REMOTE FREQUENCY CALIBRATION SYSTEM USING JJY

Haruo Saito, Shigeru Tsuchiya, Noboru Kotake, Tsukasa Iwama and Kuniyasu Imamura
National Institute of Information and Communications Technology (NICT)

Abstract

JJY is the LF radio station in Japan, which performs the dissemination service of the standard time and frequency. We have two JJY stations; one is located in the north part of the Honshu-island and another is in the Kyushu-island. These stations cover all over Japan. As watches and clocks controlled by JJY have been sold over ten million, and consequently the dissemination service of the standard time has become popular in Japan. On the other hand the dissemination service of the standard frequency of JJY is rarely used and it seems limitedly to be used in the industrial markets. In other countries such as Germany and some, however, the frequency calibration services are performed by using the standard frequency signal of the LF radio station for industrial standard.

NICT takes the responsibility for disseminating using the JJY signal as the frequency standard to Japan, because JJY has been transmitted with the standard frequency by NICT. We are planning a new remote frequency calibration system which adopts JJY signal for the frequency standard.

1. Introduction

JJY signal is unfamiliar to the public with using frequency standards now. Most of the reasons are that the signals from JJY receivers are not traceable to the National frequency standard, even though JJY signal is transmitted based on the national frequency standard of NICT. Therefore, JJY frequency standard signal is hard to use as the frequency standard in the industrial markets. And furthermore the standard signal generators using JJY are too expensive.

NICT takes the responsibility for disseminating using JJY signal as the frequency standard to Japan, because JJY has been transmitted with the standard frequency by NICT. We are planning a new remote frequency calibration system which adopts JJY signal for the frequency standard. To develop this calibration system, we aim at two targets;

One is to offer a new remote frequency calibration service which is applied to the ISO/IEC 17025, and

another is to supply the industrial markets with cheaper JJY traceable standard signal generator which can come out such as 1MHz, 5MHz and 10MHz.

2. System Configuration

2.1 Current Condition

Figure 1 shows a current condition when a client wants to use JJY signals for a frequency standard. An accuracy of a signal from a JJY receiver is assured only by a manufacturer of JJY receivers instead of NICT, even though NICT transmits JJY signal as the standard frequency. Because there are not any methods to confirm the accuracy of a received JJY signal and a signal from the JJY receiver directly on the client's place, the client needs to request a calibration company to calibrate the JJY receiver, if he wants to ensure its accuracy.

To remedy this condition, we are planning to establish a new calibration system to use JJY, to make JJY receivers for the system and to supply them to the industrial markets.

2.2 Calibration Method and JJY Receiver

The calibration method has assumed two aspects, one is to calibrate a DUT (device under test) and another is to calibrate JJY receiver's signal.

4-2-1, Nukui-Kitamachi, Koganei, Tokyo, 184-8795, Japan
Tel +81-42-327-7460, Fax +81-42-327-6689, E-mail saito@nict.go.jp

To calibrate JJY receiver's signal, we plan periodically to sift the phase of the JJY transmitting signal for a value and then to measure a phase shift of the JJY receiver's signal using DUT's signal as a reference frequency. Because it seems that a signal of the DUT is sufficiently stable for very short term. At first the data received by the calibration system are compared to the data transmitted from JJY stations, and then the frequency deviation of the signal of the JJY receiver is calculated. A signal of DUT is calibrated by using this JJY receiver's signal. Of course the accuracy of the JJY receiver must be confirmed at NICT before installing.

Figure 2 shows the schematic block diagram of a remote frequency calibration system. It consists of 2 parts; a JJY signal transmission part at JJY stations and a JJY receiver part at client's place. The JJY signal transmitting part is based on the current JJY signal transmitting system, and a phase sifting mechanism is installed to step the JJY transmitted signal for a precise value. The JJY receiver part consists of a JJY receiver, a phase comparator and a data transmitting mechanism to compare phase data.

In order to develop a cheaper system which is locked directly to the JJY signal, we plan to use OCXO for the local oscillator.

Figure 3 shows a schematic block diagram of a prototype JJY receiver with a phase comparator. It consists of a direct signal receiving part, a PLL (phase lock loop) part and a phase comparator part. And the receiver has one standard frequency output as 10 MHz and the phase comparator changing from 0 V to 5 V dc voltages according to measured phase differences. The phase comparator has the several ports to measure phase differences, and one of the ports will be selected by anticipated phase differences of measuring point.

The prototype JJY receiver costs about 8,000 US dollars for each. If they are produced in mass-quantity, the cost of a JJY receiver itself (without a phase comparator) will be under 5,000 US dollars.

2.3 Propagation Condition and Service area

Figure 4 shows the available areas of JJY signals transmitted from two JJY stations and they cover all over Japan with more than 50 dBuV/m signal strength. The strength of the signal is strong enough for radio controlled watches and clocks to function, and so over ten million of radio controlled watches and clocks have been sold in Japan. This remote frequency calibration system is designed to operate in the whole of Japan with about 40 dBuV/m or more signal strength, and the antenna is possibly installed indoors.

The conditions of propagation are another important factor to use the JJY signal for the frequency standards. Consequently, we plan to observe the propagation condition by measuring field strength at several 100 km points from each transmission station, because there are differences of propagation conditions depending on the distances. The differences of propagation conditions are the one and strong factor to degrade the accuracy of the system, and making a model of propagation conditions is required to calculate the uncertainty of the system. We will study it measuring receiving signals from JJY stations at above points.

In addition to the above, sferics noises are also an important factor. We try to measure them at the same time as much as possible. However, because it may be rather difficult to know in which paths there occurs sferics noises among all radio paths, at least we will accomplish to confirm how the propagation conditions differ according to the seasons.

2.4 Capability of Calibration

We have measured the JJY signal at NICT HQ to confirm conditions of its signal intensities and its time cords. Now, we will anticipate a capability of this system based on these data. It seems that there are two factors to estimate the capability of this system. One is what time of a day to measure, and another is how far from the JJY stations. Both of them have an influence on propagation conditions such as signal reflection of the ionosphere and so on.

Measured relative phase data of JJY 40 kHz signal at NICT HQ are shown in Figure 5. They are averaged values for one month of January and August 2008. Figure 6 shows those of JJY 60 kHz signal. Distances from JJY 40 kHz and 60 kHz stations to NICT HQ are about 230 km and 890 km respectively.

These figures indicate that the data in the daytime are stable but those during the night are unstable. Instability during the night is caused by direct signals and reflected signal of the ionosphere. In addition, these figures show that there are different conditions of phase data by different distances from the JJY stations. As the distance from the JJY stations is farther, variations of phase shifts are larger, because a density of reflected signals by the ionosphere is stronger than that of direct signals.

Figure 7 shows that stabilities of JJY 40 kHz signals and those of JJY 60 kHz at NICT HQ are shown in Figure 8. These show that variations depending on seasons are very small, but those depending on distances from the stations are large. 3:00 UTC (12:00 local time) data show that stabilities of signals in the daytime are better than those for a whole day. They are less than 1.0 E-11 per day irrespective of distance from stations. This is because the phase fluctuation in the day time is stable as shown in Figure 5 and 6. Therefore a capability of this system may be estimated about 1.0 E-11 at any spots all over Japan, if measurement is done during the daytime. Needless to say, the capability of this system should be examined by some actual studies.

Next, we will confirm the calibration method of this system. We plan to step the JJY transmitted signal for a value periodically to calibrate the JJY receiver. Figure 9 shows a phase shift data of JJY 60 kHz measured at NICT HQ on July 1st 2008. Strayed part of the data was caused by replacing a transmitting machine to redundant one at the station, because of the damage by lightning. This line graph shows that the phase shifted to about -1.9 us at 0:51 UTC and it shifted back to about +1.9 us at 1:16 UTC. The stepped values of the JJY signal at the station were -1.88 us and +1.85 us respectively, and it means that measured data agree with these values despite of a long distance from the JJY station. Of course we need to test this calibration method but it seems that this method is valid any place in Japan.

3. Future Plan

In the first year, we are making a prototype of the JJY receiver with a phase comparator for 40 kHz. We will test it at NICT HQ located about 230 km south-west from 40 kHz JJY station. At first we examine a performance to receive the JJY and the comparator and then test the calibration method.

In the following year, we will refine the prototype based on the result of the test mentioned above. Then we will produce several prototype receivers without the phase comparator, and install them at several points in Japan to measure the propagation conditions according to different distances from the JJY station. We will measure propagation data using this system for the long term, more than a year, and find out whether the calibration method is good or not.

After all, we will add it to the NICT calibration menu and get the accreditation of the ISO/IEC 17025.

4. Summary

We present our plan of the remote frequency calibration system using JJY. We have a responsibility for disseminating JJY signal as the frequency standard to Japan, and we will carry through our plan. As a result, we hope to give a report on the new system at the next ATF.

References

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[2] N. Wakai, et al., “Wintertime survey of LF field strengths in Japan”, RADIO SCIENCE, Vol.41, No.RS5S13, pp.1-7, 2006.

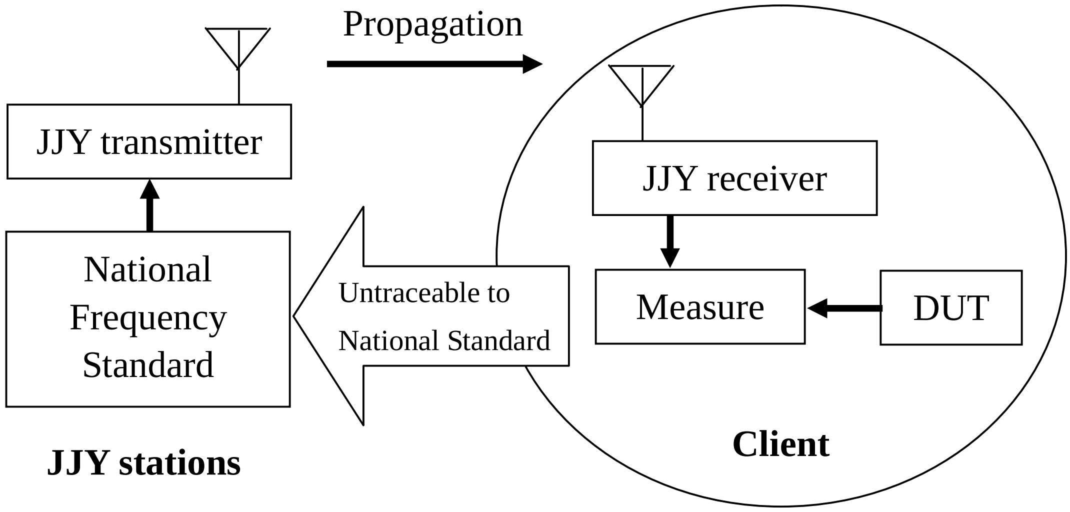

Figure 1 A current condition of JJY signal as the frequency standard

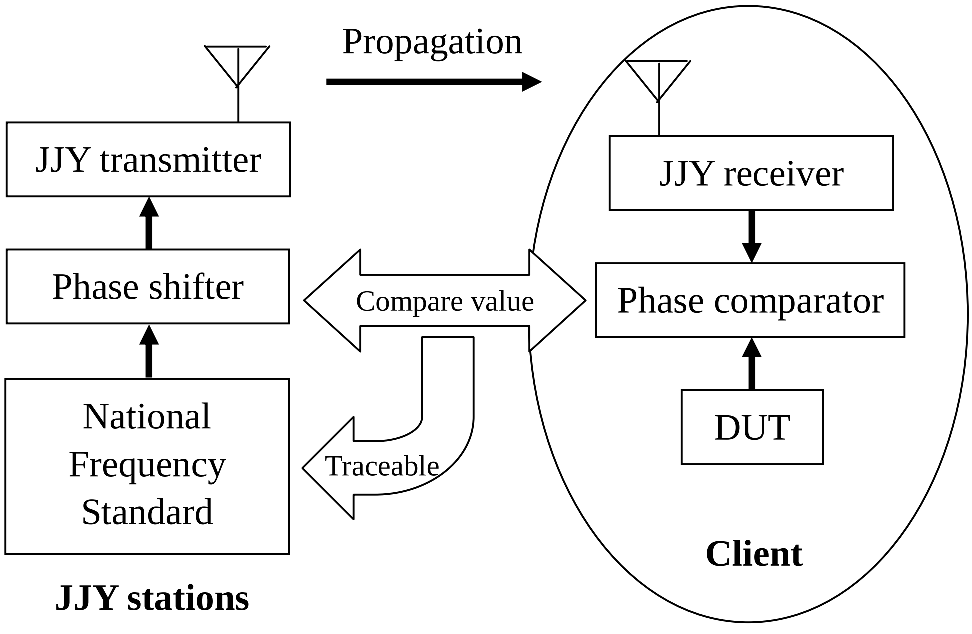

Figure 2 A calibration method of the system using JJY signal

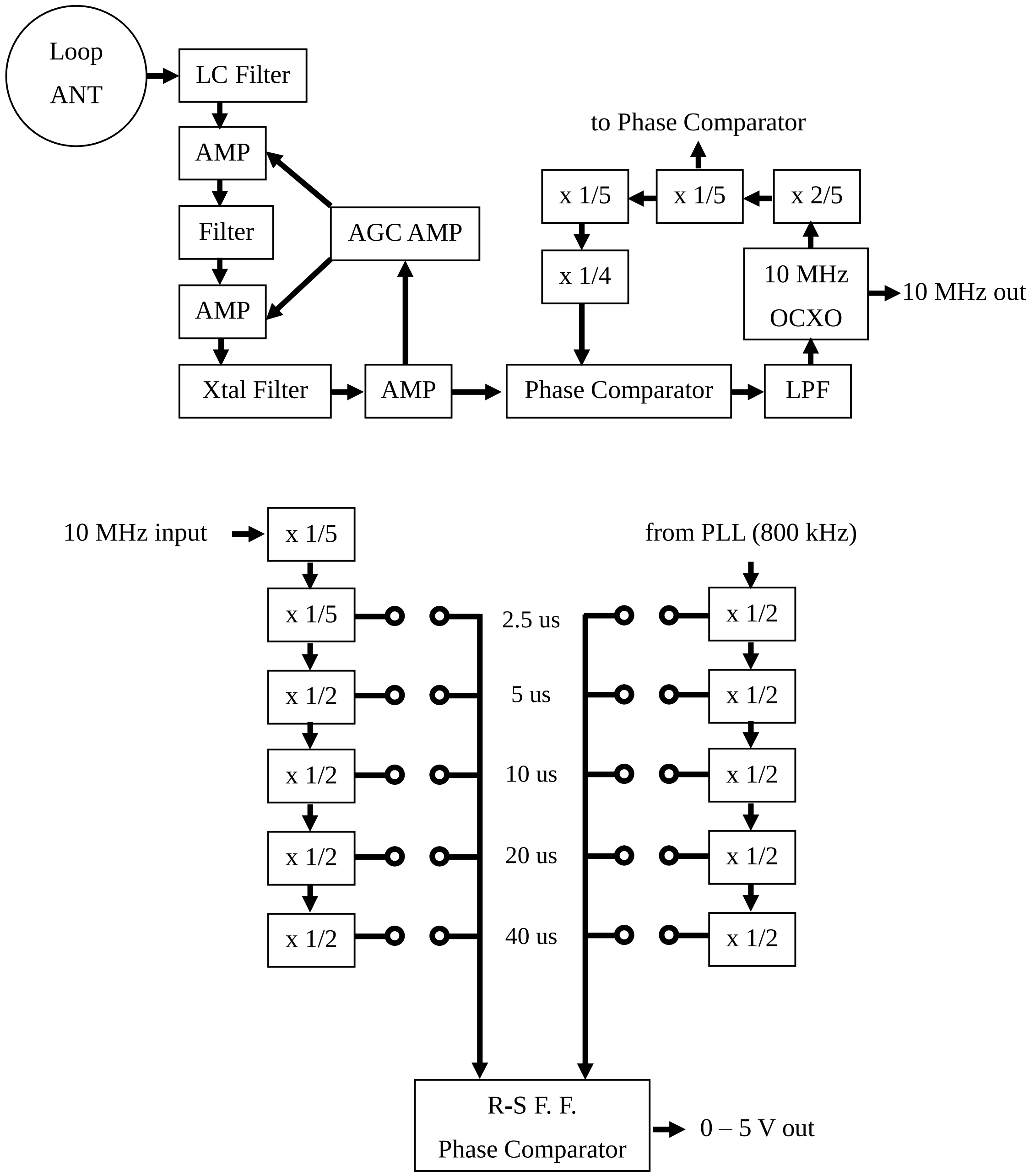

Figure 3 A schematic block diagram of a prototype JJY receiver and a Phase Comparator

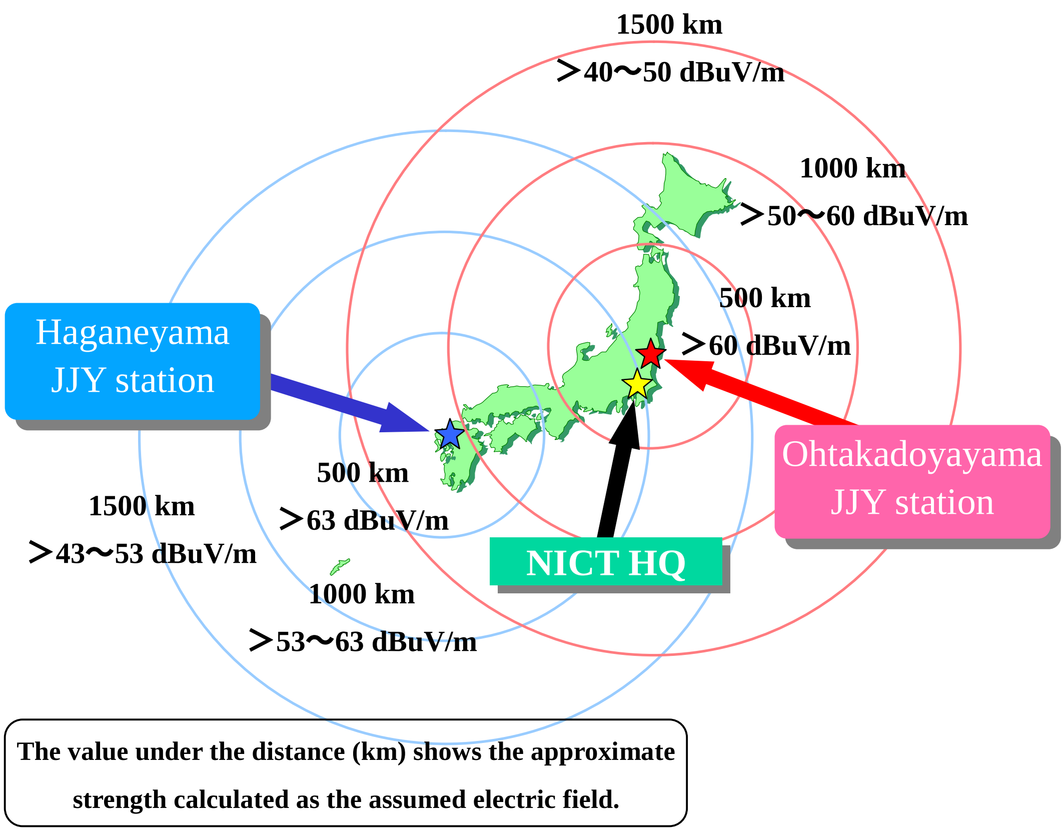

Figure 4 The available area of JJY signal

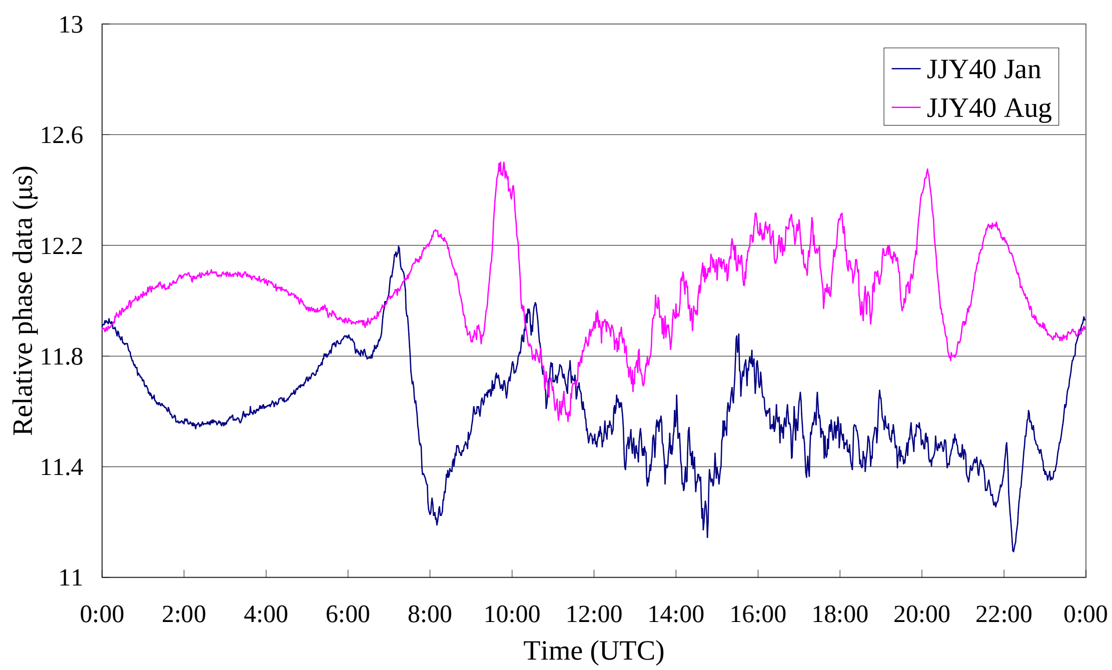

Figure 5 An averaged relative phase data for JJY 40 kHz

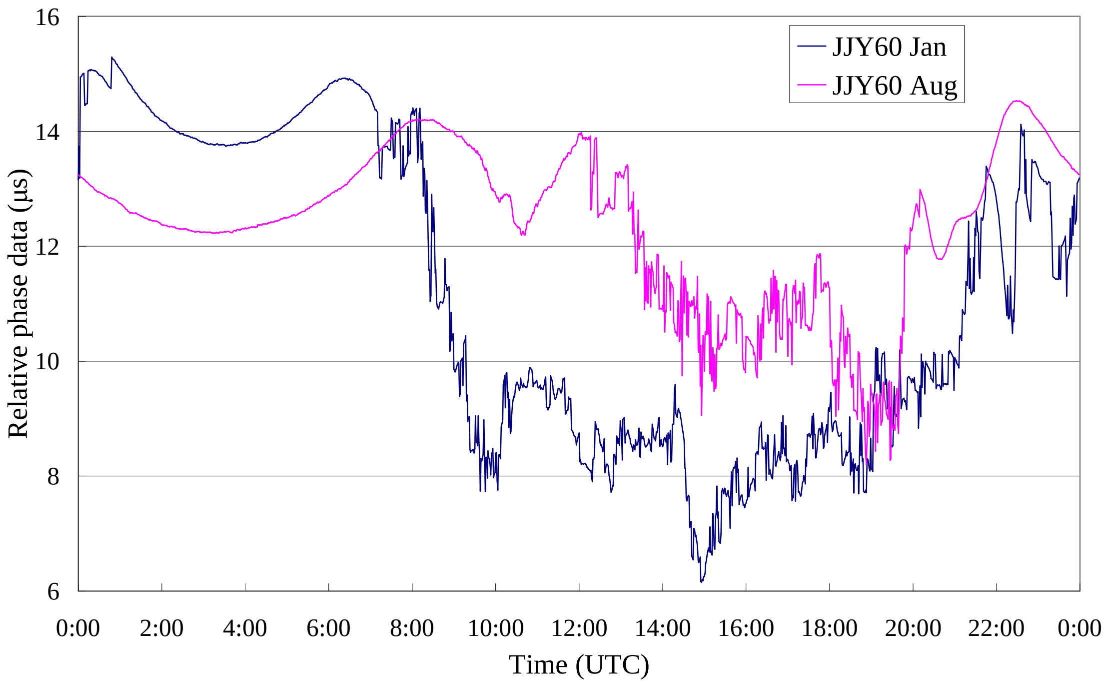

Figure 6 An averaged relative phase data for JJY 60 kHz

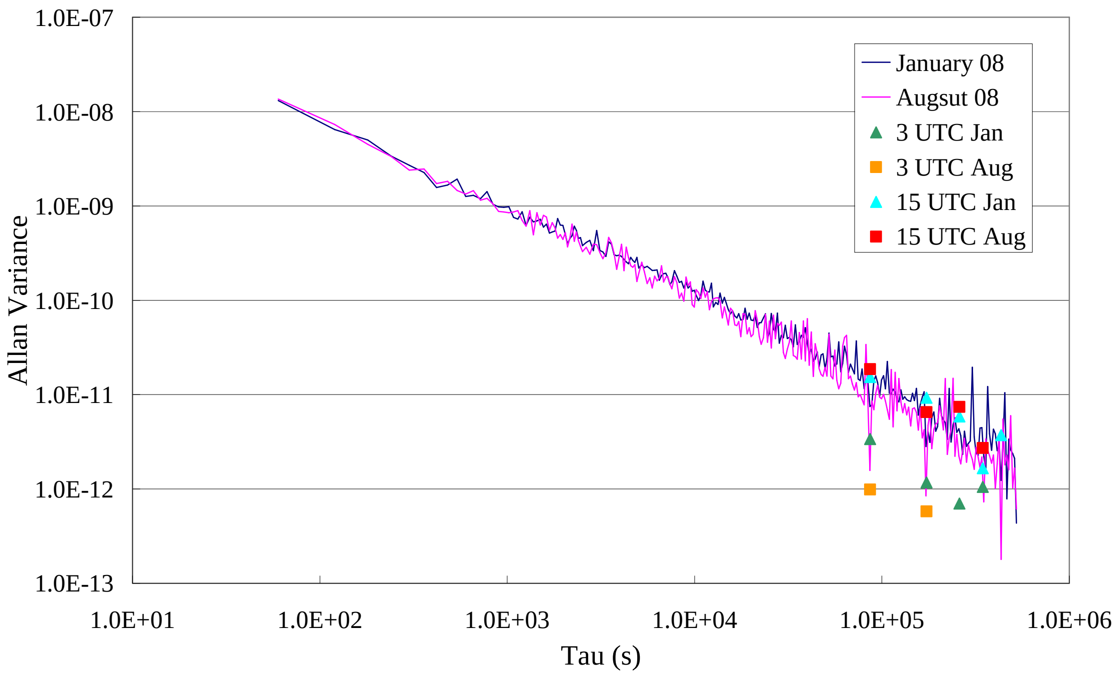

Figure 7 An Allan variance data for JJY 40 kHz

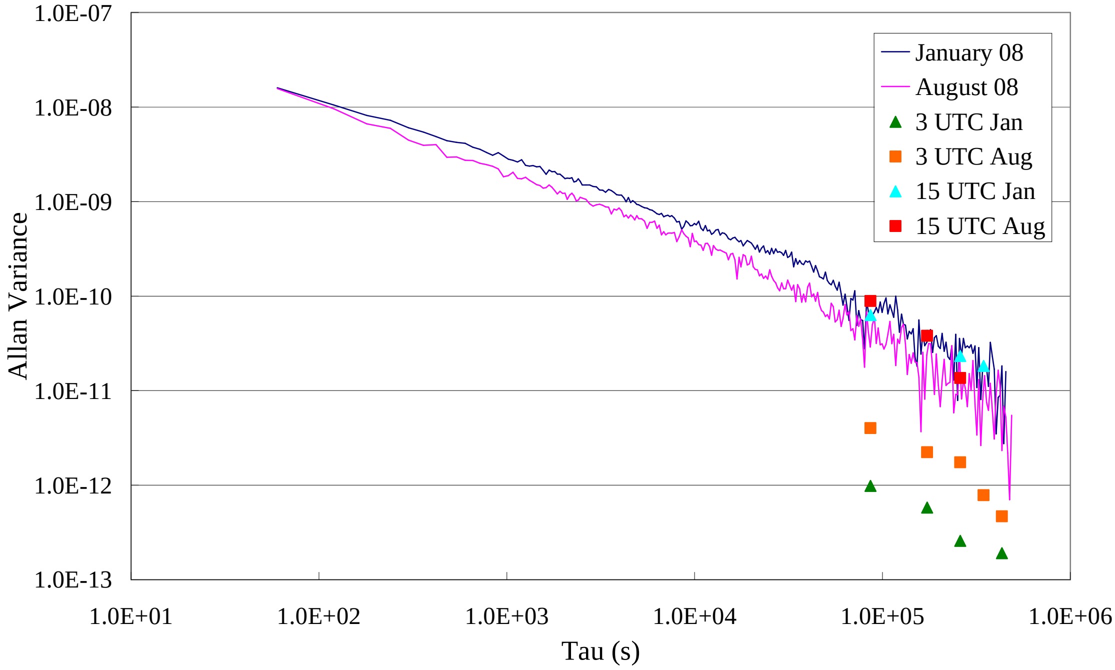

Figure 8 An Allan variance data for JJY 60 kHz

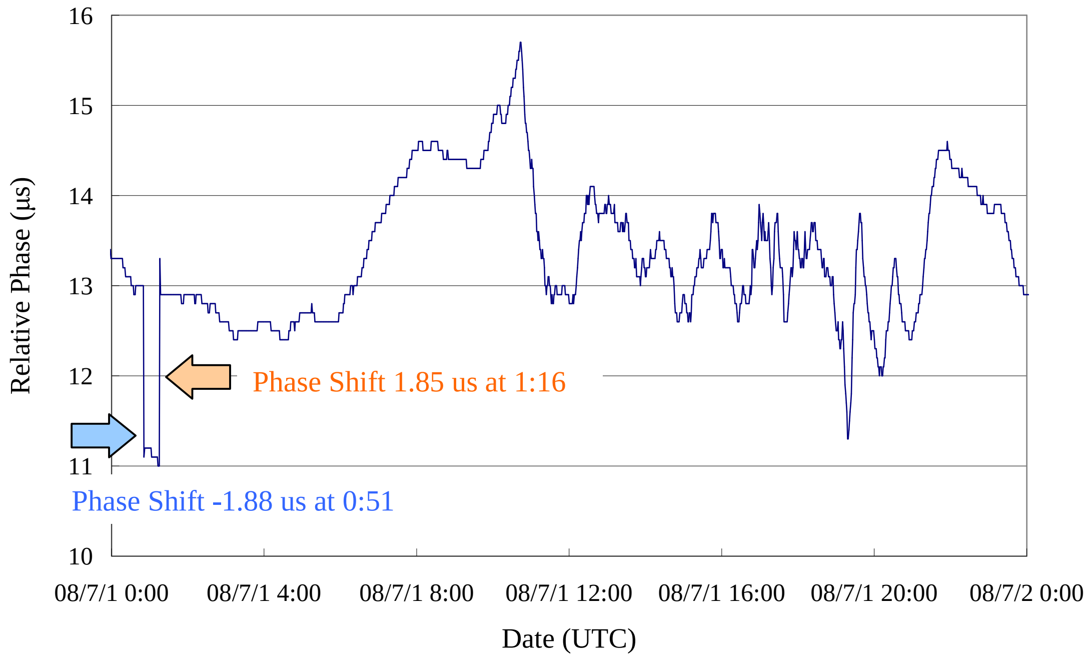

Figure 9 A phase shift data for JJY 60 kHz on July 1st 2008