EMC Problem
Digital line filtering

A high-speed digital driver is connected to a 15-pF equivalent load through a L = 100-mm-long 100 Ω microstrip line designed on an FR4 PCB. The microstrip line is routed h = 0.38 mm from a ground plane. The transition times of the signal delivered to the load must be less than 3 ns.

This line is suspected of producing excessive radiation due to the high-frequency content of the current circulating along the line. At one meter, the electric field produced by the microstrip line must not exceed 40 dBµV/m. In order to limit its radiation, a filter may be placed at the line input. The objective of this exercise is to select a filter which reduces radiation to a minimum without significantly degrading signal integrity. The filter is selected following a simulation.

In this exercise, the driver is modelled by a square waveform voltage generator with a 33 Ω series resistance. Characteristics of the equivalent voltage generator:

- Low/High voltage = 0 / 3.3 V
- Period = 50 ns
- Duty cycle = 50 %
- Rise/Fall time = 1 ns

1. How wide should the microstrip line be? Build an electrical model valid up to 5 GHz which includes dielectric and conductor losses. Use the tool 'Tools > Interconnect Parameters' to compute line parameters and build the equivalent model. The model can be embedded with a subcircuit by checking the option 'Create subcircuit'.

2. Add the models of the driver and the terminal load to the microstrip line model. Simulate the voltage waveform across the load. In IC-EMC, observe the transient waveform with 'Voltage vs. Time' tool . Measure:

- the rise and fall transition times
- the period of the oscillation following each transition
- the amplitude of the overshoot peaks following each transition

Is the signal integrity acceptable?

3. Simulate the current at the line input and plot its frequency content ('Emission vs. Frequency' tool). From the simulated current and the characteristic of the line, estimate the worst-case radiated emission produced by the microstrip line at a distance r = 1 meter at the following frequencies f: 20, 60, 140, 180, 220, 260 and 300 MHz. Is it satisfactory?

In order to estimate the worst-case radiated emission produced in far-field by the microstrip line, the following simple model is used:

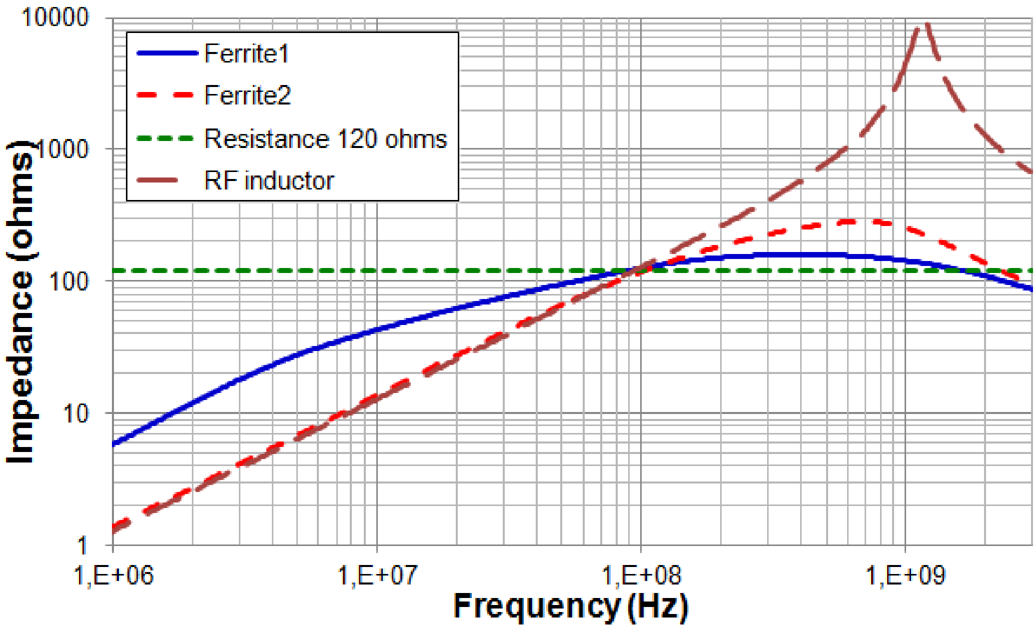
$$\begin{cases} \left|E_{\max}\right| = \dfrac{2\pi\mu_0}{c_0 r} hLf^2 I, \; L << \lambda \\ \left|E_{\max}\right| = \dfrac{2\mu_0}{r} hfI \;, \; otherwise \end{cases}$$

Where I is the current at the frequency f, L is the line length, h the distance between the trace and the reference plane, and r the distance to the measurement point. This estimation can also be done with IC-EMC (menu Tools > Radiated Emission).

4. In order to improve signal integrity and reduce radiated emission, four filters are suggested:

- a 120 Ω resistor
- two ferrite beads with 120 Ω at 100 MHz, called Ferrite1 and Ferrite2.
- 200 nH RF inductor

The impedance of these filters are plotted in the graph below. The models of the ferrite beads are given in files Ferrite1.sch and Ferrite2.sch. The model of the inductor is not given, only the measurement of its input impedance, in file RF_inductor.s1p. Build an electrical equivalent model of the RF inductor. Simulate its impedance and compare it with the measurement, with the tool 'S parameters vs. Freq' tool .



5. Compare real and imaginary parts of the impedance of these four components. Conclude about their differences.

6. Without performing any simulations, which would be the best filter?

7. Build the models of the microstrip line terminated by the driver, the load and the different filter types. For each type of filter, repeat questions 2 and 3. Compare the effects of each filter on signal integrity and radiated emission. Do the results confirm your answer to question 6?