Modeling Effect of Lightning Induced EMP on Wire Harness in Automobiles

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Abstract: A MoM-based EM code was applied to model the electromagnetic fields coupled to a vehicle by nearby lightning return strokes. The return stroke model was applied to investigate the effect of the lightning induced electromagnetic fields on wire harness in automobile that generates high peak current electromagnetic pulse (EMP) and potential EMI/EMC concerns on electrical and electronics (E/E) components. Frequency content of the lightning induced current pulse on the wire cable harness was also analyzed by Fast Fourier Transform (FFT).

I. Introduction

There has been a steady increase in the number of electronic component counts in automobiles in recent years. Current industry trend toward the introduction of more hybrid-engine and drive-by-wire in automobiles can further exacerbate the EMC/EMI concerns caused by the lightning induced electromagnetic pulses (EMP). The effect of the lightning induced EMP on automotive electronic components and cable harness has been studied experimentally and reported in the past [1].

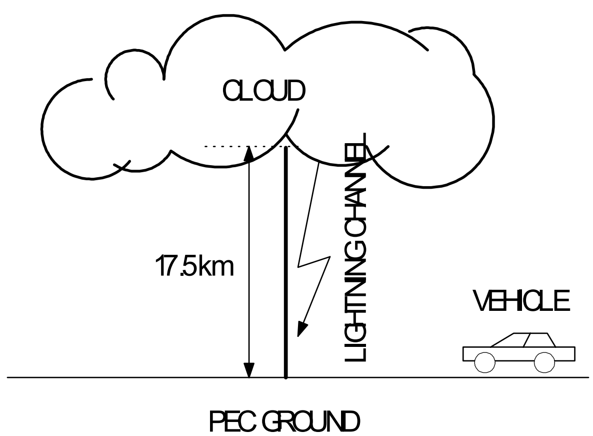


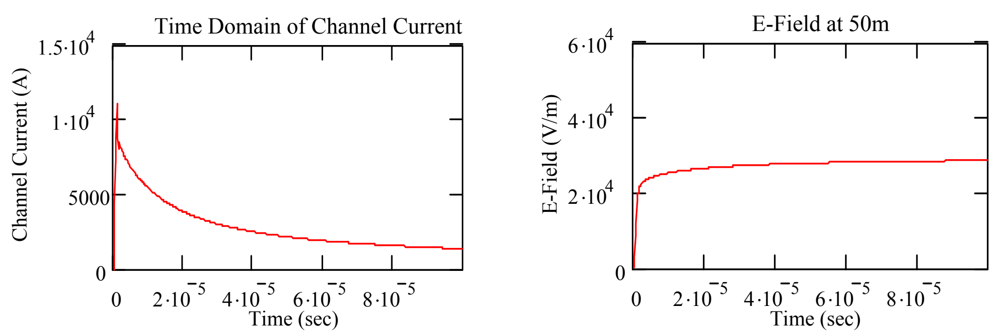
Fig. 1 Lightning return stroke model

The lightning induced EMP is the result of flow of currents through a channel formed from the cloud to the ground. The current flowing channel can be modeled as a long wire antenna as shown in Fig. 1. Various return stroke models have been reported in literatures [2-5]. By applying numerical electromagnetic code, these models have successfully reproduced some of the observed features of the lightning return stroke event such as electromagnetic fields at various distances from the lightning strike point. This paper intends to produce such EM lightning return stroke model that uses the Method of Moments (MoM) based full wave commercial code FEKO to investigate the EMC/EMI effects of the lightning induced EMP on electrical subsystems and cable harness in a vehicle.

II. Lightning Return Stroke Model and Validation

In this paper an EM stroke model for a lightning event similar to the one presented in [5] was constructed in the FEKO. The time domain results of E-fields at various distances from the lightning strike are then compared with those presented in [5] to validate the MoM-based EM stroke model. After validating the model, a vehicle with embedded wire harness is introduced in the presence of the EM return stroke model.

The time-domain results were obtained by applying the Inverse Fast Fourier Transform (IFFT) algorithm to the frequency domain results calculated from the FEKO model. The lightning channel was modeled as a 17.5km long monopole antenna with 0.05m in radius, as suggested in [5], A ramp-pulse voltage source was located at the bottom of the monopole conductor, which was connected to Perfectly Electrical Conduction (PEC) ground plane as shown in Fig.1. The ramp-pulse of 1μs rise time with 14MV was applied to the source to generate a current wave having 11kA peak amplitude as shown in Fig 2(a). Fig. 2(b) shows E-field calculated at 50m away from the lightning channel which features a characteristic flattening in E-fields within hundreds of meters from the lightning channel. These results compare very well with the results presented in [5].



(a) (b)

Fig. 2 Validation of Model (a) Return stroke channel current, (b) E-Field at 50m

This simple EM return stroke model also shows a characteristic zero crossing in E-field at 100km away from the lightning strike within 80μs as shown in Fig. 3. This feature was not demonstrated in the comparable model in [5]. Overall comparisons of the lightning induced E-field results confirm the validity of the EM return stroke model in this paper.

Magnitude of the lightning induced E-fields at 1m above the ground plane is plotted at various distances in Fig. 4. The induced E-fields rapidly diminish as the lightning strike distance gets further away; however some sensitive electronic subsystems may still be susceptible to the induced EM-fields by nearby lightning strike within tens to hundreds of meters.

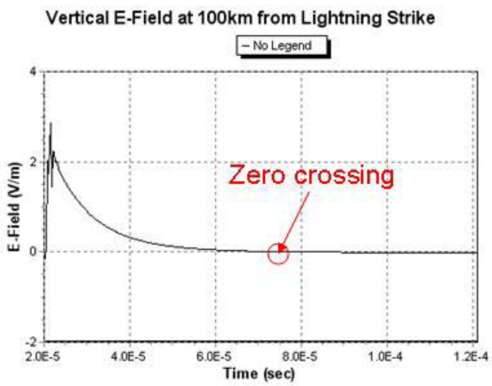


Fig. 3 Zero Crossing of E-fields at 100km

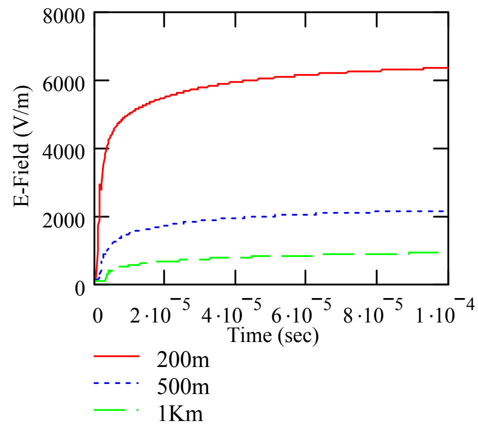


Fig. 4 Lightning induced E-Field at various distances

III. Induced Current in Cable Harness

Having confirmed the validity of the EM return stroke model of the lightning, a simple vehicle model with an embedded wire harness, which is shown in Fig. 5, is introduced at a distance of 50m from the EM return stroke model. The wire harness is terminated with a 50-ohm load which can be assumed as a sensitive electronic device. Any transient current or voltage induced by the lightning strike can be computed at the 50-ohm load. The radius of the wire harness is 1mm and is routed approximately 3-4cm above the vehicle body from the instrument panel area to the left C-pillar area. The box shape car model is approximately 1.5m wide, 4m long and 1.25m high.

In order to accurately represent the 200μs excitation ramp-pulse in the time-domain, the upper frequency of calculation was set at 1 MHz with 601 frequency samples. The calculated induced currents, due to the lightning return stroke, at the 50-ohm load at the end of the wire harness is shown Fig. 6(a). The current initially reaches its peak amplitude of 60mA and then decays rapidly. Fig. 6(b) shows its frequency content which was obtained by taking fast Fourier transform of the time-domain data. The induced currents are present mostly below 20 kHz with its peak amplitude of 0.2A observed at around 10 kHz. It clearly indicates that the effect of coupled transient current due to the lightning must be taken into account in wire harness design especially for E/E systems operation at around the 10 kHz to 20 kHz.

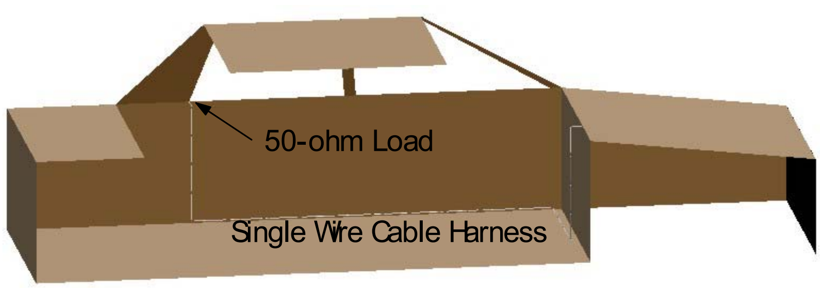
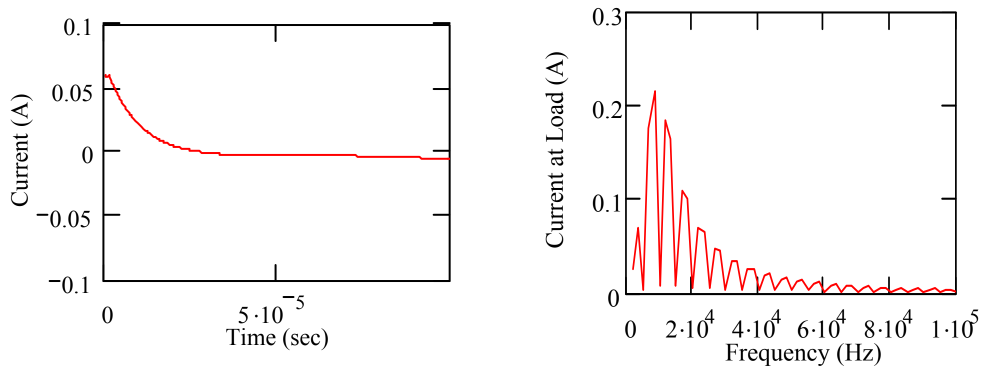


Fig. 5 Single wire cable harness route in a simple vehicle model



(a) Induced Current (b) Frequency Content

Fig. 6 Lightning induced current at 50 ohm load of cable harness.

IV. Summary

This paper discusses the application of MoM-based commercial numerical electromagnetic code to model the lightning induced electromagnetic fields and their coupling onto a wire harness in a vehicle. The lightning return stroke is modeled as a long wire monopole as discussed in the published literature [5] and its validity is confirmed by comparing some feature characteristics such as the induced EM field waveforms to those presented in [5]. Investigation shows that the transient current with 60mA peak amplitude may be presented to a 50ohm load at the end of the wire harness with a vehicle at a distance of 50m from the return stroke. Its frequency content shows most of the induced current at the 50 ohm load is around 10 kHz to 20 kHz. This preliminary investigation suggests that the lightning induced electromagnetic fields shall not be overlook in the vehicle wire harness design, especially for any vehicle electrical system operating over the 10 kHz to 20 kHz range.

References

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