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Simulation for detective field of HRO

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Abstract: HRO (Ham Radio Observation) is one of the valuable methods of observing meteor activity. However, it not only has the advantages but also suffers from unknown detective field of HRO. If the field would be transformed by zenithal position of radiation point, the number of meteor by HRO is not reliable. Thus, the purpose of this report is to prove time shift of the detective field through simulation. HRO is the meteor radar of a forward scatter system. If the surface of the meteor trail is smooth and enough size for frequency, this system can receive echo of the meteors under the following below-mentioned conditions.
-The ionized-trail touches the spheroid, for which the transmitting station and the receiving station are positioning on focus.
-The height of ionized-trail is about 100km (average height of meteor trail).

The field on this condition was calculated by Microsoft Excel and plotted values of the results. Consequently, the area transition and time shift of the detective field were successfully simulated. And in the simulation it is shown that there exists the dead time among which HRO cannot receive a specific meteor stream. Actually, the author could not receive echo of Geminids (Dec. 12-16 1999) by using HRO at midnight. In conclusion, this study established one of the basic methods to estimate the real number of meteors by HRO observation data.

1. INTRODUCTION

When the meteor enters the atmosphere, the its velocity energy is transformed into the thermal energy and photon energy and others. So this energy melts and ionizes the meteor and the atmosphere, As a result, the meteor forms the ionized-trail. The ionized-trail result in radio waves to be recieved even the transmitting and receiving stations at the distance. When the reflecting signal is observed, it indicates the presence of the meteor. So, in order that we can know that the meteor enters into the atmosphere, the HRO system was built based on the outline. The HRO stands for Ham Radio Observation. The HRO which is rader of forward meteor scattering observation using 50MHz band, can be a method to monitor the activity of meteor stream by using simple and inexpensive equipment.

However, it must be taken into account that sensitivity varies according to unknown factors. For example, as shown in Fig. 1, it can be found not only daily variation of sporadic meteors

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but unknown variation. Perhaps, unknown variations depend on zenithal position of radiation point, because as the maximum day of a meteor stream approach is getting closer, the more remarkable fall of total meteor counts can be seen. That is, when data of HRO, we must be handled taking this problem into consideration. Therefore, the purpose of this report is to show how to overcome these problem.

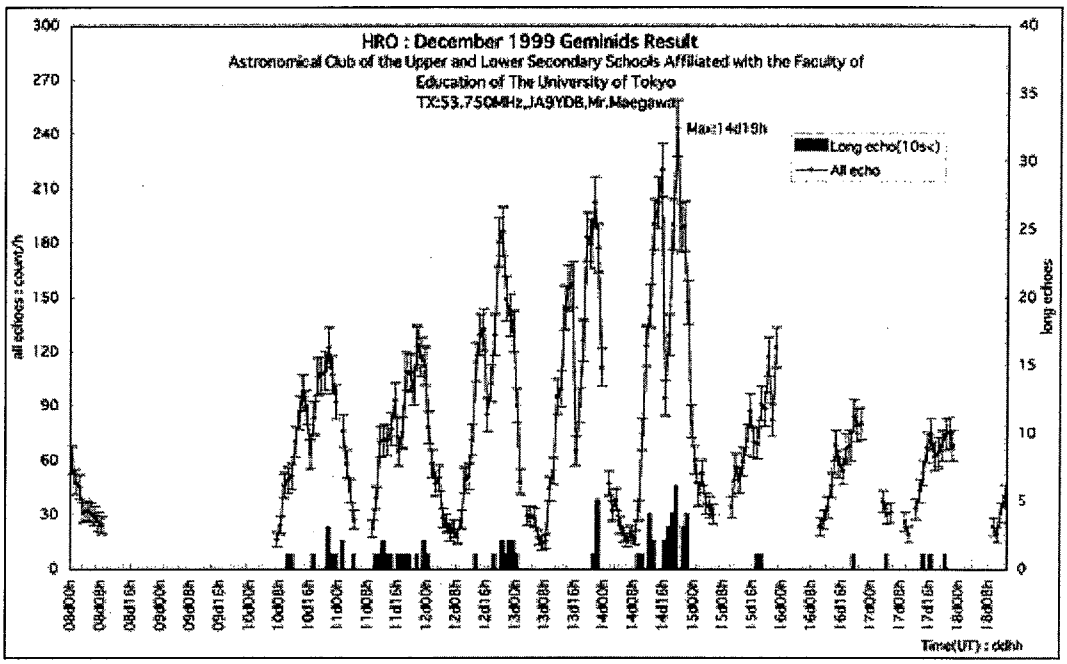

Fig. 1: Result of meteor counts (Geminids 1999, Astronomy club of Junior and Senior High School Attached to the Faculty of Education of the University of Tokyo)

2. CALCULATION METHODS

2.1 Theory

In order to solve its problem, it is necessary to calculate the situation of reflection. The radio wave is reflected when an angles of incidence and reflection are approximately equal. That is, the signal is observed when the ionized-trail touches the spheroid where the transmitting and receiving station are positioning on focus. This conditions can be expressed as the following simultaneous equations (1)(2). (Watanabe 1984)

$$\begin{cases} \dfrac{x^2}{A^2} + \dfrac{y^2}{A^2-d^2} + \dfrac{z^2}{A^2-d^2} = 1 & (1) \\ \dfrac{2x}{A^2}\cdot l + \dfrac{2y}{A^2-d^2}\cdot m + \dfrac{2z}{A^2-d^2}\cdot n = 0 & (2) \end{cases}$$

But, it is necessary to assume that the surface of ionized-trail is smooth and enough size for the applying frequency by HRO. "l, m, n" is an unit vector of radiation point of meteor stream. "x, y, z" is an ion tail position. "d" is half of a distance between transmitting station and receiving station. "A" is an optional valuable.

The equation (1) which is spheroid indicates that the angles of incidence and reflection are equal. The equation (2) is inner product of an unit vector of ion trail position and a unit vector of radiation point. This shows that an ionized-trail is made by meteor coming from the radiation point of a certain meteor stream.

2.2 Main-calculation

To calculate on the above-mentioned condition, "Microsoft Excel" was used, because it can draw a graph of calculated result easily. But as it cannot handle the equation of many valiables, it is necessary to limit to solve equations only for "x" and "y". (Here is, x-axis baseline of Transmitter and Receiver, z-axis height and y-axis crossed "x" and "z" axis.) And these solved equation showed following function, "$x(y,z,l,m,n,A)$" and "$y(z,l,m,n,A)$", insert these function into cell of Excel. At last, the autor substitutes a value of radiation point(l,m,n), height "y", distance "d", and solve these function substituting 100, 110, 120, $\cdots$, upto 500 into "A". The value 100 is for preventing major axis and minor axis from their inversion, and the value 500 is for preventing the signals having the long distance from their attenuation.

$$x(y,z,l,m,n,A) = -\left(\frac{n}{l}\cdot\frac{A^2}{A^2-d^2}\cdot z+\frac{m}{l}\cdot\frac{A^2}{A^2-d^2}\cdot y\right) \tag{3}$$

$$y(z,l,m,n,A) = \frac{-mnA^2z\pm\sqrt{D/4}}{m^2A^2+l^2(A^2-d^2)} \tag{4}$$

$$D/4 = m^2n^2A^4z^2-\left\{m^2A^2+l^2(A^2-d^2)\right\}\left[\left\{n^2A^2+l^2(A^2-d^2)\right\}z^2-(A^2-d^2)^2l^2\right]$$

2.3 Sub-calculation

The coordinates are transformed into the same condition in order to carry out comparison with other receiving locations, because the main calculation was figured out on the coordinates of which the origin was at the center of the spheroid. Here is, the result of main calculation is "x_0,y_0,z_0". "α" is the azimuthal angle on the basis of a north-south baseline.

First, a parallel movement of "x_0,y_0,z_0" carries out.

$$\begin{pmatrix}x_0\\y_0\\z_0\end{pmatrix}-\begin{pmatrix}d\cos(-\alpha+90^\circ)\\d\sin(-\alpha+90^\circ)\\0\end{pmatrix}=\begin{pmatrix}x_0-d\cos(-\alpha+90^\circ)\\y_0-d\sin(-\alpha+90^\circ)\\z_0\end{pmatrix}=\begin{pmatrix}x_1\\y_1\\z_1\end{pmatrix}$$

Second, polar coordinates system changes into orthogonal coordinates.

$$\begin{cases}r_0=\sqrt{x_1^2+y_0^2+z_1^2}\\ \theta_0=\arccos\left(\frac{x_1}{\sqrt{x_1^2+z_1^2}}\right)\\ \phi_0=\arcsin\left(\frac{\sqrt{x_1^2+z_1^2}}{y_0}\right)\end{cases}$$

And, "r_0,θ_0,ϕ_0" rotates "α" on Transmitting station.

$$\begin{pmatrix}r_0\\\theta_0\\\phi_0\end{pmatrix}-\begin{pmatrix}0\\\alpha\\0\end{pmatrix}=\begin{pmatrix}r_0\\\theta_0-\alpha\\\phi_0\end{pmatrix}=\begin{pmatrix}r_0\\\theta_1\\\phi_0\end{pmatrix}$$

Finally, orthogonal coordinates changes into polar coordinates system. Now, it has become to be able to do comparison with other locations. (We called this coordinate *the coordinate for comparison.*)

3. OBSERVATION METHODS

The composition of the HRO system is indicated on Table 1. This system is able to convert audio signal into the spectrum automatically, and the spectrum is described PNG-image. The meteor echo is examined the meteor echo in these images. The radio wave at 53.750 MHz (50W) has been kept transmitting continuously by Mr. K. Maegawa from Fukui National College of Technology (136.18E, 35.95N) in Sabae, Fukui, Japan, for meteor radio observation since 1996. The author had been observing during Leonid 2001 and Geminid 1999 activation in Komae, Tokyo, Japan (139.41E, 35.41N). The distance between Sabae and Tokyo is about 300 km, and the direction to the Sabae from Tokyo is about 270° (West). As a result, the author succeeded in detecting the meteor activity. Mr. Ookawa is the teacher of the Kasukabe High School of Technology, Saitama, Japan.

Table 1: Composition of observation equipment

Name	Equipment	Comment
IC706(ICOM)	50MHz-band SSB reciever	
CA-52HB(COMET)	HB9CV Antenna	Direction is toward trasmitter
HROFFT054	Spectrogram Software	Developed by Kazuhiko Ookawa

4. RESULTS

Fig 2 shows that the detective field moves and transforms according to zenithal position of the radiation point (according to time). This also indicates the disapearing of the detective field due to the meteor incidence angle into the atmosphere. (See Fig 4) The target of this result is the radiation point of Geminids from 14h to 19h (UT) Dec 14th. The receiving station is located in Komae, Tokyo, Japan (139.57E, 35.63N).

Fig 3 shows a overlap of detective field at many receiving stations. Since this result indicated the overlap, any data of two differet receiving stations were selected for comparison. The validation of the theory can be checked by investigating the ratio of simultaneous observation from this comparison. The target of this result is the radiation point of Leonids at 15h Nov 19th. The receiving station is located in Univ. of Tsukuba, Ibaraki, Japan (140.11E, 36.11N) , in Misato Observatory, Wakayama, Japan (135.4E, 34.13N), in Komae, Tokyo, Japan (139.57E, 35.63N), in Awa High School Amature Radio Club, Tokushima, Japan (133.35E, 34.1N) and in Kanagawa, Japan.

5. DISCUSSION

5.1 The ratio of simultaneous observations

From Fig 3, some recieving stations were turned out to have a overlap of detective fields. For proving this fact, the ratio of simultaneous observations (Sr) is investigated. The Sr was

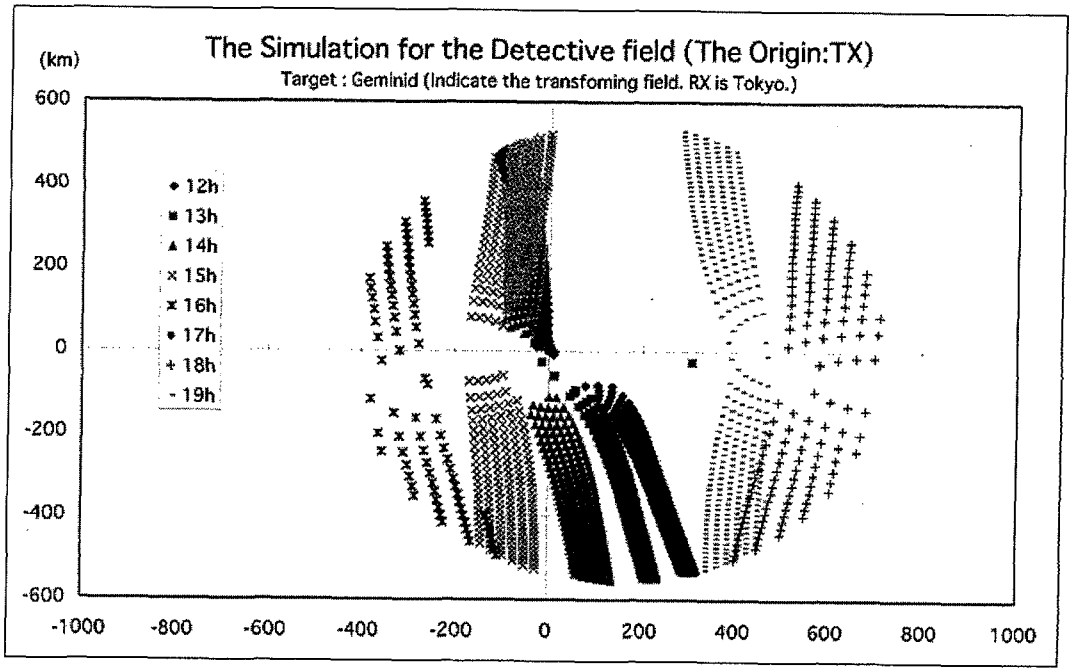

Fig. 2: Calculation result of time shift

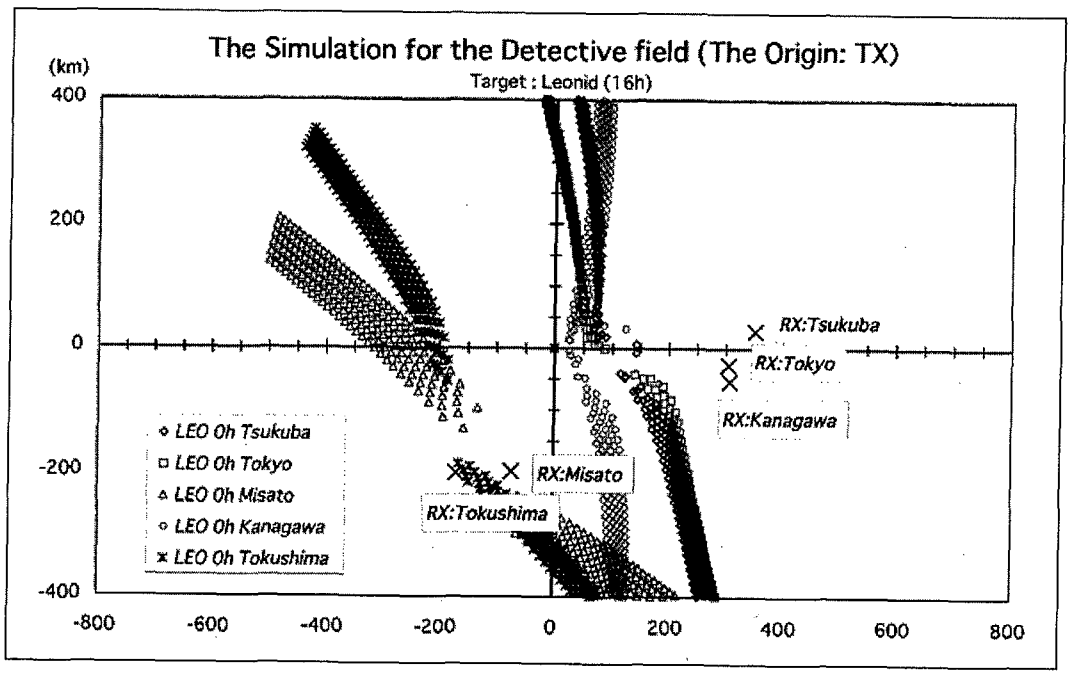

Fig. 3: Calculation result of many recieving station

Table 2: The ratio of simultaneous observations (Sr) (without "long echo")

Time	Komae - Tsukuba Univ.	Komae - Tokushima
0:00	67 %	0 %
0:10	67 %	0 %
0:20	78 %	0 %
0:30	50 %	0 %
0:40	100 %	0 %
0:50	0 %	0 %
Average	60 %	0 %

defined as the following formula (5).

$$Sr = \frac{N_s}{N_t} \times 100 \quad [\%] \tag{5}$$

N_s is the number of simultaneous ovservational echos. N_t is the number observed in the Komae receiving station. From this result (Table 2), it is found that there was no problem to use the theory.

5.2 The fall of observational sensitivity

From Fig. 2, it is found that the detective field is moved, transformed and disappeared. When the meteor incident angle is close to 90° like Fig. 4, the receiver can receive the echo having a very long distance from HRO system (like the value $A \rightarrow \infty$). However, the receiver cannot receive the echo since the ionized-trail is in the position which is far apart (Over 1000 km). Thus, the author assumes that the coodinates are a flat plane. In other words, it was not taken into account of the earth's curve on the calculation. Now, this assumption must be reconsidered again. Here is, "d"(km) is the difference from the spheroid center, "R"(km) is radius of the earth (see Fig. 5), "h"(km) is the difference between the flat plane and the real earth surface, and the author assumes that the earth is approximately the spherical. "h" is shown as following equation.

$$h = R\left(1 - \cos\frac{d}{R}\right) \tag{6}$$

When "y", the height of constructing ionized-trail, may be equal to "h", it is turned out that the theory is valid although the conditions that the meteor incident angle close to 90°. Here, "R" is 6.3×10^3. "d" for satisfying the condition is as the following variability domain.

$$1.06 \times 10^3 \leqq d \leqq 1.23 \times 10^3 \tag{7}$$

From this, the author considers the case obseved in Tokyo, it is turnd out that the ionized-trail occurence requires to have a distance of more than 1000 km from the middle point of receiving station and transmitting station for the observation with an incident angle of 90°. When this ionized-trail is observed, a distance from the transmitting station — the ionized-trail — the receiving station exeeds 2000 km. On the other hand, in case of the ionized-trail that an incident angle is 0°, the distance is about 400 km. And this extreme difference causes the sensitivity to change, because radio wave is attenuated due to a squared value of the distance. Therefore, it is explained that the fall of observational sensitivity is caused by moving and transforming of the detective fields.

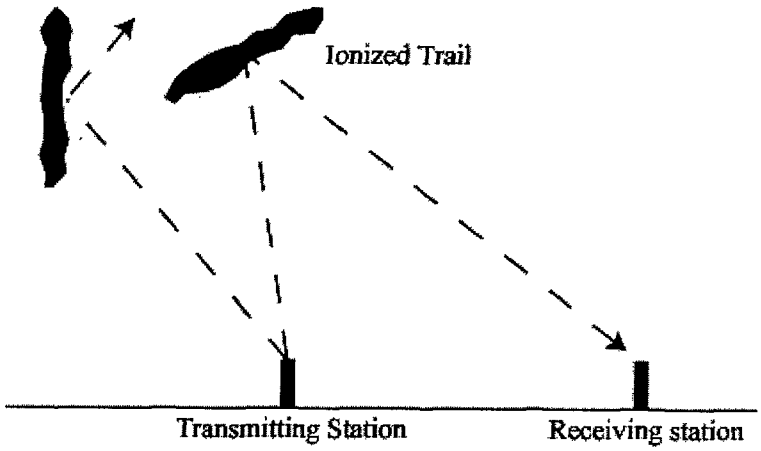

Fig. 4: Reflection model

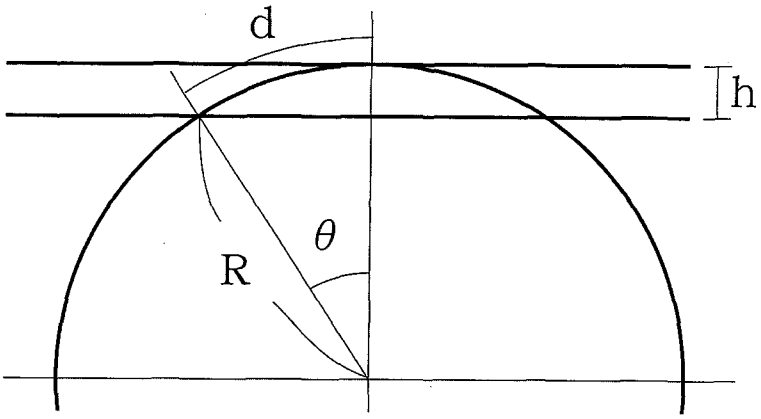

Fig. 5: The difference between the tangential plane and the surface of the earth.

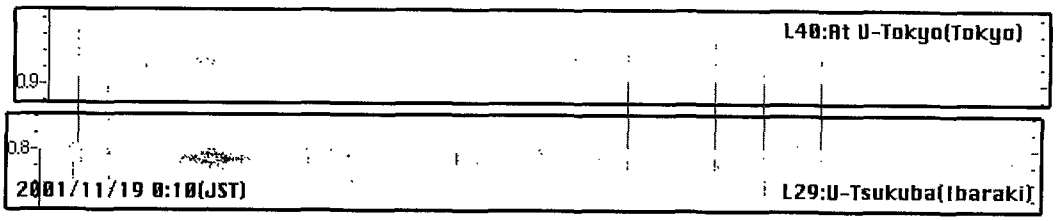

Fig. 6: Result of same echo

6. CONCLUSIONS

This study concludes as the following: The hypothesis of the incident angle of ionized-trail and the reflection angle being approximately equal is true. And, it shows that the sensitivity of HRO is fallen and what the detective fields is moved and transformed. Therefore the sensitivity is changed from one moment to another and we have to note this when treating the HRO data.

7. FUTURE WORKS

The author became capable to calculate the position of ionized-trail through this study. As a result, the author compared among the data observed by HRO and eye-light such as naked eye or high sensitivity CCD camera. If this comparison is successful the physical properties can be discussed from the HRO data. In addition, in order to estimate the real activity of the meteor streams, the author corrected many data and calculated the average "Sr" such that the investigation proved the hypothesis was right. From this, the authors should be multiplied by the HRO data.

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