

VI. MOLECULAR BEAMS

Prof. J. R. Zacharias
Prof. J. G. King
Prof. C. L. Searle
R. S. Badessa

V. J. Bates
D. A. Brown
R. Golub
W. D. Johnston
E. L. Kamen

F. J. O'Brien
J. E. Steelman
C. O. Thornburg
R. Weiss

A. CESIUM BEAM TUBE INVESTIGATION

The quadrature component referred to in Quarterly Progress Report No. 66 (page 37), which appeared as a residue preventing a true null from occurring at the output of the 100-cps amplifier, has been investigated further. Originally we believed that the quadrature was the result of second-harmonic distortion in the waveform of the frequency modulation of the X-band excitation signal. However, after trying several modulation schemes differing widely in principle and theoretically incapable of causing quadrature difficulties from this source, we have concluded that second-harmonic distortion is not the primary cause of trouble. We now believe that quadrature will occur even with distortionless modulation whenever the beam-tube resonance characteristic has a slight dissymmetry. The reason is not as obvious as it may appear, since it involves consideration of dynamic, rather than static, operation. We conclude that quadrature could be reduced substantially by extracting information from the beam tube in a manner that is not likely to be influenced by transient behavior.

During the next quarterly period, a new type of control loop is to be investigated based on the transient response studies just completed. Essentially, our method is to use pulse techniques to gate out undesirable transients. If it is successful, it will result in the attainment of a null at the output of the modulation-frequency amplifier that is a function only of the degree of detuning of the X-band excitation frequency from the peak of the static cesium resonance characteristic.

R. S. Badessa, V. J. Bates

B. MEASUREMENT OF FREQUENCY STABILITY

We have ascertained (see Quarterly Progress Report No. 66, p. 38) that a useful and enlightening criterion for judging the frequency stability of a frequency standard involves the determination of the autocorrelation of the phase difference between a reference and the standard that is being measured. In particular, it is quite easy to determine the mean-square frequency deviation for different averaging times by using this criterion. In practice, of course, rather than compare the frequency standard to a perfect frequency we can only compare one frequency standard with another frequency standard. If the two standards are identical and independent, the mean-square deviation for one standard will be half the mean-square deviation for both.

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The eventual goal is to compare a large number of frequency standards so as to determine the relative merits of each. In view of the large amount of data that is anticipated, it is desirable that the data gathering and data processing be automatic, to obviate the need for long data taking, data reduction or computation by hand.

We have built the system illustrated in Fig. VI-1 for detecting phase differences between two cesium-beam frequency standards. The voltage proportional to the phase

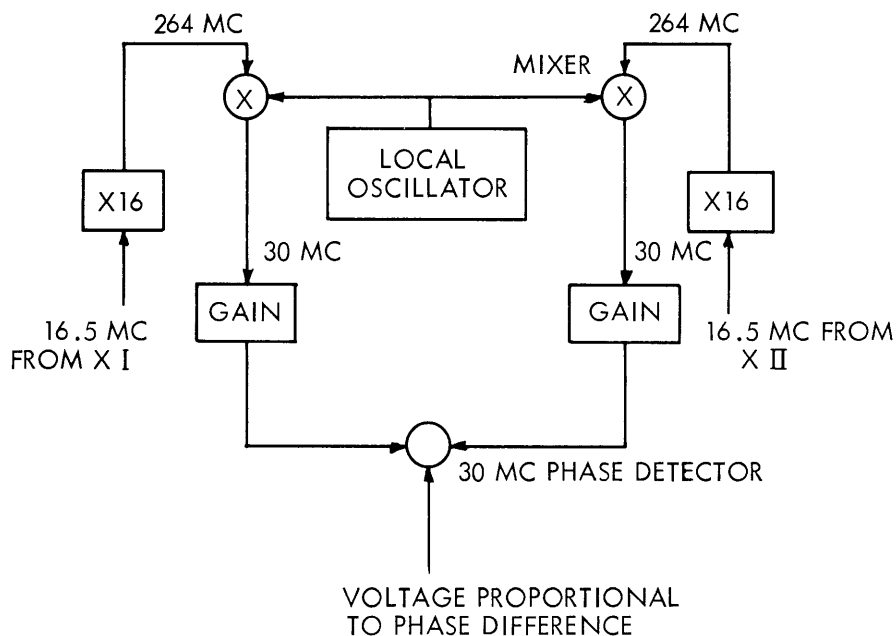


Fig. VI-1. Experimental system.

is recorded on an Ampex FM tape recorder. The tape recorder is capable of recording at 30 ips, 3 ips, and 0.3 ips, and will play back at 30 ips. When a lot of data is required, the recording is done at 0.3 ips; this allows a playback speedup of 100:1. Because of the short time available for data recording, we used 3 ips.

The analog-to-digital conversion was done at the Electronic Systems Laboratory, M. I. T., with the help of Mr. Robert Paine. The digital output was in the form of punched cards, with five samples on each card.

Three programs were developed for which Fortran and the IBM 7090 computer at the Computation Center, M. I. T., were used. The first program computed the autocorrelation by the time-average method. The second program computed the autocorrelation by the same method, but spaced the abscissa unevenly. The third program computed the autocorrelation the same way as the second, but the data were quantized more coarsely.

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The results of the computer runs show that it is very reasonable to automatically gather and process the phase information received from the frequency standards. It has also been shown that the data can be very coarsely quantized and still give good results in the autocorrelation.

This work is reported on in detail in the author's thesis.¹

D. A. Brown

References

1. D. A. Brown, Statistical Measurement of Frequency Stability, S.M. Thesis, Department of Electrical Engineering, M.I.T., August 20, 1962.

