Construction of Equivalent Circuit Model for Capacitive Voltage Probe

Capacitive Voltage Probe (CVP) is a measurement device for electromagnetic disturbances around multi-wired cables. The cable to be measured is clamped in the probe. Capacitance between the cable and inner electrode of the probe is used to obtain measurement of the voltage on the wires in the cable without coming into contact with them. This allows conducting measurements without stopping signal transmission. CVP detects presence of unbalanced i.e. common mode voltages. Device is applicable to variety types and sizes of cables.

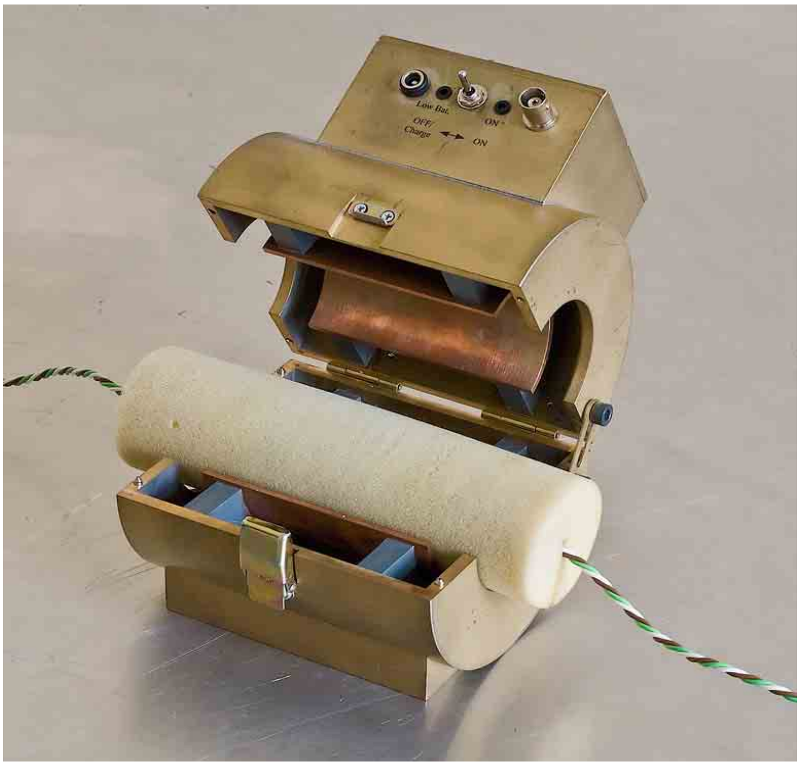

Fig. 1. Capacitive Voltage Probe

Problem Definition

In some EMC problems direct full wave Method of Moments (MoM) calculations of low frequency problems are very ineffective. Alternatively can be used low frequency circuit theory. According to low frequency circuit theory, low frequency interactions can be with high accuracy described as

27 Pekin Str., Tbilisi, 0160, Georgia
Tel.: ++995-32-389091; Fax: ++995-32-389092

quasi-static processes, where parameters (capacitances and inductances) of equivalent circuit can be obtained from the static considerations.

CVP model can be designed in the form of equivalent circuit. Analysis of obtained calculation results of the constructed model in comparison with full wave electromagnetic calculations is performed. This comparison helps to conclude whether constructed equivalent circuit model is adequate for such kind of problems.

Model for Full Wave Electromagnetic Analysis

Geometry of CVP model used for full wave electromagnetic analysis is shown in Fig.2. Electromagnetic solver TriD based on MoM is used for calculations. Surfaces of electrodes and side plates are represented with triangular meshes. CVP model is located above infinite PEC ground plane. Grounding of outer electrode and side shields is modeled as direct wire connection to infinite PEC ground plane.

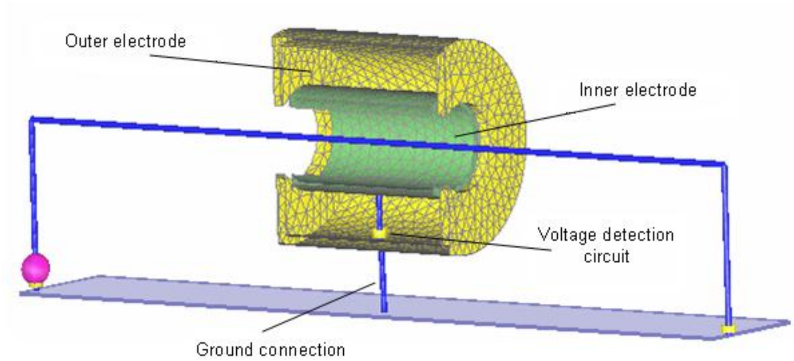

Fig. 2. Model for MoM calculations

As follows from operational principle of CVP voltage detected in output in certain manner is corresponding to the voltage in the measured cable. Relation between these two voltages is linear. However transformation coefficient is not known. Probably value of this coefficient can be derived from theoretical considerations but there is easier way to determine it via virtual calibration process. Suppose we have a cable transmitting known voltage V_{cable}. CVP will detect some voltage V_{probe}, which helps to determine calibration constant $Coef=V_{cable}/V_{probe}$. Now multiplying this constant on measured voltage in probe one can be sure that CVP is detecting correct voltages in the cable V_{CVP}.

Equivalent Circuit Model

Fig.3 illustrates equivalent circuit for simulation of CVP operation.

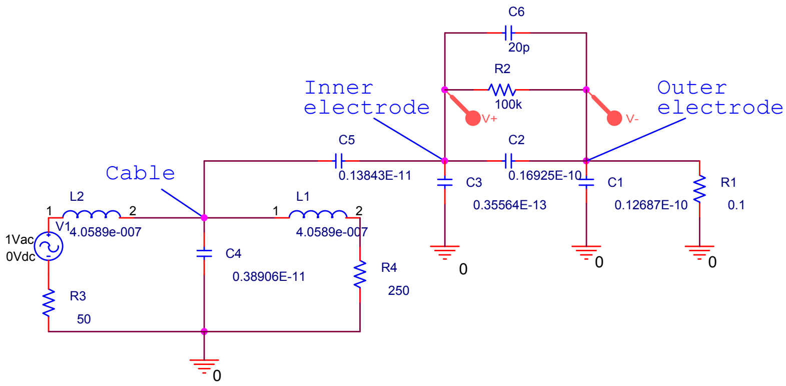

Fig. 3. Equivalent circuit model

Wire is represented with one transmission line segment (T scheme is used); LC parameters of wire calculated against zero potential are used. Capacitive connections of inner and outer electrodes with ground are represented with theirs self-C parameters. Capacitive connection between electrodes and voltage detection circuit are modeled with parallel connection of high impedance and mutual C of electrodes. Terminations of wire are represented directly with resistive elements and voltage source. Grounding of outer electrode is represented with low resistance.

For evaluation of equivalent circuit model first matrix of LC parameters is calculated using Static3D solver and than circuit is solved by circuit analyzing tool.

Numerical Results

In Fig. 4 and Fig. 5 voltages detected by CVP calculated with equivalent circuit model (Fig. 3; R3) and with MoM model (Fig. 2) are compared for two cases of cable termination loads.

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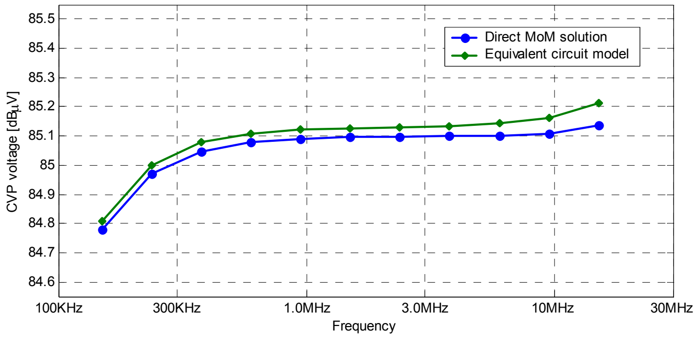

Fig. 4. Voltage coupled in CVP base model. Equal termination loads on cable (50 Ohm and 50 Ohm)

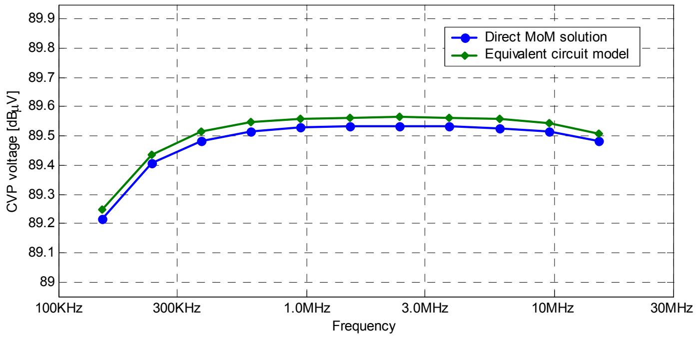

Fig. 5. Voltage coupled in CVP base model. Differing termination loads on cable (50 Ohm and 250 Ohm)

Conclusions

From the results obtained based on the listed above investigations the following conclusions are made:

- Determination of calibration constant of CVP allows virtual measurement of voltages in cables with high accuracy
- Equivalent circuit model of CVP setup is constructed and tested with full-wave electromagnetic approach. Comparison of results shows high precision of model in considered frequency range

EMCoS Consulting and Software

27 Pekin Str., Tbilisi, 0160, Georgia
Tel.: ++995-32-389091; Fax: ++995-32-389092