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A QUALITY CONTROL PACKAGE FOR THE DIGISONDE DRIFT ANALYSIS (DDA)

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13. ABSTRACT *(Maximum 200 words)*

This report discusses the implementation of a quality control system for the Digisonde Drift Analysis. The quality checking of the integrity of the drift data being recorded is available for the online (ODDA) as well as the post processing (DDA) packages. This system indicates the performance of the Digisondes in the field by interrogating the drift measurements made. Loss of receiver performance, phase data, and received signal is quickly identified by the quality control system. This system allows the operator to identify problems in the field within an hour of occuring. While for post processing of data, the package indicates how well the Digisonde system was performing even in those rare cases of data collected over a few years where logs of station maintenance no longer exist.

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1. OBJECTIVES

The purpose of the quality control package for DDA and ODDA was to assess the performance of the Digisonde 256 system and communicate any errors detected to the operator. The quality control system should address the following points.

(1) The package should contain a system/program update to inform the operator of its current status.

(2) Indicate the type of data being gathered for future processing at a glance.

(3) Test or monitor the hardware, with special emphasis on the testing of the antenna amplitude and phase characteristics.

(4) For the onsite system (ODDA), any errors detected should be communicated back to the remote terminal, and/or flags should be set with the data gathered to identify these data as good or bad. This mode has yet to be satisfactorily implemented, and will not be discussed in this report.

DDA contains two graphics windows. These windows contain:

Window 1 = ODDA QUALITY CONTROL
Window 3 = DRIFT VELOCITIES

DDA and ODDA display results in two text windows for the onsite systems and for any computers unable to support the VGA graphics options. These windows display the quality control and drift velocities in ASCII format to screen. In the following sections, the graphical and text displays will be described in detail.

2. DDA QUALITY CONTROL GRAPHICS

An example of the DDA quality control graphics screen is displayed in Figure 1. The display consists of two main sections, the Antenna status and the System status.

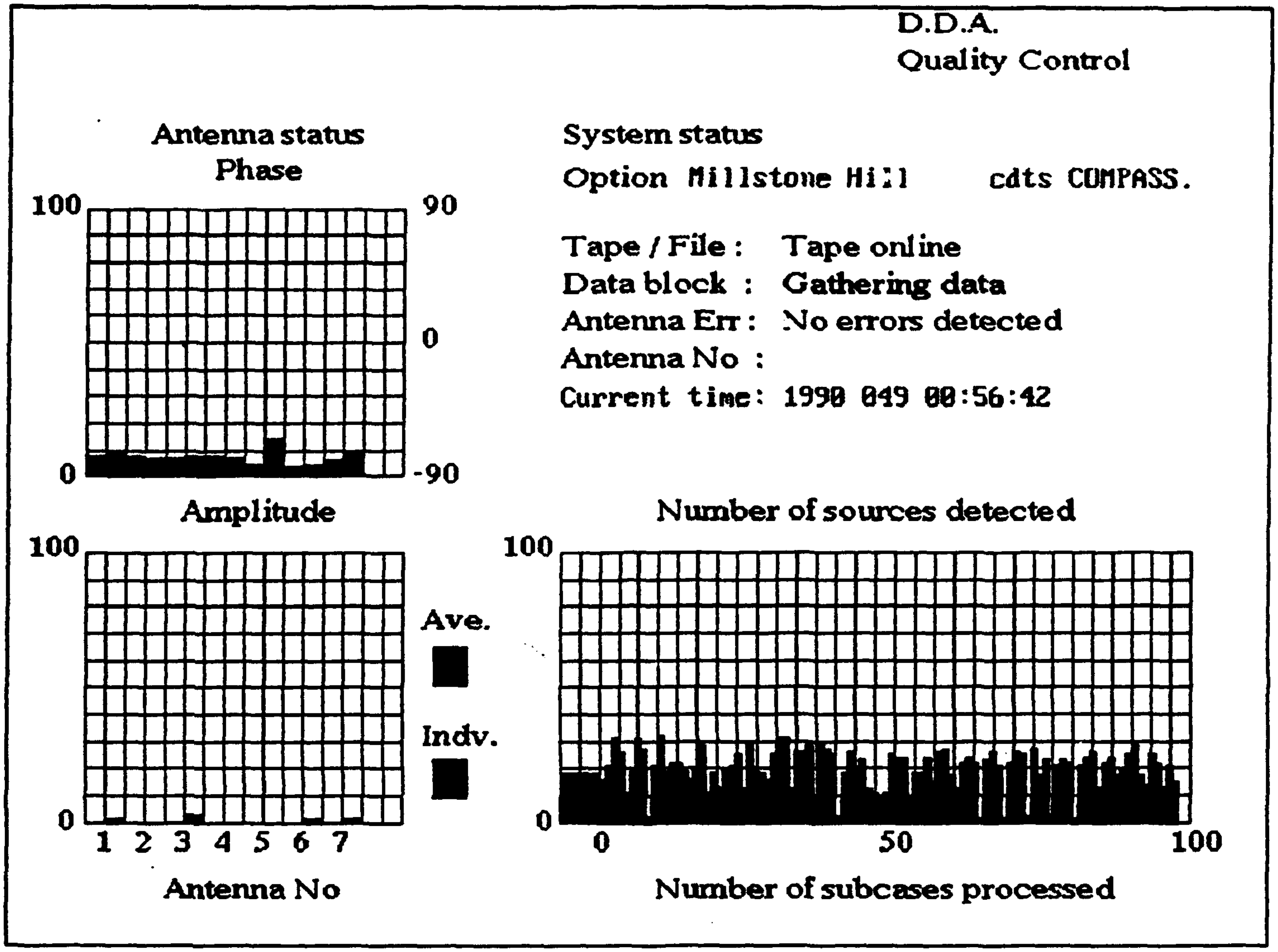


Figure 1. Digisonde Drift Analysis (DDA) Graphics Screen

2.1 System Status

The system status is further divided into a graph and text messages. The graph indicates the total number of sources detected for each subcase (i.e. all spectra in one frequency range bin). The red blocks labeled as INDV on the screen, indicate the total number of sources for each subcase. Up to 100 height spectra are displayed at any one time. After 100 subcases have been processed the overall number of sources are averaged with the previous 100 subcase average and this is then displayed by the green block preceding the first subcase, and listed as AVE on the screen. Hence, the AVE block is an accumulative average of the number of sources detected and gives an indication of the characteristics of previous measurements.

The time for the current drift data block being processed is given above this graph. This is useful when processing data from tape or disk.

Immediately under system status, the OPTION line is displayed. All optional messages tell the operator what DDA is doing, or what is to be done in case an error is detected. Below OPTION are the main system update messages. The state of DDA's program and/or if any errors are detected in the system are updated in these lines.

2.2 Antenna Status

The two graphs below the antenna status, display the performance test for each receiver antenna, cable and antenna switch combination. These separate tests can be done to verify if the antenna system is working well. The first graph labeled phase may display the "phase failure rates" or the "phase error" on each antenna. The test displayed in this graph depends on the setting of option *074 in the ODDAMENU.ONL file.

for *074 option = 1	the phase failure rates are displayed
for *074 option >1	the phase error on each antenna are displayed

The phase failure rates calibrated by the 0 to 100% scale on the left hand side of this graph test for randomness in the phase. Each time the phase characteristics of an antenna do not meet certain criteria a failure is detected and recorded for that record group and displayed by a red histogram (INDV marker). If an antenna fails consistently over 60 groups, then the red bar would be at 60 on the scale. After 100 groups the INDV values are averaged with the previous 100 group average for a cumulative average value AVE which is given by the green histograms for each antenna.

Ideally, the phase AVE failure rates (or % failure counts) of all antennas should be consistently the same. Any substantial deviation of failure rate from antenna to antenna may indicate a problem. The % failure counts should never exceed 20% if there is no problem with the system. Similarly the second graph, labeled Amplitude, also shows the INDV and AVE failure rates for each antenna but the amplitudes are tested in this case. In the second graph, the eighth column is also used and is a measure of the independence of noise and the amplitudes of the spectrum. Ideally the failure rates in amplitude should always be low, preferably below or around 10%, but definitely never greater than 20%.

Displaying the phase error on each antenna by setting option 074 > 1 in the menu file, the results are defined by the scale on the right hand side of phase graph, centered on 0. The phase error test attempts to estimate the amount of phase error consistently observed on each antenna. If the system is working well, all AVE (green histograms) for active antennas should be at 0 degrees. If the AVE histogram is smaller than the 0 degree level, this indicates a negative phase error on the antenna, while larger green bars above 0 specifies positive phase errors. This test works best for the 7 antenna system rather than the 4 antenna system.

<u>Hidden:</u> A Quality Control file is generated every time DDA or ODDA updates the AVE statistics, so that on start up DDA or ODDA can recall the current state of the system. The file is named:

QUCNTRL.DAT

When beginning a completely new drift data set, it would be advisable to delete this file and begin the statistics from the start.

3. DETERMINATION OF % FAILURE COUNTS

3.1 Amplitude Testing

The amplitude statistical routines perform two tests. First, a test of independence between the noise and maximum amplitude distribution is carried out, then the maximum amplitudes of each antenna are tested. The Most Probable Amplitude (MPA) and the maximum amplitude (A_{max}) of each spectrum, averaged over a group of drift data, are used in these tests. The Most Probable Amplitude (MPA) and A_{max} are averaged over a drift data group and their mean and standard deviation are obtained.

A drift data group is chosen in the ODDAMENU.ONL file at option *042. The value entered specifies a time interval in minutes for the gathering of drift data before the statistical testing is done. For example, dialing in a 5 would force DDA or ODDA to carry out a statistical quality control test after collecting N amount of subcases contained within a 5 minute period.

3.1.1 Independence Test

In the amplitude graph, the last two columns (not labeled) are active and display the failure rate for an independence test performed between the noise and signal distributions. Consider the problem of testing whether a signal amplitude can be considered as being related to the noise level of the spectrum. Hence, we would like to test the hypothesis that:

$$\begin{aligned} H_0&: \quad \mu_1 = \mu_2 \\ H_1&: \quad \mu_1 \neq \mu_2 \end{aligned} \tag{1}$$

where

μ_1 = Mean MPA averaged over a group of subcase and four antennas.

σ_1 = Standard deviation of MPA averaged over a group of height spectrum and four antennas.

μ_2 = Mean maximum amplitude, A_{max}, averaged over a group of subcase and four antennas.

σ_2 = Standard deviation of the maximum amplitude averaged over four subcases and four antennas.

We make the assumption that the sampling distribution of MPA and A_{max} are approximately normally distributed with mean μ_1, μ_2 and standard deviations σ_1, σ_2, respectively.

Statistically the mean of the signal (i.e. maximum amplitude of the spectrum) distribution can approach the mean of the MPA and still be considered a separate distribution as long as μ_2 does not belong to the distribution of μ_1, i.e. μ_2 cannot be less than or equal to the $Z_{\alpha/2}$ confidence level of μ_1, in such a case μ_1 and μ_2 are said to be independent. The critical region for each distribution may be given as

$$Z_{\alpha/2} = \frac{\bar{x}-\mu_0}{\sigma/\sqrt{n}} \tag{2}$$

where

α	=	Level of significance
n	=	No. of samples
$\bar{x}$	=	Testing mean = μ_2
μ_0	=	Mean of test distribution
σ	=	Standard deviation of test distribution

Since the amplitudes of sources must always be greater than the noise then the only criterion which needs to be satisfied is that

$$\mu_2 > \mu_1 + Z_{\alpha/2}\frac{\sigma}{\sqrt{n}} \tag{3}$$

As long as this criterion is satisfied the two distributions may be considered to be independent. If this condition is not met a failure count is recorded. Since the overall distribution for MPA, considered here as the noise level, and the maximum amplitude are being compared, this test allows us to determine how close the source signals are to the noise. As such, the test for independence can be used as a data quality check. The method here is only used for amplitude maximum comparisons, in effect this analysis could be done on each spectral line as an indication if source signal exists above the noise level. Currently a fixed noise level is defined and any source signal below this value would be ignored. This new method allows this threshold to be lowered (or raised) statistically and still maintain a high level of data integrity. It is not incorporated into the onsite ODDA quality control since testing every spectral line would take time, but as for playback analysis from tape (i.e. using DDA), such a system could prove beneficial in detecting "weaker" signals.

Currently, the independence test is only displayed and recorded as an indicator of data integrity. DDA or ODDA will not use this result to automatically delete data sets. The operator must decide on the value of this failure rate, whether to keep or discard data. If the independence test failure is greater than 50% in AVE, then even if a large number of sources are detected, this data set would be considered to be bad and not much confidence can be placed on the resulting skymap and velocities.

The second test performed is similarly a two-sided test, only this time the maximum amplitudes of each antenna are tested. The antenna with the highest averaged A_{max} is used as a reference antenna to test all other antennas. However, the averaged mean standard deviation σ_2 is used rather than the standard deviation calculated for the reference antenna. The test distribution then constructed should allow all the amplitudes to fall within this region. Any μ_j which does not fall within the accepted region

$$\mu_{ref} - Z_{\alpha/2}\frac{\sigma_2}{\sqrt{n}} < \mu_j < \mu_{ref} + Z_{\alpha/2}\frac{\sigma_2}{\sqrt{n}} \tag{4}$$

is regarded as a failure.

Actually, since μ_{ref} is the mean maximum amplitude possible for all antennas then only the lower part of this distribution need be tested. Hence, the only criterion that need be satisfied is:

$$\mu_j > \mu_{ref} - Z_{\alpha/2}\frac{\sigma_2}{\sqrt{n}} \ . \tag{5}$$

If satisfied μ_j belongs to the distribution and is consistently between

$$\mu_{ref} - 3\sigma < \mu_j < \mu_{ref} + 3\sigma \ . \tag{6}$$

3.2 Phase Testing

Four methods were devised to determine if phase errors exist in each antenna. The first method used the phase differences between antennas to determine the integrity of the phase measurement. Considering the geometry of the receiving antenna array, if ϕ_i is the phase recorded for a spectral line for antenna i then the equations that need to be satisfied may be written down as:

$$\begin{array}{lclr} \phi_2 + \phi_3 + \phi_4 - 3\phi_1 & = & 0 & 1 \\ \phi_5 + \phi_6 + \phi_7 - 3\phi_1 & = & 0 & 2 \\ 2\phi_5 + \phi_6 - 3\phi_2 & = & 0 & 3 \\ 2\phi_6 + \phi_7 - 3\phi_3 & = & 0 & 4 \\ 2\phi_7 + \phi_5 - 3\phi_4 & = & 0 & 5 \end{array} \tag{7}$$

Since we have seven unknowns and only five equations, we cannot solve for the individual ϕ's. But we can test the distribution for each equation from data gathered and by recording what combination of equations fail we may determine what possible combination of antennas may not be functioning. Table 1 shows the equation failure combination and which antenna combination can cause these equations to fail. A failure is recorded as 1, if on the other hand the equation satisfies the criteria then 0 is displayed, e.g. if equation 1 and equation 2 do not fall within the distribution required, but all other equations are satisfied, then Antenna 1 is in error, etc. Initially Phases are compared only for -3 to 3 Doppler lines.

Identifying the binary code for the testing of phases from antennas would then give an indication as to which antenna or antenna combination may be giving a problem. The method does have its drawbacks. These are:

1. Seven antennas would need to be sampled on a regular basis in order for this method to work for a quality control check, which should be done every time a measurement is taken.

2. If only one antenna fails then identification can be made. But for certain combinations of two or more antennas failing a large number of possible combinations exist.

3. As shown by large scale statistics produced by C. Dozois, the distributions of the equations are not centered on 0 and also tend to shift in time.

Table 1. Statistical Binary Error Code and Associated Bad Antenna(s).

Bad Antennas	Bad Equations 1--2--3--4--5	Binary Code
Antenna - 1	1--1--0--0--0	3
" - 2	1--0--1--0--0	5
" - 3	1--0--0--1--0	9
" - 4	1--0--0--0--1	17
" - 5	0--1--1--0--1	22
" - 6	0--1--1--1--0	14
" - 7	0--1--0--1--1	26
" - 1&2	1--1--1--0--0	7
" - 1&3	1--1--0--1--0	11
" - 1&4	1--1--0--0--1	19
" - 2&3	1--0--1--1--0	13
" - 2&4	1--0--1--0--1	21
" - 3&4	1--0--0--1--1	25
" - 2&3&4	1--0--1--1--1	29
" - 1&6,3&6, 2&6,2&3&6,1&2&3, 1&2&6,1&2&3&6	1--1--1--1--0	15
" - 1&5,2&5, 4&5,1&2&4,1&2&5	1--1--1--0--1	23
" - 6&7,5&7, 5&6,1&2&7,5&6&7	0--1--1--1--1	30
" - 3&7,1&7, 3&4&7,2&3&4&5	1--1--0--1--1	27
All other. combinations	1--1--1--1--1	31

It soon became apparent that testing of antennas for a quality control method required:

(a) Testing be continuous; for each measurement antennas should be tested.

(b) Antennas should be tested separately and not depend on an antenna combination outcome.

Again referring to previous statistical data, it became apparent that the phase on each antenna should be distributed randomly over a large number of samples. Similarly producing μ and σ parameters for the phases of all antennas for a number of cases, it was considered reasonable that the distribution of these phases are random, since they tend to produce a boxcar spectrum. Hence, the ability to test for randomness in the phase data may be a good test for the quality of phase data being observed. Thus, a test for randomness was introduced into the program.

Two tests for randomness are currently used. Both methods may be found in K.V. Bory (1975)[1].

3.2.1 Run Test

One of the simplest methods used to test the randomness of a set of data is to note the signs of differences in the magnitudes of consecutive measurements. As an example given a data series represented by ϕi for phase then:

$$\begin{aligned} &\text{sign} \quad (\phi_{i+1} - \phi_i) = +1 \qquad && \text{if } \phi_{i+1} > \phi_i \\ &\text{sign} \quad (\phi_{i+1} - \phi_i) = -1 \qquad && \text{if } \phi_{i+1} < \phi_i \end{aligned} \tag{8}$$

if $\phi_{i+1} = \phi_i$ the zero cases are ignored.

Then by observing the sequence of consecutive plus signs and minus signs (which is termed a run), it is possible to use this number as a test statistic, e.g. of a set of runs.

ϕ	90	162	308	308	102	110	125	205	200	10	60	15	5	100	200	30
sign	-1	-1	0	+1	-1	-1	-1	+1	+1	+1	-1	+1	+1	-1	-1	-1
		$N2_1$		$N1_1$		$N2_2$			$N1_2$		$N2_3$	$N1_3$			$N2_4$	

---

1 Karl V. Bory, Statistical Models in Applied Science, John Wiley and Sons, New York, New York, et. pp. 225-238, 1975

The row above has seven runs.

Let

N1 = the total number of plus signs = 3
N2 = the total number of minus signs = 4
U = the total number of runs = 7

then the expected value and variance of U can be given as:

$$E(U) = 1 + \frac{2N1N2}{N1+N2} \tag{9}$$

$$Var(U) = \frac{2N1N2(2N1N2-N1-N2)}{(N1+N2)^2(N1+N2-1)} \tag{10}$$

This test can be conducted to determine a value U such that

$$Pr(U \leq u) \geq 0.997.$$

If this condition is satisfied then data is random otherwise something is wrong with the phase of the antenna.

The second method to test for randomness is termed the Label Test.

3.2.2 Label Test

Consider now that the observations X_i are given labels Y = i. Clearly if the sequence of observations on X constitutes a random sample, then the measured variable X and label variable Y are statistically independent. For example, consider the data

Number of	X	100	90	35	62	73	88	102	306	250
Orders	Y	1	2	3	4	5	6	7	8	9

Now since X and Y appear in pairs the test for independence by use of the sample correlation coefficient can be applied to X and Y to check the randomness of the observations on X.

The sample correlation coefficient may be written as

$$r = \sum_{i=1}^{n} \frac{X_i Y_i - \bar{X}\bar{Y}}{n S_x S_y} \qquad (11)$$

where

S_x = variance of x

S_y = variance of y

$\bar{Y}$ = mean of Y

$\bar{X}$ = mean of X

The correlation coefficient may be tested using the t variable as

$$t = r\left[(n-2)/(1-r^2)\right]^{1/2} \qquad (12)$$

Since over four subcases n = degrees of freedom
= n - 2 = 256 - 2 = 254 > 29

then it is possible to use the infinity option of the t-distribution. Hence, at 1% critical t value $t_{1/2}$ = 2.576 for infinity. Then the calculated t value obtained from equation (1) must fall within the region

$$-2.576 < t < 2.576 \qquad (13)$$

for the test to be accepted and data to be random. DDA and ODDA quality control actually tests $|t| < 2.576$. Since the observations are compared to a monitonically increasing variable Y, the Label test is sensitive to consistent changes in the phase. Consider the case of a system adding $\Delta\phi$ to each phase measurement, the total phase recorded would be = $\phi + \Delta\phi$. If ϕ is random the run test may not detect this. The Label test, however, would observe the characteristics of $\Delta\phi$ component since the correlation between variables X and Y would increase.

3.2.3 Phase Error and Correction

The fourth method to analyze the integrity of the phase being recorded attempts to quantitatively determine the phase error consistently observed on each antenna/cable/switch system. The method uses the azimuth and zenith values calculated for each reflection source point to determine the phases on each antenna. These calculated phases are compared to the phases used in the least squares fit and the differences $\Delta\phi_i$ are recorded. After 100 sources are processed in this way, the phase differences are averaged and the averaged phase difference $\Delta\phi_{avei}$ is introduced back into the next set of phases obtained from the drift data.

This method has 3 operational modes that may be selected using option 074 in ODDAMENU.ONL.

Mode 1: Phase correction on, but do not compensate for errors.

This mode is set active by selecting 4 or 5 in option 074. Without compensating for phase differences observed this mode is useful in collecting statistics of phase errors observed in each antenna/cable/switch system. The average phase differences collected over 100 sources are averaged with the previous value. The statistic is therefore accumulative and can be represented as:

$$\Phi_{Ei} = (\phi_{Ei} + \Delta\phi_{avei})/2 \tag{14}$$

where

ϕ_{Ei} = phase error in antenna/cable/switch system i
$\Delta\phi_{avei}$ = phase differences in antenna/cable/switch system i, averaged over 100 sources

Processing drift data with this mode set active will produce a table with phase errors for each antenna/cable/switch system given as a function of frequency. The table is housed in the QUCNTRL.DAT file.

The phase error displayed in the quality control represents the accumulative error. In this way, the operator may quickly identify if the phase errors are acceptable for the drift calculation. If errors of 20° or more are observed consistently in the data set, phase correction with error compensation may be needed (i.e. use modes 2 or 3).

Mode 2: Phase correction on, compensate for errors.

This mode is set active by selecting 2 or 3 in option 074. Unlike mode 1, this option will not give a true representation of the phase errors on each antenna/cable/switch system since the original drift phases are continuously being updated. The method tries to minimize the error recorded in ϕ_{avei} by adjusting the original phases used in the least squares fit. The adjusting or correcting phase offset is given as ϕ_{Ci} and is calculated for certain criteria. The criteria are:

for

$$|\phi_{avei}| > |(\phi_{Ci})/2| \tag{15}$$

and

$$|\phi_{avei}| > 0.04 \text{ radians} \tag{16}$$

then the calculation of Φ_{Ci} is stated as:

$$\Phi_{Ci} = \phi_{Ci} + (\phi_{avei})/2 \tag{17}$$

Criterion of equation 15 sets up an error limit for the 100 source average, otherwise ϕ_{Ci} could increase to values that overestimate the actual error on the system i.

Criterion of equation 16 minimizes the error adjustment of ϕ_{Ci} for each i system. If the ϕ_{avei} value is less than approximately 5°, no update of the correcting phase offset is done.

Since the phase correction is done as data are being gathered, the first few hundred sources would not change much since the statistical data are still being collected.

In this mode the quality control display shows ϕ_{avei}. If the phase correction is working well, the value of ϕ_{avei} averaged over 100 height spectra should show small phase errors, at least less than 10°.

Mode 3: Phase correction on, calibration mode.

This mode is set active by selecting 6 in option 074. This mode is intended for use with phase errors calculated from calibration data or large scale statistics using mode 1. The phase errors on each i system as a function of frequencies are supplied in the QUCNTRL.DAT file. DDA will use only these errors to adjust phases before the least squares fit is done. As in mode 2, the ϕ_{avei} are displayed to ensure that the phase errors used do minimize the phase differences calculated from the drift data.

Analysis of Phase Correction Method Using Simulated Data

To test the DDA phase correction method, drift data were simulated for known source positions and plasma velocities. An example of the simulated drift data is given in Figure 2. The drift data were calculated for the seven antenna setup at Millstone Hill, Westford, MA, with O-ray echoes recorded. The input Digisonde parameters corresponding to this configuration would be:

X	=	0	=	no phase code
L	=	B	=	8 antenna bins
Z	=	2	=	7 antenna setup and sum of antennas
N	=	5	=	64 spectral lines
R	=	2	=	100 Hz repetition frequency
W	=	5	=	132μsec pulse width

Each reflection surface was given plasma velocities of:

Vz	=	10m/s	=	vertical velocity
Vh	=	100m/s	=	horizontal velocity magnitude
Az	=	90 Deg	=	azimuthal angle of horizontal velocity

Random noise was also introduced into each spectrum to make the drift data more realistic and allow DDA to calculate a good MPA value. The position of the sources are shown in the skymap given in Figure 3. Groups of sources located at 30° increments in azimuth and at 10 and 20° in zenith are shown.

A phase error was introduced into the antenna/cable/switch system for antenna #2. The drift data generated was then analyzed with DDA. Figure 4 shows the DDA calculated phase errors plotted against the known phase error in antenna #2. Figure 4a displays the phase difference averaged over the last 100 sources, ϕ_{avei}, while Figure 4b displays the accumulated phase error statistic Φ_{Ei} calculated over $\approx$600 sources.

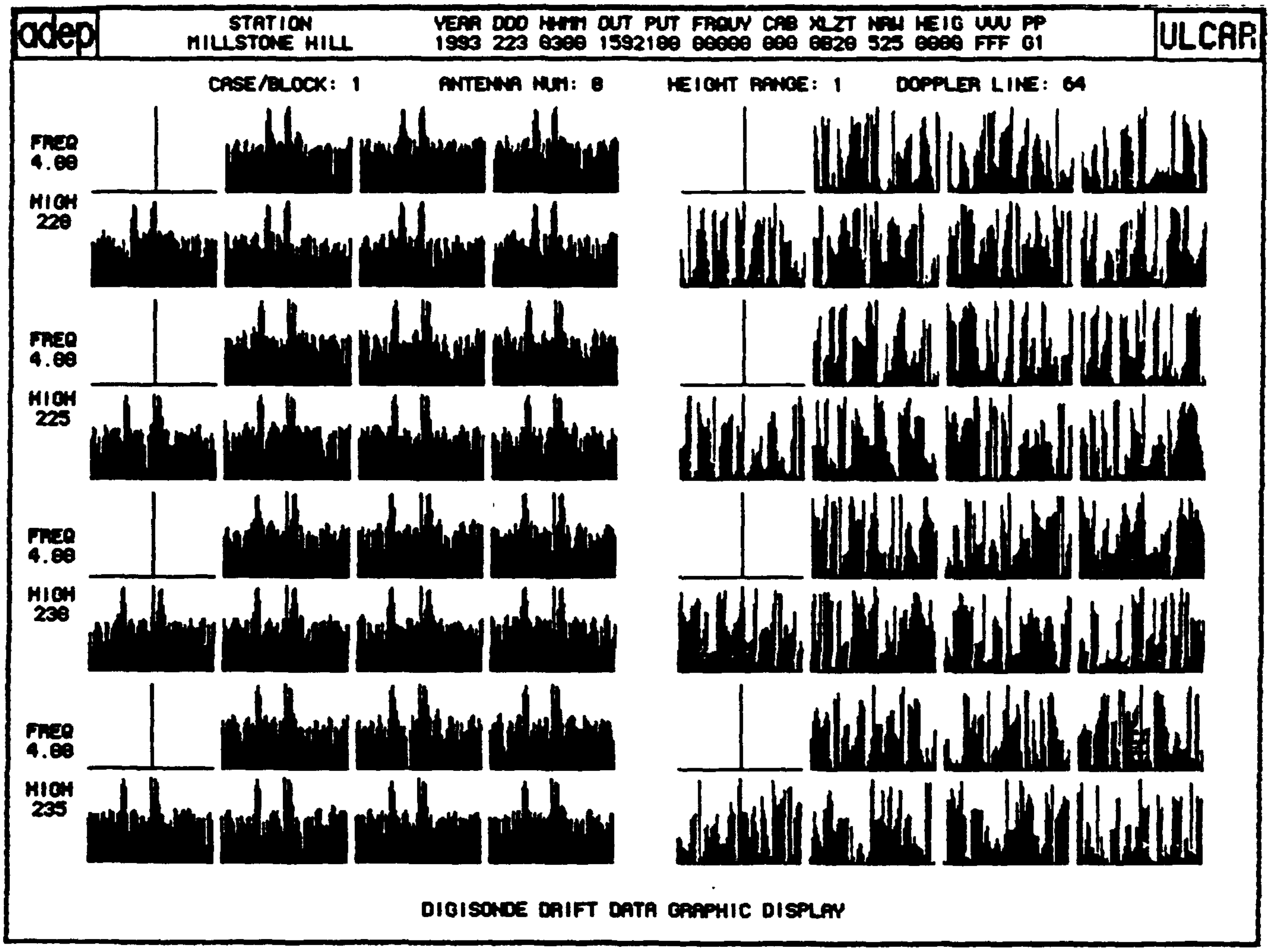


Figure 2. Simulated Drift Data, Raw Spectral Output.

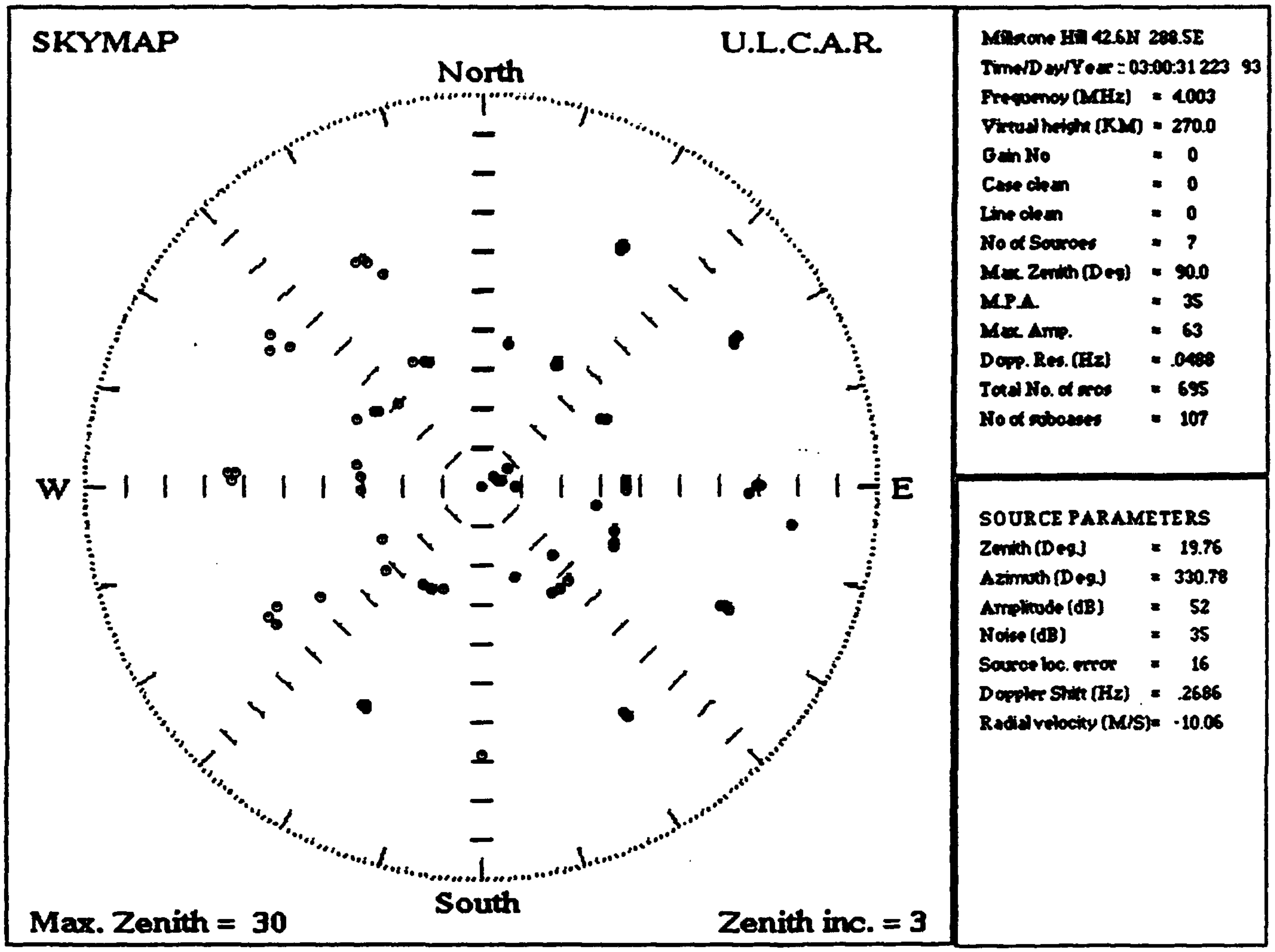


Figure 3. Skymap of Simulated Data Points.

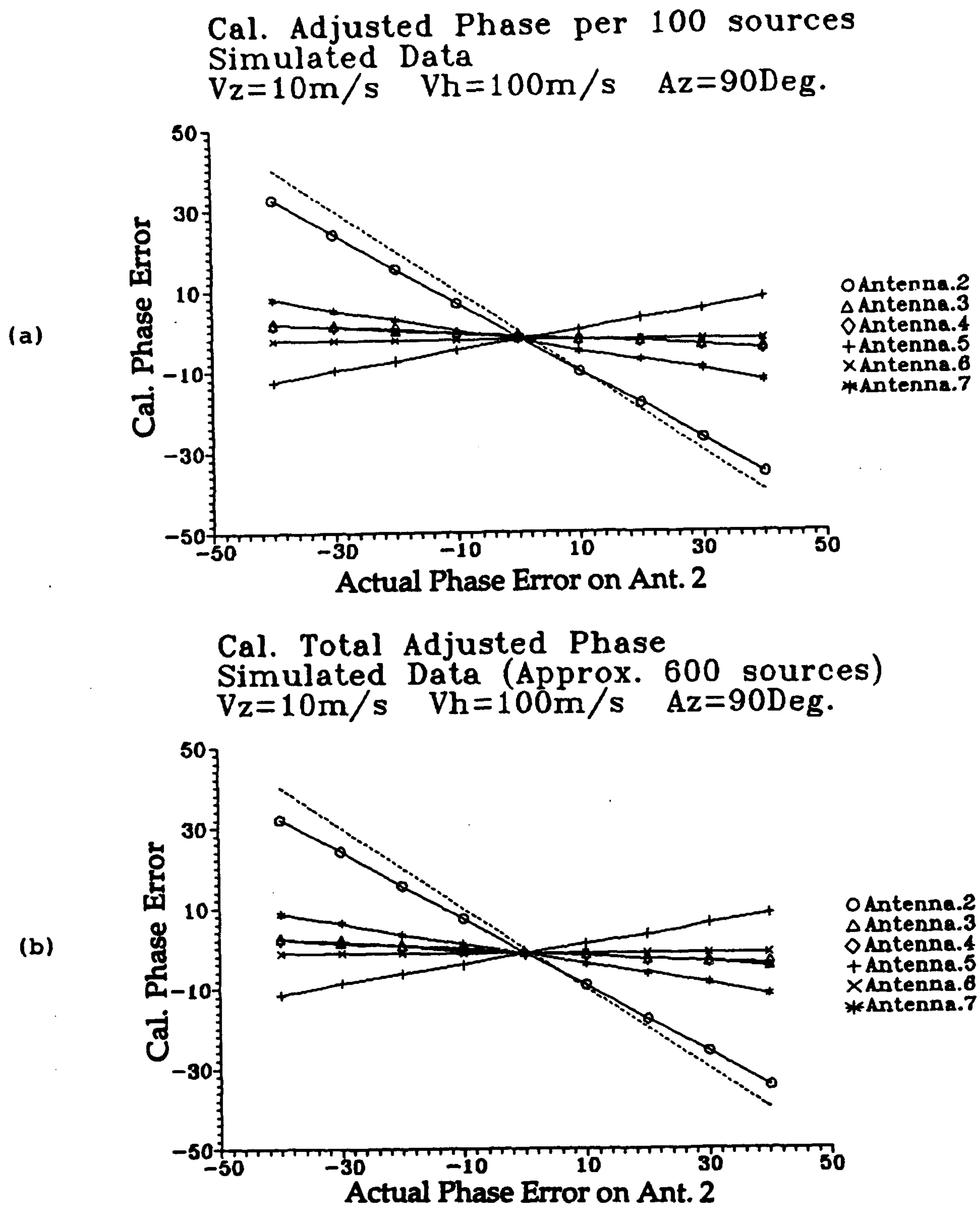


Figure 4. Calculated Phase Errors Using Mode 1.

The dashed line in both figures indicates those data points where the calculated and actual phase errors should agree. It is important to note, for example, that a known phase error of -10° DDA calculates a phase error Φ_{E1} of approximately +10°. The change in sign results since DDA calculates the compensation error to be added to the phase of antenna #2. To obtain these results, mode 1 was used so that the phases used in this least squares fit were not adjusted.

The results in Figure 4 show that the phase correction scheme is able to calculate the error on antenna #2. The corrected phase error Φ_{Ei} is underestimated for larger phase errors introduced in antenna #2. At the same time, the other antenna systems display increasing phase errors as well. The reproduction of the phase errors determined over 600 sources (Figure 4b) and those determined from only 100 sources (Figure 4a) indicates that averaging over 100 sources is a good estimate of the phase errors observed on each antenna.

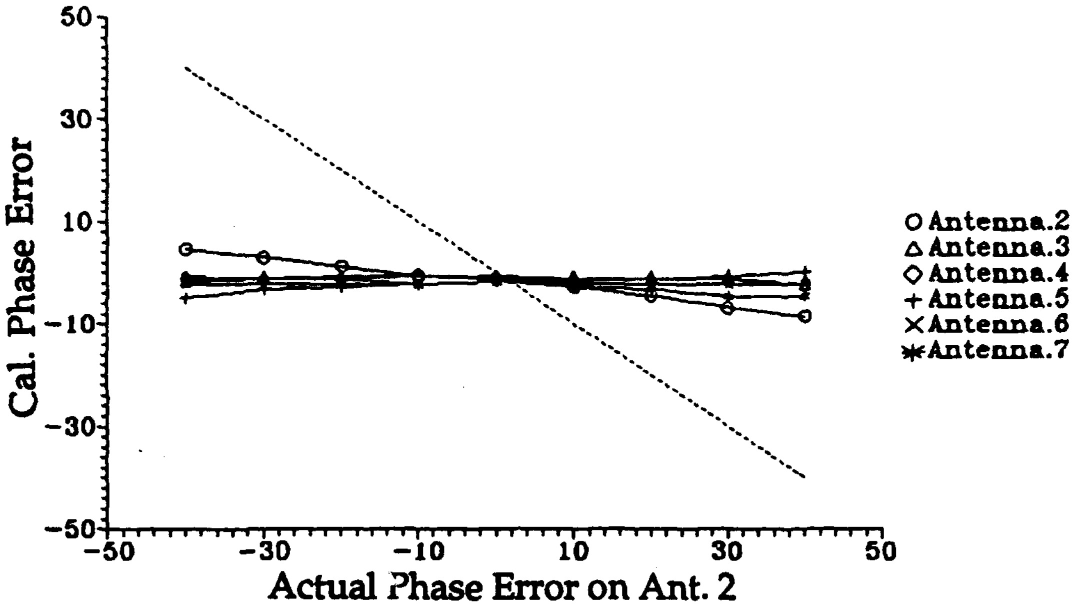
Figure 5 displays the phase correction scheme when the DDA phase correction is active and also updating the drift phases before the least squares fit. The results in this figure were obtained using Mode 2. Comparing Figure 5b and Figure 4b it is clear that the determined corrected phase errors Φ_{Ei} and Φ_{Ci} are not the same. This is to be expected since in Mode 2 the Φ_{Ci} are being used to compensate for errors in the phase before a least squares fit is done. Hence, the accumulation of statistics is affected by the updating of the input phase.

The phase difference ϕ_{avei} of the last 100 sources shown in Figure 5a displays small phase errors for each antenna system. This shows that the DDA phase correction scheme is very efficient in compensating for phase errors in antenna/cable/switch systems. The results shown here give confidence in the technique for simulated data. However, when considering using drift data collected from radio waves reflected from the ionosphere the scheme may not be able to give a true representation of phase errors on each antenna system, however, it can compensate for large phase errors and keep these errors small.

Further work in using these schemes of the quality control on real data is continuing. The results of how good the current quality control system is depends on the variety and accumulation of ionospheric data and statistics. This is an ongoing analysis effort to assess and improve the ODDA/DDA quality control package. The following section describes some preliminary experimental analysis methods.

Cal. Adjusted Phase offset per 100 sources
Simulated Data (Approx. 600 sources)
Vz=10m/s Vh=100m/s Az=90Deg.
(Phase Correction Active)

(a)



Cal. Total Adjusted Phase
Simulated Data (Approx. 600 sources)
Vz=10m/s Vh=100m/s Az=90Deg.
(Phase Correction Active)

(b)

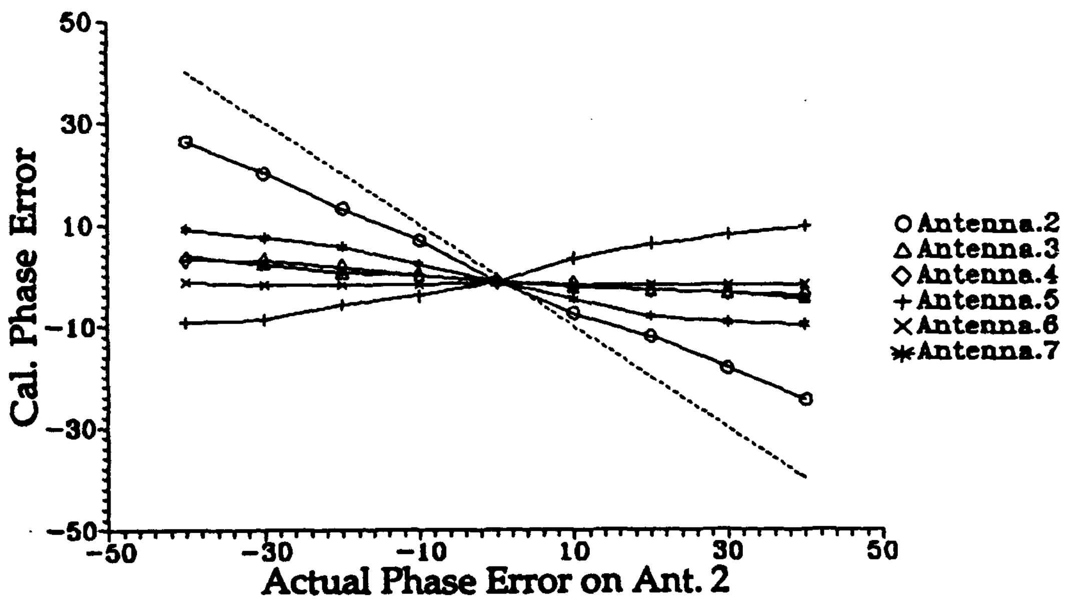


Figure 5. Calculated Phase Error Corrections Using Mode 2.

4. EXPERIMENTAL ANALYSIS

The DDA quality checking is consistently being tested when data is sampled. In most cases, data types where antennas are known to be bad are analyzed. A few examples are presented here to illustrate the effectiveness of the Quality Control System.

Figure 6 displays amplitude statistics for data collected at Qaanaaq in 1988. In this drift mode only four antennas were used. It is apparent that from day 88177 to 88180 the amplitude of antenna 6 became weak. A data sample of ≈3100 drift cases around this time was analyzed by ODDA. The amplitude and phase testing for this quality control are shown in Figure 7.

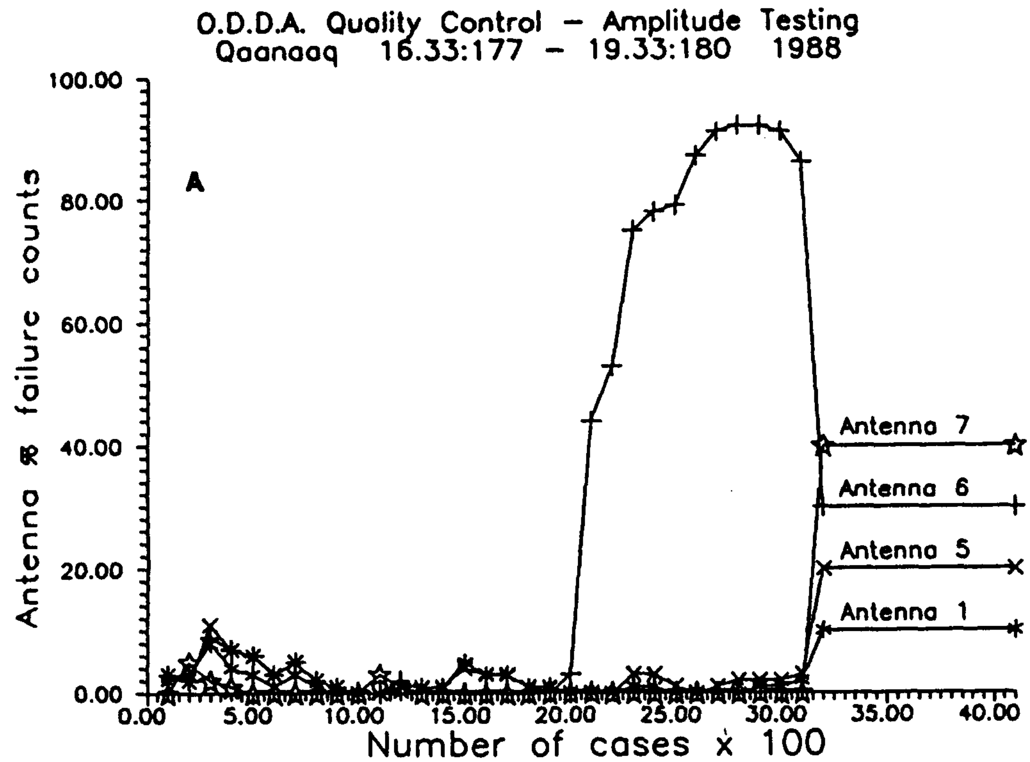
Figure 7 displays the % failure counts obtained over groups of 100 cases of drift. Recall that each time the maximum amplitude of the spectral lines averaged over four subcases, for each antenna, does not satisfy certain criteria, a failure is recorded. The number of failures recorded then constitutes a failure count. After 100 cases are sampled, this failure count is averaged with the previous 100 case average, and the result is the % failure count. For example, a large % indicates that the antenna is not functioning properly. On average all antennas should display failures for amplitude and phase of less than 20%. This figure was arrived at statistically by sampling a large data set. However, it is still recommended that a Quality Control analysis is done on the data for each station where DDA is to be installed, since this threshold of 20% could vary from station to station. During normal ionosonde operations if the % failure counts are higher than this threshold, then the antennas should be checked.

Recall that the drift mode being used for this analysis only used the four outer antennas (i.e. ANT. 1, 5, 6, 7). Figure 7a displays results of the amplitude test. It is clear that around 2000 cases antenna 6 began to fail. Within 100 cases the failure rate had increased to 40%, while the testing of the other antennas show failure counts consistently below 10%. In Figure 7b a slight increase in the failure count for the phase testing method is observed, although the failure count remains below 15%. In addition, after 2000 cases it is not surprising that antenna 6 consistently has the lowest failure rate for phase testing, since this antenna is not gathering data, then we expect more noise to be introduced in the spectra, and so the test for randomness would be more easily satisfied.

		ANTENNA #			
		1	5	6	7
88064	1347	43	43	43	43
88072	1532	42	42	42	43
88077	0107	43	43	43	43
88078	0017	43	43	43	43
88088	1617	34	34	35	34
89094	1448	35	35	35	35
88099	2317	40	40	41	40
88105	0004	42	42	42	42
88108	0017	40	40	40	40
88110	0004	22	24	24	25
88111	1504	22	24	24	24
88116	1304	40	40	40	40
88129	1804	40	40	40	40
88138	0004	27	27	27	28
88141	1704	41	41	41	43
88168	0047	24	24	24	26
88177	1404	36	35	36	38
88180	2119	35	35	*23*	38
88186	2233	41	41	*25*	43
88191	0148	39	39	*20*	42
88196	0004	28	28	*18*	30
88197	0018	40	40	*22*	43
82000	0004	39	39	*23*	42
88200	1548	37	37	*22*	40
88201	1448	39	39	*23*	42
88204	1233	34	34	*21*	37
88207	0348	38	38	*22*	41
88210	0204	39	39	*20*	43
88214	0133	41	41	*22*	44
88215	2348	37	37	*20*	40
88218	2048	42	42	*24*	45
88221	1733	40	40	*23*	43
88224	1448	40	40	*25*	43
88227	1718	40	40	22	43
88229	0007	37	37	*26*	40
88230	1422	38	38	*23*	40
88232	0018	40	40	*24*	43
88239	0018	28	28	*18*	30
88246	1818	42	41	*30*	44
88253	1433	43	42	*35*	45
88258	0004	44	44	*36*	46
88260	0018	42	42	*29*	43
88263	1304	41	41	*24*	42
88267	0133	42	43	*27*	43

<--- ANTENNA 6 BECOMES WEAK

Figure 6. Relative Amplitudes; Qaanaaq, March 4 to September 23, 1988.



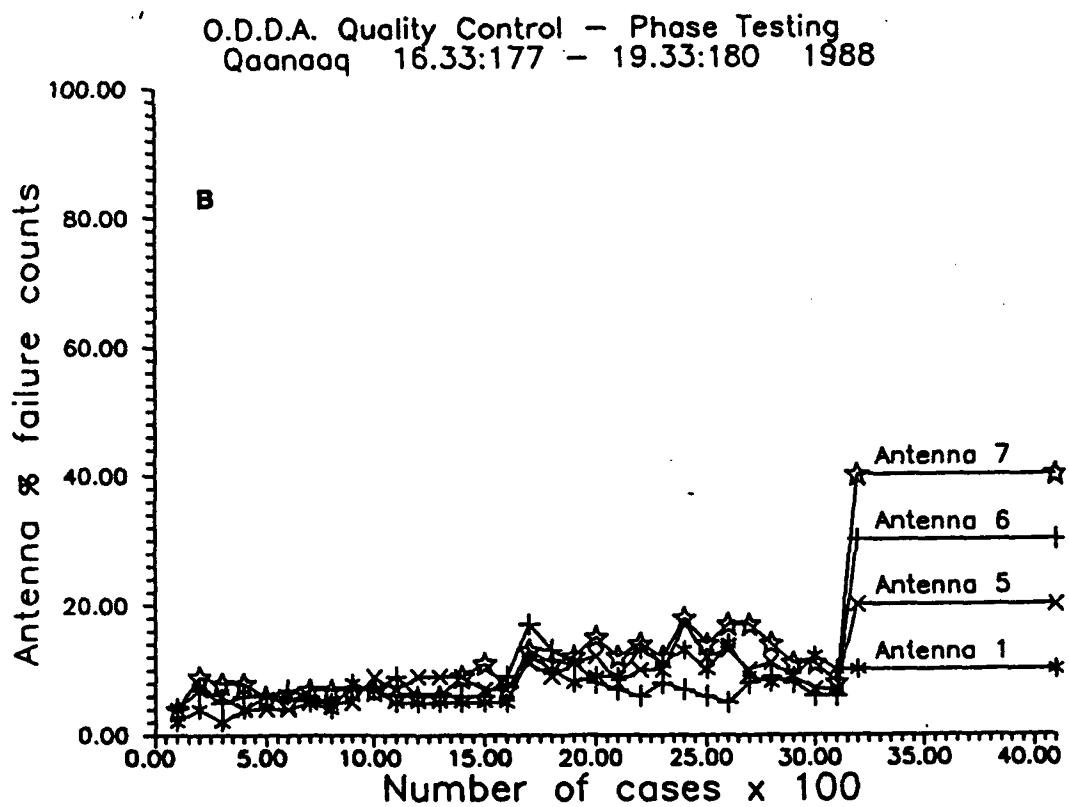


Figure 7. Percentage Failure Counts Obtained for Amplitude and Phase Testing, Qaanaaq Days 88177 through 88180.

Figure 8 displays the number of occurrences (converted to percent) of each of the phase 0 to 31 (i.e. the five MSB are used). During days 87239-87324 a problem was detected in the phases since the values are not evenly distributed and certain phases dominate. Figure 9 shows the DDA quality control testing for days 87291 through 87293. From Figure 9b, the failure counts for phase testing are high, with an average value of approximately 26%. In comparison, the amplitude testing (Figure 9a) shows no problems with the system.

Figure 10 displays the DDA quality control testing on days 87328 through 87330, after the problem with the phase was fixed. Both testing methods return values below 10%. The difference in failure counts between Figure 9b and 10b is apparent.

As with all statistics, one always prefers the largest possible data sample to test statistical methods. While the data analyzed for the verification of the DDA quality control method were large, we still consider this analysis as preliminary. However, it is clearly indicated from these results that the methods do allow us to determine if problems in the phases and amplitudes of the drift spectrum exist. What's more, only 100 cases of drift are required to determine if a problem exists. Again, how robust these techniques are under changing ionospheric and instrumentation conditions is still in question and is continuing to be investigated.

QAANAAQ

% PHASES: NO. OF OCCURRENCES OF THE 5 MSB OF THE PHASES; NO. OF OCCURRENCES GIVEN IN PERCENT.
% PHASES: 5-BIT PHASES HAVE RESOLUTION OF 11.25 DEG/UNIT.

5 MSB FOR	% PHASES:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
88296 0045	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88303 1745	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88312 0115	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88313 2345	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88323 1445	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88330 1730	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88338 1800	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88339 2345	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88343 0215	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88344 1815	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88347 0245	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88349 0115	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88351 0000	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88357 2015	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88365 1600	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88013 1445	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
88016 2345	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3

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87239 1300	% PHASES	17	2	2	2	3	2	2	2	2	2	2	1	2	2	2	10	12	2	1	1	1	1	1	1	1	1	1	1	2	2	3	11
87245 1600	% PHASES	17	2	2	2	3	2	2	2	2	2	2	1	2	2	2	10	12	2	1	1	1	1	1	1	1	1	1	1	2	2	3	11
87251 1245	% PHASES	16	2	2	2	3	3	2	2	2	3	2	1	2	2	2	9	11	2	2	1	1	1	1	1	1	1	1	1	2	2	3	11
87257 1315	% PHASES	17	3	2	2	3	2	2	2	2	2	2	1	2	2	2	10	12	2	2	1	1	1	1	1	1	1	1	1	2	2	3	11
87263 1345	% PHASES	17	3	2	2	3	2	2	2	2	2	2	1	2	2	2	10	12	2	2	1	1	1	1	1	1	1	1	1	2	2	3	11
87273 1645	% PHASES	18	3	2	2	2	2	2	2	2	2	1	1	2	2	2	11	13	2	2	1	1	1	1	1	2	1	1	1	2	2	3	12
87279 1345	% PHASES	17	3	2	2	3	2	2	2	2	2	2	1	2	2	2	10	12	2	2	1	1	1	1	1	1	1	1	1	2	2	3	11
87285 1630	% PHASES	17	3	2	2	2	2	2	2	2	2	1	1	2	2	2	11	13	2	2	1	1	1	1	1	1	1	1	1	2	2	3	12
87291 1530	% PHASES	17	3	2	2	2	2	2	2	2	2	2	1	2	2	2	11	13	2	2	1	1	1	1	1	1	1	1	1	2	2	3	12
87301 1630	% PHASES	17	3	2	2	2	2	1	2	2	1	1	1	2	2	3	11	13	3	2	1	1	1	1	1	2	1	1	1	2	2	3	12
87307 1415	% PHASES	17	3	2	2	2	2	2	2	2	2	2	1	2	2	2	11	13	2	2	1	1	1	1	1	2	1	1	1	2	2	3	12
87313 1430	% PHASES	17	3	2	2	2	2	2	2	2	2	2	1	2	2	2	11	13	2	2	1	1	1	1	2	2	1	1	1	2	2	3	11
87319 1830	% PHASES	16	3	2	2	2	2	2	2	2	2	1	1	2	2	3	11	13	3	2	1	1	1	1	2	2	1	1	1	2	2	3	11
87324 1730	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
87327 2345	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
87336 1815	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
87342 1315	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
87348 1445	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
87352 1845	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
87355 2345	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3
87364 1400	% PHASES	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3

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Figure 8. Number of Occurrences of the 5 MSB of Phase, Qaanaaq Digisonde 256

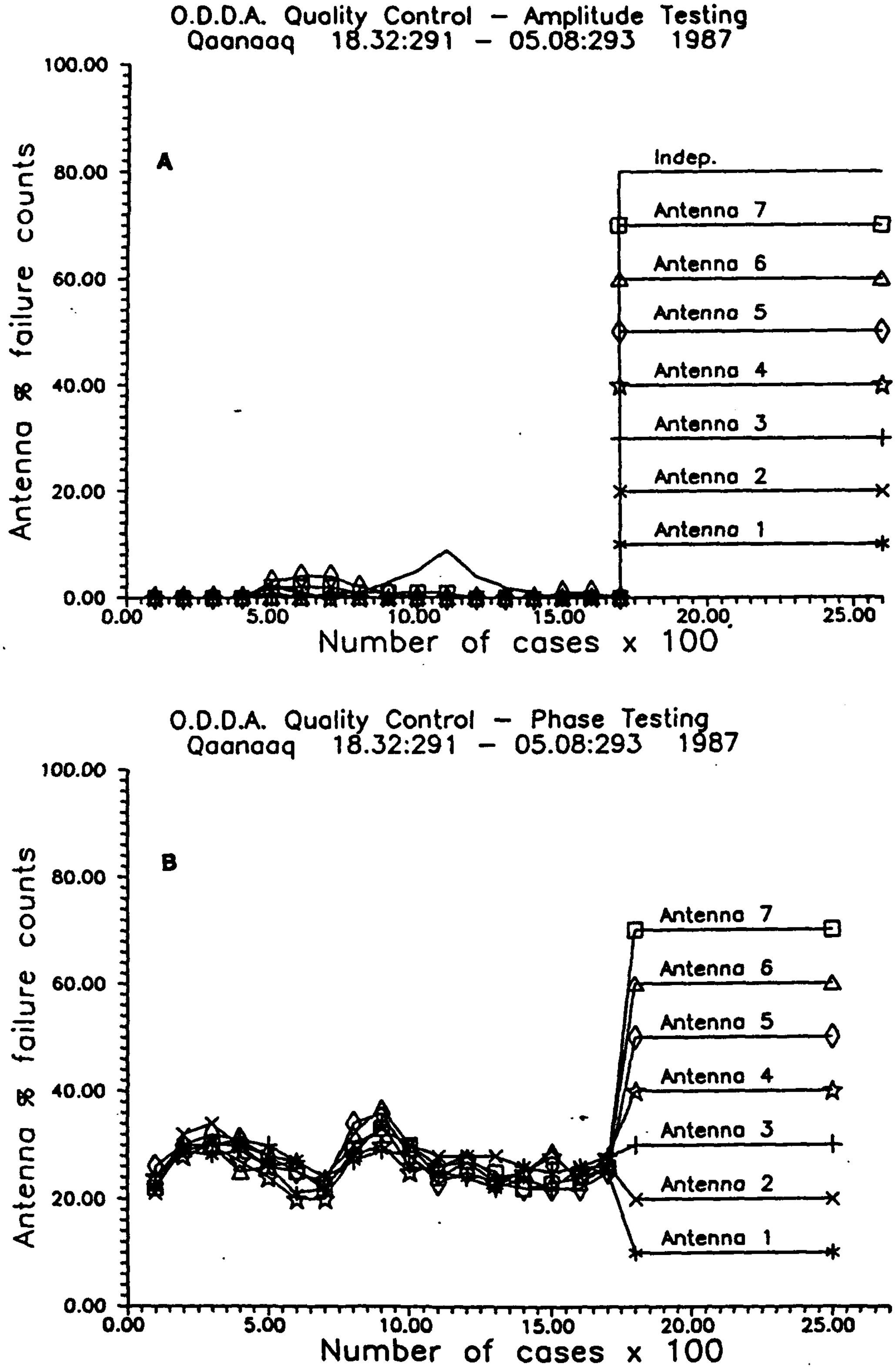

Figure 9. Number of Failure Counts for Phase Testing in Quality Control, Qaanaaq Digisonde 256, Days 87291 through 87293.

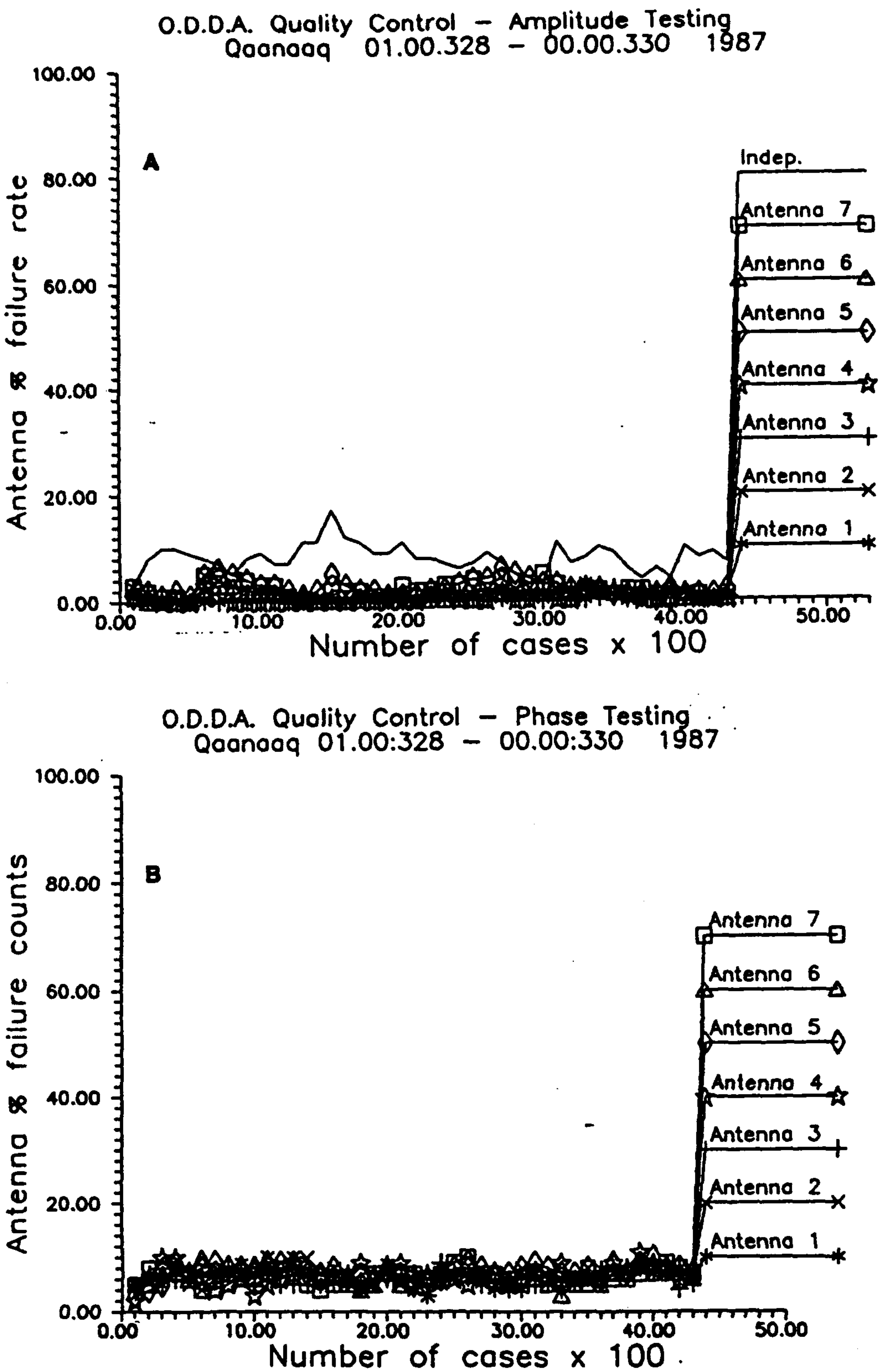

Figure 10. Number of Failure Counts for Phase Testing in Quality Control, Qaanaaq Digisonde 256, Days 87328 through 87330.