An Innovative Time service via Telephone Network - A study on its Potentiality

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Abstract - National Physical Laboratory, New Delhi, India (NPLI) has started a new time service by transmitting digital time data via telephone network in name of Teleclock service which is quite different from the usual dial-up time service. Data for the time of the day are sent five times for the sake of redundancy. The phase information related to the second pulse is also disseminated, thus providing the provision of delay compensation.

NPLI has also developed a Teleclock receiver to access this time service. Receivers have been designed to access this service either via landline network or mobile network. Real Time Clock of the receiver is set / synchronized with the received time data. The confidence in accessing correct data has been worked out. The accuracy of time signal has been studied for both landline and mobile network. The accuracy of the order of sub millisecond has been observed. Online delay compensation has been planned.

Transmission system for commissioning such time service is inexpensive and simple. Further, the cost of the receiver is affordable and mainly depends on the size of the display. So this system opens up an opportunity of staring a national time service and thus is gaining popularity in many developing countries.

This paper describes the system configuration, emphasizes the important features of this system and elaborates the uniqueness of this time service.

I. Introduction

Everybody needs time. Users who are engaged in scientific measurement and study, astronomical observation, space mission, defense activities etc require very precise time(better than sub millisecond).These users are limited in number. The accuracy of time required by Railway network, airports, public displays, supermarket, government organizations, institutions, TV channels, general public is very minimal- only of the order of few seconds.

"How to get this time" and "reliably from whom one may get correct time", are the issues for the users of time. The maintenance and dissemination of TIME are important aspects for any country. Time, being a dynamic parameter, it has to be monitored continuously for its maintenance and time has to be disseminated by some means for accessibility to users.

There are various techniques to disseminate local time of a country to its users. They differ essentially on the accuracy, coverage area, cost of maintaining the service and the ease and the cost of accessibility to the users.

The most widely popular technique is time transfer via satellites (e.g. via Geostationary satellites [2]and via Global positioning system (GPS) satellites[1]). These are very accurate and have wide coverage. But one limitation it suffers from is the cost of the receiver. For users who demand a low accuracy (say of order of few seconds) time, the service via telephone line is very useful. This type of time service has already been initiated in many developed countries. For example USNO in USA gives voice announcement of time via telephone line. One gets time announcement by dialing 174 in Delhi. The automated Computer Time Service (ACTS) has been provided by NIST since 1988 for users who need to synchronize the computer clocks to correct time. NPL, UK operates a time service which allows a PC equipped with modem to call the NPL TRUETIME service [4] and set the internal clock to UK local time. These services are accessible by a computer only. In India National Physical Laboratory, New Delhi, India (NPLI) maintains Indian Standard Time (IST) with the help of a bank of five commercial cesium clocks (all of them are HP 5071A). These clocks are continuously traceable (through GPS network) to UTC generated by BIPM. The IST maintained by NPLI should be accessible to Indian users. NPLI has also started a time service via Telephone line but with many innovations.

NPLI has developed an innovative system for transmission of digital time data via telephone line. This unique time service may not only be accessed by a computer but also by a very inexpensive system called TELECLOCK Receiver, developed by NPLI. This paper describes the functional details of this service. The important features of this service have been elaborated emphasizing the uniqueness of the service.

II. Description of the Scheme

NPLI has already started transmission of digital data of current time of IST through Telephone line[3]. The scheme of this operation is illustrated in Fig.1. The Teleclock data format generator (TDFG) is directly fed by the second pulse from the cesium clock, which maintains IST as explained earlier. TDFG generates the digital data of hour, minute and second corresponding to the current values of IST. These data are continuously transmitted through RS232 protocol at 1200-

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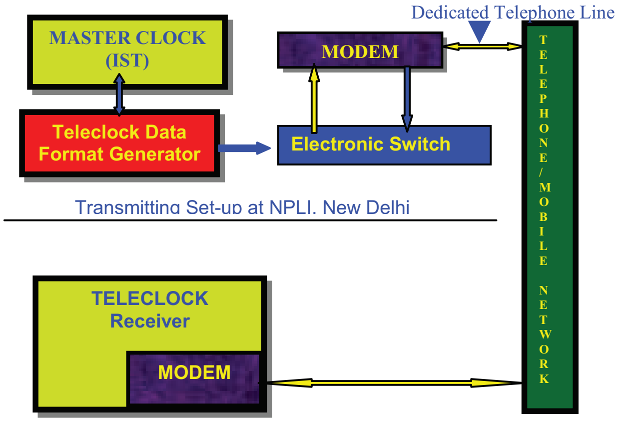

Fig 1. Scheme for Teleclock Service

baud rate in a well-planned sequence (Fig.2).

The transmitted data is linked to a Standard Telephone Modem through RS232 port. The output of the modem is connected to one telephone line, which is dedicated for this service. MODEM operates in V.22 mode. The baud rate is chosen to be 1200 as the optimum so that it is not too slow to accommodate sufficient number of bits but also not too fast to become less immune to noise. Five sets of data are sent every second so that at the receiving end there is enough provision to confirm the correctness of the data. The data sets also carry phase information of the second pulse through a special character so that the synchronization of second pulse of the receiver's clock may be achieved, if desired. The data corresponding to hour, minute and second in each set is preceded by a particular "signature-character" respectively so that the corresponding data is confidently identified. The signature-character and sequence are so chosen that the possibility of false identification of signature-character be eliminated.

To access this time service it is not essential or necessary that one needs a computer. NPLI has developed a Teleclock receiver for this purpose.

This receiver should remain connected to any direct telephone line.

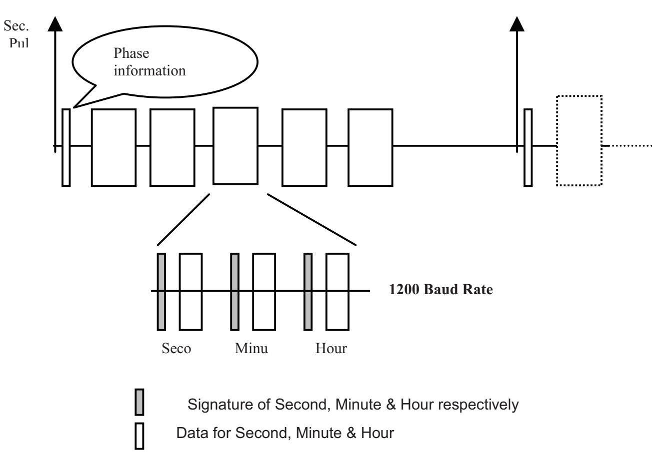

Fig.2 Data Format of Teleclock Service

It may be noted that it does not disturb the normal usage of the telephone line. Teleclock receiver has an in-built clock run by a crystal oscillator. The receiver has the provision of dialing the telephone number of the line dedicated for this service manually by pressing a switch or automatically at a pre programmed time. The frequency of automatic dialing is normally once in a day but may be increased or decreased on the user's demand. Through dialing, the receiver receives the data corresponding to the IST, sets its own time accordingly and disconnects itself from the telephone line. The frequency of the crystal oscillator is so accurate that by dialing once in a day, the receiver may maintain the time within few seconds of IST always.

A .Transmitting System

It has been seen in Fig.1, that the main component of transmitting set up is Teleclock Data Format Generator (TDFG) and its design concept of is shown in Fig.3. TDFG is designed based on a microcontroller chip IC 8951. The microcontroller generates software clock driven by an interrupt pulse generated internally every second. The interrupt pulse is generated in absolute phase synchronization with 1 PPS of the cesium clock fed externally. The use of external 1PPS directly as interrupt pulse has been avoided for two reasons. Otherwise, this makes the system sensitive to external noise and secondly any intermittent failure in cable/connector feeding external 1PPS would make the current time fall behind IST. TDFG has a good crystal oscillator at 5 MHz, which is divided down to 1Hz. External 1 PPS of Cs clock resets the counters of divider chain and thus the phase synchronization is established permanently.

It has been experienced that the noise spike may creep in through the port feeding 1PPS and reset the divider chain erratically. To get rid of this situation, interrupt pulse generates an Enable gate through the software few milliseconds earlier than the arrival of the interrupt pulse. Initially the 1PPS generated from 5MHz internally may be completely out of phase with that of 1PPS of cesium clock. In such a situation the Enable gate will also be out of phase of external 1PPS. The external 1PPS, thus, may not get any

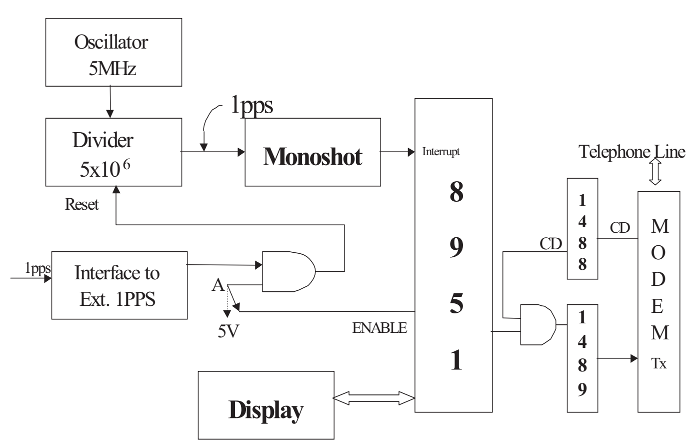

Fig.3. Scheme of Teleclock Data Format Generator (TDFG)

chance to reset the divider chain. So the provision has been made to temporarily bypass the Enable gate by manually pressing the switch SW (which forces "A" to be high) for few second so that external 1PPS, by resetting, forces the internal 1PPS to be in phase. After this initial resetting, the pressing of the SW is withdrawn so that Enable gate takes the control and phase of internal 1PPS is maintained in phase of external 1PPS always.

Interrupt Service Subroutine (ISS) updates the current time after sending a special character "O" which carries the phase information of the second pulse. 8 bit data corresponding to hour, minute and second of current time are taken out in a proper sequence at 1200 baud rate.

When a user dials the transmitter, the establishment of the link is indicated by "high" state of the Carrier Detect (CD) flag. CD flag is used to open the gate (BLKII of Fig.3) to output the time data to the telephone line through MODEM. This gate is essential as MODEM malfunctions if it senses transmitting data before CD flag is "high".

B. Design of Teleclock Receiver

The Teleclock receiver consists of three major components as shown in Fig.4. They are a Clock chip (or Real Time Clock i.e. RTC), a micro-controller and a Modem. The clock chip basically maintains time with the help of a crystal oscillator. The hour, minute and second data of the clock chip may be accessed or changed through its data port. There are many types of clock chip available in the market. For example, DS12887 has in-built crystal oscillator and few others like MSN5832 and IC6242 run on external crystal of frequency of 32.76 KHz. All of them are supported by on chip Lithium Battery. The clock chip consumes only microwatt power and thus its operation may be sustained by a small battery for years. The micro-controller chip accesses the data of the clock chip and feeds to a display unit for visual indication of the current time.

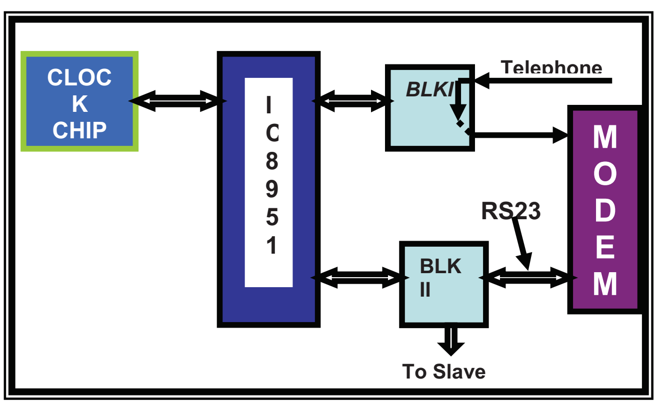

Fig.4. Schematic Diagram of a Teleclock Receiver

Through the MODEM, the micro-controller may dial a particular telephone number at a preprogrammed time or on getting a command through a switch to be operated manually. If the line is successfully connected to the Teleclock service, the micro-controller receives the correct time of IST and modifies the time of the clock chip accordingly. After successful updating of the time, the telephone line is disengaged. For landline, standard telephone modem may be used. GSM GPRS modem should be used for mobile network. The activation software will differ depending on type of network used. The flowchart shown in Fig.5, describes sequence of operation executed by the software that are fed to the CPU of the microcontroller. Samples of photos of two types of Teleclock receivers are shown in Fig.6.

Quality of crystal oscillator decides the frequency of dialing required to maintain the time of Teleclock within one second of IST.

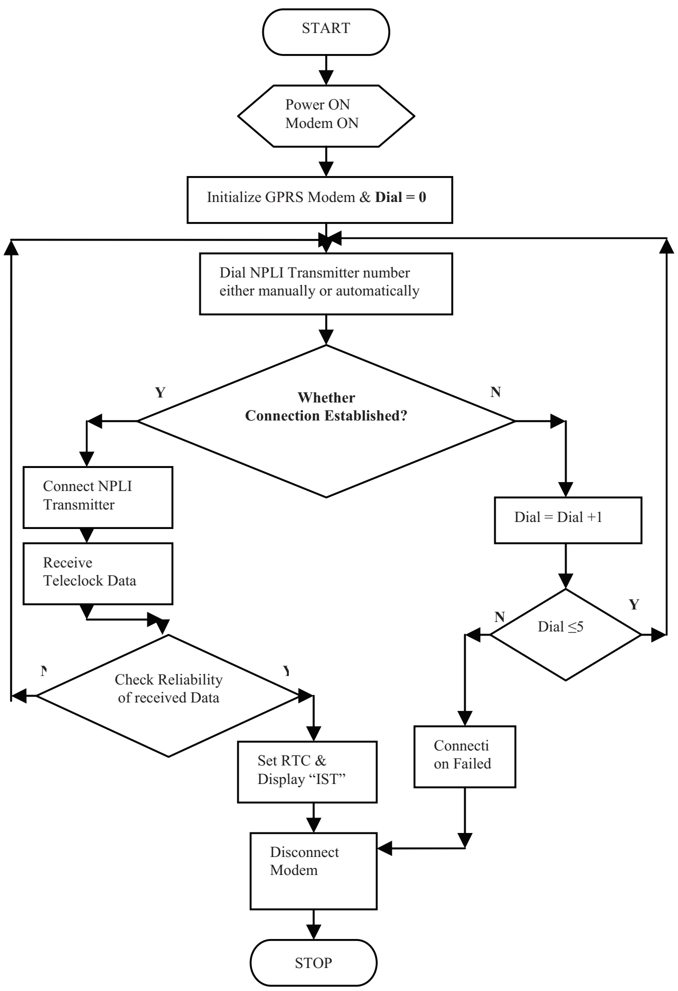

Fig.5. Flowchart explaining the working of Teleclock Receiver

Mobile Teleclock Receiver Model

Landline Teleclock Receiver Model

Fig 6. Typical Samples of Teleclock Receivers

C. Probability of Error in Deciphering Scheme of Received Data

For mobile telephone network, the data stream may be corrupted by noise. So it is necessary to study the probability of wrong data that should not be identified. This may help in optimizing the software for confident detection of data.

Let us assume that there is total **n** number of bits required for transmission of current time in hour, minute and second. Let us assume that **t** number of redundant data sets each of which contains n bits is sent.

When data is received at the receiving end, some of the bits may be corrupted due to the noise in the propagating channel. It has been planned that the few sets of data are inter-compared each time. If data sets do not match exactly, the received data is rejected. When few sets of data match exactly, the received data are accepted and used to set the time of receiver's built-in clock. So it is important to find the confidence in correctness of the received time data when the few sets of data are found to be matching exactly.

Let us assume that k number of bits is in error in the first set of received data. So the different number of combinations that the k bits of error in n number of total bits may be distributed, is ${}^{n}C_{k}$. The probability of occurrence of one particular combination of k bits of error out of n bits of data, thus, is

$$\frac{1}{{}^{n}C_{k}}$$

Let us first consider the comparison of two sets. If two data sets are exactly same, then it is matched. Matching may occur in two situations. One – both the sets are correct. Second – both the sets are incorrect in same order. Second situation may result in wrong time setting and so is not at all desirable. It is, therefore, essential to ascertain the probability of occurrence that both the sets are in error in the same order. This probability is

$$\left[\frac{1}{{}^{n}C_{k}}\right]^{2}$$

This logic may be extended for **t** number of sets. Thus, probability (P) that t number of sets have the error of exactly similar type (i.e. the probability of false detection of correct data) is

$$P = \left[\frac{1}{{}^{n}C_{k}}\right]^{t}$$

So the reliability or confidence(R) in correct data detection is

$$R = 1 - P = 1 - \left[\frac{1}{{}^{n}C_{k}}\right]^{t}$$

Let us use this general expression of P and R for the Teleclock receiver to find the reliability of the system. In this particular case 24 bits are transmitted. So n = 24. The data format has been designed such that 5 sets of data are sent.
So,$t < 5$.

Fig.7 illustrates the confidence in deciphering correct data by comparing different number of sets. This analysis dictates that more than 99% of confidence in reliability of data may be obtained by checking and comparing minimum of three sets of received data.

D. Propagation Delay Compensation:

The phase information of 1 pps available for the receiver has been compared with local standard. This measure shows a jitter of few hundreds of microsecond. This observation encourages us to plan for delay compensation. Teleclock service transmits the values of hour, minute and second of current time as data to the users. Time taken to reach the data from the transmitting end to the receiving is always much less than one second and is normally is not taken into account. Thus the phase information that is sent through a special character "O" is not used.

A new technique is being evolved to make use of this information so that path delay may be compensated, thereby,

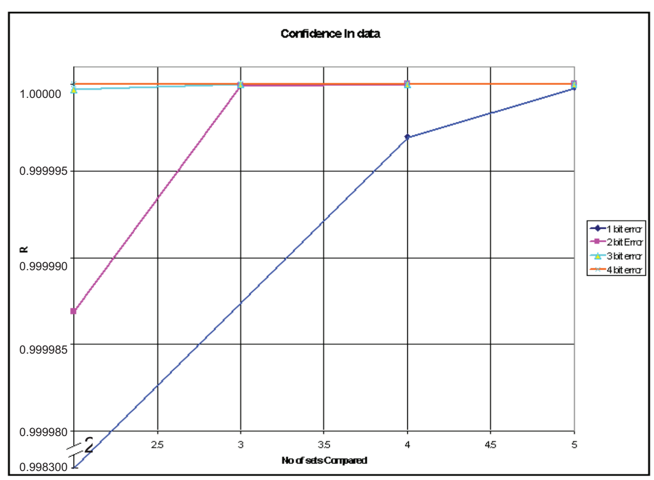

Fig.7. Confidence graph for data received by Teleclock receiver

improving the accuracy of time transfer. Propagation delay(x) cannot be predicted in advance as it varies depending on a. Location of User and b. *Telephone Route* available at the time of connection (condition of traffic at intermediate Exchanges and propagation conditions for mobile link).

The Direct Measurement of Propagation Delay(x) is tedious and very elaborate. A new scheme has been worked to implement the propagation delay. The receiver sends back "O" immediately after receiving it. The arrival time of "O" is directly measured at the transmitting end with respect to the transmitted 1pps. This delay is sum of the delay of Transmitter (Tx) to Receiver (Rx) and the delay of Rx to Tx. If it is assumed that both these delays are same then the measured delay is 2x. To compensate the delay , the advancement of 1 pps is required. Advancement of pulse is impossible. So by delaying the pulse by (1-x) seconds will simulate the same effect of pulse-advancement. Closed loop delay (2x seconds), (shown in Fig 9), at transmitting end is determined by measuring the arrival time of "O" returned by the receiver with respect to 1PPS through a time interval Counter. Half of closed loop delay may be assumed to be the actual propagation delay (x seconds).From Transmitting End, a special character "P" delaying it by (1-x) seconds with respect to 1PPS is also sent back to the particular receiver. At the Receiving end this Special character "P" is received at the instant of IPPS mark of Transmitter clock. The scheme has been simulated in computers and desired output has been obtained. The scheme is now in process of implementation.

III. Concluding remarks

The unique time service by NPLI has been in operation since early 2002. It has been found to have the following features.

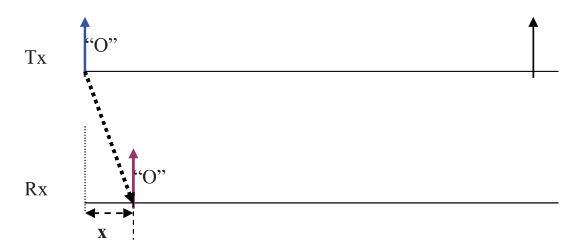

Fig.8: Timing diagram showing transmitted "O" received at the receiving end after a delay of x seconds (x< 1)

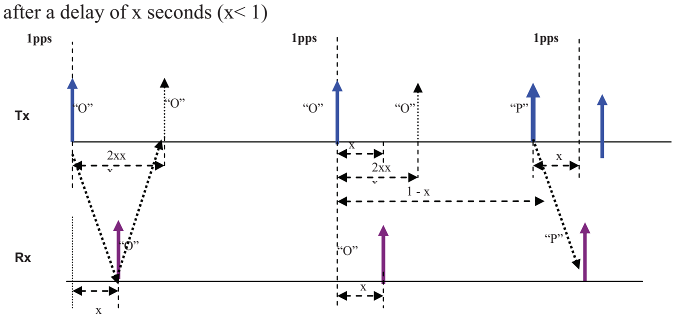

Fig.9.: Timing diagram showing scheme for delay compensation with pulse delay instead of pulse advancement

1. This unique time service may not only be accessed by a computer but *also by a very inexpensive system called TELECLOCK Receiver, developed by NPLI. This very feature is the unique novelty of this technology which makes this technology special and different from what have been started by the developed countries elsewhere.*

2. To initiate this similar time service via telephone line in any country, very small amount of investment is required for transmission system. Further, the users may access this time through *an affordably inexpensive receiver*. Encouraged by these features, Saudi Arabia and Nepal has already started the similar service with help of NPLI–developed equipment. Initiation of this service in other SAARC countries is in the pipeline.

3. This service being accessible through mobile network can be used in moving vehicles like Police Patrolling Vans, Railway traffic etc.

4. After implementation of the delay compensation scheme, this will promise to be a useful tool also for calibration of remote Time & Frequency sources with sub millisecond accuracy

5. Extension of the Range of Teleclock Service through Local Exchange:

Many institutional complexes have number of clocks scattered over a large area of the respective complex. It is desirable that all these clocks show the same time. Linking these clocks to IST or National time utilizing the Teleclock services through their local telephone network through the Private Automatic Exchange (like PAX/EPABX) is a very convenient solution . There is no need of additional cable laying over the entire complex as it is done in the conventional master slave clock system. *This is a very attractive feature and an important advantage particularly when the complex is spread over few kilometers.*

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