MONITORING RAPID VOLTAGE FLUCTUATIONS AND HARMONICS DUE TO OSCILLATOR AND RELAYS IN THE CORD CONNECTING THE EQUIPMENT TO MAINS SUPPLY

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Abstract – *Dealing with the precompliance EMC emissions testing for a new fluxgate magnetometer, in order to comply with European norms EN 55022, we experienced some difficulties, three of them being addressed in this paper:*
a)Best compromise for the mains filter; operating with an own manufactured V-LISN and a pair of 1:1 high quality transformers, the dominant component (common or differential mode conducted emissions) could be identified. Determining the major component of the conducted emission, allow us to decide which element of the filter should be modified to achieve the better compromise "size versus reduction in the total emission";
b) Best decoupling option for the electromechanical relays, mainly involved in the power management scheme and in the auto-ranging function;
c) Minimising the spectral energy at harmonics of the fundamental frequency of the oscillator with the switching power supply; by reducing the magnitude of the open loop gain (was utilized a capacitive divider), the feedback current was also decreased, with the immediate result of an improvement in the spectral envelope of the power supply current.

Keywords – Conductive emission, mains filter, LISN.

1. FRAMEWORK OF THE ADDRESSED PROBLEM

Any equipment, containing: microprocessor, clock generator, the crystal feedback using logic gates or Colpitts oscillator with the switching power supply, electro-mechanic relays involved in the power management of the device or in auto-ranging, the inrush current (when "cooler" or other motors start up), "flickers" or "glitches" could be analysed as a source of electromagnetic interference.

Basically non-linear, an oscillator produces considerable spectral energy at harmonics of its fundamental frequency. The simplest method for reducing the harmonic content of the output voltage is to pick it up from the resonator (used for fixing the oscillation frequency). But this is inefficient for the current drawn from the power supply, which is pulse modulated [1], due to the compulsory limiting in the active element. In the same time, is strongly desirable that the mains filter to act also as a surge suppressor device, offering

reliable and fast protection. The performance as surge suppressor was measured using Joule rating method combined with the let-through voltage test.

We had to perform precompliance measurements while designing and producing a multifunction fluxgate magnetometer. We considered EN 55022 (CISPR 22) (Information technology equipment) requirements as being adequate to our product. We focussed on conducted range (till 30 MHz) and not on radiated range (over 30 MHz).

So, mainly in the neighbourhood of numerous other sensitive devices (PC's, for instance) it is important to study the diminishing possibilities of these parasitic "contributions" and their efficiency.

2. V-LISN FOR UNSYMMETRIC EMISSIONS

After identifying and assuming the appropriate regulations, we have to set up the test equipment, [2]. For conducted emissions, we use a 2398 Spectrum Analyser [3], a manufactured VLISN, (working principle presented in Fig.1) and a transient limiter.
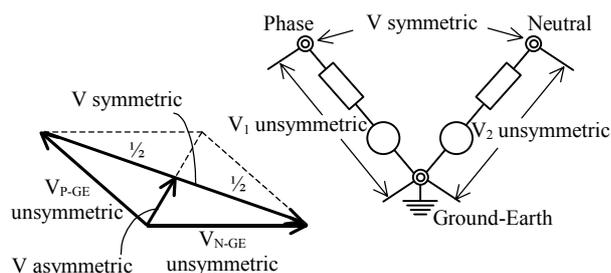

Fig.1 – V LISN, working principle and vector diagram

The LISN (line impedance stabilization network) has three main functions to play in our tests:

-to isolate the power mains from the equipment under test. The power supplied to the DUT (Device Under Test) must be as clean as possible. Any noise on the line will be coupled to the spectrum analyser and interpreted as noise generated by the DUT.

-to isolate any noise generated by the DUT from being coupled to the power mains. Excess noise on the power

mains can cause interference with the proper operation of other devices on the line.

-the signals generated by the DUT are coupled the spectrum analyser using a high-pass filter, which is part of the LISN. Signals that are in pass band of the high-pass filter see a 50Ω load (the input to the analyser).

The LISN type V is the most common one, adequate for measuring the un-symmetric voltage between line (phase or neutral) and earth-ground. The experienced circuit solution is presented in Fig.2.
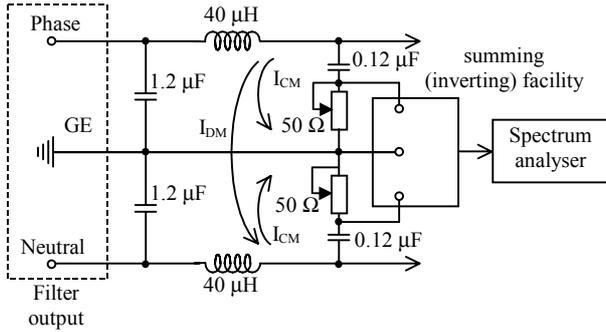

Fig.2 – Experienced V LISN circuit diagram

The 1.2 µF capacitor in combination with the 40 µH inductor is the filter that isolates the mains from the DUT.

The 40 µH inductor isolates the noise generated by the DUT from the mains. The 0.1µF couples the noise generated by the DUT to the analyser. At frequencies above 150 kHz, the DUT signals are presented with a 50Ω impedance.

There are two different types of noise currents leaving the power supply: I_{DM}, (differential mode), flowing through phase (one sense) and neutral (returning, opposite sense) and I_{CM}, flowing out phase and neutral (the same sense) and returning via ground-earth (safety earth). Considering the LISN previously presented as being close to ideal, we assumed purely resistive constant 50Ω impedances between phase (neutral) and earth ground. For the situation in Fig.2, the voltages measured by the LISN are:

$$U_{P-GE} = 50\Omega \times (I_{CM} + I_{DM}) \quad (1)$$

$$U_{N-GE} = 50\Omega \times (I_{CM} - I_{DM}) \quad (2)$$

These voltages, leaving the filter, have to be lower than regulatory limits at every frequency of interest. Using the summing (inverting) facility, we could identify the dominant noise component at the frequency where emission exceeds the limit. Two 1:1 high quality transformers are utilized for summing and then subtracting the voltages delivered by the LISN. Changes from summing to subtracting are simple made by reversing the terminals of only one primary winding, while secondary windings are additive connected and so supplied to the spectrum analyser:

$$U_{P-GE} + U_{N-GE} = 2 \times 50\Omega \times (I_{CM}) = 2U_{CM} \quad (3)$$

$$U_{P-GE} - U_{N-GE} = 2 \times 50\Omega \times (I_{DM}) = 2U_{DM} \quad (4)$$

The method is not very accurate, but this is not essential, considering that the levels related to each other are useful

while dealing with the improvements to be done to the mains filter. One element of the filter affects either common mode or differential mode component of the noise current, so, for efficient and not over-dimensioning modification, is important to identify the dominant type of emission (at a certain domain of frequency), [4].

3. BASIC TOPOLOGY OF THE MAINS FILTER

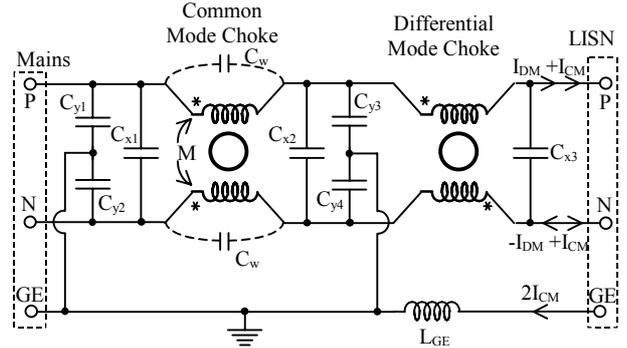We tested a quasi-standard symmetric configuration (with respect to phase-neutral), as shown in Fig.3.

Fig.3 – Tested topology of the power supply filter

The line to earth capacitors C_{y1}-C_{y4} have to divert the common-mode currents, while C_{x1}-C_{x3} bulk capacitors are diverting differential-mode ones. Special attention to be paid to the sense of wiring the two toroid chokes. The common-mode choke has no impedance to the differential-mode flows, presenting the advantage of not being saturated by the high level fundamental power frequency (mutual cancellations of magnetic fluxes in the ferrite core). The inductor L_{GE} (inserted in the wire going to ground-earth) was calculated to have about 850µH, in order to reduce the common mode part.

4. EXPERIMENTAL TESTS FOR DECREASING THE CONDUCTED EMISSIONS

The spectrum analyser alternatively displays (according to the position of the switch), the common and the differential conductive emission, in order to determine (by comparing the memorised samples) the dominant noise component in the digital fluxgate magnetometer cord. Without filter, the common mode level is lower with about 5dB, both of them exceeding the accepted limits, mainly in the interval 150KHz-1 MHz. Adding the four C_y, 3nF capacitors, were drastically reduced (about 20 dB) both components. Then, inserting two phase-to-neutral 150 nF capacitors, only differential mode was reduced (more 12-13dB), common mode remaining, under these circumstances, dominant. The attendance of 850µH L_{GE} (30 turns of wire on 1cm diameter ferrite toroid), has 15 dB decreasing influence beneath 1 MHz domain, for common-mode disturbances.

The common mode choke was designed for about 15mH inductance and the same value for the mutual inductance

(between the two windings). The results were different from the early expectations. The common mode component only slightly decreased (above 5 MHz), because L_{GE} already done it. Due to leakage inductances of the windings (inserted in phase and neutral lines), conjectured with the parasitic capacitance of the windings (approximately 40 pF), the common mode choke rejects the differential mode currents (below 5MHz), almost making useless the second (differential) choke.

5. SUPPLEMENTARY IMPROVEMENTS

The relays involved in the power management of the device and in the auto-ranging facility are "reed type" UEM-012C™, with 1 KΩ d.c. impedance. These on/off relays, together with the inrush current (when "cooler" starts up) are responsible for "glitches" and "flickers", samples being recorded [5] in Fig.4. Is compulsory to avoid the injection of this harmonics into the system.
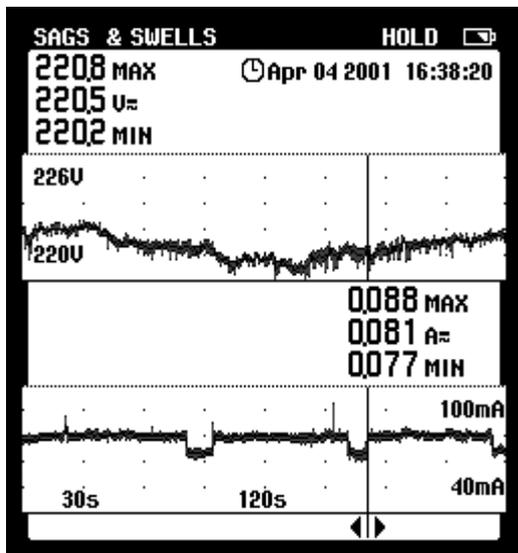

Fig.4 – Sags & Swells due to the electro-mechanical relays

An improvement was obtained through decoupling the coils with 47nF condensers and using "free wheel" fast diodes. This was also certified by measuring and comparing TDH and the r.m.s. value of the first 51 odd harmonics. The harmonics spectrum screen could be checked for any harmonics, in Fig.5 being tested the third harmonics.

Another direction in limiting the noise contribution of our DUT was to find the optimum for the open loop gain of the main oscillator, [6]. In the initial configuration, the Colpitts oscillator (10 MHz), for 21 open loop gain required a 450 mV sin voltage at the emitter to compress the magnitude to unity. Reducing the loop gain to 3, the spectral envelope of the power-supply current drawn by the oscillator decreases with about 40 dBmA in the field of 200-300 MHz. This proved to be useful, as filtering the fundamental is not enough, the harmonics are more troublesome. A compromise had to be accepted: a sufficient small-signal open-loop gain

at the fundamental frequency for ensuring reliable oscillation under worst-case conditions, without exceeding the limits.
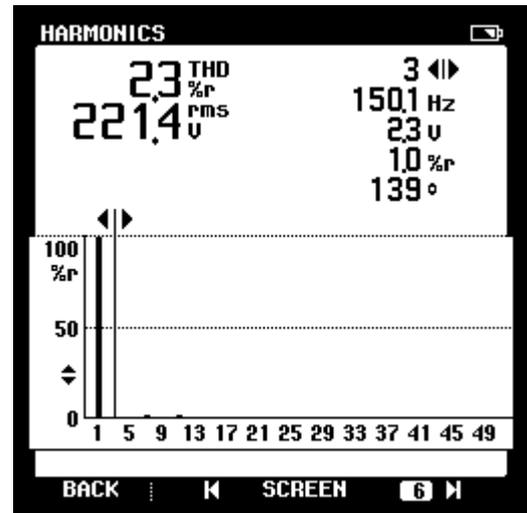

Fig.5 – Odd harmonics as indicator for better decoupling

6. SUMMARY AND CONCLUSIONS

There are presented three main package-actions experienced by the authors while dealing with design and precompliance tests of the prototype for a fluxgate, Förster type, magnetometer. There are discussed concrete values of the EMI elements, diagnostic and measuring techniques. With a simple methodology, the dominant noise conducted current could be determined (I_{CM} or I_{DM}), this being essential to an efficient modification of the filter's elements, avoiding trials and errors. An optimum value for the open loop gain of the main oscillator is advisable for decreasing the spectral envelope of the power-supply "drawn" current. An adequate decoupling of the coils of the switch on/off relays has effect against sags & swells and harmonics injected in the system.

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