OBERVATIONS OF METEOR SHOWERS BY FM RADIO METHOD

A Project
By

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It is worth mentioning my heartily gratitude towards my batch mates and juniors from astro-club, for their great help and also for solving many difficulties during the project work.

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1 Introduction

The scientific study of meteor showers is one of the oldest topics in astronomy. As I have been doing observations of various meteor showers (which are popularly known as 'shooting stars'[1]) since last 7 years by visual method, I came to know about the radio method of observations about a 2-3 years ago. Initially it was proposed to do the project for 'Kishore Vaigyanik Protsahan Yojana (KVPY)' fellowship – 2004, on the same topic i.e. 'FM Radio observations of Meteor Showers'. After successfully finishing the project I had been awarded 'KVPY fellowship – 2004' by 'Indian Institute of Science (IISc)', Bangalore. So it was decided to continue with the same topic as my final year B.Sc. project.

The Radio method of meteor shower observations is well known in the advanced countries like America, Japan, Germany and China etc. But in India it is very less popular and hence it was decided to initiate this work and to popularize among amateur astronomers from India. Initially it was found very difficult to find guidance in this field because there is hardly any person working in this field of research, from India.

The basic mechanism of the radio observations of meteor showers is as follows – Whenever a meteor enters into the Earths atmosphere, it ionizes the path through which it travels; which is able to reflect a band of radio frequencies (between 50 to 150 MHz, which encloses the FM frequency band i.e. 88 – 108 MHz), so one can receive such reflections (called as meteor echoes) at a receiving station at some specific distance from the transmitting station.

Initially we faced many problems such as – selecting a 24 hours FM transmitting station, constructing a Yagi antenna of length ~ 1.5 meters (See Figure 9) etc. Since no laptop was available, it was very difficult to record and analyze the observations. Also initially we found it very difficult to tune an analog radio receiver (available at that time) exactly to the desired frequency. These difficulties were

[1] There is no concept like shooting stars in astronomy. The artists or poets may want to express this scientific phenomenon by calling it 'shooting stars'.

solved slowly e.g. a survey of all the FM radio broadcasting stations in India (ARI website) was done, and a few of them were short listed accordingly. A proper dipole was also got fabricated from a shop in *Bhori Ali* near *Appa Balvant chowk*. An interface circuit was built between radio receiver and computer. A digital high quality FM receiver and a computer were bought for this purpose.

It took a long time to establish the firm observing setup, based on which observations of four major showers were taken during August-2005 to January-2006, which are included in this project report.

Based on the initial work 'Indian Space Research Organization (ISRO)' sanctioned a grand of Rs. 3.25 lacks to carry further research in this field under the guidance of Dr. R V Dabhade, Dept. of Physics. Fergusson College.

Papers Presented

[1] Presented a paper at the 'National Symposium on Instrumentation (NSI - 30)', between 30th Nov to 2nd Dec 2005, at Cochin University of Science and Technology (CUSAT).

[2] Presented a paper at the 'XIV National Space Science Symposium (NSSS-2006)', between 9th to 12th Feb 2006, at Department of Physics, Andhra University, Vishakhapatnam.

[3] Presented a paper at '11th National Seminar on Physics and Technology of Sensors', between 27th Feb to 1st March 2006, at Department of Electronic Science, University of Pune.

[4] Paper had been accepted at 'National Seminar on Interdisciplinary Applications of Electronics (NSIAE – 2006)' at A.S.C. College, Chopda, Jalgaon.

[Please refer to the certificates at the end of the report]

2 Theoretical Background

2.1 History

Meteors have always attracted eyes of not only astronomers but also common people since many centuries, but the exact reason of their occurrence and their origin was studied comparatively recently. The earliest record of the observations seems to appear in Indian epics as far back 300BC (***Lokanadham 1997***). The scientific observations of this astronomical phenomenon started after a very dramatic event of 'Leonids – 1833'. In the year of 1833, at the mid-night of 17^{th} November the sky over America was bursting with approximately 1.5 lack meteors per hour. An artistic picture of the event is shown in Figure 1. This was the major shower observed ever since that. People observed that the meteors were appeared to come from a common point called as 'radiant' lying in the 'Leo' constellation in the night sky.

During the mid-1970's, the advent of the personal computer made it possible for amateurs to establish forward-scatter data collection systems of an even higher level of sophistication. In order to germinate this potential within the amateur community, the AMS Radio Scatter Program was created by Dr. David Meisel in 1977. During the decade of the 1980's, this program carried out experiments involving the establishment of meteor radio scatter receiving stations by groups of amateur astronomers, as well as preliminary work in using microcomputers for data collection. Notable successes included the work of William Black (1983) of Florida; Michael Owen (1986) of New York; and Meteor Group Hawaii, led by Michael Morrow and George Pokarney (1987). Building upon the lessons learned from these previous attempts, the first full-time prototype station for the AMS became operational in March, 1993.

Figure 1: An artistic picture of the 1833 Leonid meteor shower with the ZHR[2] of 1.5 lacks i.e. meteors falling in the sky with the rate of 1.5 lacks meteor per hour.

2.2 Comets, meteors and meteor showers

There are many small, large dust particles spread in the interplanetary space, called as meteoroids. These are the particles greater in size that a molecule but smaller than in general asteroid sizes. Whenever such meteoroid enters Earths atmosphere, it burns due to friction and an event of light streak in the background of night sky is visible, called as 'Meteor'. Such meteors originated from the meteoroids in the interplanetary space are referred as sporadic meteors. The meteors which appear to come from a common point are referred as shower meteors.

[2] **Zenith Hourly Rate,** the average maximum number of shower meteors visible per hour if the radiant is located exactly overhead and the limiting magnitude equals +6.5. Actual counts rarely reach this figure as the zenith angle of the radiant is usually less and the limiting magnitude is usually lower. ZHR is a useful tool when comparing the actual observed rates between individual observers as it sets observing conditions for all to the same standards.

The relation between the meteor showers and comet was come to know very late in later years after 1833 event. It was observed that the return of such a event but now with lesser meteors per hour was noted after 1833 in later years 1866, 1899 etc along with 17th November of every year, which was suspicious at that time. A fairly connection between this periodic event and a periodic comet namely 'comet Temple – Tuttle' was establish in 1866 and the shower was given name – 'Leonid Meteor shower'.

A comet appears as a celestial body with a fuzzy (or nebulous) luminosity moving fairly rapidly against the background of a fixed star. Comet remains visible for a period of days or a few weeks at most. A comet is basically made up of dust particles, ice, rocks and many gases trapped inside them. As it approaches within one or two astronomical units, i.e. 150 – 300 million kms, of the sun, the ice starts melting and losing the dust particles forming a tail behind, which is directed away from the Sun because of the solar winds coming continuously out of the Sun. Because of the rapid motion of the comet, the tail generally appears to be curved.

A review of the orbits of shower meteors shows that in several cases they coincide almost exactly with the orbit of known comets. The most conspicuous and regular of the annual showers, the Perseids, which are visible in the Northern Hemisphere around August 12 every year, have the same orbit as a well known comet designated Comet swift - Tuttle (1862 III). The Orionids, observed annually around October 22, and in the orbit of Halley's Comet.

Shower	Date of Maximum	Comet
Lyrids	April 21	1861 I
Eta Aquarids	May 4	Halley (probably)
Beta Taurids	June 30	Encke
Perseids	August 12	Swift-Tuttle (1862 III)
Draconids	October 10	Giacobini – Zinner
Orioinids	October 22	Helley (probably)
Taurids	November 1	Encke
Andromedids	November 14	Biela
Geminids	December 13	Probably an Asteroid (3200 Phaethon)
Leonids	November 17	Temple-Tuttle (1866 I)

Table 1: Meteor Showers and their parent Comets.

Although there are some meteor showers that are not associated with known comets, it is probable that the parent comets have either been perturbed into new orbits or that they have now ceased to exist as coherent units. Meteor shower because of an asteroid has also been observed e.g. Geminids during December 13th. There are total 28 meteor showers including major and minor, due to different parent comets.

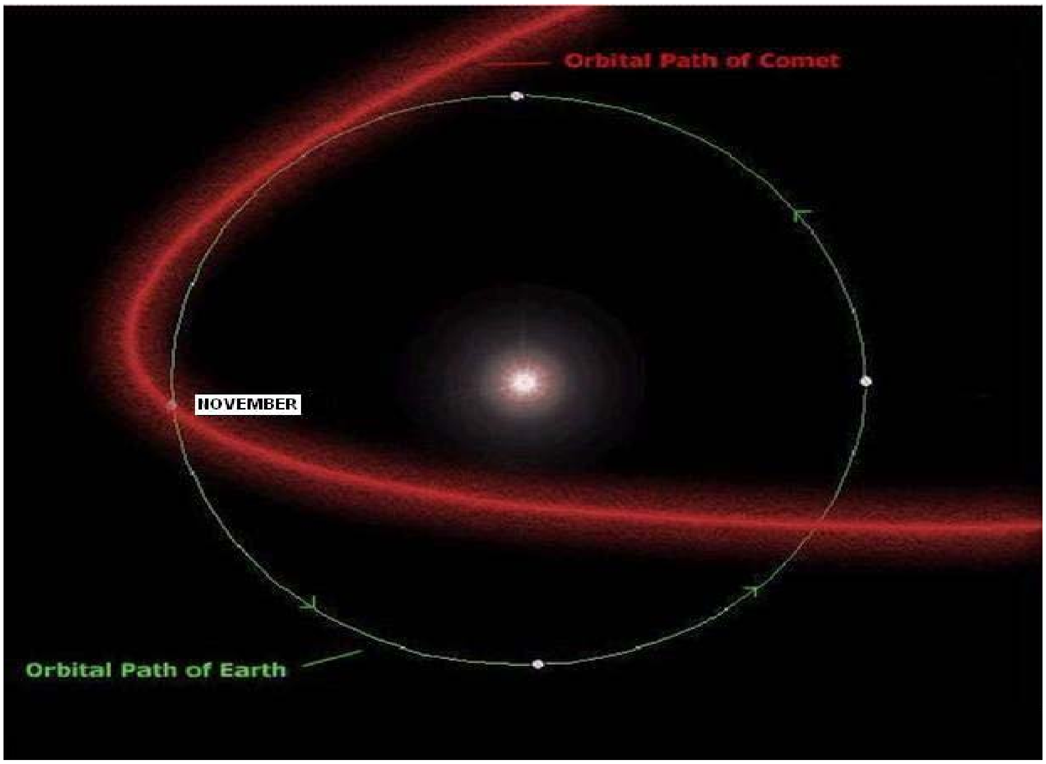

Figure 2: The dust particles left behind by a comet is shown by red colour and the circle shows Earth's orbit around the Sun. The meteor shower occurs when Earth enters into the dust belt.

When a comet passes near by the Sun, it may produce a trail of small dust particles, ions etc as explained above. As the comet progresses it leaves behind small loosely bound (by ice) dust particles in its orbit, forming a debris belt as shown in the Figure 2. When Earth enters into the debris belt, the small dust particles in it get attracted towards Earth and they enter into Earth's atmosphere with very large velocities. These particles burn in due to friction at the height approximately from 85 – 115 km. above the Earth's surface.

2.3 History of Radio observations

During the Second World War because of the development in the radio equipments, scientists were entering into the new branch of astronomy i.e. ‘Radio Astronomy’. Many radio sources were discovered such as Sun, Jupiter, galactic center, pulsars etc. Also some disturbances were recorded during the atmospheric studies by using Radar Technique. Afterwards it was found that those disturbances were because of the meteors. As we have seen when a meteor burns into Earth’s atmosphere, it ionizes the path it follows and reflects back radio waves transmitted from the ground (***Bhar 1937; McKinley 1961; Sugar 1964; Saksena 1979; Yellaiah and Sudarshan Reddy 1994, Grebowsky et al. 1998, Saksena 1998, Yellaiah et al. 2001, Lovell 1954***). There various institutes in the world related to the ‘Radio Observations of Meteor Showers’ e.g. – ‘International meteor Organization’ (IMO) Germany, ‘Japanese Meteor Society’ (JMS) Japan, ‘American Meteor Society’ (AMS) America etc.

2.4 Types of Radio observations

There are basically two main types of Radio observations of meteor showers –
I) Backward scatter Method (e.g. Radar method).
II) Forward Scatter Method (e.g. Ham radio, FM radio method).

2.4.1 Backward scatter method

Backward scatter method mainly consists of ‘Radar observation’ method. The radar receives a part of emitted signal because of reflection from the ionized trail of meteors in the sky. This method of observations is known as ‘Radar Observation Method’ (***Bourdeau 1963; Young et al. 1967, Aikin et al. 1974, Gupta 1990, Lokanadham et al. 2000***).

2.4.2 Forward Scatter Method

The ionized trail of a meteor is able to reflect a band of Very High Frequencies from ~50 MHz to 150 MHz. This band includes a part of ‘Ham frequencies’ as well as the commercial ‘FM broadcasting’ band i.e. 88MHz to 108 MHz (Z.George).

2.4.2.1 Ham radio method

There is a band of frequencies allotted to each country for the Ham amateur radio trans-receiving purpose. A Ham license holder can transmit radio signals at the allotted frequency with a particular transmission power. And any person having receiver of that frequency can receive those signals. These frequencies range from 20 MHz to 70 MHz. If there is a 24 hour transmission type Ham at one place and many receivers at distant places where no direct signal is received. At such places the receiver may receive signal reflected by ionized meteor trail reflected.

This method of observation is very common than FM method in Japan. There are ham transmitting stations located at different places in the country and the amateur hams around each of them use to monitor continuously the meteor activity using the sophisticated instruments and software.

2.4.2.2 FM radio method

In the other case one can use a commercially established 24 hour FM transmission type station e.g. Radio Mirchi 93.9 MHz, Radio City 91 MHz, located at a place and chose a location where there no direct signal is heard, and hence only signals which are getting reflected from the ionized trail will be heard. This type of observation method is cheapest among all mentioned above. Such commercial stations have a limited range of transmission ~ 100 km diameters around the transmitting tower.

This method is very common among amateur radio meteor observers in all over the world. Approximately 80% of the observers use this method for monitoring the activity.

2.5 Contribution by Indian astronomers

The earliest record of the observations of the meteor shower (especially 'Leonids meteor shower') seems to appear in Indian epics as far back 300 BC. There were a number of reports of visual observations during 1930 to 1960es, followed by a few radio observations. Also there seems to be a very few amateur groups active in India carrying out such visual observational activity till date. A systematic radio observational programme has been carried out during 1980 to 1990 from Hyderabad from which the Indian MST radar observations were added in 1996 (Lokanadham 1997). FM radio observations and MST radar observations from Hyderabad in 1993, 2001, 2003 till November 2005 are also reported (Yellaiah et al. 2001; Yellaiah and Lokanadham 1993,).

3 Theory

To understand how the radio frequencies interact with the earth's ionosphere it is equally important to understand ionosphere itself. And then how the FM band of radio frequencies is simply suitable for the meteor observations.

3.1 Earth's ionosphere and Reflection of HF and <HF waves

The ionosphere is a section of the atmosphere that acts like mirror for the reflection of HF waves, which makes long distance communication possible. The upper portion of the atmosphere, which receives sufficient energy from the sun and from cosmic rays for its molecules to split into positive and negative ions. They remain these ionized for long periods of time. There are variations in the physical properties of the atmosphere, temperature, density. At high altitudes the air of the atmosphere becomes ionized under the influence of the sunrays, cosmic rays and other factors.

The ionosphere has four main layers. They are D, E, F1 and F2 layer. Each layer reflects different frequencies of radio waves.

D LAYER – It is the lowest, existing at an average height of 70 km. This layer disappears at night. It is the least important layer in the point of HF propagation. It reflects some VLF and LF waves and absorbs MF and HF waves to certain extent.

E LAYER – It is next in height, existing at about 100 k m. Like the D layer it disappears at night. The reason for the disappearances is the recombination of the ions into molecules. One more reason is due to the absence of the sun at night, when radiation is consequently no longer received. The main effect of the E layer is to reflect some HF waves in daytime.

F1 LAYER – It exists at height of 180 km in daytime and combines with the F2 layer at night. Although some HF waves are reflected from it, most pass through to be reflected from the F2 layer. The main effect of the F1 layer is to provide more absorption for HF waves.

F2 LAYER – It is the most of important reflecting medium for HF radio waves. F2 layer height ranges from 250 to 400 km in daytime. At night it falls to a height of about 300 km because it combines with the F1 layer. It may be noted that F layer exists at night (see Figure 3).

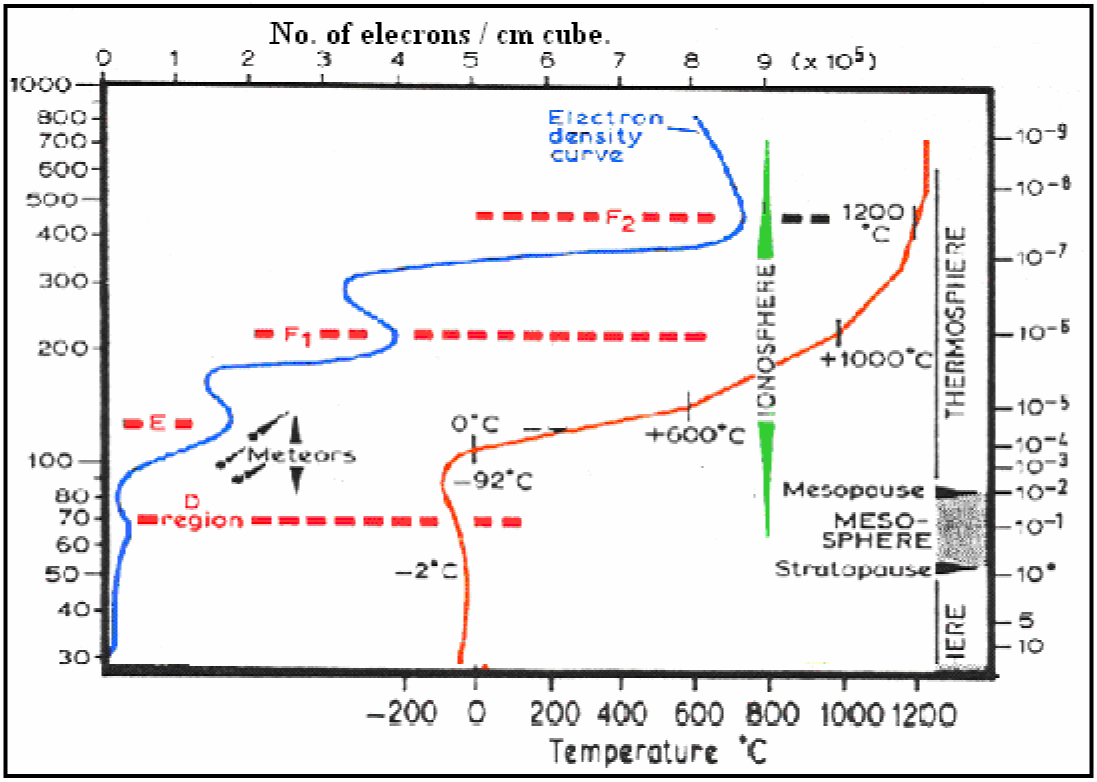

Figure 3: Shows various properties of the ionosphere such as variation of electron density, temperature with altitude.

Since this is the top most layer, it is the most highly ionized hence there is some chance of ionization to remain at night, at least to some extent. Although ionization density is high in this layer yet the action air density is not so most of the molecules in it are ionized. So ionization does not disappear as soon as sun sets. The better the reception is possible at night because of the combinations of the F1 and F2 layers into one F layer (see the Figure 3).

3.2 Reflection of VHF waves due to ionized meteor trails

The radio frequencies greater that 30 MHz and less than 300MHz are referred as 'Very High Frequencies' (VHF) band. As the frequency of an e-m wave increases the energy associated with those wave packets also increases. These waves can easily penetrate through the ionosphere and can travel into the space.

The average values of electron densities in the E and F regions are 1.5 x 10^5 e^- /cm^3 and 6 x 10^5 e^-/cm^3, in between which almost all the meteors burn after entering into the atmosphere. They burn about 85 to 115 km above the Earth's surface. These meteors produce an ionized trail along the path which they follow. The electron density in this path is 1000 times greater than that of the surrounding ionosphere electron density. Such high electron density column is able to reflect VHF waves.

3.3 Observation mechanism

In this of observations of meteor showers we are not receiving the radio emission by the ionized meteor trail, but the reflection of the signal from the trail. Hence for this purpose we need to have a ground base transmitting station, a receiving station and the meteors in between them (i.e. in the sky in between them, to reflect the waves).

A transmitting station was found be the commercially available 24 hour broadcasting type stations mostly available in metro cities, e.g. the Radio Mirchi FM 93.9 MHz station is heard only in Pune or around a 100 km diameter circle around Pune. This FM station can not be heard in Nagpur, which is at a considerably large distance. But whenever thee will be a meteor falls in between these to places, the radio waves will be reflected by its trail back to the ground, at an oblique angle and hence could be received at Nagpur, for a short time interval, as shown in Figure 4. This phenomenon of observation is called as 'forward scatter technique'. The receiving station should be any where in between 300 to 1500 km from the transmitting station.

At the receiving station we point our antenna in the direction of the transmitting station, with an inclination ranging from 0^o to 20^o (w.r.t. the ground), depending upon the distance between transmitter and the receiver.

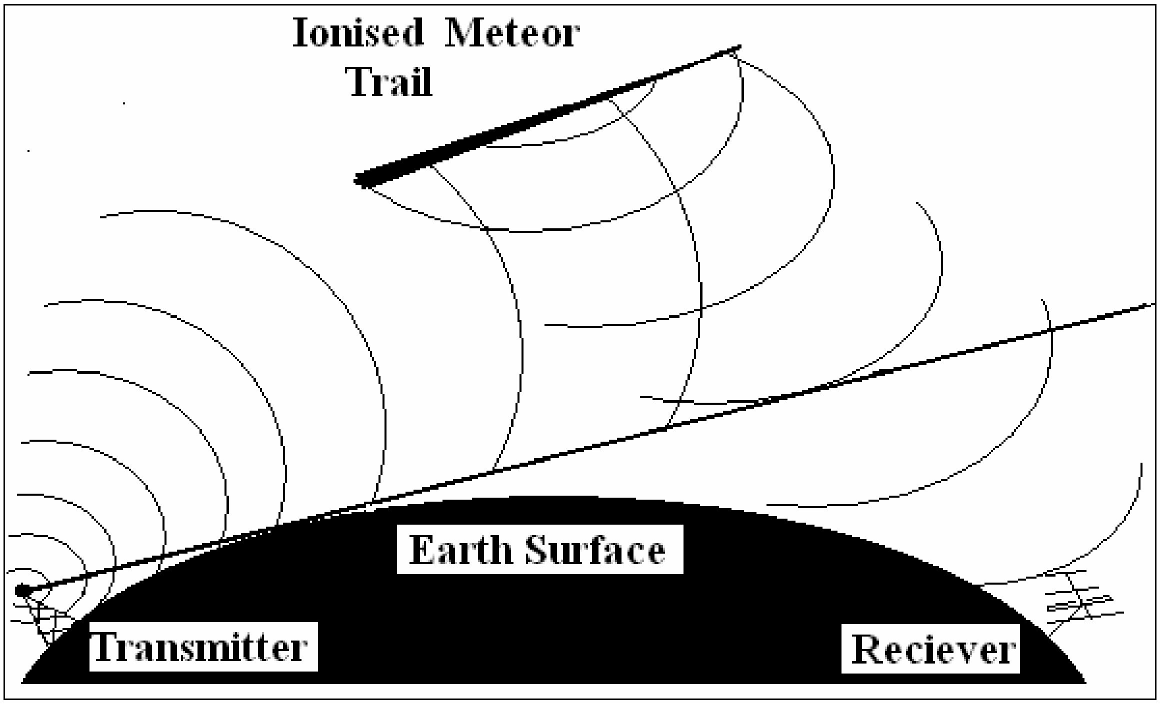

Figure 4: Reflection of Radio signal by Ionized Meteor trail.

This relation between the 'angle of inclination' to be given to the antenna and the distance is shown in the graph below (Figure 5).

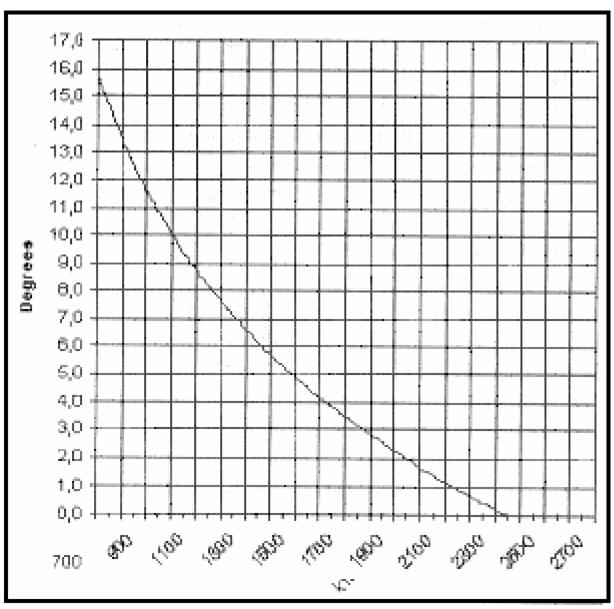

Figure 5: The graph of 'angle of inclination' to be given to the Yagi antenna, which depends on the distance between transmitter and receiver (in kilometers on X-axis).

4 Observational setup

4.1 Block diagram of observational setup

The experimental setup consists of a sensitive receiver which is tuned to a distant broadcast station in the FM (Frequency modulation) band (88-108 MHz). Due to the radio horizon, there is no signal receiver under normal circumstances. However, if a meteor enters the atmosphere, it leaves an ionized trail which is able to reflect the signal in the direction of the receiver's antenna. An incoming meteor can therefore be associated with a sharp peak in the signal strength of the receiver. 3-element Yagi antenna is contructed for 91 MHz, 105.4 MHz, 102 MHz. The antenna was connected to a car tape receiver having digital FM radio tuner (JVC company, KS-F 161 model) by using 75 Ω co-axial cable. A balloon was used between Yagi antenna and the 75 Ω co-axial cable for impedance matching, so that maximum power could be transferred from the antenna to the receiver.

The receiver is connected to the computer through a radio-computer interface. The signal strength of the receiver is continuously monitored by software called WMeteor V3.2. Each peak in the signal is detected and stored on hard disk, together with the time of occurrence. A radio setup can be used during the day as well as during the night, and is not influenced by the presence of clouds. Therefore, it is of great value for long-time monitoring projects, particularly because the system is completely automated.

4.2 Yagi antenna

4.2.1 Theory of Yagi antenna

Antenna, in electronics, system of wires or other conductors used to transmit or receive radio or other electromagnetic waves, sometimes called an aerial. The idea of using an antenna was developed by Guglielmo Marconi. In a transmitting antenna, the signal from an electronic circuit causes electrons in the antenna to oscillate; these moving electric charges generate electromagnetic radiation, which is transmitted through the air and space. Distribution of the waves depends on the design of the antenna and the polarization is parallel to the orientation of the element.

The Yagi-Uda antenna was invented in 1926 by Shintaro Uda of Tohoku University, Sendai, Japan, with the collaboration of Hidetsugu Yagi, also of Tohoku University. Yagi published the first English-language article on the antenna in 1928 and it came to be associated with his name. However, Yagi always acknowledged Uda's principal contribution to the design, and the proper name for the antenna is, as above, the Yagi-Uda antenna (or array).

Yagi-Uda Antenna, commonly known simply as a Yagi antenna, is a antenna consisting of an array of a dipole and additional parasitic elements. The dipole in the array is driven, and another element, slightly longer, operates as a reflector. Other shorter parasitic elements can be added in front of the dipole as directors. This arrangement gives the antenna directionality that a single dipole lacks. Yagis are directional along the axis perpendicular to the dipole in the plane of the elements, from the reflector through the driven element and out the director(s); if you hold out your arms to form a dipole and have the reflector behind you, you would receive signals with maximum gain from in front of you.

Yagi antennas which include one or more director elements, which, by virtue of their being arranged at approximately a quarter-wavelength mutual spacing and being progressively slightly shorter than a half wavelength, direct signals of increasingly higher frequencies onto the active dipole. Thus the complete antenna achieves a distinct response bandwidth determined by the length, diameter, and spacing of all the individual elements; but its overall gain is proportional to its length, rather than simply the number of elements.

Impedance

Impedance is similar to refractive index in optics. As the electric wave travels through the different parts of the antenna system (radio, feed line, antenna, free space) it may encounter differences in impedance. At each interface, some fraction of the wave's energy will reflect back to the source, forming a standing wave in the feed line. The ratio of maximum power to minimum power in the wave can be measured and is called the standing wave ratio (SWR). A SWR of 1:1 is ideal. A SWR of 1.5:1 is considered to be marginally acceptable in low power applications where power loss is more critical, although an SWR as high as 6:1 may still be usable with the right equipment. Minimizing impedance differences at each interface will reduce SWR and maximize power transfer through each part of the antenna system.

Gain

Gain is measured by comparing an antenna to a model antenna, typically the isotropic antenna which radiates equally in all directions. Often a dipole is also used as a practical reference as the isotropic source cannot be realised in practice, but it has 2.1 dB gain over an isotropic source. All practical antennas radiate more than the isotropic antenna in some directions and less in others. Gain is inherently directional; the gain of an antenna is usually measured in the direction which it radiates best. Gain is one dimensional (see Figure 6).

Number of Elements	Gain, dB	Beam Width, degrees
2	3–4	65
3	6–8	55
4	7–10	50
5	9–11	45
9	12–14	37
15	14–16	30

Figure 6: Characteristics of Yagi-Uda antenna

Radiation pattern is the three dimensional plot of the gain, but usually the two dimensional horizontal and vertical cross sections of the radiation pattern are considered. Especially antennas with high gain show side lobes in the radiation pattern. Side lobes are peaks in gain other than the main lobe (the "beam") (***Kraus J D***).

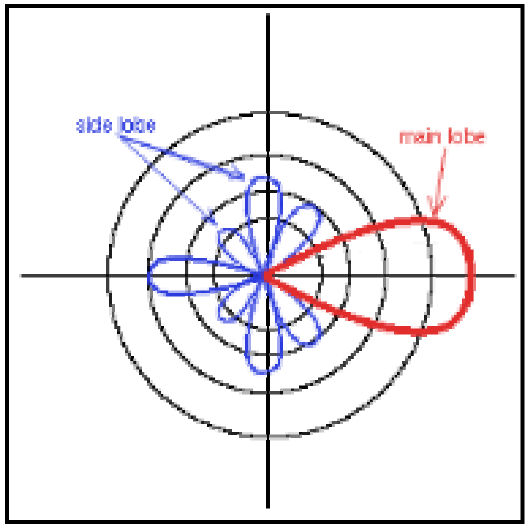

Figure 7: Radiation pattern of an antenna

4.2.2 Construction of Yagi antenna

A 3-element Yagi type-high gain directional antenna was constructed for 91 MHz frequency, to reduce the reception of local interference and to increase intensity of meteor scatter signal, for the observations of Leonids 2005, Geminids 2005, and Quadrantids 2006. A Yagi antenna of 102.6 MHz was constructed for the observations of Perseids 2005, Perseids 2004 and of frequency 105.4 MHz for Observations of Perseids 2004, Leonids 2004. The aluminum pipes of inner diameter 6mm and outer diameter 6.5mm ware used for the construction of the antenna. The lengths of the director, dipole, element 1, element 2 and boom and calculated by using formula: (As shown in Figure 8) are 164.83cm, 157.14cm, 151.64cm, 147.25cm and 148.35cm respectively for 91 MHz i.e. approximately 3 m wavelength. The separation of each of the above elements on the length of the boom is 49.45cm (***Kraus J D***).

As initially it was a very difficult part to make a dipole of length 157.14cm, hence two small (ready made) diploes were cut in such a way and connected again by giving extension of the other aluminum pipes. But because in the process of the breaking and rejoining of the pipes, the impedance of the antenna changes, so the dipole was made fabricated by a commercial TV antenna retailer from *Bhori Ali* (***ARRL Handbook; AMS website***).

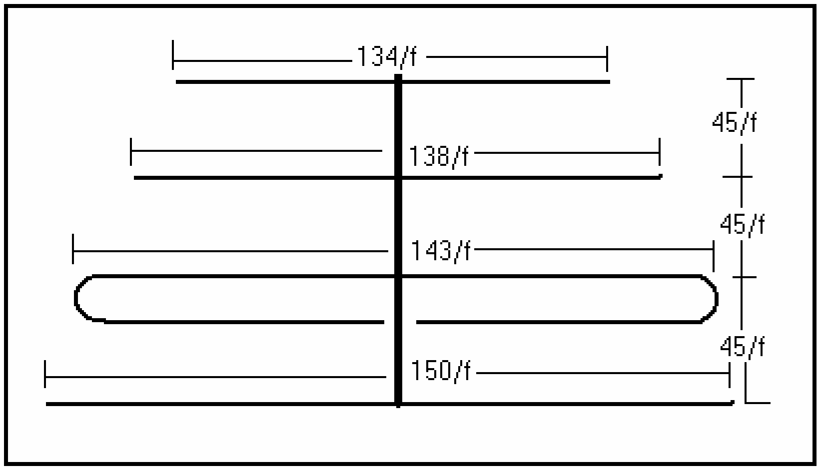

Figure 8: Dimensions of 3-element Yagi antenna.

The antenna was mounted at some height on the roof as shown in Figure 9. A compass and a map were used to point the antenna towards the direction of the transmitting station.

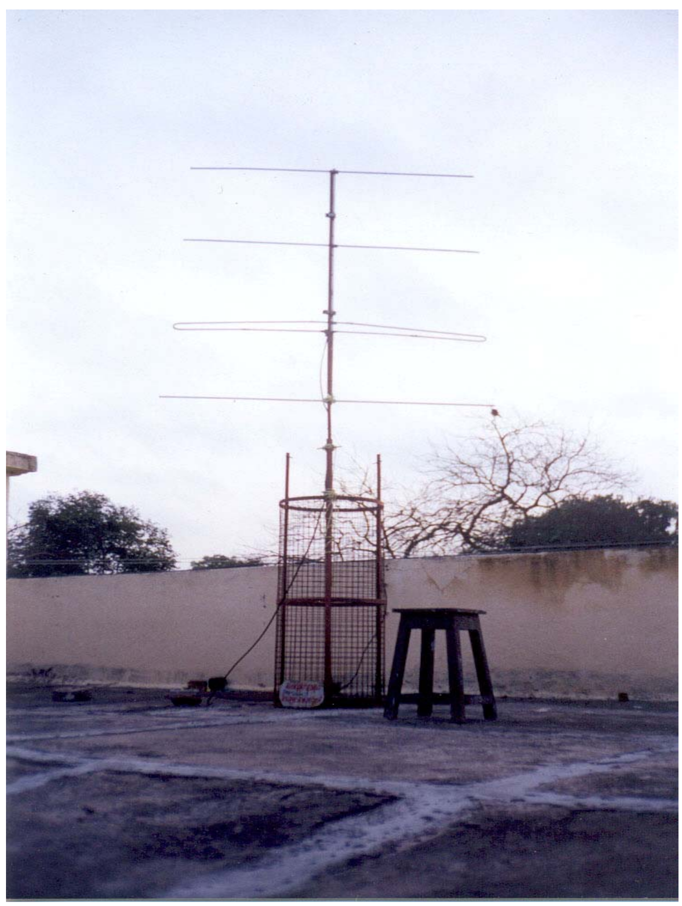

Figure 9: The 3-element Yagi Antenna of frequency 91 MHz.

4.3 Construction of interface

The interfacing circuit is used to feed the analog signals from the receiver to the computer via Serial Port. The IC used in this current project circuit is Internally Compensated High Performance dual OP-AMP [MC 1458], in which one Op-amp is used as Integrator circuit while other Op-amp is used as a Comparator. The circuit diagram is shown below (Figure 10).

One input of the comparator is the analog signal from the tape recorder and the other reference input is nothing but the integrator output. The output of comparator is given to the input of integrator circuit. As the comparator output is rectangular in nature, the integrator output waveform will be a saw tooth wave. This is used as the reference wave for the comparator. Final output of comparator is PWM type waveform. This type of circuits is of Delta modulation type. The diode is connected to protect the Op-amp from voltage switching and two capacitors of value 47 μF are connected as bipolar capacitors. The MC 1458 was designed for use as a summing amplifier, integrator or amplifier with operating characteristics as a function of external feedback components.

4.4 Software WMeteorv 3.2

Colorgramme WMeteor v3.2 is software made by an observer, Dave Swan (UK). This software enables the observer to see the received signals in waveform and it automatically shows the number of meteor per hour in the form of histogram. The waveform obtained on the screen is Flux versus Time. The total 20 sec. length waveform can be seen.

The waveform obtained on the screen is provided with two threshold marks, which can be adjusted manually depending upon the meteor shower activity. If the flux increases 20% of its initial value in a very short period of time (it may be $1/10^{th}$ sec to few hundred of sec) it will cross the threshold mark and the software will count it as 'one echo'. A snapshot of the software on the screen is shown in Figure 11.

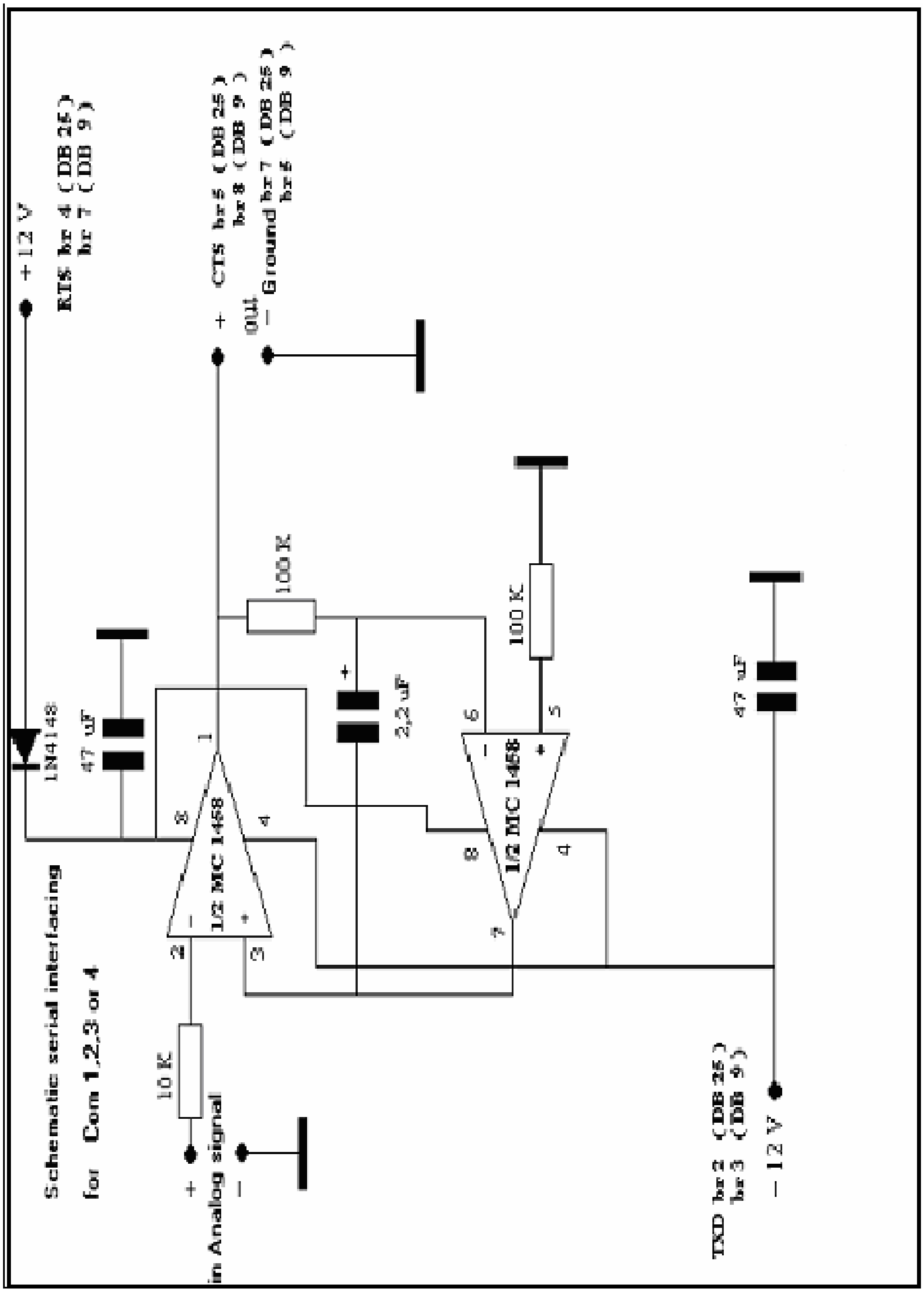

Figure 10: The circuit diagram of the interface between radio and computer.

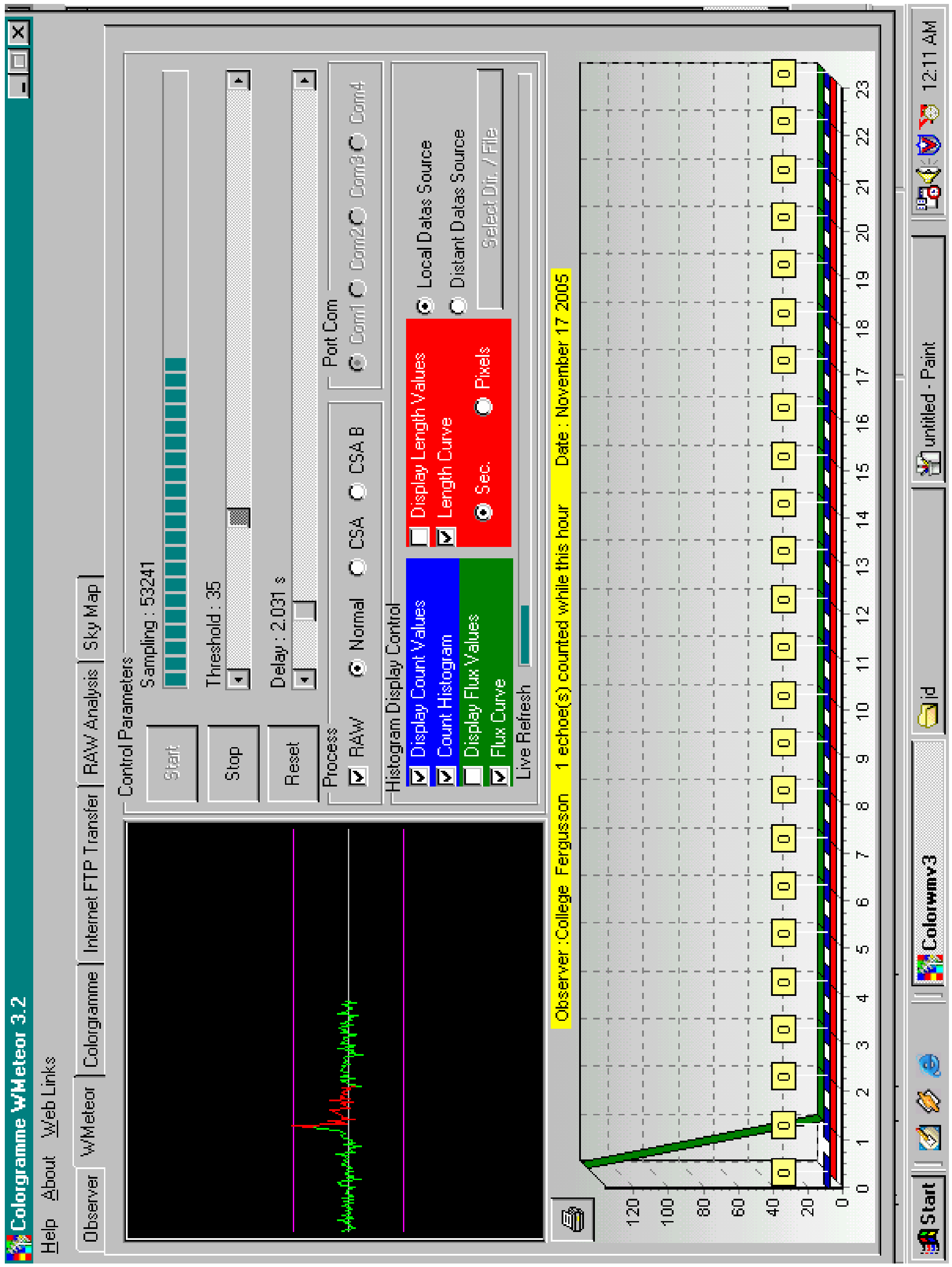

Figure 11: The above snapshot shown the software screen. The black screen shows the signal received by the receiver, with the meteor echo (shown in red colour)

5 Observations

The observations of four meteor showers were taken under this project. These meteor showers are among the major showers. These are – Perseids 2005, Leonids 2005, Geminids 2005, and Quadrantids 2006. The following table shows general information about these meteor showers (see Table 2).

Shower Name	Date	Radiant h m °	V Km/s	ZHR
Perseids	12th-14th Aug.	03 04 +58	59	110
Leonids	15th-19th Nov.	10 12 +22	71	100+
Geminids	12-15th Dec.	07 28 +33	35	120
Quadrantids	02-05th Jan.	15 20 +49	41	120

Table 2: The table shows general information of the observed meteor showers.

5.1 Perseids 2005

Active : July 17-August 24;
Maximum : August 12, 17h-19h30m UT (sol = 140.140°-140dg1);
ZHR : 100;
Radiant : alpha = 046°, delta = +58° (see Figure 12);
V : 59 km/s
r (population index[3]**)** : 2.6;

The Perseids were one of the most exciting and dynamic meteor showers during the 1990s, with outbursts at a new primary maximum producing estimated ZHRs of 400+ in 1991 and 1992. Rates from this peak decreased to ~ 100-120 by the late 1990s, and in 2000, it first failed to appear.

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[3] **r**: The **Population Index,** An estimate of the ratio of the number of meteors in subsequent magnitude classes. Simply stated: the lower the "r" value, the resulting overall mean magnitude of each shower will be brighter. "r" usually ranges from 2.0 (bright) to 3.5 (faint).

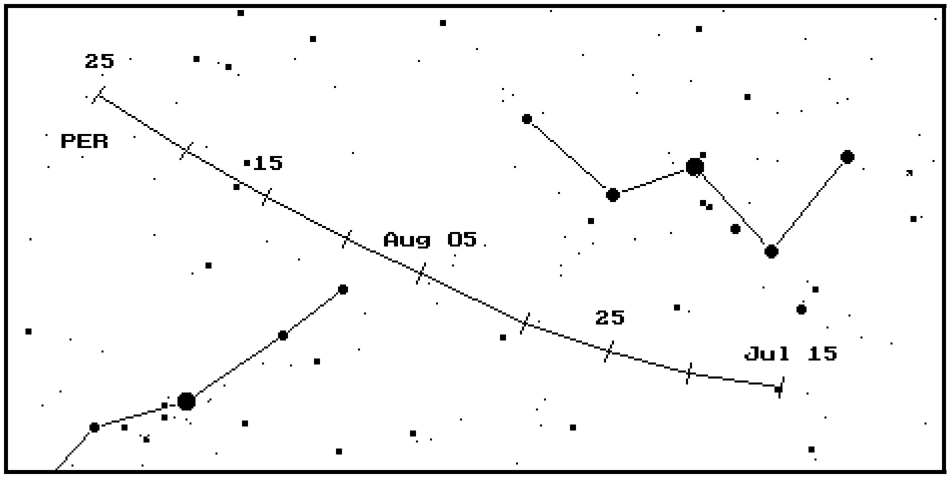


Figure 12: Radiant position of the Perseids.

This was not unexpected, as the outbursts and the primary maximum (which was not noticed before 1988), were associated with the perihelion passage of the Perseids' parent comet 109P/Swift- Tuttle in 1992. The comet's orbital period is about 130 years, so it is now receding back into the outer Solar System, and theory predicts that such outburst rates should dwindle as the comet to Earth distance increases.

Transmitter – 'All India Radio (ARI), Delhi', 102.6 MHz.
Receiving Station – Chinchwad (18.55N, 72.54E) is at 150km from Mumbai, Maharashtra.
Receiver used – JVC company KS-F 161 model with digital FM tuner.
Antenna used – For the frequency 102.6MHz.

The observations were taken from 12th to 14th August, 2005 every night. The recording of the observations of this meteor shower was tried from Chinchwad, Pune. But as Pune is approximately 150 km from Mumbai, the signal could be received directly, hence some another transmitter was chosen. The transmitting frequency was 102 MHz, but afterward it came to know that the transmitting station is not a 24 hour broadcasting. Hence we could not receive any echoes during our observing period.

5.2 Leonids 2005

Active : Nov 14-Nov 21;
Maximum : Nov 19, 1:10 UT
ZHR : 18;
Radiant : alpha = 10:12, delta = +22°(see Figure 13);
V : 71 km/s
r (population index**)** : 2.5;

In 2004, fewer but brighter Leonids were seen on November 17, near the nominal "maximum". A stronger shower of fainter meteors was seen on November 20 in 2003 and November 19 in 2004 (roughly the same time due to leap years). Some predictions were made for enhanced activity, but what was seen didn't correlate too closely with the predictions. For 2005, Mikhail Maslov has found a possible activity enhancement on November 21. The model predicts a peak ZHR of around 18 at maximum.

Because Earth runs into the orbiting particles almost directly head-on, Leonid meteors travel faster than those of any other shower — 45 miles (71 km) per second. The shower's most notable feature is its habit of producing periodic, dramatic meteor storms as Earth intercepts streams of dense material ejected at previous returns of Comet Tempel-Tuttle. Our planet passed through such streams annually from 1998 to 2003. Although small outbursts of up to 200 meteors per hour have been forecast for 2006 and 2007, computer models show that Jupiter's tug on the dense Leonid streams causes them to miss Earth until at least 2098. Because the stream responsible for the predicted outbursts was ejected in 1933, only its smallest particles have been able to drift into a path that Earth will intersect. This means any outburst, if one occurs at all will be rich in faint meteors.

Transmitter – 92.5 Red FM, Mumbai (18^{o} 55'N, 73^{o} E), 92.5 MHz

Receiving Station – Ahmedabad, Gujarat (23^{o} 02'N, 73^{o} 30' E) is at 400km from Mumbai, Maharashtra.

Receiver used – JVC company KS-F 161 model with digital FM tuner.

Antenna used – For the frequency 91.0MHz.

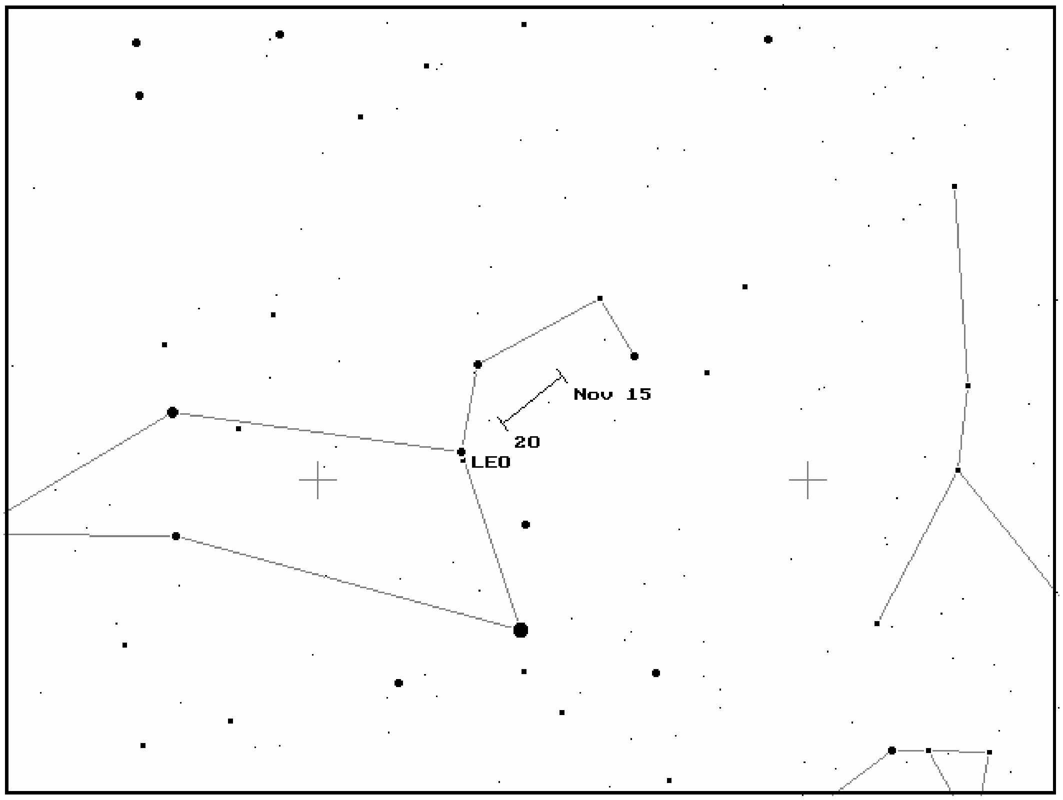


Figure 13:The radiant position of the Leonids meteor shower.

The Observations were taken from the Thaltej campus of Physical Research Laboratory, Ahmedabad, Gujarat. Total 86 echoes were detected during the four days observations of total 57 hours recording. The observation table is shown below, and the graph of no. of meteor echoes verses time is also drawn as shown in Figure 16.

The antenna was directed towards Mumbai with the help of compass (considering the angle between the Magnetic and geographic north pole of the Earth) and was mounted at a hight above the top of the apartment, and was given inclination of 16^o w.r.t the ground.

Observation Table

16-11-2005		17-11-2005		18-11-2005	
Time (UT)	**No. of Echoes**	**Time (UT)**	**No. of Echoes**	**Time (UT)**	**No. of Echoes**
13:00-14:00	12	00:00-01:00	2	00:00-01:00	2
14:00-15:00	1	01:00-02:00	1	01:00-02:00	1
15:00-16:00	0	02:00-03:00	10	02:00-03:00	0
16:00-17:00	1	03:00-04:00	3	03:00-04:00	1
17:00-18:00	10	04:00-05:00	5	04:00-05:00	1
18:00-19:00	2	05:00-06:00	0	05:00-06:00	1
19:00-20:00	3	**06:00-07:00**	Break	**06:00-07:00**	Break
20:00-21:00	0	**07:00-08:00**	Break	**07:00-08:00**	Break
21:00-22:00	0	08:00-09:00	0	**08:00-09:00**	Break
22:00-23:00	2	09:00-10:00	0	09:00-10:00	2
23:00-00:00	9	10:00-11:00	1	10:00-11:00	0
		11:00-12:00	7	11:00-12:00	0
		12:00-13:00	12	12:00-13:00	0
		13:00-14:00	0	13:00-14:00	1
		14:00-15:00	0	14:00-15:00	3
		15:00-16:00	1	15:00-16:00	1
		16:00-17:00	0	16:00-17:00	0
		17:00-18:00	0	17:00-18:00	1
		18:00-19:00	4	18:00-19:00	0
		19:00-20:00	0	19:00-20:00	0
		20:00-21:00	0	20:00-21:00	0
		21:00-22:00	1	21:00-22:00	2
		22:00-23:00	0	22:00-23:00	0
		23:00-00:00	0	23:00-00:00	0

Table 3a: The Observation table of 16-18 Nov. 2005, Leonid Meteor Shower.

19-11-2005	
Time (UT)	**No. of echoes**
00:00-01:00	1
01:00-02:00	1
02:00-03:00	2

Table 3b: The Observation table of 19th Nov. 2005, Leonid Meteor Shower.

5.3 Geminids 2005

Active : Dec 07-Dec 17
Maximum : December 14, ~4h UT
ZHR : 20
Radiant : alpha =07:28, delta = +33° (see Figure 14);
V : 35km/s
r (population index**)** :2.6;

The Geminids are a beautiful, prolific and reliable shower. Geminids are medium-speed meteors. Most of them don't leave glowing trains, but the brighter ones are often colored (yellow, green and blue are most common). The shower has a skew rate profile, with activity dropping quickly after maximum. At the same time, the proportion of bright meteors is higher during and after maximum than on pre-maximum nights.

The Geminids is active between December 7th and 17th and peaks near December 13, with typical hourly meteor rates around 80 but occasionally more than 100. Because the Geminids intersect Earth's orbit near the side directly opposite the Sun, this shower is one of the few that are good before midnight. The parent body of the Geminids is a curious object designated 3200 Phaethon. What makes Phaethon interesting is that it appears to be an asteroid instead of a comet. Planetary scientists suggest that many of the asteroids whose orbits cross Earth's may be, in fact, worn-out comets.

Transmitter – 91 Radio City , Delhi.

Receiving Station – Jalna, Maharashtra. ~350km from Mumbai, Maharashtra.

Receiver used – JVC company KS-F 161 model with digital FM tuner.

Antenna used – For the frequency 91.0MHz.

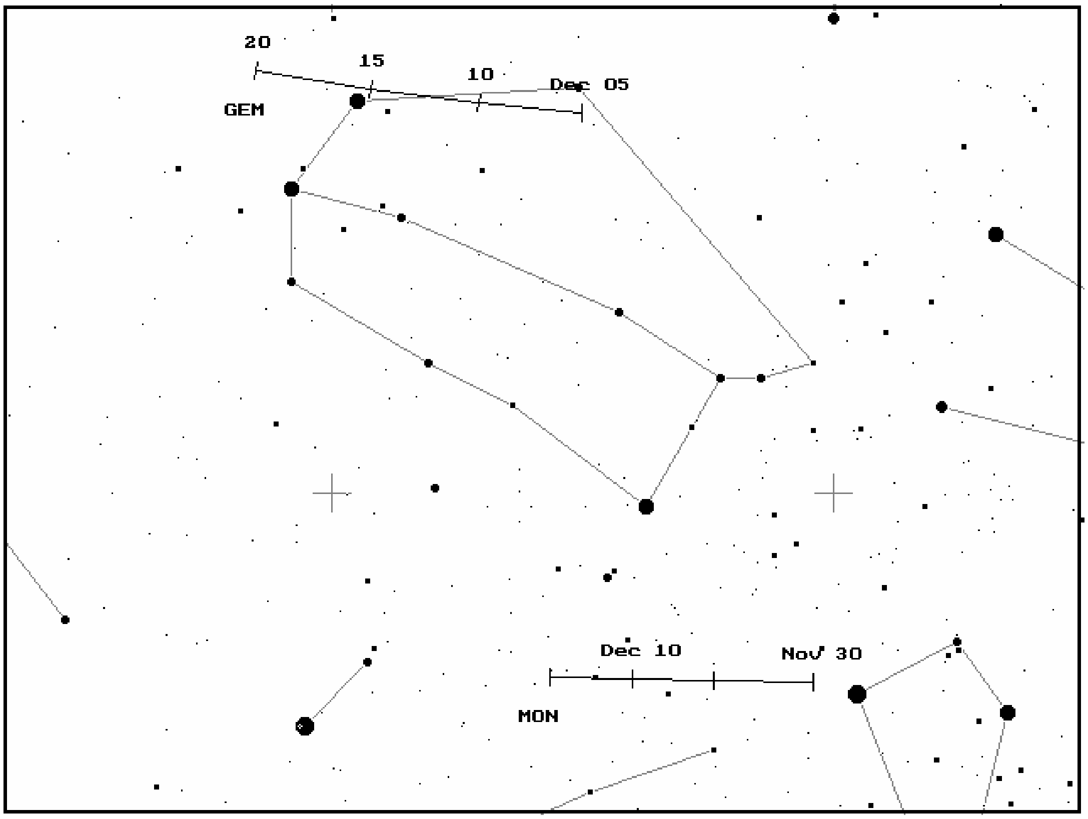


Figure 14: The radiant position of the Geminids meteor shower.

Geminids meteor shower was observed from Jalna, which is approximately 350 km from Mumbai. The frequency 91 MHz was decided previously to be used for the observations. And the transmitter was chosen as Radio City 91 FM station from Mumbai. The Yagi antenna for 91 MHz was constructed. But as soon we pointed the Yagi antenna in the direction of Mumbai with the help of compass, we started receiving direct signals clearly. This made us to change the direction of the antenna, so afterwards the antenna was pointed towards Delhi, which also has transmitting station at 91MHz frequency. The antenna was directed towards Delhi with the help of compass and was mounted at a height above the top of the apartment, and was given inclination of 10^o w.r.t the ground. Total around 100 echoes were recorded during total observation period. The observations are given in the following Table 4, and the histogram of no. of echoes verses time in draw as shown in Fig 17.

Observation Table

14-12-2005		15-12-2005	
Time (UT)	**No. of Echoes**	**Time (UT)**	**No. of Echoes**
0	4	0	3
1	0	1	6
2	0	2	0
3	0	3	0
4	11	4	2
5	14	**5**	Break
6	2	**6**	Break
7	2	**7**	Break
8	2	**8**	Break
9	1	9	0
10	1	10	0
11	2	11	2
12	2	12	0
13	2	13	2
14	0	14	0
15	3	15	0
16	6	16	0
17	0	17	0
18	0	18	1
19	6	19	0
20	6	20	0
21	5	21	2
22	4	22	2
23	6	23	3

Table 4: The Observation table of 14-15 Dec. 2005, Geminid Meteor Shower.

5.4 Quadrantids 2005

Active : January 1 —5
Maximum : January 3, 18h20m UT
ZHR : 120 (can vary ~ 60 —200);
Radiant : alpha =230°, delta = +49° (see Figure 15);
V :41 km/s
r (population index) :2.1;

Generally visible between December 28 and January 6, the Quadrantids have a sharp activity peak around January 3. Typical rates vary between 40 and 100 per hour; about 5 percent leave trains. When the shower was first recognized as annual in 1839, the radiant occurred in a constellation no longer recognized - Quadrans Muralis (Wall Quadrant). It's now divided between Hercules, Boötes, and Draco. The cold nights of northern winters and typically faint meteors keep this shower from being truly popular.

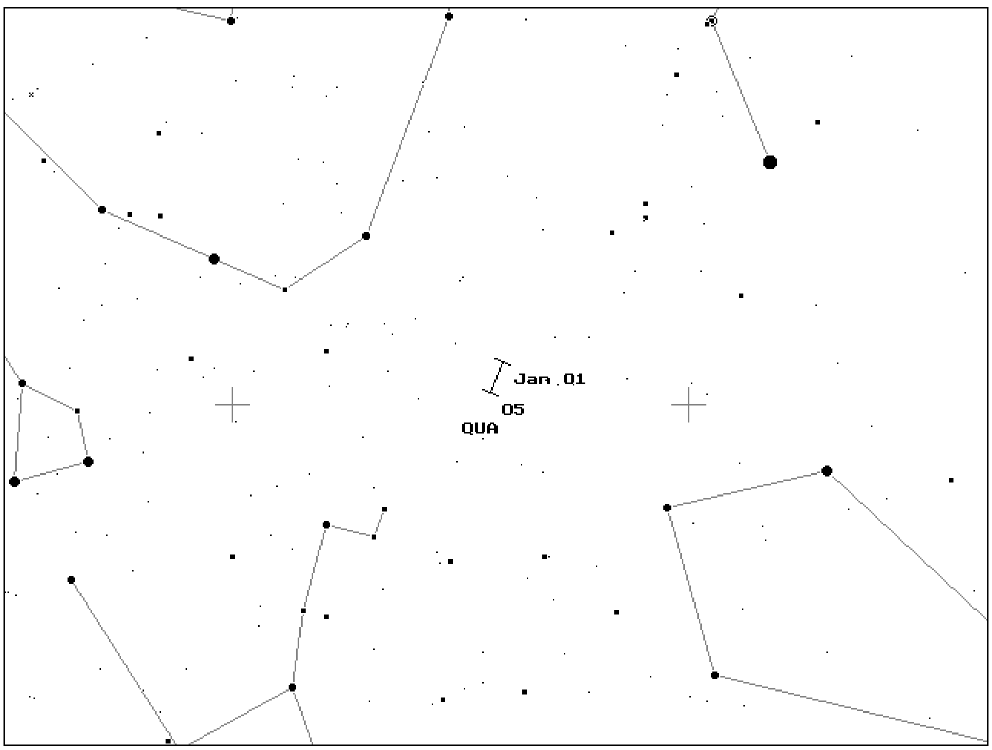


Figure 15: The radiant position of the Quadrantids meteor shower.

Until late 2003, this was the only major meteor shower whose parent body remained unknown. But that year astronomers found a near-Earth asteroid named 2003 EH1. When astronomers estimated the theoretical speed and radiant for a hypothetical meteor shower caused by particles from 2003 EH1, the results fell squarely in the middle of those measured for the Quadrantids by meteor observers. Astronomers suspect the object is a fragment from the breakup of a comet — and perhaps the event that gave birth to the Quadrantids.

The observations were taken from Nagpur University, Nagpur, Maharashtra. Total 423 echoes were detected during the four days observations (see Table 5). The observation table is shown below, and the graph of no. of meteor echoes verses time is also drawn as shown in Figure 19.

Time (UT)	**No.of Echoes**	**Time (UT)**	**No. of Echoes**
11:00-12:00	2	46-47	25
12:00-13:00	4	47-48	17
13-14	5	48-49	24
14-15	2	49-50	20
15-16	9	50-51	21
16-17	12	51-52	24
17-18	11	52-53	13
18-19	14	53-54	13
19-20	20	54-55	13
20-21	24	55-56	12
21-22	24	**56-57**	Break
22-23	20	**57-58**	Break
23-24	27	**58-59**	Break
24-25	34	**59-60**	Break
25-26	35	60-61	0
26-27	28	61-62	1
27-28	25	62-63	4
28-29	26	63-64	3
29-30	Break	64-65	3
30-31	Break	65-66	3
31-32	Break	66-67	4
32-33	Break	67-68	2
33-34	0	68-69	2
34-35	1	69-70	2
35-36	2	70-71	6
36-37	1	71-72	1
37-38	8	72-73	6
38-39	0	73-74	15
39-40	4	74-75	12
40-41	6	75-76	3
41-42	3	76-77	2
42-43	11	77-78	1
43-44	15	78-79	3
44-45	29	79-80	2
45-46	36		

Table 5: **The Observation table of 02-05 Jan. 2006, Quadrantids Meteor Shower.**

The antenna was directed towards Mumbai with the help of compass (considering the angle between the Magnetic and geographic north pole of the Earth) and was mounted at a hight above the top of the apartment, and was given inclination of 16^{o} w.r.t the ground.

6 Results and Discussions

The observations of mainly 3 meteor showers were recorded successfully namely Leonids 2005, Geminids 2005 and Quadrantids 2006. The observations of Perseids meteor shower could not be recorded mainly because the transmitting station was not a 24 hour broadcasting type and the receiving station i.e. Chinchwad, Pune is very close to Mumbai so almost all the FM stations of Mumbai could be directly received.

The Leonids and Geminids showers showed very less active this year compared to previous year's observations. The graph of number of meteor echoes verses time in UT of Leonids 2005 is shown in Figure 16. Here we have also shown the meteor echoes recorded by the software during Leonids 2005 observations in Figure 18.1-18.8. The histogram of number of meteor echoes received verses time in UT is drawn as shown in Figure 17.

Opposite to that Quadrantids maintained the activity during this year as well (See Figure 19). It is clearly visible from the graph that the Quadrantids showed two peaks, each corresponding to approximately 02 UT on 03/01/2006 and 22 UT on 03/01/2006 respectively. The observed peak by other radio observers was between 14:00 UT on the 3rd January and 08:00 UT on the 4th of January2006. This corresponds period between solar longitude[4] 282.977º and 283.741°.

[4] **Solar longitude** is measured in degrees (0-359) with 0 occurring at the exact moment of the spring equinox, 90 at the summer solstice, 180 at the autumnal equinox, and 270 at the winter solstice.

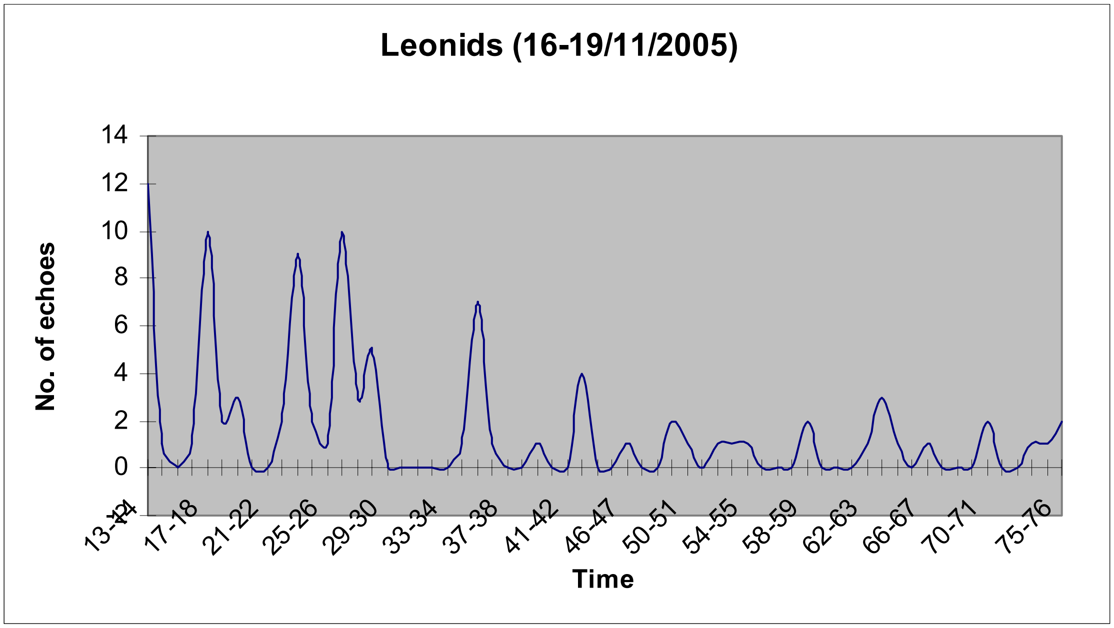


Figure 16: The graph of metoer echoes verses time (UT). The start time is 13 UT on 16th Nov. 2005. Here 24 corresponds to 00 UT on 17th Nov and so on.

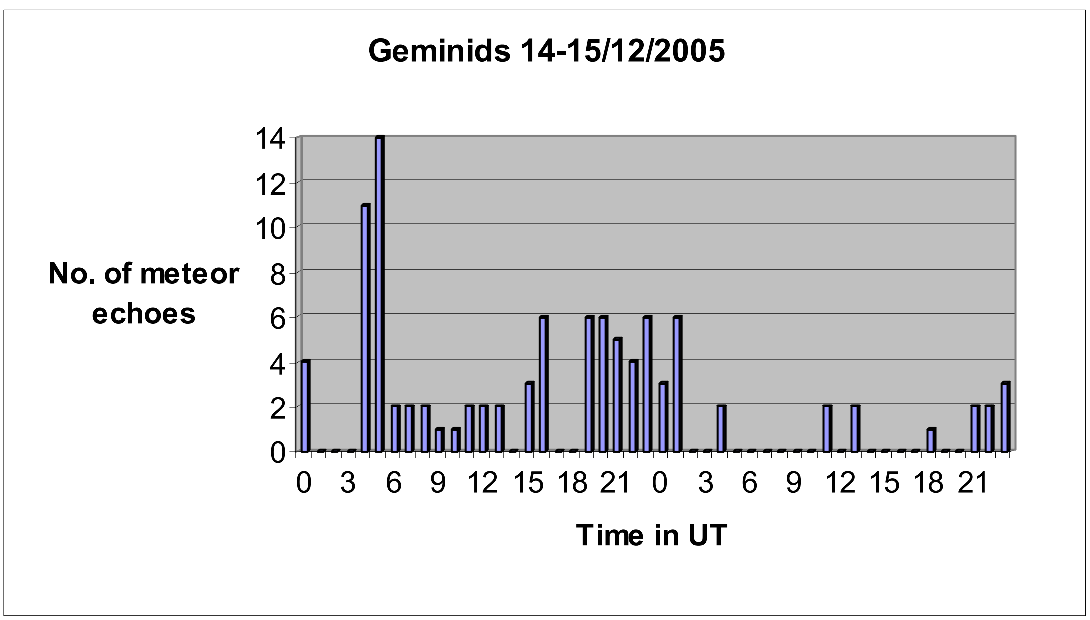
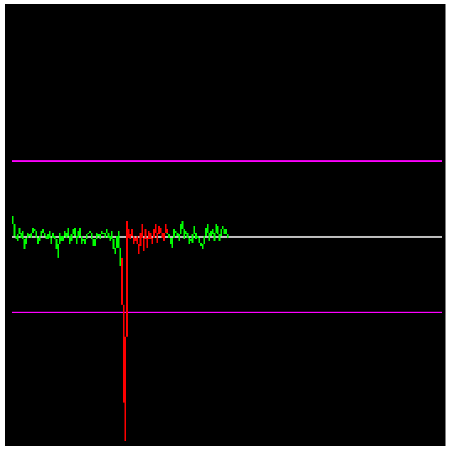
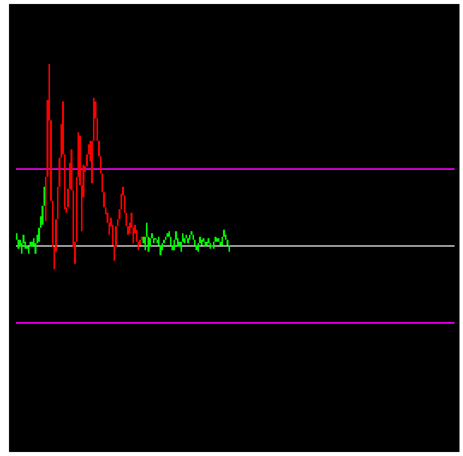


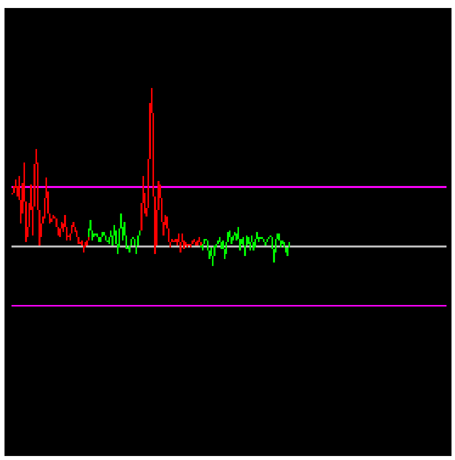
Figure 17: The graph of number of meteor echoes verses time of Geminids meteor shower. The first and second 0 on X-axis corresponds to 00 UT of 14th Dec. and 00 UT of 14th Dec. 2005 respectively.



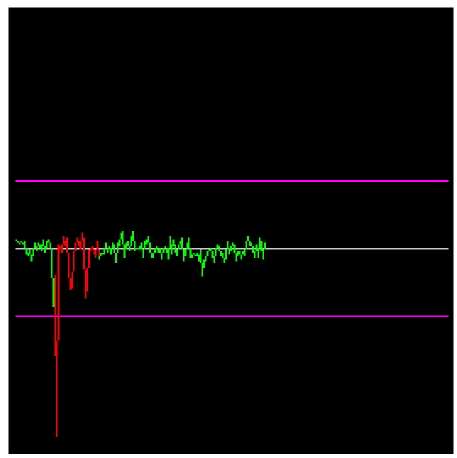
18.1: 17-18 UT (16/11/2005)



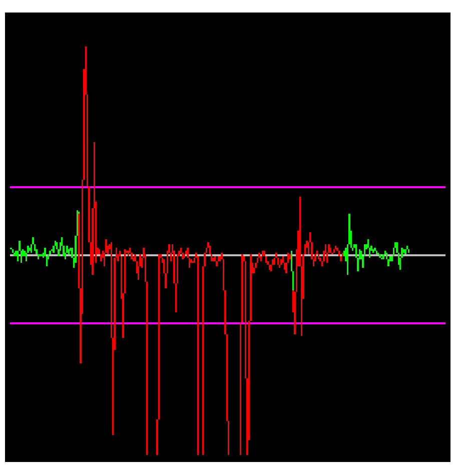
18.2: 22-23 UT (16/11/2005)



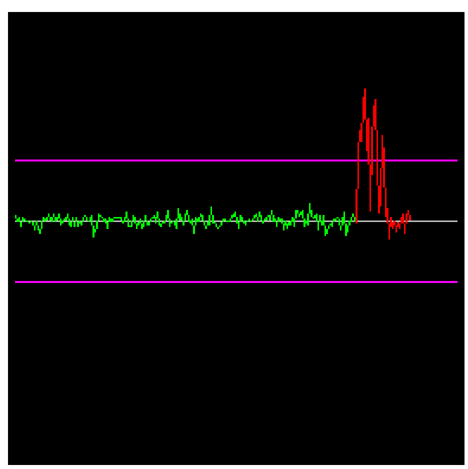
18.3: 23-00 UT (16/11/2005)



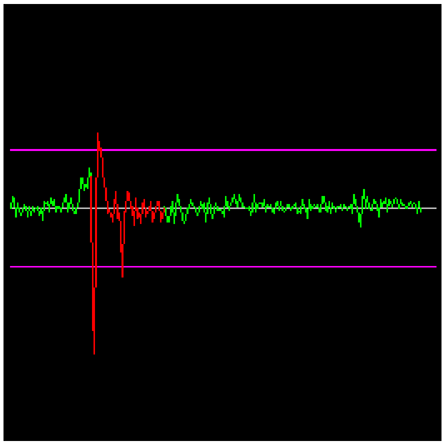
18.4: 02-03 UT (17/11/2005)



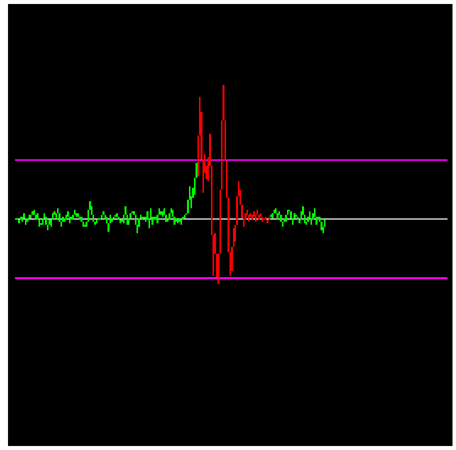
18.5: 04-05 UT (17/11/2005)



18.6 15-16 UT (17/11/2005)



18.7: 00-01 UT (18/11/2005)



18.8: 21-22 UT (18/11/2005)

Figure 18.1- 18.8: The meteor echoes recorded during 16th Nov to 19th Nov. 2005. The Y-axis shows flux values and the X-axis shows the time in seconds. Whenever a meteor appears, the signal crosses the threshold line.

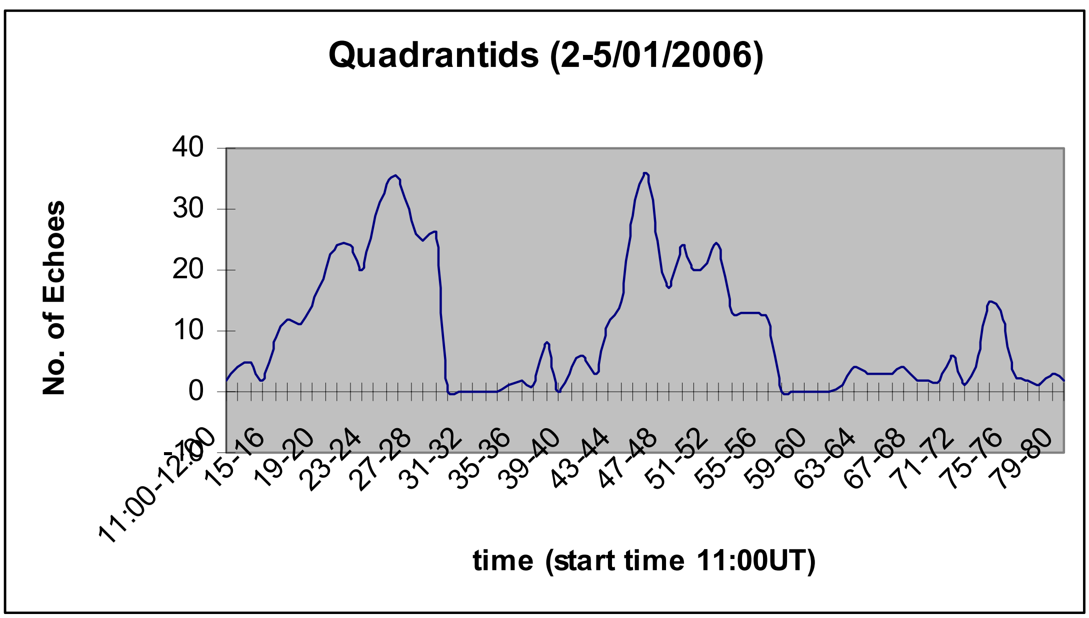


Figure 19: The graph of meteor echoes verses time (UT). The start time is 11 UT on 02nd Jan. 2006. Here 24 correspond to 00 UT on 03rd Jan and so on.

7 Conclusions and Future Scope

The observations of meteor showers – Leonids 2005, Geminids 2005 and Quadrantids 2006 were carried out successfully under this project. This method proves to be simple, economical and time saving method for the observations of meteor showers. Though the use of more sophisticated equipments and software will give better results, we conclude that this method is efficient at amateur level for the recording of meteor activity all over the world.

It is proposed to setup a proper observing unit to continuously monitor meteor activity over India. For such reason it is found that Nagpur would be a perfect receiving station, being at the center of India, we can receive meteor echoes from Mumbai, Delhi, Bangalore and Kolkatta. In future it is proposed to observe the meteor shower activity simultaneously by visual observation method for comparison, as there is a fairly simple relation between the visual magnitude of a meteor and the duration of the radio reflection.

The meteor shower activity and the micrometeors can be used to send packets of data over large distances at remote places, forming the 'Meteor Burst Communication System' (***Schanker Jacob Z***).

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