HYDROGEN MASER SUPPORT OF VLBI FOR THE NASA CRUSTAL DYNAMICS PROJECT

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For the NASA Crustal Dynamics Project VLBI network, signals from quasars are recorded simultaneously at widely separated antennas. It is well known that hydrogen maser frequency standards provide the stable frequency reference used to precisely measure the difference in arrival time of the radio signals at the different antennas, enabling the determination of precise distances between the antennas. This paper reviews the practical requirements for maser support of VLBI for the Crustal Dynamics Project and describes the means used to meet these requirements for a network of eight fixed and three mobile stations which participate in approximately 200 VLBI experiments per year at locations in North America and the Pacific.

The masers must provide a stable reference signal with frequency stability better than 1E-14 for tau's of 100 to 1000 seconds. The masers used in the Project have a stability of approximately 2E-15 for these tau's.

The extensive schedule of observations demands exceptional reliability of the network of hydrogen masers. Each maser must have a long mean time between failures and short down times for preventive maintenance and any component failures. The NR masers were developed to fulfill those needs, and BFEC has established an extensive system of communications, data acquisition and analysis, design, and logistics support to ensure this performance.

The NR maser is equipped with a microprocessor which actively monitors 64 voltage, current, temperature and signal levels. Failures are often anticipated and prevented by thorough monitoring and analysis of important performance parameters over time. For data acquisition and analysis, BFEC has established a comprehensive network of communications with the masers. At the stations, data is retrieved by a small computer through a maser RS-232 port and then relayed to BFEC through electronic mail or direct phone lines. In the mobile VLBI data systems, a lap-top computer is used for data retrieval and then taken to a nearby telephone to access electronic mail.

With data for each maser taken an average of twice a week, a large data base has been compiled over the past four years. With such an extensive history on eleven NR masers, many failures can be predicted

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and nearly all have been prevented from occurring during VLBI operations.

The frequency performance of a maser is vital in determining the quality of the standard and also in the early detection of problems. To compare the remote masers with a common reference, time position measurements are made relative to the Global Positioning System. On the mobile sites and at fixed stations, the portable computer utilized for maser data transmission receives a digital output from a GPS timing receiver. Averaged time positions are sent to BFEC headquarters via electronic mail and a data base is collected for each maser time position. From this data, frequency offsets for each maser are determined and corrected.

Frequency offsets can develop as a result of drifts in a maser's cavity thermal control point due to aging of components in the control circuitry. These aging rates cause a second order time component, a change in the maser operating frequency over time. In addition, the frequency stability of the maser degrades as changes in the thermal control point cause small changes in the physical size of the cavity. The NR maser can be programmed to offset the cavity drift by controlling the cavity heater current over time. The cavity drift of a maser must be characterized through frequent flux-tuning with a second maser as reference. Cavity tuning is performed in the BFEC laboratory and can be done elsewhere when two of more masers are located at a common site.

Cavity tuning and characterization, as well as frequency stability measurements, are performed when the mobile VLBI systems are stationed at the Mojave Base Station. The frequency difference measurements utilize a measurement system contained within each NR maser, and the hydrogen flux variations and measurements are controlled and recorded by the masers' microprocessors. This configuration is also used to measure the masers' hydrogen line quality factor (line Q). The variation in line Q for each maser is studied to detect deterioration, if any, over the years. Masers with a line Q of less than 1.0 E9 have been returned to the BFEC laboratory for improvement.

All efforts are made to assure optimum maser performance through remote data monitoring coupled with preventive maintenance. But, in addition to thorough analysis and prevention, there is a need for rapid response hydrogen maser support. The Crustal Dynamics Project requires that BFEC "fix 95% of the maser problems within 72 hours or less" for a network of eleven observatories in North America and the Pacific. Rapid response support is achieved through communications, logistics, and maintenance techniques developed over the past five years. Maser problems are answered by phone and electronic mail seven days a week, 24 hours a day. More serious problems prompt rapid shipment of replacement components or field maintenance. When necessary, a replacement maser is shipped out with all systems operating. An extensive network of air cargo and truck transport arrangements has been formed to handle maser shipments on short notice.