

IC-EMC v2 – Application Note

A model of the Bulk Current Injection Probe

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This section illustrates how to build an electrical model of the Bulk Current Injection probe (BCI), which is part of the international standard IEC 62132 [Ref 62132]. We present the BCI probe under test, make a description of the impedance measurement set-up and describe the method for BCI probe modelling.

I. BCI probe under test

The BCI test method is part of the IEC standard 62132, under reference 62132-3 “Bulk Current Injection (BCI)” [1] (Table 1).

Standard	Description	Stage in 2010
IEC 62132-1	General Conditions and Definitions	International standard
IEC 62132-2	Radiated Immunity - TEM Cell and Wideband TEM Cell Method	Committee draft for voting
IEC 62132-3	Bulk Current Injection (BCI)	International standard
IEC 62132-4	Direct RF Power Injection (DPI)	International standard
IEC 62132-5	Work Bench Faraday Cage (WBFC)	International standard
IEC 62132-6	Local Horn Injection Antenna (LIHA)	New proposal
IEC 62132-7	Mode stirred chamber	New proposal
IEC 62132-8	Micro strip-line	New Proposal
IEC 62132-9	Near field scan immunity (NFSI)	New proposal

TABLE I: Status of IEC 62132 standards for measurement of integrated circuit immunity

The Bulk Current Injection Probe we used is provided by ETS-Lindgren, model number 95242-1 [2]. It has only one N port connexion. The probe is used to inject a radio-frequency parasitic current into conductors and cables which are connected to electronic equipments. The probe is presented in 0. The central hole allows inserting cables.

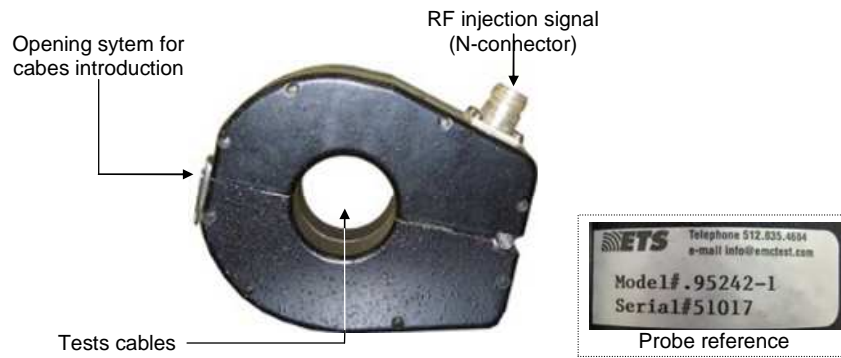
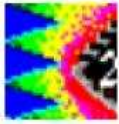


Figure 1: BCI injection probe description

The BCI Probe provides a mean to inject a controlled RF stress to a device under test (DUT) through interconnecting or power cables without requiring a direct connection to that cables. RF disturbance can be injected through a single or multiple cables, grounding and bonding straps, outer conductors of shielding conduits and coaxial cables, etc. The bulk current injection probe series is especially designed to provide minimum insertion loss between 2 MHz and 400 MHz (Fig. 1).

II. BCI Test Bench

The BCI test bench requires at least one BCI probe, the equipment under test and the line for power injection as shown in 0.

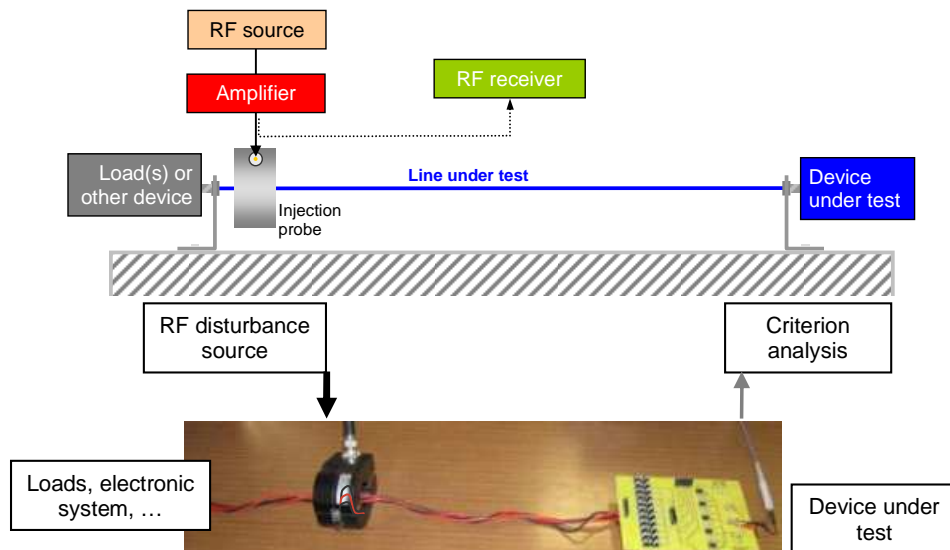


Figure 2: Simple BCI test bench : principles (top) and test example (bottom).

A RF source is used to generate the disturbance signal. A power amplifier increases the level of the signal at the desired value. The amplified signal is injected in the BCI probe. A coupler and a RF receiver (such as a powermeter) help controlling the level of forward power. The part of the forward power which is transferred to the device under test remains unknown. To monitor the power at the far end of the cable, near the device under test, another BCI probe may be used as monitoring current probe (0).

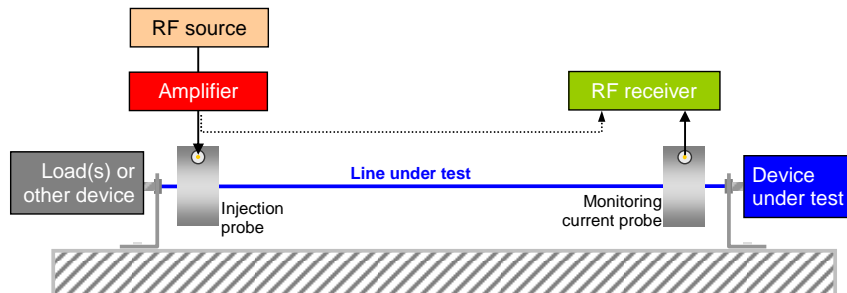
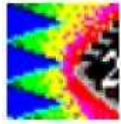


Figure 3: BCI test bench with monitoring current probe.

III. Impedance measurement setup and results

BCI probe impedance over frequency is characterized through S parameter measurements. From that measurement, we can derive an electrical model which fits the probe behaviour. We used a Vector Network Analyzer (VNA) and the port 1 for the measurement (Fig. 4). The measurement system is calibrated using appropriate short-circuit, open-circuit and 50-Ohm loads in N-connector format, so that the reference plane is at the input of the probe connector. The calibration compensates the cable effects, allowing the characterization of the probe impedance only.

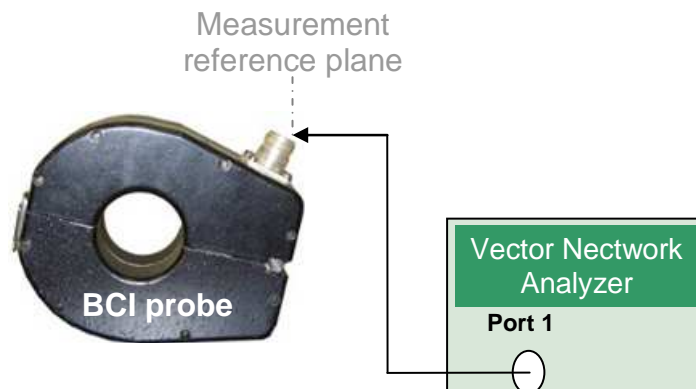
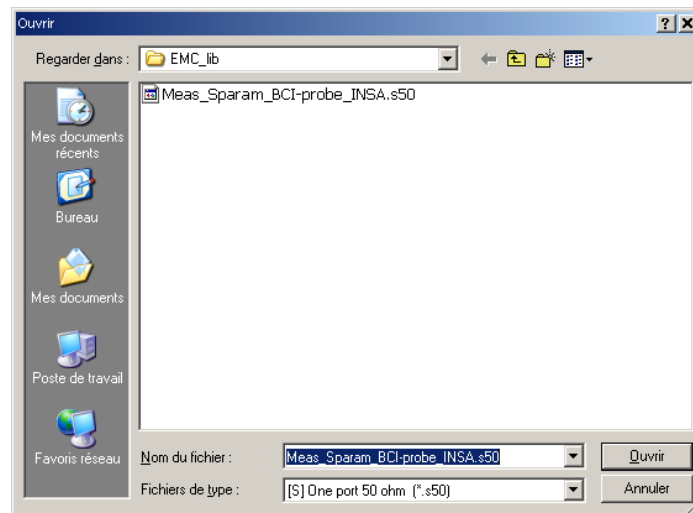
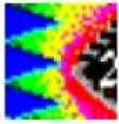


Figure 4: S parameters measurement set-up

To download the measurements, proceed as follows:

1. Click the icon "Impedance vs. frequency"
2. Click "Add measurement" and select "*.s50" format
3. In "EMC_lib", select the file "Meas_Sparam_BCI-probe_INSA.s50"



4. The following screen appears. It can be seen that the coil features a very low impedance at low frequencies (10 Ohm around 1 MHz) and ranges between 10 and 500 Ohm in the whole frequency bandwidth. The impedance profile features an inductance effect (+ 20 dB/decade) at low frequencies.

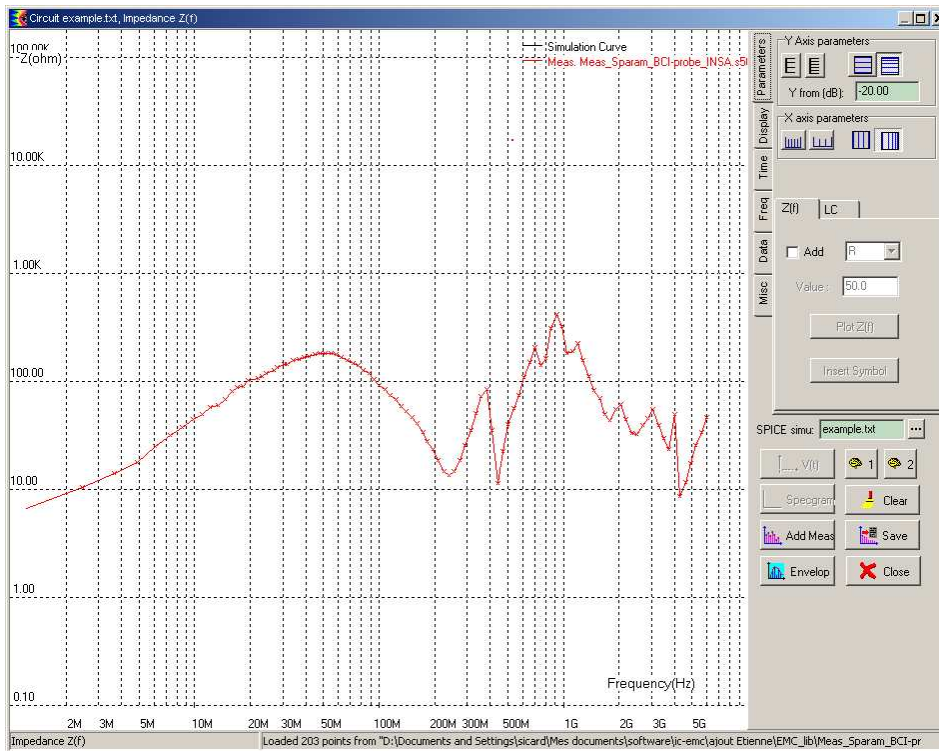
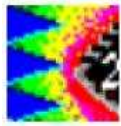


Figure 5 : Measurement of the BCI impedance from 1kHz to 6 GHz (Meas_Sparam_BCI-probe_INSA.s50)



IV. First-order model of the BCI probe

We have no precise information about the internal structure of the BCI, such as the conductor width and length, number of loops, material permittivity, transformer characteristics, etc.. This does not allow us to use physical formulations in order to calculate the corresponding impedance. We consider here the probe mainly as an inductor (L) with parasitic capacitive and resistive effects..

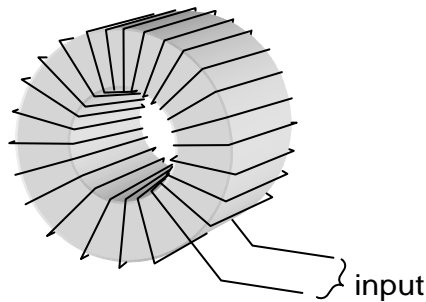


Figure 6 : BCI probe internal structure

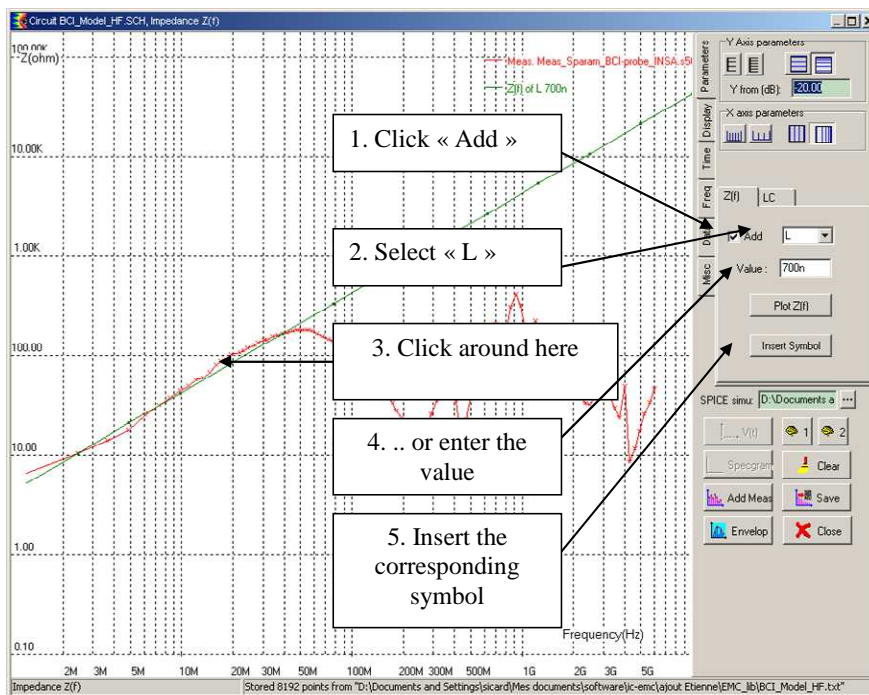
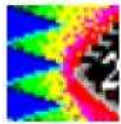


Figure 7 : Extraction of BCI R,L,C elements from impedance measurement

To identify the electrical equivalent elements, proceed as follow:

1. In the Z(f) sub-menu, Select "Add"
2. Select "L" (inductance)
3. Click along the measurement curve in the +20 dB slope (1-30 MHz)
4. The tool computes the equivalent L value (here: 700 nH). Alternatively, you may enter the value and observe the matching.



- Click “Insert symbol”. A 700 nH inductance is added to the schematic diagram for further use in the BCI model

The resonant behaviour around 50 MHz is modelled by a RLC equivalent circuit (**Erreur ! Source du renvoi introuvable.**). We use a combination of $L_{BCI}=700$ nH, $R_P=200$ Ω and $C_P=15$ pF capacitor. The serial resistance $R_{BCI}=1$ Ohm is mandatory to avoid WinSpice simulation problems. As shown in Fig. 8, the schematic diagram should also include:

- Connections to ground
- A probe symbol “Z(f)”

Convert the schematic diagram into a SPICE netlist (Command and icon “Generate Spice file”), execute the simulation using WinSpice and click the icon “Impedance Window” to compare the simulated $Z(f)$ with measured $Z(f)$ as shown in Fig. 8 bottom. The fit is quite satisfactory upto 400 MHz.

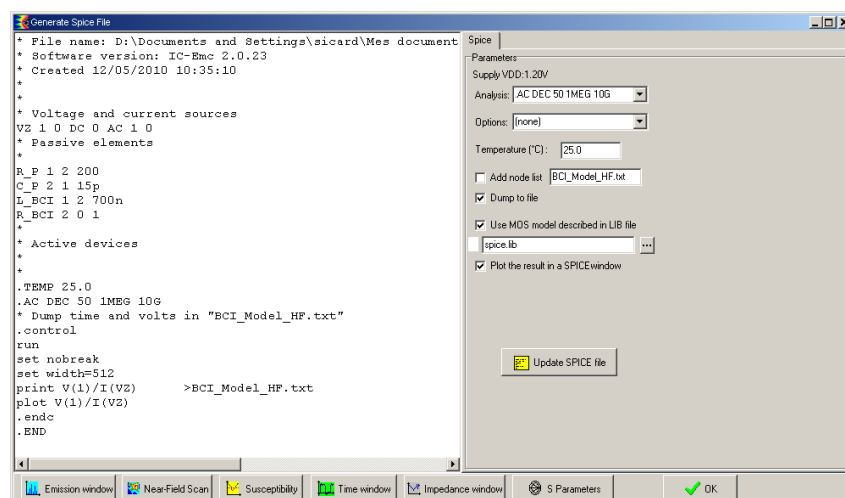
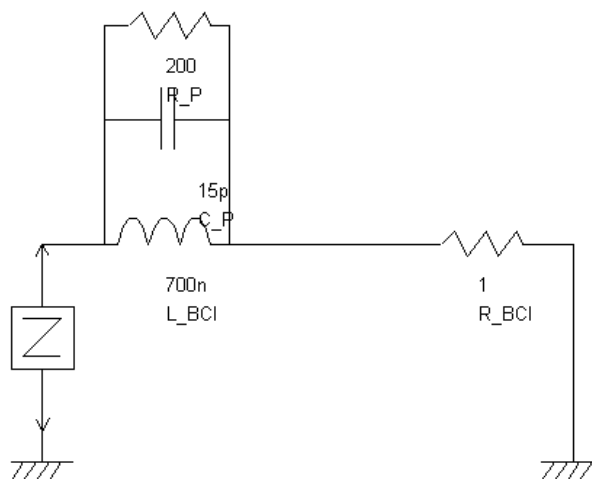


Figure 8: Schematic diagram (top) and Spice conversion (bottom) for BCI impedance simulation

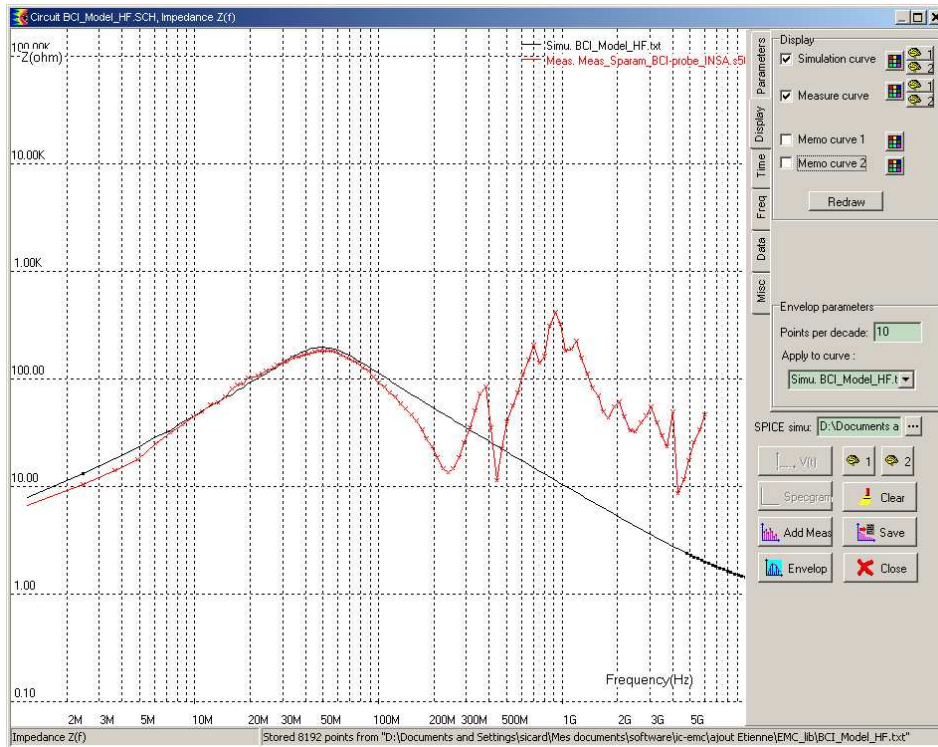
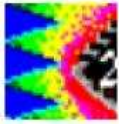


Figure 9: A simple BCI probe model valid upto 400 MHz (BCI_Model_HF.sch)

V. Accurate model of the BCI probe up to 6 GHz

In Figure 10 a more accurate model of the BCI probe is presented. Apart from the HF model described previously (L_BCI, C_P1, R_P1), a set of R,L,C elements are added to account for resonances around 200, 400, 900 and 4000 MHz. We propose to include 3 RLC cells.

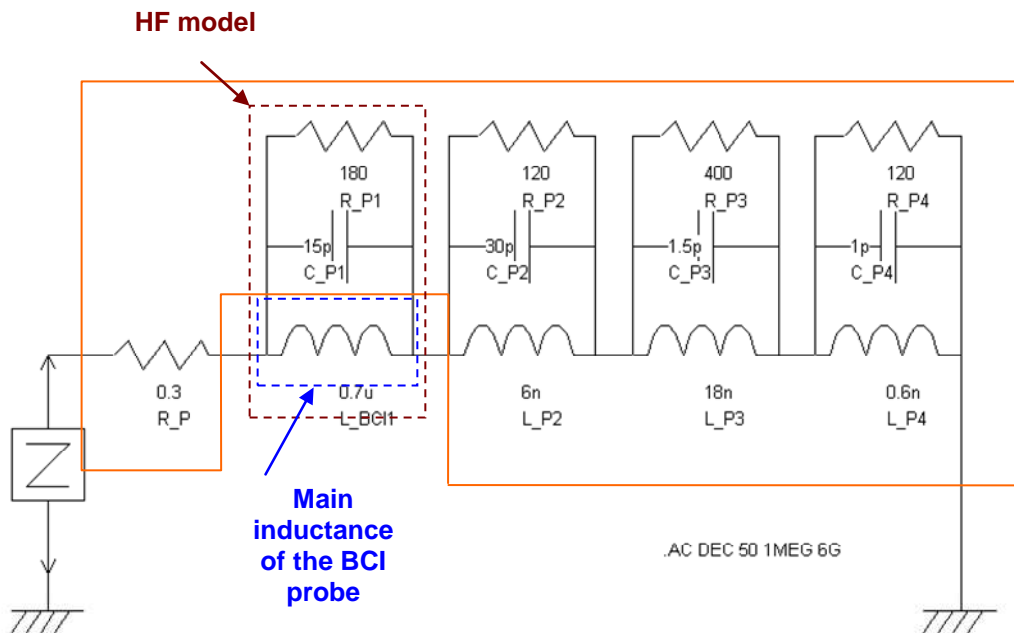


Figure 10 : BCI probe model

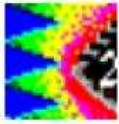


Table II describes the BCI probe electrical elements. It shows extracted and optimized values to improve the matching with measurements. The major modification concerns L_P1 and C_P2.

Element	Extracted values	Optimized values	Description
L_BCI	0.7 μ H	0.7 μ H	Probe inductance value
C_P1	15 pF	15 pF	Parasitic capacitance for 50 MHz resonance
L_P2	19 nH	6 nH	Parasitic inductance for 200 MHz resonance
C_P2	11 pF	35 pF	Parasitic capacitance 200 MHz resonance
L_P3	18 nH	18 nH	Parasitic inductance for 1 GHz resonance
C_P3	1.5 pF	2 pF	Parasitic capacitance for 1 GHz resonance

TABLE II: Description of the model elements

Figure 11 shows the comparison between the measured and simulated impedance of the BCI probe. We can notice a very good correlation between measurement and simulation from 1 MHz to 6 GHz.

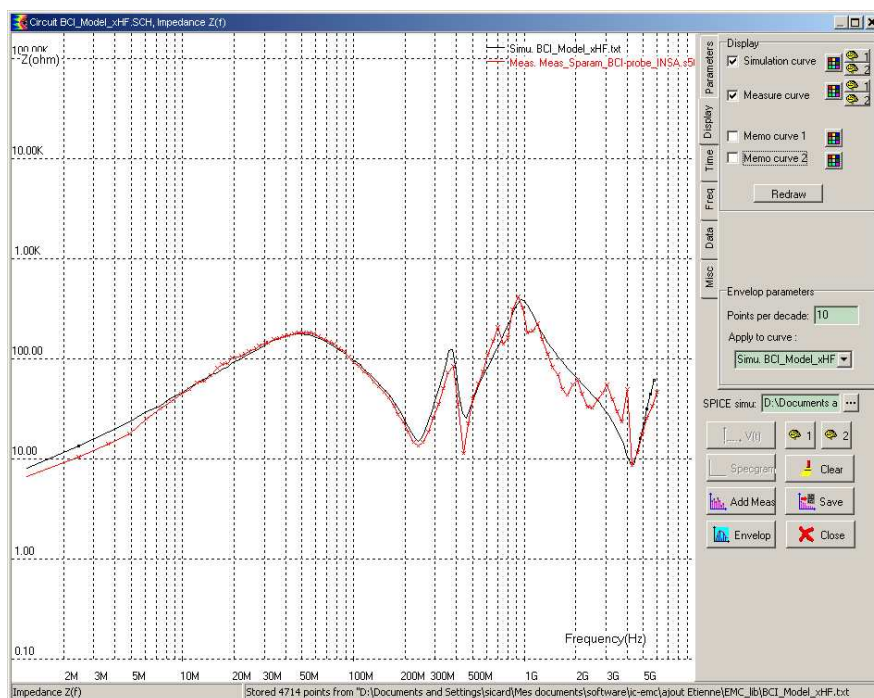
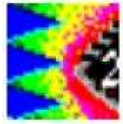


Figure 11: Comparison between measurement and simulations for the accurate model (BCI_Model_xHF.sch)



VI. References

- [1] IEC62132-, "Integrated Circuits, Measurement of Electromagnetic Immunity, 150 KHz – 1 GHz", International Electrotechnical Commission, Geneva, Switzerland, 2007 www.iec.ch
- [2] Datasheet: ETS Lindgreen, "Bulk Current Injection Probes manual", February 2005, online: <http://www.ets-lindgren.com>.
- [3] F. Lafon, Y. Benlakhoy, F. De Daran, "Modélisation d'une pince d'injection pour le test BCI sur ligne de transmission multi conducteur", CEM 2008, Paris.