5-3 JJY, The National Standard on Time and Frequency in Japan

KURIHARA Noriyuki

The Communications Research Laboratory (CRL) determines the national standard time and frequency in Japan, which is disseminated throughout Japan by the LF standard-time and frequency-signal emission, JJY. JJY is utilized as reference signal of radio controlled watches and clocks which have now come into wide use rapidly, and is being recognized as a social infrastructure which supports the people's living in Japan. In this paper, the followings are introduced: JJY facilities with dual operation system, and future utilization and development of JJY.

Keywords
Frequency standard, Japan standard time, Standard-time and frequency-signal emission, Radio controlled clock

1 Introduction

As the nation's sole agency responsible for Japan's frequency standard, the Communications Research Laboratory (CRL) produces the national standard frequency and Japan Standard Time, and disseminates these signals nationwide via LF standard-time and frequency-signal emission (JJY-LF). JJY-LF is used as a reference signal for a growing number of radio-controlled clocks and has been recognized to be a part of the national infrastructure. JJY-LF was formally operated in June 1999, with the Ohtakadoya-yama LF station (located at the top of Mt. Ohtakodoya in Fukushima prefecture) serving as the nation's first base for JJY-LF. The Hagane-yama LF station (Kyushu LF station) then began similar operations in October 2001, resulting in a dual-station nationwide system of standard-time and frequency-signal emission.

Precise Japan Standard Time and standard frequency are expected to find applications not only in the field of radio-controlled clocks but also in the areas of home appliances, time-business applications, and precision synchronization over high-speed communications networks; in fact, a number of commercial activities have already begun in these areas. This paper will briefly describe the background of the JJY-LF, completed LF station, operational conditions, precision of the distributed JJY, and future applications.

2 Overview of standard time/frequency

Since time and frequency play an important role both in daily life and in specialized areas of science and technology, consistency is essential. Each industrialized country with advanced fields of science and technology produces and takes responsibility for its own high-precision national time/frequency standard. In Japan, the CRL (Incorporated Administrative Agency) produces, maintains, and disseminates the national standard time/frequency in accordance with the Ministry of Public Management, Home Affairs, Posts and Telecommunications Establishment Law, in addition to the CRL Law. Such standard time/frequency services are widely used to calibrate in-house standards for domestic manufacturers of measurement devices and communications devices, in the TV/radio time-announcement applications that provide time to the general public, or in NTT's 117 time service.

CRL's Standard time/frequency services work consists of the following three factors:

① Generation and maintenance of standard time and frequency

② International comparison of standard time and frequency

③ Dissemination of standard time and frequency

As for the first factor, it is essential to generate a national standard time and frequency that is sufficiently accurate and precise, and to maintain this standard with a high degree of stability. The CRL generates Japan Standard Time and frequency by using 12 Cs commercial frequency standards.

In terms of the second factor, it is of importance to ensure consistency among each country's national standards, therefore, the Bureau International des Poids et Mesures (BIPM)[1] works with the standards authorities of each country to compare standards, via stationary satellites (two-way satellite time and frequency transfer: TWSTFT) and/or GPS. The results are then used to determine Coordinated Universal Time (UTC) and International Atomic Time (TAI). The CRL, appointed by the BIPM as a node station in the Asia-Pacific area of the international precise time transfer network, plays a crucial role[2] within this framework.

In terms of the third factor, some ways of dissemination according to the required accuracy must be prepared, so that the national standard may be put to wide public use.

The CRL disseminates Japan Standard Time and standard frequency to society through various methods, including LF standard-time and frequency-signal emission (JJY-LF, as the most popular ways, as described in detail below) and telephone networks.

3 Overview of LF standard-time and frequency-signal emission (JJY-LF)

3.1 History of the JJY-LF

Dissemination of the JJY began on January 30, 1940, in an effort to broadcast a standard frequency to domestic radio stations and broadcast stations. Later, beginning in August 1948, a time code was added to the JJY. This time code has been used as a reference for TV/radio time announcement services and NTT's 117 service, and has already been established in our civic life in Japan. The JJY has thus served as Japan's basis of time for more than half a century, throughout the postwar years.

At first, the standard-time and frequency-signal emission (JJY) was broadcast in the shortwave (HF) band. However, since the HF radio path depends heavily on ionospheric conditions, the use of HF raises various issues, including unstable signal receiving, insufficient frequency precision, and jamming. To solve these problems, in 1993 a committee was established inside the CRL to discuss the future standard-signal distribution policy and to conduct a comprehensive review by using questionnaires and similar means of the conventional signal dissemination regime, which relied primarily on HF standard-time and frequency-signal emission (JJY-HF). As a result, the future shape of the standard-time and frequency-signal emission was clarified; specifically, the use of an LF standard-time and frequency-signal emission (JJY-LF) was proposed to ensure appropriate precision.

After a series of efforts to realize this new broadcasting regime, construction of the Ohtakadoya-yama LF station[3] (Fukushima prefecture) began in FY 1997, and the JJY-LF began formal operation on June 10 (Time Day), 1999. With the support of the Ohtakadoya-yama LF station, the use of radio-controlled clocks or watches has grown rapidly ever since. In light of the growing role of the JJY-LF in society and in view of the CRL's continuing responsibilities as the national standard organization, in 1999, construction began on a second JJY-LF station in Hagane-yama (Mt. Hagane), located at the boundary between Saga and Fukuoka prefectures. On October 1, 2001, two years later, the facility was completed and was in operation.

Fig.1 presents an overview of the Ohtakadoya-yama LF station, and Fig.2 shows the transmission antenna of 200-m in height installed at the Hagane-yama LF station.

Fig.1 Overview of the Ohtakadoya-yama LF station

3.2 Establishment of a dual-station regime

To ensure higher reliability in broadcasting JJY-LF, it is essential to minimize service interruptions, to make the broadcast standard available nationwide, and to transmit the correct code. Although the first JJY-LF station

Fig.2 Transmission antenna of 200-m in height (Hagane-yama LF station)

was provided with double or even triple redundancy in its main systems and was equipped with a local power generator to ensure continuous operation, service interrup-

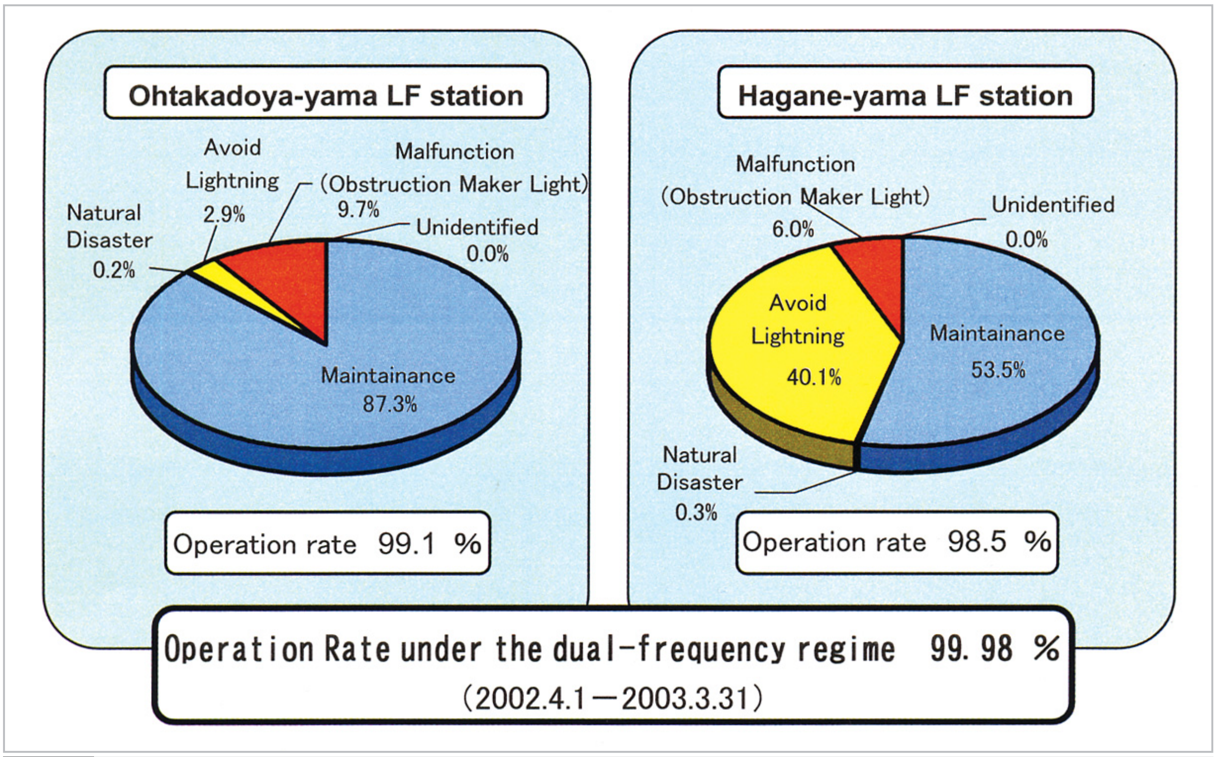

Fig.3 Operation rate and the causes of outage at the two LF stations

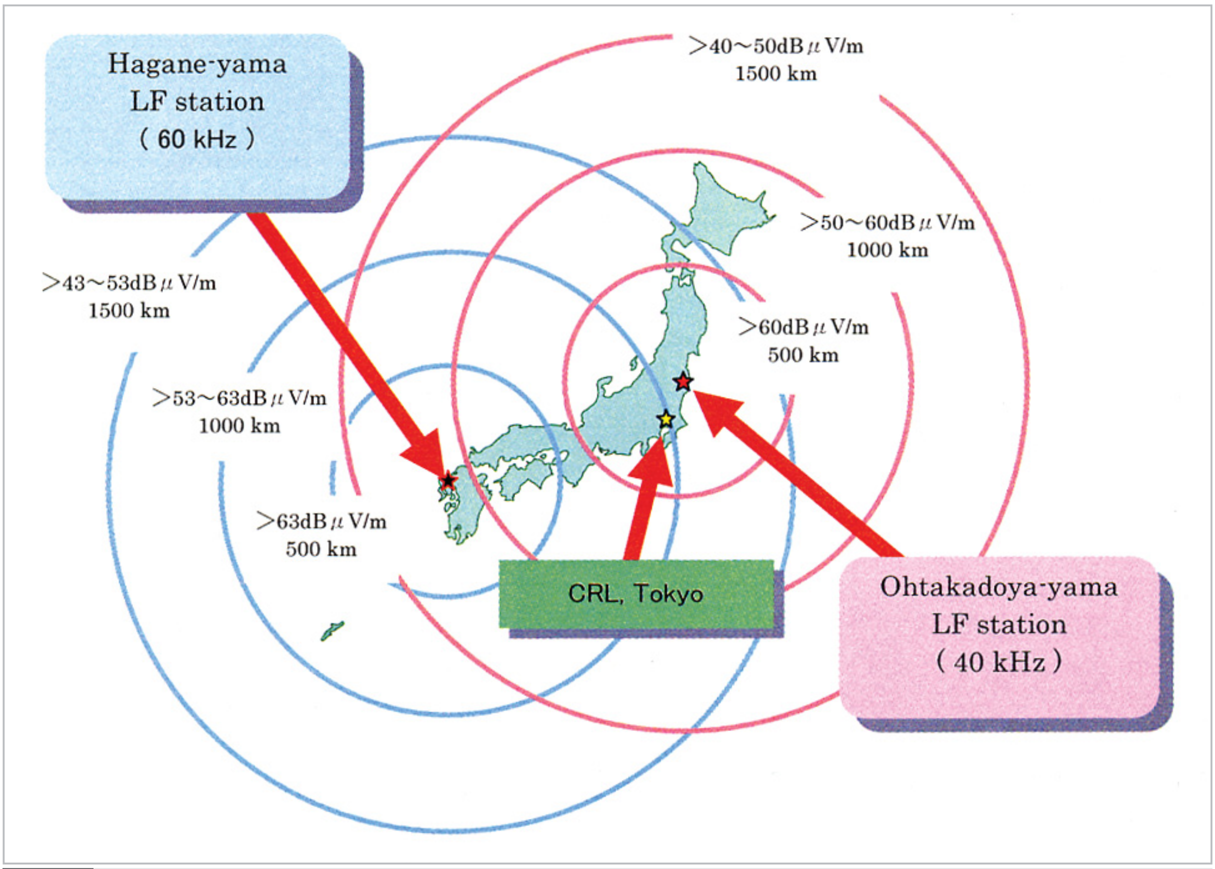

Fig.4 *Locations of the JJY-LF stations and estimated strength of JJY, μV/m*

tion time totaled approximately 81 hours in FY 2001, due to regular maintenance and to natural disasters. However, with the start of the broadcasting from Hagane-yama LF station in October 2001 and the establishment of the dual-station regime, the total time of operation outage has been sufficiently reduced. Reliability is thus ensured through each station's role as a potential backup facility for the other. Fig.3 illustrates each station's operation rate and presents the causes of outage in FY 2002. Fig.4 shows the location of each station and the electric field strength estimated from their transmission power. As demonstrated in this figure, the entire nation of Japan from Hokkaido to Okinawa is covered by the both stations, with the strength of 50 to 60 dB μV/m available everywhere.

3.3 Station description of JJY

Table 1 shows the characteristics of each JJY-LF stations. The stations broadcast on different frequencies (40 kHz and 60 kHz) to avoid frequency interference, which would make the receiving intensity lower in certain areas. The large difference in antenna efficiency (25% as opposed to 45%) stems from the different grounding efficiencies, which in turn depend on the properties and structure of local soil and ground water. The Fig.5 illustrates the block diagram of the JJY-LF stations.

The broadcasting signals of the Cs atomic clocks placed in the standard room are adjusted by an auxiliary output generator (AOG) by the common view method[4] at regular intervals via GPS/GLONASS satellites. This adjustment is performed to ensure that the timing and frequency from the clocks match the Japan Standard Time of CRL Headquarters (Koganei, Tokyo) within a margin of several nanoseconds. The carrier frequency and time code to be broadcast as the JJY-LF are generated based on the 5-MHz and 1-PPS signals output from the AOG, sent to a 50-kW transmitter, and then emitted from the antenna via the impedance matching facility room. With the exception of the matching device and other parts downstream of this, the system features double redundancy (triple redundancy for the Cs atomic clocks) to ensure maximum reliability. Each station has a 275-kVA independent power generator and a 4,000-liter underground fuel tank. The independent power generator is automatically activated in case of commercial power failure and can supply power for as long as approximately one week.

Table 1 *Characteristics of the JJY-LF stations*

	Ohtakadoya-yama LF station	Hagane-yama LF station
Running date	10th of June, 1999	1st of October, 2001
Approximate Location	Fukushima pref.	Saga/Fukuoka pref.
Latitude Longitude	N 37° 22′ E 140° 51′	N 33° 28′ E 130° 10′
Land height of the station	790m	900m
Type of antenna	Omni-directional	same as left
Antenna Height	250m	200m
Transmission power	50kW	50kW
Antenna efficiency	more than 25% or above	more than 45% or above
Carrier frequency	40kHz	60kHz
MODE	A1B	A1B
Frequency uncertainty	$\pm 1\times 10^{-12}$	$\pm 1\times 10^{-12}$

3.4 Time code format

Fig.6 shows the time code format that the JJY-LF broadcasts. The zero-second time (year, number of elapsed days from January 1, hour, and minute), day of the week, leap second data, parity, and service interruption schedule are provided every minute. Fig.6 shows 14:26, June 10, 1999, as an example. Each second signal is coded by pulse width modulation of the 40-kHz (or 60-kHz) carrier. A pulse width of 0.8 sec corresponds to binary 0, while 0.5 sec corresponds to binary 1. In addition, a pulse width of 0.2 sec corresponds to both the reference marker to indicate the start position of a minute and the position marker. Position marker P0 is sent at the rising edge of the 59th second in normal minutes. Meanwhile, P0 is sent at the rising edge of the 60th second when the leap-second is inserted (positive leap seconds) and the 59th second corresponds to a binary 0; or P0 is sent at the rising edge of the 58th second when the leap-second is removed (negative leap seconds).

Because the JJY is also used as a standard frequency source, the amplitude of modulated signals is varied between 100% and 10%, not

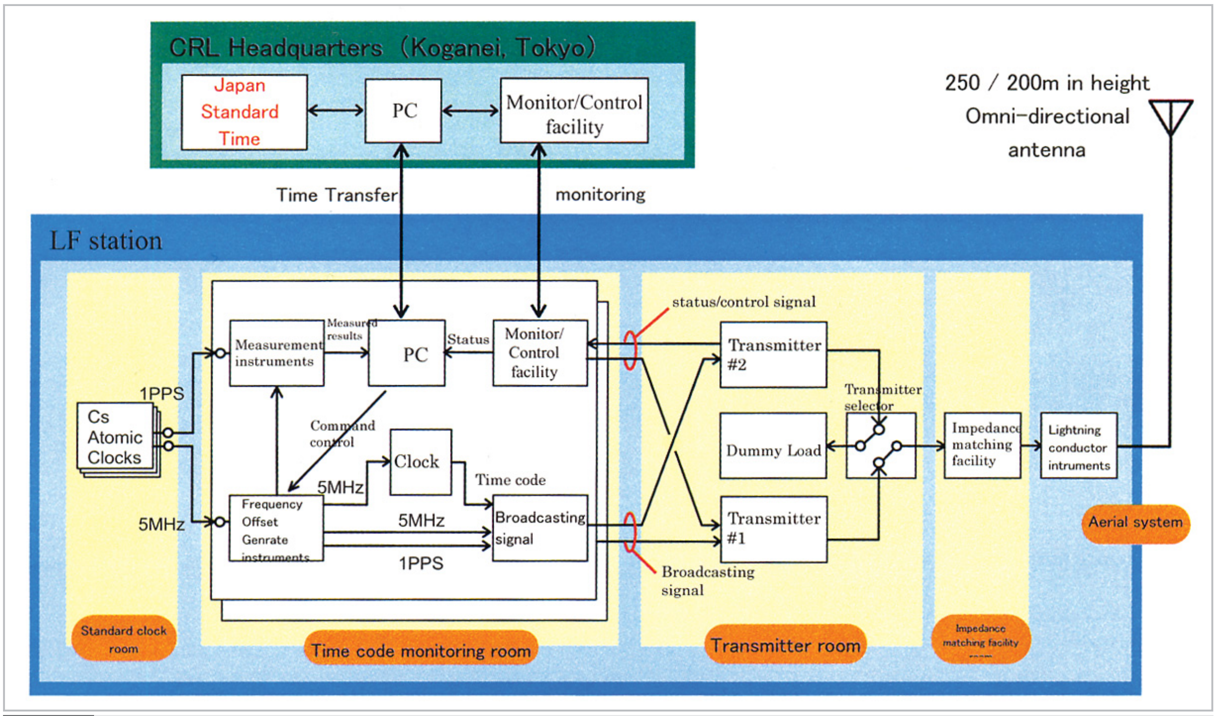

Fig.5 *A block diagram of the JJY-LF station*

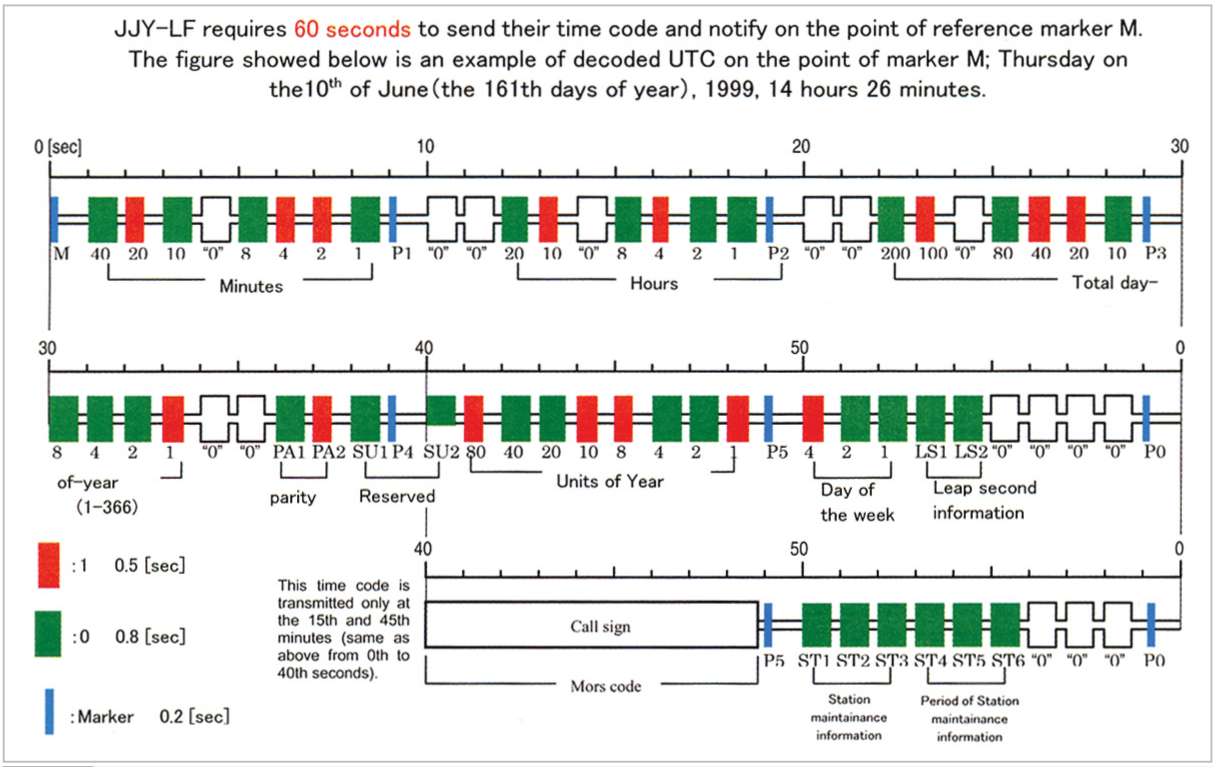

Fig.6 *JJY-LF time code format*

0%, so that the 40-kHz (or 60-kHz) carrier continues, not to be interrupted.

4 Precision of the broadcast standard time/frequency

Broadcast JJY from the LF stations are received at the CRL Headquarters of Koganei, Tokyo, and disclose the measured results of received phase variation on its homepage (http://jjy.crl.go.jp/Pub/public.html). Fig.7 shows its graph from May 10 to 24, 2002. It shows the clear daily variation in the graph of the received phase.

However, the peak-to peak variation in the phase is about 1.5μsec. But, in particular, the received phase is more stable during the daytime, with a variation of about 0.3μsec.

These measurement results imply that even LF radio waves are affected by ionospheric reflection at night. Fig.8 shows the frequency stability of received JJY-LF calculated from the data in Fig.7. The daily frequency stability after averaging is about 1×10^{-11}, whereas this value improves by one order of magnitude, to 1×10^{-12}, during the daytime, when the received phase is more stable over one day. The example in the figure illustrates

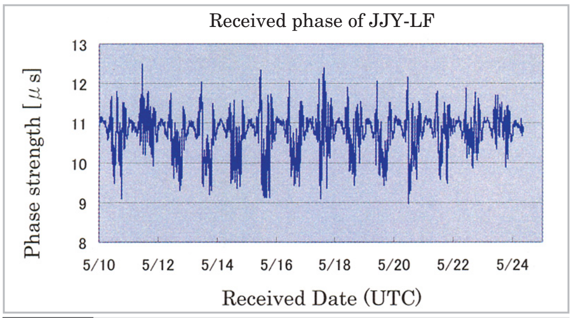

Fig.7 *Received phase variation of JJY-LF (40 kHz)*

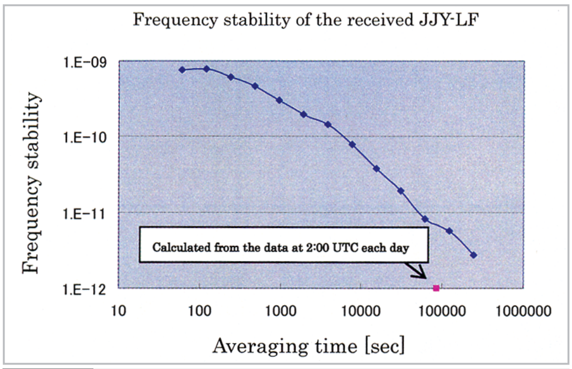

Fig.8 *Frequency stability of received JJY-LF*

a value of calculated frequency stability for only the 2:00:00 UTC (JST 11:00:00) data each day (averaging time of one day).

5 Use of the JJY

As of the end of January 2001, approximately two million radio-controlled JJY-LF clocks and watches had been sold in Japan. Subsequently, new functions such as automatic time correction gained wide attention, while the downward trend in prices continues to accelerate the spread of JJY-LF applications. By December 2002, the domestic market comprised 10 million radio sets. Today it is clear that a new market for radio-controlled JJY-LF clocks and watches is emerging in Japan, a market easily worth several hundred million yen. Fig.9 illustrates the yearly domestic market growth of radio-controlled JJY-LF clocks and watches. Furthermore, the JJY-LF is meeting with a wide range of applications: as the time source of taxi meters, time recorders, and personal computers, to control time in earthquake/weather observation devices, for blinking synchronization control for road signs, and for display panels in JR railway stations in Japan.

Meanwhile, the JJY-LF has been used as a precise frequency source, and in fact many major receiver manufacturers have begin to market highly stable frequency oscillators receiving the JJY-LF, as well as receivers capable of synchronization with the JJY-LF.

In addition, the JJY-LF is expected to be used in the internal clocks of home appliances and as a tool to establish traceability to the national standard authority (CRL).

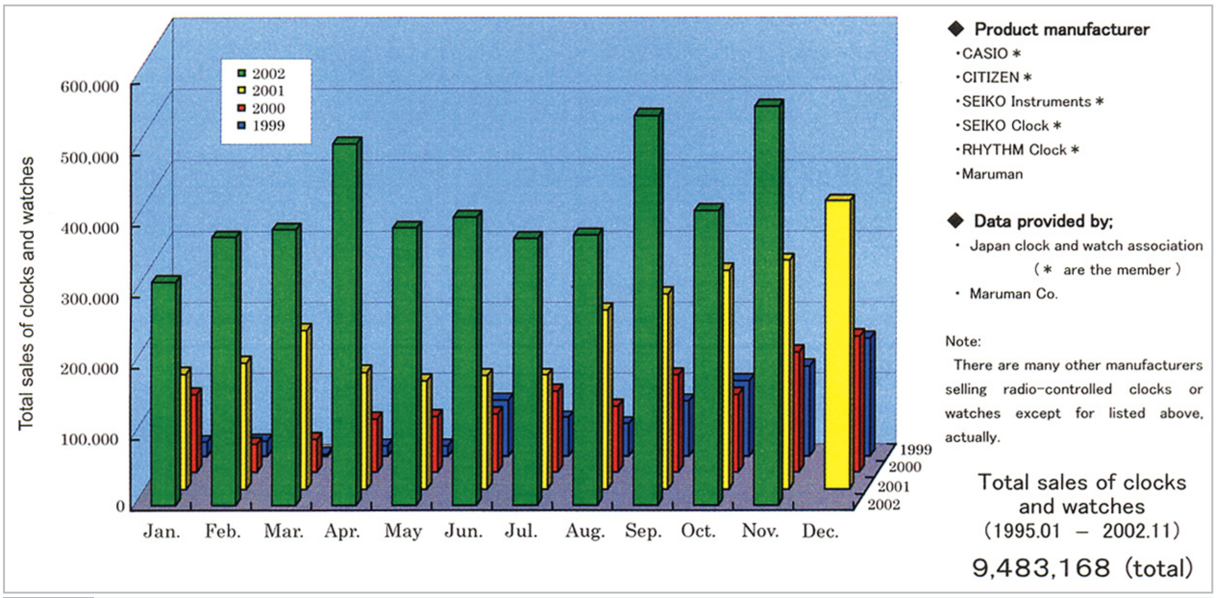

Fig.9 *Market growth of radio-controlled JJY-LF clocks and watches (1995.01 to 2002.11)*

References

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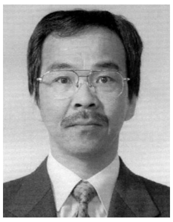

KURIHARA Noriyuki

Leader, Japan Standard Time Group, Applied Research and Standards Division

Time and Frequency Standards, Space Measurement