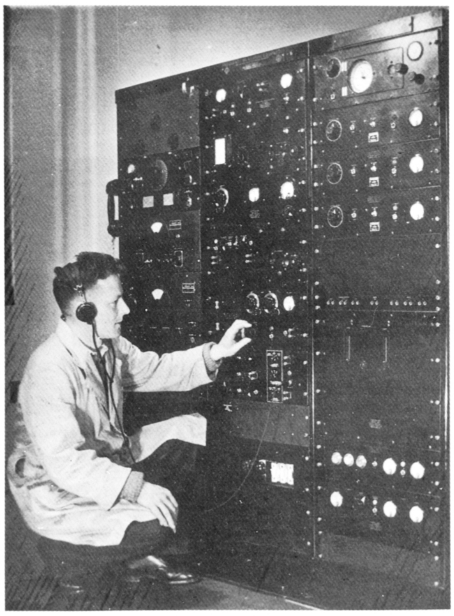
General Radio Corporation Primary Frequency Standard

The first mention of a Primary Standard is in the transmitter log in the early 1950s, the date 2KO purchased the system is unknown. There were problems with reliability over a number of years and eventually new electronics were built to increase the drive to the Synchro Clock.

Reg Motion, the Editor of the New Zealand Vintage Radio Society Journal provided a copy of an article he had printed in the New Zealand Vintage Radio Society journal in Aug 1977. It described the operation and history of a C-21-H system purchased by the New Zealand Posts and Telegraph Dept in 1938

The rebuilt 2KO unit exists and appears to reuse the front panel of the original GR unit. It requires external power supplies and a 50KHz oscillator. Terminals on the rear allowed connection to the contacts in the Synchro Clock mechanism and were used to short the output of a receiver tuned to WWV as described in the NZVR article.

By careful adjustment of the phase control, the WWV 400Hz pulses could be converted to very sharp clicks which were very sensitive to any frequency error in the local oscillator



The Primary Standard as installed at Makara Radio
(Senior Technician, S.M.Thompson operating)

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NZ's FIRST PRIMARY STANDARD OF FREQUENCY
Reg Motion

From the outset of radio usage in NZ until public telecommunications were privatised, the Post and Telegraph Department, later the NZ Post Office, was charged with the responsibility for regulating the use of radio frequencies including the monitoring of frequency usage.

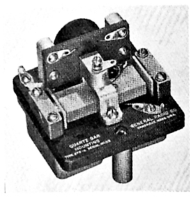
In the early days, with relatively few transmissions, satisfactory measurements could be made with good quality wavemeters but with the rapid increase in stations during the 1930's it became obvious that a more accurate standard was required.

To meet this need the Department, in 1938, purchased a General Radio type C-21-H standard frequency assembly. This assembly supplied reference standards of frequency at 10kHz intervals between 50 and 5000kHz, all of these frequencies being guaranteed accurate to better than 5 parts in 10 million. Interpolation and auxiliary equipment supplied with the standard, measured unknown frequencies by a process of finding the difference between the unknown and the nearest of the standard frequency series and then measuring this difference using a zero beat method against a calibrated 0-5kHz oscillator.

On its arrival this standard was installed at Wellington Radio, atop Tinakori Hills, but early in the war it was transferred to Radio Section headquarters in the Wellington East Post Office Building where it was located on the 7th floor.

After the war a new HF receiving station was commissioned at Makara and the standard was transferred there, where it remained in service until about 1953 when it was superseded by a more up-to-date three oscillator assembly with digital frequency read-out.

Opposite is a photo of the General Radio assembly taken during its sojourn at Makara. The nearest rack contained the equipment for generating and checking the standard frequency harmonic series with the Synchro-Clock at the top, multivibrators below it and the 50 kHz standard crystal unit just below halfway. The middle rack comprised the equipment needed to compare the standard with the unknown frequency and the far rack the three receivers used to receive the transmissions being measured (15kHz to 30MHz). A description of the various units and their use follows.



50 kHz OSCILLATOR. At the heart of the standard was a very stable 50kHz quartz crystal bar mounted as shown. This bar lengthened and contracted as it vibrated under the electrical stress produced by a vacuum tube oscillator coupled to the bar by the two

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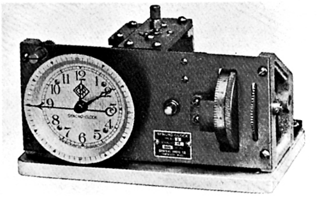
gold electrodes formed on its upper and lower faces. Suitably positioned baffle plates at the ends of the bar eliminated the effects of the 50 kHz sound waves radiated from the bar thus making the frequency practically independent of changes in atmospheric pressure. Damping produced by the mounting was minimised by clamping the bar between points at its centre.

This mounting was fine as long as there was no external vibration but it did not take into account the effects of Wellington earthquakes, one of which jolted the very large piece of quartz (about 55 x 20 x 8mm) off its axis. Luckily its operation came back to normal after careful resetting.

The temperature of the quartz bar was held to very narrow limits by enclosing it in a temperature controlled box which was then enclosed in a larger temperature controlled box that also housed the oscillator valve assembly, the whole being thermally insulated. These precautions kept the inner box temperature within .01^{0}C.

FREQUENCY DIVISION CHAIN. A multivibrator frequency divider reduced the 50kHz output of the standard frequency crystal unit to 10kHz with a waveform rich in harmonics detectable up to above 5MHz. It also drove a further multivibrator to produce an output at 1 kHz with, of course, all the frequency accuracy of the standard crystal.

ASSESSING ACCURACY - THE SYNCHRO-CLOCK. Since frequency is measured in cycles per second (Hz) the accuracy of any Primary standard must be assessed by counting the number of cycles it produces in a standard second of time. To do this the 1kHz output of the frequency division chain was amplified to drive a synchronous motor within a clock assembly which not only turned the usual clock hands but also drove a shaft at one revolution per second. On this shaft was a drum made of an insulating material which at one point in its circumference had a narrow conducting bar set into it. Two contact brushes, one alongside the other, ran on the outside of the wheel in such a manner that they were electrically connected for about 1/100th of a second once in every revolution. By means of a thumb wheel the contact assembly could be rotated around the axis of the drum thus the actual time of the contact could be made to occur at any point within the second. From a calibrated dial on the thumb wheel the timing of the contact could be read out with an accuracy of about 1/100th of a second.

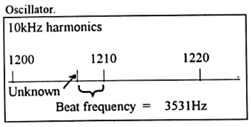


In use time signals were received from WWV every day and the brushes on the Synchro-Clock drum were connected across the headphone leads of the receiver used. Rotation of the brushes relative to the drum caused the second pips from WWV to disappear in the headphone output when the brushes were over the drum contact bar at the exact time the WWV pips took place - the headphone leads being shortcircuited at that instant. The difference in the position of the brushes at one reading and the position after the next test, say 24 hours later, gave the time error of the New Zealand standard which could be easily converted to the equivalent daily frequency error.

General Radio guaranteed a frequency accuracy of 5 parts in 10 million. Ionospheric path variations could cause problems in exact measurement but the guaranteed accuracy was certainly achieved and at most times an accuracy of 1 part in 10 million was obtained. This adequately met the needs of the time.

HETERODYNE FREQUENCY METER. The signals received for measurement were often modulated and/or fading badly making them impossible to measure directly. This difficulty was overcome by zero beating the received signal with the output or a harmonic of a highly stable oscillator which was tunable over the frequency range 100 to 5000kHz. After attaining zero beat the frequency of this oscillator, known as a Heterodyne Frequency Meter could then be measured with confidence - in effect it was a transfer oscillator.

Mixing the output of the Heterodyne Frequency Meter with the 10kHz frequency series derived from the standard assembly produced a beat of less than 5kHz which was then measured by zero beating it with a very accurately calibrated 0-5kHz Interpolation Oscillator.

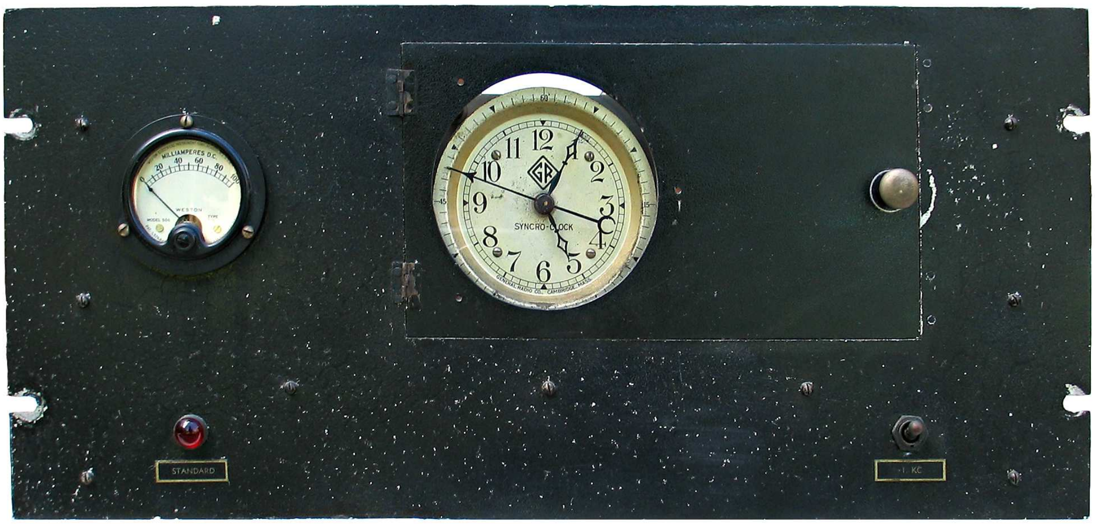


The frequency of the unknown was then accurately determined by addition as per the inserted example where the unknown frequency would be;

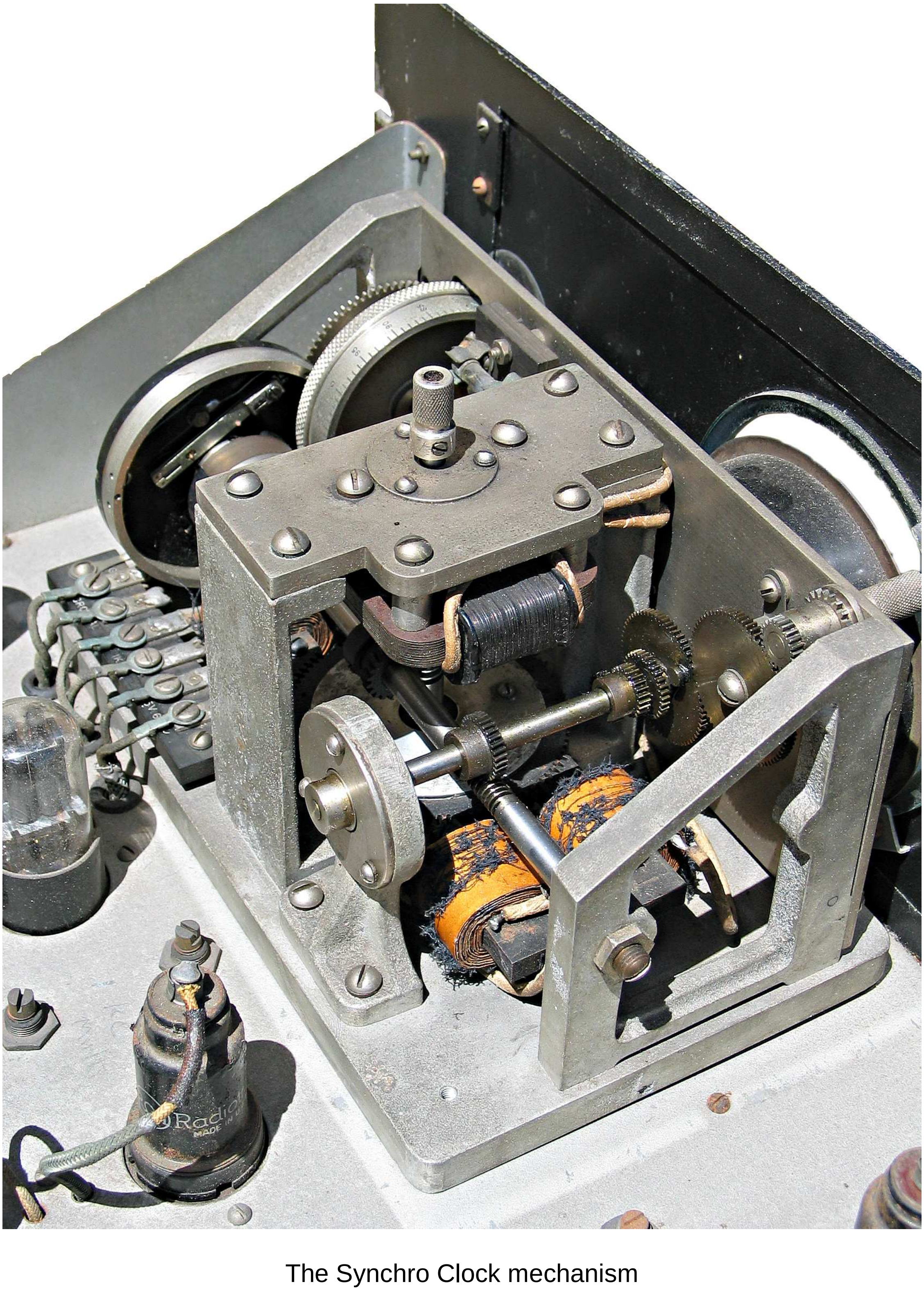
1210 - 3.531 = 1206.469kHz.

INTERPOLATION OSCILLATOR. This was a direct reading 0-5kHz oscillator accurate to within 1Hz. Interestingly, its output was obtained by beating two similar high frequency oscillators together and varying one of them to give the range required. For this purpose oscillators of exceptional stability were used. The dial reading was directly marked in 1Hz steps which calibration remained accurate over very long periods of time. Means for checking and resetting this calibration were incorporated.

COMMENT. In today's world the frequency of the Transfer Oscillator is counted digitally for a standard second of time and read out directly thus supplanting the complicated measurement procedure described above. However, in the 1940's this was not possible and it is to the credit of the operators concerned that they mastered the process and measured frequencies quite rapidly and with sufficient accuracy.



The front of the rebuilt 2KO system, the panel is different to that of the New Zealand system and looks to be original so it may have come from a model other than the C-21-H



The Synchro Clock mechanism

Reg also supplied the following pages from a GR catalogue of the time

CLASS C-21-H STANDARD-FREQUENCY ASSEMBLY (SERIES 690)

The Class C-21-H Standard-Frequency Assembly is a complete and highly precise primary standard of frequency. It is also a crystal-controlled clock of high precision. More than 38 units have been installed and are now operating in all parts of the world in industrial organizations, research laboratories, observatories, and frequency monitoring stations. Many of them are used as national standards of frequency by communications administrations in North American, European, and Asiatic countries.

The assembly is provided with a means of measuring its output frequencies in terms of standard time without reference to any other standard of frequency. Harmonic series based on fundamentals of 1, 10, and 50 kilocycles are available at its output terminals to furnish standard frequencies over the entire communication-frequency spectrum. From it can also be obtained one-second pulses and standard time. The accuracy of all output frequencies is better than ±5 parts in ten million over periods of several months. Each of the output frequencies is known with the same accuracy.

The assembly is furnished with either of two types of power supply. If line failure is rare, or if certainty of continuous timing is not demanded, the Type 696-A Power Supply operates the assembly satisfactorily. The Type 695-A Battery Charging Equipment furnishes filament and plate power to operate the complete assembly and maintains a full charge on floating batteries which will supply emergency power. The price of the floating battery assembly does not include the batteries.

On the opposite page is shown a photograph of the a-c operated assembly. It differs only slightly in appearance from the floating-battery assembly. The captions describe the function of each group of instruments in the assembly.

Complete detailed descriptions of the apparatus and the operation and uses of a Class C-21-H Standard-Frequency Assembly appear in the General Radio Company's Bulletin 10, "Frequency Measurements at Radio Frequencies." Copies of this manual of frequency measurement and monitoring technique may be had without charge upon application to the company.

SPECIFICATIONS

Frequency Range: The available outputs are seconds pulses, standard time, and standard frequencies at harmonic intervals between 1 kilocycle and 30 megacycles.

Accuracy: The accuracy obtainable after installation and adjustment in a short aging period is often better than one or two parts in 10 million. Frequency stability of the same high order can be expected. The equipment is conservatively guaranteed for an accuracy of ±5 parts in 10 million.

Power Supply: Either one of two types of equipment are supplied, depending upon the type of power supply to be used. One system operates directly from the 115-volt, 60-cycle, a-c line; the other system operates on storage batteries trickle charged from rectifiers. The power input is approximately 225 watts with heater circuits in operation.

Mounting: The entire installation with the exception of batteries is mounted on a single 19-inch relay rack. All interconnecting wiring is by means of a fully formed cable equipped with plugs which fit jacks built into each unit.

Dimensions: (Height) 69⅛ x (width) 20 x (depth) 24 inches, over-all.

Net Weight: 370½ pounds for floating-battery assembly, 352⅜ pounds for completely a-c operated assembly, relay rack included.

Description	*Code Word*	*Price*
Assembly for operation from floating batteries........	LYRIC	
Assembly for complete a-c operation...............	LAYER	

In a Class C-21-H Standard-Frequency Assembly the synchronous-motor-driven clock is the counting device for totalizing the number of vibrations of the crystal in any given time interval. When driven by a stable oscillator, this device may be used as a source of precisely determined time intervals and, conversely, when its indication is compared with standard time, a measure of the driving frequency is obtained.

The TYPE 611 Syncro-Clocks are designed to operate from the output circuit of a low-power vacuum tube. The motor is of the impulse type, and since no accelerating torque is provided in the system, the motor must be brought up to synchronous speed. A 60-cycle, 115-volt motor under control of a push-button switch on the face of the instrument is provided for this purpose. Clocks are normally supplied to keep true time on an exactly 1000-cycle source.

The micro-dial attachment consists of a rotary contact closing once a second, the instant of contact (or phase) being adjustable over a range of one second. It is used in making time comparisons and also for supplying impulses at one-second intervals.

SPECIFICATIONS

Frequency: Clocks are normally supplied to keep true time when the frequency is exactly 1000 cycles.

Power Consumption: One 41-type or 45-type tube supplies sufficient power.

Mounting: Cabinet-mounted models (for use on the laboratory bench) and panel-mounting models are available, but only the panel-mounting type with a micro-dial is regularly carried in stock.

Dimensions: TYPE 611-C, (width) 9⅜ x (depth) 6 x (height) 6 inches.

Net Weight: TYPE 611-C, 14 pounds.

Type	*Description*	*Code Word*	*Price*
*611-A	Panel Mounting without Micro-Dial	SYNCROFORD	
*611-B	Table Mounting without Micro-Dial	SYNCROFROG	
611-C	Panel Mounting with Micro-Dial	SYNCROGOOD	
*611-D	Table Mounting with Micro-Dial	SYNCROTOAD	

*Built to order, not carried in stock.