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MEASURING THE ECHO AMPLITUDES OF SPORADIC E LAYER IN SWEPT FREQUENCY IONOSPHERIC SOUNDING

by

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Abstract

A simple and accurate system of amplitude measurements in ionospheric sounding is described. The system is first linearized by controlling the gain of the ionosonde in such a way that all signals in the receiving system are in the linear range of the receiver. This can be done by using echo-controlled AGC. The output is then integrated to smooth out the fading components in the signal amplitudes. Finally another AGC is used on the averaged signal to produce an output at the desired level. After proper discrimination, the signal is used to make an ionogram. In this system the vertical o-component of the thick layers forms the reference echo against which all other amplitudes are measured. It is thus possible to measure the reflection coefficient of a sporadic E layer at any frequency and obtain the frequency dependence of the reflection coefficient of the sporadic E layer. Some examples are given.

1. *Introduction*

One of the most difficult problems in ionospheric sounding is to measure the parameters of sporadic E layers (Es). In routine soundings the parameters that are measured from Es traces in the ionograms are:

— the blanketing frequency- *i.e.* the point at which the reflection coefficient of Es is just so large that no reflections from the layers above Es can be seen

— the critical frequency- *i.e.* the point at which the reflection coefficient of Es becomes so small that the echo disappears in the ionogram
— the virtual height of Es and
— the type of Es.

Both the blanketing frequency fbEs and the critical frequency foEs are scaled from the o-component.

In routine scaling the virtual height of Es and the type of Es are also scaled but those are not discussed here.

Though the parameters foEs and fbEs are fairly easy to scale the numerical values can be misleading because the parameters are dependent on the sensitivity of the sounding system. Furthermore the determination of foEs is also more or less dependent on the subjective evaluation of the scaler. Thus owing to subjectivity and differences of equipment the data from one station are not comparable with those from others, specially at high latitudes where Es phenomena are complex. The rules for scaling the parameters are fully described in the U.R.S.I. Handbook of ionogram interpretation and reduction (PIGGOTT and RAWER, [2]), which also deals with the difficulties and limitations.

Most stations in the world use a fixed-gain receiver in the sounder. As a result, foEs and to a lesser extent, fbEs are modulated by the diurnal variation of absorption. Some stations use AGC (automatic gain control), which is controlled by the noise level. This has a tendency to overcompensate the diurnal variation of absorption, and usually the gain is set unreasonably high, causing serious saturation effects in the receiver — at least at high latitudes where E-layer scatter is common (TURUNEN, [3]). Both systems need laborious calibration to keep stable with time.

Both systems have been tested at Sodankylä and it was found that their data were incosistent (TURUNEN, [4]). In foEs the diurnal variations were in opposite phase.

It is therefore desirable to measure the amplitudes of Es layers in order to obtain meaningful data. The easiest method is to alter the receiver gain so that the amplitude of the strongest echo is kept constant. As this echo is almost always the vertical o-component from the thick layer, the ionograms are now calibrated for partial reflections. In practice, ionograms are calibrated if a F-layer o-component is seen, even if this is weaker than the underlying Es.

The system fails if the Es layer is totally blanketing. In such cases extra information is needed. For example, data on the gain can be marked directly on the ionograms. In the event of total blanketing, the gain itself carries the information needed because it depends on Es. In such cases, however, the system requires calibration, which can be done with the aid of ionograms that are free of totally blanketing Es.

2. *Technical description of the equipment*

To obtain linear amplitude data, the system must be linear. The most difficult part of the equipment to construct is the ionosonde controlling system, because echo amplitudes vary rapidly with time owing to fading, slowly with frequency because of absorption, and irregularly due to the frequency dependence of the transmitter, aerials, and receiver. Our solution is to use an active detector after the IF-stages, and then peak-detect the signal at every height sweep, after which the peak-detected amplitude is used to control the AGC loop. The time constant of this loop can be adjusted in such a way that the gain even follows the rapid fading components, but it is better to use a slower response and adjust the mean amplitude so that even the peak amplitudes caused by the fading fall within the linear range of the receiver.

After that the signals are averaged by linear integration. In the prototype equipment used in this study, the number of channels was 60 and the channel width 100 μs. For useful virtual height information, however, the channel width should be 10—30 μs and the number of channels, say, 256.

Before marking the amplitude data on the ionogram (brightness modulation is used), two procedures are needed. The first is to adjust the peak amplitude to a fixed level by controlling the gain of output amplifier. The second is simultaneously to shift the noise level, i.e. the smallest voltage in the channels, to zero. The amount of this shift is a measure of the signal-to-noise ratio and gives useful information on the reliability of the measurement. If this shift is large, proper correction is needed before amplitude information is obtained. The output is now in suitable form for recording. For simplicity sake a discriminating unit is used to divide the amplitudes into four groups before making an ionogram. The maximum dynamic range that can be used naturally depends on the noise level. At Sodankylä 30 or perhaps even 40 dB can be attained at least above 1.6 MHz. The treshold values used in the

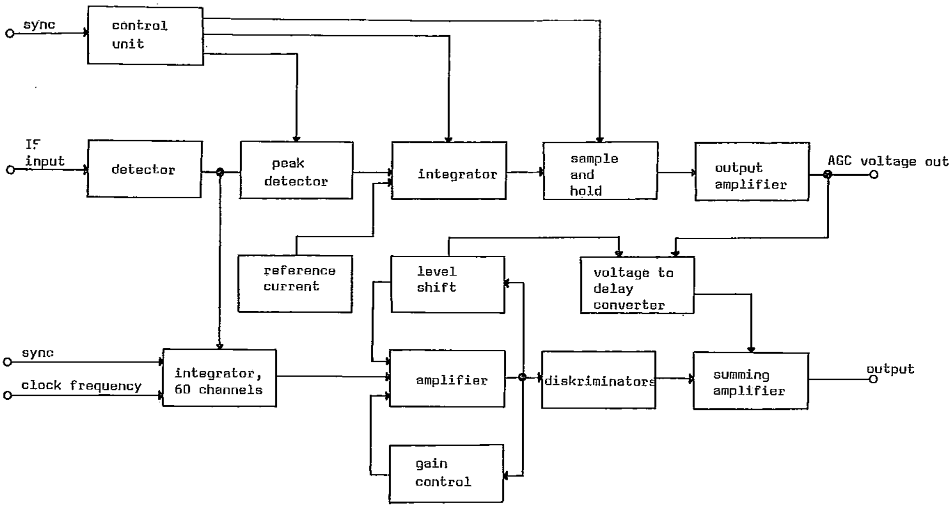

Fig. 1. Block diagram of the equipment used in the amplitude measurements.

discriminating unit have been — 3 dB, — 10 dB, — 20 dB, and — 30 dB.

With fairly simple circuitry, the AGC voltage and the noise level can be multiplexed on the ionogram to obtain the information needed when totally blanketing Es occurs.

Block diagram of the equipment is given in Fig. 1. The equipment is described in detail elsewhere (Turunen, [5]).

3. *Results*

The above system has now been used at Sodankylä for three months and the results are very promising. Some examples of amplitude variation of Es layer are given in Fig. 2. The curves show that in the studied cases the Es signal streght relative to the F-layer reflection was a fairly smooth, monotonically decreasing function with increasing frequency and the decrease was faster when the echo was strong. The result clearly indicates that both fbEs and foEs depend on the sensitivity of the equipment though the dependence is smaller in fbEs than foEs.

Fig. 3 shows the variation of the amplitude of Es echo with time. Also depicted is fm2, the minimum frequency at which second order F-layer reflection is seen. It shows a close dependence on the strength of the Es echo.

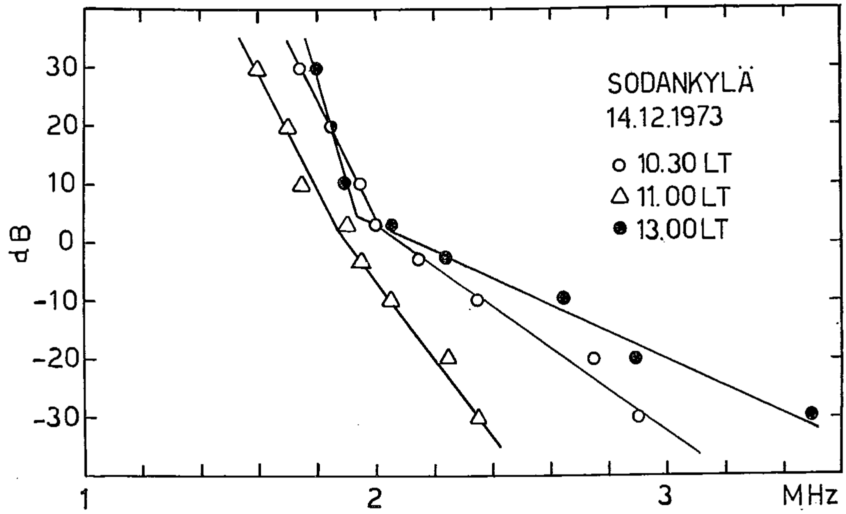

Fig. 2. Dependece of Es layer echo amplitude on frequency in a few cases. The reference echo is the F-layer echo at the same frequency.

There are surprisingly few empirical studies in the literature on the amplitude variation of Es echo. Among them is a paper by Chessell et al, who found that the main feature was rapid variation of the echo structure with time (Chessell *et al*, [1]). They discovered very few cases in which the amplitude variation behaved so well that comparison with theoretical models was possible. On the contrary, my preliminary results from Sodankylä indicate that Es behaves quite smoothly even over periods of hours. The main difference was probably in the measuring technique. Chessell *et al* used an ionosonde that had a very fast sweep (2 seconds per sweep) and my results are based on very slow sounding (8 minutes per sweep) and on linear integration over about a hundred echoes. Thus all fading components are integrated out in my measurements. I feel that as normal middle latitude types of Es usually have a life time of more than quarter an hour, it is possible to use slow sounding and a long integration time. One must remember that even if the time, which is needed to make the whole ionogram is as long as 8 minutes, the time, which is needed to measure the frequency interval where Es lies, is much less, almost always less than 2 minutes.

No theoretical work has yet been done on the Sodankylä results and there are few good examples of sporadic E behaviour. This is because

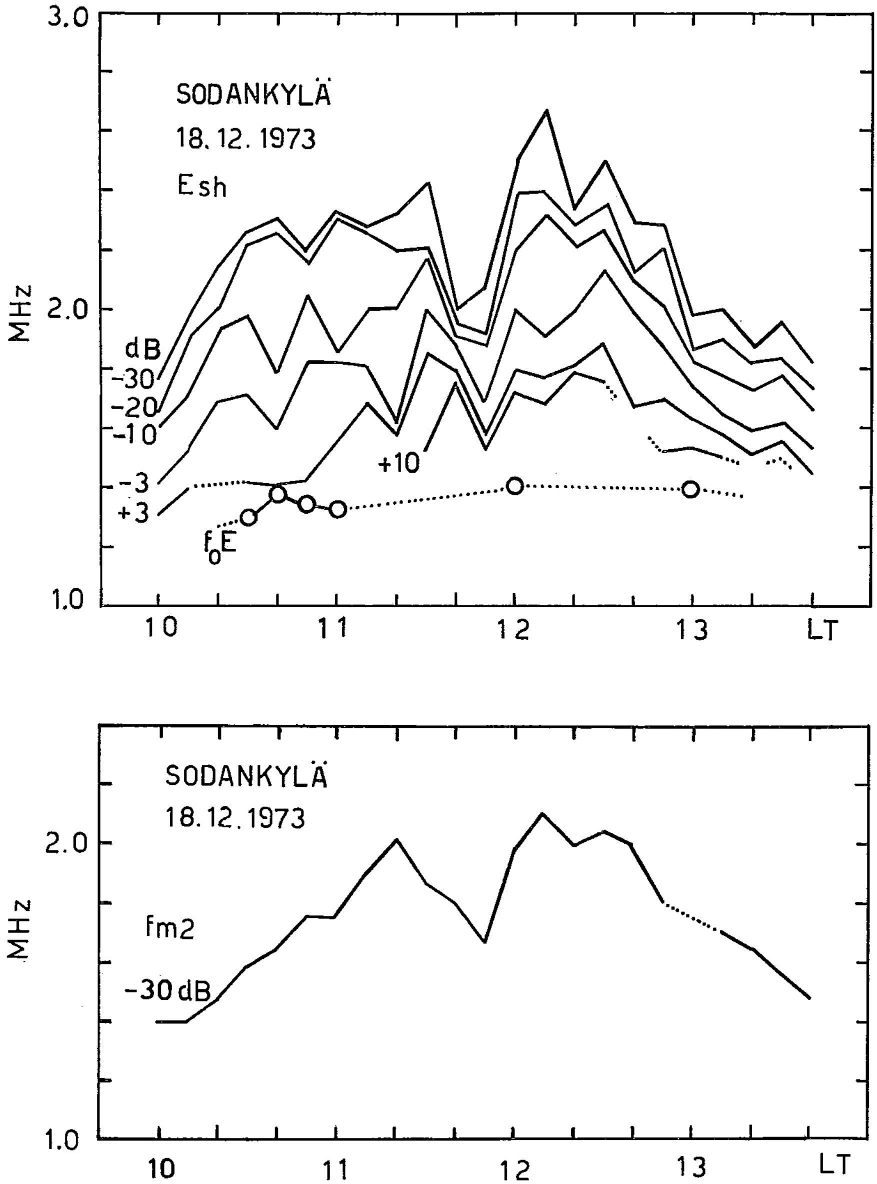

Fig. 3. Behaviour of Es layer echo amplitude with time, based on soundings taken at ten minute intervals. The reference echo is the F-layer echo at the same frequency.

the middle latitude types of Es are rare phenomena at Sodankylä in winter and the data available applies only to winter months. It is also possible to study the complex behaviour of auroral activated Es layers but this not attempted yet. In summer the signal-to-noise ratio is much better and so it is better to use summer data when difficult auroral activated Es layers are studied.

4. *Summary*

It is demonstrated that echo amplitude measurements can be made in routine ionospheric sounding and that they give useful information. The measurements show that at least in some cases Es echo amplitude is a smoothly behaving function of frequency, and that both fbEs and foEs depend on the sensitivity of the equipment.

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