A NEW FREQUENCY CALIBRATION SERVICE OFFERED BY THE NATIONAL BUREAU OF STANDARDS

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Summary

After many years of helping calibration laboratories solve frequency and timing problems on an ad hoc basis, the Time and Frequency Division of the National Bureau of Standards is offering a new frequency calibration service that is specifically matched to the user's needs. This new service is intended to take advantage of the latest in measurement instrumentation, while at the same time keeping the user costs low.

The new service consists of identifying the calibration problem, obtaining and installing the necessary measurement equipment, and finally, a training seminar for the user. The user then obtains corrections for the accumulated calibration data via a telephone modem to the NBS frequency measurement computer. The service can use low frequency radio signals, or Loran-C signals, for NBS traceability.

Introduction

A frequency calibration means that a frequency source, a crystal, rubidium, or cesium oscillator, is measured using a standard reference frequency. Data are recorded, but, for several reasons, precision oscillators are normally not adjusted during each calibration. A measurement is made and a record is kept, but adjustments are made only infrequently. As a result, considerable record keeping is involved. The new NBS Frequency Calibration system automatically measures and records these calibration data.

Historically, the user of a high quality frequency standard has purchased equipment, read the manuals, and then proceeded with the calibrations. Although this approach to frequency calibration has changed little in several decades, we at the NBS have noticed a change in the needs of frequency calibrations users. Our telephone calls, letters, visitors, and attendees at NBS seminars have shown us that frequency calibration users need a different kind of service. That's why this service will emphasize a different approach to frequency calibrations. This approach is based on NBS experiences in recent years, dealing with a wide variety of users at many levels of accuracy.

Background

To start the discussion of the new NBS Frequency Calibration service, consider the history of frequency calibration. Most laboratories simply tune WWV on short wave, and zero-beat a local oscillator against the WWV signal. This is the most widely used frequency calibration technique and is quite adequate for many users. The next step toward higher accuracies (better than a part in 10^7) involves using a VLF or a Loran receiver (Figure 1.).

The new frequency calibration system is not so much a change in what is being used, but how it is being used. A calibration laboratory must decide what equipment to buy, what it will cost, how it can be made traceable, how much manpower it will involve, and so on. Once these decisions have been made, the equipment is purchased and installed without much trouble. However, the new NBS Frequency Calibration service does not simply limit itself to equipment purchase and operation. Training for standards laboratory personnel is provided, as is a direct telephone data link to the NBS. After the equipment is installed and running, the user can be assured that the data are correct and that a traceable calibration has been performed.

As mentioned previously, the need for both training and follow-up has revealed itself over many years of customer contact. NBS has addressed this need in several ways. The two most important steps have been the offering of frequency calibration training seminars at Boulder and the publication of user-oriented technical manuals. Technical Note 559 is in a second printing and more than 8000 copies have been distributed to aid users in making choices among several different frequency calibration techniques.

Two separate frequency calibration seminars have been offered. One deals with frequency standards and clocks. It discusses time scales, international agencies for time and frequency, short and long term stability, and noise in oscillators; and reviews commercial standards, timekeeping, and clock modeling. A second seminar covers the calibration of oscillators, the use of frequency counters, the day to day measurement and adjustment of frequency standards and the use of Loran-C and VLF signals (Figure 2.)

Even after distributing several thousand copies of the NBS User's Manual and giving many seminars, there was still a missing element. The attendees many times went away with the idea that many frequency calibration techniques could be used, but they were not always quite sure how to use them. This same problem was revealed by our close contact with the manufacturers of WWVB, WWV and Loran-C receivers.

Oscillator manufacturers and others who saw this problem would often tell their customers to call NBS regarding frequency traceability.

As the equipment purchased during the 50's and 60's gradually became obsolete, users indicated a desire to upgrade their laboratory equipment. NBS is an active member in the National Conference of Standards Laboratories. The membership of that group was most vocal in wanting higher quality calibrations. As new equipment is specified and purchased, the level of calibration accuracy moves up from parts in 10^7 or 10^8, towards parts in 10^{11}. The new NBS Frequency Calibration service can accommodate all of these requirements. When companies invest in new lab equipment, they want it to meet their needs as far into the future as possible. But as they increase calibration accuracy, operator skill becomes more of a factor. These are the two main areas the new NBS Frequency Calibration system addresses: what to buy, how to use it, and more important how to insure good traceability at high accuracy levels without becoming overly labor intensive.

This is an important feature. Users want their frequency calibrations to be precise and trouble free. Many laboratories cannot afford to spend large amounts of time on frequency calibrations since they usually have other demands for available resources. The need is for an automatic system where the operator isn't required to learn a complex procedure. A suggestion was once made to call this kind of calibration service a utility, like a telephone. One can use it without much training, and if it stops working, someone else is concerned about it. The NBS goal was to deliver state-of-the-art calibrations of frequency in a way that did not unduly burden the user. It is worth noting that frequency calibrations are relatively easy to automate, even at distances of thousands of miles. This cannot be said of all the other basic standards.

In the course of a year, the NBS Time and Frequency Division handles thousands of inquiries relating to frequency calibrations. These range from the most casual use of WWV to the most sophisticated frequency users wanting to increase their calibration accuracies. Many of these users don't necessarily want superior accuracy but rather want advice on installing and operating a simple system that will not take much time to understand. Often the NBS response to these inquiries is to refer them to manufacturers of equipment that will meet their needs. NBS maintains a list of manufacturers just for that purpose. Listed are all those manufacturers of Loran-C receivers, WWV receivers, GOES satellite equipment etc., known to NBS, but without any NBS endorsement or certification of performance. This is done as a service to the manufacturers and the frequency calibration users.

For many years NBS has broadcast frequency calibration signals from several radio stations. This has been a very popular service. NBS has a close working relationship with most of the manufacturers in the frequency calibration industry and is active in standards labs organizations. Publishing calibration manuals and giving seminars have been useful activities and they have been well received. This new NBS Frequency Calibration service is also a natural step made possible by the low cost computers and telephone modems coupled with the fact that high accuracy radio signals are available nearly everywhere.

A New Frequency Calibration Service

Here is a description of the steps involved in this new NBS Frequency Calibration service. First, there is initial contact with a user. This is followed by attendance at an NBS seminar to help the user decide on choices for signals and equipment. Next, the user obtains equipment that is compatible with the NBS recommended data gathering format, and finally, the user becomes part of an NBS frequency calibration information network. This network has two parts. The first part is the receipt (by mail or computer terminal) of the current frequency data required for laboratory traceability. The second part is an on-line telephone modem link to the NBS for two-way data exchange to verify that the calibrations are correct.

If the initial contact goes beyond a simple suggestion or advice on how to better utilize existing equipment, NBS offers the option of having the user attend one of the NBS Time and Frequency Seminars. The initial contact will usually suggest the level of the difficulty and a possible solution. From experience, and especially dealings with receiver manufacturers, and the NBS staff can determine what to expect in terms of signal reception problems. This information is exchanged with users and manufacturers so that an informed solution can be sought. In addition to suggesting contacting the manufacturer or his representative for help, NBS also suggests that equipment, receivers especially, be tried at the proposed site to detect interference and signal level problems. With many years of experience in these areas, NBS can usually locate problems and suggest alternatives.

An NBS frequency seminar is the second step of the process leading to an improved calibration service. The seminar serves several purposes. It allows the user to actually see the kind of equipment that is available. In the seminar meetings, many equipment options are discussed. Also, traceability to NBS is described, and the user learns what his choices will be in terms of operator involvement. Emphasis is placed on the data and its interpretation. By the time the seminar attendee leaves, his level of familiarity is such that he can make a more intelligent choice. The seminar also lets him see a variety of equipment used to record frequency calibration data. He sees a number of options in terms of signal sources, crystal, rubidium, or cesium. He sees Loran-C, VLF, or LF reception. He is also introduced to time-of-day systems and television methods, and gets to see satellite systems at work. From this experience, the user is better able to decide what is best for his laboratory. He may well choose to stay with what he has, thinking that the possible added cost or complexity is not worth it.

If a decision is made to get a new system, the next step is obtaining the necessary equipment. This will be similar to the equipment used in the NBS seminars, and the software will match. After getting the equipment installed and working, the user can utilize the telephone data link to NBS and verify correct equipment operation. In addition, to simply exchanging recorded data, the telephone modem allows for system troubleshooting via the phone line. This has proved to be very useful for getting systems started.

To better explain the details of how this service operates, consider the following example. Imagine a user in Salt Lake City who has a frequency calibration problem. He wants to upgrade his frequency calibration service so that he can calibrate newer counters with high accuracy time bases. His actual measurement requirement is one part in 10^{10}, but he decides to exceed this, to allow for higher quality frequency calibration needs in the future. He talks to his manufacturers' representative and views several equipment demonstrations. However, he is unsure about how to achieve traceability, and at the representative's suggestion, calls NBS. From this initial contact, he learns that his options are to use WWVB at 60 kHz or Loran-C from the West Coast. To further increase his understanding, to train a member of his staff, and to see actual equipment in use, he registers to attend a NBS frequency seminar.

This user is looking for cost trade-offs and is concerned about how complex the system will be after it is installed and running. He wants to see real data being recorded and handled on a daily basis and wants to talk about his problem. So the NBS seminar is a good choice. At NBS, we have found that precision frequency calibration services have not always been well understood. Direct user training has been one result of attempts to solve this problem. Even though we how have technical literature that is fairly easy to read, hand-on experience is invaluable.

At the NBS seminar, the user sees Loran-C and WWVB equipment being used and the data from those receivers being plotted and analyzed (Figure 3.). He gets a feeling for the kind of data he will have to handle to achieve his target objective of parts in 10^{11} calibration accuracy. He sees equipment from a number of manufacturers in operation. During the seminar, he talks with other users and with them makes comparisons of the options available to him.

Finally, he decides that even though WWVB is receivable in Salt Lake City, he will select Loran-C as a calibration source and will use an automatic data logger (Figure 4.). This choice gives him state-of-the-art frequency calibrations. At the NBS seminar, the user sees Loran-C tracking receivers running with little or no attention and also notes that the data logging system takes care of power outages and is designed to minimize operator interaction. At the other end of the telephone line, NBS can provide assurance (automatically) that the data being recorded is valid. The user then gathers up his seminar material and returns to his laboratory ready for the next phase, which is getting the equipment together. Depending on his choices, the equipment costs should remain modest (Figures 5 and 6). This reflects a primary design goal by NBS to make the system affordable, automatic, and easy to operate.

As his equipment is delivered, the user will work with his manufacturers' representatives to get it installed. Using NBS-compatible software, he can go at once into a debugging phase where his data can be compared with data recorded at the NBS. This provides the assurance that the calibrations are valid. The seminar training material will also contain examples of data plots and oscillator performance evaluation.

As questions arise, the user can "see" the performance of his Loran based system by plotting data obtained at his site. Conversely, NBS can also look at his data via telephone modem. This two-way data exchange is a most valuable characteristic since it can resolve many of the problems associated with precision frequency calibrations. This user will also have a Frequency Calibration Bulletin available to him. This is a published list of the performance of some accurate signal sources, such as WWVB, Loran-C, and several VLF stations (Figure 7). He can obtain these data by telephone and will also get a copy by mail at monthly intervals. Since the software is compatible, his plots will overlay the NBS plots and he can identify system troubles.

The user now has a high quality system that he understands and that fulfills his requirements. The system runs with the least trouble and inconvenience to him and can be upgraded as new developments emerge. If the user has staff changes, he can send additional persons to an NBS seminar for training. He will feel that he is a part of larger system and that help is available. This is in contrast to the situation in recent years where each user was essentially isolated.

Another benefit is built into the system. Suppose in our example that an air base near Salt Lake City has a contractor who wants to check some timing equipment. This new user can benefit from the data base aspects of the new NBS Frequency Calibration system. Each new user in an area can compare his data, via the NBS data base, with others. In this example, if two users are tracking Loran-C, any suspicious data can be tracked down and the cause located. In an area that has many users, the overall quality of calibrations will likely improve, especially if some users maintain very high quality frequency standards.

Conclusion

The NBS feels that this new service plan will meet a critical need for frequency calibration users. It has been planned to provide all the necessary training, data logging, feedback, and follow-up. As improvements in technique are developed at NBS, they can be incorporated by substitution or modification of system software. If lower cost options or peripherals are developed, they too can be easily incorporated.

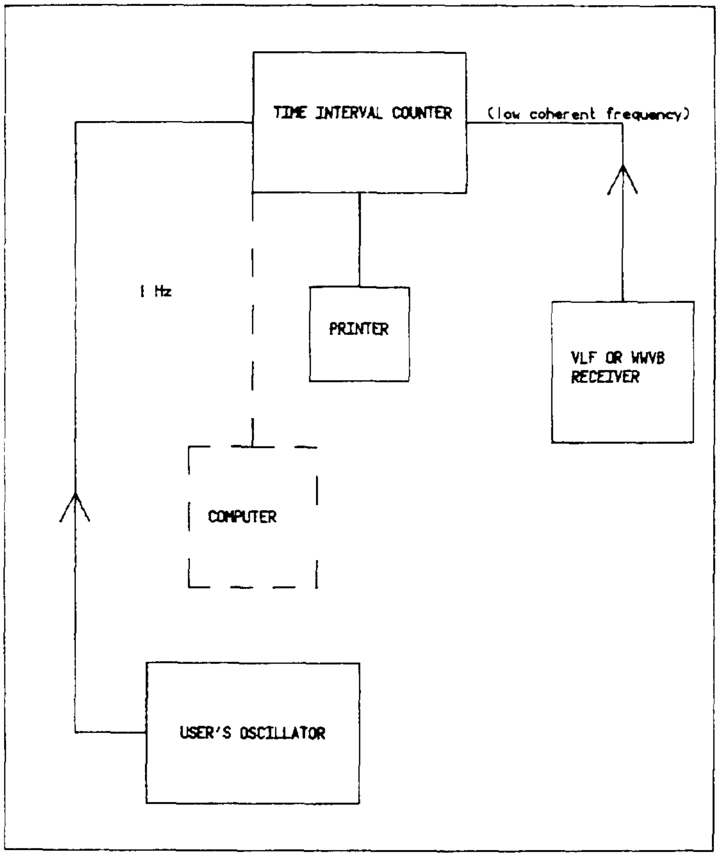


FIGURE 1. SIMPLE FREQUENCY CALIBRATION SYSTEM (COMPUTER OPTIONAL)

SEMINAR ON FREQUENCY MEASUREMENTS AND CALIBRATIONS

This is a new seminar that incorporates new material into the Time & Frequency User's Seminar given in previous years. It is intended for engineers and standards lab technicians involved in making frequency calibrations. The course will be taught at a practical level to satisfy those new in the field as well as more experienced users. Methods taught will use commercially-available equipment.

DATES: October 25, 26, and 27.

LOCATION: National Bureau of Standards
325 Broadway
Boulder, CO 80303

TOPICS COVERED:
CRYSTAL OSCILLATOR CALIBRATION
APPLICATIONS OF FREQUENCY COUNTERS
HOW TO CHOOSE A FREQUENCY CALIBRATION SOURCE
CARE AND USE OF FREQUENCY SOURCES
USING LORAN-C AND WWVB FOR FREQUENCY CALIBRATIONS
TIME AND FREQUENCY MEASUREMENT ASSURANCE SERVICES AT NBS
ORGANIZATION OF TIME AND FREQUENCY IN THE U.S.
NBS, USNO, AND OTHER PUBLICATIONS

Although all of the above subjects will be covered, emphasis will be on making practical frequency measurements and calibrations.

Registration fee includes teaching materials, supplies, coffee and refreshments, and certificate of completion.

REGISTRATION DEADLINE: October 11.

CANCELLATION: Registration fee will be refunded in full only if notice of cancellation is received at NBS prior to October 11.

MAKE CHECKS PAYABLE TO: SEMINAR ON FREQUENCY MEASUREMENTS AND CALIBRATIONS.

HOTEL INFORMATION: See page 2.

INSTRUCTIONS FOR ATTENDANCE: Complete and return attached application.

FOR FURTHER INFORMATION:

GENERAL INFORMATION: (303) 497-3212
TECHNICAL INFORMATION: (303) 497-3378

FIGURE 2. EXAMPLE OF SEMINAR ANNOUNCEMENT

FIGURE 3. EXAMPLE OF LORAN DATA AS RECEIVED AT THE NBS

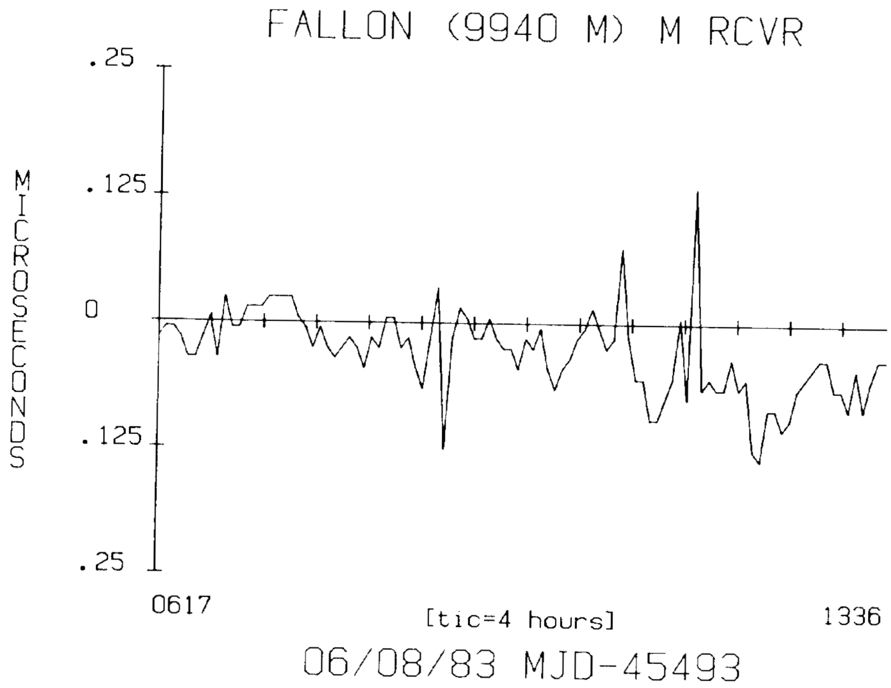


FIGURE 4. LORAN-C STATIONS IN RELATION TO A TYPICAL FIELD SITE

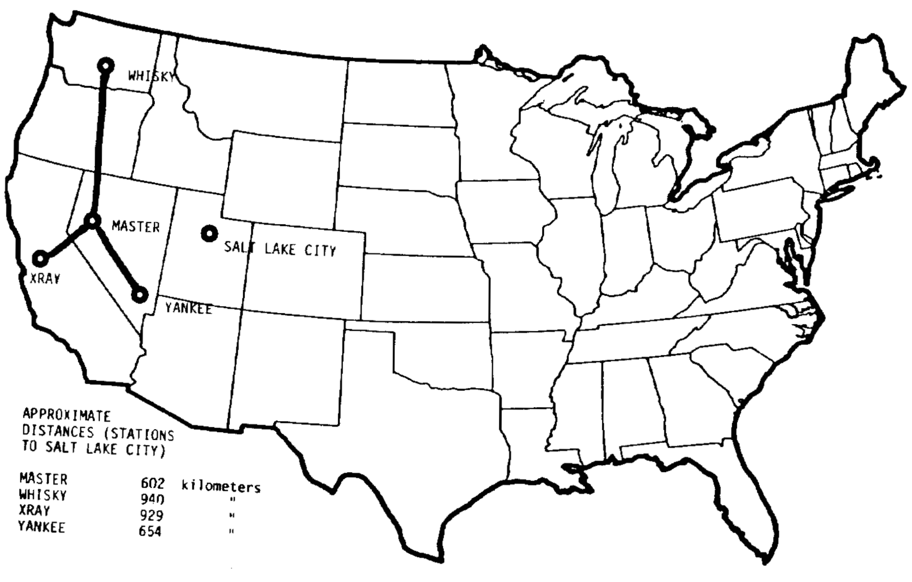


FIGURE 5. EXAMPLE OF LOW COST NBS FREQUENCY CALIBRATION SYSTEM

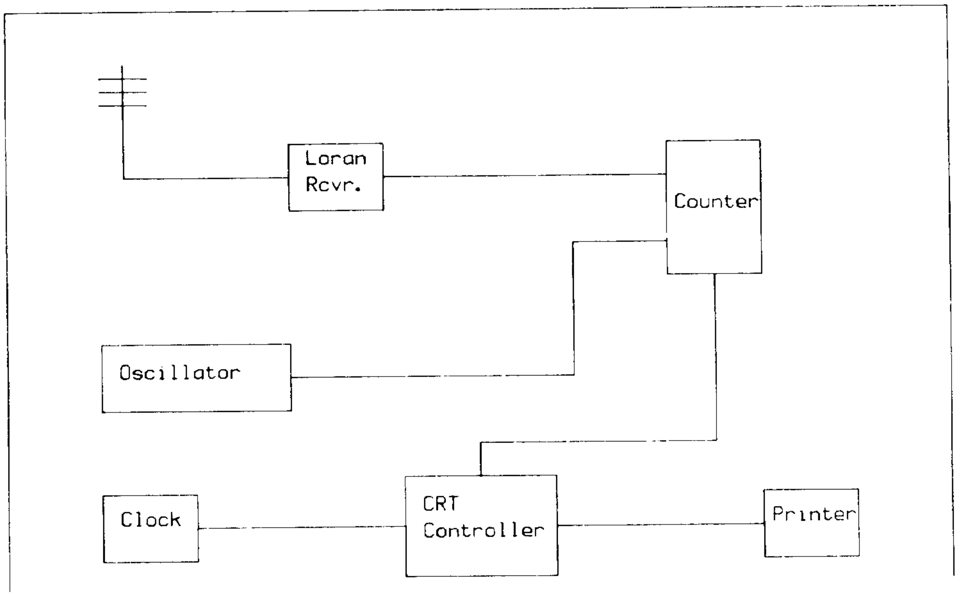
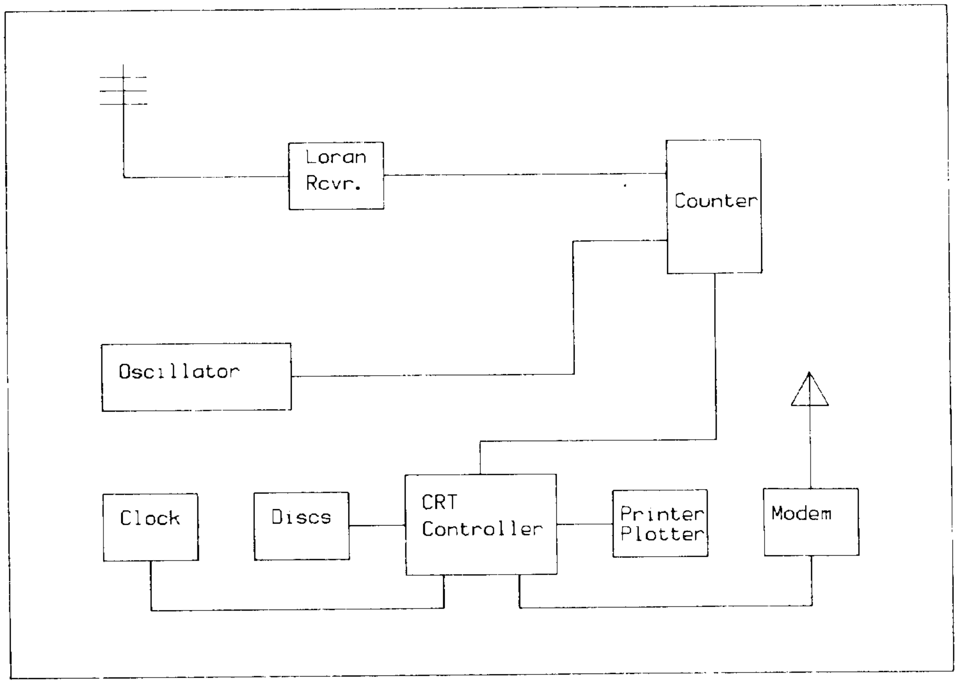


FIGURE 6. EXAMPLE OF NBS FREQUENCY CALIBRATION SYSTEM WITH MODEM AND PLOTTING CAPABILITIES



3. PHASE DEVIATIONS FOR WWVB AND OTHER NBS-MONITORED BROADCASTS

WWVB (60 kHz)

Values given for WWVB are the time difference between the time markers of the UTC(NBS) time scale and the first positive-going zero voltage crossover measured at the transmitting antenna. The uncertainty of individual measurements is plus or minus 0.5 microseconds. Values listed are for 1500 UTC.

Omega, North Dakota (13.1 kHz) and Omega, Hawaii (11.8 kHz)

Relative phase values are given for VLF stations and only the change from the previous available day's reading is published. Days when the data were satisfactory but readings were not taken (for example, on weekends or station maintenance days) are marked (-). If data were lost, continuity is also lost and the indication is (*), which means that reading cannot be compared to the previous day.

LORAN-C Dana, Indiana and LORAN-C Fallon, Nevada, (100 kHz)

Values for Loran-C (Dana) and Loran-C (Fallon) are the time difference between the UTC(NBS) time pulses and the 1 pps output of the Loran-C receiver.

APR 1983	MJD	UTC(NBS) - WWVB (60 kHz) ANTENNA PHASE (in Microseconds)	UTC(NBS) - RECEIVED PHASE (in Microseconds) OMEGA (11.8 kHz)	OMEGA (13.1 kHz)	LORAN-C (DANA) (100 kHz)	LORAN-C (FALLON) (100 kHz)
1	45425	5.80	(-)	(-)	62295.95	3947.01
2	45426	5.70	(-)	(-)	62295.83	3947.08
3	45427	5.70	+ 1.2	- 1.4	62295.84	3947.05
4	45428	5.71	+ 0.6	+ 0.1	62296.02	3947.05
5	45429	5.73	+ 0.9	+ 1.1	62295.93	3947.00
6	45430	5.69	+ 1.6	- 0.6	62295.94	3947.06
7	45431	5.79	- 2.2	+ 0.1	62295.89	3947.12
8	45432	5.70	+ 1.3	- 0.3	62295.78	3947.22
9	45433	5.72	- 0.8	+ 1.4	62295.64	3947.33
10	45434	5.74	- 0.3	- 0.1	62295.64	3947.48
11	45435	5.75	+ 0.1	- 0.6	62295.80	3947.57
12	45436	5.68	+ 0.9	- 1.5	62295.87	3947.57
13	45437	5.69	- 0.6	+ 1.1	62295.78	3947.61
14	45438	5.75	+ 2.3	- 0.8	62295.84	3947.62
15	45439	5.77	- 0.7	+ 1.4	62295.76	3947.66
16	45440	5.67	+ 0.1	- 0.2	62295.47	3947.80
17	45441	5.65	+ 0.9	+ 0.1	62295.47	3947.95
18	45442	5.64	- 0.3	0.0	62295.49	3947.95
19	45443	5.64	+ 1.2	- 0.4	62295.62	3948.02
20	45444	5.65	- 0.1	- 0.1	62295.56	3948.06
21	45445	5.72	- 0.4	- 0.3	62295.62	3948.12
22	45446	5.72	- 1.1	- 1.1	62295.71	3948.16
23	45447	5.72	- 1.9	+ 1.2	62295.42	3948.22
24	45448	5.72	+ 1.5	- 0.1	62295.41	3948.24
25	45449	5.72	+ 3.0	+ 0.6	62295.55	3948.28
26	45450	5.85	+ 0.8	- 0.7	62295.54	3948.34
27	45451	5.67	- 1.8	- 0.2	62295.58	3948.37
28	45452	5.66	- 0.9	+ 0.7	62295.57	3948.38
29	45453	5.68	+ 0.5	- 0.1	62295.63	3948.38
30	45454	5.68	+ 0.6	- 1.4	62295.52	3948.35

Values for Omega and Loran-C are as received at NBS, Boulder, Colorado. Values are 4-hour averages taken from 1600-2000 UTC daily. VLF data are reported exactly as seen. Some days show variations due to signal loss or station outages. The data are still useful.

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FIGURE 7. AN EXAMPLE OF PUBLISHED FREQUENCY CALIBRATION DATA