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# Results from Swedish oblique soundings campaigns

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**Abstract**
In the context of the COST 238, PRIME project, two campaigns of oblique soundings with the Chirpsounder receiver at Linköping, Sweden were made in parallel with vertical sounding campaigns. One campaign was made in June, 1992, when transmissions from Southern Spain were monitored, the other in December, 1992 when a transmitter at Chelveston, U.K., was monitored. The scaled values of *F*2MOF, 2-hop *F*2MOF and LOF give information on the variation of these parameters on short time scales and from day to day. High correlations between 2-hop *F*2MOF and *F*2MOF are found. Good agreement was found between the 2-hop MOF and MUF(1400)*F*2 calculated from vertical soundings at St. Peter Ording, Germany.

**Key words** *ionosphere – HF propagation – oblique sounding – Chirpsounder*

## 1. Background

As a complement to the vertical soundings, making the main data base for the PRIME project, also oblique sounding is used to add to the number of observed areas. Oblique soundings can give detailed information on the ionospheric parameters (Lundborg *et al.*, 1993). Oblique soundings using Chirpsounders (from BR Communications, U.S.A.) (Barry, 1971; Barry and Fenwick, 1976) can be done easily from any Chirpsounder transmitter if the transmitting times are known. However, these seem to change from time to time and therefore one should have up-to-date information from the transmitter to be able to conduct a campaign. On long paths, the limited frequency range (to 30 MHz) is too small, especially at high sunspot number in winter. During the measurements in June 1992, on the path from south of Spain (Rota) to Linköping (2800 km), however, the frequency range was within the limits of the system and the recordings were successful.

During the December 1992 campaign, a transmitter in U.K., Chelveston, was registered as this shorter path (1200 km) made the frequency range large enough. For this path the ionospheric reflection area is on the northern limit of the PRIME area.

In the spring of 1993 an oblique sounding path between Rome and Linköping was established, where full control of both transmitter and receiver is possible, which makes the measurements a lot easier to conduct. Results from these will be reported later by Dr. Bruno Zolesi.

## 2. Summer 1992 measurements

The soundings were made on June 11-28, 1992, between a transmitter in the south of Spain, here called Rota, and Linköping in the south of Sweden, a path length of 2800 km. A sounding was made every 15 min and

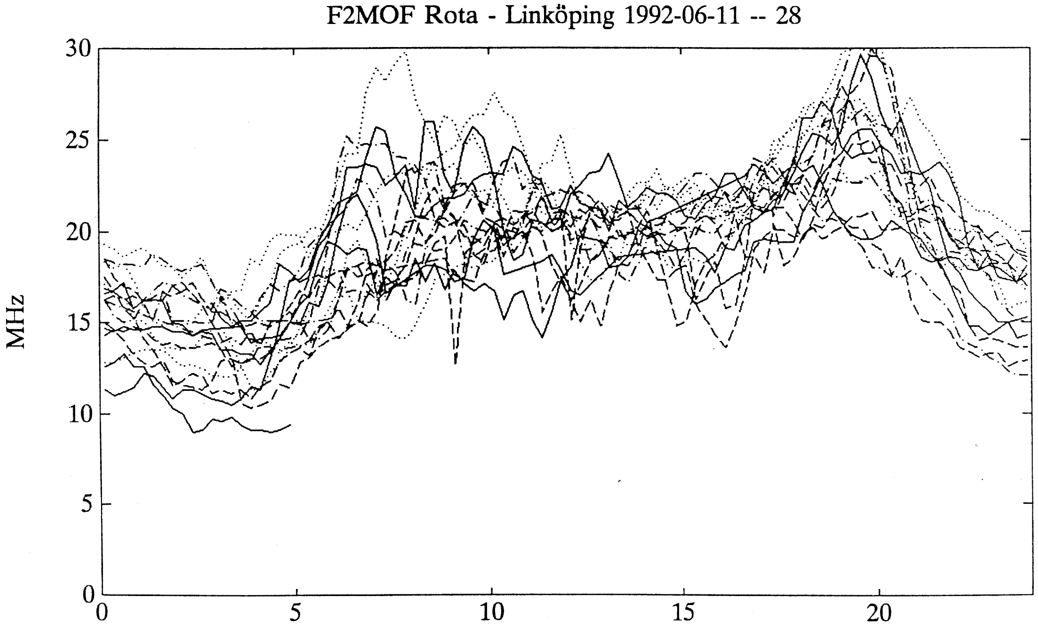

**Fig. 1.** All *F*2MOF (one value for every 15 min) as function of CET (UT + 1 h).

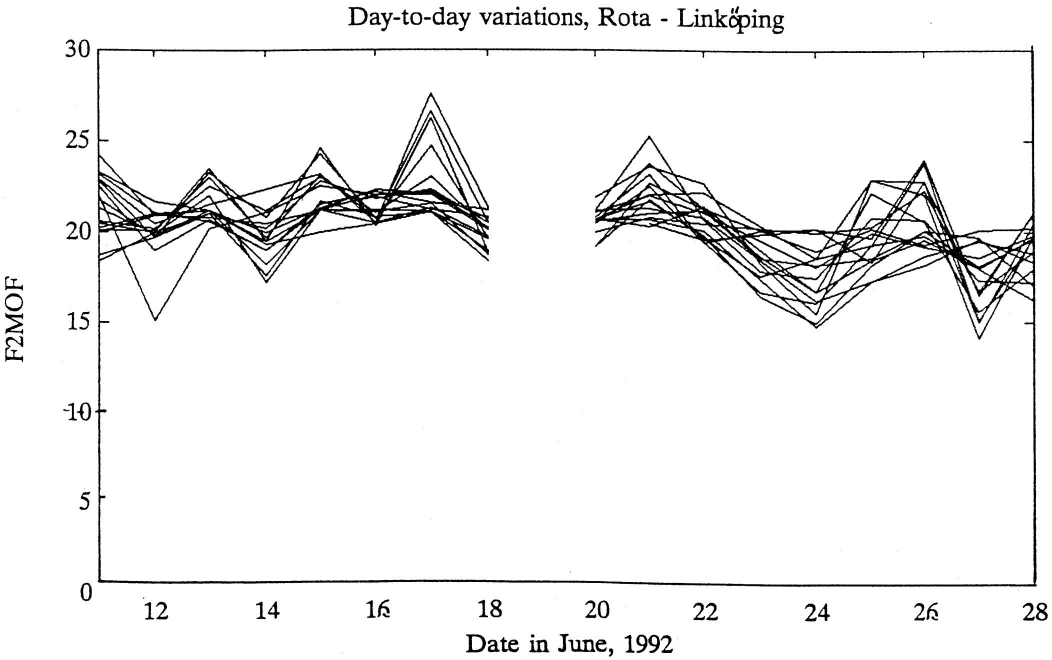

**Fig. 2.** *F*2MOF for daytime (17 curves of data for 1000-1400 CET). Data for June, 19 missing.

the ionograms have been scaled evaluating three parameters:

*F*2MOF = the highest frequency propagated by one-hop via the *F*-layer;
2*F*2MOF = the highest frequency propagated by two-hop via the *F*-layer;
LOF = the lowest frequency observed.

The *E*-layer propagation was never seen because of the low elevation angles involved. The *F*-layer was determined from the existence of high and low angle rays. The *F*2MOF values for all days of the campaign are plotted in fig. 1 as function of CET (UT + 1h). The spread is seen to be the largest in the morning and evening hours. Also very rapid variations with time can be seen going up to several MHz per hour. The variation from day to day is shown in fig. 2, which gives the 15 min data between 10 and 14 h (no data available for June 19 due to difficulties to scale the ionograms because of high absorption.) A two-day periodic variation can be seen with exception of dates 22-25 where hints of a five-day periodicity may be noticed.

In fig. 3 the median of the measured *F*2MOF and LOF is compared to MUF and LUF predicted by IONCAP. The agreement is quite good, except for the time between 15 and 20 h, when the observed MOF has a peak not predicted by IONCAP. The mean difference between the *F*2MOF and the MUF values is 0.6 MHz and the standard deviation is 1.6 MHz. The LUF prediction is based on 0 dB gains for the antennas which is a bare guess. Predictions made by ASAPS from IPS, Sydney are shown in fig. 4 compared to measured *F*2MOF and 2*F*2MOF as this program predicts both 1-hop and 2-hop MUFs. The agreement between observed and predicted curves is again quite good, except for the peaks at 19-20 h.

Comparison between the 2-hop MOF and vertical soundings at St. Peter Ording in Germany can be made as the northern sec-

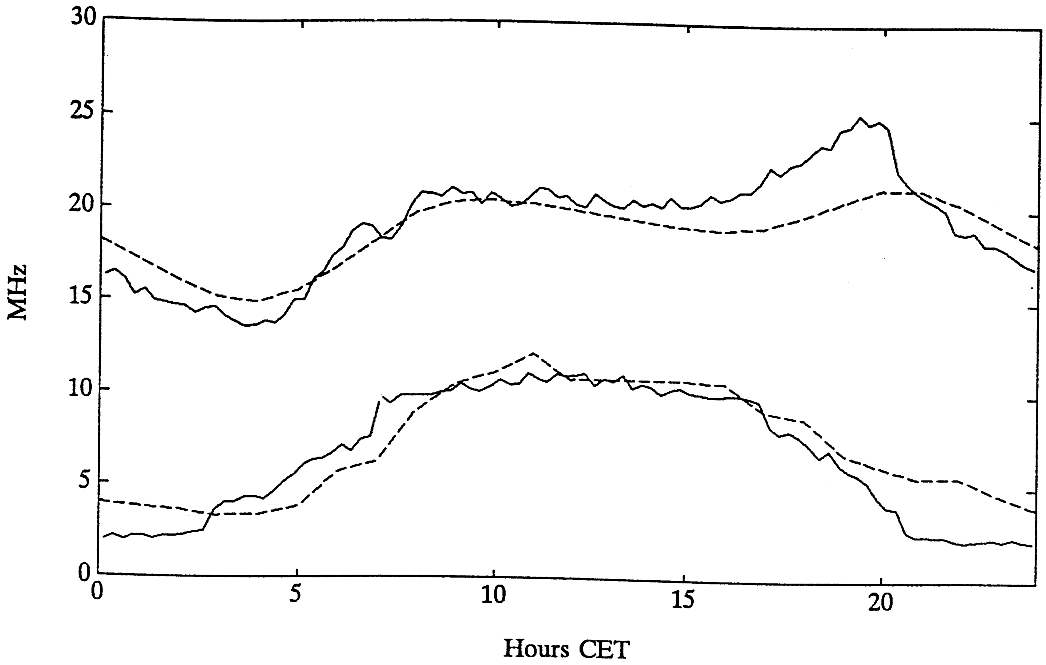

**Fig. 3.** Measured *F*2MOF and LOF compared to MUF and LUF from IONCAP (dashed line).

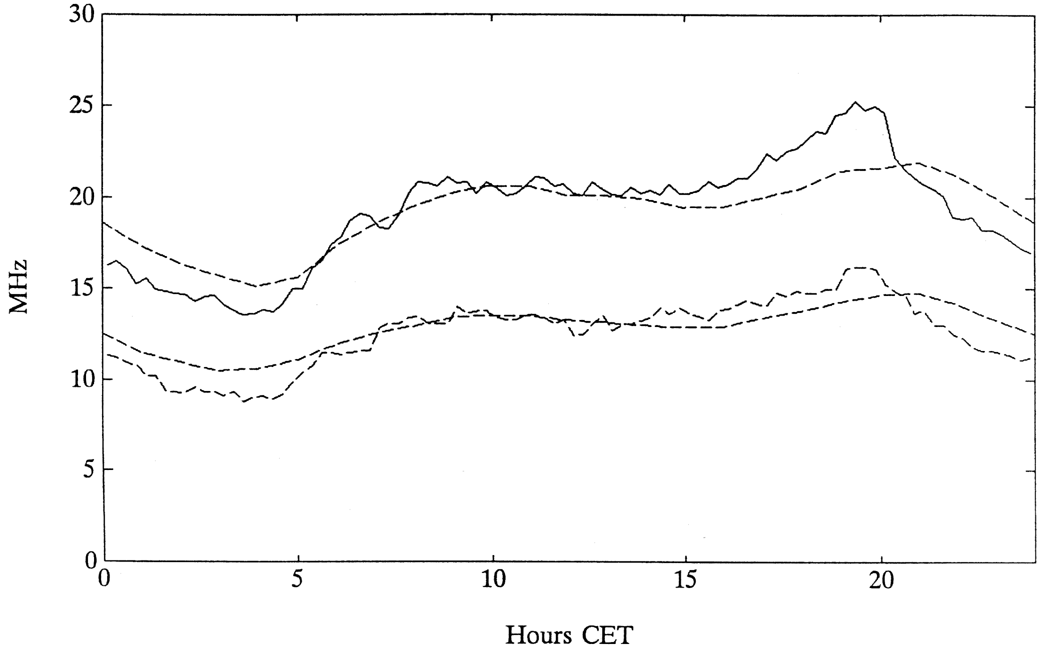

**Fig. 4.** Measured *F*2MOF and 2*F*2MOF compared to predictions of *F*2MUF and 2*F*2MUF from ASAPS (dashed line).

ond hop reflection takes place very close to this station. Normally the MUF for the southern hop is higher, therefore the 2-hop MOF is determined by the ionization at St. Peter Ording.

Figures 5 and 6 show the 2-hop *F*2MOF values for the measurement period. Plotted in these figures are also values of MUF(1400)*F*2 calculated from $f_0F2$ and *M*(3000) data measured at St. Peter Ording. The *M*(3000) being transformed to *M*(1400) for the half hop length of 1400 km and 0.7 MHz being added to get the *x*-mode. The *x*-mode being the mode scaled for MOF. The additional term for the *x*-mode is calculated according to (Davies, 1990): $f_x - f_0 \simeq f_H \cos I$. This value can however be questionable (Lundborg *et al.*, 1993).

The agreement is good, but the short time variations seen on the more frequent oblique soundings are missing on the hourly soundings of the vertical sounder. On an average the oblique 2-hop *F*2MOF is 8% higher than the calculated MUF(1400)*F*2. The standard deviation of the differences is 1.2 MHz. On some occasions the difference is larger, for example the night between June 11 and 12 and in daytime June 16. At these times the propagation probably is by mixed modes of sporadic *E* and *F*-layer. Some times these oblique ionograms are difficult to scale due to no absolute time scale and low time resolution.

## 3. December 1992 measurements

During this campaign the transmissions from Chelveston, England were recorded. The oblique ionograms were scaled in the same way as before. The variations of *F*2MOF and 2*F*2MOF during the period December 2 to 15 are plotted in figs. 7 and 8 respectively. The recordings were made ev-

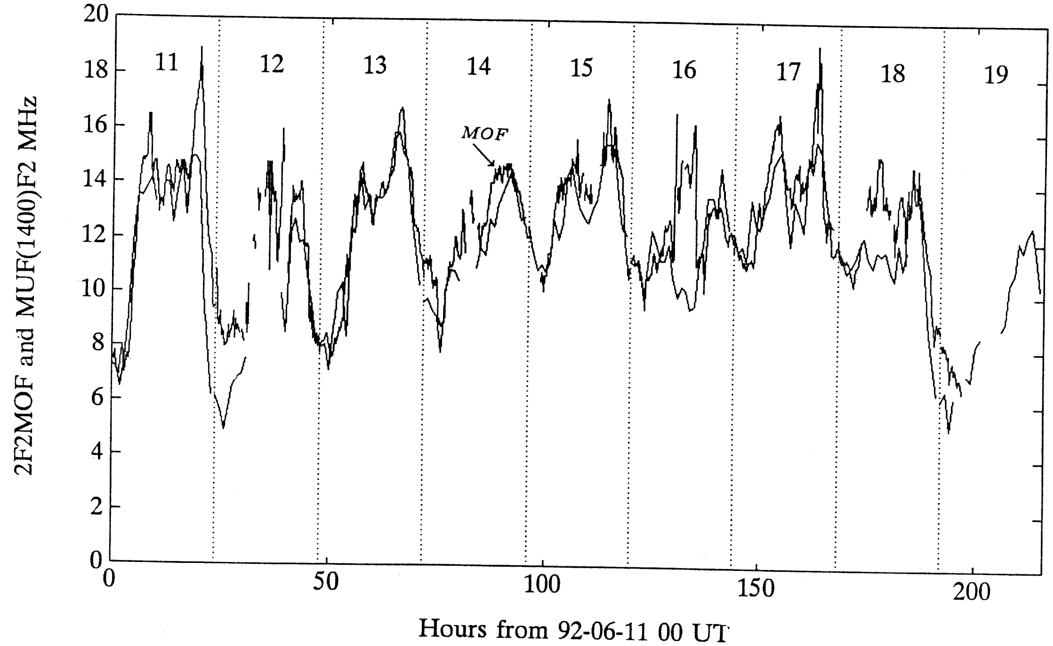

**Fig. 5.** 2-hop *F*2MOF on the path Rota-Linköping and calculated MUF(1400)*F*2 from vertical incidence at St. Peter Ording, Germany. Data for the first nine days of the measurements.

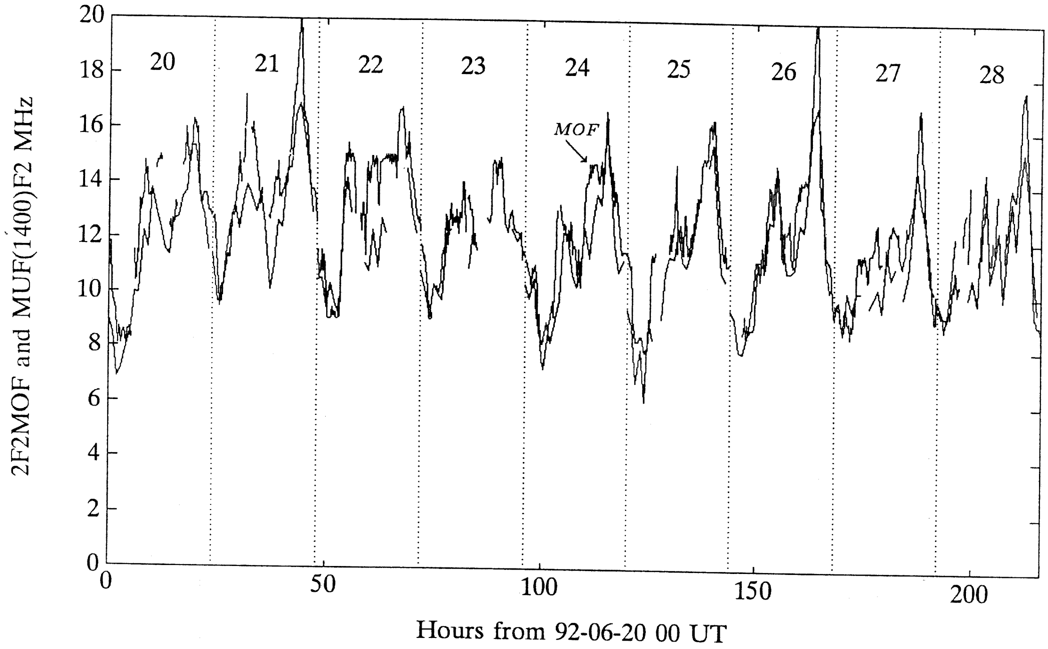

**Fig. 6.** 2-hop *F*2MOF on the path Rota-Linköping and calculated MUF(1400)*F*2 from vertical incidence at St. Peter Ording, Germany. Data for the last nine days of the measurements.

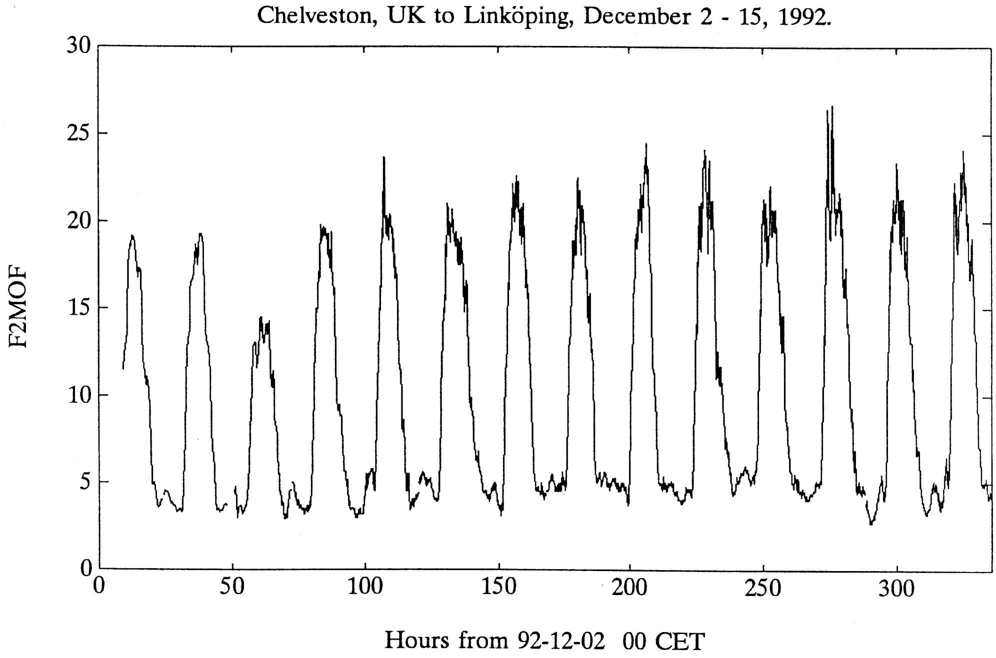

**Fig. 7.** $F2$MOF as function of time.

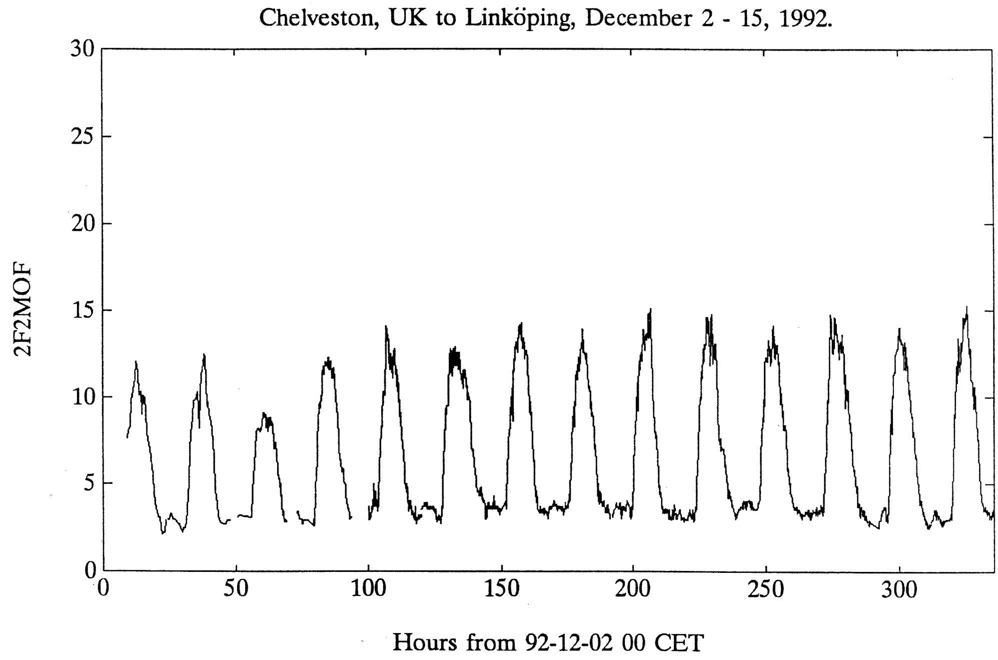

**Fig. 8.** $2F2$MOF as function of time.

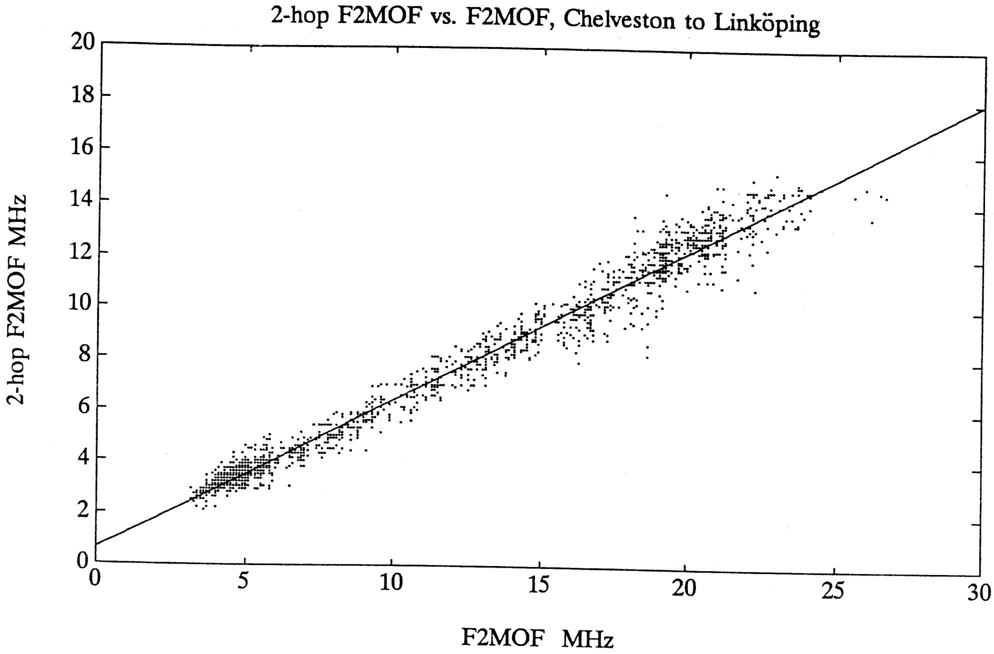

**Fig. 9.** Massplot of $F2$MOF and $2F2$MOF. The regression line is $2F2\text{MOF} = 0.58^*F2\text{MOF} + 0.6$.

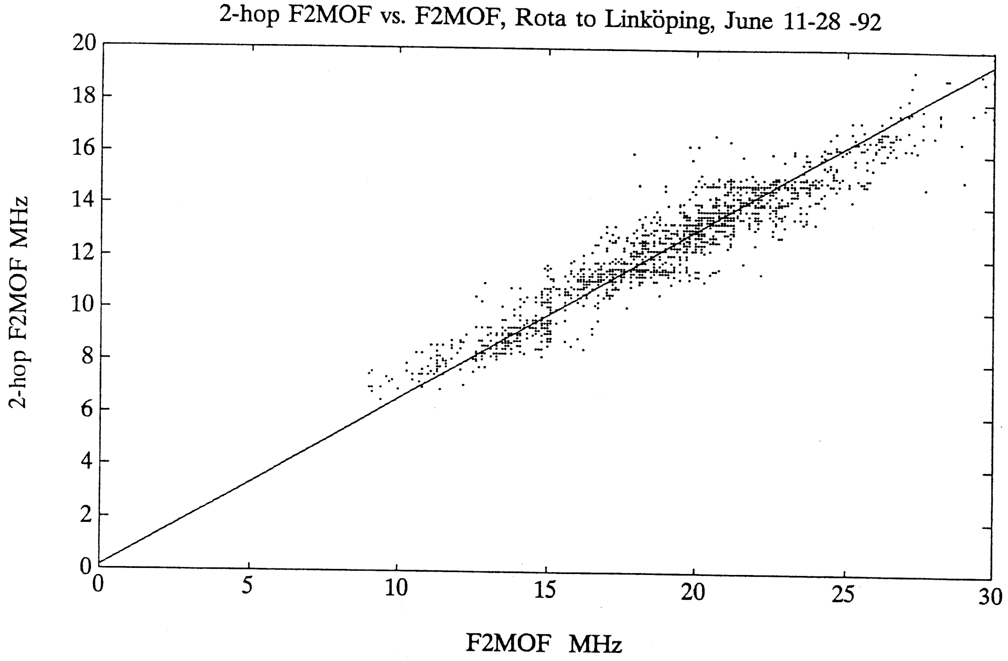

**Fig. 10.** Massplot of $F2$MOF and $2F2$MOF. The regression line is $2F2\text{MOF} = 0.64^*F2\text{MOF} + 0.14$.

ery 15 min during the first two days and eight times every hour during the rest of the period.

The overall picture is that the variation is very stable from day to day during this period with the exception of December 4, when there was a depression of daytime MOF by about 5 MHz. Also rapid variations of the daytime MOFs of about one MHz can be seen at this frequent registration with 8 measurements per hour.

## 4. Correlation between *F*2MOF and 2*F*2MOF

The variations of *F*2MOF and 2*F*2MOF are very similar to each other. This can be seen, for example, from fig. 4 for the medians. But also the individual pairs of *F*2MOF and 2*F*2MOF follow each other quite well. To study this mass plots of these pairs were made. These are shown in figs. 9 and 10 for the measurements on the paths Chelveston-Linköping and Rota-Linköping respectively. There is obviously a linear relation between the two, and the regression lines are plotted in the graphs as well. The correlation coefficient is 0.99 for the first path and 0.95 for the second. The higher correlation for the shorter path is of course natural as the distance between the two reflection areas is much shorter for this path than for the longer path. But from the fact that there is high correlation between the two MOFs, and that these depend on both the $f_0F2$ and the MUF-factor at the reflection area, it is hard to say that $f_0F2$ and the MUF-factor also are correlated.

## 5. Concluding remarks

The evaluation of the oblique ionograms gives a measure of the ionization at the reflection areas and its variation with time, hence they can be used as a complement to vertical soundings. The agreement with vertical soundings has been shown to be very good. The conversion to Ne-profiles has not been done, as no standard method has been decided yet within the PRIME project.

One problem with these recordings is that the clocks of the transmitters and the receivers are not synchronized, so no absolute time of arrival can be established. However, the use of both the 1 – and 2-hop echoes can give at least an approximate solution to this problem.

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