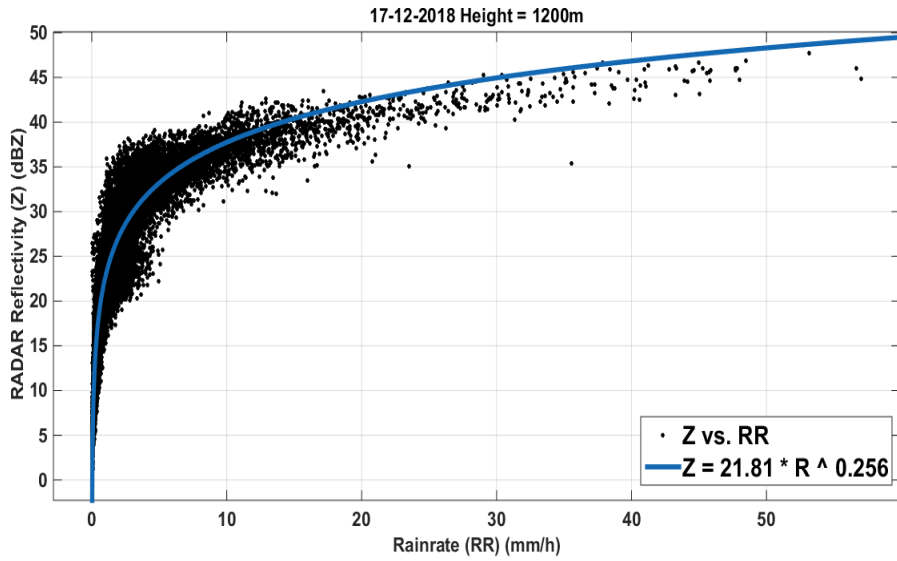
iii.

Fig. 14 - Z-R relation i.200m, ii. 1200m and iii. 2200m
On 16-12-2018

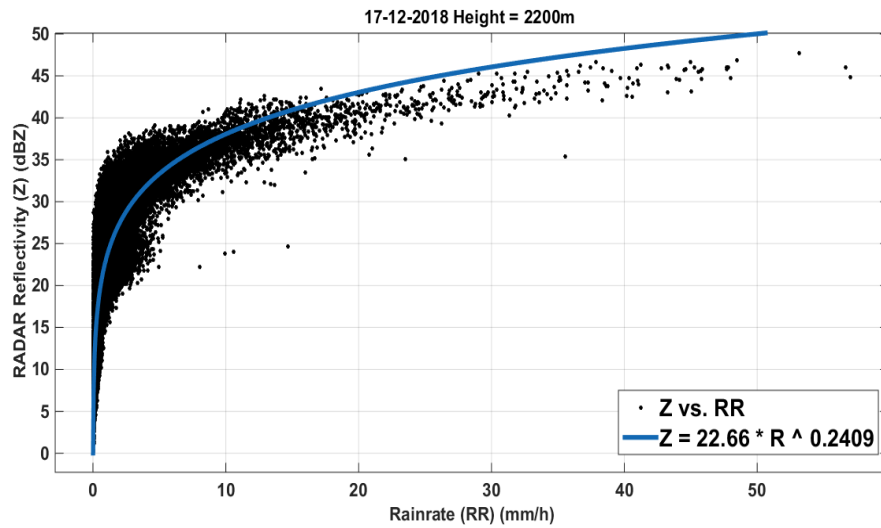
From above fig.14, The Radar Reflectivity is observed as 25 dBZ with Light mode rainfall rate RR of about 3mm and on the NWS scale the colour shades are seen as Green Colour.



i.



ii.



iii.

Fig. 15 - Z-R relation i. 200m, ii. 1200m and iii. 2200m on 17-12-2018

From above fig.15, The Micro Radar Reflectivity Z is about 50 dBZ with Heavy rain rate RR about 50mm and colour on NWS Intensity Scale is seen as Red colour which indicates heavy rain.

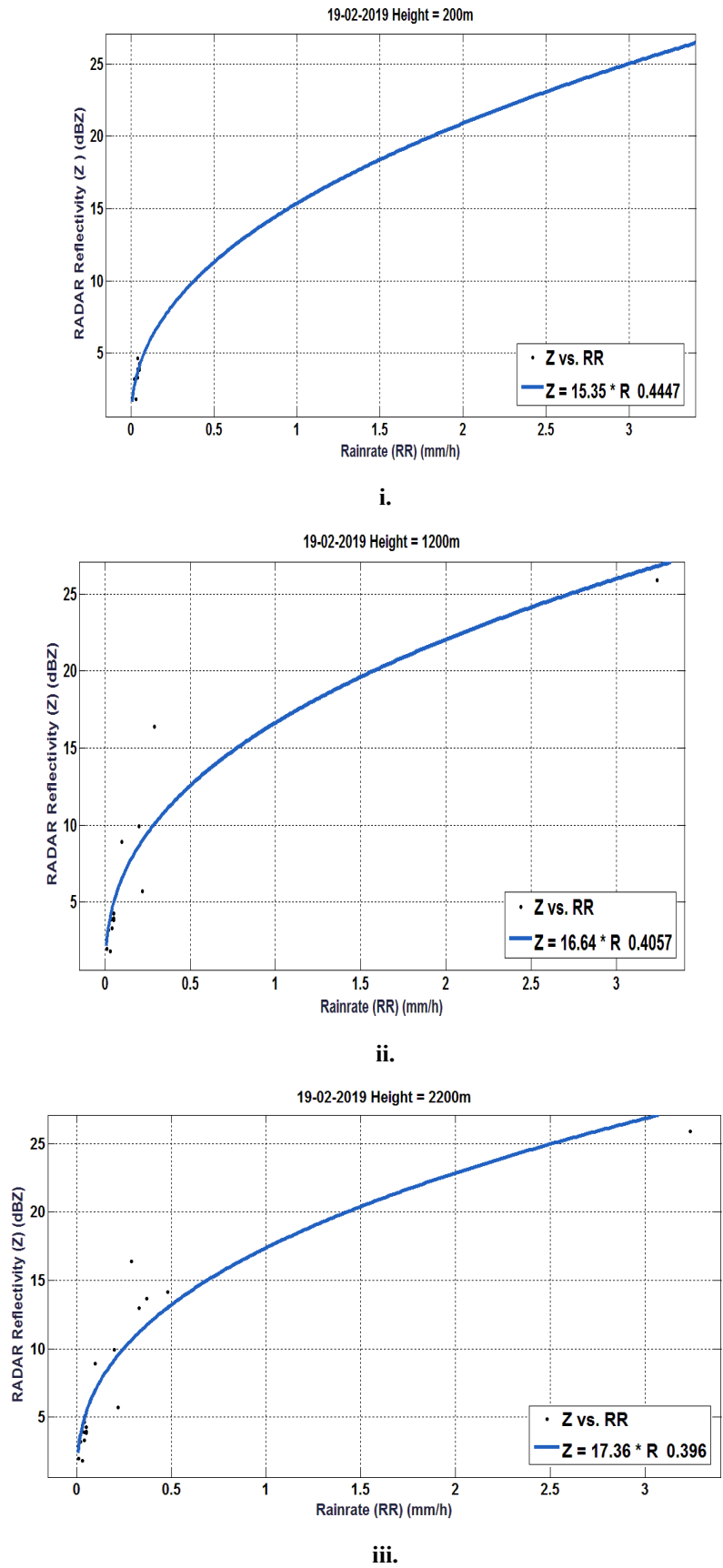


Fig. 16 - RADAR Reflectivity intensity during clear air mode i. 200m, ii. 1200m and iii. 2200m (February 2019)

From the above fig.16, The Reflectivity Z is seen as 28 dBZ with Green colour intensity on NWS Scale and has Rainfall rate RR about 3-4mm due to the presence of ghost/angel echoes along with the precipitation particles.

Table 2 - Radar reflectivity (Z) intensities with Rain Rate (R)

S.No.	Event Date	Z (dBZ)		Mode of Rain	NWS Colour Scale
		Radar Reflectivity	RR (mm) Rain Rate		
1	10-08-2018	45	30	Moderate Rain	Yellow +Orange
2	11-08-2018	48	40	Moderate Rain	Yellow +Orange
3	12-08-2018	43	28	Moderate Rain	Yellow +Orange
4	13-08-2018	40	10	Moderate Rain	Yellow +Orange
5	20-09-2018	34	15	Moderate Rain	Yellow +Orange
6	21-09-2018	48	35	Moderate Rain	Yellow +Orange
7	16-12-2018	25	3	Light Rain	Green
8	17-12-2018	50	50	Heavy Rain	Red
9	19-02-2019	28	4	Light Rain	Green

Table 3 - Climatological characters Co-efficient A and exponent b

S.No.	Event Date	Co-efficient A wrt Height (mm)			Exponent b wrt Height (mm)		
		200	1200	2200	200	1200	2200
		1	10-08-2018	20.7	19.9	19.8	0.26
2	11-08-2018	21.4	22.0	21.7	0.27	0.28	0.27
3	12-08-2018	23.8	23.4	23.1	0.26	0.27	0.26
4	13-08-2018	24.9	24.1	23.7	0.30	0.30	0.29
5	20-09-2018	27.79	26.96	23.98	0.331	0.324	0.249
6	21-09-2018	23.84	23.54	22.94	0.273	0.247	0.234
7	16-12-2018	23.51	19.73	19.03	0.559	0.454	0.440
8	17-12-2018	21.49	21.81	22.66	0.234	0.256	0.240
9	19-02-2019	15.35	0.44	16.64	0.40	17.36	0.39

From Table 2, and 3, we have $Z = A * R^b$ as Z- R relation factor,

Where Z is Reflectivity $mm^6 m^{-3}$, which are scalar quantities that do not have any directions and these are said as state variables. The event date, coefficient and exponents are measuring climatological parameters which can easily extracting information about rainfall information. R is Rain rate mmh^{-1} , which are vector quantities that have been directed flux variable and exponent. The following tabulated values are attaining from MRR rainfall radar which is fixed at KL university Guntur.

A, b are adjustable constants which varies from one place to another and also from one season to another season which also depends upon the type of precipitation particles such as stratiform, convective and orographic and snow, fog, hail, ice, rain that has a different K, Λ , N_0 , v and also these values are dependent on or varies with the observational/prediction regions of Climatic, Meteorological and physiographic conditions.

These coefficient A and exponent b are said to be positive constants and always varies with a wide range in accordance with space and interval of time.

For characterization of Reflectivity Z and Rain Rate RR, till now globally more than 70 distinct Z-R relationships have been proposed by multiple meteorologists.

6. Factors of Micro Rain Radar MRR

The main factor of Radar Reflectivity Z is Rain Drop Size Distribution DSD.

This MRR is mainly depended on backscattered volume of energy from rain drops whose uncertainty is $\pm 10\%$. [METEK, MRR Physical Basics]. The kinetic energy can effectively stimulate radar location and providing accurate rainfall estimation. The MRR profile has been measured elements like as rain rate, liquid content and drop size with continues wave radar. The spectral power and its backscatter intensity providing rainfall estimation accurately. The MRR can limited the functioning of radar reflectivity with respected to raindrop size. The veracity of Micro Rain Radar results is swayed by number of factors [11] such as Microwave Attenuation, Fall Velocity, vertical winds, raindrop shapes, Mie scattering and turbulence.

7. Applications of Micro Rain Radar MRR [MRR, METEK MANUAL]

The Micro Rain Radar MRR is used for the measurement of Liquid Water Content (LWC), Fall Velocity (W), Height (H) (Bright Band), Rain Rate, Reflectivity and Rain Drop Size Distribution from ground installation base to 6000m of vertical height. The reflectivity is an important factor in which transmitted power is return back to receiver of MRR such that getting precipitation percentage. Compared to earlier methods proposed methodology getting high detection rate and sensitivity.

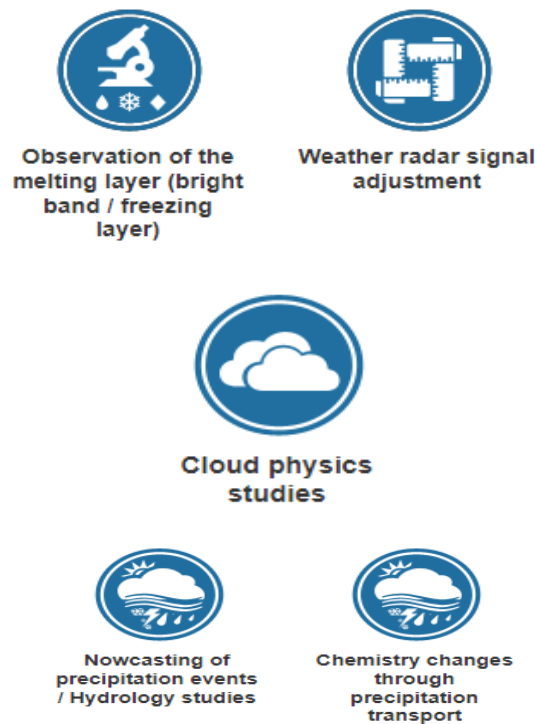


Fig. 17 - Applications of MRR

The applicatiuons of MRR is monitoring the cloud level applications with respected to MRR. The radar signal adjustment, study of hydrology and chemical changes in the environamet has been studied easliy. Moreover rainfall rate, water level in sea, droughts and thunderstromes are attained with MRR study.

8. Limitations of Micro Rain Radar (MRR)

Its vertical height of operation is up to 6000 meters only beyond signals cannot pass through. It can trace the rain particles of size about 0.25mm to 4.53mm only during the rain events, without rain occurrence there is no data.

During Light Rain conditions the evaporation of tiny rain particles and breaking up of larger rain drops causes the errors or decrease in the Z Reflectivity and RR rain rates.

The Coalescence process also causes chance of decrease/increase in Z and RR at the height of 1 km from ground which is depended on type of rain (Convective/Stratiform).

The results of this device MRR is analyzed by assuming the zero air motion where the substantial air motions and vertical winds data are being removed in MRR.

9. Conclusion

This study is mainly carried out at the sea site area/district of A.P. at Koneru Lakshmaiah Education Foundation premises 16.440N, 80.620E, which is installed at 29m ASL. This work mainly done for knowing/getting idea of Radar Reflectivity Z and Rain Rate (RR) values precisely which can be applicable for Agriculturists, Meteorological studies, for Construction works of Dams, Rivers by Engineers to know about the water flow /floods at particular passage of construction areas. We have observed that if the Radar Reflectivity Z value increases then the attenuation of signals is very large and meanwhile rain rate is also high, which can also see with National Weather Service Reflectivity Intensity Scale indicating as Green, Yellow, Red and Magenta. With this we conclude that Radar Reflectivity Z and Rain Rate RR are measured precisely at coastal location of Andhra Pradesh and but these Z-R relations are not conclusive until many greater number of rain events (for years) are to be processed for this location. We present this as Local Nudging radar for weather data prediction models and measurements. This Rain Rate and Reflectivity results are also recommended for Satellite Communication Engineers in order to develop the enhanced systems for the upcoming Satellites. Based upon the/this precipitation results ITU-R also recommends to review the Systems with appropriate changes to it.

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Abbreviations

MRR	Micro Rain Radar-MRR2
RR	Rain Rate
NWS	National Weather Service
ITU-R	International Telecommunication Union- Radio Communication

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