Duct detection over the sea by TRANSIT measurements

K.P. Gaikovich
Radiophysical Research Institute,
B.Pecherskaya st., 25, Nizhny Novgorod, Russia, 603600,
Phone: 8312 367294, Fax: 8312 369902,E-mail: gai@nirfi.nnov.su
A.N.Bogaturov, A.S.Gurvich, S.S.Kashkarov
Institute of Atmospheic Physics,
Pyzhevsky per., 3,Moscow, Russia, 109017,
Phone: 095 2316196, Fax: 095 2331652, E-mail: root@iaph.msk.su
S.N.Krivonozhkin, B.M.Shevtcov
Pacific Oceanology Institute,
Radio st., 7, Vladivostok, Russia, 690032,
Phone: 4232 310877, E-mail: poi@stv.iasnet.com
V.K.Ivanov
Institute of Radiophysics and Electronics,
Academician Proskury st.,12 Kharkov, Ukraine, 310085,
Phone: 0572 448515, Fax: 0572 441105, E-mail: ire@ire.kharkov.ua
V.D.Freylikher
Bar-Ilan University,
Ramat-Gan, 52900, Israel,
Phone: 97235318746, Fax: 97235353298, E-mail: frailiv.@alon.cc.biu.ac.il

Abstract--The results of ship-borne measurements (16-th expedition of research vessel "Academician Nesmejanov") of signals from navigation satellites TRANSIT at two frequencies (150 and 400 MHz) are presented. It was discovered that besides the basic modulation related with direct and reflected beams interference there was additional modulation with lesser (2 - 20 times) period. This modulation was evidently related with signal reflection from strong refraction index peculiarities in the atmosphere above the sea. These layers have been observed simultaneously from radiosonde refraction index profiles. The simple four-beam model was found to be in good agreement with measurements data. It appeared possible to estimate the height of reflection layers by measurements parameters.

INTRODUCTION

Ship-borne measurements (16-th expedition of research vessel "Academician Nesmejanov") of power angular dependence of the signal from navigation satellites "Transit" at two frequencies (150 and 400 MHz) and the antenna height level $h = 20$ m above the sea in various regions of Pacific ocean. The adjusted receiver MAGNA-VOX-702 has been used. The beam width of spiral antenna was 40^{o}. In the measurements regime the frequency band was 200 Hz at both frequencies, and that provided the signal to noise ratio about 40 dB at low elevation angles. The main purpose of measurements was to investigate the possibilities to use the signal parameters for atmosphere remote sensing and for wave propagation prediction.

MEASUREMENTS RESULTS

These measurements showed that in about 20% cases besides the well known (see, for example, [1]) basic modulation related with direct and reflected beams interference there was additional modulation with lesser (2 - 20 times) period. This modulation is superimposed on the basic modulation and it is observed at low elevation angles θ, typically from -1 up to 3 - 5 degrees. The effect have been observed at both frequencies, but it was much more clear at lower frequency 150 MHz. An example of ordinary basic modulation and the case with superimposed additional modulation are shown in the Fig.1,2 respectively.

Such a modulation is obviously related with the signal reflection from atmosphere layers above the sea with the strong refraction index peculiarities. These layers have been observed simultaneously from radiosonde

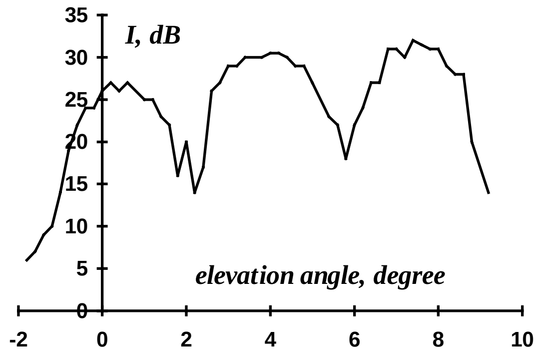

Fig.1. Signal intensity (basic interference) at 150 MHz.

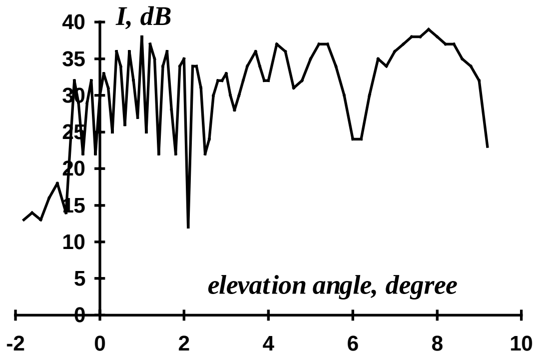

Fig.2. Additional modulation, superimposed on basic modulation.

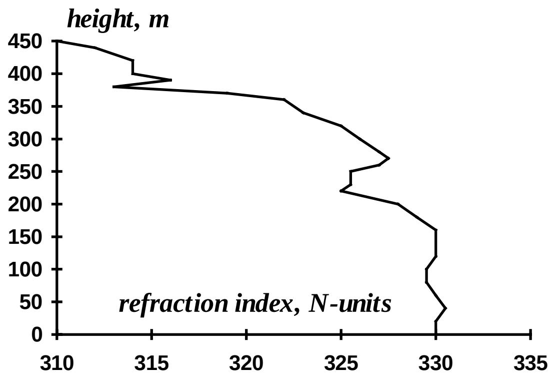

Fig.3. Refraction index height profile measured at the same time as the signal in the Fig.2.

refraction index profiles. The refraction index dependence on height measured at the time of signal measurements shown in Fig.2 is presented in Fig.3.

INTERPRETATION

The simple four-beam model was found to be in good agreement with measurements data. This model takes into account the interference of the direct beam, the beam reflected from sea surface, the beam reflected from the sea and, then, from the atmosphere layer at height level *H*, and the forth beam reflected from the sea, from atmosphere layer and, for the second time, from the sea. So, only single-reflected from the atmosphere layer beams have been considered. Assuming the reflection coefficient (for field) from sea $R_W = exp(i\pi)$ and that from atmosphere layer $R_a = k\,exp(i\varphi)$ one has the simple expression for angle dependence of the received signal intensity (in the plane Earth surface approach):

$$I = 2[1 - cos(\frac{4\pi h}{\lambda} sin\theta)][1 + k^2 - 2k\,cos(\frac{4\pi H}{\lambda} sin\theta + \varphi)]$$

On the basis of above model it is possible to estimate the reflection height *H* as antenna height *h* multiplied by relation of basic and additional modulation periods:

$$H = h\frac{\Delta\theta_{base}}{\Delta\theta_{add}}$$

Applying this formula to the case presented in Fig.2 one obtains $H = 200$ m, and it easy to see in Fig.3 that the strong inversion of refraction index is located at this height. It is also clear from this that heights of reflection layers are within the interval 50 – 500 m.

It is possible to calculate the signal intensity for spherical-symmetric atmosphere taking also into account standard refraction model. These results (assuming $k = 1$) are shown in Fig.4. This much more complicated approach gives about the same results as presented above expression for plane case at $\theta > 4^o$. But at lower elevation angles there exist some difference in interference periods and in maxima positions as it is possible to see in Fig.5.

It is clear (see Fig.2), that in reality the reflection coefficient falls drastically with elevation angle. For frequency 400 MHz it falls at lower angles.

Because the additional modulation for ascending satellites differs in about all cases from that for the same descending satellites, it is possible to make the conclusion that the horizontal size of atmosphere reflection layers must be typically some tens kilometers. Also we have observed sharp changes of reflection layers during about one hour time intervals.

In the cases of warm fronts passing above the cold water we have observed very deep additional modulation at simultaneous sharp fading of basic modulation. The most impressive case is shown in Fig.6.

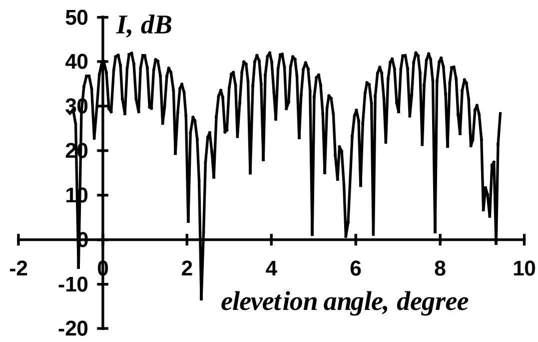

Fig.4. Results of numerical modeling.

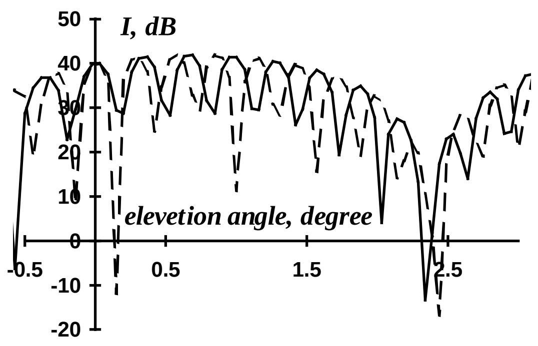

Fig.5. Results of numerical modeling.

solid - spherical geometry; dashed - plane geometry

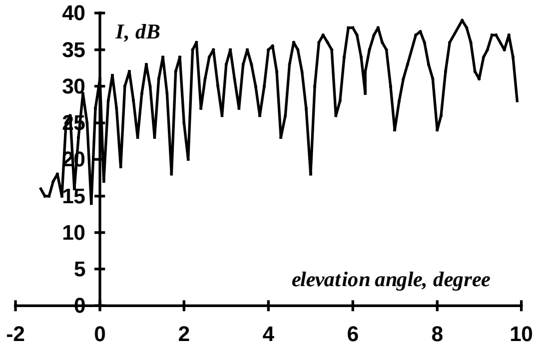

Fig.6. Signal interference during warm front passing

One can see the enhancement of modulation period with elevation angle, which can be explained if to suppose that the height of reflection point from the atmosphere inversion is decreased, i.e. there exist the horizontal inhomogeneity with the scale of some tens kilometers. The fading of basic modulation in this case can be explained taking into account that in the conditions of warm front there exist very strong temperature and humidity overfall nearly the water surface so that the corresponding refraction index inversion leads to full signal reflection not from the water surface but from this inversion at height level nearly the antenna height. In this case the period of basic modulation becomes much larger than in the ordinary case of reflection from water surface.

From the point of view of wave propagation prediction it is very interesting that in the presence of additional modulation it is possible to receive the satellite signals at by 1 - 2^{o} lower elevation angles than in its absence.

CONCLUSION

The results of ship-borne measurements of signals from navigation satellites TRANSIT at two frequencies (150 and 400 MHz) are presented. The main purpose of measurements was to investigate the possibilities to use the signal parameters for atmosphere remote sensing and for wave propagation prediction.

It was discovered that besides the basic modulation related with direct and reflected beams interference there was additional modulation with lesser (2 - 20 times) period. This modulation is explained assuming signal reflection from strong refraction index peculiarities in the atmosphere above the sea. These layers have been observed simultaneously from radiosonde refraction index profiles. The four-beam plane model was found to be in good agreement with measurements data. The method to estimate the height of reflection layers by measurements parameters has been proposed.

REFERENCES

[1] K.D.Anderson. Radio Science, vol.17, No.3, pp.653-663, 1982.