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ELECTRON DENSITY PROFILES IN THE BACKGROUND OF LF ABSORPTION DURING FORBUSH-DECREASE AND PSE

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ABSTRACT

Based on the simulation of different Forbush-decrease and particle precipitation effects in the D-region electron density profiles in the mid-latitudes the ionospheric absorption of low-frequency /LF/ radio waves has been determined. The absorption variations at different frequencies are strongly affected by the shape of the electron density profile. A structure appears which sometimes resembles the letter S /in a sloping form/. Both the height /around 70-72 km/ and the depth of the local minimum in the electron density contribute to the computed absorption changes of various degree at different frequencies. In this way several observed special absorption events can be interpreted.

INTRODUCTION

The lowest part of the D-region is formed by galactic cosmic ray ionization. After geoactive solar flares the Forbush-decrease of galactic cosmic rays can cause an ionization deficit in the bottom part of the D-region and the magnetic storm followed by particle precipitation can almost simultaneously result in an extra-ionization in the upper part of the D-region. The electron density during these ionization disturbances determines the LF absorption. It is the purpose of the present paper to give a qualitative estimation of the change of LF absorption due to a combined effect of Forbush-decrease and geomagnetic post-storm event /PSE/ by simulating them in a mid-latitude electron density profile. Results are compared with absorption measurements.

CALCULATIONS

Be $a(h)=q_{HEP}(h)/q_R$ the ratio of an ionization profile disturbed by magnetospheric high energy particles /HEP/ during a post-storm event /PSE/ to the reference ionization profile belonging to the reference electron density profile, N_R, determined for mid-latitudes. It is assumed that the lower part of the D-region electron density profile stems from the ionization effect of galactic cosmic rays, namely $q_R=q_{CR}$ and $a(h)=0$. In this case a Forbush-decrease causes a change of the electron density, ΔN_F, due to a change of the ionization, Δq_F. Using the continuity equation under equilibrium condition and neglecting transport processes one gets:

$$\Delta N_F = N_R \left[(1+\Delta q_F / q_{CR})^{1/2} -1 \right]$$

In the cosmic ray layer the relative variation of the ionization, $\Delta q_F/q_{CR}$ can be computed from the changes of the energy spectrum of cosmic rays [VELINOV, 1971].

For the geomagnetic latitude of Kühlungsborn /Φ=54.4°/ the high energy particles generally intrude into the D-region till a depth 75-80 km. LAUTER et al. [1977] estimated the ratio $a(h)$ in the upper D-region. By computing electron density variations, ΔN_F, in the lower D-region due to Forbush-decreases and using different ratios, a(h), in the upper D-region, electron density profiles disturbed by a Forbush-decrease and high energy particles /HEP/ have been simulated.

Sometimes high energy particles can intrude into the lowest D-region as shown by electron density measurements using the partial reflection technique simultaneously with satellite observations [MONTBRIAND, BELROSE, 1976] . In this case a(h) = $=q_{HEP}/q_{CR}$ corresponds to the ratio of the two particle ionization sources in the lower D-region apart from the X-ray bremsstrahlung ionization. The electron density changes, ΔN_F, due to a Forbush-decrease are then:

$$\Delta N_F = N_R (1+a)^{1/2}\left[(1+\frac{1}{1+a}\ \Delta q_F/q_{CR})^{1/2} - 1\right]$$

The left side of Fig.1 shows the simulated electron density profiles. Profile N_1 is perturbed by a Forbush-decrease in the lower D-region and by HEP in the upper D-region. Profile N_2 shows an electron density profile disturbed both by a Forbush-decrease and HEP in the lower D-region. A local minimum appears around the height of 70-72 km in the electron density profile. Profile N_3 is only modified by HEP in the whole D-region. The right side of Fig.1 shows the ratios of disturbed and reference electron density profiles.

Using these electron density profiles, the absorption of radio waves at 245 kHz and 128 kHz have been calculated by full wave solution simulating the A3 /oblique incidence/ method [SÁTORI, BREMER, 1987] . Absorption values calculated in this way can be directly compared to the experimental absorption data measured in Kühlungsborn.

Table 1 shows the absorption differences with respect to the absorption of the reference profile and it is completed by the attenuation values of VLF electromagnetic waves at 27 kHz computed on the basis of the wave-guide mode theory for a wave-guide height of 70 km [SÁTORI, 1978].

Table 1

Absorption in dB	$L_{\parallel\perp}$ (N_R)	$\Delta L_{\parallel\perp}$ (N_1)	$\Delta L_{\parallel\perp}$ (N_2)	$\Delta L_{\parallel\perp}$ (N_3)
245 kHz	67.9	0.8	6.8	14.6
128 kHz	67.1	-5.1	0.1	10.9
Attenuation in dB/1000 km	$\alpha(N_R)$	$\Delta\alpha(N_1)$	$\Delta\alpha(N_2)$	$\Delta\alpha(N_3)$
27 kHz	3.3	-0.9	1.0	1.1

These computed absorption profiles enable us to interprete unusual absorption events when there is no absorption after-effect at 245 kHz in spite of HEP condition, even more when there is an absorption decrease at 128 kHz, both due to the Forbush-decrease effect /Profile N_1/.

Actually the absorption profile computed on the basis of Profile N_2 elucidates the event of July, 1982 with a large magnetic storm and an exceptionally deep Forbush-decrease. Namely at 245 kHz and 27 kHz the PSE is evident, while at 128 kHz practically there is no change in the absorption [Fig.2]. In this case both a Forbush-decrease and a HEP condition have been assumed in Profile N_2 in the bottom part of D-region. The HEP condition that is the increased electron density was effective on the absorption and the attenuation computed at 245 kHz and 27 kHz, respectively, while the absorption without change calculated at 128 kHz was equally responsive to the HEP condition and to the decrease of the electron density due to the Forbush-decrease with a local minimum just below the reflection level of 128 kHz signals.

CONCLUSION

The ionospheric effect of a Forbush-decrease can cause a decrease of electron density with a maximum intensity about at height of 70-72 km. Occasionally it is able to modify the geomagnetic absorption after-effect of LF waves resulting in an unusual absorption fine structure differing from the PSE phases, mainly at day-time and sunset/sunrise/ conditions.

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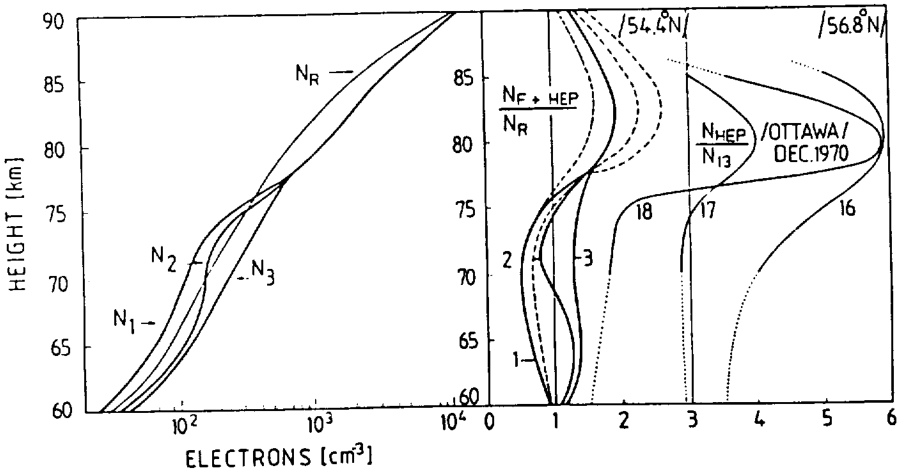

Fig.1 Electron density profiles /N_1, N_2, N_3/ simulated for Forbush-decrease and HEP conditions /left side/. The ratio of disturbed /N_1, N_2, N_3/ and undisturbed /N_R/ electron density profiles for geomagnetic latitude of 54.4^o and for the event of December 13-20, 1970 measured in Ottawa /right side/.

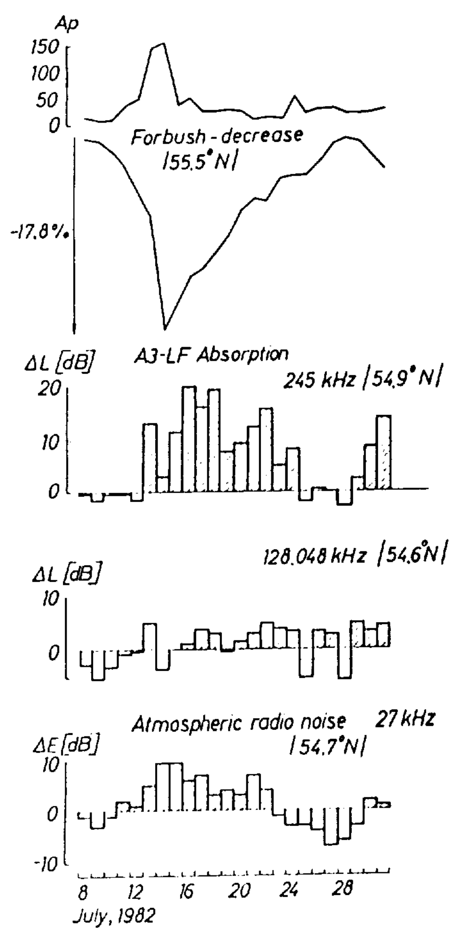

Fig. 2

A_p indices; cosmic ray intensity deviations in percents on the basis of Moscow neutron monitor data; LF absorption measured at 245 kHz and 128.048 kHz in Kühlungsborn /the average of the deviations from the monthly median at cos χ =0^o and night/ and four-hourly averages of the radio noise level recorded at 27 kHz also in Kühlungsborn /deviation from the monthly median/ during the geomagnetic storm of July, 1982.