NEW HOROLOGE FOR AIR FORCE METROLOGY LABORATORIES

by

Arnold Alpert and James F. Barnaba
Aerospace Guidance & Metrology Center
Newark Air Force Station, Newark OH 43055

INTRODUCTION

Because of increasing requirements for precise time and time interval to establish the times of occurrence of significant events, such as time-tagging data, geodetic mapping and passage of satellites over earth locations, the United States Air Force has rapidly moved to improve its capabilities for providing world-wide precise time synchronization. In order to accomplish this the Air Force designated the Air Force Metrology Standards Laboratory (AFMSL) at Newark, Ohio, as the single Air Force focal point for dissemination of precise time and frequency. An operational program was established with the United States Naval Observatory (USNO) for periodic certification of the Air Force time reference standard. This certification is provided periodically by USNO personnel who handcarry a portable Cesium clock from the Naval Observatory in Washington DC to Newark Air Force Station, Newark, Ohio. At each calibration, Universal Time Coordinated (UTC) is transferred with an accuracy of 0.1 microsecond traceable to the Department of Defense Master Clock at the USNO. The frequency between the UNSO portable clock and the AFMSL standard clock is compared to parts in 10^{13}.

Current calibration support for many precise time requirements is being provided by two-man precise time synchronization teams (PTSTs). The PTSTs handcarry portable configured Cesium beam precision clocks to Air Force activities on a periodic basis. Precise time synchronization of Air Force timing systems requiring support is performed by the AFMSL and selected precision measurement equipment laboratory (PMEL) personnel. These selected PMELs now include Elmendorf AFB, Thule AFB and Vandenberg AFB. These sites have been designated as Precise Time Reference Stations and support Air Force timing requirements in their geographical locations.

REQUIREMENTS

Within the last several years, a significant increase in precise time requirements has been identified. As an example, AGMC has provided precise time

support, (synchronization, comparisons, or audit evaluations) for approximately 50 sites. Because of the distances involved in carrying precise time to remote sites and the delays encountered in dispatching teams expeditiously to reestablish time when failures occur, coupled with the growing need for new precise time systems support, it was deemed necessary to establish additional precise time measurement facilities within the Air Force PMEL complex.

The Precise Time and Frequency (PT&F) console designed and assembled at AGMC was proposed in early 1974 to support the 616A very low frequency communication system. This system is an update of the present emergency communication system and incorporates both airborne and ground type atomic clocks. The integral parts of the console were also chosen to update existing time and frequency capability in the Air Force precision measurement equipment laboratories (PMELs). The frequency calibration standard available at the PMELs prior to the inception of the PT&F console was a VLF Receiver Model 207-1 manufactured by Fluke Montronics Corporation. The receiver is a phase tracking device that compares VLF signals from 8.0 to 31.9 kHz plus 60 kHz to the local standard. The local standards used to maintain accurate frequencies were low drift quartz crystal oscillators such as the Hewlett-Packard Model 105 or electronic counters with time base stability of 5×10^{-10} per day or better. While these receivers were deployed to the field in the early 1960s the time standards were practically nonexistent in the PMELs. Occasionally a rubidium or Cesium clock would be found in the PMEL to support the early Apollo Mission or satellite tracking facilities; therefore, the PT&F console (PTFC) will provide a new measurement capability to over 50 Air Force Laboratories.

EQUIPMENT DETERMINATION

Once the determination was made to develop a time and frequency capability at various PMELs to provide support to activities in certain geographical areas, equipment selection was the next task. In the interest of economy, redundancy, reliability and flexibility, two Austron 1210D portable crystal clocks were selected instead of one Cesium clock. In this way several benefits were realized:

a. Initial cost was reduced.

b. In case of clock failure, another one is available.

c. A precise time or frequency synchronization trip can be accomplished by removing one clock and the PT&F console maintains time and frequency with the second clock.

An Austron Model 2000C Loran C receiver and a Beta Technology Model 209 Line-10 TV timing receiver were selected to keep the two portable clocks calibrated in time and frequency. In order to use either of these items a HF timing receiver was necessary for coarse alignment and pulse determination. A Hewlett-Packard Model 5328A time interval counter with 0.1 microsecond resolution and a Tracor Model 888A phase recorder capable of comparing up to 5 MHz signals were added to compare time ticks and frequency phase differences. Also required was a chart recorder for the LORAN-C timing receiver. An oscilloscope is used with the LORAN-C and the HF receiver but was assumed to be available in the PMEL. A distribution amplifier was added to buffer some of the clock outputs and to provide more standard frequency outputs for various uses in the PMEL or at the base.

Finally, for convenience and ease of operation, a patch-panel was designed so that all significant outputs from the equipment in the console would be available in one area on the front of the console. A switch was also included so that several time interval measurements can be made easily without connecting cables each time. The following time interval measurements can be accomplished at various positions of this switch, Clock No 1 one PPS Vs:

a. External clock 1 PPS

b. Clock No 2 one PPS

c. TV Line-10

d. LORAN-C

PROCUREMENT, ACCEPTANCE, ASSEMBLY, AND CHECKOUT

After the precise time and frequency console configuration had been determined, the next phase was to acquire and assemble the required items. Specifications were written for those items not on the GSA schedule, and all items were placed on procurement including a rack cabinet, equipment support brackets, power outlet strips and interconnecting coaxial cables. Contracts were accomplished and delivery dates were established. When the equipment began arriving, it was acceptance tested and then assembled into the appropriate rack cabinet configuration.

Each PTFC was then functionally tested for proper operation as a system. The console was put on time and the frequency adjusted using the items in the console with the various timekeeping methods and appropriate frequency adjustment

techniques. The results were then verified using the Air Force Measurement and Standards Laboratory (AFMSL) master time and frequency console.

TRAINING

Training of Air Force PMEL technicians who would operate the PT&F console was outlined in the Air Force Metrology Engineering Support Plan written in February 1975. These plans are required by the Air Force Metrology Directorate to provide guidance in establishing new capabilities at selected Air Force laboratories. The plan required a minimum of two technicians from each laboratory to attend the Lowry Training Center at Lowry AFB, Denver, Colorado. To initiate the plan, a two week course was taught at AGMC in April 1976. The attendees included two Lowry instructors, a technician from the Air Force Satellite Control Facility at Mahe Island and two procedure writers from Metrology Directorate at Newark. The Lowry Training Center has now established its first course and will begin class in November 1976. The Lowry Course will last for two weeks and will provide training for four technicians on two PT&F consoles. This course will be a permanent part of the advanced precision measurement equipment school. The class has also been proposed as a DOD Training Center for all DOD agencies who are involved in precise time efforts.

IMPLEMENTATION

As each PTFC is completed and checked out, a decision is made (or has been made) as to its deployment. The console is prepared for shipment and sent to the selected lab. Upon receipt of the time console, the lab installs the PTFC in the desired location, applies power, connects appropriate antennae, and operationally checks all items in the console. After all checks have been completed and all the equipment appears to be operating correctly, and the crystal clock oscillators have stabilized, the console is then set on time with WWV or some other HF standard time station using the calculated propagation delay numbers. The PTFC should now be within a millisecond or so of the correct precise time. Next, the console is set using the LORAN-C receiver and the associated propagation delay number. Synchronization by TV Line-10 data can also be accomplished if appropriate signals are available.

Daily HF timing, LORAN-C and TV Line-10 data will be sent to AGMC for evaluation. When confidence is established that proper timekeeping techniques are being used, a clock trip from the PMEL to AGMC will be accomplished using one of the crystal clocks from the PTFC.

Upon arrival at AGMC, the PMEL technician and the AGMC lab technician will compare the precise time of the PTFC with that of the Air Force measurement and standards lab precise time console. If the time difference is less than ±40 microseconds the PT&F console initial time synchronization is considered satisfactory, the crystal clock is set on time, and the PMEL technician returns to his PTFC to refine his reference delay numbers. If the time difference is greater than ±40 microseconds, a decision is made whether or not to initiate a precise time synchronization trip (PTST) from AGMC to the particular PMEL to resolve the discrepancy and assist in the PTFC implementation.

After the comparison between the new PT&F console and the AFMSL has been accomplished, data shall be submitted to AGMC from the PMEL on a periodic basis to assure proper timekeeping methods are being adhered to.

In the future, it is planned to implement an audit program and check each PTFC on a random basis to make sure that the PTFCs at the selected PMELs are within specification with regard to precise timekeeping.

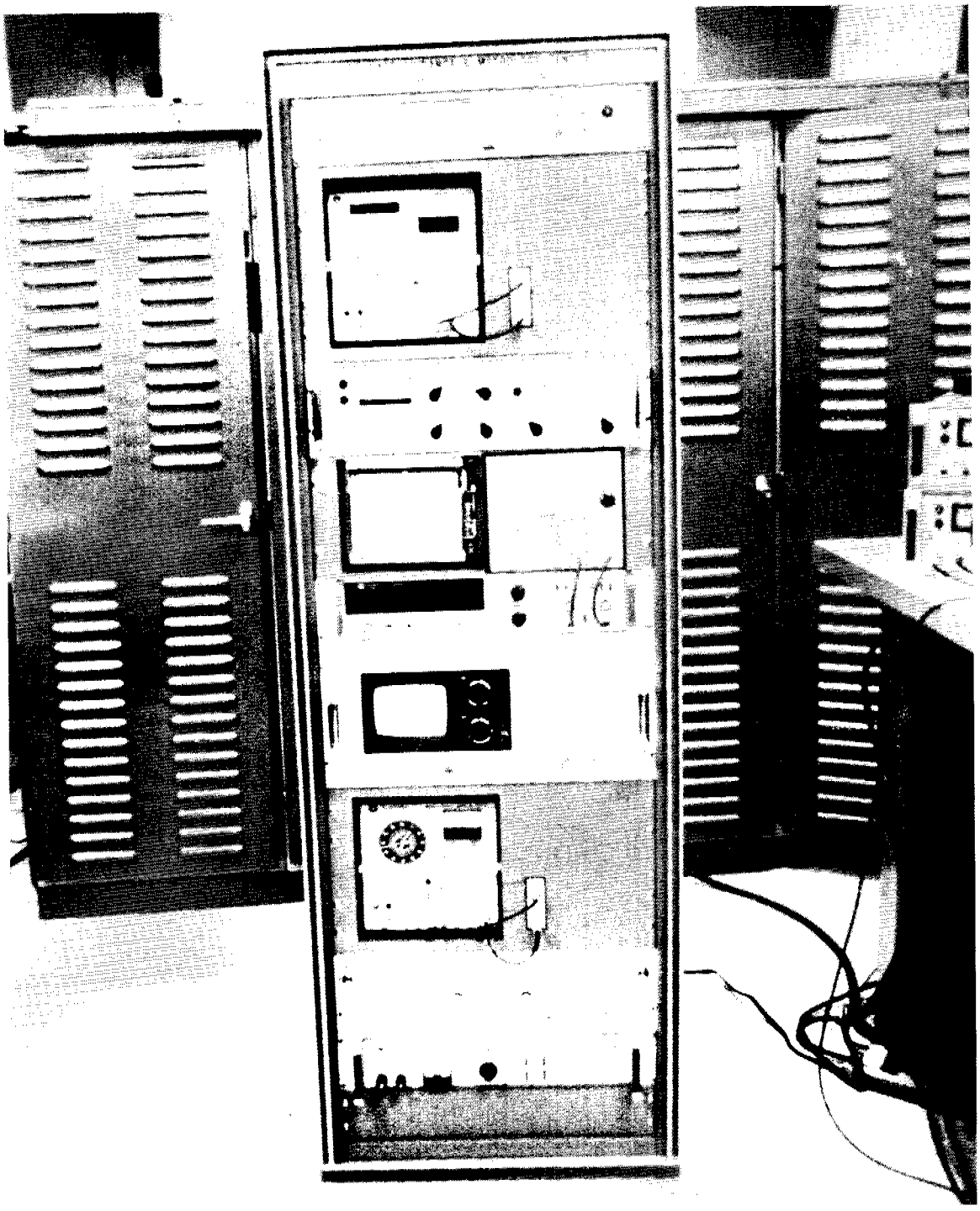

Figure 1. Aerospace Guidance and Metrology Center
Precise Time and Frequency Console

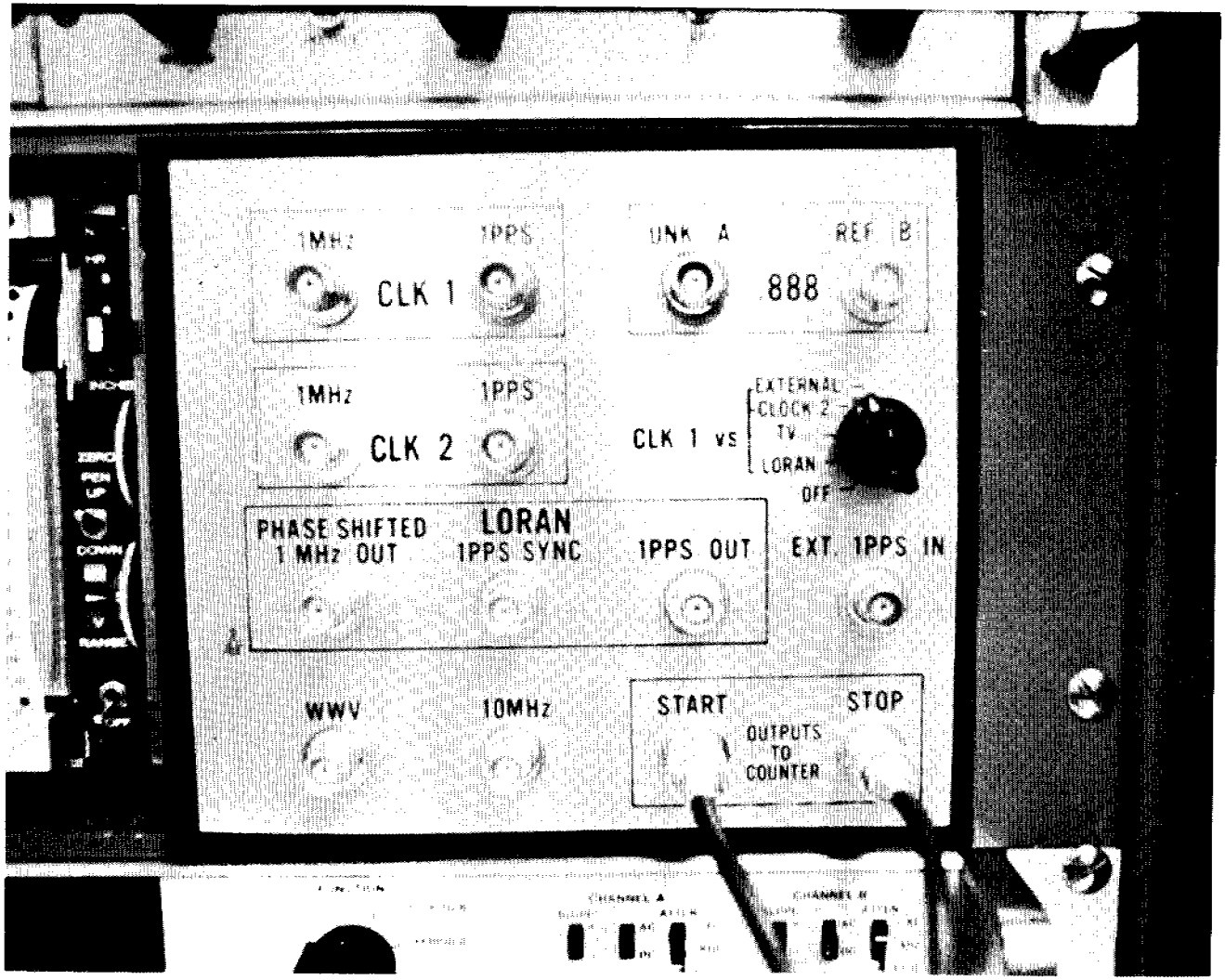

Figure 2. Precise Time and Frequency Signal Distribution Panel

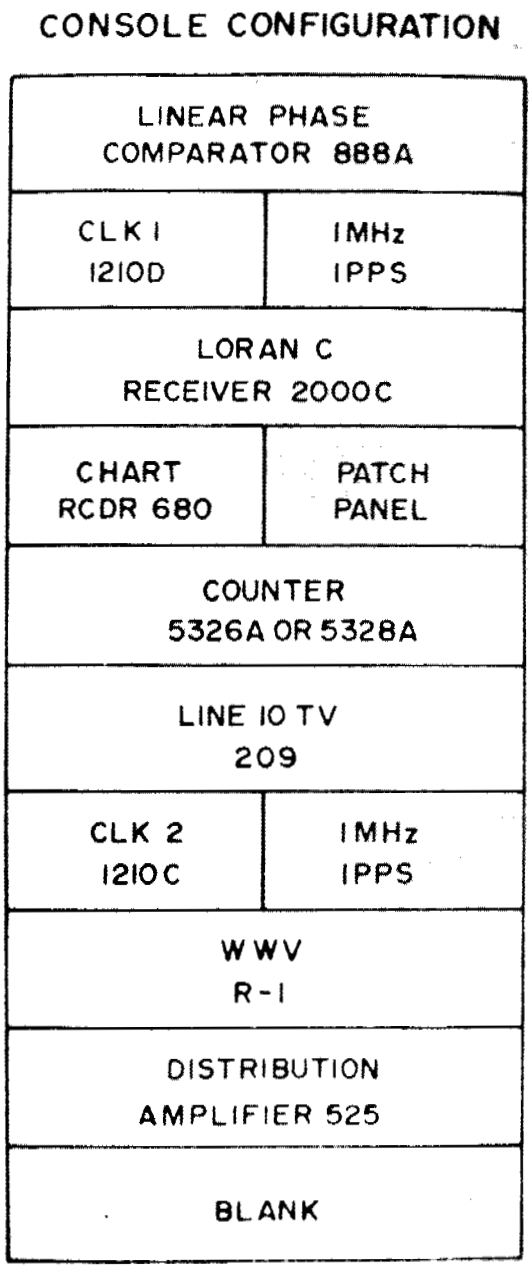

Figure 3. Console Configuration