LOW-LATITUDE NOSE WHISTLERS

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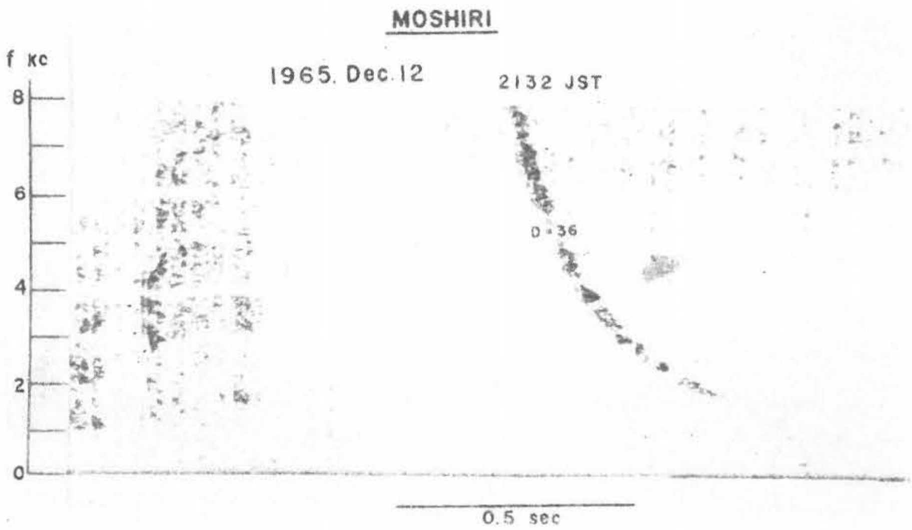
Abstract

Low-latitude nose whistlers which showed nose frequency of 55-70 kc/s were obsesved at Moshiri. Their path latitudes have been estimated to be not lower than 42° for whistlers of nose frequency 55 kc/s, and 39° for 70 kc/s. Occasionally, high-latitude nose whistlers were also observed at Moshiri. It is inferred that they emerge from the ionosphere near 60°. Some discussions are given in order to estimate the path latitude and electron density distribution. And it is shown that the low latitude nose whistlers can possibly provide informations about the electron distribution in the intermediate region.

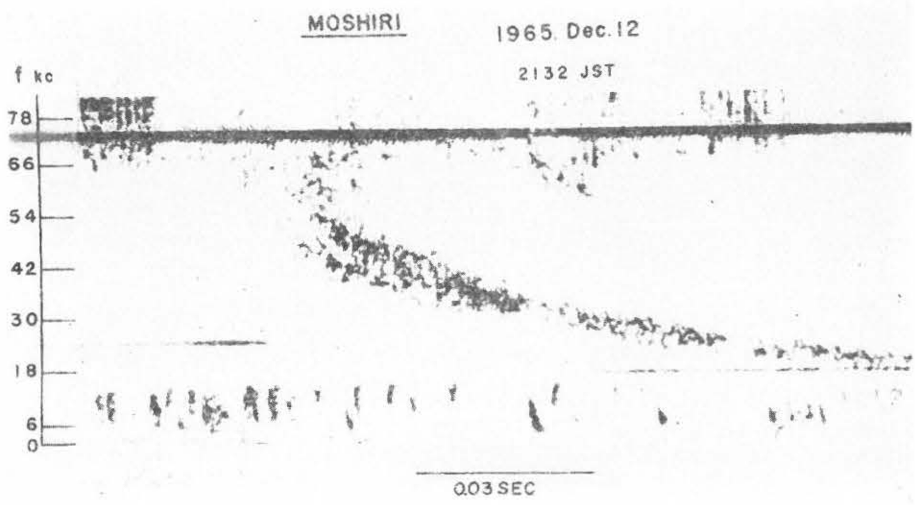
1. Nose whistlers at Moshiri

We made an observation of nose whistlers at Moshiri (geomag. lat. 34°) with a magnetic tape recorder whose recording speed is 60 inch/s. This observation continued for three days in December 1965 when intense whistlers could be heard. Through this observation, many whistlers extending over 50 kc/s were detected and in a few case, whistlers up to 70 kc/s were observed. An example of a nose whistler which was observed at 2132 JST on December 12, 1956 is shown in Fig. 1. Fig. 1 a shows one of the usual whistlers which obeys well the simple dispersion law, the value of dispersion being $36\sqrt{s}$. But when the same whistler is traced to about 70 kc/s, as shown in Fig. 1 b, it becomes quite clear that Fig. 1 a is nothing but the lower part of the nose whistler, the nose frequency of which lies around 60 kc/s. The nose frequency measured during this observation period lay between 55 and 70 kc/s and the dispersion value changed from $34\sqrt{s}$ to $36\sqrt{s}$. Fig. 2 shows part of the same nose whistler up to 48 kc/s. The solid curve in this Figure is a dispersion curve of whistlers, obeying the simple law and having the dispersion value $36\sqrt{s}$.

* Will change spelling hereafter from Outsu [óuts] to Ohtsu [ɔ:ts], because the latter seems to be easier to read like Japanese.



(a) 8 kc/s range sonagram Dispersion $36\sqrt{s}$



(b) 78 kc/s range sonagram Nose frequency around 60 kc/s

Fig. 1 Low latitude nose whistler. Moshiri (geomag. lat. 34.0)

The time difference between the observed whistler and the calculated simple law whistler becomes greater as freqency increases, which results in the nose effect. The nose effect begins to appear at about 10 kc/s, and a record up to 50 kc/s is sufficient to well confirm the existence of the nose effect. In fact, we can detect the nose effect for all whistlers measured up to 50 kc/s. The nose whistlers reported here are

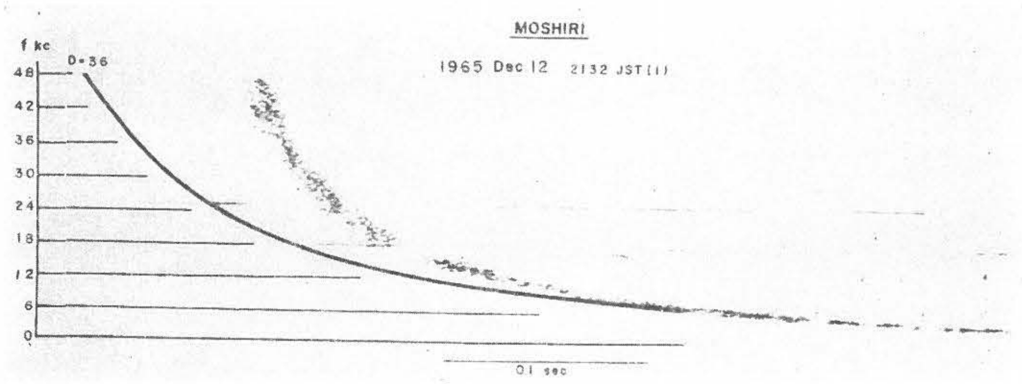


Fig. 2 48 kc/s range sonagram of the same whistler in Figs. 1a and 1b. A solid curve is a dispersion curve of simple law whistler of dispersion $36\sqrt{s}$. Nose effect is clear in this frequency range.

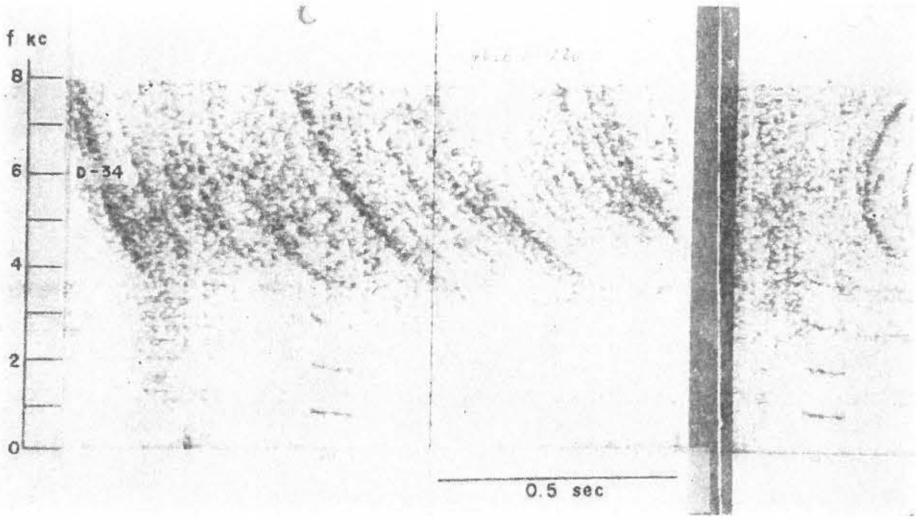


Fig. 3 High latitude nose whistlers. Moshiri, June 1, 1965, 1220 JST
Two nose whistlers can be seen near the right end. These whistlers are multipath whistlers which are generated by single lightning flash.

the first example of low-latiude nose whistlers. Before this observation, whistlers were recorded only up to about 30 kc/s so that the highest nose frequency was 20 or 25 kc/s, which still lies in the category of high-latitude nose whistlers.

Occasionally, on the other hand, the high-latitude nose whistlers have been observed at Moshiri during the routine observation with a tape speed of 7½ inch/s. Fig. 3 shows an example of such cases. A few nose whistlers can be seen near the right end of the Figure. Their nose frequency lies around 6 kc/s. A group of whistlers in the Figure are multipath whistlers which originated in a single lightning flash and propagated through different paths. And as the whistlers starting from increasing latitude reach the receiving point with increasing time delay they appear spreadingly as shown in the Figure.

2. Path latitude of nose whistlers and density distribution

To estimate the path latitude of whistlers is a very important problem. For the high-latitude nose whistlers, this problem is solved almost satisfactorily. This is

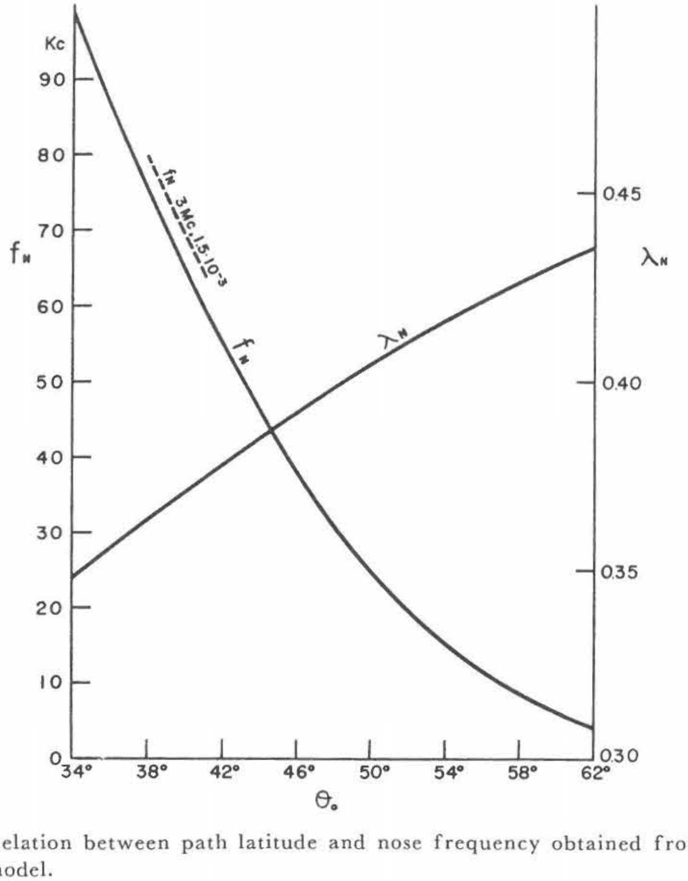


Fig. 4 Relation between path latitude and nose frequency obtained from $N_1\ (r_0/r)^3$ model.

θ_0 : starting geomagnetic latitude

f_N : nose frequency

λ_N : ratio of nose frequency to minimum gyrofrequency along geomagnetic line of force

The dotted line is obtained from a different distribution model (see text).

possible because the ratio (λ_N) of nose frequency (f_N) to minimum gyrofrequency (f_H) along the path depends only on a distribution model of electron density and not on the value of electron density itself, and the minimum gyrofrequency can be determined in a good approximation from the assumption of geocentric dipole field for the earth's magnetic field. At present, the $N_1\ (r_0/r)^3$ model obtained from the nose whistler data has been thought to be the most plausible, where r_0 is the radius of the earth, r is distance from the center of the earth, and N_1 is a constant value of electron density at a certain reference level. The curves of f_N and λ_N versus geomagnetic latitude θ_0 for this distribution model are given in Fig. 4. The path latitude or starting latitude of the nose whistlers shown in Fig. 3 can be easily read as 60° from the curve corresponding to $f_N = 6$ kc/s. Thus, it can be shown that high latitude nose whistlers observed at Moshiri come from the north, after propagating over twenty six degrees of latitude between the earth and the ionosphere.

If we calculate the electron density down to the upper part of F_2 layer using the $N_1\ (r_0/r)^3$ model, taking a reasonable value for N_1, the electron density will become too small compared with the actual density in the F_2 layer. Therefore, some different distribution model may be needed for the intermediate region between the F_2 layer and a certain level, say one or two thousand kilometers. An exponentially decreasing model or a kind of Chapman model may be used for this region.

The curves in Fig. 5, showing dispersion variation against θ_0, are obtained from calculation using three distribution functions as below:

Region I :

$$N_1 = N_{1m}\frac{r-r_m}{r_m-r_1}\left(2-\frac{r-r_1}{r_m-r_1}\right) \cdots\cdots\cdots (1)$$

$$r_{1t} \geq r \geq r_1,$$

where $N_1 = 1.24 \cdot (f_0 F_2)^2 \cdot 10^{-2}/cm^3$,
$f_0 F_2$ = the critical frequency of the F_2 layer expressed in kc/s,
$r_m = r_0 + 300$ km and $r_1 = r_0 + 100$ km,

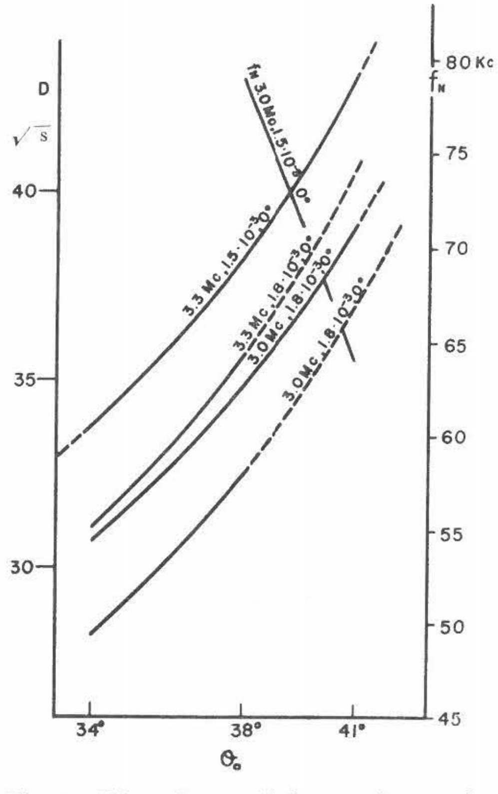


Fig. 5 Dispersion variation against path latitude.
Dotted parts of curves have been estimated by extrapolation. (as to parameter values see text, o° means longitudinal propagation.)

Region II:

$$N_2 = N_{2m} \exp\{-k(r-r_m)\} \quad \cdots\cdots (2)$$

$$r_2 \geq r \geq r_{1t},$$

r_{1t} can be decided from the simultaneous equation $N_1 = N_2$, $\frac{dN_1}{dr} = \frac{dN_2}{dr}$ at $r = r_{1t}$. This condition means that density curves for Region I and Region II connect smoothly.

Region III:

$$N_3 = N_{3m}(r_0/r)^3 \quad \cdots\cdots (3)^1$$

$$r > r_2,$$

where N_{3m} will be known if electron density at any one level is given and the r_2 can be determined from the condition that $N_3 = N_2$ when $r = r_2$.

One example of electron density distribution obtained from above distribution functions is drawn in Fig. 6, where $f_0 F_2 = 3.3$ Mc/s, averaged value of $f_0 F_2$ observed at 2100 JST, on December 12, 1965 at Wakkanai and Akita, $k = 1.5 \times 10^{-3}$ and $N_3 = 1.755 \times 10^4$. As seen from this Figure, the portion of the whistler path lying in Region

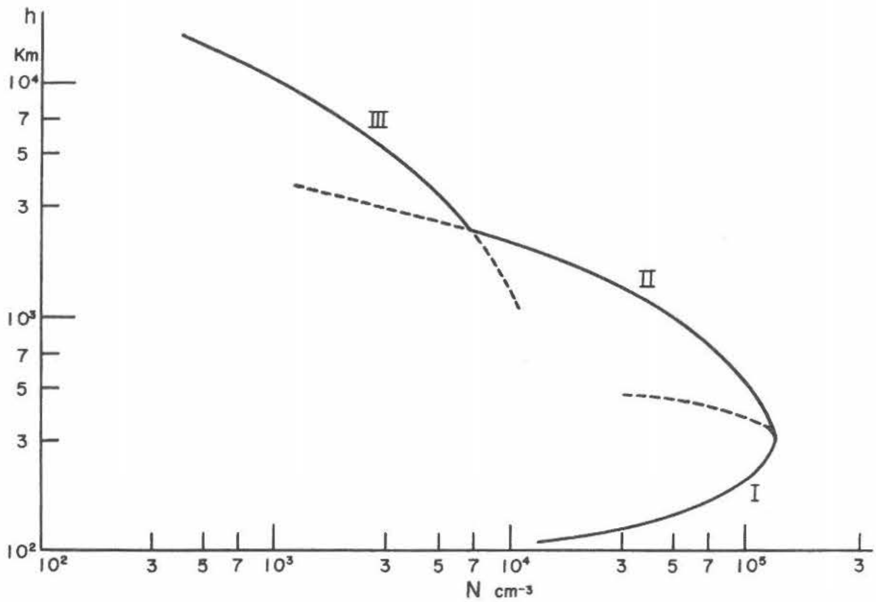


Fig. 6 One example of distribution of electron density.

Region I : parabolic distribution

Region II : exponential distribution

Region III: Anegerami-Carpenter distribution, $(r_0/r)^3$ model

$f_0 F_2 = 3.3$ Mc/s, $K = 1.5 \cdot 10^{-3}$, $N_3 = 1.755 \cdot 10^4$ cm^{-3}

III will diminish the starting latitude lowers, so that the ratio of time delay caused in Region III to that in Region II will decrease. Accordingly, a similar curve corresponding to $f_N - \theta_0$ in Fig. 4 is expected to shift to the right for the low latitude nose whistlers. The dotted curve in Fig. 4 is the $f_N - \theta_0$ curve, calculated using the above distribution function. As expected, the curve lies on the right side of that for the $N_3\ (r_0/r)^3$ model. But the difference between the two curves is slight in the calculated latitude range 38° to 41°. Though the calculation is not yet complete, it has become clear that the $f_N - \theta_0$ curve changes to some extent for different values of $f_0\ F_2$ and k, and that the path latitude and electron density distribution can not be estimated independently for precise discussions.

However, in order to estimate the path latitude of the low-latitude nose whistlers, we may utilize the $f_N - \theta_0$ curve for the high-latitude nose whistlers as the first order approximation. For the nose frequencies of 55 and 70 kc/s, the path latitude can be determined as 42° and 39° respectively. For the dispersions $36\sqrt{s}$, the path latitudes are 36.2°, 38.3° for $k = 1.5 \times 10^{-3}$, 1.8×10^{-3}, and for $34\sqrt{s}$, the path latitudes become 34.2°, 36.7° for $k = 1.5 \times 10^{-3}$, 1.8×10^{-3} when the value of 3.3 Mc/s is taken for $f_0\ F_2$. Similarly, when the values of 3.0 Mc/s is taken, the path latitudes obtained from dispersion values are 38.9°, 40.5° for $k = 1.5 \times 10^{-3}$ and 37.3°, 39.1° for 1.8×10^{-3}. Though we attempt to read the value of f_N as large as possible, path latitude can not be made smaller than 42° and 39° for nose frequencies of 55 and 70 kc/s respectively. Thus, the latitudes inferred from the nose frequency are generally higher than the latitudes inferred from dispersion value. Accordingly, it is clear that the electron density assumed here is too large though not so excessive. In the Region I, the electron density is definitely decided if the value of $f_0\ F_2$ is fixed. Since we have good informations about the values of $f_0\ F_2$, we can fix a value of electron density under the assumption of parabolic distribution. In Region III, the value of electron density may be determined fairly well from high-latitude nose whistlers. However, as we have no satisfactory information about the values of k in the Region II, it is possible to explain the observed value of dispersion by changing the value of k, and accordingly the electron density in Region II. Consequently, in order to get the same path length from the value of dispersion as from the nose whistler, it is clear that k should take a value slightly larger than 1.8×10^{-3}. Unfortunately, we can not determine the value here, because we have calculated the value of dispersion only for the two values of k as yet. However, the above fact means that the rate of decrease in electron density in Region II must be steeper than that shown in Fig. 6.

3. Conclusion

It is well known that the nose whistler is a very useful tool in obtaining information about the distribution of electron density in the magnetosphere as low as 6000 km or so. As for the intermediate region below a few thousand kilometers and above the F_2 layer, however, there had been no available data on nose whistlers to proved information on electron density. However, nose whistlers were successfully observed with a high-speed tape recorder at Moshiri, the nose frequency of which lay between 55 and 70 kc/s. These low-latitude nose whistlers seem to provide us information about electron density in the intermediate region. But, differing from the high-latitude nose whistlers, the nose frequency depends not only on the path latitude, but also on the value of electron density. Therefore, the path latitude and the electron density can not be estimated independently. Fortunately, however, the variation of nose frequency due to the change in electron density seems to be small. Consequently as the first approximation, we may estimate the path latitude from nose frequency and then determine the electron density in the intermediate region producing the value of dispersion required.

Occasionally, the high-latitude nose whistlers were observed at Moshiri. They often appear as multi-path whistlers as seen in Fig. 3. The nose frequencies of component whistlers of smaller dispersion are nearly the same as those of low-latitude nose whistlers. Thus, the nose whistlers of multi-path type will be very useful for the study of distribution of electron density in the ionoshere and magnetosphere, if we can measure the nose frequency up to that of the component whistlers of smallest dispersion.

Reference

1 Carpenter, D. L., Electron-density variations in the magnetosphere deduced from whistler data, J. G. R., **67** (9), 3345-3360 (1962)