A SPACEBORNE MULTI-ARM INTERFEROMETER FOR VLF GRAVITATIONAL WAVE DETECTION. (THE SMILE PROJECT)

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ABSTRACT. This project would be the next step in our ability to detect very low frequency (VLF) gravitational waves and the first committed spaceborne designed experiment. Present Deep Space spacecraft tracking experiments are severely limited in their detection capability. It is proposed to construct a spaceborne multi-arm microwave interferometer using current elements of design applicable for the detection of VLF gravitational waves. The elements are outlined with particular emphasis placed on the utilization of small inexpensive get away special (GAS) modules currently under development at JPL for launch in the 1990's.

1. INTRODUCTION

The search for gravitational waves of astrophysical origin is an outstanding challenge to present day physics and is being persued by eminent experimental teams in several parts of the world. Most efforts aim at the detection of high frequency, broadband pulses emitted by catastrophic event during the collapse of supernovae in our own or nearby galaxies.

Another important class of sources of gravitational waves are primordial events, collapses of nuclei of quasars and galaxies, and a full set of sources during the early epochs of the cosmos. This very low frequency (VLF) component, the cosmic background of gravitational radiation, bathes the solar system isotropically with an unknown amount of energy. This background produces a stationary spectrum in which the sensitivity of the experiment increases with the square root of the observing time. More important, one can exploit the fact that the correlation function of the observable is negative at the round trip light time in the detector.

At present we have been searching for VLF gravitational radiation using standard Deep Space tracking procedures (1). Basic limitations of the current systems are well understood and severely limit detection capabilities.

M. J. Reid and J. M. Moran (eds.), The Impact of VLBI on Astrophysics and Geophysics, 321–322.

2. THE SMILE PROJECT

One way around the current limitation is to construct a totally space based system. A spaceborne multi-arm interferometer contains elements which have recently been addressed through laboratory implementation, laboratory experimentation and in recent space experiments. The study underway proposes to implement a multi-arm microwave interferometer which will have a resolution of a few parts in 10^{17} in spatial resolution operating in the period range of 100 to 1000 seconds. This would allow measurements of G-wave background at 10^{-4} that of cosmic closure density for these wavelengths.

2.1. UTILIZATION OF CURRENT MICROWAVE TRACKING TECHNOLOGY

The design is based upon current proven techniques and would give improvement in sensitivity of over 4 orders of magnitude in power spectral density compared with current space experiments. The design uses 1 meter dish beacon transponders which are carried into position using special small ion drive propulsion modules (2).

2.2. MICROWAVE LINK MARGIN AND SYSTEM CHARACTERISTICS

The study has shown that Ka and Ku frequency bands (16 and 32 Ghz) perform with adequate link margins. Work is now preceeding to design a base module which will have two identical transmit/receive systems and make the carrier phase comparison in the interferometer. Mechanical stability of this module must be monitored to 100 μm for the time periods of 1000 seconds. Rotational stability is similarly monitored using a differential 3 component accelerometer similar in design to one component of the current ESA gravity gradiometer project.

3. CONCLUSIONS

We describe that by using current techniques it is possible to construct a spaceborne microwave multi-arm interferometer suitable for the detection of VLF gravitational waves. Spaceborne laser interferometer systems have been proposed with theoretically greater sensitivities, which however are far more difficult to build and operate than the system described here which is based upon current technology. Furthermore we suggest that the next constructive step to detect gravitational waves in space would be to deploy these small inexpensive modules. This would open up a new range of experimental sensitivities to VLF gravitational waves and allow us to overcome practical difficulties created by even more challenging experiments in the future.

4. REFERENCES

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(2) Lunar Get Away Special Ion Drive feasibility study. JPL D-4181, March 4, 1987.