Middle-East Journal of Scientific Research 23 (Sensing, Signal Processing and Security): 01-06, 2015
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2015.23.ssps.2

Very Low Frequency Electromagnetic Field Detection

[1]M. Vanathi, [2]R. Balamurali and [3]A. Prasina

[1]PG Scholar, Chennai Institute of Technology, Chennai, Tamil Nadu, India
[2]Associate Professor/ECE, Chennai Institute of Technology, Chennai, Tamil Nadu, India
[3]Associate Professor and Head/ECE, Chennai Institute of Technology, Chennai, Tamil Nadu, India

Abstract: Portable Air Core Copper Coil Sensor transducer is designed in this project which detects the electromagnetic field radiations of very low frequency range (1 KHz - 200 KHz) which is known to cause serious health effects in human beings. The man made Very Low Frequency-VLF Electromagnetic Field generating sources include television sets, video display terminals (VDT), certain medical devices, some radio terminals and Ground Wave Emergency Networks (GWEN) which are used in military communications. These radiations occur naturally from various sources like Thunderstorms, Mountain Winds and Earthquakes. The Electromagnetic Field generated from these sources is known to cause childhood leukemia, inhibition of lymphocyte activity and chronic stress. This necessitates the requirement of a Very Low Frequency-VLF detecting device. The transducer is designed as a portable Electronic system which can monitor the Electromagnetic radiations in residential and occupational areas. An inductive sensor receives the VLF signal by forming a resonant circuit with variable capacitor. The received signal is amplified and required frequency range is filtered out using a band pass filter and Fast Fourier Transform of the signal is performed using LABVIEW software to display the frequency components. Data Acquisition card USB 6008 is used to interface the real time signal with the PC.

Key words:

INTRODUCTION

The potential deleterious health effects of electromagnetic field (EMF) radiations are a continuing concern of scientists and engineers. Our environment has always contained this type of radiation as a result of solar activity, meteorological changes and biosphere activity. Naturally occurring electromagnetic oscillating fields in the very low frequency (VLF) range of the spectrum, from 1 kHz to 200 kHz are weak and difficult to detect under normal conditions. This necessitates the development of a VLF detecting device.

Objective: To design an inductive Air Core Copper Coil Sensor to detect the VLF electromagnetic radiations by designing proper signal conditioning circuit and to display the frequency components by performing Fast Fourier Transform (FFT) of the signal using LABVIEW.

Previous Works Done in this Field: Previous papers discussing instruments working in the non ionizing range of the electromagnetic spectrum have covered magnetic field monitors and sensors operating in a wide frequency range. The portion of the very low frequency range from 50 to 200 kHz has not been widely covered, despite the importance of this range to modern society.

Previously the development of a portable dosimeter with a band pass filter centered at a frequency of 60 Hz was described by C. C. Lo.

In another study, the design of a precision gauss meter with an ac bandwidth up to 10 kHz was described by J. Sedgwick. This instrument utilized a single axis Hall element probe that was not sensitive enough to detect fields in the mill gauss level and did not have embedded data logging capabilities.

A stationary system that uses a personal computer to record the magnetic field on a digital scope was described in a paper by J.L. Guttmann.

Corresponding Author: M. Vanathi, PG Scholar, Chennai Institute of Technology, Chennai, Tamil Nadu, India.
E-mail: vanathi.mit@gmail.com.

Two different sets of orthogonal magnetic field sensors were used to cover the frequency range from (40 Hz to 500 MHz). Ferrite core inductor coils were used as sensors for the low frequency magnetic fields from 40 Hz up to 5 kHz and active loop antennas were used for the high frequency range from 5 kHz to 500 MHz. The antennas had a maximum sensitivity of 4 V/mG and were flat to above 100 kHz. The antenna response decreased to 1 V/mG at 10 kHz and continued to decrease to a minimum of 0.2 V/mG for frequencies below 1 kHz. This antenna implementation caused a non-linear response in the VLF range.

There is a need to develop an instrument capable of accurately and conveniently measuring the magnetic field intensity in the very low frequency (VLF) range from 50 to 200 kHz.

Procedures For Paper Submission
Block Diagram

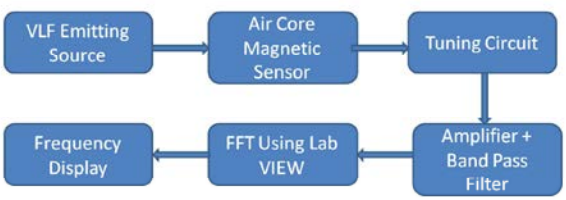

Fig. 1: Block Diagram

Hardware Components: The hardware components includes

- Air core copper coil sensor
- IC 741 Op Amp for amplification
- Band pass filter using TL084
- Power supply circuit

Sensor Description: A multi-turn copper coil is used as a field-sensing element in this detector design. A coil element is well suited for this application since its sensitivity is higher than that of a Hall Effect sensor at frequencies greater than 30 kHz. The coil is wound on a magnetic former (Air Core) with specific number of turns to form a coiled antenna which can receive radio frequency signals of required range. For receiving very low frequency signal the length of the antenna required ranges from several meters to kilometers. Such antennas are not feasible and portable so we go for a coiled antenna type where the copper coils of specified length are wound on a former to receive the electromagnetic field of several frequencies.

Coil Antenna: Antenna is a device which is used to transmit or receive the continuous wave energy radiated oscillates at radio frequencies. The extreme lowest frequency the size of the antenna in length from thousands of meters, whereas the extreme high frequency range the size of the antenna is in fractions of a millimeter. The wavelength L of a wave is related to the frequency F and velocity V of the wave by

$$L=V/F \qquad (1)$$

V= 3 × 10ˆ 8 m/s.
Let F= 125 KHz. Then the wavelength is
L=3 × 10ˆ 8/125000 = 2.4 Km

Because of its long wavelength, a true antenna can never be formed in a limited space of the device. The length of the antenna must be at least quarter of the wavelength (l/4) to receive the signal properly.

Alternatively, a small loop antenna coil that is resonating at the frequency of the interest (i.e., 125 kHz) is used. This type of antenna utilizes near field magnetic induction coupling between transmitting and receiving antenna coils. When the time-varying magnetic field is passing through a coil (antenna), it induces a voltage across the coil terminal. This voltage is utilized to activate the passive tag device. The antenna coil must be designed to maximize this induced voltage.

Principle and Construction of Receiver Coil: Faraday's law states a time-varying magnetic field through a surface bounded by a closed path induces a voltage around the loop. This fundamental principle has important consequences for operation of passive RFID devices. The copper coil is closely wound on a circular former with specific number of turns. Thus an Air Core Sensor has been used to receive the desired frequency. The copper coil is enameled and thus the enamel coating is removed in the two ends of the coil and soldered with wires to take output.

Parallel and Series Resonant Circuit: The inductance for the reader antenna coil is typically in the range of a few hundred to a few thousand micro-Henries (mH) for low frequency applications. The reader antenna can be made of either a single coil that is typically forming a series resonant circuit or a double loop (transformer) antenna coil that forms a parallel resonant circuit. The series resonant circuit results in minimum impedance at the resonance frequency. Therefore, it draws a maximum current at the resonance frequency. On the other hand, the parallel resonant circuit results in maximum impedance at the resonance frequency. Therefore, the current becomes minimized at the resonance frequency. Since the voltage can be stepped up by forming a double loop (parallel) coil, the parallel resonant circuit is often used for a system where a higher voltage signal is required. The series resonant circuit has minimum impedance at the resonance frequency. As a result, maximum current is available in the circuit. This series resonant circuit is typically used for the reader antenna.Here L and C are connected in series to an AC power supply. Inductive reactance magnitude (X_L) increases as frequency increases while capacitive reactance magnitude (X_C) decreases with the increase in frequency. At a particular frequency these two reactance are equal in magnitude but opposite in sign. The frequency at which this happens is the resonant frequency (f_r) for the given circuit.

A variable capacitance is connected in series with the coil antenna and the tuned circuit is used to receive the signal of required range or bandwidth. The capacitance value is varied to receive the desired signal at resonant frequency. The signal received will be in micro or milli volts and it needs to be amplified before giving to filter circuit.

Amplification Unit
Inverting OP-AMP

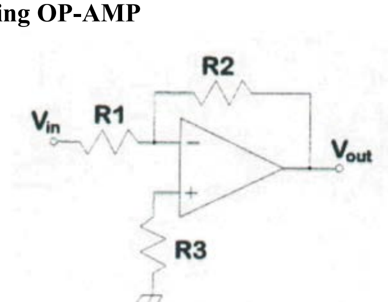

Fig. 2: Inverting Op-Amp

Two stages of amplification have been used to amplify the signal in terms of micro or milli volt to volts. The following components are used in amplification unit:

- IC TL064
- Resistors
- Power supply

TL064 is a 14 pin IC which includes 4 Op-Amps. The TL064 are high speed J-FET input quad operational amplifiers. Each of these J-FET input operational amplifiers incorporates well matched, high voltage J-FET and bipolar transistors in a monolithic integrated circuit. The device features high slew rate, low input bias and offset currents and low offset voltage temperature coefficients. Its pin configuration is given as below

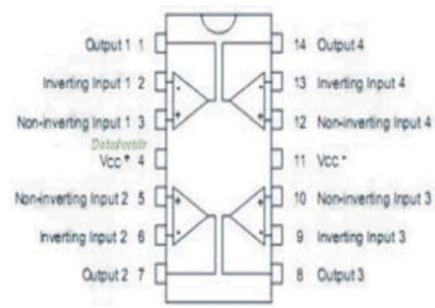

Fig. 3: Pin configuration of TL064

The resistor values which contribute for the gain include

- R1 = 1 k
- R2 = 10 M

The IC is given a supply voltage of +18 and – 18V. The output from the tuning circuit is given to the amplifier and the amplified signal is obtained at the output. The amplified signal is then given to filter circuit to select the required bandwidth.

Filter Section: The filter section includes the band pass filter. The high pass filter and low pass filter is cascaded to form bandpassfilter. In general, a band-pass filter is a device that passes frequencies within a certain range and rejects (attenuates) frequencies outside that range. The bandwidth of the filter is simply the difference between the upper and lower cutoff frequencies. The high pass filter provides the lower cut off frequency and low pass filter provides the upper cut off frequency for a bandpassfilter.

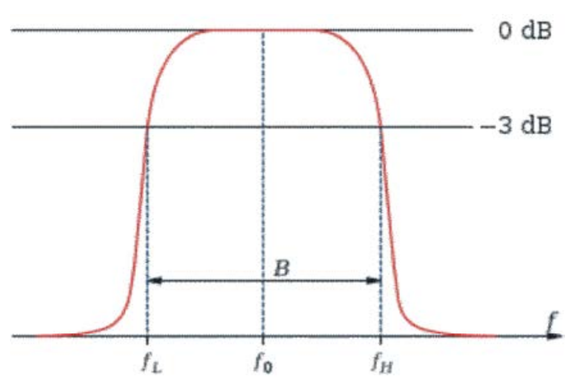

Fig. 4: Bandwidth of band pass filter

From the figure, the bandwidth B of the filter is given as

$$B= Fl - Fh$$

where,
Fl= Lower Cut Off Frequency
Fh = Upper Cut Off Frequency

The band pass filter includes two section:

- High pass filter
- Low pass filter

High Pass Filter: The high pass filter is the device where high frequency inputs greater than the cutoff frequency f0 emerges from the filter with unchanged amplitude, while those inputs with a frequency less than f0 undergo strong attenuation. The band pass filter in the filter section includes second order Butterworth active high pass filter. As the name implies, it attenuates low frequency and passes only high frequency signals. It consists of passive filter section followed by non inverting Op- Amp. The frequency response is same as that of passive filter except that the amplitude of the signal is increased by the gain of the amplifier and for a non inverting amplifier; the value of gain is given by 1+R2/R1. The filter section includes two resistors of same value R and two capacitors of value C.

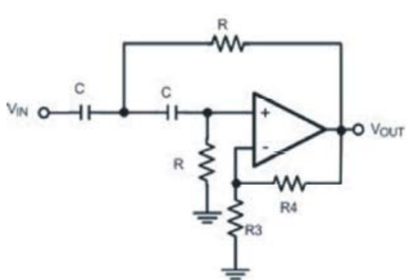

Fig. 5: Second order high pass filter

The transfer function of the second order high pass filter is given by

$$TF=(A0s^2)/(s^2+(3-A0)Wcs+Wc^2) \quad (2)$$

A0= gain of the amplifier = 1+ (R4/R3)
Wc = cut off frequency = 1/ (RC)
Fc = Wc / (2π) = 1/(2πRC)
For Butterworth Filter, 3-A0 = 1.414

The lower cut off frequency of band pass filter is Fl = 150 Hz

$$\text{Let } C = 0.01\ \mu f$$

$$\text{Then } R= 100\ k\Omega$$

The signal is attenuated at rate of 40 db / decade in case of second order high pass filter.

Low Pass Filter: The second section includes the second order low pass filter with cut off frequency of 200 KHz. It is similar to high pass filter except that the capacitor and resistor connections are interchanged. The gain is same as that of high pass filter. The low pass filter passes low frequency signals and attenuates high frequency signals.

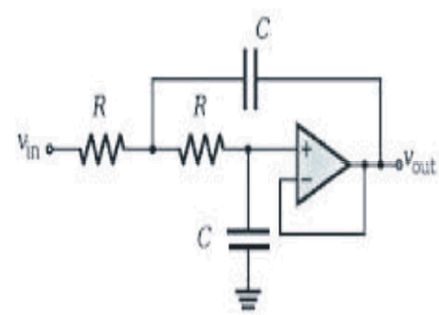

Fig. 6: Second order low pass filter

The gain of the filter is unity. The second order filter includes two resistor and capacitors and is represented by a second order transfer function.

Specifications for filter design:

Wc = cut off frequency = 1/ (RC)
Fc = Wc/ (2π) = 1/ (2πRC)
Cut off frequency F = 200 KHz
R = 820 Ω
C= 0.001 μF

Signals above 200 KHz get attenuated sharply at 40 db/decade.

The high pass and low pass filter cascaded provide the required bandwidth of Band Pass Filter. TL084 is the IC used in filter section. The TL084 is high speed J–FET input quad operational amplifiers incorporating well matched, high voltage J–FET and bipolar transistors in a monolithic integrated circuit. The devices feature high slew rates, low input bias and offset currents and low offset voltage temperature coefficient. The pin configuration of TL084 is given in the figure.

TL084 consists of 4 Op-Amps. Op-Amp 1 and 4 is used for high pass filter and low pass filter design respectively. The IC is provided with regulated DC supply voltage of +/- 18V. This voltage is given by power supply circuit discussed in the next section.

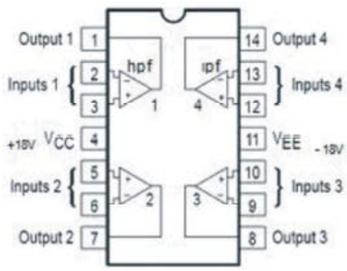

Fig 7: Pin configuration of TL084

Power Supply Circuit: The power supply circuit includes the following components:

- Centered tapped 18V (1 Amp) transformer
- IN4007 diodes forming bridge circuit
- 2200µf capacitance (35 V)
- 7918,7818 voltage regulator

The circuit diagram for the power supply circuit is given as below:

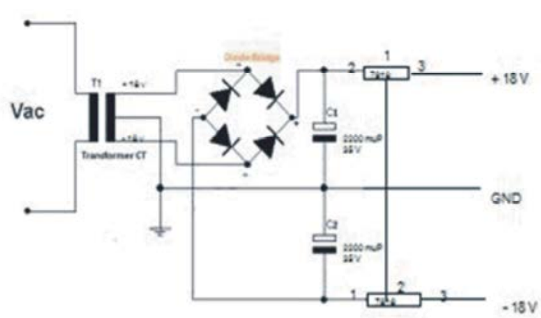

Fig. 8: Power supply circuit

Software Components: The software components include:

- Lab VIEW 8.6
- Driver software to interface DAQ USB 6008

The real time signal obtained as output from the hardware part is interfaced to pc using DAQ USB 6008. The DAQ is configured and signal is processed using FFT tool in Lab VIEW. The processed signal is displayed using waveform graph present in the software.

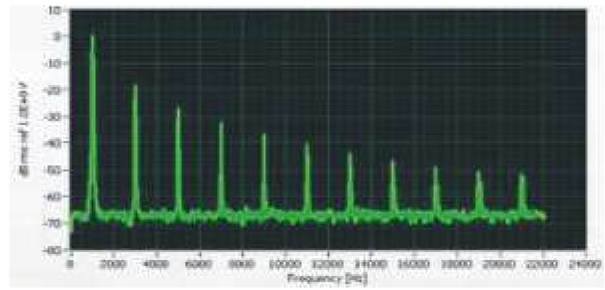

Fig. 9: Sample FFT graph

DAQ USB6008

Fig. 10: DAQ USB 6008

The device has the following specifications:

- 8 analog inputs (12-bit, 10 kS/s)
- analog outputs (12-bit, 150 S/s)
- 12 digital I/O
- USB connection No extra power-supply needed
- Compatible with Lab VIEW, Lab Windows/CVI

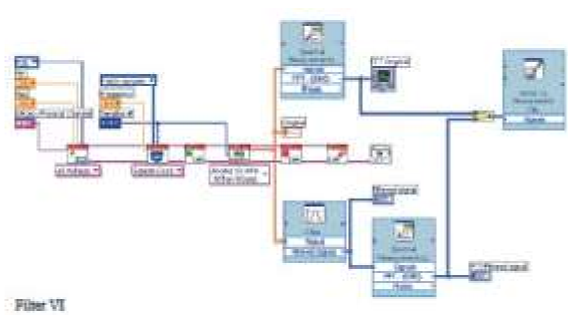

Fig. 11: Sample FFT VI

CONCLUSION

The Portable Electronic Sensor senses the Electromagnetic Radiations in Very Low Frequency Range and further the signal is processed with the help of the above discussed Signal Conditioning Circuits and the output is thus analyzed. Further these radiations can be controlled using suitable signal jammer circuits to protect the sensitive residential areas from the damage caused by the electromagnetic radiations.

REFERENCES

1. Anastasia, S., Safigianni and Christina G. Tsompanidou, 2005. "Measurement of Electric and Magnetic Fields due to the operation of indoor power d istribution substations," IEEE Trans. On Power delivery, 20(3): 1800-1801.
2. Bassett, C.A.L., 1982. "Pulsing Electromagnetic Fields. A new method to modify cell behavior in calcified and Non Calcified Tissues" Calcif Tissue Int., 34: 1.
3. Roy Chaudary, D. and Shail B. Jain, "Linear Integrated Circuits ", Second Edition.
4. Waheed-uz-Zaman1, M. and M.A.K. Yousufzai, 2011. "Design and construction of Very low frequency antenna", Journal of Basic and Applied Sciences, 7(2): 141-145.
5. Saba, A. Hanna and Yuichi Motai, Walter Varhue and Steve Titcomb, 2009. "Very low frequency electromagnetic field detector with data acquisition" a "IEEE transactions on measurement and instrumentation, 58(1).
6. Welsby, V.G., 1960. The Theory and Design of Inductance Coils, John Wiley and Son, Inc.