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Final Technical Report
September 1988

MULTIPLE USE FREQUENCY STANDARDS SURVEY REPORT

Frequency and Time Systems, Inc.

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, NY 13441-5700

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APPROVED: N. Yannoni

NICHOLAS F. YANNONI
Project Engineer

APPROVED: Harold Roth

HAROLD ROTH
Director of Solid State Sciences

FOR THE COMMANDER: John A. Ritz

JOHN A. RITZ
Directorate of Plans & Programs

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This report is a summary of a survey of Air Force systems to define the details of their needs for precision timing. The survey includes data on program name, function, organization, equipment status, compatibility with other systems, precision/accuracy of time required and other parameters related to system timing needs. The report also contains a draft specification for a cesium-beam-based frequency standard for potential widespread use in military systems.

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1.0 PROGRAM PROGRESS

1.1 Introduction

The Multiple Use Frequency Standards (MUFS) project is based on the idea that there is an uneconomically large variety of time and frequency (T & F) standards being used by the military. As part of this project, FTS conducted a survey of interested military groups to determine their perceived needs for T & F and FTS generated a draft specification.

1.2 Period of Performance

13 February 1984 through 26 April 1985.

1.3 Progress

This report completes all deliverables under contract F19628-84-C-0089.

2.0 MUFS SPECIFICATION

2.1 Introduction

A considerable amount of information has been assembled on the performance characteristics of present cesium-beam frequency standards and on the changes that might be desirable to meet existing and anticipated Air Force requirements. The principal sources of this information includes:

- Discussions with RADC/ESE personnel, other Air Force contacts, vendors, commercial and military customers.
- Survey of Air Force time and frequency requirements conducted under the present contract.
- Study of our own and competing hardware, specification, literature and manuals.
- Consideration of current military specifications for cesium standards, quartz oscillators and timing systems.

Based on the above information we have assembled a preliminary set of functional specifications and a proposed mechanical design concept for the Multi-User Frequency Standard.

2.2 Draft Specification

A preliminary outline of a new military standard for cesium standards (intended as a replacement for MIL-F-28811) is included as Appendix A of the report. Only the functional requirements section of the standard has been developed in any detail, as the purpose of this draft is to record a set of proposed characteristics and to provoke comments thereon from all interested parties. The quality assurance and other provisions of the final standard will follow naturally when the requirements have been established.

The concept underlying the new specification is that of a completely modular frequency/time standard. The cesium oscillator operates from 22-30 V dc and produces a single 5 MHz sinusoidal output and a synchronizable 1 pps output; all other functions are provided by optional modules. The cesium oscillator and the option modules plug into a base chassis suitable for either bench-top or rack-mounted operation. The specification describes, as options, all of the sinusoidal, pulse, and timing functions that might be required for various applications, and it is left to the procurement document for each contract to specify which of these sections are applicable. Similarly, the various power-supply options, configured as interchangeable modules, are described in full, but may be included or not, in any combination, as the contract may require.

2.3 Mechanical Configuration

Figure 1 is a sketch of the proposed modular cesium standard. The basic unit is a 5-1/4 inch high, 21 inch deep, rack-mountable chassis capable of accepting a variety of plug-in modules. Primary dc power is brought through the rear panel to the dc power supply, which is required in all configurations, although it is also constructed as a removable (i.e., easily replaceable) module. The function and power modules plug into a central motherboard structure which is used for power and signal distribution. RF and other signal connectors on the front and rear panels are also connected to the motherboard, allowing flexibility in distributing the various signal outputs.

2.4 Modules

Table III provides a summary of the functions and characteristics of the various modules. There are five basic module types of which three (cesium oscillator, dc power supply and control/monitor unit) are each unique. In contrast, the sine-wave, pulse and timing modules are mutually interchangeable as are the ac power and battery modules. The ability to interchange modules provides great flexibility for initial configuration and subsequent adaptation. A particular user might specify three sine-wave distribution amplifiers and no pulse outputs, for example, or might substitute a second battery pack for the ac power module during extended field operation.

The pulse and sine-wave output modules provide buffered outputs on their front panels and also through their rear connectors. The latter signals can be connected by jumpers to the distribution cables in the main unit so as to be brought out to connectors on the front and/or rear panels of the chassis. The frequencies of the RF outputs can be specified in any combination among the standard 10 MHz, 5 MHz, 1 MHz, and 100 kHz values, or in the case of the synthesizer module, at any other attainable frequency. Similarly, the pulse outputs may be 1 pps, 1 ppm, or other values as specified. The signal distribution concept facilitates the inclusion of special-purpose modules for meeting unforeseen requirements.

3.0 MUFS SURVEY REPORT

3.1 Introduction

Many Air Force systems are using independently-developed timing hardware to meet precision timing requirements. This present trend is toward increased logistics complexity and inefficiency in timing device acquisition. To remove this trend, the Air Force seeks to develop the MUFS oscillators which will be used for future systems requiring precise time and/or time interval. The development effort consists of four phases: (I) A survey of requirements and preparation of specifications; (II) Design of the MUFS units; (III) Fabrication of the oscillators; and (IV) Evaluation and documentation of performance. This report describes the results of the first task of Phase I, the survey of user requirements.

3.2 Meetings

Several meetings were held between the MUFS scientific officer (Dr. Nicholas Yannoni) and FTS personnel to discuss an efficient way to survey the needs of the end user.

2 May 1984	The overall philosophy of Phase I of the project was discussed. It was decided that as a minimum a questionnaire would be used to gather information from Air Force Personnel.
16 May 1984	The meeting was to discuss an initial questionnaire that FTS had prepared. It was decided that a shorter questionnaire would be more appropriate and a target date of 22 June 1984 was set.
22 June 1984	The abbreviated questionnaire was approved and 51 people (later to become 47) were identified as potential respondents. The people to be contacted were those surveyed by Dr. Yannoni in his "Master Reference" questionnaire (which he sent out near the end of 1983).
11 July 1984	Met with Chet Mathewson of the EJS program office and Charles Brower of Support Systems Associates, Inc. The needs of the EJS program for high quality time and frequency (T & F) were discussed.
8 August 1984	Met at their MITRE Corp. office with Asbjorn Gjelsvik and Ivan LaGarde. Talked about various Air Force T & F needs with Gjelsvik and emphasized and HAVE QUICK program with LaGarde.

17 October 1984 — The meeting was called by Dr. Yannoni and had two purposes:

1) To review the approach to, and the results from, the MUFS survey.

2) To discuss a new specification upon which to base future Air Force purchases of cesium standards.

Attendees of this meeting were: N. Yannoni and A. Kahan (RADC); Emory Boose and Asbjorn Gjelsvik (MITRE); Charles Brower (SSAI); Ira Smith (Arthur D. Little), Lt. Dave Buie (ESD), and Robert Murphy and Allan Risley (FTS).

3.3 Survey Procedure

People representing 47 organization codes were contacted. The people were either on the "Master Reference" list or were referred to by people on that list. We agreed that all potential respondents were first to be contacted by phone, and only if they agreed to fill out the questionnaire would it then be sent to them. It was, in fact, hoped that the questionnaire could be filled out during the phone call to each person on the contact list. However, it soon became apparent that it was necessary to mail the questionnaire to the potential respondents and this was done in all cases.

Almost all of the 47 people verbally agreed to fill out the questionnaire. However, only 20 questionnaires were returned. The first questionnaire was mailed from FTS in early August of 1984 and the last questionnaire returned to FTS was in mid October.

3.4 Survey Questionnaire

The survey questionnaire form is reproduced on pages 3-2a and 3-2b.

3.5 Survey Results

The responses to questions 2(b) through 14 of the survey questionnaire are tabulated on the following pages; organized as one question per page for clarity. Each page includes a brief summary of the question, a grouping of the responses into general categories and list the applicable programs in each of the categories.

SURVEY OF TIME AND FREQUENCY EQUIPMENT

This questionnaire asks about the quality, quantity and location of the time and/or frequency sources within your jurisdiction. The time and frequency sources comprising a Program (e.g., Milstar) form a system which may have more than one level of quality, i.e., a hierarchy of sources. The questionnaire allows for up to three levels in a hierarchy. The equipment may have only time requirements, only frequency requirements or both. Please respond appropriately.

1. a. Name of Respondent: ____________ b. Organization Code: ____________ c. Telephone #: ____________

2. a. Program Name: ____________

   b. Program Function: ____________

3. Equipment Status (Check One):

   a. ☐ Operational b. ☐ Being Installed c. ☐ In Design Phase d. ☐ If Not Operational, Indicate When: ____________

4. Does your program require time and/or frequency compatibility with any other Air Force Program? ☐ YES ☐ NO

5. If so, which one(s):

____

Please return completed survey to: Allan Risley, Frequency and Time Systems, Inc., 34 Tozer Road, Beverly, MA 01915

CONTRACT #: F19628-84-C-0089

CONTRACT OFFICER: Dr. N. Yannoni, USAF
RADC/ESE
Hanscom AFB
Bedford, MA 01731
617-861-2206
AV-478-2206

SURVEY OF TIME AND FREQUENCY EQUIPMENT

TIME REQUIREMENTS

	LEVEL 1	LEVEL 2	LEVEL 3
6. Maximum error allowable before recalibration (Please indicate units in microseconds, milliseconds, or seconds):	____	____	____
7. Smallest time interval before recalibration is allowed (i.e., no more often than ____ days):	____	____	____
8. "Platform", (e.g., fighter) that the equipment will be located upon:	____	____	____
9. Number of units in level:	____	____	____

10. How will you perform time recalibration?

____

FREQUENCY REQUIREMENTS

	LEVEL 1	LEVEL 2	LEVEL 3
11. a. Largest frequency inaccuracy (in Hz) that the level can tolerate?	____	____	____
b. Center frequency of this source:	____	____	____
12. Smallest time interval before recalibration is allowed (days):	____	____	____
13. Number of units in level:	____	____	____

14. How will you perform frequency calibration?

____

Twenty programs were named in the response to question 2(a) as follows:

1.	ASAT	Anti Satellite System
2.	ESAAP	EHF Satellite Adoptive Array Processor
3.	SSTS	Space Surveillance and Tracking System
4.	MILSTAR	Military Strategic and Tactical Relay System
5.	MILSTAR (MCE)	MILSTAR Mission Control Element
6.	MRT	Miniature Receive Terminal
7.	OTH-B	Over the Horizon-Backscatter Radar
8.	NCMC	NORAD Cheyenne Mountain Complex
9.	CCPDS-R	Command Center Processing and Display System - Replacement
10.	BMEWS	Ballistic Missile Early Warning System
11.	SEEK IGLOO	
12.	JTIDS	Joint Tactical Information Distribution System
13.	EJS	Enhanced JTIDS
14.	E-4B PDMP	E-4B Post Delivery Modification Program
15.	PAVE PAWS	
16.	JSS	Joint Surveillance System
17.	DSCS	Defense Satellite Communications System
18.	DPP	Defense Dissemination Program
19.	FSE/DSE	Factory Support Equipment/Deport Support Equipment
20.	CSOC	Consolidated Space Operations Communications Systems

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME
2b) Program function?		
	Airborne and Space Communications	CSOC MILSTAR MRT E-4B PDMP JTIDS DSCS
	Surveillance	SSTS OTH-B BMEWS SEEK IGLOO PAVE PAWS
	Ground Communications	NCMC MILSTAR (MCE)
	Anti-Jam Communications	ESAAP EJS
	Metrology	FSE/DSE
	Other	ASAT CCPDS-R JSS DDP

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME
3) Equipment status?		
	Operational	ASAT PAVE PAWS JSS DSCS DDP
	Being Installed	OTH-B SEEK IGLOO E-4B PDMP
	In Design Phase	CSOC ESAAP SSTS MILSTAR MRT NCMC CCPDS-R BMEWS MILSTAR (MCE) EJS JTIDS FSE/DSE

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME
4) Compatibility with other programs required?		
	No	CSOC ASAT MILSTAR OTH-B NCMC SEEK IGLOO E-4B PDMP JTIDS JSS DSCS FSE/DSE
	Yes	ESAAP SSTS MRT CCPDS-R BMEWS MILSTAR (MCE) EJS PAVE PAWS DDP

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME	RELATED PROGRAMS
5) If so, which ones?			
	Compatibility Required	ESAAP	Some Satellite Programs
		SSTS	SDI/MILSTAR/GPS/DSP
		MRT	MEECN
		BMEWS	NCMC
		MILSTAR (MCE)	MILSTAR/NESP/SCOTT
		EJS	GPS
		JTIDS	Tacan 118
		PAVE PAWS	SAC/NMCC/ANMCC
		DDP	DSC
	No Need For Compatibility	CSOC	
		ASAT	
		MILSTAR	
		OTH-B	
		NCMC	
		CCPDS-R	
		SEEK IGLOO	
		E-4B PDMP	
		JSS	
		DSCS	
		FSE/DSE	

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME
6) Maximum time error allowed (microseconds)?		
	Less than 1	FSE/DSE
	1 to 100	CSOC MRT OTH-B BMEWS EJS E-4B PDMP PAVE PAWS DSCS
	Greater than 100	CCPDS-R
	TBD	ESAAP SSTS JTIDS
	Classified	MILSTAR MILSTAR (MCE)
	No Response	ASAT NCMC SEEK IGLOO JSS DDP

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME
7) Smallest allowable recalibration interval for time (hours)?	1 to 100	CSOC BMEWS EJS E-4B PDMP PAVE PAWS
	100 to 1000	SSTS DSCS FSE/DSE
	TBD	ESAAP MRT OTH-B JTIDS
	Classified	MILSTAR MILSTAR (MCE)
	No Response	ASAT NCMC CCPDS-R SEEK IGLOO JSS DDP

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME
8) Platform?		
	Ground Fixed	CSOC SSTS MILSTAR MRT OTH-B CCPDS-R BMEWS MILSTAR (MCE) PAVE PAWS FSE/DSE
	Aircraft	EJS E-4B PDMP JTIDS
	Satellite	ESAAP DSCS
	No Response	SSTS NCMC SEEK IGLOO JSS DDP

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME
9) Number of units in Level 1?		
	1 to 100	CSOC ASAT CCPDS-R E-4B PDMP PAVE PAWS
	10 to 100	MILSTAR MRT
	Greater than 100	EJS
	TBD	SSTS JTIDS DSCS
	Classified	MILSTAR (MCE)
	No Response	ESAAP OTH-B NCMC BMEWS SEEK IGLOO JSS DDP FSE/DSE

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME	CALIBRATION TECHNIQUE
10) How will time recalibration be performed?			
	Recalibration Technique Known	CSOC	WWVB
		ESAAP	Host Satellite
		MILSTAR	GPS
		MRT	Cesium-Fixed
		OTH-B	Loran
		BMEWS	Cesium-Traveling
		MILSTAR (MCE)	Cesium-Traveling
		EJS	GPS
		E-4B PDMP	Cesium-Fixed
		PAVE PAWS	Loran
	To be determined	SSTS	
		CCPDS-R	
		FSE/DSE	
	No Response	ASAT	
		NCMC	
		SEEK IGLOO	
		JTIDS	
		JSS	
		DSCS	
		DDP	

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME
11a) Largest fractional frequency inaccuracy allowed?		
	Poorer than 1 x 10^{-10}	DSCS
	Better than 1 x 10^{-10}	SSTS MRT E-4B PDMP
	Classified	MILSTAR MILSTAR (MCE) EJS
	TBD	JTIDS FSE/DSE
	No Response	CSOC ASAT ESAAP OTH-B NCMC CCPDS-R BMEWS SEEK IGLOO PAVE PAWS JSS DDP

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME
11b) Center frequency?		
	5 MHz or Less	CSOC MILSTAR MRT MILSTAR (MCE) DSCS
	1 GHz or Greater	E-4B PDMP JTIDS
	Classified	EJS
	No Response	ASAT ESAAP SSTS OTH-B NCMC CCPDS-R BMEWS SEEK IGLOO PAVE PAWS JSS DDP FSE/DSE

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME
12) Smallest allowable recalibration interval for frequency (hours)?		
	1 to 100	CSOC EJS
	100 to 1000	SSTS E-4B PDMP DSCS FSE/DSE
	TBD	MILSTAR MRT JTIDS
	Classified	MILSTAR (MCE)
	No Response	ASAT ESAAP OTH-B NCMC CCPDS-R BMEWS SEEK IGLOO PAVE PAWS JSS DDP

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME
13) Number of units in Level 1?		
	1 to 100	CSOC MILSTAR MRT E-4B
	Over 100	EJS PDMP
	TBD	ESAAP SSTS JTIDS DSCS
	Classified	MILSTAR (MCE)
	No Response	ASAT OTH-B NCMC CCPDS-R BMEWS SEEK IGLOO PAVE PAWS JSS DDP FSE/DSE

SURVEY REPORT

QUESTION NUMBER	CATEGORY	PROGRAM NAME	CALIBRATION TECHNIQUE
14) How will frequency recalibration be performed?			
	Frequency Recalibration Technique Known	CSOC	Loran
		MILSTAR	GPS
		MRT	Cesium-Fixed
		BMEWS	Cesium-Fixed
		MILSTAR (MCE)	Cesium-Traveling
		EJS	GPS
		E-4B PDMP	Cesium-Fixed
	To be Determined	SSTS	
		PAVE PAWS	
		FSE/DSE	
	No Response	ASAT	
		ESAAP	
		OTH-B	
		NCMC	
		CCPDS-R	
		SEEK IGLOO	
		JTIDS	
		JSS	
		DSCS	
		DDP	

3.6 Conclusions

One major conclusion is that the respondees placed much more emphasis upon their need for time than for frequency.

For recalibrating time, 50% of the total number of people answering the questionnaire said they will be using a cesium-based master clock.

More than half of the people answering the questionnaire described their system as being in the design phase. Only 25% of the programs were described as operational.

Nine of the 20 respondees described their programs as needing time (and/or frequency) compatibility with other programs. Eight of those were specific about what those other programs were. Studies could be done to see whether the planned means of being compatible are adequate.

APPENDIX A

PRELIMINARY DRAFT

MILITARY SPECIFICATION

Frequency Standard, Cesium-Stabilized

1.0 SCOPE

This specification defines the performance requirements for a self-contained frequency standard which utilizes the cesium ground-state hyperfine transition as a frequency reference. The standard provides an extremely high order of frequency accuracy and is designed for use in airborne and ground environments.

2.0 APPLICABLE DOCUMENTS

2.1 Government Specifications and Standards. Unless otherwise specified, the following specifications, standards, and handbooks, of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation, form a part of this specification to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-C-6781B	-Control Panel, Aircraft Equipment, Rack or Console Mounted.
MIL-E-4158E	-Electronic Equipment, Ground, General Requirement for
MIL-E-5400T	-Electronic Equipment, Airborne, General Specification for
MIL-M-38510E	-Microcircuits, General Specification for
MIL-P-15024	-Plates, Tags, and Bands for Identification of Equipment.
MIL-S-19500F	-Semiconductor Devices, General Specification for

STANDARDS

FEDERAL

FED-STD-595A	-Color

MILITARY

MIL-STD-129	-Marking for Shipment and Storage
MIL-STD-130	-Identification Marking of U.S. Military Property
MIL-STD-275	-Printed Wiring for Electronic Equipment
MIL-STD-454	-Standard General Requirements for Electronic Equipment
MIL-STD-461	-Electromagnetic Interference Characteristics, Requirements for Equipment
MIL-STD-462	-Electromagnetic Interference Characteristics, Measurement of
MIL-STD-810	-Environmental Test Methods
MIL-STD-883	-Test Methods and Procedures for Microelectronics
MIL-STD-45662	-Calibration Systems Requirements

2.2 Other Documents

The following documents form a part of this specification to the extent specified herein.

U.S. Department of Commerce/National Bureau of Standards
NBS Monograph 140 - Time and Frequency: Theory and Fundamentals
EIA-RS-310-C-7 - Racks, Panels, and Associated Equipment

2.3 Source Documents

Copies of listed federal and military standards and specifications should be obtained from:

DoD Single Stock Point
Commanding Officer
Naval Publications and Forms Center
5801 Tabor Avenue
Philadelphia, PA 19120

2.4 Order of Precedence

In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

3.0 REQUIREMENTS

3.1 Equipment Description

The cesium frequency standard defined by this specification shall contain a source of cesium atoms (such as a cesium beam tube), a quartz oscillator, and a means of maintaining the oscillator frequency at a suitable submultiple of the Cesium 133 ground-state hyperfine transition frequency (9, 129, 631, 770 Hz at zero external magnetic field, by international agreement). A complete instrument shall consist of a Base Chassis, a Cesium Oscillator Module, a dc Power Module, and if required, one or more additional functional modules as defined herein.

3.2 General Requirements

3.2.1 Performance

The stability, accuracy and other fundamental performance characteristics of the instrument shall be limited solely by the Cesium Oscillator Module. No power supply, signal distribution, or other additional circuitry shall be allowed to degrade this performance unless otherwise specified herein.

3.2.1.1 Warm-up

The instrument shall be fully operable and shall conform to all the requirements of this specification with $\leq$TBD minutes from a cold start at any ambient temperature in the range -TBD°C to +TBD°C.

3.2.1.2 Accuracy

The instrument, without reference to or calibration against an external standard, shall produce a primary output frequency that is within $\pm 1.0 \times 10^{-11}$ of 5.00 MHz referred to the international standard. This accuracy shall be maintained for all ambient conditions specified in 3.4.

3.2.1.3 Reproducibility

The instrument shall be capable of returning to its previous frequency within $\pm 1 \times 10^{-11}$ after having been turned off or having any one of its electronic modules (exclusive of cesium reference elements) repaired or replaced and properly aligned and the instrument replaced in the same environment.

3.2.1.4 Settability

The instrument shall be capable of being set to within $\pm 2 \times 10^{-12}$ of a reference standard over a total range of six parts in 10^{11} centered around 5 MHz.

3.2.1.5 Long-Term Stability

The instrument shall display no systematic drift and shall not change from its original frequency more than $\pm 1 \times 10^{-11}$ for the life of the cesium reference element. Frequency measurements made for this specification at different times shall be made in the same environment with the following tolerances:

a. Temperature: $\pm 5°C$
b. Magnetic Field: $\pm .2$ gauss
c. Humidity: ± 10 percent relative humidity

3.2.1.6 Short-Term Stability

The standard deviation of the two-sample fractional frequency variation shall not exceed the limits shown in Figure 3.

3.2.1.7 Phase Noise

The single sideband phase noise of the primary 5 MHz sinusoidal output shall not exceed the limits shown in Figure 2.

3.2.1.8 Pulse Temperature Stability

The phase jitter of the leading edges of any pulse outputs shall be <TBD ns referenced to the primary 5 MHz output, averaged over TBD consecutive pulses.

3.2.2 Output Characteristics

3.2.2.1 Sinusoidal Outputs.

The primary 5 MHz output and all other sinusoidal outputs from the standard, including optional modules, shall conform to the following requirements, unless otherwise specified in the detailed module specifications.

3.2.2.1.1 Frequency: As specified.

3.2.2.1.2 Amplitude

1.2 ± 0.25 V rms into 50 ohms.

3.2.2.1.3 Harmonic Distortion

At least 40dB below rated output.

3.2.2.1.4 Non-Harmonically Related Output

At least 80 dB below related output except during vibration and magnetic field inputs.

3.2.2.1.5 Isolation

For any pair of sinusoidal outputs, the signal isolation shall be >TBD in the frequency range TBD for an interferring signal amplitude of 0 dB relative to the rated level of the output under test.

3.2.2.1.6 Short-Circuit Protection

Each output shall be protected against damage by a short circuit of indefinite duration. Such a short circuit shall not harm or degrade any other output of the standard.

3.2.2.2 Pulse outputs

The primary 1 pps output and all other pulse outputs from the standard, including optional modules, shall conform to the following requirements, unless otherwise specified in the detailed module specifications.

3.2.2.2.1 Pulse Repetition Frequency

1 pulse per second, 1 pulse per minute, or as otherwise specified.

3.2.2.2.2 Amplitude

TBD volts into 50 ohms.

3.2.2.2.3 Width

TBD us, ± TBD

3.2.2.2.4 Rise Time

10% to 90% ... TBD

3.2.2.2.5 Fall Time

90% to 10% ... TBD

3.2.2.2.6 Isolation

>TBD dB between any pair of pulse outputs for a 1.0 V rms sinusoidal interferring signal ≤TBD Hz to TBD Hz.

3.2.2.2.7 Short-Circuit Protection

No damage, no performance degradation, for short circuit of arbitrary duration.

3.2.3 Mechanical Requirements

3.2.3.1 Dimensions. The dimensions of the complete instrument, including the covers, fasteners, rear connectors, guards, and optional modules, if installed, shall be 17 inches wide and not more than 5 1/4 inches high or 21 inches deep behind the front panel. The front panel shall be 19 inches wide by 5 1/4 inches high with mounting holes. Detachable drawer slides shall be provided with provisions for mounting the slides on the instruments for installation in a 19-inch rack. Mounting holes for the equipment slides shall be in accordance with EIA-RS-310-C-7.

An outline drawing of the Base Chassis is given in Figure 1. This drawing also shows mounting details for the different modules, including connector locations and other interface information.

3.2.3.2 Weight. The weight of the instrument shall be held to a minimum consistent with the other requirements of this specification and shall not exceed 60 pounds without the Battery Module, or 70 pounds including one Battery Module.

3.2.3.3 Construction. The instrument shall include miniature unitized construction where possible. Optimum use of replaceable subassemblies shall be made

3.2.3.3.1 Accessibility. The construction shall allow maximum accessibility to replaceable assemblies.

3.2.3.3.2 Rough usage. The design of the equipment shall be such as to preclude damage to the equipment when handled by relatively unskilled personnel.

3.2.3.3.3 Finish. The front panel finish of the equipment shall be light gray enamel, type III, class 2, or MIL-E-15090. Finish of all surfaces shall be in accordance with MIL-E-16400.

3.2.3.3.5 Materials. The materials used in this equipment shall be selected in accordance with the material requirements of MIL-E-16400. The use of mercury is prohibited.

3.2.3.4 Connectors. All connectors on the base chassis and modules shall conform to the requirements of Table 1.

Table 1

CONNECTOR REQUIREMENTS

Location	Quantity	Function	Connector Type	Mating Connectors and Covers
Front Panel Base Chassis	6	Signal Out	TBD	
Front Panel Modules	Various	Signal Out Zeeman In Sync In	TBD TBD TBD	
Rear Panel Base Chassis		Signal Out Time Code Out	TBD TBD	
Rear Panel Modules		ac Power In dc Power In Time Code	TBD TBD TBD	

3.2.3.5 Modules. Five standand module sizes are defined in Table II. These modules fit into the Base Chassis in the manner indicated in Figure 1. Additional descriptive and interface information is provided in Table III.

Table II

MODULE DIMENSIONS

Module Type	Function	Overall Dimensions (inches)	Panel Size (inches)
A	Cesium Oscillator	5 x 7 5/8 x 15 1/2	None
B	DC Power Supply	4 7/8 x 7 3/8 x 3	5 x 7 1/2
C	Signal Distribution Time Code/Clock Synthesizer	1 3/8 x 5 7/8 x 8	1 1/2 x 6
D	ac Power Supply Battery/Charger	3 3/8 x 4 3/8 x 10 1/2	3 1/2 x 4 1/2
E	Control/Monitor	4 3/8 x 6 3/8 x 1 3/4	4 1/2 x 6 1/2

3.3 Detailed Requirements

3.3.1 Cesium Oscillator Module

3.3.1.1 Description

The cesium oscillator module operates from 22-30 volt dc input and produces two outputs, a buffered 5 MHz sinusoidal signal and a synchronizable 1 pulse-per-second timing signal. Provision shall also be made for operating the quartz oscillator independently of the cesium reference.

3.3.1.2 Performance Requirements

3.3.1.2.1 Cesium Reference

The accuracy, stability, settability, and reproducibility of the module when operating under cesium control shall be as specified in 3.2.1.

3.3.1.2.2 Controls and Indicators

The cesium beam module shall be provided with control inputs and indicator outputs that, with associated circuits, will permit the optimum adjustment and operation of the frequency standard. All controls and monitor signals shall be connected via TBD connector, wired as shown in Figure 5.

3.3.1.2.2.1 Alarm Indicator

An alarm indicator shall be provided to indicate that adjustable parameters critical to the operation of the instrument exceed tolerance limits.

3.3.1.2.2.2 Continuous Operation Indicator

A continuous operation indicator shall be provided to indicate that all circuits are functioning properly and have been so functioning continuously since the last operation of the logic reset control (§3.5.7).

3.3.1.2.2.3 Oscillator Frequency Control

An oscillator frequency control shall provide quartz crystal oscillator frequency adjustment of not less than +5 parts in ± 5 parts in 10^7. The resolution shall be at least $\pm 1 \times 10^{-9}$.

3.3.1.2.2.4 Fine Tuning Adjustment

Means shall be provided for adjusting the output frequency of the standard over a range of TBD with a resolution of at least TBD. This adjustment may take the form of a C-field control for the cesium beam tube, or other as appropriate.

3.3.1.2.2.5 Modulation Control

A MOD-ON-OFF input shall be provided for the module. It shall control the low frequency modulation of the microwave energy applied to the cesium reference element.

3.3.1.2.2.6 Loop Gain Control

A loop gain control shall be provided to adjust the gain of the quartz crystal oscillator stabilization loop.

3.3.1.2.2.7 Logic Reset Control

At input shall be provided to reset the instrument alarm logic circuits (subsequent to any disturbance in the operation of the instrument that causes an alarm indication).

3.3.1.2.2.8 Automatic Synchronization

An input shall be provided to initiate the automatic synchronization function for the 1 pps output.

3.3.1.2.2.9 Mode Control

A control input shall be provided to select the instrument mode of operation. Two modes shall be provided:

a) OPERATE: The normal mode with the quartz crystal oscillator locked to the atomic frequency.

b) LOOP OPEN: All circuits are energized, but the frequency control loop is open.

3.3.1.2.2.10 Circuit Check Indicators

Analog and/or digital signals shall be provided to indicate the value or functionality of critical voltages, beam tube parameters of the system.

3.3.1.2.3 Pulse Output

The 1 pps output signal shall conform to the requirements of section 3.2.1.

3.3.1.2.3.1 Automatic Synchronization.

It shall be possible to synchronize the 1 pps output automatically to the leading edge of an external sync pulse. The synchronization error shall not be greater than ± 0.25 us. An external sync input jack shall be provided on the front panel of of the base chassis. The external sync pulse shall have an amplitude of not less than +5 volts, rise time of not more than 50 ns from 0.5 volts to 4.5 volt, and a pulse width of not less than 500 ns into 50 ohms nominal impedance. A control input shall be provided to initiate synchronization.

3.3.1.2.4 Power Input

The cesium module shall operate satisfactorily and meet all specified performance requirements when supplied with dc power within the range of 22-30 volts. Ripple, max. power consumption, etc. TBD.

3.3.1.2 Mechanical Requirements.

The dimensions of the module, connector type and locations, etc, are shown in Fig 1. Maximum weight is 60 pounds.

3.3.2 DC Power Supply Module.

3.3.2.1 Description

The dc power supply module accepts 22-30 V power from an ac power supply module, an external DC input, or a battery/charger module. If more than one of these sources is present and within tolerance, it automatically selects one, in the order of precedence given in the above list. The module passes the input dc power directly to the cesium oscillator module, and to the battery/charger module if that module is not serving as the power source. It also provides regulated +18, +5, and -18 volt power for distribution to the optional modules.

3.3.2.2 Performance Requirements

3.3.2.3 Mechanical Requirements

3.3.3 AC Power Supply Module

3.3.3.1 Description

The ac power supply module accepts 115 or 230 V ac single phase input power, 47-400 Hz, and converts it to 26 V dc.

3.3.3.2 Performance Requirements

3.3.3.3 Mechanical Requirements

3.3.4 Battery/Charger Module

The battery/charger module maintains normal operation of the cesium standard in the absence of external power. The battery is recharged automatically upon application of ac power.

3.3.5 Sinewave Distribution Module

3.3.5.1 Description

The sinewave distribution module accepts 5 MHz input from the cesium oscillator and produces a total of four separately buffered sinewave outputs. These outputs may be at 5 MHz, 10 MHz, 1 MHz or 100 kHz, in any combination, as specified in the procurement documents.

3.3.5.2 Performance Requirements

The electrical characteristics of the output signals shall be as specified in 3.2.2.

3.3.5.3 Mechanical Requirements

3.3.6 Pulse Distribution Module

3.3.6.1 Description

The pulse distribution module accepts the 1 pps input pulse from the cesium module and produces four buffered timing pulse outputs at 1 pps, 1 ppm, or any other rate specified in the procurement document. A pulse advance feature is included to allow the time of the leading edges of the pulse outputs to be adjusted from the front panel over a range of 1 second, in discrete steps of 0.1 us resolution, with respect to the 1 pps output from the cesium module.

3.3.6.2 Performance Requirements

3.3.6.3 Mechanical Requirements

3.3.7 Time Code/Clock Module

3.3.7.1 Description

The time code/clock module contains digital clock circuitry to maintain accurate day-of-year and time-of-day information. It may provide this information in any or all of three forms, as required:

(a) a visible clock display, settable from the front panel.

(b) a time-code output at the rear panel, also settable.

(c) a 1 ppm output pulse.

Both functions are driven by the 1 pps output of the cesium module.

3.3.7.2 Performance Requirements

3.3.7.2.1 Clock Display

3.3.7.2.1.1 Display Format

Digital display, 24 hour sequence, showing day-of-year, hours, minutes and seconds.

3.3.7.2.1.2 Timing

The clock shall indicate 00 seconds with the occurrence of the 1 ppm output pulse, if provided. Changes to the clock time as described in the next paragraph shall be reflected in the time of occurrence of the 1 ppm output pulse. Use of the automatic synchronization feature (see 3.3.1.2.3.8) shall cause a 00 second clock indication coincident with the external sync pulse.

3.3.7.2.1.3 Settability

Operationally simple controls shall be provided to set the clock. This operation shall not affect the time position of the 1 pps output pulses.

3.3.7.2.1.4 Time Scale Adjustment

The time scale step of 1 second provided to facilitate approximation of UT according to U.S. Naval Observatory revised procedures beginning 1 January 1972 shall be applied to the clock as well as the time of occurrence of the 1 ppm.

3.3.7.2.2 Time Code Output

3.3.7.2.2.1 Code Format

The standard code word shall be a 24-bit serial binary-coded decimal (BCD) word. The first bit shall be the most significant bit of the most significant digit of the hours. The 24th bit shall be the least significant bit of the least significant digit of the seconds. At the termination of the 24th bit the signal shall hold at a mark until the beginning of the next code word. The BCD code shall be the 8421 code. Other code formats may be provided, if specified.

3.3.7.2.2.2 Timing

The leading edge of the first bit shall be coincident (within ± 100 us) with the leading edge of each 1 pps output of the instrument. The signaling rate shall be 50 bits per second.

3.3.7.2.2.3 Digital Sense

A digital one state (mark) shall be denoted by a positive voltage 6 volts ± 1 volt and a digital 0 state (space) by a negative voltage -6 volts ± 1 volt.

3.3.7.3 Mechanical Requirements

3.3.8 Synthesizer Module

3.3.8.1 Description

The synthesizer module provides four buffered sinewave outputs at any specified frequency, form a slave oscillator which is phase-locked to the cesium 5 MHz output. The performance characteristics of this module must be specified in detail in the applicable procurement document.

3.3.9 Control/Monitor Module

3.4 Environmental Requirements

3.4.1 Shock, Vibration, Inclination

3.4.2 Temperature and Humidity

3.4.3 Altitude

3.4.4 Magnetic Fields

3.5 Safety

3.6 Reliability, Maintainability

3.7 Nuclear Hardness

3.8 Workmanship

4.0 QUALITY ASSURANCE PROVISIONS

5.0 PREPARATION FOR DELIVERY

6.0 NOTES

TABLE III

MODULES

TYPE	MODULE	DESCRIPTION	SIZE (INCHES)	CONNECTORS	POWER REQ.
A	Cesium Oscillator	Basic cesium frequency reference 5 MHz, 1 pps outputs	5 x 7 5/8 x 15 1/2	dc in 5 MHz out 1 pps out	22-30 V dc 1.5 a warmup 1 a run
B	DC Power Supply	Input 22-30 V dc Automatic switchover among sources. Order of precedence: ac, external dc, internal battery. Output +18 V, +5 V	3 x 5 x 7 1/2	EXT dc in ac/dc dc in Batt. dc in	
B	Sinewave Distribution	Four buffered sinewave outputs frequencies as specified	1 1/2 x 6 x 8	5 MHz in pwr in/ref out 4 sine out	+18 V -18 V
C	Pulse Distribution	Four buffered pulse outputs 1 pps, 1 ppm or other	1 1/2 x 6 x 8	1 pps in PWR IN/PULSE OUT	+5 V +18 V

TABLE III con't

MODULES

TYPE	MODULE	DESCRIPTION	SIZE (INCHES)	CONNECTORS	POWER REQ.
C	Synthesizer	Synthesize specified frequency provide buffered outputs	1 1/2 x 6 x 8		
D	AC Power Supply	Input: 110/220 V ac 10 47-400 Hz Output: 34 V dc nominal TBD amp	3 1/2 x 4 1/2 x 10 1/2	CTRL/MON PWR/ON	+5 V +18 V
D	Battery/Charger	24 V 54-hr sealed lead acid cells Charge from primary ac or dc source automatic switchover fast/trickle	3 1/2 x 4 1/2 x 10 1/2	ac IN dc OUT	
E	Control/Monitor (front panel)	Switches for cesium control meter, lamps to monitor cesium power supplies	1 3/4 x 4 1/2	CTRL/MON PWR IN	+5 V +18 V
	Base Chassis 19" rack mountable		5 1/4 x 17 x 21	As Required for Modules	

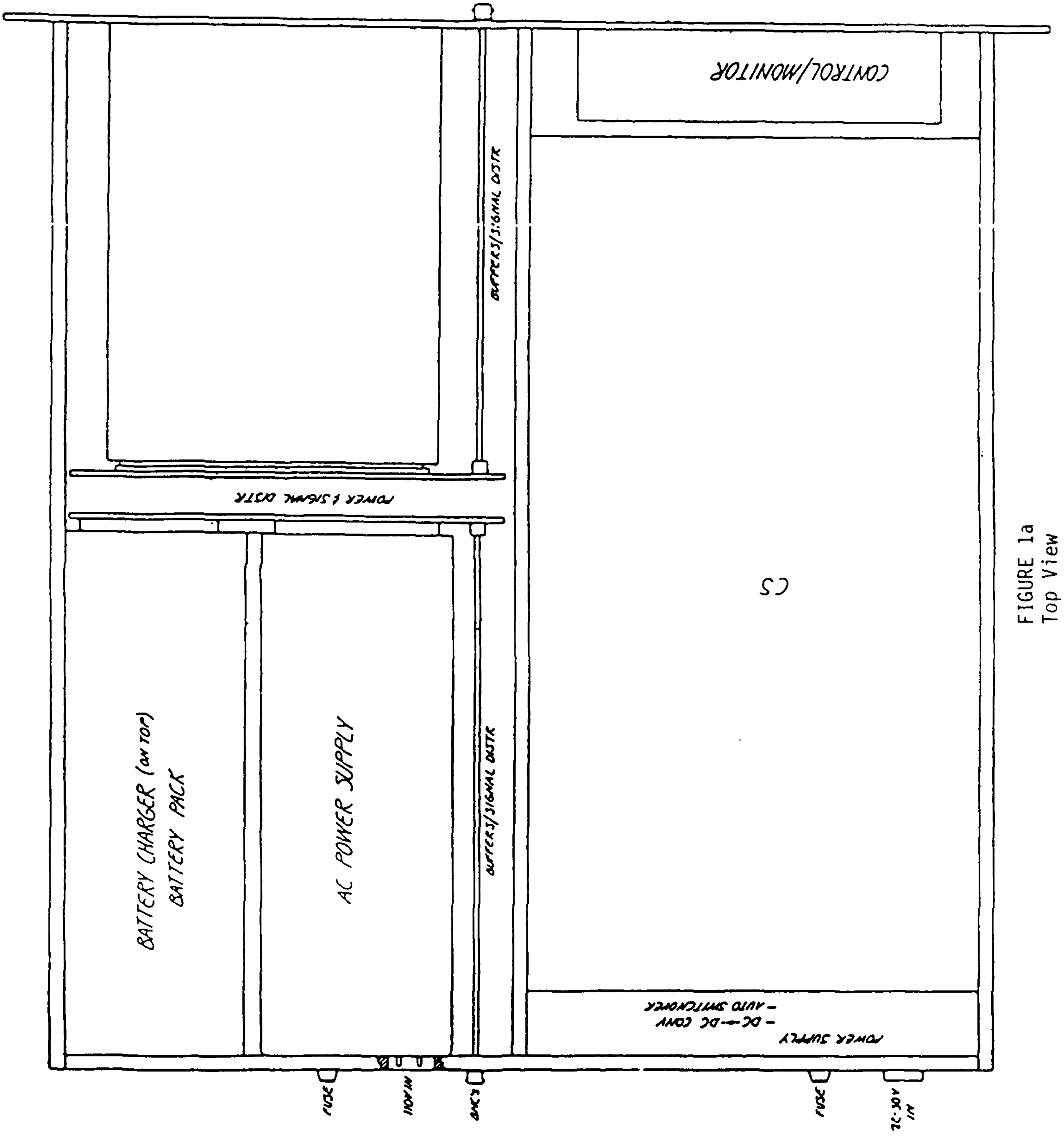

FIGURE 1a
Top View
CESIUM-STABILIZED FREQUENCY STANDARD CHASSIS

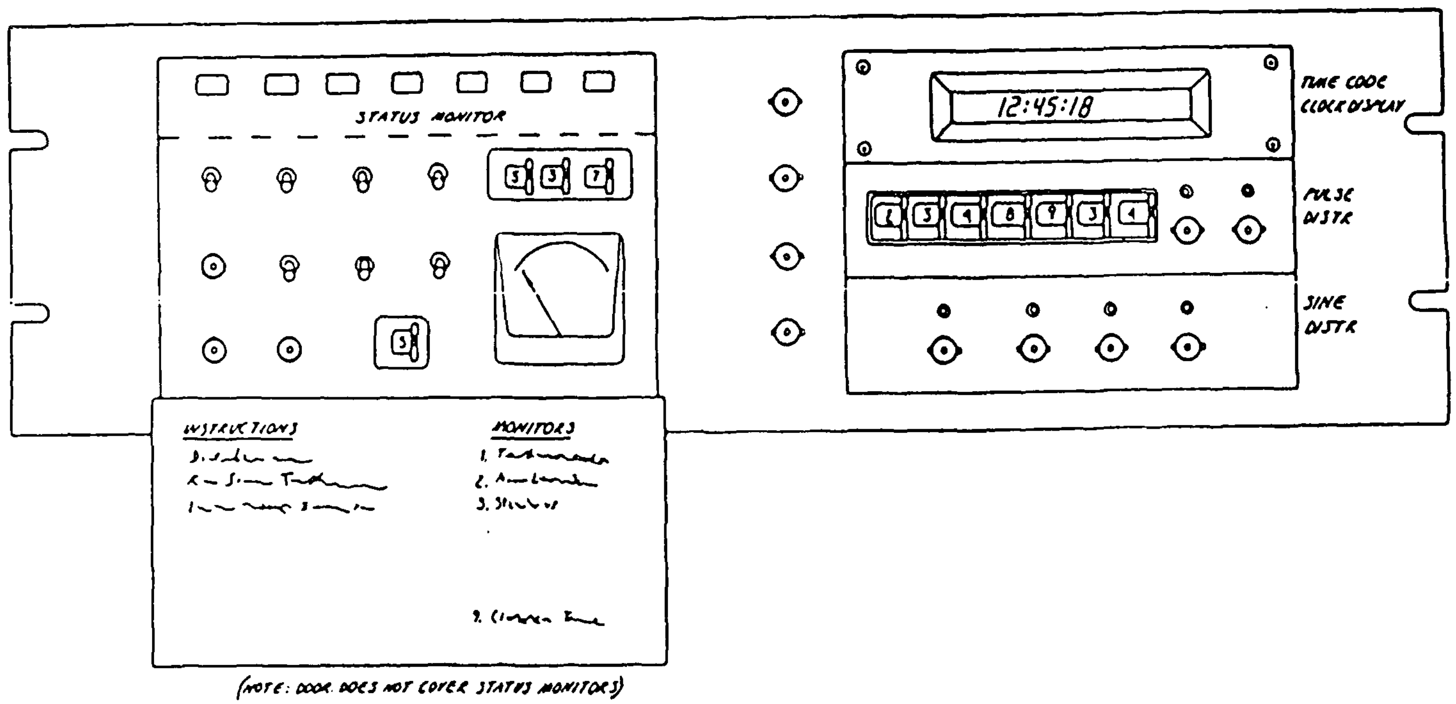

FIGURE 1b

Bottom View

CESIUM-STABILIZED FREQUENCY STANDARD CHASSIS

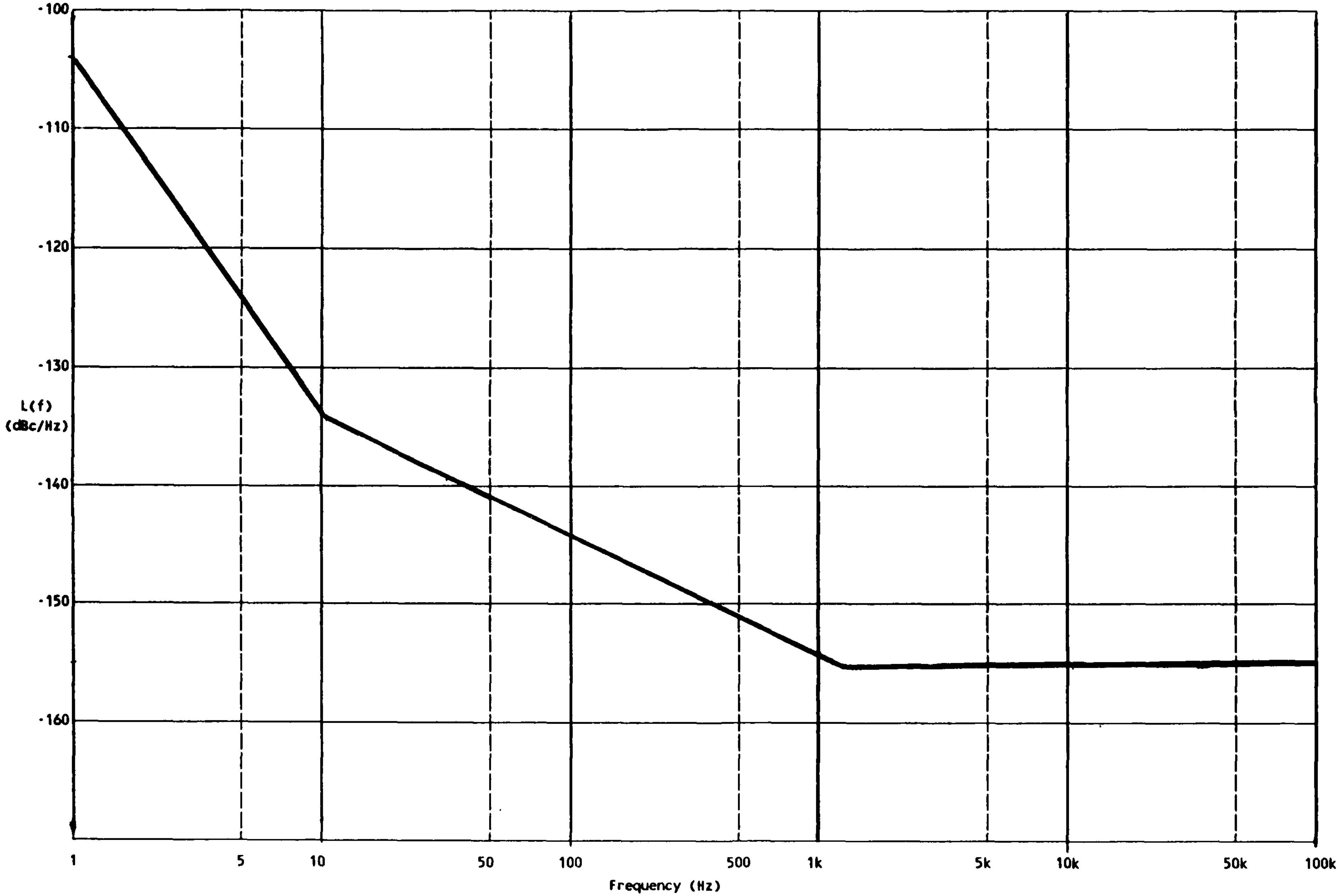

FIGURE 2
SINGLE SIDEBAND PHASE NOISE AT 5 MHz

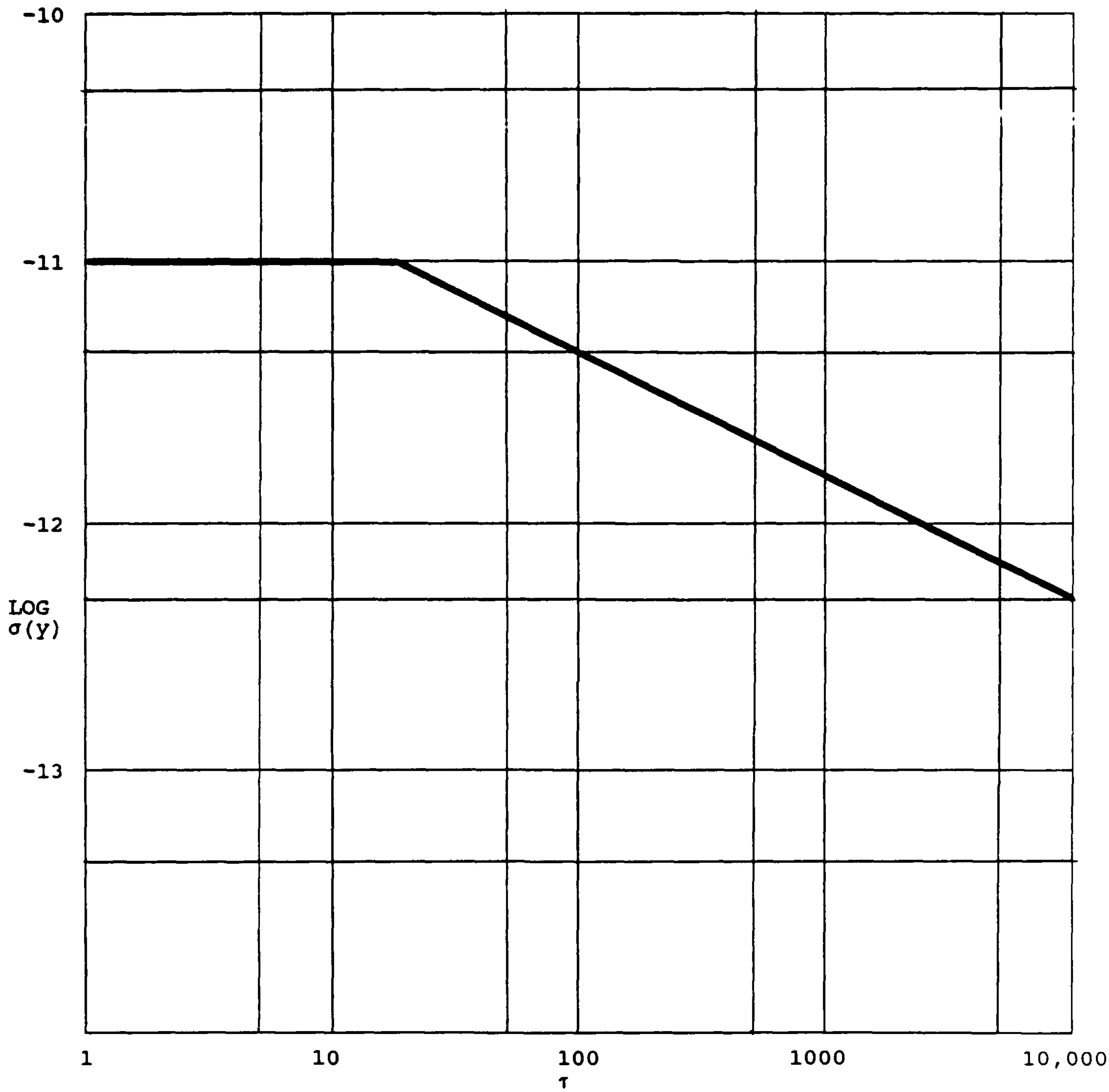

FIGURE 3
TWO SAMPLE VARIANCE FOR THE CESIUM OSCILLATOR

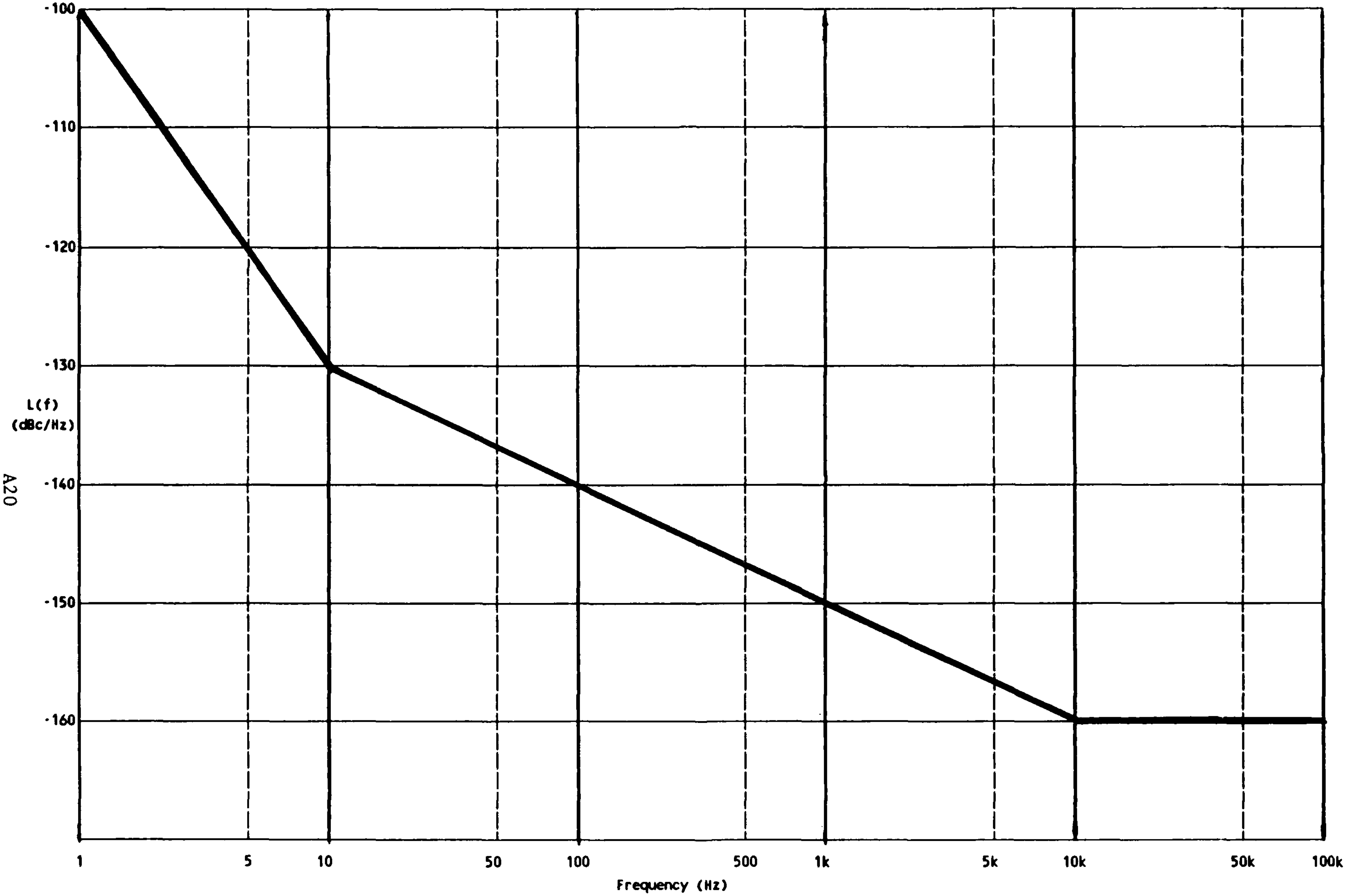

FIGURE 4
SINGLE SIDEBAND PHASE NOISE
FOR QUARTZ CRYSTAL OSCILLATOR AT 10 MHz

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