The detection of the Earth rotation and revolution effect using the daily and annual variation of sporadic meteor echo 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 started the observation of the daily and annual variation of sporadic meteor echoes with paired two-element loop antennas (F/B ratio is 10 dB) at the Nagano National College of Technology (Nagano, JAPAN) using the beacon signals at 53.750MHz, 50W from Fukui National College of Technology (Sabae, Fukui, JAPAN) from Aug.2000. The direction of one of this paired antenna was west toward Sabae and the other was east. This system could be roughly detected the direction of the radio echoes. Using this system, we observe the daily variation of sporadic meteor echoes; the echo rose from midnight with the peak coming at about 6 a.m. and decreasing to the noon, the peak echoes were observed from the West antennas at 4 a.m. and the peak from East antenna was at 10 a.m. This daily variation is interpreted as the effect of the Earth rotation and revolution around the sun and same peculiar property of forward meteor scattering observation. We also discuss the annual variation of sporadic meteor echoes.

keywards: meteor, sporadic meteor, HRO

1. Introduction

Radio meteor scatter is an ideal technique for observing meteors continuously (McKinley 1961). Using this method, we can monitor the activity of meteors and meteor stream (Suzuki & Nakamura 1995, Yrjölä & Jenniskens 1998 Maegawa et al. 1999,).

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We have constructed the directional determination system using paired loop antennas, one of these directions is the *Eastward* and the other is *Westward*. These antennas are called as *East antenna* and *West antenna*, respectively. This system can detect the direction roughly where the radio echo comes from. Then we can monitor the meteor streams and outburst with the knowledge of the rough direction of the meteor echoes. Using this simple and inexpensive equipment, we have confirmed the shift of reflection point of meteor echoes which is the fundamental property in the forward meteor scattering observation (Ohnishi et al. 2001a, hereafter cited as Paper I). And furthermore, we can research these subjects:

- to get the spatial distribution and velocity distribution of meteoroid on the near Earth orbit by the observation of the sporadic meteors echoes rate.
- to get the fundamental data of sporadic me-

teor activity and anisotropy for monitoring the meteor streams and outburst.

- to investigate the correlation of the variation of the degree of ionization in the upper atmosphere (~100km) due to the solar radiation and solar activity and the counted echoes variation.
- to investigate the effect of the Earth rotation and revolution in the variation of detected meteor echoes .

For the first step of our research, we try to get the fundamental data of the sporadic meteor activity and anisotropy using the directional determination system. And we have found the difference in the observed diurnal variation of the *East antenna*'s echoes and *West antenna*'s echoes. This difference seems to be concerned with the radio reflection mechanism and the rotation and the revolution of the Earth. We could not find any remarkable variation of the trend of the diurnal variation of *East echoes* and *West echoes* in one year observation. These data are good demonstration of the spatial distribution of meteoroid on the near Earth orbit. And more, these becomes a good database to check the formula of the *response function* (*observability function*) for sporadic meteors by the forward meteor scattering observation (e.g. Eshleman & Manning 1954, Hines 1955, Hines & Vogan 1957, Elford et al. 1994, Wislez 1995, Yrjölä & Jenniskens 1998, Ceplecha et al. 1998, Ohnishi et al. 2001b).

2. Observation System

We have constructed the directional determination system by using paired handmade loop antenna. The antenna beam pattern is ±30° and has no side lobe. Its front/back (F/B) rate is 10dB. The direction of one of them is toward the Transmitter (*West antenna*) and the other is an opposite direction of Transmitter (*East antenna*). The details of this system are shown in Paper I.

The detection sensitivity is depend on the location of the transmitter and receiver, and also the incident angle of meteor. For example, the sensitivity is high when the meteor trail is on the same plane with the transmitter and receiver baseline. In our situation, the transmitter (Fukui-NCT) is the *Westward* from the receiver (Nagano-NCT). Then the east-west directional trail is highly sensitive. On the other hand, the north-south directional trail is less sensitive. In this experiment, we call it *East echo* or *West echo* when the difference of received power of the same meteor echo between by *East antenna* and by *West antenna* is larger than 3dB; that is, corresponding to the area of E (W) is that the reflection position of echo exits within an upward 70° angle and ±60° horizontally in the direction of East(West). We call *Other echo* when the difference of received power by paired antenna is less than 3dB.

3. Diurnal variation of sporadic meteor

Fig.1 show that the daily variation of the 4 days' average of the detected echoes rate by *East antenna* and *West antenna* at 10-minute intervals in January 2001. The echo rate will vary from a minimum around 18:00 hours local time to a maximum in the early morning hours. Total number variation are clearly explained as the effect of the Earth rotation.

The Earth revolves around the sun with the velocity of 30km/s. In the early morning, the zenith is consistent with the direction of the Earth revolution (Apex). Then the Earth collides with many meteoroids. On the other hand, in the evening time, only a few meteoroids, which the velocity is larger than 30km/s and the direction is the same as the Earth exist to collide with the Earth (Anti-apex). Therefore, if no appreciable shower activity is present, the rate of arrival of meteors will vary from a minimum around 18:00 hours local time to a maximum in the early morning hours. However, there are some peculiarities in forward scattering radio meteor observation. For example, we can detect the difference of rate of the *East echoes* and the *West echoes*.

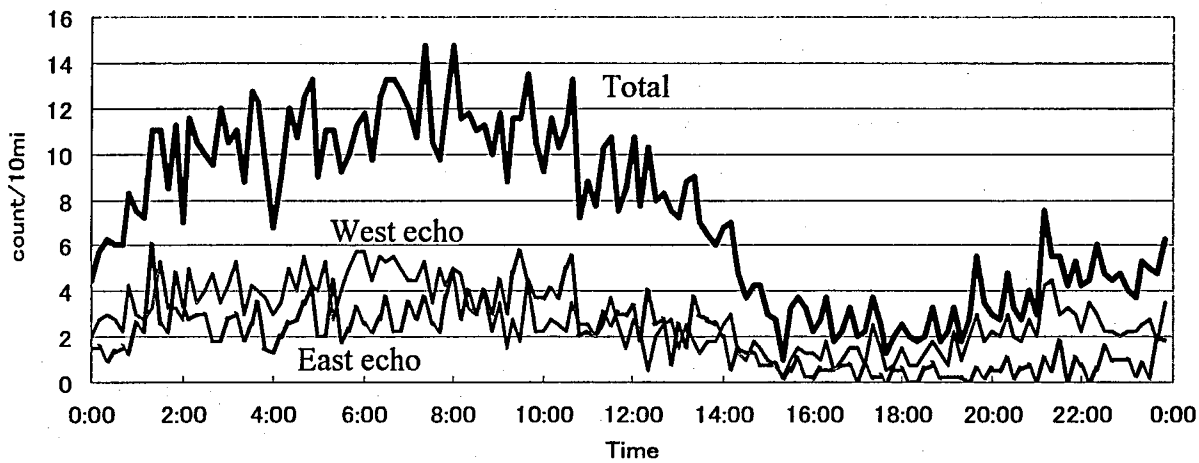

Fig.1 The daily variation of the total echoes by the *East antenna* and *West antenna* at 10-minute intervals in January 2001. The thick line indicates the total echoes, thin line is *West echoes* and dot line is *East echoes.*

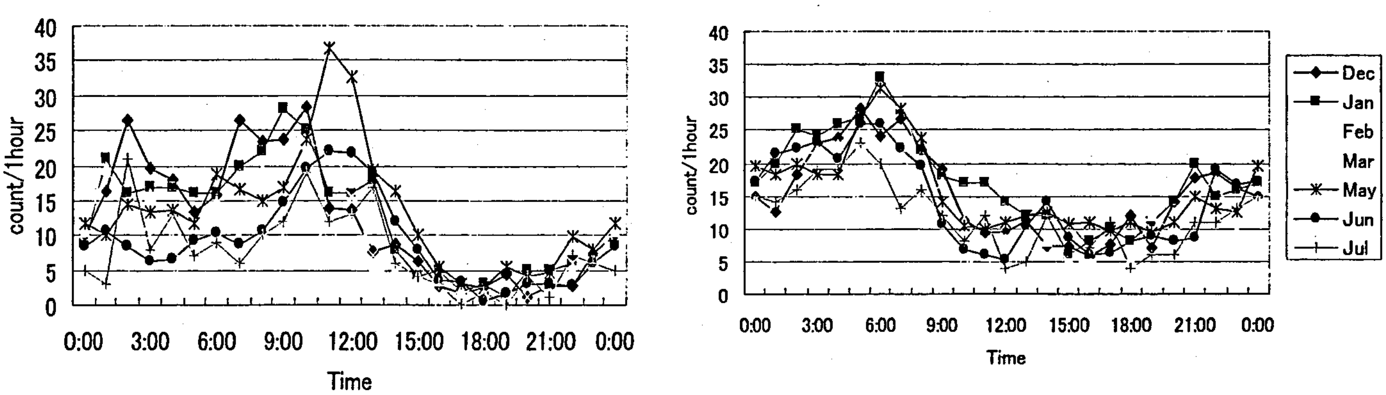

Fig.2 Monthly average of the daily variation of sporadic meteor. Left panel is the sporadic meteor by *East antenna* and right panel is the sporadic meteor by *West antenna.*

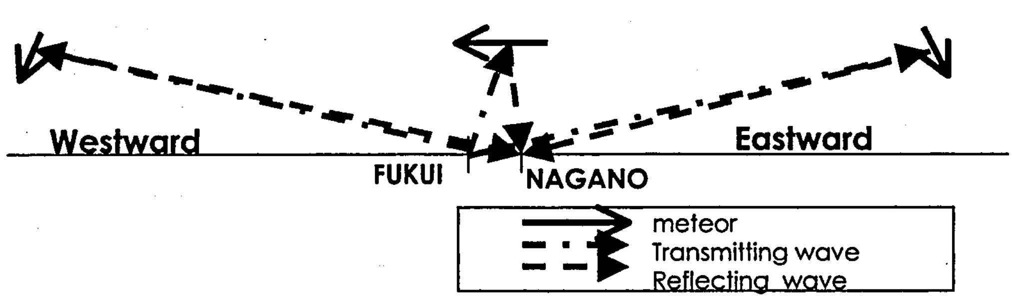

Fig.3 The relation of the incident angle of the meteors and the reflection point of the echoes. In the case that the incident angle θ of the meteors is nearly 90°, the direction of the reflection point will change the *Westward* to *Eastward* at $\theta = 90°$.

4. Sporadic meteor by East antenna and West antenna

Fig.2 shows the monthly average of the daily rate distribution of sporadic meteor (from Dec.2000 to Jul.2001). Each monthly data are represented to the average of several days' data, which do not affect the artificial noise, and/or the disturbance of an ionosphere.

The reflection of radio wave off meteor trails is secular. Therefore the reflection point is very sensitive to the incident angle of the meteor (See Fig.3). If the incident angle θ is nearly $90°$, the distance of the reflection point is more than 1000km (See Fig.5 in Paper I). And more, if the incident angle of meteor is $\theta < 90°$, the reflection point of it is *Westward* sky, and, if $\theta > 90°$, the reflection point is *Eastward* sky. Then, we can detect *West echoes* in the case of $\theta < 90°$, and *East echoes* in the case of $\theta > 90°$.

Fig.4 shows the diurnal variation of *East echoes* minus *West echoes*. *West echoes* is larger than *East echoes* before 6:00 a.m. On the contrary, *East echoes* is larger than *West echoes* after 6:00 a.m. We can explain this phenomenon that the average reflected region of echoes change in time; *Westward* at around 3:00A.M. and *Eastward* at around 10:00A.M. From 10-months observation, we find that the trend of *East-West echoes* rate is no change in time. Therefore, this phenomenon would be caused not by the external factor, e.g., anisotropy of the spatial distribution of meteoroid, but by the intrinsic factor, e.g.,*"response function"* and/or the motion of the Earth. At the presence, we think that this is caused by
(1) the anisotropy of the average of the meteor radiant due to the effect of the Earth revolution (See Fig.5), and
(2) the radio reflection mechanism in forward scattering radio meteor observation (See Fig.3).

For an intuitive interpretation this phenomenon, we consider the simple situation; the meteor trajectory is vertically and the sporadic meteor velocity is nearly the same as the Earth velocity (30km/s). One-dimensional velocity toward the Earth is about 17km/s. In this situation, the average incident angle of the sporadic meteor seen from the observer vary as in Fig.5, the average incident angle is *Eastward* before 6:00 a.m., *Westward* after 6:00 a.m.

5. Fluctuation of the direction of reflection point

We show the other evidence of our interpretation. Fig.6 show the time variation of the standard deviation(thick line) and the average(thin line) of *East* minus *West* for 12 days within Dec.2000 and Jan.2001 and Mar. 2001. At 6:00 a.m., the zenith of observer is consistent with the Apex. Then the incident angle of each meteor seen from the Earth would be converged on the direction to the zenith. That is that the average incident angle becomes almost $90°$. At this case, the reflection point of the each meteor with large incident angle will be shaken to *Eastward* or *Westward* according to its incident angle ($\theta > 90°$ or $< 90°$). Therefore, at this time, the fluctuation of the direction of reflection point will be maximum value.

6. Concluding Remark

Using paired loop antennas system, we can monitor the meteor streams and the outburst with the information from the rough direction of meteor. For the first step, we have tried to get the fundamental data of sporadic meteor activity and anisotropy, and have found that
(1) Detection the *East echoes* and *West echoes* daily variation of sporadic meteor that is cased by the Earth rotation and revolution effect.
(2) Detection of the Earth rotation and revolution effect in the *East echoes* and *West echoes* annual variation of sporadic meteor. This variation is due to the varying altitude of the ecliptic plane over the year.
We can see this from the monthly average data in Fig.1. On the northern hemisphere, echo rates are expected to the peak in the Autumnal Equinox (about September 21) and to be lowest during the Vernal Equinox (March 21).

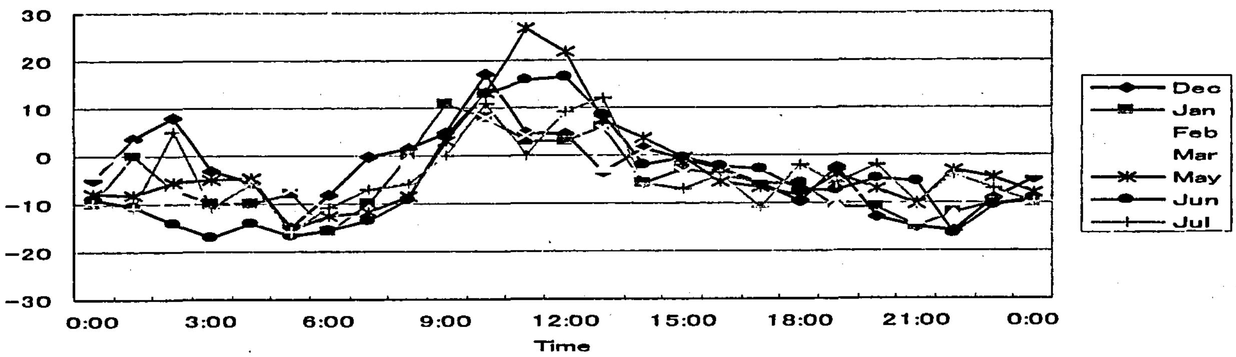

Fig.4 The number variation of *East echoes* minus *West echoes* at one-hour interval. The *West echoes* number is larger than *East echoes* one around 3:00 a.m. and the reverse around 10:00 a.m.

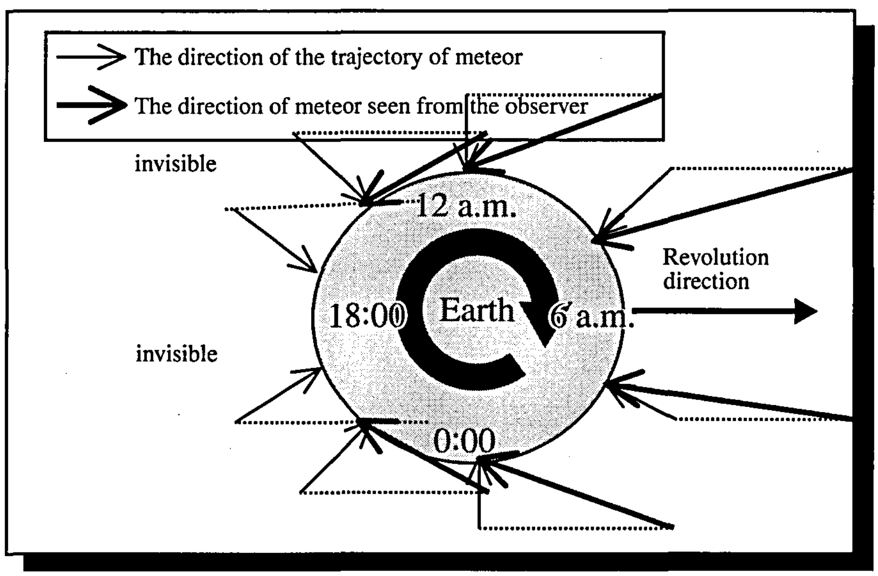

Fig.5 Before 6:00A.M., the average incident angle of meteors $\bar{\theta}$ is less than 90° (i.e. an average meteor comes from *Eastward*), then an average reflection point of the echoes is *Westward*. That is that the number of *West echoes* is larger than that of *East* one. After 6:00 a.m., $\bar{\theta} > 90°$, then, an average reflection point of the echoes is *Eastward*. This simple interpretation can be explained the variation of *East-West echoes* tendency in Fig.5.

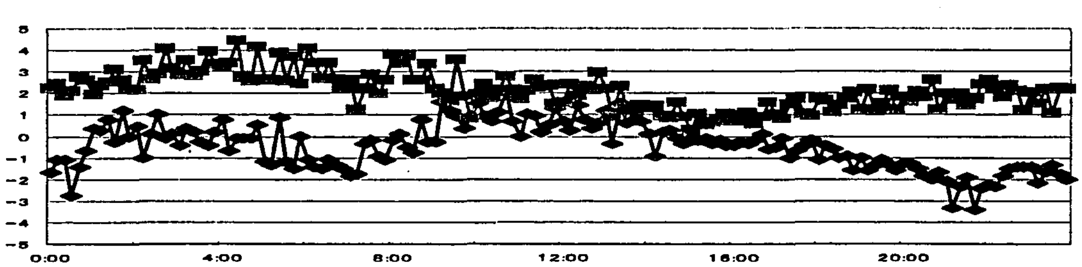

Fig.6 The average of the standard deviation (thick line) and the average of number (thin line) of *East echoes* minus *West echoes* at 10-minute intervals. The fluctuation of the direction of reflection point will be maximum value at 6:00 a.m.; the zenith of observer is consistent with the Apex.

At the presence, the observed baseline is only one; *East-West* baseline. To get the sensitivity for *North-South*, we are planning to construct two other observational sites.

One is the Misato Astronomical Observatory at Wakayama. The other is the Institute of Space and Astronautical Science at Sagamihara, Kanagawa, and Nishi-Harima Astronomical Observatory at Hyogo. The former is the Northwest-Southeast baseline. The latter is the West-East baseline.

To combine the data from these sites, We can obtain the spatial distribution and velocity distribution of meteoroid on the near Earth orbit by the observation of the number of the sporadic meteors.

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