IMPROVED MASTER CLOCK REFERENCE SYSTEM AT USNO

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ABSTRACT

The first phase of the NAVELEX/NRL/USNO Master Clock (MC) upgrade program[1] has been completed with the delivery of two VLG11B Hydrogen Masers to the U. S. Naval Observatory (USNO). After installation in a specially prepared Maser Laboratory with redundant environmental control, and a ten-day "burn-in" operation, the masers were independently tuned. Their subsequent performance caused a review of our plans for their operational use as part of the USNO MC complex. A revised concept is the basis for system integration presently in progress.

INTRODUCTION

For short time intervals, the performance of the USNO Master Clock is limited by the performance of the frequency standard which drives the phase stepper, pulse divider, time code generator and distribution amplifier complex. The data amplifier complex comprises one of the several "Reference Clocks" which implement the master clock time reference. For long time intervals, currently longer than one day, the reference clocks are phaselocked to the computed reference time scale MEAN(USNO). This phase lock is done by a once a day setting by computer of the respective phase microstepper.

In September 1983 USNO received delivery of two VLG11B hydrogen MASERS (produced by Dr. Vessot's group at Smithsonian Astrophysical Observatory, production number S-18 and S-19) which are currently being incorporated into the master clock as superior driving frequency standards. The performance we have measured will permit us to operate the reference clock (which is to be driven by one of the MASERS) in an improved way.

INITIAL MASER PERFORMANCE

Figure 1 shows a conventional sigma-tau plot for the differential stability of the MASERS. These data have been obtained by the offset-beat method. For our application, however, the actual overall performance within our system is of greater relevance. Figure 2 tabulates 5-day solutions of the MASERS in reference to our MEAN(USNO). Two observations are obvious. First, we note the drift of both units (which is entirely within specifications and was expected to be larger by a factor of two to three). Second, we can see that the residuals of the 120 hourly time measurements are indeed less than one nanosecond, i.e. the stability of both the time scale and the MASERS is slightly better than we expected on the basis of older data. Figure 3 is a plot of MASER #18 which shows a change in the drift rate which we correlate with work in the room at that time (#19 was tuned).

The following pictures show the differential stability of the two MASERS expressed as residuals after subtraction of a quadratic fit in phase for progressively longer time intervals. If the drift stays very constant, then we can apply the phasestepper corrections with a time constant longer than one day and thereby further reduce the phase noise in the reference clock (the noise of t MASER is considerably less than the noise from the time scale for time intervals up to a fe days). Table 1 summarizes the essential features of Figures 5-8.

LENGTH OF FIT days	RMS RESIDUALS ps
7	150
15	196
26	1150
40	1870

Table 1

Figure 8 is particularly impressive because it shows that for the full duration of 40 days or three incremental (over and beyond the constant drift) frequency changes occurred. These a 6.7, -4.5 and 3.0 parts in ten to the fifteen. The belief is, therefore, justified that we will able to utilize the outstanding stability of these two units for times much longer than one day.

MASTER CLOCK MASER SUBSYSTEM CONCEPT

The MASERS are not only superior clocks and cost commensurately more than industrial hi performance cesium clocks, they also require much more attention. They must be tuned eve month in the interest of continuing high stability. We also expect more interruptions for oth reasons. It is for the provision of more required operational flexibility which will be requir that we arrived at a subsystem concept as depicted in Figure 9. At the heart of the system our standard system controller, an HP9915 computer with two interfaces: An IEEE 488 bus measurement and control and an RS 232C for communication with our IBM Series 1 mi computer. The concept allows for switching the driving standards at any time because t synthesizer of one unit will be remotely adjusted to keep the output of both units in phase at times. This way tuning and repair can be performed on a unit without interruptions in t operating system, barring catastrophic failures. Forty channels of test voltages for each u are under constant surveillance for diagnostic purposes. The system concept follows our gene principle of local control so that this subsystem is entirely independent in between the da communications with the IBM operations controller. It also uses to the maximum extent hi quality industrial components and subsystems. This subsystem is currently being assembled a interfaced. We expect to be in operation in spring 1984.

REFERENCE

1) Ralph Allen (1980), The Navy PTTI Program (Update), Proceedings 12th PTTI Conferen p. 127

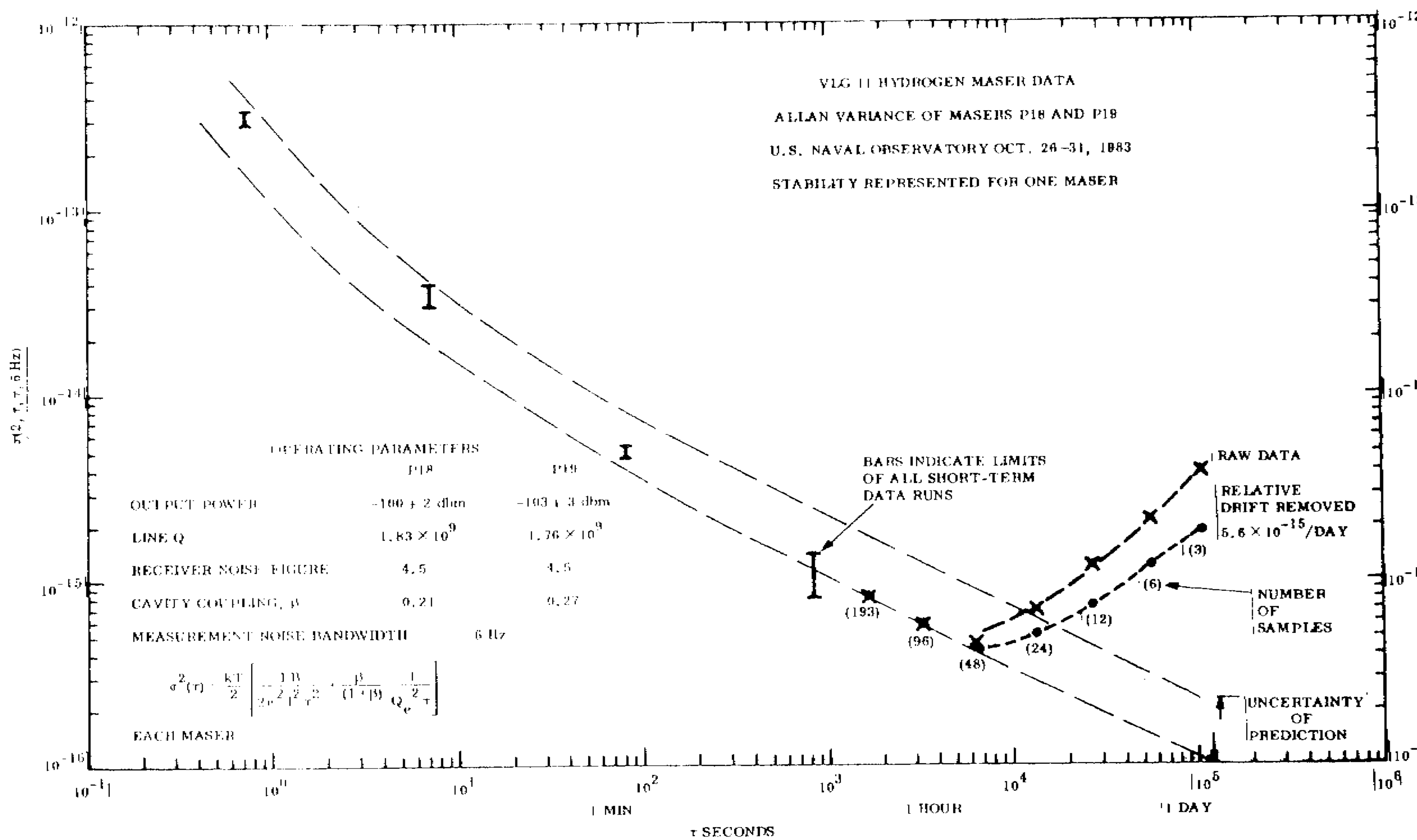

FIGURE 1 STABILITY DATA TAKEN WITH THE OFFSET - METHOD (COURTESY DR. VESSOT)

5-DAY SOLUTIONS FOR USNO VLGIIB MASERS

(MEAN(USNO - MASER)

	Maser A		Maser B	
	S-18		S-19	
MJD	Rate(ns/d)	Sigma	Rate(ns/d)	Sigma
45607	-17.0	0.8		
45612	-12.8	0.9		
45617	-6.4	1.0		
45622	-4.1	0.6		
45627	-1.2	0.5		
45632	+2.9	0.6		
45637	+5.9	0.8		
45642	+7.7	0.5	-3.1	1.1
45647	+10.6	1.1	+3.4	1.6
45652	+12.9	0.8	+9.4	1.6
45657	+15.4	0.6	+15.8	1.3
45662	+17.0	0.5	+20.5	1.0
45667	+19.4	0.5	+25.3	0.4

FIGURE 2 LONG-TERM MASER STABILITY MEASURED IN REFERENCE TO MEAN (USN

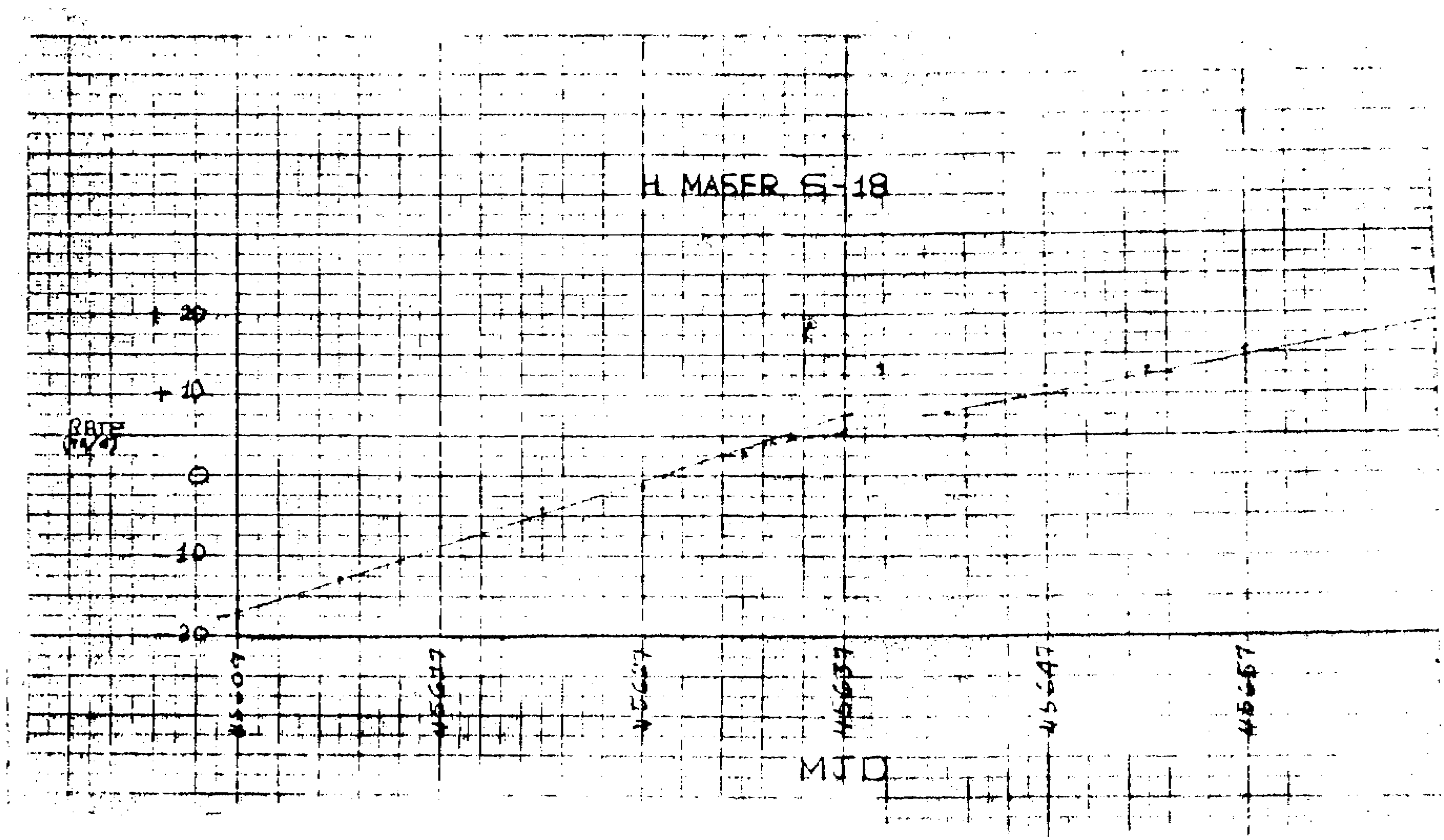

FIGURE 3 FIVE-DAY RATES OF MASER #18

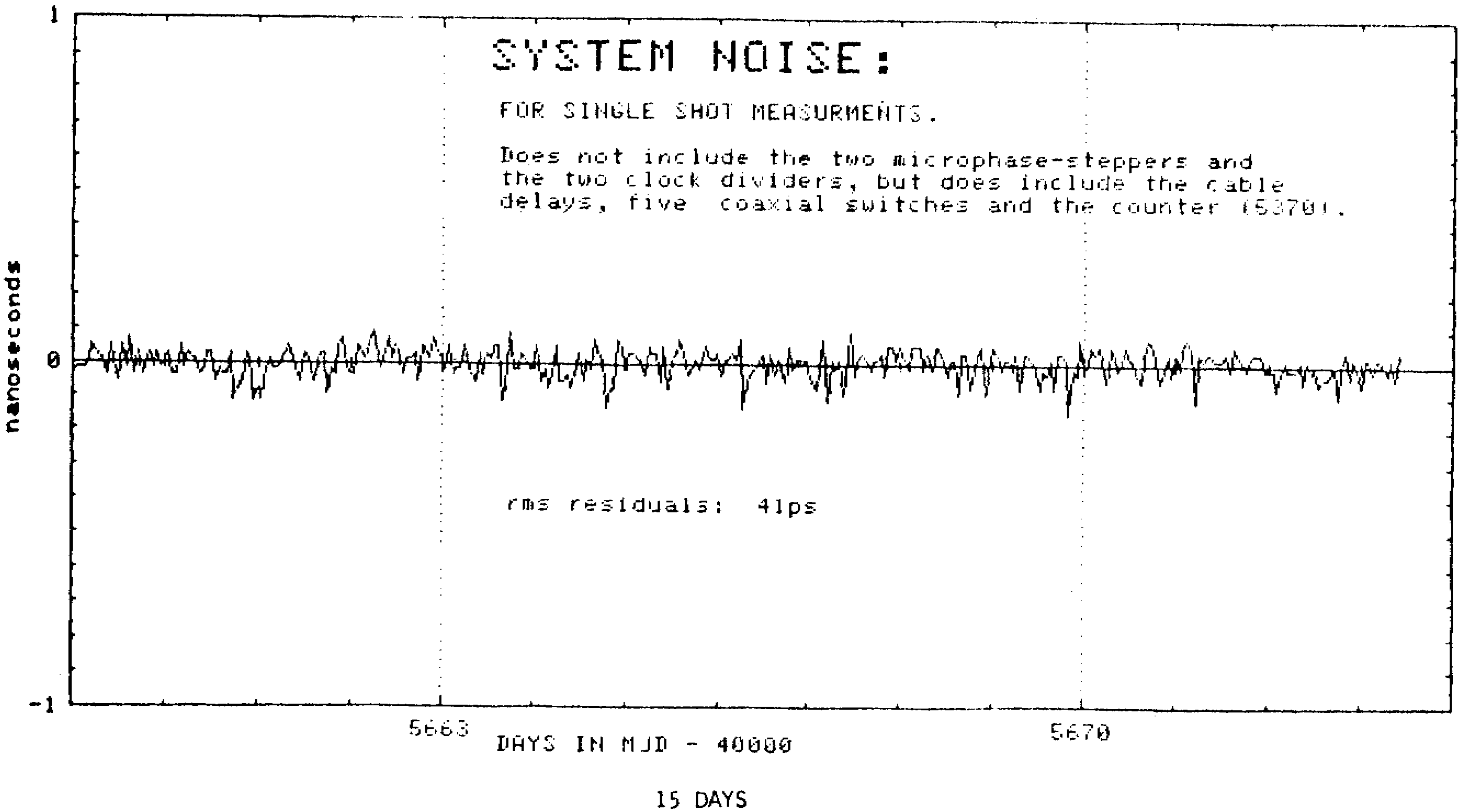

FIGURE 4 SYSTEM NOISE FOR THE HOURLY 1pps TIME DIFFERENCE MEASUREMENTS.

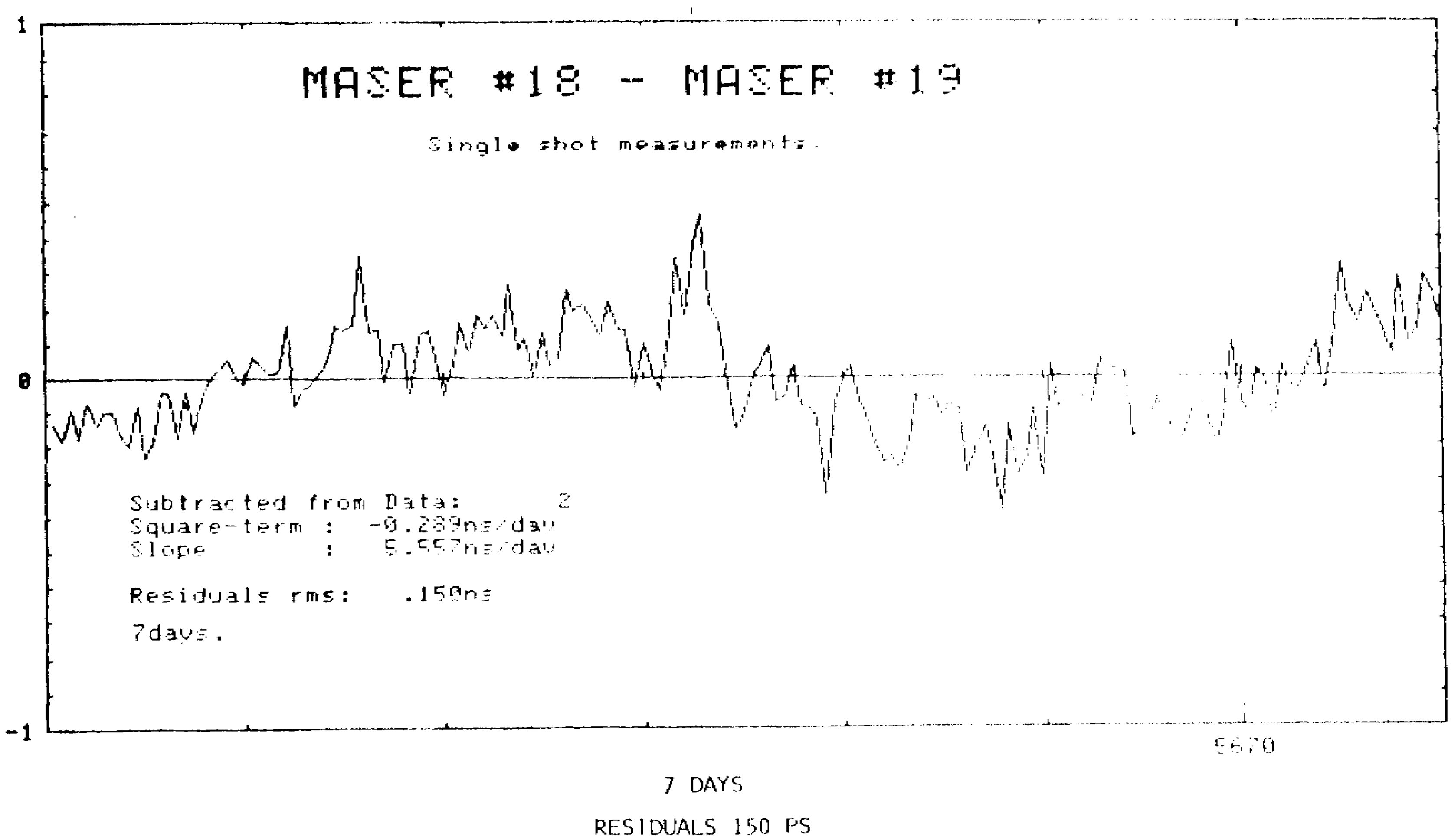

FIGURE 5 MASER DIFFERENTIAL STABILITY

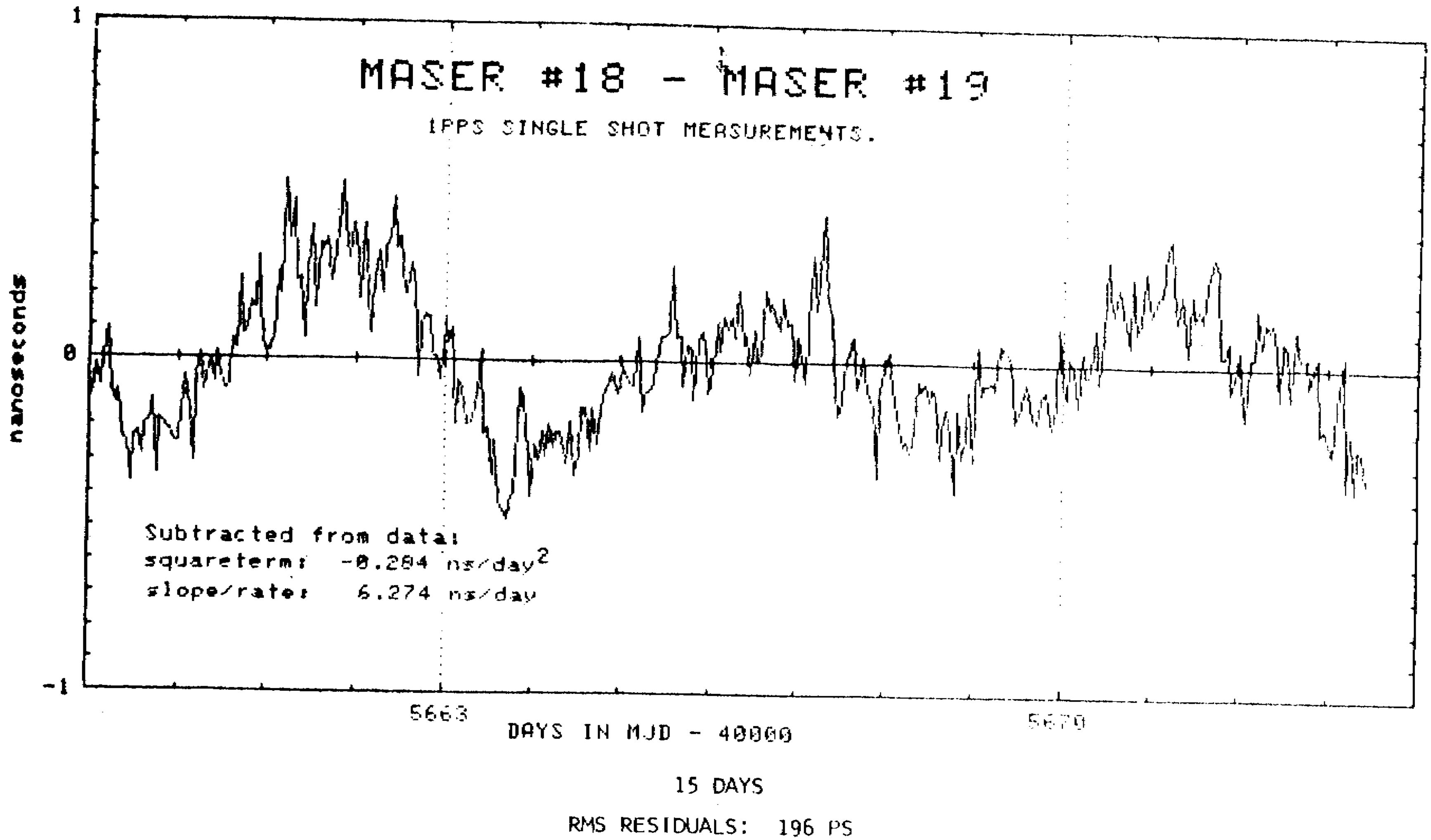

FIGURE 6 MASER DIFFERENTIAL STABILITY

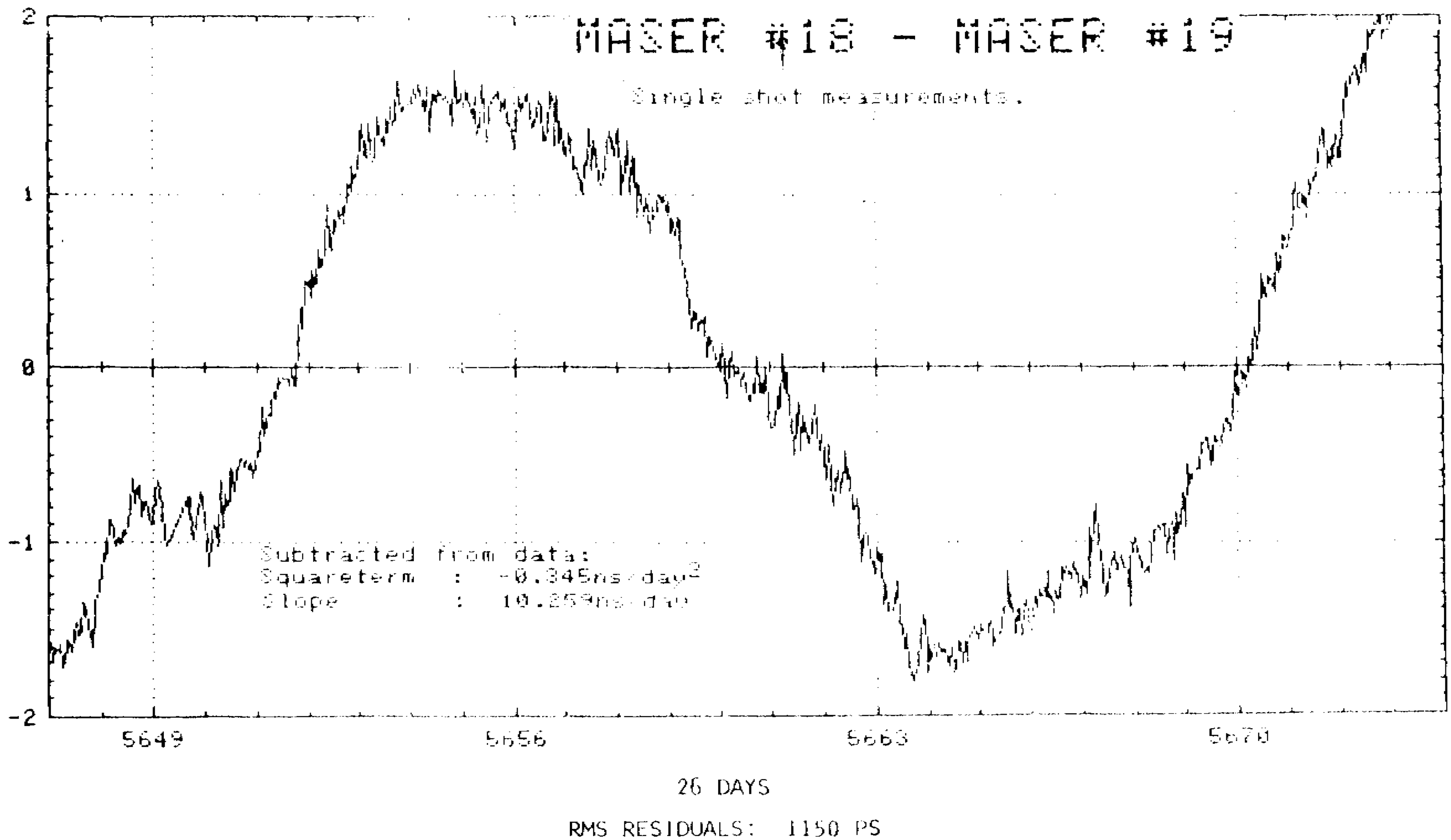

FIGURE 7 MASER DIFFERENTIAL STABILITY

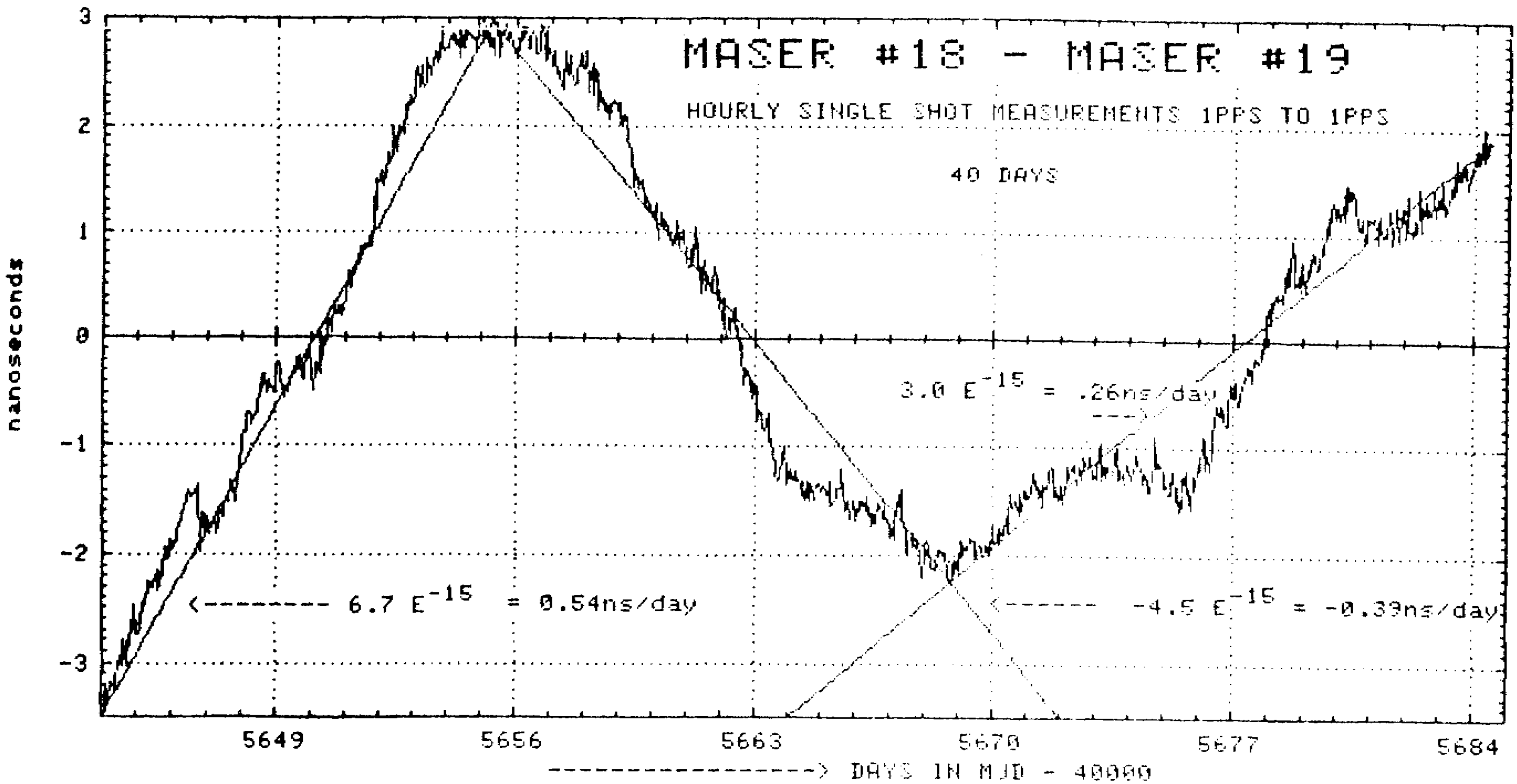

FIGURE 8 QUADRATIC FIT RESIDUALS, SLOPE: 7.7ns/d, SQUARE TERM $-0.33 ns/d^2$, RMS. RESIDUALS: 1.66ns.

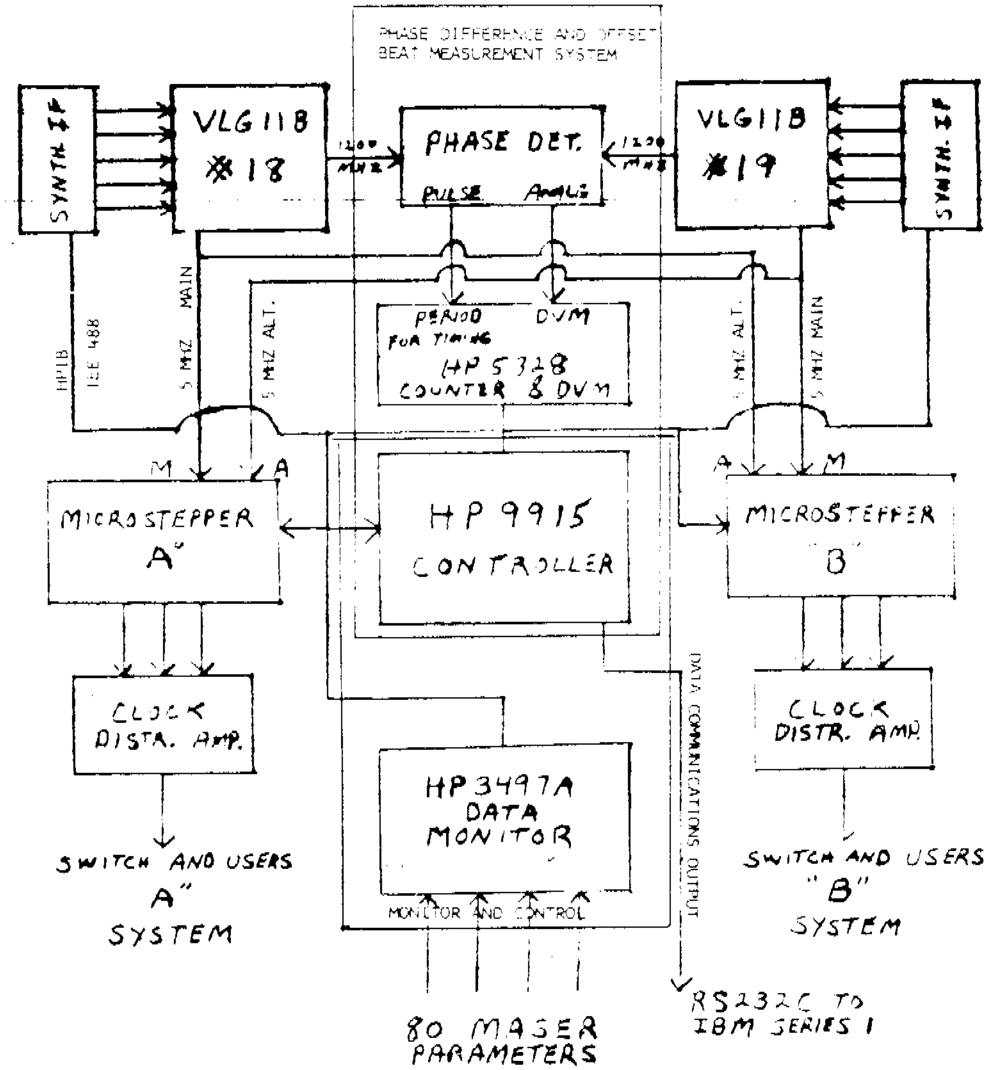

FIGURE 9 NEW MASTER CLOCK MASER SUBSYSTEM

QUESTIONS AND ANSWERS

MR. WARD:

Sam Ward. I have two questions. First, what is causing that periodicity that I saw in the sort of data?

DR. WINKLER:

That is an effect that you can see in every record which has a limited data length. The affect has been discussed at length by Jim Barnes a few years ago. It's simply the low frequency spectral content of the variations which the masers show; and you have the combination of a filter due to the cutoff of the data, and low frequency content appears for a final data piece as some kind of indication of a sine wave.

If, however, you take the next spot, the sine wave looks different. If you continue sampling the sine wave changes period. It is really not the sine wave. It is the low frequency content of the disturbances, and you find it in any such record between highly stable standards. Your second question?

MR. WARD:

The second question deals with the convenient means of measuring the Zeeman so that you can see whether the magnetic environment for both of them has changed.

DR. WINKLER:

We plan to be able at any time, by pushing a button on the controller, to shift--System B, for instance, if that one requires a Zeeman measurement to be operated from the first maser, or in fact from an additionally available Cesium signal that will come from one of our cesium clock vaults and then the maser is available for anything. You can make your Zeeman measurements. You can take it apart if you want to, and you can do anything. You can tune it as often as you please. The idea has been to have a system which will allow maximum use of these two beautiful clocks that we now have and are better by a factor of 10 what our specifications have called for; and I am very happy to acknowledge here the excellent cooperation between the three Navy agencies involved, namely, NAVELEX which provided the program management; N.R.L., with Joe White who wrote the specifications, and our contractor, Smithsonian Astrophysical Observatory, which delivered the masers, and really took every pain to make sure that they operate at this performance level.

My purpose was to report the initial performance of the masers, and to do that I felt some kind of an obligation because in the past there were some quite critical remarks which I made about the performance of masers, and I'm happy to correct myself and say that now we have clocks that are better than anything I have ever seen. Thanks.