PRECISE TIME TRANSFER UNIT (PTTU)

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ABSTRACT

The Precise Time Transfer Unit (PTTU) was developed by the Naval Ocean Systems Center in support of an effort by the US Army Communications Command to demonstrate the feasibility of transferring PTTI from the Army Satellite Communications Station at Camp Roberts, California, to a remote location, via the existing Federal Aviation Administration Radar microwave link system. The demonstration will be in two phases:

> Phase 1, a loop test, sending PTTI information from Camp Roberts to the Temblor Radar Microwave Link/Repeater where it is looped back and returned to Camp Roberts.
>
> Phase 2, transfer of PTTI information from Camp Roberts to a user site.

Time at stations having precise time standards is compared by this system. Each station transmits its time, and receives time sent by the other station. Received time is then compared with local time at each end, and given the two measurements, the difference between the two clocks is computed. The computation removes propagation time and assumes only that the propagation time is the same in both directions.

In order to implement this test two configurations of the basic equipment were developed. (1) A terminal configuration, which receives the incoming 3.2MHz timing signal, correlates a locally generated pseudo random sequence with the received signal to acquire the inherent microsecond timing, and decodes the one

second epoch information. The received time is then compared with local time and the difference displayed on the equipment front panel. The terminal output encodes the local time on a 3.2MHz carrier for transmission. (2) A regenerator configuration, which receives the modulated 3.2MHz timing signal, correlates a locally generated pseudo random sequence with the received signal, and encodes the received one second epoch information on the locally generated pseudo random sequence. This signal is then used to bi-phase modulate a 3.2MHz carrier for re-transmission on another microwave link.

Phase 1 tests were conducted during October and November 1977. These tests demonstrated the feasibility of this technique with tenths of a microsecond accuracy. Concurrently it was proved that the PTTI signal did not interfere with existing FAA signal traffic.

I. INTRODUCTION

This paper presents some results of a test to demonstrate PTTI transfer over the Federal Aviation Administration Radar Microwave Link System. The phase I test was run 19–21 October 1977 with Army SATCOMSTA, FAA Western Region, and Naval Ocean Systems Center personnel participating. It successfully demonstrated the time transfer technique between Camp Roberts, California, and the FAA Temblor Radar Microwave Link/Repeater (RML/R) located approximately 65 miles to the southeast. The time transfer demonstration was repeated 1, 2 November 1977 by the original test participants, and witnessed by Army Communications Command and Naval Observatory representatives.

A number of requirements were placed upon time transfer equipments, as follows:

a. Provide entry and exit to the FAA System.

b. Do not degrade existing traffic on the microwave link.

c. Maintain existing inter-system isolation when crossing between the FAA Systems.

To achieve this the Precise Time Transfer Unit (PTTU) was developed by NOSC[1]. Section II discusses, in brief, the design of the PTTU and the two configurations used in the Phase I test. Figure 1 is an illustration of this equipment.

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[1]The NOSC design was based on a Satellite PTTI Modem design by J.A. Murray of NRL (ref. 1). The name Precise Time Transfer Unit (PTTU) was chosen to avoid confusion with the existing CM-427 Time Transfer Unit.

Ref. (1) J.A. Murray, "Mini Modem for PTTI Dissemination", Proceedings of the Third PTTI Conference, pp 103-110, 1971.

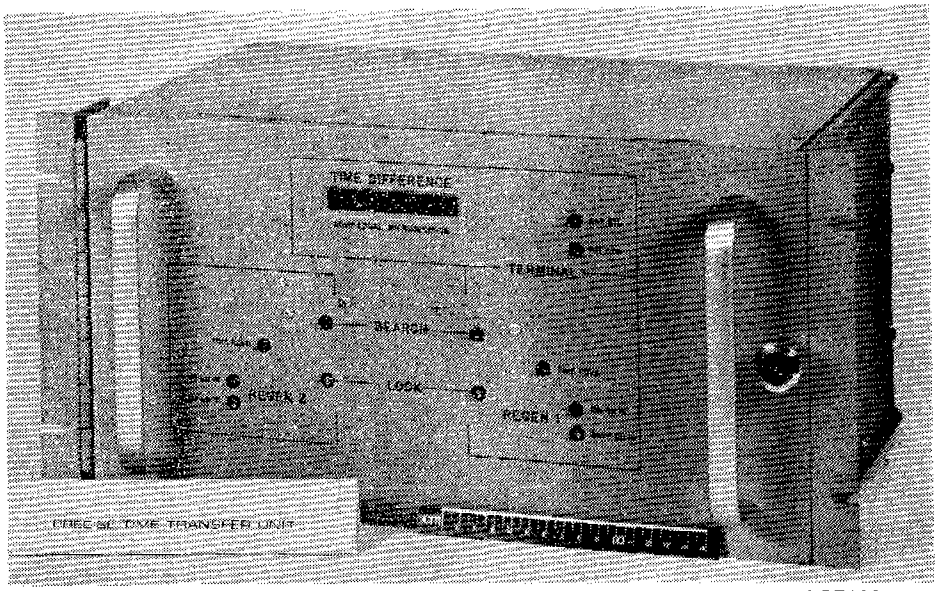

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Figure 1. Photograph of PTTU

II. PTTU DESIGN

Time is transferred between stations with precise time standards. Each station sends its time and receives time sent from the other station. The received time is then compared with the local time standard. The measurable quantitites at each end are the time differences between received time and local time. The desired quantity is the difference between the two clocks, however the measurable quantity also contains the transmitter to receiver propagation time, which is in general not known[2]. If the propagation time is the same in both directions, the clock difference is half the difference between the measurable quantities at each end, i.e.,

$$C_2 - C_1 = \frac{M_1 - M_2}{2} \tag{1}$$

where C_1 = station 1 clock time

C_2 = station 2 clock time

M_1 = measured difference between received time and local time at station 1

M_2 = measured difference between received time and local time at station 2

This is illustrated in figure 2.

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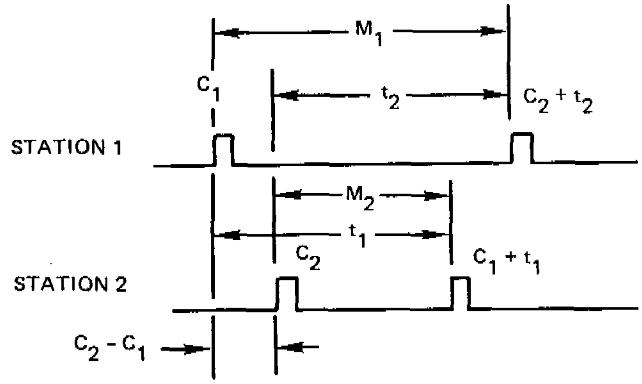
[2]It is anticipated that propagation time will be calibrated in an operational system, making one-way time transfer possible. However this is not a necessary condition.



$$C_2 - C_1 = \frac{M_1 - M_2}{2}$$

$$M_1 = C_2 + t_2 - C_1$$

$$M_2 = C_1 + t_1 - C_2$$

where t_1 = propagation time from station 1 to station 2

t_2 = propagation time from station 2 to station 1

$$C_2 - C_1 = \frac{(C_2+t_2-C_1)-(C_1+t_1-C_2)}{2}$$

$$= \frac{2C_2-2C_1+t_2-t_1}{2}$$

$$= C_2 - C_1 \text{ if } t_2 = t_1$$

Figure 2. Difference between clocks located at different terminals

The time is sent by synchronizing a pseudo random sequence (prs) so that the "all ones" state coincides with the local clock each second. The prs is bi-phase modulated onto a 3.2MHz carrier for transmission. A maximal length prs of length $2^{13}-1=8{,}191$ states truncated to an even 8,000 state length is used. The sequence is clocked at 1MHz which establishes an integer relationship of 125 periods per second[3]. The 191 deleted states represent only 2.3% of the sequence length so the correlation properties of the prs are not appreciably degraded by this procedure.

The 8,000 state prs is used to bi-phase modulate the carrier to produce a spread spectrum signal. The timing information is not conveyed by a time domain pulse, but rather by the

[3]The original 8,191 state sequence does not have a real time cyclic integer relationship using standard, or easily derived, clock frequencies. For example: at a clock frequency of 1MHz an 8,191 state sequence, with a period of 8,191 microseconds, has 122.08521 . . . periods per second, thus precluding synchronizing the sequence with one pulse per second time ticks from a local clock.

correlation properties of the prs modulation. Correlation to the prs provides fractional microsecond timing, but with an ambiguity period of 8 milliseconds. The phase of every 125th prs is reversed to indicate the 1 second time tick.

Two different PTTU configurations were required for the test:

a. TERMINAL Configuration; to provide entry and exit to the microwave system.
b. REGENERATOR Configuration; to provide the link to cross over between independent microwave systems.

Figure 3 illustrates these configurations. The basic PTTU can be put into each configuration by plugging in the proper printed circuit cards.

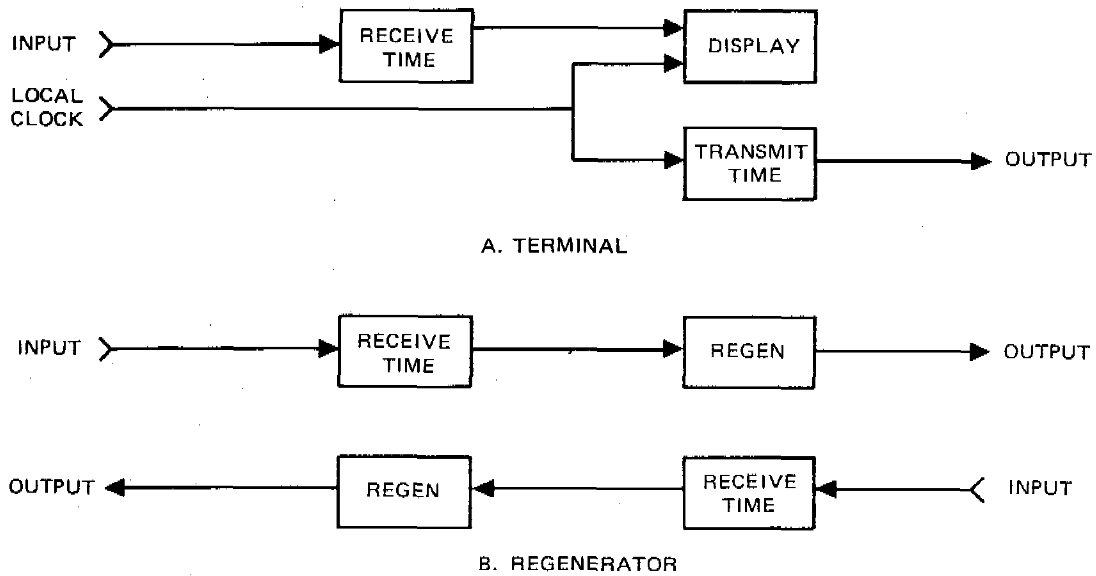


Figure 3. PTTU configurations

Figures 4 and 5 are block diagrams of the PTTU configurations. Much of the circuitry is common; the basic differences being in input and output circuitry. The two configurations accomplish the following:

Terminal Configuration. The terminal receives the incoming modulated 3.2MHz timing signal, correlates a locally generated pseudo random sequence with the received signal to acquire the inherent microsecond timing (8 millisecond ambiguity), and decodes the one second epoch information. The received time is then compared with local time and the difference displayed on the front panel. The terminal output encodes the local time on a 3.2MHz carrier for transmission.

Regenerator Configuration. The regenerator receives the modulated 3.2MHz timing signal, correlates a locally generated pseudo random sequence with the received signal, and encodes

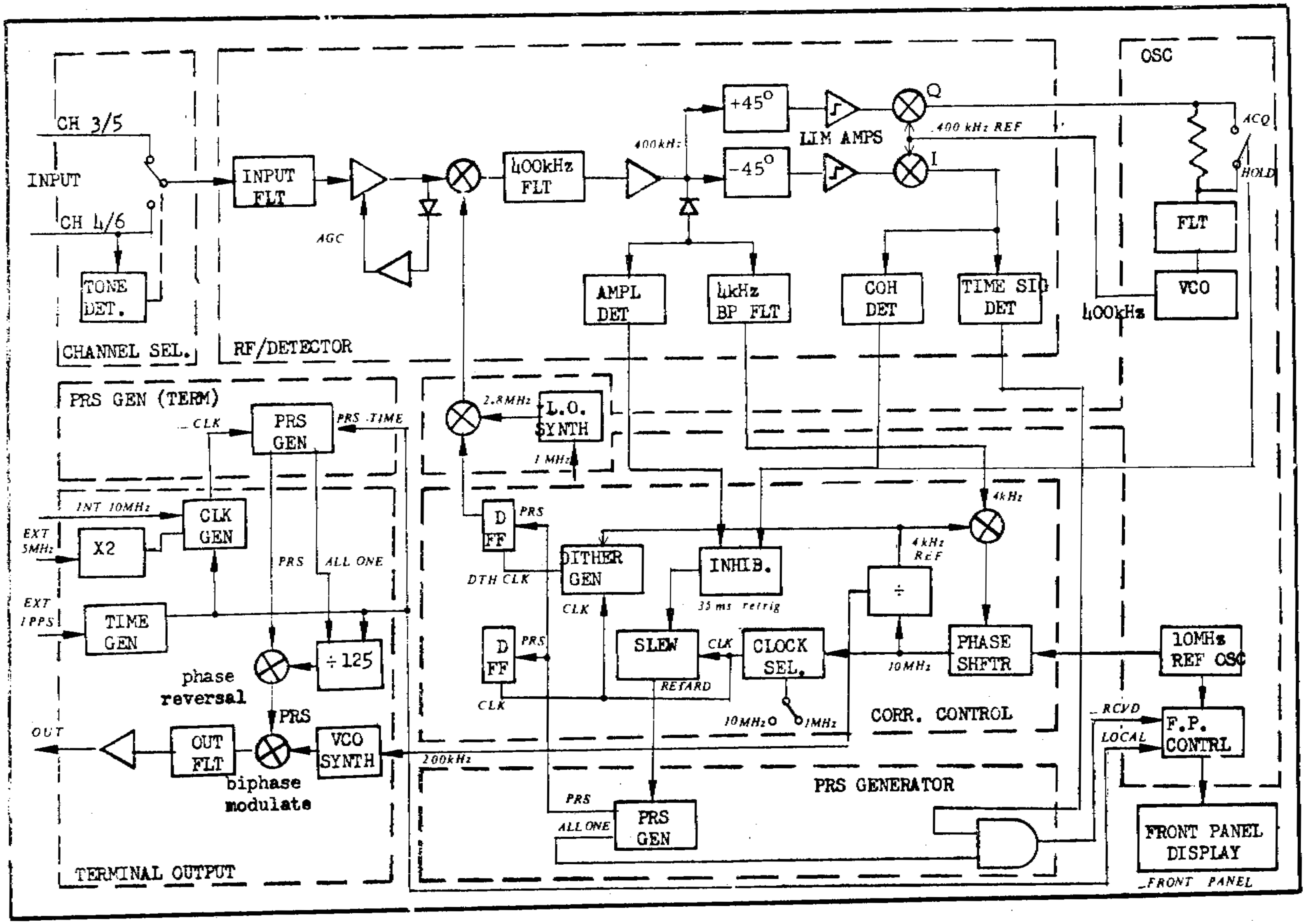


FIG 4 TERMINAL CONFIGURATION

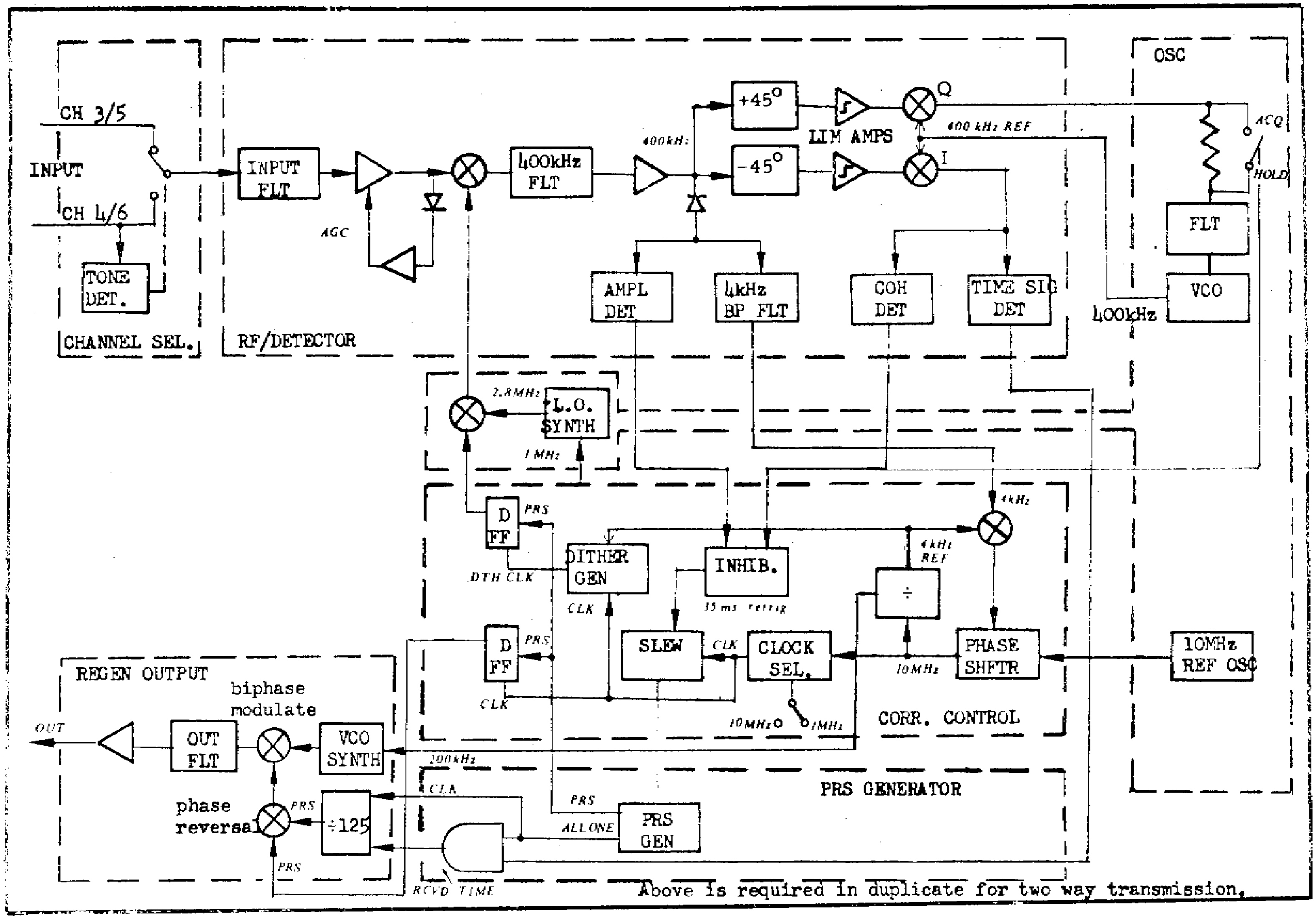


FIG 5 REGENERATOR CONFIGURATION

the received one second epoch information on the locally generated pseudo random sequence. This signal is then used to bi-phase modulate a 3.2MHz carrier for re-transmission on another microwave link. This configuration thus "regenerates" the received timing signal and passes it on. No local clock is required. There are two regenerator circuits; one to pass the PTTI signal in each direction.

III. TEST DESCRIPTION

The objectives of the phase I test were:

1. To demonstrate feasibility of this PTTI transfer technique.
2. To determine whether this PTTI signal is compatable with the FAA microwave system.
3. To determine the desirability of continuing on to the phase II tests.

The PTTI signal was sent from the Camp Roberts Satellite Communications Station to the Paso Robles Radar Microwave Link/Repeater (RML/R) by way of a two way 15GHz microwave radio link. At the Paso Robles RML/R it was entered into the FAA microwave system and sent to the Black Mountain Long Range Radar (LRR) site, where it was transferred from the FAA Oakland System to the FAA Los Angeles System and sent on to the Temblor RML/R. The time transfer demonstration was carried out between Camp Roberts and Temblor.

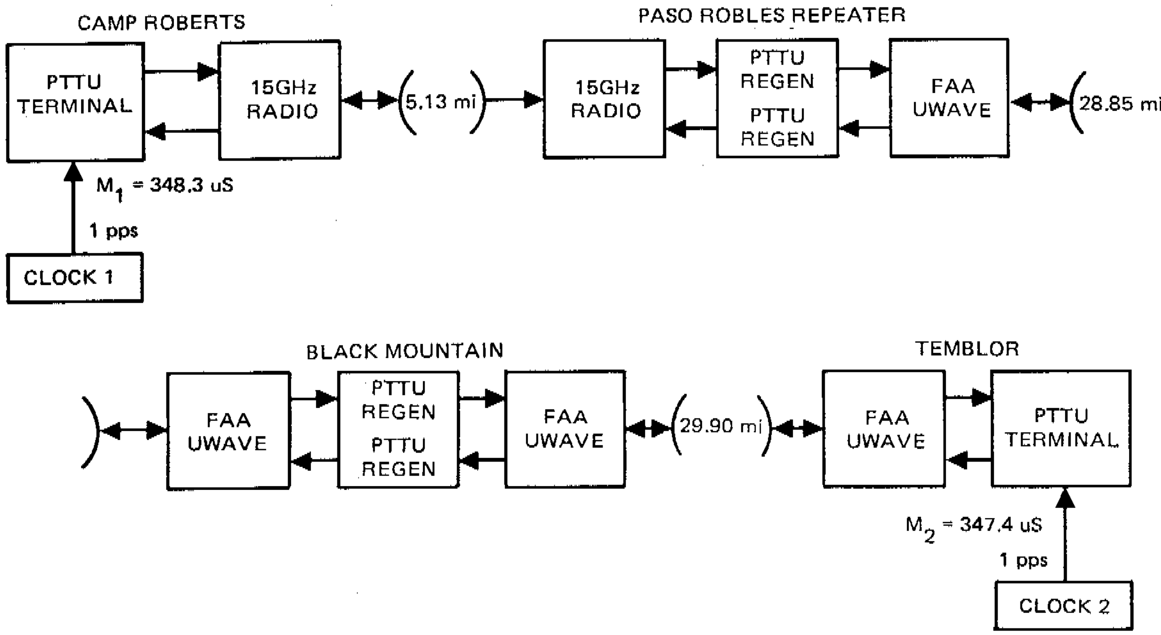
PTTUs in the REGENERATOR configuration were installed at the Paso Robles RML/R, and at the Black Mountain LRR. TERMINALS were installed at Camp Roberts and at the Temblor RML/R.

IV. TEST RESULTS

The following is a summary of the results of the Phase I test:

1. Feasibility of transferring PTTI over the FAA system using this spread spectrum technique was demonstrated. Fractional microsecond timing was successfully transferred between Camp Roberts and the Temblor RML/R, some 65 miles distant.
2. The spread spectrum PTTI signal was demonstrated to be compatible with the FAA system. No interference with normal FAA operations was noted by FAA test participants, or by FAA control centers in Los Angeles and Oakland.
3. Desirability of continuing on to the Phase II test was clearly established.

Figure 6 presents the test results in greater detail.



TIME TRANSFER:

M_1 (measurement at Camp Roberts) . . . . 348.3 uS

M_2 (measurement at Temblor) . . . . 347.4 uS

$C_2 - C_1$ (time transfer clock difference calculation) =

$$\frac{M_1 - M_2}{2} = \frac{348.3 - 347.4}{2} = \text{ . . . . 0.45 uS}$$

(NOTE: Expected accuracy for this system ±0.2 uS)

$C_2 - C_1$ (clock difference measured between the two clocks before transporting CLOCK 2 to Temblor) . . . . 0.42 uS

RECIPROCITY:

TIME DELAY ROBERTS TO TEMBLOR 347.4 + 0.4 (clock error) . . . . 347.8 uS

TIME DELAY TEMBLOR TO ROBERTS 348.3 - 0.4 (clock error) . . . . 347.9 uS

Figure 6. Tests between Camp Roberts and Temblor, time transfer

[redacted]