# PRECISE TIME/FREQUENCY FOR THE DEFENSE COMMUNICATIONS SYSTEM

by

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The role of Precise Time and Time Interval (PTTI) in the Defense Communications System (DCS) is becoming significant as a result of increasing digital transmission rates and advancing communication technology. Dynamic advances in PTTI technology are providing high degrees of precision with reliability. Therefore, it is now economically feasible to address the distribution and application of PTTI on a worldwide system basis.

During November 1970, DCEO and NSA conducted a field test to determine the effects of system timing accuracy variations on the performance of time division multiplexed (TDM) digital transmission trunks. The results showed that existing DCS timing facilities were not precisely on the same frequency and that these discrepancies had an adverse effect on the performance of the TDM circuits.

Action was then initiated to provide effective system timing to support the implementation of a TDM network. Further, it was recognized that all DCS station timing facilities should be analyzed to determine their present and potential ability to satisfy the present and future DCS requirements for precise timing and frequency.

During this analysis, it was found that many independent efforts were being pursued in the transfer and application of PTTI, but no unified systems approach was being taken by anyone. Therefore, the Defense Communications Agency, in coordination with the Naval Observatory, established the Defense Communications Committee for Precise Time and Time Interval Policy (known as the Music Man Committee). The objective of this group is to develop a DCS PTTI subsystem concept that will not only satisfy current and future DCS PTTI requirements but will also provide the capability for serving other users within the DOD.

The primary motivation for providing precise timing facilities in a communications network is the need for the maintenance of frequency coherence between the transmission nodal points. Every nodal timing facility must be on the same frequency and must have the required degree of long-term stability. In addition, a major nodal point must not be dependent on any other nodal point for its timing reference. This arrangement allows the network to continue operation through diversified routes if a nodal facility fails. In addition, the retiming of digital signals at each node serves as a means of blocking low frequency oscillations and preventing other perturbations from propagating through each link of a tandem connection in a network.

The timing facilities that are currently employed in the DCS are adequate in their present applications since they are point-to-point transmissions using relatively low data rates. However, their specified performance is not easily maintained, and they have a limited capability to satisfy the more precise requirements in a worldwide network environment.

Figure 1 shows a widely used scheme in the DCS. It consists of triplicated crystal oscillators with stabilities ranging from $1 \times 10^{-9}$ to $1 \times 10^{-10}$ per day. These are calibrated against a standard VLF signal and can be manually adjusted to an accuracy of $1 \times 10^{-10}$. Experience in the field, however, has shown that this scheme is particularly vulnerable to

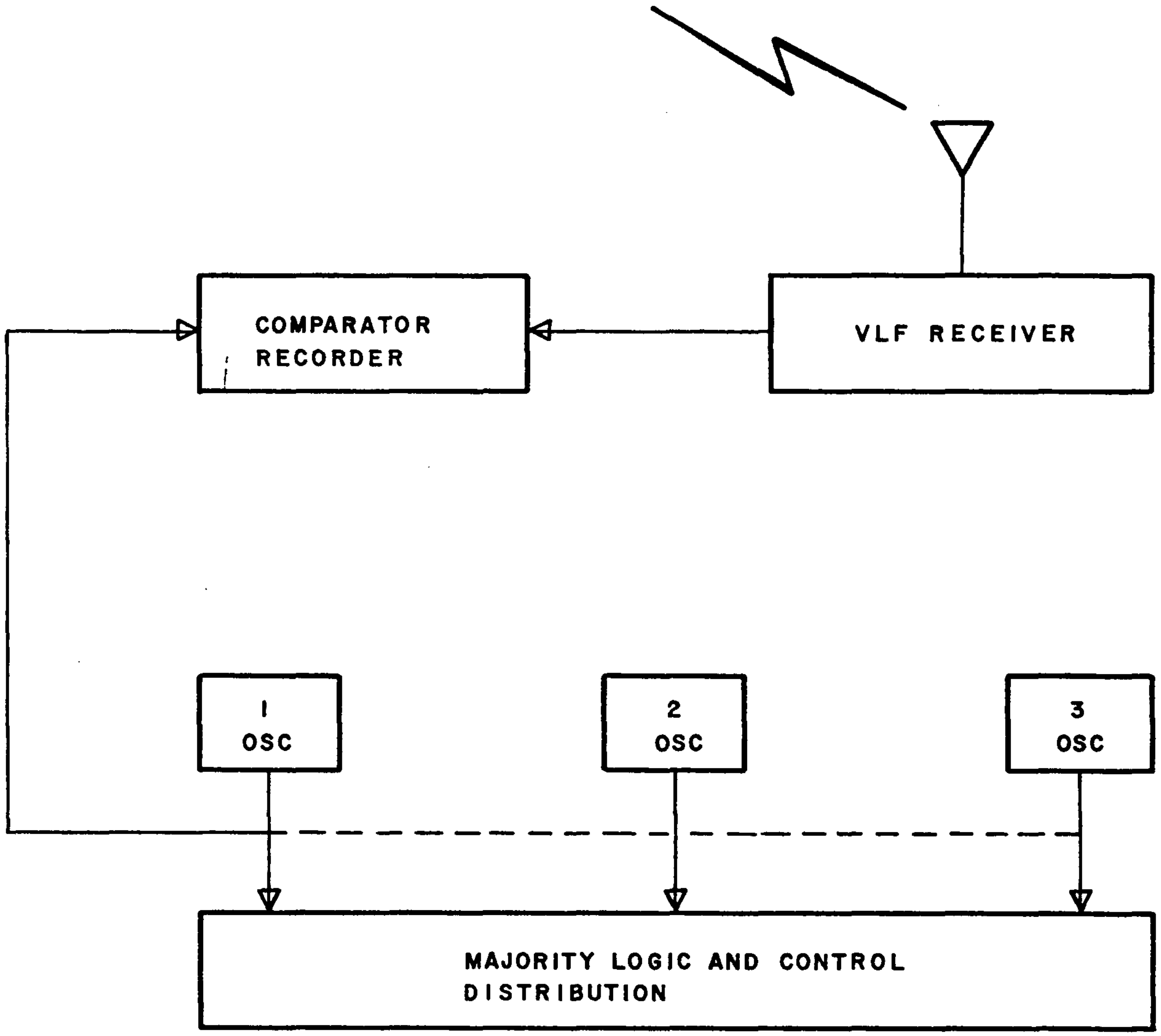


Figure 1. EXISTING MANUAL SCHEME

human error made in determining the corrections required and in making the oscillator adjustments. A high level of maintenance discipline is required to achieve optimum performance.

Another timing system in the DCS shown in Figure 2 uses phase locked oscillators which track either against timing recovered from a received data signal or against a reference derived from a rubidium frequency source. The data-recovered timing is subject to severe perturbation through the transmission media, which limits its performance. When a rubidium frequency source is used, periodic manual calibration against a precise standard is required to ensure continuing accuracy.

An approach that will overcome the limitations experienced with the existing timing facilities should provide for an automatic correction of station oscillators by use of a precise reference that is traceable to the master reference at the Naval Observatory. Advances in state-of-the-art time transfer techniques and electronic servo control of crystal oscillators now make it possible to maintain frequency coherence throughout a worldwide communication network to within $1 \times 10^{-12}$ per day.

Figure 3 illustrates the concept of a typical precise timing facility at a major nodal point consisting of:

- A continuous precise reference source derived from the Naval Observatory master reference.
- An alternate precise reference source for applications where high accuracy reliability is required.
- Duplicated disciplined oscillators with state-of-the-art crystals and electronic servo control.
- A majority logic control, alarm, and distribution unit to serve as the nerve center. When the primary reference signal is lost, the alternate reference will be automatically switched into the system. Faulty units will be detected through the majority logic and alarm circuits.

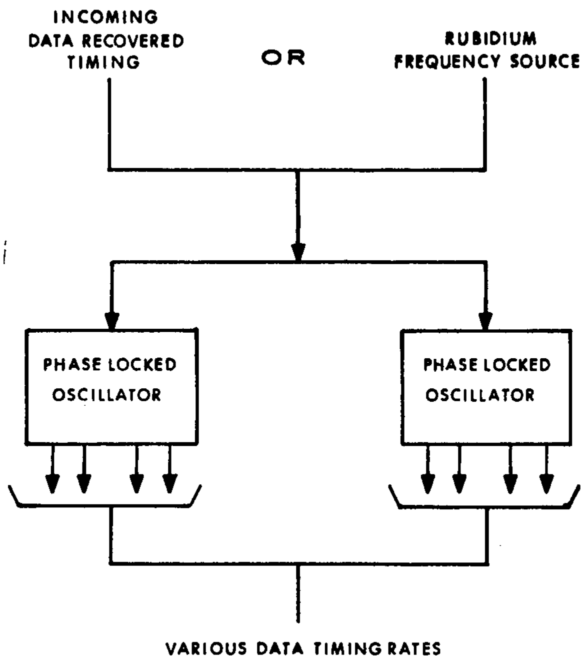


Figure 2. EXISTING TIME RECOVERY PHASE LOCKED SCHEME

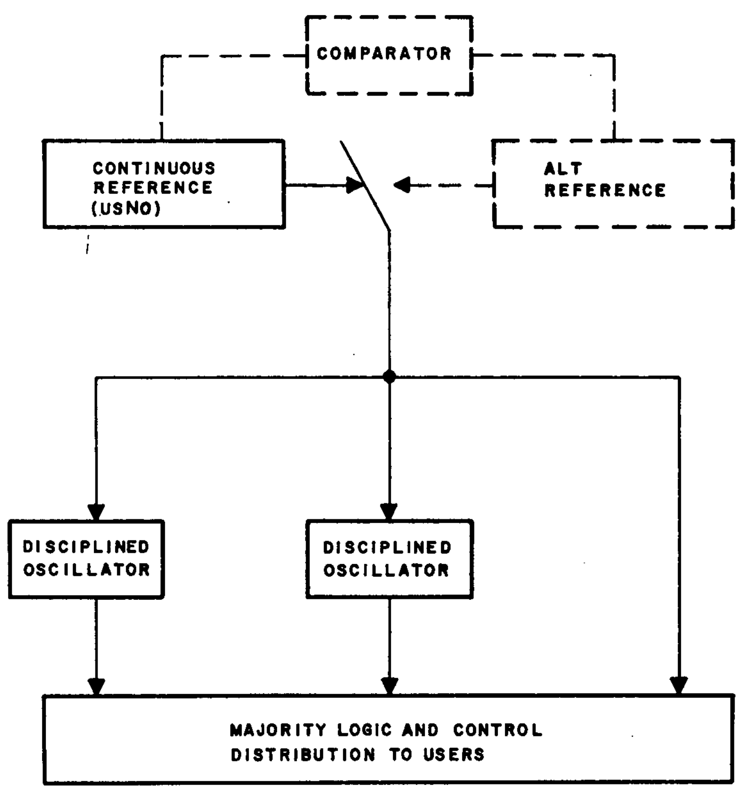


Figure 3. TYPICAL NODAL TIMING FACILITY

This system is triplicated to ensure a continuous uninterrupted precise source and identification of any frequency change that may occur in one of the sources. Standard outputs of 1 MHz are then distributed for user application. By further employing a time tic or code with the frequency reference, the facility will be able to provide precise time as well as time interval.

To satisfy immediate requirements, the AN/GSQ-174 Loran-C/disciplined oscillator scheme is currently being implemented for a number of nodal points in the DCS. This system provides a precise facility in consonance with the concept presented.

The application of the AN/GSQ-174 scheme provides an initial step in the establishment of a worldwide DCS PTTI subsystem. A system hierarchy as shown in Figure 4 must be developed from the Naval Observatory master reference, down through precise primary and secondary nodal point facilities, then distributed through various levels of precision as necessary to meet user requirements. Diversification of primary reference routes to the Naval Observatory will be essential to ensure survivability. At primary PTTI nodes, the reference should be obtained from combinations of two sources such as the Defense Satellite Communications System (DSCS), Loran-C, on-site cesium standard and other reliable methods as they are developed. Further distribution can be accomplished with NRL's Mini Modem over microwave links, UHF, balanced digital transmission devices (BDTD) on metallic cable pairs, optical fiber cables and local portable standards. End user facilities can then employ electronic servo controlled crystal oscillators updating against a continuously or periodically received reference.

The Music Man Committee is presently identifying user requirements in both the DCS and DOD that may be served by a DCS PTTI subsystem. The various identifiable PTTI techniques and applications may then be combined with the requirements in order to develop the concept and policy

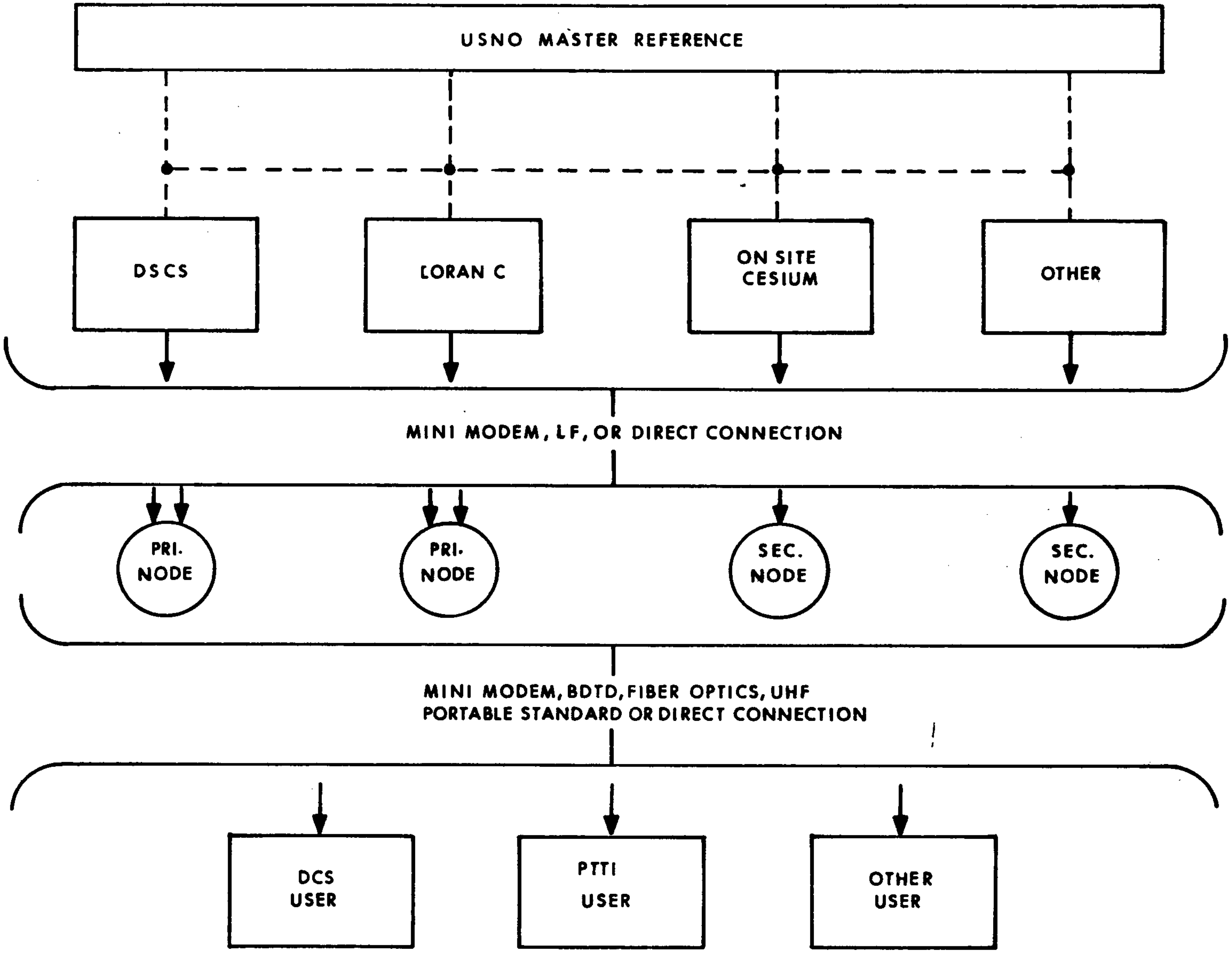


Figure 4. BASIC SUBSYSTEM HIERARCHY CONCEPT

guidelines for a DCS PTTI worldwide subsystem. The order accruing from a unified systems approach will lead to effective satisfaction of advancing communication requirements and will allow the extension of service to many other DOD PTTI users.

As this effort progresses, many additional benefits are expected to be realized from the evolution of a dynamic PTTI subsystem. The reliable and economical availability of PTTI to the user in the field should now stimulate new considerations throughout the spectrum of time and frequency applications to determine the potential benefits of reduced costs, simplified designs, and improved operational performance.

# DISCUSSION

DR. REDER: I'm a little bit concerned about an implication in your paper: That if you go cesium in these stations as a replacement of VLF, for instance, this will solve all your problems. I don't think that it will.

MR. FOLTS: No sir, definitely not.

DR. REDER: Okay, because there are also possibilities that you have had a failure in the cesium standard without knowing it, if you mistakenly consider a straight line on the recorder of VLF as the natural thing. There is no substitute, I think, for proper education and proper training if you want this kind of a position.

MR. FOLTS: Yes sir, I think you are absolutely right, and we are quite well aware of this. If a cesium was used as an alternate source, it would be under continual monitoring status, and this would be done in the case where we couldn't get any other alternate source for the precise facility. There are a tremendous number of problems in the field with cesium standards. I know that in our Ground Satellite stations, we have had many problems where the troops have opened them up to show a new toy to everybody that visits and, of course, then they do not perform very well. A great deal of effort will have to be put into education in use of these facilities. This is one area that we found is very weak and will have to pursue very strongly.

MR. GATTERER: Continuing along the line of that same question, I think that you said, I believe the attitude manifested at the military communications sites is that people are not only encouraged to keep their hands off but are deliberately not trained in the fundamentals of standards. I wonder if that approach itself has created some problems. I am thinking of one case where people who were trying hard to educate themselves were greatly discouraged because of the policy that they should not be taught anything about the standard because if they were, they might touch it. This leads to the circumstances that were mentioned where a VLF receiver may be running for months not locked up without it being known. Would you comment on that please?

MR. FOLTS: I suppose it is a case of one extreme or the other, but I don't think there is any substitute for good education. Lots of times with any new thing that comes out, people that do not understand it want to ignore it and become afraid of it; this happens all too often. It's the overkill --if it's delicate, don't touch it, forget it and leave it alone. Now, we will really have to look at it in terms of turning out proper education overall in the PTTI area. This is the whole lack of understanding in PTTI which prevails not just in the maintenance and the field, but the whole area. This has been one of our biggest difficulties in getting this effort going and developing our committee. I think in the actual output, PTTI education is going to be an area that will be addressed and put into effect before we can effectively implement PTTI techniques in the field.

DR. WINKLER: I would like to comment on Mr. Gatterer's comment. I think he refers to a situation where at certain ground terminals, we are between two phases: one is the completed feasibility study or feasibility experiment to transfer time and the second is a complete operational condition with all training materials available, manuals distributed, a support service established for the cesium standards, and so on. I think we will hear more about that in Capt. Enright's talk. But at this moment, there are procurement actions under way, the manuals which have been printed are on the way to the stations, and there is no question, of course, that the personnel must be trained. I don't believe that there is anyone who would advise against training ground station personnel. I think the main point of Mr. Folts' papers is that as much as you can, you should go automatic and not rely on daily frequency adjustments to be done manually with some interpretation of the operator on what he has to see. I think that in the face of increasing operator problems and qualification problems, we should try to do as many things automatically as we can. However, this does not mean that the people will not have manuals or some training on what they are supposed to do. This has to be distinguished, and you should not base your judgment on one station which you have visited which has just been caught in between these two phases. Where one initial experiment was performed, equipment has been removed because there is no cesium standard in that station which I mentioned; it will, of course, have it again and then operations will begin. It's a different thing.

MR. GATTERER: I know to what you are referring, Dr. Winkler, but I'm not discussing that. I'm thinking of a particular Autodin communication terminal where there was a specific policy that the people were to stay as far away from the standards as they could other than the daily adjustment in the FSQ44. The reason I think it is important to respond is that it is my belief that there is a distinct policy that people shall stay away from the standards . I have not formed my own judgment as to whether or not that's good, but I do know it leads to the situations like the ones Mr. Folts mentioned.

MR. FOLTS: So this is the case of Autodin! I'm glad you identified that, because it clears up your question a little bit more. Autodin itself is not dependent upon highly accurate timing. As a matter of fact, in the tests we

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found that one Autodin center was off one part in $10^6$, and still running very well with their traffic. Autodin is not a network situation; it is a point-to-point operation. In the Autodin school they teach: "this is a VLF receiver, now that you know what it looks like, forget about it," and so on. That is an entirely different situation and environment than we are now developing through Music Man.

LCDR POTTS: I would like to make a small comment regarding maintenance of standards. I am sure that there are differing philosophies, especially whether one considers crystal standards, rubidium standards or cesium standards. Fortunately or unfortunately we fell into the category of owning a lot of cesium standards; we have 86 now, we will have more in the future. In the early days we were on the learning curve and the curve was rather bumpy; we had problems with cesiums, we had problems with people. But to make the story short, our maintenance philosophy is paying off in terms of the performance we are getting from the standards now. We have experimented with training people to do maintenance in the field; we have trained them rather well. It just has not worked out in the case of the cesium standards so our philosophy now is hands off and it's paying off.

DR. REDER: I think the philosophy should be hands off the standards, hands off the equipment but stay close to the recorders.