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NUMERICAL MAPPING AND MODELLING AND THEIR APPLICATIONS TO PRIME

COST 238/PRIME Workshop

Eindhoven, The Netherlands
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OVERVIEW

The volume contains a selection of papers presented at the May 1994 COST 238 Workshop on 'Numerical mapping and modelling and their applications to PRIME'. It is a pleasure once again to be associated with a full PRIME Workshop - this time the sixth in a series extending over as many years. PRIME (Prediction and retrospective ionospheric modelling over Europe) was formally initiated as Project COST 238 in March 1991 as a four-year project aimed at developing improved models of the European ionosphere for telecommunications applications, but the work has its origins earlier arising from existing collaborations in the areas of vertical and oblique-incidence sounding. We now have active participation from groups within 18 Western and Eastern European countries and again all were represented at this latest Workshop.

COST (Cooperation in Scientific and Technological Research) was initially established for European Union Member States, with each country joining those projects in which it has interest on a case-by-case basis. However, over recent years the numbers of COST countries have grown and there is now provision for participation of individual institutes from non-COST countries. In our case we have three such institutes involved.

The Workshop gave prominence to progress in developing NEW empirical mapping techniques along lines first proposed at a limited Workshop held in Abingdon, UK in December 1993. Following tests by specially appointed computer experts who had been assessing the relative accuracies of various candidate approaches the previous week in Eindhoven, latest developments were considered. Discussions centred on what further improvements could be incorporated. Subsequent to a successful specialist Workshop on instantaneous mapping which took place in Warsaw in March 1994, this topic was also addressed at length and a number of optional approaches considered.

The work of PRIME as a whole covers the topics of vertical and oblique-incidence sounding, short-term and long-term ionosphere mapping and modelling and short-term forecasting of ionospheric characteristics. Some 30 presented papers addressed different aspects of these subjects. In addition there were 9 poster papers. As always, time constraints limited full review of every facet, but by restricting the numbers of presented papers to invited topics it became possible to identify the key points and to take important decisions on the way ahead. I am grateful to Dr Leon Kamp and to the Working Group Leaders for their help in formulating the Workshop programme.

Each Session Chairman and Working Group Leader has provided a summary covering the ensuing discussion. Thanks should be extended to all who contributed to the Workshop both in preparing presentations and in participating in the discussions. I believe that in a very full programme optimum use was made of the available time and that good and timely overall progress is being made towards our agreed goals.

We are all particularly grateful to Dr Kamp on behalf of the Eindhoven University of Technology for hosting us and for the painstaking way in which he made the local arrangements. We extend our sincere thanks to him and his colleagues for all they did to ensure the event was a success. We especially thank Professor F W Sluijter and the University for hosting an accompanying social excursion and dinner.

Thanks are accorded to the University, The Netherlands Foundation for Fundamental Research on Matter, Océ van der Grinten, Stichting Universiteitsfonds Eindhoven, PTT Research and to the European Commission for financial support in making the meeting possible. Finally too our thanks go to Dr Kamp for arranging this present publication.

Peter A Bradley
Chairman COST 238

Are the foF2 and M(D) deduced from OS comparable with those of the VS of the near midpoint? The case of Dourbes-Roquetes link.

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Introduction

Vertical soundings have been the main source of knowledge of the ionosphere for a long time. Facing the complexity and variability of the ionograms, many parameters were defined and rules of determination were established to build a large data base in order to decribe the ionosphere in a geophysical background.

The critical frequencies for different regions correspond often to clearly determined quantities in the process of scaling. In the case of foF2, there are few exceptions such as noisy band,spread F,high Es ... The Maximum Usable Frequency for a distance of 3000km (MUF3000) and the corresponding M factor (M3000) for the F region are operational quantities.

By definition

$$M3000F2 = MUF3000F2 / foF2$$

Is there a relation which permits to have an accurate determination of one of these parameters or should we rely on an approximation?

Basic relations

Consider a flat earth (and ionosphere) and compare a wave reflected with oblique incidence with a wave reflected with normal incidence from the same true height. The secant law gives the relation between the frequencies of the two waves (Davies K.,1990,p157):

$$fO = fV * \sec(\Phi 0)$$

For a ground distance D we have

$$fO = fV * \mathrm{sqrt}[1 + (D/2h')^2]$$

For a fixed distance D and in a diagram with the same h' and logarithmic scales as those of the experimental h'= function(fV) we could draw on a transparency a curve h'= function(sec(Φ0)) but going from right to left (fig 1). If one places this diagram on the experimental vertical ionogram intersections give the graphical solutions. There are two points A and B corresponding to the low and high angle respectively. The frequencies fVA and fVB are the frequencies which correspond both to the same oblique frequency fO. Sliding the overlay till the sec(Φ0) curve is tangent to the ionogram (fig.2) one has the highest fO possible which is the MUF. On the sec(Φ0) scale one reads the M-factor at the foF2.

For linear frequency scale, this method is not possible.

Inclusion of the Earth curvature leads to a new relation between Φ0, D, and the effective height ho of the ionosphere (Davies K.,1990 ,p169):

$$\tan(\Phi 0) = \frac{\sin(\Theta)}{1 + ho/a - \cos(\Theta)}$$

with a = Earth radius
Θ = half the angle at the center subtended by D

so we get for M3000 = sec(Φ0)

$$M3000 = \mathrm{sqrt}\left\{1 + \frac{\sin^2(1500/a)}{[1 + ho/a - \cos(1500/a)]^2}\right\}$$

and M3000 for curved Earth is always less than M3000 for flat Earth

Inclusion of ionosphere curvature breaks the validity of Breit and Tuve theorem and Martyn's one so none of these relations are valid for large distances.
N.Smith in 1939 introduced a correction factor k(D) to the flat Earth formula (fig. 3):

$$fO = k * fV * \sec(\Phi 0)$$

This is the base of the practical rule for scaling ionograms given in the U.R.S.I. handbook (report UAG - 23A July 1978). The standard transmission curve gives the ratio of the equivalent vertical and 3000 km oblique incidence frequencies which are reflected from a given virtual height assuming a standard simplified propagation model. It is a simple graphical solution for the calculation of the standard MUF3000F2. From the URSI handbook (p23):

"The shape of the transmission curve is defined by the ratio at each virtual height given in the table below.

h' (km)	200	250	300	350	400	500	600	700	800
ratio	.220	.247	.274	.300	.325	.372	.417	.455	.490
M(3000)	4.55	4.05	3.65	3.33	3.08	2.69	2.40	2.20	2.04

..If the ionogram has a frequency scale other than logarithmic a set of standard MUF curves is prepared from the standard transmission curve, each curve corresponding to a certain MUF value (fig.4). The curve which just touchs the trace gives the MUF; the M3000 is obtained by division by the critical frequency of the corresponding layer."

According to W.R.Piggott and K.Rawer, the effect of the Earth Magnetic Field is small (few %) for not too small distances.

Analysis of oblique propagation with parabolic electron profiles and ray tracing shown similar results as those of Smith with the correction factor. Paul gives an analytical formula (for D=3000 km) which is reproduced in Davies-1990's book p172:

$$M3000 = fO / fV = (67.654 - 0.01494 * h') / \mathrm{sqrt}(h') \quad (1)$$

This expression is within 0.5% of the value given in the URSI handbook.

One must realize that these methods for MUF or M-factor are approximations and not determinations.

ARTIST Automatic procedure

In the first ARTIST sofwares, the modified secant law with a curved Earth was used (a=6370km). However since ARTIST V this was changed with Paul's empirical equation (1).
For different distances D between 0 and 4000 km, ARTIST uses now the CCIR (1978) MUF equation:

If MUF(zero)F2 = foF2 +1/2fH (gyrofrequency) = crit.freq. of X wave

and MUF(4000)F2 = 1.1 * MUF(3000)F2 then

$$MUF(D)F2 = MUF(zero)F2 + K * [MUF(4000)F2 - MUF(zero)F2] \quad (2)$$

with $K = 1.64*10^{-7} * D^2$ if $0 \le D \le 800$ km or

$$K = 1.26*10^{-14} *D^4 -1.3*10^{-10} *D^3 +4.1*10^{-7} *D^2 -1.2*10^{-4}*D \quad (3)$$

if $800 < D \le 4000$ km.

Oblique Sounding data

A Critical frequency for F region at midpath point

As one knows the determination of foF2 is not easy even if the oblique ionogram is perfect . Most often for our case, the upper branch of the oblique ionogram is at least partly missing (fig. 5). One could visualy extrapolate the trace.

We could also use a similar procedure as the one used for M3000 from vertical soundings assuming the reflection at the same true height for the 1128 and 3000 path. Starting from

$$fO = k(1128) * fV / sqrt(1 - 11282/P'^2)$$

and with the same vertical and horizontal scales as on the oblique ionogram we draw a set of curves labeled with integer values of fV on a transparent overlay. The highest value of fV where there is an echoe or where one could extrapolate the trace with the curves as guide is taken as foF2 (fig.6).

A another way is to linearly interpolate or take the mean between foF2(Roquetes) and foF2(Dourbes) since the two stations are nearly on the same meridian. However the vertical soundings are not simultaneous of the oblique ones (15' before and after).This needs another interpolation.

B MUF3000 or M3000 for F region at midpath point

By definition the MUF is not to be compared with the Maximum Observed Frequency (MOF) but well to the Junction Frequency (JF). For the Dourbes Roquetes link, D is 1128 km. When ionogram is good enough to determine this JF we take JF = MUF(1128)F2. Using the CCIR equation (3) it is straiforward to get: K = .220134 and from (2)

$$MUF(3000)F2 = [MUF(1128)F2 - 0.779866 * MUF(zero)F2] / 0.242147$$

An estimation of the error leads to 10 to 20%.

Another procedure could be used assuming the reflection at the same true height. This leads to the formula

$$M3000 = k(3000)*sqrt\{1500^2*[(M1128^2/k^2(1128))-1]/564^2+1\}$$

$$M3000 = 1.115 * sqrt[7.073 * (M1128^2/1.05 - 1) + 1].$$

As an exemple, Table 1 gives the different numbers.

Conclusions:

1 The values of M3000 (or MUF3000F2) from the past are not to be considered as determinations but approximations.

2 The manual scaling of oblique ionograms produces values of midpath foF2 and M3000 which are also approximations.

3 In any case the best way would be to construct the midpoint electronic profile with inversion sofware and compute the searched values. For that see the paper of Krashenninikov et al..

References:

Davies K. Ionospheric Radio, P.Peregrinus Ltd London 1990

Smith N. The relation of radio sky-wave transmission to ionosphere measurements Proc.IRE 27,p.332 1939.

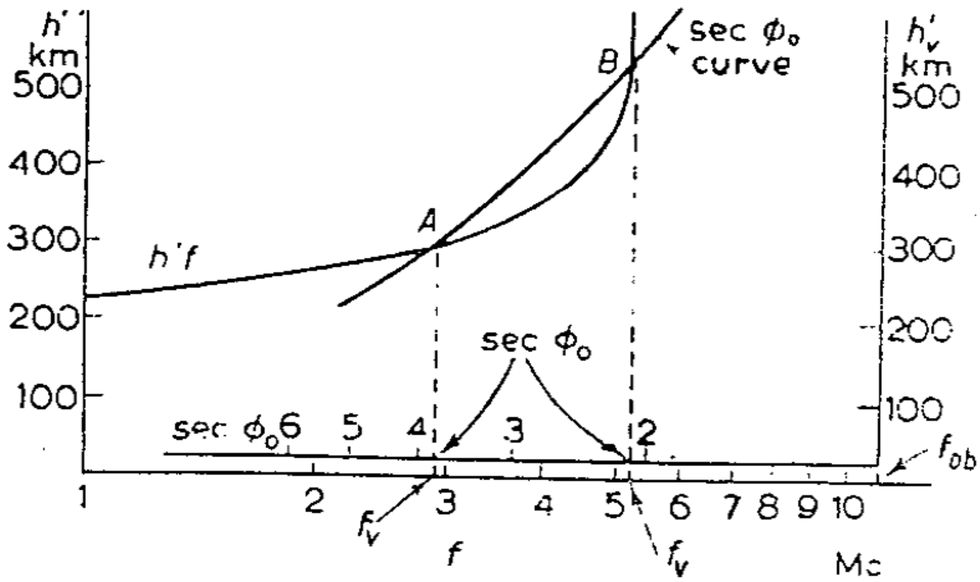

Fig. 1 Use of the overlay to show relation between fv and

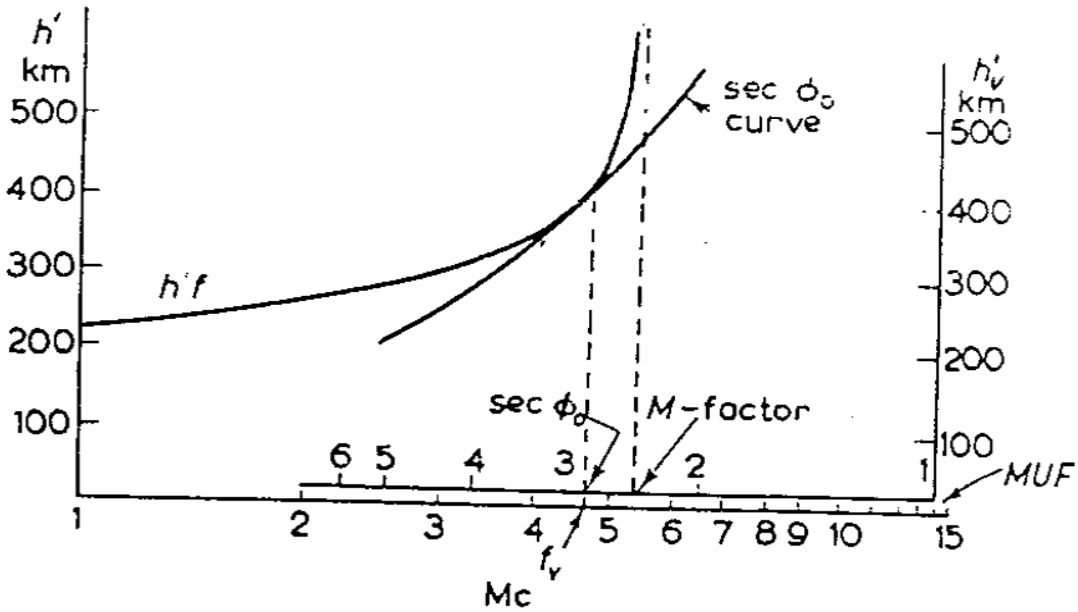

Fig. 2 Use of the overlay to get the MUF and M factor

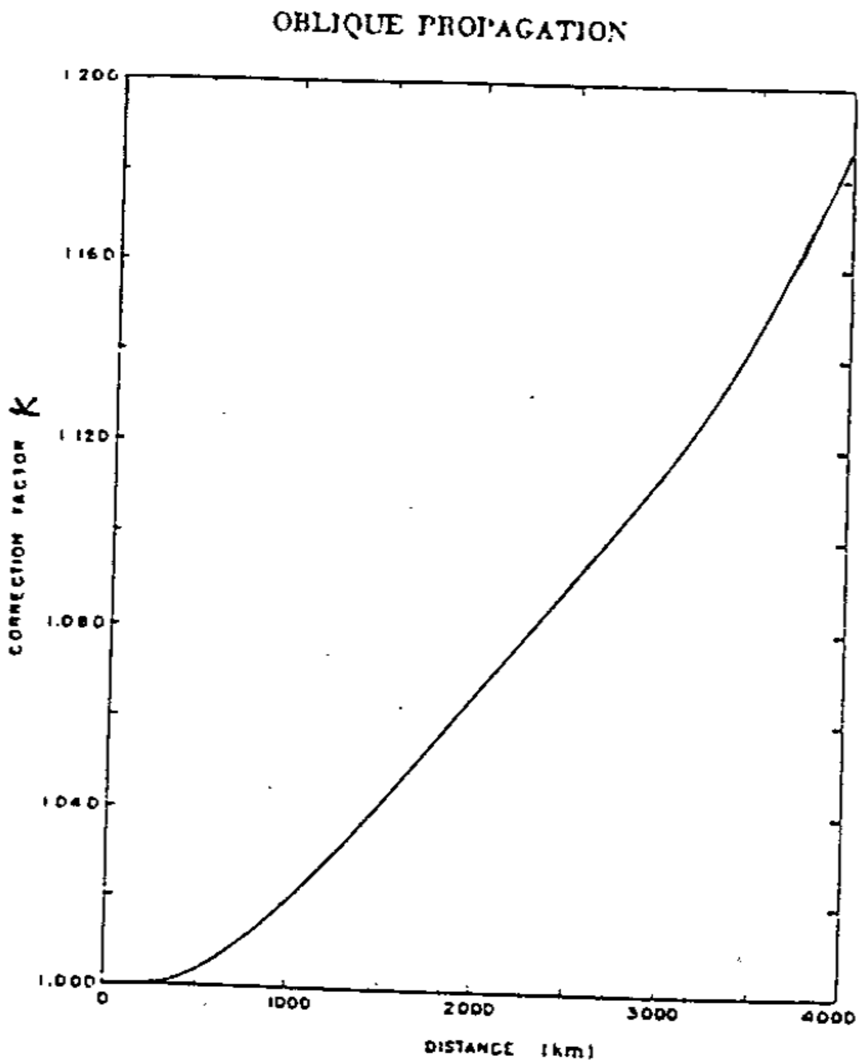

Fig. 3 Correction factor as function of the distance

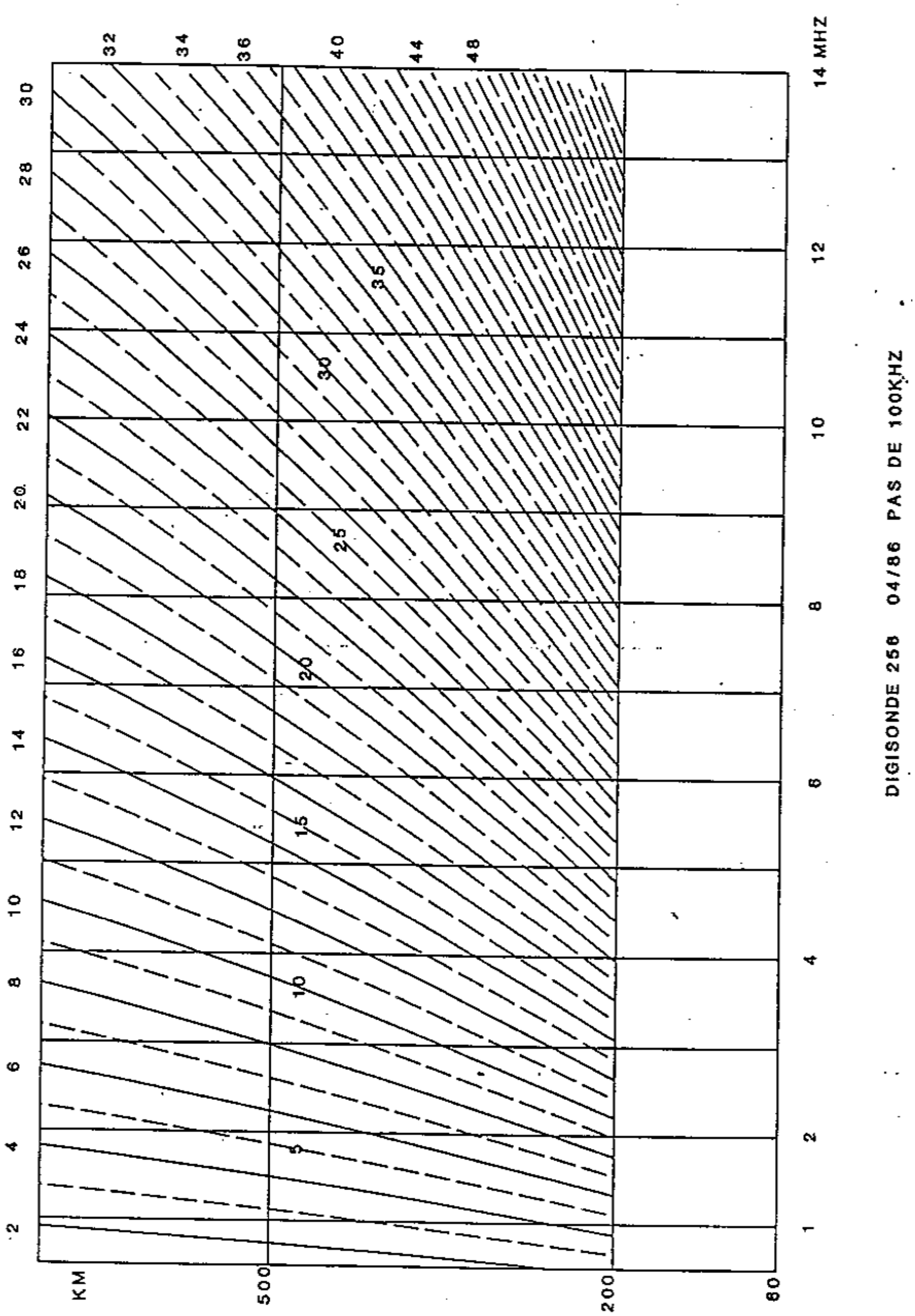

Fig. 4 Standard transmission curves (Mhz) for the Digisond

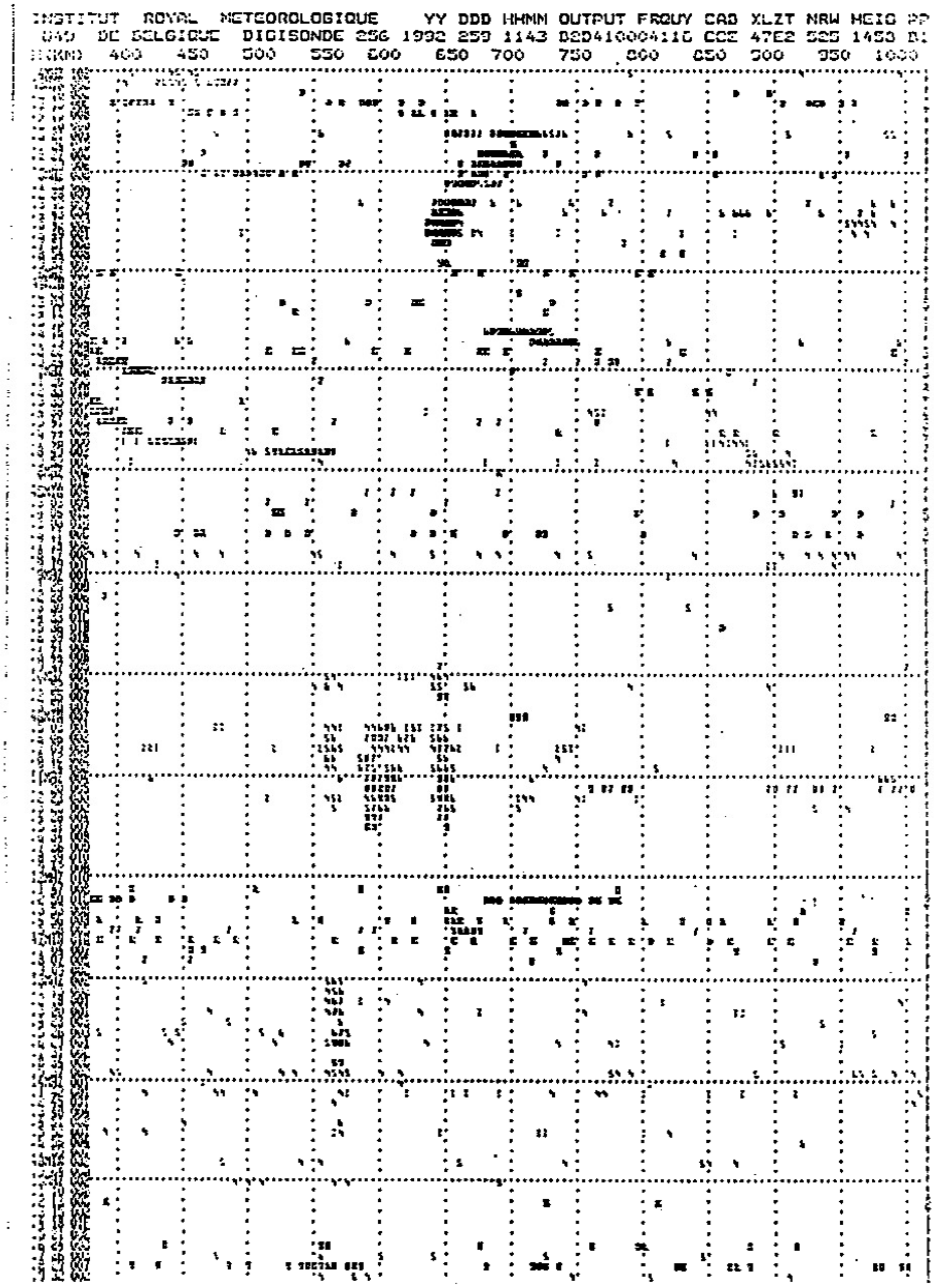

Fig. 5 Oblique ionogram for the Roquetes-Dourbes link wher echoes from the E,F1 and F2 regions show up to the of the middle frequency

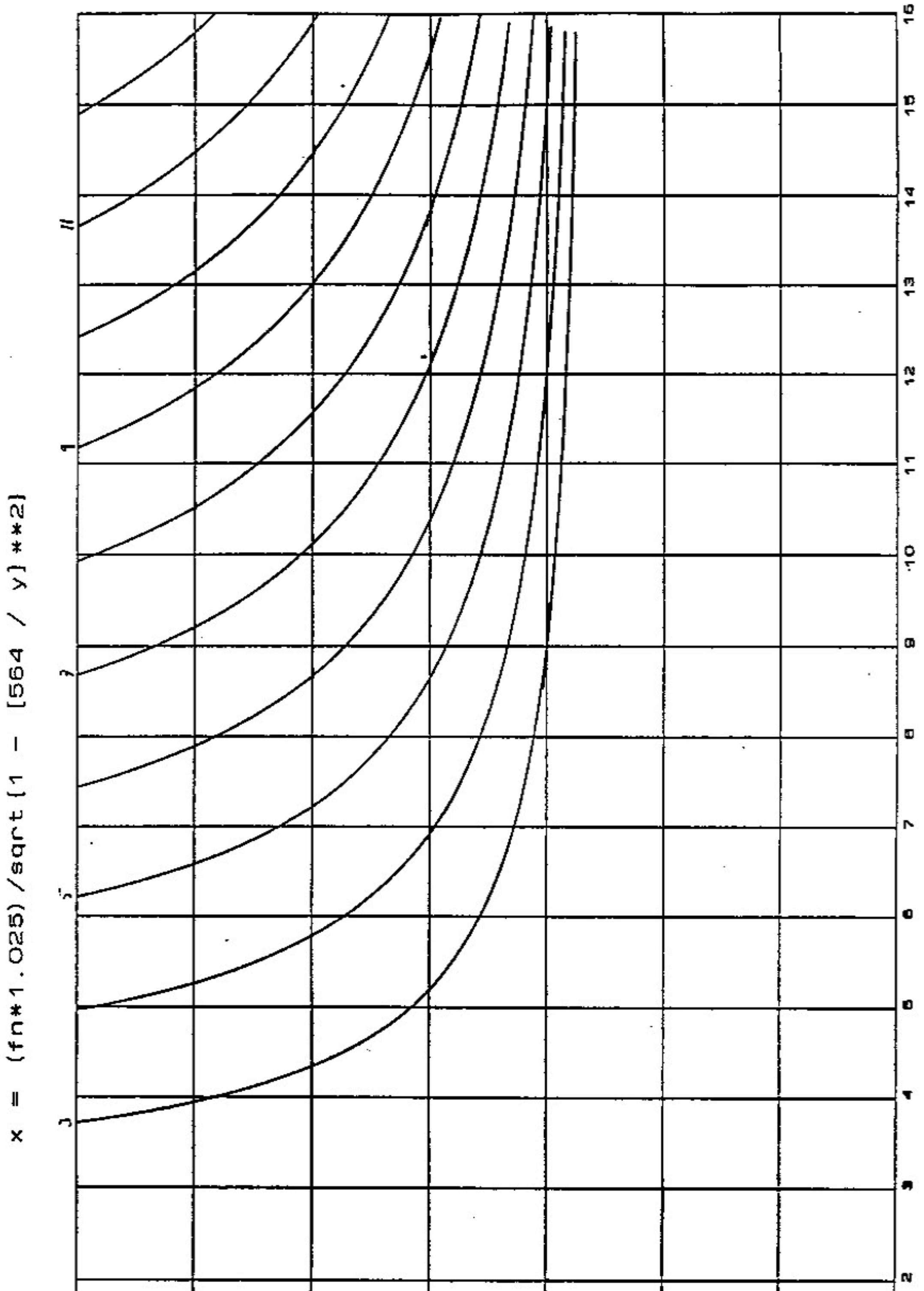

Fig. 6 Overlay for use to scale oblique **ionogram** for foF2 labels in Mhz) assuming the **same virtual** height for path of 1128 and 3000km

Day Time	JTF	foF2	M(1128)	M(3000)	M3-Poitiers-foF2		M3 CCIR
258	(sep14,1992)						
9					32	69	
9.14	131	69	1.9	48			32.33
9.44	133	72	1.85	46			33.09
10					32	79	
10.14	142	75	1.90	48			34.26
10.44	138	72	1.92	49			33.38
11					30	77	
12					32	83	
12.14	143	74	1.93	49			34.07
12.44	134	65	2.05	52			31.66
13					32	77	
13.14	139	72	1.93	49			33.42
13.44	132	72	1.83	54			33.00
14					31	79	
14.14	136	75	1.81	49			33.89
14.44	144	76	1.89	47			34.56
15					31	84	
15.14	150	77	1.95	49			35.11
15.44	140	78	1.79	44			34.79
16					31	82	
16.14							
16.44	140	65	2.15	56			32.09
17					32	78	
17.14	141	63	2.24	57			31.79
17.44	136	62	2.19	57			31.28
18					31	72	
19					31	72	
19.14	113	56	2.02	51			28.63
19.44	112	52	2.15	56			27.90
20					30	64	
20.14	101	49	2.06	51			26.55
21					27	50	
23					26	53	
23.44	71	41	1.73	43			22.61
24					26	53	

Table 1