Defence Science Journal, Vol. 57, No. 4, July 2007, pp. 471-480

Nickel-substituted Lithium-Zinc-Manganese Ferrite for the Suppression of Radiated Emission Noise

N.C. Joshi[1], Anjali Verma[2], Nitendar Kumar[3], Satheesh Kumar O.B[3], and S.S. Islam[1]

[1]*Jamia Millia Islamia, New Delhi-110 025*
[2]*Indian Institute of Technology, New Delhi-110 016*
[3]*Solid State Physical Laboratory, Delhi-110 054*

ABSTRACT

Nickel-substituted lithium-zinc-manganese ferrite of the composition, $Li_{0.25-x/4}Zn_{0.5-x/2}Ni_xMn_{0.1}Fe_{2.15-x/4}O_4$ where x = 0, 0.1, 0.2, 0.3, 0.4, 0.5 have been investigated for electromagnetic interference (EMI) suppression to meet the EMI standards. Various compositions were prepared by the conventional ceramic technique using mixed oxides. The ferrites were characterised for their structural, electrical, and magnetic, properties. The ferrites were found to posses high saturation magnetisation, permeability, Curie temperature and resistivity, which are the desirable characteristics for noise-suppression application. The operating frequency of the ferrite ranged from 1 MHz–700 MHz, which is high enough for absorbing the electrical fast transients and radiated emission noise suppression as shown for three devices–currency counting machine, energy meter and dc-dc converter where the radiated emission noise is suppressed from 10 dB to 20 dB. In energy meter where the electrical fast transients (EFTs) are suppressed up to 5.5 kV, 4.5 kV, 3.5 kV, 2.8 kV, 1.6 kV, and 1.2 kV with composition x = 0, 0.1, 0.2, 0.3, 0.4, 0.5, respectively. This material has tremendous scope of application in military equipment to comply the EMI requirements of the military standards.

Keywords: Electromagnetic interference suppression, EMI suppression, nickel-substituted fererites, ceramic ferromagnetic materials, EMI control, noise–suppression, eletromagnetic compatibility, lithium ferrites

1. INTRODUCTION

The widespread introduction of digital computing technology and densely packed PC board have contributed to an increase in electromagnetic interference (EMI) concern. These circuits either generate electromagnetic noise or are susceptible to the EMI which may result in their malfunction. Hence, for safe and stable operation of the equipment, suppression of the EMI is indispensable. Interference can reach the victim system through two basic routes: (i) conduction along cables, and (ii) electromagnetic radiation. When the EMI, whether conducted emission or radiated emission, is below a certain level[1] as specified by the EMI Regulatory Agencies, and do not interfere with normal operation of the electrical and electronic equipment, electromagnetic compatibility (EMC) is said to be achieved.

The suppression of EMI has always been an important part of the development of electronics. Soft ferrites are ceramic ferromagnetic materials widely used for EMI control[2]. Their lossy wideband nature results in reliable suppression characteristics.

Received 09 May 2006, Revised 8 November 2006

Ferrite toroids, beads, and sleeves are often regarded as the miracle remedies to suppress the noise or enhance the immunity of the electrical and electronic equipment. The ferrite core for EMI suppression, exhibits high impedance, low conductivity, and high environmental resistance. Therefore, these can be usefully applied for EM noise reduction inside or between electronic devices, either at the design stage or with retrofitting. The choice of the soft ferrites depends on its composition and the electrical and magnetic characteristics, dictated by the design consideration such as frequency and bias current, and ambient condition such as temperature.

Lithium ferrites are useful in a variety of microwave devices and have many properties that make these ideally suited for EMI suppression. The basic lithium-ferrite formula $Li_{0.5}Fe_{2.5}O_4$ can be molecularly engineered to provide excellent temperature stability of magnetic properties[3].

The *Ni*-substituted *Li-Zn-Mn* ferrites represent a new line of magnetic absorbers and EMI suppression elements that operate in the frequency range of 1 MHz-700 MHz.

2. EXPERIMENTAL PROCEDURE

2.1 Sample Preparation

The *Ni*-substituted[3] *Li-Zn*-Mn ferritesare having the following composition

$$Li_{0.25-x/4}Zn_{0.5-x/2}Ni_xMn_{0.1}Fe_{2.15-x/4}O_4 \tag{1}$$

where, x varies from 0 to 0.5, in the step of 0.1. Analytical grade raw materials in the form of oxide/ carbonate of lithium, zinc, nickel, manganese, and iron are taken for processing the ferrites. To avoid escape of lithium at high sintering temperatures, a small quantity of Bi_2O_3 (0.5 Wt %) was added in the initial mixing as a sintering aid in all the compositions[4]. The materials were thoroughly mixed using standard wet-ball milling technique. The samples were calcined at 750 °C for 4 h. Few drops of polyvinyl alcohol (2 % solution) were added to the calcined powder as a binding agent. The dried powder was pressed in to circular disc and toroids rings by applying a pressure of 5 ton/cm^2. The outer dia (OD), inner dia (ID), and thickness (t) of the toroids were 20 mm, 10 mm, and 5 mm, respectively. The samples were further sintered at a rate of rise of temperature 3 °C/min in the atmosphere at 1050 °C for 6 h. The furnace was cooled at the same rate of 3 °C/min.

2.2 Characterisation

(i) The x-ray diffraction patterns of all the samples were recorded on a Rigaku Geiger flex 3 kW x-ray diffractometer (XRD).

(ii) Density of the sample was measured by Archimedes method.

(iii) Saturation magnetisation was measured using a vibration sample magnetometer (EG&G Princeton Applied Research model 155).

(iv) The Curie temperature was measured using the arrangement made by Soohoo[5].

(v) The impedance and inductance were measured by the HP 4191 and HP4284 impedance analyser. Insertion loss was measured using R&S test receivers (ESH3 335.8017).

(vi) The electrical fast transients (EFT) were generated by EFT simulators of make M/s Keytek[6].

(vii) Spectrum analyser HP 8466 B, absorbing clamp makes R&S type MDS 21 measured radiated noise of house-hold appliances.

(viii) Spectrum analyser HP 8466 B, bi-conical and log periodic antennas were used to measure the radiated emission noise in the anechoic chamber.

(ix) Resistivity of the silver-coated discs was measured by the two-probe method.

3. RESULTS AND DISCUSSION

The *Ni*-substituted *Li-Zn -Mn* ferrite characterised structural, electrical, and magnetic properties for the radiated emission noise suppression. The magnetic saturation (*Ms*), resistivity (ρ), Curie temperature (T_c), permeability (μ), insertion loss (*IL*), and impedance

(Z) are the indispensable parameters for the EMI suppression.

The x-ray diffraction analysis revealed that the samples crystallize in a single-phase cubic spinal structure. The lattice constant (a) and the x-ray density of the samples of different composition were calculated using x-ray diffraction patterns. The percentage porosity in the samples is found to be in the range 4.6 to 10 (Table 1). The porosity increases with increase in nickel-substitution in the composition of the ferrite. The density of the ferrite material was calculated by the Archimedes formula $d_x = W_{air}/W_{air}-W_{water}$.

Table 1. Electrical and magnetic properties of $Li_{0.25-x/4}Zn_{0.5-x/2}Ni_xMn_{0.1}Fe_{2.15-x/4}O_4$ ferrite

x	μ_I at 10 kHz	T_c (°C)	ρ (Ω cm)	Ms (Gauss)	Porosity %
0	484	297	1.78×10^6	4201	4.6
0.1	467	303	1.35×10^7	4434	5.2
0.2	298	350	2.45×10^8	4665	6.8
0.3	192	359	8.8×10^8	4875	7.9
0.4	180	365	9.8×10^8	4185	8.9
0.5	165	395	9.7×10^8	4185	10.0

When ferrite material was placed in a magnetic field, atoms experience a torque called magnetic moment denoted by m, which is an important and fundamental quantity and merits special consideration. For a bar magnet of length l and pole strength p, m is equal to $p \times l$ and is expressed as Weber-meter. The magnetic moment per unit volume is called magnetisation (M) and is also defined as pole strength per unit area expressed in emu/cm^3 or gauss. If the intensity of magnetisation is M, then each square centimeter of the surface of the material has pole strength of M, and $4\pi M$ lines originate from it. The magnetic flux density through a magnetised body is equal to the intensity of magnetisation M multiplied by permeability of free space μ_0. That is

$$B = \mu_0 M \text{ (no applied field)} \tag{2}$$

When a ferromagnetic material is placed in a magnetic field H, poles are produced at the ends of the material with lines of magnetic flux emanating from them.

$$B = \mu_0 (M + H) \tag{3}$$

The saturation magnetisation (Ms) determined for the various *Li-Ni-Zn* ferrite compositions are shown in Table 1. The variations in Ms values with x are in accordance with the trend reported in literature[7,8] for zinc containing ferrite. A relation between permeability, resonance frequency, gyro magnetic ratio and saturation magnetisation is shown in Eqn (6). A high magnetisation is usually desirable for EMI application. For designing of a filter, if the coil consists of thin wire with many turns, saturation limits the performance of the core. Operation of electronic circuits gives rise to an increase in temperature which causes heating of the core, resulting thereby is a decrease of saturation level, that deteriorates the performance of the core in the circuit.

The Curie temperature (T_c) is the transition temperature above which the ferrite material loses its magnetic properties. A ferrite core for EMI filter application should also possess a high Curie temperature[9] T_c to prevent it from losing its ferromagnetic nature due to heating of the core during circuit operations especially involving high input current, which causes heat dissipation. The operating temperature should always remain below the Curie temperature. T_c values obtained for the different compositions are shown in Table 1 and are higher than the normal temperature encountered during the circuit operations.

The room temperature dc resistivity (ρ) of the *Ni*-substituted *Li-Zn-Mn* ferrite series was found to be in the range of 1.78×10^6 to 9.8×10^8 ohm-cm. A high resistivity is indispensable as well to avoid short circuits when the copper winding sits directly on a non-coated core[9]. The formula used for the measurements of resistivity is $\rho = R.A/d$, where R is the resistance, A is the area, and d is the thickness of the pellets.

Initial permeability (μ_I) was measured at low flux and at 10 kHz frequency. It has the advantage that every ferrite can be measured at that density without any risk of saturation. This data should be used only for illustrative purpose and comparative evaluation of material and not for design. The compositional variation of initial permeability μ_I of the series is shown in Table 1.

Permeability is a complex property comprising real (reactive) and imaginary (resistive) components. The real parts represent reactive portion and the imaginary parts represent the losses. These are expressed as μ'_s and μ''_s and shown in Figs 1 and 2, respectively for the composition x = 0. The complex permeabilities μ'_s and μ''_s vary as a function of frequency. At higher frequencies, real permeability μ'_s will approach zero and imaginary permeability μ''_s will reach a maximum value. Figure 1 shows that the real part of permeability at 110 MHz is 18. The imaginary part of permeability at 110 MHz is > 75.

At low frequencies, a ferrite inductor is a low-loss constant self-inductor where μ'_s is highest and the suppression core is mostly inductive, rejecting the EMI signal to the source. At high frequencies where the μ''_s parameters becomes more significant, the inductors shows high impedance and become resistive and dissipate interfering signals rather than reflecting these to the source[10].

3.1 Impedance

Ferrite cores are most frequently used as two-terminal circuit elements, or in groups of two terminal elements. The unique high frequency noise suppression performance of ferrites core can be traced to their frequency-dependent complex impedance Z. The impedance Z of a ferrite suppression core is a combination of the intrinsic parameter (μ' and μ'' real and imaginary parts of permeability) of the ferrite as well as the core dimensions shown in Eqns. (4) and (5). The relation between the series impedance Z and the complex permeability[11] is given by

$$Z = j\,\omega\, Ls + Rs = j\,\omega\,(\mu_s' - \mu_s'')\, Lo \qquad (4)$$

where $Lo = 1.17\, N^2\, H \log_{10} \mathrm{OD/ID}\; 10^{-9}$ Henry (5)

where Lo is the air core inductance, Ls and Rs are inductance and series resistance of the core, respectively and ω is the angular frequency. In Eqn (5) OD is the outer dia, ID is the inner dia, H is the height of the core and N is the number of turns.

The frequency variation of impedance shown in Figs 3 and 4 for the composition x = 0.1 with number of turns used 2 and 6, respectively. The resonance frequency peaks are the results of the absorption of energy due to matching of the oscillation

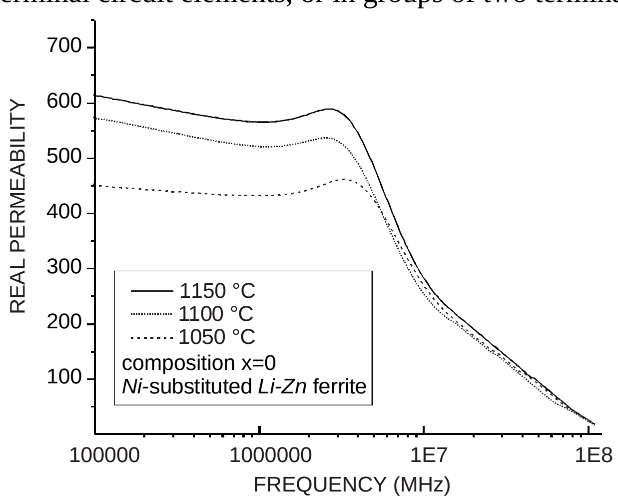

Figure 1. Real permeability (μ'_s)/frequency of ferrite composition x=0, $Li_{0.25}Zn_{0.5}$-$Mn_{0.1}Fe_{2.15}O_4$ ferrite material sintered at 1050 °C, 1100 °C, and 1150 °C.

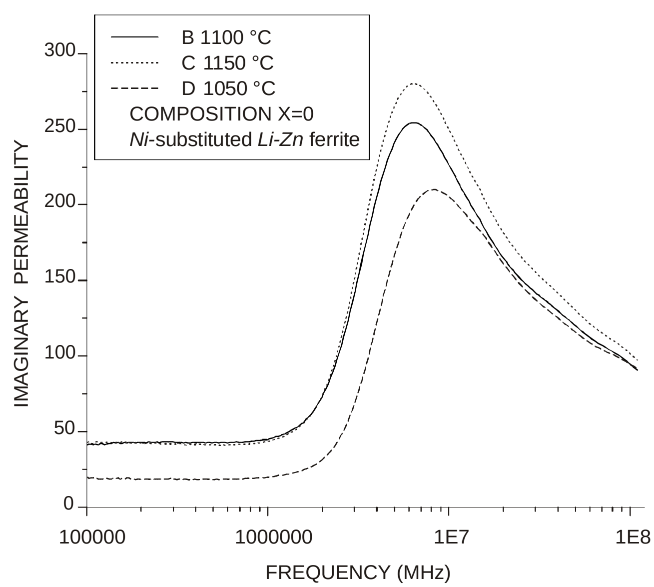

Figure 2. Imaginary permeability (μ''_s)/frequency of ferrite composition x=0, $Li_{0.25}Zn_{0.5}$-$Mn_{0.1}Fe_{2.15}O_4$, ferrite material sintered at 1050 °C, 1100 °C, and 1150 °C.

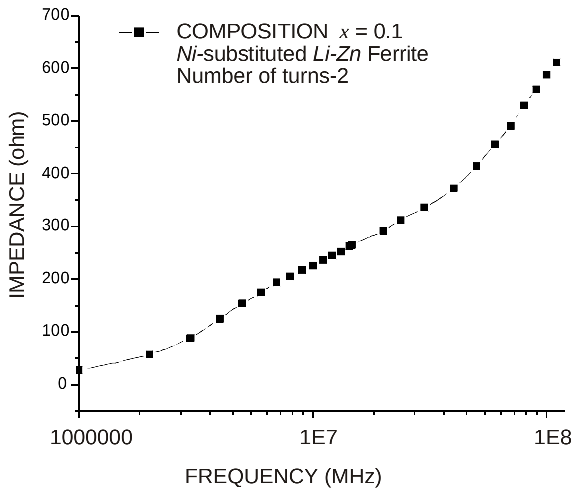

Figure 3. Impedence versus frequency of Ni–substituted *Li-Zn* ferrite $Li_{0.25-x/4}Zn_{0.5-x/2}Ni_xMn_{0.1}Fe_{2.15-x/4}O_4$ where $x = 0.1$.

frequency, of the magnetic dipoles and the applied frequency. The resonance peak one cannot see in Fig. 3 is indicative of the fact that for the samples investigated, the resonance frequency was higher than 110 MHz. In Fig. 4, it was observed that the resonance peak shifted to below 110 MHz due to interwinding capacitance.

Snoek found the following relation between resonance frequency (where maximum losses take place) and static initial permeability[12] shown in Eqn (6).

$$f_r\ (\mu_0 - 1) = 4/3\gamma Ms \tag{6}$$

where γ is gyro magnetic ratio, Ms is saturation magnetisation, and f_r is the resonance frequency. The product of frequency and permeability remains constant. When frequency is low, permeability is high and when frequency is high, permeability is low. Thus, an effective limit of product of frequency and permeability is established.

It is observed and shown in Table 1 that the initial permeability decreases with the increase in *Ni* concentration. The resonance peak of the *Ni*-substituted *Li-Zn* ferrite observed with 6 number of turns varies from 80 MHz to 120 MHz, shifting to higher permeability from lower permeability.

It was also observed that increasing the concentration of *Ni* in the compositional formula shown in Eqn (1), i.e., x varies from 0 to 0.5 in the step of 0.1, the lossy nature of the ferrite below 30 MHz has been reduced. The *Ni*-substituted *Li-Zn* ferrites cores are magnetic components that exhibit significant and useful loss over a frequency range of 1-700 MHz for all the compositions. When properly selected and implemented, these cores can provide significant EMI reduction while remaining transparent to normal circuit operation. Increasing the number of turns (Fig. 4), improves the performance of the core below 100 MHz. The selection of the number of turns for EMI suppression depends upon the frequency of the interference signal that must be suppressed.

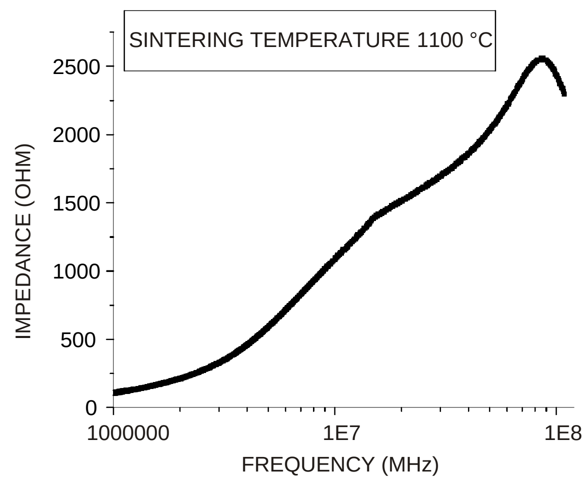

Figure 4. Impedance versus frequency of *Ni*–substituted *Li-Zn* ferrite $Li_{0.25-x/4}Zn_{0.5-x/2}Ni_xMn_{0.1}Fe_{2.15-x/4}O_4$ where $x = 0.1$.

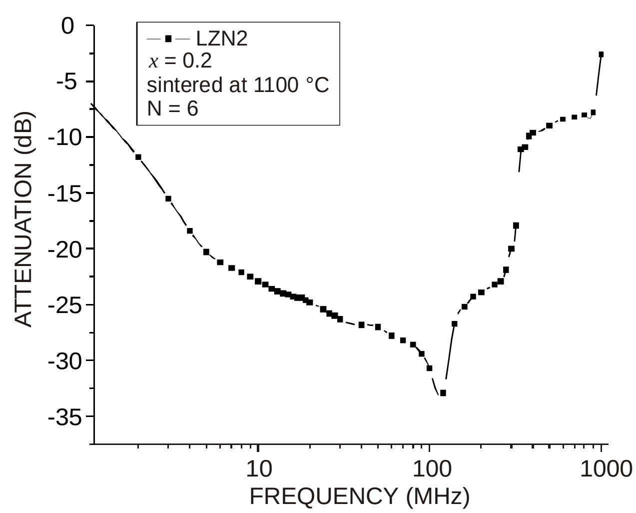

Figure 5. Insertion loss versus frequency for the composition $x = 0.2$, number of turns $n = 6$.

3.2 Insertion Loss

In most electronic devices, an inductive suppression component is connected in series with the interference source (Fig. 6). The regular signal is normally either a dc supply or 50 Hz mains for which an inductor only presents a small copper resistance. At RF frequencies, the inductor shows high impedance, which suppresses the unwanted interference. The resulting voltage over the load impedance will be lower than the voltage without the suppression components. The ratio of the two is the insertion loss.

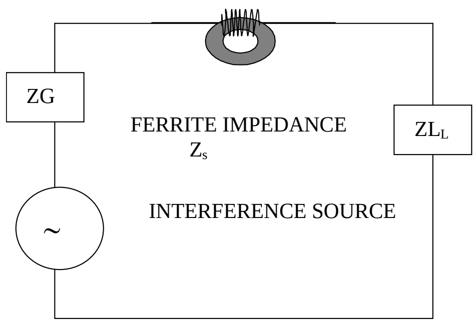

Figure 6. Application of ferrite core in the interference circuit.

Insertion loss (IL) depends on source and load impedance, so it is not pure product parameters like impedance[2,13]. Due to this reason, insertion loss can be considered standardised parameter for comparisons, but it will not directly predict the attenuation in the applications. The IL is expressed logarithmically in the following equations:

$$\text{IL} = 20\ \log_{10}\ (E_0/E) \quad (7)$$

$$\text{IL} = 20\ \log_{10}(Zg+ZL+Zs)/(Zg+ZL) \quad (8)$$

where Zg is noise source, ZL is load, and Zs is the impedance of ferrite for a 50Ω/50Ω system.

$$\text{IL} = 20\ \log_{10}[1+Zs/100] \quad (9)$$

Insertion loss of *Ni*- substituted *Li-Zn-Mn* ferrite core measured for the frequency range of 1 MHz to 30 MHz and 1 MHz to 1000 MHz, with input and output impedance of 50 Ω, is shown in Figs 5 and 7. It is observed that IL increases with the frequency for all the compositions x = 0 to 0.5. As the substitution level of *Ni* increases, the IL decreases

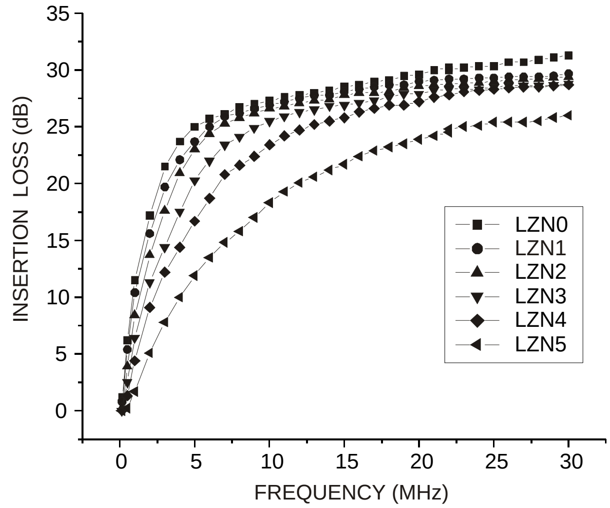

Figure 7. Insertion loss versus frequency (Mhz) for all the composition x=0 to 0.5 (frequency range 1-30 MHz) number of turns *N*=6.

(Fig. 7). Figure 5 shows IL of *Ni*-substituted *Li-Zn* ferrite is –10dB to –30dB in the frequency range of 1-500 MHz.

Once the behaviour of the material wrt impedance versus frequency is known, the impedance may be further improved in two ways, i.e., by increasing the core dimension and the number of turns. In Eqns (4) and (5), doubling the height (H) will double the volume and also impedance. Doubling the core volume by changing the OD and ID will only increase the impedance[9] by approximately 40 per cent. In Eqn (4), the impedance of the ferrite core is directly proportional to N^2 where N is the number of turns. The interwinding capacitance and lead length affect the performance of the core. Figure 4 shows that increasing the number of turns improves the core performance below the resonance frequency.

4. APPLICATION

In general, EMI problem can be represented by three components: (i) interfering source, (ii) coupling path, and (iii) victim equipment. The coupling can be via metallic conductors such as power or signal cables, if these exist, or more generally, by electromagnetic radiation (radiated emission) from one equipment to another. The noise generally produced due to switching and use of high frequency for operation in the culprit equipment and received by the victim equipment through a cable or direct radiation. The conduction mechanisms may be capacitive, inductive, galvanic and through radiation. The RF currents can be induced into the cable connected (inside or outside) to the victim equipment. The ferrite core will prevent the circulation of induced current conversely, if a signal source contains undesired spurious noise and it will prevent this current from propagating and making the wire a radiating and receiving antenna[14].

4.1 dc-dc Converter

Radiated emission noise of dc-dc converter was measured as per MIL Standard 461 C, RE 02, and is shown in Fig. 8. The curves 1 and 2 show the radiated emission requirement of Army and Air Force equipment, respectively. Narrow band radiated emission noise of the dc-dc converter crosses the regulatory limits in the frequency band of 60 MHz to 300 MHz.

Ferrite core composition x = 0 and 0.1 used to suppress the radiated emission noise is shown in Fig. 9. The culprit wires in the dc-dc converter, are working as an antenna and radiating the noise. The same wire with three turns around the combined core (x = 0 and 0.1 added to increase the height of the core) used to suppress the noise. It was observed that noise suppressed from 10 dB to 20 dB.

4.2 Currency Counting Machine

The *Li-Zn* ferrite core are also used in electrical/electronic equipment like currency counting machine and energy meter which are the source of conducted and radiated emission noise. In these equipment, the power cord act as an antenna and a significant source of radiation.

The absorbing clamp method is used for measuring radio noise power in currency counting machine and energy meter in accordance with International Standards CISPR 14-1. The absorbing clamp method is a CISPR standard method of measuring the interference power level on cables connected to electronic devices in lieu of radiated emission measurements. The absorbing clamp consists of a calibrated ferrite current transformer operating in the frequency range 30–1000 MHz and two groups

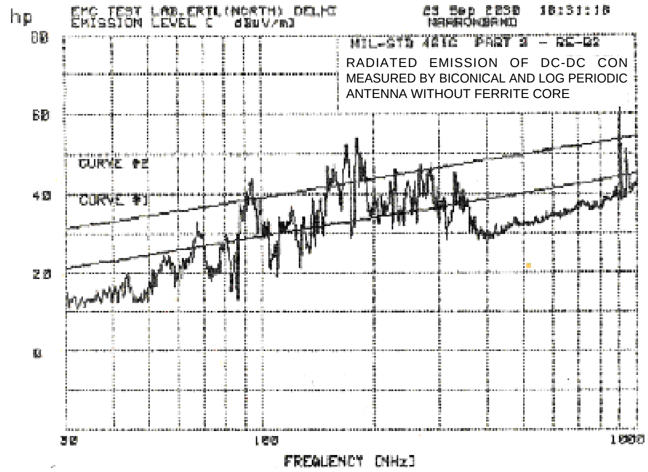

Figure 8. Noise (dBmV/m) versus frequency RE noise of dc-dc converter measured as per MIL-461-C.

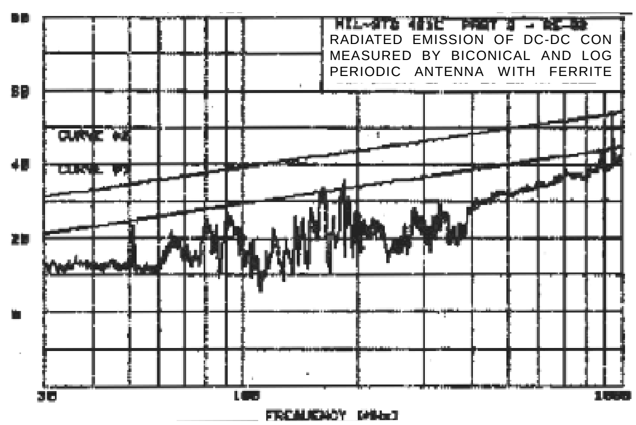

Figure 9. Noise (dBmV/m) versus frequency *Ni*–substituted *Li-Zn* ferrite core x = 0 and 0.1 used to suppress radiated emission noise of dc-dc converter measured as per MIL-461-C.

of ferrite rings. The regulatory limits shown in Table 2 and Figs 10 to 12. The limit line represents the limit above which the device may degrade the functioning or performance of other equipment.

The ferrite rings act as absorbers of energy and stabilises the impedance. The absorbing clamp acts as toroidal currents probe and produces an output voltage proportional to the RF current flowing on the cable under testing. Signal reading from the

Table 2. CISPR–14 regulatory limits

Frequency (MHz)	L Emission limits (dBpW)	
	Quasi-peak	Average
30-300	45-55	35-45

EMI meter is compared with that obtained during calibration of the clamp in a special jig and recorded on calibration chart[15]. The measurement of RF power available at each frequencies of interest is made by substitution method.

The radiated emission of currency counting machine was measured and is shown in Fig. 10 in the frequency range of 30-300 MHz as per CISPR-14-1. Data reveal that peak emission noise of currency counting machine exceeds the average and quasi-peak regulatory limit in the frequency range of 30-300 MHz by > 80 dBpW to 45 dBpW as shown in Fig. 10.

There are three modes of noise detection in EMI analysis[17]. In peak noise detection, the envelope of a signal is measured and displayed with its measured value compared to the RMS of the continuous wave (*cw*) signal. If no modulation exist on the signal, then the peak voltage of the carrier is detected. The peak emission is the worst-case condition for emission data obtained.

In average detection, averaging is simply integration or averaging of random noise. This detection is generally used for analysing narrow band emission signals.

In quasi-peak detection, the broadband emission signals are determined by incorporating various charge and discharge time constants (depending on the frequency range) as a function of the pulse repetition rate. It is used to evaluate the annoyance factor.

The ferrite core of the composition x = 0.1, and dimensions OD/ID/H: 28/12/9 mm with N = 6 turns, in common mode was used at the input of power supply (220 V ac/2 A) of the currency counting machine. The peak emission of currency counting machine measured with core is shown in Fig. 11. It shows a noise suppression of approximately 10–20 dB. The peak noise is still crossing the regulatory limit lines in the frequency range of 30-180 MHz. Such result calls for an average and quasi-peak analysis of the peak emission that exceeded the regulatory limits.

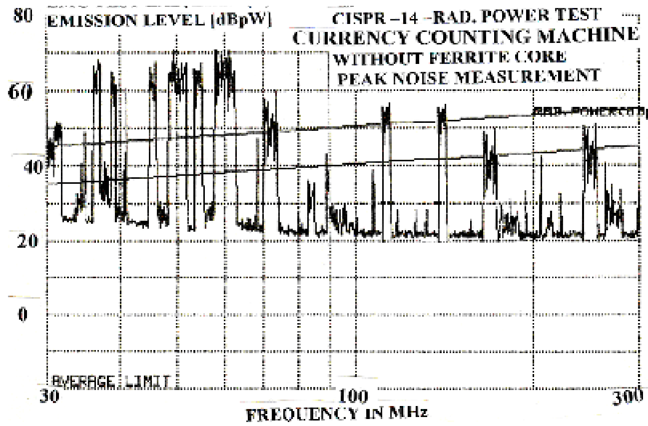

Figure 10. Peak Noise (dBpW) versus Frequency (MHz). Noise radiated by the currency counting machine (No Ferrite used to suppress the electromagnetic noise).

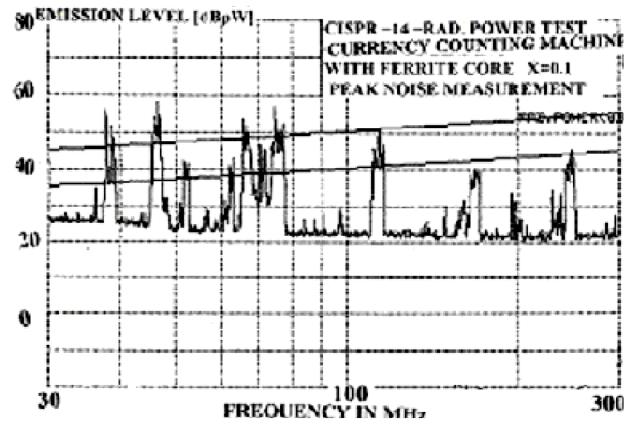

Figure 11. Peak Noise (dBpW) versus Frequency (MHz). Noise radiated by the currency counting machine (nickel-substituted *Li-Zn-Mn* Ferrite composition x=0.1 used to suppress the electromagnetic noise).

The average noise detector was used to measure the average noise in the frequencies shown in Table 3. It is observed that the average EMI noises are below the regulatory limits. The quasi-peak noise measured in the frequency range 30-80 MHz (Fig. 12). It is observed that noises are well below the limit line. It shows that the ferrite core is suppressing the EMI noise of currency counting machine in the frequency range 30-300 MHz.

Table 3. Average noise measured after using ferrite core of composition x = 0.1

Frequency (MHz)	38	46	54	62	76	88	135
Level (dBpW)	32	34	23	25	33	29	30

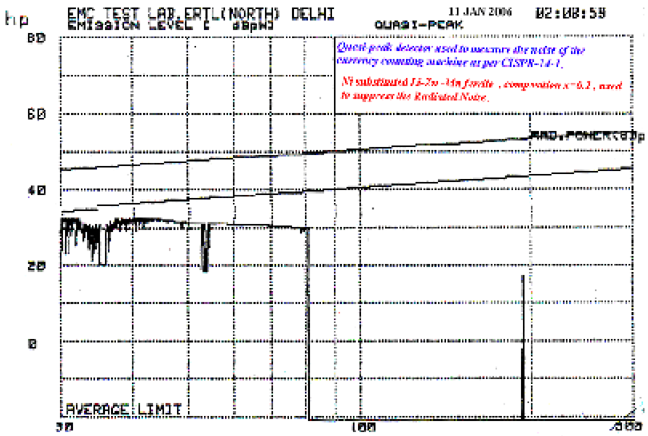

Figure 12. Quasi peak noise (dBpW) versus frequency (MHz). Radiated noise of currency counting machine measured by the quasi peak detector (*Ni*-substituted *Li-Zn-Mn* Ferrite composition *x* = 0.1 used to suppress the noise)

The suppression of the noise below the limits line shows that there is at least 80 per cent probability that it will not affect the nearby equipment[18].

5. SUPPRESSION OF ELECTRICAL FAST TRANSIENTS

Growing immunity requirements for the electronic equipment demand more efficient transient's suppressors. The electrical fast transients, electrostatic discharge, and surges affect the performance of the electronic equipment. The electrical fast transients can occur any time due to variation of inductive load and switching. The waveform produced by EFT is approximately 5/50 ns pulse with 1 to 4kV of amplitude. Owing to its broadband spectrum[19], covering kHz up to at least 60 MHz. It will track down most of the EMC weakness of the digital as well as analog equipment.

The envelope of the burst can be mistaken by logic circuits as a valid series of bits, while individual short pulse can trigger edge sensitive gate input. With analog circuits, sensitive amplifier can detect the envelope of the burst in a similar manner as pulse modulated CW interference.

The electrical fast transients propagate to the other equipment via metallic path or radiate extreme interference field to the environments. Hence, the system and installation in the neighbourhood can be disturbed or performance may be affected. Above 500 V, it may generate spark discharge. Therefore, explosive environment may be highly affected by the transients. *Ni*–substituted *Li-Zn-Mn* ferrite with a operating frequency range from about 1 MHz to 500 MHz may be used in electronic equipment for the suppression of EFT and improves the immunity of the same equipment.

To find out the effectiveness of the ferrite core to suppress the EFT noise, The microcontroller-based energy meter can be used without any transient suppresser and filter. EFT noise is superimposed in the power line, which is connected to the energy meter. It is observed that the EFT renderes the energy meter completely non-functional at 400 V.

However by applying the ferrite cores of different compositions *x* = 0, 0.1, 0.2, 0.3, 0.4, and 0.5 with 6 turn in common mode at the input supply (220 V ac) of the energy meter, the immunity level of energy meter increased up to 5.5 kV, 4.5 kV, 3.5 kV, 2.8 kV, 1.6 kV, and 1.2 kV, respectively.

6. CONCLUSION

The *Ni*-substituted *Li-Zn-Mn* ferrites are employed for EMI suppression application. Application of the ferrites in devices such as dc-dc converter, currency counting machines, and energy meter is found to effectively suppress the EMI to about 10–20 dB. The most important property for this purpose is the ferrite core impedance, which is a function of frequency. The ferrite shows wide bandwidths ranging from 1-700 MHz. The ferrites utilised in the present work are found suitable for the suppression of radiated emission as well as the EFTs in the frequency range of 1-700 MHz.

REFREENCES

1. Morgan, David. A handbook for EMC testing and measurement.
2. Technical Note. Phillips Magnetic Products. Soft ferrite for EMI suppression.
3. http://www.emsstg.com/ferrite/mmat_lithium.asp.

4. Kishan, Pran; Sagar, D.R.; Chatterjee, S.N.; Nagpaul, L.K. & Kumar, Nitendar. *Advances in Ceramics*, 1986, **15**, 507.
5. Soohoo, R.F. Theory and applications of ferrites. Prentice-Hall, Englewood Cliffs, N.J, 1960. pp. 252.
6. Electrical fast transients/burst test standards EN61000-4-4.
7. Chikazumi, S. Physics of ferromagnetism. Clarendon Press, Oxford, 1977.
8. Smit, J. & wijn, H.P.J. Ferrite. Physics Technical Library, Eindhoven,The Netherlands,1959.
9. Ferrites for chokes in commutation motors. Interfere Technology Master, 1999. pp. 35-40.
10. Snelling, E.C. Soft ferrites, properties and application. Ed. 2. Butterworth, 1988.
11. How to choose ferrite component for EMI suppression. Ed. 14. Fair-Rite Products Corp. www.fair-rite.com.
12. Snoek, J.L. *Physics*, 1948, **4**, 207.
13. Data handbook on soft ferrites, MA01, Eindhoven.
14. Mardiguian, Michel. Electromagnetic control in components and devices: Transformers and Magnetic coupling components: Vol. 5.
15. Swank. A theory of operation of the CISPR absorbing Clamp. *In* Proceding of IEEE Symposium on EMC, 1988, PP 141-43.
16. CISPR 14: Electromagnetic compatibility-Requirements for household appliances, electric tool and similar apparatus.
17. Specification for radio disturbances and immunity measuring apparatus and methods, radio disturbances and immunity measuring apparatus CISPR 16-1.
18. CISPR 22: Information technology equipment-Radio disturbances characteristics - limits and methods of measurements.
19. Mardiguian, Michel. EMI troubleshooting technique. McGraw Hill.

Contributors

Mr N.C. Joshi obtained his MSc (Physics) with specialisation in electronics from the Kumaon University, Almora, Uttrakhand. He joined Electronic Regional Test Laboratory (North) under Ministry of Information and Technology, New Delhi, in 1984. At present, he is working as a Scientist in EMI/EMC lab and pursuing his PhD in Synthesis and Characterisation of *Li-Zn* ferrite for the suppression of Electromagnetic Noise, from Jamia Millia Islamia University, New Delhi.