Report on NATO PTTI

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Abstract

This paper covers the work of the NATO Working Group on precise time and frequency (AC302/SG4/WG4) since its inception in 1988 to the end of 1993. The aim of the group was to produce STANAG 4430 detailing a standard interface for the transfer of precise time & frequency to assist the interoperability of NATO forces. The design of the interface is outlined together with the concepts leading to the design. The problem of providing and maintaining a traceable UTC in military user systems is described.

Background to Precise Time Standards in NATO

The NATO nations' forces already have, or are bringing into service, a range of systems that require precise time and frequency (PT&F) for their operation as well as for the real–time transfer of information between them. There is already a sizable precise time user community with an increasing number of users as further PT&F dependent systems are brought into service. Numerically the largest PT&F user community is expected to be AJ communications, PT&F user systems will include the following:

- identification
- data links
- V/UHF AJ communications
- satellite communications
- radar systems

The provision of precise time for user systems has been dealt with on a system specific basis. Until recently there was no overall military policy, the associated PT&F infrastructure to coordinate their operation and to support interoperability has yet to be deployed. Future operations may well involve NATO forces in increased cooperation, such operations will depend on the ability of forces to communicate rapidly and reliably.

AC302/SG4/WG4– The NATO Precise Time & Frequency Working Group

In 1988 the Precise Time & Frequency Special Working Group was established to produce STANAG 4430, with the objective of aiding NATO interoperability by defining a standard interface for the transfer of precise time & frequency between equipments. The aim of the STANAG was to define a common interoperability interface as well as stopping the proliferation of user specific 'standards'. The secondary objective was to provide an alternative interface for use on systems to overcome the problem of one PT&F user on a platform being unable to transfer time to another system due to interface and message incompatibilities. The nations providing the major contribution to the STANAG were France, Germany, Netherlands, Norway, UK and the USA.

Initially the WG reviewed the PT&F user base and identified fundamental issues such as time distribution architectures, time references and time dissemination methods currently in use. As a result of the group's work it became apparent that interoperability was more complex than the definition of a standard interface and included the standardisation of a time reference, the management of time, its dissemination and military operational issues. The working group have nearly completed the draft of STANAG 4430, it is anticipated that it will be circulated within the nations during 1994.

The Management of Precise Time

Within the scientific community precise time is generally considered to be time that is accurate to a millisecond or better. Some military systems require time to at least this accuracy but even those requiring accuracies of a second will benefit from the automatic acquistion and maintenance of time. The management of time to millisecond accuracy or better requires that the time reference be identified. Most nations maintain their own time references using atomic clocks; time from these references is known as UTC(laboratory) e.g UTC(USNO). (UTC is universal coordinated time and USNO is the US Naval Observatory.)

National clocks are synchronised by the BIPM in Paris, currently their objective is to maintain synchronism to a few microseconds; it should be noted that, in general, the coordination and management of UTC is a civilian activity. Figure 1 shows how national UTCs have been maintained with respect to BIPM. As UTC is the time reference used by national governments and civilian users it is appropriate that it should also be used by NATO. UTC is adjusted to retain synchronism with the earth's rotation (the latter is less consistent than the time given by an atomic clock and may vary by a millisecond in a day). UTC synchronisation with the earth's rotation is maintained by the addition or subtraction of a 'leap second' as appropriate. Leap seconds are only applied at the end of July or the end of December. The application of leap seconds is controlled by a civilian organisation the International Earth Rotation Society (IERS).

UTC user systems have to develop strategies to accommodate the leap second change, and to take account of time dissemination systems with different ways of including leap seconds.

In some broadcast time references, leap seconds are only included within some hours of its application, and not necessarily simultaneously for all transmitters. NavStar GPS broadcasts GPS time (which corresponds to UTC at the time the system was started), the time message includes the number of leap seconds required to correct GPS time to UTC. Leap second changes can lead to confusion for UTC users; this can be avoided if the leap second information is included in the time message so that the user system can automatically compensate at the correct time.

PT&F Architectures

Figure 2 shows a generic time distribution architecture, which includes time transfer interfaces at points A, B and C. (This was the architecture used by the group to collect data on user systems.) The time reference is disseminated to the user system at interface A. A local reference, disciplined to the disseminated UTC, can then pass the time to the systems on the user platform. A platform reference can also be disciplined to the reference UTC via the local reference or directly from the time dissemination system. In this context the platform may be a military base, a ship, an aircraft or other user such as a man–pack radio. If the platform is required to have an autonomous capability then it must have some form of platform oscillator capable of maintaining time consistent with the integrity required by the platform user systems. For an aircraft this may be a few hours for a ship it could be days or weeks.

Time Management – TFOM

Systems having a PT&F autonomous capability must also manage the time within the system. An allowance should be made for the gradual increase in uncertainty in the accuracy of the time following synchronisation from an external time dissemination system. Uncertainty arises from unquantified errors in the distribution of time around the system as well as drift in the 'flywheel' oscillator. Oscillator drift will be exacerbated by environmental effects such as temperature changes and vibration. The time message should include a time figure of merit (TFOM), this is the current uncertainty in the system time accuracy with respect to UTC. When the TFOM exceeds system limits the performance of user systems can be expected to deteriorate. Comparison of the platform's TFOM with that of an external dissemination source, or of another platform, identifies whether the platform clocks accuracy will be improved or degraded by accepting time from that source. The degree of time management required within a system depends on the system specification.

Definition of the Draft STANAG 4430 Interface

The definition of the interface covers the time message information message, two different formats for the transmission of the message, the electrical interface and the connector specification. The interface can pass the following information:

- 1 pulse per second signal

- Standard Time Message (STM)
- Extended Have Quick Message (XHQ)
- An optional 5MHz signal

The interface is bidirectional enabling the information to be transferred in the direction required for interoperability. To ensure maximum utility the interface can be implemented as a bidirectional interface, a transmitter or a receiver. The implementation chosen depends upon the requirements of the system to which it is connected and the purpose of the port. For example a simple user may only require a time fill in which case only the receive function need be implemented. An interoperability port on a timing centre may only be required to transmit time, in which case only this function need be implemented.

The contents of the time information message are based on the groups analysis of the requirements of the systems analyzed, consideration of future requirements and the need for backwards compatibility to existing standards (e.g. Have Quick 2 and NavStar GPS PTTI). The time message format is shown in figure 3. The message, up to the TFOM, is the same as the Have Quick message. Additional information is given in the last two fields the leap second indicator shows if a leap second has been applied, and the last field the day on which it is to be applied. The TFOM is coded in two parts the first gives the TFOM decade (compatitable with the PTTI message), the second part gives additional precision (i.e. the TFOM is in exponent and mantissa form).

The design of the message and of the electrical coding scheme takes account of currently used standards and maintains a degree of compatibility with the NavStar GPS PTTI (precise time & time interval) interface as well as Have Quick 2. The interface disseminates the time message in two electrical formats one compatible with Have Quick 2 (an extended Have Quick format) and the other using an industrial standard interface and chip sets (the standard time message format using the EIA RS–485 standard). These formats are capable of transferring time with different accuracies, operating with different interconnecting cable lengths and having different noise immunities. This arrangement was chosen to simplify the interface required between the STANAG 4430 interface and current user equipment as well as making it more readily applicable as an interface between equipments. The specified connector uses a standard MIL–C–83723 shell with standard pins and inserts. The one pulse per second time marker, is available for high precision timing, and the 5 MHz signal for precise frequency users and oscillator calibration. Implementation of the standard frequency signal is optional, as not all systems can use it and some will be unable to generate the signal to the required accuracy and stability.

Application of the STANAG 4430 Interface

The standard interface requires an electrical connection so that the transmitting and receiving systems must be capable of making a physical connection. The connection could be a cable from a timing centre to the user, a cable connecting two user platforms or an interface for a travelling clock or electronic transfer device (ETD). These methods of time transfer meet the NATO military forces interoperability requirement of the interface. Interoperability is enabled since the interface receiver and transmitter can be on different platforms, of the same or different nations, and a standard message is transferred. The interface can also be used to transfer the time message between user systems on a platform, assuming that it is cost effective to do so. This application enables platform user system interoperability but is not directly enabling NATO military forces interoperability.

Implications of the MOR on PT&F

A NATO Military Operational Requirement (MOR) for precise time & frequency has been developed and the implications of its implementation are currently under review. The key requirements contained within the MOR are given in below.

The MOR requires that the reference time in user systems is referenced to UTC this is partly met by the use of NavStar GPS, the time message also includes leap second correction and is available to all user equipments.

The MOR requires that UTC be available continuously, as well as at the start and during a mission. The provision and maintenance of UTC requires a calibrated path from the time reference (typically a laboratory atomic clock) through to the reference clock in the user equipment. The infrastructure providing this traceability is likely to require time reference centres, which could be located at selected military bases, and probably deployable units to support assets away from their home base. To maintain UTC, and meet the requirement for autonomous operation, implies the availability of a 'flywheel' oscillator on platforms; the latter to be disciplined to UTC by a time processor. Output to users could be via a STANAG 4430 interface and broadcast transmissions possibly using Have Quick or MIDS.

The co–ordination of UTC is the responsibility of international civilian authorities who may not be able to maintain this function if they are denied access to long distance time transfer systems during wartime. Consequently, the implementation of the MOR has implications for the continual maintenance of UTC, its international co–ordination and the implementation of leap seconds.

The STANAG 4430 interface meets part of the MOR in particular it has an application in the transfer of time to a user system or platform at the start of a mission. The standard interface enables the transfer of PT&F to users, of any NATO nation, by any other nation, if available at external system and platform interfaces.

Conclusions

The NATO working group on PT&F has made considerable progress in defining a standard interface, the details are given in draft STANAG 4430. The STANAG defines not only the electrical and mechanical interface but also a standard time message; the specification is based on an analysis of the PT&F requirements of current users as well as an assessment of future user needs. Consideration has been given to the backwards compatibility of user equipments requiring compatibility with Have Quick and NavStar GPS PTTI formats. The aim of the interface is to support the interoperability of NATO forces, the STANAG contains information to assist with the design of timing architectures and to allow the traceability of the user systems UTC to that of the reference UTC.

Figure 1

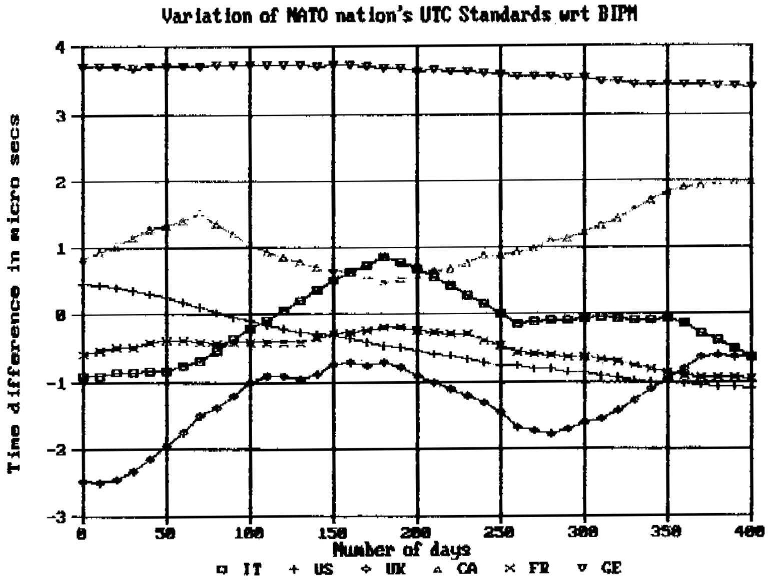


Figure 2

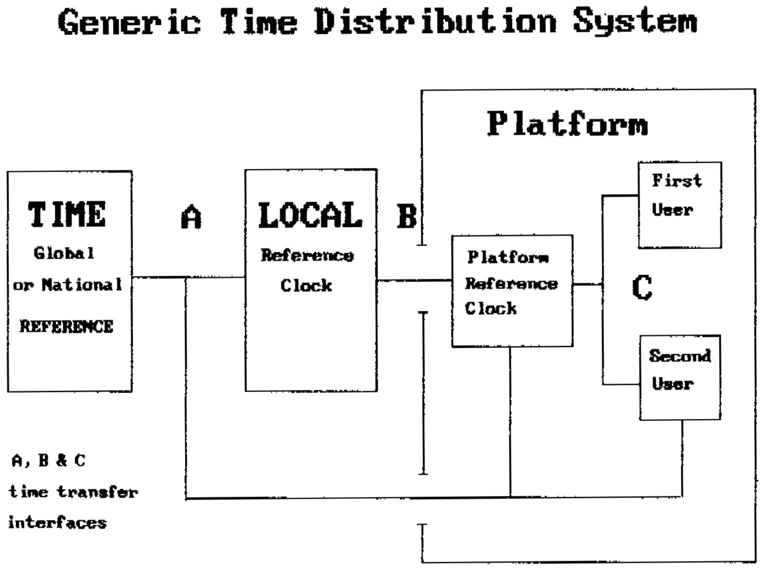


Figure 3

HOURS	MINUTES	SECONDS	DAYS	YEARS	TFOM	LEAP SECOND INDICATOR	LEAP SECOND DAY

Figure 1

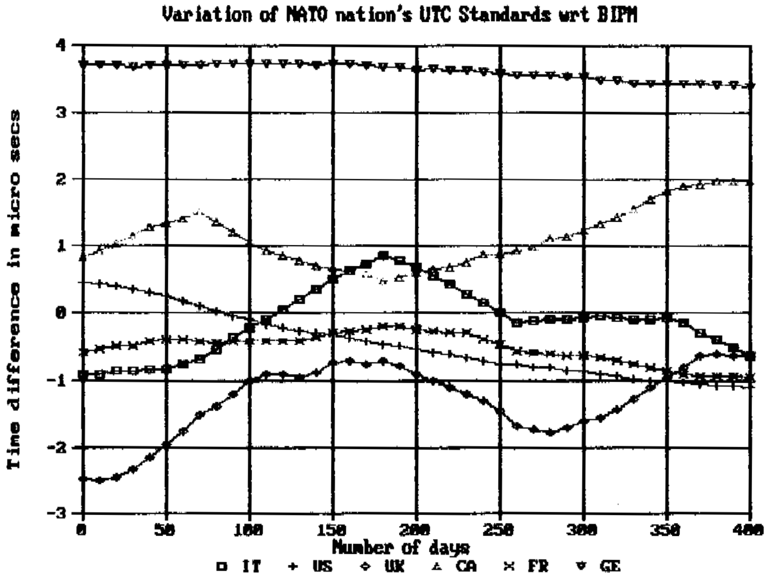
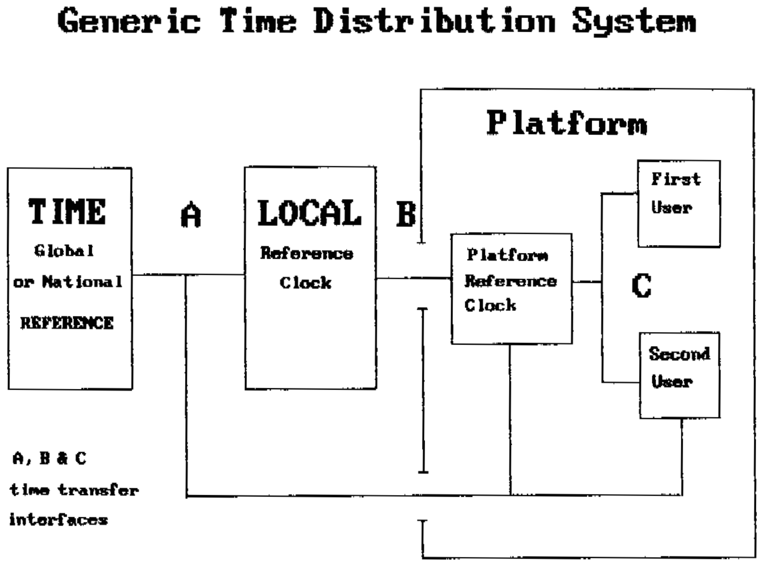


Figure 2



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