A VERY LOW FREQUENCY GRAVITY WAVE ANTENNA

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Abstract

This paper briefly describes a very low frequency (VLF) gravity wave antenna, and the difficulty of detecting the small signals expected.

1. Introduction

Gravity waves carry a tidal force, just like the force that drives the tides in the oceans. Ocean waves are so similar to gravity waves that understanding one is a help in understanding the other.

Suppose two boats floating sideways in the waves are connected together with a bungee cord at their middles. As they go over the crest, they are on opposite sides of the wave for a moment trying to go in opposite directions. The bungee cord stretches, absorbing the energy and storing it until the boats reach the other side where it will give back the stored energy by pulling the boats back together in the trough. All the energy is returned. From a distance the boats are seen to ride the waves, separating on the crests, but always returning to the original separation in the troughs. The variation in distance is synchronized with the waves; the vibration occurs at a frequency dependent on the speed of the waves and the distance between the crests—i.e., the wavelength.

A gravity wave antenna, shown schematically in Figure 1, responds in much the same way as the boats in the water. Instead of a bungee cord, a length of music wire under tension between the antenna's pendula stores and returns the energy of passing gravity waves. Gravity waves, moving at the speed of light, can resonate to amplify the spacing between the antenna's pendula, but the antenna must be synchronized exactly with the wave to take advantage of its very high efficiency. Unfortunately, the wavelength, and therefore its frequency, is an unknown; however, by changing the effective length of its music wire, the antenna can be tuned and enabled to scan a band of frequencies in search of gravity waves.

2. A very low frequency antenna

A "conventional" high frequency gravity wave antenna takes the form of a large aluminum bar weighing several tons. The cost of an aluminum bar antenna exceeds the resources of an amateur, so I am building a very low frequency (VLF) antenna which will tune from 0.1 Hz (below the seismic noise band) down to 0.009 Hz. I will build a frequency scanner that will scan between 0.1 and 0.009 Hz automatically. Metering drums on each pendulum will very slowly replace 0.1 mm music wire with 0.15 mm wire to scan from 0.009 to 0.014 Hz; 0.2 mm wire will then replace the 0.15 mm to scan to 0.018 Hz and so on up to 0.1 Hz.

I used a coil in a magnetic field to detect vibrations in a prototype antenna. The voltage induced in the coil was amplified and recorded on a seismograph drum to measure the frequency very accurately. I will use the same system on the VLF antenna. The coils can also be used as a signal generator for testing the antenna.The addition of moving capacitor plates that de-tune an oscillator will provide a more sensitive detector. I have also designed an interferometer that will detect vibrations in the nanometer range,

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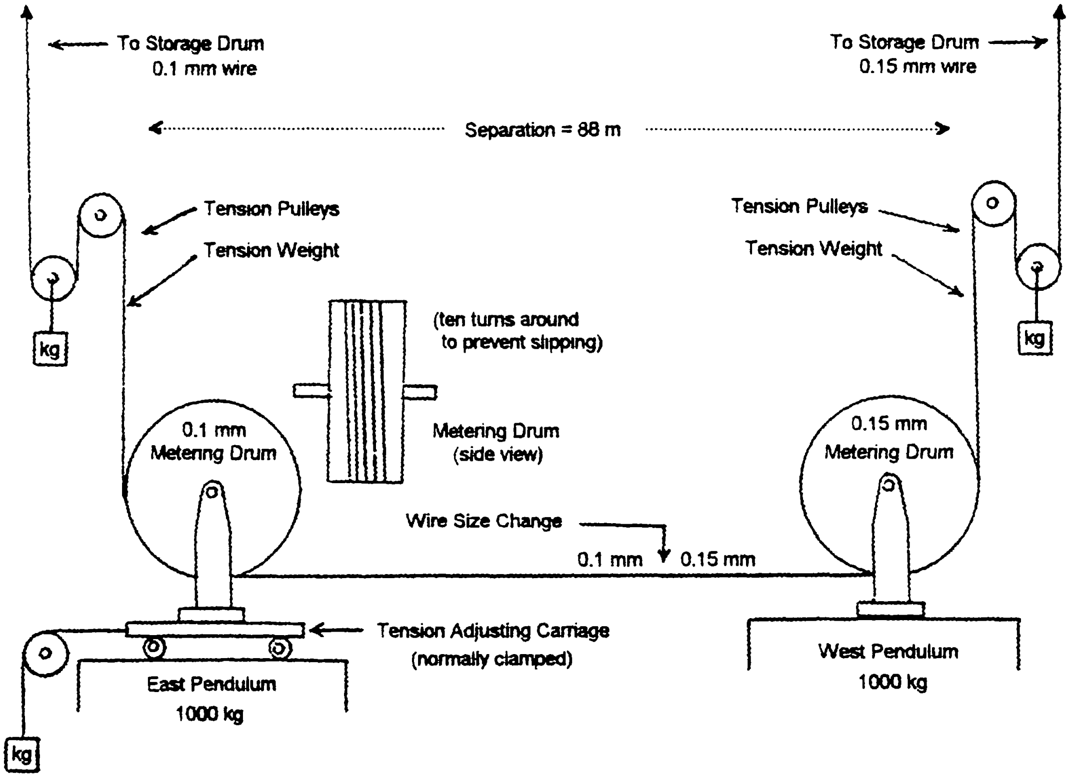

Figure 1. Schematic of a very low frequency (VLF) gravity wave antenna.

using a strand of optical fiber stretched between the pendula instead of mirrors. The loop of optical fiber will be under tension and vibrations will change its length and therefore the length of the light path through it. This will move a fringe on a photodiode to produce an electrical signal at the resonant frequency of the antenna. The signal will be amplified and filtered and recorded on the seismograph drum.

My pendula are separated by 88 m because I have a lot of space. They could be closer together but some sensitivity would be lost and it would be harder to tune the antenna to the lower frequencies.

More detailed information about building this antenna is available from the author.

3. Sources of gravity waves and the improbability of detecting them

Whenever two stars rotate around each other in a binary orbit, gravity waves are emitted. The energy radiated depends on the masses of the stars and the distance between them. If two neutron stars, each having a mass equal to the Sun, radiate away their orbital energy over millions of years, they will come closer and closer together until at last they coalesce in a final burst of tremendous energy.

When the diameter of their orbit is 100 km, they will be making 80 revolutions per second and radiating at a frequency of 160 Hz. Their energy radiated is 10^{51} erg/sec. During the next second the frequency will sweep through 1600 Hz as the stars coalesce, emitting 10^{52} erg. This final burst of energy should be detectable from anywhere in the galaxy by the aluminum bar antennas that resonate in the 1 kHz range. 10^{52} erg is equal to about 1% of the rest mass of the system and compares to the 10^{53} erg, mostly neutrinos, radiated by supernova 1987A during the second or so it took to collapse into a neutron star. (The sun's total luminescence, by contrast, is only 10^{33} erg/sec.)

From the above it would appear that gravity waves should be undetectable at the 0.1 – 0.009 Hz range of the antenna described above. However, a low frequency antenna detects changes in distance between the pendula while passing along the energy instead of absorbing it as do aluminum bar antennas that resonate in the 1.0 kHz range. Its cross-section is very tiny because frictional damping (air resistance) is negligible at 0.01 Hz, nearly the same as if the antenna were in a vacuum.

The vibrations vary inversely as the square of frequency. The antenna's low frequency range of .009 Hz differs by a factor of more than 100,000 from the 1000 Hz signal of the aluminum bar antennas. Squaring this amounts to a gain in sensitivity of over ten billion. This tremendous gain is due to the much longer time the tidal force has to accelerate the antenna in one direction, and goes a long way toward overcoming the power handicap at low frequencies. It is also an advantage to search the low frequencies because the remaining lifetime of binary systems varies inversely as the power radiated. The lower the frequency, the greater the number of possible sources of gravity waves and the more likely one will be near enough to the solar system to be within the capability of the antenna to detect it.

Gravity waves have never been detected directly and our knowledge of them is all based on theory. About the best that can be said is with considerable luck it is probably not impossible to detect a signal with an antenna scanning the frequencies below the seismic noise band. The only way to find out is to try. If history can be trusted, there may be surprises in store. When radio was in its infancy, theory predicted that radiation at radio frequencies from the stars would be negligible and undetectable. Nobody tried and it was left to Karl Jansky to discover cosmic radio waves by accident. Even then astronomers did not seem to appreciate their importance and left it to an amateur, Grote Reber, to build the first radio telescope and make the first radio map of the galaxy. Will history repeat itself? Nobody can say, but it might just be worthwhile to check those very low frequencies where no one has looked so far.

4. Acknowledgements

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