USE OF PRECISION TIME AND TIME INTERVAL (PTTI)

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INTRODUCTION

An introduction, or rather a reintroduction for many, to the practical utilization of time synchronization and time interval measurements on the various DoD test ranges is the topic for today. The presentation will review the overall capabilities of various missile ranges to determine precise time-of-day by synchronizing to available references and applying this time point to instrumentation for time interval measurements. Global and downrange test sites will not be addressed.

A backward look over the past 20 years indicates that the origin and evolution of the ranges has been directly proportional to the DoD development efforts in the aircraft, missile, and defense systems fields. Tremendous advances in range technology paralleled industrial efforts to improve weapons systems. Range timing applications have historically fitted into the scheme of testing weapons systems even in the earliest days of testing. Interestingly enough, the essential importance of instrumentation time interval measurements has not changed over the years. Only the methods used in the determination of precise time and the formulation of interval measurement codes have changed.

An important aspect of range operations must be remembered; PTTI on a test range is actually separated into two distinct disciplines, time synchronization to a known source and the development of synchronized codes for interval measurements. These integral tasks are accomplished routinely every day, but range people normally interpret TIME as being related to time interval measurement, i.e., time code application, rather than time synchronization.

SYNCHRONIZATION

A review of range time synchronization methods over the past years suggests a chronological outline for the technical development of the ranges. As a beginning, visualize that in the 1950s installations similar to Eglin Air Force Base were used to test relatively simple weapons. Instrumentation film cameras were common and tape recorders were coming into good use. In the latter 1950s the Armament Development & Test Center (ADTC), along with other potential missile test centers, began preparations for the missile era. Sophisticated range instrumentation was installed which required accurate time correlation of events such as tracking radar time space position information (TSPI). Computer analysis of data demanded time correlation between sites to machine process the data. During this period, the IRIG Standard Time Codes were published and the Naval Observatory began PTTI with Loran transmissions. ADTC was one of the ranges fortunate enough to be within easy range of the East Coast chain. Our synchronization problems were eliminated. Other ranges, particularly in the West, were not so fortunate. In fact, until 1973, the Western ranges did not have Loran transmissions for PTTI purposes. In the summer of 1973, the Loran-D site at Nellis AFB, NV, came into being. Until that time, the Hawaiian Loran chain, WWV, or portable atomic clocks had to be used. This Loran-D installation made available accurate Loran synch to all the Western ranges and for the first time, low-cost, accurate time-of-day synch to the Naval Observatory was available to all the continental ranges and sophisticated time correlation was easily available. Of course, even today all ranges are not synched to Loran as there is no need for all ranges to be so accurately synchronized. However, today's ranges are converting to Loran synchronization techniques because of the inherent accuracy and cost effectiveness, a giant step forward. A few years ago, 10 microsecond synchronization was a debatable subject for everyday range operation, today it is expected.

APPLICATIONS

The DoD test range mission support requirements and capabilities are intricate and ever changing. Instrumentation equipment and test schemes vary widely from coast to coast according to the requirements and type of testing conducted for each service, i.e., Army, Navy, Air Force. Considering the three services, it is easy to imagine that ground, air, and water testing will require different physical as well as instrumentation environments. Each service has specialty, such as Ft. Huachuca for the Army, AFWR for the Navy, and AFFTC for the Air Force. With such diversity, it is difficult to realize any commonality between installations, yet there is one data system mutual to all DoD test ranges. This is PTTI.

PTTI has two general classes of range applications, These two types of applications can be described as the WWV millisecond synch type and the WWV-Loran microsecond synch type. Within these two techniques, the former application can be applied more readily to ranges smaller in physical size and generally operate within the range boundaries. The second type application refers to larger installations which must operate timing equipment closely synchronized over large distances which prohibit synch distribution by practical methods. Also, this includes the larger national and space ranges which must operate together in real-time for tracking and data work. These large ranges have the more stringent synchronization accuracy requirements.

Typical examples of the above WWV synch type ranges which operate within their own boundaries are: NWL, Dahlgren, VA., Tonopah Test Range, NV., Dugway Proving Ground, UT., Ft. Huachuca, AZ, and Holloman AFB, NM. These ranges operate within smaller restricted physical sizes which allows time distribution from a central point. Synchronization is maintained at the central facility to the required accuracy and distribution of the time signals is by transmission over VHF or data line to the local users. The accuracy of time correlation between the closely positioned points is limited by the time delay of the distribution system and is usually in the order of milliseconds. This is not to say that some of the smaller ranges do not have precision PTTI requirements for data correlation. In fact, some of the most difficult and precise time interval measurements are required in the unusual environments of ballistics tunnels or other weapons ballistics tests.

The second type of PTTI application involves WWV-Loran type synch and ranges which use this type synch are: NATC, Patuxent River, MD., ADTC, EAFB, FL., WSME, NM., COR Ranges, NWC., and Yuma Proving Ground, AZ. These ranges employ two different concepts of approaching PTTI: (1) a central timing facility with associated distribution system and/or (2) independently synchronized installations.

A range which can be used as a prime example of the central timing facility concept is WSMR. WSMR has a central timing facility equipped with Loran synch receivers and three primary atomic standards for stable time base sources. After development of the proper timing signals, distribution is made from the timing central to a VHF transmission system and various combinations of microwave and data line drivers for utilization on theodolite stations, high-speed cameras, etc. One of the more important and interesting aspects of this distribution system is the resynchronization technique used for stabilizing distant radar or satellite installations with the timing central in lieu of individual site synchronization with Loran. This type system was developed in the Western part of the continent in the late 1950s and early 1960s for the simple reason that Loran was not available and WSMR had requirements for accurate intrarange synch at remote installations. The results were the problem was technically solved by measuring round trip transmission delays and correcting for these delays in the receiving unit. Until the Dana, Oh, Loran station came into existence, this was the only feasible method WSMR or any other Western range had of achieving PTTI. As an example, when WSMR had a requirement to operate a tracking site at Green River, UT, in 1965, the only method available to achieve the required accuracy at this site 600 miles from the timing central was to use portable atomic clocks. Of course, the Nellis Loran-D installation has made all these type PTTI problems history.

A second approach to achieving accurate PTTI is separately to synchronize each site or installation to a Loran transmission. This method is used at such installations as: ADTC, AFETR, SAMTEC, AFWR, and PMR for interrange and intrarange PTTI solutions. This method requires that each site to be used have a Loran synch system capable of independent determination of PTTI, and can either be composed of the newer automatic tracking receivers or a manual system be used. An advantage of the independent method is that each site can independently maintain a synchronization to the Naval Observatory and eliminate the problems associated with transmission systems reliability. Cost is not appreciably increased for these sites and if the cost of the transmission system were considered, the independent synch method would be the most cost effective method. Very good PTTI is available with this concept of range synchronization.

As previously stated, global and down-range sites will not be discussed. When the site is not within range of a Loran transmission, then some of the advanced techniques explained in the earlier papers must be employed.

Any discussion of DoD range PTTI would not be complete without a few words on the airborne data correlation situation. Correlation of airborne collected data with ground instrumentation had historically been a problem. In today's world of electro-optical weapons, airborne data correlation has become even more important. Ranges involved in this type testing have two alternatives for time tagging airborne data: (1) transmission of a time code or, (2) an onboard PTTI device. The former case of the transmitted time code is often inadequate as the data correlation is on the order of milliseconds. The latter case of an onboard clock poses the problem of synchronizing the clock accurately enough to satisfy the requirements over the time profile of the mission. Certainly, the clock frequency standard must be stable enough to maintain adequate synch after the initial setup. An interesting and obvious situation develops during preflight clock synch if the aircraft is not on aircraft internal power. During power switch, errors can be injected in the clock so caution must be exercised.

Within the past 12 months, ADTC has been required to support electro-optical type tests with very demanding time correlation. For instance, one particular laser decoy test required time correlation and resolution within 1 microsecond between airborne and ground instrumentation. As of this time, ADTC has not actually achieved a data correlation this accurate for this test.

CONCLUSION

This paper has attempted to present the status of the majority of DoD test ranges in regard to PTTI. The status of PTTI for these ranges is that time-of-day synchronization to the U. S. Naval Observatory via Loran methods has eliminated synch accuracy problems within the continental boundaries of the U. S. Time interval measurements are likewise being satisfied by a diversity of methods. This is not to imply that all PTTI problems are solved, as they are not. Fortunately, this country has the technical resources from organizations such as the Naval Observatory, Bureau of Standards, and AGMC to help solve existing and future PTTI problems. One thing is always certain in PTTI applications, accuracy requirements always seem to increase.

QUESTION AND ANSWER PERIOD

DR. REDER:

What is the particular transmission reliability problem in the South? Why is the South different from the West, from the East, from the North?

MR. TAYLOR:

One is lightning. For some reason, the communication lines in the South, if they are buried or above ground don't seem to last very long, especially on the Florida coast. We can't rely on landline transmission. If we have bad storms in a particular mission off another part of the range, microwave gets interfered with quite a bit, too.

DR. REDER:

Well, you also mentioned problems with air borne synchronization—synchronization of equipment on fighter planes. Has this been formulated properly, and has it been brought to the attention of all the research labs? You know, the research labs are dying to get something to do which is relevant.

MR. TAYLOR:

Generally when you get into a problem like this, it runs into something like we have a problem, and it shows up, how do you solve it, do you have money to solve it? You have got to consider we need something that operates in the outboard powerline of an F-4 and have a part 10^9 stability. And how do we run this clock and synchronize it?

It has just now become evident that we are going to have to develop something of this nature to solve these problems. Maybe the Navy or somebody will feedback into the labs so we can come up with a product.

DR. REDER:

Do they really know what the problem is? Has it been spelled out?

MR. TAYLOR:

It is becoming very evident right now because of the type missile, the EO devices, we are using now. They are becoming very sticky about testing those devices.

DR. REDER:

I hope you do spell it out soon and feed it to the research labs.

LCdr. KIES:

LCdr. Kies, East Coast Loran-C Chain.

One question. I understand the D chain is going back to Europe the first of the year. And I wonder what plans were out West.

MR. TAYLOR:

I think the status is — I am almost certain — that the master station at Nellis will be permanent, won't leave.

Does anybody from the Observatory know that now?

MR. LAVANCEAU:

Jean Lavanceau from the U.S. Naval Observatory.

The crew of the station of the Loran-D network are being deployed now to Germany. However, the master station located in Nellis Air Force Base will remain and operate the timing equipment for the Western part of the United States.

As far as I know, time transmission will still be available with the same high frequency, same precision, as you now have available from Nellis Air Force Base.