Detection of Low Frequency Electromagnetic Radiation in the Laboratory

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Personal Details
After completing the Diploma in Applied Science (Physics Option) in 2002, I transferred into the Degree in Physics & Physics Technology. I took most of the subject options available in final year. I was class rep for both the Diploma and Degree courses. I have been continually involved in many areas outside the academic field, while in college. My interests and hobbies include music, reading, swimming, cycling, aviation, neolithic history, archaeo-astronomy, cinema and socialising.

Project Summary
A detection system for Extremely Low Frequency (ELF) and Very Low Frequency (VLF) electromagnetic radiation was constructed and its performance between 0 – 45 Hz was examined. An octoloop antenna and associated circuits were constructed. Different software packages were tested for capturing and analysing the signal. Data was recorded and analysed using the investigated software.

Results showed large quantities of low frequency background radiation in the environment of the laboratory. The majority of it was generated from electrical devices in the laboratory and in the surrounding vicinity. It was not possible to identify specific sources or emitters of electromagnetic radiation.

Electromagnetic energy is radiated in the form of a wave as a result of the acceleration of electric charges. A moving charge gives rise to a magnetic field and if the motion oscillates, then the magnetic field varies and in turn produces an electric field. The configuration of these fields varies in space and time and propagate as traveling waves of a wide range of frequencies.

Sources of LF are both natural and artificial. Electrical devices and power lines emit EM fields and pulses of varying intensities. The main natural sources of electromagnetic radiation are the Sun, the Earth and where they interact in the magnetosphere. The magnetosphere is a cavity above the ionosphere generated by the interaction of Earth’s magnetic field and solar wind.

It is known that natural resonant cavities exist in the magnetosphere and they are sources of particularly low frequency radiation. The plasmas contained within the cavities of the magnetosphere are dispersive. The effect of this is that when an electromagnetic wave propagates within cavities, it’s different frequency components travel at different velocities. The waves propagating in these cavities range in frequency from 1 Hz to 100 MHz. They are detected as radio signals and are known as sferics. Others when converted to audio can be heard as tones of decreasing frequency, know as whistles. Sferics are the snap, crackle and pop of lightning storms and whistlers are sferics that have become dispersed in time to the point of becoming a descending tone. It was hoped at the outset to detect such phenomena.

A shielded octoloop antenna was constructed. It had a diameter of 2.45m. It was built on a wooden frame that was mounted on a tripod and the frame was gimbaled so it could be rotated in order to null out noise. The effective length of wire in the antenna was almost 300m and the antenna had an effective aperture of $170m^2$.

Two circuits were constructed; a tuning circuit and a amplifier circuit. The receiver-amplifier circuit was used in the experiment. It had a cut-off frequency around 47 Hz. Four software packages were tested for recording and analysing the captured signal. None worked perfectly however due to time constraints, the better of the packages was used for the analysis procedure.

A magnet was rotated in front of the antenna, which induced a regular magnetic field and the
responsiveness of the apparatus was tested. This resulted in a visible change in antenna output signal, as captured by the computer (see figure 1).

The software plotted two sets of results; an upper user-defined spectral plot of the signal versus intensity and a lower waterfall plot of the frequency spectrum versus time versus intensity – in colour. Black and blue indicates low intensity, red, orange and yellow represents high intensity and green represents medium intensity, relative to the two extremes.

Large amounts of low frequency background radiation were detected, particularly during the daytime (see figure 1). Very large transient power spikes were detected when the relatively small circuit was switched on / off. Other obvious transients detected were computer monitors being turned on or off in the lab. Background levels were much lower at night-time (see figure 2).

Electrical earthing and shielding was an issue with the circuit. The noise factor in the data sampled was at times almost as large as the signal detected. The gimbal wasn’t effective due to the quantity of EM noise in the area surrounding the antenna. No atmospheric interactions were sampled during the experiment due to the quantity of background radiation in the area.

Figure 1. Signal response from regular induced magnetic field. Note daytime background levels of radiation before and after induced magnetic field and harmonics at 10, 20, 30 and 40 Hz.

Figure 2. Night-time signal response. Note average low frequency EM levels are much lower.