# Observations of Leonids'99 by Meteor-Echoes of FM Broadcasting Waves

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## 1 Introduction

The Leonids is well-known as one of the most famous visible meteor shower. The observation of Leonids was expected in the middle of November in 1999, because it had been predicted that the earth would pass close to a debris trail[1]. However, since it was Leonids'99 appearance peak time around 2 o'clock on November 18, 1999 of the universal time[2], the visual observations of Leonids'99 were not fully able to performed in Japan.

On the other hand, some meteor observations except for visual observations have been developed and performed, and these systems can observe the meteor by receiving the meteor-echo which is the reflective wave at the plasma tube (meteor burst) formed on the meteor trace[3]. These systems utilize some VHF band electric waves, such as MU radar wave (46.5MHz)[4], amateur radio wave (53.75MHz)[5] and FM broadcasting wave (76$\sim$90MHz in Japan).

In conventional FM radio observations, an analog FM tuner was generally used for receiving the meteor-echo of reflective FM radio waves. However, in addition to that we can hardly obtain the analog tuner, it can only count the number of meteor appearance, and cannot measure the accurate received level of the meteor-echo.

In order to easily realize the meteor observation system which can not only count the number of meteor-echoes but also measure the accurate received level, this paper proposes the observation method by use of the PLL (Phase Locked Loop) type digital FM tuner. The proposed method can record the received level of meteor-echo as digital data in a PC (Personal Computer). We constructed the observation equipment at Hiroshima City University, and observed the Leonids'99. Consequently, we confirmed that the observation method can sensitively receive the radio wave level around -120 dBm and a lot of meteor-echoes of FM broadcasting wave by Leonids were detected by our observation system at the peak appearance time.

This paper describes the observation method and observation results.

## 2 Observation Method

### 2.1 Principle of meteor-echo observation

Figure 1 shows the principle of meteor-echo observation using FM broadcasting from the remote broadcasting center. A meteor appears when a debris ejected by a comet goes into the Earth's atmosphere. Then the friction between the meteor and the atmosphere forms a plasma tube on the meteor trace in height of 100 km as shown in Figure 1. The meteor observation utilizes the meteor-echo of the FM broadcasting wave which is reflected at the plasma tube.

VHF band (30 - 300 MHz) radio wave normally was not reflected in the Earth's atmosphere. However, in the time of a meteor appearance, we can received the reflective FM broadcasting wave from remote broadcasting center in duration of plasma tube. Moreover, the level of a reflective electric wave depends on the electron density in the plasma tube[3].

### 2.2 Observation equipment

We constructed the observation equipment at Hiroshima City University as shown in Figure 2. In this system, the antenna on the roof receives the meteor-echo of FM broadcasting wave, and then the PLL type FM digital tuner detects the input signal level and demodulates the FM radio signal to recover the FM broadcasting sound. This system can record the received level of meteor-echo in the PC after passing through an A/D converter, and also record the demodulated sound.

Table 1 shows specifications of this observation system. There are two Yagi antennas in this system, one is directed toward the east and other is directed toward the south.

Table 1: Specifications of this observation system

| | |
|---|---|
| Receiver (FM tuner): | PLL type FM digital tuner |
| Antenna: | 5-element Yagi antenna |
| Sampling frequency (time): | 5 Hz (200 msec) |
| Response time of receiver: | 3msec/10dB |
| Observation site: | lat.34°26′14″ N, long.134°25′03″ E |

We used four digital FM tuners in this observation. Each digital FM tuner can measure the received level of -120 dBm (0.001 pW) in high sensitivity. Table 2 shows the tuning frequency band of each tuner and also shows FM broadcasting centers and the transmission power.

Table 2: Observing frequency band

| Direction | Frequency | Broadcasting center | Transmission power |
|---|---|---|---|
| East | 76.1 MHz | FM inter-wave (Tokyo) | 10 kW |
| East | 89.4 MHz | FM Kyoto (Kyoto) | 3 kW |
| South | 85.6 MHz | NHK-FM Kagoshima (Kagoshima) | 1 kW |
| South | 89.1 MHz | FEN Okinawa (Okinawa) | 6 kW |

Four FM broadcasting waves shown in Table 2 are not usually received in Hiroshima since each FM broadcasting center is enough far from Hiroshima and there are no line-of-sight radio links between Hiroshima and each broadcasting center.

## 3 Observation Results

### 3.1 Received level of meteor-echo

We could observe many meteor-echoes of Leonids'99 from the dawn to noon on November 18 in Japanese standard time. Figure 3 shows the received level of meteor-echo observed for 24 hours on November 18, and Figure 4 expands and shows the received level from 10 to 12 o'clock. In Figure 3 and Figure 4, top and second lines shows the received level of the 76.1 MHz and 89.4 MHz FM broadcasting wave from the east, respectively, and third and bottom lines show the received level of the 85.6 MHz and 89.1MHz FM wave from the south, respectively. In order to easily recognize the characteristic, we have shifted 10 dB of each characteristic upwards.

From Figure 3, we can see that the received level increases about 10 to 30 dB higher to the steady state when meteor-echo appears. And we can also confirm that the meteor appearance concentrates for 3 hours from 9 to 12 o'clock. This result is well in agreement with a report of IMO (International Meteor Organization)[2].

From Figure 4, we can see that the received level rise continues several minutes or more, 3 times. LEONID MAC (Multi-Instrument Aircraft Campaign) mission[1], which was performed over the Mediterranean Sea by NASA, and the other organization report that there were some fireballs which have persistent trains for this observation time. Therefore, we can consider that some of meteors observed in our system may be also fireballs.

Moreover, we could clearly listen to the demodulated sound of the Tokyo FM broadcasting wave for the duration of the received level rise.

### 3.2 Peak received level distribution

Figure 5 shows the cumulative probability of the peak received level of meteor-echoes, which is observed for two days from November 18 to 19. In this figure, we considered some of meteor-echoes whose received level is more than -115 dBm. The probability decreases as the received level increases. From this figure, we can see that the 50 % of whole observed meteor-echo was received, which was more than -108.5 dBm in peak received level, and the 4 % of whole was received, which is 20 dB higher to the steady level (-120 dBm), in peak received level.

### 3.3 Correlation between received level and duration time

Figure 6 shows the correlation between the peak received level and the duration time of meteor-echoes observed for two days from November 18 to 19. We counted the number of meteor-echoes whose received level were more than -115 dBm, and plot the obtain data in this figure. From this figure, we can see that the duration time of meteor-echo becomes longer as the received level becomes large.

## 4 Conclusions

Since it was Leonids'99 appearance time around universal time 2 o'clock (Japanese standard time 11 o'clock) on November 18, visual observations of Leonids '99 were not fully able to performed in Japan. In order to realize the method of observing meteors easily and correctly, we combined PLL type FM digital tuner and PC which is excellent in operativity, and built the observation system which can receive the meteor-echo of reflective FM broadcasting wave. This observation system can measure the received level of -120 dBm in high sensitivity. The result of the meteor observation using this system is shown below.

- We observed many meteor-echoes of Leonids'99 and confirmed that the peak appearance time was correspond to the time the meteor shower was observed around the Mediterranean.
- 10 to 30 dB increased to the steady state (-120 dBm) in the received peak level when meteor-echo was received.
- The 50 % of whole meteor-echo was observed, which was more than -108.5 dBm in peak level, and the 4 % of whole was observed, which was 20 dB higher to the steady level in peak level.

## References


[1] http://leonid.arc.nasa.gov/ (As of 2000.3.1)

[2] http://www.imo.net/leo99/leo99index.html (As of 2000.3.1)

[3] A. Fukuda, "Meteor Burst Communications (in japanese)", *Corona-sha*, (1997)

[4] http://rasc5.kurasc.kyoto-u.ac.jp/˜ mu/ (As of 2000.3.1)

[5] Y. Ono, "Observation of Leonids by Using VHF Electromagnetic Waves (in japanese)", *Educat. Earth Sci.*, no.52(5) pp.191-201, (1999)

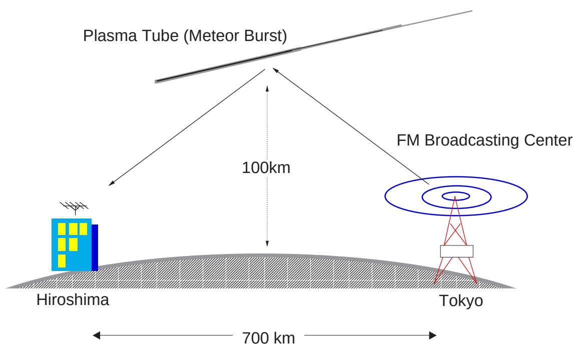


Figure 1: Principle of meteor-echo observation

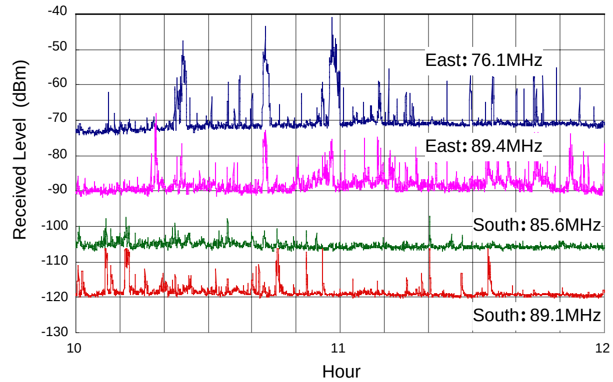


Figure 4: Received level of meteor-echoes observed from 9 to 11 o'clock on November 18

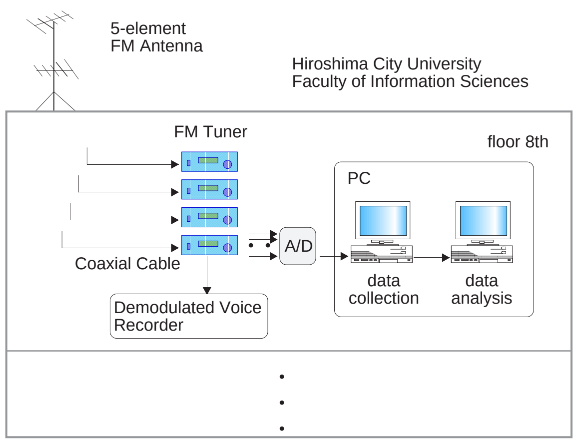


Figure 2: Observation system constructed at Hiroshima City University

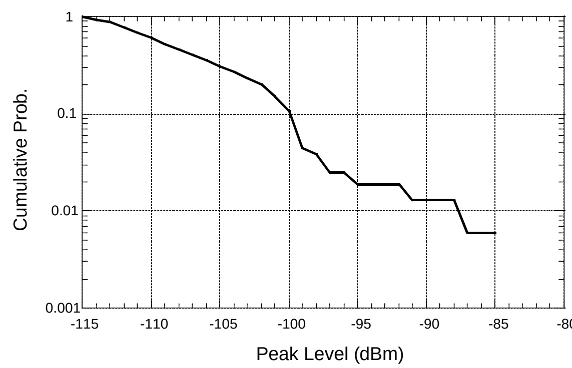


Figure 5: Cumlative probability of the peak received level

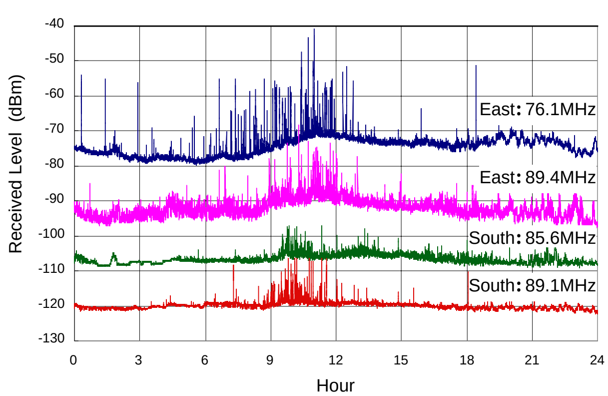


Figure 3: Received level of meteor-echoes observed for 24 hours on November 18

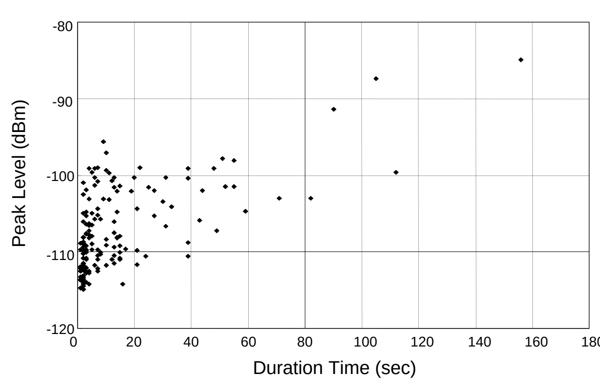


Figure 6: Correlation between the peak received level and the duration time