IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 11, Issue 3, Ver. II (May-Jun .2016), PP 39-46
www.iosrjournals.org

Electromagnetic Compatibility to Bio-Medical Signals Using Shielding Methods

M. Satish Kumar [1] ,A. Jhansirani [2]

[1]*Assistant Professor, Department of Electronics and Communication Engineering, Sri Vasavi Engineering College, T.p.Gudem,, India.*
[2]*Professor, V. R. Siddhartha Engineering College, Vijayawada, India*

Abstract: *This paper presents The Electromagnetic Interference effect from power line noise in Multi Speciality Hospital to Bio-Medical signals. The study includes the design of Bio-Medical signal Generating circuits that is used to eliminate the power line noise from the signal. The Bio-Medical system basically is a combination of Instrumentation Amplifier, High pass filter, Low pass filter, and Notch filter. There are several other circuits developed in this study which are voltage reference, ac-coupling circuit and low pass filter for voltage input from USB power supply. The usage of shielding methods is to get the real Bio-Medical signal without electromagnetic interference from the power line. Shield Methods prevents a range of outside noise from coming into the shield. Therefore, the data taken inside the shield is free from Electrical noise without using notch filter. The result of this study showed that faraday shield can eliminate 50Hz power line noise in Bio-Medical signal*

Keywords: *Bio Medicalsignal, Electromagnetic Interference, Rejection Frequency, Power-line Noise, Faraday shield*

I. Introduction

ECG is an Example for Bio-Medical signal and A diagnostic tool for examining some of the functions of the heart. The ECG is an electrical signal generated by the heart beat in which its signal has an amplitude between 0.5mV to 4mV and signal frequency range of 0.05Hz to 100Hz [1]. There are many factors that should be taken into consideration in the design of an ECG amplifier, such as the frequency distortion, saturation distortion, interference from electric devices and other sources. There are three types of predominant noise that commonly contained in the signal: (i) baseline wander interference, and (iii) 50Hz power line interference. A major source of noise when one is recording or monitoring the ECG is the electric power system [2].

Electromagnetic interference from nearby high power radio or television can also be picked up by a close loop of lead wires. Shield Methods prevents a range of outside noise from coming into the shield. Therefore, the data taken inside the shield is free from Electrical noise without using notch filter

Methodology

EMI is a kind of environmental pollution. With the national emphasis today on the elimination or reduction of environmental pollution, most people readily recognize and understand water, air, noise and other forms of pollution. Most people probably have not heard or know much about spectrum pollution. It cannot be directly seen, tasted, smelled, or felt. Shielding serves to protect Bio-Medical Signal Generating Equipment from High power Radio Frequency(RF) Transmitters Protect personnel working within buildings RF radiation Prevent classified information is intercepted through the utilization of espionage techniques

Shielding Methods and Calculations Of Shielding Effectiveness

EMI interferes into the system in two ways by either radiation or conduction. EMI is considered to be a silent and unknown threat. As explained above malfunctions and random

Failures of equipment are experienced by many users. They are attributed to be due to the presence of EMI Design methods for EMC Electromagnetic wave shielding is the means by which the transmission of electromagnetic waves to the exterior is prevented by reflection off, the wave shielding material or by the absorption into the material. The shielding capability is defined by how much the electromagnetic waves incident upon a substance can be attenuated.

According to Shelkunoff's theory on passive electromagnetic shielding, the shielding effect exerted by a metallic sheet is denoted as the synthesis of three kinds of losses, i.e., absorption loss, reflection loss and

multiple reflection loss. Generally, the sum, Se (dB), of the individual shielding effects observed when electromagnetic waves impinge on a metallic sheet or material as follows.
Se (dB) = A (dB) + R (dB) + M (dB)
Where A is the absorption loss in dB, or the attenuation due to transmission into a metallic surface; and M is the multiple reflection loss in dB due to the repeated reflections on both surfaces of a metallic sheet.

First, A is calculated using specific electric conductivity,□ □ r, and a specific permeability□ □ r, to copper as follows:

A (dB) = 131.4*t* SQRT(f σr μ r)

Where t is the thickness of copper sheet (m) and f is the frequency (Hz) A is thus proportional to (f σr μr) . As far as copper is concerned. sr = 1 and mr = 1. Specific absorption loss k1 ( ) *r r f* s m = 1 where k1 is a proportional constant and is equal to 1. This value is considered an index of the magnitude of a shielding effect due to the attenuation, with the value of copper being taken as unity. The data for various metals is shown in the table 1 along with the data for both the specific electric conductivity and specific permeability. It is clear from the table that the specific absorption loss for iron is much larger than that for copper.

Absorbing Material Based On the Below Calculations

Layer design depends upon the character of the EMI. EMI wavelengths much larger than the sizes of the systems of interest require quite different procedures than for smaller wavelengths. EMI absorption is a two-part problem; the first part is to get the offending field to penetrate the absorber and the second part is to absorb it. As we have seen just off the surface of an ideal conductor the magnetic field is tangential to the surface the electric field has a normal component. Normal electric fields support wave that travel along the surface. Tangential magnetic and electric field components have maximum and minimum values, respectively; just off the surface of an ideal conductor, therefore thin absorbers may be useful if they support a magnetic field loss. They are not if they support and electric field loss for inside the layer a tangential electric field is small and a normal component is 1/ □ times the external one

Metal	Specific Electric Conductivity σ r	Specific Permeability μ r (≤ 10 kHz)	Specific absorption loss in dB A = k1 (σ r μ r)	Specific reflection loss in dB R = k (σ r / μ r)	Shelkunoff's Shielding effectiveness factor in dB Se (dB) = R(dB)+A(dB)
Silver	1.064	1	1.03	1.3	2.06
Copper(Solid)	1.00	1	1.00	1	1
per (flame Spray)	0.10	1	0.316	0.316	0.632
Gold	0.70	1	0.836	0.836	1.672
Chromium	0.664	1	0.814	0.814	1.628
Aluminum (Soft)	0.63	1	0.79	0.79	1.58
Aluminum (tempered)	0.40	1	0.632	0.632	1.264
Aluminum (household foil,1mil)	0.53	1	0.728	0.728	1.456
Aluminum (flame spray)	0.036	1	0.189	0.189	0.378
Brass (91% cu,9%zn)	0.047	1	0.216	0.216	0.432
Brass (66%Cu,34%Zn)	0.35	1	0.59	0.59	1.18
Zink	0.305	1	0.552	0.552	1.104
Tin	0.151	1	0.388	0.388	0.776
supermalloy	0.023	100,000	47.9	0.000479	47.9
78 Perm alloy	0.108	8,000	29.3	0.0036	29.3036
Purified Iron	0.17	5,000	29.15	0.0058	29.1558
ConeticAA	0.031	20,000	24.8	0.0012	24.8012
4-79 Perm alloy	0.0314	20,000	25.05	0.00125	24.05125
Mumetal	0.0289	20,000	24.04	0.0012	24.0412
Permendur	0.247	800	14.05	0.0175	14.0675
Hyperlink	0.0345	4,500	12.45	0.00276	12.45276
45 Perm alloy (1200 anneal)	0.0384	4,000	12.39	0.0030	12.3930
45 Perm	0.0384	2,500	9.79	0.0039	9.7939

1)**DIELECTRIC ABSORBERS**

Since maximum electric fields occur away from conductors, conductor backing is not important for dielectric absorbers. Instead, thick layers are needed. In thick layers, the absorption requirement is that the internal wave.impedance be nearly that of free space. Since the relative permeability is one, it follows that the relative permittivity should be as close to one as possible, consistent with power absorption. A problem is, however, that since ceramics have a relative permittivity that ranges from about 4.5 for A12 O3 to 15 or more for ceramics containing dielectrics, therefore, are generally not useful as absorbers. Even low permittivity organic materials have values of □ that are too large for direct use. For example in in MHz frequency ranges, the permittivity of polyvinyl chloride is about 3, and polystyrene is about2.3. The front face reflection from a thick layer with □ = 2.3 is R = 0.16, a number that is usually far too large to be acceptable. To produce useful dielectric absorbers, note that the effective permittivity seen by an incoming wave is the average value over an area of about a wavelength on each side.

2)MAGNETIC ABSORBERS

Since the absorber front face is a magnetic reflector and the conductor is an electric reflector, the two have opposite phases therefore, Phase cancellation from this layers is possible magnetic absorbers have losses dependent upon the magnetic field.

Frequencies as low as 50 Hz, both penetration loss and reflection loss becomes small for magnetic fields, indicating that for low frequencies very thick metallic barriers would be necessary to shield against magnetic fields. For example from the table 2 we can understand that, to obtain a shielding effectiveness of 100dB at 60 Hz for magnetic fields, it will be necessary to provide an iron barrier with a permeability of 1000 and a thickness of 300 mils.

The reflection loss varies by the space impedance and differs between a near field and far field. For instance in a far field (in the case of a plane wave) the reflection loss (R_p) is denoted as follows

$$Rp=108.2 - 10 \log (f/10^6) + 20 \log \left(\sqrt{\sigma_r/\mu_r}\right)$$

$$Se (dB) = A (dB) + R (dB)$$

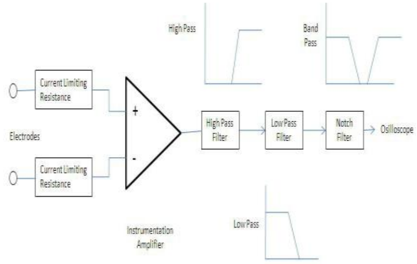
Grounding provides conducting path between the electronic devices and the ground. The ideal ground is characterized by zero potential and impedance. The grounding plane is in the form of a wire or a conducting rod. Single point grounds are used to reduce the ground current and to control the EMP energy.

The important factors for absorbing layers are

1. A lossless, conductor backed layer of material has the same reflection coefficient as the conductor
2. A Uniform layer with loss supports a reflection from its front face and another from a penetrating wave that reflects off, the backing conductor and returns through the front face. The two fields add as vectors; depending upon conditions, they will augment or cancel. The design task with thin absorbers is front face cancellation.
3. A thick uniform layer with loss supports reflection from the front face only, which dependent upon the permeability (□) to permittivity (□) ratio. If □ = □ the reflection is zero with power absorbed in the layer itself.
4. Non uniform layers differ from uniform one; in such a case reflection occur throughout the layer in addition to the interfaces.

A model of faraday shield was built from metal net to experiment the theory and concept of faraday shield before building the human size faraday shield. The human size shield has been built using PVC pipe as the basic shape and all of the surfaces shielded with metal net [6].

A 1-channel ECG circuit and notch filter are used to test the effect of faraday shield [2]. The outcome of ECG signal and noise signal were collected in different setting of places which are outside the shield, inside the shield and outside the building (far away from the shield). The signals were being transformed to frequency domain using Fast Fourier Transform (FFT) in MATLAB and compared them to see the difference of amplitude at 50Hz frequency when placed outside the shield, inside the shield and outside the building. The study of relationship between faraday shield and the effect on power line in ECG system was conducted in those situations.



Blockdiagram of ECG system

High pass filter

It is also known as DC restore circuit which acts as an ac- coupling circuit to put ECG baseline at zero volts. The advantage of feedback approach with an active integrator is, it is linear and easier to control than RC coupling circuit. The time constant of the feedback DC restorer is a multiple of R and C. The lower frequency of ECG is 0.5 Hz, it is adequate to monitor the ECG signal.

Low pass filter -The function is to determine the high cutoff frequency for the signal and amplifies the signal in accordance to the requirement of ADC. The gain is 38.5 to complement the gain 26 at the instrument amplifier to achieve total gain of 1001. Bessel 4^{th} order with 100Hz cutoff frequency is the best design that has least distortion and the group delay is constant.

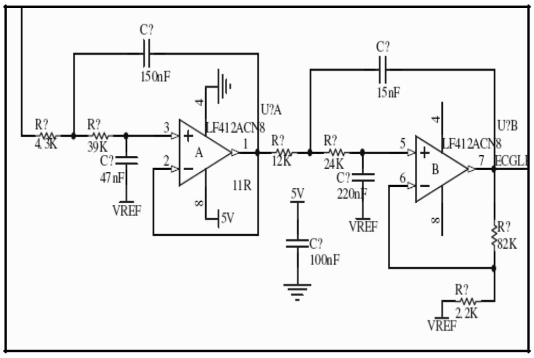


Fig. 3 Bessel filter 4^{th} order with 100Hz cutoff frequency using FilterPro

A single supply has been used for ECG circuit because the outside power outlet cannot be used inside the faraday shield. The function of the voltage reference circuit is to set the voltage reference to 2.5V to avoid signal distortion. AC-coupling circuit is added to the input to eliminate DC offset from electrode. The cutoff frequency is 5Hz.

Then, a low pass filter is added in the input voltage from the USB codec to filter out the noises at the presence at input voltage from USB power supply. The cutoff frequency is 3.39Hz and the range is 1Hz-4Hz.

ECG circuit needs a very sharp band rejection or notch filter to suppress the power line noise. The rejection frequency is 50Hz to eliminate 50Hz power line noise in ECG signal. Potentiometer is used to adjust the Q factor.

A single supply has been used for ECG circuit because the outside power outlet cannot be used inside the faraday shield. The function of the voltage reference circuit is to set the voltage reference to 2.5V to avoid signal distortion. AC-coupling circuit is added to the input to eliminate DC offset from electrode. The cutoff frequency is 5Hz.

Then, a low pass filter is added in the input voltage from the USB codec to filter out the noises at the presence at input voltage from USB power supply. The cutoff frequency is 3.39Hz and the range is 1Hz-4Hz.

A. Experiments

There are some experiments to be conducted in order to investigate the electromagnetic interference effect from power line noise in ECG signal using faraday shield. The first experiment called preliminary experiment to prove the theory of faraday shield before continuing to build the human size faraday. The first experiment used the radio frequency to replace power line noise.

The second experiment is to determine frequency range that can penetrate through the human size faraday shield. The frequency range that can penetrate through the shield need to be determined by placing the radio inside the human size faraday shield.

The third experiment is to test faraday shield with 3 different sources:

1) 240V device (radio) with battery powered,
2) 240V power outlet using shielded wire from outside of the shield,
3) 240V power outlet using unshielded wire from outside of the shield.

This is to determine whether the radio inside the shield can receive the signal with the setting of frequency that cannot penetrate through the faraday shield which has been determined from the second experiment.

The fourth experiment is to collect ECG signal and noise signal: (i) before low pass filter, (ii) after low pass filter and (iii) after notch filter iv) from 10 subjects in several different places as described in diagram of Fig. 4. The differences of voltage of right arm and left arm gives the data of ECG. For noise signal, all of the points have been placed at right arms so that there is no difference of voltage taken (ECG data) (refer to Fig. 5).

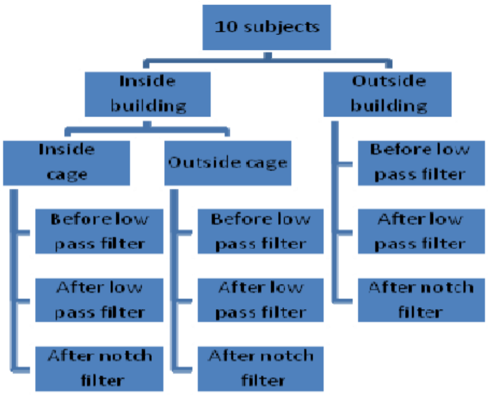


Fig. 4 **Several setting of places to capture ECG signal**

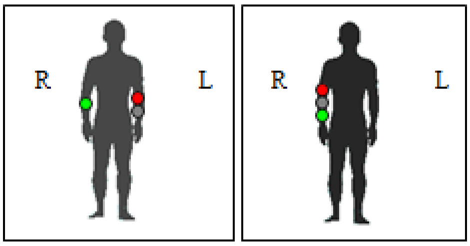


Fig. 5 [Left] Points to take ECG signal [Right] Point to take noise signal

The fifth experiment is to analyze ECG signal and noise signal from third experiment using FFT in MATLAB. Every data has been cut to 5s and the result of every FFT is focuses at 50Hz frequency amplitude.

The concept of faraday shield had been proven from the first experiment. The radio frequency cannot penetrate through the model of faraday shield but the hand phone frequency can. The reason behind this is because the hand phone wavelength is small enough to penetrate through the holes of the model faraday shield.

From the second experiment, the 50 Hz noise cannot penetrate through the faraday shield because 50Hz is in between 0Hz to 100MHz (the frequency range that cannot penetrate through the shield). The size of the hole determined the frequency range that can penetrate through the faraday shield.

For the third experiment, the radio with 240V outside power outlet with shielded or unshielded wire both gave the same result which is the radio signal at frequency lower than 100MHz that supposedly cannot be receive inside the faraday shield can be receive inside the faraday shield. The reason is because noise from outside can reside through the cable from outside power outlet. Although the radio cable has been shielded, the result was still the same as the experiment with unshielded wire because the wiring inside the building was still unshielded. The fifth experiment is to analyze ECG signal and noise signal from third experiment using FFT in MATLAB. Every data has been cut to 5s and the result of every FFT is focuses at 50Hz frequency amplitude.

III. Results, Discussions & Future Scope

The concept of faraday shield had been proven from the first experiment. The radio frequency cannot penetrate through the model of faraday shield but the hand phone frequency can. The reason behind this is because the hand phone wavelength is small enough to penetrate through the holes of the model faraday shield.

From the second experiment, the 50 Hz noise cannot penetrate through the faraday shield because 50Hz is in between 0Hz to 100MHz (the frequency range that cannot penetrate through the shield). The size of the hole determined the frequency range that can penetrate through the faraday shield.

For the third experiment, the radio with 240V outside power outlet with shielded or unshielded wire both gave the same result which is the radio signal at frequency lower than 100MHz that supposedly cannot be receive inside the faraday shield can be receive inside the faraday shield. The reason is because noise from outside can reside through the cable from outside power outlet. Although the radio cable has been shielded, the result was still the same as the experiment with unshielded wire because the wiring inside the building was still unshielded

In fourth experiment, 9 ECG signals and 9 noise signals have been recorded for every subject. Every signal is 30s in length and 8 kHz sampling frequency captured in .wav file.

The most accurate 5s signal has been selected from the 30s recorded signal to be analyzed in the fifth experiment. The results are shown in Table I. The units of data in Table 1 are in quantization level of ADC 16 bit from 0 to 5V. 16 bits ADC has 65530 quantization levels. Each level is equivalent to 76.3µV.

Table I-Result Summaries From The 5th Experiment (Data Taken After Low Pass Filter)

Subject	**inside building**		**outside building**
	Outside shield	**Inside shield**	**Outside shield**
1	65	6	4
2	21	5	7
3	27	1	5
4	26	5	7
5	38	1.5	3
6	192	14	9
7	28	10	11
8	120.5	60	65
9	83	12	5
10	27.5	4.5	3.5
Min	**62.80**	**11.90**	**11.95**

The difference of amplitude at frequency 50 Hz can be seen in Fig. 8 until Fig. 9 which the data is taken from subject 3. The data taken inside building (outside shield), inside building (inside shield) and outside building (outside shield) have been used to see the effect of using notch filter, whether the notch filter is effective in eliminating 50 Hz frequency component or not [10]. From Fig. 7 (right), Fig. 8 (right) and Fig. 9 (right), it can be seen that the amplitude at frequency 50 Hz has been eliminated after notch filter. The signals that have been taken inside the building (outside faraday shield) have very high 50 Hz frequency amplitude which is 62.80 (min) due to the power line noise that exists inside the building.

The signals that have been taken inside the building (inside faraday shield) have low 50 Hz frequency amplitude which is11.90 (min). Although the signals have been taken inside the building, the 50 Hz frequency amplitude is low because the faraday shield has eliminated outside frequency from coming into the shield.

The signals that have been taken outside the building (outside faraday shield) also have low 50 Hz frequency amplitude, merely same with the 50 Hz frequency amplitude inside the building (inside faraday shield) which is 11.95 (min). This is because 50 Hz noise frequency only exists inside building.

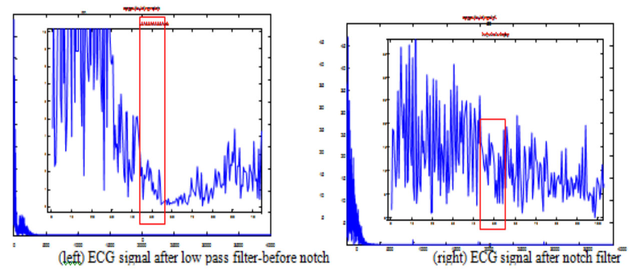


Fig. 7 Comparison before notch filter and after notch filter: filter (data taken inside building, outside faraday shield

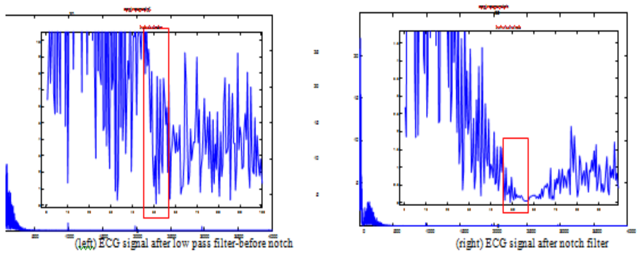


Fig. 8 Comparison before notch filter and after notch filter: filter (data taken inside building, inside faraday shield)

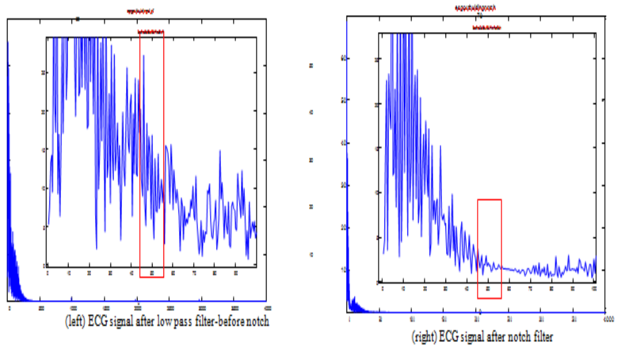


Fig. 9 Comparison before notch filter and after notch filter: (data taken outside building, outside faraday shield

Faraday shield is a useful Technique to The Electromagnetic Interference in biomedical signal. This study only focused on the effectiveness of removing power line noise in ECG signal using faraday shield, because power line noise is the most significant noise contained in biomedical signal such as ECG and it resides in the ECG signal itself that make it harder to be removed. Notch filter is identified as a tool to remove power line noise. It has eliminated not only the power line noise but also the ECG signal itself.

The faraday shield can eliminate the power line noise in ECG signal. In conclusion, faraday shield can be an alternative to remove the 50 Hz power line frequency and other noises in the frequency range in biomedical signal. It is recommended to record biomedical signal inside faraday shield because normal surrounding is exposed to various kind of noise. Faraday shield can be a prevention media to eliminate unknown noise that might present in environment provided that the frequency is in the range that can be eliminated by the faraday shield.

As The Future scope of the work, one can go for The better combinations of the Shield materials to get The best Results against the Electromagnetic Interference in the Bio-medical Embedded System Design.

References

[1]. M. N. Jamaluddin. *Real-Time Implementation of Twelve-Lead Automated ECG System*, Master Thesis, Universiti Teknologi Malaysia, 2007.

[2]. J. G. Webster. Medical Instrumentation: Application and Design, 3rd edition, Wiley & Sons, 1998.

[3]. Mohit Kumar and Vivek Agarwal, IEEE TRA NSACTIONS ON ELECTROMAGNETIC COMPATIBILITY, VOL. 48, NO. 1, FEBRUARY 2006

[4]. "*Effect of Material Parameters on Shielding Parameters of a Three layered Layered Laminate Electromagnetic Shield at X-Band",* 978-0-7695-4209-6/10 $26.00 © 2010 IEEE, DOI 10.1109/CNC.2010.63.

[5]. *Laminate Electromagnetic Shield at X-Band", ",* 978-0-7695-4209-6/10 $26.00 © 2010 IEEE, DOI 10.1109/CNC.2010.63.

[6]. "*Estimation of Reflectivity and Shielding Effectiveness of Three Layered Laminate Electromagnetic shield at X-band*", Progress In Electromagnetics Research B, Vol. 20, pp.205-223, 20

[7]. N.A. Zakaria, R. Sudirman, M.N.Jamaluddin. Electromagnetic Interference Effect form Power Line Noise in Electrocardiograph Signal using Faraday Cage. 2nd IEEE Conference on Power and Energy (PECon08). 666-671, 2008.