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Fabrication of a Portable ULF Signal Receiver for Monitoring Electromagnetic Earthquake Precursors

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Abstract: A portable Ultra Low Frequency (ULF) signal receiver, which can be made available in Physics laboratory was designed and fabricated for detection and identification of seismo electromagnetic signals that can be considered as precursory phenomena of earthquakes. The receiver circuit has four major sections that function as sophisticated signal processing and amplifier and powered by +5 to -5 V regulated source. A low pass filter circuit, in which a Butterworth filter was the gate of the circuit, was employed to receive Ultra-Low Frequency (ULF) signals of desired frequency. The frequencies of interest are those ranging from 0.001-45 Hz. The desired frequencies then passed through a series of filters to remove transient noise, Electromagnetic Interferences (EMI) and 50 or 60 Hz frequency caused by commercial power, which could cluster the desired signal on the oscilloscope.

Key words: Fabrication, portable ULF signal reciever, monitoring, electromagnetic

INTRODUCTION

The reliable geophysical instrumentation for the detection and identification of seismo-electromagnetic signals that could be considered as precursory phenomena of earthquakes has become a fundamental aspect of earthquake prediction research. This has made the research for earthquake precursory phenomena gained new dynamics by focusing on electric, magnetic and electromagnetic transient variations that precede seismic activities. Such anomalous effects have been repeatedly reported from field observations (Frasher-Smith *et al*., 1990; Di Bello *et al*., 1996; Cuomo *et al*., 1997; Varotsos *et al*., 1993; Nomikos and Vallianatos, 1996, 1997; Vallianatos and Nomikos, 1998; Hayakawa *et al*., 2000).

It is now widely accepted that the earthquake preparation processes consist of not only seismic (tectonic or elastic) but also electromagnetic events (Hayakawa and Fujinawa, 1994; Hayakawa *et al*., 1996; Hayakawa and Molchanov, 2002). Such electromagnetic phenomena could appear in a wide frequency range, from DC to MHz frequencies and these precursory seismo-electromagnetic effects are expected to be useful for the mitigation of earthquake hazards.

In our approach, we directed attention to fabrication of low cost equipment capable of collecting ULF electromagnetic waves in the range of 0.001-45 Hz. This band was chosen based on the fact that higher frequency components cannot propagate over long distances in the lithosphere due to severe attenuation, but ULF waves can propagate up to an observation point near the earth's surface with small attenuation. And also, the amplitude of these signals varies in linear proportion to distance when propagating through the earth. Thus, with many receive stations place strategically, the source and strength of the signals can be determined. Due to the penetrating ability of this ULF, electromagnetic signal near the earth surface, it may then be useful to determine if there is a feasible method of detecting seismic events of significant importance, with enough reliability and timing to warn the people living near the active seismic zones of an impending disaster. This early warning could be very useful in determining if the seismic anomaly is going to take place in a populated area or not.

MATERIALS AND METHODS

In our attempt to construct a reliable receiver capable of collecting ULF signals of desired band, the electronic circuit of the receiver was designed and arranged into 4 stages (Fig. 1). These stages are:

- Pre-amplification stage
- Low frequency filtering stage
- Low pass filtering stage
- Post amplification and noise filtering stage

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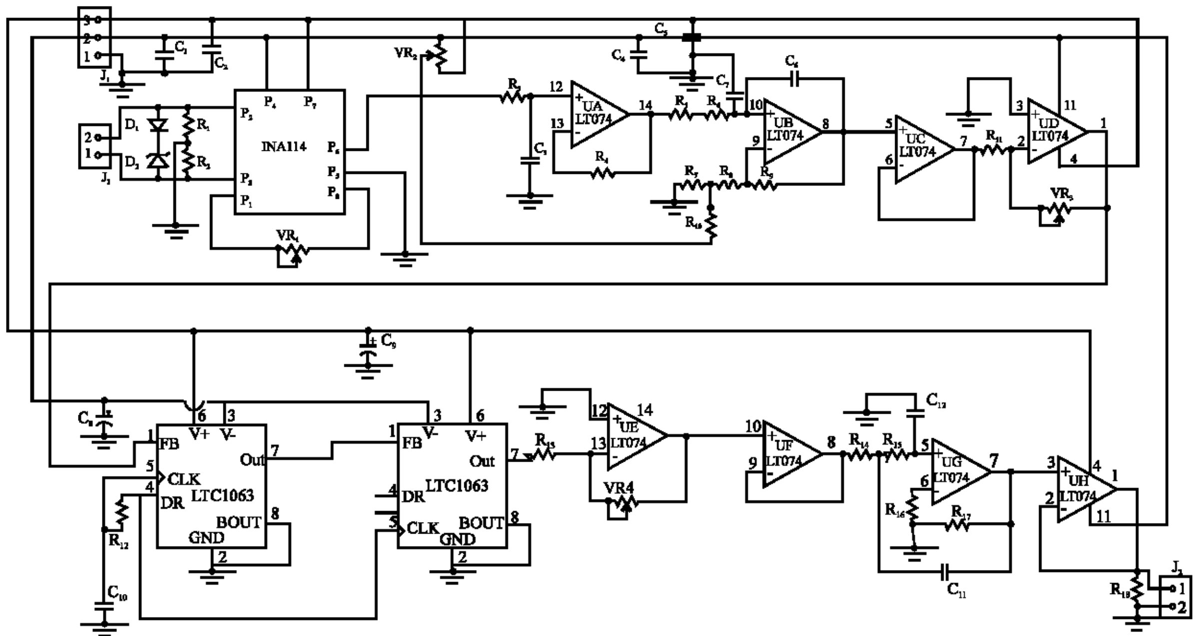

Fig. 1: The schematic diagram of the ULF receiver

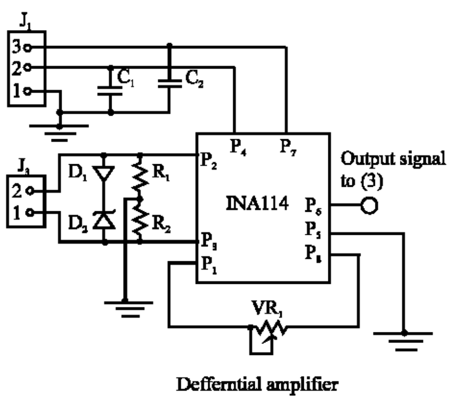

Fig. 2: High gain high impedance differential amplifier

Pre-amplification stage: The high impedance differential instrumentation amplifier was employed as a signal processing pre-amplifier that enables the impedance of the circuit matches with that of the antenna. This step was taken to enhance the efficient and effective transmission of the signal strength from the source to the electronic circuit of the receiver and also to ensure that the circuit is not damaged due to a current surge that may occur in case of high voltage spikes, which is quite possible during lightening and thunderstorms. The conformity between the impedance of circuit and the antenna was achieved due to the impedance matching resistors R_1 and R_2 that are connected to the input of the differential amplifier. INA 114 Integrated Circuit (IC) manufactured by linear technology is the high impedance differential amplifier employed to perform the task stated above (Fig. 2). The schematic is shown in Fig. 3.

Low frequency filtering stage: The output signals from the pre-amplification section of the circuit was filtered and amplified here to remove both cultural noise and electromagnetic interference or disturbances that might have been insinuated with the desired signals. TL 074 integrated circuit manufactured by Texas instruments was used to execute this buffer filtering amplification process. It is a 14 pin integrated circuit that houses 4 operational amplifiers. The main purpose of the operational amplifiers, is to amplify to a reasonable amplitude the low frequency from the pre-amplification stage and attenuating or filter off the higher frequency signals. Therefore, the signals are being conditioned or shaped for the actual processing that will be carried out by the next stage (Fig. 4).

Low pass filter stage: The low pass filter integrated circuit was so configured to attenuate high frequency, which might have escaped from the previous low frequency filtering section and also to shunt to the ground any form of noise contributed as a result of Electromagnetic Interferences (EMI), noise generated as a result of current through the components that is thermally noise generator, improper component grounding and the noise from the antenna. The two low pass filter circuit used here is known as Butterworth low pass filter ICs manufactured by

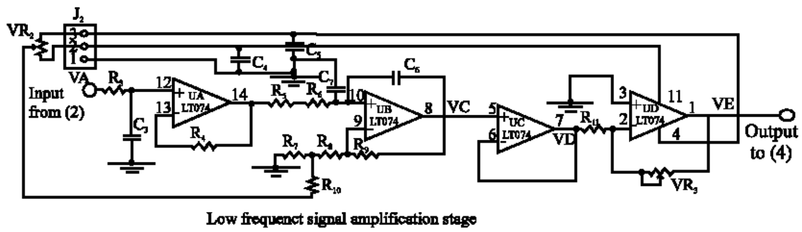

Fig. 3: Schematic diagram showing low frequency filtering amplifier

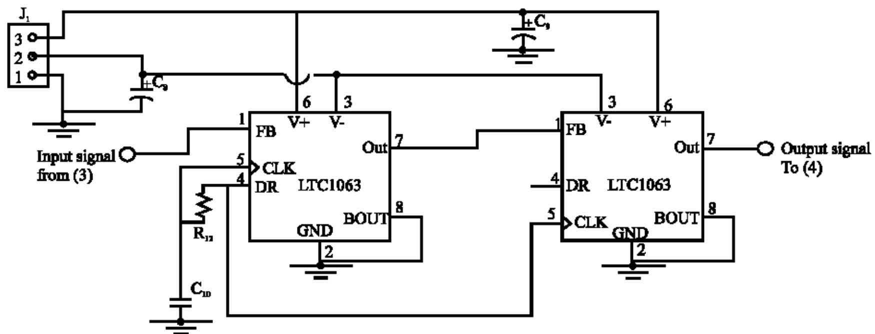

Fig. 4: Four stages Butterworth low pass filter

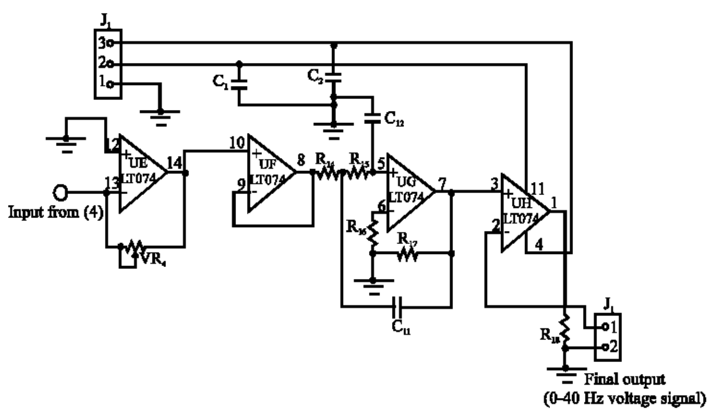

Fig. 5: Schematic diagram of the noise filtering high current post amplification

linear Technology. The two ICs are cascaded in such away that they will generate the output gains of 1.152 and 2.235. These values were so chosen to avoid dynamic range problems and combination of identical resistors and capacitors were introduced as smooth filtering circuit to set the desired frequency to 3 dB point.

$$RC = \frac{1}{2\Pi f_C}$$

Where, f_c is the desired 3Db frequency of the entire filter. The Butterworth filter, which produces extremely flat response at the expense of steepness in the transition region has the amplitude as shown:

$$\frac{Vout}{Vin} = \frac{1}{\left(1+\left(\frac{f}{f_c}\right)^{2n}\right)^{1/2}}$$

Where:

n = In the order of the filter, which is 2 in this case

f_c = The cut-off frequency which is equal to 30 Hz

The two cascaded LTC1063 were used in this stage as a DC accurate low pass filter that served as a signal passing gate to improve offset voltage. The basic idea here is to put the filter outside the DC path, letting the low frequency signal components couple passively to the output. This will make the filter grabs the signal line of high frequencies and rolls off the response by shunting the signal to the ground. Being that Butterworth filter ICs are clock controlled, the clock frequency was set at 3000 Hz by the gain. This then configured the chips to a frequency of 30 Hz and a clock ratio of 1/100.

Post amplification and noise filtering stage: The buffer amplifier and analog low pass filter were used here to remove any residual clocking pulses or noise from the final output desired signal, which might have been caused by Butterworth low pass filter in cascade (Fig. 5).

RESULTS AND DISCUSSION

Since, the signals coming from the antenna are weak signals, using conventional measuring devices such as the voltmeter, ammeter or even the low impedance oscilloscope, the results obtained would not in any way be of any significance. The measuring device would simply shunt the weak incoming signals to nothing.

Thus, to obtain a good result worthy of computation, a signal generator was used to generate a signal of known amplitude and frequency and used as discussed below. The signal at the signal generator is as shown in Fig. 6.

The output response, Bx, of the ULF receiver to the signals from the signal generator is also shown in Fig. 7.

The observed response to the signals received from the antenna by the ULF receiver is shown in Fig. 8.

Figure 6 shows the signature of the 'pure' signals coming from the signal generator and Fig. 7 is the response of the ULF receiver to the 'pure signals received and processed by the filter circuit. It could be easily seen that the response was amplified to an appreciable extent.

Figure 8 shows the signature of the output response to the input signals received from the antenna. We can see that there is a marked departure from theoretically expected response that is that of the signal generator, represented by the dotted line. This observation obtained shows that both amplification and filtering stages are working normally and have removed any unwanted signals like Electromagnetic Interferences (EMIs), components thermal noises, inadequate shielding or unshielded components terminals, co-channel interferences and component tolerance that can lead to ground loop problems when using the equipment on the field.

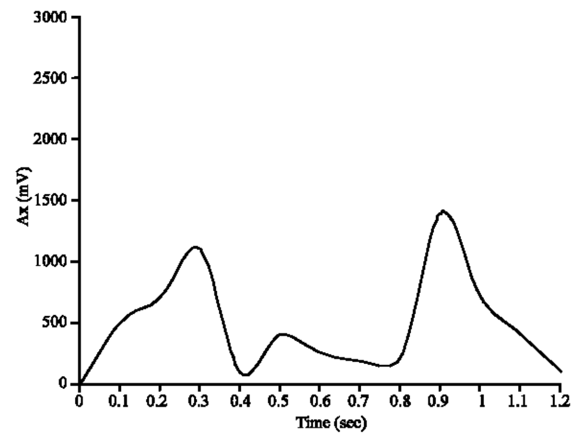

Fig. 6: The graph of the signal from the signal generator with time

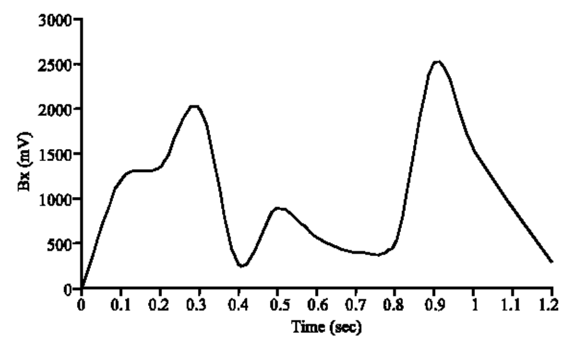

Fig. 7: The output response of the ULF receiver to the input from the signal generator with time

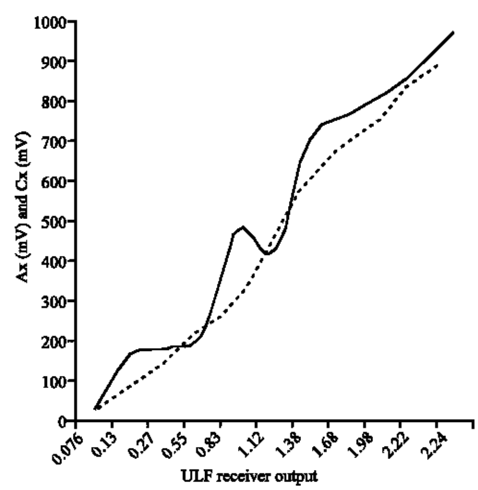

Fig. 8: The graph of the signal from the antenna and the expected signal from the signal generator against the output of the ULF receiver

CONCLUSION

Within the limits of experimental errors, we can conclude that the ULF receiver has performed well under service and test conditions and can therefore, be used to detect and measure the level of the frequency disturbances in the earth to an appreciable level of accuracy.

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