ELECTROMAGNETIC MODELING OF PARASITICS AND MUTUAL COUPLING IN EMI FILTERS

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Abstract

MSW has been used to predict mutual coupling between inductors mounted on PCB and mutual coupling reduction techniques between two inductors mounted on PCB. Measurement and modeling results agree very well. Therefore, it is possible to successively use the CST MSW in EMI power filter inductor impedance analysis, mutual coupling analysis and mutual coupling reduction technique analysis. An accurate prediction of EMI-filters' insertion loss requires the correct calculation of mutual coupling between the circuits' components as well as of the components parasitic. It does need some experience to define crucial point of coupling and it would be best to calculate them by a field solver like the PEEC-method, which has become state-of the-art in high speed chip design. Selection of the particular EMI mitigation method depends on the various requirements on the system such as performance, size, cost, and topology. EMC design is not only minded to not disturb surrounding systems but also mainly the reliability of the target system. Normally, different noise suppression techniques have to be applied simultaneously to comply with the specific standard.

Keywords: EMI Filters, Electromagnetic compatibility, Electro Magnetic Interference

Introduction

Electromagnetic compatibility (EMC) is the branch of electrical sciences which studies the unintentional generation, propagation and reception of electromagnetic energy in conductive form and as radiation, leading to unwanted effects- electromagnetic interference (EMI). EMC ensures the correct operation of electronic equipment in electromagnetic environment. Alternatively, it can be defined as- EMC is the control of EMI. Besides, understanding the phenomena by it, EMC also addresses the countermeasures, such as control regimes, design and measurements, which should be taken into account to prevent malfunctioning of electronic equipment.Nowadays, electronics is integrated in a wide band of products available in market. Electronics clock speeds are still increasing, leading to low pulse rise-times and fall-times. Electronic components are shrinking in weight and volume, thus leading to compact and light weight electronic devices. Compact placement of electronic components leads to interaction between them.The usage of EMI power line filter is one of possibilities to limit conductive noise propagation in the environment. Also, filters are shrinking in size and weight following the electronics evolution. It leads to closely spaced inductors and capacitors that interact to each other, reducing filter performance. Mutual inductance and parasitic capacitance between filter components and PCB becomes a very important aspect in high quality filter design.

Electro Magnetic Interference (EMI)

Electro Magnetic Interference (EMI), also known as Radio Frequency Interference (RFI), is unwanted electromagnetic energy polluting the environment. Its propagation via radiation and power conduction over system signal and power lines can affect the operating of electrical equipment around the source. It is generated, by rapidly changing electric or magnetic fields. Common sources of EMI are electric motors, relays and switches where rapid changes of current flow produce a broad range of interference frequencies. Initially, when the switch is open, there is an electric field, E only around the wire connected to the battery. This is a static field and does not induce interference in surrounding circuits. When the switch is closed, magnetic fields, H are established around the conductors and an electric field is established in the right hand half of the circuit. The establishment of thefield flux in the space around the wires involves rapid charges of these fields.

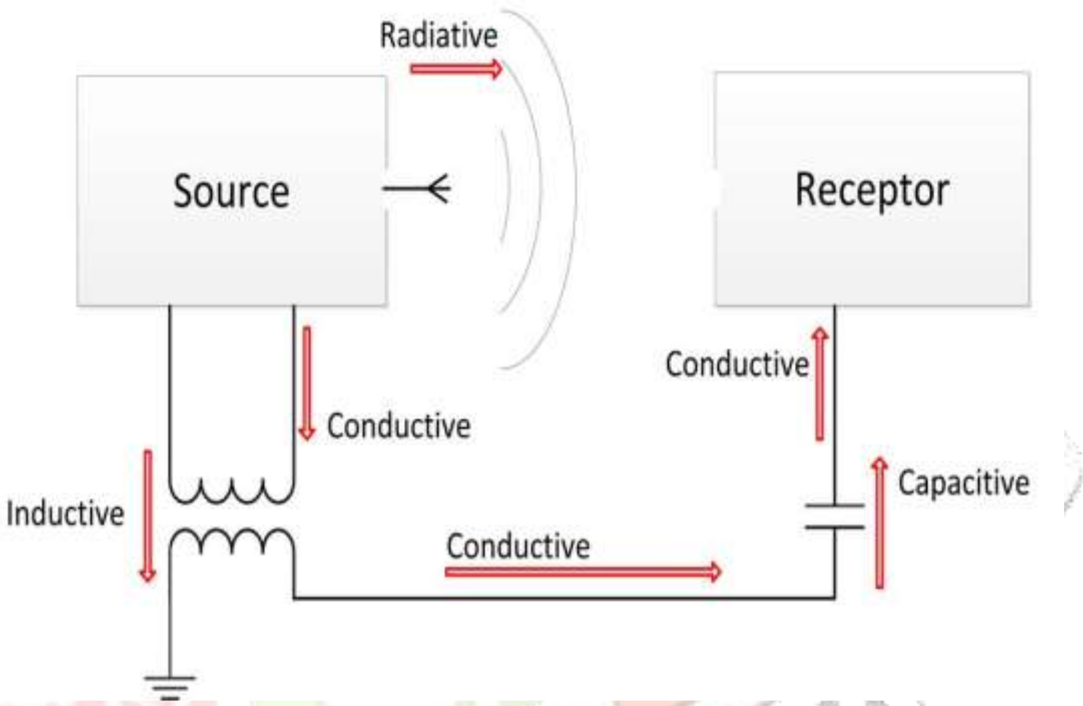
High-Frequency Modelling Of Emi Filters Considering Parasitic Mutual Couplings

With an ever increasing demand for low conducted electromagnetic emissions, electromagnetic interference (EMI) filters have become an integral part of modern electronic devices used in household appliances, industrial and spacecraft electronic equipment. As electronic equipment becomes smaller and smaller, miniaturization of EMI filters is of primary concern. Reduction of passive EMI filter size can be achieved, mainly, by placing the filter components very close to each other. However in this case miniaturization of EMI filters becomes very challenging owing to increased parasitic inductive couplings between filter inductors and capacitors. The mutual couplings lead to decreased EMI attenuation in the high-frequency range.

High-frequency modeling of EMI filters considering the parasitic couplings is usually performed using partial element equivalent circuit (PEEC) method which is integrated in 3D simulation tools, such as GeckoEMC. However, there are few studies considering finite integration technique (FIT) for EMI filter modeling. FIT is integrated in 3D simulation tools, such as CST MWS. 3D electromagnetic modeling of differential mode Ê type EMI filter with two capacitors and one inductor using CST MWS.

EMI Filters and Their Issues

Because EMI produced by switch mode power supplies usually exceeds acceptable levels, the emissions must be reduced. In most practical cases, noise suppression is accomplished by using low pass filters. For instance, a typical L-type low pass filter used to attenuate high frequency noise, Z1 (in the series path), which requires high impedance; is normally implemented by inductor. Meanwhile, low impedance characteristics are required for Z2 (in the shunt path), which is normally implemented by capacitors. Basically, electromagnetic compatibility is concerned with the generation, transmission and reception of electromagnetic energy. These three aspects are illustrated in figure given below Source generates the emission and a transfer or coupling path transfers the emission energy to a receptor, where it is resulting in either desired or undesired behavior. Electromagnetic interference (EMI) occurs if the received energy causes the receptor to behave in an undesired manner.



Conductive coupling happens when the coupling path between the source and the receptor is formed by direct contact with a conducting body. Conducting body can be formed out of transmission lines, PCB trace, wires, cables, heat sinks or enclosures. Inductive coupling happens when a varying magnetic field exists between two conductors in a close distance, inducing a current in nearby conductor. Capacitive coupling happens when a varying electrical field exists between two adjacent conductors in a close distance, inducing a change across the gap between these two conductors. Electromagnetic coupling happens when source and receptor are separated by a large distance, source emits electromagnetic energy and receptor receives electromagnetic energy in terms of electromagnetic waves. It should be noted that “close distance” in EMC usually is defined as distance where magnetic field is dominant and field strength varies as 1/r3, 1/r2, where r is distance from radiation source. “Large distance” is a distance in which the field strength varies as 1/r2 and wave impedance depends on medium it is propagating through (e.g. 377 Ω in vacuum).

Conclusion

Therefore, it is possible to successively use CST MSW in EMI power filter capacitor impedance analysis, mutual coupling between capacitors and mutual coupling reduction technique analysis.CST MSW has been used to predict mutual coupling between inductors mounted on PCB and mutual coupling reduction techniques between two inductors mounted on PCB. Measurement and modeling results agree very well. Therefore, it is possible to successively use the CST MSW in EMI power filter inductor impedance analysis, mutual coupling analysis and mutual coupling reduction technique analysis.An accurate prediction of EMI-filters' insertion loss requires the correct calculation of mutual coupling between the circuits' components as well as of the components parasitic. It does need some experience to define crucial point of coupling and it would be best to calculate them by a field solver like the PEEC-method, which has become state-of the-art in high speed chip design.

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