

Mitigation of Conducted and Radiated EMI Generation in High-Frequency Switching Devices

P. Sripodok, and C. Jettanasen

Abstract—The purpose of this paper is to investigate the electromagnetic interference (EMI) propagation paths and how to mitigate these generated high-frequency noises in high-frequency switching devices. Both conducted and radiated EMI can be produced when the devices are in operation. This results in restriction of power electronic devices' evolution. In order to effectively reduce EMI generation or overcome EMI problems, an Electromagnetic Compatibility (EMC) regulation should be applied. The conformity to the standard will guarantee the performance and the compatibility of the electrical/electronic devices/equipments to be employed or installed in the sensitive electromagnetic environment. The EMC standard is defined in the frequency range of 150 kHz to 1 GHz: 150 kHz to 30 MHz for conducted emission measurement and 30 MHz to 1GHz for radiated emission one. A switching device connecting to tuner kit (FM radio) is herein focused as an EMI source. The generated noises will be reduced by using grounding and shielding methods. The obtained results will be compared with an EMC standard (EN55022 class B) in order to reveal the effectiveness of the applied EMI mitigation techniques. The analysis and experimental results finally show that the conducted emission can be diminished by using multi-point grounding whereas the radiated emission is effectively reduced by using single-point grounding and shielding, in particular at high frequencies.

Index Terms—Electromagnetic interference (EMI), grounding, high-frequency switching devices, mitigation technique, shielding

I. INTRODUCTION

NOWADAYS, high-frequency switching devices have been increasingly employed in many domestic and industrial applications owing to their numerous advantages. A car radio receiver or a portable radio receiver, which mainly receives AM/FM signal from broadcasting station, is an example of high-switching frequency devices that may be sometimes in radio signal interference situation. Hence, the considered EMC problem herein is focused on undesirable electromagnetic noises issued from the switching device and/or tuner kit (FM radio) that can interfere with the normal

operation of the other nearby electrical/electronic devices or systems. This will affect the functionality of the radio-navigation system and communication services. The main principle in controlling the EMI noise level is to know the EMI propagation paths and to investigate the fundamental frequency of the conducted and radiated noises of the generation devices [1], [2]. There are a number of traditional and innovative conducted and/or radiated EMI attenuation techniques; however, this paper focuses principally on grounding and shielding techniques. Different configurations of grounding and shielding will be carried out. Ground is a main path in an electrical/electronic circuits/systems; it can cause severe problem to most sensitive electronic devices as well as telecommunication equipments if it is not properly connected or wired. For some applications, a noise may be added to original signal, and then, causes the AC line frequency hum in the system. In any systems, a ground loop can be unintentionally created when there is more than one ground connection part between two parts of equipment and interconnection via signal line or power line. The ground loop is a complete circuit consisting of the signal path and part of ground structure, which has two characteristics. First, it has multiple ground connection that provides multiple return paths: these allow significant flowing current in the grounding structure. Second, it unbalances the circuit. Either circuit isolation or balance may remove the mentioned problem [3]. For shielding technique, it is based on absorbing or echoing electromagnetic energy via all kinds of shielded material to prevent external interference (passive shielding) or restricting devices electromagnetic energy in certain area to prevent interfering other devices (initiative shielding). Both grounding and shielding methods will be applied to the studied system, which is the FM radio signal receiver kit.

II. STUDIED SYSTEM, EMI TESTING, AND EMI ATTENUATION TECHNIQUES

A. Studied System

The studied system is an FM radio signal receiver kit, consisting of 1) switching devices connected to 220Vac supply, 2) regulator used to adjust dc voltage from input 12Vdc to output 9Vdc, and 3) tuner connecting to antenna to receive FM radio signal from broadcasting station. The block diagram is shown in Fig. 1.

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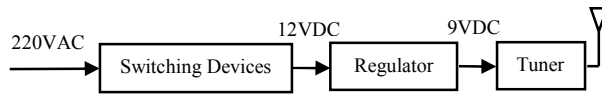


Fig. 1. Block diagram of the studied system

B. Setup for Conducted Emission Testing

The conducted EMI emission measurement is normally carried out in a shielded enclosure in EMC laboratory. The conducted emission is measured from 9 kHz to 30 MHz according to EMC standard (such as CISPR, EN, FCC standards). The measurement procedure requires EMI receiver and line impedance stabilization network (LISN) with 50Ω/50μH impedance for testing. The LISN must be inserted between the equipment under test (EUT) and the ac utility line to provide specified measuring impedance for noise voltage measurement. It also serves to isolate the EUT and the measuring equipment from the utility at radio frequencies. The setup configuration of conducted emission is illustrated in Fig. 2. The EUT in Fig. 2 refers to the switching device and tuner.

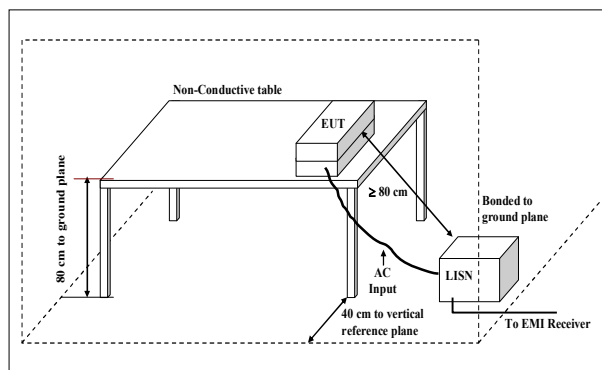


Fig. 2. Setup configuration of conducted emission testing

C. Setup for Radiated Emission Testing

The radiated emission measurement is performed with antenna and EMI receiver to observe the emission characteristics and identify the frequency of emission that has the highest amplitude relative to limit by operating the EUT with a typical configuration.

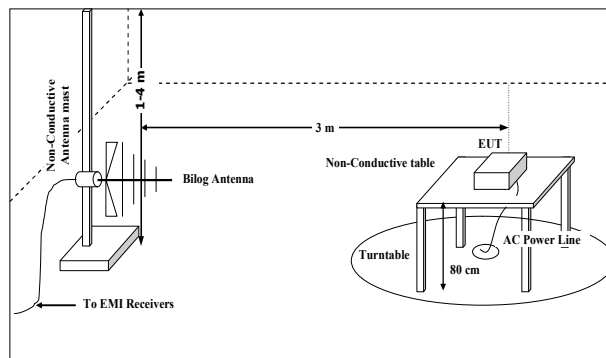


Fig. 3. Setup configuration of radiated emission testing

The EUT and cable configurations of operation are determined for producing the maximum level of emissions. The EUT is placed on the 80cm height non-metallic table on a 1m radius turntable. The Bi-Log antenna (30MHz–2GHz) is used to receive the noises of EUT and put on the antenna mast. They are all inside the semi-anechoic chamber. The testing method and the EUT setup are performed according to EN 55022. The EUT setup configuration is shown in Fig. 3.

D. Grounding Technique

Grounding technique is a kind of traditional EMI mitigation techniques. It can be applied either single-point grounding or multi-point grounding; it depends on the noise frequency intended to be reduced. The objective of grounding technique is to minimize the ground impedance, and thus to reduce the potential of the ground loop from circuit of switching devices. Where the external current in the ground structure generates potential difference between the ground connections then the duplicate ground paths form the equivalent of a loop antenna which very efficiently picks up interference currents. The induced voltage by this grounding loop can be determined using equation (1) [3].

$$V_{induced} = \frac{-d\phi}{dt} = -s \frac{dB}{dt} \tag{1}$$

Where s is the loop area in m^2 , and dB/dt is a change in time of magnetic flux intensity through the vertical of loop. As a consequence of ground loop induced voltages, the ground reference in the system is no longer a stable potential, so signal overlaps with the noise. The induced voltage is expressed in equation (2) [3].

$$V = i_g (r_g + j\omega L_g) - s \frac{dB}{dt} \tag{2}$$

Where i_g is an instantaneous current, and $(r_g + j\omega L_g)$ is impedance at point g referenced to earth [2]. Two grounding techniques are considered in this study. The single-point grounding is generally good for low current (< 1 A) and low frequency range (< 1 MHz) while the multi-point grounding is normally effective for high current (> 1 A) and high frequency range (> 100 kHz) [4]. The single-point grounding connection is illustrated in Fig. 4 it has effect to radiated emission and the multi-point grounding connection is illustrated in Fig. 5; this affects to conducted emission.

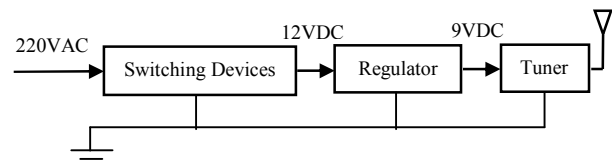


Fig. 4. Single-point grounding configuration

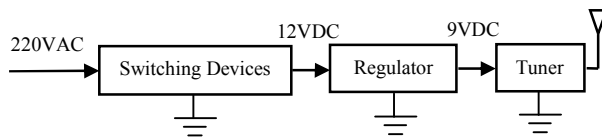


Fig. 5. Multi-point grounding configuration

E. Shielding Technique

Shielding technique is usually used for radiated EMI reduction. Shielding is absorbing or echoing electromagnetic energy via all kinds of shielded material to prevent external interference (passive shielding) or restricting devices electromagnetic energy in certain area to prevent interfering other devices (initiative shielding). Hence, shielding has similar property to Faraday cage. Shielding is important technology of restraining EMI as good restraining effect on not only radiant interference but also electrostatic interference, engineering design, good shielding is realized under breezy condition. In communication system, shielding is commonly a thin piece of metal that is placed between a circuit board and other circuit boards or electronic equipment and on is a thin metal placed on a casing that contains the circuit board [5]. The shielding made of shielding tapes and/or metal case/sheet can be employed to directly reduce or restrict radiated emissions. The main parameter related to this kind of electromagnetic noise is skin depth, which is defined as the distance from the surface of the metal where the current density has fallen to 1/e or 37 percent of its value at the surface. The relationship between material properties and skin depth of the shielding metal is shown in equation (3) and added protection sheet for shielding is depicted in Fig. 6. [6]

$$\delta = \frac{1}{\sqrt{\pi f \mu \sigma}} \quad (3)$$

Where δ is skin depth (m), f is frequency (Hz), μ is permeability with the relation of $\mu = \mu_0 \mu_r$ (H/m) where μ_0 is permeability of free space, equal to $4\pi \times 10^{-7}$ (H/m) and μ_r is relative permeability, and σ is electric conductivity (S/m).

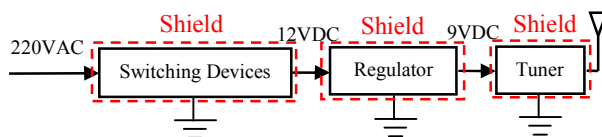


Fig. 6. Added protection sheet for shielding

III. RESULTS AND DISCUSSION

The switching device; a part of radio signal receiver generates conducted noise in frequency domain as shown in Fig. 7. It shows that its switching frequency is 25 kHz (the first harmonic) [7].

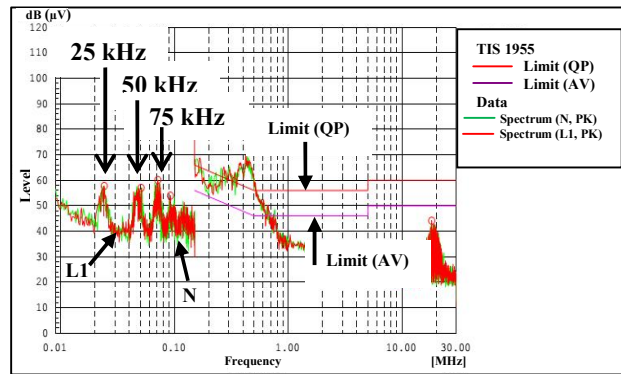


Fig. 7. Conducted noise generated by the switching device

According to the EMC standard, the EMI measurement of switching device will be carried out for both conducted and radiated emissions. The testing results of conducted and radiated noise level for only switching device (disconnected tuner kit) are illustrated in Fig. 8 and Fig. 9, respectively.

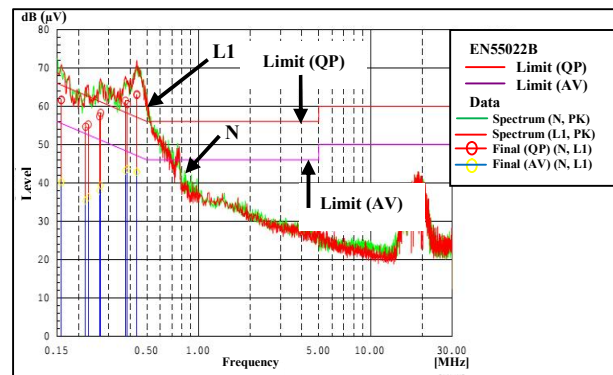


Fig. 8. Conducted noise generated by only switching device

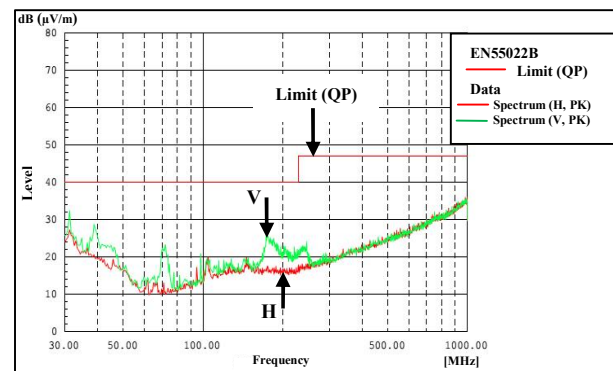


Fig. 9. Radiated noise generated by only switching device

Note that, conducted EMI level exceeds the standard in the frequency range of 150 kHz – 800 kHz while beyond these frequencies and in the frequency range of radiated emission, the generated EMI respects to the standard.

Then, the switching device connecting to tuner kit (FM radio) is taken into account for EMI emission measurement. The testing results of conducted and radiated noises for multi-point grounding and without shielding are illustrated in

Fig. 10 and Fig. 11, respectively. They are compared with the EN55022 class B standard. We notice that the conducted noise has similar spectrum to the case of only switching device as EUT (as in Fig. 8). This means that only the switching device generates noise in this mode. When comparing the spectrum in Fig. 11 and Fig. 9, it is obvious that the tuner has effect to EMI generation. Moreover, the radiated noise surpasses at around 35MHz.

When applying single-point grounding and shielding to the FM radio signal receiver, the testing results are depicted in Fig. 12 and Fig. 13. It is clearly seen that the radiated noise level becomes lower than the previous case around 12 dB (for the highest peak). This confirms the effectiveness of grounding and shielding techniques for EMI mitigation.

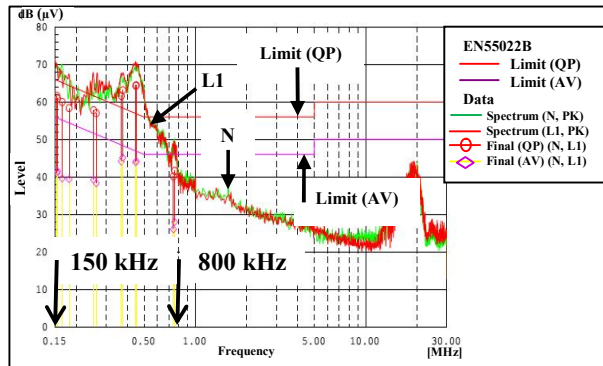


Fig. 10. Conducted noise of switching device and tuner kit (with multi-point grounding)

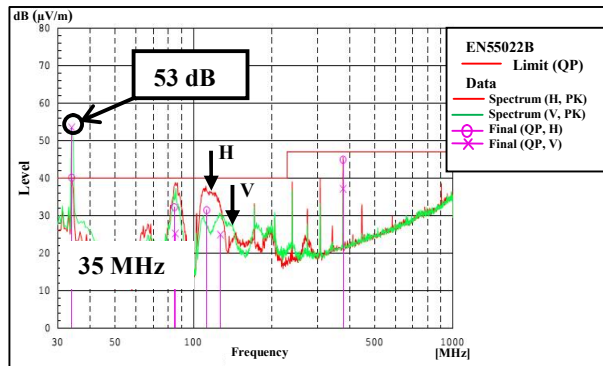


Fig. 11. Radiated noise of switching device and tuner kit (with multi-point grounding and without shielding)

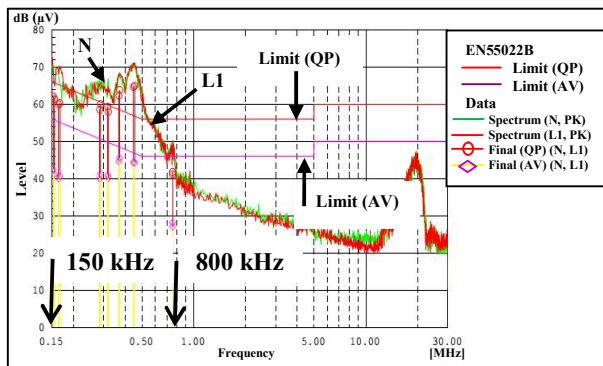


Fig. 12. Conducted noise of switching device and tuner kit (with single-point grounding)

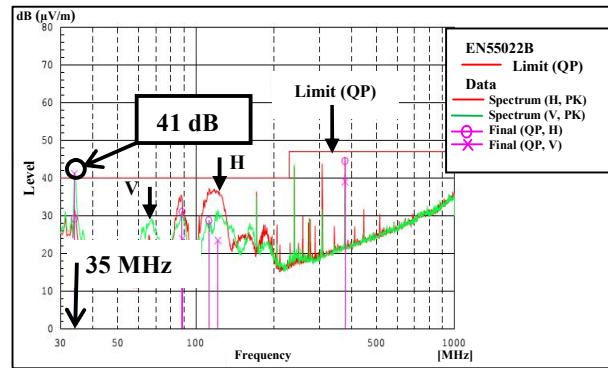


Fig. 13. Radiated noise of switching device and tuner kit (with single-point grounding and with shielding)

IV. CONCLUSION

The analysis and experimental results showed that the conducted noise could be attenuated by using multi-point grounding method whereas the radiated emission can be reduced by using single-point grounding with shielding approach. Finally, the both techniques are effective for mitigating noises issued from the switching devices of FM radio signal receiver.

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