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ON THE REAL-HEIGHT PROFILES OF THE F2-LAYER

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ABSTRACT

Since modern digital ionosondes and minicomputers are now generally accessible there is no justification any more for using inversion schemes in which the influence of the magnetic field is ignored or a monotonous profile is assumed so that the regular presence of valleys is neglected. Therefore inversion schemes like POLAN and ARTIST should at least be applied.

We propose a new global and analytical representation of the F2-layer profiles which is found to be helpful for specific ionospheric situations.

A NEW INVERSION METHOD

Ionogram selection

A general discussion of the inversion of ionograms encounters too many problems: missing information, presence of valleys, uncertainties in the critical frequencies and in the virtual heights, and so on. It is also difficult to evaluate the precision that can be achieved. We shall therefore restrict our considerations to rather simple ionospheric conditions: namely night-time at mid-latitude stations.

In this case the ionogram normally shows only traces from the F-layer at frequencies above a minimum frequency fmin (often near 1.6 MHz). The critical frequency of the E-layer is not observed but can be evaluated using statistical results obtained from other measurements /1/ or from the X-trace. Further, when the separation between foE and fmin exceeds about 0.8 MHz, the retardation $R_V(f)$ due to the ionisation beneath the top of the valley becomes less than 5 km, decreasing slowly with frequency approximately like $(f - foE)^{-2}$. Figure 1a shows one of the profiles used in the simulations; more details of the profile and of the ionogram above h_V (the top-height of the valley) can be found in Figure 1b.

Extrapolation

The initial step consists in extrapolating the virtual O-trace from fmin to foE. Of course, this extrapolation can be made in different ways. In the following we assume a linear F layer profile between foE and fmin, and we match the corresponding virtual height trace connecting it smoothly with the observed trace that was previously corrected for the effect $R_V(f)$ of the ionisation beneath the top of the valley. The resulting trace will be denoted as $h'*(f)$.

This yields a first approximation over the whole frequency range to the virtual F-profile; it gives at the same time an approximate value of h_V, the top-height of the valley.

Comparisons with simulations using parabolic F profiles have shown that, when the gap between foE and fmin is not greater than 1 MHz, the differences between the extrapolated values of h_V rarely exceed 10 km. For an example see Figure 2 (fmin = 1.5 MHz).

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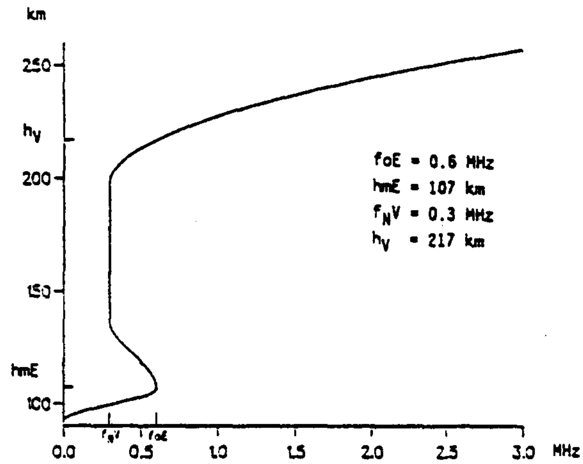

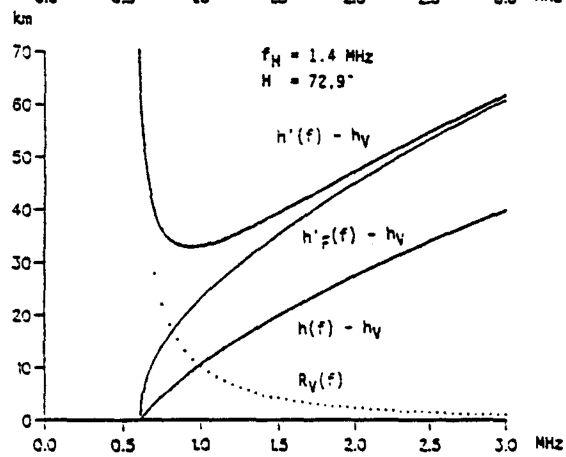

Fig. 1a. Example of profile used in the simulations

Fig. 1b. Ionogram, virtual and real heights of the F region, retardation R_V in the valley

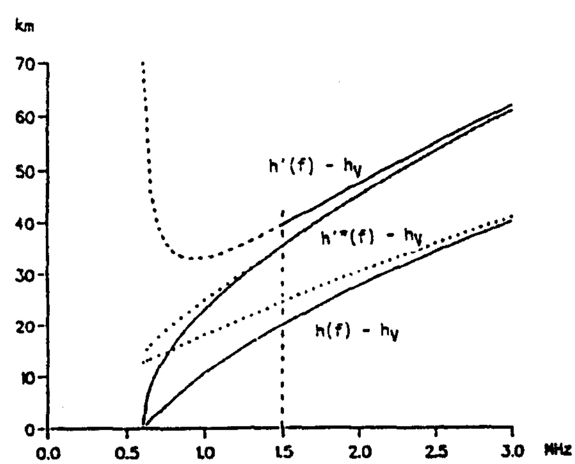

Fig. 2. Same ionogram as in Fig. 1b. Comparison of the virtual and real height F-profiles. Full lines: original profile - dotted lines: linear extrapolation beneath 1.5 MHz

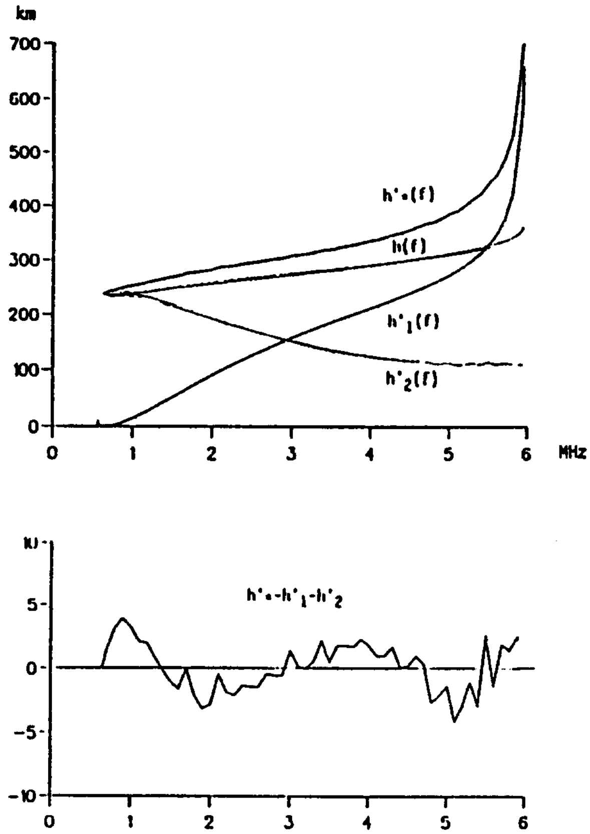

Fig. 3. Millstone Hill 1989, 210, 07UT
foE = 0.61 MHz, fmin = 1.60 MHz, foF2 = 5.94 MHz
h_V = 234.3 km, h(fmin)= 250.6 km, hmF2 = 362.1 km

Analytical Representation

Without entering into too many details, we propose to construct the true height profile h(f) in two steps such that:

$$h(f) = h_1(f) + h_2(f)$$

The function $h_1(f)$ is first determined; it shall mainly represent the profile near foF2. An earlier approach /2/ is used in which the value of foF2 is improved if needed.

Method /2/ has now been slightly modified by introducing a $\cos^2$ filter function that equals one at foF2 and zero at foE so that $h_1(f)$ cannot affect the virtual heights near foE and also their derivatives with respect to the frequency.

$h_1(f)$ then takes the following shape:

$$h_1(f) = \cos^2(\pi g/2) \{A_1 (1 - g^{1/2}) + A_2 (1 - g^{3/2})\}$$

with

$$g = \ln(f/f_S)/\ln(f_I/f_S), \ f_I = \text{foE}, \ f_S = \text{foF2}.$$

In a second step we substract the virtual heights contribution $h'_1(f)$ that is due to of $h_1(f)$ from the corrected virtual heights; the difference $h'_2(f)$ is approximated using a function $h_2(f)$ defined by

$$h'_2(f) = h'*(f) - h'_1(f) = h'*(f) - \int \mu' \, dh_1/dg_N \, dg_N$$

$$= \int \mu' \, dh_2/df_N \, df_N$$

(f_N plasma frequency, g_N corresponding value of g).

For $h_2(f)$ the following set-up is finally used so that $h'_2(f)$ is satisfactorily represented:

$$h_2(f) = h_V + \Sigma B_i \, [(f - f_I)/(f_S - f_I)]^i \quad (i = 1,..4).$$

With 3 given parameters: f_I = foE, f_S = foF2, $h_V = h(f_I)$, the 6 coefficients A and B can be obtained in the approximation, e.g. by least squares fitting.

The geophysical value of the profile finally obtained depends on the precision of the inversion and on that of the extrapolation.

Figure 3 shows the different steps of the procedure applied to a Millstone Hill ionogram, and the differences between $h'*(f)$ and the corresponding sum $h'_1(f) + h'_2(f)$.

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