WILKINSON

MANUAL OF IONOGRAM SCALING

Third Version

by

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Japan

PREFACE

"URSI HANDBOOK OF IONOGRAM INTERPRETATION AND REDUCTION, Second Edition, November 1972" (Report UAG-23) and "REVISION OF CHAPTERS 1 - 4 OF URSI HANDBOOK, 1978" (Report UAG-23A) are being widely utilized by geophysicists and engineers as the best guidebooks for the fundamental understanding of the ionosphere as well as for the scaling of ionograms. There is such an aspect, however, that their contents, being described too much in details, can not be necessarily suitable for beginners. At the same time, there is a demand for a simplified handbook which can be utilized for the short-term training of the ionogram scalers, as a matter of fact. This manual was compiled to cope with this purpose.

Even the experienced scalers are apt to be confused frequently, when they face at complicated ionograms in the procedure of scaling. The ionograms, however, whose interpretation seems to be difficult, could be easily scaled, if the deformation of traces from fundamental patterns would be mastered.

This manual has been compiled in terms of ionospheric parameters, laying emphasis on the most fundamental matters. Consequently the repetition of some parts is inevitable. As for the composition of contents, attention has been paid to the following points:

1. The philosophy of interpretation and the scaling practice are generally based on the so-called "Ionogram Handbook" (URSI Handbook of Ionogram interpretation and Reduction, Second Edition, 1972, Report UAG-23) including the Revised Edition of the same (Report UAG-23A).
2. Examples of ionograms are selected mainly out of those from mid-latitude stations. This manual, however, is expected to be useful for those who work at high or low latitude stations.
3. The idealized patterns of ionogram are shown systematically in diagrams (not in glossy prints).
4. The explanations corresponding to the diagrams are minimized for simplifying the contents.
5. The relevant knowledge necessary for understanding is also mentioned in the explanations of each parameter.

This manual has been compiled after exhaustive discussions made by the research staffs from the Ionospheric Radio Prediction Section of the Radio Wave Division as well as from the Radio Wave Observatories, Radio Research Laboratories.

We earnestly hope that this manual will be fully utilized not only by the scaling specialists but also ionospheric physicists and telecommunication engineers.

March, 1985

N. Wakai, H. Ohyama and T. Koizumi
Radio Research Laboratories

PREFACE FOR REVISED EDITION

The Manual of Ionogram Scaling was published in March 1985 and distributed to the users at ionospheric sounding stations over the world as well as to the members of the INAG.

Since then a fairly large number of requests for the Manual and encouragement for the revised edition including comments and advices to the Manual reached the authors. The comments by Drs. R. W. Smith and A. S. Rodger of U. K. are particularly valuable, being based on thorough and careful examination over the whole pages of the Manual.

We held several times the meeting for refining the Manual during the passage of one year. The revised edition thus completed includes the following modification in the text, while the composition is basically same as the first one:

1. Some figures are re-drawn for avoiding misinterpretation.
2. Local rules are entirely replaced by international ones.
3. Additional informations such as multiple and mixed reflections and the spread-F are incorporated.
4. Descriptions on the particle E layer are modified.

Radio Research Laboratory has authorized to publish the revised edition of the Manual and distribute it to the users as in the case of the first edition.

Again we hope that this Manual will be used as a training text for ionogram scalers and give some help to engineers or physicists who work with the ionograms.

July, 1986

N. Wakai, H. Ohyama and T. Koizumi
Radio Research Laboratory

PREFACE FOR THIRD VERSION

The Revised Edition of the Manual of Ionogram Scaling was completed in July 1986 and more than 200 copies of it were distributed to world-wide ionospheric sounding stations, World Data Centers and a lot of users upon requests.

After the publication of the Revised Edition, we have found out several careless mistakes in typescript.

In last February, the IPS experts of Australia have sent us very kindly comments and suggestions, pointing out inaccurate or inappropriate notations and expressions through careful examinations of the whole text.

Thus we have challenged again to refine the Manual by replacing more than 70 pages, and to publish the result as the third version.

Some comments by IPS experts, however, have not been reflected on the version, because we have considered that they might be based on the local rules used at IPS.

In order to make easy to find out the pages retyped or modified in the text of the Revised Edition, they are marked by (R) at their inner bottom corner.

We wish to express sincere thanks to Dr. P. J. Wilkinson and experts at the IPS Radio and Space Services for their valuable contributions.

October 1987

N. Wakai, H. Ohyama, T. Koizumi
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MEMO

EXPLANATION

This manual contains about 160 examples of the ionograms which are usually observed in the middle latitude region. In order to facilitate users' understanding, the frequency axis of ionograms is indicated by the linear scale, and hence the logarithmic scale is applied only for the reduction of the M factor.

The compilation is made in the following order:

1. Simplified model ionogram.
2. Definition on all qualifying and descriptive letters used for the ionogram scaling.
3. Accuracy Rules for Individual Measurements.
4. All ionospheric parameters to be reduced in conformity with the URSI Ionogram Handbook are explained one by one in the following order:

   fmin, foE, h'E, foEs and h'Es, type of Es, fbEs, foF1, h'F, h'F2, foF2, fxI and M factor.

These ionospheric parameters are made up of the following contents:

1. The form of description for each parameter has been unified, i.e., on the first page, the definition of parameter, scaling accuracy, indication of scaled value, and notices for scaling are put in order, together with concrete examples. Concerning the Es reflection in particular, the distinction of traces, classification of types and decision of fbEs are incorporated.

2. The pages following the first page of each parameter should be used in pairs, i.e., 4 examples of typical observation are illustrated on the left page and explanations corresponding to such examples are given on the right page. By way of reference, the correct value to be scaled is indicated on the right margin of each ionogram.
3. The description in the explanation on the right pages are divided into 3 parts. As for the "Observation", the appearance conditions of trace are described briefly, and as for the "Interpretation" it is explained how to interpret the traces appearing in the ionogram and moreover how to obtain the scaled values which seem to be most adequate for the parameters. Finally as for the "Comment", the comments or reference items concerning the interpretation, such as the way of distinguishing the confusing letters or traces, are indicated partially by means of diagrams, and in addition the origin of quotation from ionogram handbooks referred to is also indicated clearly.

HOW TO USE THIS MANUAL

When one can not find the way to interpret an ionogram, it is recommended to take procedures as follows:

Open the page where the parameter in question is dealt with.

Find out an illustration which is most similar to the ionogram in question.

Read carefully the corresponding explanations on the right page.

Decide the scaled value based on correct interpretation.

It is further recommended to read through pages of the other parameters relating to the parameter in question.

UNIT, SYMBOL & REFERENCES

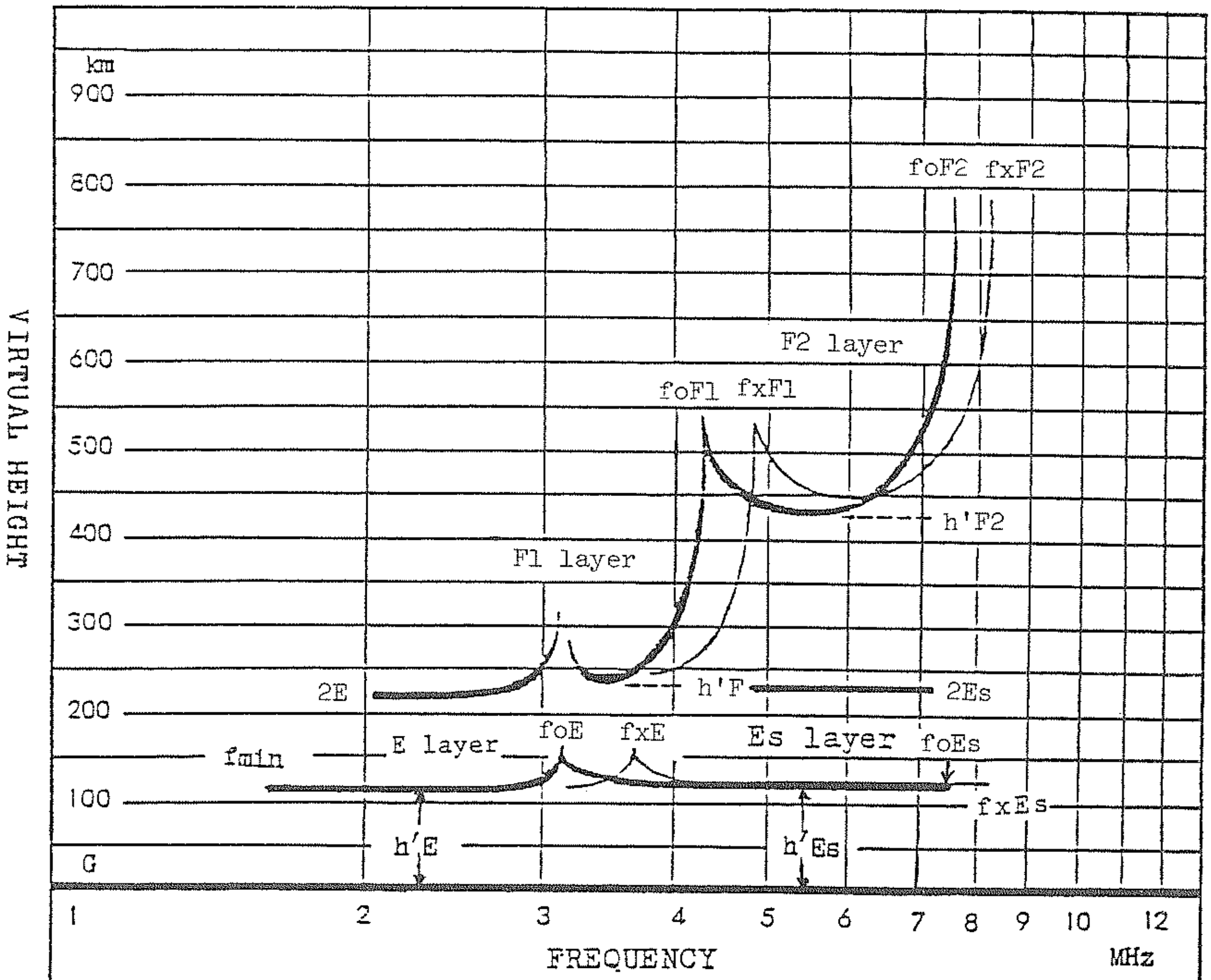
In scaling the final numerical values concerning the frequency, the correct indication is to omit the decimal points (e.g. 7.0 MHz ⟶ 70).

Only one alphabetical letter applied should be the descriptive letter. In the presence of two letters, the first one is the qualifying letter and the second one is the descriptive letter (e.g. 315US).

Notes on abbreviations of References.

I.H. --- Ionogram Handbook (URSI Handbook of Ionogram Interpretation and Reduction, Second Edition, 1972, Report UAG-23).

R.H. --- Revised Handbook (Revision of Chapters 1-4 of Ionogram Handbook, 1978, Report UAG-23A), Contents



TYPICAL IONOGRAM

The ionogram is a record of ionospheric conditions indicated by the relationship between the frequency of radio pulse emitted upward and the virtual height of echoes reflected from the ionosphere.
In the case of the normal ionogram, the frequency range covers 1-20 MHz and the height range covers 0-1000 km.

The radio waves are reflected from the ionosphere after penetrating more deeply into the ionosphere as the frequency increases. In the frequency range close to the highest plasma frequency of the ionospheric layers, the radio echoes are observed being split into two traces (the ordinary and extraordinary components corresponding to lower and higher frequency traces respectively, which are separated by about fB (electron gyro-frequency)/2), owing to the presence of the geomagnetic field.
For example, foF2 and fxF1 stands for the ordinary wave critical frequency of the F2 layer and the extraordinary wave critical frequency of the F1 layer respectively.

The height scale of ionogram is marked on the assumption that the radio waves propagate in the ionosphere at the speed of light.
As a matter of fact, however, they propagate more slowly in such an ionized medium as the ionosphere. Therefore, the recorded heights always tend to be higher than the real heights of reflection. Thus the recorded height refers to the virtual heights (h') which are indicated as h'E, h'F etc. layer by layer.

Qualifying and Descriptive Letters (R.H.pp.34-35)

A - Qualifying letter: less than. Used only with fbEs. (See section 3.1.)
  Descriptive letter: Measurement influenced by, or impossible because of, the presence of a lower thin layer, for example, Es.
B - Measurement influenced by, or impossible because of, absorption in the vicinity of fmin.
C - Measurement influenced by, or impossible because of, any non-ionospheric reason.
D - Qualifying letter: greater than.
  Descriptive letter: Measurement influenced by, or impossible because of, the upper limit of the frequency range in use.
E - Qualifying letter: less than.
  Descriptive letter: Measurement influenced by, or impossible because of, the lower limit of the frequency range in use.
F - Measurement influenced by, or impossible because of, the presence of frequency spread.
G - Measurement influenced or impossible because the ionization density of the layer is too small to enable it to be made accurately.
H - Measurement influenced by, or impossible because of, the presence of stratification.
I - Qualifying letter only: Missing value has been replaced by an interpolated value.
J - Qualifying letter only: Ordinary component characteristic deduced from the extraordinary component.
K - Particle E layer present.
L - Measurement influenced or impossible because the trace has no sufficiently definite cusp between layers. Mixed spread F present (see section 2.8.)

M - Interpretation of measurement questionable because ordinary and extraordinary components are not distinguishable.
  Qualifying letter: Used with descriptive letter which shows why components not distinguishable.
  Descriptive letter: Used when interpretation is doubtful and a qualifying letter needed for other reasons (e.g., U, D, E).
N - Conditions are such that the measurement cannot be interpreted.
O - Qualifying letter: Extraordinary-component characteristic deduced from the ordinary component. (Used for x characteristics only.)
  Descriptive letter: Measurement refers to the ordinary component.

P - Man-made perturbations of the observed parameter; or spur type spread F present (see section 2.8).

Q - Range spread present. (See also Section 2.8)
R - Measurement influenced by, or impossible because of, attenuation in the vicinity of a critical frequency.
S - Measurement influenced by, or impossible because of, interference or atmospherics.
T - Qualifying and descriptive letter: Value determined by a sequence of observations, the actual observation being inconsistent or doubtful. (See section 6.9.).
U - Qualifying letter only: Uncertain or doubtful numerical value.
V - Forked trace which may influence the measurement.
W - Measurement influenced or impossible because the echo lies outside the height range recorded.
X - Measurement refers to the extraordinary component.
Y - Lacuna phenomena (also Section 2.75) or severe F-layer tilt present.
Z - Qualifying letter: Measurement deduced from the third magneto-electronic component.
  Descriptive letter: Third magneto-electronic component present.

In Chapter 3 the use of each letter is discussed in detail.

The following descriptive letters are used to show spread F types where spread F types are tabulated in the Standard F tables. They then take precedence over all other letters. (See section 3.2, p. 74).

F - Frequency spread present. foF2 and fxI tables only.
L - Mixed spread present. foF2 and fxI tables only.
P - Polar spur. fxI table only.
Q - Range spread present. h'F, h'F2 tables. Rarely in foF2 or fxI tables.

Accuracy Rules for Individual Measurements (R.H.pp.31-34)

2.21. General: The accuracy rules give the desirable accuracy applicable when the structure of the ionosphere and characteristics of the ionosonde permit. They also indicate the extent of the uncertainty permitted for doubtful or extrapolated values and enable such values to be identified. The rules imply that, in general, the reliability of data is determined by the percentage inaccuracy allowed except when this percentage is less than the reading accuracy Δ. The general properties of the rules are illustrated in Fig. 2.1, which shows, in graphical form, the rules applicable to all critical frequencies with reading accuracies Δ = 0.1 MHz and Δ = 0.05 MHz.

It must be remembered that the accuracy rule limits apply to reasonable doubt, not to absolute certainty. Thus, if an F trace shows some scattered echoes beyond the limit range and is such that it is unlikely that foF2 is really above the limit range. A numerical value for foF2 should be scaled. The scattered traces are scaled in accordance with the rules of section 2.83.

2.22. Conventions for assigning the level of accuracy: The maximum reading unit Δ has been defined in the table of recommended reading values given above (section 2.13). Numerical values whose reliability is influenced by certain phenomena are qualified by symbols (section 2.3) according to the following rules.

(a) If the estimated uncertainty of a value does not exceed ± 2%, or ± Δ, whichever is greater, then the numerical value is unqualified.

(b) If the estimated uncertainty of a value exceeds ± 2%, or ± Δ, whichever is greater, but does not exceed ± 5%, or ± 2 Δ, whichever is greater, the value is considered doubtful and the qualifying letter U is used with the number together with the descriptive letter which most nearly represents the reason for the uncertainty.

(c) If one boundary is certain and the other possible boundary of uncertainty lies within ± 10%, or ± 3 Δ, whichever is greater from it, the most probable value is taken as being midway between the observed limits, and the qualifying letter U is used with the number and appropriate descriptive letter.

(d) When the possible error exceeds that in paragraph (b), but it is estimated that the true value lies within 20%, or 5 Δ, whichever is greater, of an observed boundary of possible positions of the principal echo, then this observed limit is tabulated with the qualifying letter D or E, whichever is applicable, and with the appropriate descriptive letter.

(e) When the extreme limit of the principal echo is judged to differ from the true value of the parameter by more than 20%, or 5 Δ, whichever is greater, a descriptive letter only is tabulated without a numerical value. A descriptive letter used in this context is often termed a replacement letter (See Section 2.3).

The rules for frequencies are summarized in Fig.2.1a.

2.23. Accuracy rules in total range of uncertainty forms: Operators who prefer to consider the total range of uncertainty may use the following rules which are equivalent to those given above.

(a) If the total range of uncertainty does not exceed 4% or 2Δ, whichever is greater, then the numerical value is unqualified.

(b) If the total range of uncertainty exceeds 4% or 2Δ, whichever is greater, but does not exceed 10% or 4Δ, whichever is greater, the value is considered doubtful and the qualifying letter U is used with the most probable value together with the descriptive letter which most nearly represents the reason for the uncertainty.

(c) If one boundary is certain and the other possible boundary lies within 10% or 3Δ, whichever is greater from it, the most probable value is taken as being midway between the observed limits, and the qualifying letter U is used with this value and the appropriate descriptive letter.

(d) When the total range of uncertainty exceeds that in paragraph (b) but is less than 20% or 5Δ, whichever is greater, of an observed boundary of possible positions of the principal echo trace, then this observed limit is tabulated with the qualifying letter D or E, whichever is applicable, and the appropriate descriptive letter.

(e) When the total range of uncertainty exceeds 20% or 5Δ, whichever is greater, a descriptive letter only is tabulated without a numerical value.

The application of these rules to F-region frequency parameters Δ = 0.1 MHz and E-region parameters with Δ = 0.05 MHz are shown graphically in Figs. 2.1 (a) and (b), respectively."

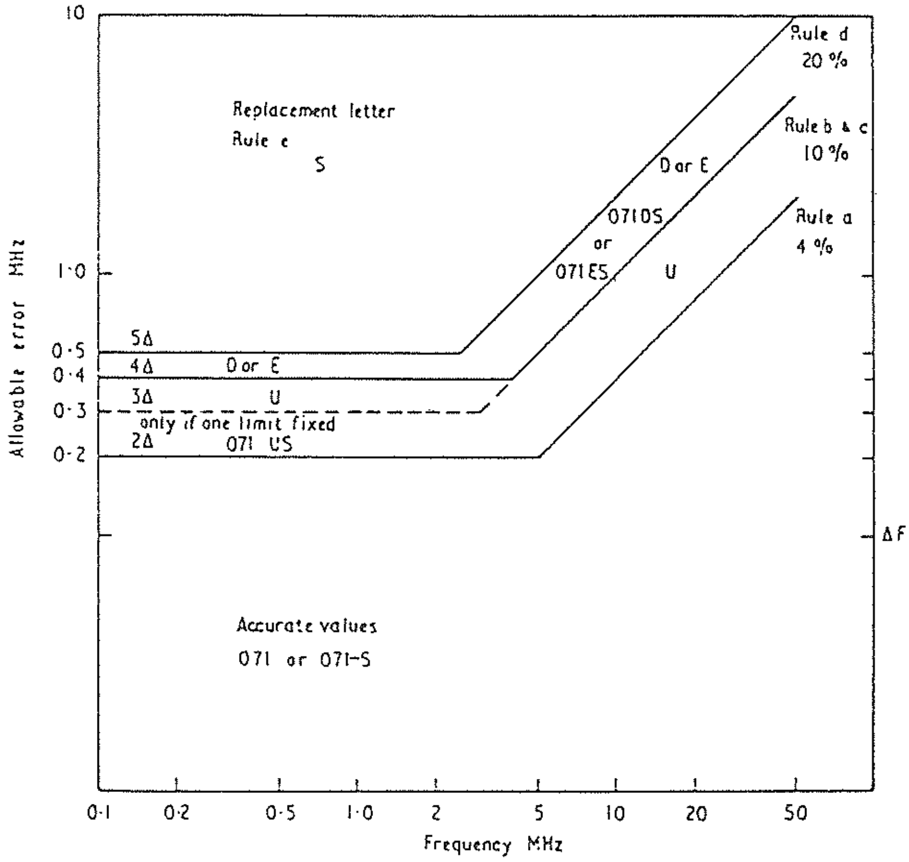


Fig. 2.1a Accuracy rules for F region frequencies Δ = 0.1 MHz in terms of total range of error.

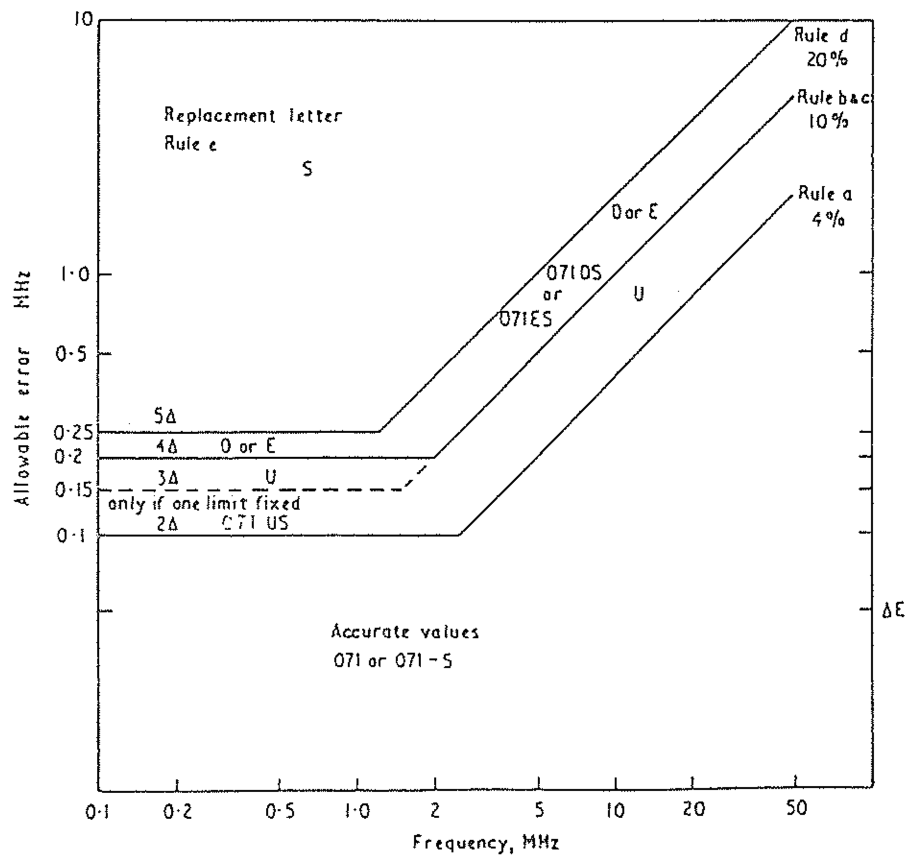


Fig. 2.1b Accuracy rules for E region frequencies Δ = 0.05 MHz in terms of total range of error.

fmin

@ Definition : fmin (minimum frequency) is the lowest frequency of reflection wave recorded in the ionogram.

@ Scaling accuracy :

fmin is scaled at the accuracy of 0.1 MHz (e.g. 1.6 MHz)

@ Indication of scaled value :

fmin is indicated by a numerical value in unit of 0.1 MHz with or without letters or by a letter only.

(Examples)

C --- Numerical values cannot be obtained because of the defect of the ionosonde.

16C --- C is a descriptive letter.

46EC --- E is a qualifying letter, C is a descriptive letter.

@ Notices for scaling :

1. The fmin should basically be scaled from the ordinary wave traces. In the actual scaling it is recommended that the lowest frequency of the first order reflection trace recorded in its ionogram be scaled. It is seldom that fmin has to be scaled either from the extraordinary waves or Z components. In the case of the scaling from the Z component, a descriptive letter Z should be given to its numerical value (e.g. 16Z).

2. The very weak reflections should be ignored.

3. When fmin is high a normal trace may look very weak. But it should be treated as a strong trace from which fmin is scaled in a usual way. The strength of absorption can be deduced from the value of fmin.

4. fmin must not be scaled from the d type Es trace (a weak diffuse trace at a virtual height below 95 km : see Case 9 of Es type), not from traces reflected obliquely or traces appearing suddenly and/or changing rapidly.

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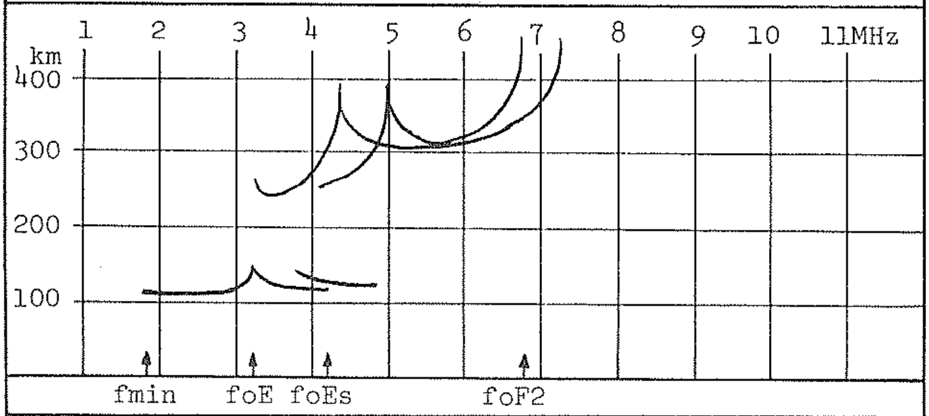
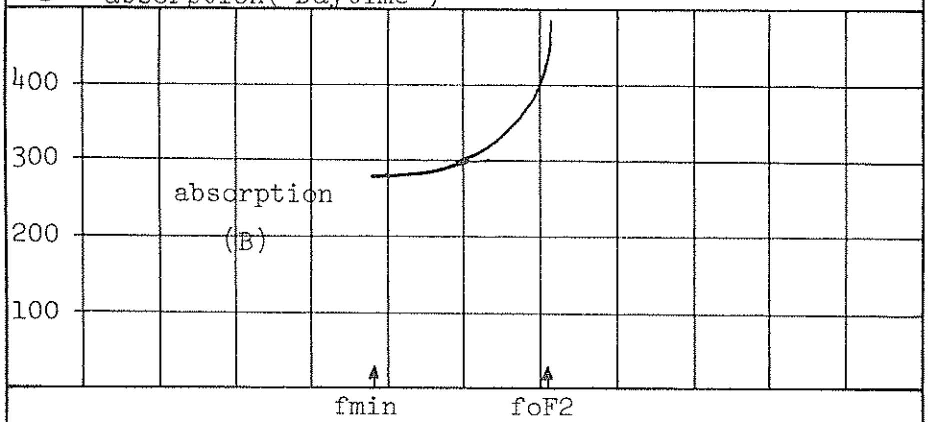
fmin- 1

① Normal ionogram (Daytime)



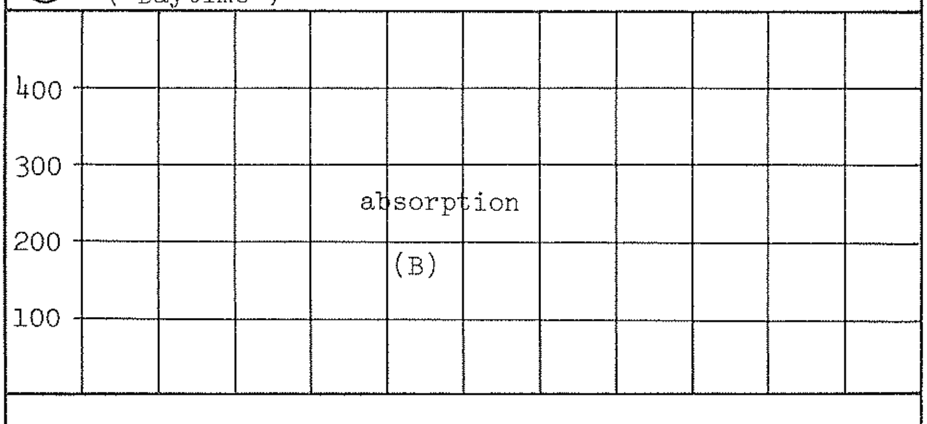
fmin	18
foE	315
h'E	110
foEs	42
fxEs	48
h'Es	115
Es type	c1
fbEs	32EG
foF1	44
h'F	245
h'F2	305
foF2	67
fxI	

② A lower part of traces disappeared owing to the absorption(Daytime)



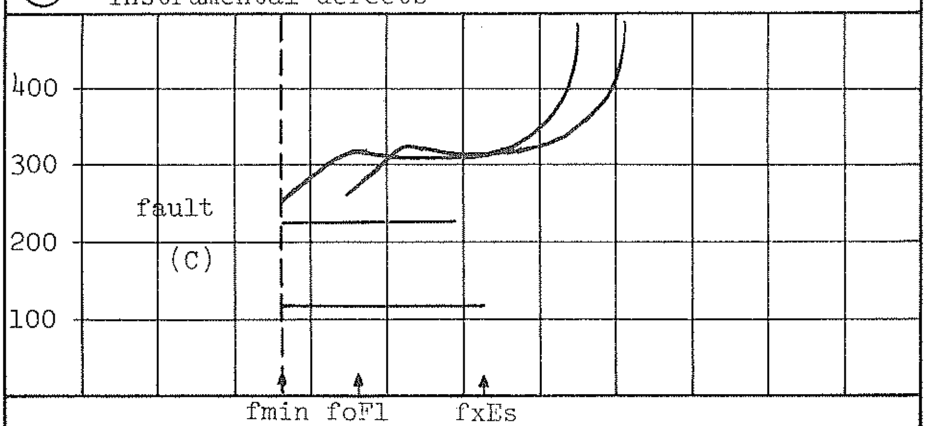
fmin	48
foE	B
h'E	B
foEs	48EB
fxEs	
h'Es	B
Es type	
fbEs	48EB
foF1	B
h'F	B
h'F2	275
foF2	71
fxI	

③ All the traces disappeared owing to the absorption (Daytime)



fmin	B
foE	B
h'E	B
foEs	B
fxEs	
h'Es	B
Es type	
fbEs	B
foF1	B
h'F	B
h'F2	B
foF2	B
fxI	

④ A lower part of traces is missing due to instrumental defects



fmin	36EC
foE	C
h'E	C
foEs	57JA
fxEs	63
h'Es	115
Es type	c2
fbEs	36EC
foF1	L(46)
h'F	250EC
h'F2	305
foF2	75
fxI	

(1)

Observation: The ionogram usually seen in the summer daytime. The normal E, F1, F2 layers and the c type Es layer are observed.

Interpretation: The lowest frequency of the traces in this ionogram is 1.8 MHz.

fmin = 18

Comment : In the case where the condition of the ionosphere is undisturbed and the ionosonde works normally, the value of the daytime fmin will be approximately between 1.5 to 2.0 MHz. Increase in fmin due to the decrease in the sensitivity of ionosonde must not be confused with that due to the increase in absorption. In these cases, the descriptive letter expressing the malfunction of the ionosonde should be attached (e.g. fmin = 25EC).

(2)

Observation : The trace below 4.8 MHz disappeared owing to the high absorption (E and F1 layer traces are not visible).

Interpretation : The frequency of fmin is high when the absorption is strong. fmin is important as a parameter which indicates the degree of absorption. fmin of this ionogram is expressed simply with numerical values.

fmin = 48

Comment : The absorption is rarely observed in the nighttime at midlatitude.

(3)

Observation: No trace is observed on the ionogram. There is almost no interference.

Interpretation: This is the case where the absorption condition is stronger than that in Case 2. When the ionosonde works normally, the black-out on ionogram is caused by the sudden ionospheric disturbances (SID). As the SID progresses, the disappearance of the trace starts very quickly from the lower part of frequency. The recovery usually occurs slowly from the higher part of frequency. All parameters are indicated by the letter B, including fmin but excluding Es types.

fmin = B

(4)

Observation: The trace below 3.6 MHz is not recorded owing to the defect of the ionosonde. Both the second order reflection of Es layer and the F1 layer not fully developed are visible.

Interpretation: The frequency band below fmin is affected by the defect. Therefore, the numerical value should be accompanied by the qualifying letter E and the descriptive letter C.

fmin = (fmin)EC = 36EC

Comment : When the cause is ascribed to the interference, the descriptive letter S is used instead of C.

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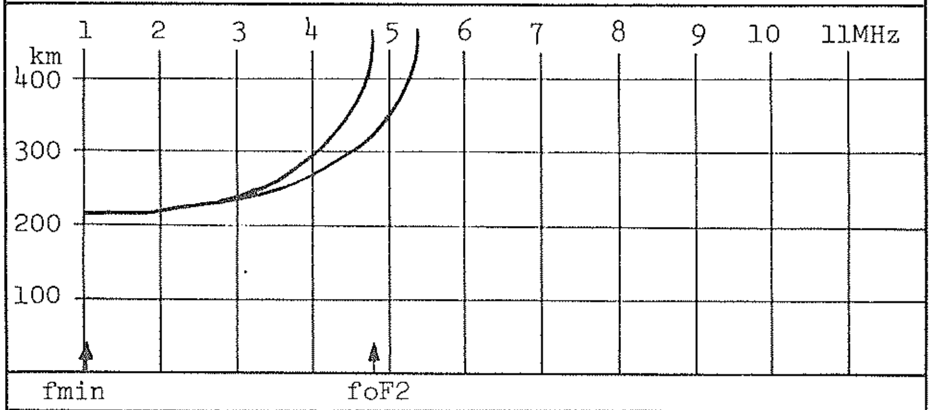
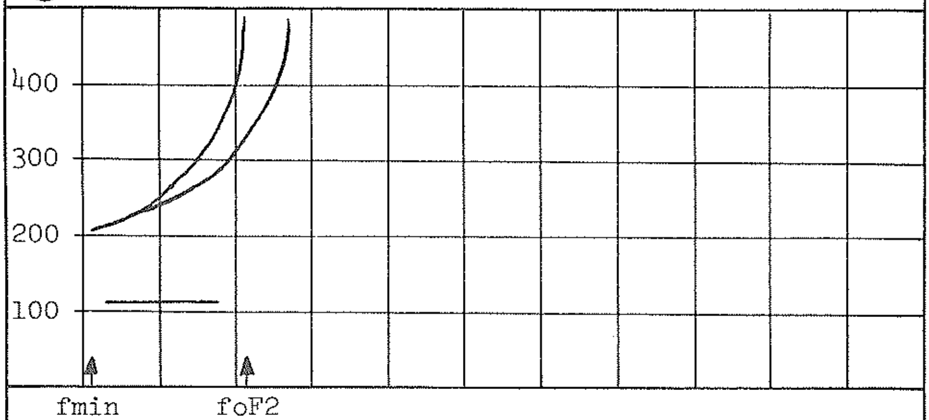
fmin - 2

⑤ Normal ionogram (Nighttime)



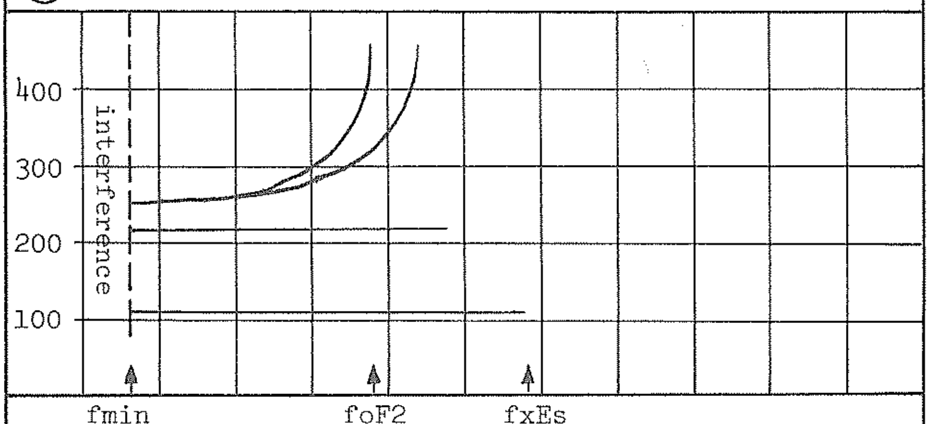
fmin	10EE
foE	
h'E	
foEs	10EE
fxEs	
h'Es	E
Es type	
fbEs	10EE
foF1	
h'F	210
h'F2	
foF2	48
fxI	54X

⑥ Normal ionogram (Nighttime)



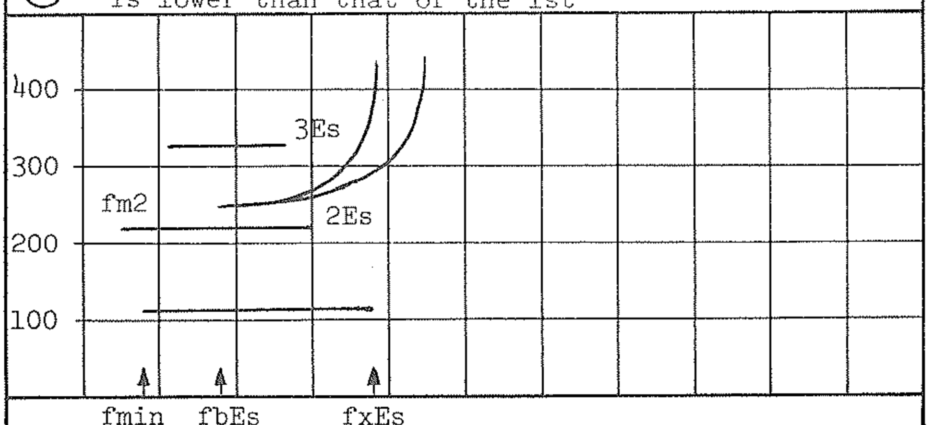
fmin	11
foE	
h'E	
foEs	21JA
fxEs	27
h'Es	110
Es type	f1
fbEs	11EB
foF1	
h'F	205EB
h'F2	
foF2	31
fxI	37X

⑦ foE is affected by the interference (Nighttime)



fmin	16ES
foE	
h'E	
foEs	62JA
fxEs	68
h'Es	110
Es type	f2
fbEs	16ES
foF1	
h'F	250
h'F2	
foF2	48
fxI	54X

⑧ The lowest frequency of the 2nd order reflection is lower than that of the 1st



fmin	18
foE	
h'E	
foEs	42JA
fxEs	48
h'Es	110
Es type	f3
fbEs	28
foF1	
h'F	250A
h'F2	
foF2	49
fxI	55X

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(5) Observation : A normal ionogram observed in the nighttime. Only the F layer trace appears from the lowest frequency of the ionosonde.

Interpretation : It is interpreted that the trace extends down to below the lowest frequency 1.0 MHz of the ionosonde. Therefore, both the qualifying letter E (less than) and the descriptive letter E (below the lower limit of frequency) should be given to the numerical value 1.0 to be more accurate, but the use of only the descriptive letter E may be allowed for simplification.

fmin = 10EE

(6) Observation : The F layer trace is observed from 1.1 MHz and the f type Es is seen at the height of 110 km.

Interpretation : The lowest frequency 1.1 MHz of the trace recorded on the ionogram is regarded as fmin.

fmin = 11

(7) Observation : Below 1.6 MHz, the trace is not observed owing to the interference caused by the broadcasting wave.

Interpretation : Every sounding station is exposed to the interference during hours just before sunset to at least midnight and after sunrise.

If there were no interference, the trace would be observed down to below 1.6 MHz. The value of the lowest frequency of trace should be accompanied by the qualifying letter E (less than) and the descriptive letter S (interference).

fmin = (fmin)ES = 16ES

(8) Observation : The f type Es is observed up to the third order reflection. The lowest frequency (fm2) of the second order reflection is lower than that (fmin) of the first order reflection.

fm2 = 1.5 MHz

Interpretation: Since the second order reflection suffers from much more absorption than the first order one, the ionograms such as this example can rarely be observed. In the normal scaling, fmin should be scaled from the first order reflection, rather than from the second one.

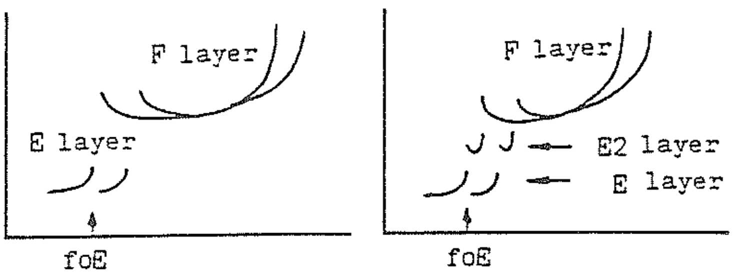
fmin = 18

(R)

foE

@ Definition : foE is the ordinary wave critical frequency of the lowest thick stratification in the E region. [According to the magneto-ionic theory, the frequency separation between the ordinary and extraordinary mode traces is equal to about fB/2, where fB is the gyro-frequency (the frequency at which the electrons gyrate around the geomagnetic field). The value of fB varies depending on the location of the station and the ionospheric height concerned. In middle latitudes, it is about 1.2 MHz].

foE is closely related to the solar zenith angle, having usually the highest value around the local noon in smooth diurnal variation.



@ Scaling accuracy :

foE should be scaled with an accuracy of 0.05 MHz. Therefore, the last digit of scaled value is always 0 or 5 (e.g. 2.00 MHz, 3.15 MHz).

@ Indication of scaled value :

foE is expressed by a numerical value with or without letters, or by only a descriptive letter according to the accuracy rule.

(Examples)

S --- No numerical value can be obtained owing to the interference.

315R --- R is a descriptive letter which expresses the attenuation around the critical frequency.

300UR --- U is a qualifying letter (uncertain).

@ Notices for scaling :

1. The time of appearance and disappearance of the normal E layer varies with the season and the latitude of the station. foE should always be scaled during this time interval. It is convenient for

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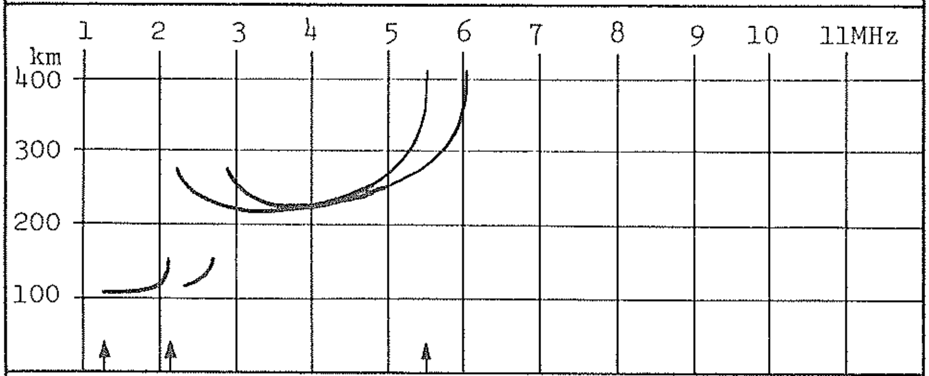
scalers to know beforehand the time interval for each month in reference to the past data.

2. Before sunrise, such stratifications as the h or c type Es and the E2 layer are observed in the E region prior to the development of the normal E layer. These traces must not be confused with the normal E layer. The h or c type Es and the E2 layer are usually observed with a virtual height greater than that of the normal E layer. In particular the short-lived E2 layer appears in the vicinity of about 150 km. The E2 layer as well as the normal E layer shows the retardation at the highest frequency.

3. If the particle E layer is observed, the value of foE should be scaled even in the nighttime and denoted in the table with the descriptive letter K.

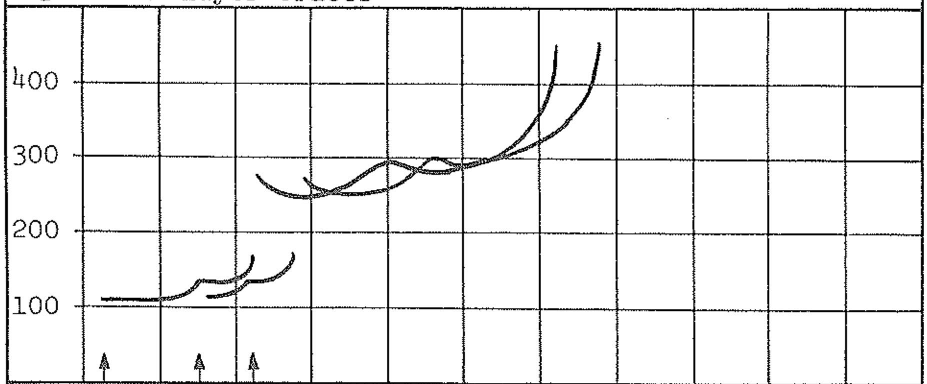
foE – 1

① Normal ionogram



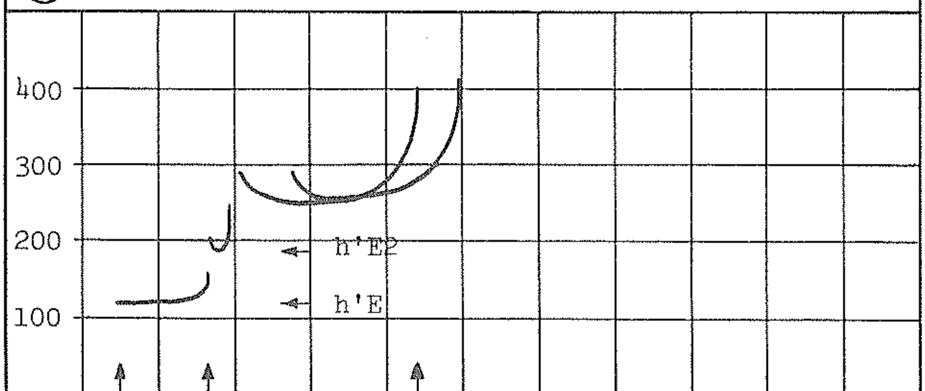
fmin	13
foE	210
h'E	105
foEs	21EG
fxEs	
h'Es	G
Es type	
fbEs	21EG
foF1	
h'F	215
h'F2	
foF2	55
fxI	

② Cusps due to underlying stratification are observed in E layer traces



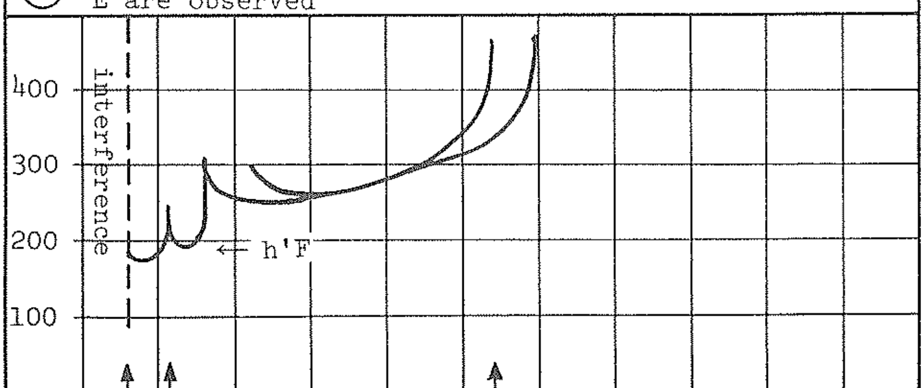
fmin	13
foE	320H
h'E	105H
foEs	32EG
fxEs	
h'Es	G
Es type	
fbEs	32EG
foF1	50UL
h'F	250
h'F2	280
foF2	72
fxI	

③ E2 layer is present



fmin	15
foE	265
h'E	120
foEs	27EG
fxEs	
h'Es	G
Es type	
fbEs	27EG
foF1	
h'F	245
h'F2	
foF2	54
fxI	

④ Cusps due to stratifications other than the normal E are observed



fmin	16ES
foE	S
h'E	S
foEs	16ES
fxEs	
h'Es	S
Es type	
fbEs	16ES
foF1	
h'F	195H
h'F2	
foF2	64
fxI	

®

foE – 1

(1)

Observation : Ionogram in quiet ionosphere. The Es and F1 layers are not observed.

Interpretation : foE is to be determined in consideration of the shape of retardation of the E region trace. foE is nearly equal to the lowest frequency of the F layer trace.

foE = 210

Comment : Since the extraordinary component is usually characterized by larger absorption than that for the ordinary component, sometimes the trace becomes weak or not visible at all. In cases where the retardation cusp of the trace near fxE is missing, care should be taken not to confuse with an Es layer trace.

(2)

Observation : A cusp is visible near 2.5 MHz of the E layer trace. The F1 layer does not develop sufficiently.

Interpretation : The cusp near 2.5 MHz is caused by an underlying stratification (see R.H. p. 83, letter H). Therefore, foE should be accompanied by the descriptive letter H which expresses the influence by the stratification.

foE = (foE)H = 320H

Comment : The retardation cusp appears also at the lower end of the F region trace. The cusp of the E region which usually appears first in the vicinity of foE moves toward the lower frequency, becoming weak with the passage of time. When the lower cusp is widely separated from foE, it is not necessary to attach the descriptive letter H. In this case, H should be applied to h'E.

(3)

Observation : The trace of the E2 layer is observed between the normal E and F layers. The F1 layer does not exist.

Interpretaion : Both the E and E2 layer traces are sometimes connected and sometimes not. It should be carefully examined which retardation is foE.

Comment : The appearance of E2 layer should be remarked in an appropriate column of the scaling table. The E2 layer is transient and thick layer which appears between the normal E layer and the F layer, and it is mainly observed for 1 - 2 hours around sunrise and sunset hours. The other traces than those of the particle E layer observed in disturbed conditions can be regarded as the E2 layer (see I.H. p.17).

(4)

Observation : Below 1.6 MHz, no trace is observed owing to the interference. Some cusps are observed in the E region.

Interpretation : Ionograms like this are seen early in the morning. The virtual height of the E region traces is too high to be the normal E layer. It could be identified from an examination of a sequence of records or from the diurnal trend of foE values. Since the normal E layer is considered to be masked by the interference,

foE = S.

Comment : If it can be judged from the sequential check of records that foE exists near fmin, foE may be deduced from the retardation of the lower part of traces but care should be taken to ensure that the cusp is not associated with an E2 layer.

foE = 160ES

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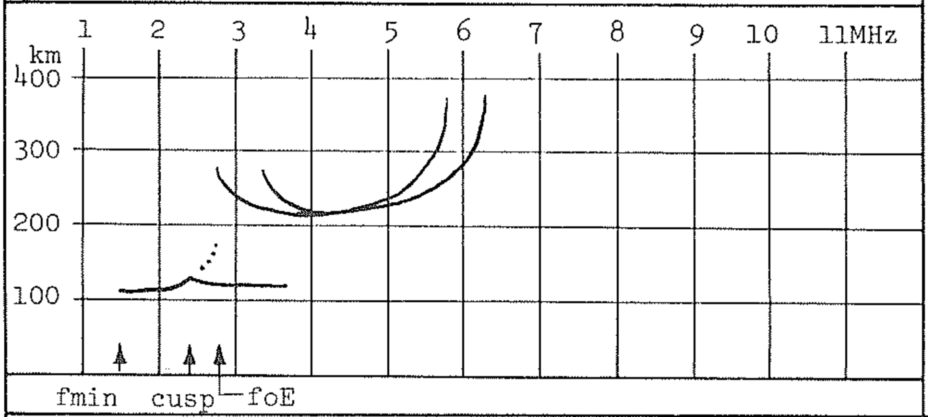
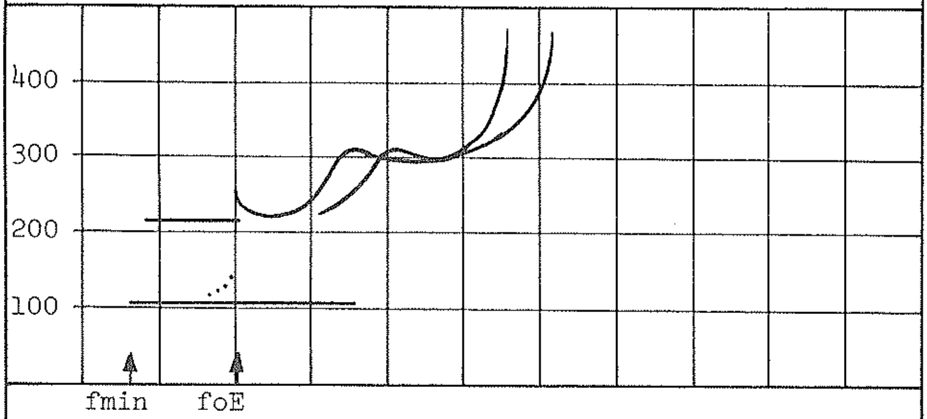
foE − 2

(5) Cusp except foE is observed in E layer traces



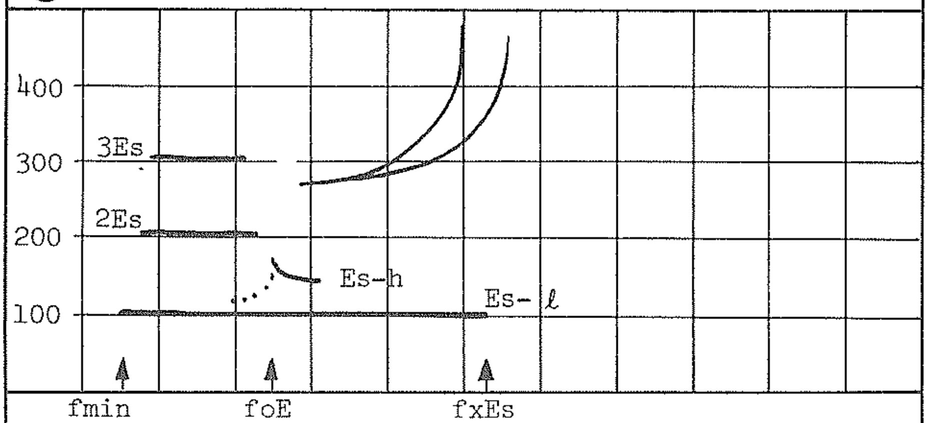
fmin	15
foE	280UA
h'E	110
foEs	30JA
fxEs	36
h'Es	115
Es type	cl
fbEs	28
foF1	
h'F	215
h'F2	
foF2	58
fxI	

(6) E region traces are blanketed by Es layer



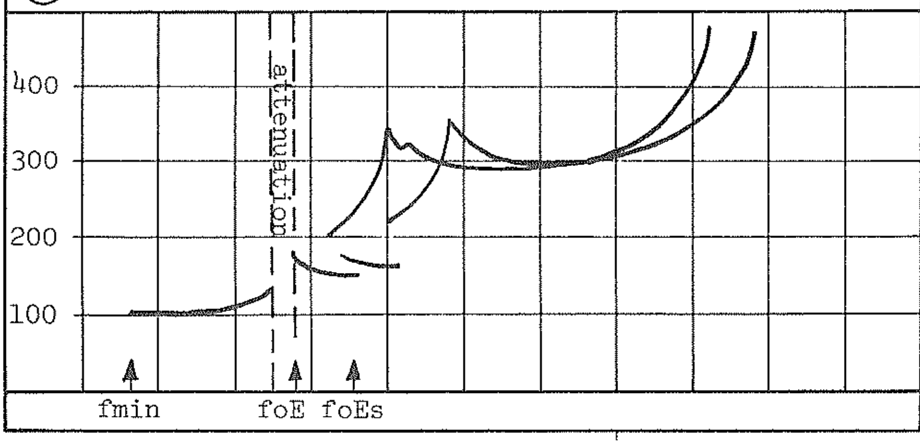
fmin	16
foE	300UA
h'E	A
foEs	40JA
fxEs	46
h'Es	105
Es type	ℓ2
fbEs	30
foF1	45L
h'F	220
h'F2	295
foF2	66
fxI	

(7) E region traces are blanketed by Es layer



fmin	15
foE	350UA
h'E	A
foEs	57JA
fxEs	63
h'Es	100
Es type	ℓ3h1
fbEs	35
foF1	
h'F	270
h'F2	
foF2	60
fxI	

(8) No traces are observed near foE



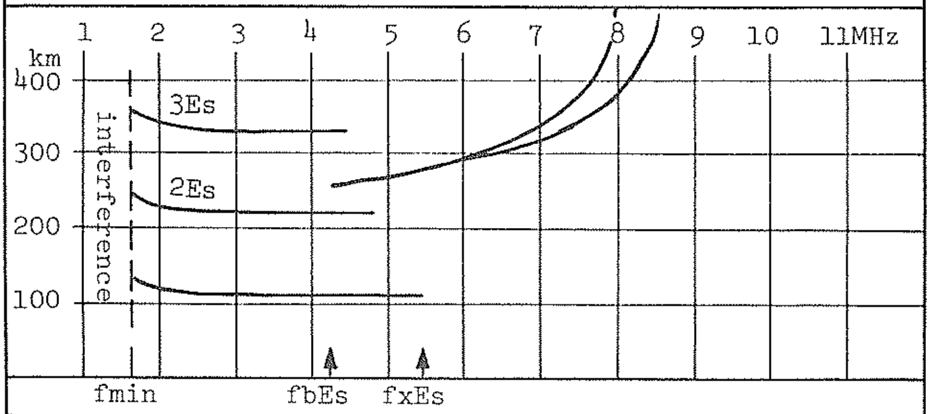
fmin	16
foE	365UR
h'E	100
foEs	46
fxEs	52
h'Es	150
Es type	hl
fbEs	42
foF1	50
h'F	200EA
h'F2	290
foF2	92
fxI	

5	Observation : A small cusp is observed near 2.4 MHz which is separated from fminF by about 0.4 HMz. Interpretation : The normal value of foE is 2.8 MHz (dotted lines). The cusp at 2.4 MHz is considered to be produced by stratification. In this case it is interpreted that the vicinity of foE is blanketed by the c type Es. In consideration of the lower part of the F layer trace, the value of foE can be obtained by extrapolation. If necessary, a letter is applied according to the accuracy rule. foE = 280UA
6	Observation : Only the ℓ type Es is observed in the E region. The retardation is observed at the lower end of the F layer trace. Interpretation : The normal E layer is blanketed by the ℓ type Es. Judging from the shape of the lower part of the F layer trace, it can be inferred (dotted curve) that foE is nearly same as fbEs. However, care should be taken to ensure that the F layer retardation is not caused by the presence of an E2 layer. foE = (fbEs) UA = 300UA Comment : In this case, fbEs, which is usually plotted by dots in the f-plot diagram, should be plotted by an open circle.
7	Observation : The normal E layer is completely blanketed by the ℓ type Es. The ordinary wave component of the h type Es is observed at the height of 140 km. The retardation is not observed in the low frequency part of the F layer trace, in contrast to Case 6. Interpretation : foE should be close to the low frequency end of the h type Es (dotted curve). Being based on the same interpretation as Case 6, foE can be obtained from the shape of retardation in the low frequency part of the h type Es. foE = 350UA In the case of no retardation, foE = A.
8	Observation : The trace is lost in the frequency range of the vicinity of foE. The h type Es is observed. Interpretation : The disappearance of trace in the vicinity of foE is not caused by the interference. Therefore, the attenuation can be regarded as the cause. foE must be in this part and so it can be obtained by extrapolating the traces. If necessary, the accuracy rule is to be applied. The indication of scaled value is adequately decided by the width of frequency range of the disappeared trace. foE = 365R, 365UR, 350DR or R Comment : In the case of interference, R is replaced by S. As for the accuracy rules, see pp. 3-4 of this manual.

Ⓡ

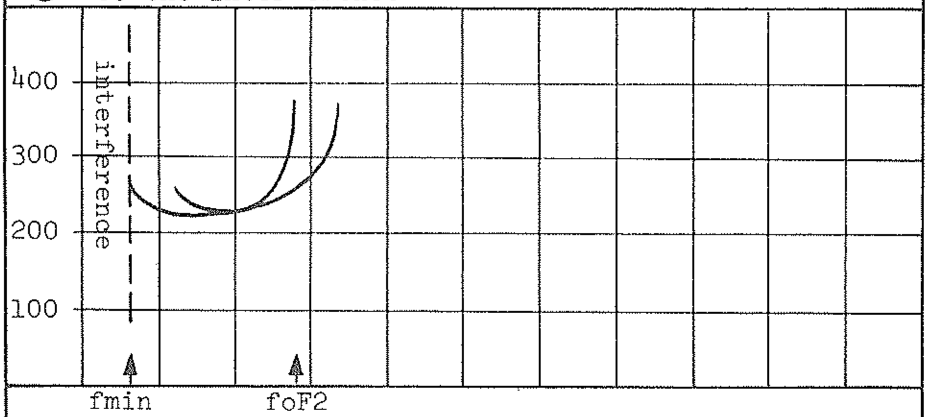
foE — 3

⑨ E layer traces are not clear owing to the interference



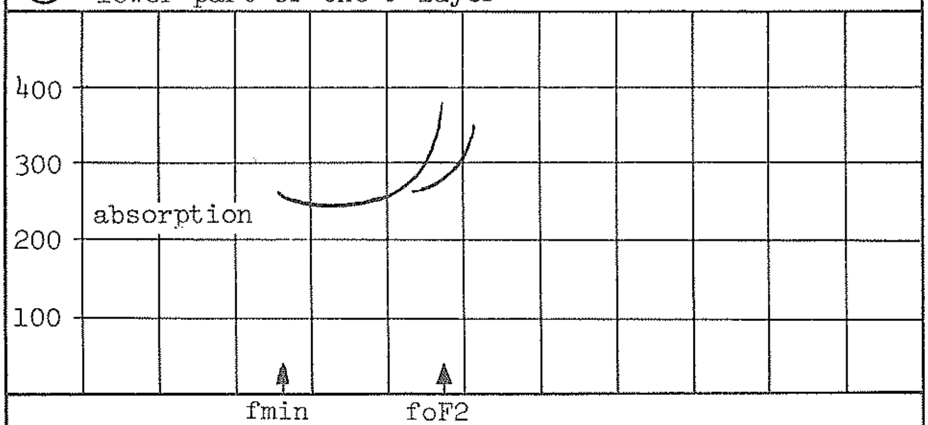
fmin	16ES
foE	S
h'E	S
foEs	48JA
fxEs	54
h'Es	110
Es type	c3
fbEs	42
foF1	
h'F	255EA
h'F2	
foF2	80
fxI	

⑩ All traces of the E region are not clear owing to the interference



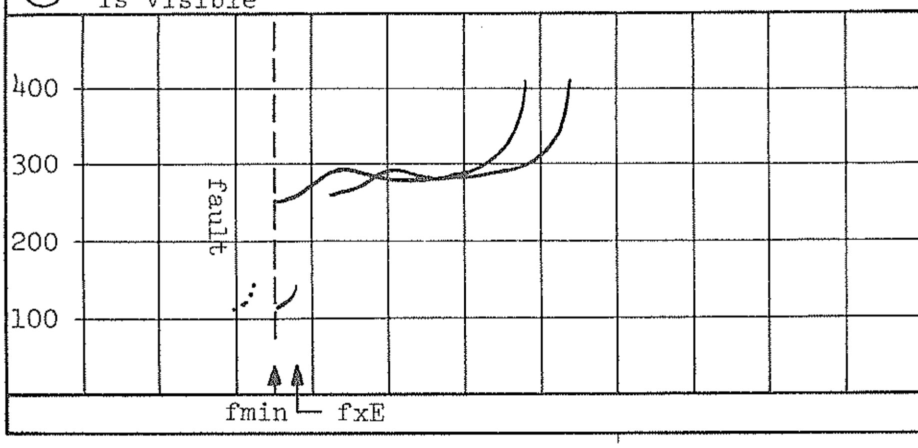
fmin	16ES
foE	S
h'E	S
foEs	16ES
fxEs	
h'Es	S
Es type	
fbEs	16ES
foF1	
h'F	220
h'F2	
foF2	38
fxI	

⑪ No traces are observed from E region and the lower part of the F layer



fmin	36
foE	B
h'E	B
foEs	36EB
fxEs	
h'Es	B
Es type	
fbEs	36EB
foF1	
h'F	245
h'F2	
foF2	57
fxI	

⑫ Only the extraordinary component of the E layer is visible



fmin	35EC
foE	320JC
h'E	C
foEs	G
fxEs	
h'Es	G
Es type	
fbEs	G
foF1	L(44)
h'F	250
h'F2	275
foF2	68
fxI	

(9) Observation : Below 1.6 MHz the trace is not clear owing to the interference. Es is of the c type and it can be seen up to the third order reflection. foEs = 4.8 MHz

Interpretation : Judging from the retardation of the lower part of the c type Es, foE is considered to be present in the interference range. The numerical value cannot be scaled and so it is expressed by the letter.

foE = S

(10) Observation : Below 1.6 MHz the E region trace is not clear owing to the interference.

Interpretation : This ionogram is frequently seen early in the morning or after sunset. In the diagram, foE can be presumed from the retardation of the lower part of the F layer trace (see Case 6).

foE = 150US

Comment : When no retardation is seen in the F layer trace, foE is scaled as smaller than fmin or expressed only by the letter.

foE = 160ES or foE = S

(11) Observation : Below 3.6 MHz all the traces disappeared owing to the strong absorption (SID).

Interpretation : The absorption caused by the solar flare always occurs in the daytime. Even when the E layer trace is not visible, the column for foE must be filled in.

foE = B

Comment : In the case where the retardation is seen in the low frequency part of the F layer trace and the value of foE can be inferred from fmin F, as in Case 6.

If the cause of missing traces is interference (S) or a defect of the ionosonde (C), S or C is used instead of the letter B.

(12) Observation : The traces below 3.5 MHz including the ordinary component of the E layer trace are missing owing to the defect of the ionosonde.

fxE = 3.80 MHz

Interpretation : Since fxE is clear, foE is obtained by subtracting fB/2 from fxE. foE should be accompanied by the qualifying letter J and the descriptive letter C.

foE = (fxE - fB/2) JC = 320JC

Comment : Concerning the separation between foE and fxE, see Definition of foE on p.10.

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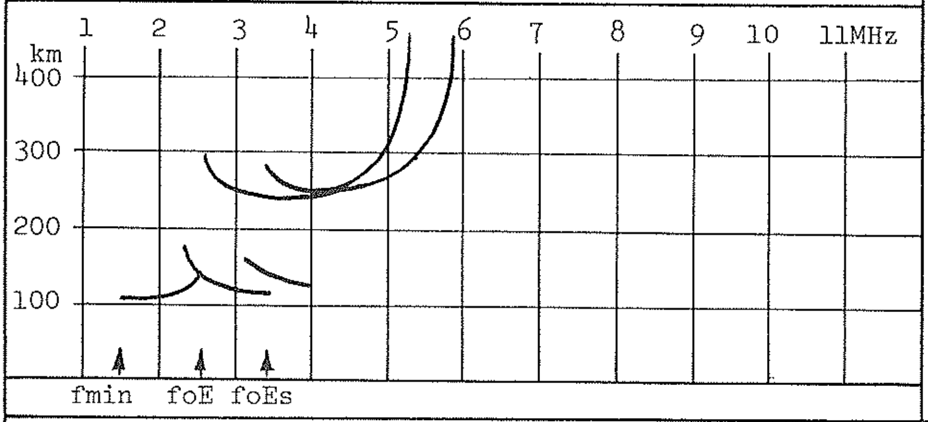
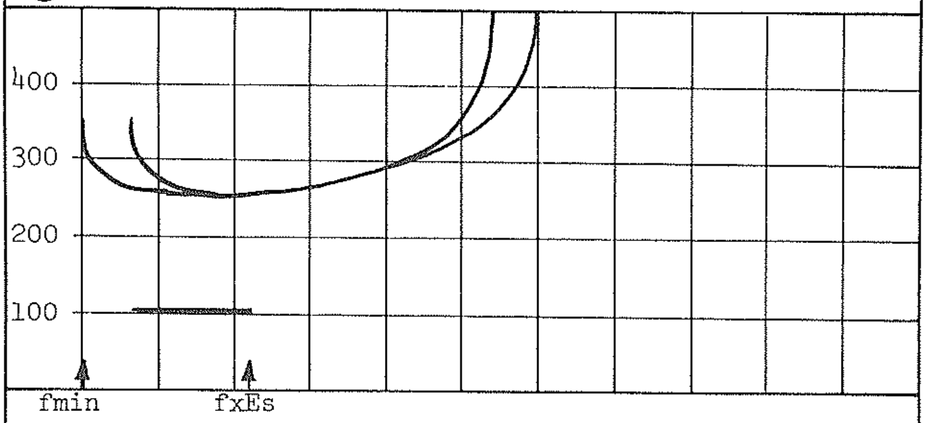
foE – 4

(13) The trace near foE is an abnormal shape (λ type)



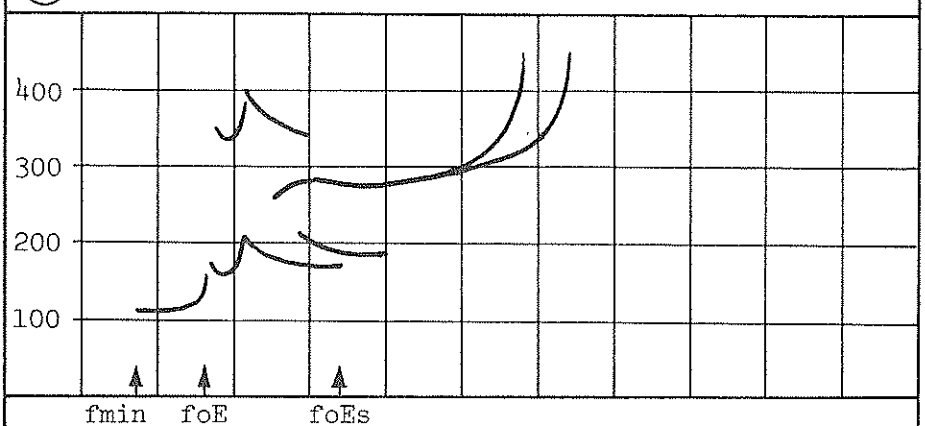
fmin	15
foE	255
h'E	105
foEs	34
fxEs	40
h'Es	115
Es type	c2
fbEs	25EG
foF1	
h'F	245
h'F2	
foF2	53
fxI	

(14) foE exists below the lowest frequency of the ionosonde



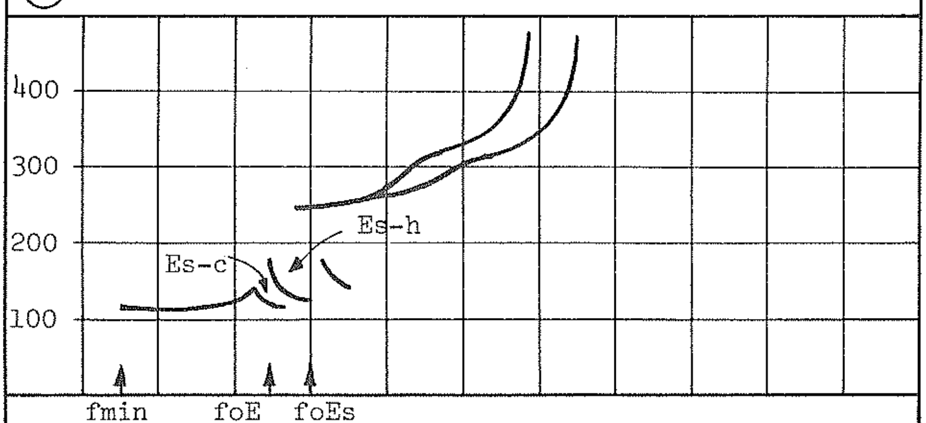
fmin	10EE
foE	100EE
h'E	E
foEs	26JA
fxEs	32
h'Es	100
Es type	ℓ 1
fbEs	E
foF1	
h'F	250
h'F2	
foF2	64
fxI	

(15) Several cusps are present near foE



fmin	17
foE	265
h'E	11C
foEs	44
fxEs	50
h'Es	165
Es type	h2
fbEs	35
foF1	L(40)
h'F	A
h'F2	270
foF2	68
fxI	

(16) Two Es types are visible near foE



fmin	15
foE	345UA
h'E	110
foEs	40
fxEs	46
h'Es	125
Es type	h1c1
fbEs	38
foF1	L
h'F	245
h'F2	L
foF2	69
fxI	

Ⓡ

(13) Observation : The normal E layer is connected to the c type Es with a λ-shaped overlapping of the retarded part of trace.

Interpretation : This shape is considered to be produced by simultaneous occurrence of the reflection by the normal E layer and the oblique reflection from the Es layer.

foE = 255

Comment : A comment should be included with the scaled values for such cases.

(14) Observation : Ionogram at sunrise. The retardation is visible in the lower part of the F layer trace. The Es is of the ℓ type.

foEs = 2.6 MHz

Interpretation : The retardation of the lower part of the F layer trace shows that the normal E layer is present below fmin. Since the trace is appearing from the lower frequency (1.0 MHz) of the ionosonde, foE and h'E are expressed by the descriptive letter E.

foE = 100EE

(15) Observation : Two cusps are visible near foE (2.65 MHz and 3.05 MHz). The Es is of the h type. foEs = 4.4 MHz

Interpretation : This kind of echo pattern which is likely to appear in summer morning frequently causes confusion in determining foE. foE should be decided in consideration of a sequence of ionograms (the f-plot is effective). In this ionogram the cusp at 2.65 MHz corresponds to foE, while the cusp at 3.05 MHz which is connected with the h type Es is considered to be the cusp by a different stratification.

foE = 265

(16) Observation : The trace in the E region shows the cusp by the frequency of 3.25 MHz and two Es layers of different types are observed.

foEs = 4.0 MHz and 3.6 MHz

Interpretation : The lowest frequency 3.45 MHz of the h type Es trace is the real foE. In this case the c type Es of 3.3 - 3.6 MHz is blanketing in the vicinity of foE. The interpretation given for Case 5 is also applicable to this case.

foE = 345UA

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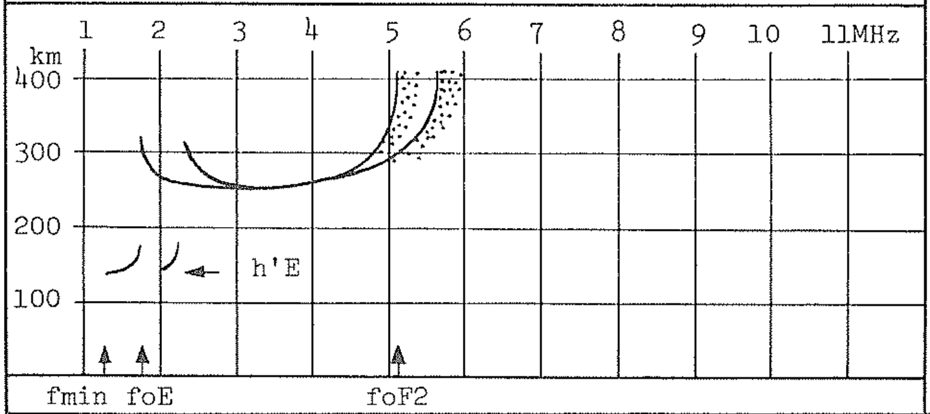
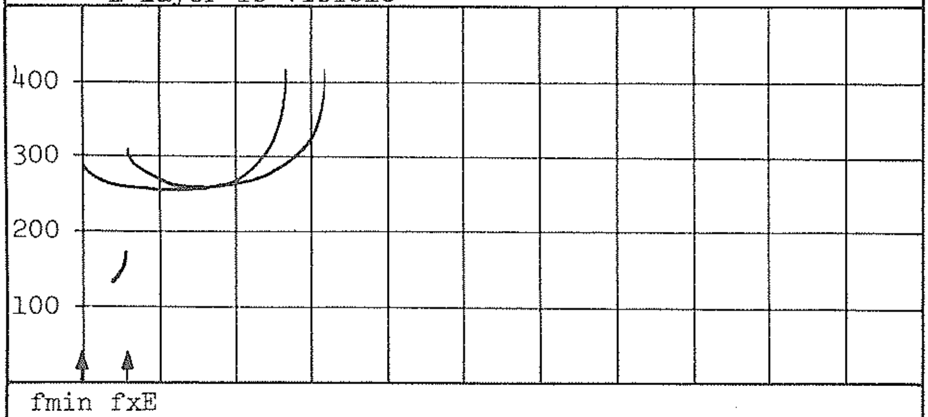
foE – 5

⑰ The particle E layer is appearing



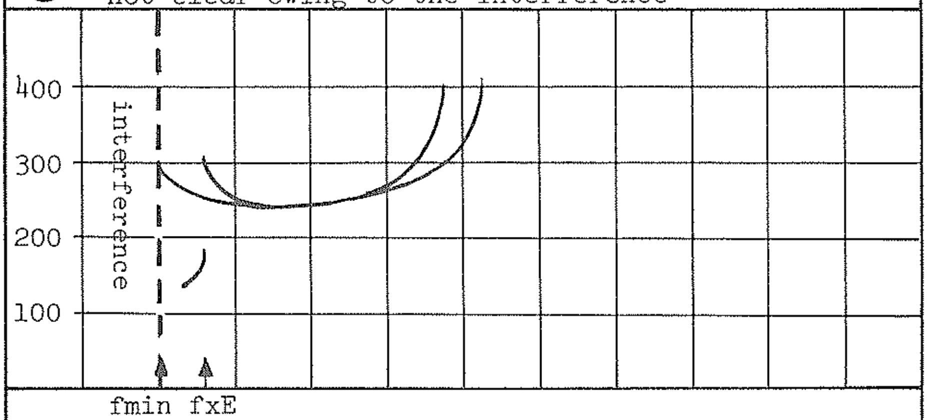
fmin	13
foE	170K
h'E	135K
foEs	17K
fxEs	23K
h'Es	135K
Es type	kl
fbEs	17K
foFl	
h'F	250
h'F2	
foF2	51F
fxI	60

⑱ Only the extraordinary component of the particle E layer is visible



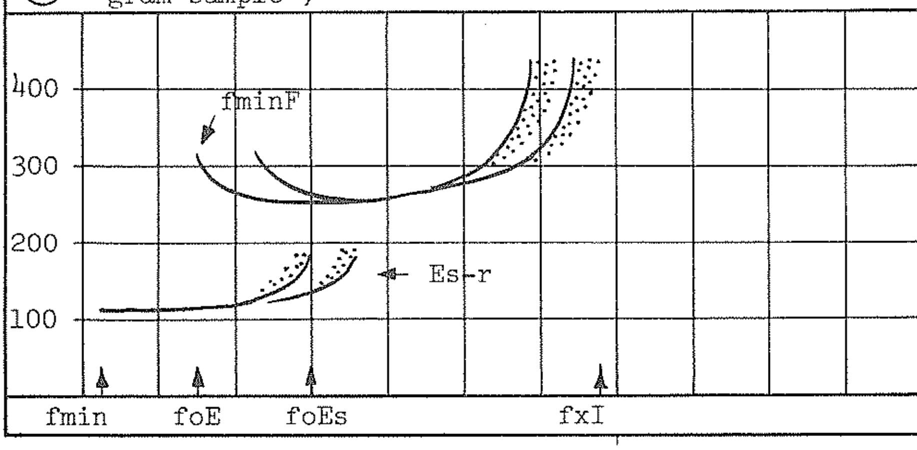
fmin	10EE
foE	090JK
h'E	E
foEs	09JK
fxEs	15K
h'Es	E
Es type	kl
fbEs	09K
foFl	
h'F	255
h'F2	
foF2	36
fxI	42X

⑲ The ordinary component of the particle E layer is not clear owing to the interference



fmin	20ES
foE	200JK
h'E	S
foEs	20JK
fxEs	26K
h'Es	S
Es type	kl
fbEs	20K
foFl	
h'F	240
h'F2	
foF2	57
fxI	63X

⑳ The r type Es is appearing (High latitude ionogram sample)



fmin	12
foE	250UK
h'E	A
foEs	40F
fxEs	46F
h'Es	110
Es type	rlkl
fbEs	25UK
foFl	
h'F	250
h'F2	
foF2	69F
fxI	77

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(17) Observation : Ionogram at night. The particle E layer (foE = 1.70 MHz) is observed. h'E= 135 km. The F layer traces are weakly spread near the critical frequency.

Interpretation : The particle E layer is produced by the precipitating particles into the lower atmosphere during ionospheric disturbances, showing larger virtual height than that of the normal E layer. foE usually agrees with fminF.

foE = (foE)K = 170K

Comment : The letter K stands for the particle E layer. When the particle E layer appears, foE and h'E should be written in the tabulation sheet.

(18) Observation : The F layer trace is appearing from the lowest frequency (1.0 MHz) of the ionosonde. The trace at 135 km in the E region seems to be the extraordinary wave.

Interpretation : Judging from the retardation of the low frequency part of the F layer trace, the trace in the E region is interpreted as the particle E layer. This case is substantially the same as Case 17 with the frequency scale shifted slightly. The value of fxE subtracted by fB/2 (about 0.6 MHz) is marked with the letter JK.

foE = (fxE - fB/2) = 090JK

Comment : Both the descriptive letter K (particle E layer) and E (less than the lowest frequency) are applicable. But the priority is given to K rather than E. Concerning the separation between foE and fxE, see Definition of foE on p.10.

(19) Observation : The extraordinary wave trace from a thick layer is observed at a height of about 140 km. Traces below 2.0 MHz can not be observed owing to the interference.

Interpretation : Judging from the retardation of the lower part of the F layer traces, the trace in the E region must be the extraordinary component of the particle E layer. This case is also almost same as Case 18, when the interference is supposed to be at lowest limit of Case 18. The procedure of scaling is the same as Case 18.

foE = (fxE - fB/2)JK = 200JK

Comment : When the retardation of the F layer ordinary trace is clear, foE (particle E layer) may be scaled from this frequency.

foE = (fminF)UK = 200UK

(20) Observation : The r type Es is observed in the E region. Weak spreads are visible both in the Es and F layer traces.

foEs = 4.0 MHz

Interpretation : As the penetration frequency of E region traces exceeds the lowest frequency of F layer traces, the E region trace should be the r type Es. The retardation near fminF stands for the existence of underlying particle E layer. Therefore, it can be interpreted that the particle E layer is blanketed by the r type Es.

fbEs = (fminF)UK = 25UK

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Note

h'E

@ Definition : h'E means the minimum virtual height of the normal E-layer.

@ Scaling accuracy :

h'E is scaled with an accuracy of 2 km (see R.H. p.30 section 2.13).

@ Indication of scaled value :

h'E is indicated by a numerical value and/or letters. The letter is used according to the accuracy rule (see p. 3) as usual.

(Examples)

B --- No numerical value can be obtained, being affected by absorption.

100C --- C is the descriptive letter (trouble with ionosonde).

115UC --- U is the qualifying letter (doubtful).

@ Notices for scaling :

1. When the accuracy of height markers is worse than ± 5 km, h'E should not be scaled numerically.
2. h'E must be scaled when foE is scaled (for the whole daytime and in the presence of the particle E-layer even at night), keeping in mind that foE and h'E are not necessarily numerical values only.
3. The minimum virtual height of a reflected wave is scaled from the horizontal part of trace. In cases, however, where there is no horizontal part, or the trace is blanketed by an underlying layer (Es), the scaled value should be expressed with appropriate qualifying and/or descriptive letters in accordance with the accuracy rule (see p. 3).
4. When the particle E layer is observed, h'E is also accompanied by the descriptive letter K (see Cases 17 - 20 of foE).

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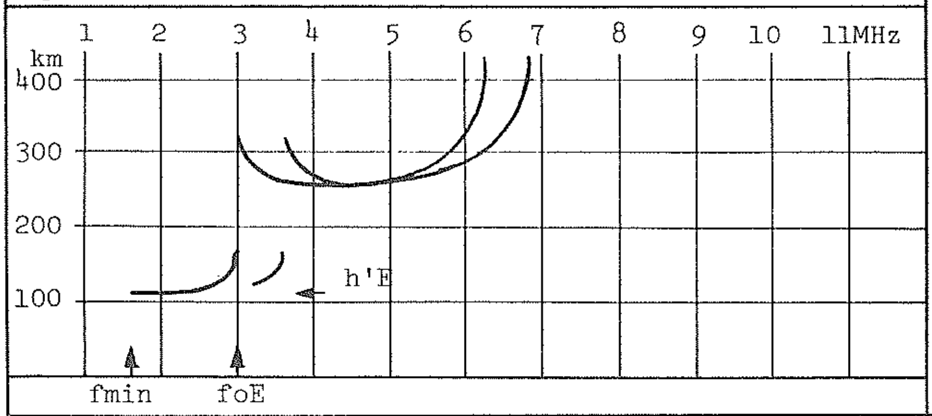
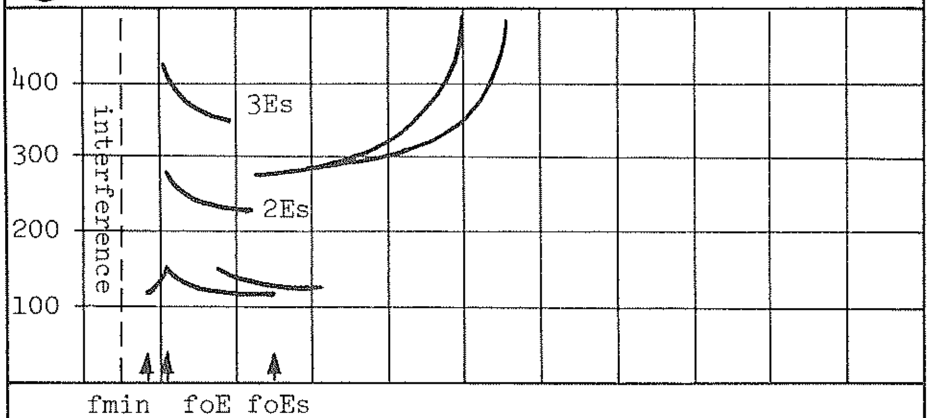
(1) Normal ionogram



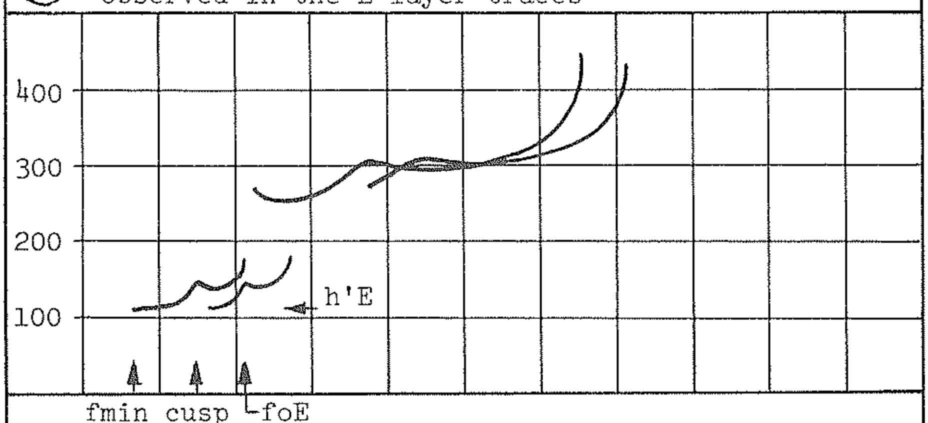
fmin	16
foE	300
h'E	110
foEs	30EG
fxEs	
h'Es	G
Es type	
fbEs	30EG
foF1	
h'F	255
h'F2	
foF2	63
fxI	

(2) Trace is not horizontal near fmin



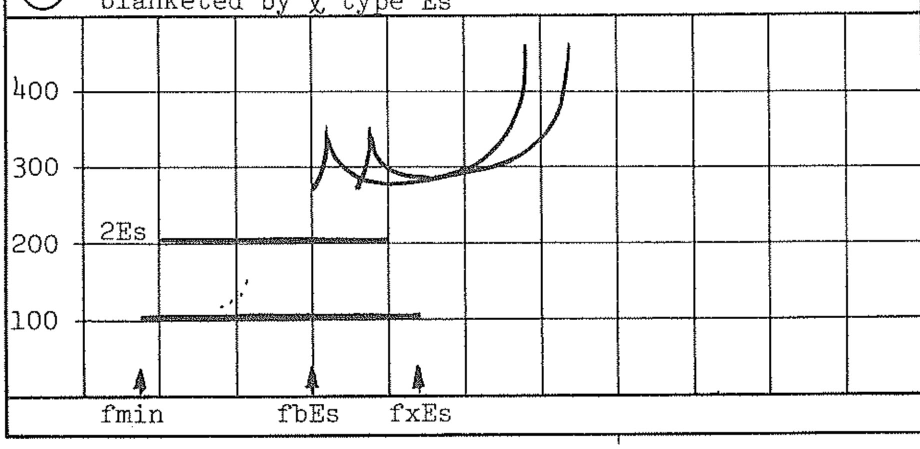
fmin	18
foE	205
h'E	120EB
foEs	35
fxEs	41
h'Es	115
Es type	c3
fbEs	32
foF1	
h'F	270A
h'F2	
foF2	60
fxI	

(3) Cusps due to underlying stratification are observed in the E layer traces



fmin	16
foE	310H
h'E	110H
foEs	G
fxEs	
h'Es	G
Es type	
fbEs	G
foF1	48UL
h'F	255
h'F2	295
foF2	75
fxI	

(4) Traces of E layer and lower part of F1 layer are blanketed by ℓ type Es



fmin	18
foE	A
h'E	A
foEs	48JA
fxEs	54
h'Es	100
Es type	ℓ2
fbEs	40
foF1	42
h'F	A
h'F2	275
foF2	68
fxI	

(1) Observation : Normal ionogram in the daytime. No Es traces are observed.

Interpretation : h'E is scaled from the lowest part of E layer trace which is almost horizontal.

h'E = 110

(2) Observation : Interference is severe up to 1.5 MHz. E region traces are observed from 1.8 MHz. Es of c type is observed up to 3rd order reflection.

Interpretation : Normal E layer trace shows the retardation. h'E is expressed by the lowest height observed, together with the qualifying letter E (less than) and descriptive letter B (absorption). h'E = 120EB

Comment : If there is interference up to 1.8 MHz, S is used instead of letter B.

(3) Observation : In the vicinity of 2.5 MHz on the trace of ordinary wave component of normal E layer, other cusp than foE (3.10 MHz) is observed. No Es layer trace exists.

Interpretation : In the case where the cusp is close to fmin, h'E is possibly influenced. Therefore, the numerical value is followed by the descriptive letter H.

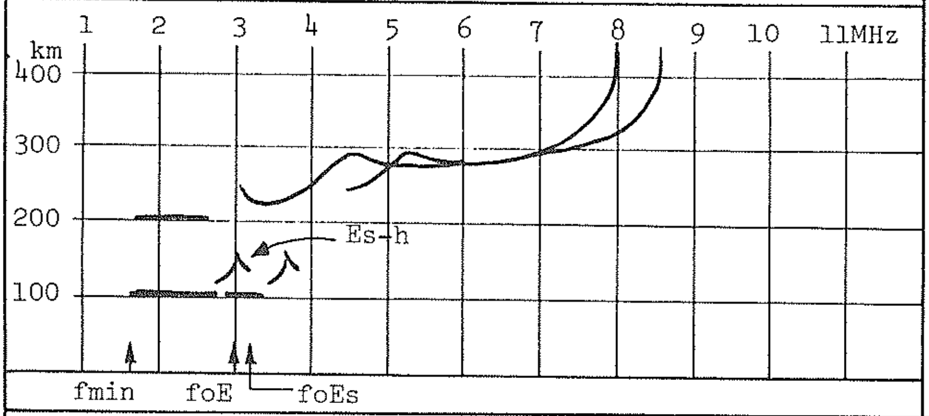
Comment : When the cusp is close to foE, i.e. h'E is not influenced by the presence of stratification, the descriptive letter H of h'E can be omitted but should be included on foE (see Case 2, p. 12).

(4) Observation : ℓ type Es is observed at the height of 100 km. Traces of normal E layer and of F1 layer below 4 MHz are not observed.

Interpretation : Since the ionogram is obtained at the time when foE is expected to be in the vicinity of 3.20 MHz, it is interpreted that normal E layer is blanketed by Es layer. Letter A is used.

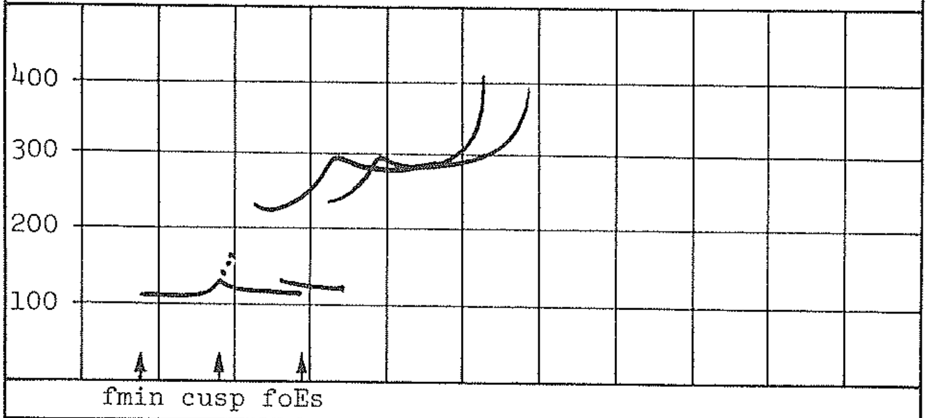
h'E = A

(5) The lower part of E trace is blanketed by ℓ type Es



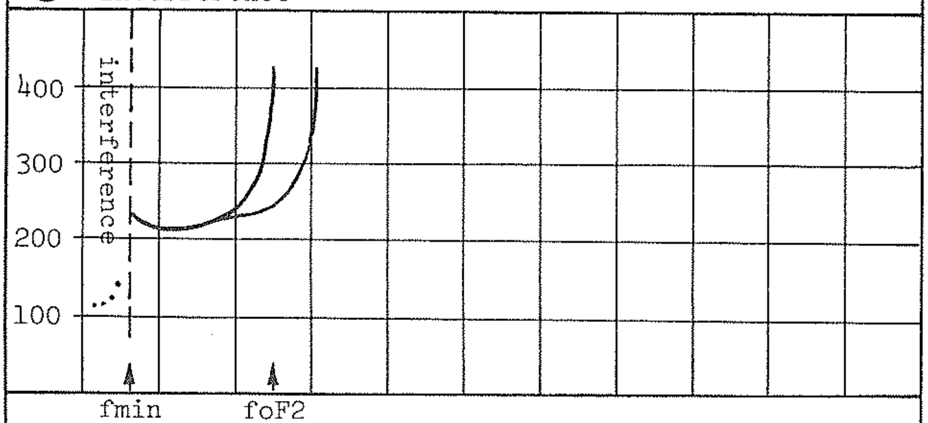
fmin	16
foE	300
h'E	120EA
foEs	32
fxEs	38
h'Es	140EG
Es type	h1ℓ2
fbEs	30EG
foF1	45UL
h'F	225
h'F2	275L
foF2	80
fxI	

(6) The vicinity of foE is blanketed by c type Es



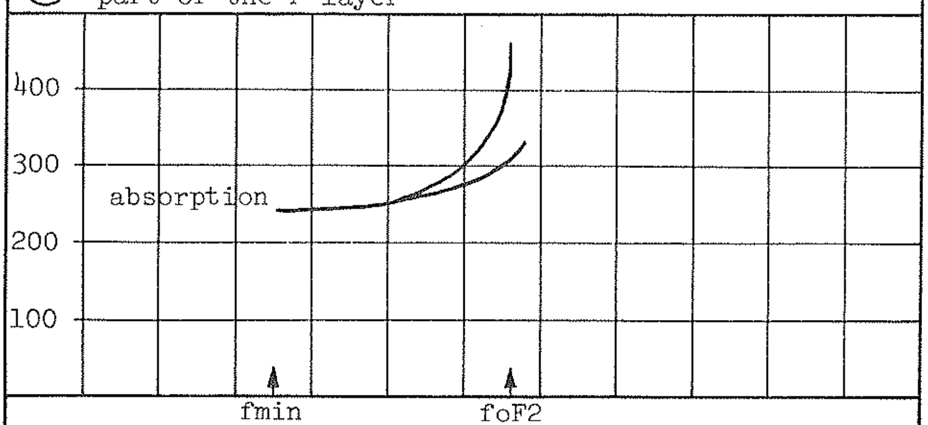
fmin	17
foE	A
h'E	110
foEs	39
fxEs	45
h'Es	115
Es type	c1
fbEs	32
foF1	43L
h'F	225
h'F2	280
foF2	63
fxI	

(7) E region traces are not observed owing to the interference



fmin	16ES
foE	S
h'E	S
foEs	16ES
fxEs	
h'Es	S
Es type	
fbEs	16ES
foF1	
h'F	210
h'F2	
foF2	35
fxI	

(8) No traces are observed from E region and the lower part of the F layer



fmin	35
foE	B
h'E	B
foEs	35EB
fxEs	
h'Es	B
Es type	
fbEs	35EB
foF1	
h'F	240
h'F2	
foF2	66
fxI	

(5) Observation : E layer traces below 2.7 MHz are blanketed by ℓ type Es.
foE = 3.00 MHz, foEs = 2.7 MHz (ℓ type).

Interpretation : Only a part of normal E layer trace is observed. Since the trace near 2.7 MHz is not horizontal, h'E is considered to be lower than 120 km. Therefore, the numerical value should be followed by the qualifying letter E and the descriptive letter A.

h'E = 120EA

Comment : When the influence of blanketing by Es layer is more significant only descriptive letter A is used.

h'E = A

For ℓ type Es layer, foEs = 27G, fbEs = 27G and h'Es = 100.

(6) Observation : The cusp near 2.8 MHz is related to foE but not foE itself.

The trace from 2.8 MHz to 3.9 MHz is of c type Es.

Interpretation : The cusp observed near 2.8 MHz is to be extended as dotted line to obtain foE. It is interpreted that the proximity of foE is blanketed by c type Es. Since the traces below 2.8 MHz are of normal E layer, h'E can be scaled by numerical value.

h'E = 110

(7) Observation : This kind of ionogram is often observed early in the morning or after sunset. Below 1.6 MHz the traces are not clear owing to interference. Retardation is observed in the lower part of F layer traces.

Interpretation : Judging from the expected value of foE and from the retardation observed in the lower part of F layer traces, foE is considered to be near 1.50 MHz. Since, however, no information on h'E is obtained, it is expressed only by the symbol.

h'E = S

(8) Observation : In the region below 3.5 MHz no traces are recorded at all.

Interpretation : The ionogram seen at the time of absorption. Since it is interpreted that all echoes from E region including the interference are influenced by fairly strong absorption, the letter B is used.

h'E = B

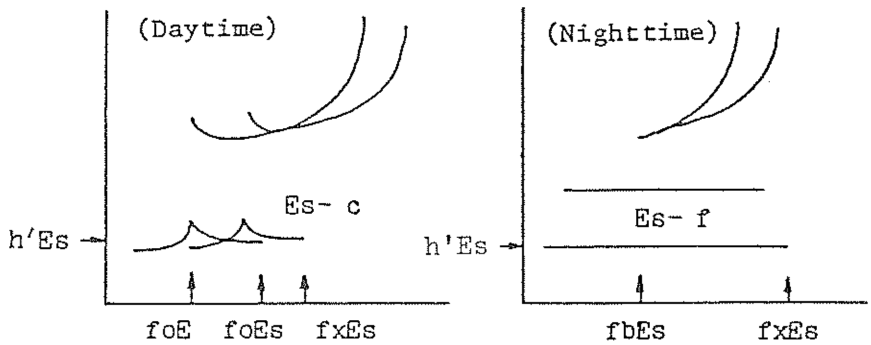
Comment : Descriptive letters are properly used according to the causes of disappearance of traces (e.g. C for Ionosonde trouble, S for interference, etc.).

foEs, h'Es

@ Definition : foEs is the top frequency of the ordinary wave component of continuous Es traces.

The Es-layer is a thin layer which shows rapid change and is observed in the height range from about 100 km to 170 km. In this region, any traces which cannot be clearly identified as the normal E layer or E2-layer should be always treated as Es reflections.

h'Es (the minimum height of the Es layer) is the lowest virtual height of the trace from which foEs is scaled.



@ Scaling accuracy :

foEs is scaled with an accuracy of 0.1 MHz (e.g. 5.3 MHz).

h'Es is scaled at the accuracy of 2 km (see R.H. p.30, section 2.13).

@ Indication of scaled value :

foEs is expressed by a numerical value and/or letters.

(Examples)

30EG --- Es layer traces are not seen in the condition that the normal E layer is observed (Daytime). It is interpreted that Es is embedded in the normal E layer (foE = 3.0 MHz).

16ES --- E is the qualifying letter and S is the descriptive letter.

52JA --- J is the qualifying letter and A is the descriptive letter.

h'Es is expressed by a numerical value and/or letters.

(Examples)

S --- The numerical value cannot be obtained owing to the interference.

150EG --- E is the qualifying letter and G is the descriptive letter.

@ Notices for scaling :

1. foEs and h'Es should be scaled over the whole day.

2. The following characteristics should be referred to in identifying the presence of an Es trace:

(1) Since Es is a thin layer, no retardation is usually observed (except r and k type in high latitudes or at mid-latitudes under disturbed conditions) near its critical frequency.

(2) Es layer traces are usually observed in the height range from 100 km to 150 km. But the height occasionally exceeds 150 km in the case of h type Es.

(3) Es layer is classified into one of 11 types in which ℓ, c, h and f types are generally observed in the middle latitudes.

These types of Es appear sometimes independently or simultaneously.

3. h'Es should be scaled at the lowest height where Es layer trace becomes horizontal.

@ Scaling rules of Es trace :

1. Traces caused by oblique reflections should be ignored.

2. Scaling should not be based on very weak and intermittent traces.

3. Short-lived or rapidly changing phenomena like the meteor echoes are not to be scaled. In identifying those, several sequential ionograms should be cross-checked.

4. The values of foEs, fbEs and h'Es are scaled from the trace having the highest frequency.

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5. When Es traces of different types appear simultaneously, respective foEs and h'Es are scaled type by type. In this case, the scaling is made in order of the critical frequency, and if the frequency is same the priority is given to the greater virtual height.

6. The auroral and retardation type Es are scaled regardless of the above rules 1-3 even when no overhead reflection is present.

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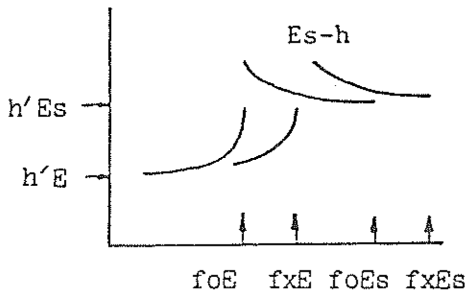
How to distinguish between foEs and fxEs

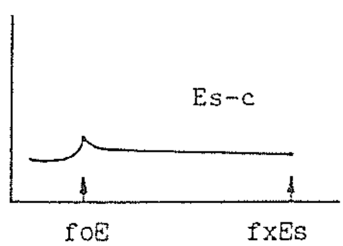
In scaling Es traces, difficulty often arises in identifying foEs (ordinary wave critical frequency of Es layer). As a matter of fact, the ordinary and extraordinary components of f or ℓ type Es traces cannot usually be distinguished. In this case, the value of foEs is deduced by subtracting fB/2 (≒0.6 MHz in the middle latitudes) from ftEs (top frequency of the Es layer), assuming that the echo having the highest frequency is the extraordinary component.

As shown in the figure, the distinction of Es layer traces appearing together with the normal E layer traces is not so difficult (in the case of h type and c type).



In most cases, however, the ordinary and extraordinary components of the Es layer traces overlap each other at the same height and so it cannot be simply decided which component gives ftEs.

The interpretation of ftEs is to be made according to the processes shown in Cases 7-16.



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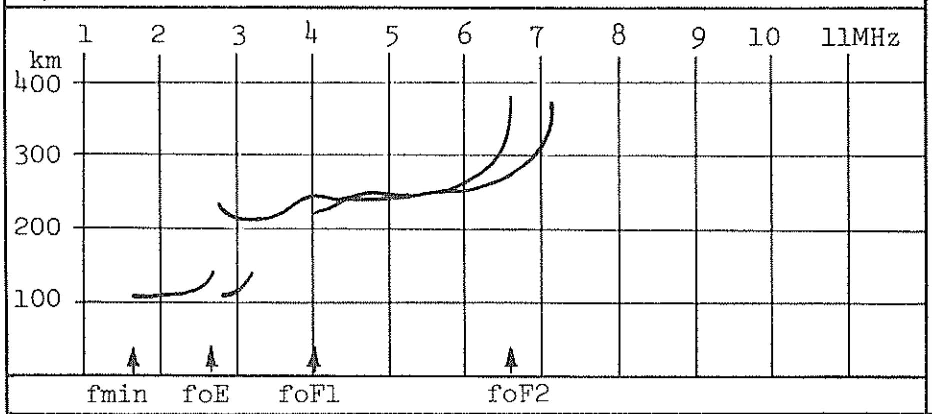
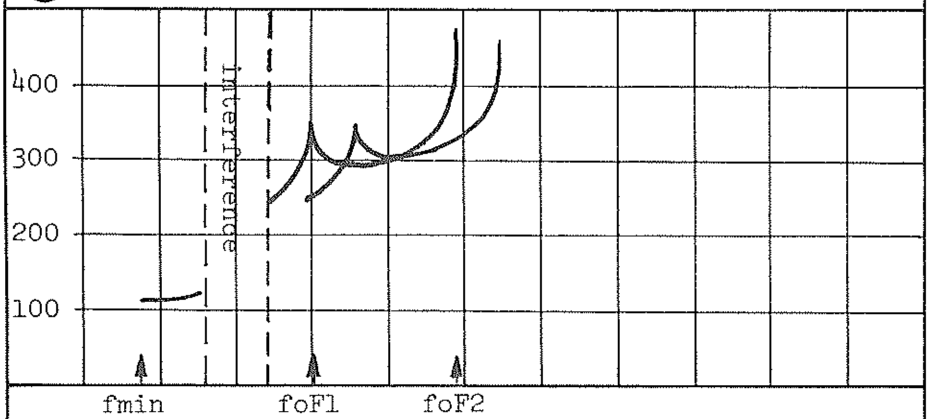
foEs h'Es – 1

① Es layer is not observed (Daytime)



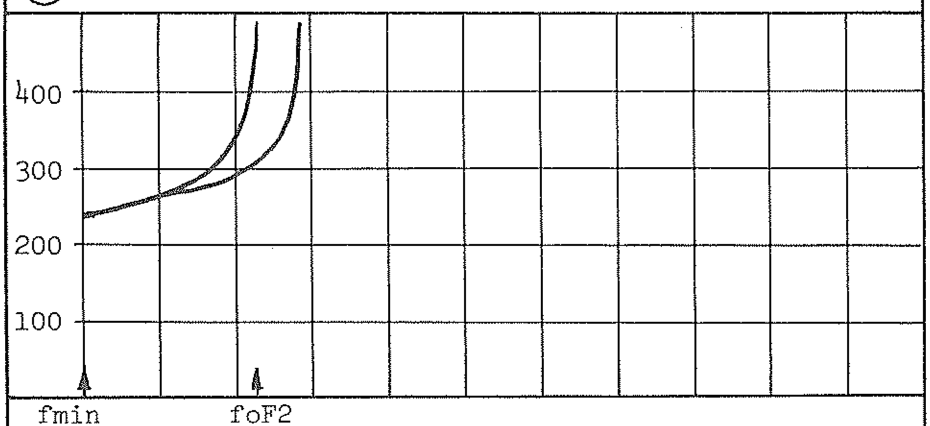
fmin	16
foE	270
h'E	105
foEs	27EG
fxEs	
h'Es	G
Es type	
fbEs	27EG
foF1	L(40)
h'F	210
h'F2	240
foF2	66
fxI	

② Es layer is not observed (Daytime)



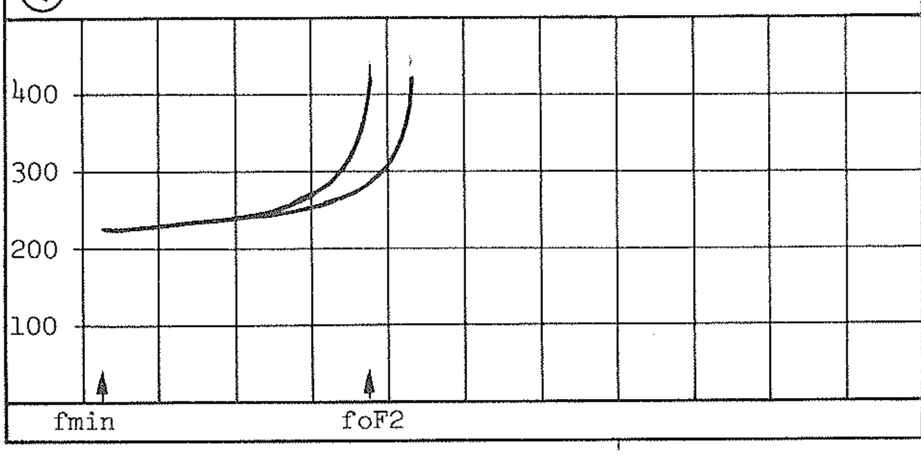
fmin	17
foE	S
h'E	110
foEs	G
fxEs	
h'Es	G
Es type	
fbEs	G
foF1	40
h'F	245ES
h'F2	290
foF2	59
fxI	

③ Es layer is not observed (Nighttime)



fmin	10EE
foE	
h'E	
foEs	10EE
fxEs	
h'Es	E
Es type	
fbEs	10EE
foF1	
h'F	240EE
h'F2	
foF2	33
fxI	39X

④ Es layer is not observed (Nighttime)



fmin	13
foE	
h'E	
foEs	13EB
fxEs	
h'Es	B
Es type	
fbEs	13EB
foF1	
h'F	225
h'F2	
foF2	48
fxI	54X

(1) Observation : An ionogram to be observed usually in the daytime. Traces in E region (105 km) are of the normal E layer (foE = 2.70 MHz).

Interpretation : The ionosphere is considered to be quite normal. In the E region, only traces of the normal E layer are clearly observed and no trace of Es layer exists. In the lower part of F layer

foEs = (foE)EG

h'Es = G

(2) Observation : In the frequency range from 2.6 MHz to 3.4 MHz, traces are not clear owing to the interference. Traces in the E region (110 km) are of the normal E layer.

Interpretation : The value of foE cannot be scaled owing to the interference. But in cases where traces at 110 km are identified as the normal E layer, and where Es layer is not observed even by referring to ionograms obtained before and after the time concerned the letter G is applied for all the scaling parameters of Es. The letter S is suitable for other cases.

foEs = G

(3) Observation : An ionogram at night. Only F layer traces are observed from 1 MHz (the lowest frequency of ionosonde). No trace exists in the E region.

Interpretation : Since F layer traces appear from the lowest frequency of ionosonde, it is interpreted that foEs is less than this frequency.

foEs = (fmin)EE

h'Es = E

Comment : The use of descriptive letter E is limited to the nighttime.

(4) Observation : An ionogram at night. fmin (1.3 MHz) is scaled from F layer traces. No trace exists in the E region.

Interpretation : If the ionosonde works normally, the cause of no echo below 1.3 MHz is ascribed to the absorption of ionosphere. Therefore, descriptive letter B is used.

foEs = (fmin)EB = 13EB

h'Es = B

Comment : When the cause is ascribed to the interference, see Case 5.

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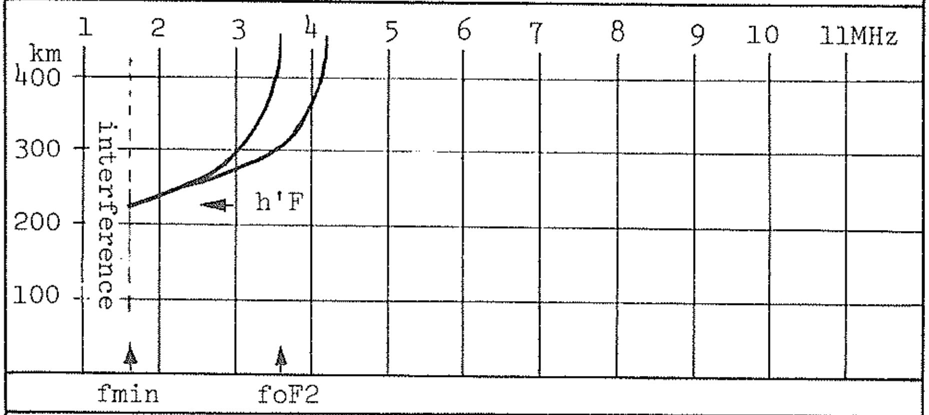
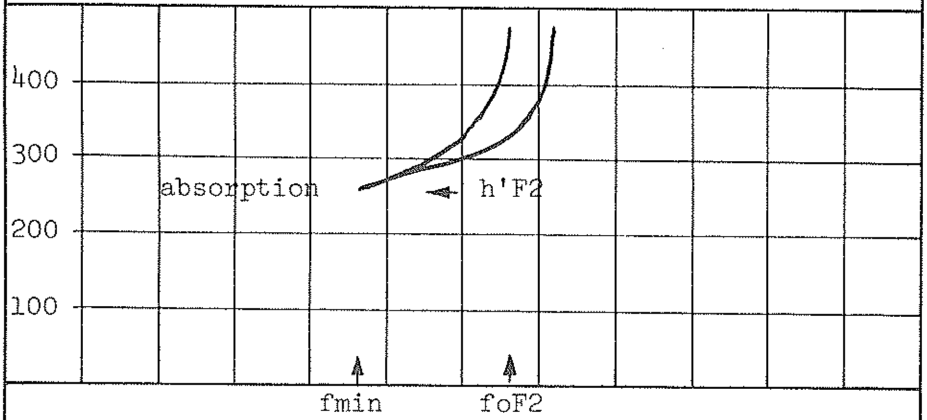
⑤ No Es layer is observed (Nighttime)



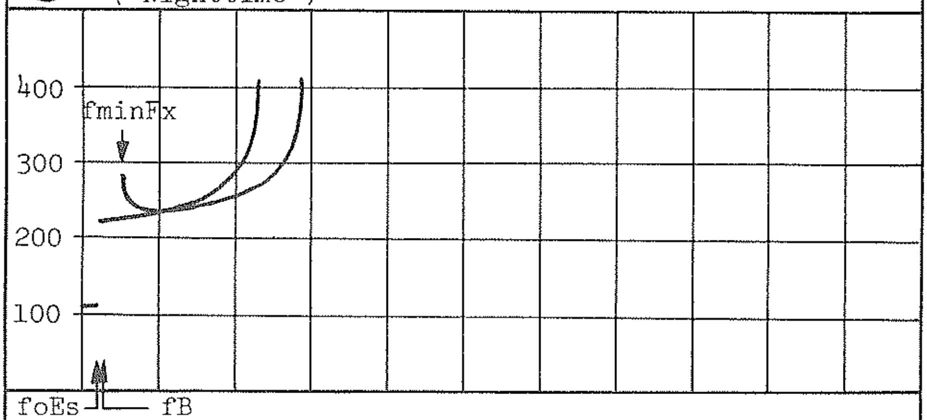
fmin	16ES
foE	
h'E	
foEs	16ES
fxEs	
h'Es	S
Es type	
fbEs	16ES
foF1	
h'F	220ES
h'F2	
foF2	36
fxI	42X

⑥ No Es layer is observed owing to absorption



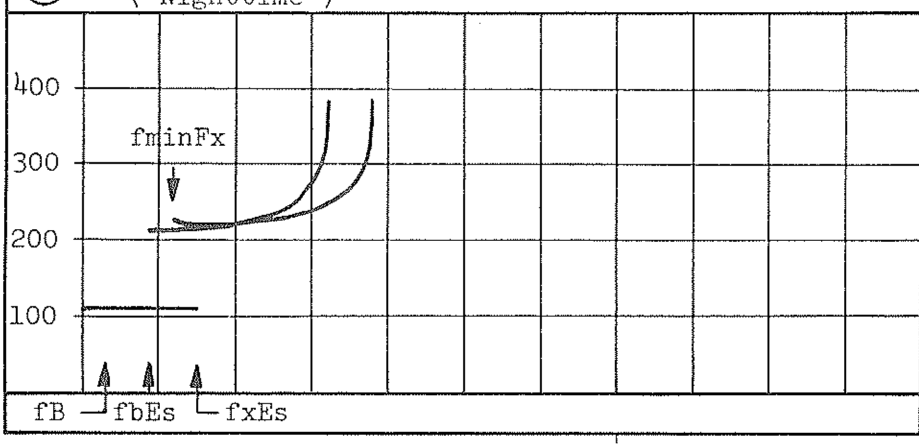
fmin	46
foE	B
h'E	B
foEs	46EB
fxEs	
h'Es	B
Es type	
fbEs	46EB
foF1	B
h'F	B
h'F2	255EB
foF2	66
fxI	

⑦ ftEs (top frequency of Es layer) is low (Nighttime)



fmin	10EE
foE	
h'E	
foEs	12
fxEs	
h'Es	110
Es type	f1
fbEs	12
foF1	
h'F	220
h'F2	
foF2	33
fxI	39X

⑧ ftEs is higher than fB (gyro frequency) (Nighttime)



fmin	10EE
foE	
h'E	
foEs	19JA
fxEs	25
h'Es	110
Es type	f1
fbEs	19
foF1	
h'F	210
h'F2	
foF2	42
fxI	48X

(5) Observation : An ionogram at night. Traces below 1.6 MHz are not clear owing to severe interference.

Interpretation : MF broadcast interference as shown in the figure is recorded usually on ionograms obtained at midlatitude stations during nighttime hours. This type of ionogram is frequently seen during dark hours except those from midnight to dawn when the BC stations stop their services. The descriptive letter expressing the cause of lack of traces should be used in the same way as fmin. h'Es would usually be only the letter.

foEs = (fmin)ES = 16ES

h'Es = S

Comment : If the cause is the trouble with the ionosonde, C is used instead of the letter S.

(6) Observation : In the frequency range below 4.6 MHz, no traces are observed.

Interpretation : Malfunction, interference and absorption can be considered as the cause of disappearance of traces. This figure refers to the absorption which occurs mainly in the daytime and sometimes lasts for several hours. The absorption condition can be easily distinguished from others, since it makes weak both the interference and the echoes. Es traces are interpreted to be below fmin.

foEs = (fmin)EB = 46EB

h'Es = B

Comment : In the case where the traces are not observed at all owing to the absorption, all the parameters are expressed by the symbol B.

(7) Observation : An ionogram at night. The top frequency of Es layer (ftEs) is 1.2 MHz.

Interpretation : In the lower part of F layer traces the extraordinary component (fminFx) is also observed. Since f type Es traces extending up to 1.2 MHz are observed from the lowest frequency of ionosonde, there would be almost no absorption. When the value of ftEs is small, foEs should be determined in comparison with fB. In this case, since ftEs is smaller than fB, ftEs = foEs.

foEs = 12 h'Es = 110

Comment : fB: gyro-frequency (the frequency at which the electrons gyrate around the geomagnetic field). The value of fB varies depending on the location of the station and the ionospheric height concerned. In middle latitudes, it is about 1.2 MHz.

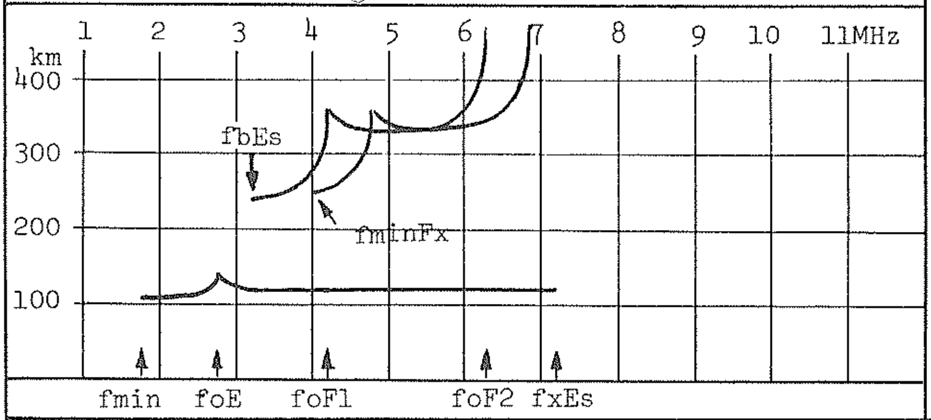
(8) Observation : An ionogram at night. The top frequency of f type Es (ftEs) is 2.5 MHz.

Interpretation : Since Es layer traces are observed from the lowest frequency of ionosonde, the absorption should be small. In this case, since ftEs is much larger than fB, ftEs = fxEs.

foEs = (fxEs - fB/2)JA = 19JA

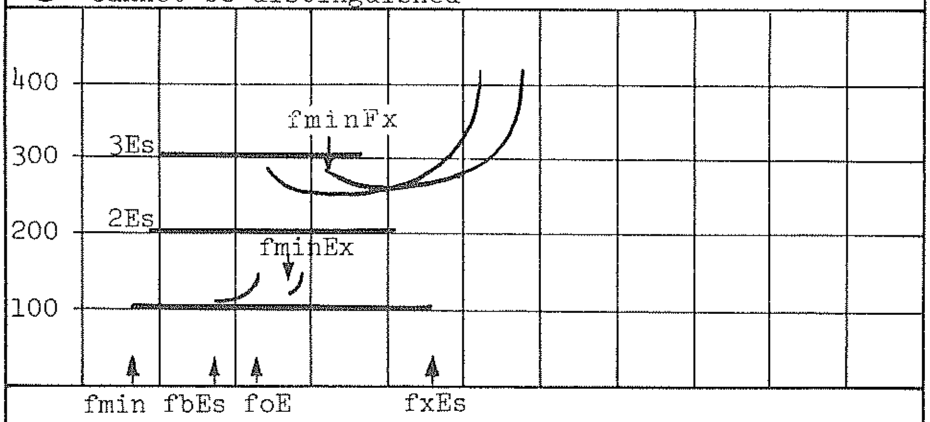
h'Es = 110

(9) Near ftEs, ordinary and extraordinary components cannot be distinguished



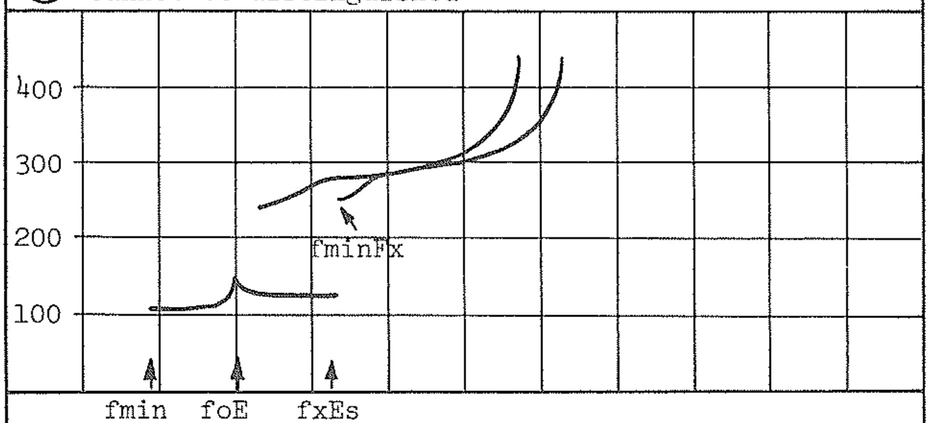
fmin	17
foE	275
h'E	110
foEs	66JA
fxEs	72
h'Es	115
Es type	cl
fbEs	32
foF1	42
h'F	240
h'F2	330
foF2	63
fxI	

(10) Near ftEs, ordinary and extraordinary components cannot be distinguished



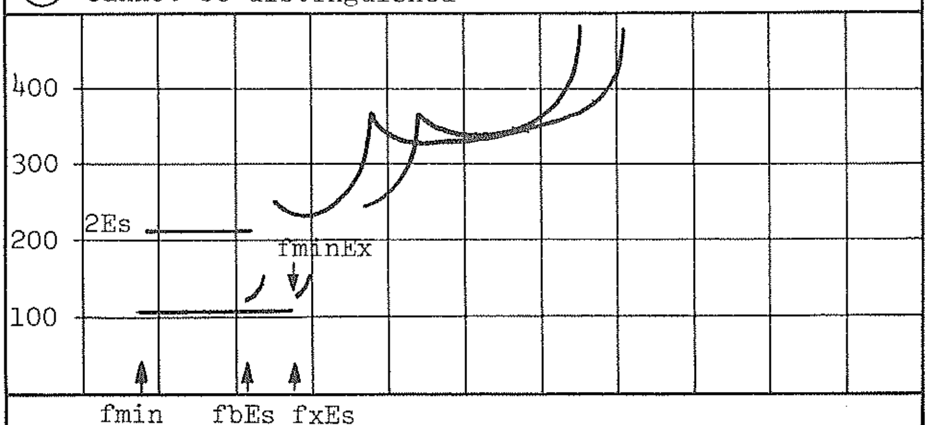
fmin	16
foE	330
h'E	110A
foEs	50JA
fxEs	56
h'Es	100
Es type	ℓ3
fbEs	27G
foF1	
h'F	250
h'F2	
foF2	62
fxI	

(11) Near ftEs, ordinary and extraordinary components cannot be distinguished



fmin	19
foE	300
h'E	105
foEs	37JA
fxEs	43
h'Es	125
Es type	cl
fbEs	33
foF1	L(42)
h'F	240
h'F2	275L
foF2	67
fxI	

(12) Near ftEs, ordinary and extraordinary components cannot be distinguished



fmin	17
foE	340
h'E	120EA
foEs	31JG
fxEs	37
h'Es	105
Es type	ℓ2
fbEs	31G
foF1	48
h'F	230
h'F2	325
foF2	75
fxI	

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(9) Observation : The c type Es is observed. ftEs = 7.2 MHz. The lower part of F1 traces is blanketed by the Es layer.

Interpretation: Since the ordinary and extraordinary components of Es trace overlap each other near ftEs, they cannot be distinguished. foEs should be identified in comparison with the lowest frequency of the extraordinary component (fminFx) of a higher trace. In this case, ftEs is larger than fminFx and so ftEs is fxEs.

foEs = (fxEs - fB/2)JA = 66JA

h'Es = 115

(10) Observation : The ℓ type Es is observed up to the 3rd order reflection. ftEs = 5.6 MHz. This ℓ type Es is blanketing the lower part of normal E layer.

Interpretation : It is not clear whether ftEs of ℓ type Es is ordinary or extraordinary component. Being based on the same principle as in Case 9, the lowest frequency of E layer trace extraordinary component (fminEx) is compared with ftEs. Since ftEs is much larger than fminEx and fminFx, ftEs should be identified as fxEs.

foEs = (fxEs - fB/2)JA = 50JA

h'Es = 100

(11) Observation : ftEs of the c type Es observed is 4.3 MHz.

Interpretation : Ordinary and extraordinary components of Es layer cannot be distinguished. It is to be interpreted in the same way as in Case 9. Since ftEs is equal to fminFx, ftEs = fxEs.

foEs = (fxEs - fB/2)JA = 37JA

h'Es = 125

(12) Observation : ftEs of ℓ type Es is 3.7 MHz and 2nd order reflection is observed. Traces of F1 and F2 layers are normally observed.

Interpretation : The interpretation given in Case 11 is also valid for this case. Since ftEs of ℓ type Es is equal to fminEx, ftEs = fxEs. In this figure, since foEs is smaller than foE, the descriptive letter G is applied.

foEs = (fxEs - fB/2)JG = 31JG

h'Es = 105

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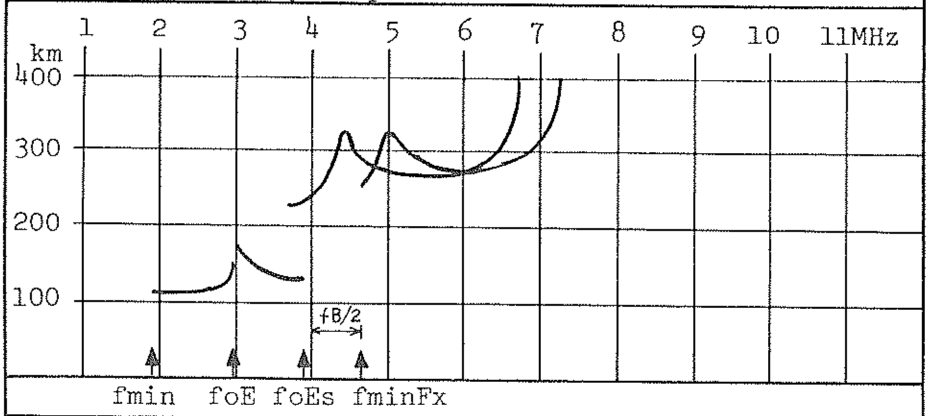
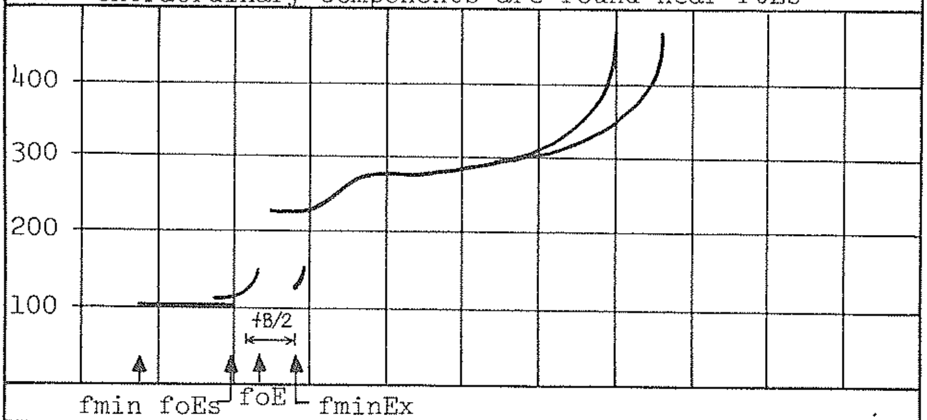
foEs
h'Es – 4

(13) No signs for distinguishing between ordinary and extraordinary components are found near ftEs



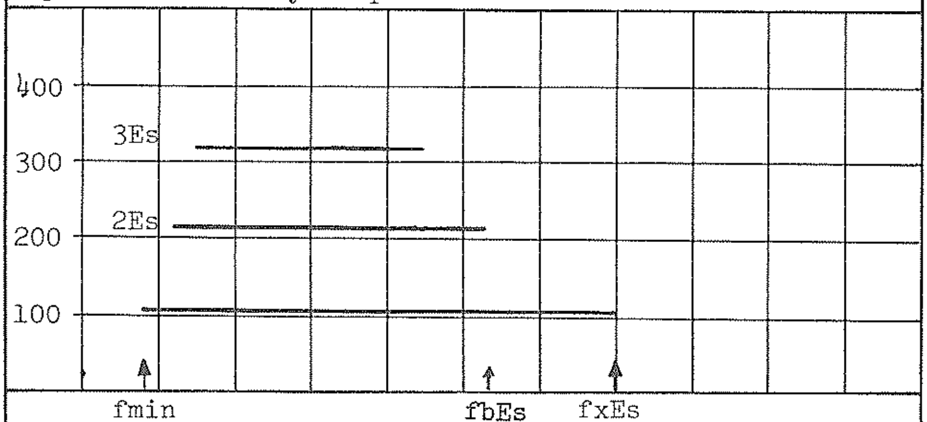
fmin	19
foE	295
h'E	110
foEs	39
fxEs	
h'Es	130
Es type	hl
fbEs	37
foFl	44
h'F	225
h'F2	260
foF2	67
fxI	

(14) No signs for distinguishing between ordinary and extraordinary components are found near ftEs



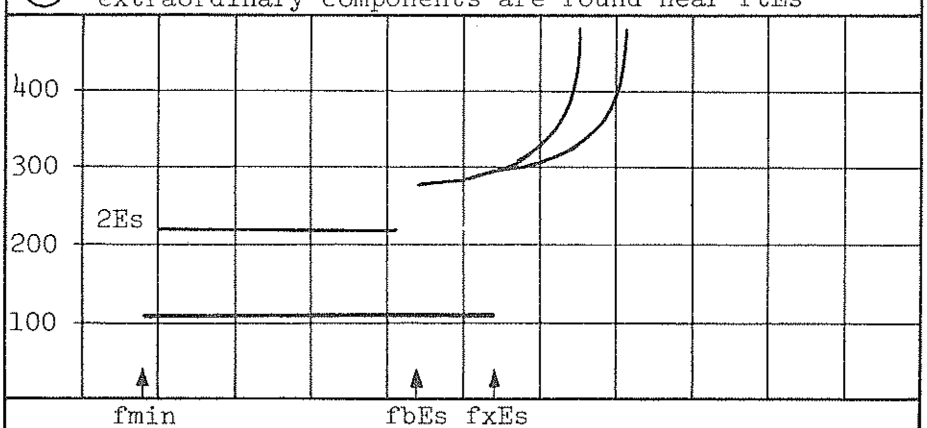
fmin	17
foE	335
h'E	110A
foEs	30G
fxEs	
h'Es	100
Es type	ℓ1
fbEs	27G
foFl	L(47)
h'F	225
h'F2	275
foF2	80
fxI	

(15) No signs for distinguishing between ordinary and extraordinary components are found near ftEs



fmin	18
foE	A
h'E	A
foEs	74JA
fxEs	80
h'Es	105
Es type	ℓ3
fbEs	63AA
foFl	A
h'F	A
h'F2	A
foF2	A
fxI	

(16) No signs for distinguishing between ordinary and extraordinary components are found near ftEs



fmin	18
foE	A
h'E	A
foEs	58JA
fxEs	64
h'Es	110
Es type	ℓ2
fbEs	54
foFl	A
h'F	A
h'F2	270A
foF2	75
fxI	

(13) Observation : The h type Es trace is tangential to the E layer trace at foE. ftEs = 3.9 MHz.

Interpretation : It is to be interpreted in the same way as in Cases 9 and 11. When ftEs and fminFx are compared, fminFx is larger than ftEs and the separation between them exceeds fB/2 (about 0.6 MHz). Hence, ftEs = foEs.

foEs = 39

h'Es = 130

(14) Observation : The ℓ type Es ftEs of which is equal to 3.0 MHz blankets the lower part of normal E layer trace.

Interpretation : foEs is determined by applying the interpretation of Case 13 to E region trace as follows: Since ftEs of ℓ type Es is smaller than the value (fminEx - fB/2), ftEs = foEs. Since this foEs is clearly smaller than foE, it is marked with the descriptive letter G.

foEs = 30G

h'Es = 100

Comment : When ftEs falls in a range between fminEx and (fminEx - fB/2), ftEs should be interpreted as fxEs. The descriptive letter G is necessary.

foEs = (ftEs - fB/2)JG = xxxJG

(15) Observation : The ℓ type Es layer trace extends up to 8.0 MHz and even the 3rd order reflection is observed. F layer trace is completely blanketed.

Interpretation : In the case of total blanketing, fminF cannot be obtained from the procedures as mentioned in Cases 7 - 14. It is interpreted that the F layer extraordinary component is blanketed by Es layer extraordinary component. Generally speaking, if both the absorption condition and the F layer are normal, ftEs = fxEs.

foEs = (fxEs - fB/2)JA = 74JA
h'Es = 105

Comment : The above interpretation cannot be applied to the case where the F layer electron density has been unusually reduced (foF2 is low) owing to the geomagnetic storm, for example.

(16) Observation : F layer trace below 5.4 MHz is blanketed by ℓ type Es. ftEs = 6.4 MHz.

Interpretation : The ordinary and extraordinary components overlap each other in the lower part of F layer trace. Therefore, it is impossible to identify the component of ftEs from fminFx. In this case it is necessary to apply the following rules to the Es trace itself:

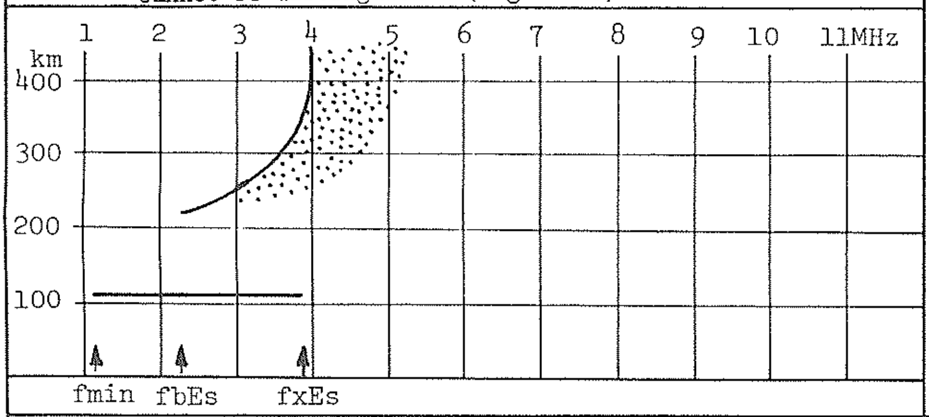
1. Absorption is small (fmin is low). ----- ftEs = fxEs
2. The ftEs is nearly equal to foEs (it is interpreted that the extraordinary component of Es layer trace is absorbed). ----- ftEs = foEs
3. The ftEs is much higher than foE (it is considered that extraordianry component exists naturally). ----- ftEs = fxEs

In Case 16, either 1 or 3 is applied.

foEs = (fxEs - fB/2)JA = 58JA
h'Es = 110

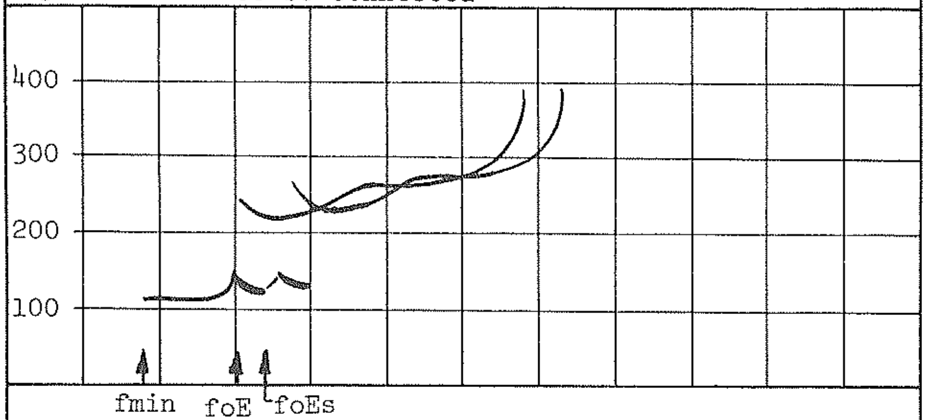
Ⓡ

(17) Near ftEs, ordinary and extraordinary components cannot be distinguished (Nighttime)



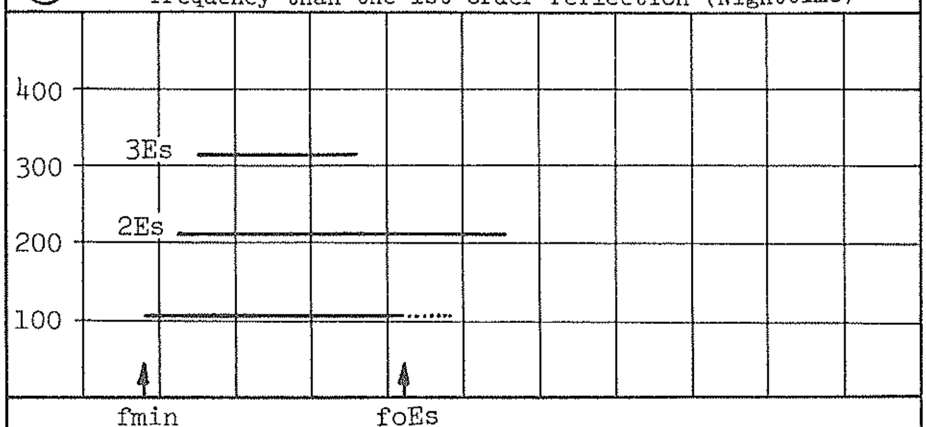
fmin	11
foE	
h'E	
foEs	33JA
fxEs	39
h'Es	110
Es type	f1
fbEs	23
foF1	
h'F	220EA
h'F2	
foF2	40F
fxI	52

(18) Es layer ordinary and E layer extraordinary traces are seen to be connected



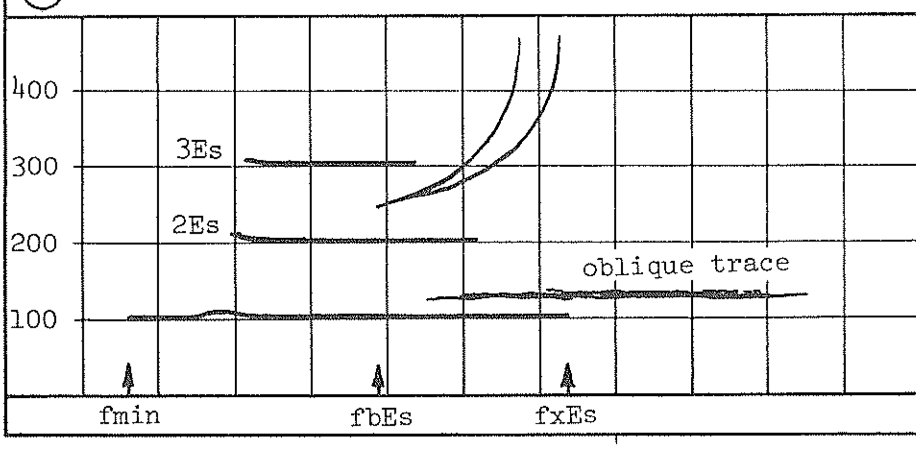
fmin	17
foE	300
h'E	110
foEs	34
fxEs	40
h'Es	120
Es type	c1
fbEs	30EG
foF1	L(47)
h'F	220
h'F2	265
foF2	68
fxI	

(19) The 2nd order reflection extends up to higher frequency than the 1st order reflection (Nighttime)



fmin	18
foE	
h'E	
foEs	52
fxEs	
h'Es	105
Es type	f3
fbEs	52AA
foF1	
h'F	A
h'F2	
foF2	A
fxI	A

(20) Oblique reflection trace is observed



fmin	16
foE	A
h'E	100
foEs	68JA
fxEs	74
h'Es	100
Es type	c3
fbEs	49
foF1	A
h'F	A
h'F2	250UA
foF2	67
fxI	

(17) Observation : The spreading of echoes are seen in F layer trace. The f type Es is observed. ftEs = 3.9 MHz.

Interpretation : The fminFx cannot be determined from F layer traces in this figure. In addition, since fmin is 1.1 MHz, it is considered that there is almost no absorption. Applying Rule 1 in Interpretation of Case 16, ftEs = fxEs.

foEs = (fxEs - fB/2)JA = 33JA

h'Es = 110

(18) Observation : The ordinary and extraordinary components of c type Es are observed separately.
foEs = 3.4 MHz, fxEs = 4.0 MHz.

Interpretation : This is a very common ionogram. As shown in the figure, discontinuity of trace at foEs which is deduced from fxEs is usually found by careful examination of trace.

foEs = 34

h'Es = 120

Comment : Attention should be paid to the case where the 2nd order reflection of Es layer sometimes overlap the F layer trace (see Case 11 of h'F).

(19) Observation : Multiple echoes of f type Es are recorded. The 2nd order reflection extending up to 6.6 MHz shows higher top frequency than that of the 1st order reflection.

Interpretation : It is found in ordinary ionograms that as the number of reflections increases the trace becomes weaker lowering the top frequency. Therefore, this ionogram seems to be affected by oblique reflections, although heights are consistent with overhead reflections.

foEs = 52

h'Es = 105

(20) Observation : The c type Es is seen up to the 3rd order reflection. fxEs = 7.4 MHz. Another trace is observed from 5.5 MHz to 10.6 MHz at a virtual height of 130 km.

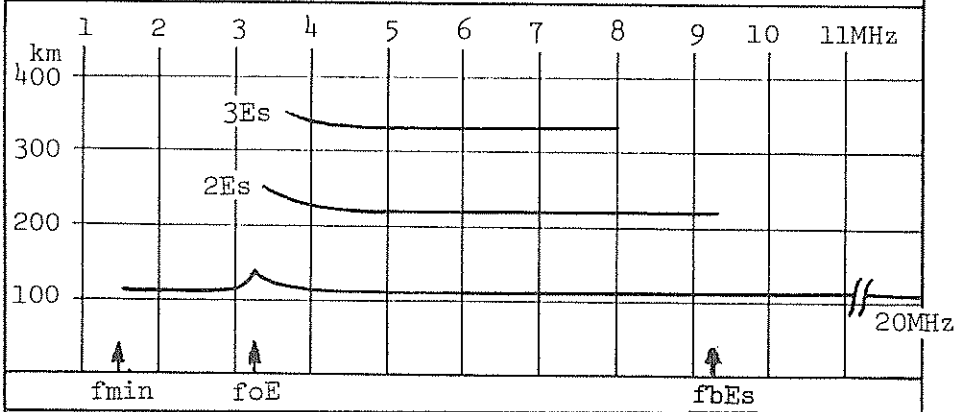
Interpretation : Multiple echoes of c type Es are regarded as vertically reflected ones from relative difference of the virtual height. Since the trace near 130 km which is observed neither before nor after the time of this ionogram shows slight spreading, this should be interpreted as an oblique reflection. Therefore, no scaling is necessary.

foEs = (fxEs - fB/2)JA = 68JA

h'Es = 100

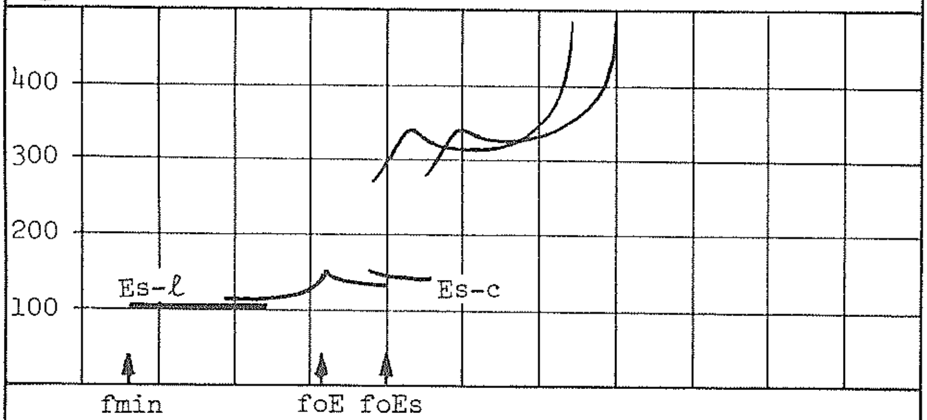
Ⓡ

(21) Es layer trace exceeds the upper frequency limit of ionosonde



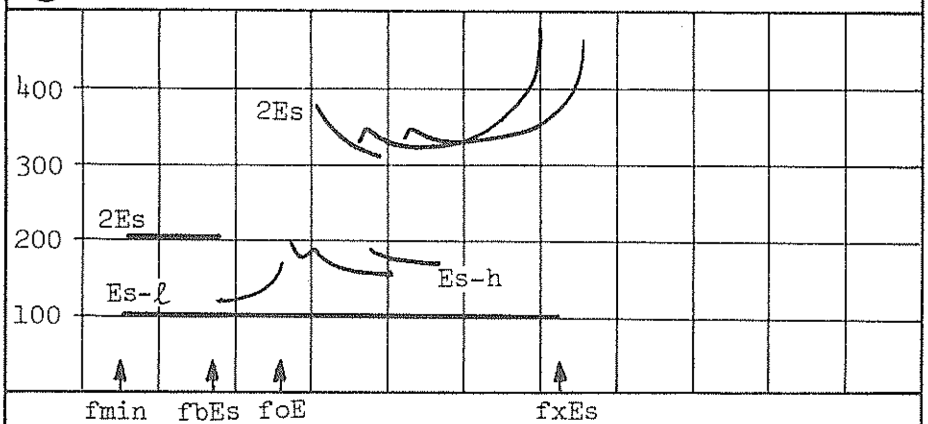
fmin	15
foE	320
h'E	110
foEs	200DD
fxEs	
h'Es	110
Es type	c3
fbEs	93AA
foF1	A
h'F	A
h'F2	A
foF2	A
fxI	

(22) Two types of Es are observed



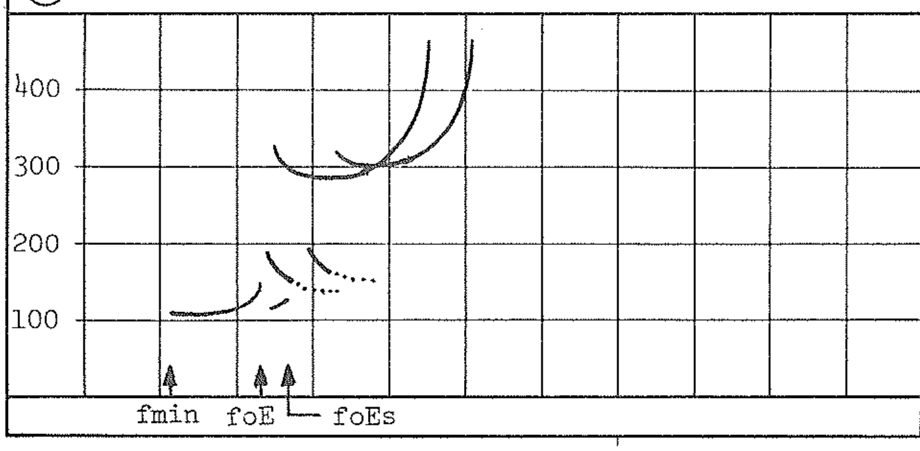
fmin	16
foE	415
h'E	115A
foEs	50
fxEs	56
h'Es	135
Es type	c1ℓ1
fbEs	48
foF1	54
h'F	A
h'F2	310
foF2	74
fxI	

(23) Two types of Es are observed



fmin	15
foE	360
h'E	120A
foEs	66JA
fxEs	72
h'Es	100
Es type	ℓ2 h2
fbEs	27G
foF1	47
h'F	A
h'F2	320
foF2	70
fxI	

(24) Es layer traces are not horizontal



fmin	210
foE	330
h'E	105
foEs	36
fxEs	42
h'Es	150EG
Es type	h1
fbEs	33EG
foF1	
h'F	280
h'F2	
foF2	55
fxI	

(21) Observation : Top frequency of c type Es exceeds the maximum frequency (see Comment) of ionosonde. F layer traces are entirely blanketed by Es layer (total blanketing).

Interpretation : In summertime (May-July in the Northern Hemisphere) when Es layer develops, this type of record is sometimes seen for more than one hour. In this case foEs is expressed referring to the upper frequency limit of ionosonde with the qualifying letter D (larger) and the descriptive letter D (exceeding the limit).

foEs = (upper frequency limit of ionosonde)DD = 200DD

h'Es = 110

(22) Observation : The ℓ type Es (h'Es = 100 km) blankets the lower part of normal E layer, while c type Es (h'Es = 135 km) blankets the lower part of F1 layer traces.

Interpretation : In this ionogram are observed two types of Es each of which has its own critical frequency. But the higher foEs should be scaled in the table as representative.

foEs = 50

h'Es = 135

Since foEs of ℓ type Es is lower than foE, the foEs is expressed with the descriptive letter G. foEs = 34G

(23) Observation : The h and ℓ types Es are recorded at the height of 155 km and 100 km respectively having the 2nd order reflections.

Interpretation : This type of ionogram is often seen in the season when the Es activity is large. The h type Es is likely to change into c type and then ℓ type, lowering the virtual height. Since the top frequency of ℓ type Es is the highest one, it is regarded as a representative value.

foEs = 66JA

h'Es = 100

For h type Es, foEs = 51, h'Es = 155 and fbEs = 46.

(24) Observation: Both components of h type Es are observed in clear separation, although horizontal parts of trace are missing.

Interpretation : In this case, when the Es trace does not become horizontal, the virtual height at foEs is qualified by letter U or E as required by the accuracy rules, and described by the letter G.

foEs = 36

h'Es = 150EG

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Classification of Es types

@ Es types :

Es traces are classified into one of 11 types. There are f, ℓ, c, h, q, r, a, s, d, n and k. Types to be observed at a station are not so many. The f, ℓ, c and h types are observed in the middle latitude, while a and r types are normally but not exclusively observed in the high latitude.

@ Classification :

1. All Es traces recorded in the ionogram should be classified with the identification of types.
2. The rules state that foEs, h'Es and fbEs should not be scaled from weak or oblique reflections. However, all Es types should be included in the table (e.g. d type Es or s type Es).
3. When the gain of ionosonde is low or when the type cannot be identified because of complexity of traces, the ionograms of high gain observation or the observation made within one hour should be referred to.

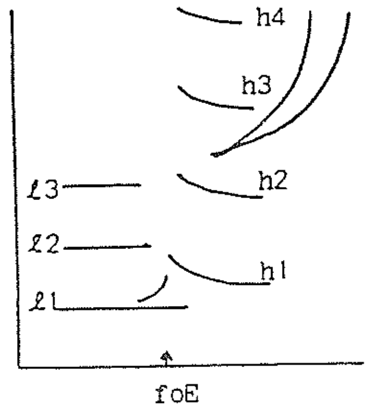
@ How to indicate Es types and multiple reflections :

1. The lower case letters should be used for Es types to be indicated in the scaling table.
2. When several kinds of Es types are seen in an ionogram, the type of trace from which the representative value of foEs is scaled should be indicated first. The types of the rest of Es traces are indicated in sequence of descending order of multiples.
3. In recording the types in the scaling table, they should be followed by the number (not exceeding 9) of multiple reflections (For details, see I.H. p. 179, Table 8.1).

[Example]

In the figure, h and ℓ types are seen up to 4 and 3 reflections respectively. Es type is expressed as follows:

h4ℓ3



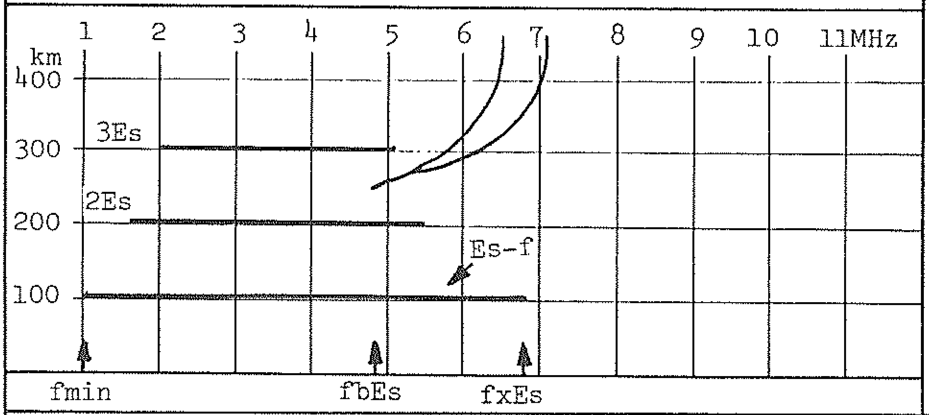
In the case of no multiple reflections, omission of the number of reflections is allowed excepting the tabulation for computer input.

For example: h4ℓ3

4. Each column of the scaling table has a space for 5 letters. This means that there is no space for the number of reflections of 3rd type of Es (e.g. h3c2ℓ). For details, see I.H. p.179 , Table 8.1.

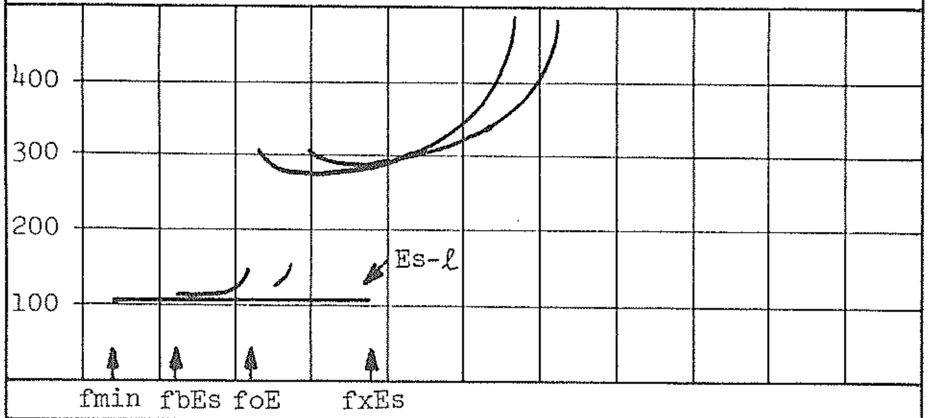
type of Es -1

① Es type f, flat



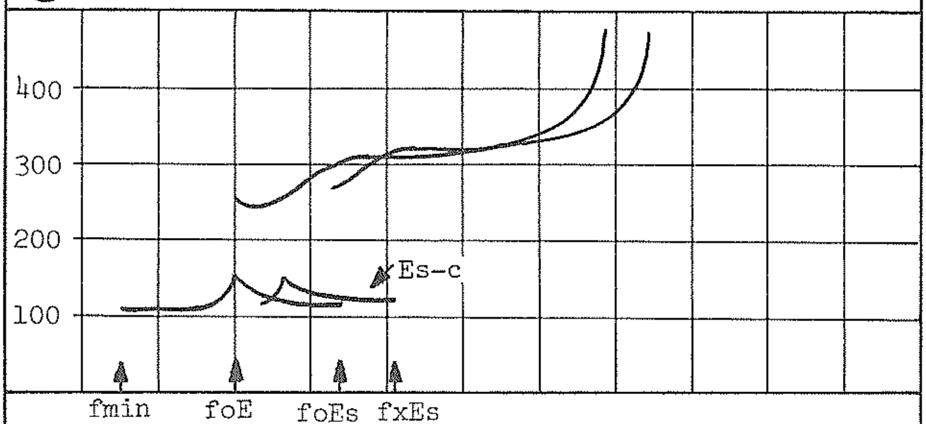
fmin	10EE
foE	
h'E	
foEs	62JA
fxEs	68
h'Es	100
Es type	f3
fbEs	48
foF1	
h'F	250EA
h'F2	
foF2	65
fxI	71X

② Es type ℓ, low



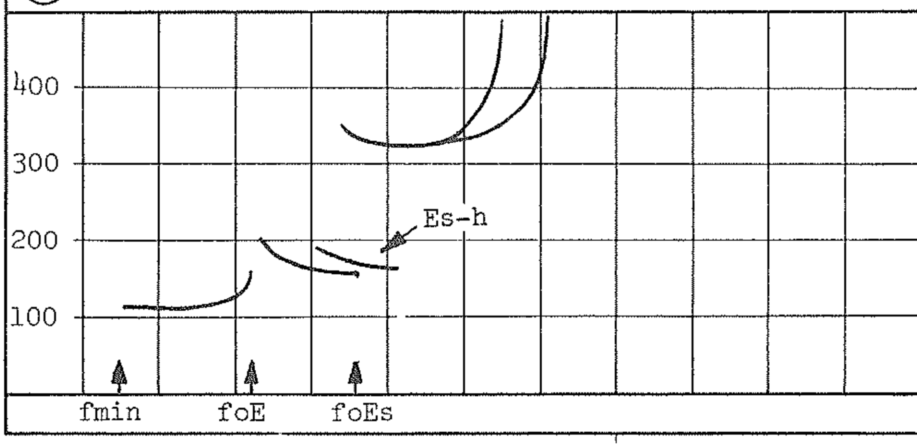
fmin	14
foE	315
h'E	115
foEs	42JA
fxEs	48
h'Es	105
Es type	ℓ1
fbEs	22G
foF1	
h'F	270
h'F2	
foF2	67
fxI	

③ Es type c, cusp



fmin	15
foE	300
h'E	105
foEs	44
fxEs	51
h'Es	110
Es type	c1
fbEs	30EG
foF1	L(46)
h'F	245
h'F2	310
foF2	79
fxI	

④ Es type h, high

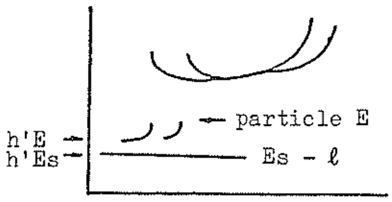


fmin	15
foE	320
h'E	110
foEs	46
fxEs	52
h'Es	155
Es type	h1
fbEs	44
foF1	A
h'F	A
h'F2	320
foF2	65
fxI	

type of Es – 1

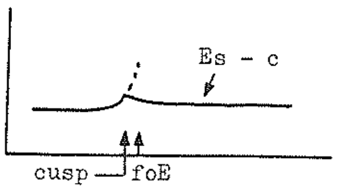
(1) f (flat) type is a type whose virtual height does not change as the frequency increases. This type is observed at any latitude. This classification is applied exclusively in the nighttime. The flat Es layer trace which is observed in the daytime should be classified into ℓ, c or h types, depending on its virtual height relative to that of the E layer.

(2) ℓ (low) type is a flat Es trace appearing at a height equal to or less than the minimum virtual height of the normal E layer. Therefore, this classification is applied mainly to Es in the daytime.



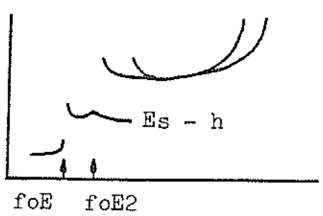
When the particle E layer is observed in the nighttime, a flat Es layer is tabulated as the ℓ type, as in the case of daytime.

(3) c (cusp) type is an Es trace which shows a comparatively symmetrical cusp at a frequency at or below foE. A part or the whole of the cusp is sometimes missing. This type of Es is observed up to higher frequencies, being connected to the thick E layer trace, and hence can be applied only in the daytime, or nighttime to particle E.



In this figure, the trace in higher frequencies above the cusp is c type Es which masks dotted part of the normal E trace.

(4) h (high) type is an Es trace showing a discontinuity in height with the normal E layer trace at or above foE. The cusp is not symmetrical, the height of the low frequency part of the Es trace being clearly higher than that of the high frequency part of the thick E layer trace. It is applied only in the daytime, or nighttime particle E.



In the figure, the Es trace having a cusp made by the intermediate stratification (E2 layer) is also treated as the h type.

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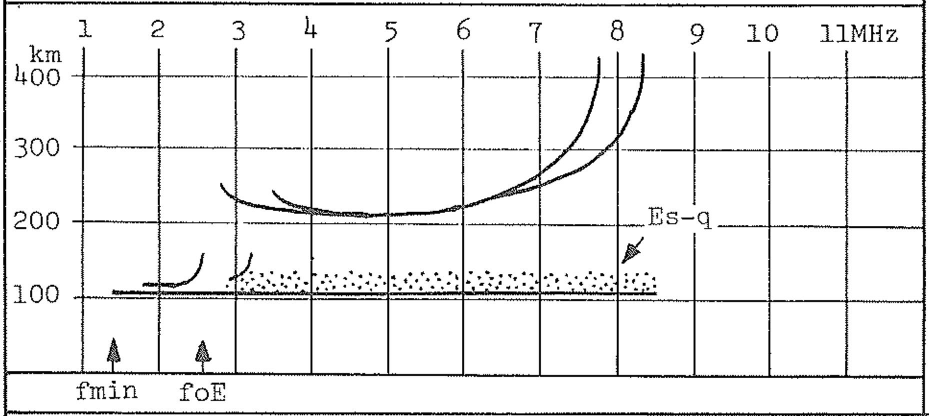
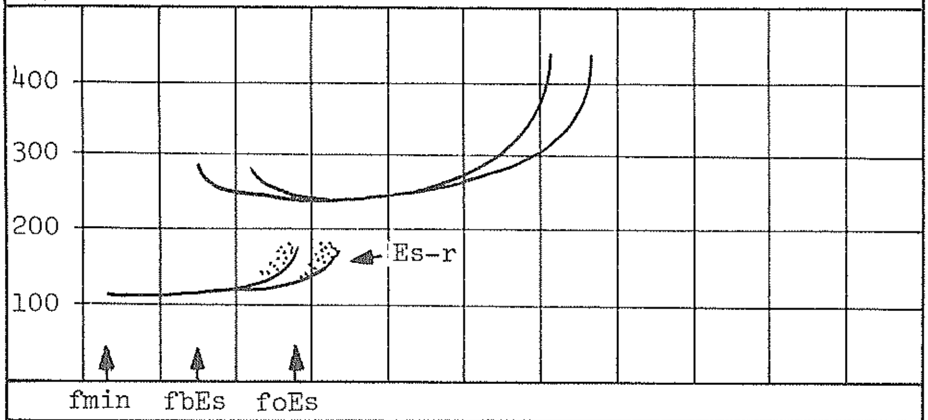
type of Es – 2

5 Es type q, equatorial



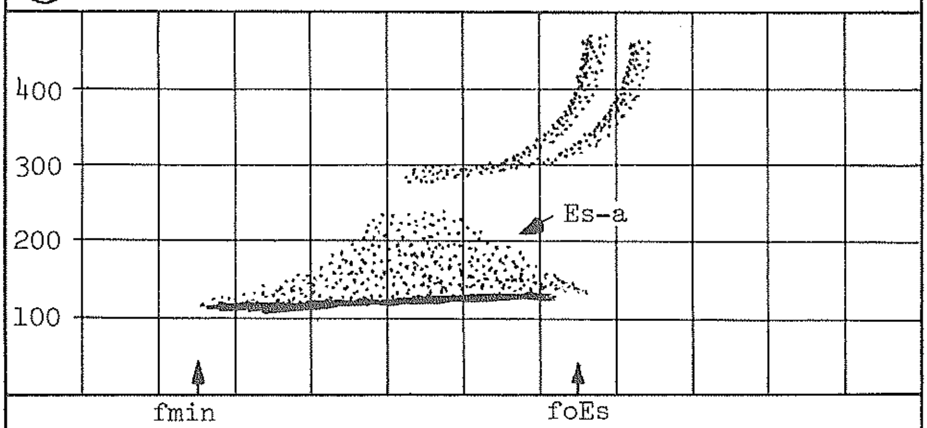
fmin	14
foE	260
h'E	110
foEs	79JA
fxEs	85
h'Es	110
Es type	ℓ1ql
fbEs	17G
foF1	
h'F	210
h'F2	
foF2	78
fxI	

6 Es type r, retardation



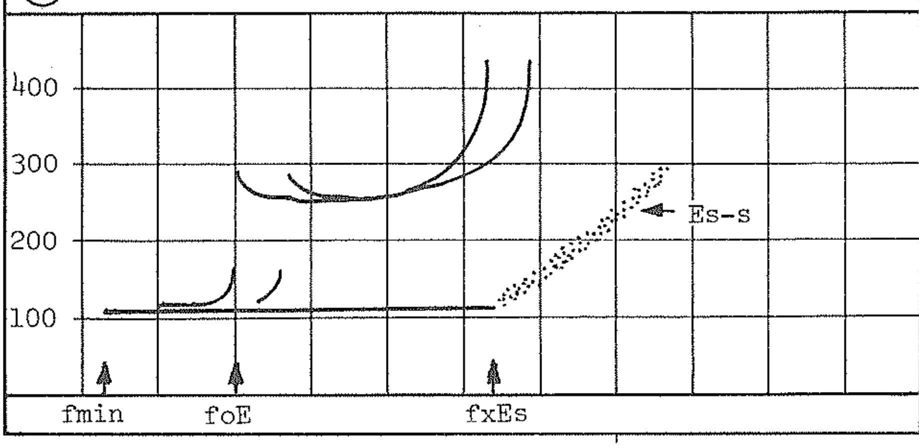
fmin	13
foE	250UK
h'E	A
foEs	38F
fxEs	44F
h'Es	110
Es type	r1k1
fbEs	25UK
foF1	
h'F	240
h'F2	
foF2	71
fxI	77X

7 Es type a, auroral



fmin	25
foE	
h'E	
foEs	75F
fxEs	
h'Es	110F
Es type	a1f1
fbEs	52
foF1	
h'F	280F
h'F2	
foF2	76F
fxI	84

8 Es type s, slant



fmin	13
foE	300
h'E	115
foEs	58JA
fxEs	64
h'Es	110
Es type	ℓ1s
fbEs	20G
foF1	
h'F	250
h'F2	
foF2	64
fxI	

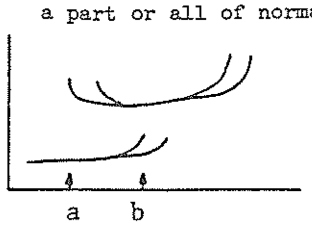
type of Es – 2

(5)

q (equatorial) type is an Es trace which is commonly found during daytime in the vicinity of the magnetic dip equator, showing diffuse and transparent characteristics. The lower edge of the trace is relatively well-defined. This type of Es is frequently observed in coexistence with other types of Es. Another important feature is that foEs greatly exceeds fbEs for an Es-q layer.

(6)

r (retardation) type is an obliquely reflected particle E trace showing an increase in virtual height near the top frequency similar in shape to the group retardation of a normal E layer. The trace blankets a part or all of normal E and F layer traces.



In the figure in this column, if b is larger than a, this Es layer should be scaled as r type, while if b is nearly equal to a, the Es would be the particle E layer.

(7)

a (auroral) type is usually observed only in high latitudes but can be observed at mid-latitudes in association with auroral activity. This type is applied to various types of spread Es traces. The spreading ranges over several hundred kilometers in virtual height. Echo patterns show flat or slowly rising lower edge having rapidly changing stratified structure. The width of the trace is greatest usually at frequencies below ftEs and sometimes at frequencies near fminF. The Es pattern usually alters rapidly in time.

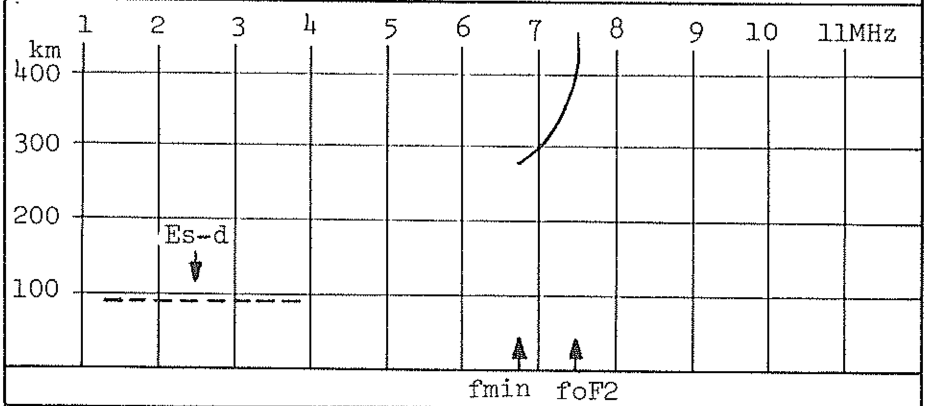
(8)

s (slant) type is a diffuse trace the virtual height of which increases steadily with frequency, emerging usually from such a point of underlying horizontal traces as the foE, fxE, foEs, fxEs, or an intermediate point in the Es trace. The s type must not be applied to the horizontal part, but should be applied to just the slant part of trace. This type is mainly observed in high latitudes, the starting point of slant part varying with the magnetic latitude.

The s type trace must not be used to determine foEs, fbEs or h'Es, but should be included in the type of Es table.

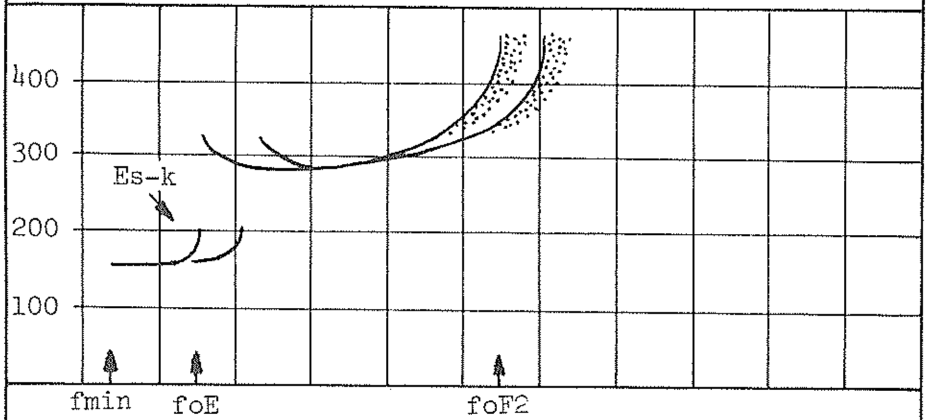
type of Es – 3

⑨ Es type d, Partial reflection from absorbing layer



fmin	67
foE	B
h'E	B
foEs	67EB
fxEs	
h'Es	B
Es type	d1
fbEs	67EB
foF1	B
h'F	B
h'F2	280EB
foF2	75
fxI	

⑩ Es type k, particle E



fmin	14
foE	250K
h'E	150K
foEs	25K
fxEs	31K
h'Es	150K
Es type	k1
fbEs	25K
foF1	
h'F	280
h'F2	
foF2	65F
fxI	74

○

400
300
200
100

fmin	
foE	
h'E	
foEs	
fxEs	
h'Es	
Es type	
fbEs	
foF1	
h'F	
h'F2	
foF2	
fxI	

○

400
300
200
100

fmin	
foE	
h'E	
foEs	
fxEs	
h'Es	
Es type	
fbEs	
foF1	
h'F	
h'F2	
foF2	
fxI	

9

d (D region) type is a weak diffuse trace which appears normally at heights below 95 km, being associated with high absorption (large fmin). Since this is not strictly an Es trace, it should not be used for determining fmin, foEs and h'Es.

This type has no blanketing capability but the associated absorption may prevent reflections from higher layers. In practice, it is often observed at heights near 80 km.

10

The letter K means the presence of particle E layer. The particle E layer is a thick layer which is sometimes seen at greater heights up to about 170 km in the nighttime, having much higher critical frequency than the normal E layer. It is often observed with type r or type a trace in high latitudes. As for the examples of particle E layer, refer to Cases 17-20 of foE.

fbEs

@ Definition :

fbEs is the blanketing frequency of the Es layer, namely the frequency at which the Es layer first allows reflections from upper layers. In other words, it corresponds to the frequency from which the reflections from a higher layer than the Es layer begin to appear. Thus, fbEs is a measure expressing the transparency of the Es layer.

fbEs is always decided by the lowest frequency of the ordinary component of a higher layer observed through the Es layer.

@ Scaling accuracy :

fbEs is scaled at the accuracy of 0.1 MHz (e.g. 2.6 MHz).

@ Indication of scaled value :

fbEs is expressed by the numerical value with or without letters, or by only a letter.

(Examples)

G --- Descriptive letter to be used when no numerical value of fbEs is given in the daytime.

46UY --- U is the qualifying letter, Y is the descriptive letter.

@ Notices for scaling :

1. Since fbEs is affected by the sensitivity of the ionosonde, it should always be scaled from the ionogram obtained with the normal gain.
2. All the columns of fbEs in the table should be filled in with any numerical values and/or letters.
3. fbEs should always be scaled from the ordinary component.
4. Except in special cases, the value of fbEs must be equal to or smaller than that of foEs (for a special case, see Case 11).

5. Since fbEs varies with time, it is desirable to obtain as many numerical values as possible so that the number of counts for calculating the monthly median be increased.

6. fbEs should be an indication of blanketing effect of the Es trace whose foEs is tabulated. If the several types of Es layer are recorded on an ionogram, the tabulated value of fbEs is always given by trace with highest value of foEs (R.H. p.121, Fig. 4.19).

7. In scaling fbEs when the complete blanketing occurs, refer to rules (a) and (b) on p.68 and Figs. 3.1 and 3.2 on p.69 in R.H.

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How to decide fbEs

In scaling fbEs, it is recommended to examine the ionogram according to the following steps.

1. First of all, it should be examined whether or not the Es trace is observed on the ionogram. If it is not go to step 2. If it is observed, go to step 3 and the succeeding ones.

2. The case where the Es layer is not observed.

   (1) The ionogram is normal.

   The letter G is appropriate for the daytime, while the letter E for the nighttime. For example:

   fbEs = (foE)EG for the daytime,

   fbEs = (fmin)EE or

   (fmin)ES for the nighttime.

   (2) The ionogram is affected more or less by interference, instrumental fault or absorption.

   a. No traces at all.

   The same letter as used for other parameters is also applied to fbEs (e.g. B,C).

   b. Traces are partly observed.

   For example: fbEs = (fmin)ES.

3. A case where the Es layer is observed but does not seem to affect upper layers.

   This case is envisaged when the lowest frequency of the Es layer, fminEs, is at or above that of upper layers.

   The letter G is appropriate for the daytime, while the letter E for the nighttime. For example:

   fbEs = (foE)EG for the daytime,

   fbEs = (fmin)EE or

   (fmin)ES for the nighttime.

4. A case where the Es layer observed seems to affect upper layers.

   (1) Only the Es trace is observed on the ionogram.

   a. It entirely blankets upper layers(see Item 7 on p.53).

   For ftEs = foEs, fbEs = (foEs)AA

   For ftEs = fxEs, fbEs = (fxEs - fB/2)AA

   b. Both Es traces of the first and second order reflections exceed the upper frequency limit of ionosonde.

   fbEs = (upper frequency limit of ionosonde)AA

Ⓡ

c. One of Es traces of the first and second order reflections exceed the upper frequency limit of ionosonde.

fbEs = ftEs of the other order reflection

d. The F trace is obscured due to the interference and other causes but seems to be foF2 > foEs.

fbEs = (foEs)ES. S: Interference

(2) ftEs of the Es trace is compared with the lowest frequency of upper layers (fminF or fminE).

a. The ordinary and extraordinary components of Es trace are clearly separated.

For foEs $\geqq$ fminF (or fminE), fbEs = fminF (or fminE).

For foEs < fminF (or fminE), fbEs = (foEs)UY or (foEs)ES

b. ftEs is regarded as foEs.

For foEs $\geqq$ fminF (or fminE), fbEs = fminF (or fminE).

For foEs < fminF (or fminE), fbEs = (foEs)UY, (foEs)UR or (foEs)ES.

c. ftEs is regarded as fxEs.

For (ftEs - fB/2) $\geqq$ fminF (or fminE), fbEs = fminF (or fminE).

For (ftEs - fB/2) < fminF (or fminE), fbEs = (foEs)UY.

[Note]

Concerning the interpretation that ftEs is either foEs or fxEs, see Cases 7 - 16 of foEs.

(3) foEs of ℓ type Es is smaller than foE.

fbEs = (fminE)G

5. When two or three types of Es are recorded, fbEs of respective type should be tabulated in the column of fbEs according to the steps 3 to 4. Priority is given to the fbEs corresponding to Es trace having the highest foEs. It is the representative value of fbEs for the ionogram.

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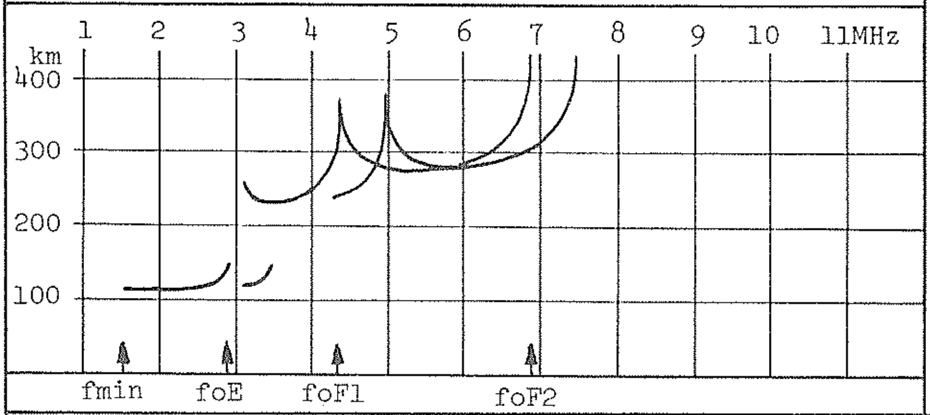
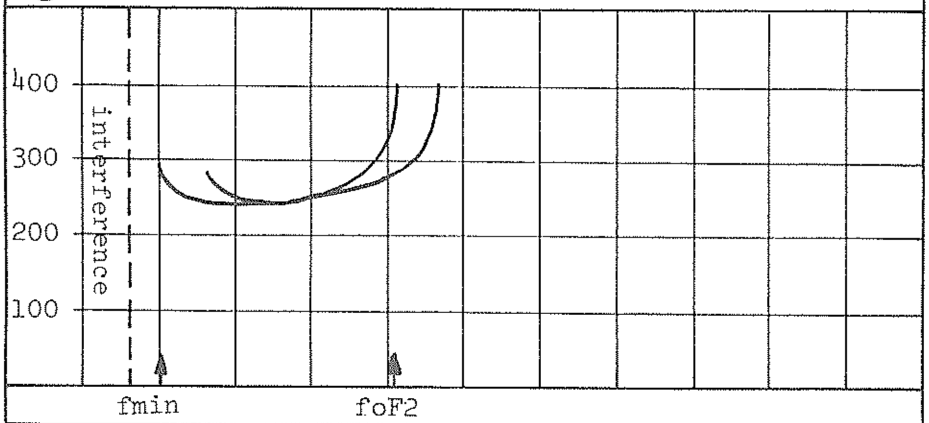
fbEs — 1

(1) No Es trace is observed (Daytime)



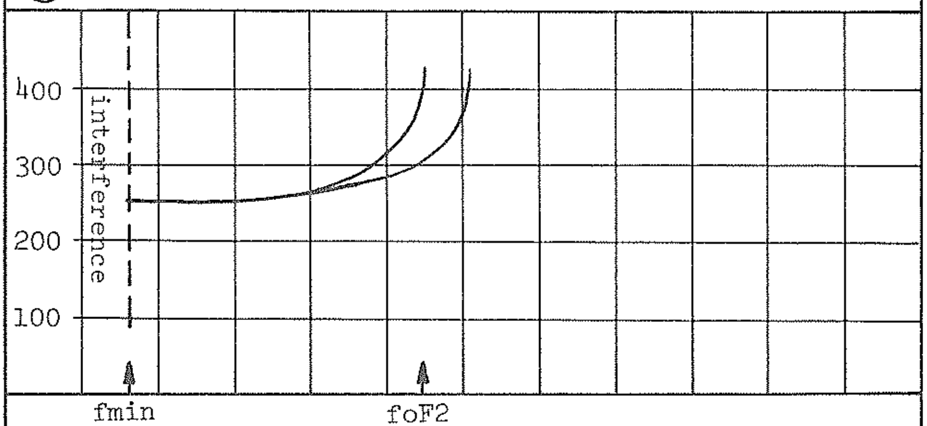
fmin	15
foE	290
h'E	110
foEs	29EG
fxEs	
h'Es	G
Es type	
fbEs	29EG
foF1	44
h'F	230
h'F2	275
foF2	69
fxI	

(2) Presence of Es trace is not identified (Daytime)



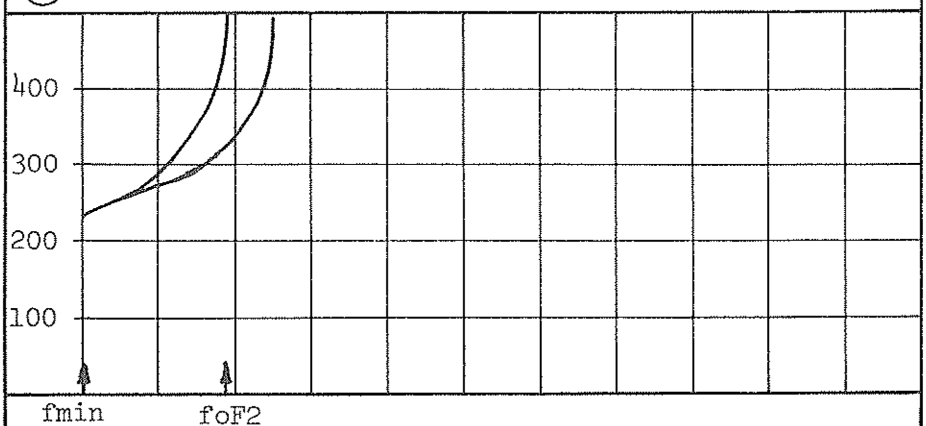
fmin	20R
foE	200UB
h'E	B
foEs	20EB
fxEs	
h'Es	B
Es type	
fbEs	20EB
foF1	
h'F	240
h'F2	
foF2	51
fxI	

(3) No Es trace is observed (Nighttime)



fmin	16ES
foE	
h'E	
foEs	16ES
fxEs	
h'Es	S
Es type	
fbEs	16ES
foF1	
h'F	250
h'F2	
foF2	55
fxI	61X

(4) No Es trace is observed (Nighttime)



fmin	10EE
foE	
h'E	
foEs	10EE
fxEs	
h'Es	E
Es type	
fbEs	10EE
foF1	
h'F	230EE
h'F2	
foF2	29
fxI	35X

®

fbEs - 1

①

Observation : The ionogram in quiet conditions. The E region trace is of the normal E layer. foE = 2.90 MHz

Interpretation : In case where only the normal E layer is observed in the E region (no Es trace is observed), all the parameters concerning Es are expressed with the letter G.

fbEs = (foE)EG

②

Observation : In the range below 1.6 MHz the trace is not clear due to the interference. The F layer trace is observed from 2.0 MHz but both the normal E and Es traces cannot be identified.

Interpretation : There is no interference between 1.6 and 2.0 MHz. foE can be deduced to be 200UB from the retardation of the lowest part of the F trace.

foEs = 20EB.

Therefore, fbEs = 20EB

③

Observation : Only the F trace is observed. No trace is observed in the frequency range below 1.6 MHz due to the interference.

Interpretation : This kind of ionogram is found often in the nighttime when the Es activity is low. The interference by MF Broadcasting is very common in the nighttime at mid-latitude sounding stations. Since the existence of Es cannot be identified below fmin due to the interference, the letter S is to be used for Es parameters.

fbEs = (fmin)ES = 16ES

Comment : In the case of no traces due to some instrumental failure, the letter C is used instead of S.

④

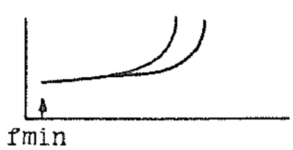
Observation : Nighttime ionogram. The F trace is observed from the lower frequency end of ionosonde. fmin = 10EE

Interpretation : There is no Es trace in the frequency range above 1.0 MHz. In this case the Es trace is considered to exist below the lowest frequency limit of the ionosonde.

fbEs = (10)EE

Comment : If fmin is higher than the lowest frequency as shown in the figure,

fbEs = (fmin)EB.



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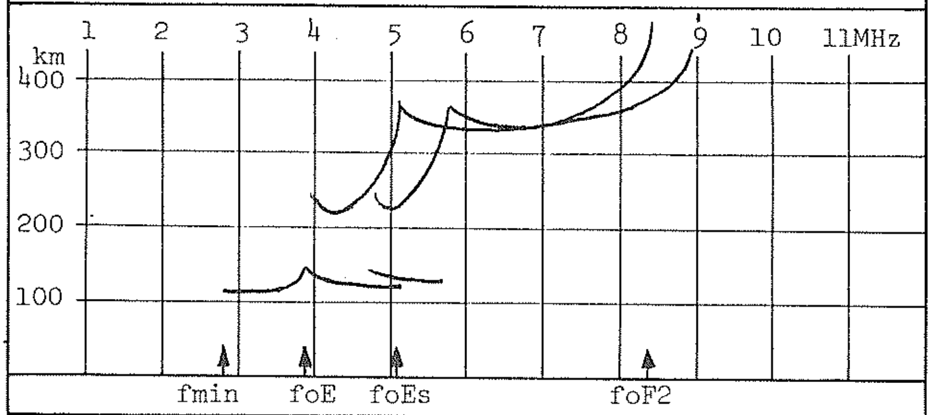
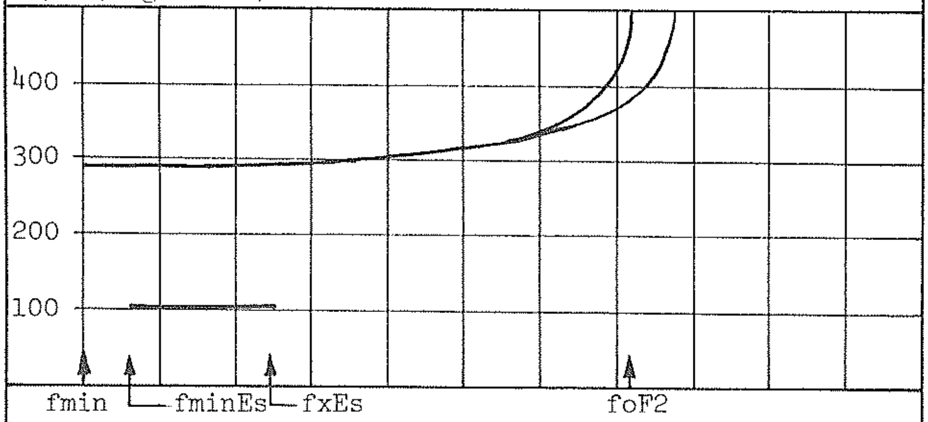
fbEs – 2

⑤ The Es layer does not affect the upper layer (Daytime)



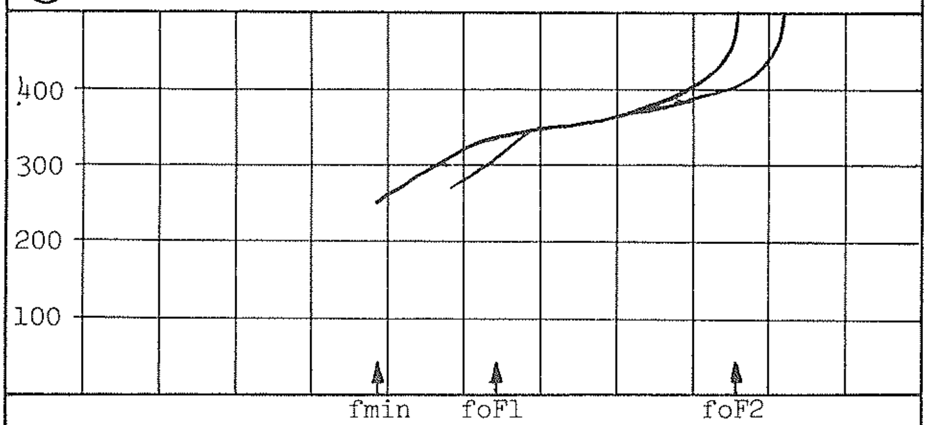
fmin	28
foE	390
h'E	110
foEs	51
fxEs	57
h'Es	120
Es type	c1
fbEs	39EG
foF1	51
h'F	215
h'F2	330
foF2	84
fxI	

⑥ The Es layer does not affect the upper layer (Nighttime)



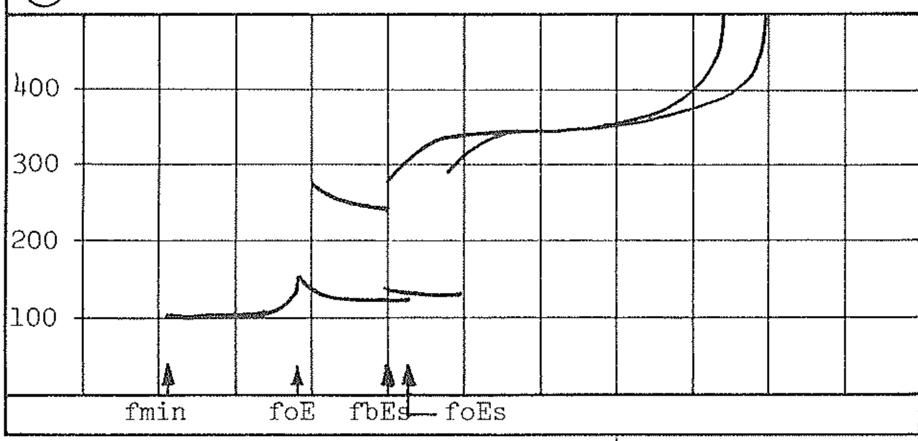
fmin	10EE
foE	
h'E	
foEs	29JA
fxEs	35
h'Es	100
Es type	f1
fbEs	E
foF1	
h'F	285
h'F2	
foF2	82
fxI	88X

⑦ The lower part of traces is missing



fmin	49
foE	B
h'E	B
foEs	49EB
fxEs	
h'Es	B
Es type	
fbEs	49EB
foF1	L(64)
h'F	250EB
h'F2	330L
foF2	96
fxI	

⑧ The Es layer affects the upper layer (Daytime)



fmin	21
foE	385
h'E	100
foEs	53
fxEs	60
h'Es	120
Es type	c2
fbEs	50
foF1	L(58)
h'F	A
h'F2	340
foF2	94
fxI	

Ⓡ

(5)

Observation : foE is 3.90 MHz and c type Es is observed. The retardation is seen at the lower frequency end of the F trace. fmin is a little higher than usual.

Interpretation : Where the lower part of F trace shows the retardation like this case, it can be interpreted that there is no influence of Es on the F layer.

fbEs = (foE)EG

(6)

Observation : Nighttime ionogram. The f type Es is seen at the height of 100 km. The F trace is observed from the lowest frequency of ionosonde.

fmin ≤ 1.0 MHz.

Interpretation : fbEs should be decided from the comparison of fminEs (the minimum frequency of Es trace) with fminF (the minimum frequency of F trace). If both are equal or fminEs is larger than fminF, it is interpreted that there is no influence of the Es layer.

fbEs = E (The letter E corresponds to the letter G used for daytime).

(7)

Observation : Only the F trace is observed from 4.9 MHz. fmin = 4.9 MHz.

Interpretation : It is necessary to confirm by referring to the sequence of ionograms the cause of the disappearance of the trace. In this case, the cause would be the absorption (B) due to SID (Sudden Ionospheric Disturbance). fbEs is expressed by marking the numerical value of fmin with the qualifying letter E (smaller) and the descriptive letter B (absorption).

fbEs = 49EB

Comment When the cause is other than absorption, the descriptive letter is changed to conform (e.g. C for non-ionospheric reason).

(8)

Observation : Both components of c type Es are observed in the vicinity of 120 km, together with the ordinary component of the second order reflection.

foEs = 5.3 fxEs = 6.0 MHz.

The value of foF1 is around 5.8 MHz.

Interpretation : fminF (5 MHz) is lower than foEs. Therefore, it is interpreted that the F1 trace below 5 MHz is totally blanketed by c type Es.

fbEs = 50

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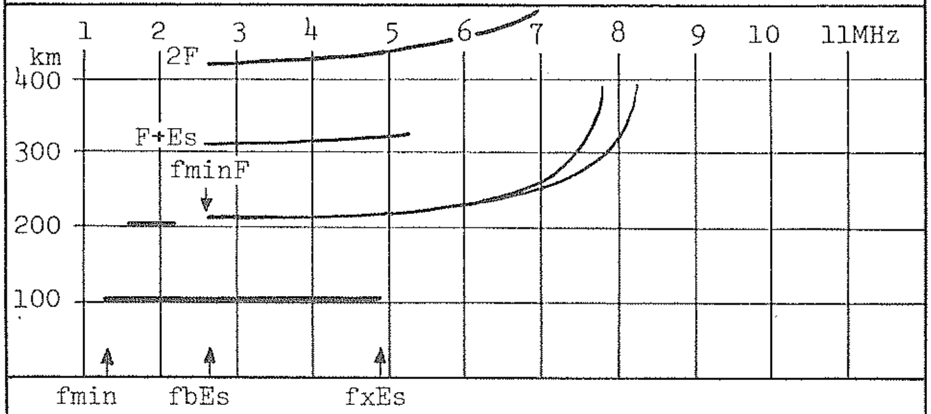
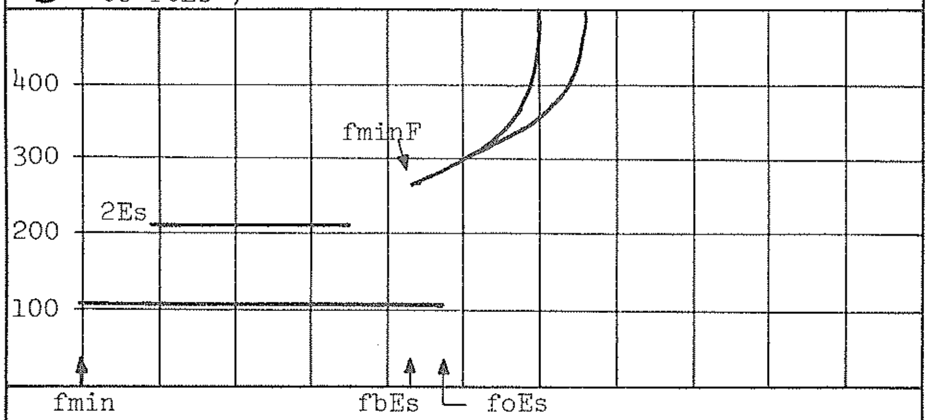
fbEs – 3

⑨ The Es layer affects the F layer (Nighttime)



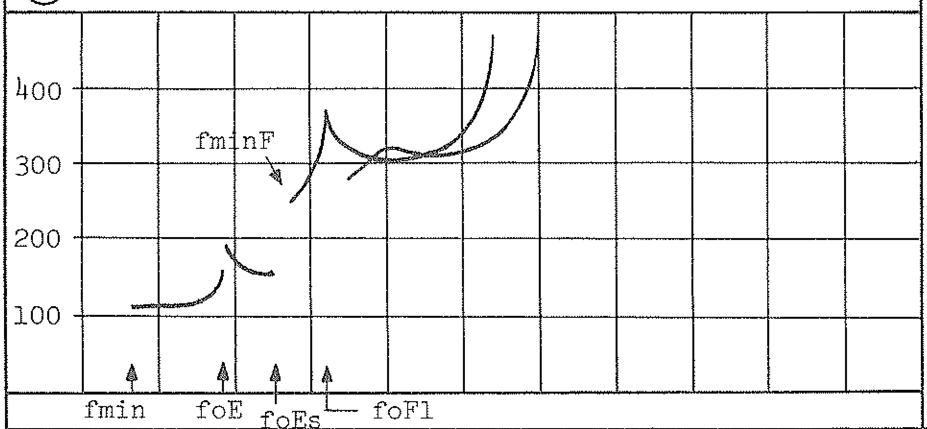
fmin	13
foE	
h'E	
foEs	43JA
fxEs	49
h'Es	100
Es type	f2
fbEs	26
foF1	
h'F	210
h'F2	
foF2	78
fxI	83X

⑩ The Es layer affects the F layer (fminF is close to ftEs)



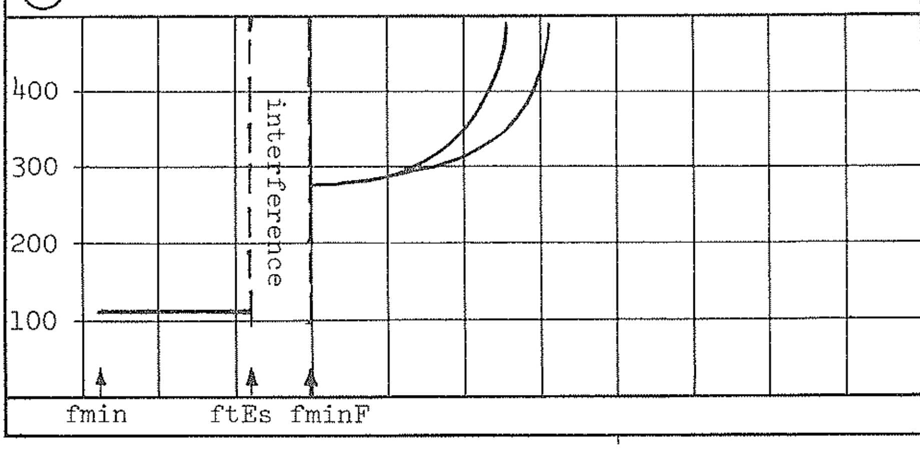
fmin	10EE
foE	
h'E	
foEs	57
fxEs	
h'Es	105
Es type	f2
fbEs	53
foF1	
h'F	A
h'F2	
foF2	70
fxI	76X

⑪ There is a frequency gap between foEs and fminF



fmin	16
foE	285
h'E	110
foEs	35
fxEs	
h'Es	150
Es type	h1
fbEs	35UY
foF1	42H
h'F	250EY
h'F2	300
foF2	64
fxI	

⑫ The interference is seen between ftEs and fminF



fmin	12
foE	
h'E	
foEs	32DS
fxEs	
h'Es	110
Es type	f1
fbEs	32DS
foF1	
h'F	270S
h'F2	
foF2	65
fxI	71X

Ⓡ

(9) Observation : The f type Es extending up to 4.9 MHz blankets the F trace below 2.6 MHz. A mixed reflection is recorded.

Interpretation : No particular consideration is needed, if ftEs (the top frequency of Es layer) and fminF are separated by more than half of the gyro frequency (fB/2 = 0.6 MHz), as shown in this figure.

fbEs = 26

If not, foEs and fminF should be compared to determine fbEs, after confirming whether ftEs = foEs or ftEs = fxEs.

Comment : Detailed explanation related to this Case is given at Step 4(2) in "How to decide fbEs" on page 55. As for the mixed reflection, see Appendix 1 on p.118 of this manual.

(10) Observation : The f type Es extends up to 5.7 MHz, showing also the second order reflection. The F trace below 5.3 MHz is blanketed.

Interpretation : This Case is similar to Case 9. But fminF in this ionogram is separated from ftEs by only 0.3 MHz.

If ftEs = foEs, fbEs = 53.

If ftEs = fxEs, foEs = (fxEs - fB/2) = 51JA. Therefore, foEs < fminF. According to Step 4(2)c on p. 55 of this manual, fbEs = (fxEs - fB/2)UY = 51UY.

(11) Observation : The ordinary component of h type Es is observed at about 150 km. foEs = 3.5 MHz. A gap of 0.2 MHz is seen between foEs and fminF.

Interpretation : Basically fbEs cannot be greater than foEs. Since it is inferred that the F trace near fminF is influenced by the oblique reflection, the letters U (doubtful) and Y (F layer tilt) are used.

fbEs = (foEs)UY = 35UY

Comment : When the inference is not certain, indication by only the letter is preferable.

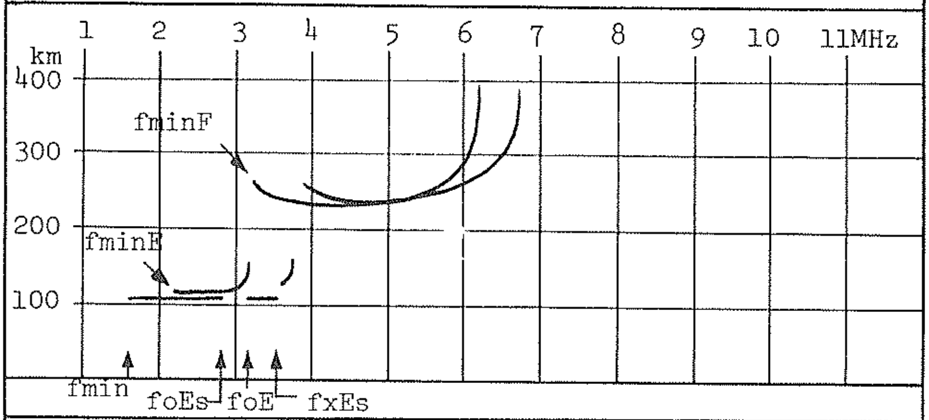
(12) Observation : Nighttime ionogram. The trace between 3.2 and 4.0 MHz is not clear owing to the interference.

Interpretation : fbEs is considered to be between 3.2 and 4.0 MHz. fbEs is expressed by marking the numerical value of ftEs with the letters D (greater) and S (interference).

fbEs = (ftEs)DS = 32DS

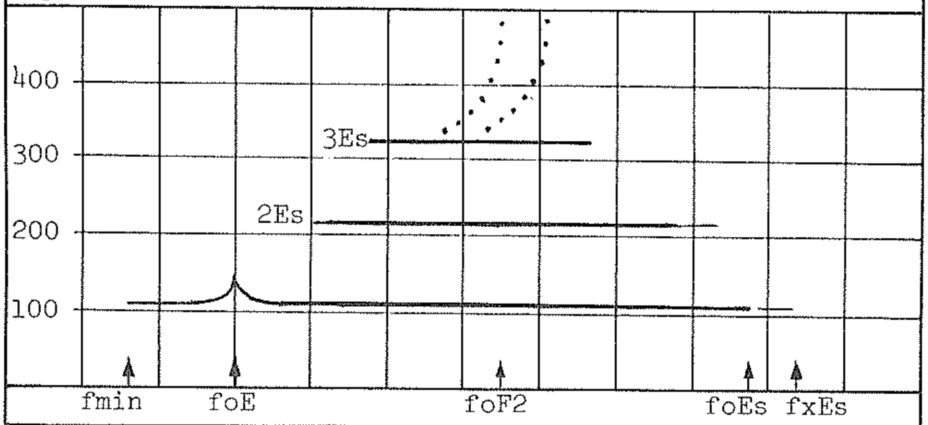
Comment : Since the ambiguity of fbEs increases as the interference gap in frequency becomes large, it is rather desirable to express fbEs only by the descriptive letter S.

13 foEs of ℓ type Es is less than foE



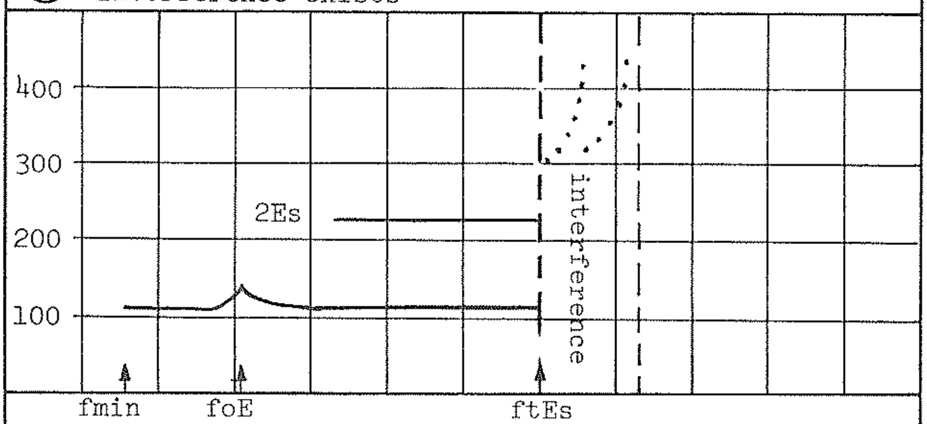
fmin	16
foE	315
h'E	115A
foEs	28G
fxEs	34G
h'Es	105
Es type	ℓ1
fbEs	22G
foF1	
h'F	230
h'F2	
foF2	62
fxI	

14 The Es layer completely blankets the upper layer



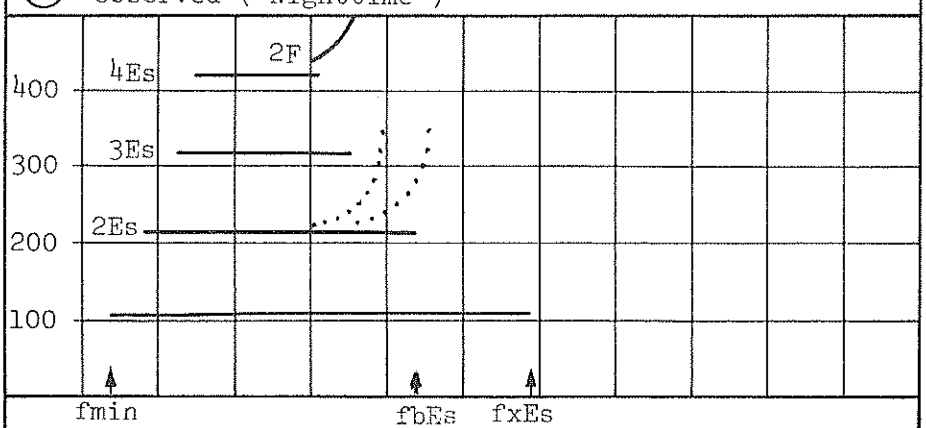
fmin	16
foE	300
h'E	110
foEs	97
fxEs	104
h'Es	110
Es type	c3
fbEs	97AA
foF1	A
h'F	A
h'F2	A
foF2	A
fxI	

15 The Es layer blankets the upper layer, although interference exists



fmin	16
foE	305
h'E	110
foEs	70DS
fxEs	
h'Es	115
Es type	c2
fbEs	70DS
foF1	A
h'F	A
h'F2	A
foF2	S
fxI	

16 The first order reflection of the F layer is not observed (Nighttime)



fmin	14
foE	
h'E	
foEs	63JA
fxEs	69
h'Es	110
Es type	f4
fbEs	54AA
foF1	
h'F	A
h'F2	
foF2	A
fxI	A

(13) Observation : The ℓ type Es is observed both the components of which are clearly separated. foEs (2.8 MHz) is lower than foE (3.15 MHz). No F1 layer is observed.

Interpretation : This ℓ type Es blankets the lower part of the normal E layer. In order to express that foEs is less than foE, both the numerical values of foEs and fbEs are accompanied by the letter G.

fbEs = (fbEs)G = 22G

Comment : In the case where fmin of ℓ type Es is equal to or larger than fminE, it is interpreted that there is no influence of the Es layer. Thus, fbEs = G

(14) Observation : The c type Es traces are observed up to the third order reflection. foEs = 9.7 MHz and fxEs = 10.4 MHz. The F layer trace is blanketed by the c type Es (Total blanketing).

Interpretation : The total blanketing gives us no information of fbEs. Assume that foF2 be approximately 6.5 MHz being inferred from the sequence of ionograms. Since foF2 (6.5 MHz) is much smaller than foEs (9.7 MHz), fbEs is scaled with the qualifying letter A (smaller than) and the descriptive letter A (affected by Es) as follows:

fbEs = (foEs)AA = 97AA

Comment : In the case where ftEs is close to the inferred foF2 and it is not clear whether ftEs is foEs or fxEs, foEs has to be decided firstly and then Case 15 is referred to.

(15) Observation : The c type Es extends up to 7.0 MHz. The lower part of the F trace is blanketed by this Es layer. Severe interference masks all traces from 7.0 MHz to 8.3 MHz.

Interpretation : In this ionogram it is not clear whether ftEs is foEs or fxEs. If foF2 inferred from the sequence of ionograms is considered to be in the band of interference,

fbEs = foEs = (ftEs)DS = 70DS

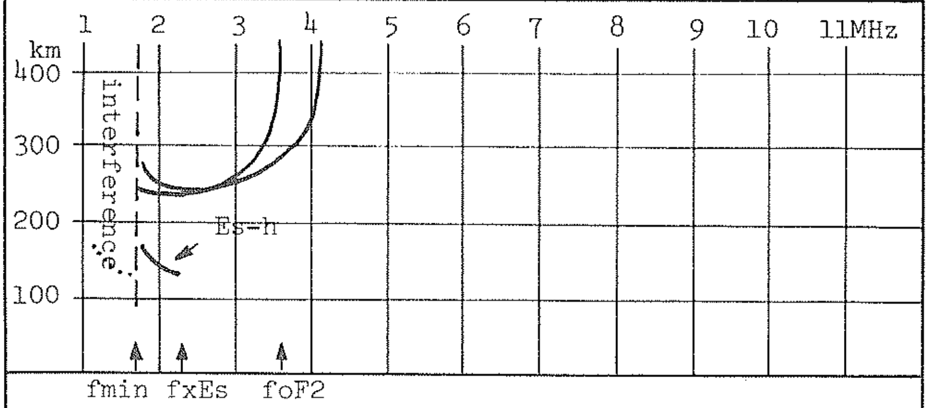
(16) Observation : The f type Es traces are observed up to the fourth order reflection. ftEs = 6.9 MHz. The F trace is of the second order reflection.

Interpretation : The first order reflection from the F layer is not recorded owing to the blanketing by the Es layer (dotted lines). Since fbEs should be scaled from the second order reflection, the recorded F trace is ignored.

fbEs = (top frequency of 2Es)AA = 54AA

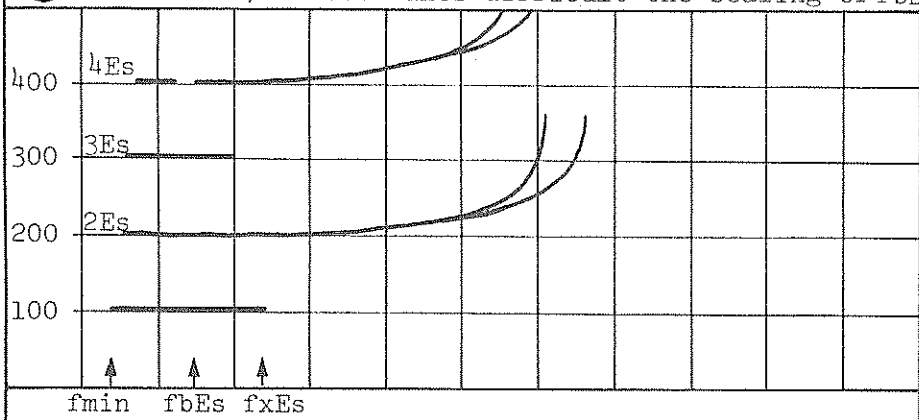
Ⓡ

(17) Only the extraordinary component of Es trace is observed



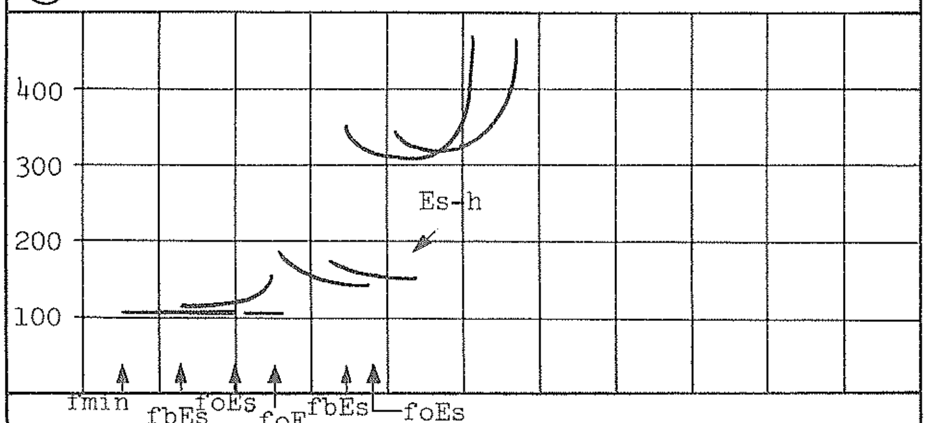
fmin	17ES
foE	S
h'E	S
foEs	17JS
fxEs	23
h'Es	S
Es type	h1
fbEs	17ES
foF1	
h'F	235
h'F2	
foF2	36
fxI	

(18) Overlapping of the F layer and Es layer (second order reflection) traces makes difficult the scaling of fbEs



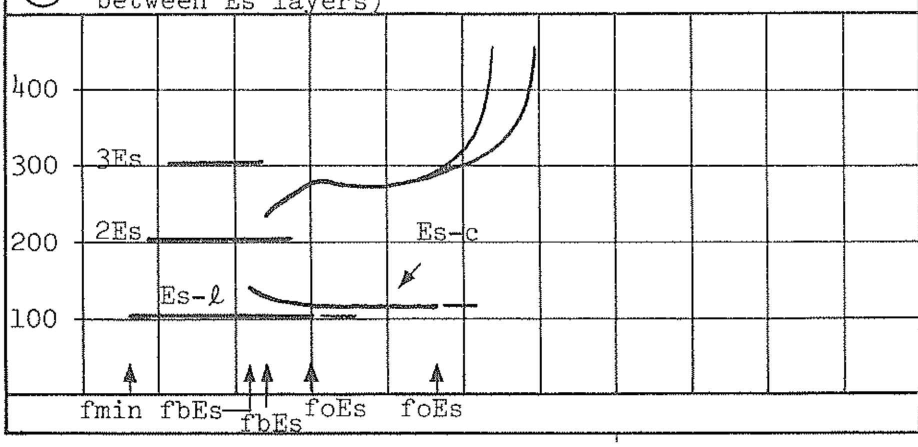
fmin	14
foE	
h'E	
foEs	28JA
fxEs	34
h'Es	100
Es type	f4
fbEs	25UA
foF1	
h'F	200A
h'F2	
foF2	71
fxI	77X

(19) Two types of Es are observed



fmin	15
foE	350
h'E	115A
foEs	48
fxEs	54
h'Es	140
Es type	h1ℓ1
fbEs	45
foF1	45UA
h'F	A
h'F2	305
foF2	61
fxI	

(20) Two types of Es are observed (Mutual blanketing between Es layers)



fmin	16
foE	310UA
h'E	A
foEs	56
fxEs	62
h'Es	115
Es type	cℓ3
fbEs	34
foF1	L(41)
h'F	240EA
h'F2	270
foF2	64
fxI	

(17) Observation : No trace is seen below 1.7 MHz owing to the interference. The trace in the E region seems to be the extraordinary component of h type Es. fxEs = 2.3 MHz. There is a weak retardation in the low frequency part of the F trace.

Interpretation : This kind of ionogram appears frequently around sunrise or sunset. Traces of the normal E layer and of the ordinary component of h type Es (dotted lines) are masked by the interference. Same interpretation as Case 3 is appropriate.

fbEs = (fmin)ES = 17ES

(18) Observation : The f type Es traces are recorded up to the fourth order reflection. foEs = 2.8 MHz. Lower part of F trace is apparently merged into the Es layer second order reflection at the height of 200 km.

Interpretation : This kind of ionogram appears frequently when the Es activity is high. In this Case, the reference to the second order reflection of the F layer would be helpful in identifying fbEs, as shown in the figure. Since, however, the numerical value is doubtful, the qualifying letter U is used.

fbEs = 25UA

Comment : Even in the case where the second order reflection cannot be utilized, the approximate values of fbEs can be decided often by referring to the width of each trace and the sequence of ionograms.

(19) Observation : foEs of h type Es at 140 km is 4.8 MHz, while foEs of ℓ type Es is 3.0 MHz. The F1 layer is blanketed by the h type Es.

Interpretation : fbEs is scaled for each type of Es. Since fbEs is the blanketing frequency for the layer seen through the Es layer, two values of fbEs corresponding to h and ℓ type Es traces must be obtained independently from the F and E layer traces respectively. Larger value of fbEs for h type Es is tabulated first as the representative value.

fbEs = 45 (h type)

fbEs = 23G (ℓ type; the letter G is attached because foEs < foE).

(20) Observation : Both c type Es (foEs = 5.6 MHz) and ℓ type Es (foEs = 4.0 MHz) are affecting the upper layers respectively.

Interpretation : fbEs for c type is 3.4 MHz, while fbEs for ℓ type Es which blankets the normal E layer is 3.1 MHz.

fbEs = 34 (for c type)

fbEs = 31 (for ℓ type)

Note

foF1

@ Definition :

foF1 is the ordinary wave critical frequency of the F1 layer.

According to the magneto-ionic theory, the frequency separation between the ordinary and extraordinary mode traces is equal to about fB/2, where fB is the gyro-frequency (the frequency at which the electrons gyrate around the geomagnetic field). The value of fB varies depending on the location of the station and the ionospheric height concerned. In middle latitudes, it is about 1.2 MHz.

The F1 layer is formed during the daytime mainly in summer at heights above about 150 km. foF1 varies from 4 to 6 MHz with the solar zenith angle in midlatitudes.

This layer sometimes appears in a complicated way under the influence of other stratifications (e.g. TID: Travelling Ionospheric Disturbance). In addition, it tends to be more stable in the diurnal variation, in contrast to the large depression of the F2 layer during the geomagnetic storm.

@ Scaling accuracy :

foF1 is scaled at the accuracy of 0.1 MHz (e.g. 4.5 MHz).

@ Indication of scaled value :

foF1 is expressed by a numerical value with or without letters, or only a letter.

(Examples)

L --- The numerical value cannot be obtained due to the lack of clear cusp.

45S --- S is the descriptive letter (interference).

45UH --- U is the qualifying letter (doubtful), and H is the descriptive letter which indicates the influence of a different stratification.

@ Notices for scaling :

1. The F1 layer is not observed throughout the year in the daytime. Therefore foF1 is scaled only when the formation of F1 layer is recorded on the ionogram. When the F1 layer is not observed, the columns in the table should be left open for the parameters M(3000)F1 and h'F2 as well as for foF1.

2. In the case where such a transient stratification as the F0.5 layer is observed in the vicinity of h'F, the value of foF1 is not necessarily scaled with the letter H (see R.H. p.20).

3. The short-lived traces like a transient layer or a oblique reflection should be neglected in scaling.

4. The value of foF1 is closely linked with foE at midlatitude.

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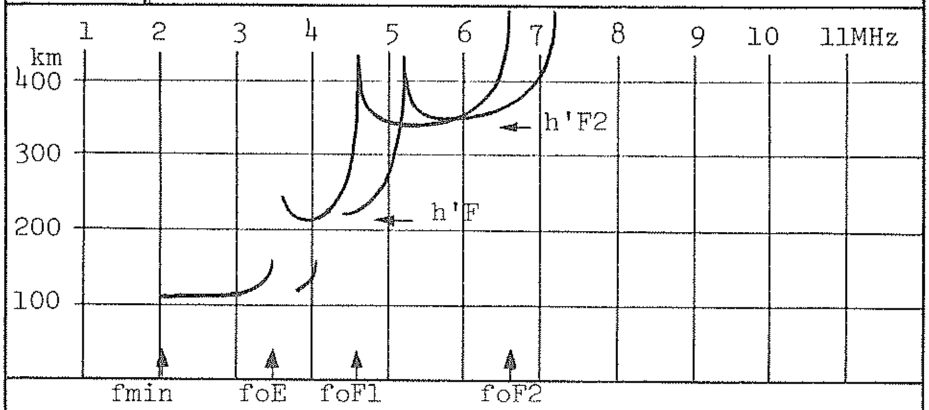
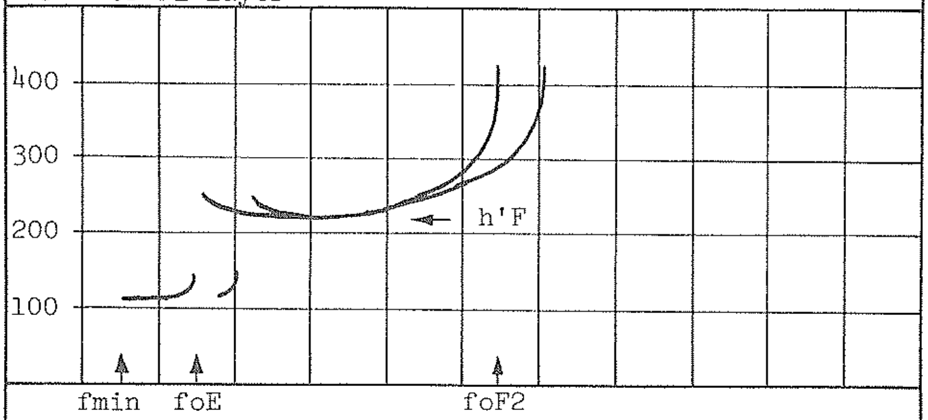
① A typical daytime ionogram showing incidence of F1 layer



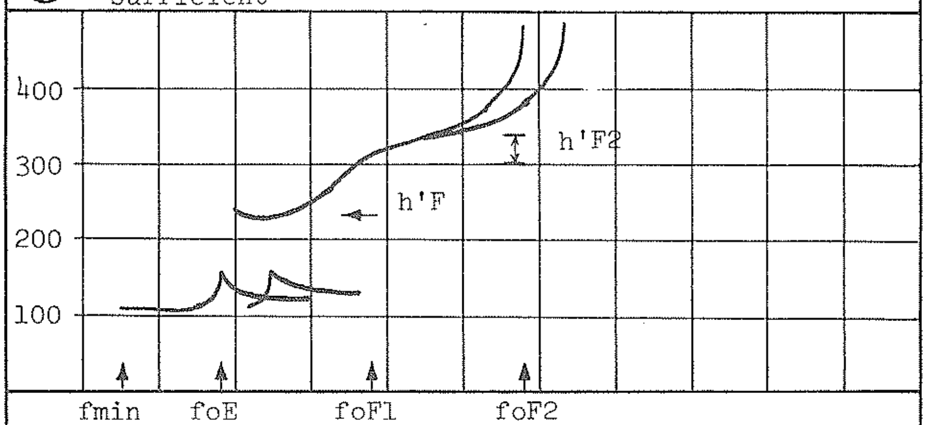
fmin	20
foE	350
h'E	110
foEs	35EG
fxEs	
h'Es	G
Es type	
fbEs	35EG
foF1	46
h'F	210
h'F2	340
foF2	66
fxI	

② A typical daytime ionogram showing no incidence of F1 layer



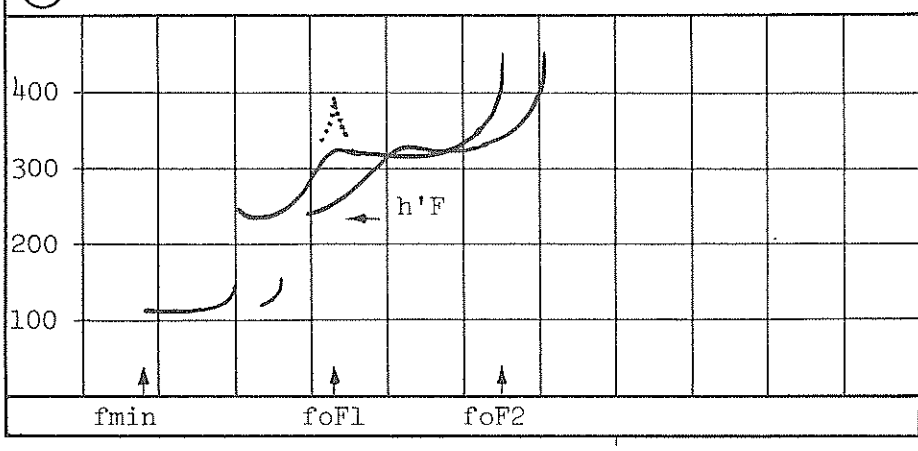
fmin	15
foE	250
h'E	110
foEs	25EG
fxEs	
h'Es	G
Es type	
fbEs	25EG
foF1	
h'F	215
h'F2	
foF2	65
fxI	

③ The stratification in the F region is not sufficient



fmin	15
foE	280
h'E	105
foEs	40
fxEs	46
h'Es	120
Es type	cl
fbEs	30
foF1	L(48)
h'F	230
h'F2	L
foF2	68
fxI	

④ The cusp at foF1 is not fully developed



fmin	18
foE	300
h'E	110
foEs	G
fxEs	
h'Es	G
Es type	
fbEs	G
foF1	43UL
h'F	230
h'F2	315
foF2	65
fxI	

Ⓡ

(1)

Observation : This is a typical daytime ionogram in summer, although no Es trace is recorded. The E, F1 and F2 layers are fully stratified.

Interpretation : Since well-shaped cusps are seen at the critical frequencies of the F1 layer, foF1 can be scaled with a sufficient accuracy required by the accuracy rules.

foF1 = 46

(2)

Observation : The retardation at 6.5 MHz corresponds to foF2. No F1 trace is observed in this ionogram.

Interpretation : The F1 layer is observed only in the daytime except during 1 - 2 hours around sunrise or sunset. It cannot be observed in wintertime at higher mid-latitude stations.

Comment : The formation of the F1 layer is recognized by the change in curvature of the F region trace in the frequency range of about 3 - 6 MHz.

(3)

Observation : The change in curvature due to the F1 layer is observed near 5 MHz. The Es trace is of c type.

Interpretation : The F1 layer is not fully formed. Since no clear cusp is observed between the F1 and the F2 traces, foF1 is expressed only by the descriptive letter.

foF1 = L(48)

Comment : When only the letter L is applied, it is recommended to infer the approximate value of foF1 (4.8 MHz for this Case) from the monthly trend and to put it in the column of the scaling table. The letter L should be plotted at the place of the inferred frequency on the f-plot sheet.

(4)

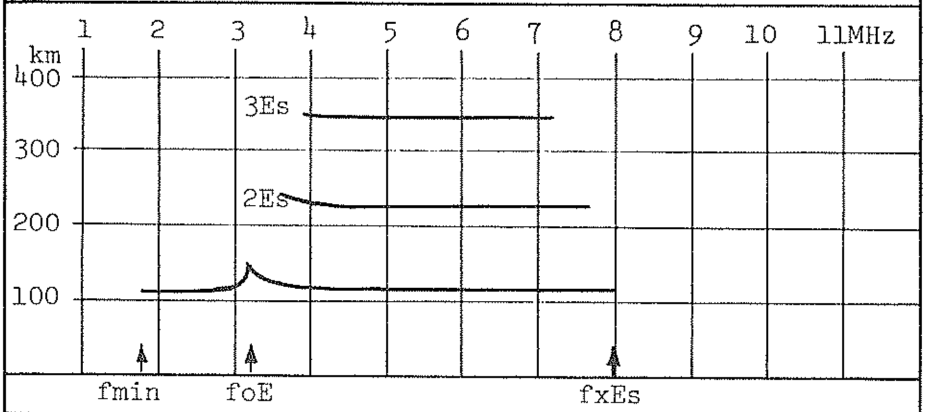
Observation : foF1 is scaled from the cusp at about 4.3 MHz, although it is neither typical nor clear. The F2 layer trace has horizontal parts which make easy in reducing h'F2.

Interpretation : The typical cusp as shown in dotted curve is expected from the well-developed F1 stratification. In cases where the degree of the cusp is equal to or less than this Case, the qualifying letter U is used with the descriptive letter L.

foF1 = (foF1)UL = 43UL

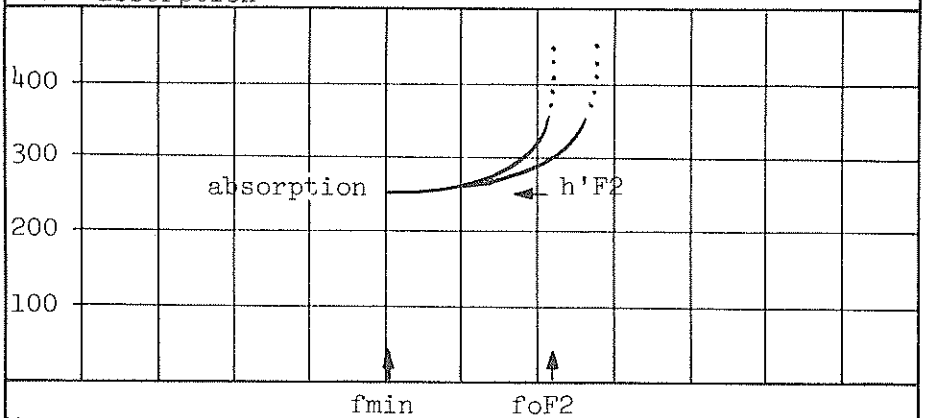
Comment : When the shape of the ordinary and extraordinary wave traces is different from each other, the use of H instead of L is recommended as in the right: (foF1)UH

⑤ Total blanketing by the Es layer



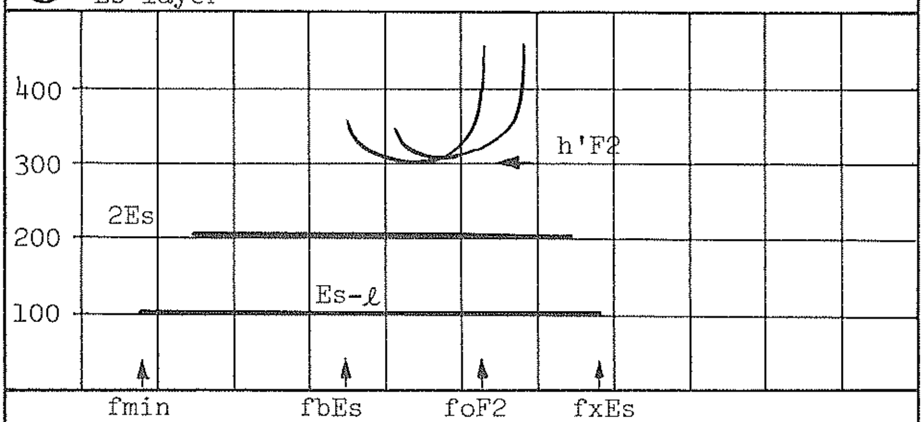
fmin	18
foE	315
h'E	110
foEs	74JA
fxEs	80
h'Es	115
Es type	c3
fbEs	74AA
foF1	A
h'F	A
h'F2	A
foF2	A
fxI	

⑥ Lower part of traces is missing due to the absorption



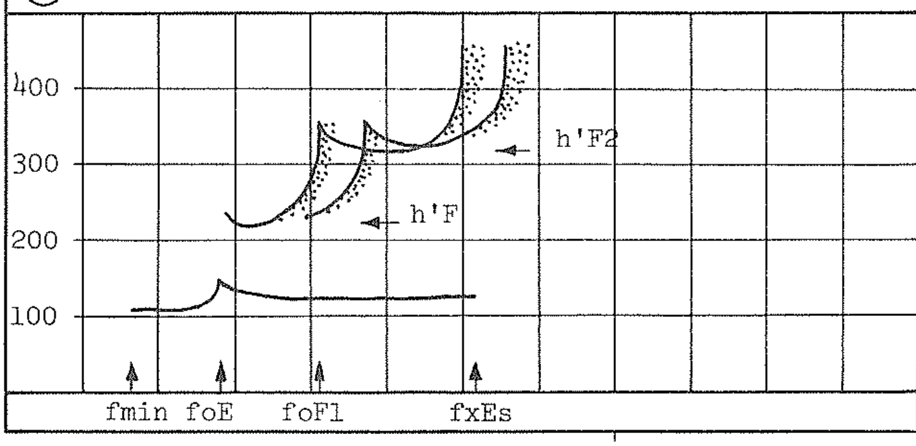
fmin	50
foE	B
h'E	B
foEs	50EB
fxEs	
h'Es	B
Es type	
fbEs	50EB
foF1	B
h'F	B
h'F2	250
foF2	72R
fxI	

⑦ The F1 layer is not observed being blanketed by the Es layer



fmin	18
foE	A
h'E	A
foEs	72JA
fxEs	78
h'Es	100
Es type	ℓ2
fbEs	45
foF1	45UA
h'F	A
h'F2	300
foF2	63
fxI	

⑧ The F region traces show the spreading



fmin	16
foE	280
h'E	105
foEs	56JA
fxEs	62
h'Es	120
Es type	c1
fbEs	28EG
foF1	41F
h'F	220
h'F2	315
foF2	60F
fxI	69

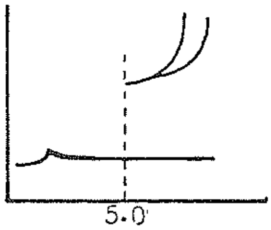
Ⓡ

(5)

Observation : Only the multiple reflections of the c type Es extending up to 8.0 MHz are recorded in the frequency range where the F layer echoes are expected.

Interpretation : It is interpreted that the F layer trace is totally blanketed by the c type Es. All the parameters for the F region are expressed by the letter A. foF1 = A

Comment :



This figure shows an example in which the blanketing takes place in the frequency range below 5 MHz. Only the parameters for the F1 layer are expressed by the letter A. foF1 = A

(6)

Observation : No trace is observed at all below 5.0 MHz. In addition the traces near the critical frequencies of the F2 layer are weaker than usual.

Interpretation : The cause of the disappearance of the trace below 5.0 MHz should be examined. When the cause is ascribed to absorption, little interference is recorded. When the cause arises from the interference, the influence would be seen over the whole part of the height range. This case is considered to be due to the absorption.

foF1 = B

(7)

Observation : The ℓ type Es having up to the second order reflection is observed, fxEs = 7.8 MHz. Neither F1 nor E layer traces are recorded.

Interpretation : The traces below 4.5 MHz are blanketed by the ℓ type Es. Since the retardation at the low end of the F2 trace is clear, the value of foF1 can be deduced. The numerical value is accompanied by the letter UA.

foF1 = (fbEs)UA = 45UA

(8)

Observation : The spreading of the F1 and F2 traces is observed. The c type Es is also seen.

Interpretation : The spreading of the F1 trace in the mid-latitudes is occasionally associated with ionospheric disturbances. The descriptive letter F stands for the presence of spread echoes.

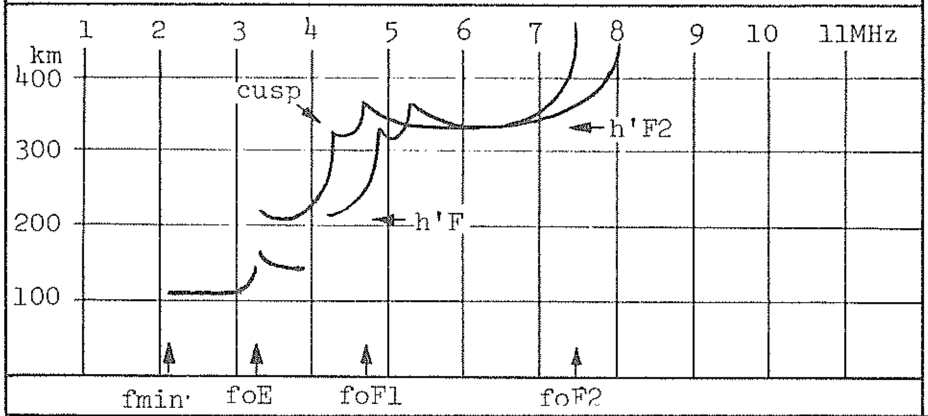
foF1 = (foF1)F=41F

For a doubtful value of foF1, foF1 = (foF1)UF.

Comment : For both the ordinary and extraordinary components, the width of the spreading along the frequency axis should be scaled and entered in the remarks column (e.g. 41 - 43 and 47 - 49 for this Case), for convenience of plotting in the f-plot sheet.

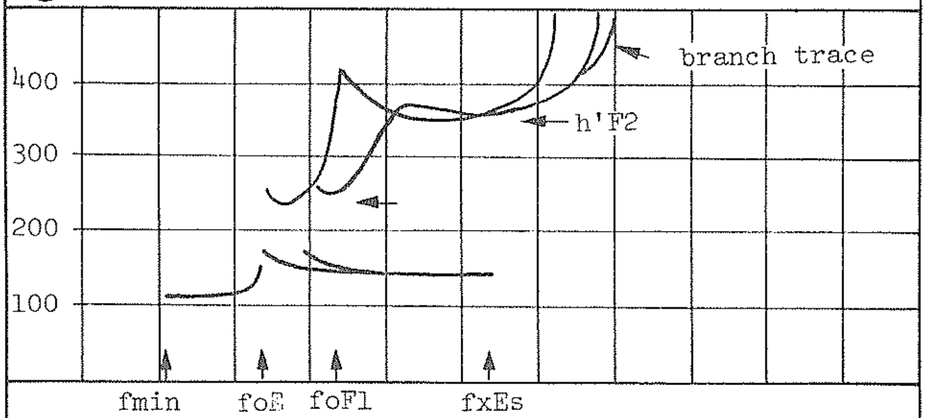
foF1 — 3

(9) The cusps by another stratification than the regular one are seen in the F1 traces



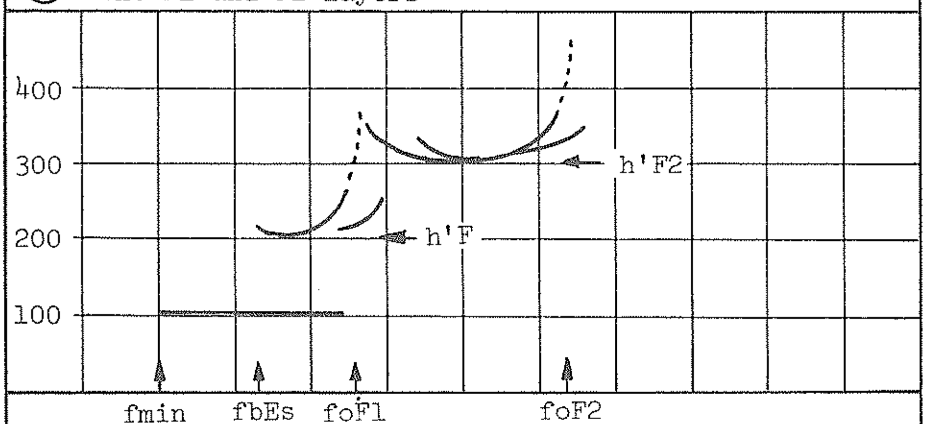
fmin	21
foE	325
h'E	110
foEs	39
fxEs	
h'Es	140
Es type	hl
fbEs	33EG
foF1	47H
h'F	205
h'F2	330
foF2	75
fxI	

(10) The shape of the ordinary component is not similar to that of the extraordinary one



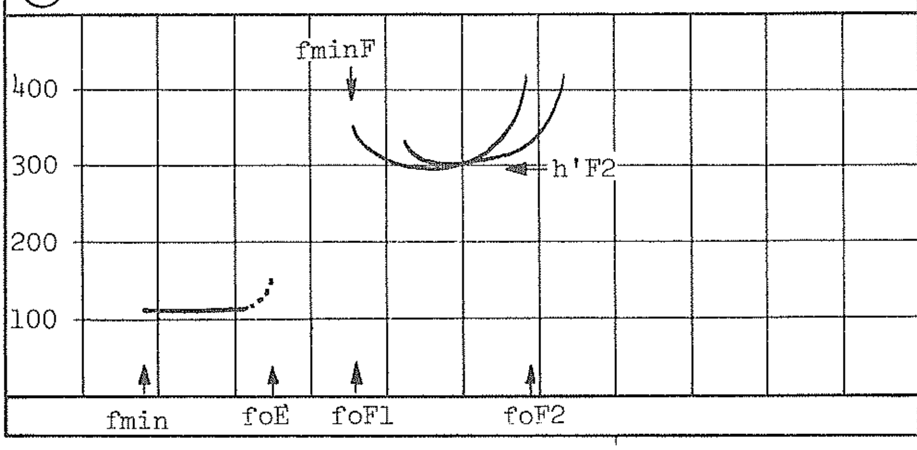
fmin	21
foE	335
h'E	110
foEs	58JA
fxEs	64
h'Es	145
Es type	hl
fbEs	34EG
foF1	44UH
h'F	235
h'F2	350
foF2	72
fxI	80X

(11) The trace is weak near the critical frequencies of the F1 and F2 layers



fmin	20
foE	A
h'E	A
foEs	38JA
fxEs	44
h'Es	100
Es type	
fbEs	33
foF1	46R
h'F	200
h'F2	300
foF2	74R
fxI	

(12) The F1 trace is missing (Lacuna Effect)



fmin	18
foE	Y
h'E	110
foEs	G
fxEs	
h'Es	G
Es type	
fbEs	G
foF1	46UY
h'F	Y
h'F2	295
foF2	69
fxI	

(9)

Observation : There are two cusps at 4.3 MHz and 4.7 MHz (foF1) in the ordinary wave trace (4.9 MHz and 5.3 MHz for the extraordinary wave trace). Es is of the h type.

Interpretation : This kind of small cusp which seems to be caused by the oblique reflection or the TID tends to appear in the vicinity of foF2 and move to the lower frequency range with the passage of time. The incidence of the cusp in upper frequency range of F1 trace is expressed by marking the numerical value with the letters UH, depending on the accuracy. foF1 = (foF1)UH = 47UH

Comment : When the cusp appears at the lower frequency range of the F1 trace, there would be no direct influence on foF1, but on h'F. Therefore, only h'F is indicated with the letter H.

(10)

Observation : The shapes of the ordinary and extraordinary components of the F1 trace are different from each other. In addition, the F2 extraordinary wave trace shows a branch trace near the critical frequency.

Interpretation : The slant reflection causes the discrepancy in the shape of two component traces. Since it is interpreted that foF1 is doubtful, foF1 is expressed in a numerical value accompanied by the qualifying letter U and the descriptive letter H.

foF1 = (foF1)UH = 44UH

(11)

Observation : Upper parts (dotted curves) of the F1 and F2 layer traces disappear. The trace in the E region is only the ℓ type Es.

Interpretation : The missing part of the trace is considered to suffer from the deviative absorption (letter R). Since the deviative absorption increases with the frequency, the trace may weaken with increasing frequency.
Depending on the frequency gap of the missing part, the scaling of foF1 based on the accuracy rules is made.

foF1 = (foF1)R, (foF1)UR, (upper end of trace)DR,
or only the letter R.

In this case, foF1 = 46R.

(12)

Observation : No trace is recorded in the frequency range from 3.2 MHz to 4.6 MHz. The lower part of the F2 trace suffers from the retardation.

Interpretation : This is a typical example of the F1 Lacuna. Since the ionogram is obtained in the daytime, the trace in the E region is of the normal E layer and foE is inferred from the mean diurnal trend to a certain degree. foF1 can be scaled from the retardation at the lower end of F2 trace with some ambiguity. Therefore it is expressed with the qualifying letter U (doubtful) and the descriptive letter Y (Lacuna)

foF1 = (fminF)UY = 46UY

Comment : The F1 Lacuna, which extends from the normal E layer region up to the highest part of the F1 layer in this Case, is characterized by sudden disappearance of traces on the ionogram (As for the details of Lacuna, see R.H. pp.53 ∿ 57.)

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Note

h'F

@ Definition :

The virtual height of the F layer, h'F, is defined as the lowest virtual height of the F layer ordinary wave trace.

In the daytime the F layer is offen doubly stratified into the F1 and F2 layers (Fig.a), while in the nighttime these two layers unite into one (Fig.b).

As h'F is always the lowest virtual height of any trace recorded in the F region, h'F = h'F1 in the daytime.

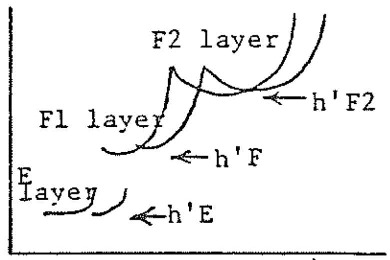

Fig. a(daytime)

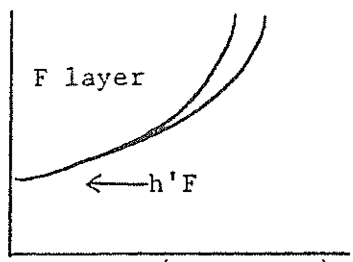

Fig. b(nighttime)

@ Scaling accuracy :

h'F is scaled with an accuracy of 5 km (e.g. 210 km or 255 km).

@ Indication of the scaled value :

h'F is expressed by the numerical value with or without letters, or only the letter.

(Examples)

A --- No F layer trace is seen being blanketed by the Es layer.

250EA --- E is a qualifying letter (less than), and A is a descriptive letter.

@ Notices for scaling :

1. h'F should be scaled even when the F1 layer is not observed in the daytime.
2. h'F is scaled from the horizontal part of the lowest major stratification in the F region. When the horizontal part is lost by Es blanketing or other reasons, h'F is expressed with a letter describing the reason.
3. The cross-reference to a sequence of ionograms obtained before and after the time in question usually helps to identify and scale some complicated trace including multiple Es reflections or slant echoes.

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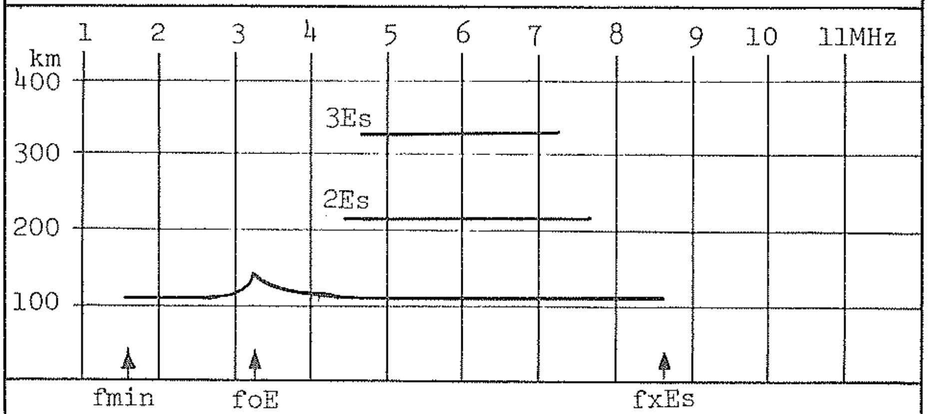
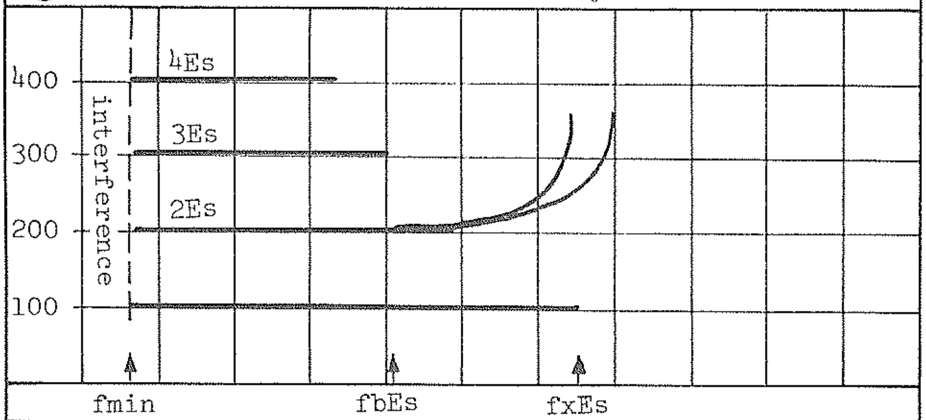
h'F – 1

(1) Total blanketing by the Es layer



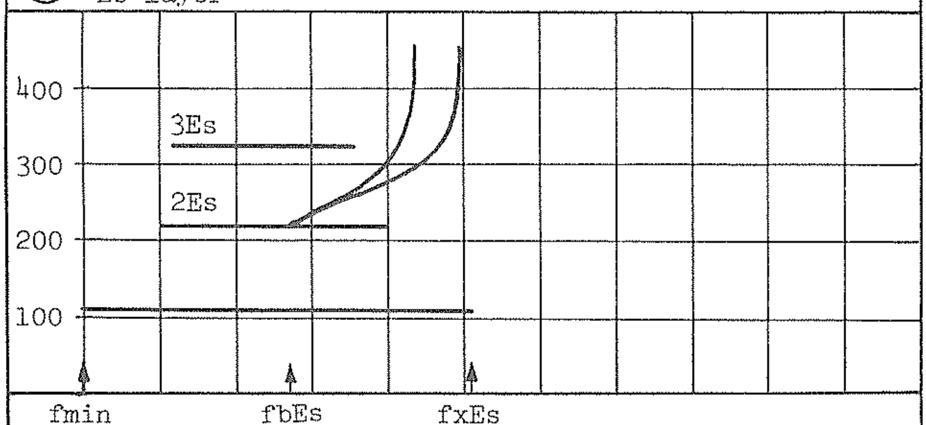
fmin	16
foE	325
h'E	110
foEs	80JA
fxEs	86
h'Es	110
Es type	c3
fbEs	80AA
foF1	A
h'F	A
h'F2	A
foF2	A
fxI	

(2) Overlapping of the F trace on the second order reflection trace from the Es layer



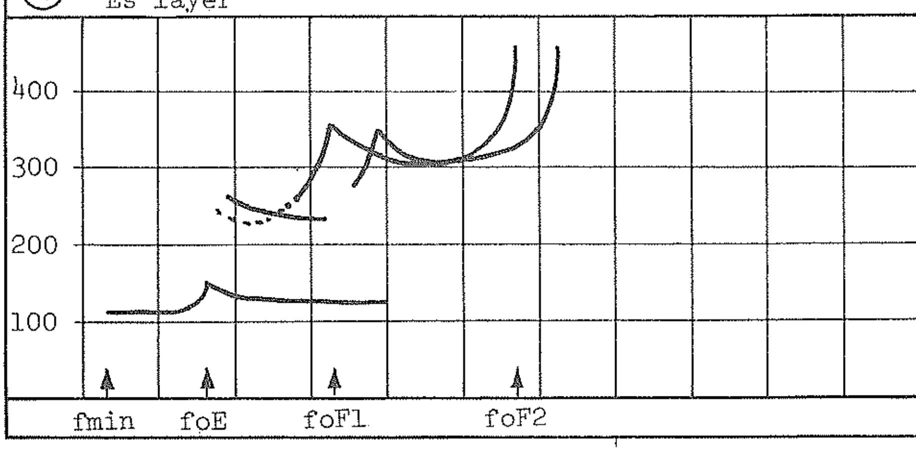
fmin	16ES
foE	
h'E	
foEs	69JA
fxEs	75
h'Es	100
Es type	f4
fbEs	51
foF1	
h'F	200A
h'F2	
foF2	74
fxI	80X

(3) Lower part of the F trace is blanketed by the Es layer



fmin	10EE
foE	
h'E	
foEs	55JA
fxEs	61
h'Es	110
Es type	f3
fbEs	37
foF1	
h'F	220EA
h'F2	
foF2	54
fxI	60X

(4) Lower part of the F1 trace is blanketed by the Es layer



fmin	13
foE	265
h'E	110
foEs	44JA
fxEs	50
h'Es	120
Es type	c2
fbEs	38
foF1	43
h'F	A
h'F2	300
foF2	67
fxI	

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h'F – 1

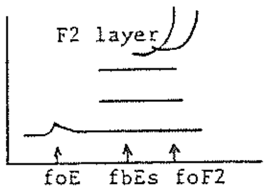
①

Observation : The c type Es having multiple reflections extends up to 8.6 MHz. The F layer trace is not observed (Total blanketing).

Interpretation : This kind of ionogram is frequently seen in the summertime (May – July) when Es activity is high. It is interpreted that the F layer trace is blanketed by the c type Es. All the parameters concerning the F layer are expressed by the letter A.

h'F = A

Comment :



In the case where only the F1 layer is blanketed as in the left figure, h'F2 and foF2 can be scaled, whereas h'F = A and foF1 = A.

②

Observation : The f type Es traces with multiple reflections are observed. foEs = 6.9 MHz. Lower end of the F trace merges into the Es trace.

Interpretation : The pattern like this case is frequently seen just before and after sunset. Careful examination of the width or slope of traces is helpful for discrimination between the F and Es traces. h'F is scaled with the letter A or letters UA, depending on the error involved in the scaled value.

h'F = 200A or h'F = 200UA

Comment : The interpretation described above is also valid for the scaling of h'F2.

③

Observation : The F trace below 3.7 MHz is blanketed by the f type Es. The lower part of the F trace is not horizontal.

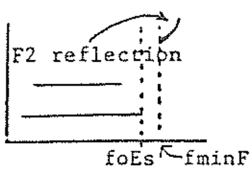
fbEs = 3.7 MHz.

Interpretation : Though this Case is similar to Case 2,it is very easy to discern the F trace from the second order reflection of the Es layer. h'F in this Case is expressed with the qualifying letter E (less than) and the descriptive letter A.

h'F = (h'F)EA = 220EA

If the slope of the lower end of the F trace is more steep, h'F = A is more appropriate.

Comment :



In the left figure, it can be interpreted that h'F is affected by the Es even when there is a gap between fminF and foEs. h'F = A

④

Observation : The trace seen at the height of 120 km is of the c type Es. The F1 trace is not observed below 3.8 MHz.

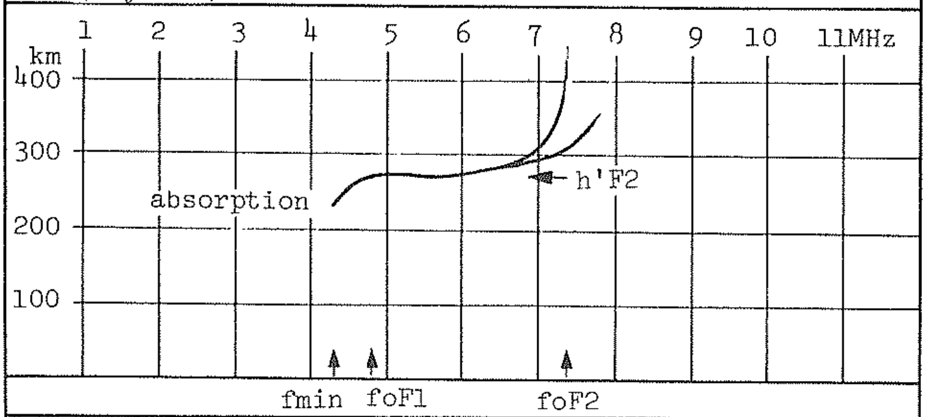
Interpretation : If there were no influence of the Es layer, the F1 trace would be observed as the dotted curve. Since the slope of the F1 trace is steep, h'F is expressed only by the letter.

h'F = A

If the slope of the trace is more moderate as seen from the dotted curve at around 3.6 MHz, h'F = 250EA.

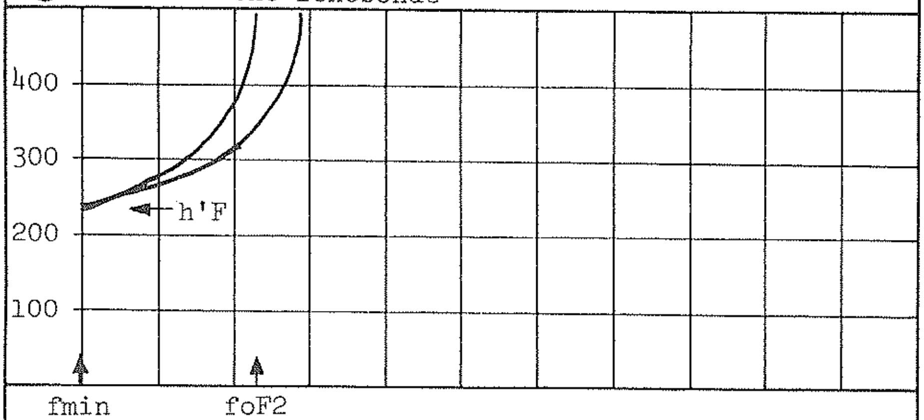
h'F — 2

(5) The trace partly disappears owing to the absorption (Daytime)



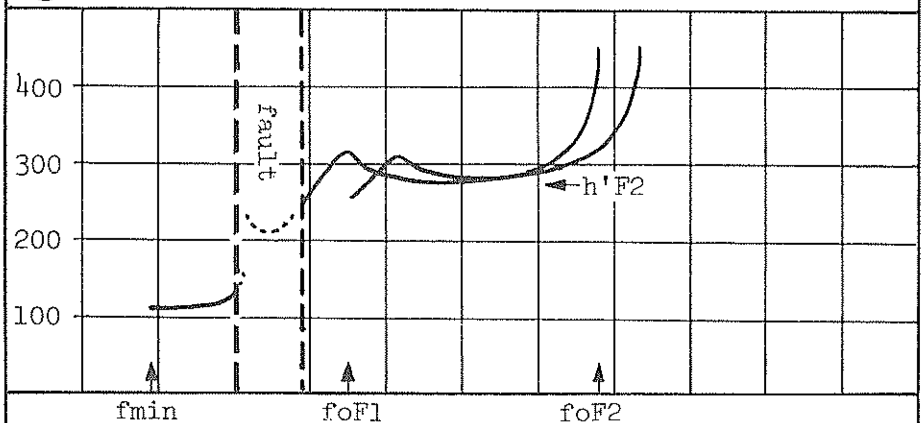
fmin	43
foE	B
h'E	B
foEs	43EB
fxEs	
h'Es	B
Es type	
fbEs	43EB
foF1	L(48)
h'F	220EB
h'F2	270
foF2	74
fxI	

(6) The F trace is observed from the lowest frequency limit of the ionosonde



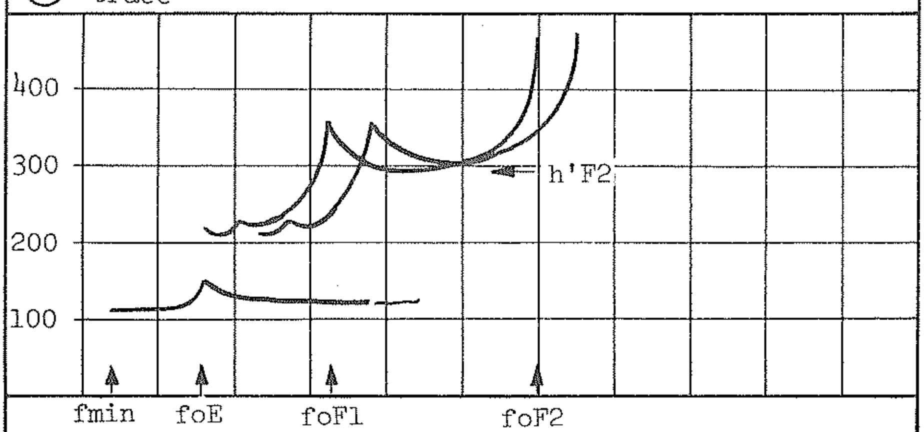
fmin	10EE
foE	
h'E	
foEs	10EE
fxEs	
h'Es	E
Es type	
fbEs	10EE
foF1	
h'F	240EE
h'F2	
foF2	33
fxI	39X

(7) The trace is partly lost owing to the malfunction of ionosonde



fmin	19
foE	310C
h'E	110
foEs	39EC
fxEs	C
h'Es	C
Es type	
fbEs	39EC
foF1	45L
h'F	C
h'F2	275
foF2	78
fxI	

(8) Small cusps are seen in the lower part of the F1 trace



fmin	14
foE	260
h'E	110
foEs	48
fxEs	54
h'Es	120
Es type	cl
fbEs	26EG
foF1	43
h'F	205H
h'F2	295
foF2	70
fxI	

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(5) Observation : Neither the trace nor the interference is observed in the frequency range below 4.3 MHz. fmin = 4.3 MHz

Interpretation : The cause of high fmin would be absorption. The slope of the F1 trace is so steep that h'F should be expressed only by the letter.

h'F = B (Absorption)

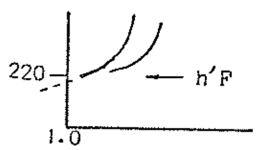
Comment : In the case where no trace is observed at all due to the strong absorption, the letter B is used for all parameters except Es type. Generally, it is important to identify the cause of no trace and then to select a suitable letter corresponding to the cause.

(6) Observation : A typical nighttime ionogram. The F trace is observed from the lowest frequency limit (1.0 MHz) of the ionosonde.

Interpretation : Since the trace is not horizontal at the lowest limit of frequency, h'F is expressed by the numerical value with the qualifying letter E (less than) and the descriptive letter E (below the lowest frequency).

h'F = (h'F)EE = 240EE

Comment :



When a gap is observed between the lowest limit of frequency and the lower end of the F trace as shown in left figure, it is usually caused by the absorption.

h'F = 220EB (or only the letter)

(7) Observation : The trace is missing between 3.0 and 3.9 MHz. No Es layer is observed.

Interpretation : The trace within the frequency band is considered to be influenced by a defect in the ionosonde (C) or interference (S). The influence will usually extend over the full height range (0 – 500 km in this figure). Depending on the slope of the lowest part of the F1 layer ordinary wave trace, h'F is scaled as

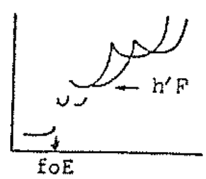
h'F = C, h'F = (h'F)EC or h'F = (h'F)C.

(8) Observation : Small cusps are seen in the lower part of the F1 layer traces (3.1 and 3.7 MHz). The Es layer is of the c type.

Interpretation : The appearance of an abnormal stratification usually influences the parameters of the normal layer. Therefore, since the numerical value is doubtful, it is expressed with the letters UH.

h'F = (h'F)UH = 205UH

Comment :



The trace separated from the F1 trace as shown in the left figure is not treated as the F layer trace, but a transient trace in the E region.

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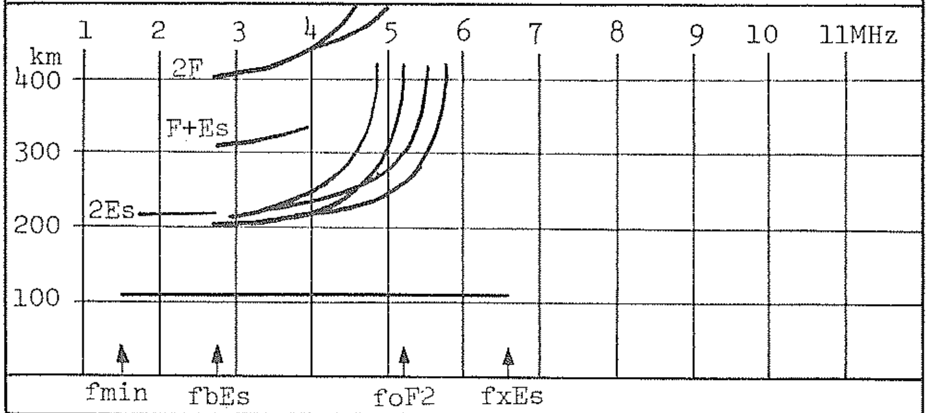
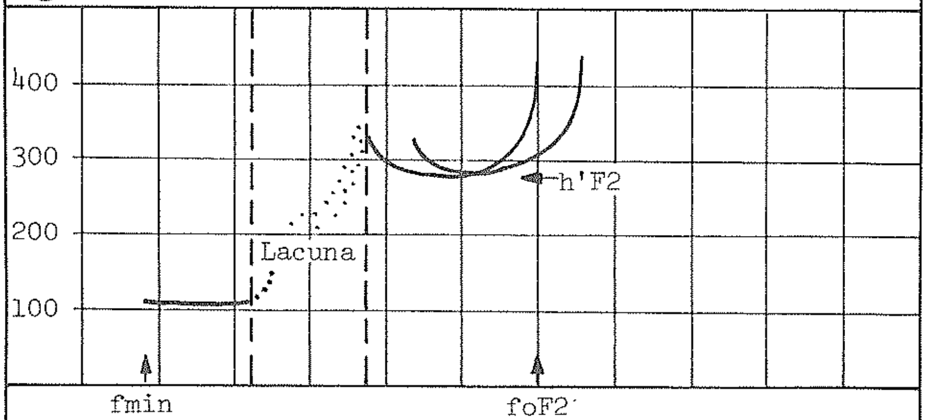
(9) Oblique reflections are observed



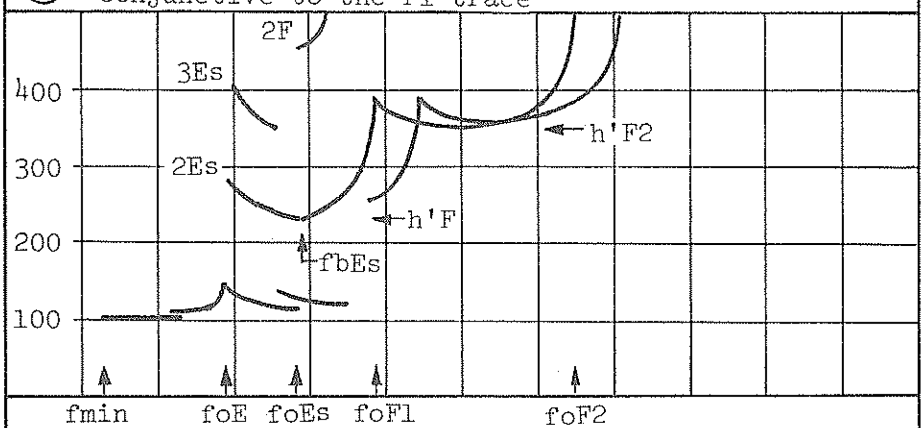
fmin	15
foE	
h'E	
foEs	60JA
fxEs	66
h'Es	110
Es type	f2
fbEs	27
foF1	
h'F	200
h'F2	
foF2	52
fxI	58X

(10) F1 traces are very obscured (F1 Lacuna)



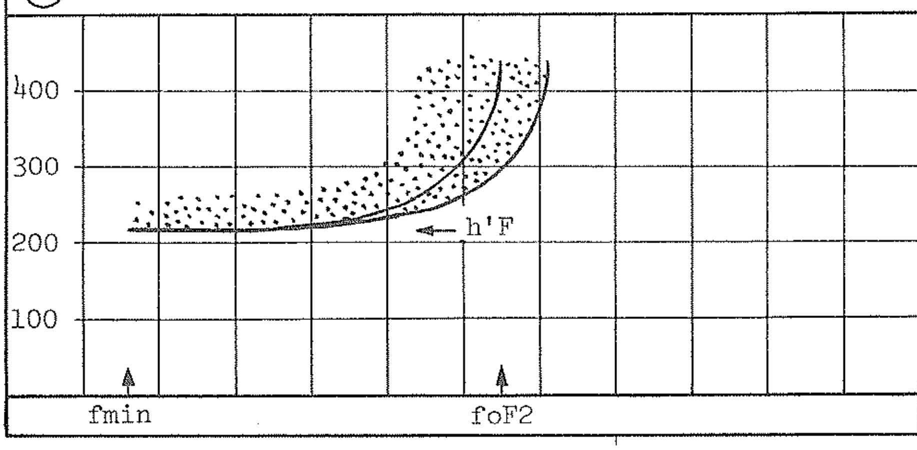
fmin	18
foE	Y
h'E	105
foEs	G
fxEs	
h'Es	G
Es type	
fbEs	G
foF1	46UY
h'F	Y
h'F2	275
foF2	70
fxI	

(11) Es layer second order reflection is almost conjunctive to the F1 trace



fmin	13
foE	290
h'E	110
foEs	39
fxEs	45
h'Es	115
Es type	c3ℓ1
fbEs	39
foF1	49
h'F	230EA
h'F2	350
foF2	75
fxI	

(12) The echo spreading is seen in the F trace



fmin	16
foE	
h'E	
foEs	16EB
fxEs	
h'Es	B
Es type	
fbEs	16EB
foF1	
h'F	215Q
h'F2	
foF2	65F
fxI	71

(9) Observation : A nighttime ionogram. The F traces other than the regular F traces with the second order reflection are observed at 210 km. Multiple reflections of the f type Es are also recorded.

Interpretation : The trace seen at 210 km is an oblique reflection which appears with the passage of a slant layer. When the vertical and oblique reflections are observed simultaneously at almost same height, it gives much confusion in the scaling. The cross-reference to the multiple reflection and the critical frequency as well as sequence of ionograms usually helps in scaling parameters.

h'F = 200

Comment : Attention should be paid to an oblique echo stronger than the normal one.

(10) Observation : In the frequency range from 3.2 to 4.7 MHz, the normal E and F1 traces are very weak.

Interpretation : This is the typical F1 Lacuna. The stronger the Lacuna effect, the more the F1 trace becomes weak. h'F is expressed only by the descriptive letter Y.

h'F = Y

Comment : As for Lacuna, refer to Case 12 of foF1.

(11) Observation : Two kinds of Es trace are observed. Multiple reflections of both c type Es and F1 layers are recorded.

foEs = 3.9 MHz (c type) foEs = 2.3 MHz (ℓ type).

Interpretation : The Es second order reflection seems to be connected to the lower part of the F1 trace at 3.9 MHz (230 km in height). Careful examination of traces including multiple reflections is effective for avoiding misinterpretation. In this Case the F1 trace starts from 3.9 MHz and h'F would be lower than 230 km.

h'F = (h'F)EA = 230EA

(12) Observation : Both types of echo spreading are observed on this ionogram; one is the range type (the trace extends in the direction of the height) and the other is the frequency type (see Cases 17, 18 and 20 of foF2).

Interpretation : If the width of the trace near h'F exceeds 30 km it is regarded as the range type spreading and the descriptive letter Q is applied to the virtual height. Whether h'F = (h'F)Q or h'F = (h'F)UQ depends on the sharpness of the lower edge.

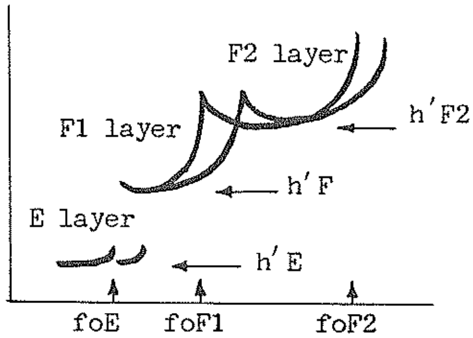
h'F = 215Q

Note

h'F2

@Definition :

h'F2 is the minimum virtual height of the ordinary wave component of the highest stable stratification in the F region.



@Scaling accuracy :

h'F2 is scaled at the accuracy of 5 km (e.g. 300 km or 305 km).

@Indication of scaled value :

h'F2 is expressed either by a numerical value with or without letters, or only by a letter.

(Examples)

A --- expresses the presence of the blanketing effect of the Es layer.

L --- as the descriptive letter, indicates that the foF1 cusp is so smooth that the F2 layer height cannot be reduced accurately.

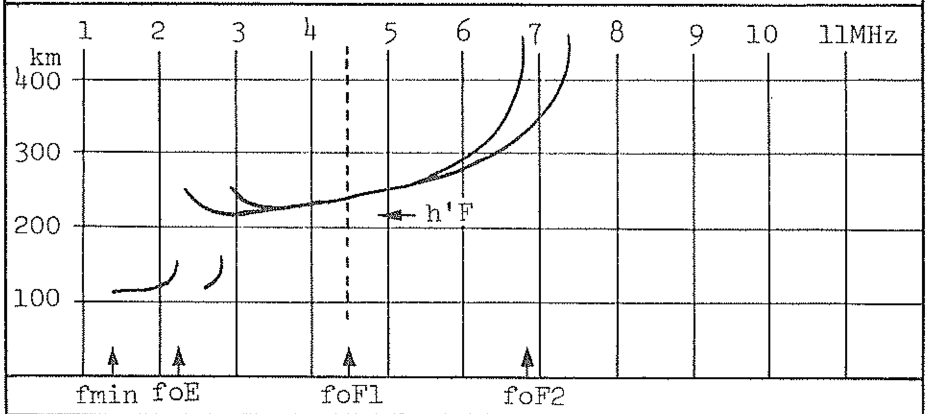
310EC --- The numerical value is affected by some instrumental reasons (C), and h'F2 should have a lower value (E) than 310 km.

@Notices for scaling :

1. When the stratification of the F1 layer is not observed, the column of h'F2 in the table is kept open.
2. h'F2 is scaled from the horizontal part of the F2 layer ordinary wave trace. When the horizontal part of the F2 trace is lost by some reason, a letter appropriate to express the reason is used according to the accuracy rules as written on pp.11 ∿ 12.
3. When the F2 trace extends down to the F1 trace without having the horizontal part at its lower end, the letter L is used. In this case, it is recommended to write an approximate range of height in the remarks column of the table.
4. Almost the same rules of scaling for h'F are applicable to h'F2.

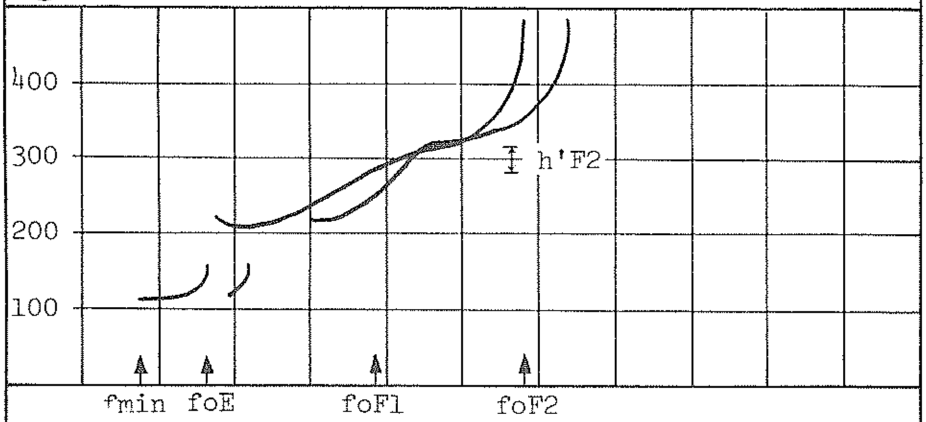
h'F2 — 1

(1) No F1 layer is observed (Daytime)



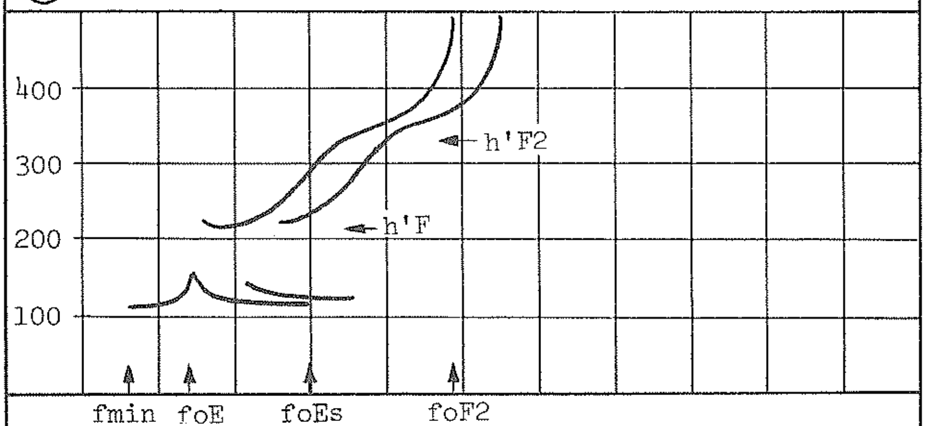
fmin	14
foE	225
h'E	110
foEs	23EG
fxEs	
h'Es	G
Es type	
fbEs	23EG
foF1	
h'F	220
h'F2	
foF2	68
fxI	

(2) The formation of the F1 layer is not enough



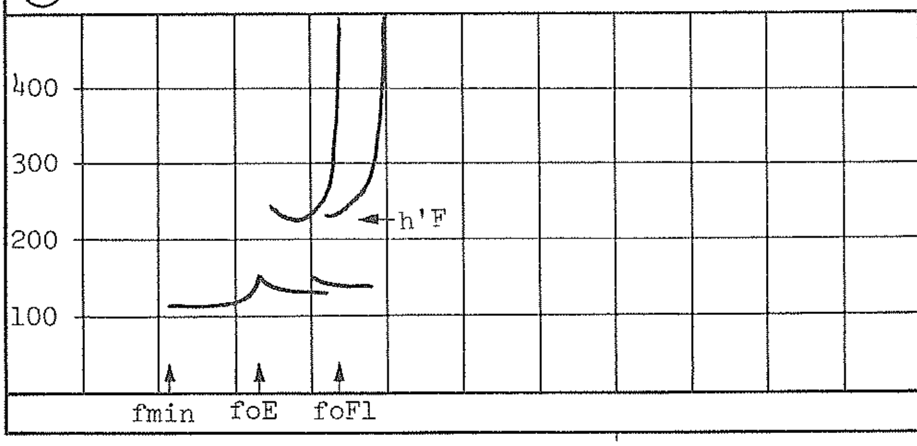
fmin	17
foE	265
h'E	110
foEs	27EG
fxEs	
h'Es	G
Es type	
fbEs	27EG
foF1	L
h'F	205
h'F2	L
foF2	68
fxI	

(3) The cusp at foF1 is not fully developed



fmin	16
foE	245
h'E	110
foEs	40
fxEs	46
h'Es	115
Es type	cl
fbEs	25EG
foF1	L(44)
h'F	210
h'F2	L
foF2	59
fxI	

(4) No F2 trace is observed (G condition)



fmin	21
foE	330
h'E	110
foEs	42
fxEs	48
h'Es	130
Es type	cl
fbEs	33EG
foF1	44
h'F	225
h'F2	G
foF2	44EG
fxI	

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h'F2 - 1

1

Observation : A daytime ionogram. The normal E layer is seen while the F1 layer is not observed.

Interpretation : foF1 cusp is usually expected near the frequency shown by the dotted line. But since no F1 layer is developed in this ionogram, columns for foF1 and h'F2 in the table are kept open.

Comment : A transient layer which looks like the F1 trace sometimes appears at around sunrise or sunset. This kind of layer varies so fairly rapidly with time so that it is easily distinguished from the normal F1 layer. The occurrence of a transient layer is expressed by the descriptive letter H attached to h'F.

2

Observation : The F1 layer is not so fully developed as to be able to scale h'F2.

Interpretation : Although the F2 trace has no horizontal part, foF1 may be inferred as 4.8 MHz with a considerable error from both the ionogram and the monthly mean value for the hour.
Since both h'F2 and foF1 are doubtful, the letter L is to be used.

h'F2 = L and foF1 = L

Comment : When h'F2 is scaled as L, it is preferable to remark a probalbe range of height (from 270 to 315 km as shown by the mark ↕ in the figure) in the table for convenience of the h'-plot.

3

Observation : The F1 layer is observed while the lower part of the F2 trace is not horizontal.

Interpretation : The scaling of h'F2 and foF1 is much easier than that in Case 2. foF1 would be in the vicinity of 4.4 MHz.
According to the accuracy rules, h'F2 is expressed either with the qualifying letter U (doubtful) and the descriptive letter L or with only the letter L for more developed F1 layer.

h'F2 = (h'F2)UL = 330UL or
h'F2 = (h'F2)L = 330L

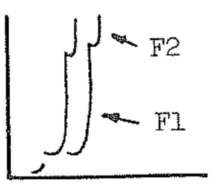
4

Observation : The F1 trace is clearly observed while the F2 trace is not recorded. foF1 = 4.4 MHz. The Es trace is of c type.

Interpretation : This kind of ionogram is often observed during the ionospheric disturbance associated with the geomagnetic storm, when foF2 decreases and h'F2 increases often in the morning as a typical case. Since this Case is interpreted that foF2 is equal to or smaller than foF1, the letter G is used (see Case 5 of foF2).

h'F2 = G

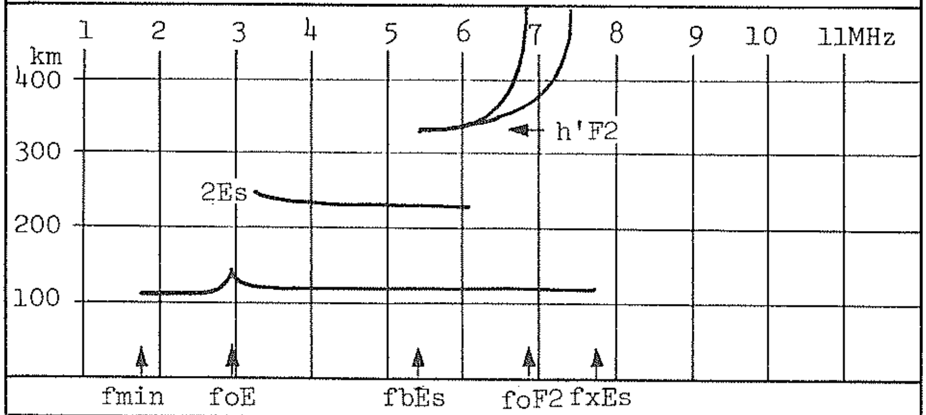
Comment :



This Case is a developed stage having a lower foF2 and higher h'F2 than in the left figure. In the interpretation of ionogram like this Case, there is also a case where the adoption of R may be more appropriate.

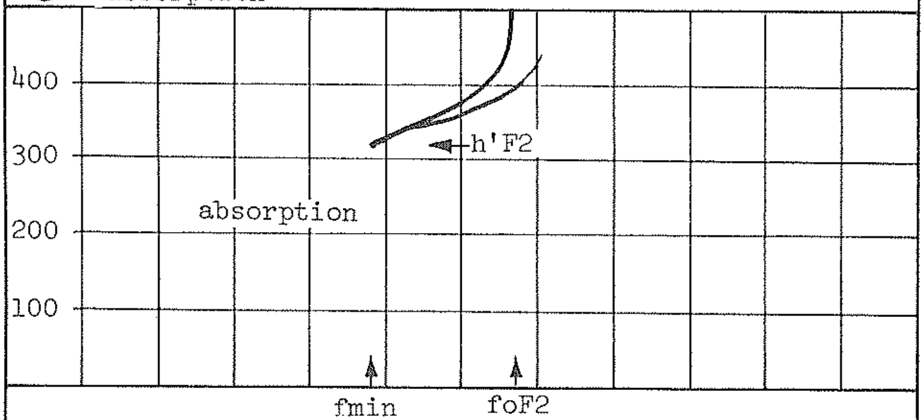
h' F2 – 2

5 The F1 trace is blanketed and the lower part of the F2 trace is almost horizontal



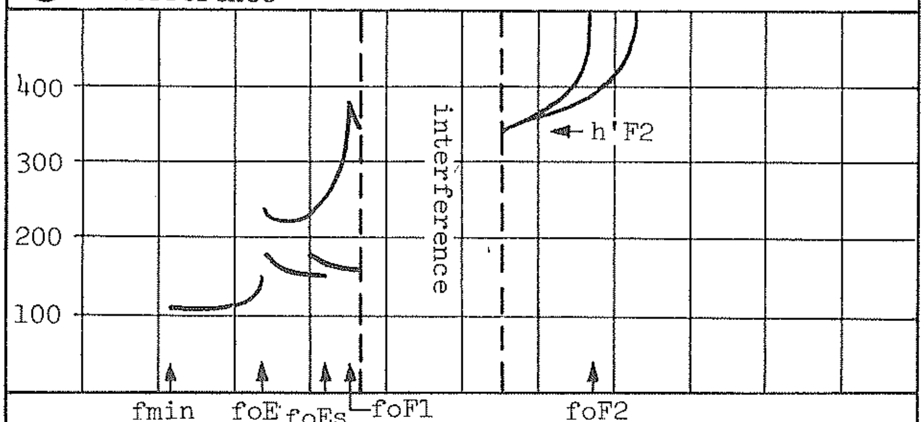
fmin	17
foE	295
h'E	110
foEs	71JA
fxEs	77
h'Es	115
Es type	c2
fbEs	54
foF1	A
h'F	A
h'F2	330
foF2	69
fxI	

6 The lower F region is not observed owing to the absorption



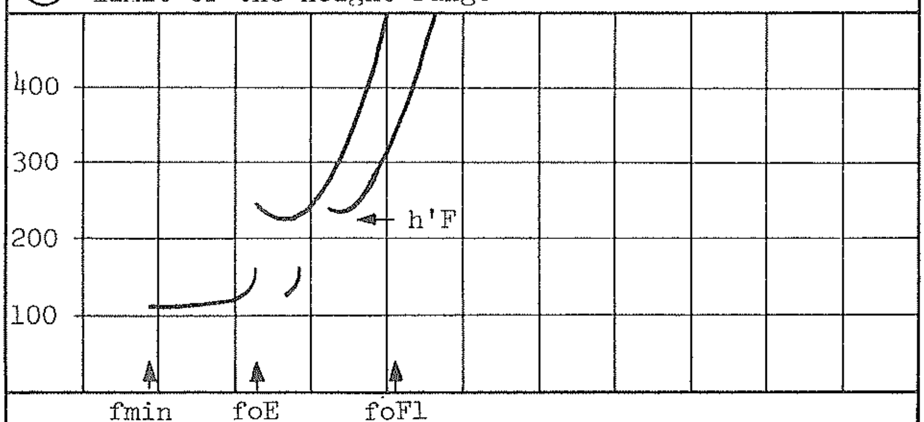
fmin	48
foE	B
h'E	B
foEs	48EB
fxEs	
h'Es	B
Es type	
fbEs	48EB
foF1	B
h'F	B
h'F2	315EB
foF2	67
fxI	

7 F region traces in a frequency band are lost by the interference



fmin	21
foE	335
h'E	110
foEs	42
fxEs	46DS
h'Es	150
Es type	h1
fbEs	34EG
foF1	45
h'F	220
h'F2	340ES
foF2	77
fxI	

8 The F2 trace seems to be present beyond the upper limit of the height range



fmin	19
foE	325
h'E	110
foEs	33EG
fxEs	
h'Es	G
Es type	
fbEs	33EG
foF1	51UW
h'F	225
h'F2	W
foF2	W
fxI	

h'F2-2

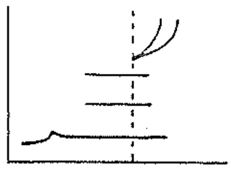
5

Observation : The c type Es extends up to 7.7 MHz. The F trace below 5.4 MHz is not seen at all.

Interpretation : The F trace below 5.4 MHz is blanketed by the Es layer. Since the lower part of the F2 trace is horizontal, there is no difficulty in scaling h'F2.

h'F2 = 330

Comment :



fbEs

h'F2 depends on the slope of the F2 trace at its lower end.

h'F2 = (h'F2)EA = 330EA

If either the slope is larger than that of the trace in the left figure or the F2 trace is totally blanketed, the letter A is used. h'F2 = A

6

Observation : Only the F2 trace is observed. There is no trace below 4.8 MHz.

Interpretation : The recorded trace is the F2 one, being judged from the height and critical frequency. It is considered in this Case that the lack of lower traces is caused by the absorption (B) rather than by the defect of the ionosonde (C) or the interference (S). Since the lower part of the F2 trace is not horizontal and there exists rather high absorption, the qualifying letter E (smaller) and the descriptive letter B should be attached to a numerical value.

h'F2 = (h'F2)EB = 315EB

Comment : When no traces are recorded on the ionogram, the cause of the lack of traces should be examined. A letter suitable for the cause is to be used.

7

Observation : No traces are seen between 4.6 and 6.5 MHz. The Es trace is of h type foEs = 4.2 MHz.

Interpretation : The traces in the central part of the record are lost owing to the interference. The value of h'F2 is scaled according to the slope of the F2 trace at its lower end, being based on the scaling rules as follows:

h'F2 = (h'F2)ES = 340ES

h'F2 = (h'F2)US = 340US

h'F2 = 340 (The trace is horizontal)

h'F2 = S (The slope of the trace is steep)

8

Observation : The F2 trace can not be identified within the maximum height limit of record. foF1 = 5.1 MHz.

Interpretation : When the existence of the F2 trace in a height above the maximum height is inferred from the reference to the sequence of records, the descriptive letter W is used.

h'F2 = W

The maximum height of the ordinary ionogram is about 800 ∿ 1000 km.

Comment : Attention should be paid to the difference between the G condition as illustrated in Case 4 and the W condition in this Case.

Note

foF2

@ Definition :

foF2 is the ordinary wave critical frequency of the highest stratification in the F region. This definition, however, is not valid for the case where foF2 decreased down to a value less than foF1, known as the G condition which sometimes occurs during the geomagnetic storm.

foF2 is the most important parameters for telecommunication applications.

According to the magneto-ionic theory, the frequency separation between the ordinary and extraordinary mode traces is equal to about fB/2, where fB is the gyro-frequency (the frequency at which the electrons gyrate around the geomagnetic field). The value of fB varies depending on the location of the station and the ionospheric height concerned. In middle latitudes, it is about 1.2 MHz.

@ Scaling accuracy :

foF2 is scaled at the accuracy of 0.1 MHz (e.g. 8.2 MHz).

@ Indication of scaled value :

foF2 is expressed either by the numerical value and/or the letters.

(examples)

S --- The numerical value cannot be obtained owing to the interference.

62S --- There exists the interference not affecting the accuracy of the numerical value.

62US --- The numerical value is affected by the interference. U is the qualifying letter (doubtful).

@ Notices for scaling :

1. A transient layer which sometimes appears near foF2 is usually associated with the travelling ionospheric disturbances. In scaling such a layer, the cross-reference to a sequence of ionograms obtained before and after the time concerned is usually very helpful.
2. foF2 must not be scaled from the oblique reflection trace.
3. The reference to the accuracy rules (pp. 3 - 4) is particularly desirable in scaling foF2.
4. The rules to be applied when foF2 is scaled by extrapolation are summarized on the following pages. See R.H. PP. 35 - 39 for more details as well.
5. The scaling rules of the spread echoes are given in detail on pp. 58 - 63 (Definition of spread F types) and pp. 75 - 78 (letter F) of R.H.

Extrapolation

In the case where the trace near the critical frequency is not clearly recorded owing to the interference, defect of the ionosonde or some ionospheric reasons (e.g. absorption or scattering), it is recommended to obtain the most reliable value of foF2 by extrapolation. Extrapolation can be made by extending hypothetically the traces up to the most probable value of the critical frequency. Since the accuracy of extrapolated value depends necessarily on the amount of extrapolation, the accuracy rules (see pp. 3 - 4) should be applied to in scaling as described in the following examples.

In order to obtain the most probable value by extrapolation, it is important to imagine the most typical shape of retardation near the critical frequency. In doing this, cross-reference to the ionograms obtained in similar conditions is useful, although the shape of the trace is not always the same.

@ Examples:

Four cases are illustrated to obtain 8.0 MHz of foF2 by extrapolation. Upper parts of the F trace are assumed to be lost by interference (S) in these examples, although there are actual cases where R (attennation) may be appropriate. An " a " in the explanation of figures denotes the percentage of extrapolated part relative to 8.0 MHz. The use of the qualifying letter is defined in the accuracy rules.

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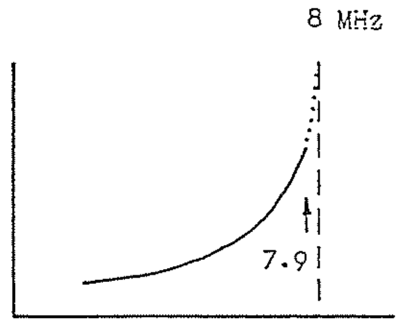
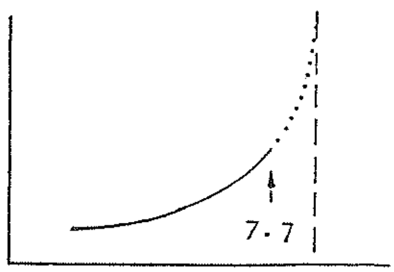
Extrapolation



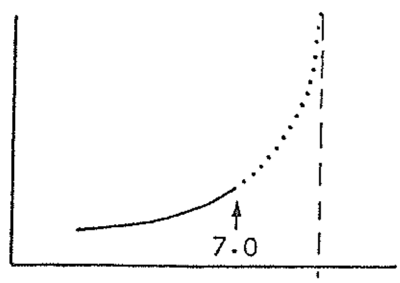
@ The highest frequency of the trace recorded is 7.9 MHz. The extrapolated frequency range (0.1 MHz) is less than 2% of 8.0 MHz. The descriptive letter S is attached to the numerical value.

foF2 = 80S



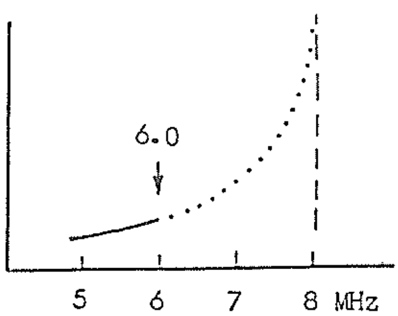
@ The highest frequency of the trace recorded is 7.7 MHz. The extrapolated frequency range (0.3 MHz) is about 4% of 8.0 MHz. Since $2\% < a < 5\%$, the numerical value is followed by the qualifying letter U (doubtful) and the descriptive letter S.

foF2 = 80US



@ The highest frequency of the trace recorded is 7.0 MHz. The extrapolated frequency range (1.0 MHz) is about 13% of 8.0 MHz. Since $10\% < a < 20\%$, the numerical value is followed by the qualifying letter D (greater than) and the descriptive letter S.

foF2 = 70DS

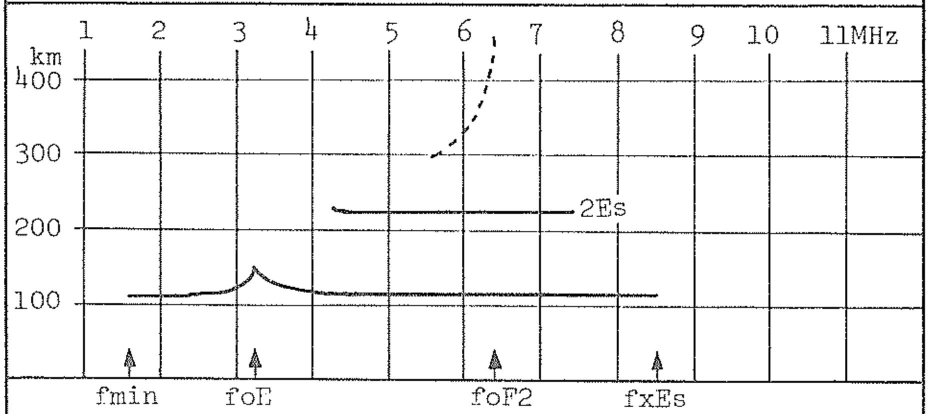


@ The highest frequency of the trace recorded is 6.0 MHz. The extrapolated frequency range (2 MHz) is 25% of 8.0 MHz. Since a exceeds 20%, only the descriptive letter is used.

foF2 = S

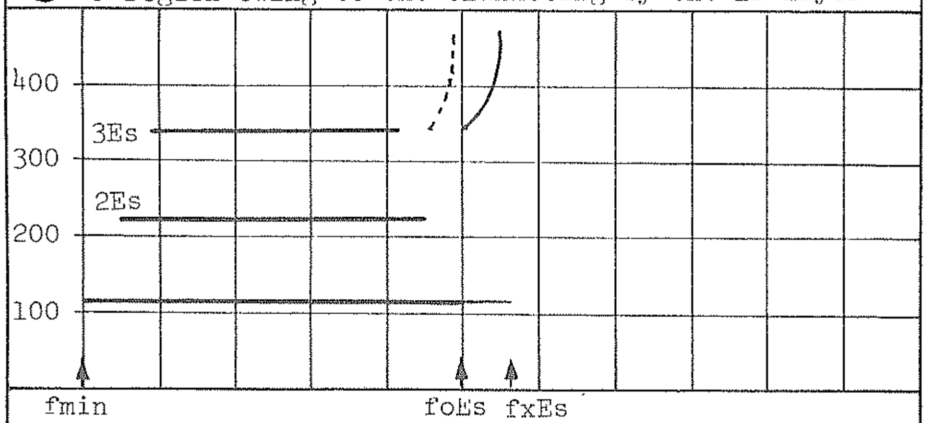
foF2 -1

(1) No F2 trace is observed owing to the blanketing by the Es layer



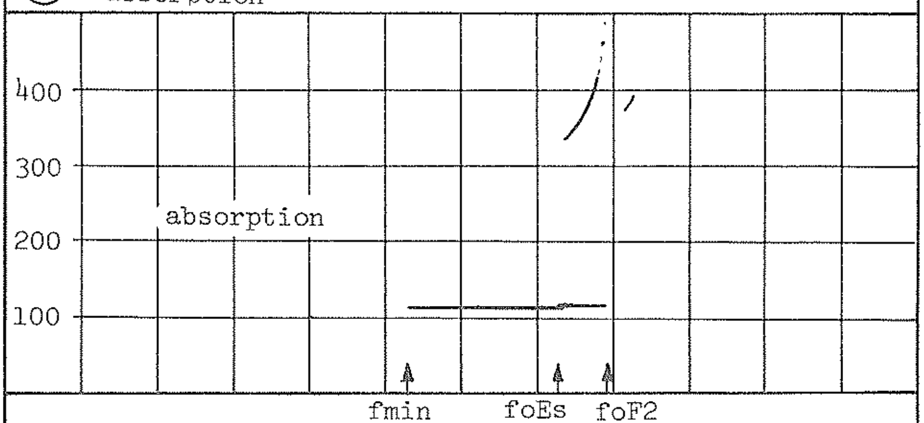
fmin	16
foE	325
h'E	110
foEs	79JA
fxEs	85
h'Es	115
Es type	c2
fbEs	79AA
foF1	A
h'F	A
h'F2	A
foF2	A
fxI	

(2) Only the extraordinary component is observed in the F region owing to the blanketing by the Es layer



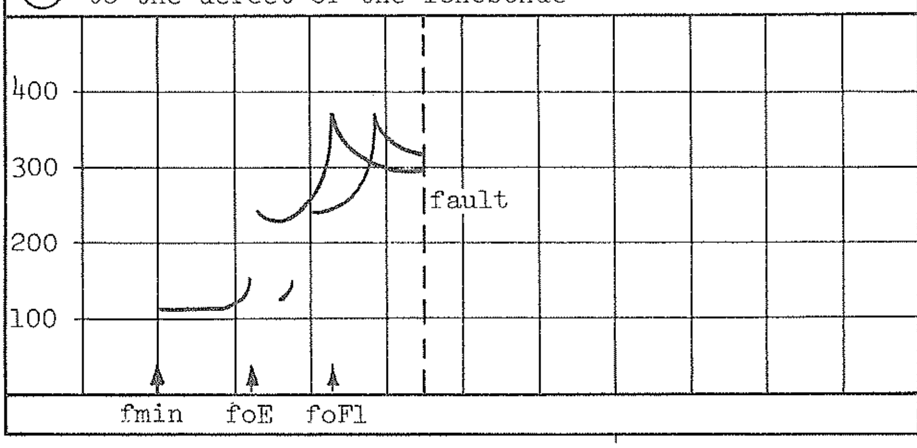
fmin	10EE
foE	
h'E	
foEs	60
fxEs	66
h'Es	115
Es type	f3
fbEs	60AA
foF1	
h'F	A
h'F2	
foF2	59JA
fxI	65X

(3) Lower part of traces disappears owing to the absorption



fmin	53
foE	B
h'E	B
foEs	73
fxEs	79
h'Es	115
Es type	c1
fbEs	73
foF1	B
h'F	B
h'F2	A
foF2	79R
fxI	

(4) The upper part of traces disappears abruptly owing to the defect of the ionosonde



fmin	20
foE	315
h'E	110
foEs	32EG
fxEs	
h'Es	G
Es type	
fbEs	32EG
foF1	43
h'F	230
h'F2	295C
foF2	C
fxI	

foF2—1

1

Observation : The c type Es having the second order reflection extends up to 8.5 MHz. The F layer is entirely blanketed by this Es layer.

Interpretation : A value of foF2 predicted from the sequence of ionograms should be compared with foEs. Since the foF2 is smaller than foEs in this Case, it is considered that the F2 layer is blanketed by the Es layer. Therefore, the letter A is used.

foF2 = A

Comment : As for the derivation of foEs from ftEs recorded, see Cases 7 to 16 of foEs.

2

Observation : The f type Es is so intense that it entirely blankets the ordinary component of the F trace. foEs = 6.0 MHz

Interpretation : The F trace above 6.0 MHz is supposed to be the extraordinary component, judging from a sequence of ionograms. The value of foF2 which can be derived from fxF2 is expressed with the qualifying letter J and the descriptive letter A.

foF2 = (fxF2 - fB/2)JA = 59JA

Comment : When foF2 derived from fxF2 is greater than foEs, the descriptive letter A is not appropriate. In such a case, the use of the letter S or R should be taken into account depending on the presence of the interference.

3

Observation : No trace is recorded below 5.3 MHz. fmin = 5.3 MHz.

Interpretation : There is so intense absorption that fmin is high and the F2 trace is also weak.

foF2 = (foF2)R = 79R

Comment : When only one component of the F2 trace is recorded, the decision whether it is the ordinary component or not is to be made by utilizing a sequence of ionograms.
The extraordinary component usually suffers from much more absorption than the ordinary. When no trace is recorded at all, all parameters are expressed by the letter B.

4

Observation : The F1 trace is clearly recorded but the traces above 5.5 MHz are lost abruptly.

Interpretation : The disappearance of traces would be caused by the defect of ionosonde. Therefore, the letter C is appropriate.

foF2 = C

Attention should be paid to the difference between S (interference) and C conditions.

Comment : The ionogram produced by a malfunctioning ionosonde is not so simple. For example, the following cases are expected to occur: The trace disappears entirely or sometimes partly. The background noise disappears completely. The traces appear intermittently. The height of traces change irregularly. The frequency or height markers are not normal.

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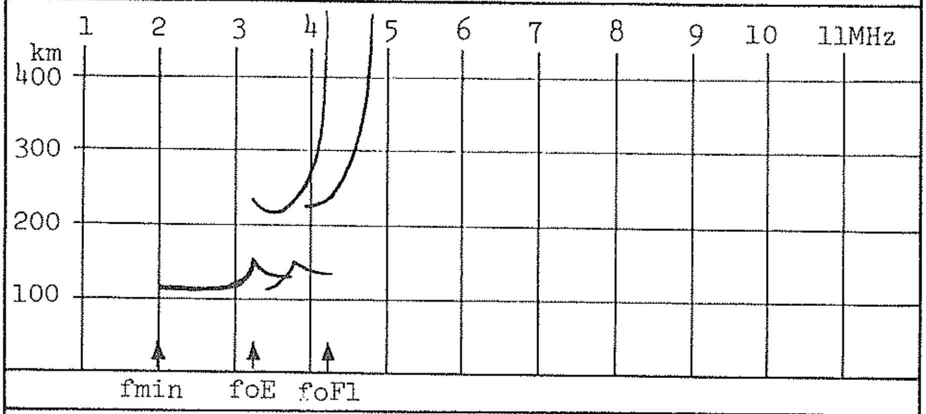
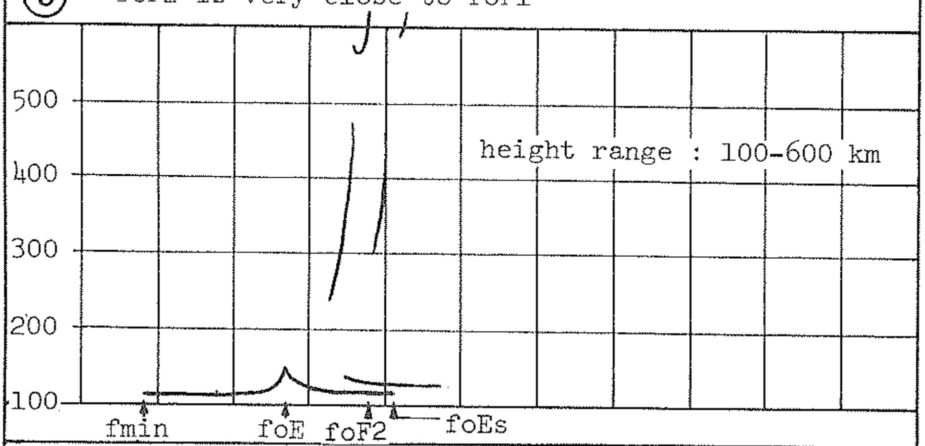
foF2 – 2

⑤ No F2 trace is recorded (G condition)



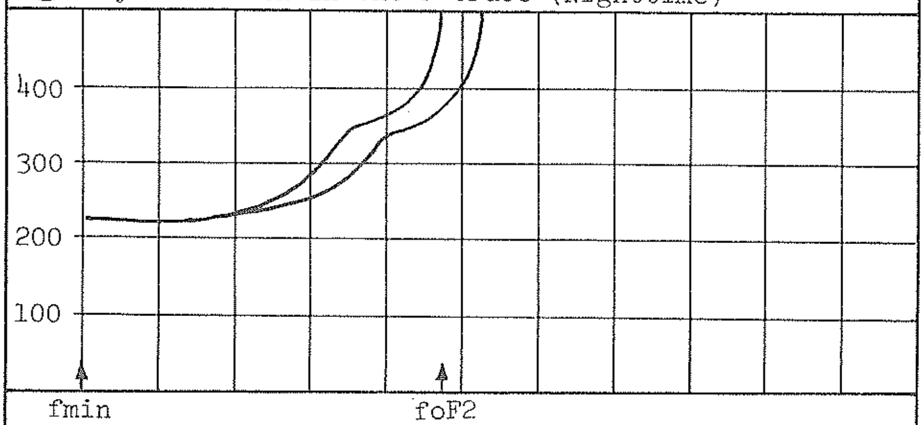
fmin	20
foE	320
h'E	110
foEs	37
fxEs	43
h'Es	125
Es type	cl
fbEs	32EG
foF1	42
h'F	210
h'F2	G
foF2	42EG
fxI	

⑥ foF2 is very close to foF1



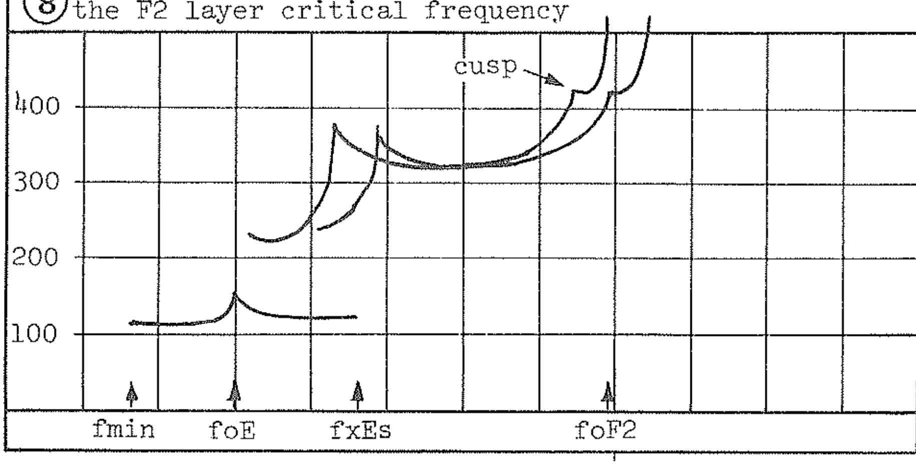
fmin	18
foE	370
h'E	110
foEs	51
fxEs	57
h'Es	115
Es type	cl
fbEs	43
foF1	46
h'F	230EA
h'F2	560
foF2	47
fxI	

⑦ Unusual cusp by a stratification other than the F2 layer is seen in the F trace (Nighttime)



fmin	10EE
foE	
h'E	
foEs	10EE
fxEs	
h'Es	E
Es type	
fbEs	10EE
foF1	
h'F	220
h'F2	
foF2	57H
fxI	63X

⑧ The cusp by a transient stratification is seen near the F2 layer critical frequency



fmin	16
foE	300
h'E	110
foEs	40JA
fxEs	46
h'Es	115
Es type	cl
fbEs	31
foF1	43
h'F	220
h'F2	315
foF2	79H
fxI	

(5)

Observation : The trace in the F region on this ionogram is not that of the F2 layer but of the F1 layer. foF1 = 4.2 MHz. The Es trace is of c type.

Interpretation : The F2 layer is in the so-called G condition which usually occurs during ionospheric disturbances associated with the geomagnetic storm. It corresponds to the condition that the electron density in the F2 layer becomes equal to or lower than that in the F1 layer. foF2 is expressed by the numerical value of foF1 with the qualifying letter E (smaller) and the descriptive letter G.

foF2 = (foF1)EG = 42EG

Comment : Attention should be paid to the following two confusing cases: One is the case where the F2 trace disappears owing to either the interference or the attenuation. The other is the case where the trace cannot be recorded because of its extremely high virtual height exceeding the limit of height range (see Case 15). The letter S or R is suitable for the former while the letter W is suitable for the latter.

(6)

Observation : The F2 trace has a height of 560 km and the F1 trace is partly absorbed. foF1 = 4.6 MHz.

Interpretation : The ionogram like this case is often seen just before or after the time when the ionogram like Case 5 is observed. Attention should be paid to the trend of the virtual height change which is apt to be overlooked.

foF2 = 47

Comment : When foF2 approaches closer to foF1 with time, use of the letter G is usually appropriate. On the other hand, when the virtual height of the F2 trace increases with time keeping some separation of frequency, the letter W is to be applied.

(7)

Observation : Nighttime ionogram having an unusual cusp near 4.4 MHz.

Interpretation : Almost all such cusps appear suddenly and vary quickly. The appearance of this kind of stratification usually affects the critical frequency and even the virtual height. Therefore, even when no effect is expected on the accuracy of scaled value, the letter H should be attached to the numerical value.

foF2 = (foF2)H = 57H

Comment : In this ionogram, h'F which is not influenced by the stratification should not be accompanied by the letter H. In the daytime, attention should be paid not to confuse such a cusp with foF1.

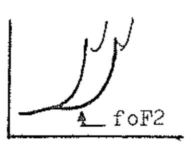
(8)

Observation : Daytime ionogram. An abnormal cusp (appearance of a stratification) is observed at 7.4 MHz of the F2 layer ordinary component.

Interpretation : The cusp which appears near foF2 tends to move towards lower frequencies with time. When the transient stratification influences foF2, the letter H is attached.

foF2 = (foF2)H = 79H

Comment :

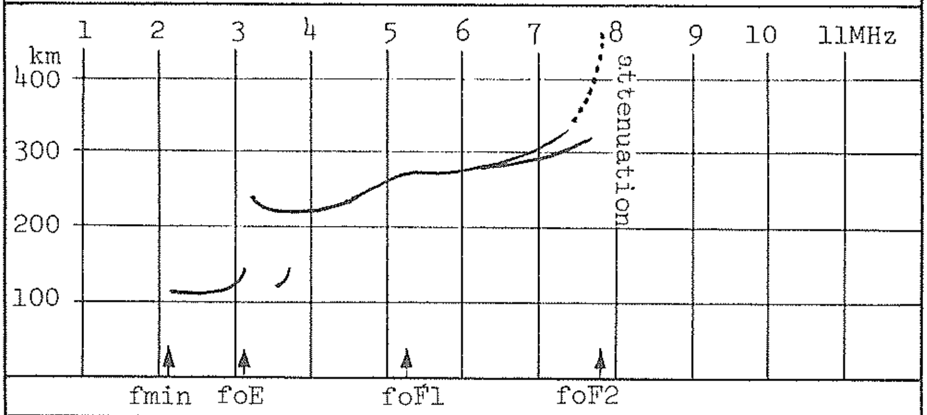


In the left figure, foF2 should be scaled from the solid trace in lower frequencies rather than from the higher thin trace which might be a transient reflection.

(R)

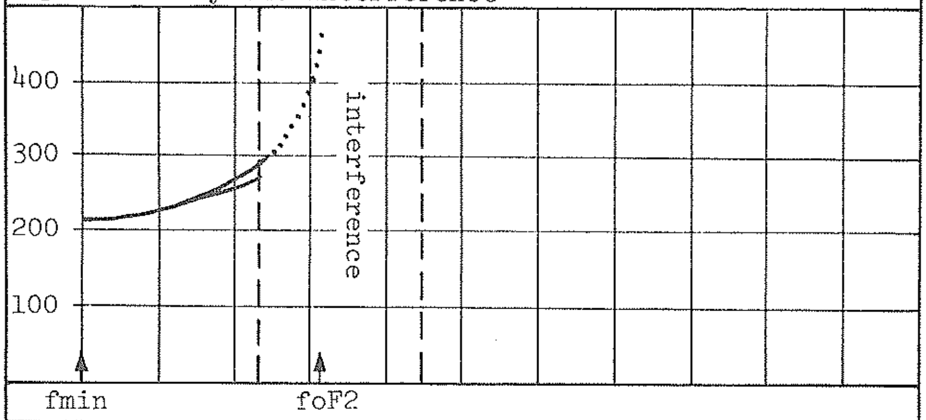
foF2 – 3

(9) The trace near the F2 layer critical frequency is absorbed



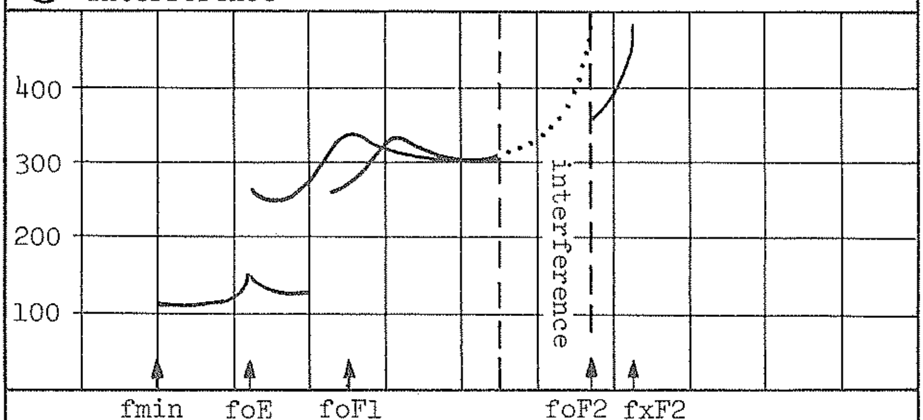
fmin	21
foE	310
h'E	110
foEs	31EG
fxEs	
h'Es	G
Es type	
fbEs	31EG
foF1	L(52)
h'F	215
h'F2	270
foF2	78UR
fxI	

(10) The trace near the F2 layer critical frequency is masked by the interference



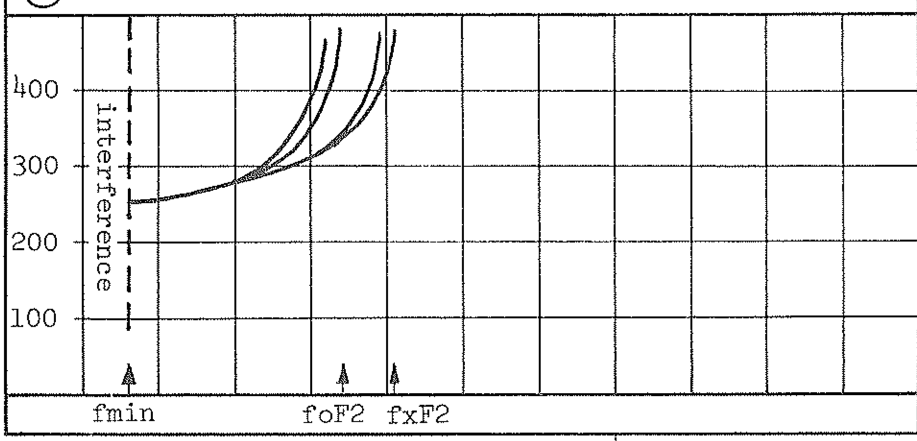
fmin	10EE
foE	
h'E	
foEs	10EE
fxEs	
h'Es	E
Es type	
fbEs	10EE
foF1	
h'F	210
h'F2	
foF2	33DS
fxI	S

(11) Upper part of the F2 trace is masked by severe interference



fmin	20
foE	315
h'E	110
foEs	40
fxEs	
h'Es	125
Es type	cl
fbEs	32EG
foF1	45UL
h'F	250
h'F2	300
foF2	77JS
fxI	

(12) A fork-shaped trace is observed



fmin	16ES
foE	
h'E	
foEs	16ES
fxEs	
h'Es	S
Es type	
fbEs	16ES
foF1	
h'F	250
h'F2	
foF2	44V
fxI	51X

Ⓡ

(9)

Observation : Uppermost parts of the F2 trace are not recorded. The cusp of foF1 is not clear, while the normal E layer is clear.

Interpretation : It is interpreted that both components of the F2 trace are weakened by the attenuation (R) near 7.4 and 7.7 MHz respectively. Since foF2 extrapolated by extending the trace as dotted curve differs roughly 5% from the top frequency recorded (7.4 MHz), the qualifying letter U is used.

foF2 = (foF2)UR = 78UR

Comment : The attenuation (correctly, the deviative absorption) in the F region increases as the retardation does. This is also true for the F1 and E traces.

(10)

Observation : Nighttime ionogram in which the F trace is observed from 1.0 MHz. No trace, however, is recorded in the frequency range above 3.3 MHz owing to the interference.

Interpretation : The value of foF2 is obtained by assuming the shape of trace as the dotted curve (extrapolation). Then an appropriate qualifying letter is looked for depending on the quantity extrapolated. Since the quantity (4.1 - 3.3 = 0.8 MHz) does not exceed 20% of foF2 (4.1 MHz) in this case, the letter D is appropriate according to the accuracy rules of extrapolation.

foF2 = (Upper limit of observation) DS = 33DS

If the quantity exceeds 20%, only the descriptive letter is used.

foF2 = S

Comment : As for the accuracy rules of extrapolation, see pp. 90-91 of this Manual.

(11)

Observation : The traces in the frequency range from 6.5 to 7.7 MHz are not clear, while the traces of the normal E and the F1 layers are clearly observed.

Interpretation : The traces are obscured by the interference (S). Since the extraordinary component of the F2 trace is seen, foF2 is deduced from it. Therefore, the letters J and S should be used.

foF2 = (fxF2 - fB/2)JS = 77JS

(12)

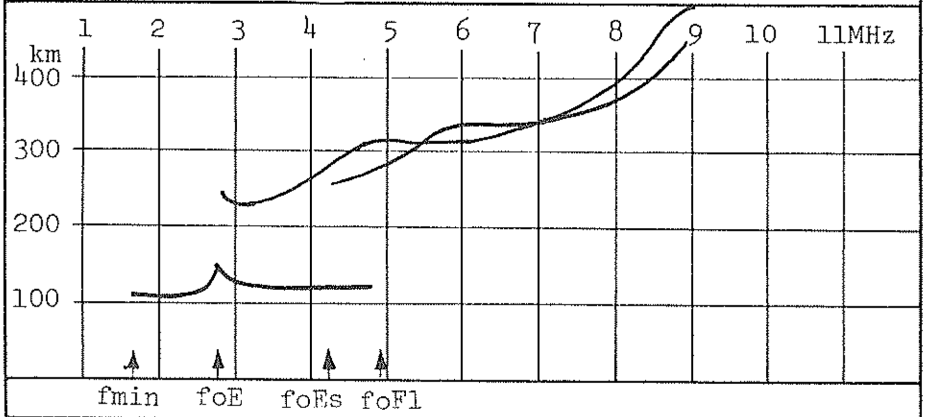
Observation : A fork-shaped F2 trace is observed.

Interpretation : It is easily understood that the F trace consists of two pairs of the ordinary and extraordinary components (one pair is 4.4 and 5.1 MHz, and the other is 4.2 and 4.8 MHz). The pair at higher frequencies should be scaled with the descriptive letter V, as representing the critical frequency. Therefore,

foF2 = (foF2)V = 44V

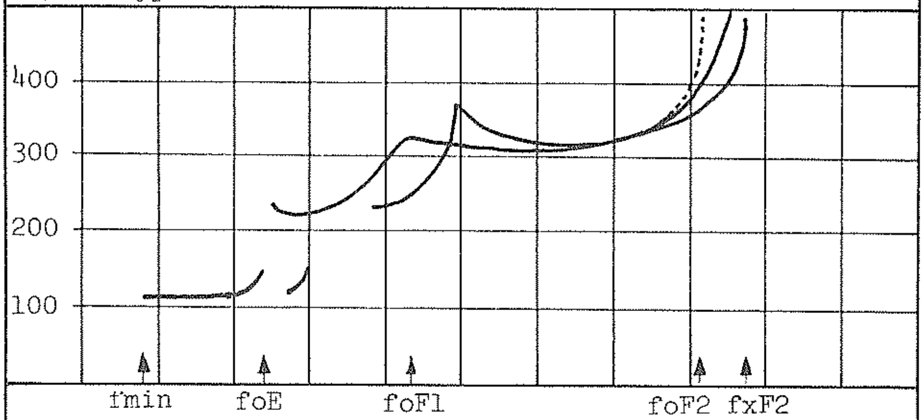
Comment : This type of trace is rarely observed in the sense that some of the four prongs are usually missing. When the ordinary component is missing, foF2 can be deduced from the extraordinary trace. It should not be confused with the oblique reflection, the spread echo or the different stratification. It is recommended to scale and write in the Remarks column of the scaling sheet the critical frequencies of four prongs, because they are needed in the plotting.

⑬ The trace disappears suddenly near the F2 layer critical frequency



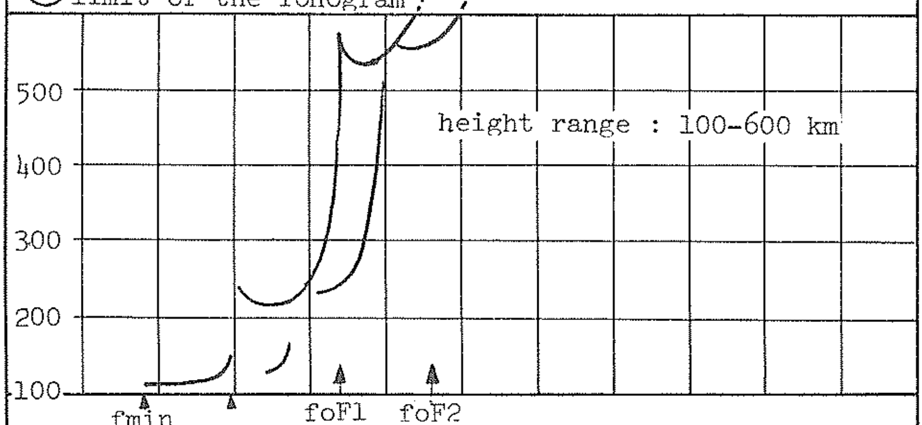
fmin	16
foE	275
h'E	110
foEs	42JA
fxEs	48
h'Es	120
Es type	c1
fbEs	28EG
foF1	L(49)
h'F	230
h'F2	315
foF2	90EY
fxI	

⑭ The F1 and F2 traces are somewhat deformed from a typical shape



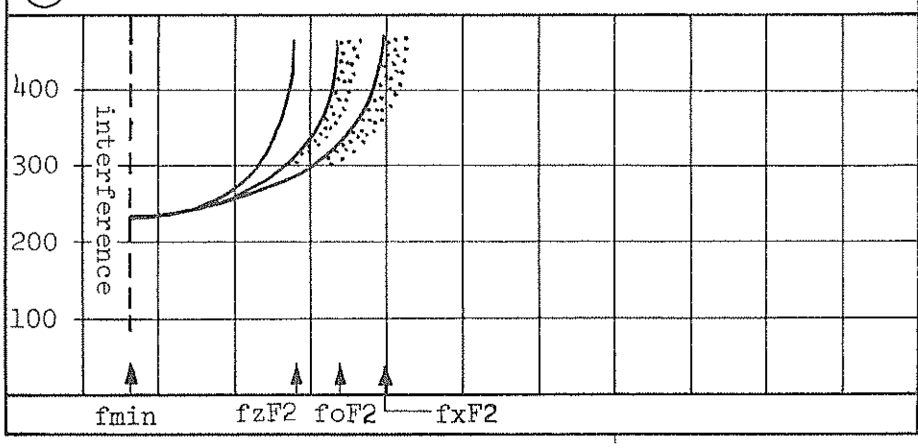
fmin	18
foE	340
h'E	110
foEs	34EG
fxEs	
h'Es	G
Es type	
fbEs	34EG
foF1	53UH
h'F	220
h'F2	305
foF2	91JH
fxI	

⑮ The upper part of the F2 trace exceeds the height limit of the ionogram



fmin	16
foE	295
h'E	110
foEs	30EG
fxEs	
h'Es	G
Es type	
fbEs	30EG
foF1	44
h'F	215
h'F2	540
foF2	56UW
fxI	

⑯ The z component is observed in the F trace



fmin	16ES
foE	
h'E	
foEs	16ES
fxEs	
h'Es	S
Es type	
fbEs	16ES
foF1	
h'F	230
h'F2	
foF2	44Z
fxI	53

Ⓡ

(13)

Observation : The trace near the F2 layer critical frequency (above 8 MHz) is abnormal in shape and both components suddenly disappear in the vicinity of 9 MHz. The F1 trace is also not normal.

Interpretation : When the layer tilt is large, the trace approaching up to foF2 sometimes disappears suddenly. Since such trace is the reflection from an oblique direction, foF2 should not be derived from it. foF2 is to be represented by the limiting value accompanied by the qualifying letter E (smaller) and the descriptive letter Y.

foF2 = (limiting value) EY = 90EY

Comment : The letter H is generally used to indicate the presence of a stratification or a tilted layer, whereas the letter Y expresses the presence of severe tilt in the F region. Note that the meaning of Y is different from that for Lacuna (see Case 12 of foF1).

(14)

Observation : The ordinary components of F1 and F2 layers show some deformation, resulting in an unusual cusp at foF1 and insufficient separation (0.3 MHz) of o and x components near foF2.

Interpretation : When there is an ionospheric tilt in N-S direction, the recorded frequency separation between the o and x components may differ usually from fB/2, and sometimes one component is modified in shape. In this case, since the extraordinary component is normal, foF2 can be deduced from fxF2 as dotted curve.

foF2 = (fxF2 – fB/2)JH = 91JH

Comment : For the layer tilting in E-W direction, no significant difference is expected between shapes of both components.

(15)

Observation : The virtual height of the F2 trace is so high (540 km) that the traces near the F2 critical frequencies are beyond the maximum height range (600 km in this Case).

Interpretation : Since the height limit of ionosonde is about 800 ∿ 1000 km, the ionogram like this Case is not likely to be seen actually. Only in the case where traces seem to still exist at a height exceeding the height limit, the letter W can be applied (refer to Cases 5 and 6).

foF2 = (foF2)UW =56UW

The portion of trace outside the height limit should be extrapolated being based on the accuracy rules. When the letter W is applied, the numerical value is to be followed by the letters D or U.

(16)

Observation : The F traces are split into three branches (z, o and x components).

Interpretation : The critical frequency seen at 3.8 MHz is of the z mode which is the third magneto-electronic component propagating along the geomagnetic field line. This kind of ionogram is not so common, since the field line runs far from the vertical in mid-latitudes. Slight spreading is seen on both ordinary and extraordinary components. The difference between fxF2 and fzF2 is equal to fB (the gyrofrequency), with foF2 occurring about the middle of both components. The appearance of the z component is expressed by the letter Z.

foF2 = (foF2)Z = 44Z

Comment : Both of the descriptive letters Z and F are applicable to this case. Concerning the selection of letter, follow the selection rules described in 3.2 on page 67 of R.H.

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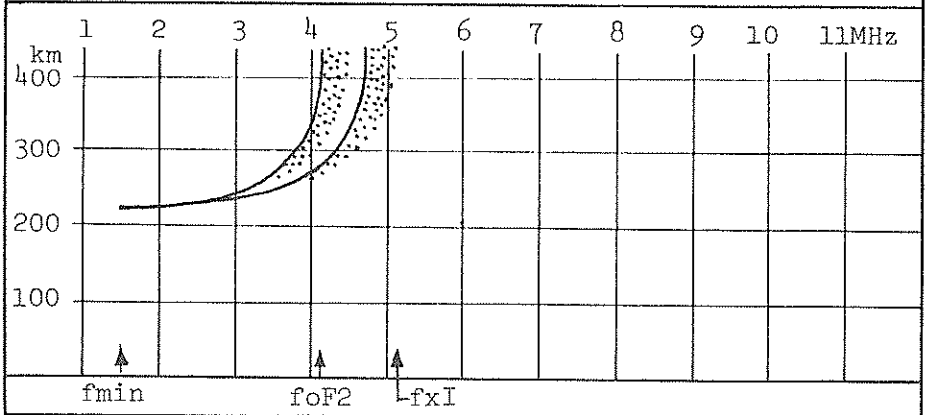
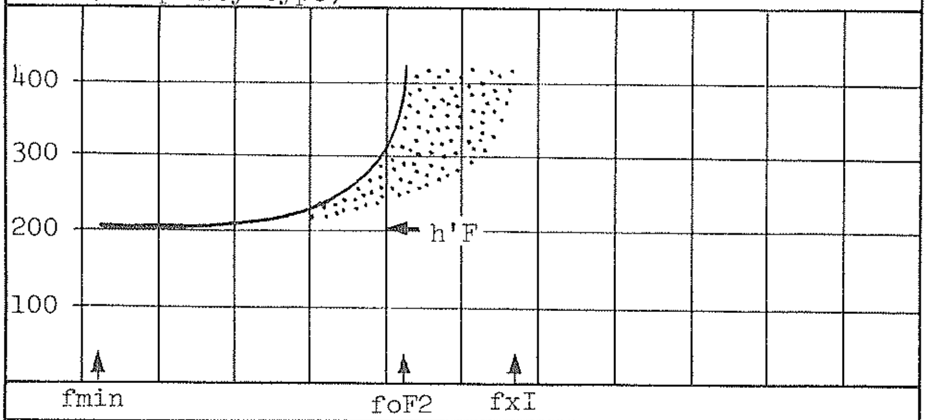
⑰ Both ordinary and extraordinary components of the F trace are in spread condition



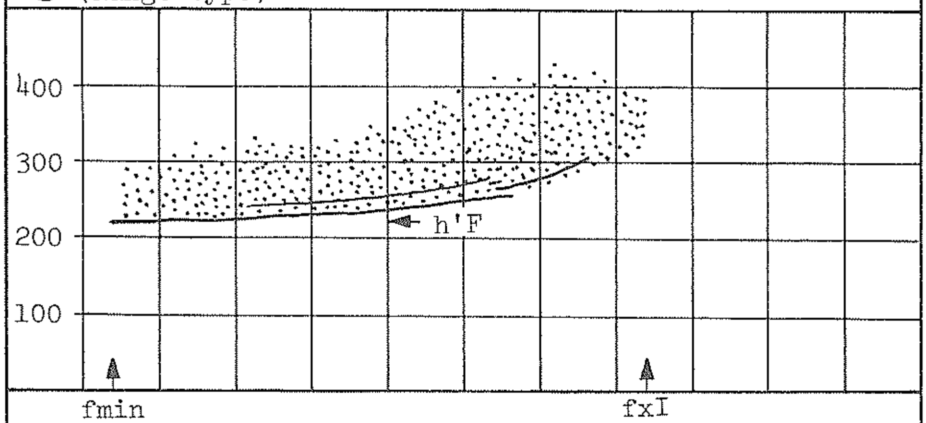
fmin	15
foE	
h'E	
foEs	15EB
fxEs	
h'Es	B
Es type	
fbEs	15EB
foF1	
h'F	220
h'F2	
foF2	41UF
fxI	51

⑱ The F trace is spread along the frequency axis (Frequency-type)



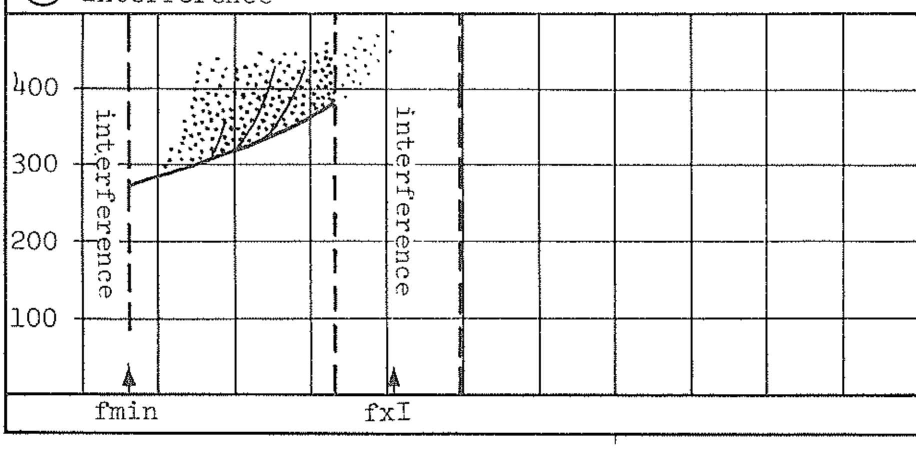
fmin	12
foE	
h'E	
foEs	12EB
fxEs	
h'Es	B
Es type	
fbEs	12EB
foF1	
h'F	200
h'F2	
foF2	52F
fxI	67

⑲ The F trace is spread along the height axis (Range-type)



fmin	14
foE	
h'E	
foEs	13EB
fxEs	
h'Es	B
Es type	
fbEs	13EB
foF1	
h'F	220Q
h'F2	
foF2	Q
fxI	84

⑳ The frequency-type spreading influenced by the interference



fmin	16ES
foE	
h'E	
foEs	16ES
fxEs	
h'Es	S
Es type	
fbEs	16ES
foF1	
h'F	270ES
h'F2	
foF2	F
fxI	51

(17) Observation : Echo spreading is seen for both components of the F trace.

Interpretation : In this Case, the inner edge (lower side of frequency) of each component is clear and the traces spread towards higher frequencies. The main trace is in the clear-cut side. Therefore, foF2 = 4.1 and fxF2 = 4.7. Since the width of the echo spreading exceeds 0.3 MHz which is the threshold value for indicating the presence of echo spreading, the numerical value is followed by the letter F. The echo spreading brings basically error in scaling to some extent. Therefore, the letter U is usually applied together with the letter F. foF2 = (foF2)UF = 41UF.

Comment : As shown in the left figure, if the outer edge (higher side of frequency) of each component is observed clearly, this should be regarded as the main trace from which foF2 can be scaled. The case of clear inner edge is more common than that of clear outer edge. The width of the spreading is to be noted for both components in the Remarks column of the scaling sheet.

(18) Observation : The maximum width of the echo spreading along the frequency axis is about 1.5 MHz (5.2 ∿ 6.7 MHz).

Interpretation : This kind of spread pattern is called the frequency-type spreading. The clear inner edge would be the main trace from which foF2 is scaled, provided that the F layer is horizontally stratified.

foF2 = (foF2)UF = 52UF

If there is a clear trace from which fxF2 is scaled, foF2 may be deduced from it.

foF2 = (fxF2 - fB/2)JF

The width of the echo spreading (5.2 ∿ 6.7 MHz) is noted in the Remarks column.

Comment : The second order reflection is conveniently used in identifying foF2, since it is likely to be observed more clearly (without the spreading) than the first.

(19) Observation : The echo spreading occurs mainly along the height axis. The virtual height of the trace increases very slowly with frequency.

Interpretation : This kind of spread pattern is called the range-type spreading. It is difficult to scale foF2 from this type of ionogram which does not show the presence of clear main trace. Thus, for this Case, foF2 is expressed only by the letter Q.

foF2 = Q

Comment : The width of the spreading (1.4 ∿ 8.4 MHz) is noted in the Remarks column of the scaling sheet. For expressing the presence of the range-type spreading, h'F is followed by the letter Q.

(20) Observation : A nighttime ionogram. The echo spreading is seen above 2.6 MHz. The interference effects on the observation in both frequency ranges below 1.7 and above 4.3 MHz.

Interpretation : This is an example of frequency-type spreading. The frequency range with the spreading is so wide that only the letter F is eligible.

foF2 = F

Comment : Attention should be paid, when severe interference covers the whole frequency range. Generally speaking, if two causes affect on the scaling, the priority is to be given to the bigger cause. Therefore, the following two scalings are correct depending on the situation concerned.

foF2 = FS or foF2 = SF

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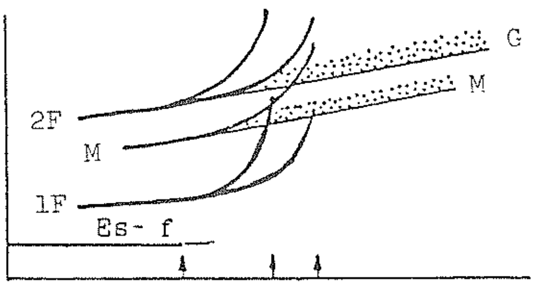
fxI

@ Definition :

The parameter fxI is defined as the highest frequency at which the reflection from the F region (F1 or F2 layer) is recorded, independent of whether it is reflected from vertical or oblique directions (note that parameters other than fxI should not be scaled from oblique reflections).

fxI is a parameter indicating the presence of the F layer scattering which contributes to an actual propagation at oblique incidence. fxI is also applied to the polar or equatorial spurs, but not applied to traces of ground backscatter.



G: Ground backscatter tangential to the second order F reflection.

M: Es backscatter tangential to the M(2F-Es) trace which is described in detail in Appendix 1 (p.118 of this manual).

@ Scaling accuracy :

fxI is scaled at the accuracy of 0.1 MHz (e.g. 4.3 MHz).

@ Indication of scaled value :

fxI is expressed either by the numerical value with or without the letter, or the letter only.

(Examples)

A --- The descriptive letter expressing that the F trace is blanketed by the Es layer.

93 --- The highest frequency of the spread F trace.

45X --- X is the descriptive letter expressing the fxI is equivalent to fxF2 in the absence of the echo spreading.

@ Notices for scaling :

1. fxI should be scaled from the ionogram observed with the normal gain of the ionosonde receiver.

2. Concerning the frequency separation between the ordinary and extraordinary components as necessary for deciding fxI, see Definition of foF1 on p. 67.

3. In the scaling of fxI, the descriptive letters A, B, C, D, E, G, S and Y can be applied (for details, see pp. 102-103 of R.H.). The scaling of fxI is classified into the following two cases:

   a. In the presence of the echo spreading and/or the oblique reflection in the F region, the highest frequency is scaled as fxI including the letters attached.

(Examples)

fxI = 55

fxI = 50X, when fxF2 = 50S

fxI = (foI + fB/2)OB = 420B, when foI = 36

   b. In the absence of the echo spreading and the oblique reflection in the F region, the value of fxF2 is scaled as fxI including the letters attached. In this case, the numerical value of fxF2 is used with descriptive letter X.

(Examples)

fxI = (fxF2) X = 49X, when fxF2 = 49

fxI = 49X, when fxF2 = 49S

fxI = 46UX, when fxF2 = 46US

fxI = fxF2 = S, when fxF2, foF2 = S

fxI = 460X, when foF2 : numerical value
fxF2 : no numerical value

4. Appendix 2 (p.119 of this manual) which is extracted from the INAG Bulletin (INAG-33, pp. 32-33 May 1981) gives much more variety of examples for fxI scaling.

5. Monthly tabulation sheets may be left blank for columns at hours for which spread F traces are seldom or never seen, as in the practice for E and F1 parameters (p. 102 R.H. 3.32(c)). Most groups find it more efficient to tabulate fxI at all hours.

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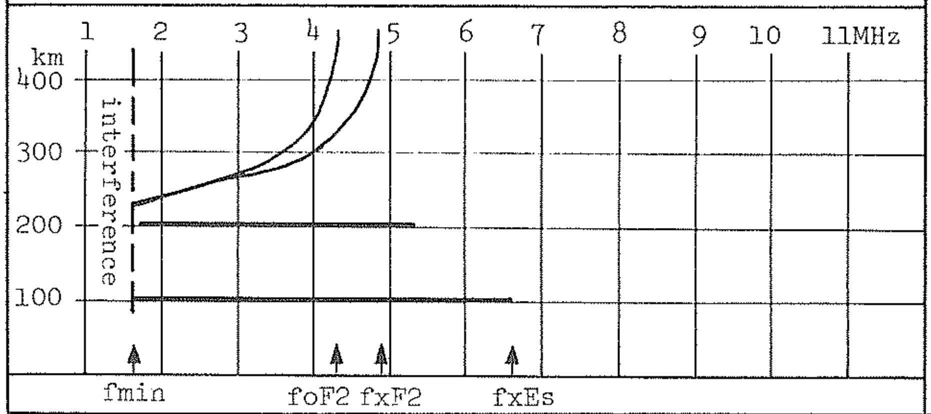
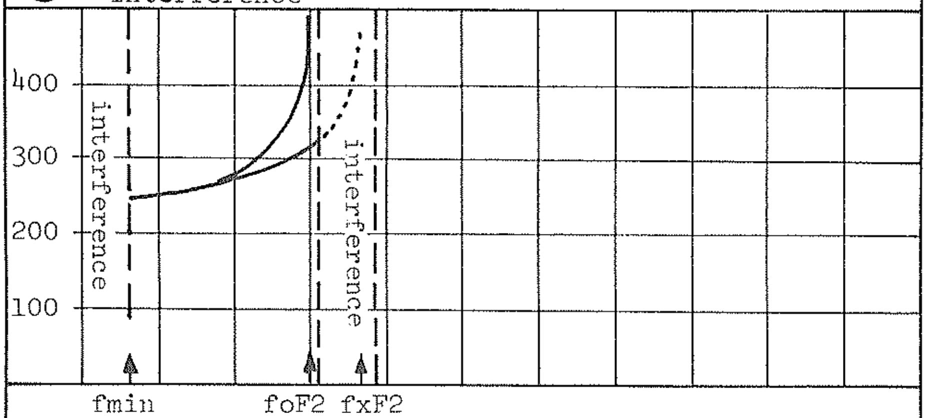
fxI – 1

1 Ionogram without the spread echoes (Nighttime)



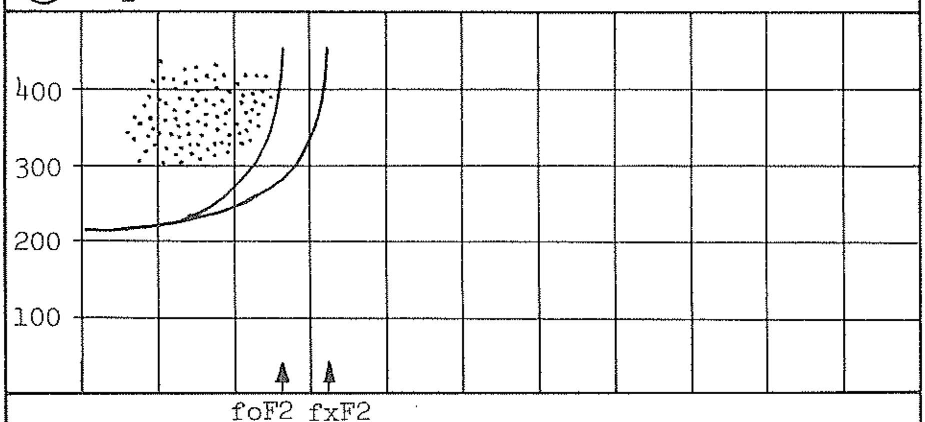
fmin	16ES
foE	
h'E	
foEs	60JA
fxEs	66
h'Es	100
Es type	f2
fbEs	16ES
foF1	
h'F	230US
h'F2	
foF2	43
fxI	49X

2 The extraordinary F trace is masked by the interference



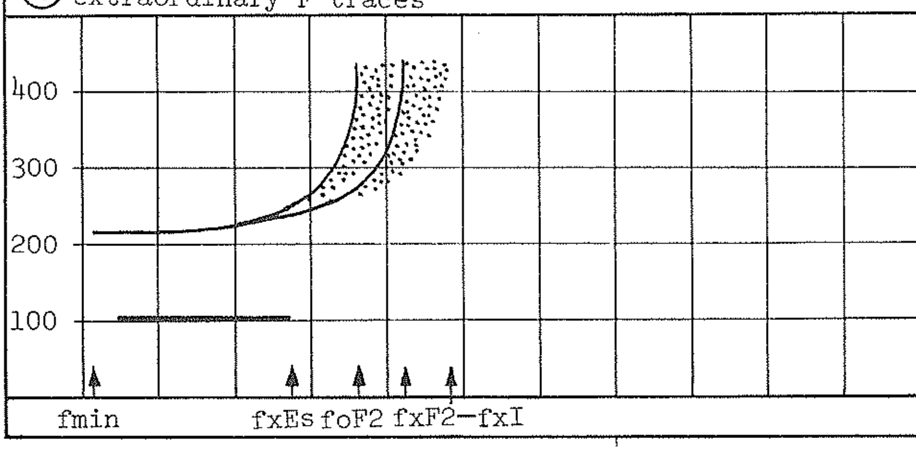
fmin	16ES
foE	
h'E	
foEs	16ES
fxEs	
h'Es	S
Es type	
fbEs	16ES
foF1	
h'F	250
h'F2	
foF2	40
fxI	460X

3 The spread echoes are recorded in a lower frequency range than foF2



fmin	10EE
foE	
h'E	
foEs	10EE
fxEs	
h'Es	E
Es type	
fbEs	10EE
foF1	
h'F	210
h'F2	
foF2	36
fxI	42X

4 The echo spreading is seen on both the ordinary and extraordinary F traces



fmin	11
foE	
h'E	
foEs	31JA
fxEs	37
h'Es	100
Es type	f1
fbEs	11EB
foF1	
h'F	215
h'F2	
foF2	46UF
fxI	58

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fxI – 1

1

Observation : Nighttime ionogram. foF2 = 4.3 MHz, fxF2 = 4.9 MHz.

Interpretation : No echo spreading is recorded in the F trace of this ionogram. Therefore, fxI is expressed by the value of fxF2 followed by the letter X. The Es layer has no relation to the scaling of fxI.

fxI = (fxF2)X = 49X

2

Observation : foF2 = 4.0 MHz. The trace near fxF2 is masked by the interference.

Interpretation : fxF2 can be obtained by the extrapolation from the extraordinary trace itself. In this Case, however, deduction of fxF2 from foF2 is more practical.

fxI = (foF2 + fB/2)OS = 46OX

Comment : The qualifying letter O means that the extraordinary component is obtained by means of the ordinary component. The descriptive letter X has priority over S since no echo spreading in the F trace is seen.

3

Observation : Spread echoes other than the F layer trace are recorded in the frequency range from 1.6 to 3.5 MHz above the height of 300 km.

Interpretation : Such echoes do not influence on the scaling of fxI, since fxI is to be expressed by the highest frequency of the F trace. Following the same process as in Case 1,

fxI = (fxF2)X = 42X

Comment : When fxF2 is expressed by a numerical value with some letters, fxI can be scaled as fxF2 itself.

fxI = fxF2 = 42US

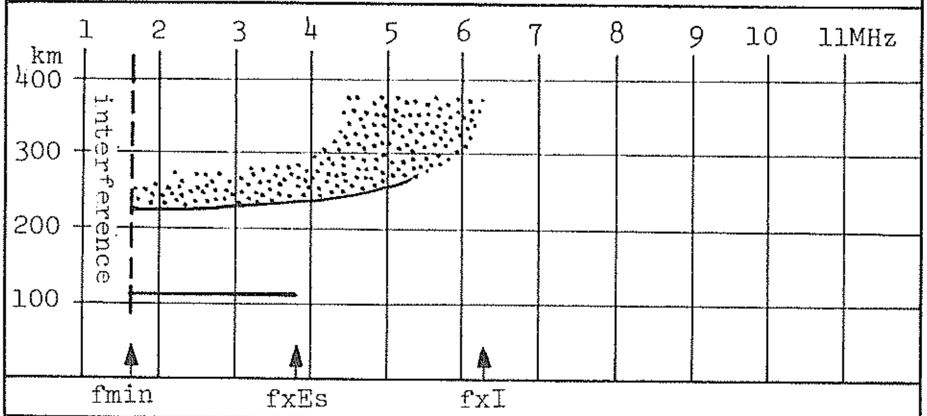
4

Observation : The ordinary F trace spreads over 4.6 ∿ 5.1 MHz, while the extraordinary trace does over 5.3 ∿ 5.8 MHz.

Interpretation : The spreading is not so severe. In this ionogram, the inner edge (lower side of frequency) is the main trace. The highest frequency of the extraordinary component is scaled as fxI.

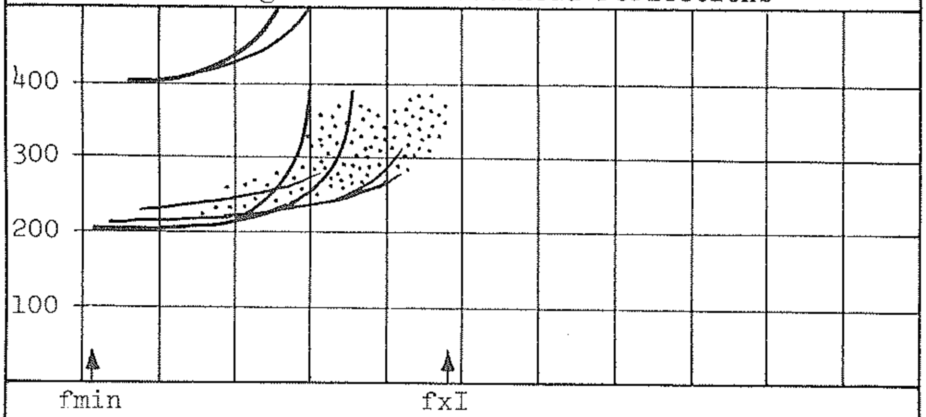
fxI = 58

(5) The spreading is recorded over the whole frequency range of the F trace



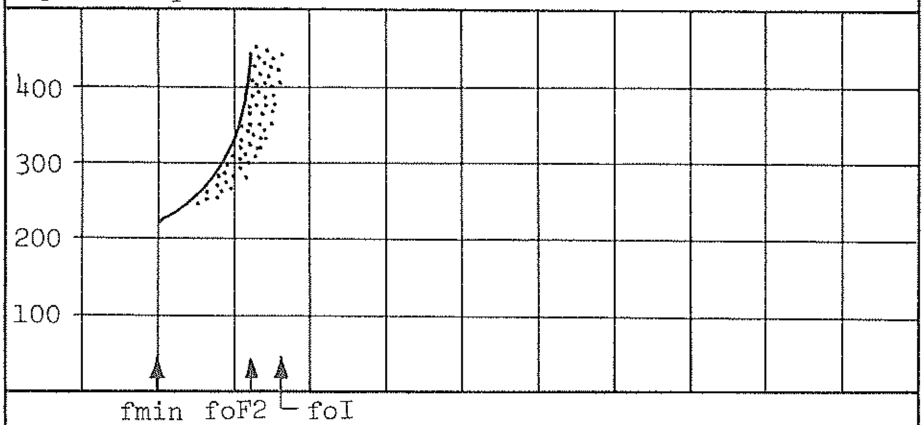
fmin	16ES
foE	
h'E	
foEs	32JA
fxEs	38
h'Es	110
Es type	f1
fbEs	16ES
foF1	
h'F	225Q
h'F2	
foF2	F
fxI	63

(6) The oblique reflection with echo spreading is recorded together with overhead reflections



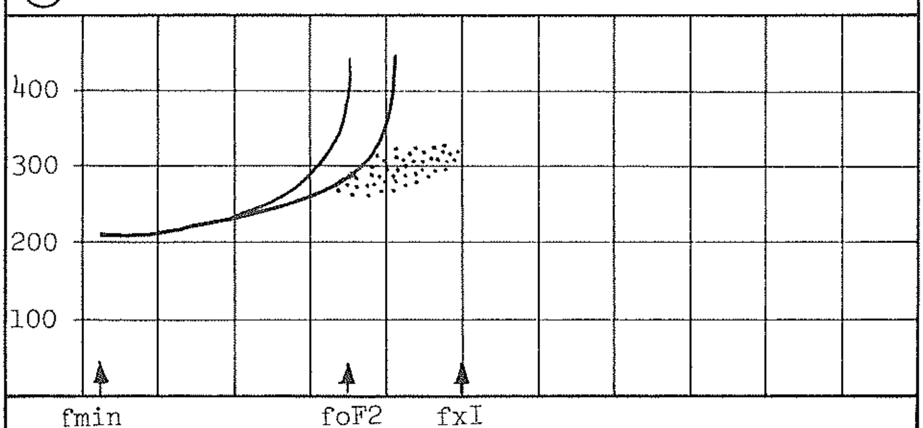
fmin	11
foE	
h'E	
foEs	11EB
fxEs	
h'Es	B
Es type	
fbEs	11EB
foF1	
h'F	200
h'F2	
foF2	40
fxI	58

(7) The extraordinary trace disappears owing to the absorption



fmin	20
foE	
h'E	
foEs	20EB
fxEs	
h'Es	B
Es type	
fbEs	20EB
foF1	
h'F	220EB
h'F2	
foF2	32F
fxI	420B

(8) Appearance of spurs



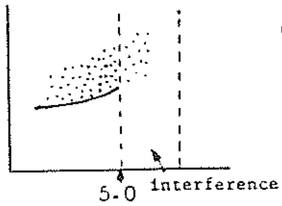
fmin	12
foE	
h'E	
foEs	12EB
fxEs	
h'Es	B
Es type	
fbEs	12EB
foF1	
h'F	205
h'F2	
foF2	45
fxI	60P

(5)

Observation : The echo spreading is observed over the whole frequency range of the F trace. No distinct reflection is found out of rather uniformly spread part.

Interpretation : The highest frequency of the F trace including the spread part is fxI. Therefore,

fxI = 63



Comment : A part of spread echoes is sometimes obscured by severe interference.
In this case

fxI = F, foF2 = 50DS

(6)

Observation : A spread F trace is recorded together with the regular F trace with the second order reflection.

Interpretation : The trace accompanying the echo spreading at a height of 210 km is the reflection from an oblique direction from which the value of fxI is scaled.

fxI = 58

Comment : An oblique reflection tends to approach down to the virtual height of the regular F layer from a higher height at which it appeared in the beginning, and then to increase its height again until it disappears. This can be explained by assuming some irregular structure which moves horizontally when passing over a sounding station.

(7)

Observation : A nighttime ionogram. Only the spread trace of the F layer ordinary component is observed.

Interpretation : fmin is so high that the extraordinary component seems to be lost owing to the large absorption (B). In this case, fxI can be extrapolated from foI (the highest frequency of the spread ordinary F trace) by adding fB/2 to foI. Thus, the letters to be attached are the qualifying letter O and the descriptive letter B.

fxI = (foI + fB/2)OB = 420B

Comment : As for fB, see Case 7 of foEs.
If there is no echo spreading, this Case is equivalent to Case 2 in scaling fxI.

(8)

Observation : The F trace is normal but the spur develops from the extraordinary trace.

Interpretation : The spur has the highest frequency in this ionogram.

fxI = 60P

Comment : The spread echo attached to the extraordinary component is called "spur" because it resembles the spur in shape. This kind of echo is likely to appear when the ionosphere is severely tilted or has an irregular structure in it.

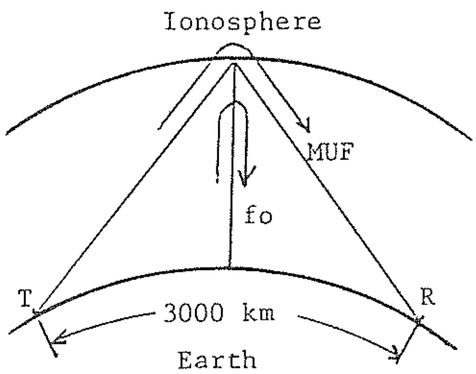
NOTE

M factor

@ <u>Definition</u> :

The M factor (Maximum Usable Frequency Factor) is a conversion factor for obtaining the maximum frequency usable in a given oblique propagation distance from the critical frequency at vertical incidence (fo). The M factor for the standard distance of 3000 km is called M(3000) which is usually expressed with the name of reflection layers as M(3000)F2 or M(3000)F1.

M(3000) can be obtained by applying the standard transmission curve (see pp.23 ∿ 25, R.H.) for the ground distance of 3000 km to the ordinary component of the first order reflection from the layer concerned. Practically, M(3000) is related to MUF(3000) (Maximum Usable Frequency for 3000 km path length) and fo (the ordinary wave critical frequency at vertical incidence) as below:



$$M(3000) = \frac{MUF(3000)}{fo}$$

@ <u>Scaling accuracy</u> :

Both M(3000)F2 and M(3000)F1 are scaled at the accuracy of 0.05. (e.g. 3.15 or 4.20).

@ <u>Indication of scaled value</u> :

M(3000) is expressed by the numerical value with or without letters, or the letter only.

@ Notices for scaling :

1. M(3000) should be scaled from the ordinary component of the F2 or F1 layers.

2. The qualifying and descriptive letters to be attached to M(3000)F2 or M(3000)F1 are usually the same as those for foF2 or foF1 respectively.

   (Examples)

   M(3000)F2 = F, when foF2 = F.

   M(3000)F1 = L, when foF1 = L.

   M(3000)F2 = 305F, when foF2 = 34F.

   M(3000)F2 = 320JR, when foF2 = 44JR.

3. There are some exceptions where M(3000) accompanies different letters from what foF2 or foF1 does.

   (Examples)

   M(3000)F2 = C, when foF2 = 153DC. (No trace above 15.3 MHz)

   M(3000)F2 = G, when foF2 = 42EG. (foF1 ≧ foF2)

   M(3000)F2 = A, when foF2 = 98. (Blanketing by Es trace as in Case 2)

   M(3000)F1 = B, when foF1 = 52. (Large absorption)

   M(3000)F1 = Y, when foF1 = 46UY. (F1 Lacuna as in Case 12 of foF1)

How to obtain graphically the M factor

The procedure to be followed to obtain graphically the M factor is different for the ionogram with the logarithmic frequency scale and that with the linear frequency scale.

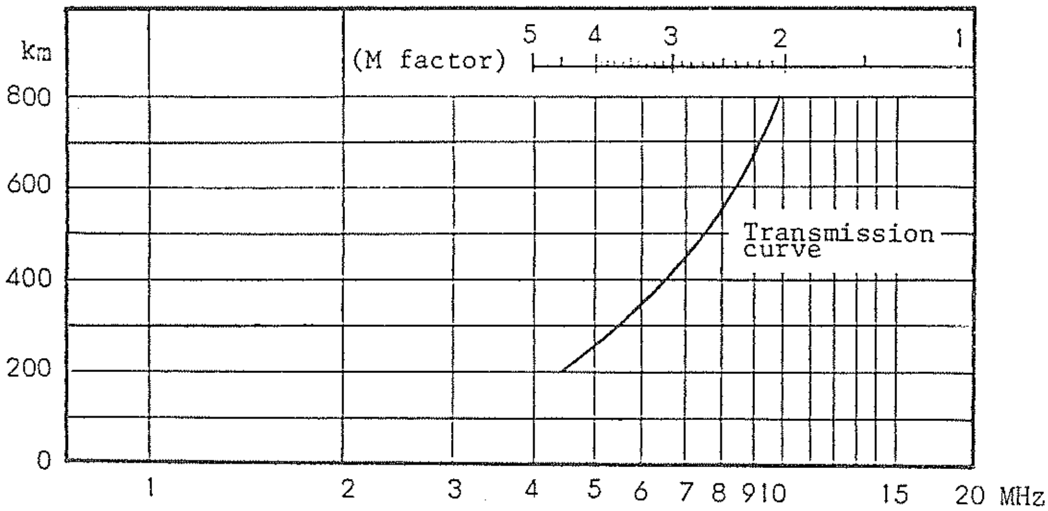
The M factor can be read out directly from the ionogram with the logarithmic frequency scale by means of the slider (Fig.a on p.113) on which the standard transmission curve is depicted. The procedure to be followed in doing this is described in the following "Scaling practice...".

On the other hand, the procedure to obtain the M factor from the ionogram with the linear frequency scale is rather complicated. Instead of one transmission curve in the case of the logarithmic scale, a set of standard MUF curves has to be prepared from the standard transmission curve. The MUF curve which just touches the trace gives the MUF. The M factor is obtained by dividing this MUF by the critical frequency of the trace.

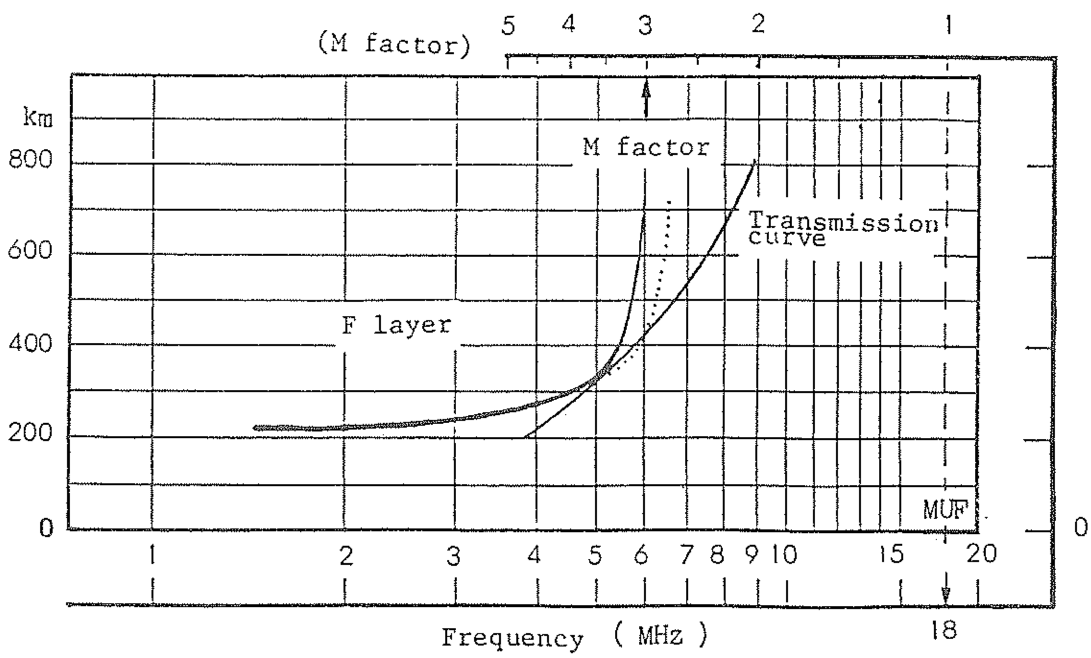
This Manual illustrates the Cases for scaling the M factor from the ionograms with the logarithmic frequency scale.

Scaling practice of the M factor from the ionogram with logarithmic frequency scale

1. A transparent slider (Fig.a on p.113) on which the standard transmission curve for 3000 km is depicted should be prepared. The shape of the standard transmission curve is defined by the table given on page 23 of R.H.
2. The slider is laid over the ionogram so that both the height scales coincide with each other.
3. The slider is moved until the transmission curve touches the outer edge of the reflection from the layer concerned as shown in Fig.b on page 113(For details, see pp.23-24 and p.78 of R.H.).
4. Thus a value on the M factor scale (arrow in the Figure) corresponding to the critical frequency of the layer on the ionogram can be read out. This value is the M factor.
5. The frequency which coincides with 1 on the M factor scale is the MUF.
6. The procedure mentioned above is also applicable to the F1 layer trace.

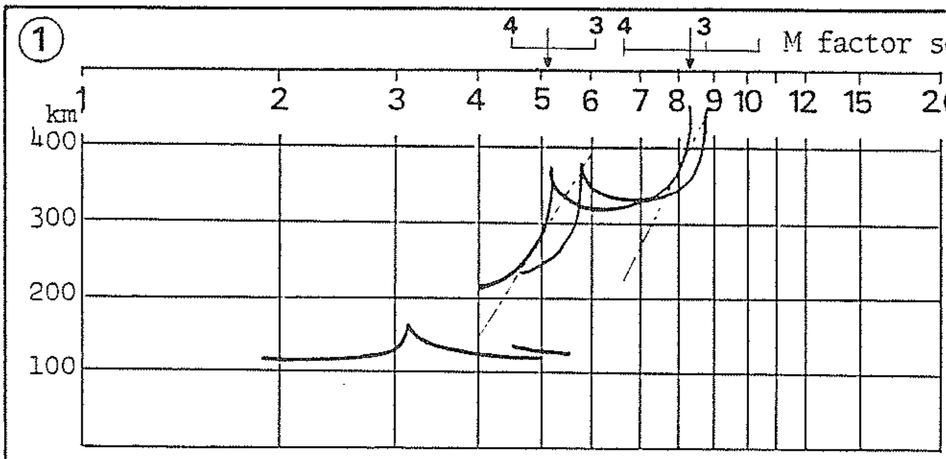


(a) M factor slider

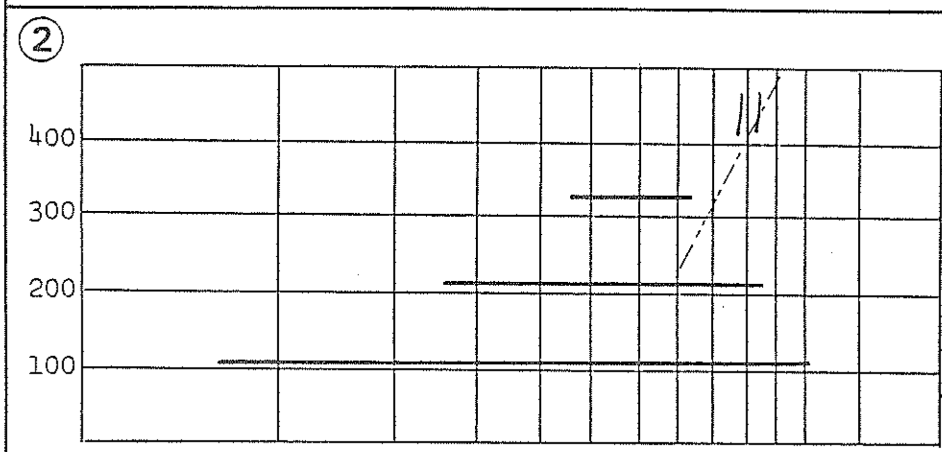


(b) Use of M factor slider

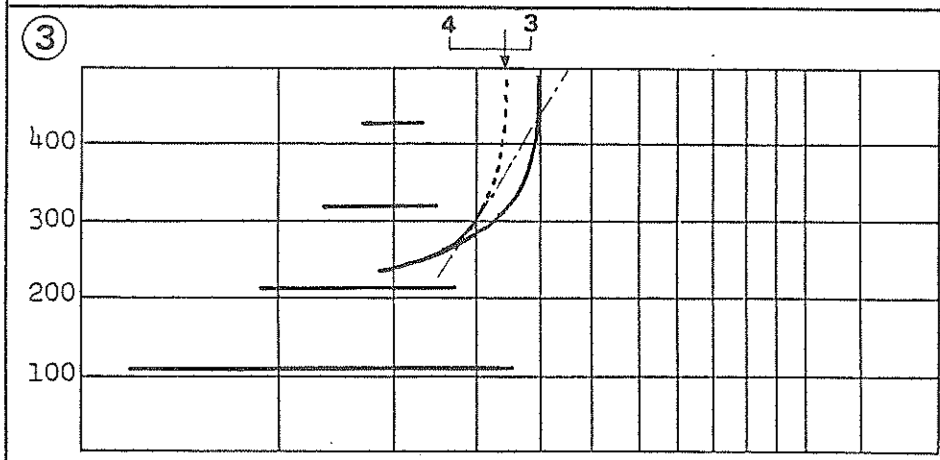
M factor –1



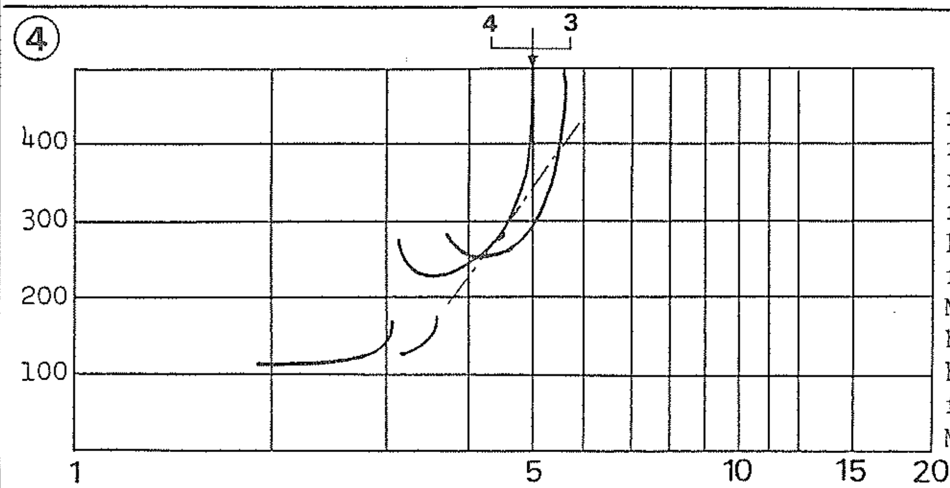
fmin	19
foE	310
foEs	50
fbEs	40
Es type	cl
foF1	52
M(3000)F1	355
h'F	210
h'F2	315
foF2	82
M(3000)F2	315



fmin	17
foE	A
foEs	114JA
fbEs	97
Es type	ℓ3
foF1	A
M(3000)F1	A
h'F	A
h'F2	A
foF2	98
M(3000)F2	A



fmin	12
foE	
foEs	39JA
fbEs	28
Es type	f4
foF1	
M(3000)F1	
h'F	240A
h'F2	
foF2	44JR
M(3000)F2	330JR



fmin	19
foE	305
foEs	31EG
fbEs	31EG
Es type	
foF1	50
M(3000)F1	345
h'F	220
h'F2	G
foF2	50EG
M(3000)F2	G

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M factor - 1

1

Observation : A typical ionogram in summer daytime. Traces for both F2 and F1 layers are recorded very clearly.

foF1 = 52, foF2 = 82.

Interpretation : Both M(3000)F2 and M(3000)F1 can be scaled by fitting the transmission curves (dash-dot curves) to the F2 and F1 traces respectively.

M(3000)F2 = 315

M(3000)F1 = 355

2

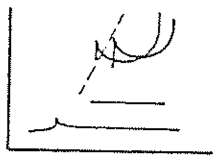
Observation : As far as the F region reflection is concerned, both foF2 and fxF2 can be scaled by numerical values only, although the trace below 9.7 MHz is blanketed by the Es layer.

Interpretation : Since the curved parts of the F2 and F1 traces are blanketed by the Es layer, both the M factors are expressed by the letter A.

M(3000)F2 = A

M(3000)F1 = A

Comment :



In an example as shown in the left figure, foF1 can be scaled, whereas the lower part of F1 trace is blanketed.

M(3000)F1 = A

3

Observation : A nighttime ionogram. In the F region, the extraordinary component is clearly observed, while the ordinary one is lost.

Interpretation : First of all, foF2 is deduced from fxF2.

foF2 = (fxF2 - fB/2)JR = 44JR

Then the ordinary wave trace is reproduced imaginarily as the dotted curve to which the transmission curve is applied. M(3000)F2 should have the same letters as foF2 in this Case.

M(3000)F2=330JR

Comment : If the cause of the disappearance of the ordinary F trace is the interference, the letter R is replaced by the letter S.

4

Observation : No F2 trace is recorded.

Interpretation : The trace in the F region is the F1 trace. The F2 layer is in the so-called G condition where foF2 decreases down to foF1 or lower value (see Case 5 of foF2).

M(3000)F2 = G

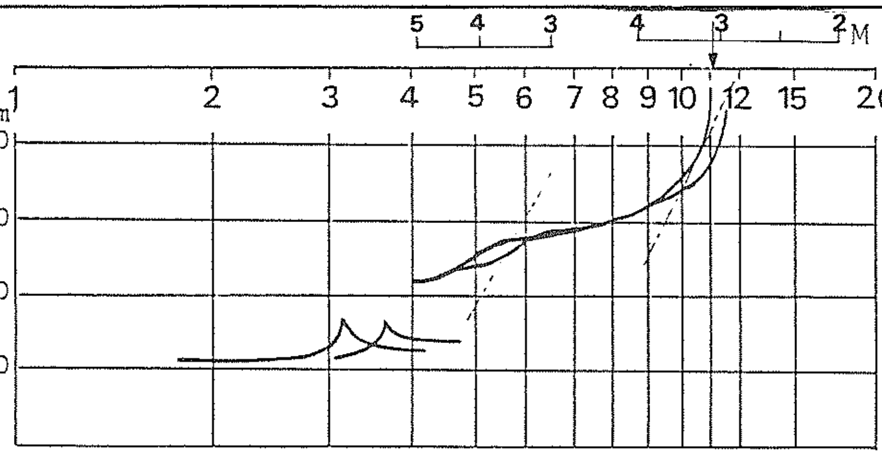
M(3000)F1 = 345

Comment : It is very important in interpreting the G condition to take into account the progress of ionospheric disturbances and the sequential variation of foF2 and h'F2, because the G condition may be confused with the case for which the letter W should be applied.

Ⓡ

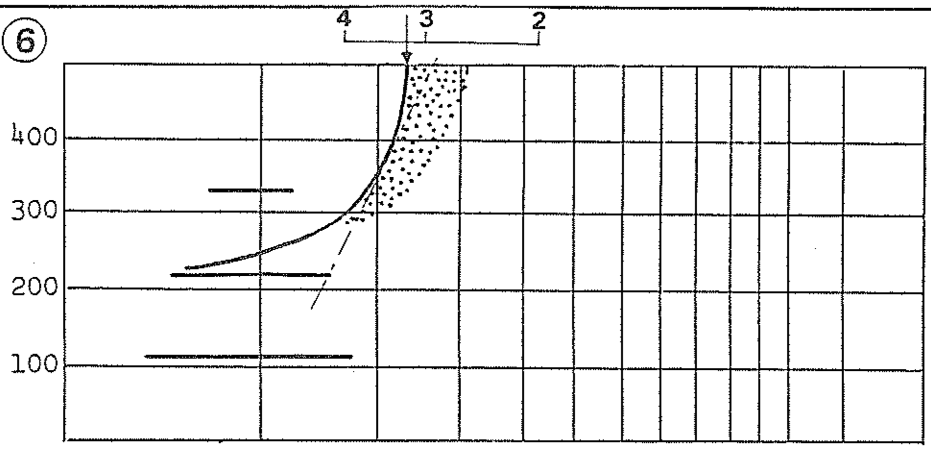
M factor − 2

⑤



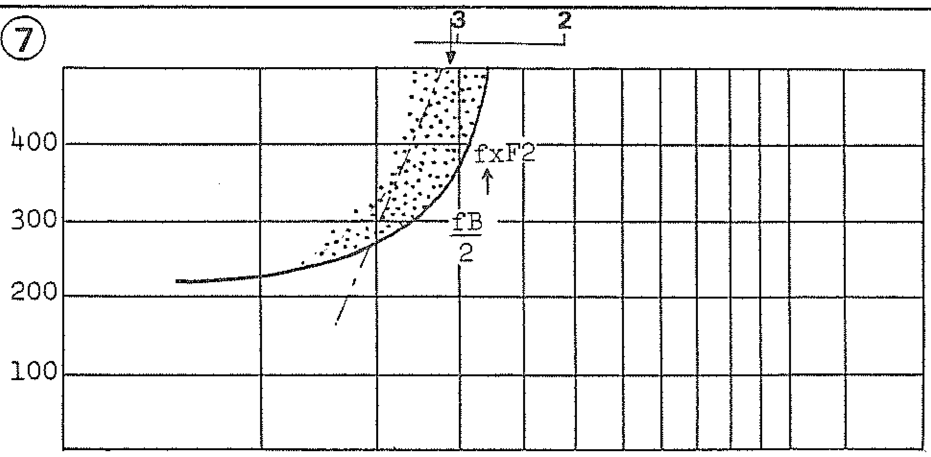
fmin	18
foE	310
foEs	41
fbEs	40
Es type	cl
foF1	L(55)
M(3000)F1	L
h'F	220
h'F2	270
foF2	110
M(3000)F2	310

⑥



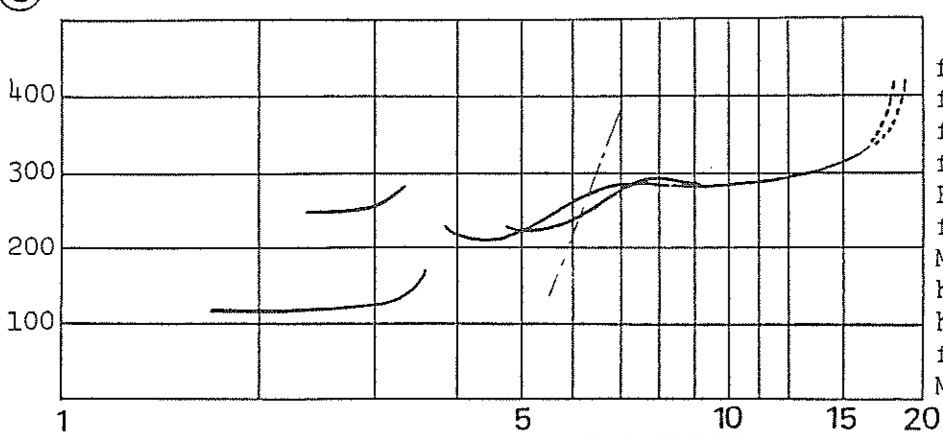
fmin	14
foE	
foEs	21JA
fbEs	15
Es type	f3
foF1	
M(3000)F1	
h'F	225
h'F2	
foF2	34F
M(3000)F2	320F

⑦



fmin	15
foE	
foEs	15EB
fbEs	15EB
Es type	
foF1	
M(3000)F1	
h'F	215
h'F2	
foF2	38JF
M(3000)F2	305JF

⑧



fmin	17
foE	355
foEs	36EG
fbEs	36EG
Es type	
foF1	L(70)
M(3000)F1	L
h'F	205
h'F2	280
foF2	167DR
M(3000)F2	R

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(5)

Observation : Since the cusp of foF1 is not clear, it is scaled as foF1 = L (55). The F2 layer is normal.

Interpretation : M(3000)F2 is scaled easily, whereas there is no tangential point on the F1 trace to the transmission curve. Therefore, M(3000)F1 is expressed only by the letter L.

M(3000)F2 = 310

M(3000)F1 = L

(6)

Observation : A nighttime ionogram. The frequency-type spreading is observed. foF2 = 34F

Interpretation : The inner edge (lower side of frequency) of the trace is clear. The M factor is scaled by applying the transmission curve to the clear ordinary trace. It is expressed by attaching the descriptive letter F to the numerical value.

M(3000)F2 = 320F

Comment : The second order reflection is conveniently used in identifying the ordinary component trace, since it is likely to be observed more clearly (without the spreading) than the first.

(7)

Observation : The F trace is spread over a fairly wide frequency range. The outer edge of the trace is clear.

Interpretation : The clear edge is interpreted as the extraordinary component. fxF2 = 4.4 MHz

Since the ordinary component can be inferred from the extraordinary one, the M factor is to be scaled by fitting the transmission curve to the ordinary component trace inferred. M(3000)F2 is expressed by applying the qualifying letter J and the descriptive letter F.

M(3000)F2 = 305JF

Comment : The width of echoes should not be overlooked in fitting the transmission curve even to the inferred trace. In other words, the curve is adjusted so as to touch the outer edge of the inferred trace. Similar caution should be paid to Case 3 and Case 6.

(8)

Observation : The F trace above 16.7 MHz is not recorded. Since the frequency width of trace to be extrapolated does not seem to exceed 20% of foF2 (see Case 10 of foF2). foF2 = 167DR.

Interpretation : Since foF2 is scaled with the qualifying letter D (greater), M(3000)F2 is expressed by only the letter which describes the reason for the disappearance of the trace.

M(3000)F2 = R

Concerning M(3000)F1, the situation is same as Case 5.

M(3000)F1 = L

Appendix 1

Ionograms frequently show multiple and mixed reflections. (R.H. pp.15-17)

A multiple reflection is the name given to a trace which has been reflected from the ionosphere more than once. An echo which results from two reflections from the same layer, with an intermediate reflection from the ground, is called a second order; three reflections give a third order, and so on. Orders as high as fifteen or more occasionally occur when absorption is extremely low. These very high orders are still being reflected between the ground and the ionosphere after a time greater than that of the time base period and consequently appear on the ionogram. Fig. 1.9(b) shows a typical example of these 'round-the-time-base' traces, orders 8 to 11 are visible.

It is possible for mixed reflections between the E and F layers to occur when sporadic E is present. The most common of these is a second order reflection from the top of a sporadic E layer - the M reflection at a height (2h'F-h'Es). The mixed mode F reflection followed by Es reflection, or vice versa, are also common at a height (h'F + h'Es). Both are shown in Fig. 1.9(c). The M reflection often gives a stronger trace than the 2F normal mode when absorption is present, as it has only passed through the absorbing D region twice instead of four times. Higher multiples also occur and can be easily identified by noting that the M and N traces are a constant distance (h'Es) from the 2F and 1F traces, respectively. Higher modes 2F + E, 3F - E, etc., are identified similarly. A typical ionogram showing E, F and mixed mode multiple reflection is shown in Fig. 1.9(d) together with the mode identifications.

Under normal circumstances, M and N reflections are not scaled but can be used occasionally to give a numerical value of foF2 when the layer is tilted so that the normal F traces are missing.

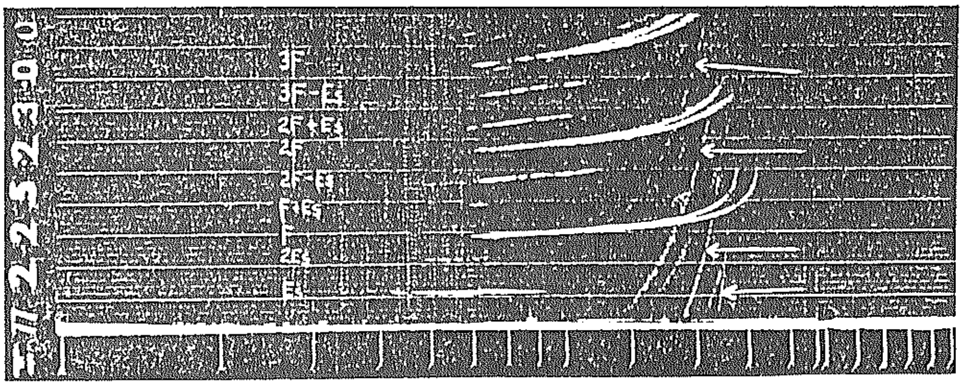


Fig. 1.9(b) Ionogram showing very high order F region reflections, also multiple reflections.
Arrows indicate 'round-the-time-base' traces.

Paths of M and N reflections

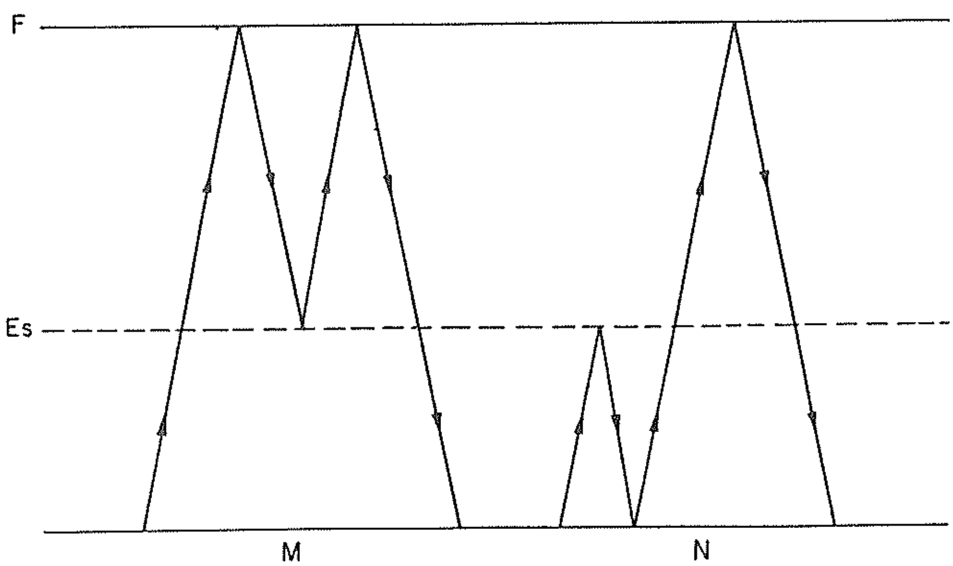
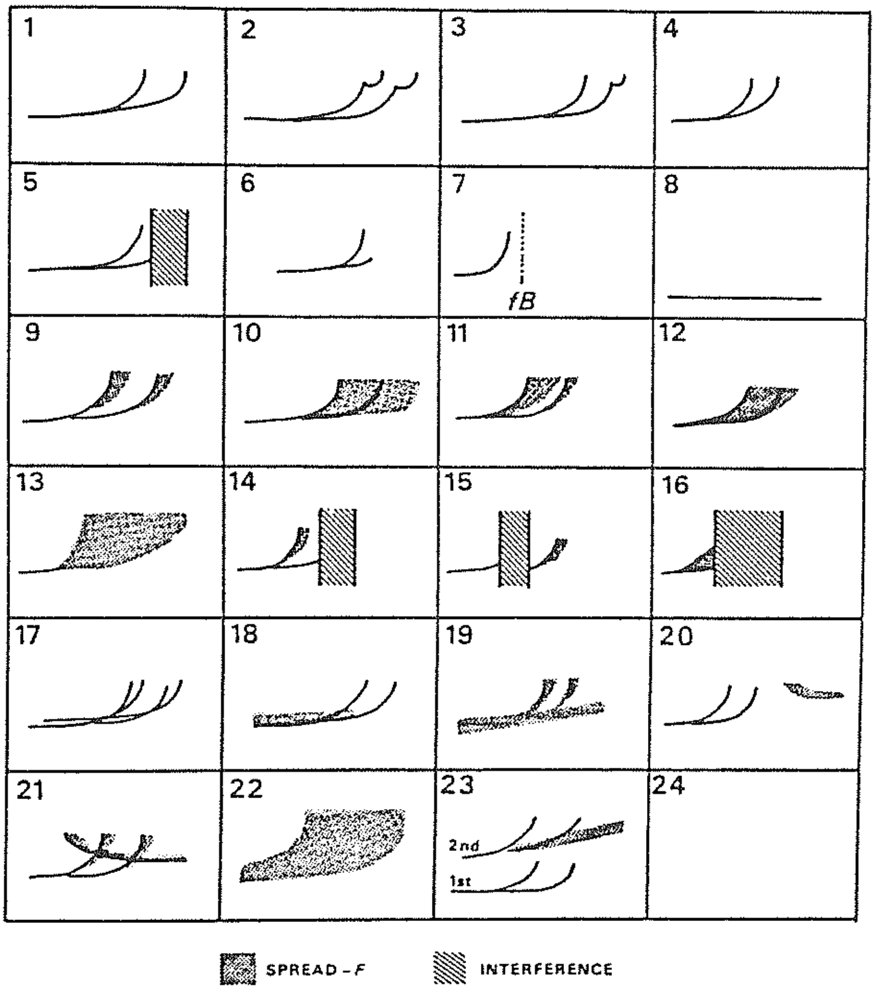


Fig. 1.9(c) Virtual height of M reflection 2F-Es, N reflection F+Es.

Appendix 2 (INAG Bulletin No. 33, pp.32-33)

SPREAD *F* AND *fxI* SCALING



Ex.	foF2	fxI	h'F	Comment
1	044	050-X	250	Normal ionogram
2	044-H	050-X	250	No scatter present priority X on fxI
3	044	050-X	250	No scatter present, priority X on fxI
4	038EG	044-X	250	F2 region in G condition, fxI ≡ fxF1
5	044	0500X	250	fxI determined from o mode, priority X on fxI
6	044	0500X	250	fxI determined from o mode, priority X on fxI
7	010	016	250	fxF2 not seen as close to gyro-frequency
8	A	A	A	Complete blanketing by Sporadic E
9	044-F	053	250	Spread-F exceeds 0.3MHz; -F on fxI optional
10	044-F	057	250	More severe Spread-F than 9 but scaling similar different degree of Spread-F on o and x traces
11	044-F	054OB	250	fxI value determined from foI
12	044-F	056OB	250	More severe Spread F than 11 but similar scaling
13	044DF or F	060	250	Very severe Spread-F; resolution of o and x- traces not possible
14	044-F	053OS	250	fxI = foI + fB/2, with descriptive letter for interference
15	044JS	053-F	250	foF2 = fxF2 - fB/2, Presence of Spread-F indicated on fxI
16	038DS	F	250	F given priority over other letters in fxI to show presence of Spread-F
17	044	053-X	250-Q	Simple range spread; no frequency spread hence -X
18	044	050-X	250-Q	Different form of range spread
19	044-F	058-Q	250-Q	fxI value determined from range spread structure
20	044	070-P	250	Polar spur gives fxI value
21	044-F	070-P	250	Polar spur gives fxI value
22	F	070	Q	Extensive mixed spread present
23	044	050-X		Ground backscatter trace, not used to evaluate fxI
24	B	B	B	Complete absorption

POSTSCRIPT

The original edition of this Manual was completed by H. Ohyama in 1980 for the training of young specialists of ionogram scalings. The publication of this Training Manual was announced by N. Wakai, the Japanese INAG representative, at the INAG meeting which was held in Geneva on the occasion of CCIR Study Group Meeting in June to July 1980.
Mr. W. R. Piggott, the chairman of INAG, encouraged him to translate the Manual written in Japanese into English.

After one year experience by the experts at local Radio Wave Observatories, Radio Research Laboratories, the revised edition in Japanese was published by H. Ohyama and T. Koizumi in March 1981 for domestic use in Japan. Since then the translation has been made by a small group in RRL.

The wording in English might not necessarily be consistent with the Ionogram Handbook and its revised Edition. The philosophy of interpretation, however, should be same. Comments by the INAG members as well as the users on expressions and scaling procedures in this Manual are highly invited.

We wish to express many thanks to Miss Y. Nagano for her assistance through the typewriting.

March, 1985

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POSTSCRIPT FOR REVISED EDITION

Reorganization of RRL was effective on April 8, 1985, just after the publication of the first edition of this Manual. The research section responsible for the revision work of the Manual was transferred to Ionospheric Observation Section, Technical Information Division from Radio Wave Division. Revised texts and re-drawn figures were prepared at the section with the assistance by Mrs. R. Nemugaki.

Requests of additional copies and comments on the content of the Manual are invited to send to the following address:

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July, 1986

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H. Ohyama

T. Koizumi

Radio Research Laboratory

POSTSCRIPT FOR THIRD VERSION

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