Primary Reference Clock

This brief technical note is intended to highlight design problems associated with the proposed highly redundant frequency standard and to suggest areas where detailed theoretical analysis is required.

A possible implementation of the redundant standard is shown in the block diagram. The objective is to combine a considerable number of diverse frequency standards so as to result in a single output, which has improved performance (the measure of performance is the short, medium and long term frequency stability of the source), and high reliability in that the output should not show any sudden phase glitches if the output of one or more of the sources should fail. In addition, it would be desirable that the random behaviour of the output phase of a source should be detectable by comparison with the phase of the other sources.

The sources may be divided into two classes: The first is the free running oscillator type of source, which may show a frequency offset from an internationally defined time scale. The hydrogen maser and the rubidium oscillator are in this class. They may have excellent stability, but can still have an unknown frequency offset

The second class of source is the type, which supplies a replica of a time scale elsewhere. The GPS standard and the lf tracking receiver are of this type. They provide a link to an ensemble of standards, which is it monitored and referred to other internationally maintained time scales. The quality of this link controls the short and medium term stability of the standard. In the long term the stability of this class of source will approach the host time scale.

The local standards of the first class are likely to have much better short and medium term stability than standards of the second class. For example, the hydrogen maser will be superior to either the GPS standard or the lf tracking receiver to averaging times of weeks. The final outputs of the PRC should have the short-term quality of the hydrogen maser, but the long-term quality of the GPS.

The redundancy requirement poses several problems. The outputs of the various standards can only be combined if they are all in phase. If sine waves are added without phase alignment, the output sine wave may have zero amplitude with some combinations of input phase. If we consider a simple system where one source is considered to be the master, then the other sources may be phase aligned to the master, and all the sources may be added together with equal amplitude weighting. If one source should now fail, the amplitude of the output will only drop by the ratio of the number of sources to be combined. This simple system would work quite well if all the sources were of the same class and the same degree of frequency (phase) stability. If we were combining 3 Rubidium oscillators, we would want to give them equal amplitude weighting, as the expected short-term stabilities are the same. One will even derive performance benefit as the phase noise (instability) of each will be uncorrelated, and thus the output noise of the ensemble will be lower than that of the individuals.

If we are combining sources of quite different performance levels, the output should be substantially that of the best standard, in this case the hydrogen maser. Any addition of output from the other standards can only degrade the performance. However, of the hydrogen maser should fail, the output may fall to an unacceptably low level. Thus the performance requirement conflicts with the redundancy requirement.

One could argue that one could improve the short-term stability of the lesser sources by phase comparison with the hydrogen maser, and then phase adjustment. This is certainly true, and one could then use a higher percentage of the improved (phase adjusted) standard in the final output. If the hydrogen maser did fail, then the reference source for the phase adjustment would suddenly vanish, and then basic noise characteristics of the lesser sources would suddenly reappear. The next best source, for example the rubidium oscillator could then be designated the master and used for phase alignment. It would be difficult to achieve a smooth change over, however.

A better solution might be to derive a notional time scale based on phase measurement of all the sources and phase align all the sources to the notional time scale. In this way, the need for a master is overcome. Careful consideration of the weighting of each source contribution to the notional time scale would be required, with a different contribution at different averaging times. To clarify this, a source of the second class would have more weight over the phase averaged over a long period of time as it directly references an international time scale.

A major part of this project is in the computer algorithms used to derive the notional time scale, and to control the phase alingers that condition the outputs of each standard before they are added together. It is also important that the phase aligners themselves do not contribute noise and phase drift. The successful implementation of the PRC will combine state of the art electronic design, and software analysis and control algorithms.