X. SATELLITE TIME-DILATION MEASUREMENT[*]

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Investigations are being carried out in preparation for a short-term measurement of gravitational red shift in an earth satellite. System design studies and preliminary circuit construction and testing are continuing. Also, short-term stability measurements on highly stable quartz crystal oscillators are being performed.

A. Gravitational Red Shift Investigation

1. Measurement system

a. System stability. The advantages of a cw system as compared with a pulse system for the communication link with the satellite were presented in Quarterly Progress Report No. 57 (page 179). A serious problem with the cw system is the possibility of
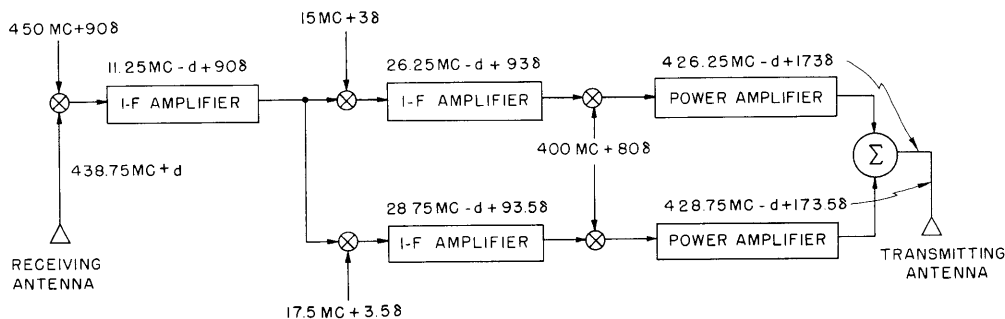

Fig. X-1. Proposed satellite equipment for cw operation. (Ground-transmitter frequency, 438.75 mc; δ is gravitational red shift of 5-mc oscillator; d is first-order Doppler shift.)

self-oscillation in the satellite as a result of spurious generation of the received signal in the mixers and harmonic generators. To determine whether or not the satellite system that is now under consideration (Fig. X-1) would present this difficulty, a portion of the satellite receiver was constructed and tested. There are four rf signal frequencies that would be present, together with the desired signal from the ground transmitter. These signals were applied to the satellite receiver input (Fig. X-2). The ground-transmitter
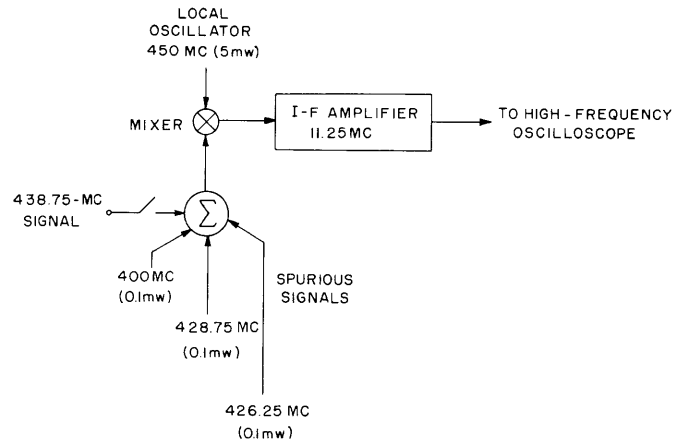
Fig. X-2. Arrangement for investigation of stability
with spurious signals.

signal was included in order to check the receiver performance. When this signal was removed, the output of the i-f amplifier was reduced to noise, which indicated satisfactory performance in the presence of spurious signals.

In conjunction with the proposed satellite experiment, a frequency synthesizer was constructed to furnish all of the pertinent signals from a 5-mc frequency standard.

b. Transistor UHF power amplifier. Two power amplifiers at a frequency of 425 mc are required to provide suitable satellite transmitter signal levels for the proposed experiment. To investigate the capabilities of transistor amplifiers in this application, a two-stage amplifier was designed and constructed. A Western Electric 2N1195 transistor (225-mw power dissipation, 750-mc alpha cutoff frequency) was used as the driver, and a Texas Instrument 2N1142 transistor (750 mw, 600 mc) as the output. Design specifications called for a 20-db power gain with a 0.5-mw drive level. The actual output power level of 20 mw represented a power gain of 16 db. Further investigation of transistor amplifiers will be postponed until the oscillator stability requirements are achieved.

c. Low-frequency reference-signal generation. A system has been constructed to provide selected low-frequency reference signals for determination of the relativistic frequency deviation of the received signal at the ground station. A series of discrete frequencies in 2-cps steps from 490 cps to 510 cps is generated as shown in Fig. X-3. The 10-kc output from an HP 100D secondary frequency standard is divided down to 2.5 kc and modulated with narrow pulses at a rate of 10 cps to provide a "comb" spectrum centered at 2.5 kc. The spectrum is transferred to 100 kc by mixing with a 102.5-kc signal obtained from a voltage-tunable oscillator. The 100-kc comb spectrum is then applied to a crystal filter with sufficient selectivity to pass only one component
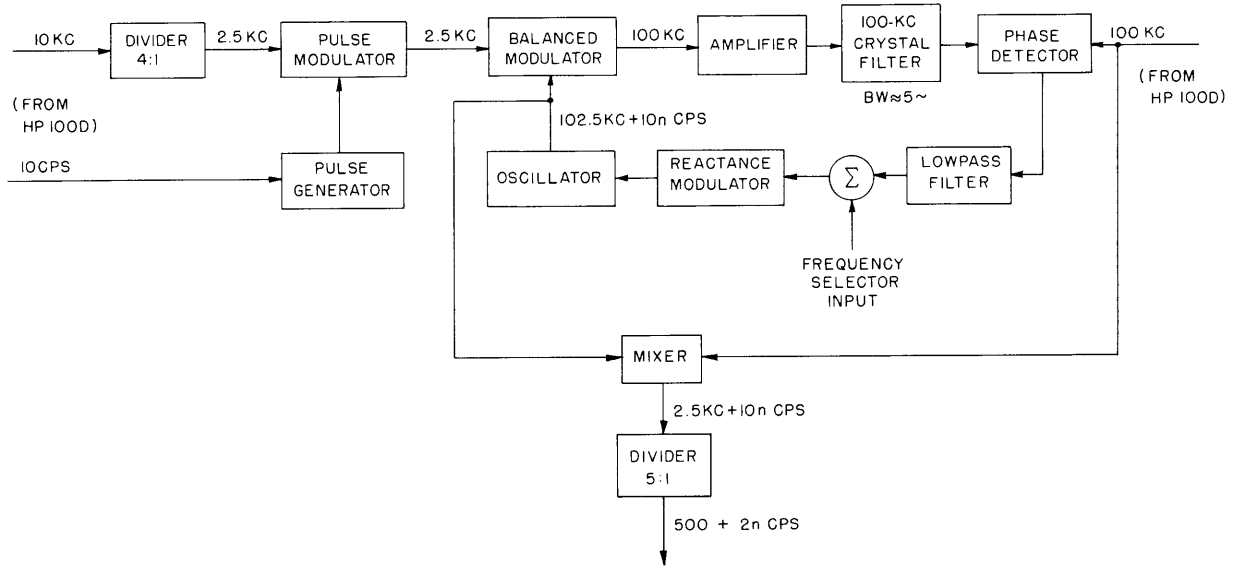
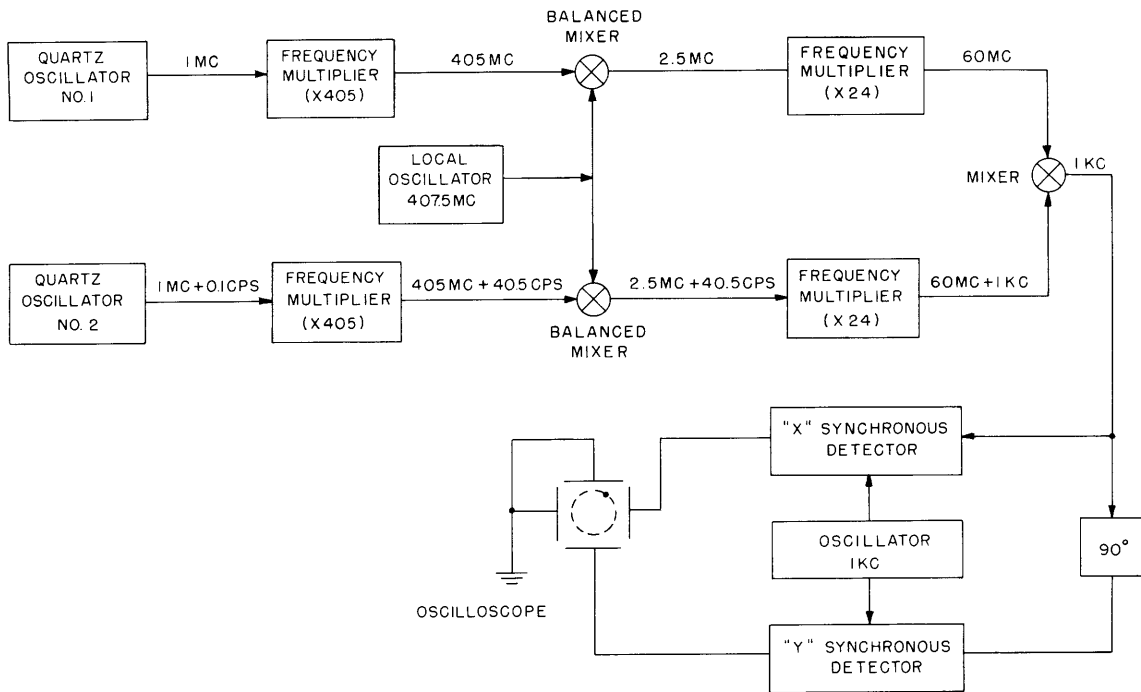Fig. X-3. Low-frequency reference generator.

Fig. X-4. Oscillator stability-measurement system.

of the spectrum. The tunable oscillator is phase-locked to a selected component by means of a 100-kc phase detector that compares the crystal-filter output with a 100-kc reference signal from the frequency standard. The final output at 490-510 cps is obtained by mixing and frequency division from the phase-locked oscillator.

The measured stability of the output was found to be $\pm 2 \times 10^{-4}$ for a measurement interval of 0.02 sec (10 cycles at 500 cps), as a result of residual 10-cps modulation of the signal. For measurement intervals of 1 minute or longer, however, the stability is essentially that of the secondary standard, which is stated to be $\pm 1 \times 10^{-6}$. For a gravitational red shift measurement at 500 mc, the low-frequency reference stability is sufficient to permit a measurement accuracy of 1 per cent.

B. Oscillator Stability Studies

In order to permit short-term frequency comparison of two highly stable quartz oscillators, a system of frequency multipliers and mixers, shown in Fig. X-4, is being assembled. An effective multiplication of frequency difference by approximately 10,000 is provided. The output phase difference is displayed unambiguously on an oscilloscope and can easily be determined with an accuracy of 15° at any instant. Thus, a frequency difference between oscillators, averaged over a 100-sec interval, can be measured with an accuracy of

$$\frac{\Delta f}{f} = \frac{\Delta \phi}{T f_o N} = \frac{15°}{360° \times 100 \times 10^6 \times 10^4} \approx 4 \times 10^{-14}$$

The measurement accuracy is approximately two orders of magnitude greater than the desired oscillator stability.

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