CONSEQUENCE OF SOURCE RIPPLE FACTOR IN CONDUCTED VOLTAGE EMISSION MEASUREMENT

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Abstract

Huge dv/dt and di/dt due to high switching frequency and ripples present in AC-DC converter infallibly introduce unwanted Electromagnetic Interference (EMI) noise voltage through parasitic/distributed parameters of the DC source. In this paper, the entire test setup for conducted emission (CE) is made to measure the conducted voltage disturbance of Equipment Under Test (EUT) due to various DC sources with different percentage ripple factors used to supply. The measurement carried out in the frequency band 150kHz to 30MHz as per CISPR 11 [2]/ CISPR 22 [1]. The dominated DC source responsible for the significant conducted voltage disturbance measurement results are analyzed and to mitigate the conducted emission manoeuvring based on DC source is proposed. Practical measurement are used to validate the mitigation method.

Keywords: Ripple factor, Electromagnetic Interference, DC-AMN, Conducted Emission

I. Introduction

Majority electrical and electronics equipment placed in to the market have to achieve the necessitous requirements of EMC measurement and validation of either European or American EMC Directive and get complies before entering in to the market. When electromagnetic energy in any form generates and conducts through nearby environment, it can interfere to the devices operating in the same environment. Seeing from its production and R&D perspective, it is difficult and cost consuming both to manage electrical noise emission and immunity of the devices. So, it is an essential part of both system and product design. Failure in reduction of emission sources and achieving susceptibility during developmental stage will leads to a time wasting and costly fixes later on.

The DC power supply operated equipment can use either a linear power supply source or switching power supply source. Ripple is an unwanted AC component present in the output of any AC-DC converter. The ripple factor is a ratio of this AC component to the average DC output of converter circuitry and the value of ripple factor is always less than unity. Ideally ripple factor shall be zero in a pure DC source but due to presence of power electronics switches it possesses some AC components. Generally switching power supplies offer high ripple and noise and have decent transient behavior. They are, however, efficient and offers low heat dissipation. They are also compact, whereas the linear DC power supply shows the completely opposite characteristics. But a compromise has to be made between linear and switching power supply sources depending upon source applications, EUT requirements with which they are associated and sometimes with product standard requirements.

Automotive, military and some other standards and regulations are prepared to outline a limit of radiation generated from the commercial electrical and electronics products. Some regulations also defines conducted emission limits applicable to dc power lines. As recent development of products have adopted electronics which are nonlinear loads on the power distribution system. They have input current of non-sinusoidal waveform consisting of harmonics, ripples and switching transients that can have a detrimental effect on the performance of Electrical and Electronics Equipment connected to the same power distribution system. These equipment themselves are not large enough to be an efficient radiator for frequency range below 30 MHz but when the power distribution system is concerned, it can be an efficient antenna. And hence the conducted voltage emission test is performed in laboratories for the frequency band 150 kHz to 30 MHz with the use of DC-AMN according to CISPR22 [1], CISPR11 [2] and other similar EMC standards.

Normally, Differential Mode and Common Mode currents generated from equipment are too small to interfere directly to other products placed in the same surrounding or connected to the same power line but cumulatively all the equipment connected to the same power line possibly generate enough amount of current to cause the power line to become a source of interference, so the measurement was carried out in DM and CM mode as per CISPR.

II. Measurement Technique

The DC-AMN is used for the assessment of conducted voltages disturbance at DC power ports. DC-AMN gives a predefined common mode (CM) 150 Ω termination impedance for the supply port of the EUT during measurements of Conducted Voltage emission at test sites. It is made to provide, in the required frequency range from 150 kHz to 30 MHz and specific termination impedances for symmetric (or DM) and asymmetric (or CM) measurement components.

Differential mode tracks the same path as the input power i.e. from line to line as shown by blue trace in Figure 1, while the common mode has a current path via earth as shown by red trace in Figure 1.

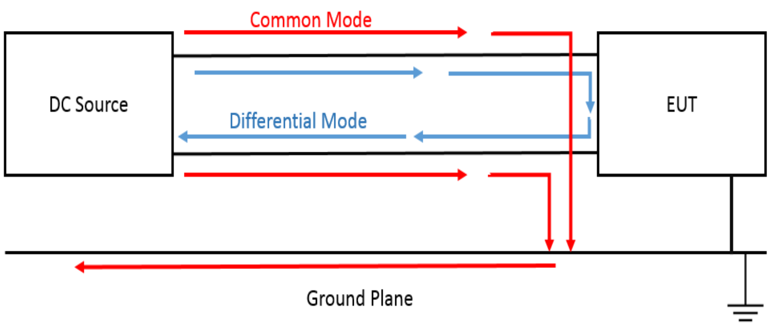

Figure 1: *CM & DM Measurement*

Further, the DC-AMN offers a decoupling network (i.e. an LC-filter) such that adequate decoupling is provided between EUT port input and mains supply, in order to avoid RF disturbances from the laboratory DC power source to actual measurement results, which in turn provides repeatable, valid and reliable measurement results [2].

Measurement of the conducted voltage emission on DC power ports is made by the 150 Ω DC-AMN in UM, DM and CM mode.

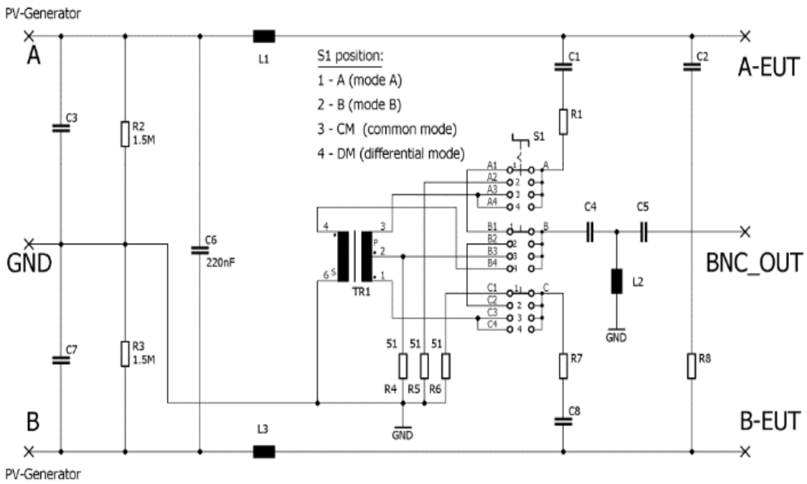

Figure 2: *Basic Circuit Diagram of 150 Ω DC-AMN [2]*

Positive or negative terminal (UM): The unsymmetrical voltage emission is measured from either positive or negative terminals to ground (V-AMN).

Common mode (CM): The sum of voltage emission of positive and negative terminal is measured against ground (T-AMN, asymmetrical voltage).

Differential mode (DM): The symmetrical voltage emission between the positive and negative terminals is measured (Delta AMN).

In these three different approaches of measurement the input impedance and differential impedance seen from the device under test is 150 Ω.

To measure the conducted voltage disturbance for frequency Band B (150 kHz to 30 MHz), FFT based measuring EMI receiver with the reference bandwidth 9 kHz in average mode detector is used. [3]

The measurements was carried out with reference to Figure 3 setup as followed to CISPR 22 guideline. The lamp load (as an EUT) was placed on the electrically insulated table 80 cm above the horizontal ground plane and placed 40 cm away from vertical ground plane, which was bonded with the floor and the EUT was connected to DC-AMN, which was earthed to the horizontal aluminum ground plane.

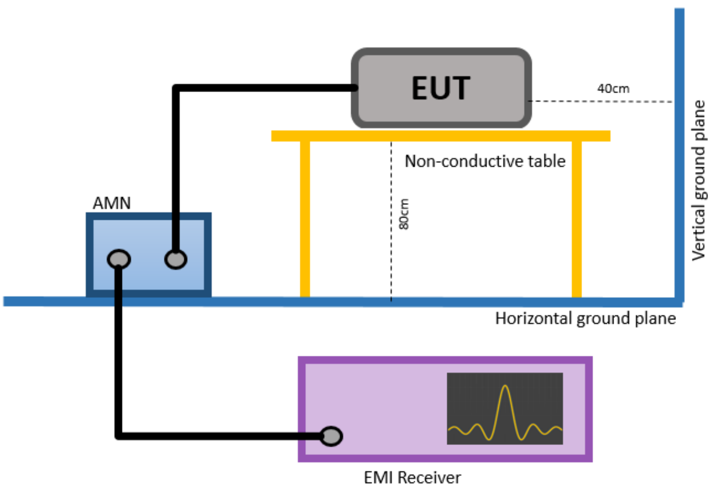

Figure 3: *Test setup block diagram*

III. Measurement

It was comprehended during measurement that UM and CM measurements were representing nearly the same graph patterns. So, the CM and DM measurement in average detection mode was carried out on DC operated EUT with various DC sources having different ripple factors. The measured ripple factor of different DC sources are as stated in TABLE 1.

Table 1: *DC sources' % R.F.*

DC Sour	Type of Source	V_{RMS}	V_{DC}	% R.F.
1	Switching	2.90	24.6	11.7
2	Switching	1.42	24.5	5.79
3	Linear type	0.39	24.0	1.62
4	Battery	0.18	23.7	0.75

The percentage ripple factor was calculated as below:

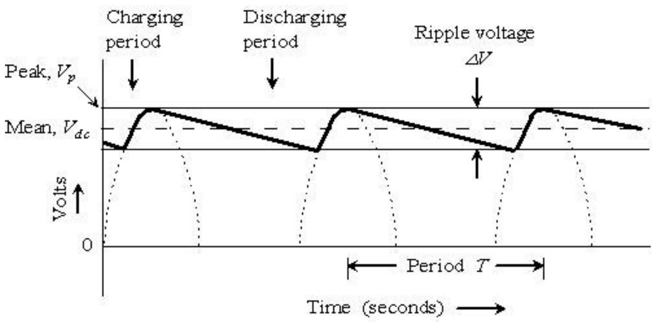

Figure 4: *Generalize output waveform of DC switching power source*

$$\% \, Ripple \ Factor = \frac{RMS \ value \ of \ AC \ component}{\text{Average value of DC output}} \times 100 \tag{1}$$

$$\%R.F. = \frac{V_{RMS}}{V_{DC}} \times 100 \tag{2}$$

The mentioned DC sources have been evaluated for its conducted voltage emission characteristics without EUT and with EUT in order to determine the consequence of ripple factor in actual measurement separately.

I. DC Source - 1 with % R.F. = 11.78%

The DC Source - 1 was switching type power supply. The results of conducted voltage emission in

CM and DM without EUT are shown in Figure 5 & 6 and with EUT in Figure 7 & 8.

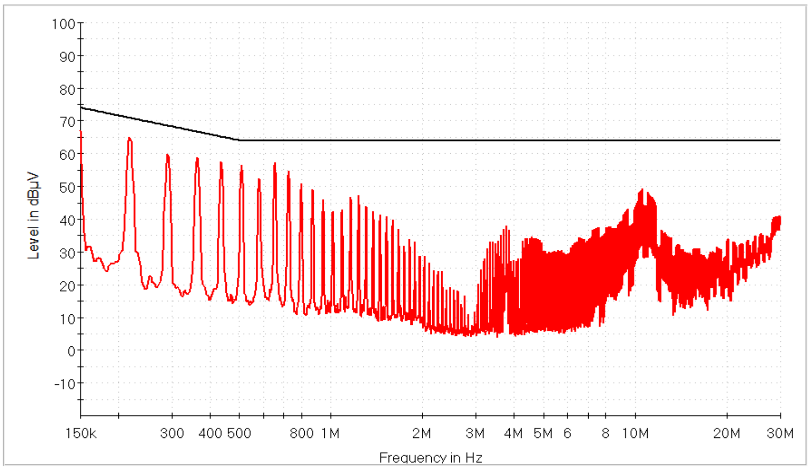

Figure 5: *CM measurement of DC source - 1 without EUT*

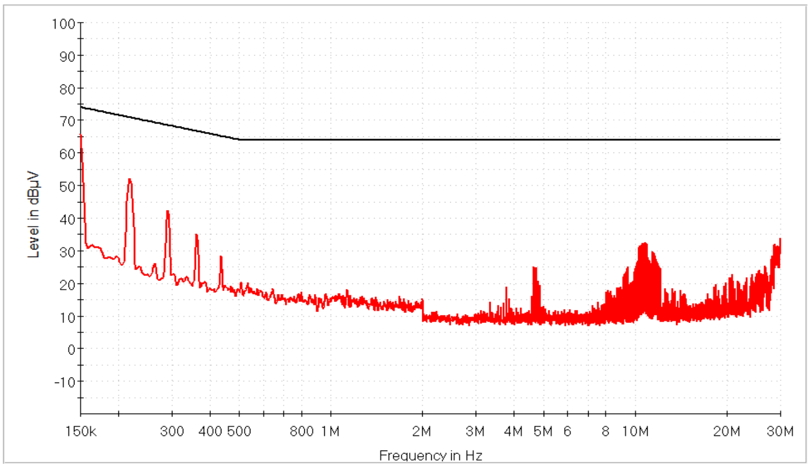

Figure 6: *DM measurement of DC source - 1 without EUT*

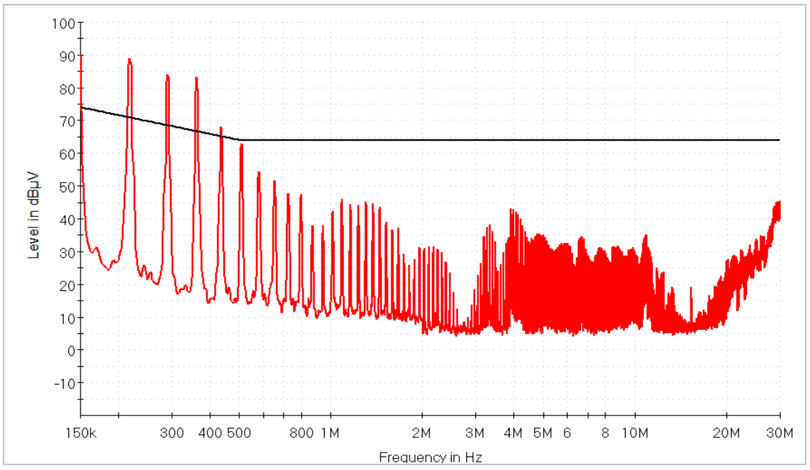

Figure 7: *CM measurement using DC source – 1 with EUT*

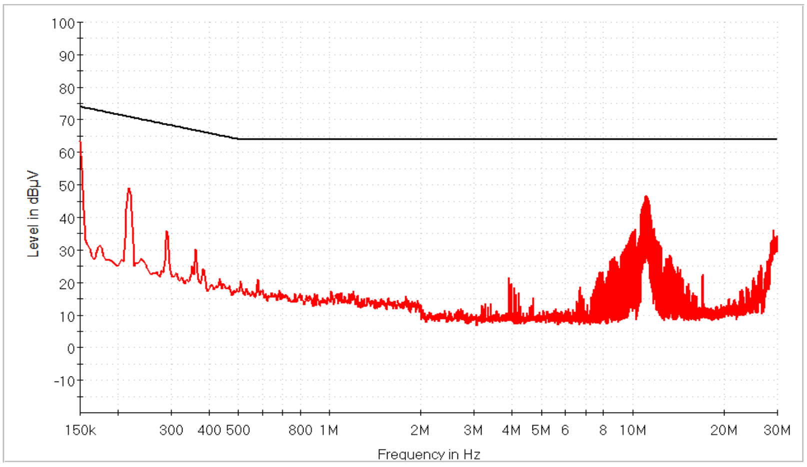

Figure 8: *DM measurement using DC source - 1 with EUT*

II. DC Source - 2 with % R.F. = 5.79%

The DC Source - 2 was switching type power supply. The results of conducted voltage emission in CM and DM without EUT are shown in Figure 9 & 10 and with EUT in Figure 11 & 12.

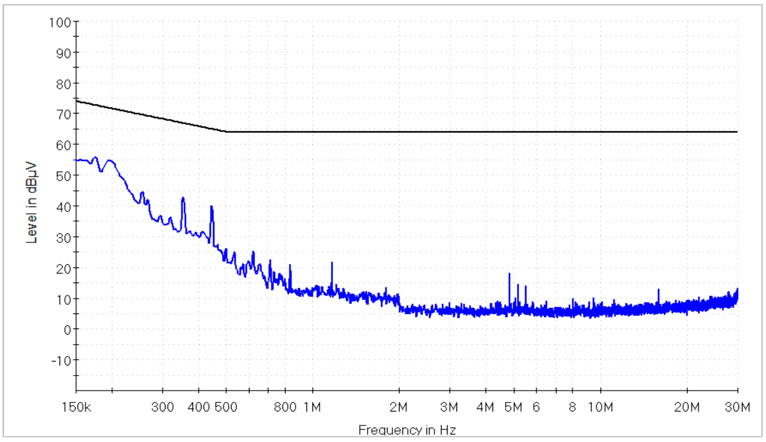

Figure 9: *CM measurement of DC source - 2 without EUT*

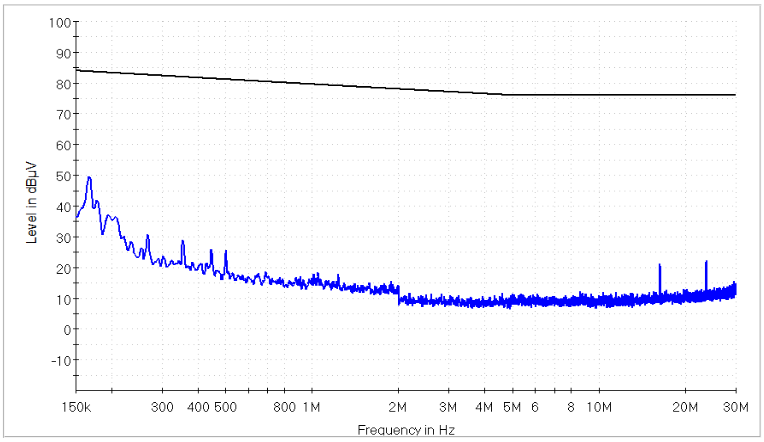

Figure 10: *DM measurement of DC source - 2 without EUT*

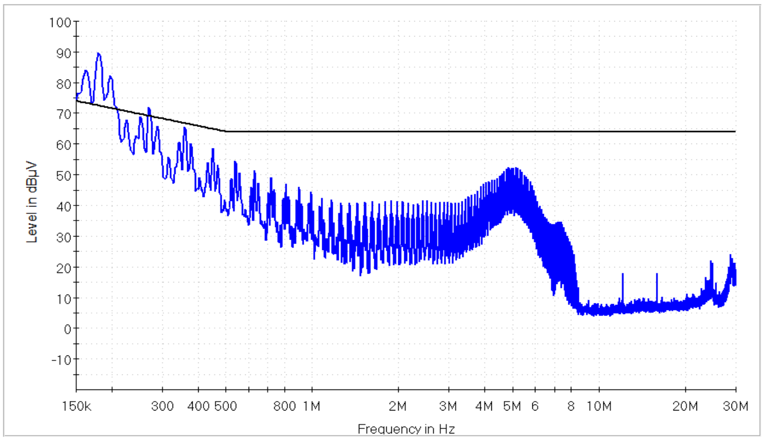

Figure 11: *CM measurement using DC source – 2 with EUT*

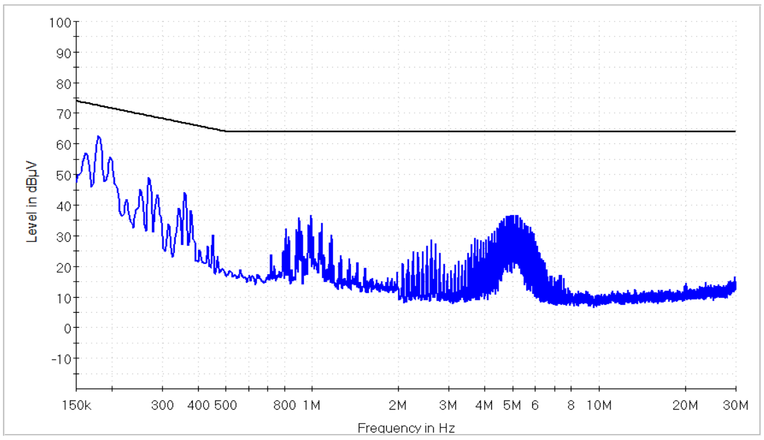

Figure 12: *DM measurement using DC source - 2 with EUT*

III. DC Source - 3 with % R.F. = 1.62%

The DC Source - 3 was linear type power supply. The results of conducted voltage emission in CM and DM without EUT are shown in Figure 13 & 14 and with EUT in Figure 15 & 16.

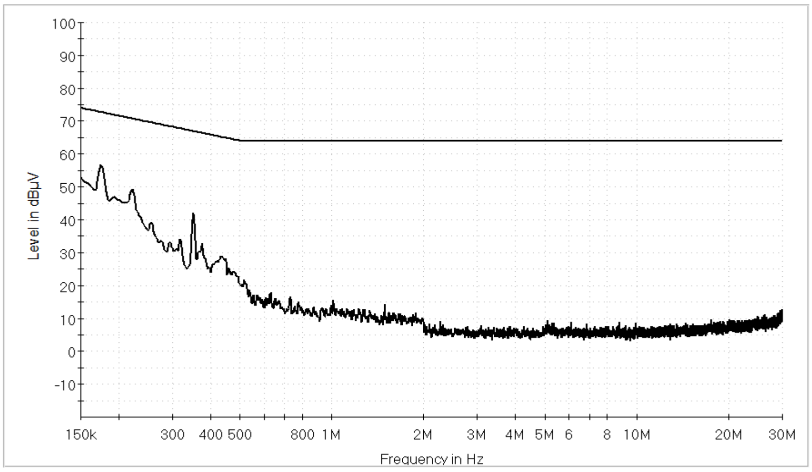

Figure 13: *CM measurement of DC source - 3 without EUT*

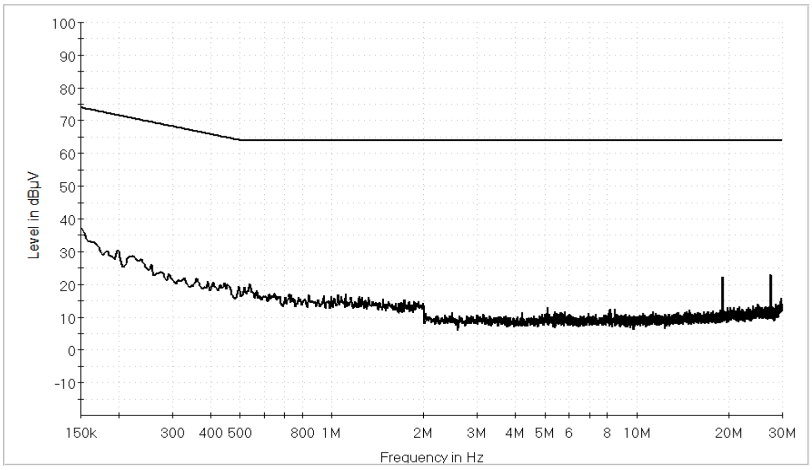

Figure 14: *DM measurement of DC source - 3 without EUT*

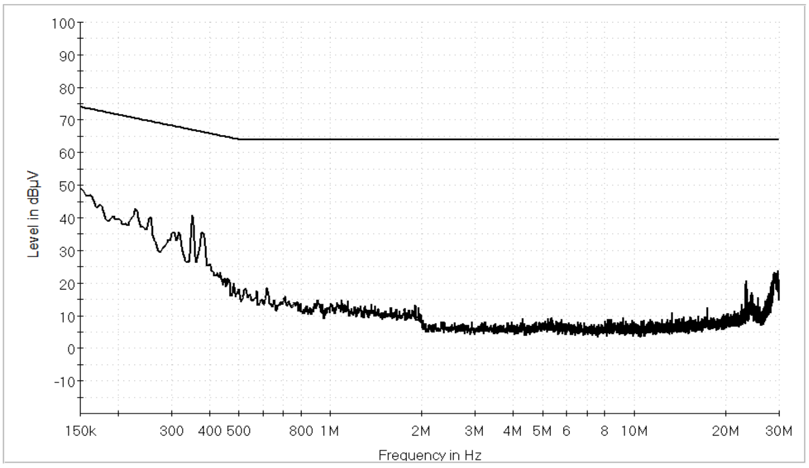

Figure 15: *CM measurement using DC source – 3 with EUT*

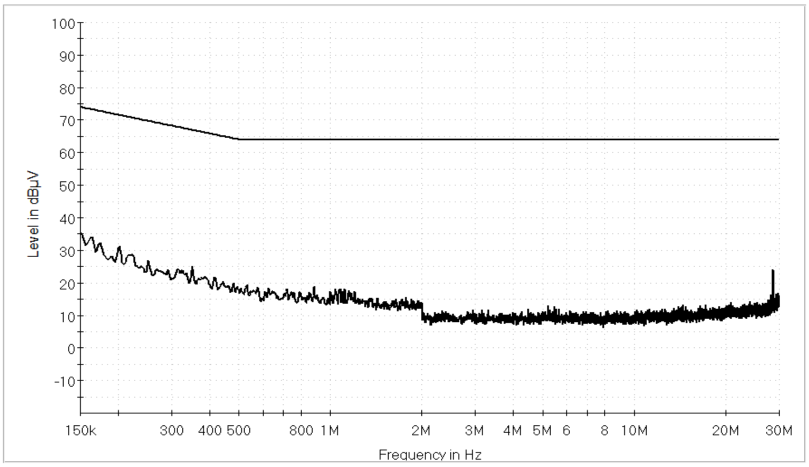

Figure 16: *DM measurement using DC source - 3 with EUT*

IV. DC Source - 4 with % R.F. = 0.75%

The DC Source - 4 was a battery. The results of conducted voltage emission in CM and DM without EUT are shown in Figure 17 & 18 and with EUT in Figure 19 & 20.

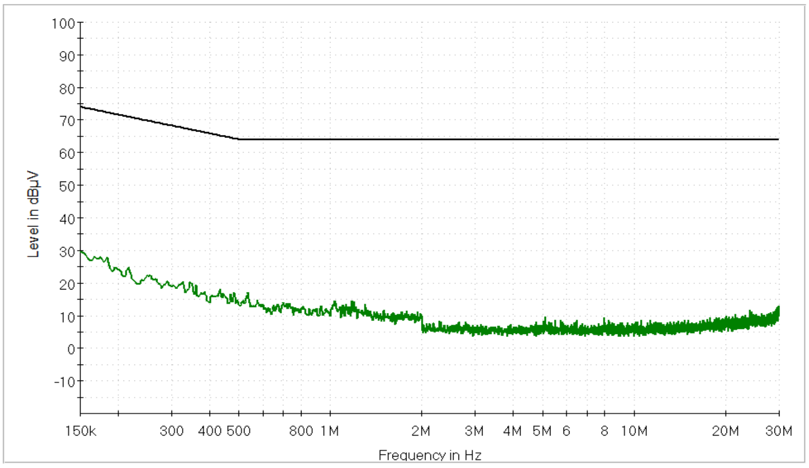

Figure 17: *CM measurement of DC source - 4 without EUT*

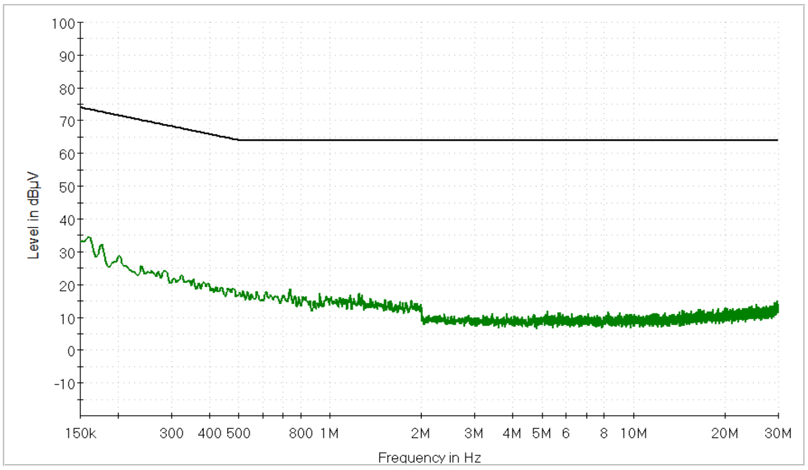

Figure 18: *DM measurement of DC source - 4 without EUT*

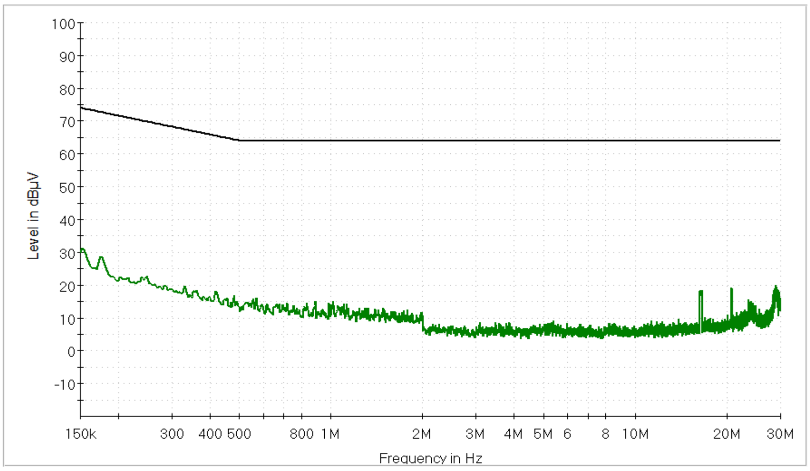

Figure 19: *CM measurement using DC source – 4 with EUT*

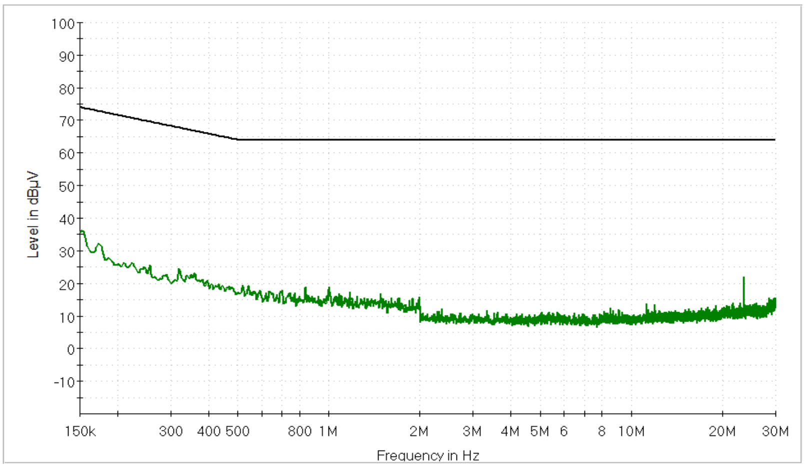

Figure 20: *DM measurement using DC source -4 with EUT*

IV. Observations

From the graph it can be clearly observed that DC Source having higher percentage ripple factor contributes more conducted voltage emission as compared to the source having lower percentage ripple factor.

As evident from Figure 7, 11, 15 & 19; the presence of switching frequencies spikes of switched type power supply sources can inject additional noise in the actual measurement (Figure 7 & 11), however those are absent in a case of linear power supply sources (Figure 15 & 19).

It has been observed that the source having higher percentage ripple factor i.e. DC source – 1, was showing a major change between without EUT (Figure 5 & 6) and with EUT (Figure 7 & 8) traces. While reducing the percentage ripple factor i.e. DC source – 4 had benefited in the traces of both without EUT (Figure 17 & 18) and with EUT (Figure 19 & 20) by showing the same patterns i.e. lesser changes in both traces.

Apparently the variations between with EUT and without EUT results were reduced as value of percentage ripple factor was decreased from DC source – 1 to DC source – 4.

V. Conclusion

In this paper effect of percentage ripple factor of four different DC power sources in conducted voltage emission in the frequency band from 150 kHz to 30 MHz is analyzed. It is observed that linear DC power supply having lower output ripple generates minimum conducted voltage emission, whereas switching DC power supply is not properly designed, having high ripple and it will generate more conducted voltage emission. In switching DC power supply, it is inherent characteristics that it operates at hard switching for several kHz frequency which interferes and generates more conducted voltage emission and hence to mitigate the effect of conducted voltage emission generated by DC source in the test setup linear power supply shall use over switching power supply. Although factors such as the transient response, slew rate, load and line regulation play an important role, it is inferred from this paper that the DC source having ripple factor less than 1.62% shows lesser effect on final conducted voltage emission and complies with the limits specified in CISPR 11.

VI. Acknowledgment

We heartily acknowledge the support received from Director-ERDA, Vadodara and ERDA staff to carry out this experiment.

References

[1] CISPR 22: IEC International Electrotechnical Commission, International Special Committee on Radio Interference, "Information Technology Equipment - Radio Interference Characteristics – Limits and methods of measurement".

[2] CISPR 11: IEC International Electrotechnical Commission, International Special Committee on Radio Interference, "Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement".

[3] CISPR16-1-1: IEC International Electrotechnical Commission, International Special Committee on Radio Interference, "Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus".

[4] CISPR16-1-2: IEC International Electrotechnical Commission, International Special Committee on Radio Interference, "Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Coupling devices for conducted disturbance measurements".