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CONFERENCE REPORTS

Precise time and frequency

Symposium on time and frequency
19th General Assembly of URSI
1–4 August 1978; Helsinki, Finland

This symposium of the International Union of Radio Science focused on precise time and frequency dissemination and coordination, and as such was the first comprehensive meeting on this topic. Papers (22 contributed, 11 invited) covered navigation and communication satellites, very-long-baseline interferometry, effects of special and general relativity, radio frequency communication and navigation networks, and reviews of time and frequency metrology.

The intimate relationship between navigation and clock development over the centuries was highlighted by G M R Winkler (US Naval Observatory, Washington DC). He focused on the cost and reliability question to be addressed or solved by the use of high-performance clocks. Of course, good clocks are also needed for two technical reasons: (i) low-phase noise which allows improvement for example, in radar application, and (ii) the traditional uses of good long-term stability to allow long resynchronisation intervals, time-of-arrival mode of navigation, independence from interference and other disturbances, and the use of PRN codes.

R F C Vessot (Smithsonian Astrophysical Laboratory and Harvard College Observatory, Cambridge Massachusetts) surveyed the further possibilities of using clocks for detection of relativistic and gravitational effects. These tests include tests of non-metric theories which predict that different kinds of clocks (mechanical versus atomic) have a different frequency dependence on the gravitational potential. Ether drift experiments by one-way versus two-way speed of light are possible and the constancy in space–time of nongravitational constants could be studied. Deflection of radio waves near the sun, geodetic effects and drag phenomena are also of interest.

The effects of relativity on clocks may appear theoretical, but in practice these can be of the order of several hundred nanoseconds – enough to limit the precision of time frequency links via aircraft and spacecraft if not properly accounted for. N Ashby (University of Colorado) and D W Allan (National Bureau of Standards, Colorado) drew attention to these effects and advocated the establishment of a coordinate clock network which is transitive and is based on proper clocks with relativistic corrections and adjustments as needed for the particular local circumstances of the clock (gravitational potential and movement).

There are some interesting solutions by smaller countries in establishing national or multinational time and frequency services. For example, in Finland the time service is based on clocks, phase locked to Loran-C. These clocks are crystal oscillators and achieve with this method the full long-term stability of the caesium clock ensemble on which the Loran-C system is based, i.e. submicrosecond time keeping can be realised at relatively low cost. Also, preliminary experiments show that submicrosecond precision can be realised by using the vertical syncronisation pulses of Russian TV stations.

In India, the problem is its relatively large geographical size and lack of fully developed communication channels, versus the need to have submicrosecond precision in certain widely separated locations. Their linking up could be by satellite, and preliminary experiments via Symphony-II show that this can be done with a precision of much better than 1 μs. Yugoslavia plans to have a geostationary satellite broadcasting television programme in 1982. Their experimentation indicates that time signals could be easily encoded on such a television broadcasting system and would make submicrosecond timing available for Yugoslavia and neighbouring countries.

L J Rueger (Johns Hopkins University, Maryland) reported the following interesting data on the Nova Satellite Time Experiment, which linked the USNO and NBS-Boulder. Orbit errors seem to be reducible to the 10 ns level for a single acquisition; all other errors are below the 10 ns level. Thus, with averaging of successive acquisitions, 10 ns timing seems to be possible. The present data indicate that timing was achieved with a precision (scatter) of 30–100 ns, depending on the experiment, and an accuracy (from comparison by portable clock) of 40 ns. The crystal oscillator on board the spacecraft can apparently be modelled to the level of 3×10^{-13} per day.

An experiment was reported by J A Steele (National Physical Laboratory, UK) which realised

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with a communications system (Intelsat IVA–F1) the use of time-division multiple-access (TDMA) for time transfer to South Africa. Relativistic effects were included in the data analysis, and a timing accuracy (from a portable clock trip comparison) of 60 ns was achieved. The Symphonie experiment between NRC in Ottawa and the LPTF in Paris has yielded a statistical time precision of 6 ns: however, no figure on accuracy is yet available because no successful portable-clock trip took place.

In summary, nanosecond time transfer appears possible via satellite facilities such as Symphonie and the Global Positioning System, as well as through very-long-base-line interferometry (using radio telescopes). The opportunity to transfer time with nanosecond precision is intimately related to requirements of these same systems to obtain, for their functioning, nanosecond timing.

H Hellwig

New applications for NMR

4th International Meeting on NMR Spectroscopy
Chemical Society
2–7 July 1978 at the University of York, England

The theme of this meeting was new techniques and applications of NMR spectroscopy, and much exciting work was reported. Only highlights of the wide range of topics can be reported in the space available here.

The recent application to medical imaging has received much publicity. One of the pioneers, Professor E R Andrew (University of Nottingham), gave an excellent plenary lecture describing spin imaging, which maps proton spin density in three dimensions. Three orthogonal time-dependent field gradients define a small-volume element (called a sensitive point) in the sample which may be scanned in successive planes to build up a 3-D spin density map. The image which is formed with 128×128 pixels (picture elements) is displayed on an oscilloscope in black and white or colour. The use of the multisensitive point method, in which one of the alternating gradients is replaced by a fixed DC field gradient, was also described. This is faster, since a whole line of 128 elements can be obtained simultaneously after Fourier transformation in a minicomputer.

Objects up to 8 cm diameter can be imaged with a spatial resolution of 0·5 mm. Professor Andrew compared in particular the NMR cross-sectional image of the left wrist of one of his associates with an anatomical diagram. The bones were clearly defined, as were the extensor and flexor tendons, subcutaneous fat, arteries and other details. Further work is being undertaken to construct a whole-body imaging system using the multisensitive point method with a magnet capable of accepting objects up to 40 cm diameter. The technique appears to be very safe, no damage being known to be caused to humans by magnetic fields and radiofrequency electromagnetic radiation. The potential applications of this technique in medical diagnosis is very exciting.

Dr C W Hilbers (University of Nijmegen) described the use of a new photonuclear spin polarisation technique, recently developed by Kaptein, to obtain information about proteins in solution. A dye is excited by a laser pulse to its triplet state which then abstracts a proton from an amino acid residue, forming a radical pair whose subsequent recombination causes enhanced intensities for the amino acid resonances. When flavins are used as the dyes, resonances due to tyrosine, histidine and tryptophan which are accessible can be selectively enhanced. The method should prove very useful as a 'surface probe' for the identification and simplification of complex protein spectra. Dr K J Packer (University of East Anglia) gave a brief account of how to overcome the line broadening effects which arise from dipolar couplings and chemical shift anisotropies in the study of solids. It was very pleasing to see that narrow lines could be obtained by the use of double resonance cross-polarisation and 'magic angle' spinning. It is evident that once the considerable technical difficulties are overcome this field will yield much interesting information about the structure of solids.

Further developments in two-dimensional Fourier transform spectroscopy, which reveals chemical shifts in one dimension and spin coupling in the other, were reported. Professor R Ernst (ETH, Zurich) concentrated on the more theoretical side, giving a lucid explanation of the technique and its uses in studying the normally forbidden multiple quantum transitions. Dr R Freeman (University of Oxford) described the more chemical applications, including an interesting discussion of the correlation of ^{13}C and ^{1}H chemical shifts in two dimensions. The usefulness seems to be in the realm of the pure NMR spectroscopist since only first-order spectra may be interpreted at present.

An application of spin-echo NMR techniques in screening for the deficiency of lactate dehydrogenase in human red blood cells was outlined by Dr I D Campbell (University of Oxford). Glucose was added to sugar-depleted cells and the lactate concentration monitored by the lactate methyl resonance. The quest for even higher magnetic fields, which give greater signal intensity and frequency separation, continues and Professor J Dakok (Carnegie-Mellon University) gave an insight into his experiences in obtaining spectra on a new 14 T superconducting magnet operating for ^{1}H at 600 MHz. The magnet, which is not persistent, was capable of attaining line resolution of better than 1 Hz. It was clear that, although this is not an easy area to work in, the