Technical Report ARAED-TR-95009

Anechoic Chamber Upgrade

Steven Weiss and Andrew Leshchyshyn

May 1995

U.S. ARMY
ARMAMENT MUNITIONS
& CHEMICAL COMMAND
ARMAMENT RDE CENTER

U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Armament Engineering Directorate

Picatinny Arsenal, New Jersey

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 1995	Final, January–August 1994

4. TITLE AND SUBTITLE

Anechoic Chamber Upgrade

5. FUNDING NUMBERS

DA PR: 62624
PE: 62624

6. AUTHOR(S)

Steven Weiss and Andrew Leshchyshyn

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

ARDEC, IMD
Information Research Center
Attn AMSTA-AR-IMC
Picatinny Arsenal, NJ 07806-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army ARDEC, Fuze Division
2800 Powder Mill Road
Adelphi, MD 20783

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

ARAED-TR-95009

11. SUPPLEMENTARY NOTES

AMS code: 622624.H18
ARDEC PR: 52AKAA

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Hardware and software upgrades have been made recently to an anechoic chamber at the Adelphi Laboratory Center (ALC). A new data acquisition system (using Scientific Atlanta equipment) has been installed and connected to a Dell 386 personal computer. This computer has been dedicated to the chamber to be used solely for data acquisition and analysis. The computer can be connected to the ALC facility network so that data can be downloaded to any location within the ALC campus.

14. SUBJECT TERMS

Anechoic chamber, antenna measurement

15. NUMBER OF PAGES

22

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

Preface

The project described in this report represents a cooperative effort between the employees of the Armament Research, Development, and Engineering Center (ARDEC) and the Army Research Laboratory (ARL) in automating an anechoic chamber at the Adelphi Laboratory Center through the installation of a new computer. John Clark headed the organizational end of the effort, making sure that all the various tasks facilitating the upgrade were performed; he is the point of contact for scheduling use of the chamber (301-394-3800). The computer network hookup was installed by James Griffin.

The Scientific Atlantic equipment was integrated into the control room of the anechoic chamber by Steven Weiss and Robert Tan. Questions pertaining to the system setup may be directed to Steven Weiss (301-394-3710).

The computer algorithm was developed by Steven Weiss and Andy Leshchyshyn after consultations with Robert Dahlstrom. All the computer hardware interface equipment was designed and debugged by Andy Leshchyshyn; he also wrote the computer code for the data acquisition portion of the software. A routine that plots data to the computer's monitor was prepared by David Gerstman. Any questions concerning the computer code (error message, bugs, etc) may be directed to Andy Leshchyshyn (301-394-2420). The computer was provided by ARL through Jeffrey Sichina.

Other people who contributed to this upgrade are as follows:

The ARL participants were Jeffrey Sichina, Robert Dahlstrom, John Clark, David Gerstman, James Griffin, Eric Adler, Robert Tan, Roger Kaul, and Gregory Smith.

The ARDEC participants were Steven Weiss, Andy Leshchyshyn, and Kathy Ludke.

Contents

Figures

Table

1. Introduction

Hardware and software upgrades have been made recently to an anechoic chamber at the Adelphi Laboratory Center (ALC). This chamber is primarily used for the measurement of the patterns and gains of antennas developed by Army Research Laboratory (ARL) and Armament, Research, Development, and Engineering Center (ARDEC) engineers located at ALC. A new data acquisition system (using Scientific Atlanta equipment) has been installed and connected to a Dell 386 personal computer. This computer has been dedicated to the chamber to be used solely for data acquisition and analysis. The computer can be connected to the ALC facility network so that data can be downloaded to any location within the ALC campus.

This report first presents a system overview to aid the users in the initial setup of the chamber's measurement equipment. Different configurations for operation above and below 1 GHz are discussed. The report also presents an example of an actual antenna measurement run with an illustration of the various ways the data can be presented. The appendix presents a detailed overview of the data acquisition algorithm.

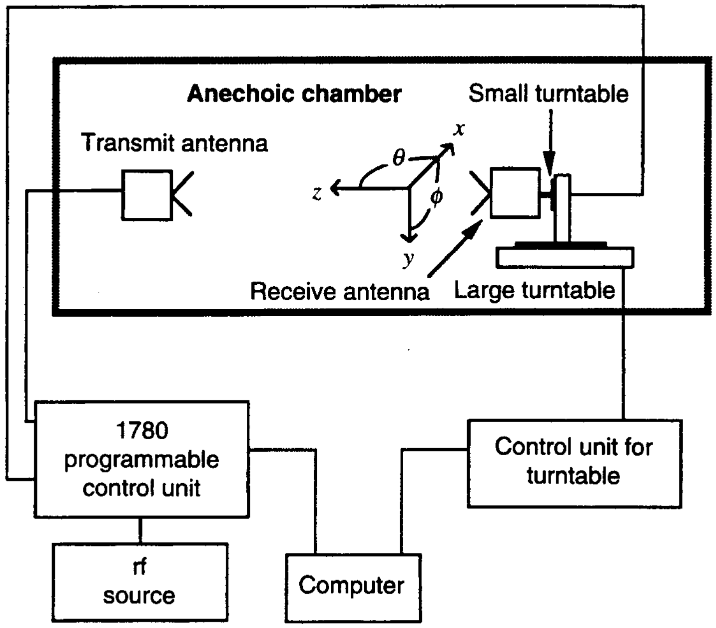
2. System Overview

A series 1780 Programmable Microwave Receiver (PMR), manufactured by Scientific Atlanta, has been installed into the control room of the anechoic chamber. This equipment replaces the older Scientific Atlanta receiver, which had become outdated. The 1780 PMR automates many preliminary tasks that had been done manually with the older equipment. Consequently, the amount of time spent in the initial setup of the receiver has been reduced, because the complexity of the setup has been reduced.

The chamber is commonly used to measure the two principal planes (electric, *E*-, and magnetic, *H*-planes) of an antenna. These measurements have been automated by the integration of the Dell 386 with the 1780 PMR. A block diagram of the data acquisition system is shown in figure 1. In this diagram a test antenna (to be evaluated) is placed on a turntable at one end of the chamber, and a calibrated transmitting antenna, excited by an rf source, is placed at the other end. The test antenna is then revolved in a circle so that its pattern can be determined as a function of the elevation angle θ. A second (smaller) turntable lets the user perform measurements as a function of the azimuthal angle ϕ.

The computer's primary tasks are to keep track of the position of the turntable and to take data from the 1780 PMR. As the turntable rotates, the computer polls the 1780 PMR for amplitude (in decibels) and phase (in degrees) information at predesignated intervals (e.g., 0.1°, 0.5°, and 1.0°). When the turntable completes one revolution, the computer terminates the data acquisition portion of its algorithm and proceeds to plot a normalized radiation pattern to the monitor. Finally, the data are stored to an ASCII file on the hard drive.

Figure 1. Block diagram of a typical measurement setup.



The stored data are organized into three columns. The first column corresponds to the position of the turntable (in degrees). The second and third columns of information correspond to amplitude (in decibels) and phase (in degrees) measurements gathered from the receive antenna. The executable file that runs the acquisition system is titled "anc." This file is found in the "chamber" directory on the Dell 386 computer.

Typically, the operator may perform many runs for various antenna pattern cuts. The data for these cuts are stored in the chamber directory, unless the computer is otherwise directed. If the operator desires to see the acquired data again on a polar plot, an executable file named "pdata" can be run. This file will prompt the operator for the data's file name and then plot the data to the monitor. At the conclusion of the work, the user should clear out all data files from the chamber directory.

If measurements are desired at frequencies between 0.1 and 1.0 GHz, the 1780 PMR must be configured in accordance with figure 2. Note that the 1733 low-frequency converter and the 1780 local oscillator (LO) unit are modular components of the 1780 PMR.

At these frequencies (0.1 to 1.0 GHz), all mixing operations are done internally to the system, and the user runs cables directly from the antennas to the appropriate type-N connectors on the back of the 1733. Cables must also be run from the 1733 to the 1780 LO unit. Figure 2 shows the back view of these units. A number of other cables, not shown in this diagram, are also attached to the units. These cables are properly placed and should not be moved. The 1780 PMR automatically defaults to an internal algorithm that assumes that the user has properly configured the system when it is operating between 0.1 and 1.0 GHz.

At frequencies above 1 GHz, the user must configure the 1780 PMR in accordance with figure 3. At these frequencies, mixing is done externally (usually with Model 14-5 harmonic mixers). The external mixers run directly to the 1780 LO unit; the 1733 is bypassed. Again, the 1780 PMR will default to an internal algorithm that assumes that the user has configured the system appropriately when it is operating above 1.0 GHz.

If more information is needed on this new data acquisition equipment, users can find the manuals for the Scientific Atlanta equipment in the anechoic chamber's control room. These manuals should not be removed from this room. Further questions about test measurements should be directed to Steven Weiss.

Figure 2. Rf system for operation between 0.1 and 1.0 GHz.

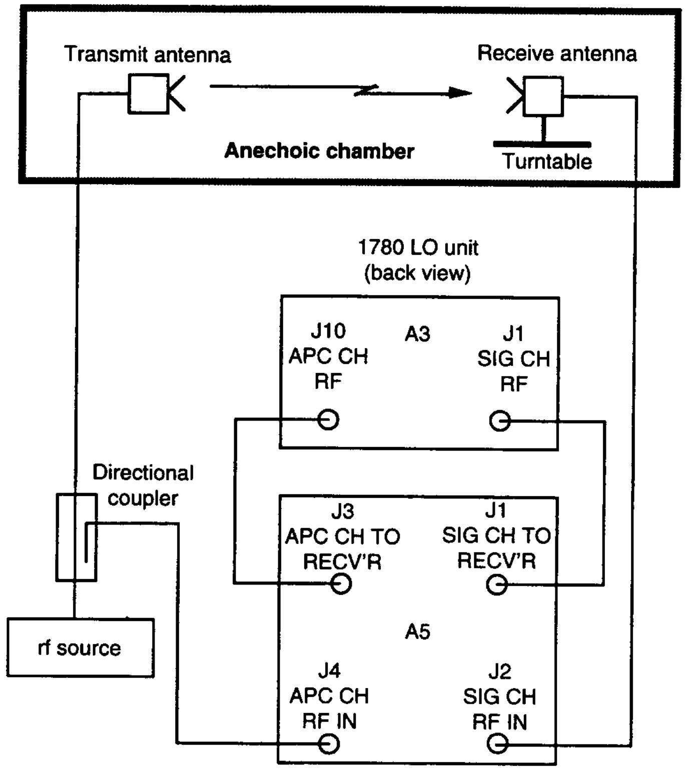
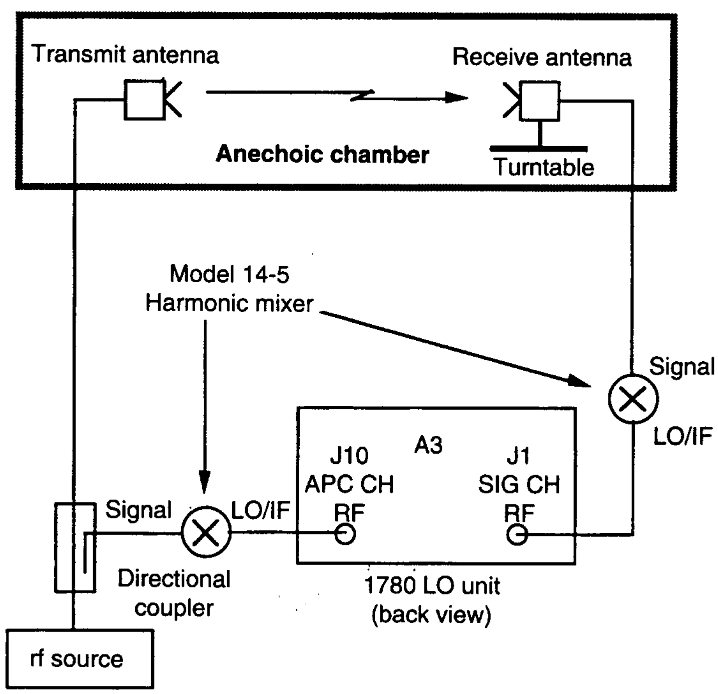


Figure 3. Rf system for operation above 1.0 GHz.



3. Examples of Acquired Data

An example of some typical acquired data is presented in table 1. The turntable data (first column) are resolved to an accuracy of 0.01°. These data were taken in 1° increments.

Once acquired, the data can be plotted on a radiation pattern graph. Two such plots are shown in figure 4. These graphs were generated from a package developed with Mathematica software. It is up to users to provide their own software for graphics.

Table 1. Measured data.

Turntable position (°)	Amplitude (dB)	Phase (°)
–179.99	–20.86	198.9
–178.99	–21.36	203.6
–178.	–21.9	203.6
–176.99	–22.01	207.4
–176.	–22.63	213.7
–174.99	–23.16	215.7
–173.99	–24.2	224.7
–173.	–25.47	237.9
.	.	.
.	.	.
.	.	.
171.01	–22.89	197.9
172.	–22.26	192.3
173.01	–21.8	193.2
174.	–21.83	189.9
175.01	–21.29	188.3
176.01	–21.44	191.6
177.	–20.94	190.
178.01	–21.41	192.4
179.	–20.82	194.9

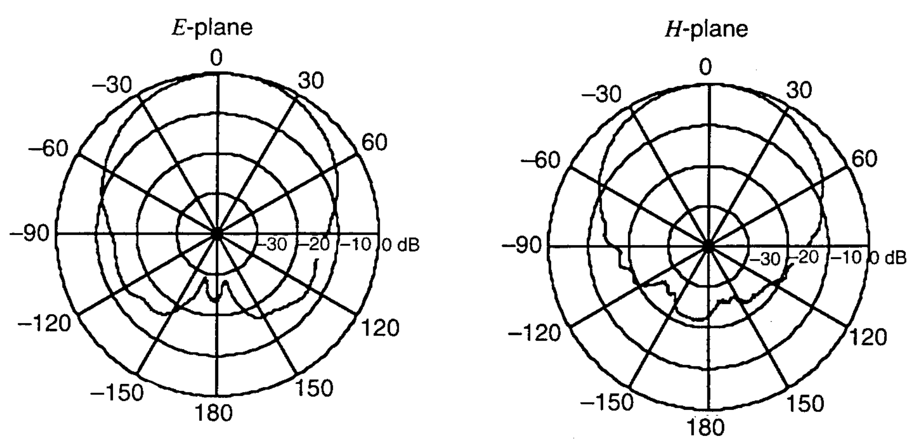


Figure 4. Plotted data for typical *E*- and *H*-plane measurements.

4. Using the Software

The following is a step-by-step outline for using the data acquisition software.

1. Turn on the computer and monitor using the power strip switch. The light-emitting diode (LED) on the synchro-to-digital converter box should light up. The box sits on top of the computer.

2. Turn on the turntable drive motor.

3. Turn on and set the signal source.

4. Turn on and set the Scientific Atlanta receiver.

   The receiver must be set properly for the program to work. The best way to test your settings is to do a manual test without running the software. This allows you to observe the LED display. If any of the data displayed are in inverted LED mode, then the receiver is being overdriven. Once the receiver is fully functional, proceed with the rest of these instructions.

5. The computer should be in the **CHAMBER>** directory. Type **anc** and press return.

6. The software will ask you a few questions and will explain how to run a test.

   a. Select azimuth or elevation. Please note that "elevation" refers to the large horizontal turntable; "azimuth" refers to the small vertical turntable.

   b. You are given a choice of the accuracy with which degrees will be measured. The choices are 0.1°, 0.5°, and 1°. Resolution does affect the maximum allowable spin rate for the turntable. Selecting 1° resolution allows the fastest turntable speed.

      - at 1° resolution—you select the fastest safe speed by turning the knob two notches in the clockwise or counterclockwise direction.

      - at 0.1° resolution—you select the fastest safe speed by turning the knob one notch in the clockwise or counterclockwise direction.

   c. Basically the computer determines where 0° is and then asks the user to turn the table to –180°. The computer tells you when –180° is reached. You are then told to reverse direction. The computer will record degrees, amplitude, and phase until the turntable reaches 180°. Then you are prompted to stop the turntable.

   If the turntable spins too fast, a message will appear on the screen. Slow down and continue the test, but be aware that the output file has missing or corrupted data.

   d. When the message "Stop the Turntable" appears on the screen, please do as instructed. Once this is done, you will be prompted to hit c to continue. A normalized plot will be displayed on the screen. Once again, press c to continue.

e. At this point you must decide if the data are worth saving to a file. If so, select the name of the output file. If you wish the data to go directly to disk, type a:filename (for 5¼-in. floppy), or b:filename (3½-in. floppy). The data stored will be in three columns: DEGREES, AMPLITUDE, PHASE.

f. The software will turn the APC off and return the receiver to manual mode. The manual specifies that the APC should always be off before the receiver is turned off.

If you wish to do another run, do not forget to turn the APC back on.

7. When finished, remember to turn everything off.

Certain problems may arise:

The software will alert you if the turntable is spinning too fast to gather data, or if a communication error has occurred between the computer and the receiver.

- If you do not follow the suggested speeds (see step 6b) and a message "too fast" appears, remember that your data have been corrupted, and when the program completes, you must repeat the entire process.
- If a communication error occurs between the computer and the receiver, you will get a message that says "Parallel Poll Error, Serial Poll Error," and then a brief description of what the error was (these descriptions are from the users manual). Hardware errors will generally mean that there is a problem with the way the receiver was set up, or with the signal being provided by the function generator. Please refer to the users manual for more information.

The Scientific Atlanta receiver must be set properly for the software to function properly. Please read the users manual carefully before attempting to use the receiver. The software will not set the receiver for you.

5. Conclusion

This report gives an overview of the upgraded equipment and software installed in the anechoic chamber at ALC. It can be used as a quick reference when the chamber is used for antenna measurements. A basic understanding of the equipment is assumed. This report does not take the place of the operating manuals for the Scientific Atlantic equipment. Many important details concerning the setup of the equipment are contained within these documents, and the user should become familiar with the equipment before attempting to use it.

Appendix. Data Acquisition Algorithm

An algorithm has been developed and implemented so that the position of a turntable (located within an anechoic chamber at the Adelphi Laboratory Center (ALC)) can be monitored by a computer. The purpose of this implementation is to enable users to measure the amplitude and phase of an antenna signal with respect to the degree of turn of the turntable in the anechoic chamber. Amplitude and phase information is provided by a receiver and is not discussed here.

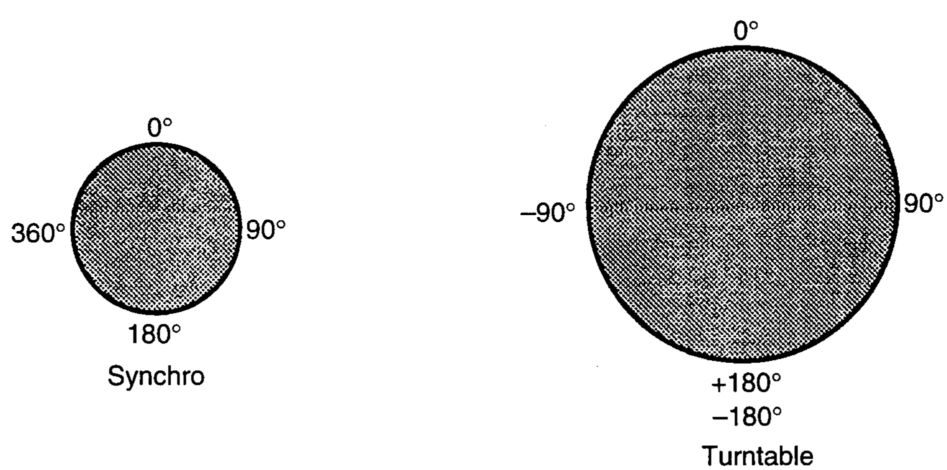
A-1. Synchro-to-Turntable Relationship

The position of the turntable is available through synchros that continuously provide relative phase information. This information is available to a port on the computer through a parallel input/output interface card.

The algorithm was complicated by two issues. First, there is a 36 : 1 ratio between the degrees measured by the synchro and the degrees actually turned by the turntable. Second, the turntable can turn both clockwise and counterclockwise. It is easy to keep track of degree changes, but difficulties can arise in keeping track of turntable direction. These difficulties are not obvious, but with a thorough description of the algorithm they become clear.

To understand the concept of the 36 : 1 ratio between the synchros and the turntable, it is easiest to envision two circles as in figure A-1. The small circle represents the synchro, and the large circle represents the turntable. For every revolution of the synchro circle, 360°, the large turntable turns 10°. This also means that for every 3.6° of change on the synchro circle, the turntable has changed 0.1°. Since the finest resolution desired is 0.1° on the turntable, the software must look for a 3.6° change from the synchros. This resolution is referenced by the variable "deg_res." Since it is a variable, it is easily changed. The user is prompted to select a resolution (the "resolution" function is labeled in the comments to the code). The user is given a choice of 0.1°, 0.5°, or 1° resolution with respect to the turntable. (Should

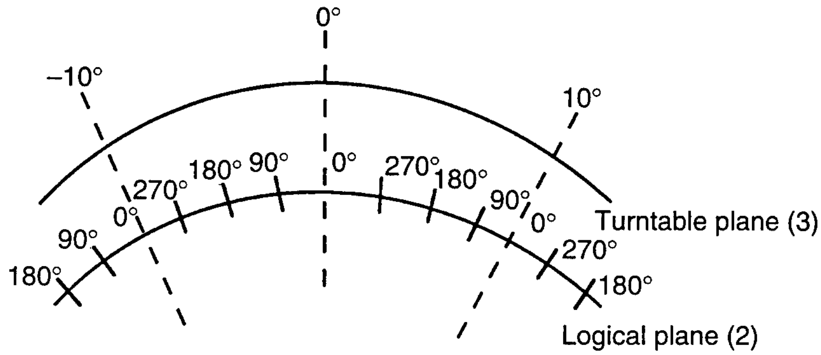
Figure A-1. Synchro and turntable orientations.



different resolutions be requested, the increments must be multiples of 0.1, where the multiplier is a whole number. For example, we could create a 0.2° or 0.3° multiplier but not a 0.25° multiplier. This limitation has to do with array element increments, which are discussed in sect. A-3.)

Another way of looking at the relationship between the synchro and the turntable can be seen in figure A-2. The relationship can be viewed in terms of reference planes. Reference plane 2 refers to the synchro (normalized), while reference 3 refers to the turntable. Reference plane 1 refers to absolute synchro data (unnormalized). Reference plane 1 is discussed in section A-6.

Figure A-2. Turntable and logical planes.



A-2. Determining Direction of Spin

The algorithm for determining the direction and position of the turntable depends on the correct interpretation of successive angular measurements. In its most primitive form, a positive change in successive readings means that the turntable is turning counterclockwise. Negative changes mean the turntable is turning clockwise. Five sample calculations of turntable angle, given the synchro angle, are shown in table A-1.

At this point the algorithm looks very straightforward. The question is how to convert a logical angle to a turntable angle. The key to this conversion is the 36 : 1 ratio. If we call the starting position of the turntable 0°, and measure the change in the logical angle, we can determine not only the amount of change in degrees of the turntable but also the direction. When a 0.1° (turntable) resolution is selected, the computer reads the degree measurement from the synchro waiting for a 3.6° change. As soon as a 3.6° change has occurred, the computer knows that the turntable has shifted by

Table A-1. Sample turntable angle calculations.

Trial no.	Synchro angle	Calculation: new – last valid	Interpreted synchro direction	Turntable angle direction (°)	Turntable direction
1	0	0 – 0 = 0	No change	0.0	—
2	4	4 – 0 > 3.6	Forward	–0.1	CCW
3	9	9 – 4 > 3.6	Forward	–0.2	CCW
4	7	7 – 9 ≥ –3.6	Not enough change to be intrepreted	—	CW
5	4	4 – 9 > –3.6	Backward	+0.1	CW

0.1°. If the computer keeps track of the direction of change and the number of 0.1° increments, the position of the turntable will always be known.

A-3. Storing Data

From a poll of users, the consensus is that the finest resolution needed for the turntable is 0.1°. Since processing speed was a vital consideration, it was necessary to minimize the number of calculations so that the program would execute quickly. To reduce the overhead associated with degree changes of the synchros and degree changes of the turntable, we decided to keep track of the specific synchro angle measurements and reference them to fixed increments of the turntable. Using pointers and storing data in arrays seemed like the optimal solution, since it takes much less time to store data in an array than to write it to a file directly. It is also faster and easier to process data in an array. Each location in the array corresponds to a specific turntable location. By assigning a degree measurement to each element of the array, we could keep track of the location (in degrees) of the turntable without going through a time-consuming calculation. When each element of the array corresponds to a 0.1° increment, the 0.1° resolution is achieved. While measurements are being taken, an exact degree is not calculated. What is initially stored is the degree error between the measurement and the exact degree expected. After measurements have been completed and speed of execution is no longer a priority, the exact degree is calculated. The exact degree is calculated by the contents of the array (the degree error) being added to the expected degree value.

The arrays had to be large enough to handle at least 3600 data elements, given a resolution of 0.1° (360° at 0.1° increments = 3600). Each increment of the array corresponds to a 0.1° increment of the turntable. Each element refers only to a specific degree. In reality, the turntable can turn to positive 200° and negative 200°. Consequently, it made sense to make the array large enough to hold 4000 elements of data. Location 2100 was arbitrarily selected to represent 0° with respect to the turntable. The relationship can be seen in table A-2.

Table A-2. Correspondence between element number and degree data.

Element	Degree
300	–180.0
299	–179.9
298	–179.8
.	.
.	.
.	.
2100	0.0
2101	0.1
2102	0.2
.	.
.	.
.	.
3898	179.8
3899	179.9
3900	180.0

When data are gathered at a 0.1° resolution, 3600 elements of the array are filled. If a 0.5° resolution is selected, every fifth element is filled with data (720 total points). For a 1° resolution, every tenth element is filled (360 total points).

The beginning of the program establishes a 0° reference in the logical plane and points the array pointer to the 0° reference point in the array, which is location 2100. When a 3.6° logical angle change is found (0.1° turntable resolution), the turntable has turned by 0.1°, the array pointer is incremented (or decremented, depending on direction of turn), and amplitude and phase data are gathered from the receiver and stored in that element of the array.

At this point in the discussion, the question might arise of why an algorithm was not created that would keep track of the direction of the turntable in only one direction. The user would be instructed to turn the table to –180°, and the software would establish this as a reference and keep track of forward motion only. This would have cut the calculations in half. However, using that approach would lead to a problem if the user turned the turntable in the wrong direction once it was at –180°. Also, it seems more intuitive for the user to align the antenna with the receiver by pointing the antenna forward rather than backward. So the decision was made to keep track of the direction of the turntable spin at the expense of processing speed.

Having demonstrated that we must keep track of both degrees and direction, we are ready to proceed with an explanation of the algorithm used to keep track of the logical angle. A quick review of variable names is provided to help in understanding the equations that will follow. The "angle" is the degree measurement coming from the synchro. The "physical reference" is the first measurement to come from the synchro when the user aligns the turntable so that the transmitter points at the receiver. The "logical angle" is the angle normalized with respect to the physical reference (normalization is explained in the sect. A-6). "Element" refers to a particular location in the array. A new variable that has not yet been introduced is "last logical," which refers to the last logical reference.

A-4. Calculations in Logical Plane

The logical plane is where the bulk of processing occurs to determine the direction and magnitude of degree change. The logical plane can be viewed as a circle divided into 100 parts, spaced 3.6° apart (see fig. A-3).

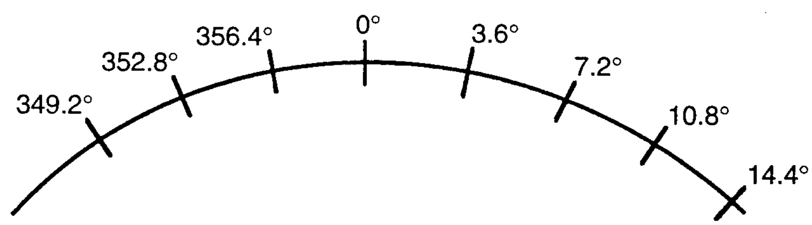


Figure A-3. A view of the logical plane.

A complication is that if the data generated by the synchros indicate a clockwise progression, the direction of the turntable will actually be counterclockwise, and vice versa. As the degree measurement of the synchro increases, the turntable moves counterclockwise (negative towards –180°) and the array is decremented.

Tests show that the communication with the Scientific Atlanta receiver is the single most time-consuming portion of the software routine. However, there is no need to measure amplitude and phase in the negative (counterclockwise) direction, since it can be gathered in the forward direction as the turntable moves from –180° toward +180°. This allows the turntable to be turned in the reverse direction much faster than in the forward direction.

To illustrate a potential ambiguity in the position of the turntable as understood by the computer, we present an example. We begin at 0 logical degrees with the turntable also positioned straight ahead at 0°. For discussion purposes, the degree resolution selected is 0.1° turntable resolution, which equals a 3.6° synchro resolution. The array pointer is pointing to location 2100. The user begins turning the turntable counterclockwise, and the computer begins sampling the synchro-to-digital converter. The "last logical" value was 0. If the logical angle exceeds 3.6°, the turntable has moved –0.1°, so the array is decremented to location 2099. The new "last logical" that was exceeded was 3.6°. So now the computer is looking for the next 3.6° increment, which is 7.2°. When the "logical angle" exceeds this value once again, the array pointer is decremented, and 7.2 is stored as the "last logical." This process continues unless the direction is reversed. If that happens, the array pointer is incremented and now the amplitude and phase are recorded. The pseudo code for this is as follows:

FORWARD
IF (logical angle – last logical) > 3.6°
THEN decrement the array, and add 3.6 to the last logical value.

REVERSE
IF (last logical – logical angle) > 3.6°
THEN increment the array, and subtract 3.6 from the last logical value.

Since a circle has 360°, and the synchro-to-digital converter puts out values only between 0 and 359.99, the last logical cannot be incremented beyond 360, and cannot be decremented below 0. This has two effects. The first is that if the algorithm adds to the "last logical" and 360 is exceeded, then the new "last logical" is set to 0. If the algorithm subtracts from the last logical and 0 is exceeded, then the new "last logical" is set to 360. Furthermore, the above equations do not hold when the turntable is moving forward and the "last logical" is just under 360, while the "logical angle" has exceeded 360 and is just over 0. The turntable is moving forward, yet this scenario satisfies the REVERSE conditions. For this reason, a special check was created:

CROSS 0 FORWARD
IF (last logical > 315) and (logical angle < 45)
THEN decrement the array and set the last logical to 0°.

The value of 315 was selected rather arbitrarily. It needed to be in the quadrant between 270 and 360, yet leave enough room for large jumps in measured values. The same approach had to be taken for moving in the reverse direction and crossing 0.

CROSS 0 REVERSE
IF (logical angle ≥ 315) and (last logical < 45)
THEN increment the array and set the last logical to 360°.

A-5. Processing Speed Limitations

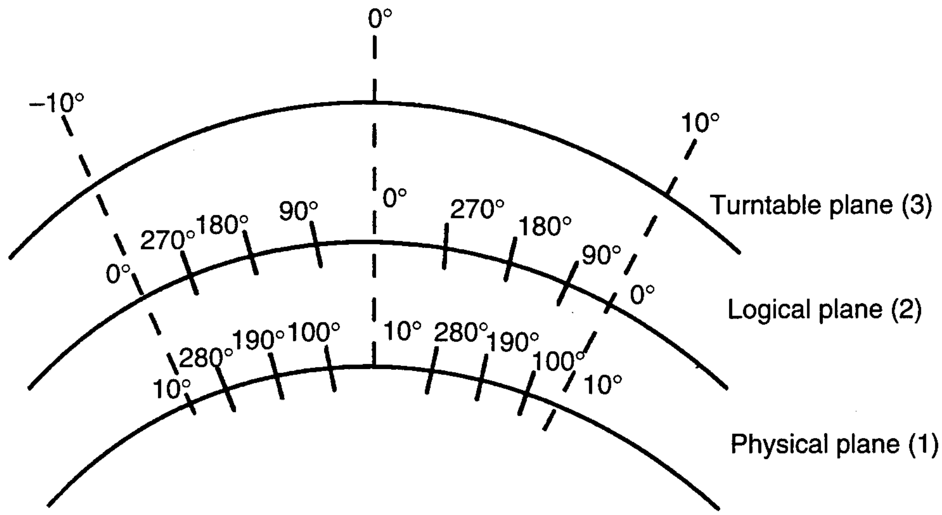
As mentioned previously, the most time-consuming portion of the software is communicating with the Scientific Atlanta receiver. The holdup is due to the internal workings of the receiver and cannot be sped up by the software. This creates the problem that it is possible to rotate the turntable faster than the computer can gather data. To deal with this problem, we chose to monitor whether the degree change exceeds twice the degree resolution, and alert the user that the turntable is turning too fast. Under normal operating conditions, the intention is to update the last logical each time the angle changes by more than the resolution step, and store data. If the computer has detected that the data coming from the synchros have changed by more than twice the resolution, data have been lost, since the array pointer has incremented twice without data being stored in the first of the two locations. If the recommended speed of the turntable is not exceeded, no data loss will occur. Once data have been stored in the arrays, it can be processed or written out to files.

A-6. Physical Reference Plane

At this point the difficulty with keeping track of direction when the turntable crosses 0 (360) should be apparent. Up until now we considered the relationship between the logical plane (2) and the turntable plane (3) with 0° from the synchros lining up nicely with 0° on the turntable. But this depends on the assumption that at 0° in the turntable plane, the synchros will put out a value of 0. Unfortunately, we cannot count on the synchros to provide a 0° reference when the turntable is at 0°. This means that the synchros could put out any arbitrary value between 0 and 359.99. When the synchros started at 0, we had a fixed reference plane to keep track of the last logical values: 0, 3.6, 7.2, 10.8, ... 352.8, 356.4, 0. If the original measurement is arbitrary, what is the initial value of the "last logical"? The software would have to keep track of when we cross $(x + 3.6)$, $(x + 7.2)$, $(x + 10.8)$, etc. It would need to track when $(0 + x)$ and $(360 + x)$ are crossed, adding to the complexity of the algorithm.

Reflecting the fact that the original synchro angle is not necessarily 0°, a more realistic example of the relationship between the turntable and the synchros is shown in figure A-4. The new plane of reference is called the

Figure A-4. Turntable, logical, and physical planes.



physical reference plane (reference plane 1). A hypothetical situation is shown in figure A-4, where the first synchro angle is 10°, while the turntable angle is 0°. We refer to this original synchro measurement as the "physical reference point." Once determined, the physical reference point will be held constant for the duration of the run.

Having determined that it is much easier to deal with a reference point of 0°, and think in terms of the logical plane, we created a short routine to normalize all angle measurements coming from the synchros with respect to 0. To do this we convert from the physical synchro reference plane (plane 1) to the logical synchro reference plane (plane 2). The arbitrary original physical reference point coming from the synchro is the equivalent of 0° in the logical plane. Once the physical reference is established, it is used to convert all the other physical degree data (plane 1) coming from the synchros to logical data (plane 2). The following equations are used:

change = (physical reference) minus (synchro angle measured)

a. if change = 0
   then logical angle = 0.

b. if change < 0
   then logical angle = (change) multiplied by (−1.0)

c. if change > 0
   then logical angle = (360) minus (change)

For example, in figure A-4, the physical reference is 10°. A synchro angle (in the physical plane) is measured 190°.

(physical reference) − (angle) = 10 − 190 = −180 ; −180 is <0;

so −180 × −1 = 180, which is the logical angle.

Once a logical angle has been computed, it can be used to determine direction and magnitude of change as described earlier.

A-7. Error Analysis

Even though the exact value of the turntable is not calculated while the turntable is spinning, it can be calculated later. Since the computer is looking for the degree change to equal or exceed the specified resolution before recording amplitude and phase data, there will inherently be some error. The error associated with the measurement can be derived from the "logical angle" and the new "last logical." For example, if the "last logical" was 7.2° and the servo is turning in the forward direction, then the computer is looking for the logical angle to exceed 10.8°. When 10.8° is exceeded, then a new "last logical" is calculated by the addition of 3.6. This is 10.8, which was the target value to exceed. So if we subtract the new (last logical) from the "logical angle," the result is the error by which the computer missed the synchro target angle. To convert this to error with respect to the turntable, divide by 36 (because of the 36 : 1 ratio). So hypothetically speaking, instead of getting an amplitude measurement at 181.1°, you get a measurement at 181.13°. This is acceptable since the error is less than the minimum stipulated resolution.

$$\text{(Turntable degree error)} = \left|\ \text{(logical angle)} - \text{new (last logical)}\ \right| \div 36$$

Although the algorithm worked successfully under normal operating conditions, two circumstances were discovered that would allow the algorithm to miss the angle by the resolution selected. In other words, if the resolution selected was offset by 0.1°, the data would all be shifted by 0.1°. The first circumstance that creates this error is if the user first turns the table clockwise, instead of counterclockwise as instructed by the computer. The first problem is eliminated if the user simply follows directions as instructed by the computer during execution.

The second way for the data to be offset by 0.1° was if directions were reversed just as the logical angle crossed 360° (0°). This second problem was caused by the "CROSS 0 FORWARD" and "CROSS 0 REVERSE" equations mentioned earlier. They were needed to deal with crossing 0° (360°) and to reset the last logical to 360 (or 0 depending on the case). However, if 0 were crossed without 3.6° being exceeded (0.1° turntable resolution) and then 0 were crossed again, the last logical would be set to the origin twice, and the array pointer would be incremented to be off by one element. From here on measurements would continue and all elements of the array would be filled, but they would all be shifted by one element.

To resolve this problem, we created a flag that was set when the last logical value was greater than 315 but less than 360 and the logical angle was greater than 0 but less than 45. In other words, 0 was crossed in the forward direction. As long as direction is not suddenly reversed, the flag is cleared. If direction is reversed before the flag can be cleared, the array pointer is adjusted to correctly adjust array alignment.

As an additional preventative measure, the user is alerted to change directions after the turntable exceeds –181°. This takes into account the largest of the degree resolutions down to the smallest and eliminates any possible ambiguity caused by the turntable stopping too close to –180°.

A-8. Warning

This appendix discusses the accuracy of the turntable from a software point of view. The accuracy of the manual alignment of the transmitter with the receiver has not been addressed, however, since this is not a software issue. The user should bear in mind that the zero position reference in the tabulated data is only as good as the initial physical alignment of the turntable.

Distribution

Admnstr
Defns Techl Info Ctr
Attn DTIC-DDA (2 copies)
Cameron Sta Bldg 5
Alexandria VA 22304-6145

US Army Materiel Systems Analysis Activity
Attn AMXSY-MP Tech Lib
Aberdeen Proving Ground MD 21005-5066

Chemical/Biological Defense Agency
US Army Armament Munitions & Chemical Cmd
Attn AMSCB-CII Library
Aberdeen Proving Ground MD 21010-5423

US Army Edgewood Rsrch Dev & Engineering Ctr
Attn SCBRD-RTB
Aberdeen Proving Ground MD 21010-5423

US Army Rsrch Lab
Attn AMSRL-OP-CI-B Lib
Aberdeen Proving Ground MD 21005-5066

Benet Weapons Lab CCAC
Armament Rsrch Dev & Engineeering Ctr
Attn SMCAR-CCB-TL
Watervliet NY 12189-5000

US Army TRADOC
Analysis Cmd-WSMR
Attn ATRC-WSS-R
White Sands Missile Range NM 88002

US Army TACOM ARDECArmament Eng Directorate
Attn AMSTA-AR-AE A G Nash
Attn AMSTA-AR-AE G R Taylor
Attn AMSTA-AR-AE B W Bushey
Attn AMSTA-AR-AEF-A G McNally
Attn AMSTA-AR-AEF-A J Beard
Attn AMSTA-AR-AEF-A R Christopherson
Attn AMSTA-AR-AEF-M R Goodman
Attn AMSTA-AR-IMC (3 copies)
Attn AMSTA-AR-GCL
Picatinny Arsenal NJ 07806-5000

US Army Rsrch Lab
Attn AMSRL-OP-SD-TA Mail & Records Mgmt
Attn AMSRL-OP-SD-TL Tech Library (3 copies)
Attn AMSRL-OP-SD-TP Tech Pub
Attn AMSRL-SE J M Miller
Attn AMSRL-SS V DeMonte
Attn AMSTA-AR-AEF-A S Weiss (4 copies)
Attn AMSRA-AR-AEF-AT A Leshchyshyn (4 copies)