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HOW REPRESENTATIVE ARE NIGHTTIME DETERMINATIONS OF THE UPPER EDGE OF THE EF-VALLEY?

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ABSTRACT

Applying the author's extrapolation procedure to a summer and a winter set of midlatitude nightime digital ionograms the uncertainty of the upper edge of the EF-valley is found to be up to 10 km but has no noticeable effect on the peak altitude determination. The retardation near fmin is 12 to 30 km.

INTRODUCTION

Having eliminated from the recorded virtual heights the effect of the underlying ionization the true profile of the considered region may be represented by a monotonous function of the plasma frequency. This elimination requires an adequate knowledge of the plasma distribution in the lower layers and a precise analysis of the virtual profile in its lower frequency part /1-6/. We assume in the following that the true profile of the E-region is known and F1 is absent - night conditions.

The height of the upper valley edge (D in Figure 1) is an important parameter the determination of which is difficult particularly at midlatitudes where the echo recording is obstructed by man-made noise. We have to find out whether this height (and possibly other parameters) may be determined from the information contained in the ionogram trace near fmin. By night at midlatitudes this frequency is about 1.6 MHz since a broadcasting band obstructs all echoes. At hours when foE is below that limit no information at all is available from a more or less important frequency range. We have proposed an extrapolation procedure /7/ that may reasonably be used in this condition.

In this paper we shall accurately describe this approach, evaluate the influences upon the valley edge and the layer peak that may be produced by parameters implicitely introduced when applying this procedure. Effects of the valley structure shall be estimated. Our valley model is represented in Figure 1. As input our study exclusively uses nighttime digigrams from Millstone Hill (42.6N, 288.5E): 01 to 08 UT in July 1989 and 23 to 11 UT in November 1990.

DESCRIPTION OF THE ALGORITHMS

Four key parameters of a profile (see Figure 1) are needed in the following:

h_V true height of the upper valley edge (point D) [unit km];
h_M true height of the layer peak (above the drawing) [unit km];
$p_4 = e_4 / [2*(foE - f_V)]$ profile slope at the base of layer F [unit km/MHz];
$\Delta h = (h'_* - h)_{f=fmin}$ difference between corrected virtual and true heights at f=fmin [unit km].

The neighbourhood of foF2 is analyzed first in order to obtain a more accurate value of foF2. To this end the uppermost part of the profile is represented as /8/:

$$h(f) = h(f_C) + g_C^{1/2} * (A_1 + A_2 * g_C) \qquad |A1| >> |A2| \qquad g_C = Ln(f/f_C)/Ln(foE/f_C) \quad f_C = \text{foF2 corrected} \quad (1)$$

The second algorithm establishes a composite virtual profile between foE and fmin by extending the trace after having corrected it for effects of underlying ionization. This is achieved by using the profile of Figure 1 where the prolongation of the valley between foE and fmin is linear and where the parameters e_3 and e_4 are obtained as the result of the fit of the computed and observed virtual profiles near fmin. Then the observed virtual trace h'(f) is replaced by $h'_*(f)$. Since one starts with estimates of foE and of $f_V = k * foE$, a first rating can be made of h_V as well as of e_3 and e_4. It is assumed that this algorithm gives reasonable values if e_3 and e_4 are both positive.

Finally, in order to obtain from the corrected virtual heights the full true profile we apply the following development:

$$h(f) = h_V + \cos^2(\pi/2 * g_C) * [A_1 * (1 - g_C^{1/2}) + A_2 * (1 - g_C^{3/2})] + \Sigma B_i * [(f - foE)/(f_C - foE)]^i \qquad i = 1,\dots,4 \quad (2)$$

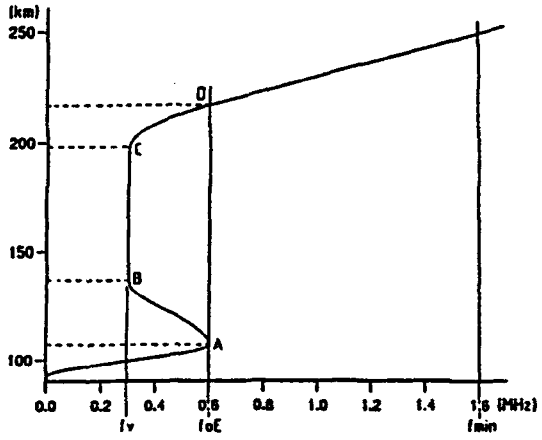

Figure 1. Valley model: $h_A = 107$ km, $h_B = 137$ km, $e_3 = h_C - h_B$, $e_4 = h_D - h_C$, $h_V = h_D$

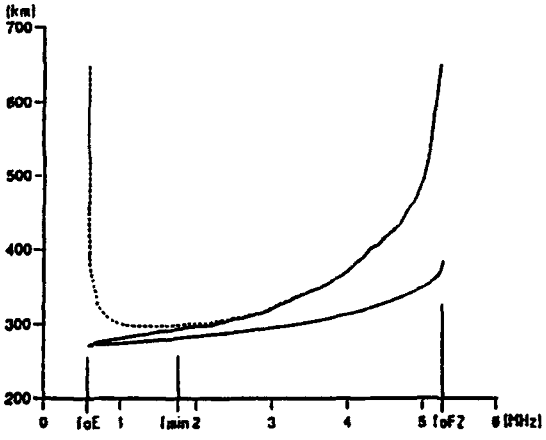

Figure 2. Millstone Hill 1990, day 331, 03 UT.
upper curve : h'(f), intermediate : h'*(f),
lower : h(f)

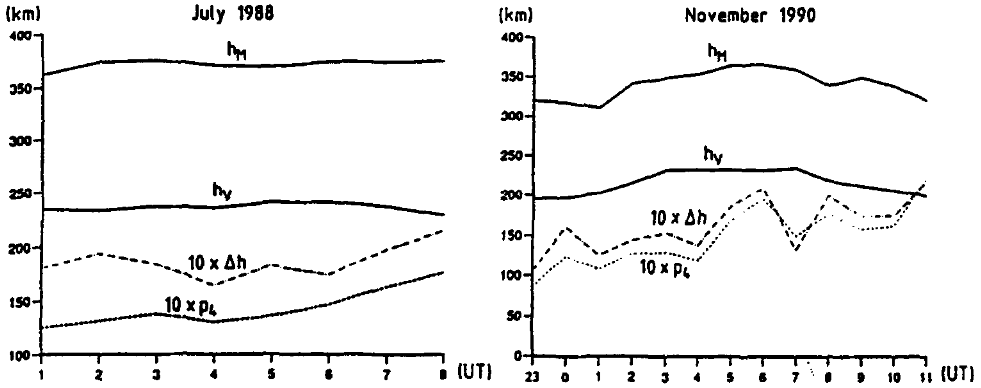

Figure 3. Millstone Hill. Variation with time of:
h_M height of the layer peak [km]
h_V height of the upper valley edge [km]
p_4 *profile slope at the base of layer F [km/MHz]*
Δh difference between corrected virtual and true heights at f=fmin [km]

the coefficients B_i are found by a least squares fit of the computed and corrected virtual height profiles. The so found expression (2) almost always represents very accurately the wanted true profile, differences in the virtual heights being of the order of a few km, departures up to 10 km are very rare. The reduction is achieved with seven coefficients (h_V, A_1, A_2, B_1,....B_4) only. (Figure 2)

So, provided foE and f_V are evaluated, all four key parameters mentionned above are determined at the end of this calculus. There remains the problem of introducing correct values of foE and f_V. In the numerical examples we have taken foE values either from the digigram reductions or from Bradley's compilation /9/. In order to find eventually the adequate value of f_V = k * foE we have varied k from 0.9 down to 0.1 in steps of 0.2.

RESULTS AND DISCUSSION

[Tables in Appendix G]

Applicability of the algorithms. In its present form our procedure (the above set of three algorithms) has given satisfaction in more than 95% of the night observations in July 1989, and in more than 80% in November 1990. Almost all records that had to be rejected in November 1990 had an extremely low foF2 (< 3MHz) so that the number of data points was restricted while the virtual height variation was quite important.

Proximity of fmin to foE. Our procedure was applied either to a subset given by the condition (fmin - foE) ≤ 1 MHz (option A) or to all records (option B). Results can be found in Table 1; ΔQ is the quartile range. It appears that the restriction is statistically unimportant except near sunrise and -set. The sequence of quartile ranges is well coherent in July, not so well in November. (This may be due to a particular structure near fmin to which the present procedure is not fully adapted). The final result anyway confirms our assumption that the real height variation in the frequency range between foE and fmin may be considered as practically linear.

Influence of foE. In determining foE we have mainly used Bradley's compilations /9, 10/ while admitting the limiting condition /11,12/ and we admit also /13/:

With these edge data we have further assumed:
- for sunset an average of the values given in /10, 12, 14, 15/,
- for sunrise a similar average of /11, 12, 14, 15/
- and in between Bradley's formula /10/ where t_1 is the time run down after sunset (in hours).

Table 2 shows the four key parameters obtained with (A) foE taken from the digigram reductions and (B) from the above formulas. As long as the foE values differ by not more than 0.2 MHz the computed h_V values are almost identical; if the difference between the evaluated and the theoretical foE was greater then the two h_V values differ more and more with increasing difference of the foE.

This illustrates how important is a good estimate of foE.

Influence of the choice of f_V (or k). The four key parameters were determined for each k in the chosen set (see above), k being a measure of the depth of the valley. Distinguishing potential options and calling option A that preferred by Titheridge (k = 0.5), we have also computed average values of h_V for the higher k's (0.9, 0.7, 0.5 - option B, shallow valley) and for all together (option C), see Table 3 [no restriction on (fmin - foE)]. Admitting choice A to be representative then lines B and C by their deviation from A show the achieved accuracy, see Table 4.

We conclude with respect to the medians that the uncertainty of the k-value, i.e.of the valley depth has the following consequences:

i) an inaccuracy of mostly less than 10 km of the upper edge of the valley. [The uncertainty about the valley shape itself is not surprising because the decisive frequency range (just above foE) is screened by man-made noise].

ii) no noticeable effect on the peak altitude of the F-layer.

Further results of our analysis are:

iii) the profile slope at the F-base is between 8 and 22 km/MHz;

iv) the difference between virtual and real height at fmin is greater than 10 km, it lies normally between 16 and 20 km, may however reach 30 km. (Figure 3)

The correlation between the profile slope and the difference between virtual and real height at fmin is particularly noticeable in November and an increase of both parameters from sunset towards sunrise seems to exists.

CONCLUSIONS

As a result of geophysical importance it may be noted that the values we have found for the height of the upper edge of the valley agree with those found by incoherent scatter technique /16, 17/; temporal variations must be admitted. No valley depth can be determined from night ionograms but it has no importance in determining the peak altitude. It provokes, however, an uncertainty at the upper edge of the valley that goes upto 10 km near sun-set and -rise. Near fmin the slope of the true profile is of the order of 20 km/MHz. Virtual and real heights differ by about 15 km near fmin. This important fact, not taken into account in some inversion procedures must be admitted in any method claiming higher quality. Its knowledge could also be helpful in reduced inversion methods since it procures one additional point.

By using high precision electronics as applied in digisondes and modern means of numerical computing we could perform a high quality analysis of records that had not undergone some cleaning before use. The procedure we have developed could possibly yet be better adapted to routine application.

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[Tables in Appendix G]