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Use of modern telephone network for time transfer: An innovation

Pranalee P Thorat* & P Banerjee**

National Physical Laboratory, Council of Scientific and Industrial Research, New Delhi 110 012

*E-mail: pranuthorat@gmail.com; **E-mail: pbanerjee@nplindia.org

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NPL has started a new time service by transmitting digital time data via telephone network in name of Teleclock service. This is quite different from the usual dial-up service in other countries. This unique service can be accessed by the landline telephone as well as by the mobile telephone network. Both types of receivers have been developed by NPL, New Delhi. The concept of this service has been described in this paper. The important features and uniqueness of this system have also been elaborated.

Keywords: Telephone network, Teleclock service

1 Introduction

There are various techniques to disseminate local time of a country to its users. They differ essentially on the accuracy, coverage area and cost of maintaining the service and the ease and the cost of accessibility to the users. The most popular technique used worldwide is time transfer via satellites[1] [e.g. via Geostationary satellites and via Global positioning system (GPS) satellites]. These techniques are very accurate and have wide coverage. But one limitation it suffers from is the cost of the receiver. Normally, available GPS receiver cannot also easily be connected to a large display system for public display. For users who demand time with low accuracy (say of order of few seconds), the service via telephone line is very useful.

Advanced technology and unprecedented advancement of miniaturization have ushered in a revolution in telephone system. These days, one is not handicapped by frequent non-functionality of the telephone. Non-availability of a new connection due to lack of expandability of the local exchange is no longer a limitation. With the introduction of cellular network, the telephone scenario has changed altogether. Mobile system has immensely matured at an accelerating space. Co-existence and marriage of mobile and landline telephone networks lead to the unique feature of interoperability. Many inherent disadvantages of landline telephone could be overcome through the synergy of two systems. Consequently, unthought-of applications have emerged enjoying the specific advantages of both networks. Keeping in mind all the features of the current smart telephone system, a new time transfer system has been conceived of. This has been developed and made operational by National Physical Laboratory (NPL), New Delhi.

Unique features of this technique include its inexpensive and simple transmitting system. The accessibility of this type of service is easily adaptable for various applications particularly where the requirement of sub-second accuracy is not essential and important.

In India, NPL has developed an innovative system for transmission of digital time data via telephone line. This time data corresponds to Indian Standard Time (IST) maintained by NPL with the help of the commercial cesium clocks traceable[3] (through GPS network) to UTC generated by BIPM. This unique time service may not only be accessed by a computer but also by a very inexpensive system called TELECLOCK Receiver, developed by NPL. This paper describes the functional details of this service. The important features of this service have been elaborated emphasizing the uniqueness of the service.

2 Description of the Scheme

It has been pointed that the telephone network, these days, has altogether a different complexion with the co-existence of two different technologies and its consequent intercomparability to derive fullest advantages of two independent systems. Keeping these in mind, the new time dissemination technique has been conceived of according to the scheme as shown in Fig. 1. The transmitting set-up utilizes the landline network only. The logic behind this option is

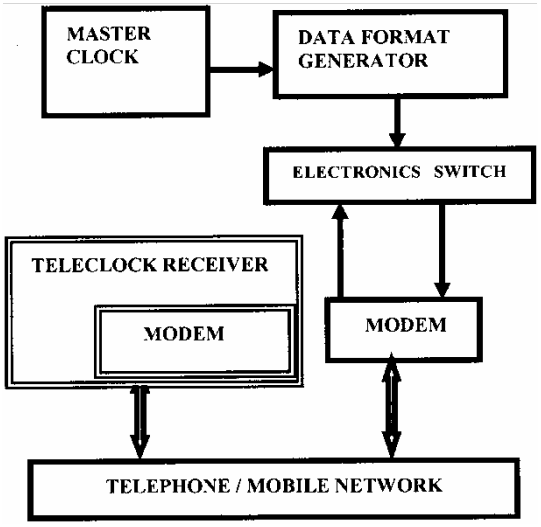

Fig. 1 — Scheme of Teleclock service

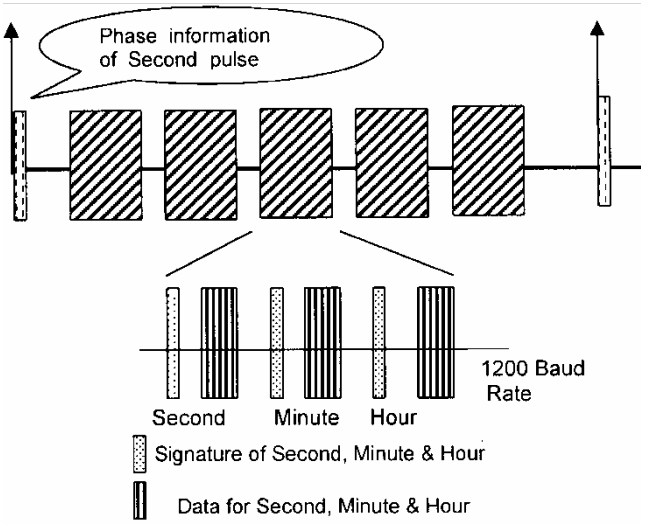

Fig. 2 — Teleclock data format

the availability of the hardware line confirming the connectivity of the signal. This ensures round the clock connectivity without any possibility of interruption unless there is any system breakdown. The data format generation of the current time available from the reference master system is linked to a standard modem for further connection to one "dedicated" telephone line. There are several similar systems in place to cope with the demand from many customers at the same time. The provision of "hunting mode" operation facilitates the use of one telephone number by the receiver to access any of the available numbers out of all the lines in operation.

It is interesting to note that two types of receivers have been designed to take advantages of one of the technologies depending on the applications. One type utilizes the landline network and the other makes use of mobile network. The later type serves the purpose of most of the applications. The system has been designed in such a way that the device to access this service should be simple and inexpensive. Accordingly time data format has been planned. Obviously, the basic component of the transmitting system is data format generator (DFG) in synchronous with the time of the master clock. The transmitter set-up has been shown in Fig. 1.

The transmitted data is linked to a Standard Telephone Modem through RS232 port to be connected to one dedicated telephone line. Five sets of data as shown in Fig. 2 with an optimum baud rate of 1200 are sent every second for redundancy. The baud rate of 1200 has been chosen judiciously. It is not too fast to be less immune to noise but at the same time is not too slow to accommodate five sets of data per second. 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. Interrupt Service Subroutine (ISS) updates the current time after sending a special character "O" which carries the phase information of the second pulse. The data is sent to the Modem only after the establishment of the link with the receiver which is indicated by "high" state of the Carrier Detect (CD) flag.

2.1 Design of Teleclock receiver

There may be various design of Teleclock receiver depending on the application. However, basic structure of the receiver being the same, in general, consists of three major components as shown in Fig. 3. They are a clock system, micro-controller and a Modem. The clock system is the clock which maintains time of the day, modem receives the data and MC deciphers the correct data and sets the time of the clock system. The micro-controller chip accesses the data of the clock chip and feeds to a display unit for visual indication of the current time. Teleclock receivers[3,4] use telephone modem (Standard telephone for landline and GSM GPRS modem for mobile network) to access the time service. The flowchart shown in Fig. 4 describes the algorithm to decipher the correct data. BLK is the interface which has multi-functions. It converts the data output from MC to RS

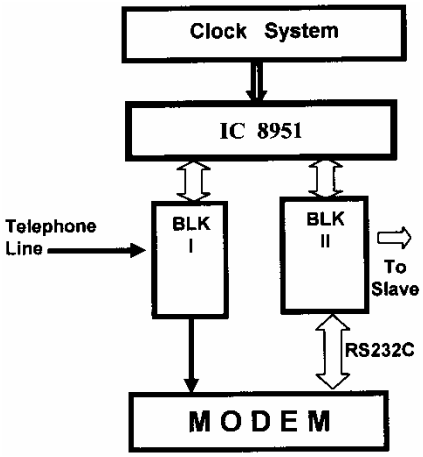

Fig. 3 — Functional diagram of Teleclock receiver. BLK I and BLK II are interfaces

232 protocol making it compatible for MODEM. It also makes the compliable to drive display unit and also to feed slave system. The clock system may be Real Time Clock (RTC) chip whose time may be accessed or altered through data port.

In another type, the clock system may be an external crystal oscillator with a divider chain to generate 1 PPS to serve as interrupt of MC for software clock. This may have the provision to synchronize the 1 PPS with the received phase information through character O.

NPL has developed the Teleclock receiver and have granted patent in India and foreign countries. The know-how has been transferred to few manufacturers. Samples of Teleclock receivers are shown in Fig. 5(a and b).

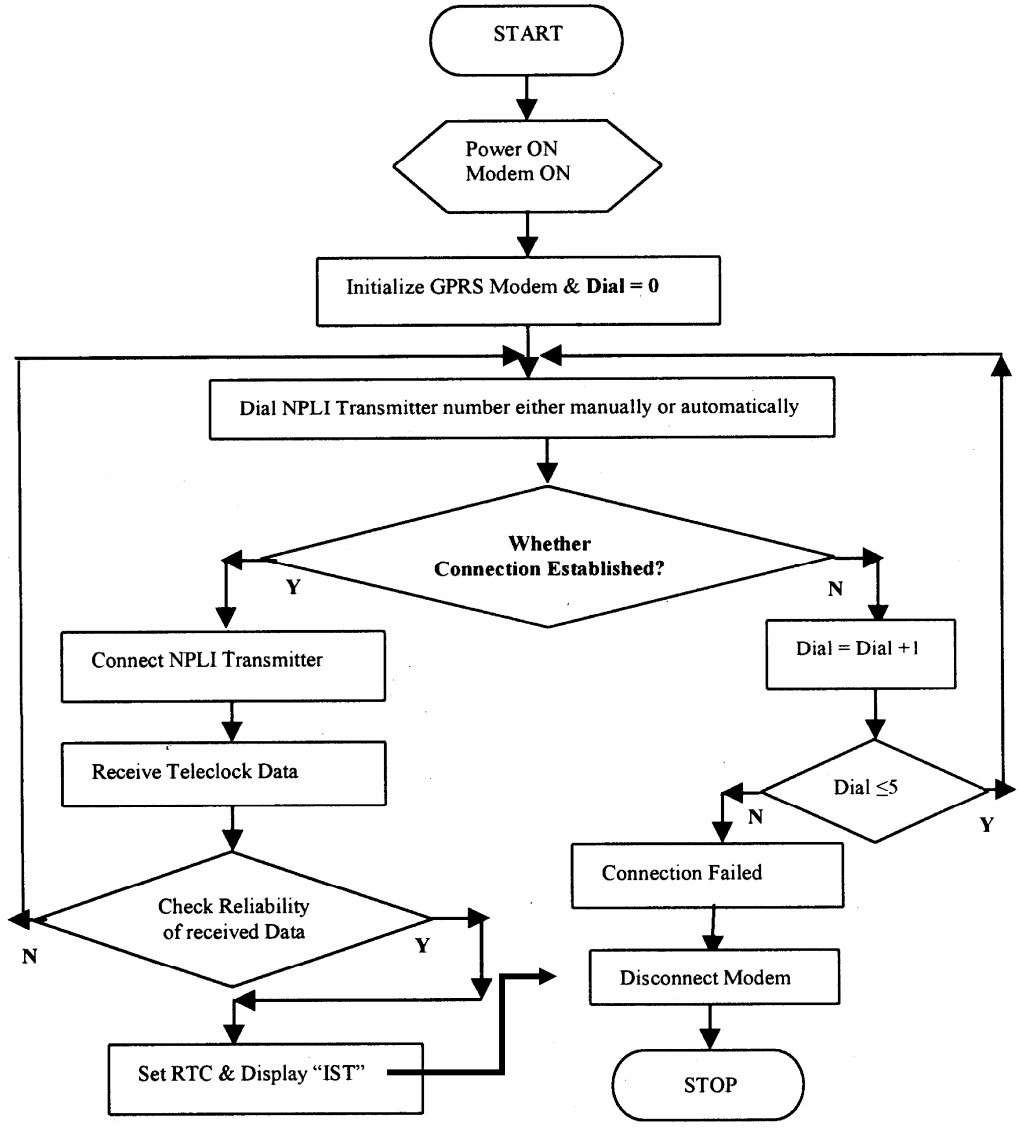

Fig. 4 — Algorithm to decipher correct data

Fig. 5 — Sample of a Teleclock receiver (a) mobile and (b) landline

2.2 Probability of error in deciphering scheme of received data

For landline network, the strength of the received signal is normally sufficient for error free detection of data. For mobile telephone network, the data stream may be corrupted by noise.

Let us assume that n is the number of bits required for transmission of current time in hour, minute and second in one data set and t is the number of identical such data sets. Let us find out the probability of identifying the correct 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 the 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 $1/{}^{n}C_{k}$. Let us first consider the comparison of two sets. If two data sets are exactly the same, then it is matched. Matching may occur in two situations. One-both the sets are correct. Second-both the sets are incorrect in the same order. Second situation may result in wrong time setting. The probability of occurrence that both the sets are in error in the same order is $[1/{}^{n}C_{k}]^{2}$.

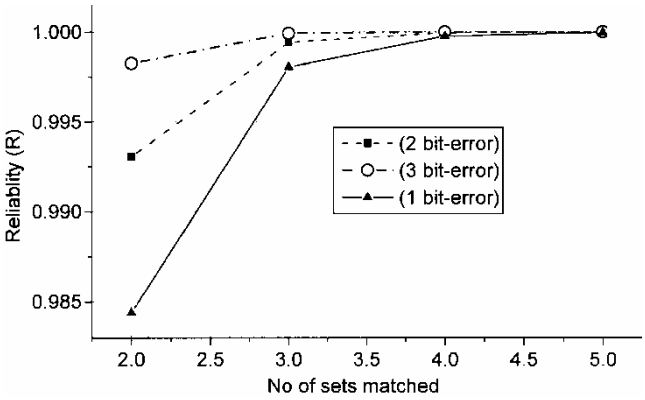

Fig. 6 — Reliability of correct data retrieval

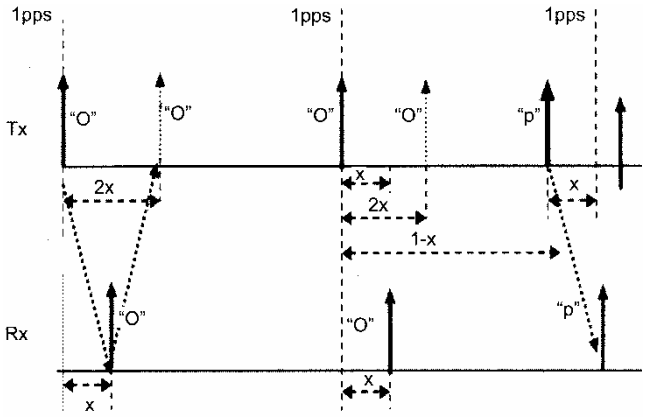

Fig. 7 — Plan of delay compensation

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 $P=[1/{}^{n}C_{k}]^{t}$. So the reliability or confidence (R) in correct data detection is $1-P=1-[1/{}^{n}C_{k}]^{t}$.

In the case of a Teleclock receiver, n = 24 as 24 bits are transmitted. The data format has been designed such that 5 sets of data are sent. Figure 6 shows 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 comparing three or more sets of received data. Accordingly in the software three sets of data are compared and then the data are used for setting the clock. Exhaustive field trial confirmed the efficacy of this scheme.

3 Delay Compensation

A scheme as shown in Fig. 7, has been worked out to compensate the propagation delay. The receiver may send back "O" immediately after receiving it. The arrival time of "O" is directly measured at the

transmitting end with respect to the transmitted 1 pps. This delay 2x is sum of the delay of Transmitter (Tx) to Receiver (Rx) and the delay of Rx to Tx. It is assumed that both these delays are the same. So the delaying the pulse by (1−x) seconds at the transmitting end will compensate the delay of propagation at the receiving end. From Transmitting End, a special character "P" delaying it by (1−x) seconds with respect to 1PPS of the transmitting end 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 the transmitter clock. Initial experimental study shows a sub-milliseconds rms jitter in the delay measurement. The scheme is now in the process of implementation.

4 Concluding Remarks

This unique time service is normally accessed by a very inexpensive system called TELECLOCK Receiver[4], developed by NPL. One may also set the time of a computer by feeding the signal from a landline telephone line to the internal telephone modem of the computer. The new version of receiver using mobile network[5] has, recently, been launched for public use. This has added a new dimension to this service. The new receiver can find extensive application in moving vehicles like Police Patrolling Vans, Railways, Cars etc.

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 NPL-developed equipment. Initiation of this service in other SAARC countries is in the pipeline.

A very convenient solution for linking the clocks scattered over large area of an institution complex to IST may be done by utilizing the Teleclock services through the Private Automatic Exchange (like PAX/EPABX) of their local telephone network. This does not require any cable lying over the entire complex. Initial study on the scheme to compensate the delay shows that this may improve the accuracy of time transfer to a millisecond or so.

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