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ARTIST Tape Output Formats

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The format of the ARTIST data and raw data records written to magnetic tape are described. The contents of each record type are fully explained making possible an unpacking of the data for subsequent analysis.

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1.0 INTRODUCTION

A new generation of modern ionosondes is now being deployed world-wide. These are the University of Lowell Center for Atmospheric Research (ULCAR) Digisonde 256 and AN/FMQ-12 DISS systems. The Digisonde 256 network [Reinisch, 1986] will provide a consistent data set of ionospheric parameters that are automatically scaled in real time. The automated stations output the standard ionospheric parameters, the h'(f) traces with amplitudes and Doppler frequencies, and the electron density profiles. There are currently 32 systems (see Appendix A) in operation or are close to being installed. The global station distribution, as shown in Figure 1, is very uneven, the majority of sites lying in the northern hemisphere, and there are no equatorial stations. Nevertheless this network provides an extensive data base of ionospheric parameters in digital form, making it easy to process and analyze the data in terms of average diurnal variations, storms, and irregularities. This data base will be invaluable for the testing of global ionosphere models.

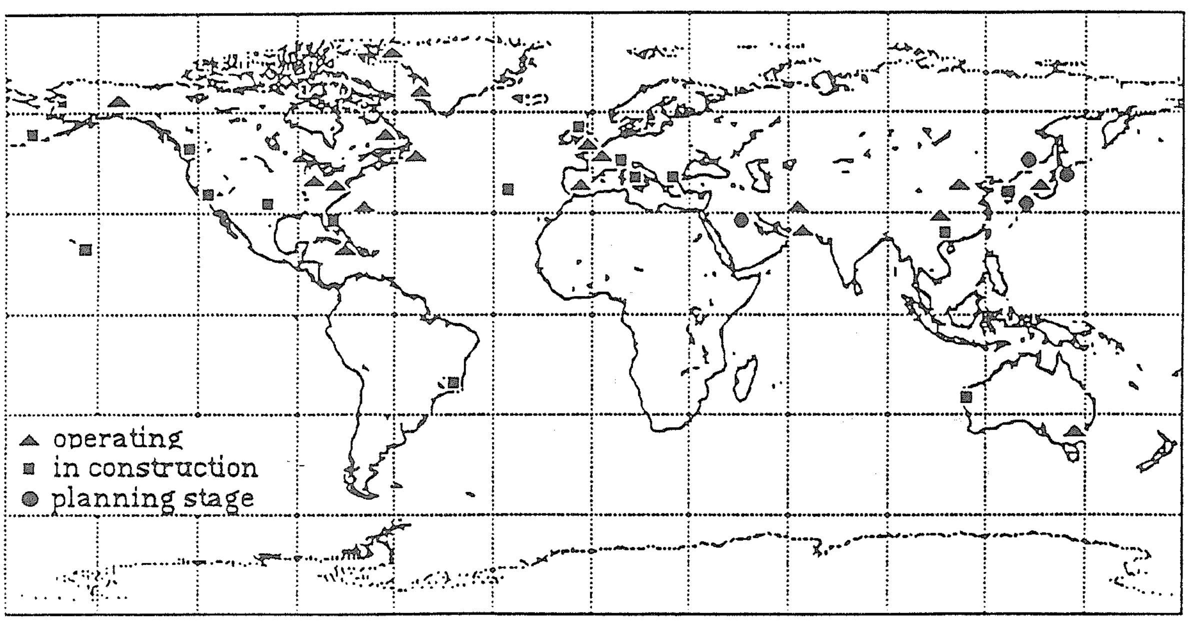

Figure 1. Global Digisonde 256 Network

The scaled ionogram parameters and/or the raw ionograms can be remotely accessed via voice grade telephone lines operating at 1200 or 2400 baud. Currently only the U.S. Global Air Weather Service is networking in a real time mode by polling all their DISS's and centrally collecting the ionospheric parameters as soon as an ionogram scan and the 20 to 30 second ARTIST processing is completed. In general, all stations record the raw ionograms and the autoscaled data on half-inch magnetic tape (1600 bpi). Raw ionogram data is recorded on tape in the P1 = 1 former defined in Appendix B. These are designated as data levels 1 and 2 by the Ionospheric Informatics Working Group (IIWG) G4 [Gamache and Reinisch, 1989] and the formats defined by the ionosonde and autoscaler. In this report the format of the autoscaled data magnetic tapes is reviewed.

The Digisonde 256 has three basic modes of operation: (1) vertical incidence ionograms, (2) drift observations, and (3) oblique incidence (bistatic) ionograms. The discussion below focuses on the mode 1 operation. DISS stations produce only mode 1 vertical incidence ionograms.

Automatic scaling of the ionograms is accomplished within 20 to 30 seconds after completion of the ionogram scan using the ARTIST (Automatic Real Time Ionogram Scaler with True Height) routine [Reinisch and Huang, 1983]. The ARTIST is a hardware/software system housed in an IBM-PC/AT. Figure 2 is an example of a typical on-line printout from the University of Lowell station at Millstone Hill in Westford, MA (42.6°N, 71.5°W geogr.). The small numbers using optically weighted font [Patenaude et al., 1973] give the amplitudes in multiples of 4 dB for the vertical incidence echoes with ordinary polarization, the X indicates extraordinary polarization, and the arrows point in the direction from where oblique echoes were received. The arrows composing the Es trace at 130 km all point to the north-east. The oblique F echoes between 4.5

```
+---------------------------------------------------------------------------+
+      ULCAR - MILLSTONE HILL, WESTFORD, MASSACHUSETTS                      +
+               LAT 42.6, LONG 71.5W        DIP 72.9   fH 1.4              +
+      DIGISONDE 256 - VS.02.B        UNIVERSITY OF LOWELL, USA            +
+---------------------------------------------------------------------------+

STATION YEAR DAY H  M      OUT OPT B  E  Q CAB XLZT NRW HEIG PROGRAM
  033   1987 293 14: 4 UT 1483100 01-11 1 32E 41D3 334 123A    2
                 --------

FOF2  FOF1  H'F   H'F2  M3000 FMIN  FOES  MUF   FMINF
 7.7  3.7   233.  248.  3.16   1.6   2.8  24.3   2.9

FXI   FMINE FOE   H'E   H'ES  QF    QE    FF    FE
 8.5  1.6   2.8   113.  113.   5.    5.   ***    .4

AUTOSCALED TRACES [KM]:
-------------------
 2. ***** ***** ***** ***** ***** ***** ***** ***** *****  265.
 3.  200.  200.  210.  215.  225.  230.  238.  243.  245.  245.
 4.  246.  246.  246.  246.  246.  246.  246.  246.  246.  246.
 5.  246.  246.  246.  251.  251.  251.  251.  256.  256.  261.
 6.  261.  266.  266.  271.  276.  281.  286.  296.  301.  316.
 7.  336.  361.  386.  416.  461.  511.  561.  621.
 1. ***** ***** ***** ***** ***** *****  105.  110.  110.  110.
 2.  115.  115.  115.  120.  120.  125.  130.  140.  160.

NORMALIZED AMPLITUDE AS AT REFLECTION HEIGHT 100KM IN [DB]
       TOPF    2.    3.    4.    5.    6.    7.
 F      29.    0.   45.   64.   60.   69.   66.
 E      21.   46.
ES      21.   46.

PROFILE - ULCAR
--------------
   W =  22.6  KM
   FSTART PEAK HT   A0       A1       A2       A3       A4    DEV    ROOTS
   [MHZ]  [KM]     [KM]     [KM]     [KM]     [KM]     [KM]   [KM]/PT
E   .199 114.690 -25.478  -1.943   -2.277                      3.2    -
F1 2.810 164.253 -18.404  -8.591    1.993  -1.203    -.765    3.7    -
F2 3.710 271.301 -98.323 -14.870  16.480 -18.795    8.458   25.6    -
```

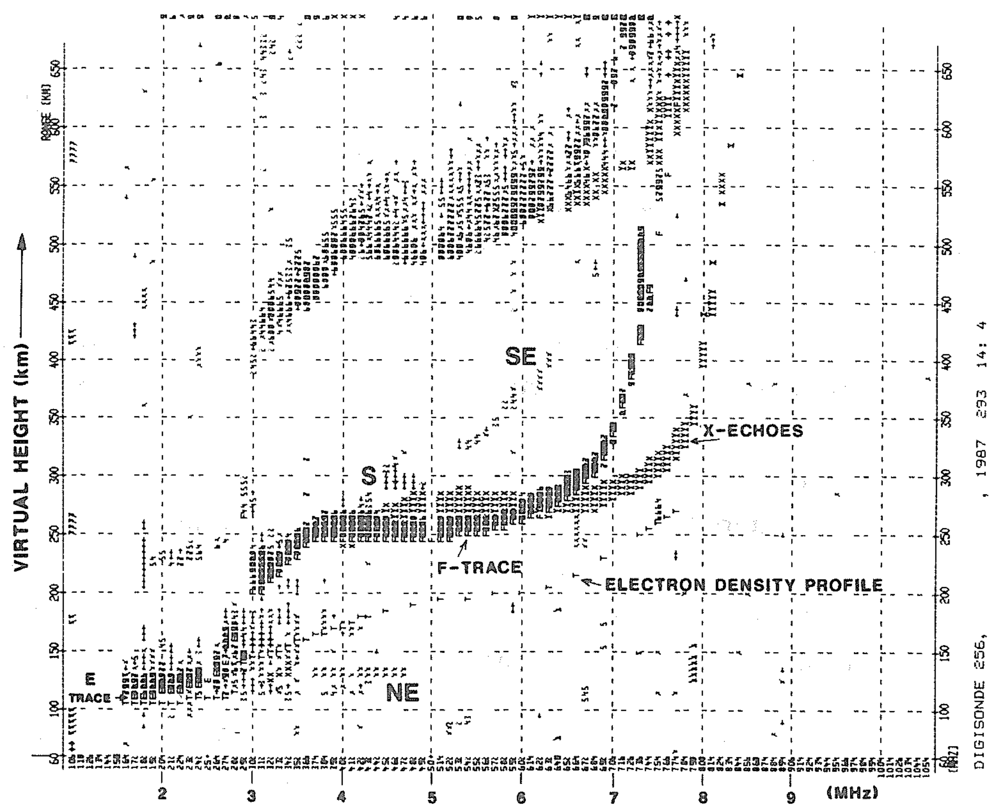

Figure 2. Autoscaled Mid-Latitude Ionogram
Millstone, MA 20 Oct 1987 09:04 (EST)

and 6.5 MHz come from the south and southeast. ARTIST finds the leading edge of the overhead echo traces for the E and F layers. The autoscaled h'(f) traces, marked by the letters E and F, are superimposed on the raw ionogram, thus providing a means of checking the ARTIST performance. The letter T is used for presenting the calculated true height profile. For each layer, E, F1 and F2, the profile is given in terms of a modified sum of Chebyshev polynomials [Gamache et al., 1985]. ARTIST scales the following ionogram parameters: foF2, foF1, foE, foEs, MUFF2(3000), fminF, fminE, h'F, h'F2, h'E and h'Es. The frequency spread for both E and F is determined, and also the average range spread (listed as FE, FF, QE and QF in Figure 2). The virtual height traces h'(f)E and h'(f)F are recorded together with the measured echo amplitudes and Doppler frequencies.

The ULCAR group has recently developed the ARTIST Data Editing Program (ADEP) to establish quality control for the ARTIST data. Inconsistent values are automatically detected, the raw ionogram together with the ARTIST traces are displayed on a computer display screen, and an operator can make the required corrections. The electron density profiles are updated automatically. The edited ARTIST data are then recorded on a 1.2 Mbyte floppy disk which can store the characteristics for about 1,200 ionograms. The format of the data is called the ADEP database [Gamache et al., 1989] and is considered level 2 by the IIWG. Besides the standard ionospheric parameters the disk contains the echo traces, i.e. h'(f), the echo amplitudes and Doppler frequencies and the coefficients for the calculation of the electron density profiles.

The ARTIST can read back and process ionograms that were recorded in either P1 = 1 or the dump mode (P1 = 6) format. It is achieved by selecting two options, READ TAPE and continue to READ/WRITE in the ARMENU prior to running ARTIST program. The ARTIST output data can also be read back by using the program

AROUTPUT which will print out the scaled parameters and traces in the exact format used for the routine ARTIST printout, allowing easy verification of the tape recording quality. AROUTPUT is not available on DISS systems. The program is activated by entering AROUTPUT on the IBM-PC-AT followed by the enter key. AROUTPUT then displays questions on the screen which the user answers to set the parameters used to read back tapes.

In Appendix B, the tape format for the DGS 256 scanning ionogram (MMM'ed output) and raw ionogram data output are presented.

2.0 ARTIST TAPE OUTPUT

The tape recording formats for drift data and P1 = 1 ionogram data were described in detail in the Digisonde 256 General Description Manual. We are going to describe only the ARTIST results format in this report.

After processing an ionogram, the results are written onto a 9-track magnetic tape of density 1600 bit per inch (BPI). The results for each ionogram are recorded in a 4K byte block. Each byte is placed with two characters in binary coded decimal (BCD) format except the preface, the block type character and the control character, which have only one binary character per byte.

The first byte of the block is the block type (hex OF for ARTIST results). The next two bytes are the total number of bytes in the block including the end code characters. The results contain information for the whole ionogram for archiving purposes. They include the ionogram preface, scaled parameters, trace heights, amplitudes and Dopplers, and the electron density profile coefficients. The information is represented in groups. Each group is given a code for identification. Table 1 lists the code numbers and the corresponding groups. The groups are of various lengths, in terms of the number of bytes. The length of certain groups will change from ionogram to ionogram because of the variation in trace length. However, the length of each datum within a group is fixed. For example, one byte is used for each preface character, two bytes are reserved for each ionospheric parameter so a value of 12.5 will be stored as 01H 25H. Each group is headed by a group of four bytes. The first two bytes are control characters (CCH) which serve as a separator between groups followed by a byte for group code, and the last byte defines the data length. At the end of the last

INDEX CODE	No. of Bytes for Each Data	CONTENTS	UNIT
00	1	Preface 100 bytes are reserved, only 57 bytes are used.	
01	2	30 ionospheric parameters	
02	2	Leading edge of F-trace	km
03	1	Amplitudes of maximum F-trace	0-31 levels
04	1/2	Doppler number of maximum F-trace	
05	2	Leading edge of E-trace	km
06	1	Amplitudes of maximum E-trace	0-31 levels
07	1/2	Doppler number of maximum E-trace	
11	1	Median amplitudes of F-trace at the cusp and each MHz	dB
12	1	Median amplitudes of E-trace at the cusp and each MHz	dB
13	1	Median amplitudes of Es-trace at the cusp and each MHz	dB
14	3	E-region profile coefficients	
15	3	F2-region profile coefficients + average error + slab thickness + void	km
16	3	Monotonic solution, one set of coefficients for E and F regions	
17	1	20 flags	
18	3	F1-region profile coefficients	
19	3	The start frequency for true height analysis of E, F2, F1 layers	
20	2	Station characteristics	
40	1	AWS station ID in ASCII	
77	1	End of ionogram indicator	
0CCH	1	Control character used as group separator	

Table 1. Definition of Code of Block Type 15

output group, two bytes of end code (077H) are appended. Figure 3 shows the actual storage of one ionogram block.

Code 0 is assigned to the preface and uses one byte for each character. Code 1, assigned to the scaled ionospheric parameters, uses two bytes for each value. Tables 2 and 3 list the preface and parameters, respectively. Codes 2 to 4 are reserved for the F-trace information. Code 2 contains the h'(f) values in km starting at the minimum frequency of the layer, incrementing in 100 kHz steps to the critical frequency. Two bytes are used for each trace point. If an echo is not found for a particular frequency, 9999 is filled in. Code 3 contains the amplitude of the maximum trace point. The amplitudes range from 0 to 31 and the datum length is one byte. The magnitude in decibels can be calculated by checking the value of Z in the preface; for Z smaller than 8, the amplitude unit is 2 dB, for Z greater than or equal to 8, the unit is 3 dB. Code 4 records the Doppler number which has a datum length of half a byte. Ionograms that measure the O and X polarization have a maximum of eight Doppler lines. In this case, the number 0 to 7 are used to represent the Doppler lines where 0 always stands for the most negative and 7 denotes the most positive Doppler. Similar format characteristics of the E-trace are stored for Codes 5 through 7. Currently, Codes 8, 9, 10 are not used. Codes 11 through 13 contain the median amplitudes of the F, E, and Es traces, respectively, occupying one byte each. The median amplitudes are presented for each MHz and are normalized to the reflection height of 100 km. Special consideration is given to the cusp region where the median amplitude is selected among the last five frequencies of the trace. The first data byte stores the total number of amplitudes calculated for the trace at 1 MHz intervals. For example, if the trace runs between 2 to 5 MHz, excluding the cusp frequencies, the number 4 will be stored in the first byte; the second byte is the average cusp amplitude, and the third byte is the start frequency in MHz (in this case 2) followed by the amplitudes at 2, 3, 4 5 MHz.

```
                                    BLOCK TYPE
                                    NUMBER OF BYTES IN BLOCK
                                    CONTROL CHARACTER
                                    CODE 0 (PREFACE)
                                    DATA LENGTH:  1 B

                               OF 04-23  CC CC 00 01 09 08 05
         03 05 01 01 09 02 09  00-05  01 01 03 02 00 00 00
         00 00 01 00 00 00 00  00-00  08 03 02 00 00 00 01
         01 00 08 03 02 0E 0A  04-07  04 01 0B 02 03 02 05
         00 00 05 01 02 03 05  00-00  00 00 00 00 00 00 00
         00 00 00 00 00 00 00  00-00  00 00 00 00 00 00 00
         00 00 00 00 00 00 00  00-00  00 00 00 00 00 00 00
         00 CC CC 01 02 00 54  99-99  03 63 01 96 00 15 00   CODE:  1
         21 00 22 00 15 00 21  00-62  02 25 99 99 01 00 01   DATA LENGTH:  2 BYTES
         00 01 05 00 15 00 05  99-99  00 00 00 10 00 10 99   foF2 = 5.4 MHz
         99 00 04 CC CC 02 02  02-25  02 32 02 29 02 24 02   foF1 NOT FOUND, ETC.
         19 02 19 02 24 02 19  02-24  02 24 02 24 02 24 02
         24 02 29 02 29 02 29  02-29  02 29 02 34 02 34 02
         29 02 39 02 44 02 44  02-44  02 44 02 44 02 49 02
         54 02 64 02 74 02 99  03-69  CC CC 03 02 19 19 18
         00 25 18 24 17 27 28  30-27  30 30 31 31 31 31 31
         31 31 31 31 29 30 31  31-29  00 31 31 27 26 CC CC
         04 00 21 14 11 12 22  21-12  22 22 21 22 21 22 22
         42 22 24 CC CC 05 02  01-00  01 00 01 00 01 05 01
         05 01 10 01 15 CC CC  06-01  18 16 17 15 16 16 15
         CC CC 07 00 12 12 12  24-CC  CC 11 01 03 35 03 61
         70 70 CC CC 12 01 00  17-CC  CC 13 01 00 17 CC CC
CODE 14  14 03 99 69 01 00 00  03-18  88 81 34 97 00 69 51
CODE 15  91 CC CC 15 03 24 19  02-00  00 05 52 72 81 10 07
                                         ^---------------   NUMBER OF COEFFICIENTS
         01 77 38 80 23 29 00  23-63  00 21 09 00 15 00 01
         00 00 00 CC CC 17 01  01-02  00 00 00 00 00 00 00
         00 00 00 00 00 00 00  00-00  00 CC CC 77 77 00 00   END CODE
```

Contents of Code 14 (E-region)
Data Length: 3 bytes
Z(foE) = 99.69 km
There are 3 polynomial coefficients, -18.88, 3.497, 0.6951

Code 15 (F-region)
Data Length: 3 bytes
Z(foF2) = 241.9 km
There are 5 coefficients, -52.72, 10.07, -7.738, 2.329, -2.363
absolute error per point = 2.109 km
Slab Thickness = 15.00 km
Void = 0.0 km.

Figure 3. Actual Storage of One Ionogram Results in Memory

PREFACE CHARACTER	SYMBOL	FUNCTION
Date and Time		
1 - 2	Y = YY	Year
3- 5	D = DDD	Day
6 - 7	H = HH	Hour
8 - 9	M = MM	Minute
10 - 11	S = SS	Second
General Control Parameters		
12	S	Program Set
13	P	Program Type
14 - 19	J	Journal (internal controls)
Nominal Frequency		
20 - 25	F = FFFFFF	Frequency (100 Hz)
Output Controls		
26	P1	Tape Write Control
27	P2	Printer Control
28	P3	Maximum Method Options
29	P4	Printer Cleaning Threshold
30	P5	Printer Gain Level
31	P6	Control for Intermittent Transmissions
32	P7	Used for Drift
Frequency Choice		
33 - 34	S = FR	Start Frequency (MHz)
35	Q	Frequency Increment
36 - 37	U = UY	End Frequency (MHz)
Test Output		
38	C	Trigger
39	A	Channel A: Digital
40	B	Channel B: D/A

Table 2. Tape Recorded Preface

PREFACE CHARACTER	SYMBOL	FUNCTION
Station Identification		
41 - 43	V	Station No. from INCPU Personality
Operating Parameters		
44	X	Phase Code
45	L	Antenna Azimuth
46	Z	Antenna Scan
47	T	Antenna Option and Doppler Spacing
48	N	Number of Samples
49	R	Repetition Rate
50	W	Pulse Width and Code
51	K	Time Control
52	I*	Frequency Correction (from CORE)
53	G*	Gain Correction (from CORE)
54	H	Range Increments
55	E	Range Start
56	I	Frequency Search
57	G	Nominal Gain
Drift Parameters		
58 - 60	H1 = HHH	Height 1 (km)
61	G1 = G	Gain 1 (-6 dB)
62 - 65	F1 = FFFF	Frequency 1 (10 kHz)
66 - 68	H2 = HHH	Height 2
69	G2 = G	Gain 2
70 - 73	F2 = FFFF	Frequency 2
74 - 76	H3 = HHH	Height 3
77	G3 = G	Gain 3
78 - 81	F3 = FFFF	Frequency 3
82 - 84	H4 = HHH	Height 4
85	G4 = G	Gain 4
86 - 89	F4 = FFFF	Frequency 4

*Used for internal data management only.

Table 2. Tape Recorded Preface (Continued)

ORDER	SCALED CHAR.	DESCRIPTION	UNIT
1	foF2	F2 layer critical frequency	100 kHz
2	foF1	F1 layer critical frequency	100 kHz
3	M(D)	MUF(D)/foF2 (see #24)	
4	MUF	Maximum usable frequency for D = 3000 km	100 kHz
5	fmin	Minimum frequency for E or F echoes	100 kHz
6	foEs	Es layer critical frequency	100 kHz
7	fminF	Minimum frequency of F-trace	100 kHz
8	fminE	Minimum frequency of E-trace	100 kHz
9	foE	E layer critical frequency	100 kHz
10	fxI	Maximum frequency of F-trace	100 kHz
11	h'F	Minimum virtual height of F1 trace	km
12	h'F2	Minimum virtual height of F2 trace	km
13	h'E	Minimum virtual height of E trace	km
14	h'Es	Minimum virtual height of Es layer	km
15	HOM	Maximum trace height of E layer using parabolic model	km
16	Ym	Half thickness of E layer	km
17	OF	Average range spread of F-trace	km
18	OE	Average range spread of E-trace	km
19	Down F2	The lowering of maximum F-trace to the leading edge	km
20	Down E	Lowering of E-trace	km
21	Down Es	Lowering of Es-trace	km
22	FF	Frequency spread between fxF2 and fXI	100 kHz
23	FE	As FF but considered beyond foE	100 kHz
24	DMUF	Distance used for MUF calculation	km
25	fMUF	fMUF = MUF/obliquity factor	100 kHz
26	h'MUF	Virtual height at fMUF	km
27	ΔfoF2	Frequency difference between calculated (from hyperbolic fitting) and truncated foF2 cal. foF2 = foF2 + ΔfoF2	km
28	foEp	Predicted foE value	100 kHz
29	f(h'F)	Frequency at which hminF occurs	100 kHz
30	f(h'F2)	Frequency at which hminF2 occurs	100 kHz
31	foF1p		

*Used for internal data management only

Table 3. ARTIST Scaled Characteristics Recorded on Magnetic Tape

Codes 14 and 15 contain the profile coefficients of the E and F traces, respectively. Each coefficient takes up three bytes; i. e. 6 digits. The format is the same as in the AWS message: AAAAPN where AAAA are the four most significant digits of the coefficient which represents A∘AAA, P is the sign indicator for both AAAA and power N. The coding for P is as follows:

7 = AAAA and N negative
8 = AAAA negative, N positive
9 = AAAA positive, N negative
0 = AAAA and N positive
N = power of 10 with which AAAA is multiplied.

For example, a coefficient of -29.23 will be stored as 29H 23H 81H. The recording order is listed as follows:

Byte	
1 - 3	the true height of the layer peak in km
4 - 6	the number of terms of coefficients (M)
7 - 9	first coefficient
10 - 12	second coefficient
∘	
∘	
∘	Mth coefficient; n = 3*M + 4
n - n + 2	Average Absolute Error per point in km between calculated and scaled virtual height
n+3 - n+5	slab thickness in km } only in Group 15
n+6 - n+8	void in km } only in Group 15

Code 16 is used for the monotonic solution and has the same format as Code 14. Code 17 contains a set of flags with data lengths of one byte each. Table 4 lists the contents of the flags.

FLAG ORDER	CONTENT	DESCRIPTION
1	0	E-trace is not found
	1	Scaled E-trace
	2	Predicted foE is used
2	0	No profile, since no F trace found
	1	E profile only, F trace too short
	2	Separate set of coefficients for E and F
	3	Monotonic solution
	9	No profile, terminal error encountered
3	Number of roots	If roots are found in F profile
4	1	foF1 is scaled
5	0 - 9	Qualifying number, refer to AWS IONOS
•	Not used	
•	Not used	
•	Not used	
20	-	Internal use in ARTIST execution

Table 4. Contents of Code 17 for ARTIST Result

Code 18 is used for the profile coefficients of the F1 trace and has the same format as Code 14. Code 19 contains the start frequencies used for the E, F1, F2 layers for true height analysis. Each frequency takes up three bytes; i.e. 6 digits, specifying the frequency in units of 100 Hz. If a particular trace is not found, the corresponding start frequency is set to 00H 99H 00H. Code 20 is used for the station coordinates; each datum consists of two bytes. The list is shown in Table 5. The minus sign for the latitude is indicated by a 9 in the most significant digit. Code 40 records the AWS station identification in ASCII characters. For example, the station ID for Argentia, Newfoundland, is stored as 'HICN6 CYAR 71807'. In order to read back the above codes from tape, corresponding adjustments have been added to the program AROUTPUT.

SEQUENCE #	DESCRIPTION	UNIT
1	Gyrofrequency	1 kHz
2	Dip Angle (0. to 90.0°)	0.1 degree
3	Geographic Latitude (0. to ±90.0°)	0.1 degree
4	Geographic Longitude (0. to 359.9°)	0.1 degree
5	Mean Sunspot Number of Current Year	
6	ARTIST Program Version Number MMYY	(Month, Year)

Table 5. Tape Format for Station Coordinates

3.0 REFERENCES

Gamache, R. R., W. T. Kersey and B. W. Reinisch, "Electron Density Profiles from Automatically Scaled Digital Ionograms. The ARTIST's Valley Solution," Scientific Report No. 1, AFGL-TR-85-0181, ADA180990, 1985.

Gamache, R. R., T. W. Bullett, Z. Zhang, B. W. Reinisch and W. T. Kersey, "ARTIST Data Editing and Printing Output Format," University of Lowell Center for Atmospheric Research, 1989.

Gamache, R. R. and B. W. Reinisch, Proceedings from the International Workshop on "Digital Ionogram Data Formats for World Data Center Archiving," University of Lowell Center for Atmospheric Research, November 1989.

Patenaude, J. A., K. Bibl and B. W. Reinisch, "Direct Digital Graphics, The Display of Large Data Fields," American Laboratory, pp. 95-101, September 1973.

Reinisch, B. W., "New Techniques in Ground-Based Ionospheric Sounding and Studies," Radio Science, 21, No. 3, pp. 331-341, May-June 1986.

Reinisch, B. W. and Huang Xueqin, "Automatic Calculation of Electron Density Profiles from Digital Ionograms. 3. Processing of Bottomside Ionograms," Radio Science, 18, 3, pp. 477-492, May-June 1983.

APPENDIX A

DIGISONDE STATION LOCATIONS

DIGISONDE STATION LOCATIONS

January 1990

Operating and Near Term Planned

GEOGRAPHIC

STATION	LATITUDE	LONGITUDE
Quezon City	N14.7	E121.1
Ramey	N18.5	E292.9
Maui	N20.5	E203.7
Karachi	N24.8	E 67.1
Ft. Walton Beach	N30.5	E273.5
Central Texas	N29.4	E261.7
Bermuda	N32.4	E295.3
Islamabad	N33.8	E 72.9
Vandenberg	N34.7	E239.4
Xinxiang	N35.3	E113.9
Kokubbunji	N35.7	E139.5
Kunsan	N36.0	E126.6
Wallops Is.	N37.9	E284.5
Sacramento	N38.4	E238.5
Beijing	N39.9	E116.5
Roquetes	N40.8	E .3
Pirinclik	N41.2	E 28.9
Lowell	N42.6	E288.5
Coltano, Italy	N43.5	E 10.3
Argentia	N47.6	E307.3
Munchen	N48.2	E 11.6
Dourbes	N50.1	E 4.6
Amchitka	N51.0	E201.0
Croughton	N52.0	E358.8
Goose Bay	N53.3	E299.5
Slough	N51.5	E359.4
Petersburg	N56.5	E226.5
Narsarsuaq	N61.2	E314.6
College	N64.9	E212.2
Sondrestrom	N67.0	E309.0
Qaanaaq	N77.5	E290.8
Learmonth	S22.1	E114.0
Sao Paulo	S23.5	E313.5
La Trobe	S37.8	E145.0

APPENDIX B

TAPE FORMAT FOR DGS 256

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TAPE FORMATS FOR DGS 256

1. Tape Description

All tapes are 9-track 1600 BPI PE format, except for Belgium with 800 BPI NRZI. Odd parity is used. All records on tape have 4096 characters or bytes of 8 bits each. It is possible with some tape recorders that actually 4097 characters will be written due to variations in meaning of the last word command to the tape formatter. When this happens, the last character is meaningless.

2. Record Types

The RECORD TYPE is encoded into the 4 least significant bits (LSB) of the first character of each record. Table 1 lists the types of records and summarizes the contents of each; more details are found in the sections below. The Tape Write Control parameter P1 in the ionogram preface directs the Output Computer to write the data on tape (P1 = 0 indicates 'no output to tape'); the record type indicates to the tape reader the type of data in each record.

2.1 Scanning Ionogram, MMM'ed Output (Record Types 08H and 09H)

A routine scanning ionogram consists of 128 or 256 amplitudes and statuses for 128 or 256 range bins at each sounding frequency. In general several records are required for each ionogram; the first record of each ionogram is labelled 09H, and the other records are labelled 08H.

Each record of MMM'ed (Modified Maximum Method) ionogram data contains three initial characters plus 57 4-bit preface

RECORD TYPE*	DATA TYPE	CONTENT	P 1 **
08H	Scanning ionogram, MMM'ed output	amplitude + "status"*** 128 ranges, 30 freq/block or 256 ranges, 15 freq/block	1
09H	First block of MMM'ed ionogram		
0AH	Drift	1 or 2 cases/block	>0
0CH	Dump of raw ionogram data (16 channels/frequency)	amplitude and phase: 1 freq/block	6
0DH	Dump of raw ionogram data (16 channels/frequency)	amplitude only: 2 freq/block	7

*Encoded into the 4 LSB of the first character of each block; for tape reader's information.

**Tape Write Control (programmable by operator; P1 = 1 is default).

***Actually, channel number; status must be converted from channel number.
See section 2.1.1, and in particular, Table 6.

Table 1. Recorded Data: Record Types

characters, followed by a maximum of 30 blocks (30 frequencies) of data with 128 height ranges per block, or a maximum of 15 blocks (15 frequencies) of data with 256 height ranges per block (Table 2). The three initial characters plus preface characters and the 15 or 30 blocks of data do not add up to a full record of 4096 characters. In addition, the last frequency of an ionogram may not be the 15th or 30th frequency of the record. After the end of the last block of ionogram data there is an "END" character (0EH), which indicates to the tape-reading program to ignore the remainder of the record.

The three initial characters consist of the RECORD TYPE (08H or 09H), the LENGTH of the preface area (presently 60 characters: 3 initial + 57 preface), and a SPARE character (zero). These three plus the preface are encoded into the 4 LSBs of the first 60 bytes of the record (the 4 most significant bits (MSB) of the first 60 bytes are 0), except that the LENGTH is an 8-bit number.

The preface (Tables 3a and 3b) indicates the time and frequency of transmission, the station number, and other relevant operating and control parameters. The date and time, the frequency of transmission, the begin and end frequencies and the station number are multiple-digit values, with each BCD digit encoded into a separate 4-bit preface character•number from which the amplitude was selected, encoded into the 4 LSB. The status is obtained from the channel number, using Table 6.

Block type 2 used up to 3990 of the 4096 bytes: 60 + (262 × 15); i.e. 60 preface + ([6 prelude + 256 data] × 15 frequencies). Character 3991 or the character following the last block of data is the END character. The bit structure of each byte is AAAAASSS: a 5-bit amplitude encoded into the 5 MSB, and a 3-bit STATUS in the 3 LSB. SSS, which is actually the 3 MSB of the channel number, must be converted back to a 4-bit channel number before being used to determine the status from Table 6: for the first 128 range bins of

RECORD CHARACTER		CONTENT OF EACH RECORD
1	4 LSB	Record Type (08H; 09H if first record of ionogram)
2	8 bits	Length of preface area including the 3 initial characters (3CH: 3 + 57)
3		Spare (always zero)
4-60	4 LSB	57 4-bit preface characters
61-4080	8 bits	30 blocks of data (128 ranges/block)
4081*		End of information on record (0EH)
4082-4096		Not used

Table 2a. 128 Height Bins: Block Type 1
(See Table 4a, also)

RECORD CHARACTER		CONTENT OF EACH RECORD
1	4 LSB	Record Type (08H; 09H if first record of ionogram)
2	8 bits	Length of preface area including the 3 initial characters (3CH: 3 + 57)
3		Spare (always zero)
4-60	4 LSB	57 4-bit preface characters
61-3990	8 bits	15 blocks of data (256 ranges/block)
3991*		End of information on record (0EH)
3992-4096		Not used

Table 2b. 256 Height Bins: Block Type 2
(See Table 4b, also)

*Or after the last block of data if the ionogram ends before block 30 (128 height bins) or before block 15 (256 height bins).

Table 2. Record Organization of Recorded MMM'ed Ionograms

PREFACE CHARACTER	SYMBOL	FUNCTION
Date and Time		
1 - 2	Y - YY	Year
3 - 5	D = DDD	Day
6 - 7	H = HH	Hour
8 - 9	M = MM	Minute
10 - 11	S = SS	Second
General Control Parameters		
12	S	Program Set
13	P	Program Type
14 - 19	J	Journal (internal controls)
Nominal Frequency		
20 - 25	F = FFFFFF	Frequency (100 Hz)
Output Controls		
26	P1	Tape Write Control
27	P2	Printer Control
28	P3	Maximum Method Options
29	P4	Printer Cleaning Threshold
30	P5	Printer Gain Level
31	P6	Control for Intermittent Transmissions
32	P7	Used for Drift
Frequency Choice		
33-34	S = FR	Start Frequency (MHz)
35	Q	Frequency Increment
36 -37	U = UY	End Frequency (MHz)
Test Output		
38	C	Trigger
39	A	Channel A: Digital
40	B	Channel B: D/A

Table 3a. Tape Recorded Preface

PREFACE CHARACTER	SYMBOL	FUNCTION
Station Identification		
41 - 43	V	Station No. from INCPU Personality
Operating Parameters		
44	X	Phase Code
45	L	Antenna Azimuth
46	Z	Antenna Scan
47	T	Antenna Option and Doppler Spacing
48	N	Number of Samples
49	R	Repetition Rate
50	W	Pulse Width and Code
51	K	Time Control
52	I *	Frequency Correction (from CORE)
53	G*	Gain Correction (from CORE)
54	H	Range Increments
55	E	Range Start
56	I	Frequency Search
57	G	Nominal Gain
Drift Parameters		
58 - 60	H1 = HHH	Height 1 (km)
61	G1 = G	Gain 1 (-6 dB)
62 - 65	F1 = FFFF	Frequency 1 (10 kHz)
66 - 68	H2 = HHH	Height 2
69	G2 = G	Gain 2
70 - 73	F2 = FFFF	Frequency 2
74 - 76	H3 = HHH	Height 3
77	G3 = G	Gain 3
78 - 81	F3 = FFFF	Frequency 3
82 - 84	H4 = HHH	Height 4
85	G4 = G	Gain 4
86 - 89	F4 = FFFF	Frequency 4

Table 3b. Tape Recorded Preface

each frequency, chan. # = 2 × SSSS; for range bins 129 to 256, chan. # = 2 × SSS + 1.

2.1.1 Block organization of ionogram data

The 15 or 30 blocks of ionogram data are organized as shown in Table 4. The data for each frequency are preceded by a prelude, which is detailed in Table 5. The block type is determined from the range increment parameter H: with H < 8, there are 128 range bins (block type 1); with H ≥ 8, 256 range bins (block type 2).

Block type 1 uses up to 4080 of the 4096 bytes: 60 + (134 × 30); i.e. 60 preface + ([6 prelude + 128 data] × 30 frequencies). Character 4081 or the character following the last block of data is the END character (0EH). The bit structure of each byte of data is AAAASSSS: a 4-bit AMPLITUDE encoded into the 4 MSB, with a 4-bit STATUS (actually, the channel number from which the amplitude was selected) encoded into the 4 LSB. The status is obtained from the channel number, using Table 6.

Block type 2 uses up to 3990 of the 4096 bytes: 60 + (262 × 15); i.e. 60 preface + ([6 prelude + 256 data] × 15 frequencies). Character 3991 or the character following the last block of data is the END character. The bit structure of each byte is AAAAASSS: a 5-bit amplitude encoded into the 5 MSB, and a 3-bit STATUS in the 3 LSB. SSS, which is actually the 3 MSB of the channel number, must be converted back to a 4-bit channel number before being used to determine the status from Table 6: for the first 128 range bins of each frequency, chan. # = 2 × SSS; for range bins 129 to 256, chan. # = 2 × SSS + 1.

BLOCK	CHARACTER	CONTENT (1 FREQ/BLOCK)	PRELUDE ORGANIZATION: see Table 5
1	61-66	Prelude	BIT STRUCTURE (DATA): AMPL (4 MSB) + STATUS (4 LSB)*
	67-194	128 Data	
2	195-200	Prelude	RANGES/FREQUENCY: 128 (H < 8)**
	201-328	128 Data	
• • •	• • •	• • •	GROUP SIZE: 134 (6 + 128) bytes
30	3947-3952	Prelude	MAXIMUM GROUPS/BLOCK: 30
	3953-4080	128 Data	
	4081	0EH End of information on record	
	4082-4096	Not Used	

Table 4a. Block Type 1

BLOCK	CHARACTER	CONTENT (1 FREQ/BLOCK)	PRELUDE ORGANIZATION: see Table 5
1	61-66	Prelude	BIT STRUCTURE (DATA): AMPL (5 MSB) + STATUS (3 LSB)*
	67-322	256 Data	
2	323-328	Prelude	RANGES/FREQUENCY: 256 (H ≥ 8)**
	329-584	256 Data	
• • •	• • •	• • •	GROUP SIZE: 262 (6 + 256) bytes
30	3729-3734	Prelude	MAXIMUM GROUPS/BLOCK: 15
	3735-3990	256 Data	
	3991	0EH End of information on record	
	3992-4096	Not Used	

Table 4b. Block Type 2

*Actually channel number: the 4-bit channel no. (see text about converting the 3-bit channel no. to 4 bits) must be converted to status using Table A-6.

**H = Range Increment Parameter

Table 4. Group Organization of Recorded MMM'ed Ionograms (Tape Write Control P1 = 1)

CHARACTER		CONTENTS OF PRELUDE
1		Block type (1, 2, . . .)*
2	4 MSB 4 MSB	10 MHz BCD digit 1 MHZ BCD digit
3	4 MSB 4 MSB	100 kHz BCD digit 10 kHz BCD digit
4	4 MSB 4 MSB	Frequency search parameter "I" Gain parameter "G"
5	4 MSB 4 MSB	10s of seconds BCD digit Units of seconds BCD digit
6		Most probable amplitude for this frequency (0 - 31 range)

*Only block types 1 and 2 are presently implemented.

Table 5. Prelude Organization

# OF DOPPLERS	2		4		8		16
# OF HEIGHTS*	128	256	128	256	128	256	128
ANTENNA OPTION (T)	3, 7,11,15	2, 6,10,14	2, 6,10,14	1, 5,9,13	1, 5,9,13	0,4,8,12	0,4,8,12
CHANNEL	STATUS		STATUS		STATUS		STATUS
0	8		8		8		8
1	9		9		9		9
2	10		10		10		10
3	11		11		11		11
4	12		12		12		13
5	13		13		13		13
6	14		14		14		14
7	15		15		15		15
8	0		4		6		7
9	1		5		7		6
10	2		6		4		5
11	3		7		5		5
12	4		0		2		3
13	5		1		3		2
14	6		2		0		1
15	7		3		1		0

*H < 8: 128 heights; H ≥ 8: 256 heights

Table 6. Status Number as Function of Dopplers, Heights, Antenna Option and Channel Number

2.2 Dump of Raw Ionogram Data (Record Types 0CH and 0DH)

Each record of type 0CH contains the amplitudes and phases of all 16 channels of data (16 × [128 amplitudes + 128 phases]; see Table 7a) outputted from CORE for one ionogram sounding frequency. Each record of type 0DH contains the amplitudes only of all channels of data for two sounding frequencies (16 × 128 amplitudes + 16 × 128 amplitudes; Table 7b). All amplitudes and all phases are 8-bit binary numbers; however, as explained below, the lowest bit(s) of some amplitudes are undefined because they have been replaced by preface information.

For both dump types, the preface area consists of a 4-bit record type and 57 4-bit preface characters. These 58 characters are encoded serially into the lowest bit of each of the first 232 (4 × 58) amplitude characters of each record, as illustrated in Table 8. (Note that in the 0CH dump, the first 232 amplitudes are in two groups separated by a group of 128 phases; i.e. in record characters 1 to 128 and 257 to 360 -- Table 7a; in the 0DH dump, the first 232 amplitudes are in record characters 1 to 232 -- Table 7b). The lowest-order bit of each of amplitudes 1 to 4 is replaced by one of the 4 bits of the record type, with the LSB of the record type encoded into amplitude 1; similarly, each preface character is encoded into a group of four amplitude characters, with the LSB of the preface character encoded into the first amplitude of the group. In addition, the record type without being serialized is encoded into the 4 LSB of the first character of each record, with both the serial and parallel representations of the record type sharing the same LSB.

The meaning of each preface character is given in Tables 3a and 3b; see also the last paragraph in Section 2.1. The Drift parameters (preface characters 58 - 89) are only defined in the 0AH record types.

RECORD CHARACTER	CHANNEL	CONTENTS: AMPLITUDE / PHASE	CONTENTS: PREFACE (Table A-8)
1		A1 4 MSB	Block Type (parallel)
2 - 4	1	A2-A4 7 MSB	Block Type (serial)
5 - 128		A5-A128 7 MSB	Preface 1-31
129-256		ø1-ø128 8-bit	
257-360		A1-A104 7 MSB	Preface 32-57
361-384	2	A105-A128 8-bit	
385-512		ø1-ø128 8-bit	
• • •	• • •	• • •	
3841-3968	16	A1-A128 8-bit	
3969-4096		ø1-ø128 8-bit	

Table 7a. Record Type 0CH: Amplitudes and Phases
(1 Frequency/Record)

RECORD CHARACTER	FREQ	CHAN	CONTENTS: AMPLITUDE	CONTENTS: PREFACE (Table A-8)
1			A1 4 MSB	Block Type (parallel)
2 - 4		1	A2-A4 7 MSB	Block Type (serial)
5 - 128			A5-A128 7 MSB	Preface 1-31
129-232	1	2	A1-A104 7 MSB	Preface 32-57
233-256			A105-A128 8-bit	
• • •		• • •	• • •	
1921-2048		16	A1-A128 8-bit	
2049-2176		1	A1-A128 7 MSB	
2177-2280		2	A1-A104 7 MSB	
2281-2304	2		A105-A128 8-bit	
• • •		• • •	• • •	
3969-4096		16	A1-A128 8-bit	

Table 7b. Record Type 0DH: Amplitudes Only
(2 Frequencies/Record)

Table 7. Dump of Raw Data: Record Organization

	CHANNEL 1									CHANNEL 2						
	1	2	3	4	5	6	7	8	• • •	101	102	103	104	105	• •	
MSB AMPLITUDE	A_1^7	A_2^7	A_3^7	A_4^7	A_5^7	A_6^7	A_7^7	A_8^7		A_{101}^7	A_{102}^7	A_{103}^7	A_{104}^7	A_{105}^7	A_{106}^7 •	MSB AMPLITUDE
	A_1^6	A_2^6											A_{104}^6	A_{105}^6		
	A_1^5	A_2^5	•	•	•	•	•	•	• • •	•	•	•	A_{104}^5	A_{105}^5	• •	
	A_1^4	A_2^4	•	•	•	•	•	•		•	•	•	A_{104}^4	A_{105}^4	• •	
MSB RECORD TYPE	T^3	A_2^3	•	•	•	•	•	•		•	•	•	A_{104}^3	A_{105}^3	• •	
	T^2	A_2^2											A_{104}^2	A_{105}^2		
	T^1	A_2^1	A_3^1	A_4^1	A_5^1	A_6^1	A_7^1	A_8^1		A_{101}^1	A_{102}^1	A_{103}^1	A_{104}^1	A_{105}^1		
LSB	T^0	T^1	T^2	T^3	P_1^0	P_1^1	P_1^2	P_1^3	• • •	P_{57}^0	P_{57}^1	P_{57}^2	P_{57}^3	A_{105}^0	A_{106}^0 •	LSB
	LSB RECORD TYPE MSB				LSB PREFACE 1 MSB				• • •	LSB PREFACE 57 MSB						

See Table 7 for the record characters which contain amplitudes.

Table 8. Dump of Raw Data (Record Types 0CH and 0DH): Encoding of Record Type and Preface Into 232 Amplitude Characters