# The Detection of the motion of radio meteor reflection point of Geminids by HRO *

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Ham-band Radio Observation (HRO) is one of the observational techniques for the forward scatter observation of meteors. We observe the meteor echo with two-element loop antennas (F/B ratio is 10 dB) at the Nagano National College of Technology (Nagano, JAPAN) using the continuous transmission of beacon signals for meteor observations at 53.750MHz, 50W from Fukui National College of Technology (Fukui, JAPAN). To prove that the radio echo is really the echo due to meteor, we construct the Direction Determination System using the paired antennas that can detect the direction roughly where the radio echo come from. The direction of one of this paired antennas was West toward Sabae and the other was East which has proved to be the most sensitive for this research. Using this system, we detected the change of the direction of reflection point of meteor radio signal of Geminids in 2000; from the westward to eastward before and after the culmination of the radiant which is consistent the formula of reflection point of meteors. At the same time, we detected the change of an intensity and a trend of the Doppler shift of meteor echoes. This result is consistent of the meteor wind data of MU Rader of Radio Science Center for Space & Atmosphere (RASC), Kyoto University.

**keywards:** meteor,Geminids, HRO

## 1. Introduction

The forward meteor scattering observation can be a method to monitor the activity of meteor and meteor stream by using simple and inexpensive equipment (McKinley 1961, Schilling 1993, Yrjölä & Jenniskens 1998). Using the forward meteor scattering observation, many results have been published about the monitor of meteor activity and outbursts of streams(e.g. Suzuki 1976,Shimoda et al. 1993, Suzuki & Nakamura 1995, Maegawa et al. 1999) However, we must note that the number of detected meteor is out of proportion to the flux of the meteoroid in this observation. For example, if the meteor incident angle is nearly 90 degree, the reflected radio signal can not be received any receiver station(see Fig.1).

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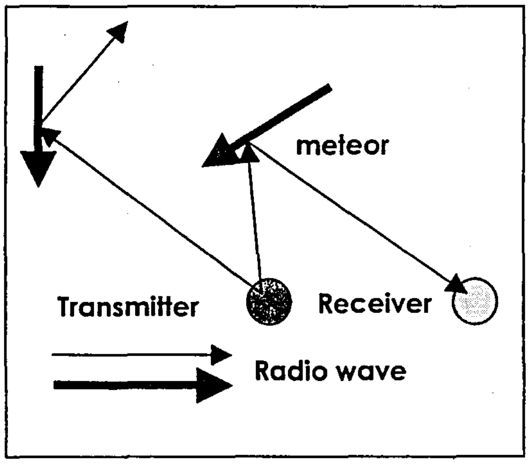


Fig.1 Radio reflection due to meter trails

In the visual meteor observation, the detectable region of the meteor is fixed all the time so that the number of detected meteor is proportion to the flux of the meteoroid. On the other hand, the detectable region of the meteor stream changes due to the transition of the incident angle of meteor stream in the forward radio meteor scattering observation. Therefore, to monitor the meteor stream activity by the forward radio meteor scattering observation, we must compensate the observed data for some peculiarities of the radio meteor observation (e.g.*response function* or *observability function* by Hines 1955, Hines & Vogan 1957, Elford et al. 1994,Yrjölä & Jenniskens 1998, Ceplecha et al. 1998).

- the location of the transmitter and receiver.
- the incident angle of the meteor $(\theta_r, \phi_r)$.
- the antenna pattern and the gain of the transmitter.
- the antenna pattern and the gain of the receiver.

We have made a simple formula for the compensation of above peculiarities. Using this formula, we have analyzed the data from 3 receiver sites for Leonids and Geminids 2000, and have found that this data is consistent (Ohnishi et al.2001).

To analyze each effect of these peculiarities more deeply, we must identify each effect directly. In this research, we concentrated only on finding point the shift of radio reflection point of the ionization trail of meteor in meteor stream. For this purpose, we used the paired antenna and receivers, and the FFT spectrogram software with PC. And we have tried to show the evidence of the shift of radio reflection point by

(1) Detecting the change of the direction of meteor echo.
(2) Detecting the variation of the received power due to the shift of reflection point.
(3) Detecting the change of a trend of the Doppler shift of meteor echoes due to the shift of reflection point.

For our results, we have detected (1) and (2) clearly. Though we could not get the direct evidence in (3), our data is consistent of the meteor wind data of MU Rader of Radio Science Center for Space & Atmosphere (RASC), Kyoto University.

## 2. Introduction of HRO

### 2–1 HRO

Radio meteor scatter is an ideal technique for observing meteors continuously. Meteor trails can reflect radio waves from distant transmitters back to earth, so when a meteor appears one can sometimes receive meteor echoes from radio source away from the observing site. The general principle of meter observation by forward scattering of radio waves off meteor trails is illustrated in Fig.2. For radio observation of meteors, amateur Ham-band beacon signals are useful as a stable radio source. Since 1996, K.Maegawa has been keeping up the continuous transmission of a beacon signal at 53.750MHz(50 W) from Fukui National College of Technology (136.18E, 35.95N) in Sabae, Fukui, Japan, for meteor radio observation (Maegawa 1999). We started the direction determination system of automating HRO (Ham-band Radio Observation) by monitoring the signals from the radio receiver with computers in August 2000. In this research, the receiver is located at Nagano National College of Technology (138.18E, 36.63N )in Nagano, Nagano, Japan. The distance between Sabae and Nagano is about 200km, and the direction to the Sabae from Nagano is almost due west. Fig.3 show the location of the transmitter and the receiver.

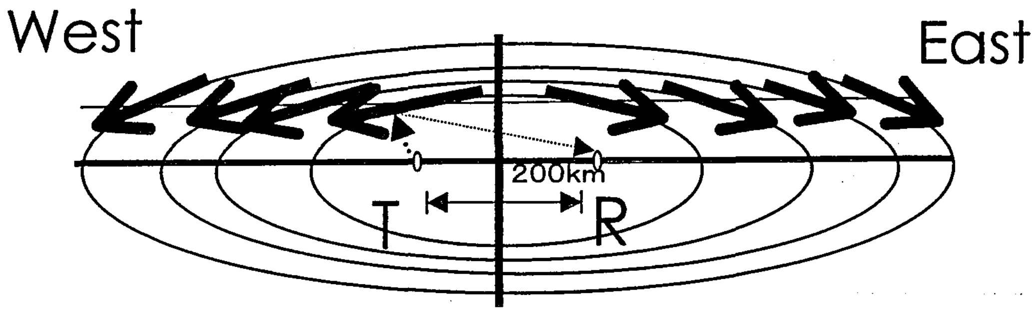


Fig.2 HRO observation and the shift of reflection point

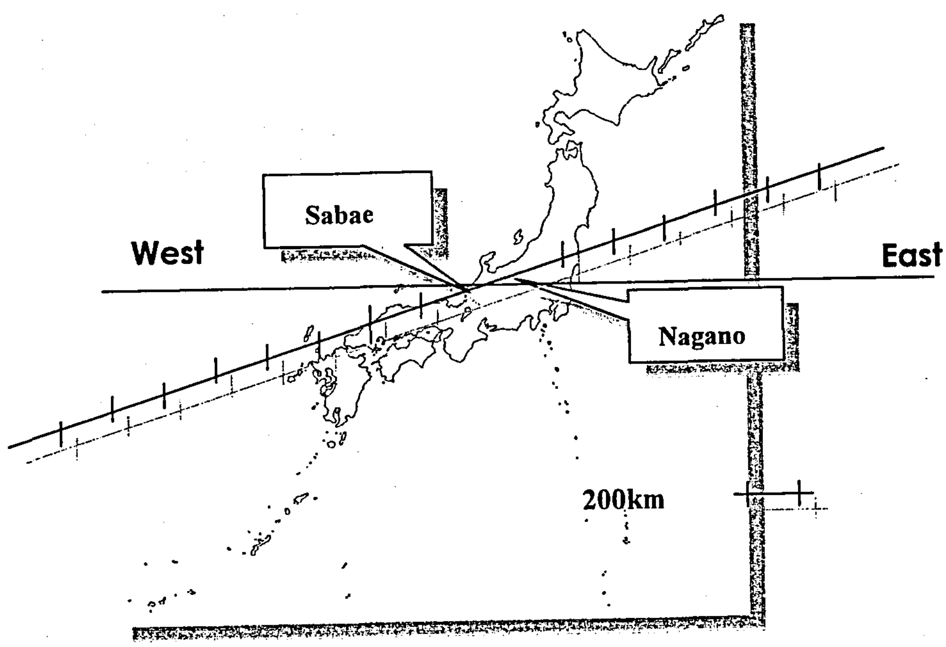


Fig.3 Baseline of the Transmitter and Receiver: Transmitter at Fukui National College of Technology (136.18E, 35.95N) in Sabae, Fukui, Japan Receiver at Nagano National College of Technology (138.18E, 36.63N ) in Nagano, Nagano, Japan.

### 2−2 Incident angle and reflection point

The relation of an incident angle of meteor and the distance of reflection point from the receiver is illustrated in Fig.4 and are shown in Fig.5. As the incident angle of meteor becomes large, the reflection point shift far away. Especially, when the incident angle is beyond 80°, the distance of reflection point becomes larger quickly and its distance becomes more than 1000km.

The detection efficiency of meteors depends on the position of transmitters and receivers and incident angle of meteor. The baseline from Transmitter(Sabae) to Receiver(Nagano) is almost *East* and *West* baseline. In this case, the detection efficiency of east-west directional meteor is high and that of north south is low.

## 3. Observation

### 3−1 To detect the shift of reflection point

To know the position of meteor echo is very important for investigating the meteor physics, for example, the near-Earth dust environment et al.(Yrjölä & Jenniskens 1998). The position is possible to determine by Radar and an interferometer (McKinley 1961). On the other hand, an ordinary forward scattering observation using only one antenna cannot determine the positional information of echoes at all.

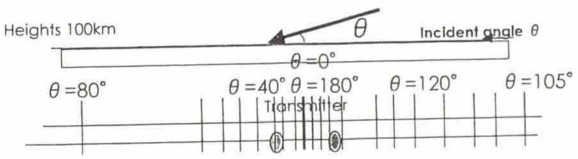


Fig.4 The relation of the incident angle $\theta$ and the reflection point

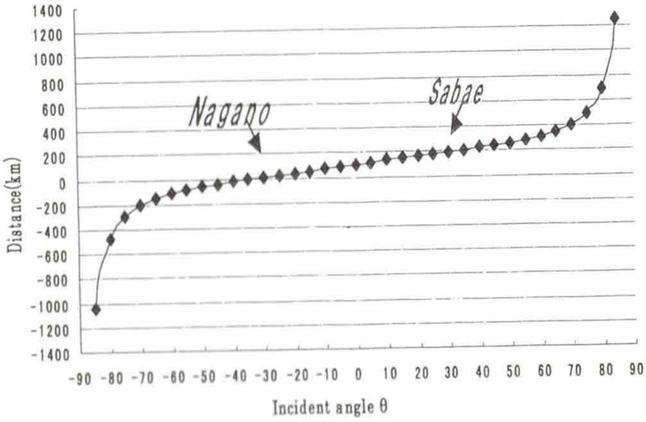


Fig.5 The incident angle and the distance of the reflection point from Nagano.

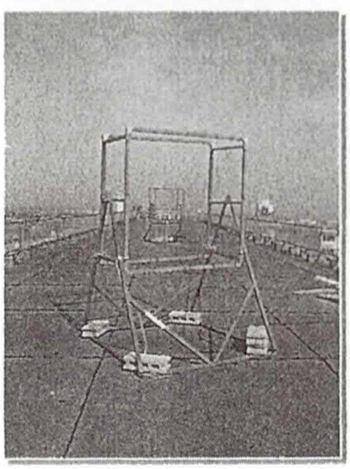

Fig.6 Loop antenna

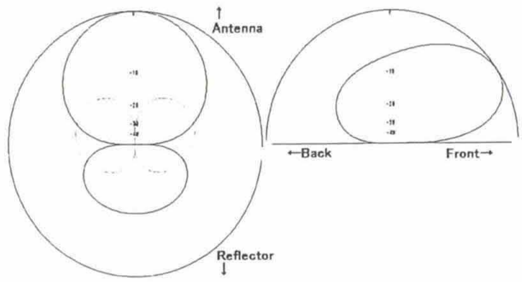


Fig.7 Antenna beam pattern

Using some antennas that have an adequate directivity, we can detect the direction roughly where the radio echo comes from. In this research, we used one paired two-element Loop Antennas that are illustrated in Fig.6. This beam pattern is shown in Fig.7. This directivity is $\pm 30$ degree and has no side lobe. Its front/back (F/B) rate is 14dB in our measurement. Using two Antennas, we have constructed a direction determination system; the direction of one of this paired antenna is toward the transmitter (hereafter, we called this *West antenna*) and the other is an opposite direction to the transmitter (*East antenna*). When the difference of received power of the same meteor echo between *East antenna* and *West antenna* was larger than 3dB, we call them either *East echoes* or *West echoes* in this experiment; that is, corresponding to the area of *E (W)* is that the reflection position of echo exits within an upward 70-degree angle and $\pm 30$ degree horizontally in the direction of East(West).

### 3–2 Observation System

The Direction Determination System is shown in Fig.8. This system chart is illustrated in Fig.9. Using an SSB receiver(ICOM IC-R75), we convert radio frequency echoes into the audio spectrum. To detect the weak echo and to store the date, a spectrogram software (HROFFT) with PC (Epson Edi cube with Intel Celeron766MHz ,128MB,HD20GB) is used. This HROFFT is developing by Kazuhiko Ookawa at Kasugabe High

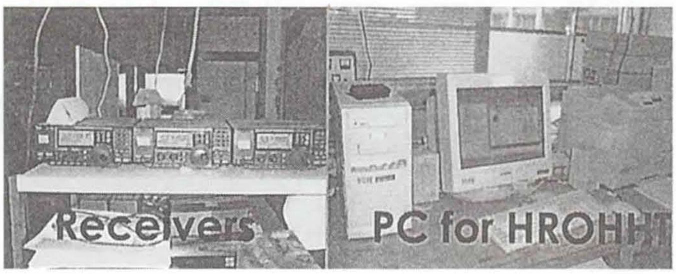


Fig.8 Receiving System

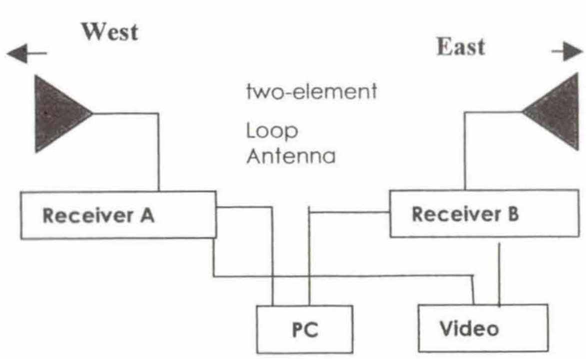


Fig.9 System Chart

school of Technology, Saitama, Japan. In this observation, we use the 2ch-HROFFT spectrogram which could be used with the synchronous 2-channal Fourier transformations (signal from the *East antenna* and *West antenna* at the same time). The images of 2ch-HROFFT are shown in Fig.12. Upper panel in this image shows the *East echoes* and lower panel shows the *West echoes*. The received signal power are shown above baseline with S/N bar graph grid at 10,20,30dB in each panels. From this image, we can identify the *East echoes*and *West echoes*.

## 4. The Detection of Reflection Shift in Geminids

### 4–1 Daily variation by Sporadic Meteors

Fig.10 shows the mean daily variation of *East* and *West* echoes rates at 10 - minute intervals due to sporadic meteors. This value is the average of 6 days, 1-6 Dec.2000; that is just 2-weeks before the maximum of Geminids. The rate of *East* and *West* echoes will vary from a minimum around 18:00 hours local time to a maximum in the early morning hours. This variation is clearly explained as the effect of the Earth rotation.

Fig.11 shows the daily variation of 12-13 Dec.2000; that is the periods of Geminids. The maximum elevation of the Geminids radiant at Nagano was found to be 85.4° at 01:49 JST. At when the radiant was just around the culmination, the severe decrease in echo rate due to high elevation angle of radiant could be seen. This is the consistent with the formula of reflection point of meteors as shown in Fig.1.

### 4–2 Subtract the Sporadic meteor

To get the echoes due to Geminids, we subtract the mean daily sporadic meteor echoes from the echoes at the periods of Geminids. Fig.12 shows that the number of detected echoes rates minus the number of the average sporadic meteor echoes rates.

We obtain that from Fig.12;

1) There are no Geminids when the radiant of Geminids is under the horizon.
2) the severe decrease in echo rate due to high elevation angle of radiant was detected clearly.
3) The change of the direction of reflection point of meteor radio signal was detected; from the *West echoes* to *East echoes* before and after the culmination of the radiant.

These results are consistent with the formula of reflection point of meteors.

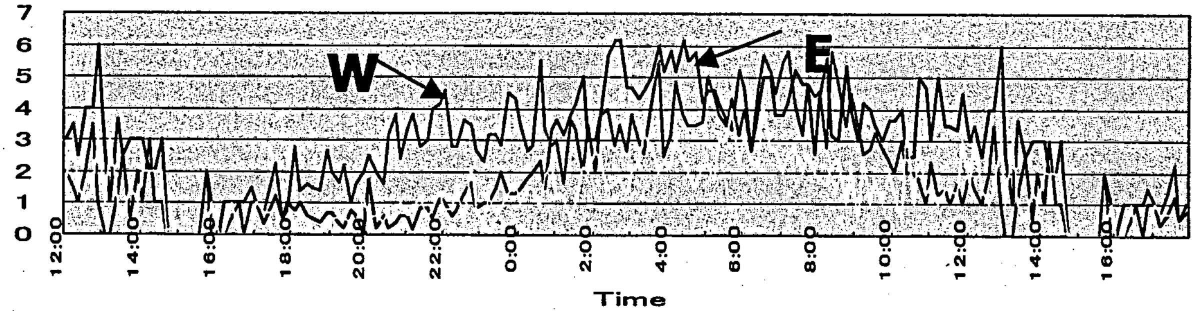


Fig.10 Mean Sporadic meteor (2000.12.1-6) at 10-minute intervals.

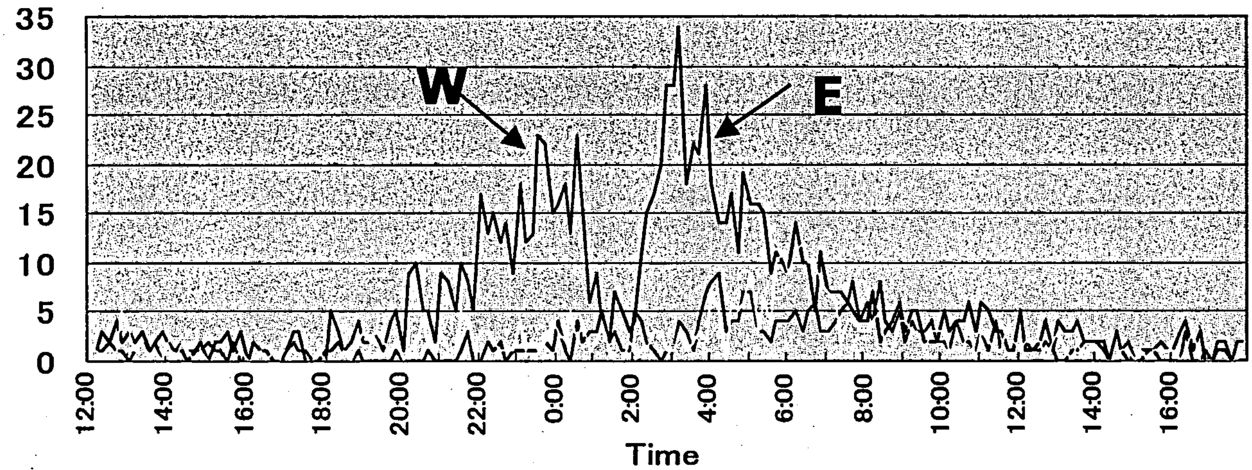


Fig.11 Geminids (2000.12.12 – 13) at 10-minute intervals.

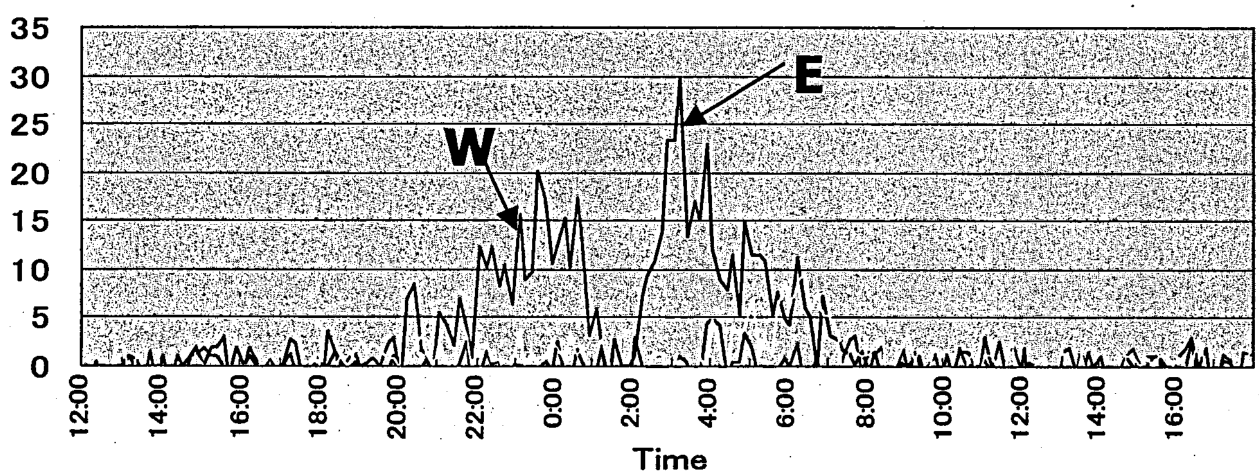


Fig.12 Geminids minus sporadic meteor at 10-minute intervals.

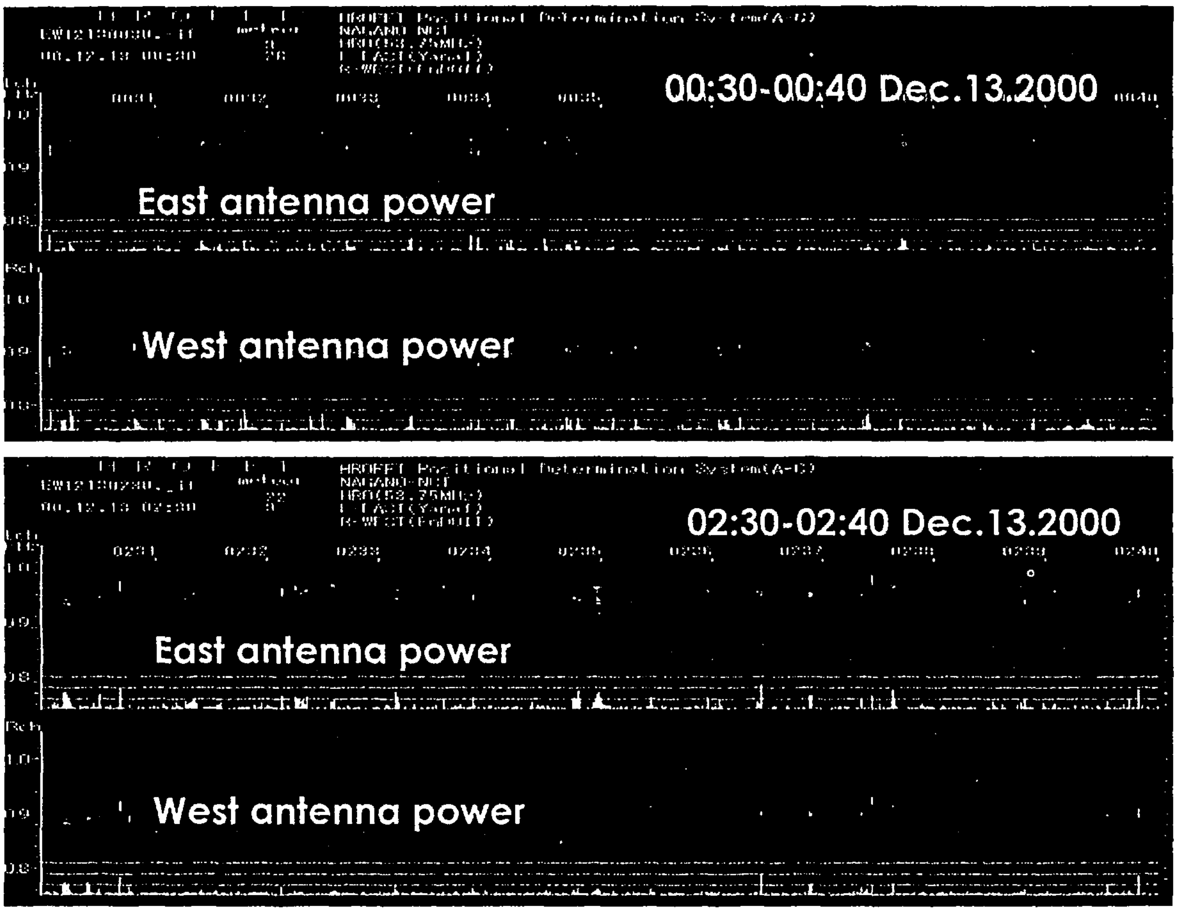


Fig.13 Shift of reflection point from *West* to *East* before (Upper panel 00:30-00:40 Dec.13.2000 JST) and after ( Lower panel 02:30-02:40 Dec.13.2000 JST) the culmination of the radiant. The time of meridian passage of the radiant of Geminids is 01:49 JST at this day. From the upper panel, we can see that the average power of the echoes by *West antenna* is larger than that by *East antenna*. From the lower panel, we can see that the average power of the echoes by *East antenna* is larger than that by *West antenna*.

### 4–3 Received power variation due to the shift of reflection point

The received power $P$ from the meteor trail relative to

$$P \propto \frac{1}{R_T R_R (R_T + R_R)}, \tag{1}$$

where, $R_T$ and $R_R$ are the distance between the transmitter and the reflection point and the distance between the receiver and the reflection point, respectively (McKinley 1961). The decrement of received power is shown as

$$G(t) = -10 \log \left( \frac{P(t)}{P(t_0)} \right) [\mathrm{dB}], \tag{2}$$

here received power $P(t)$ is normalized by received power $P(t_0)$ at the time $t_0$. Fig.14 shows the theoretical decrement of received power $G$ due to the shift of reflection point with time and the observed variation of the averaged received power

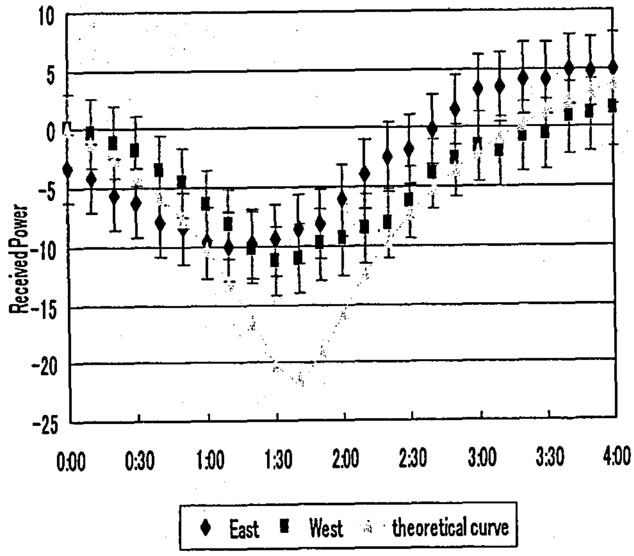


図 14 Fig.14 The variation of Received Power. of meteor echoes. From this,
1)The observed time variation of received power coincides with the theoretical decrement curve. This is explained due to the effect of the shift of reflection point.
2) The difference of the received power between *West antenna* and *East antenna* is 10dB. This is consistent with the fact that F/B ratio of our antenna is 10dB.

## 5. Concluding Remark

(1) We detected the shift of the reflection point of meteor by the number counting of *West echoes* and *East echoes.*
(2) We detect the decrement of received power of echoes which is consistent with theoretically. These are the direct evidence that the meteor echo really come from the meteor trails. We also detected the change of a trend of the Doppler shift of meteor echoes. At the presence, the resolution of frequency in this observation is some Hz, so that, it is insufficient to measure the meteor wind with a few m/s accuracy. However, this result is consistent of the meteor wind data of MU Rader of Radio Science Center for Space & Atmosphere (RASC), Kyoto University.

At the presence, observed baseline is only one; the East-West baseline. To get the sensitivity for North-South, we are planning to construct the other three observational sites, Misato Astronomical Observatory at Wakayama, the Institute of Space and Astronautical Science at Sagamihara, Kanagawa, and Nishi-Harima Astronomical Observatory at Hyogo. The former is Northwest-Southeast baseline. The latter 2 sites are West-East baseline. To combine these sites date, We can monitor the meteor wind by counting the number of meteors.

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