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PROGRESS ON ARTIST IMPROVEMENTS

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Digisonde ionograms are automatically scaled in ARTIST (Automatic Real Time Ionogram Scaler with True Height). The presence of multiple Es traces had caused errors in the autoscaling. New software has been developed that allows to properly track the F trace by identifying the multiple Es echoes before the F trace identification is initiated. Multiple F traces are also identified in order to more securely identify the 1F trace in the presence of mixed-mode echoes (M and N traces). The new ARTIST software is now operative and very robust for difficult ionograms.

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1.0 INTRODUCTION

The automatic ionogram scaling algorithm for Digisonde ionograms, known as ARTIST (Automatic Real Time Ionogram Scaler with True Height) was developed using Digisonde ionograms obtained at Goose Bay and Argentia, Newfoundland as a data base [Reinisch et al., 1982; Reinisch et al., 1983]. ARTIST has performed well under diverse ionospheric conditions at many locations. With the deployment of additional DISS and Digisonde 256 systems at more moderate latitude locations (such as Wallops island, VA, Bermuda NAS, and Millstone Hill, MA) and the rapid rise of solar cycle 22 to large sunspot numbers, problems caused especially by multiple Es returns with high top frequencies have become apparent. The Es problem and other shortcomings in the ARTIST program are discussed in this report together with steps to overcome them.

The scaling problems caused by multiple Es traces are discussed first. When blanketing Es layers obscure part of the F trace, multiple Es traces are often identified as F trace. This problem is addressed in Section 2.0.

Section 3.0 deals with the structure of the ARTIST program. Because of the many additions and changes the program has become difficult to manage. To eliminate this difficulty, version numbers were added to each subroutine, module, and to the ARTIST algorithm as a whole. This will allow better control of configuration management and will simplify program maintenance. Under the new scheme, the ARTIST version number will completely specify the program with all the particular subroutines used in that version.

Another area of concern has been the often observed roughness of the h'(f) traces. The ARTIST autoscaling often produces traces that are not smoothly varying for the entire trace. Several of the points drop down or jump up from the main trace abruptly, or a few points may oscillate up and down from the trace. A smoothing procedure is being sought that can be applied to the variety of shapes that the virtual height traces may take. The current status of this work is described in Section 4.0.

2.0 RECOGNITION AND ELIMINATION OF MULTIPLE SPORADIC E TRACES

Multiple Es echoes often are incorrectly identified as F echoes when they have larger signal amplitudes than the F echoes, or when part of the F layer was blanketed. The reason for these mistakes is that the ARTIST algorithms did not search for and identify the 2Es and 3Es echo traces. Typical examples for incorrect F trace identifications are shown in Figures 1 and 2. The ionogram in Figure 1 shows a strong sporadic E trace with four multiple echo traces. The F trace is blanketed for $f < 2.7$ MHz, and ARTIST chose the 2Es trace as the F trace for $f < 3.2$ MHz. A similar situation exists in Figure 2 where between 2 and 3.5 MHz, ARTIST includes the 2Es and 3Es as part of the F trace.

In order to avoid erroneous scaling of the F trace, the multiple Es echoes must be recognized. The method employed is as follows. (Step 1) All potential second order echoes in the range 175 km to 305 km are identified and tagged by comparing recorded amplitudes with the 1Es echoes as in the previous ARTIST algorithm [Tang et al., 1988] (see Figure 3a). (Step 2) At each frequency, a 4 range-bin-high window is positioned at two times the 1Es height and the tagged echoes in the window are counted and recorded, Figure 3b. (Step 3) If more than four frequencies are tagged between the minimum frequency of the scaled E trace and foEs, a search for higher order multiples is applied within this frequency range. If four or less are found it is assumed there is no multiple Es echo trace.

For the search (Step 4) the average height of the 2Es trace is determined from the tagged echoes found in the windows of Step 2. A four bin window template is then placed at this height to check every frequency that was not tagged in Step 2, Figure 3c. (Step 5) If ordinary echoes are found in the window and either

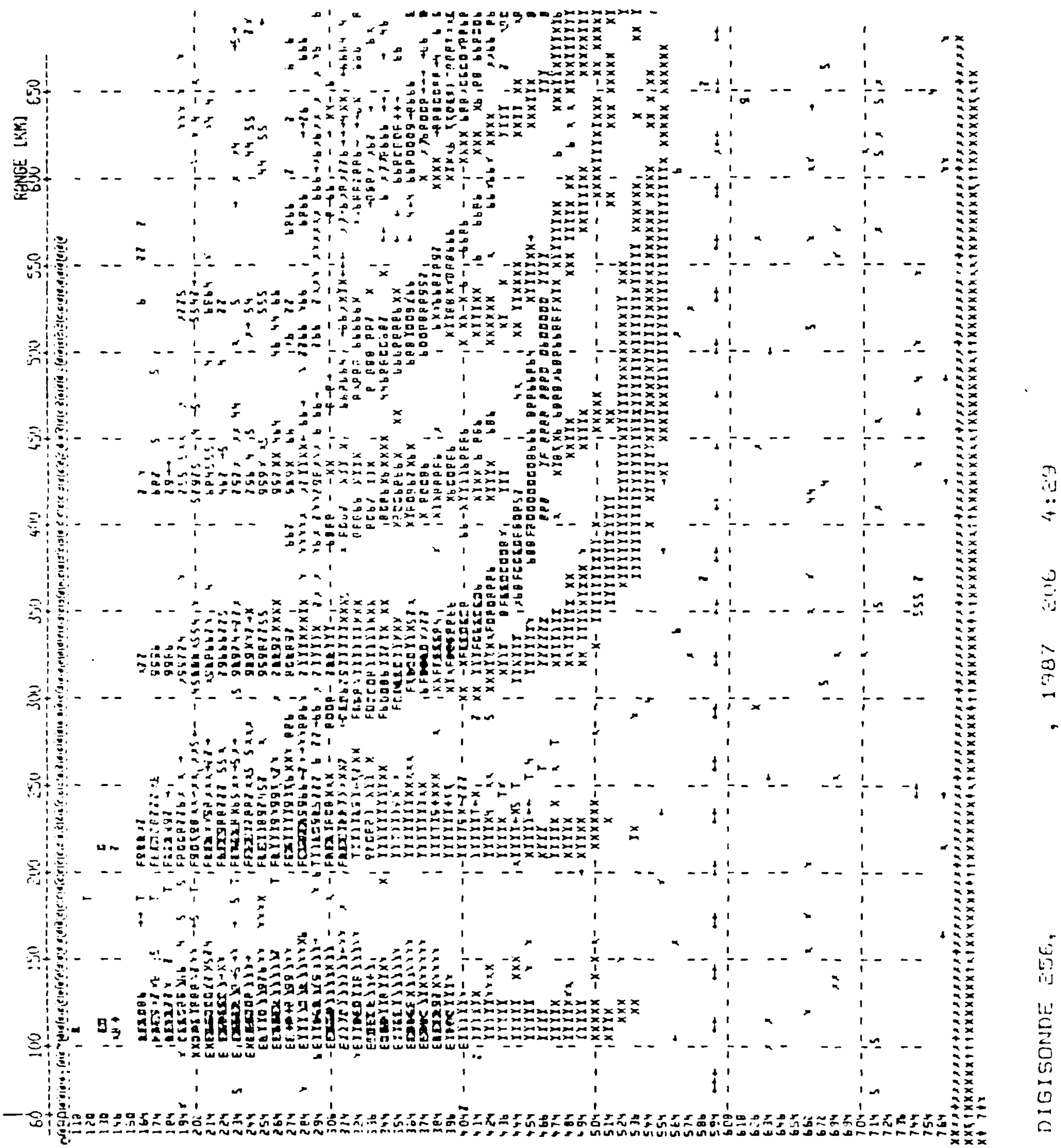

Figure 1. Autoscaling Without Elimination of Multiple Es

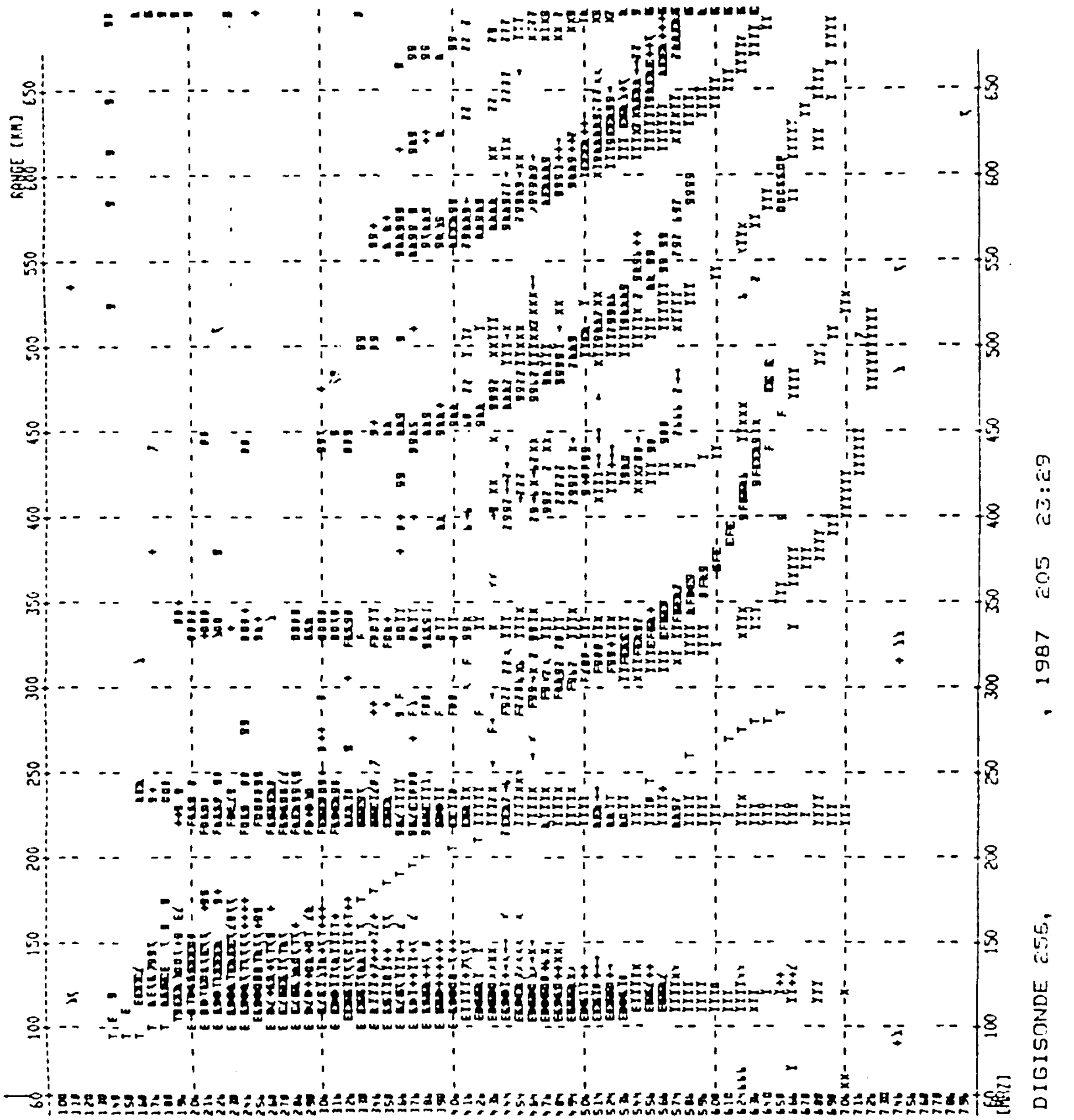

Figure 2. Autoscaling Without Elimination of Multiple Es

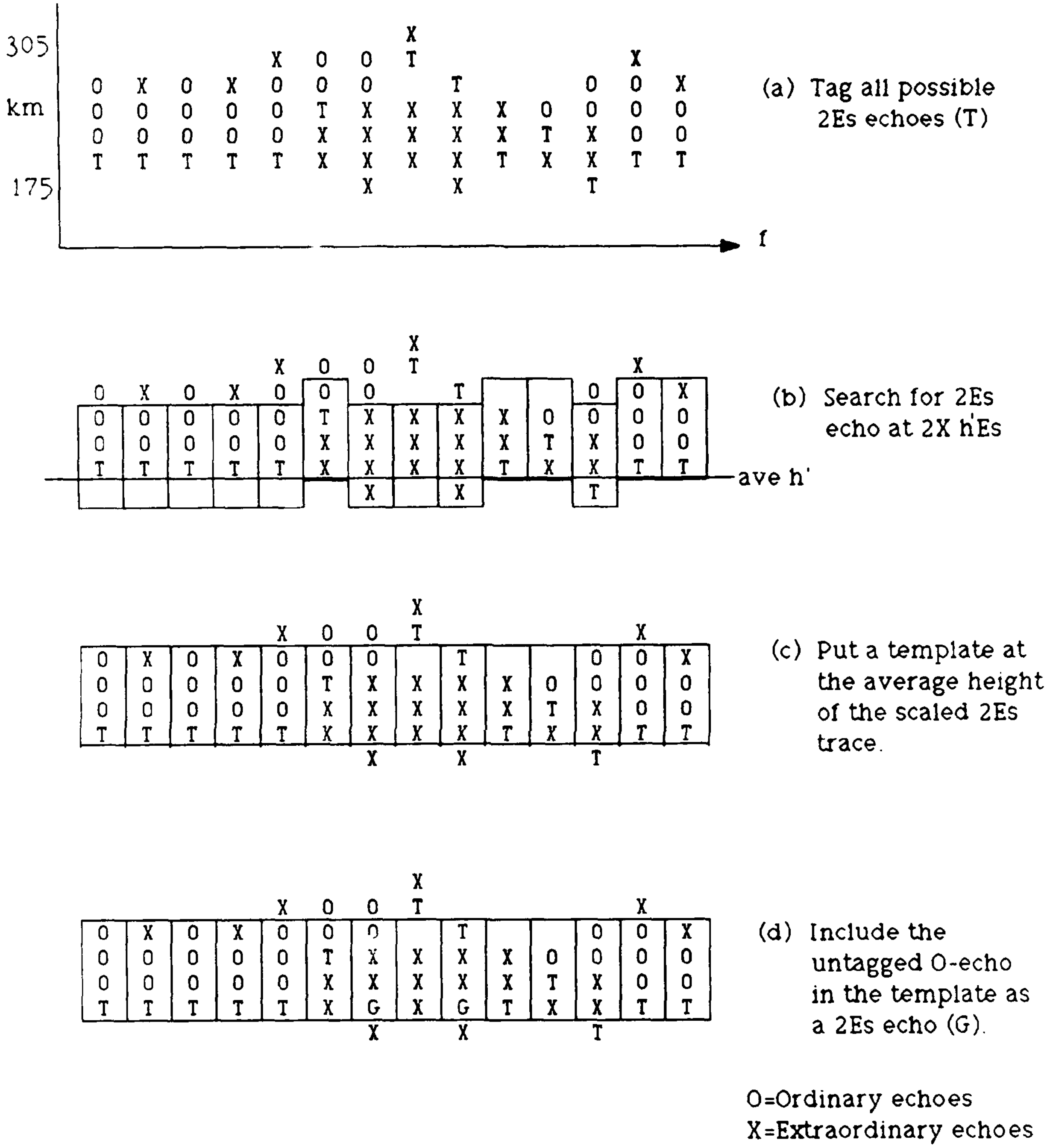

Figure 3. Es Search Procedure

adjacent frequency was tagged then these frequencies are also tagged (marked by G's) as 2Es echoes at the average 2Es height recorded for that frequency, Figure 3d. This procedure is repeated to determine the higher order multiples up to the sixth order Es trace. To minimize errors, the 2Es trace height is used as the reference height to locate the higher order multiples. After the above process is completed, the individual multiple echoes, the average height and the highest frequency of each multiple trace are recorded for reference. Finally, the multiple Es echoes are eliminated by temporarily tagging them as oblique signals. Figure 4 and 5 show the improved results of the corresponding ionograms of Figures 1 and 2. In these figures, the multiple Es echo is represented by an up arrow to illustrate the effect of the tagging of the multiple echoes.

There are, however, cases where the multiple Es trace mixes with the F trace and the elimination of high order echoes may not work that well, and in fact, may introduce errors. Figure 6 shows results obtained with the previous ARTIST algorithm; the F trace was (almost) correctly scaled even though some of the 3Es echoes are mixed with the F trace. Figure 7 displays the results obtained with the new algorithm. The F trace between 3.2 and 4.1 MHz is incorrectly scaled, because the attempted removal of the 3Es trace inadvertently suppressed the F echoes. Another example is illustrated in Figure 8. The minimum frequency of the F trace is scaled too high. The algorithm incorrectly included the F echoes in the 2Es trace for the frequency interval from 2.1 to 2.9 MHz. Figure 9 shows the scaling done by the old algorithm.

The scaling errors in Figure 8 could be avoided by making use of the second order echoes of the F trace. Before eliminating the 2Es layer, tests need to be done to check if the 2F trace is also present; if so, it can be used to save the actual 1F echoes. This test is presently being implemented.

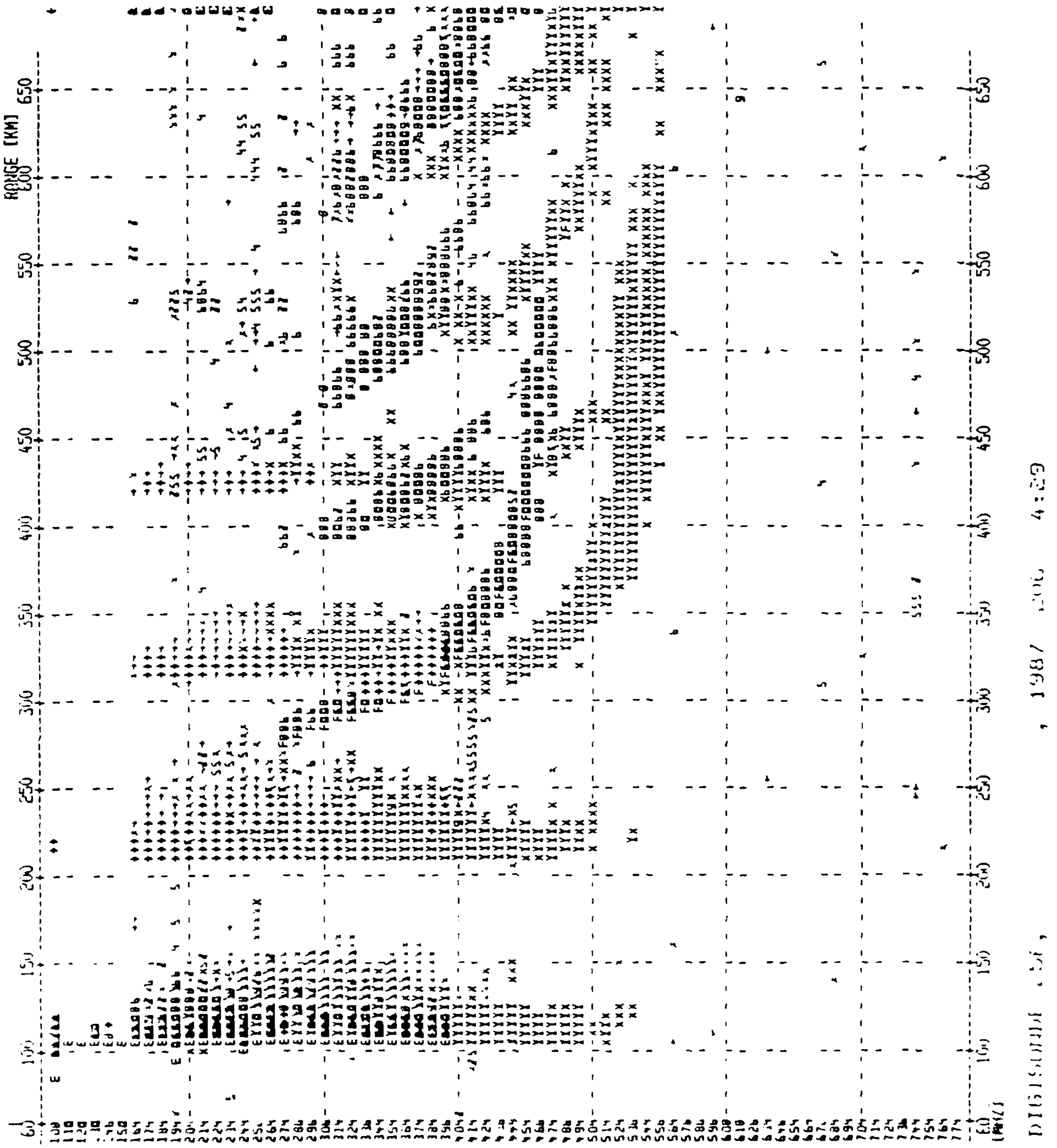

Figure 4. Autoscaling With Elimination of Multiple Es

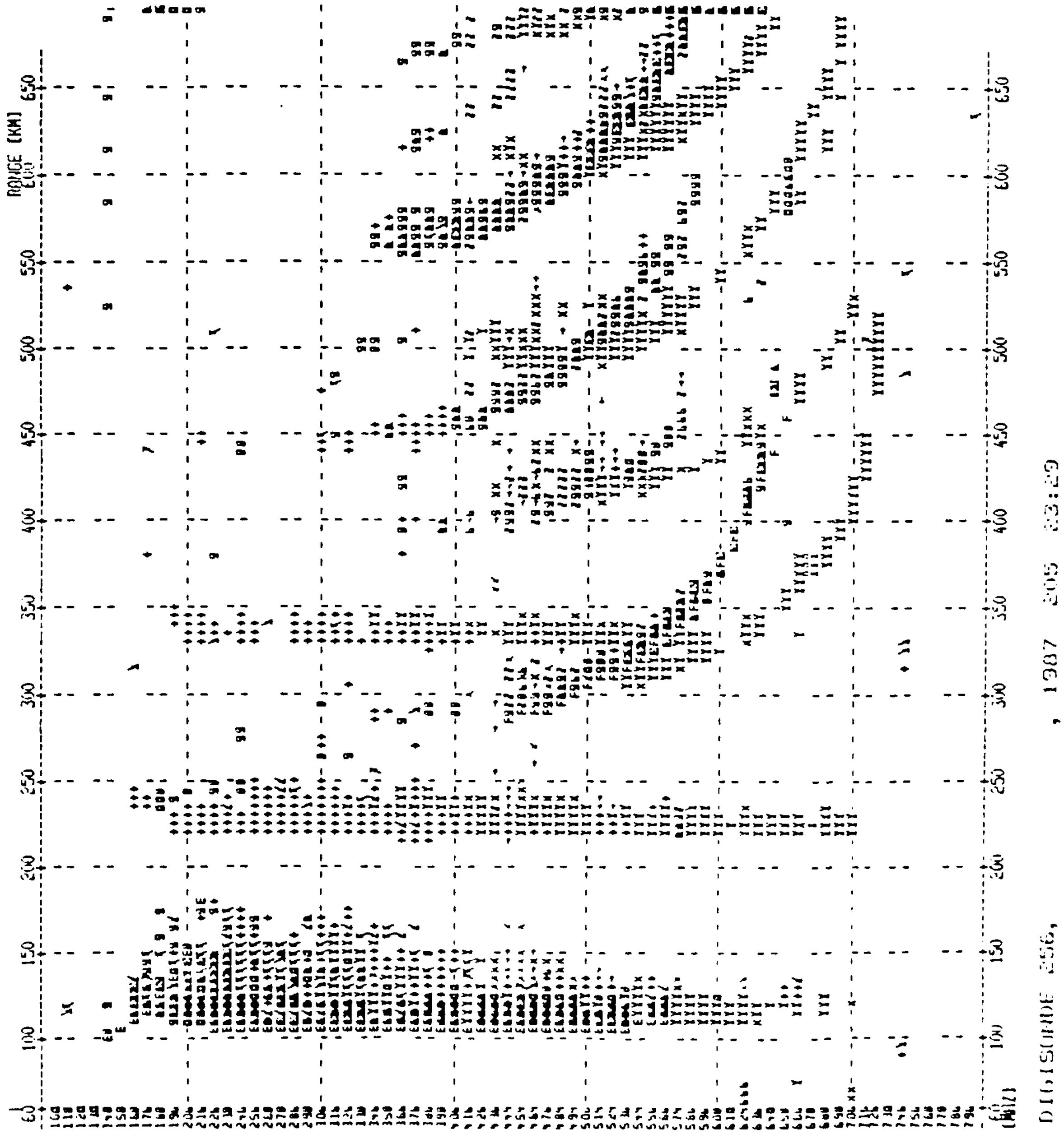

Figure 5. Autoscaling With Elimination of Multiple Es

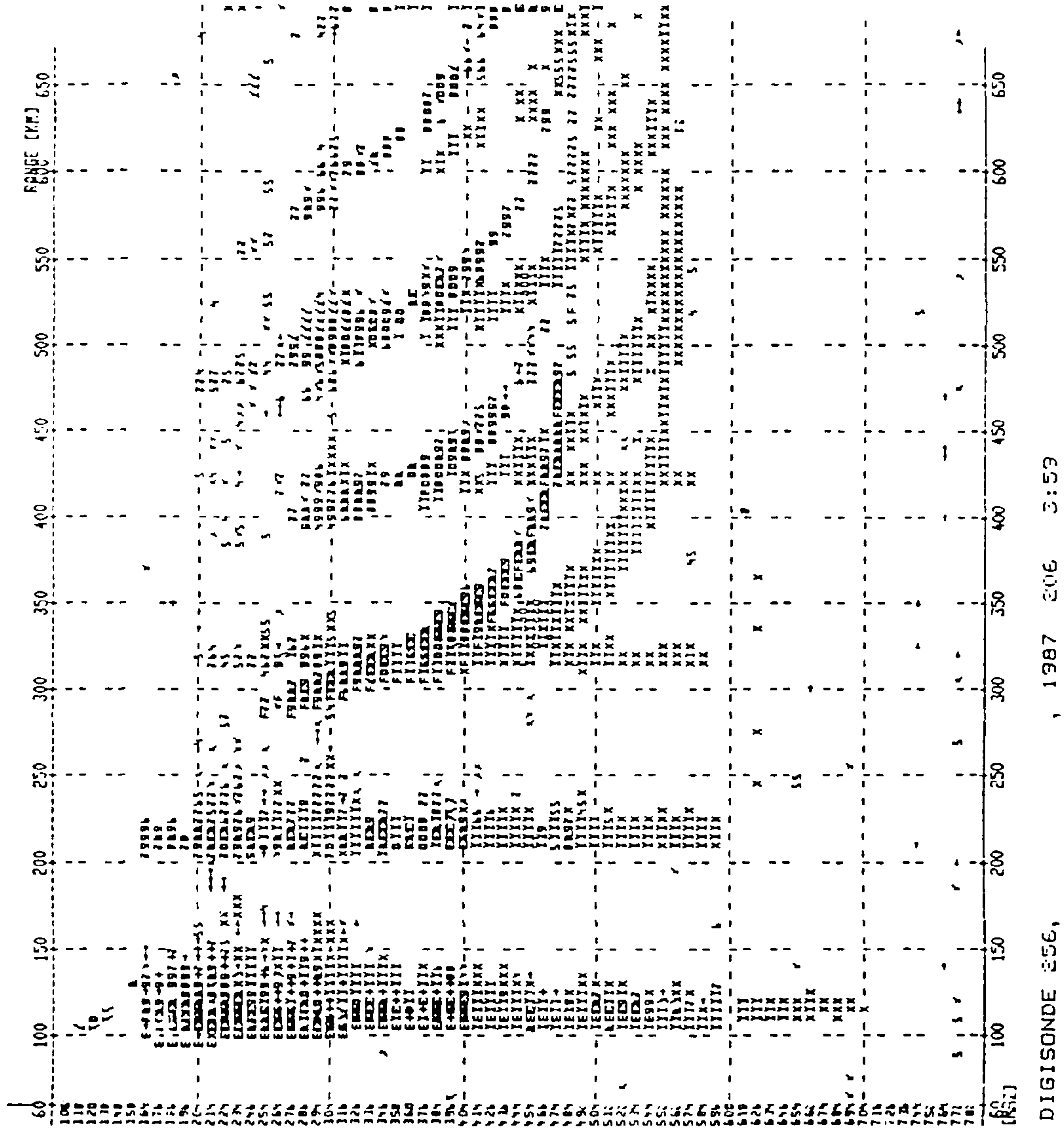

Figure 6. Autoscaling Without Elimination of Multiple Es

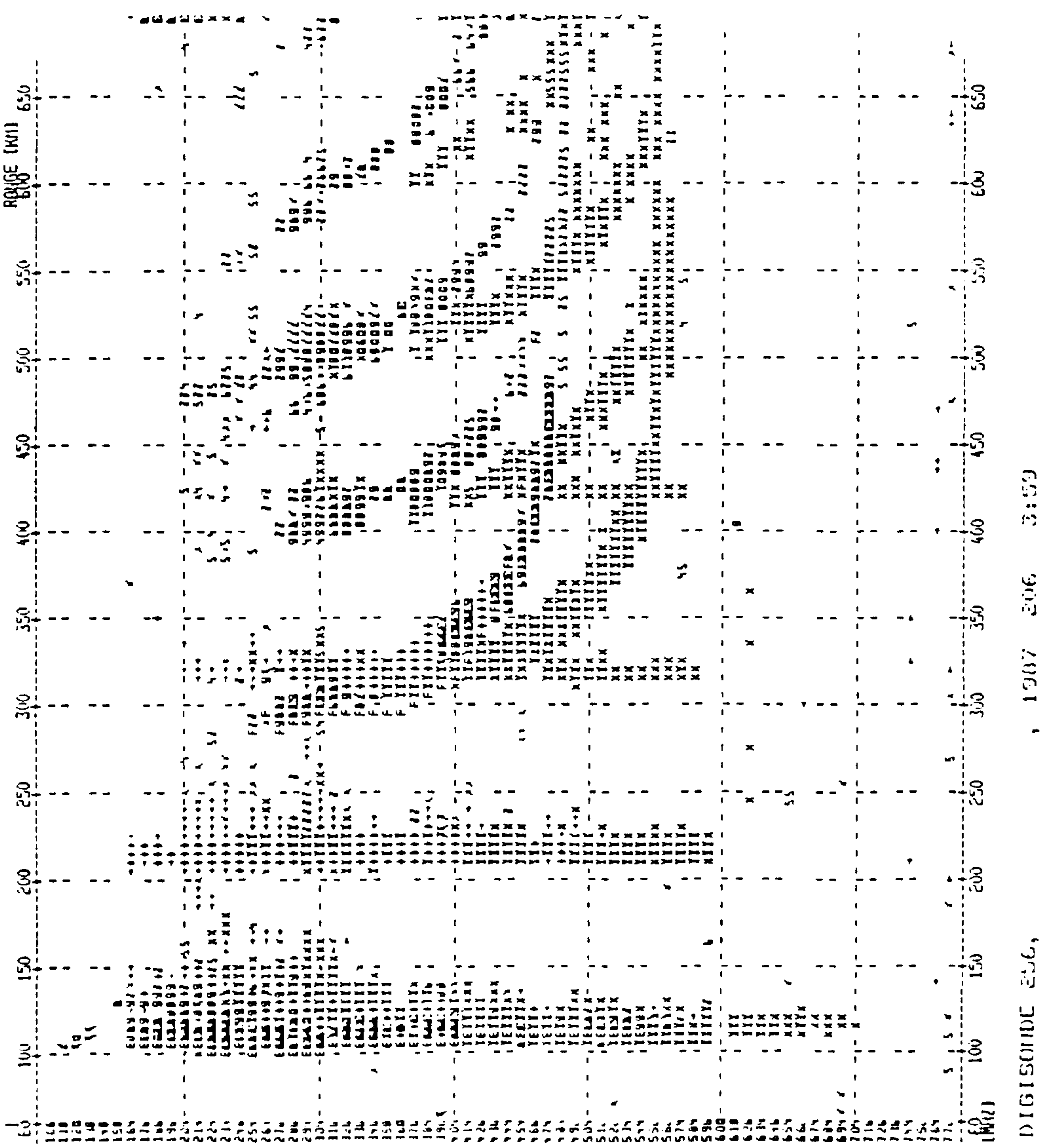

Figure 7. Autoscaling With Elimination of Multiple Es

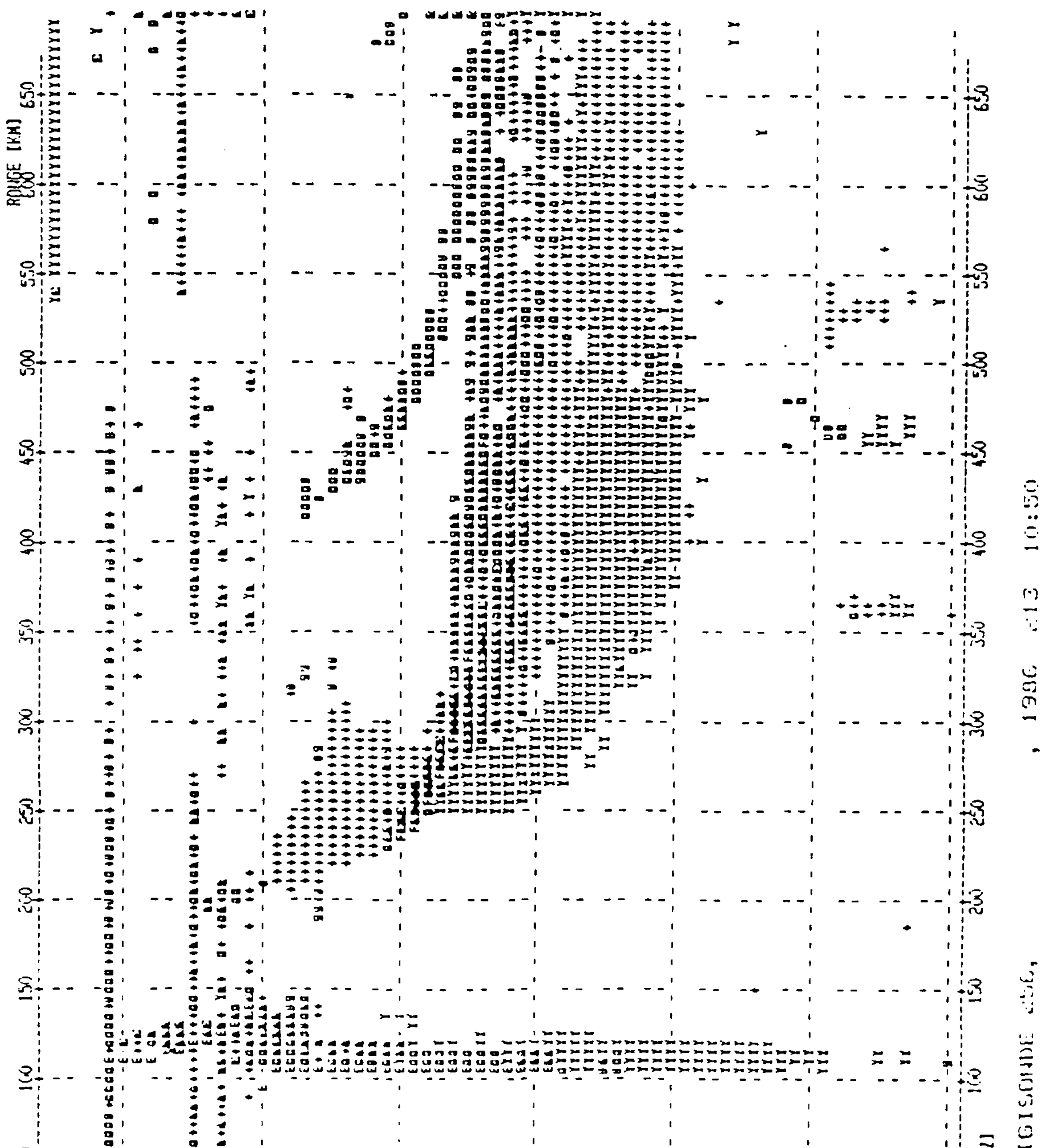

Figure 8. Autoscaling With Elimination of Multiple Es

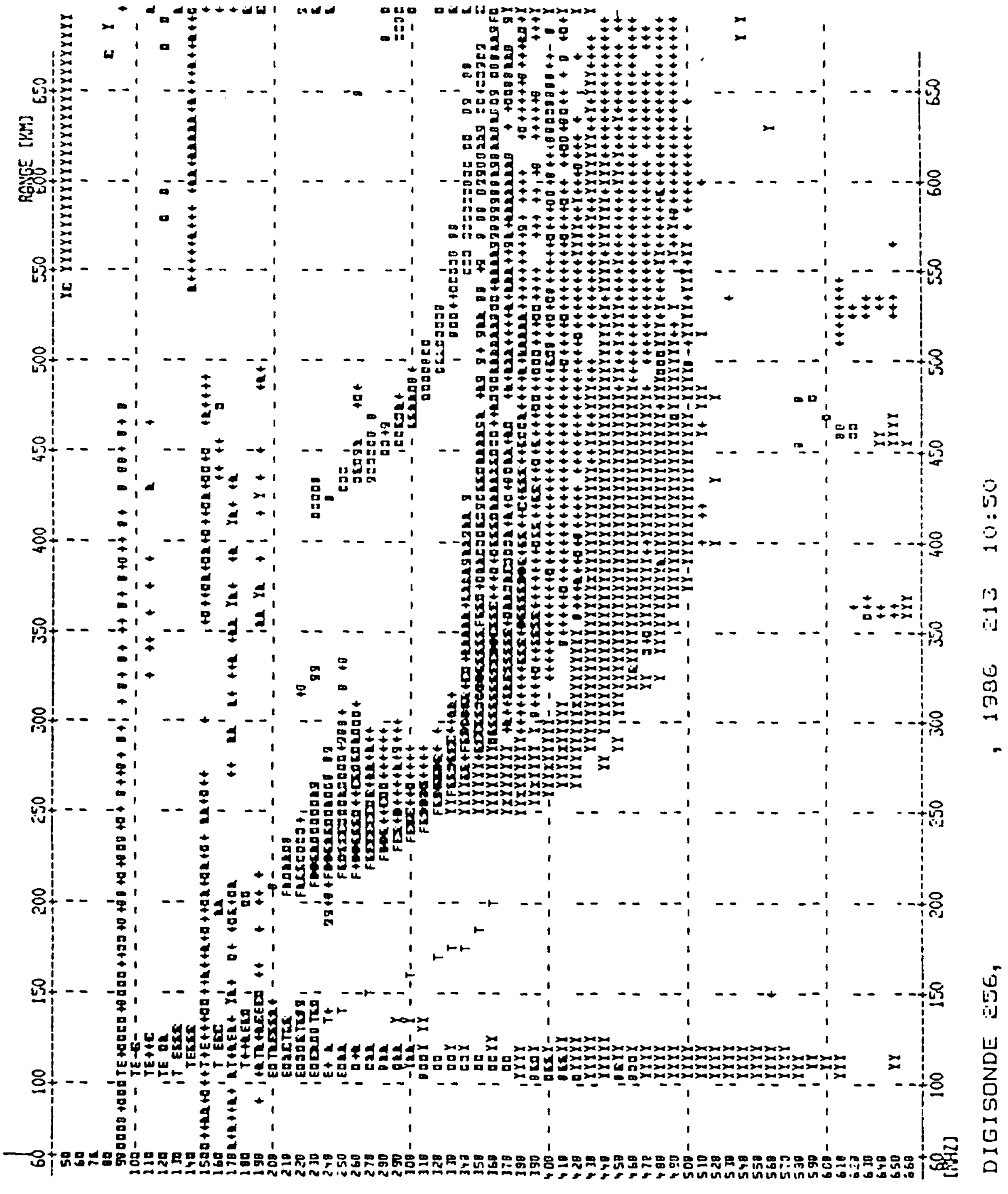

Figure 9. Autoscaling Without Elimination of Multiple Es

Fifty-three ionograms were selected to test the algorithms. Of these ionograms, 29 have strong multiple Es traces (as shown in Figures 1, 2, etc.), while the other 24 are regular, less complicated ionograms which serve as the control data. The results from the new algorithm are very promising. The F trace scaling is improved in 13 of the 29 cases with multiple Es, unchanged in 12, and worse in three cases. For 24 control ionograms, one case is found to have a better scaled F trace, 23 cases are concluded to be the same as the previous results. The three ionograms in the multiple Es data group for which the F scaling worsened show the 2Es echoes mixing with the F trace. For one ionogram in the control ionogram group the F trace was mistaken as the 2Es layer. Table 1 summarizes the results from this study.

Table 1. F Trace Scaling Results* with Multiple Es Search Algorithm

Data Group	Total # of Ionograms	# Improved Scaling	# Worse Scaling	# Unchanged Scaling
Multiple Es	29	13	3	12
Control Group	24	1	1	23

*Results compared with the previous algorithm, scaling quality relative to manual scaling.

3.0 ARTIST VERSION NUMBER

The current ARTIST program consists of approximately 50 modules. Each module contains from three to ten routines. To provide for tighter configuration management and to assist in software maintenance, each subroutine and module has been given a version number. The version number combines the DISS Configuration Item Number (CIN) of the routine and the date the routine was last changed. The version number is coded into the routine and thus exists in the execution code as well as in the source code. The version format is defined as follows:

Subroutine	-xxxMMDDYY	(xxx = CIN number of routine)
Module	-zzzMMDDYY	(zzz = module name)
ARTIST Program	-VSMMYY	

with MM = month
DD = day
YY = year

The ARTIST program version number is printed in the ARTIST header output of each ionogram. A sample printout is shown in Figure 10. A utility program, SEARCHVS, was developed to list all associated version numbers in the ARTIST program. The list is in alphabetical order by subroutine and module name and the sample list is attached in Appendix A.

```
+------------------------------------------------------------------------+
+      ULCAR - MILLSTONE HILL, WESTFORD, MASSACHUSETTS                   +
+              LAT 42.6, LONG 71.5W       DIP 72.9  fH 1.4               +
+      DIGISONDE 256 - VS.08.88       UNIVERSITY OF LOWELL, USA          +
+------------------------------------------------------------------------+

STATION YEAR DAY H  M      OUT OPT B  E  O CAB XLZT NRW HEIG PROGRAM
  042    1987 206  4:29 UT 1084100 01- 8 2 12E 41D3 434 123E     1
                   --------

FOF2  FOF1  H'F   H'F2  M3000 FMIN  FOES  MUF   FMINF
 4.8  ***   288.  ****  2.92   1.0   3.9  14.0   2.7

FXI   FMINE FOE   H'E   H'ES  QF    QE    FF    FE
 5.7  ***    .6P   90.   97.  15.   ***    .2   ***
AUTOSCALED TRACES [KM]:
-------------------
 2. ***** ***** ***** ***** ***** ***** *****  275.  280.  283.
 3.  283.  288.  288.  293.  293.  298.  298.  303.  308.  313.
 4.  323.  333.  343.  358.  378.  403.  438.  488.  568.
*NOTE: NO  E-TRACE FOUND
       PREDICTED FOE IS USED

NORMALIZED AMPLITUDE AS AT REFLECTION HEIGHT 100KM IN [DB]
       TOPF     1    2    3    4 [MHz]
 F      30      0    0   53   58
 E      0
ES      22      0   46   57
```

Figure 10. ARTIST Printout to Show the Current Version Number

4.0 SMOOTHING OF THE AUTOSCALED TRACES

The ARTIST autoscaling often produces traces that are not smoothly varying over the entire trace. Several of the points jump up or down from the main trace, or a few points may oscillate up and down from the trace (see Figures 11 and 12). This is due in part to the digital nature of the data, and to the methodology employed in the scaling algorithms. Methods that can take the ARTIST trace and smooth it via a polynomial fit are currently being explored. Several possible approaches to the problem have been under investigation. One method considered was to employ polynomials (3rd to 5th order) and to apply the fit with the constraint that the 2nd derivative of the polynomial does not change sign. This approach, however, would not be valid for all types of recorded h'(f) traces. The use of Robust Regression (RR) methods may better suit this problem. Robust Regression is an iterative least squares method that uses weighting that varies with iterations. It has been suggested [Hawkins, 1988] that this method employing Chebyshev polynomials for correlation and linearly decreasing weighting for fit stability will yield the best results. This method will be investigated and tested on a large number of traces. If it is found to be reliable it will be added to the ARTIST software.

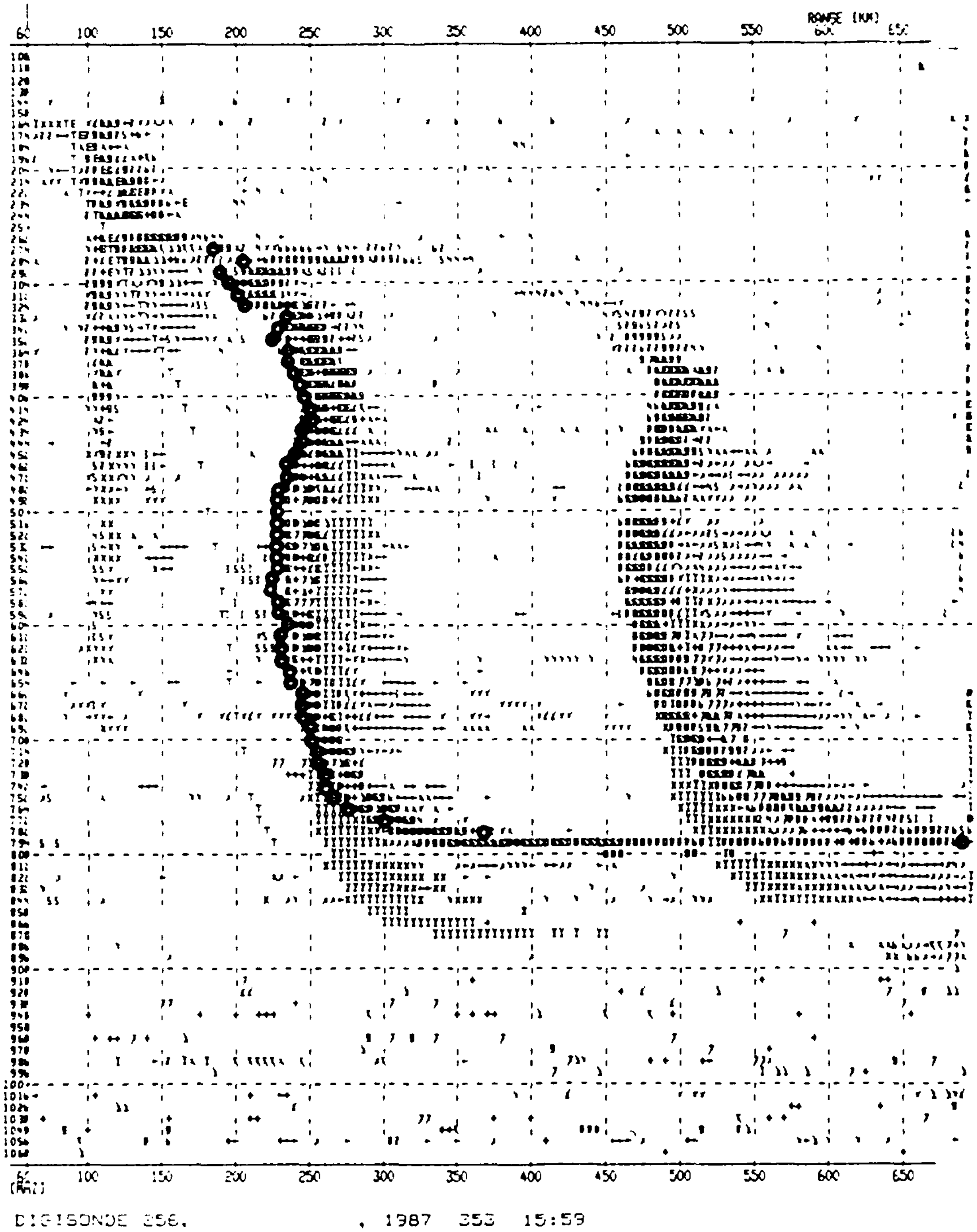

Figure 11. ARTIST Autoscaling Ionogram

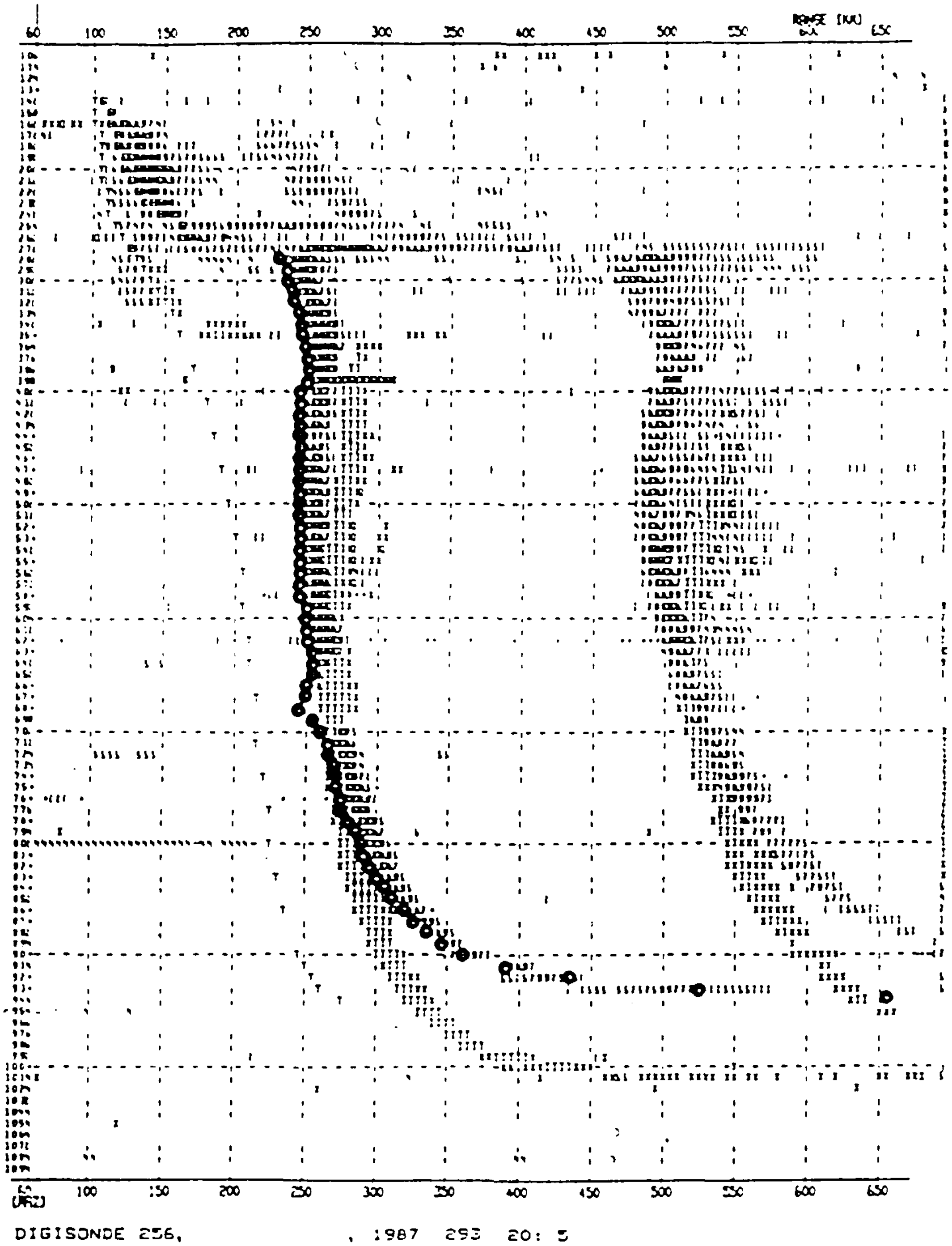

Figure 12. ARTIST Autoscaling Ionogram

5.0 REFERENCES

Robert Hawkins, private communications, Air Force Geophysics Laboratory, Hanscom Air Force Base, MA, 1988.

B. W. Reinisch, R. R. Gamache, J. S. Tang and D. F. Kitrosser, "Automatic Real Time Ionogram Scaler with True Height Analysis - ARTIST," Scientific Report No. 7, AFGL-TR-83-0209, 1983. ADA135174

B. W. Reinisch, J. S. Tang and R. R. Gamache, "Automatic Scaling of Digisonde Ionograms, Test and Evaluation Report," Scientific Report No. 4, AFGL-TR-82-0324, 1982. ADA125830

J. Tang, R. R. Gamache, E. Li, D. F. Kitrosser and B. W. Reinisch, "Status of ARTIST Upgrade," Interim Status Report, University of Lowell Research Foundation, GL-TR-89-0183, September 1988.

APPENDIX A

Version Listings for ARTIST Routines

#$200	072787	#$370	032487	#$487	042187
#$201	072787	#$380	031088	#$488	042187
#$202	072787	#$390	032487	#$489	042187
#$203	072787	#$391	042187	#$490	042187
#$204	052087	#$394	112587	#$491	042187
#$206	072787	#$3AX	062388	#$492	042187
#$207	052087	#$3BX	032487	#$493	042187
#$209	052087	#$400	021788	#$494	042187
#$20X	072787	#$401	042187	#$496	081288
#$270	100388	#$410	042187	#$497	040287
#$271	062388	#$411	042187	#$498	081288
#$27X	100388	#$420	042187	#$4AX	081288
#$305	062388	#$421	042187	#$4BX	081288
#$310	040588	#$430	021788	#$500	040588
#$315	062388	#$433	081288	#$505	040588
#$320	062388	#$435	021788	#$515	040588
#$321	062388	#$437	021788	#$520	040588
#$322	062388	#$438	021788	#$521	040588
#$325	040588	#$439	021788	#$522	040588
#$333	040588	#$440	021788	#$530	040588
#$335	031088	#$441	021788	#$535	040588
#$336	031088	#$442	021788	#$540	040588
#$338	031088	#$443	021788	#$542	042187
#$340	080487	#$444	021788	#$545	040588
#$342	080487	#$44X	021788	#$546	040588
#$343	080487	#$450	050688	#$547	040588
#$344	031088	#$451	050688	#$548	040588
#$345	031088	#$452	050688	#$550	040588
#$346	031088	#$453	050688	#$551	040588
#$347	031088	#$455	050688	#$555	092286
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#$349	031088	#$457	050688	#$55X	092286
#$350	031088	#$45X	050688	#$560	092286
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