THE ELETROMAGNETIC INTERFERENCE (EMI) ON A PUSH-PULL CONVERTER FOR TELECOMMUNICATION APPLICATION

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Abstract* – This paper presents a sequence of testing which took place for the legal certification of a push-pull converter project for telecommunication application, in order to attend the technical qualifications of emission of electromagnetic noise. The focus is on the measurements of conducted and radiated emission. A very simple form of research from origin of the noise source is shown, as well as its location on the printed circuit board (PCI). A digital oscilloscope and a home-made near-field probe are used for that. From those observations a few actions are indicated to minimize the electromagnetic interference (EMI) of the power supply.

***Key-words:* EMC, EMI, switched power supply, electromagnetic noise.**

I. INTRODUCTION

The Brazilian National Telecommunication Agency (ANATEL) has been one of the most effective regulatory agents on certifying devices, especially in what is regarded to electromagnetic compatibility (EMC). For that reason, telecommunication device cannot emit electromagnetic noise above an established emissions standard determined by international technical rules. Manufacturers, as a whole, find a major difficulty on the execution of their projects, due to higher complexity of the necessary testing to attend those standard.

The objective of this paper is to present a sequence of testing and measures to attend some of those standards, related mainly to electromagnetic interference (EMI), the problems found and the solutions presented for the accordance of the device to the regulations. For that, a push-pull power supply was chosen (Fig. 1), for the application in the telecommunication area, with the basic specifications that follow:

Input voltage: 48 Vcc (36 Vcc to 60 Vcc)
Output Voltage: 12V
Output current maximum: 30 A

Conducted and radiated emission testing was made for an output charge condition of 110 W, as this was the necessary charge condition for the legal certification of this device.

The CISPR 22 Class A [8] were adopted as reference for the measurements (which are the same limits adopted on the resolution number 237 of ANATEL [11]).

The instrumentation used on the testing of conducted emission was the EMI TEST RECEIVER ESPC, the LISN ESH3-Z5 and the control software ESPC-K1, manufactured by ROHDE&SCHWARZ. For the radiated emission was used the EMI TEST RECEIVER ESPC and the control software EMC-32, both by ROHDE&SCHWARZ, besides the EMCO GTEM 5411 cell manufactured by ETS Lindgren.

For the voltage and electromagnetic noise measurements an HP54603B digital oscilloscope and the scope software HP34810A BenchLink 1.4, a conventional voltage probe and a home-made near-field probe based on reference [3] were used. This easily home-made probe is assembled with any copper wire, has a 20mm diameter, it is connected between the reference and the test point of an oscilloscope voltage probe (see Fig. 8). It is used for the location of the noise source on the PCI. This probe does not have the purpose of measuring the signal amplitude, but to help on the identification of the source and the presence of noises in determined positions of the circuit and in which frequency switching they occur.

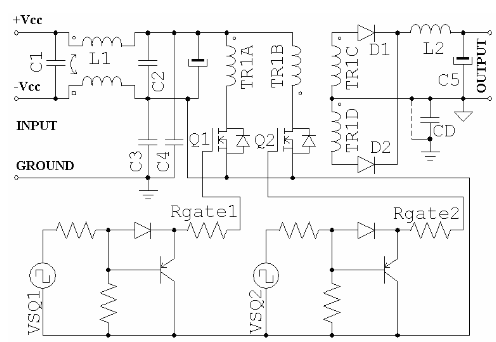

Fig. 1. A Push-pull converter with EMI input filter and MOSFET gate drive circuit.

II. EXECUTION OF THE EMI TESTING

Usually, in most of the switching power supply projects the use of input filters to reduce the electromagnetic interference is necessary. In this case, a basic filter configuration was assembled, according to references [1, 2, 3, 4, 5, 6 and 7] dimensioned for this converter. It is formed by a single stage filter, in the PI configuration (Cx capacitors, C1 and C2, and coupled inductor L1) and two Cy capacitors (C3 and C4) between + Vcc and the ground wire and – Vcc and the ground wire. At the beginning, the project was executed to attend the specifications, including EMI, through the snubber use in the MOSFETs and diodes and previous arrangement of the components.

The first conducted emission test was executed under those conditions, as presented in figures 2, which shows that the emission of power supply behaves well in almost all the spectrum. However, a thorough amplitude increase of the measured signal is observed after 20 MHz, exceeding the limits of the standard in about 30 MHz. In the radiated emission measurement, as observed in figure 3 the same decreases a little higher than 30 MHz, but also out of the standards.

In figures 4 and 5 new conducted and radiated emissions tests are shown, where we are able to notice that the power supply fulfills the requisites of the standard under the tested work condition for all the frequency range, but close to the limit in the radiated emission test next to 30 MHz. Those measurements were taken after an alteration in the disposal of a decoupled capacitor (CD in fig. 1).

The final conducted and radiated emission tests are shown in figures 6 and 7, where it is evident that the power supply easily fulfills all the requisites of the standard under the tested work condition, concerning to CISPR 22. In this case, besides the alteration described before, there was a change in the MOSFET gate drive circuit (Rgate in fig. 1).

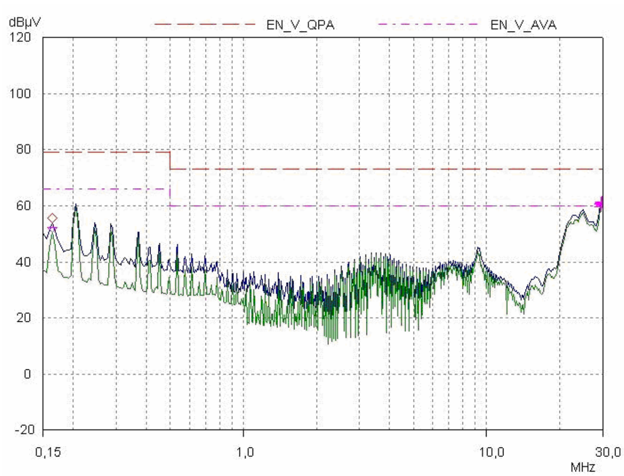

Fig. 2. Conducted emission with decoupled capacitor in the original position.

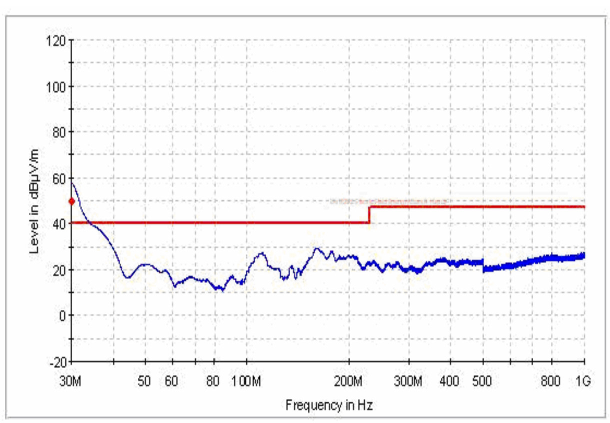

Fig. 3. Radiated emission with decoupled capacitor in the original position.

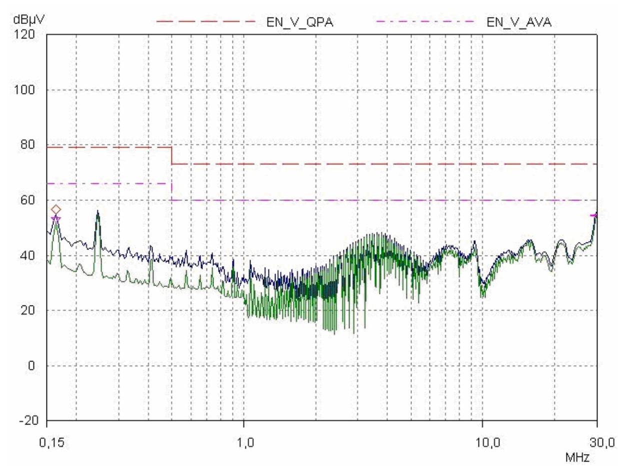

Fig. 4. Conducted emission with decoupled capacitor near the transformer.

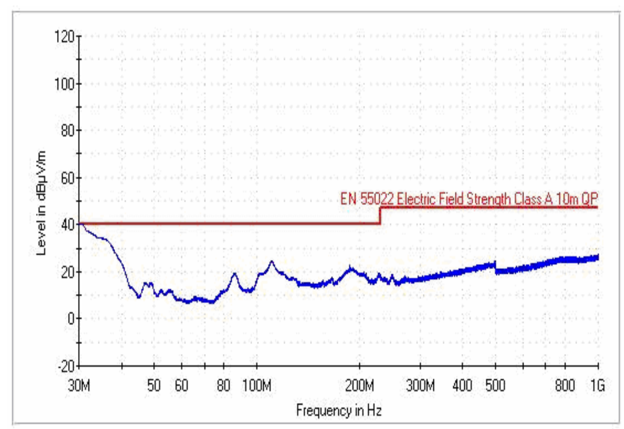

Fig. 5. Radiated emission with decoupled capacitor near the transformer.

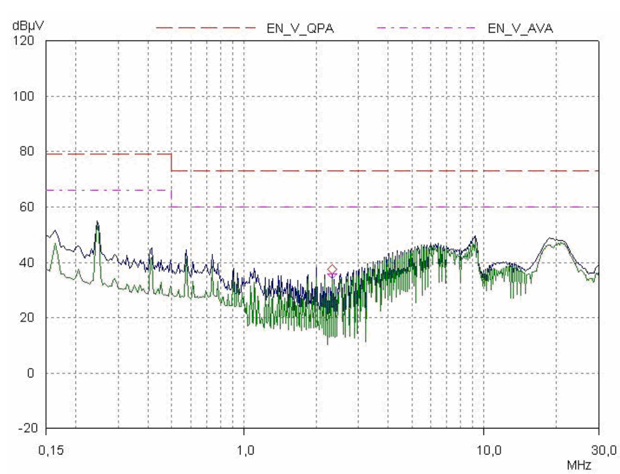

Fig. 6. Conducted emission with capacitor near the transformer and drive alteration.

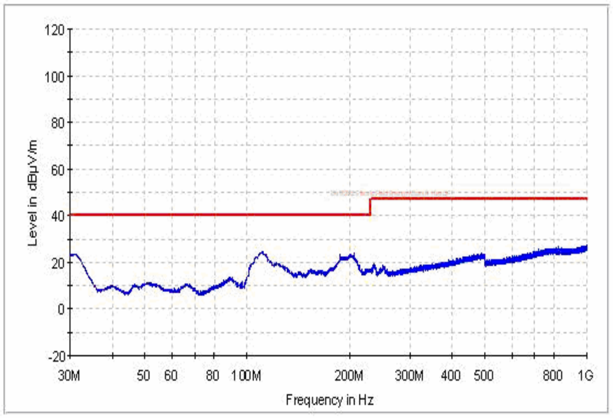

Fig. 7. Radiated emission with capacitor near the transformer and drive alteration.

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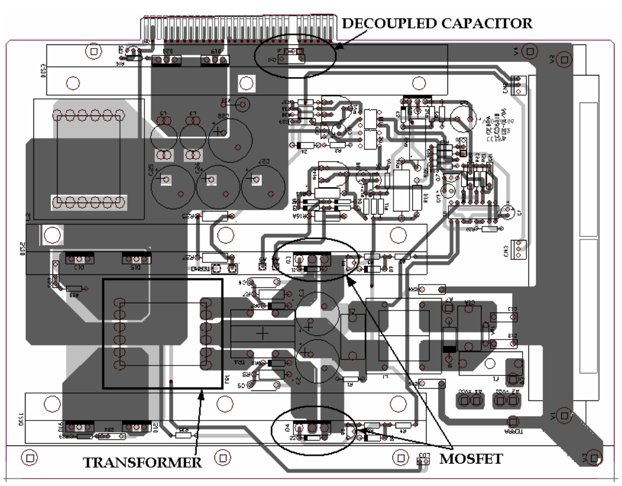
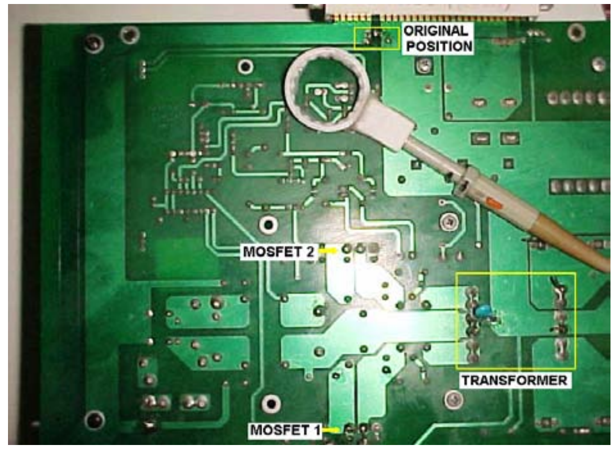
III. NOISE SOURCE RESEARCH

In some electronics applications is very common that the safety grounding wire passes through the power supply until it gets to the circuits it must feed. This can be a specification to be attended by the power supply manufacturer. In other applications, as in computer power supply, the ground wire is short-circuited in the power supply itself, with a zero volt output. There are also cases where this assembling can be done through a decoupled capacitor. The fact is that this assembling exists, creating a problem, as it establishes a common current return path in the switch circuit of the switching power supply that propagate through parasite capacitances between the primary and the secondary of the transformer and through other paths too, like the ones which tracks to the cabinet, where the circuit is assembled and usually ground wired.

Figure 8 shows the power supply PCI, layout and bottom side, under test, where it is presented the original decoupled capacitor position and the final position near the transformer. It is also possible to observe the near-field probe used and in which position the measurements were taken as shown in figures 9 to 12.



(a)



(b)

Fig. 8. (a) Layout of PCI, (b) measurement with home-made near-field probe, in the noise area.

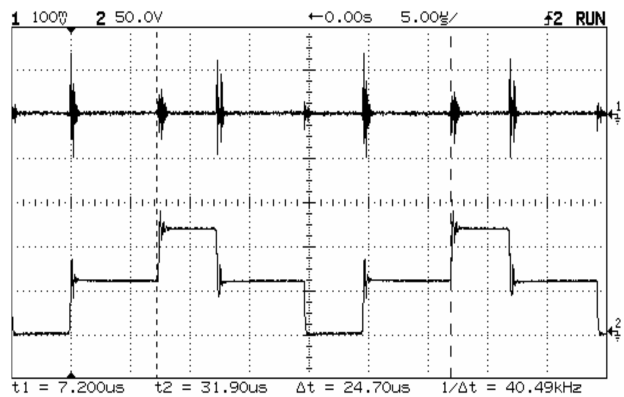


Fig. 9. Wave shape of the capted noise with capacitor in the original position (channel 1), and drain voltage of the MOSFET (channel 2) in switching frequency.

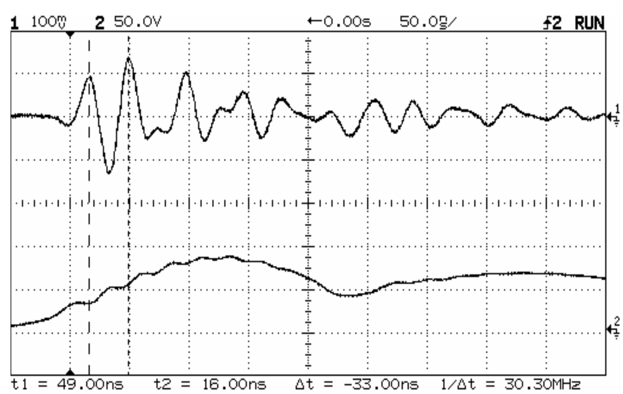


Fig. 10. Wave shape in the frequency of the capted noise with capacitor in the original position (channel 1), and drain voltage of the MOSFET (channel 2) in its turning off.

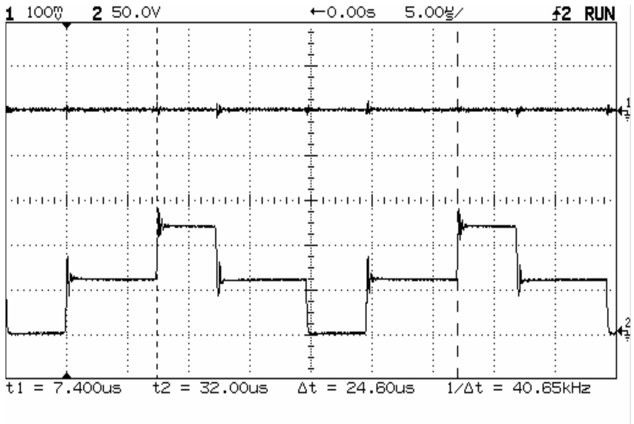


Fig. 11. Wave shape of the capted noise with capacitor near the transformer (channel 1), and drain voltage of the MOSFET (channel 2) in switching frequency.

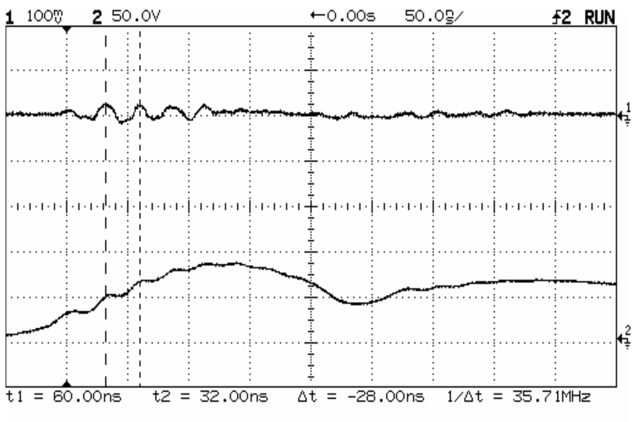


Fig. 12. Wave shape in the capted noise frequency with capacitor near the transformer (channel 1), and drain voltage in the turning off of the MOSFET (channel 2).

With the capacitor in the original position a closed loop was formed [1], in PCI, which helped the propagation of the high-frequency noise (around 30 MHz) to the power supply cable, as it can be observed through the analysis of figures 2, 3, 9 and 10. It is important to observe in figure 10 that the frequency of the measured noise is about 30 MHz.

When the capacitor is set in the final position (Fig. 8), it is clearly observed a decreasing of the noise amplitude measured by the near-field probe and also a decreasing of the conducted emission amplitude measured by the receiver, as it is possible to verify through the analysis of figures 4, 5, 11 and 12. In the conducted emission (figure 4) and radiated emission (figure 5) curves, one can observe that in 30 MHz frequency the amplitude of the measured signal is the most significant in relation to the limits of the standard, what is in accordance with the results shown in figure 10.

When the near-field probe is put together to the MOSFET, the frequency near 30 MHz is once more observed. This is present in figure 13, where it is also possible to see the drain current. In figure 14 the capted noise in the near-field probe and the drain current at the time of the turning off of the MOSFET is shown. The similarity between the two wave shapes is pretty clear and the importance of the switching in the noise generation is confirmed once again.

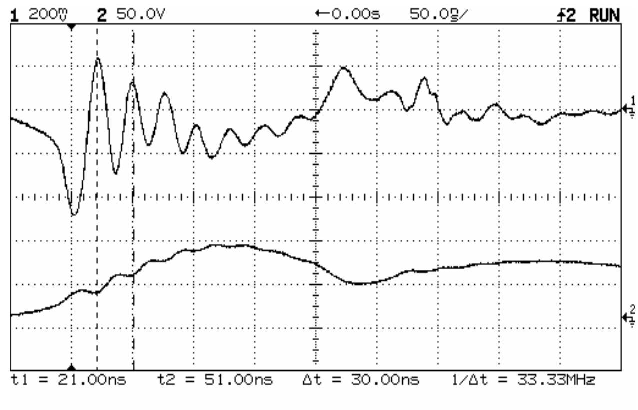


Fig. 13. Wave shape of the capted noise (channel 1), and drain voltage of the MOSFET at the turning off (channel 2).

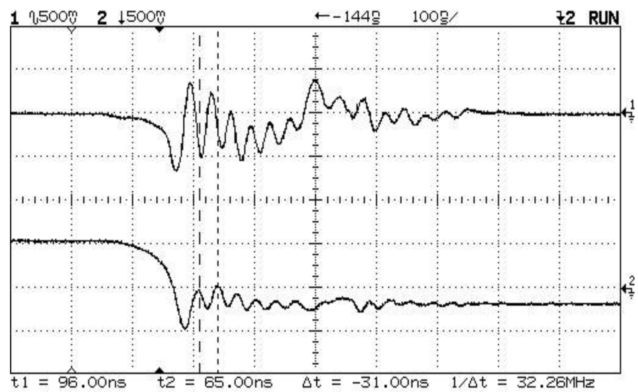


Fig. 14. Wave shape of the capted noise (channel 1) with the near-field probe next to the MOSFET, and drain current of the MOSFET at the turning off (channel 2).

Another important observation in curves 8, 9, 10 and 11 is that the noise capted by the near-field probe is in synchronism with the turning on or turning off of the two switching MOSFETs. A noise in each moment of transition is clearly observed. In this case the noise is higher at the turning off. During the transitory of the turning off of one of the MOSFETs, two important closed loops are formed with LC circuit (figure 15). Closed loop 1 is formed by the leakage inductance of the transformer (TR1a) and the output capacitance (Coss) of the MOSFET, when Q1 is off. Closed loop 2 is formed by the PCI track inductance and the input capacitance (Ciss) of the MOSFET when Q3 is on. From the basic theory of the circuits the existence of a resonance frequency in any RLC configuration is known, according equation 1:

$$f = 1 \ / \ 2\pi\sqrt{LC} \tag{1}$$

Where: f = frequency (Hz);
L = inductance (H);
C = capacitance (F).

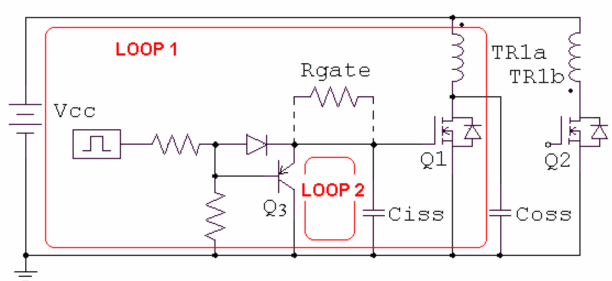


Fig. 15. Part of the potency circuit and the gate drive of the MOSFET of the 'push-pull' converter.

From the analysis of the presented curves, we can easily identify two superposed resonance frequencies, fr1 = 1/250 ns = 4 MHz (figures 17 and 19) and fr2 = 33 MHz (figures 10 and 17). In closed loop 1 we know that Coss = 603 pF and the resonance frequency fr1 = 4 MHz, therefore from equation 1 we can determine that Ld = 2,6 uH. We know that the magnetization inductance of TR1 = 270 uH, therefore according to [12] we can state that this is a compatible value for the leakage inductance as we have a coupling coefficient of 0, 99.

In closed loop 2 we know that Ciss = 4057 pF and the resonance frequency fr2 = 33 MHz, therefore from equation 1 we can determine L = 5,7 nH. According to [4], a PCI track of 1 onza thickness, 2 mm width and 50 mm length has inductance of L = 16 nH. On the layout of the studied circuit, closed loop 2 has a track length of 20 mm, therefore the approximated inductance of the track is L = 6,4 nH.

Knowing this data, we can minimize even more the noise emission of this converter, by adding another serial resistor (Rgate in figures 1 and 15) with the gate drive circuit of the MOSFET. The purpose is to dampen the oscillation and increase the turning off time, what also provides advantages related to EMI [9, 10]. It is possible to observe the results in noise emission in the measurements shown in figures 6 and 7, and the effect of this alteration in the wave shape of the drain current and the drain voltage of figures 16 to 19. The alteration in the gate drive increases the switching losses could increase the temperature of MOSFET. In the case of this converter, that uses fans, this problem it is minimized.

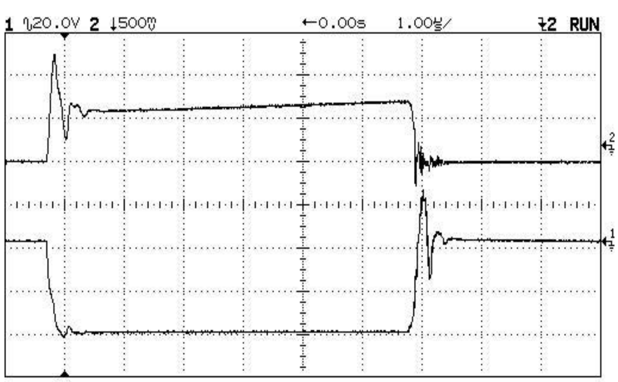


Fig. 16. Wave shape of the drain voltage (channel 1), and drain current of the MOSFET (channel 2).

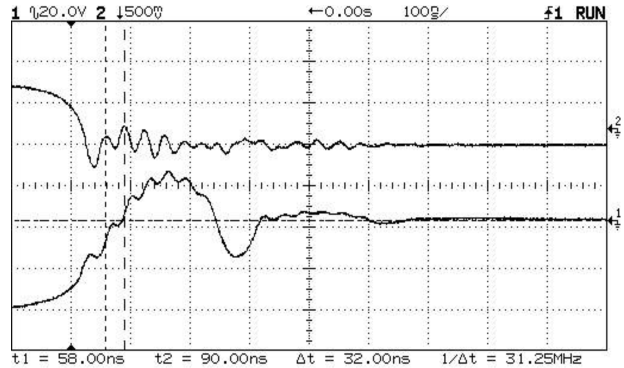


Fig. 17. Wave shape at the turning off of the drain current (channel 1), and the drain voltage of the MOSFET (channel 2).

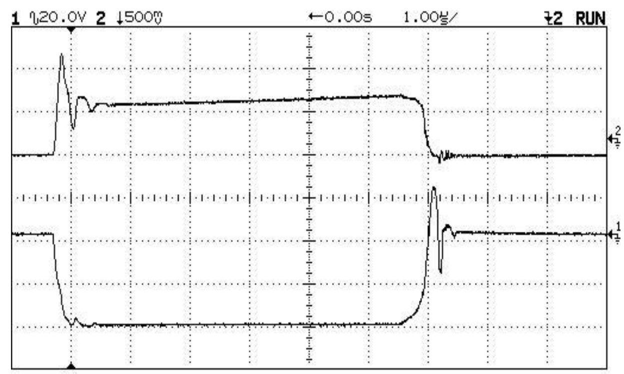


Fig. 18. Wave shape of the drain current of the MOSFET (channel 1), and drain voltage with alteration of the gate drive (channel 2).

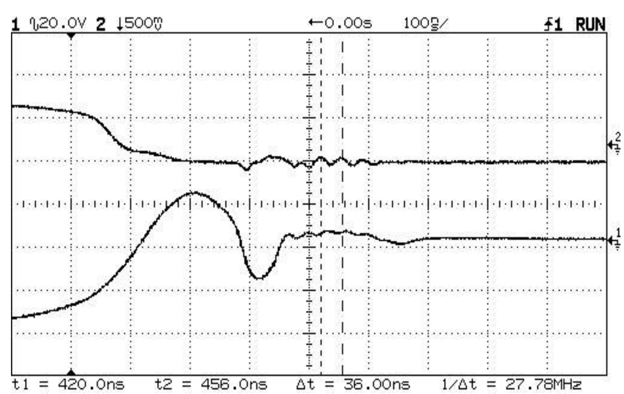


Fig. 19. Wave shape at the turning off of the drain current (channel 1), and drain voltage of the MOSFET with alteration of the gate drive (channel 2).

Finally the near-field probe is set in the output rectifier diode area. It is possible to observe through the analysis of figure 20 that during the conduction of the diode, there is an oscillation frequency of about 30 MHz probably originated from the switching of the MOSFET. When the diode is turning off, the near-field probe capted a frequency of about 120 MHz, from the diode recuperation current, as shown in figure 21. By comparing the results of this measurements (figure 22), with the measurement of the radiated emission in figures 3, 5 and 7, we can clearly notice an increase in the amplitude of the noise around this 120 MHz frequency, but without exceeding the limits of the standard.

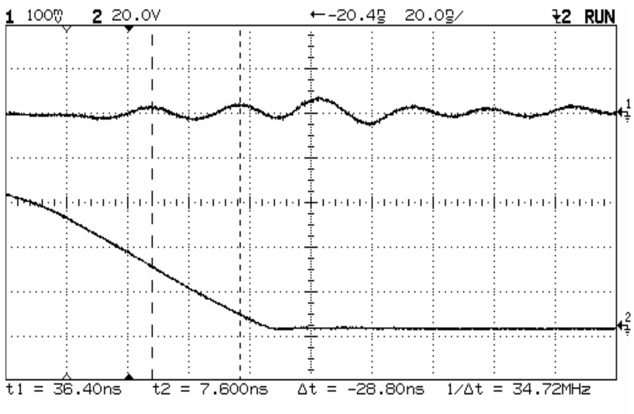


Fig. 20. Wave shape of the noise capted with the near-field probe next to the output rectifier diode area (channel 1), and output diode voltage during conduction (channel 2).

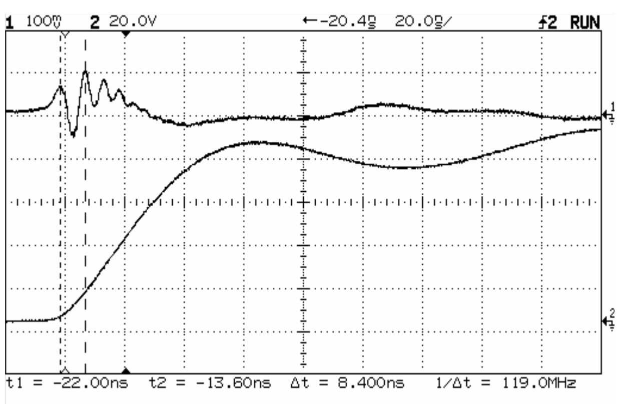


Fig. 21. Wave shape of the frequency of the noise capted with the near-field probe next to the output rectifier diode area (channel 1), and the output diode voltage during the turning off (channel 2).

IV. CONCLUSION

In this paper the results of the electromagnetic interference of a switching power supply for telecommunication application testing were shown, focusing on a legal certification of a product at ANATEL.

We identified where noises appear and how they propagate in this switching power supply project, in a very simple way. We also presented an investigation method of those problems by using measurement devices accessible to all designers.

One can once more verify the importance of the switching MOSFET, the transformer and the output rectifier diode when operating in high-frequencies, in generation, and along PCI, in the electromagnetic noise, either in conducted emission or radiated emission.

It is also evident that small alterations in the components disposal or in the circuit, can make a huge difference on attending or not the standard demanded by the regulation agent for the legal certification. This proves the importance of a good layout.

The study methodology used in this paper can serve easily as reference for research in other converter topologies, with different input and output specifications.

It is also important to have proper instrumentation for the application and evaluation of electromagnetic interference (EMI) or electromagnetic compatibility (EMC), especially when aiming for legal certification of a product.

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