Appeared on 2nd July 2007

The best clocks find a way to agree

It is not enough if just one person is punctual, says S.Ananthanaryanan.

The other person also needs a great time-keeper and the two watches need to be tallied. Present day chronometers have mind-boggling accuracy. But how to compare two such time-keepers separated by a distance was a problem that has been somewhat treated by Nathan Newbury and colleagues at Boulder, Colorado.

The Global Positioning System precisely determines where it is installed, with the help of an array of 24 satellites in fixed orbits around the earth. A GPS station, which fixes its position with a method called ***trilateration***, does the trick with the help of the time it takes a microwave signal to get to three satellites. But because its clock is not good enough, in practice it needs to talk to one or more additional satellites, to make sure. But better the clock, greater the precision.

Better clocks

Clocks work by counting any regular and repetitive action – like the swing of a pendulum. If the pendulum can be adjusted to swing once every second, it is a simple matter to set up the clock to count one second for each swing and read out the minutes and hours. The trouble is that pendulums do not keep time that well, changes in temperature alter their lengths, changes in humidity affect their swing, and so on.

Clocks that work on compression and release of metal springs, like in the older wrist-watches, work at higher speeds and are more accurate. The springs are made of a combination of materials to compensate for temperature and these watches are quite hardy. The next development was the crystal clock, which works on the frequency of vibration of crystals – and as they vibrate, thousands of times a second, they develop electric charges, which are picked up by electronics to work out and display the time.

The best clocks regularly used are the atomic clocks, which depend on the energy difference between 2 energy states of an atom. Unlike springs or crystals, every atom is exactly the same and the energy states are the same for every atom. The difference of the states corresponds to a very high frequency or pendulum ‘swings’ of a very short space of time. Counting such short and steady oscillations then makes for a very accurate clock. The way of converting the energy difference into frequency was to create a microwave laser, or ***maser***, with the help of the atom and the frequency of the radiation defines the time interval.

The standard of time has been fixed with reference to the cesium 133 atom, using not masers but the frequency at which ultra-cold cesium atom absorb light, corresponding to a frequency of exactly 9,192,631,770 cycles a second. These are the timekeepers at the heart of current-day modern GPS installations.

Synchronising clocks

But the most accurate clocks cannot become truly useful unless they can be compared with one another, and one is sure that they are keeping the same time. Two such clocks in the same room or laboratory, yes, they could be compared. But take them even a modest distance apart and it became impossible to keep pace with their feverish speed of oscillation.

The problem is to transfer their time signals to the other place without loss of even one beat, and this has proved difficult over even modest distances. But the scientists at the National Institute of Standards and Technology at Boulder have succeeded in loading the clock oscillation on to a light wave oscillating hundreds of times faster than the clock.

This is a process called ***modulating*** a wave and is routinely used in radio and television transmission. The Boulder scientists have mounted the ‘ticks’ of the atomic clock on the wave of a 1.5 micron (millionth of a metre) light beam, the carrier used in normal telecom networks. The carrier can routinely handle ordinary digital data signals, where the priority is high bandwidth. But faithfully transmitting a high frequency load, with minimal distortion has been a challenge.

The Boulder scientists used ultra-accurate laser sources to ‘add’ and ‘subtract’ the signal and have managed faithful transmission over 750 metres. Making it work for 50 kms appears to be feasible, holding out the hope for use in worldwide telecom networks.