FREQUENCY CONVERTER FROM 3.58 MHz to 5.0 MHz FOR FREQUENCY COMPARISON BY MEANS OF TV COLOR SUB-CARRIER

Tadao Inouye (National Research Laboratory of Metrology) and Chikao Takeuchi (Fujitsu Limited)

ABSTRACT

For frequency comparison by TV color sub-carrier, a frequency converter has been joined newly in the comparison system. This is a phase locked oscillator, in which a voltage controled crystal oscillator locks its output frequency, 5.0 MHz, to the 3.58 MHz sub-carrier. The measurement scheme realizes comparisons between two round frequency signals, and results of the comparisons between the sub-carrier and a cesium frequency standard show the resolution of 1 ns and the frequency stability within 2×10^{-12} at averaging time of 20 minutes. Phase jumps occured by station breaks have no influence on the frequency comparison, because the measurements can effect its purpose during one live program of broadcasts.

INTRODUCTION

In Japan, an experiment of frequency comparison of cesium clocks by TV color sub-carrier which is used as a reference frequency was made also between Radio Research Laboratories and International Latitude Observatory of Mizusawa in 1972[1].

In the previous[1)2)3)], freqency comparisons have been made between a local frequency standard and color sub-carrier, frequency of the local standard was synthesized into 3.58 MHz so far. But, it is convenient to convert frequency of sub-carrier to 5.0 MHz which is fed to one input of a linear comparater, because of a round frequency and utilizing plain comparaters. Of course, another input of the comparater is a round frequency from the local standard. It seems that this converter is usefull especially for calibrating some frequency sources by color sub-carrier derived from a rubidium controled oscillator of a TV studio. This paper describes the theory of operation of the converter and the result of frequency stability measurement on a prototype one. Commercial type of this frequency converter which is named Phase Lock Oscillator has been sold by Fujitsu Limited.

THEORY OF OPERATION

Figure 1 shows schema of the converter. Output frequency of a voltage controlledcrystal oscillator, 5.0 MHz, is divided by eighty eight. The divided signals, about 51.818 kHz, are shaped to pulses with 0.1 μs width, which are supplied to a gate. In time of the pulse width, the gate samples amplitude of sinusoidal signal of the color sub-carrier which comes from a color TV receiver. Pulse heights of the sampled pulses are averaged by passing through a lowpass filter and becomes DC voltage in proportion to the pulse heights. The DC voltage continues to vary, until the relation between the output frequency of VCXO and frequency of the color sub-carrier reaches to the ratio of 88 to 63. When the circuit is not inphase, wave form being observed actually at the gate output, voltage is already averaged and changed in steps increasingly or decreasingly each one period of 51.818 kHz, due to a capacitor added to the input of the amplifier.

Lock range is about $\pm 2 \times 10^{-7}$ in fractional frequency, and synchronizing characteristic of frequencies at input and output is shown in Fig. 2 for manifesting linearity of the characteristics in the half of lock range.

FREQUENCY STABILITY FOR RECEIVING TV SIGNALS

Figure 3 is a representative strip chart record comparing the output frequency of the converter with the NRLMs frequency standard. The phase difference can be resolve to 1 ns on the chart. Block diagram of the phase comparison system is shown in upper part of Fig. 4. Under part of Fig. 4 shows the measuring system for short term stability. Fractional frequency stability of the output of the converter in terms of Allan variance is given typically in Fig. 5. The squares in Fig. 5 show the stability data calculated by reading of the linear traces such as Fig. 3. Also plotted in Fig. 5 as the circles are the data of the short term stability obtained by a computing counter. This stability is not worse than the previous experiments[1)3)]

These values are given by next formulas. With M values of f_i, which is output frequency of the mixer, about 40 kHz, the displayed value of the computing counter, σ, is:

$$\sigma = \frac{1}{f} \left[\frac{1}{2(M-1)} \sum_{i=1}^{M-1} (f_{i+1} - f_i)^2 \right]^{\frac{1}{2}}$$

It being dispersed by the frequency multiplier, frequency stability, $\sigma_y(\tau)$, is:

$$\sigma_y(\tau) = \frac{f}{K\ n\ F_o} \sum_{m=1}^{K} (\sigma)_m$$

at K times measurements, where n is multiple factor of frequency multiplier,and F_o output frequency of the converter. In this measurement n equals 10.

It is estimated that the stability at averaging time larger than 100 seconds is limited mainly by receiving broadcasts signal and uncertainty of drawing a straight line on the linear trace, and short term stability by instability of VCXO mainly.

These broadcasts received in the above measurements were General program of NHK which is a public television networks in Japan.

FREQUENCY OF THE MAJOR TV NETWORKS IN JAPAN AND NOTE FOR CALIBRATIONS

Frequency resettability of the broadcast has been measured during about one week, average and distribution of frequencies are shown in Fig. 6 and Table 1. These data were calculated from the strip chart records, in which continuous traces were used except any phase jumps by station breaks and other sources of distortion.

Table 1 indicates that it is enough for a continuous trace made by the comparison during 10 minutes to get the precision to one part in 10^{11} (three sigma).

The broadcasting stations are not responsible for deviation of the signals being so accurate. It seems by monitoring frequency of color sub-carrier, that frequency of rubidium controled oscillators used by the major TV networks have been adjusted to keep its deviation in one part in 10^{10}, a local frquency source can be calibrated by the comparison to within 1×10^{-10} in Japan. On the calibration for the local frequency sources except atomic standards, it is necessary to observe with a notice that frequencies of two major networks, NHK and NET which is a big one of broadcasting companies in Tokyo, are close to each other within one part in 10^{10}.[4)]

Since frequency deviations of color sub-carrier are measured a week by RRL also, and these values of NHK and NET are given within one part in 10^{12} by the bulletin published with RRL and the journal of the institute of electronics and communication engineering of Japan, it is serviceable for the users wanting more accurate calibrations.

CONCLUSION

It is convenient for the calibration that this converter generates a round frequency by converting color sub-carrier. On the frequency comparison with the converter, these chart records indicate that it is possible to resolve the phase difference between the converted 5.0 MHz from the sub-carrier and the local frequency sources to 1 ns. It is estimated that stability of frequency comparison between the sub-carrier and the cesium standard of NRLM, in terms of Allan variance, was 2×10^{-12} at averaging time of 20 minutes.

Mutual frequency comparison between two remote cesium clocks by using the converter within the comparison system each can be expected a good result, it is scheduled to make by NRLM at Tokyo and Osaka in Japan.

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REFERENCES

1) Saburi,Y., Yasuda,Y., Kobayashi,S. and Sato,T. "Precision comparison of time and frequency by means of TV signals" (in Japanese) Rev. of RRL, Vol.18, 433-444, Nov. 1972.
2) Davis,D.D. "Frequency standard hides in every color TV set" Electronics, Vol.44, No.10, 96-98, May 10 1971.
3) Allan,D.W., Blair,B.E., Daivis,D.D. and Machlan,E.H. "Precision and accuracy of remote synchronization via network television broadcasts, Loran-C and portable clocks" Metrologia, Vol.8, April 1972.
4) Kobayashi,S. "Standard frequency and time emission and its utilization" (in Japanese) Butsuri, Vol.30, 741-747, Oct. 1975.

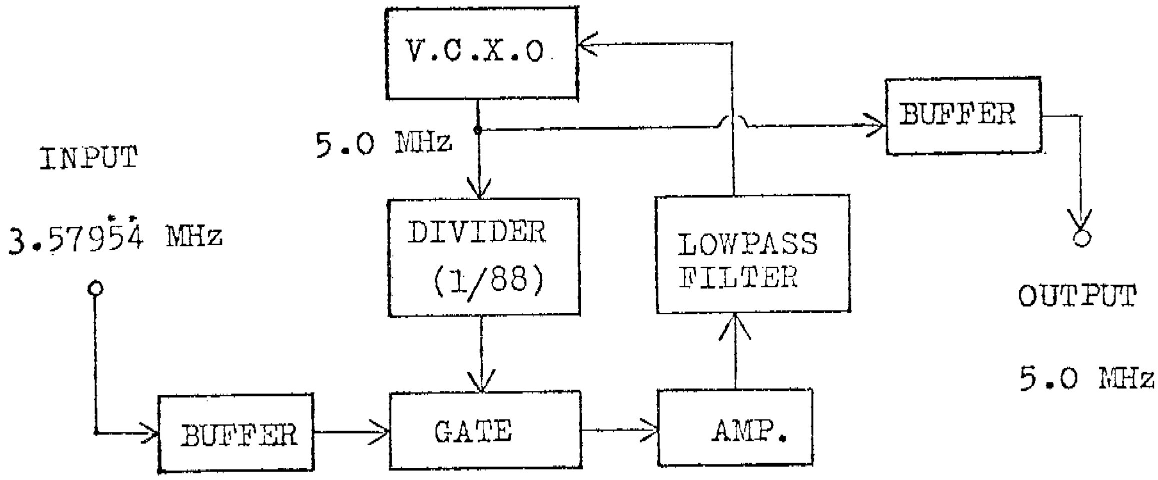


Fig.1 Scheme of freuency converter from 3.58 MHz to 5.0 MHz

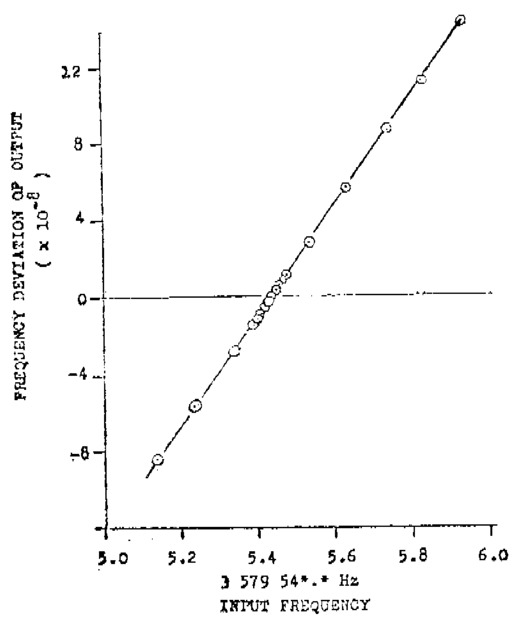


Fig. 2 Synchronizing characteristic between I/O frequencies of the converter.

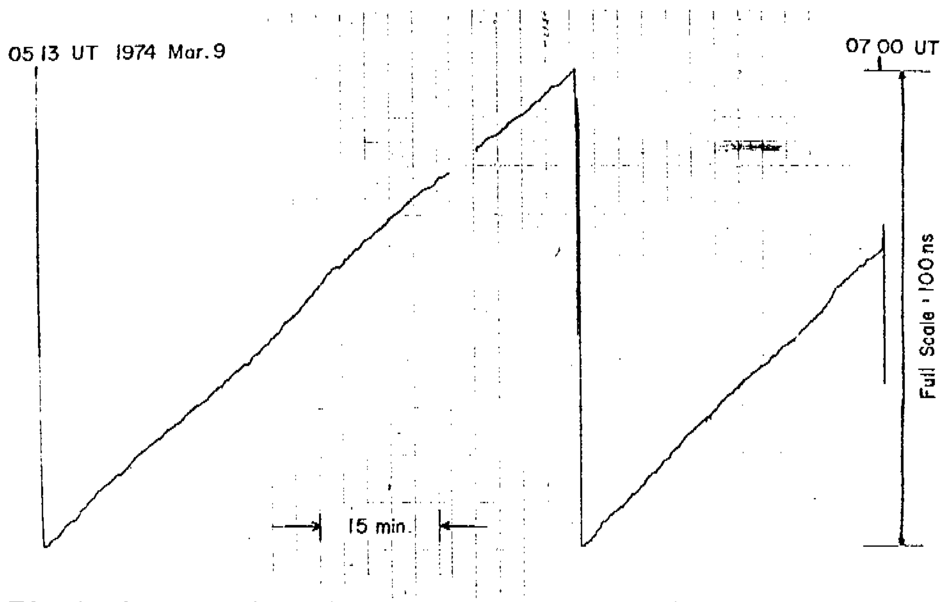


Fig. 3 An example of the strip chart record of the phase comparison

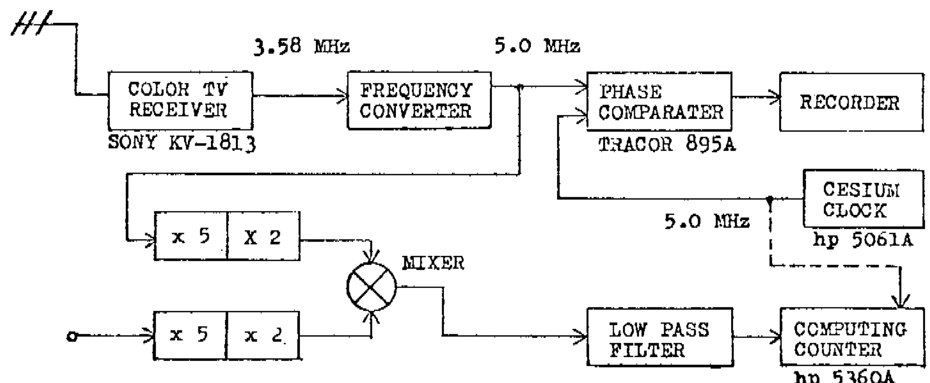


Fig. 4 Measurement system for phase comparison and frequency stability.

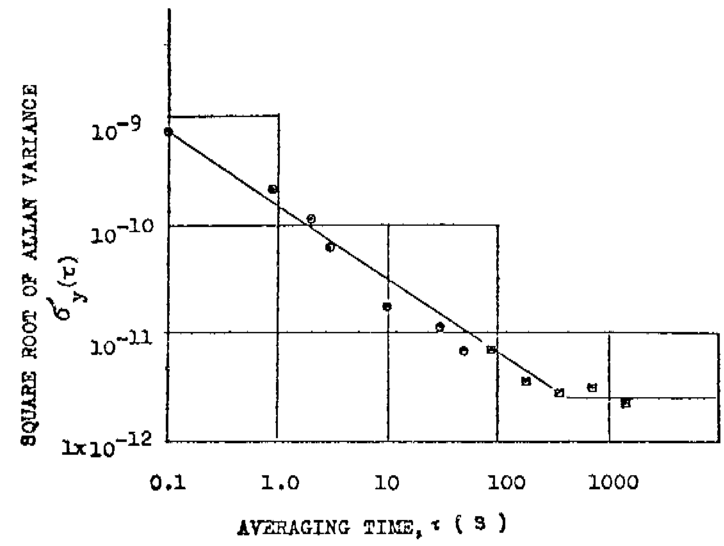


Fig.5 **Relative fractional frequency stability for a color TV sub-carrier**

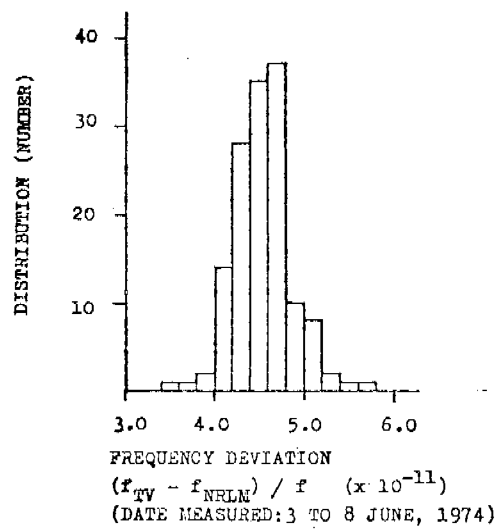


Fig. 6 Distribution of measured frequency on a color sub-carrier.
(NHK General program)

Table.1 Mean value and standard deviation of frequency of a color sub-carrier (NHK General program)

MEAN VALUE OF FREQ. DEVIATION ($\times 10^{-11}$)	STANDARD DEVIATION ($\times 10^{-11}$)	AVERAGING TIME (MIN.)	SUM OF DATA NUMBER
4.5_3	0.3_3	10	140
4.5_2	0.2_0	20	52
4.4_8	0.1_5	30	18

(MEASUREMENT PERIOD:3 TO 8 JUNE, 1974)

APPENDIX

CLOCK COMPARISONS BY TV, SELECTED TOPICS PERTAINING TO JAPAN

Precise time comparisons by TV synchronizing pulses have been performed in many countries. In Japan, succeeding to an experiment of time comparison by TV pulses made first by the Radio Research Laboratories (RRL) in 1970[1), time comparison experiments by TV pulses among atomic clocks in various institutions have been carried on[2)3)]. The line 10 timing method has been used in the comparison. Some improvements of receiving equipments have been made in order to obtain higher stability and accuracy, and these improvements have brought good results on the comparison in practice[4)-7)].

At present, clock comparison by TV signals has been made on a routine basis among five institutions, RRL, the National Research Laboratory of Metrology (NRLM), the International Latitude Observatory of Mizusawa (ILOM), the Tokyo Astronomical Observatory (TAO), and the Kanozan Geodetic Observatory (KGO). Fig. 1 shows locations of these institutions. Distances from a common transmitting antenna are less than 50 km, except ILOM which is situated about 400 km north of Tokyo.

Items of the improvements adopted in the present comparisons are

(a) to stabilize the frequency of the local oscillator in TV tuner,

(b) to fix the setting of the automatic gain control (AGC) in IF amplifier.

Fig. 2 shows a result of comparison between cesium clocks at NRLM and RRL, which is given by frequency dispersion in μs/day obtained from 5 day differences in time comparison data. During the period A in the figure, the measurements at NRLM were made by adjusting the fine tuning control of a TV tuner, monitoring the level of color burst signal. While, during another period B, a quartz crystal local oscillator was used in the TV tuner and the trigger level of the pulse selector for line 10 pulses was fixed. Frequency stability in terms of Allan variance of the result is ahown in Fig. 3. The value during the period B attained to 1×10^{-13} at averaging time of 10 days, including the instability of the two clocks concerned[4)7)].

An experiment has been made by NRLM to measure variation in relative time delay between two improved equipments of the same type. The variation could be reduced to 10 ns (one sigma) for a single equipment, as compared with that of 20 to 30 ns (one sigma) given in the case of commercial TV receivers[4)].

In the comparison of cesium clocks via TV pulses made between TAO and KGO, to keep the starting voltage of AGC and to observe the frequency of the local oscillator in TV tuner were taken into consideration in particular. The standard deviation of 40 ns from a linear trend was obtained from the data during a month in 1974[5)7)].

When the frequency of the local oscillator is changed by adjustment of fine tuning control or any other cause, the change in the phase and amplitude of a detected signal must be raised according to the band-pass characteristics of the IF amplifier. When the starting voltage of AGC in the TV receiver varies, the output voltage from the IF amplifier, hence the delay time in the receiver, is changed by the same reason as mentioned above. Fig. 4 shows the variation in delay time against the frequency of local oscillator in a commercial TV receiver, for three levels of the starting voltage of the AGC as parameter. Abscissa in the figure is given by the frequency in the IF amplfier instead[5)].

In the comparison through microwave links via two different routes made between RRL and ILOM, it was found that the accuracy of ± 2 µs was obtained except abrupt changes in the microwave networks[3)].

The leading edge of line 10 pulses is measured as usual in the time comparison. It may be recommended to use the trailing edge of the TV pulse for higher stability, as the slope of the trailing edge is much steeper than that of the leading edge at their sliced points. The trailing edge may be less sensitive to the change in the video signal amplifier and to the noise. A result of comparison between the measurements on the trailing edge and the leading edge, made at RRL, is shown in Fig. 5, where the abscissa gives the amplitude of the synchronizing pulse in the video signal and the ordinate the relative delay time. The variation in the former case is less than half of the latter. It may be said from this result that the variations in the delay time would be further reduced[7)].

The time of transmission of TV synchronizing pulses and the frequency deviation of color subcarrier on the NHK and the NET signals have been published by RRL since April 1975. Interests to the use of TV synchronizer are growing in Japan, but the user market for them is still limited. Any gadget for time comparison by TV synchronizing pulses has not yet been commercially producted in Japan.

The authors are much indebted to Prof. S. Iijima and Dr. N. Matsunami of TAO, Dr. Y. Saburi of RRL, Mr. Y. Koga of NRLM, and their staff for the compilation of this report.

REFERENCES

1) Saburi, Y., Yasuda, Y., Kobayashi, S. and Sato, T., "Precision comparison of time and frequency by means of TV signals" (in Japanese), Rev. of RRL, Vol. 18, 433-444, Nov. 1972.

2) Horiai, K., Hara, T. and Aihara, M., "Time comparison by network television broadcasts" (in Japanese), Proc. of ILOM, No. 13, March 1973.

3) CCIR Document 7/26-E, Oct. 1973.

4) Inouye, T. and Nara, M., "The stability of time comparison by TV signal of common emission" (in Japanese), Trans. Society of Instrument and Control Engineers, Japan, Vol. 11,

No. 3, June 1975.
5) Fujiwara, K., Kato, T., Hokugo, S. and Miyazaki, K., "Precise clock comparison by mens of TV signals" (in Japanese), Univ. of Tokyo, Tokyo Astron. Obs. Report, Vol. 17, No. 2, March 1975.
6) National Report of Japan presented to URSI (Lima), page 4 Aug. 1975.
7) CCIR Document of Study Group 7, 1976 Interim Meeting, submitted from Japan.

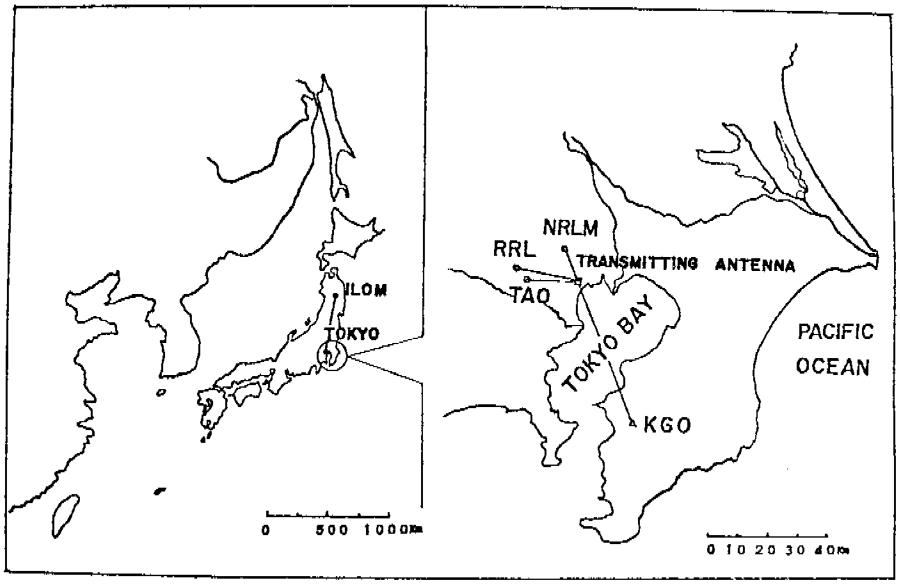


Fig.1 Locations of laboratories

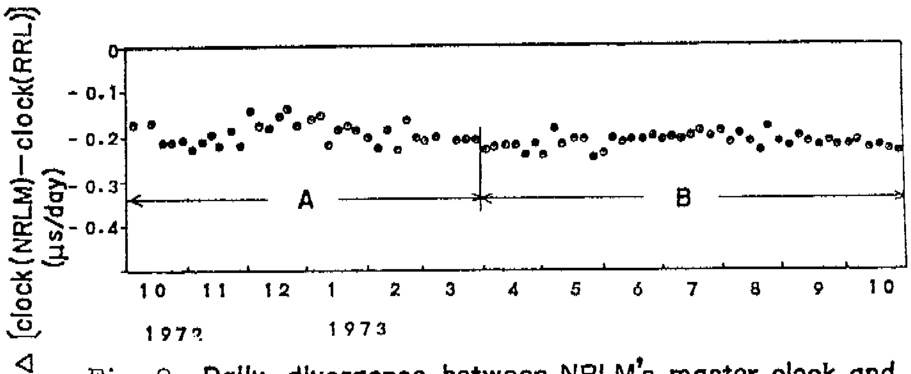
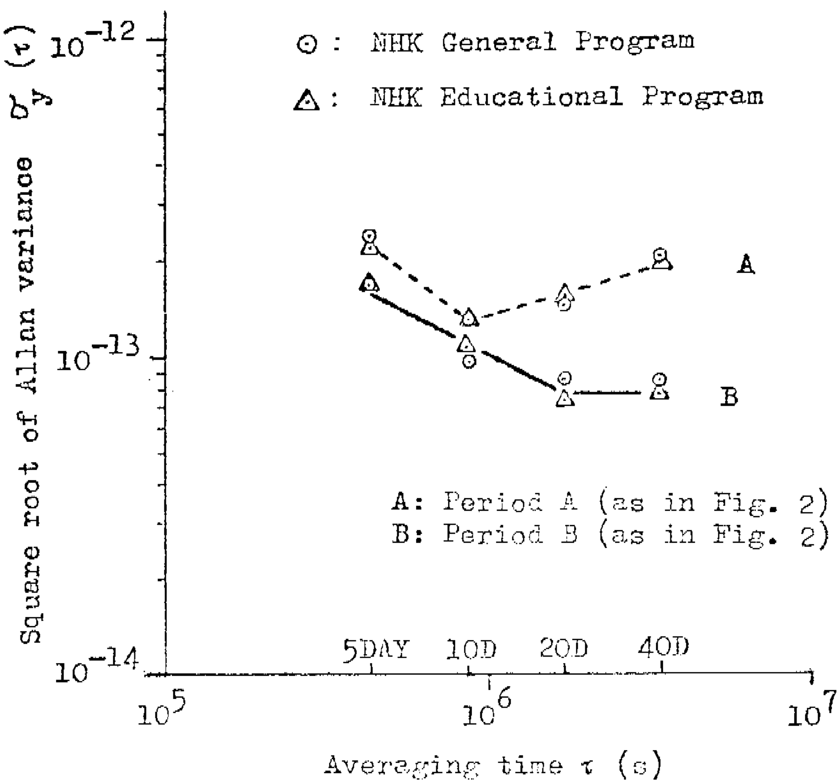


Fig.2 Daily divergence between NRLM's master clock and RRL's one via TV signal of NHK General program



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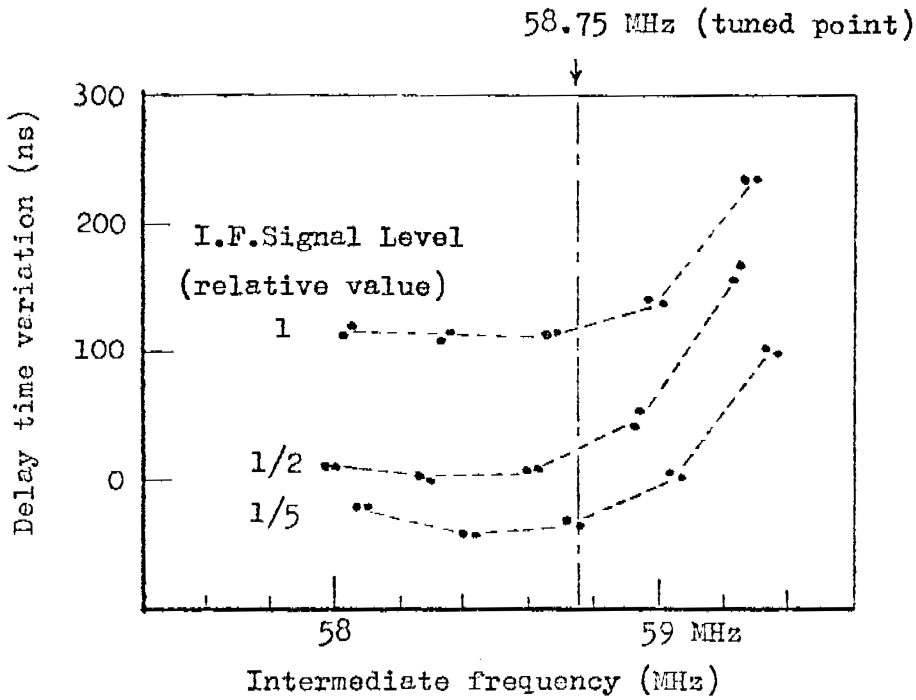
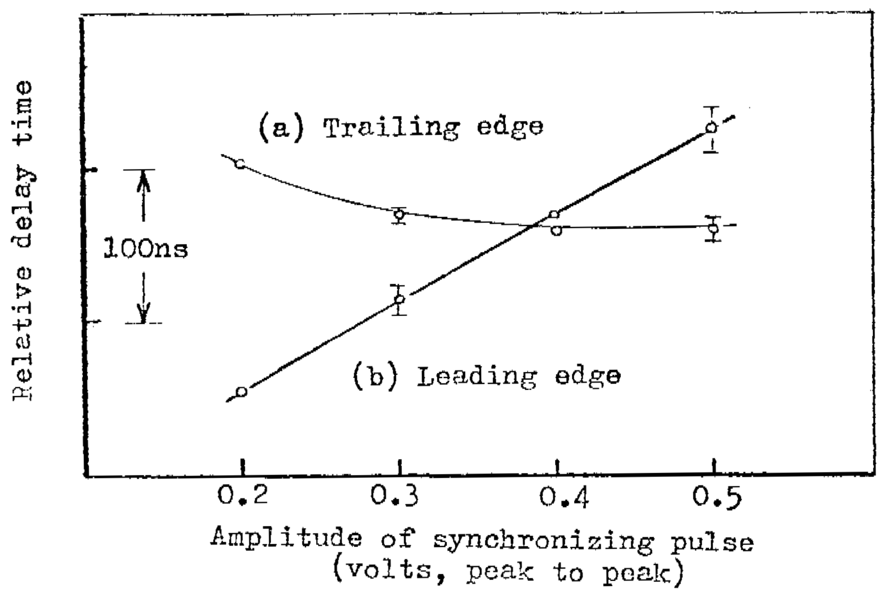


Fig.4 Variation of delay time caused by the adjustment of the starting voltage of AGC.



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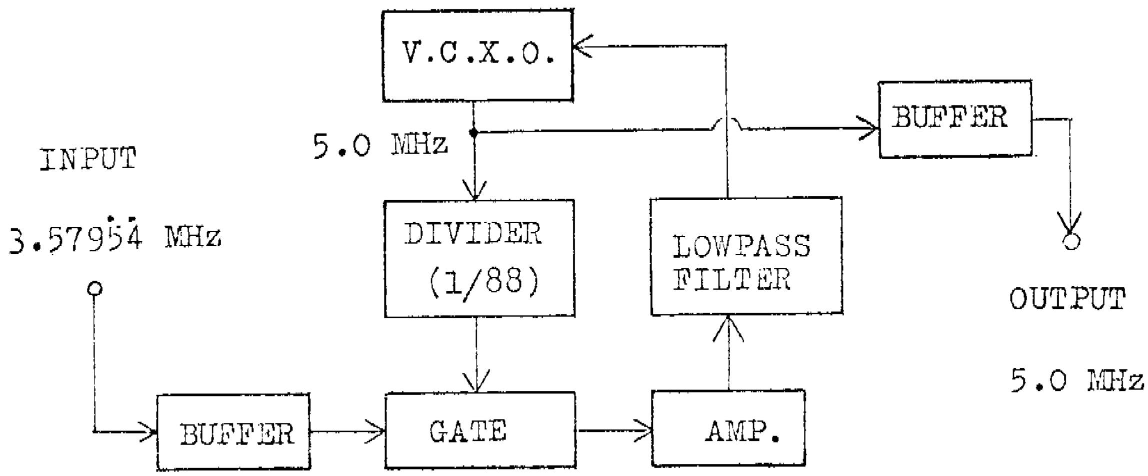

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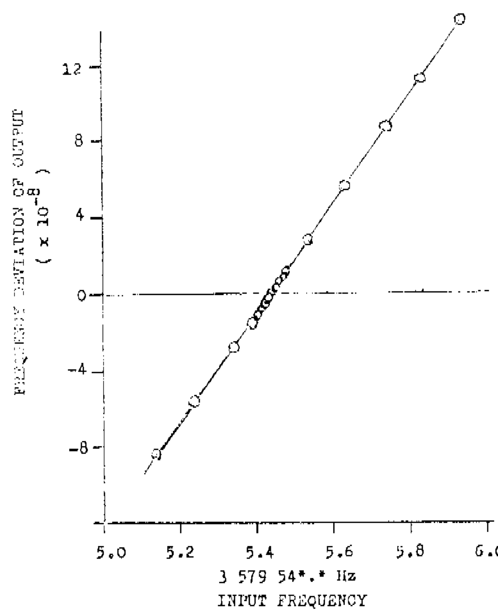

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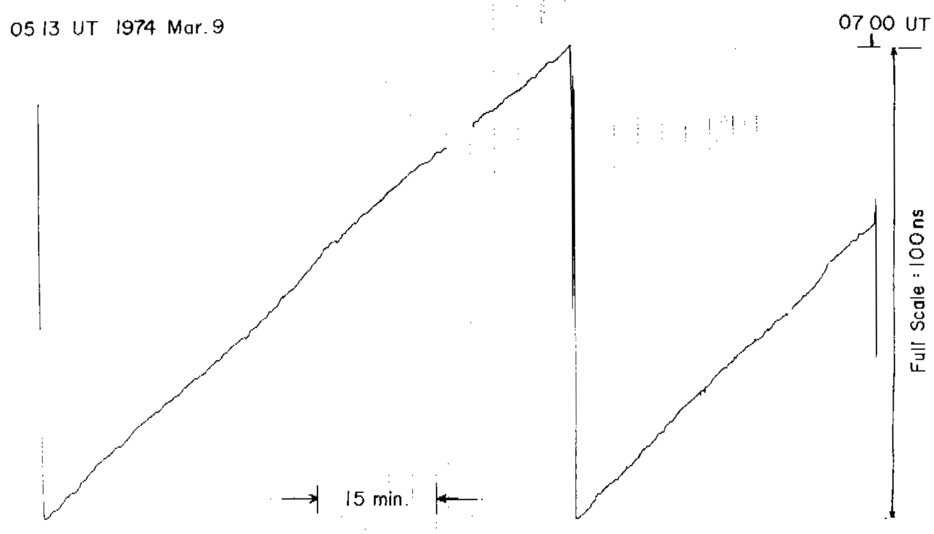

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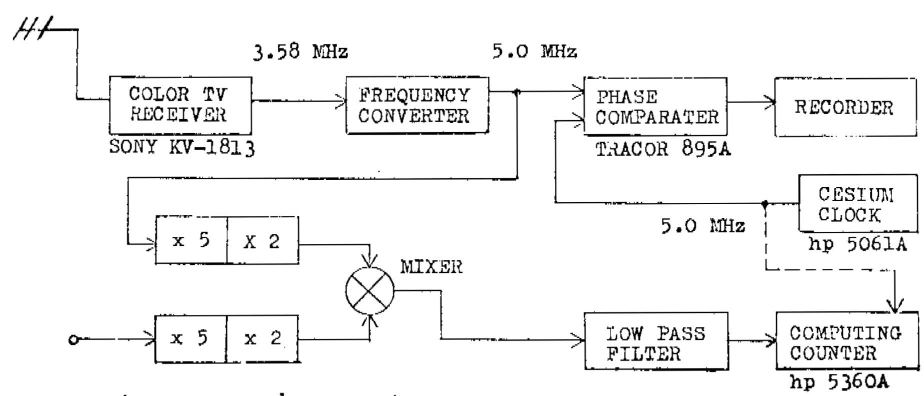

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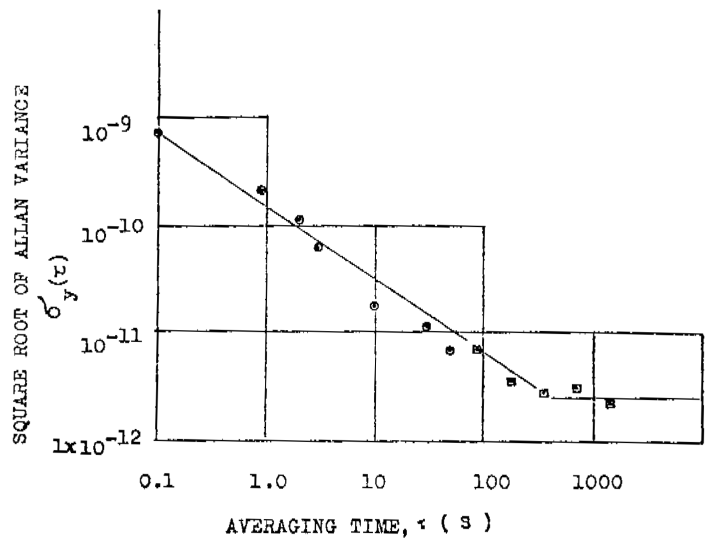

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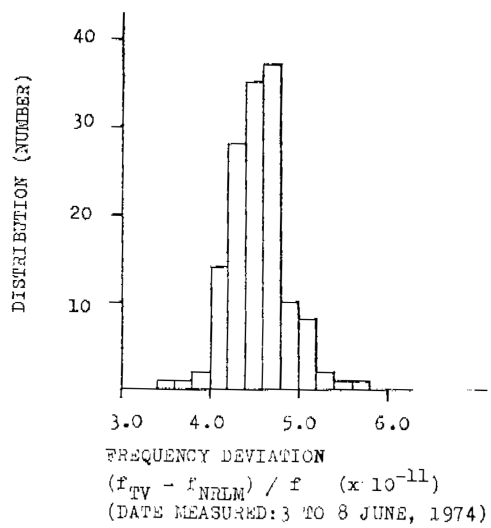

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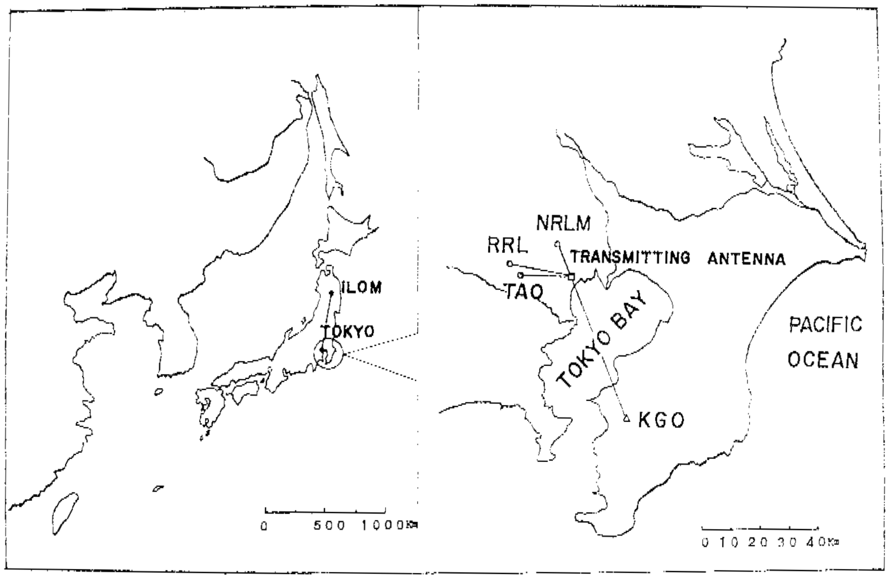
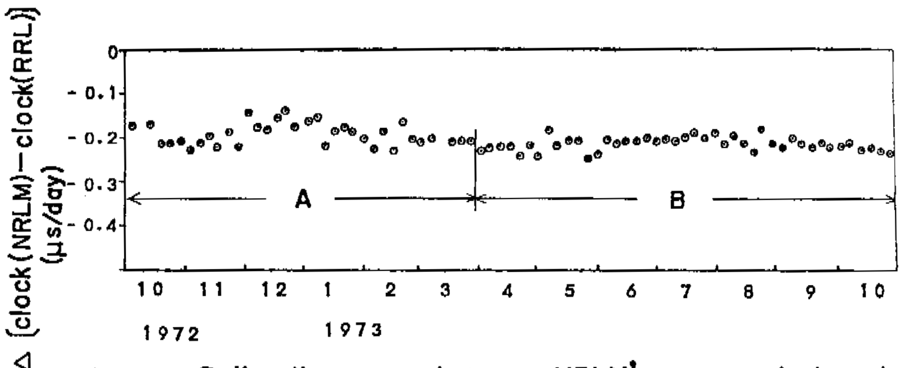


Locations of laboratories



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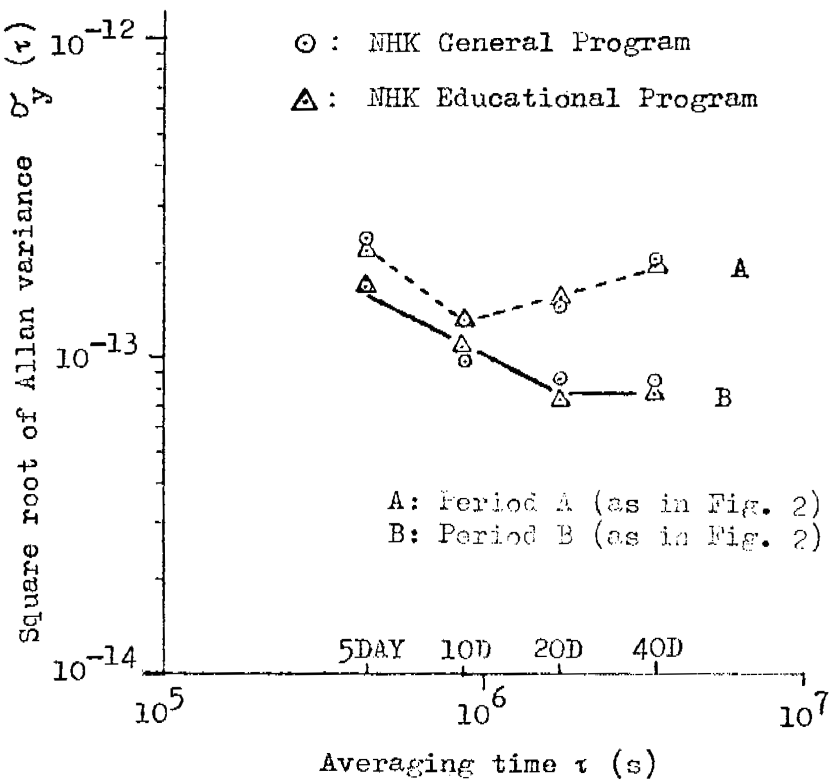

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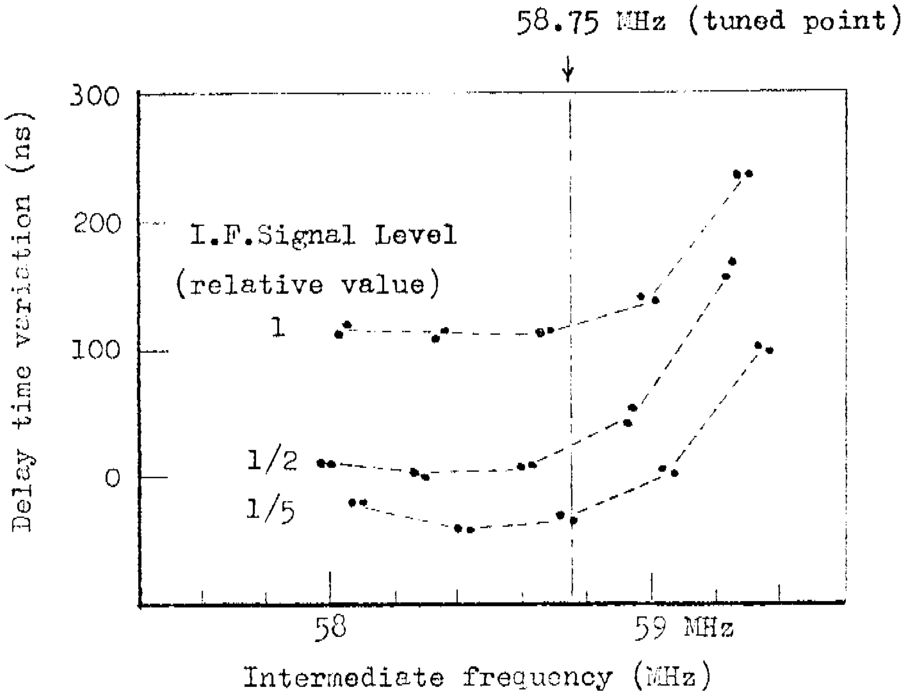

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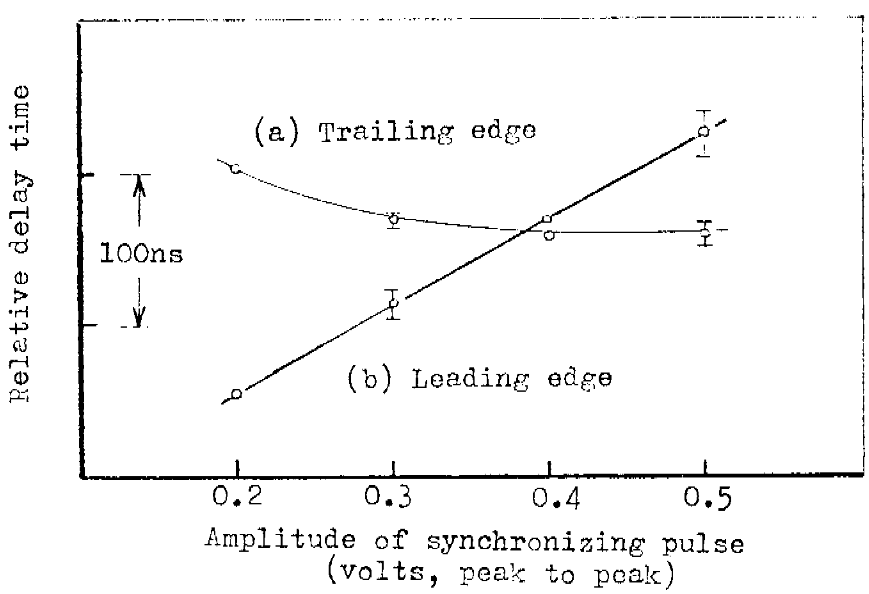

Fig.5 Relative delays and scatters (one sigma) of separated synchronizing pulse vs. amplitude of the synchronizing pulse in video signals.

QUESTION AND ANSWER PERIOD

DR. SHEPARD:

Shepard, ILC Industries.

We may have a communications problem here. The synchronizing pulses and the subcarrier, were they taken from the synchronization separator within the television or were they separated outside from the composite video signal?

DR. INOUYE:

At present, we use another receiver, two different receivers.

DR. SHEPARD:

One for the synchronization pulses and one for the subcarrier?

DR. INOUYE:

Yes.