R 82-2601, Parts I and II

Automatic Test Equipment Calibration/Performance Verification Evaluation and Research Program (JLC/DoD Subtask 30702)

EXECUTIVE SUMMARY Part I

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Electronics and Electrical Engineering
Electrosystems Division
Washington, DC 20234

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Electromagnetic Technology Division
Boulder, CO 80303

December 1982

Prepared for

Joint Logistics Commanders Panel on Automatic Testing
DoD Joint Technical Coordination Group for Metrology
DoD Calibration Coordination Group
USAF ASD/AEGB MATE Program Office

NBSIR 82-2601, Parts I and II

AUTOMATIC TEST EQUIPMENT CALIBRATION/PERFORMANCE VERIFICATION EVALUATION AND RESEARCH PROGRAM (JLC/DoD SUBTASK 30702)

EXECUTIVE SUMMARY Part I

Barry A. Bell, Thomas F. Leedy, Paul S. Lederer

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Electronics and Electrical Engineering
Electrosystems Division
Washington, DC 20234

William L. Gans, Robert E. Nelson

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Electromagnetic Technology Division
Boulder, CO 80303

December 1982

Prepared for
Joint Logistics Commanders Panel on Automatic Testing
DoD Joint Technical Coordination Group for Metrology
DoD Calibration Coordination Group
USAF ASD/AEGB MATE Program Office

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

Preface

The work described in this report was performed in response to a request by the Joint Logistics Commanders Panel on Automatic Testing (JLC/AT). The final report issued by the Industry-Joint Service "Automatic Test Project" (June 1980) strongly urged NBS leadership for the metrology and calibration support of automatic test equipment (ATE). The contents of this report are the results of an initial attempt to respond to this mandate.

As an organization, the National Bureau of Standards (NBS) has little experience with large, multi-function automatic test systems. The Bureau does not manufacture, procure, or use these systems. The strength of NBS is in metrology, and it is this strength that was applied to characterizing the performance of automated test systems. The work reported here is experimental in nature. It does not constitute an evaluation, certification, or endorsement of any equipment or systems. The experiment was to determine the feasibility of applying a portable calibration standard at the interface of third generation automatic test equipment. There was no attempt to technically evaluate the system measurement capability beyond what is reported.

Third generation automatic test equipment is characterized by extensive use of computer technology to implement signal generation and measurement within the system. The software required to program the computer is generally "invisible" to the user of such systems. No attempt was made to understand the system software in detail. Errors in such software could cause apparent measurement errors. Additional software, the NBS test applications programs, were written in ATLAS to actually implement the measurement processes. Knowledge that the application software was completely error free or performed exactly what was intended is not certain.

The choice of the automatic test system for this experiment (AN/USM-410 or EQUATE) was by mutual consent of representatives from the U.S. Army, Air Force, and Navy. This particular system seemed a reasonable candidate since each service used at least one such system and all could profit by the work. No attempt should be made to compare the results from the two test stations used in this experiment. This comparison would be unjustified from several points of view. First, each service uses their test sytem in a different manner and for different purposes. The particular Army system tested is used primarily for testing field communications equipment; the Navy station primarily tests digital logic assemblies. Secondly, somewhat different maintenance and calibration philosophies are applied by the various services. Thirdly, the test stations are of different age, the Navy system being the oldest. The age of the particular machine impacts both its hardware and software and the maintenance experience used in its support.

It should be reemphasized that this work was entirely an experimental investigation of a limited nature that was performed on only two automatic test systems. Accordingly, any conclusions and recommendations in this report reflect this limited sampling. Nevertheless, the results are probably representative of many automatic test systems and demonstrate the value of using an on-site calibration support scheme to reveal potential measurement problems.[1]

[1] In order to adequately describe the systems and experiments discussed in this report, commercial equipment and instruments are identified by manufacturer's name or model number. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

AUTOMATIC TEST EQUIPMENT CALIBRATION/PERFORMANCE VERIFICATION EVALUATION AND RESEARCH PROGRAM

EXECUTIVE SUMMARY

Barry A. Bell, Thomas F. Leedy, William L. Gans,
Paul S. Lederer, and Robert E. Nelson

1. BACKGROUND OF PROJECT

Complex, high-speed ATE systems have unique calibration requirements by virtue of their wide dynamic measurement range, their ability to both supply and measure electrical signals, and their extensive use of computer technology and software for the control of the systems.

The Department of Defense (DoD) is especially concerned that ATE systems perform properly since such equipment is vital to assure readiness of weapons systems. Additionally, to comply with MIL-STD-45662, Calibration Systems Requirements, DoD needs the calibration of ATE systems to be traceable to national standards.

In recognition of the fact that automatic testing is an extremely complex and highly dynamic technology, a Joint Logistics Commanders Panel on Automatic Testing was established by the services in July 1979. The Panel identified over 80 technical tasks needed to achieve its goals. Subtask 30702, "Calibration of ATE," has the purpose to "determine and develop concepts (policies, standards, techniques, practices and procedures) for on-line and off-line calibration to verify performance of the DoD family of automatic test equipment (ATE), with special emphasis to be placed on performance verification of third generation and later generations of ATE."

This report describes the detailed work performed by the National Bureau of Standards for the Joint Logistics Commanders Panel on Automatic Testing under JLC Subtask 30702. This work was undertaken to assess the requirements necessary for the proper calibration support of automatic test equipment. Additionally, an experiment was performed to determine the feasibility of applying portable calibration sources, characterized at NBS, directly to two automatic test systems of similar type located at different DoD facilities. The application of such sources to automatic test equipment does not imply that the equipment is thereby traceable to NBS standards. Also, the measurements described in this report represent experiments which were not performed with the statistical rigor of an NBS calibration service.

2. OBJECTIVES

Key objectives of this project for FY 1980 included:

(1) The selection of representative military ATE systems following consultation with DoD representatives; (2) site visits, selection of electrical parameters, and the formulation of plans for their on-site measurement and verification; and (3) the preparation of procedures and instrument packages at NBS laboratories to carry out such measurements.

The objectives for FY 1981 were:

(1) The procurement, testing, characterizing, and calibration of instruments for the field testing of selected ATE systems; (2) the conducting of field measurements/verifications of ATE systems; (3) the analysis of data and assessment of station performance quality; and (4) the planning of a more comprehensive approach to ATE station performance verification procedures.

3. APPROACH

Based on a number of visits to various DoD ATE installations in the Fall of 1980 (described in detail in section 3 of the complete report), two basic decisions were made with the concurrence of DoD. First, the AN/USM-410 (EQUATE) ATE System was selected for on-site testing and evaluation. The primary reasons for choosing this system were: (1) it is a third generation ATE system using sampling techniques for virtually all measurements and digital synthesis for most waveform stimuli; (2) it is used by all three services; (3) it measures/generates a wide variety and range of signals; and (4) it uses the IEEE Standard 416-1978 ATLAS language. Following this decision, efforts were made to obtain access to one or more EQUATE systems in each of the three services. With the help of the service sponsors committee, access was obtained to one Army and one Navy installation. An extensive ongoing workload at the Air Force installation selected necessitated postponing a field test of that particular EQUATE system.

The primary elements of the technical approach followed the objectives stated above and can be summarized as follows:

The first phase was the selection (and possible modification) and laboratory characterization of commercial signal sources. The selection of those sources was dictated by the choice of ATE system to be investigated (i.e., its voltage, frequency or pulse measurement characteristics) as well as the availability at NBS of adequate capability for characterizing the sources. Commercial availability, price, delivery time, and portability aspects were also considered, as was computer control capability.

Following the selection of the EQUATE system, test parameters were chosen based on the knowledge of its specified measurement capabilities, combined with knowledge of the output capabilities of potential signal sources. For the dc and low frequency ac work, it was decided to use dc voltages from ±100 mV to ±200 V and ac voltages from 300 mV rms to 140 V rms (at frequencies from 50 Hz to 10 MHz). For the pulse work, pulse duration over a range from 50 to 1000 ns was selected as the initial pulse measurement parameter.

The second phase was that of field measurements and performance verification of selected ATE stations. For this purpose, calibrated sources with suitable interface adapters/connectors were taken to the ATE station. The station was programmed to measure and record a range of source output signals as applied to randomly selected pins on the station interface panel. In this approach, the ATE station treats the source as a typical unit under test (UUT).

The third phase was the evaluation of the field measurement data at NBS in the light of knowledge about the performance characteristics of the sources. Based on this, conclusions could be drawn as to the actual measurement capability of the ATE station. Additional observations about station operation during the field measurements were also to be compiled.

It was recognized that these field experiments would represent only a limited sampling of the measurement capability of selected ATE systems. Therefore, the fourth phase of the approach was the development of a more comprehensive proposed program for assuring better measurement capability and traceability of military ATE systems.

4. CHARACTERIZATION OF SIGNAL SOURCES

A major part of the work for this project consisted of the testing and calibration of stable signal sources that could provide known stimulus values of dc and low frequency ac voltage, as well as pulsed voltage waveforms of known duration to the ATE system under test (AN/USM-410 EQUATE in particular). Several alternatives were possible for this purpose:

(1) Design and construction of suitable sources at NBS.

(2) An assembly of several commercially available instruments.

(3) The use of commercial sources.

For dc and low frequency (50 Hz to 10 MHz) ac voltages, the third alternative was taken since several meter calibrators were commercially available which had the necessary voltage and frequency ranges. For pulse duration, the second approach appeared to be the most feasible. The first alternative was not possible since time restrictions did not permit the development of NBS-designed packages.

4.1 DC and AC Voltage Source

The dc and ac source selected for the experiment was evaluated at NBS to determine its suitability for providing known voltage amplitudes over a range of environmental conditions. Specifically, the possible correlations in the output of the source were measured as a function of input line voltage, temperature, start-up time, and time stability over a period of approximately seven months. From these data it is possible to assign uncertainties to the values of the dc voltages of less than 200 parts per million (ppm) over a range of 0.1 to 200 V dc, and uncertainties of less than 1200 ppm to the values of ac voltages over the range of 0.3 to 140 V rms ac. The assignment of uncertainty was made by summing the errors of the output of the source for each of the environmental conditions listed above.

Figure 1 summarizes the results of the temperature tests for all dc voltage outputs used from the source. The shaded area shows the limits in the changes of these dc output levels over the temperature range from 0° to 40°C relative to their value at 23°C. Less than ±100 ppm of change in output voltage was measured due to temperature changes over the 40°C range observed. However, since the source was not subjected to more than a ±5°C departure from the nominal 23°C reference temperature during any field test, the assigned uncertainty range for dc voltage (due to temperature) was conservatively estimated to be no greater than 40 ppm.

Figure 2 shows the errors (departures from nominal) that were recorded for a set of four different dc voltages over a seven-month test period. The data shown for observation number 28 are not anomalies, but resulted from making voltage measurements when the source and voltmeter used for these tests were not in thermal equilibrium. These particular measurements were made less than an hour after the instruments were exposed to ambient temperatures during one of the field visits. Using this accumulated data, the 3σ value of the 252 observations was calculated to be 55 ppm (due to time instability), and this value was assigned to the uncertainty of the dc voltages of the calibrator.

The dc output voltages of the source were intercompared twice to the U.S. Legal Volt, maintained by the Electrical Measurements and Standards Division of NBS. This standard presently has an uncertainty of less than 1.0 ppm and intercomparisons are possible to this level. Normally, comparisons are made in the range of 0.015 to 10 V dc. The first comparison was made on March 19, 1981 to calibrate the source over a range of 0.01 to 10 V. Five months later, the source was again compared to the NBS Legal Volt to determine if the former had drifted significantly. For the second comparison, the calibration range for the source was extended to 200 V by special arrangement with the Electrical Measurements and Standards Division. The data obtained during both calibrations are shown in figure 3. From these data, a 3σ uncertainty of 38 ppm was assigned to the dc voltage source as compared to NBS standards over a range of 0.10 to 200 V dc.

The above uncertainties due to temperature, time, and offset from the legal volt, therefore, sum in quadrature (square root of the sum of the uncertainties squared) to 78 ppm. Together with effects due to line voltage and start-up characteristics (described in detail in the complete report), an overall worst-case uncertainty range in dc output voltages of the source was found to be less than 200 ppm. It should be noted that each component contributing to the uncertainty of dc output voltage is independent of other components.

The ac temperature stability was measured in the same manner as the dc temperature stability. Figure 4 shows the changes in ac output voltage referenced to the output of the source at 23°C. The maximum change in the ac output voltage over all voltages and frequency combinations measured was 400 ppm over the temperature range of 0 to 40°C. The assigned uncertainty range for ac voltage was estimated to to be no greater than 80 ppm over the 23 ±5°C temperature range encountered in the field tests.

Figure 5 shows the errors observed during the same seven-month period indicated in figure 2 for four voltage/frequency ac outputs from the source. As expected, the ac outputs exhibit considerably more uncertainty and time instability than for the dc outputs. It is shown in the complete report that the predominant source of both the dc and ac drifts were due to time instability of the voltmeter used for making these tests. Consequently, the uncertainty assigned to the source due to stability with time is quite conservative. Using 264 observations, a 3σ uncertainty of approximately 1720 ppm was calculated over the seven-month interval. However, for the one- to two-week intervals used for field testing, the time stability of the ac voltage outputs is conservatively in the range of 800 ppm.

The ac voltage of the source was measured as a function of amplitude and frequency by means of an NBS "Type F" set of ac-dc thermal voltage converter standards. The details of using these standards for making ac-dc difference measurements (in order to determine absolute ac voltage corrections for the source) are contained in the complete report. Figures 6a and 6b show plots of the offset corrections applied to the ac source on the dates shown. The voltage and frequency range of the data presented is 8 to 20 V rms and 50 Hz to 50 kHz, respectively. From these 69 observations, the source was assigned a 3σ uncertainty range of 93 ppm as compared to NBS standards.

The above uncertainties due to temperature, time, and offset from the legal volt, therefore, sum in quadrature to 810 ppm. Together with effects due to line voltage and start-up characteristics, an overall worst-case uncertainty range in the ac output voltages of the source was conservatively estimated to be less than 1200 ppm. Again, the components contributing to the uncertainties of the ac output voltage are essentially independent of each other.

For both the ac and dc measurements, interconnection between the source and the voltmeter was made with a 2 m (6-ft) long length of RG-58C/U cable. All measurements described above were made at the end of the cable and interface connector combination, i.e., right at the output connector pins. This is the same length and type of cable used to interconnect the source and the ATE system during subsequent field tests.

4.2 Pulse Duration Source

The system used to calibrate the pulse duration source is the NBS Automatic Pulse Measurement System (APMS). This system consists of a minicomputer interfaced to a wideband (dc-18 GHz) sampling oscilloscope through a 14-bit analog-to-digital (A/D) and digital-to-analog (D/A) converter unit. Both the high-speed sampling hardware and the data acquisition and signal analysis software developed for this system are described in detail in the complete report. Also, both the time axis calibration and the voltage axis calibration and their associated uncertainties (±1% of nominal/cm) are fully covered in the larger report.

Once the APMS time and voltage axis were calibrated in a manner traceable to NBS standards, the system was used to calibrate the PULSE DURATION source. Since the pulse source was to be used to test the ability of the EQUATE ATE station to measure the parameter PULSE DURATION, it was necessary to calibrate the source, as nearly as possible, at a reference plane electrically and mechanically matched to the EQUATE UUT reference plane. Because the EQUATE station has two such planes, the direct interface unit (DIU) and the programmable interface unit (PIU), it was deemed necessary to provide a set of calibrated PULSE DURATION waveforms for each of the two different planes. The EQUATE station is capable of measuring pulse duration (often termed "time interval" in the manufacturer's literature) in the range of 20 ns to 10 μs. To test this capability, the pulse source was calibrated at nominal PULSE DURATIONS of 50 ns, 100 ns, 200 ns, 500 ns, and 1 μs.

The problem of providing a known pulse waveform in the nanosecond/microsecond time range is primarily a problem of maintaining a known wideband impedance match from the generator to the measurement plane. The pulse generator output impedance is 50 Ω and the EQUATE station DIU is, in fact, a 50 Ω BNC coaxial connector, so the problem of maintaining pulse wave shape fidelity at the DIU measurement plane was simply solved by using a 2 m length of 50 Ω RG-58C/U coaxial transmission line as a wideband interconnection. For purposes of testing the DIU, then, the pulse source was configured as the combination of the commercial pulse generator with a 2 m section of RG-58C/U connected to its pulse output port.

Attempting to provide a known pulse waveform to the EQUATE PIU measurement plane was somewhat more complicated. Physically, the PIU measurement plane is a zero-insertion-force (ZIF) 650 pin connector configured in such a way that signal pins and signal shield pins are interspersed in a checkerboard pattern. Behind each signal and signal-shield pin pair are I/O buffering and terminating electronics such that each pin pair can be switched-selected for use as a signal source port or a signal measurement port. To provide a known pulse waveform at the PIU plane, it was necessary to use special filters and connectors during the calibration procedure in order to minimize distortion at the PIU connector pins. All of these details are provided in the complete report.

The major problem that arises in the practical measurement of PULSE DURATION is the definition and determination of the PULSE BASELINE and PULSE TOPLINE amplitudes. Actual measured pulses seldom exhibit perfectly flat baselines or toplines so that in performing the measurement one usually is forced to choose, perhaps arbitrarily, a method or algorithm for determining these two amplitudes. Of the four algorithms for determining PULSE BASELINE and PULSE TOPLINE magnitudes [1],[2] two were chosen for use in this work. The first is the PEAK MAGNITUDE algorithm which consists simply of choosing the smallest and largest voltage values of the recorded waveform as the PULSE BASELINE and PULSE TOPLINE, respectively. The second algorithm chosen, the MODE OF DENSITY DISTRIBUTION, is a bit more complicated. The recorded pulse waveform is superimposed upon a grid of small Δt rectangles in the voltage-time plane. Then a probability density histogram is constructed by counting the number of Δm - Δt rectangles through which the waveform passes for each incremental magnitude, Δm. The PULSE BASELINE and PULSE TOPLINE are then defined to be the lower and upper modes (or peaks) of this bimodal histogram, respectively.

Figures 7 and 8 are replicas of the graphical/alphanumeric printout obtained from a pulse waveform analysis program used in the APMS. The waveform shown in figure 7 is of the nominal 50 ns duration pulse from the NBS source applied directly to the APMS, with the analysis based on the MIN-MAX definition for the 0 percent and 100 percent amplitude levels. Figure 8 is the same pulse except that its parameters are based on the HISTOGRAM definition of these levels. It is apparent from the data on base magnitude and top magnitude where the remaining differences for pulse start time, stop time, first and second transition duration (rise and fall times), and, finally, pulse duration occur. The pulse duration using the HISTOGRAM algorithm was about 59 ps longer than that obtained using the MIN-MAX method. The "+F" in the comments line means that a Gaussian nine-pole filter was placed on the output of the pulse source having a nominal transition duration of 5 ns. Because the EQUATE system uses a sampling algorithm based on a MIN-MAX technique, the NBS-calibrated value for the pulse durations from the pulse source was obtained using the MIN-MAX algorithm on the APMS.

The pulse source was calibrated via the APMS in April 1981 and again in June/July 1981. In the complete report are contained figures similar to those of figures 7 and 8 herein which show all of the pertinent calibration data gathered, as well as test programs, test configurations, etc. Included also are figures showing the effects on the pulse waveforms when they are applied to the EQUATE PIU connector via NBS adapters. Table 1 summarizes the results of the calibration data taken for both PIU and DIU connections using the MIN-MAX 50 percent pulse duration method. The pulse duration figures shown are the mean value of three different measurement runs made on the source by the APMS for a given nominal pulse duration. As indicated in the last column, the change (Δt) over about a three-month period shows a time stability of well less than ±1 percent. For the one- to two-week interval used for field testing, the time stability is on the order of ±0.2 percent.

---

[2] Numbers in brackets refer to the literature references listed at the end of this report.

5. FIELD TESTS OF ATE SYSTEMS

The second major part of the work on this project consisted of transporting the calibrated sources described in section 4 to DoD field sites where the AN/USM-410 (EQUATE) stations were located, and running dc and low frequency ac voltage and voltage pulse duration measurements. The two available sites that were visited are located at the U.S. Army Depot, Tobyhanna, PA and the U.S. Naval Avionics Center, Indianapolis, IN. EQUATE-ATLAS test programs were written for making the necessary measurements with the assistance of system programmers and operators at these locations familiar with developing test program sets for the EQUATE system.

5.1 DC and AC Voltage Tests

The basic test procedure used with the dc and ac source applied to the EQUATE system was as follows. A preprogrammed tape of test voltages was prepared prior to the visit. After the on-site equipment had been operated for at least eight hours, the tape was loaded into the source. The voltage test signal from the source was applied to the PIU connector through an adapter designed to apply the voltage to selected pairs of measurement pins. The pairs of measurement pins were randomly chosen to emulate a UUT that might be connected to the EQUATE system. In general, six pin-pairs were chosen for the measurements and, of these, four pairs were remeasured to determine if measurement errors were associated with specific pairs.

Part of the experimental design of the field test included the choice of voltage sequences that would be measured by the EQUATE systems. It was decided that the test voltages to be measured should be a random sequence of amplitudes and frequencies in order to emulate the testing of a UUT whose output could assume a wide range of values. The voltage sequence covered the range of ±0.1 through ±195 V dc and from 0.3 V ac rms through a maximum of 130 V ac (184 V ac peak). This range was chosen to be well within the specifications of the EQUATE system measurement capability since initial testing at upper voltage limits gave rise to potential measurement problems. Other difficulties concerning the field testing are detailed in the complete report.

During each field test, the measurement data were printed on a hard copy printout on the console writer as well as written into a disk file. In this manner the measurements were stored in machine readable form for later data analysis. Additionally, hard copy and magnetic tape outputs were made of the ATLAS programs that were used to acquire the data. At NBS the magnetic tape was read, and the data on the tape were checked against the hard copy output from the EQUATE station. The recorded measurements were then compared to the preprogrammed values that were applied from the calibrator and the deviations were calculated. The dc measurements consisted of 440 data points, representing 44 voltages presented to each of the six PIU pin-pairs with four pin-pairs replicated.

Tables 2 and 3 give a summary of the 440 dc voltage observations taken at each of the Army and Navy test sites, respectively. A listing of the test program used for obtaining the data, the run sequence of applied voltages, sample printout of the program data, etc., are all contained in the complete report. The mean, maximum, and minimum errors in percent are calculated on the basis of the following expressions:

$$\text{Percent error} = \frac{\text{NBS source - Measurement}}{\text{Measurement}} \times 100 \text{ .}$$

Mean percent error is the arithmetic average of the percent errors.

Minimum percent error is the smallest percent error.

Maximum percent error is the largest percent error.

Standard deviation is a measure of the dispersion or spread of the percent error data.

Table 2 shows that the largest measurement uncertainties occurred at the smallest voltage levels. These uncertainties are considerably larger than what would be expected from published specifications [2-5]. Obviously, greater errors are incurred when making null types of measurements with such an uncertainty distribution. Also, summarizing all of the measured data as shown does not show the channel to channel reproducibility nor the effects of replication as detailed in the complete report. Table 3 shows a rather different distribution of errors including an obvious malfunction indication at the +10 and +100 V levels. Asymmetry effects in the errors are also apparent, but may be related to the malfunctions. It was subsequently learned that this second system had a defective data converter which produced erroneous measurements only when near its full-scale input.

Tables 4 and 5 give a summary of the 463 ac rms voltage observations taken at the Army test site. Table 4 shows the distribution of errors for observations at the applied voltage levels from 0.30 to 70.00 V rms. Table 5 shows the distribution of these same observations as a function of frequency from 50.00 to 50,000.00 Hz. The listing of the test program, sample printout of the program data, the run sequence of applied voltage/frequency combinations, etc., are contained in the complete report. As indicated by the mean percent error distribution in table 4, there is a distinct degradation in the mean errors for the ac voltage measurements at 7.00, 30.00, and 70.00 V rms as compared to the three lower levels at 0.30, 0.70, and 3.00 V rms. However, the randomness of the observations is considerably larger at the lower voltage levels as indicated by the larger maximum percent errors and corresponding standard deviations. Table 5, on the other hand, shows how relatively independent the ac voltage rms measurement uncertainties were with respect to frequency, except at 50 kHz where considerable dispersion occurred (only two samples per period are taken by EQUATE). In general, these uncertainties are in the range of the errors anticipated, although a significant number of observations (~50%) fall outside the published specifications [2-5].

Tables 6 and 7 give a summary of the 463 ac rms voltage observations taken at the Navy test site. Data were also taken at the 130.00 V rms level in this case. The distribution of these errors is rather different than the distribution of the errors for ac voltage measurements summarized in tables 4 and 5. As indicated by the mean percent error distribution shown in table 6, there is a distinct degradation in the mean errors for the four lower voltages (0.30, 0.70, 3.00, and 7.00 V rms) as compared to the three higher voltage levels (30.00, 70.00, and 130.00 V rms). Again, however, table 7 shows that the standard deviation of the measurement errors increases somewhat at 20 kHz and substantially at 50 kHz, being relatively independent of frequency over the remaining range. The large maximum percent error at the 7.00 V level in table 6 was observed at 50 kHz. Except for the test points noted, most of these observations are well within the range of the anticipated errors.

5.2 Pulse Duration Tests

Along with the dc and low frequency tests described above, the EQUATE systems were tested for their ability to measure the parameter PULSE DURATION over a range of 50-1000 ns. Briefly, this testing was accomplished by programming the EQUATE station to measure the PULSE DURATION parameter of a variety of pulses generated by the NBS calibrated pulse source described in section 4.2.

The NBS pulse source was used to test the EQUATE station's ability to measure PULSE DURATION through both the PIU and DIU measurement ports. For each of these ports, pulse source pulses with a nominal pulse amplitude of 400 mV and a pulse repetition rate of 20 kHz were used. As mentioned earlier, nominal PULSE DURATIONS of 50, 100, 200, 500, and 1000 ns were generated by the pulse source for measurement by the EQUATE station through the calibrated UUT output interfaces for both the PIU and DIU connectors.

On the EQUATE system, the measurement of the parameter PULSE DURATION is a three-step process. First the value of the 100 percent voltage level of the pulse is measured (VOLTAGE-P-MAX). Then the value of the 0 percent voltage level is measured (VOLTAGE-P-MIN). Finally, a time interval measurement is conducted between the computed 50 percent level positive slope portion of the pulse and the computed 50 percent level negative slope portion. This latter measurement yields the value of the PULSE DURATION.

There are a number of important subtleties encountered when making PULSE DURATION measurements both in terms of the pulse sampling electronics and the measurement algorithm used in the software. The particular problems encountered during these field tests concerning the pulse amplitude measurements (low-speed and high-speed voltage sampler, duty cycle, number of samples, etc.), as well as the ATLAS instructions used to obtain the minimum/maximum voltage levels and pulse duration, are fully described in the complete report.

Table 8 summarizes the pulse duration measurements made at the Army test site showing the 50 percent pulse duration mean deviations from the calibrated NBS value in percent. Five tables are provided in the complete report, each one containing the measurement results for all pulses measured on a particular PIU pin or DIU connector. These five tables each contain the observed data (five sequential measured values of pulse duration), the mean value of the five measurements, and the standard deviation of these readings (for each of the six nominal pulse durations of 50, 100, 200, 500, and 1000 ns), along with other pertinent data. What is shown in Table 8 under each PIU pin-pair or DIU connector is the difference in percent deviation from nominal of the mean value of the pulse measurements. Consequently, these data do not contain the maximum, minimum, and standard deviations shown for the dc and ac voltage measurements summarized in tables 4 through 7. Nevertheless, table 8 does provide a good indication of the variability in pulse duration error distribution, both as a function of the nominal duration from 50 to 1000 ns and the channel to channel reproducibility. The measurements made via the DIU ports (wider bandwidth channels) do not appear to be significantly better than those made via the PIU channels (note -16.1% maximum deviation). Since the NBS pulse source has an uncertainty well below ±1 percent, these deviations are real and significant. The small differences in NBS pulse durations at a given nominal value are due to the differences in the calibrated values for either a PIU or DIU connector (cf table 1).

The available documentation on the EQUATE system provided by the manufacturer contains no information concerning measurement accuracy specifications. The Army's system performance specifications (1976 and 1978 versions) do contain these specifications, but there is disagreement between the two documents and in some cases the specifications are very confusing.

For example, the accuracy specification in the 1976 document for "rise/fall time and pulse width measurement is

$$\pm(5 \text{ ns} + \text{trigger error}),"$$

where, on another page, trigger error is defined to be "less than

$$\pm \frac{3.2 \times 10^{-3}}{N} \times \frac{\text{sensitivity}}{\text{signal amplitude}},$$

where N = number of cycles of input signal over which measurement took place."

In the first expression, it is deduced that trigger error, being added to 5 ns, must have units of ns also. It is not at all obvious that the second expression for trigger error has units of ns. In addition, the interpretation of the meaning of N, for a pulse parameter measurement, is by no means clear nor is the meaning of the units of the term "sensitivity." In short, NBS personnel were unable to clearly determine the accuracy specification for these parameters. Also, these problems are not corrected or clarified in the 1978 document.

Table 9 summarizes the results of these same pulse duration measurements made at the Navy test site. Tests with the 500 ns (sharp cutoff) pulse duration were not made at Indianapolis due to time limitations. The nominal pulse source amplitude in this case was 2.50 V and the nominal pulse repetition frequency was 100 kHz in all cases. Also, the buffered mode of making voltage peak pulse measurements was utilized on the PIU channels. How voltage peak maxima exhibit a monotonic increase with longer nominal pulse durations or shorter duty cycles (which affect the resulting pulse duration measurement) is described in the complete report. Somewhat similar to the Tobyhanna data, the data in table 9 show erratic variation from -11.9 percent to -0.3 percent. In general, the buffered PIU measurement data appear to be in closer agreement with the NBS values than the unbuffered PIU data.

5.3 Time Domain Reflectometry Tests

The results of making PIU and DIU time domain reflectometry (TDR) tests are shown in figures 9 through 11. Figure 9 shows the 50 Ω TDR signature looking into the single available DIU BNC connector. Ideally, if the channel exhibited a perfect wideband 50 Ω impedance match, then the signature would appear as a smooth, uniformly flat-topped step waveform. The small deviations from flatness observed in the second and third time divisions are due to the TDR test pulse used and the EQUATE system connector. The wiggles in the seventh and eighth time divisions, however, <u>are</u> caused by the EQUATE DIU channel and indicate small (a few ohms) mismatches in impedance.

Figures 10 and 11 are the TDR signatures of pin-pairs 1 and 1S of the PIU channel in the unbuffered and buffered modes, respectively. In this case the impedance deviations are much more significant than in the DIU case. As a function of distance starting from the PIU ZIF connector and looking into the PIU channel, the impedance first rises to about 100 Ω (positive peak at the beginning of time division four), drops to about 25 Ω, and then meanders erratically back to about 50 Ω in the ninth time division. The buffered and unbuffered TDR signatures differ noticeably only in time divisions six through nine. These large deviations of impedance are strong indications that pulses in the nanosecond domain measured through the PIU are appreciably distorted.

6. CONCLUSIONS AND RECOMMENDATIONS

This report describes the executive summary of a limited experimental investigation of the measurement performance of two ATE stations (AN/USM-410 EQUATE). From the experience of preparing transport standards, collecting the test data, participating in various ATE-related meetings and conferences, perusal of pertinent literature, other on-site visits, etc., conclusions and recommendations concerning future efforts are summarized below. A more complete discussion regarding future efforts is contained in the full report.

6.1 Feasibility of Using Dynamic Transport Standards

The concept of performing an on-site, "in-situ" test of the system performance characteristics at the stimulus/measurement interface connector, using well-calibrated transport standards, has been demonstrated to have merit. Measurement uncertainties that would otherwise be undetermined can be quantified. An independent verification of the accuracy specification for basic dc and ac voltage and pulse duration measurements, common to most ATE system capability, can be established. The accuracy of other measurement (and stimulus) parameters are also capable of being verified in similar fashion. The in-situ system test/calibration procedure accounts for hidden errors due to signal path losses, noise interference from pickup and crosstalk, and drifts or offsets in the electronics of the ATE. More subtle deleterious effects due to special algorithms used in the computer software or transmission/decoding errors in the digital interfaces of the system are also reflected in the data obtained from system performance verification/calibration testing. Section 5 in this report describes in detail the measured deviations from the nominal NBS value of the dc/ac voltage and pulse duration data on specified channels of the two AN/USM-410 systems studied. These systems utilize built-in secondary standards for dc and ac voltage as well as for frequency (time base). Self-check and calibration software (SYSCAL) is also provided for these systems. Nevertheless, significant deviations, both in magnitude and number of data points, were obtained from these two systems. Consequently, the feasibility of the dynamic transport standard (DTS) concept for performance checking and system calibration purposes has been verified within the limitations mentioned.

6.2 Calibration and Characterization Methods

Several approaches and procedures are in common usage for providing calibration support of ATE [6]. As detailed in many of the papers referenced in [6], there are numerous shortcomings to the present piecemeal approach of removing instruments or built-in standards from the system for calibration at a remote metrology laboratory. Because of the need for performing maintenance and/or repair on these items, however, it is recognized that such "off-line" procedures are often very practical or may be the only viable calibration support available. In some cases, the mean-time-between-failures (MTBF) of the system is low so that the time to run a system calibration significantly reduces the available up-time for UUT testing. Nevertheless, where the MTBF of the ATE system is high enough and transport standards can be made available which are compatible (UUT/interface device adapter connectors, loading impedances, signal levels, etc.), procedures for calibrating the system on-site at the UUT/interface device adapter terminals are preferable.

The measurement data contained in this report (from the limited experimental investigation of two EQUATE stations) does not constitute a comprehensive system calibration of these stations. However, these data are an indication that such a system calibration procedure could be used either routinely or as an occasional verification test that system specifications are being met, in-situ. Various schemes for providing internal calibration tests, and associated hardware adjustments or software generated offset and gain/attenuation corrections, are being incorporated in many ATE systems. As microcomputers are utilized more in individual instrument building blocks within a system, these internal calibration means are distributed throughout the system. Therefore, whether the system computer is directly involved as part of the stimulus and measurement capability, as in the architecture of third generation systems such as EQUATE, or whether the signal processing is more distributed, as in the architecture of "distributed intelligence" fourth generation systems, independent verification of the calibrated system performance at the UUT/interface adapter connector plane is an important task in the metrology support of the system.

Figure 12 illustrates the method whereby the present calibration services and Measurement Assurance Program (MAP), provided by NBS for basic electrical quantities, can be augmented with the capabilities of both ATE-specific and high accuracy DTSs, as described in [6]. A viable method for supplementing the present ATE calibration hierarchy would be to make use of the DTS concept. As indicated by the solid arrowed lines, the normal path of support by means of an NBS DTS is through a key standards or calibration laboratory. Commercial "roll-up" standards which serve as working accuracy DTSs (dedicated, perhaps, to a specific ATE system) are then calibrated using the NBS DTS and any other appropriate standards. The commercial DTS, in turn, is periodically used to provide a system calibration at the UUT/interface device adapter of the ATE. This periodic testing of system performance serves as a verification that built-in self-tests are maintaining the quality of the measurements of the system. The removal of certain "core" stimulus or measurement equipment or built-in standards for testing and/or calibration in a laboratory is still optional, of course, but may not be necessary.

6.3 Needs at NBS for Automated Calibration Support Systems

To assure that the metrology support of ATE system performance can efficiently be traced back to national laboratory standards at NBS, there is a considerable need at this time for developing appropriate automatic test and calibration systems. Some of the calibration services at NBS, in fact, are already automated. But these setups are primarily dedicated to providing support for the relatively few and generally fixed-value transfer standards passed between NBS and corporate level standards laboratories. The DTS concept and calibration support strategy implies a system whereby the relatively complex DTSs can be readily maintained, i.e., well-characterized and calibrated. Because of the various kinds, ranges, and levels of calibration parameters of interest, and the need for a considerable amount of documentation, automation of the calibration support system is essential. Desk-top or minicomputer-based systems are anticipated at NBS and at the key standards or calibration laboratory to interface with the DTSs and make the necessary comparison measurements. A more comprehensive description of this calibration support strategy is given in the complete project report.

6.4 Recommendation for Future NBS ATE Efforts

Having demonstrated the need for, and viability of, in-situ ATE performance verification by means of well-characterized and calibrated sources used as transport standards, we propose to continue and expand the work. In view of the great leverage obtained by a properly performing ATE system on military weapons readiness, an expanded NBS program is felt to be of significant cost effectiveness to the DoD. The beneficial results of continuing this work are the improvements in system internal calibration and self-test programs, and maintaining better test consistency, uniformity, and traceability of measurements made by DoD's large inventory of ATE systems.

Immediate efforts of the present JLC 30702 Project will be directed at extending the field studies that have been carried out by NBS staff at both the Gaithersburg and Boulder laboratories. The details of the proposed work are outlined under the following tasks in the complete report.

(1) Field Studies of Selected ATE Systems

(2) Dual-Channel Signal Source for On-Site Calibration of ATE

(3) Improved Characterization Methods for Signal Sources

(4) Improved Pulse Waveform Stimulus Source

(5) Improved Automatic Waveform Analysis and Measurement System

The above tasks will build a foundation at NBS for providing basic metrology for supporting both present and future ATE systems used by the DoD. We also propose a longer range effort which would develop similar support for other critical measurement parameters in the low frequency and pulse waveform domain, as well as coverage of RF, microwave/millimeter wave, and optical regions of the electromagnetic spectrum. For example, an RF signal source capable of generating signals with amplitudes from 0.1 to 7 V rms and frequencies up to 100 MHz will be accurately characterized for stability, temperature dependence, and other environmental effects, and its traceability rigorously established by calibration against higher echelon laboratory standards at NBS. This source, and other high-frequency dynamic transport standards to be developed, will also need automatic calibration systems at NBS for proper support as described in section 6.3.

7. REFERENCES

[1] IEEE Standard on Pulse Measurement and Analysis by Objective Techniques, IEEE Std. 181-1977, July, 1977.

[2] Performance Requirements, Test Station, Electronic Equipment, AN/USM-410(XE-3)(V), ET & DL 75-04513-002, Frequency Control and Signal Processing Devices Technical Area, U.S. Army Electronics Technology and Devices Laboratory, U.S. Army Electronics Command, 13 April 1976, pp. 36, 37, and 42.

[3] Performance Requirements, Test Station, Electronic Equipment, AN/USM-410(XE-4)(V), ET & DL 76-410XE4-AAH, Frequency Control and Signal Processing Devices Technical Area, U.S. Army Electronics Technology and Devices Laboratory, U.S. Army Electronics Command, 10 September 1976, Revised 1 June, 1978, pp. 25, 26.

[4] Hardware Development Specification, Type B, Electronic Equipment Test Station, AN/USM-410( )(V), (EQUATE), Contract No.: DAAK80-79-C-0033 SLIN 0006AR, RCA Corporation, Automated Systems, Government Systems Division, Burlington, Mass., 15 September 1980, Revised 10 April 1981, Tables 3.2.1.4.1-1, 3.2.4.3-1, and 3.2.4.3-2.

[5] EQUATE ATLAS Programming Manual for AN/USM-410( )(V), Electronic Equipment Test Station, Volume 1, Change 3, RCA, January 1982, p. 9-107 and p. 9-115.

[6] B. A. Bell and O. Petersons, ATE Calibration by Means of Dynamic Transport Standards, Proceedings of AUTOTESTCON '81, Oct. 19-21, 1981, pp. 280-287.

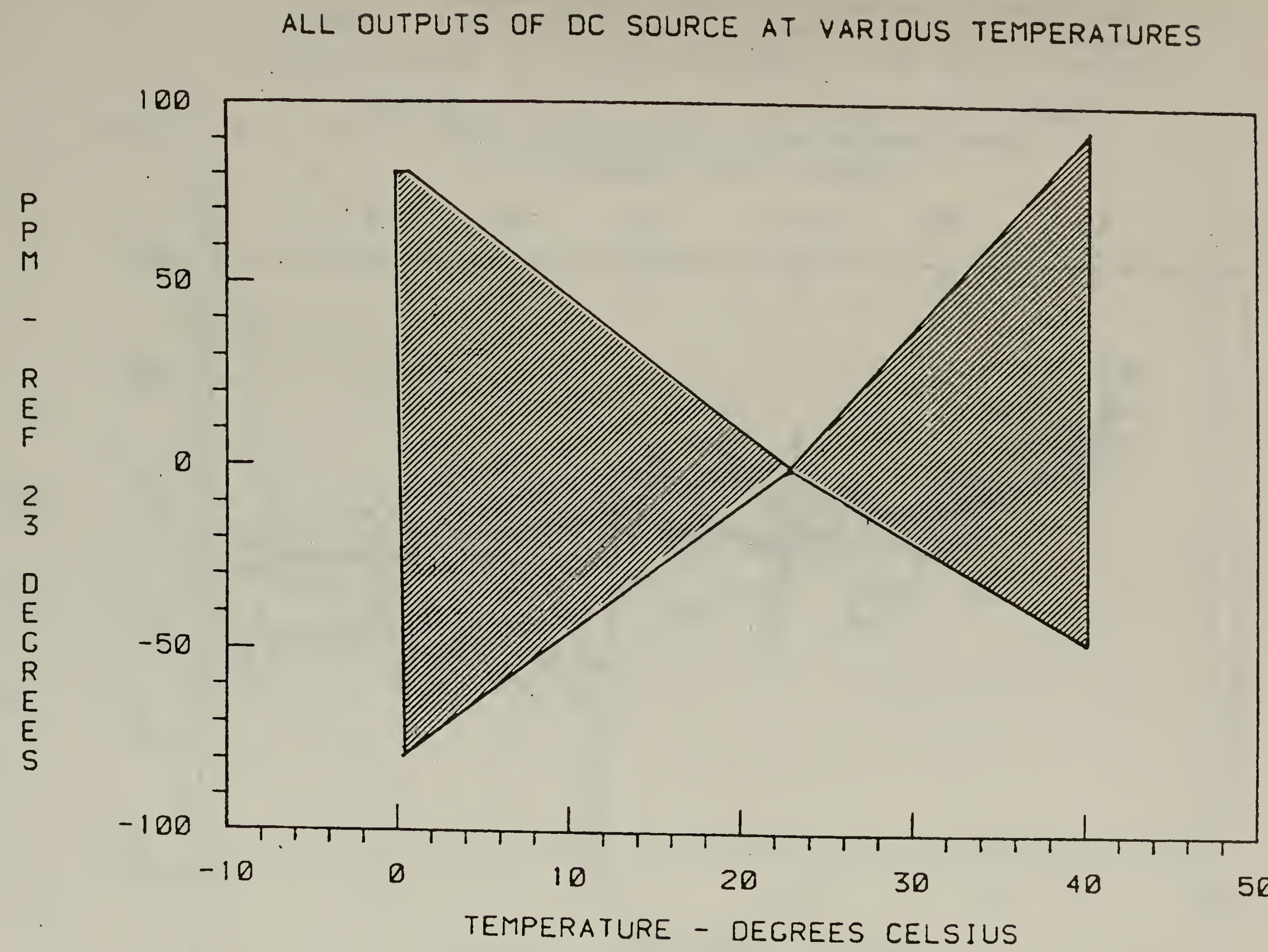


Figure 1. The limits in the changes of the output voltage of the source over the temperature range 0° to 40°C.

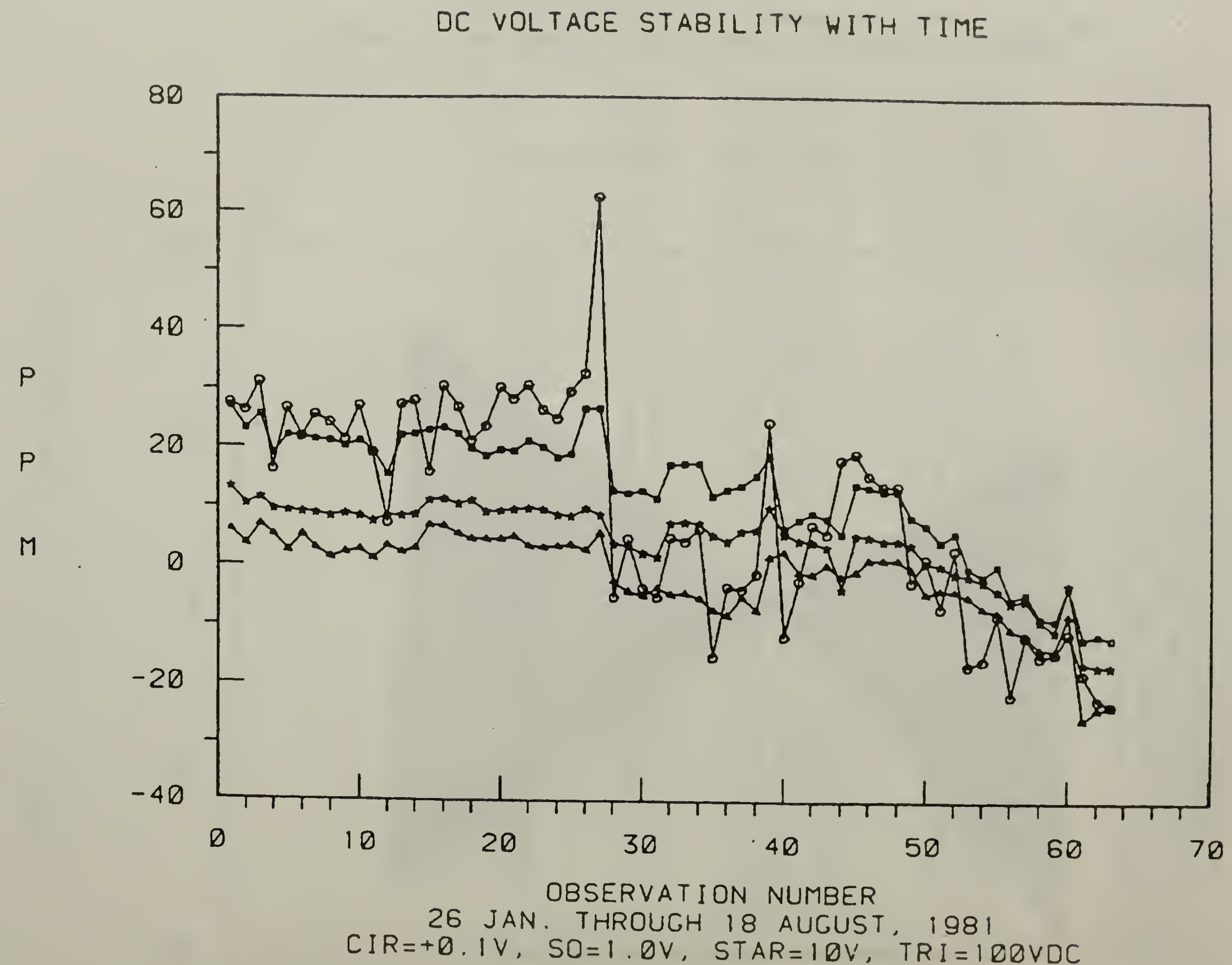


Figure 2. The change of the dc voltage output at four selected voltages over a period of approximately seven months.

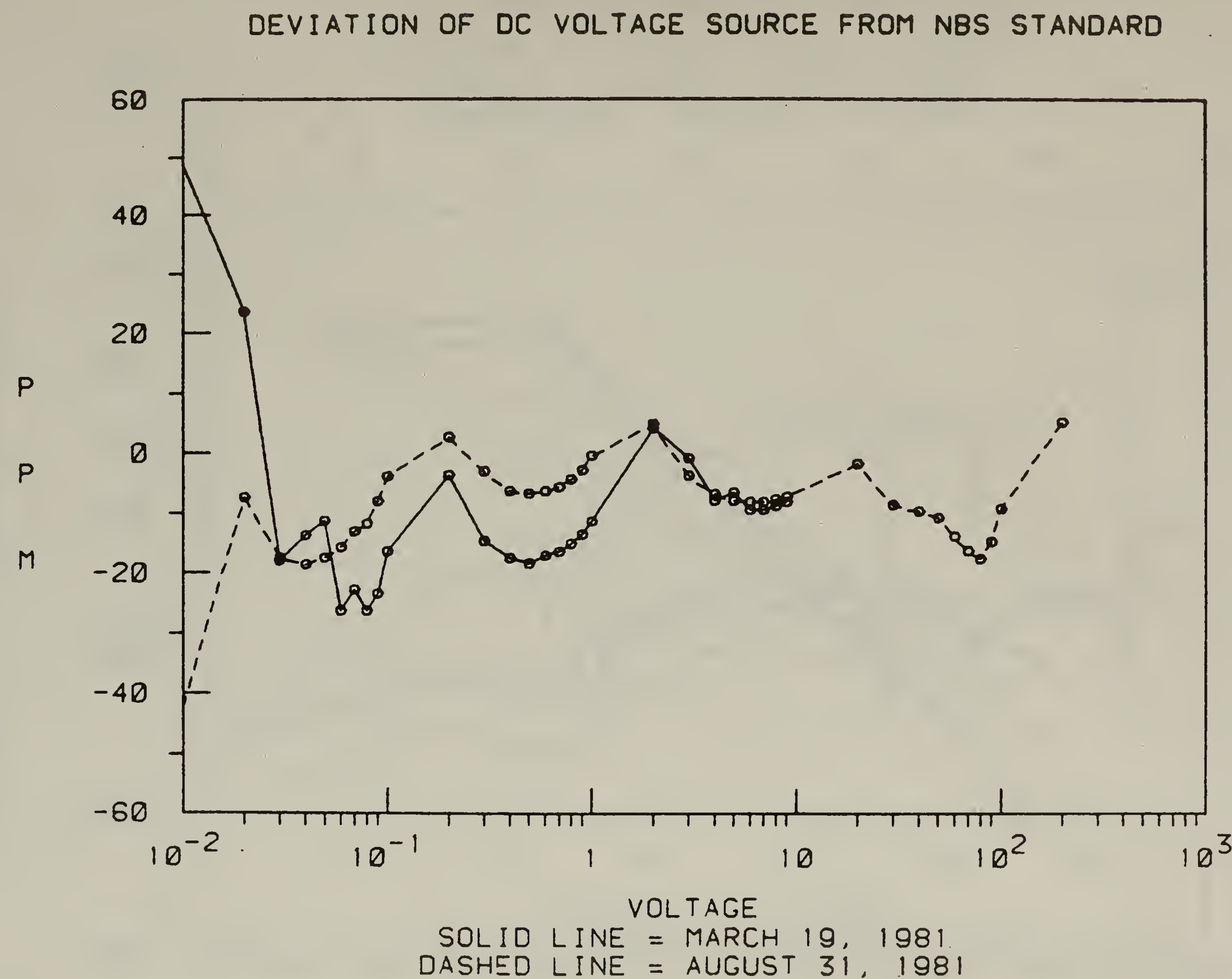


Figure 3. The difference, on two occasions, between the dc output voltage of the source and the NBS Legal Volt as maintained by the Electrical Measurements and Standards Division of NBS.

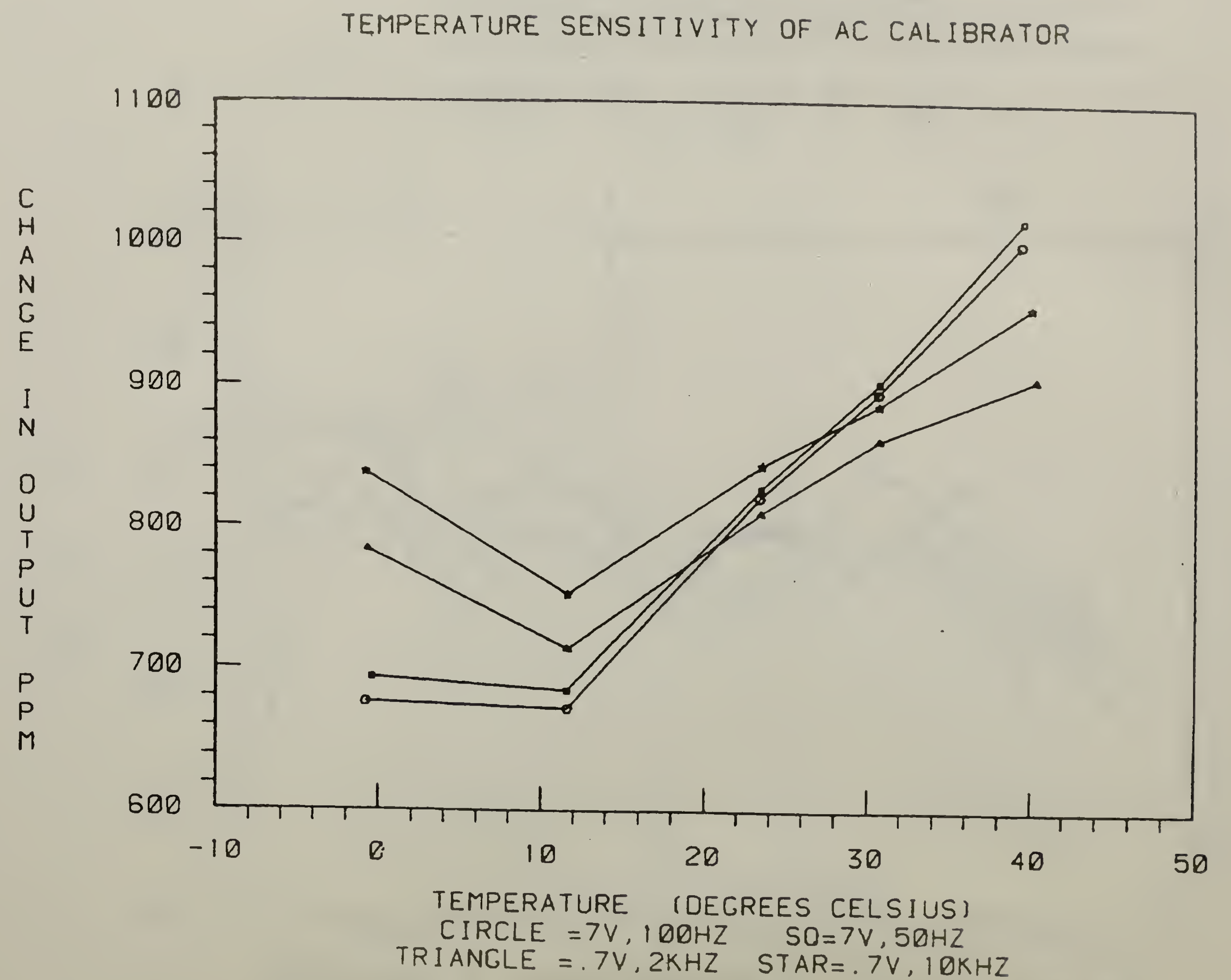


Figure 4. The change in ac output voltage as a function of ambient temperature.

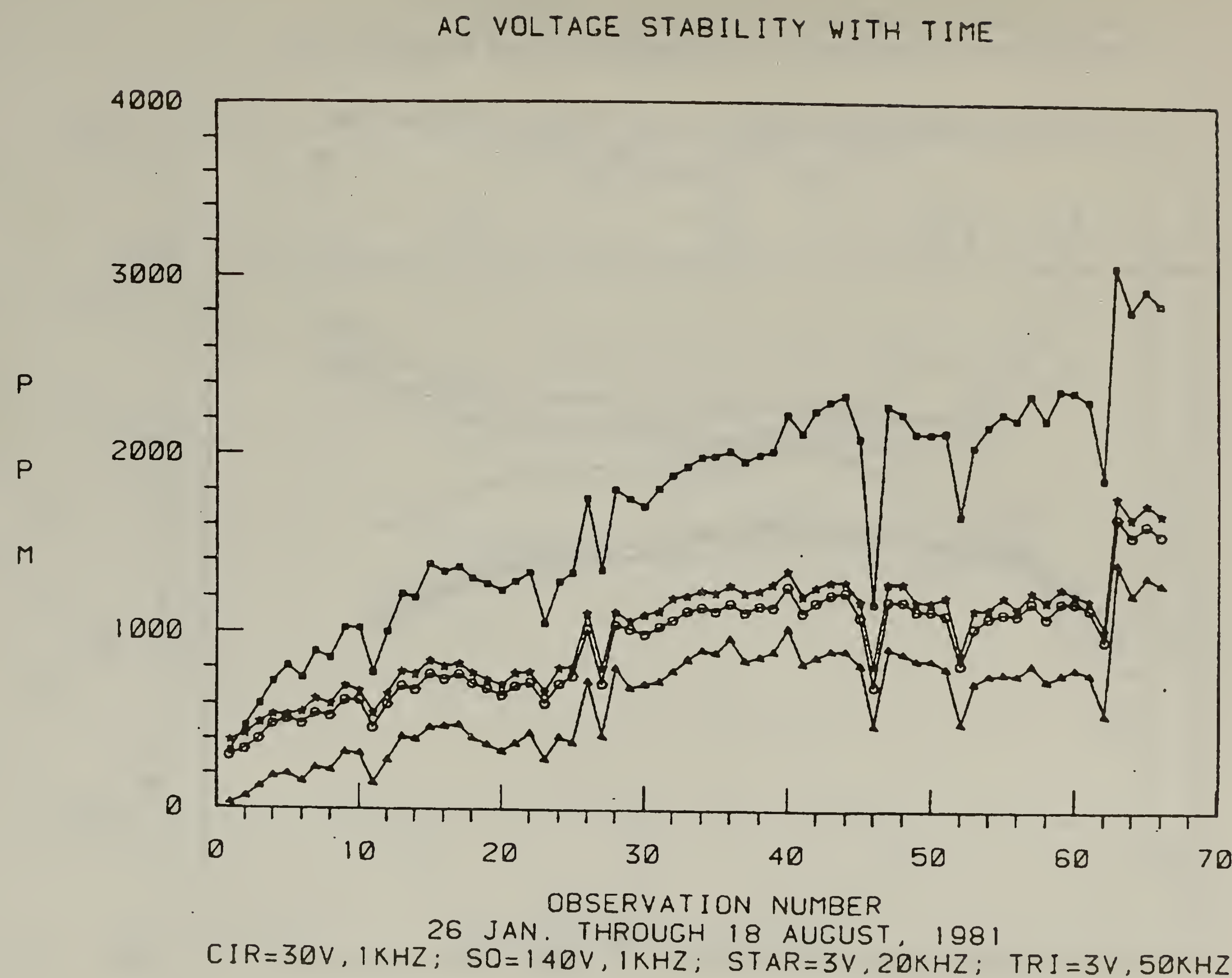


Figure 5. The change of the ac voltage output of the source at four selected voltage and frequency combinations over a period of approximately seven months.

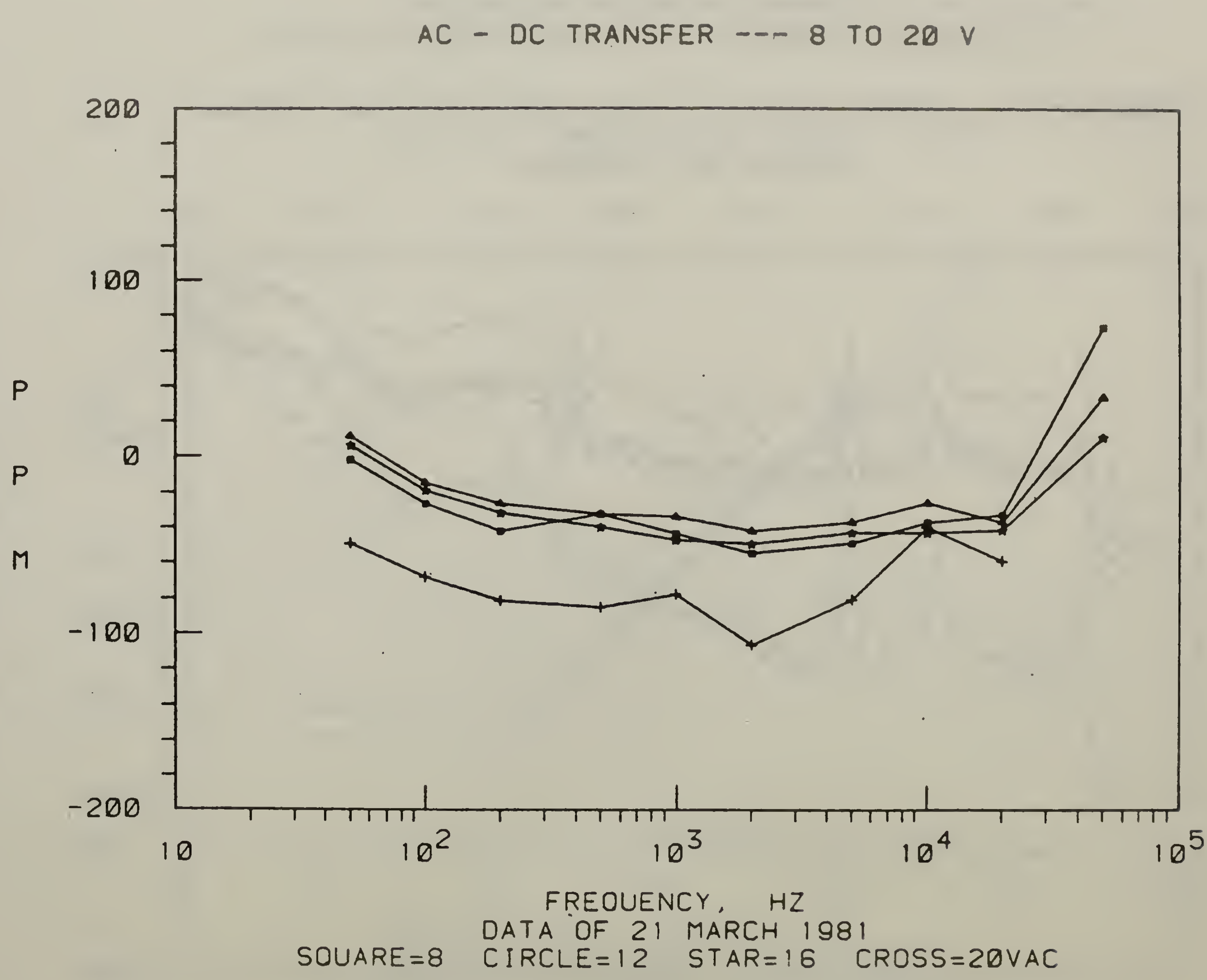


Figure 6a. The results of the ac-dc intercomparison over the range of 8 to 20 V ac and over the frequency range of 50 Hz to 50 kHz.

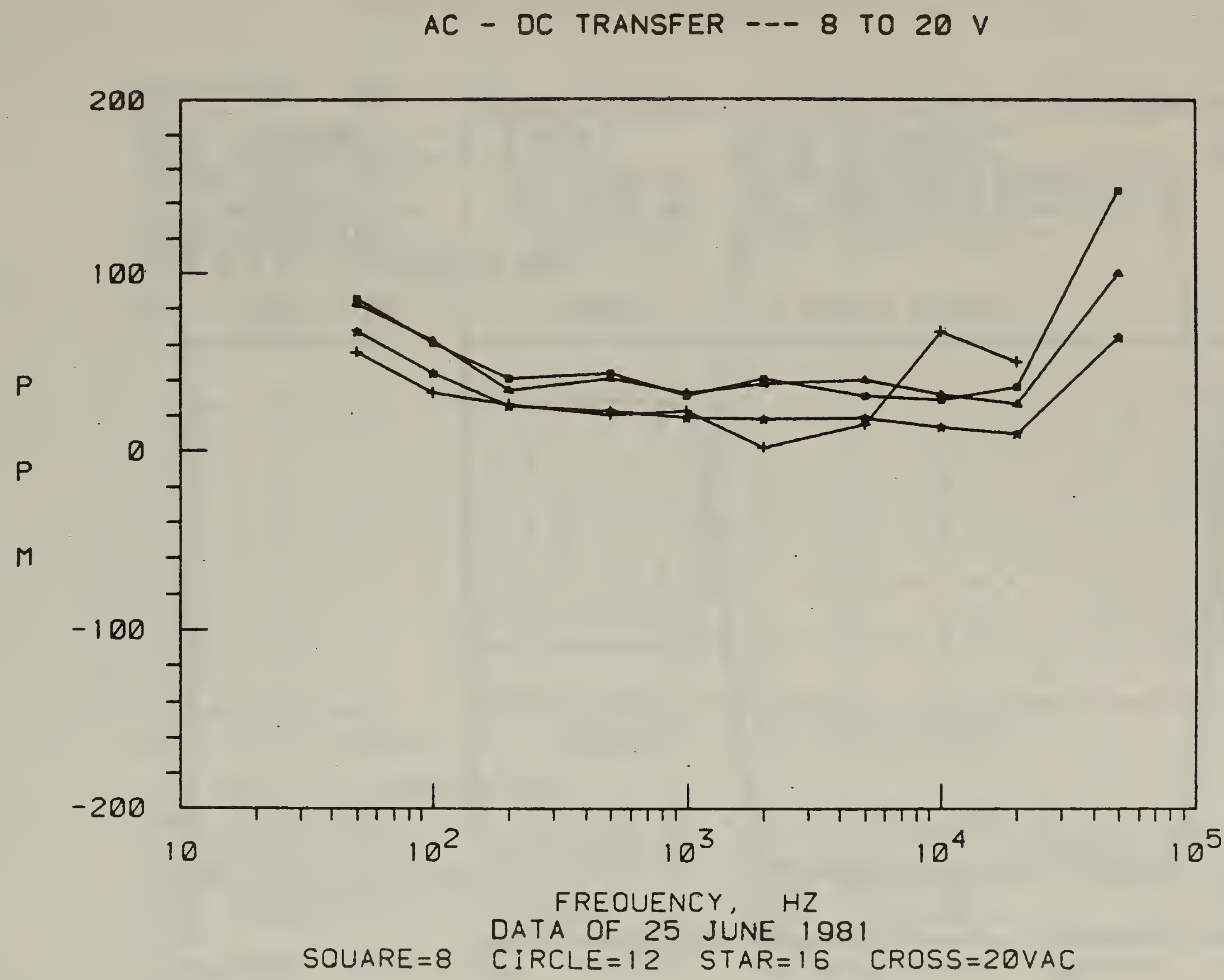


Figure 6b. The same intercomparison as shown in figure 6a performed three months later.

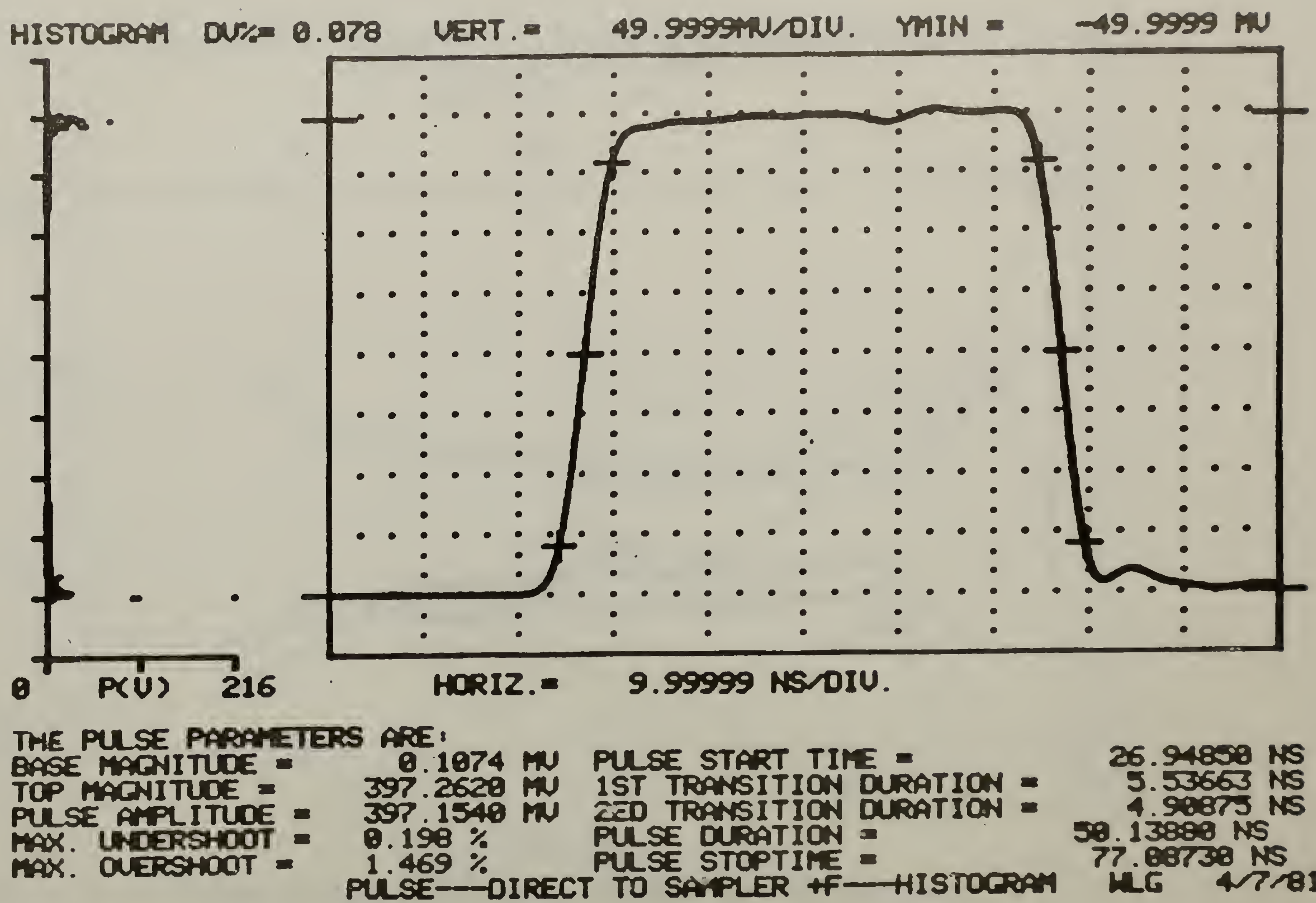
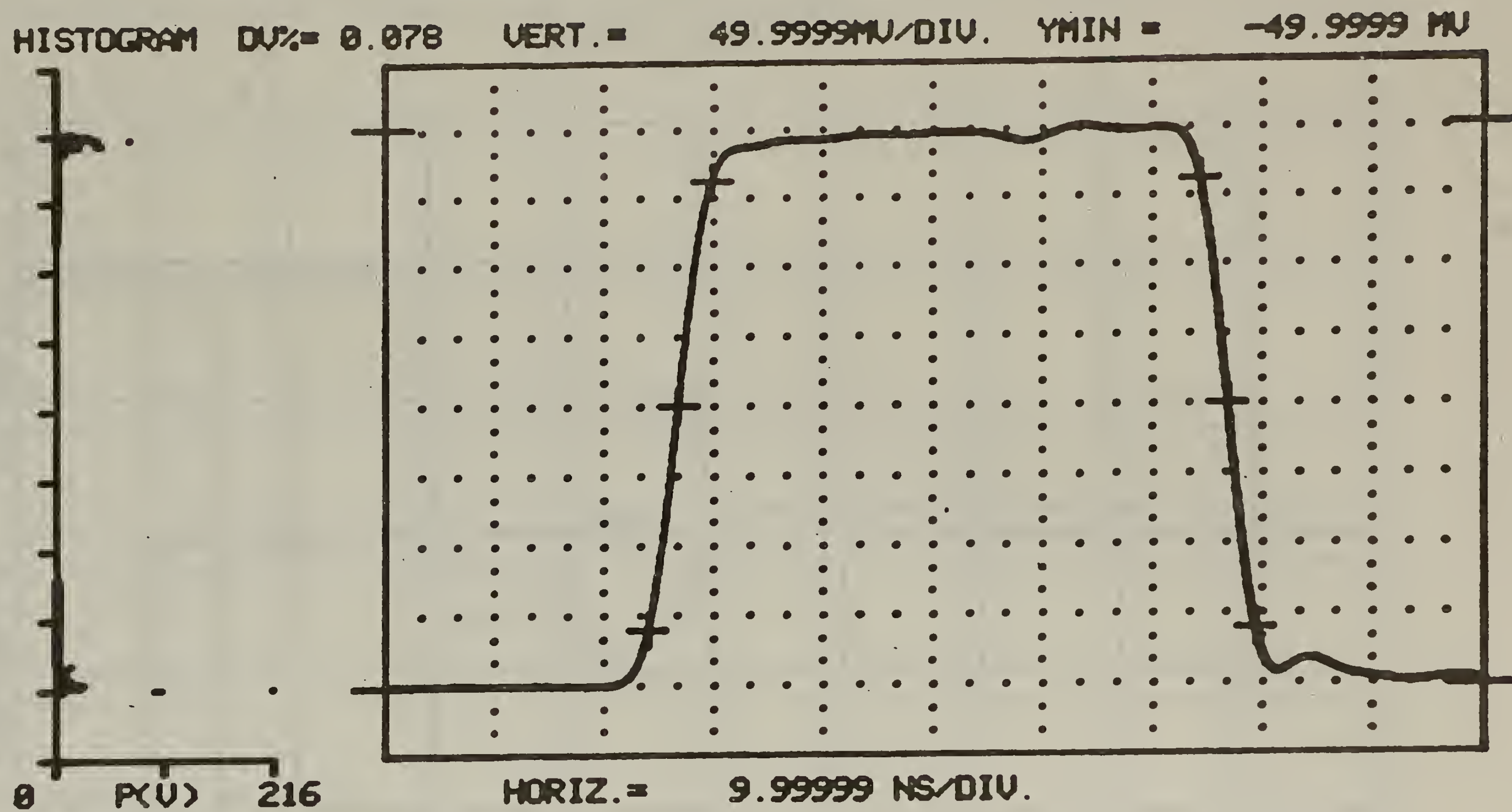


Figure 7. NBS pulse source 50 ns pulse direct to APMS sampler with 5 ns NBS filter (HISTOGRAM definition).



THE PULSE PARAMETERS ARE:
BASE MAGNITUDE = -0.6812 MV
TOP MAGNITUDE = 403.0980 MV
PULSE AMPLITUDE = 403.7790 MV
MAX. UNDERSHOOT = 0.000 %
MAX. OVERSHOOT = 0.000 %
PULSE START TIME = 26.97730 NS
1ST TRANSITION DURATION = 5.755[illegible]8 NS
2ED TRANSITION DURATION = 5.05453 NS
PULSE DURATION = 50.08020 NS
PULSE STOPTIME = 77.05760 NS
PULSE---DIRECT TO SAMPLER +F---MIN-MAX WLG 4/7/81

Figure 8. NBS pulse source 50 ns pulse direct to APMS sampler with 5 ns NBS filter (MIN-MAX definition).

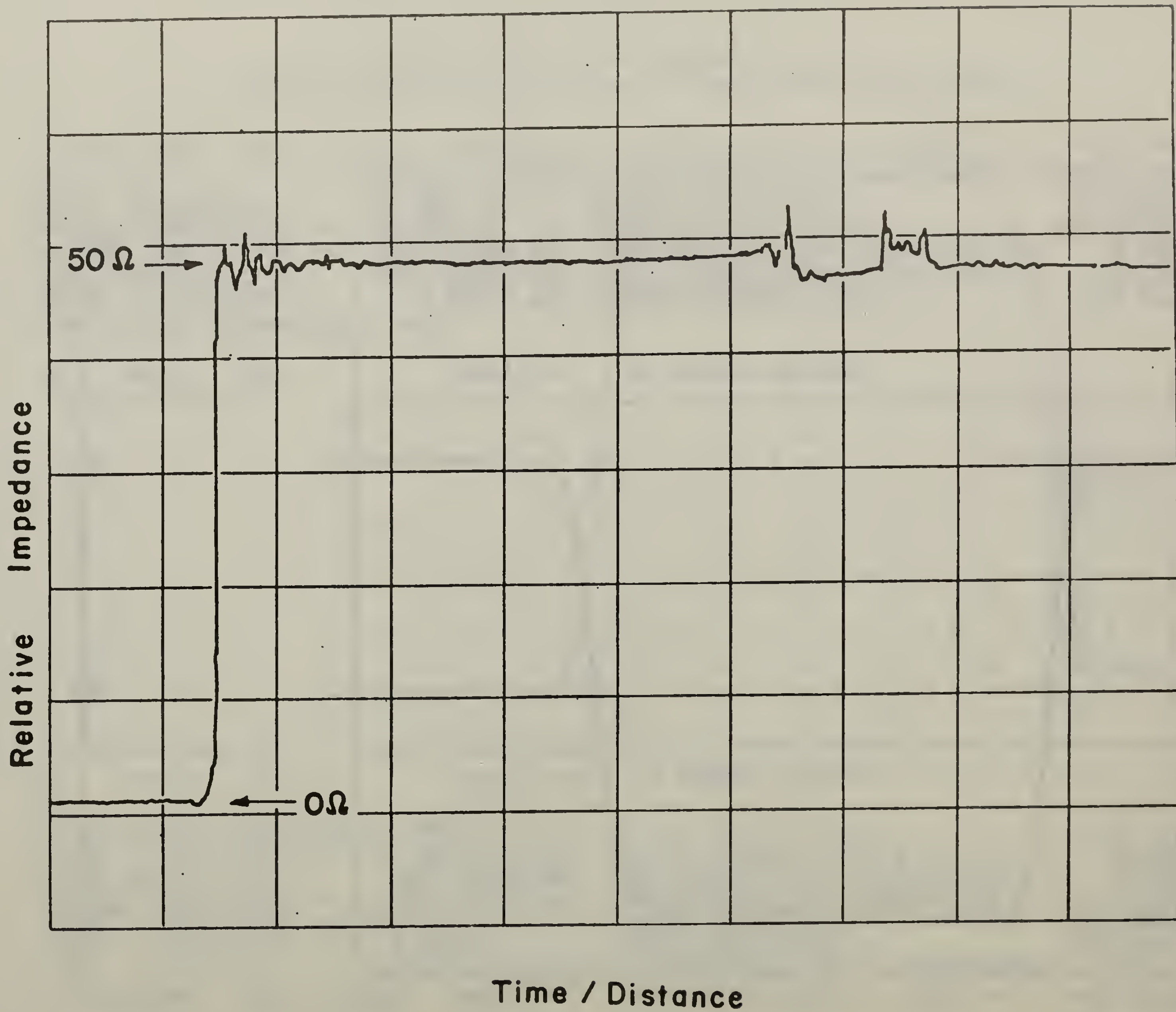


Figure 9. A time domain reflectometry signature of the 50 Ω DIU BNC connector port to EQUATE.

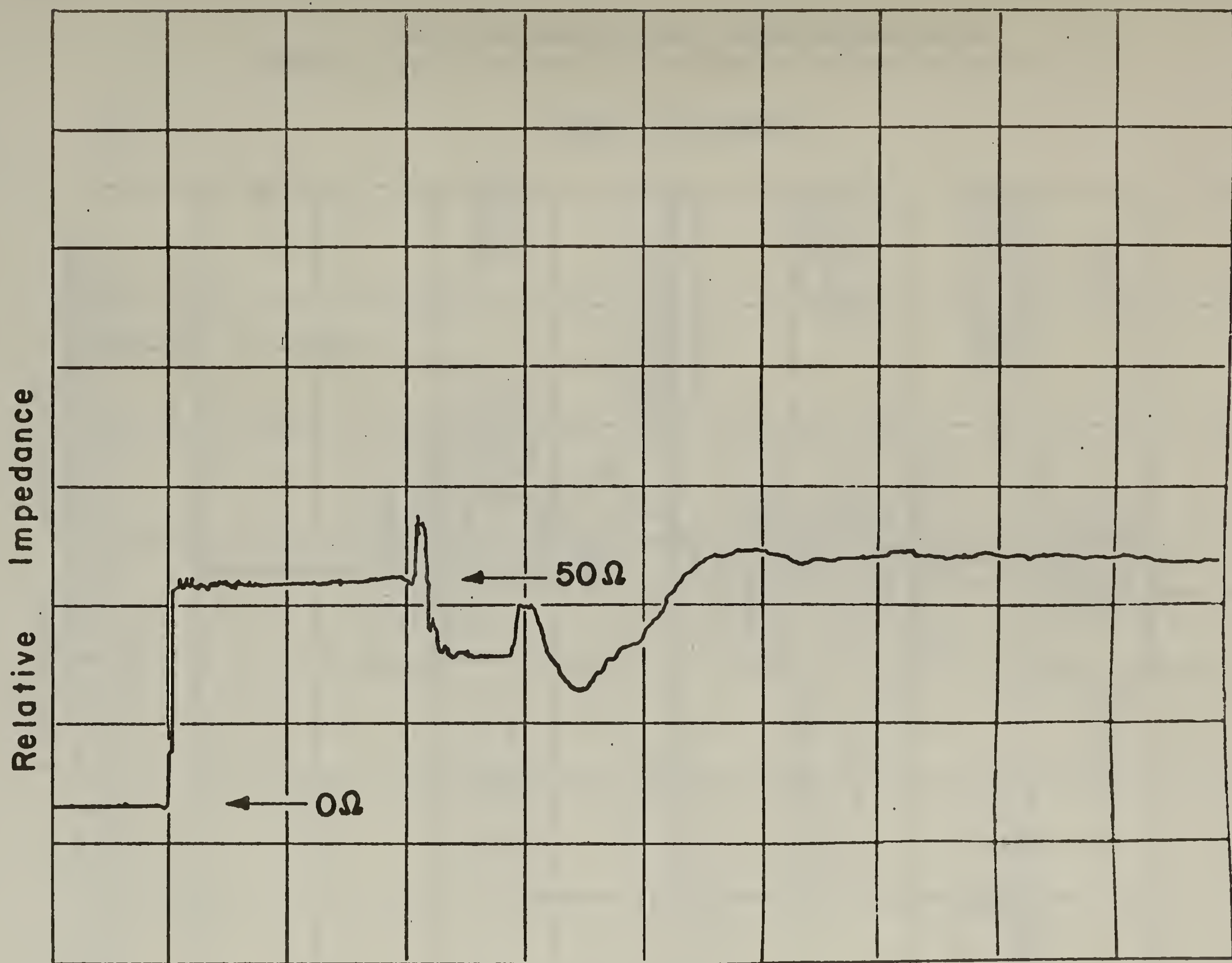


Figure 10. The time domain reflectometry signature of pin-pair 1 and 1S of the PIU input in the unbuffered mode.

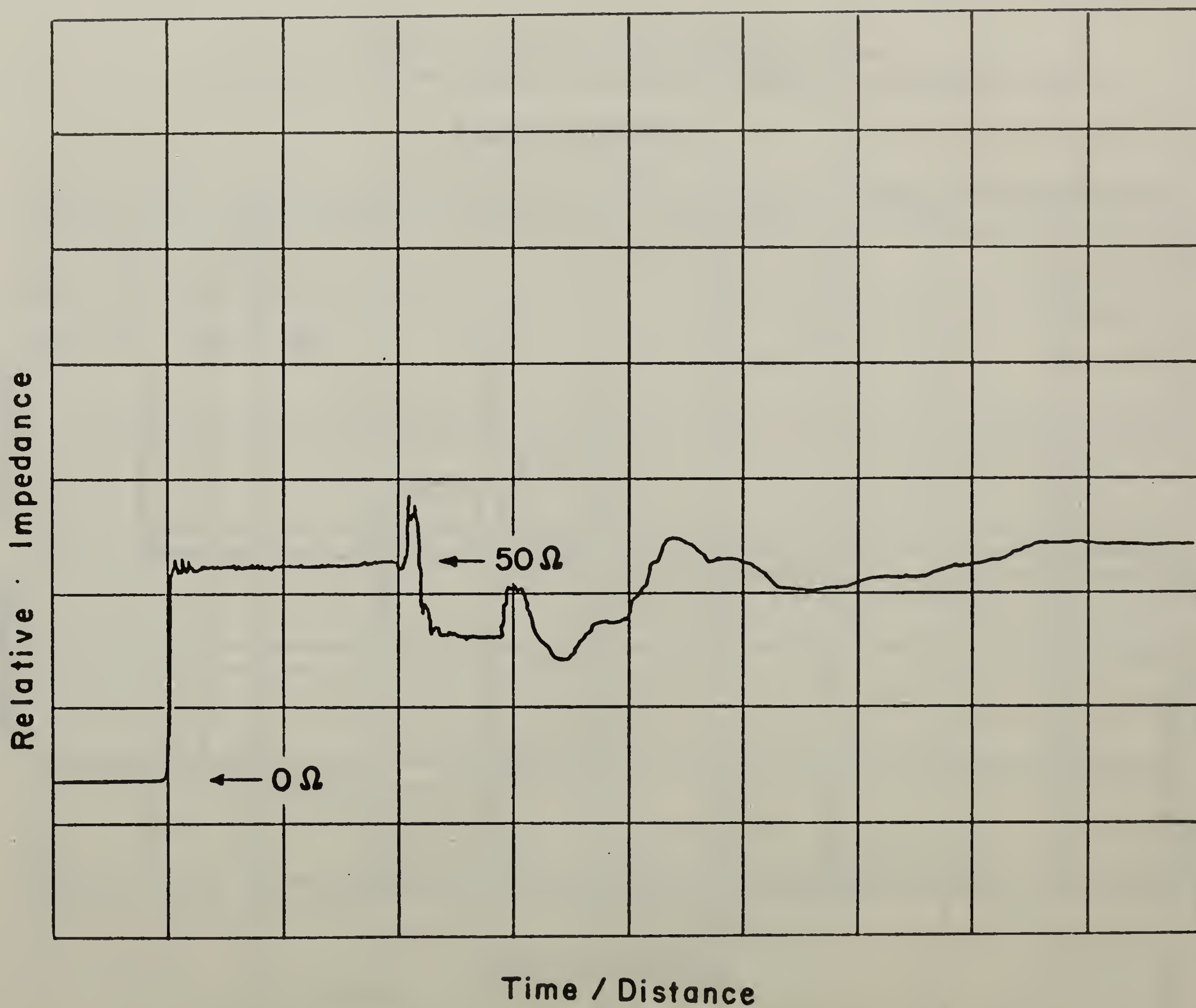


Figure 11. The time domain reflectometry signature of pin-pair 1 and 1S of the PIU input in the buffered mode.

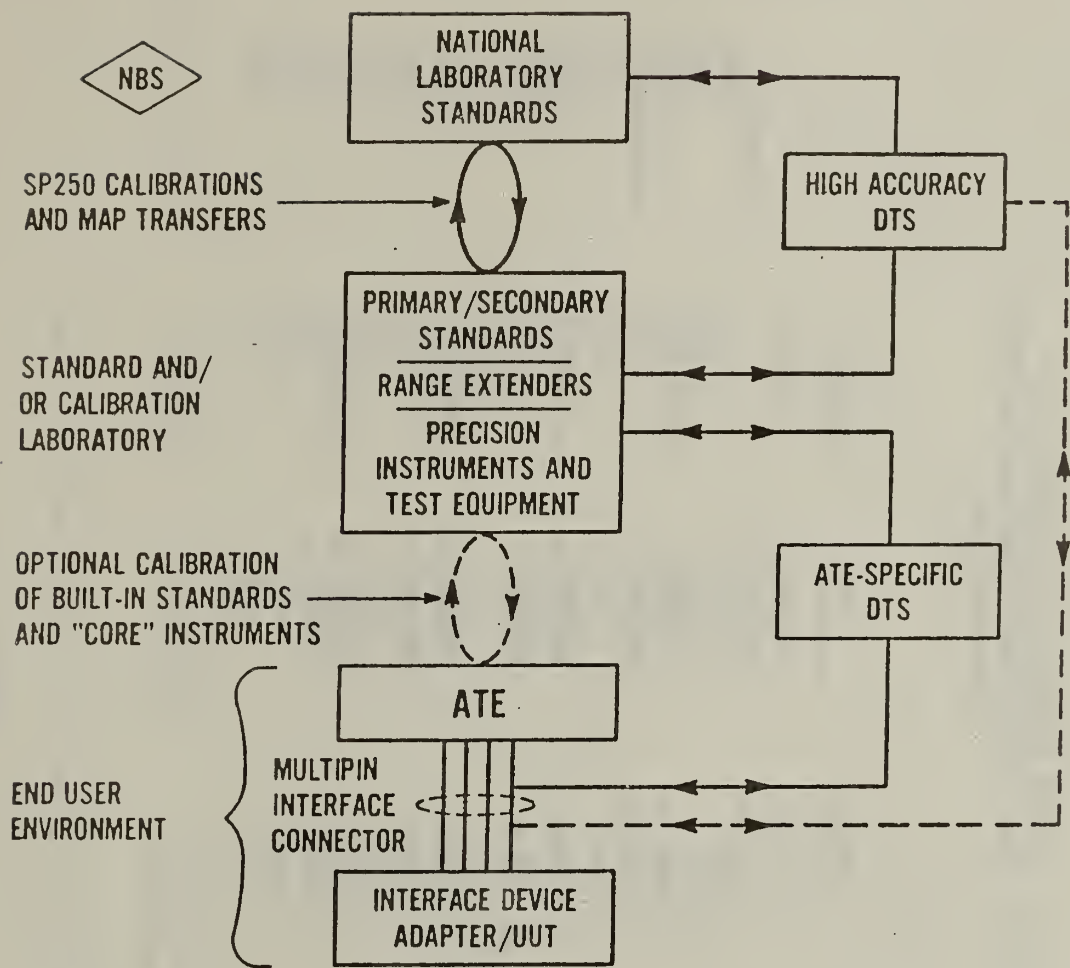


Figure 12. A Dynamic Transport Standard concept and support strategy. Dashed lines indicate that the transport standard is physically moved from one location to another.

Table 1

Pulse Generator Time Stability
Min.- Max. 50 Percent Pulse Duration Method
Calibration Data

Nominal Pulse Duration	Connector	Filter	4-7/8	6-25/26/30	7-1/2	$\Delta\tau$ (%)
50 ns	BNC (DIU)	5 ns	50.066 ns	50.320 ns		+ 0.51
	ITT (PIU)	5 ns	50.079 ns		49.875 ns	- 0.41
100 ns	BNC	5 ns	99.758 ns	100.337 ns		+ 0.58
	ITT	5 ns	99.752 ns		99.637 ns	- 0.12
200 ns	BNC	50 ns	200.177 ns	199.627 ns		- 0.28
	ITT	50 ns	200.268 ns	- - -		- -
500 ns	BNC	50 ns	501.841 ns	499.976		- 0.37
	ITT	50 ns	501.815 ns	- - -		- -
1000 ns	BNC	50 ns	999.745 ns	999.648 ns		- 0.01
	ITT	50 ns	999.784 ns	- - -		- -

Table 2

Summary of Army DC Voltage Observations

Nominal Voltage	No. of Obsv'ns	Maximum % Error	Mean % Error	Minimum % Error	Standard Deviation of % Error
-195.00	10	-.093	-.075	.000	.026
-100.00	30	.088	.067	-.006	.037
-50.00	30	.092	.077	.051	.010
-10.00	30	-.073	.031	.040	.030
-5.00	30	-.423	-.130	-.020	.112
-1.00	30	-2.167	-.728	-.195	.554
-.50	30	-4.415	-1.651	-.641	1.081
-.10	40	-18.939	-7.717	-3.334	4.519
.10	20	30.905	10.159	3.748	7.734
.50	30	4.951	1.839	.762	1.205
1.00	30	2.482	.938	.420	.587
5.00	30	.469	.175	.068	.114
10.00	30	.237	-.006	.001	.098
50.00	30	.085	.058	.044	.010
100.00	30	-.287	-.265	-.228	.016
195.00	10	-.203	-.188	-.173	.008

Table 3

Summary of Navy DC Voltage Observations

Nominal Voltage	No. of Obsv'ns	Maximum % Error	Mean % Error	Minimum % Error	Standard Deviation of % Error
-195.00	30	-.476	-.471	-.467	.002
-100.00	30	-.617	-.606	-.598	.005
-50.00	30	-.242	-.240	-.239	.001
-10.00	30	-.544	-.539	-.533	.003
-5.00	30	-.003	-.001	.000	.001
-1.00	30	-.096	-.084	-.070	.007
-.50	30	.024	.006	.000	.008
-.10	40	-.301	-.234	-.028	.048
.10	20	.264	.202	.110	.037
.50	30	.074	.060	.041	.008
1.00	30	1.715	.879	.281	.457
5.00	30	.021	.001	.000	.004
10.00	30	2531.080 *	-292.840 *	-244.954 *	549.074
50.00	30	-.081	-.079	-.077	.001
100.00	30	-200.132 *	-200.127 *	-200.115 *	.004
195.00	30	-.028	-.023	-.019	.002

* These large errors were attributed to a data converter found to be defective during the field tests.

Table 4

Summary of Army AC Voltage Observations

Nominal Voltage	No. of Obsv'ns	Maximum % Error	Mean % Error	Minimum % Error	Standard Deviation of % Error
.30	80	9.54	.48	.00	1.74
.70	88	-7.99	-.07	.01	1.31
3.00	80	-12.61	-.37	.01	2.50
7.00	80	-8.70	-2.03	.07	1.72
30.00	72	-3.16	-2.13	-1.91	.35
70.00	64	-2.25	-1.75	.00	.62

Table 5

Nominal Frequency	No. of Obsv'ns	Maximum % Error	Mean % Error	Minimum % Error	Standard Deviation of % Error
50.00	48	-1.93	-.66	.04	1.00
100.00	56	-1.97	-.66	.00	.99
200.00	48	-1.99	-.74	.02	1.01
500.00	48	-2.00	-.94	-.01	1.00
1000.00	48	-1.99	-.94	.02	1.00
2000.00	48	-2.03	-.94	.01	1.01
5000.00	48	-2.08	-.93	.01	1.02
10000.00	48	-2.42	-1.08	-.01	1.08
20000.00	40	-3.16	-.73	.00	1.18
50000.00	32	-12.61	-1.90	1.22	6.01

Table 6

Summary of Navy AC Voltage Observations

Nominal Voltage	No. of Obsv'ns	Maximum % Error	Mean % Error	Minimum % Error	Standard Deviation of % Error
.30	70	2.85	.39	.00	.78
.70	70	2.45	.33	.00	.70
3.00	70	-1.47	-.15	.00	.45
7.00	70	-35.32	-3.57	.00	10.58
30.00	63	-.44	-.03	.00	.14
70.00	56	.44	.03	.00	.12
130.00	35	.59	.08	.01	.14

Table 7

Nominal Frequency	No. of Obsv'ns	Maximum % Error	Mean % Error	Minimum % Error	Standard Deviation of % Error
50.00	49	.22	.08	.00	.07
100.00	49	.59	.08	.00	.18
200.00	49	.23	.05	.00	.08
500.00	49	.15	.03	.00	.07
1000.00	49	.19	.05	.00	.07
2000.00	42	.19	.07	.00	.08
5000.00	42	.26	.07	.00	.08
10000.00	42	.22	.00	.00	.10
20000.00	35	-.61	-.18	.11	.35
50000.00	28	-35.32	-7.89	-1.37	15.90

Table 8

Pulse Duration Measurements
by
EQUATE System #5 at Tobyhanna Army Depot, April 20, 1981
Min. - Max. Sampling, 50 Percent Pulse Duration Mean Deviations
From Calibrated NBS Value in Percent

	PIU			DIU		
NBS Pulse Duration, ns	Pins 1 & 11	Pins 44 & 28	Pins 120 & 92	BNC # 1	BNC # 2	BNC # 4
50.07				-16.1	-16.1	-16.1
50.08	- 1.0	- 12.1	+ 1.4			
99.75	- 8.6	- 8.6	- 7.4			
99.76				- 7.8	- 7.4	- 7.4
200.2				- 1.7	- 1.7	- 1.1
200.3	- 1.5	- 2.7	- 0.3			
500.6				- 1.3	- 1.2	- 1.3
500.8	- 2.2	- 2.2	- 1.8			
501.8	- 2.4	- 2.6	- 1.9	- 0.9	- 0.9	- 1.0
999.7				- 0.2	- 0.3	- 0.2
999.8	- 1.2	- 1.1	- 0.9			

Table 9

Pulse Duration Measurements
by
EQUATE System #1 at Naval Avionics Center, July 8, 1981
Min. - Max. Sampling, 50 Percent Pulse Duration Mean Deviations
From Calibrated NBS Value in Percent

	PIU			
NBS Pulse Duration, ns	Pins 1 & 1s	Pins 19 & 19s	Pins 58 & 58s	DIU BNC # 1
50.07				- 1.3
50.08	- 4.6	- 8.1	- 3.2	
	-9.9*	- 9.5*	-11.9*	
99.75	-1.2	- 2.4	- 0.7	
	+9.1*	+ 2.8*	- 0.3*	
99.76				+ 0.04
200.2				- 4.4
200.3	-2.2	- 2.2	- 2.4	
	-3.8*	- 3.9*	- 2.2*	
501.8	-1.0	- 1.3	- 1.1	- 2.2
	-2.0*	- 2.1*	- 1.7*	
999.7				- 1.0
999.8	-0.4	- 0.5	- 0.5	
	-1.2*	- 1.2*	- 1.1*	

* Unbuffered input

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions)	1. PUBLICATION OR REPORT NO. NBSIR 82-2601 PARTS I & II	2. Performing Organ. Report No.	3. Publication Date December 1982

4. TITLE AND SUBTITLE
AUTOMATIC TEST EQUIPMENT CALIBRATION/PERFORMANCE VERIFICATION EVALUATION AND RESEARCH PROGRAM (JLC/DoD Subtask 30702)
EXECUTIVE SUMMARY PART I

5. AUTHOR(S) Barry A. Bell, Thomas F. Leedy, William L. Gans, Paul S. Lederer, Robert E. Nelson

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

7. Contract/Grant No.

8. Type of Report & Period Covered
Final

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP)
Prepared for
Joint Logistics Commanders Panel on Automatic Testing
DoD Joint Technical Coordination Group for Metrology
DoD Calibration Coordination Group
USAF ASD/AEGB Mate Program Office

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This work describes an experimental approach to verify the performance of selected third generation automatic test systems. The approach consisted of careful laboratory characterization of two types of signal sources. One was a dc and low frequency ac voltage source covering the range of approximately 100 mV to 200 V dc, and 300 mV to 140 V ac rms over a frequency range of 100 Hz to 10 MHz. The second source was a precision time synthesizer used to generate pulses of known durations from 50 to 1000 ns. Both of these sources were used to verify the ability of two automatic test systems to measure ac and dc voltages and time intervals. The methods used to characterize these sources and the measurement results of applying the sources to the two automatic test systems are discussed in detail. Recommendations for future efforts to improve the measurement capabilities and traceability of automatic test systems are also presented.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)
ATE; automatic test systems;calibration; characterization; dynamic transport standard; evaluation; field calibration; performance test; third generation system.

13. AVAILABILITY

☐ Unlimited
☒ For Official Distribution. Do Not Release to NTIS
☐ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
☐ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES

15. Price

USCOMM-DC 6043-P80