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EMC guidelines

Guide to analyze and avoid some of the possible causes of EMC issue within a GSM mobile phone design

Massimo Pros

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Sources of EMC interference within mobile phone system

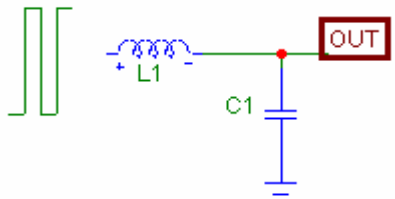
- Magnetic coupling
  - Magnetic field generated by inductors
  - Magnetic field generated by power supply traces with high current
  - Magnetic field generated by acoustic devices
- Radiated digital signals spurs
  - Memory bus
  - Display
  - Camera
- Conducted high frequency coupling
  - PA fundamental and harmonics

Magnetic coupling (1)

- Magnetic field generated by inductors
  - In mobile phone application there is often the need to introduce DC/DC converters
    - Step down to supply baseband with a voltage lower than battery voltage
    - Step up to drive LED backlight that needs a voltage higher than the battery one
  - The step down DC/DC converters to keep a good efficiency and an high current are switching type inductor based
  - The step up converters to drive LED are either switching inductor based if an high current is needed either switched capacitor type

Magnetic coupling (2)

- The switching regulators generate a square wave based on input supply voltage which frequency depends on the specific device, with a range usually between hundreds of kHz up to some MHz
- To generate the wanted DC voltage this square wave is applied to a circuit based on inductors and capacitors



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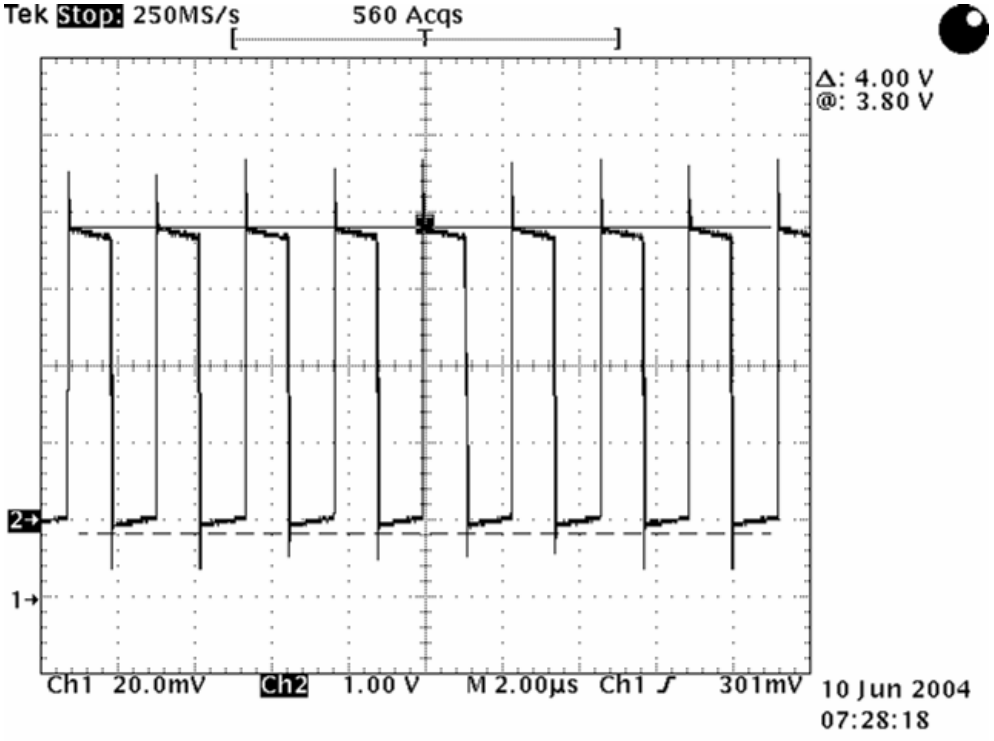
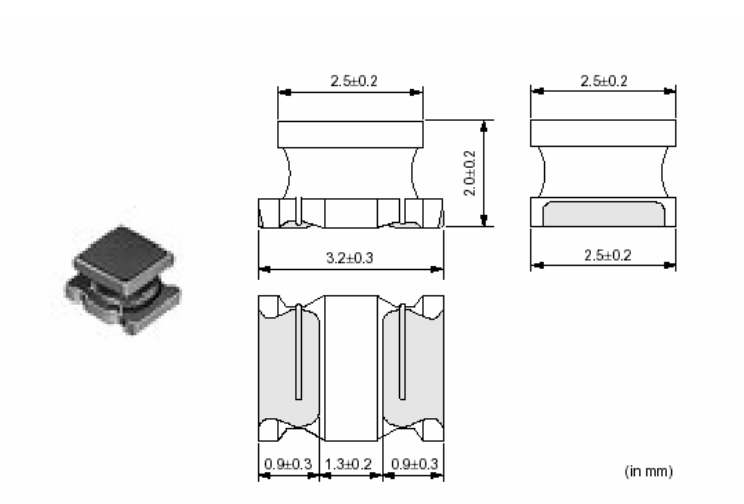
Magnetic coupling (3)

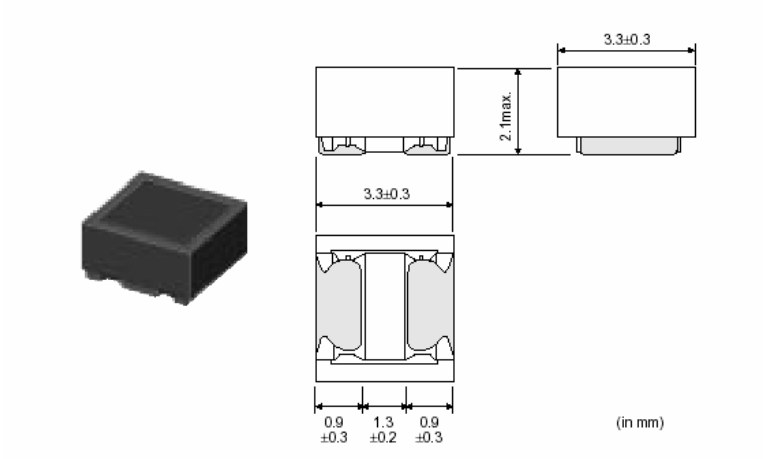


This is a sample waveform taken from EPOWERlite switching step down regulator, and it shows a square wave at around 550kHz, with amplitude equal to the battery voltage

Magnetic coupling (4)

- The inductors used for the switching DC/DC converters can be shielded or unshielded, however due to the current flow throught them and the switching frequency, they generate a variable magnetic field that is not blocked by the copper of the PCB





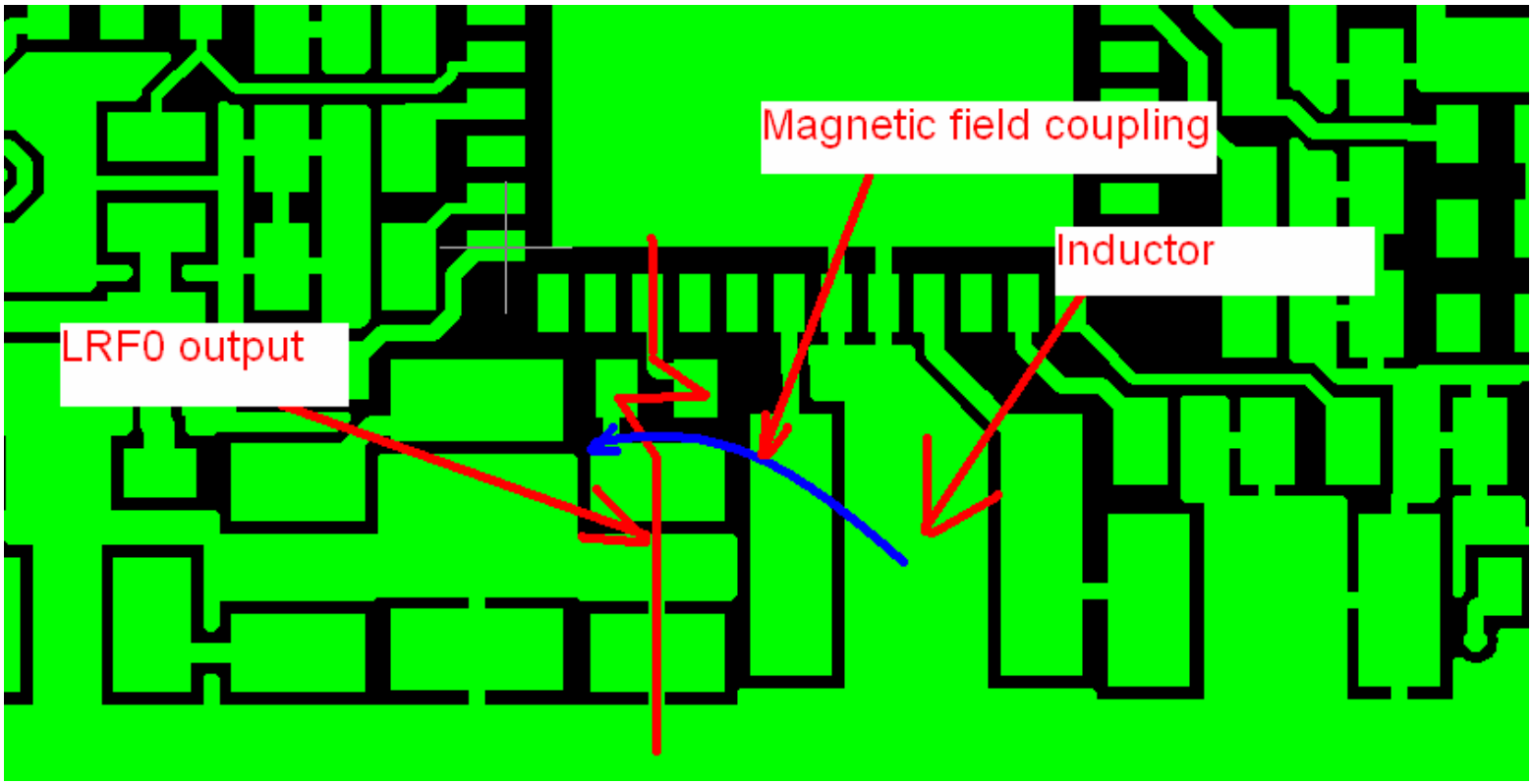
Examples of unshielded (left) and shielded (right) inductors that can be used for DC/DC converters

Magnetic coupling (5)

- If the magnetic field is than coupled to some sensitive device or traces as can be a VCO, a loop filter or a power supply, then some spectral degradation will be generated

An example is given in the next page: on first relese of Globe1 board there was a coupling between the magnetic fileld generated by the inductor of the DC/DC converter of EPOWERlite and the LRF0 linear regulator output. The coupling determined a worse behavior of the transmitter output spectrum, more precisely two simmetrical peaks, 570 kHz far from the carrier, appeared, causing the spectrum to be up to 10 dB higher at that frequencies. To reduce the coupling in order to remove the spectral degradation it was enough to keep the smaller case for the capacitor and solder it on the bigger pads available moved far from the inductor, so it’s fundamental to keep in mind that even a small tuning of the layout can determine the solution of a problem.

Magnetic coupling (6)



Examples of layout problem causing a magnetic coupling: the series components on LRF0 output are a 0 Ohm and a 2.2uF capacitor, behaving as a short for the coupled frequencies

Magnetic field generated by power supply traces with high current (1)

- In the GSM Mobile phone design there are several traces where a high current flows. The worst case always is represented by the trace that supply the power amplifier from the battery. Even if the power amplifiers are always improving their efficiency the current flowing in this trace can easyly reach values around 2.5 A.

- The high current flowing in the trace generates a magnetic field that is not shielded by PCB and so these kind of traces must be kept as far as possible from every sensitive traces on which the coupled field can generate noise or degradation of performances

Magnetic field generated by power supply traces with high current (2)

- Some of the circuits or devices that are pretty sensitive to these kind of coupling are:
  - synthetizers (VCOs, charge pumps, loop filters and their power supplies)
  - Cristal oscillators and their power supplies
  - Audio devices (amplifiers, buzzers and acuostic transducers)

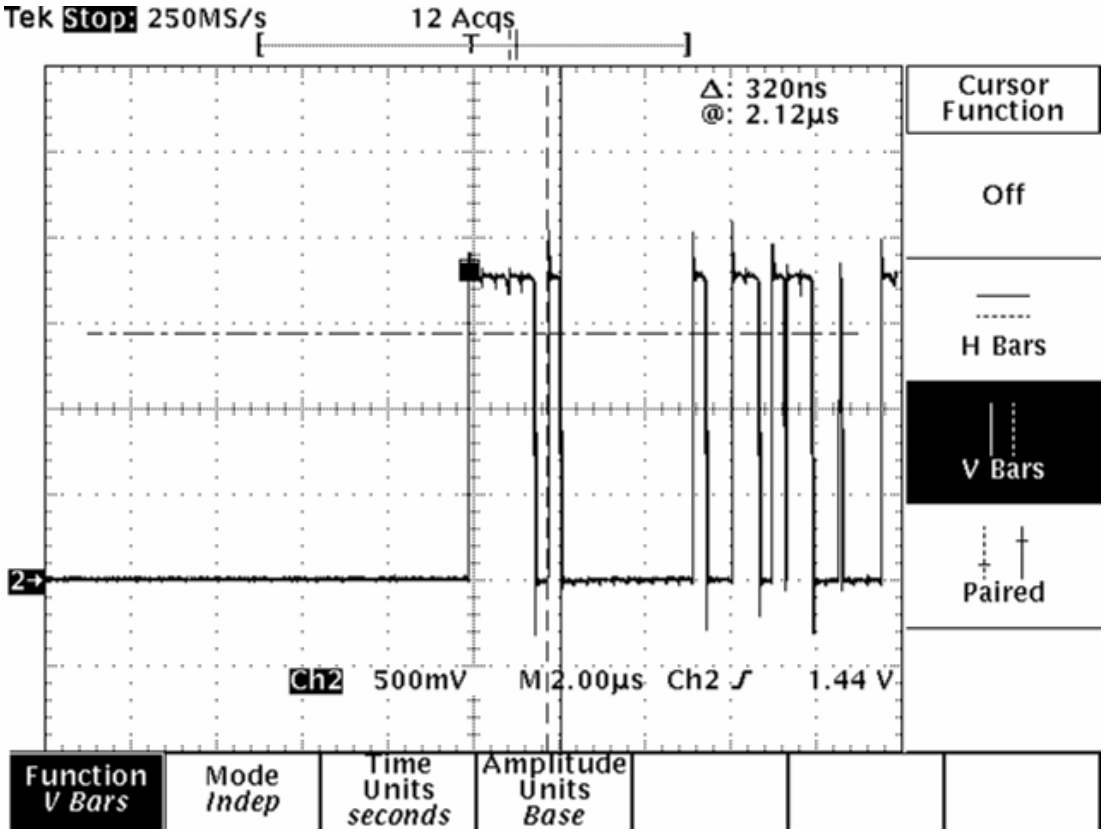
Magnetic field generated by acoustic devices

- In mobile phone systems there are several electro-acoustic transducers
  - Receivers (this is the usual way to describe the small speakers dedicated to deliver the phone audio to the ear of the user)
  - Microphones
  - High power speakers
  - Buzzers
- The last two types of transducers, due to their structure, and to the high level of power with which they are usually driven, are a good source of magnetic field
- These type of devices has to be located far from the sensitive devices and circuits already described in the previous section

Radiated digital signals spurs (1)

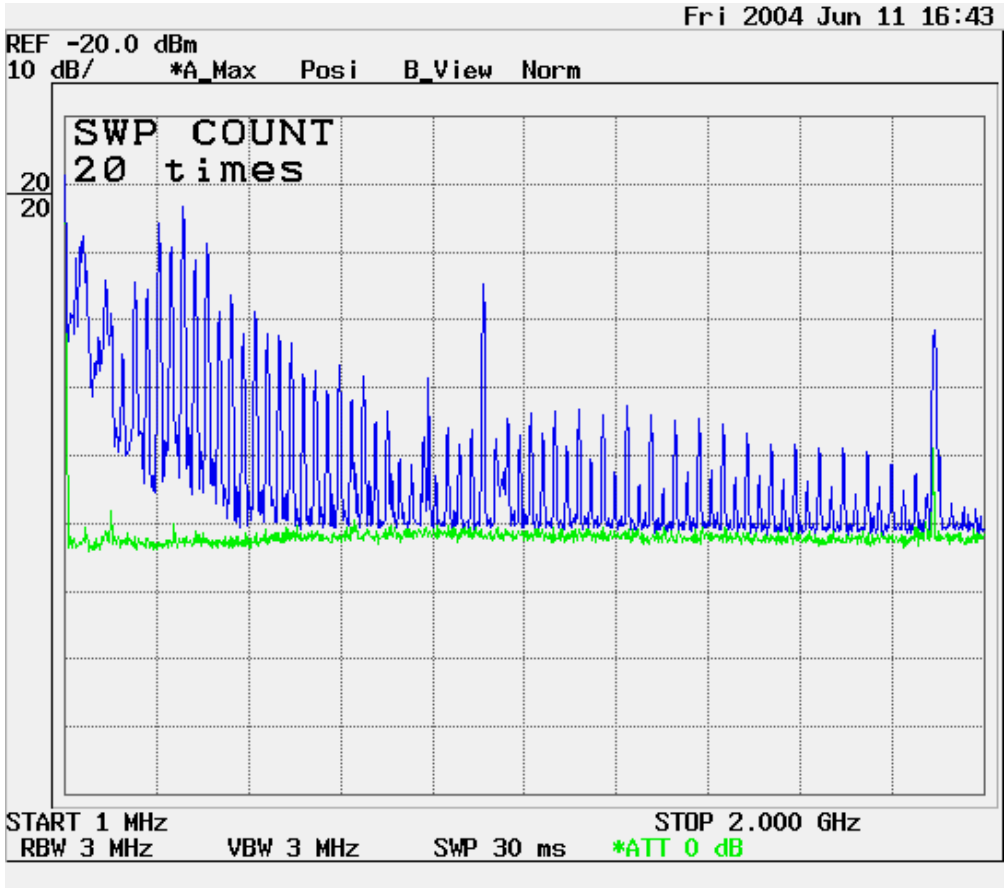
- Memory bus
  - In the mobile phones the performances requested to the digital part are always growing and are mainly related to the multimedia applications that are becoming a need also for the low end products
  - To gain performances the basabands processors are increasing more and more the master clock frequencies
  - The microprocessor, according to his architecture, runs code from internal memory, external RAM and FLASH memories and control several peripherals directly or by companion chips

Radiated digital signals spurs (2)



A tipical waveform taken from the memory bus of a GLOBE2 board is shown in the picture

Radiated digital signals spurs (3)



A tipical spectrum of a memory bus signal of a GLOBE2 board is shown in the picture

Radiated digital signals spurs (4)

- After the previous considerations the routing of the memory bus is a very critical task (from EMC point of view):
  - Traces have to be kept well isolated from other adjacent signals, because it can occurs very easyly to create unwanted directional couplers in the inner layers in memory area
  - Traces have to be shielded by ground planes and ground vias from every opening in the board as can be the edge of the board, every big pad used to connect some periferal like sim card interface, speaker, vibrator, and many more
- As a final consideration: a patch antenna, very common now in the mobile phones, is a small piece of metal, with a certain shape, usually with a feeding point and a ground. Even a shield can become an antenna if for example the bus is routed under its pads and the grounding is a too poor !

Radiated digital signals spurs (5)

- Display (1)
  - The request for multimedia features is heavily involving the displays: from EMC point of view the diplay is a good source of interference for GSM receiver: there are several possible configurations
    1. Parallelly driven display directly controlled by the microprocessor (8/16 bits or and up to 18 bits if the processor can handle them)
    2. Parallelly driven display controlled by the microprocessor throught a level translator
    3. Parallelly driven display controlled by a companion chip
    4. Serially driven display
  - The display can be shielded by metallic can or by conductive painted platstics
  - The display can be connected with capton flexible connection, spring contacts, conductive rubber zebra contacts

Radiated digital signals spurs (6)

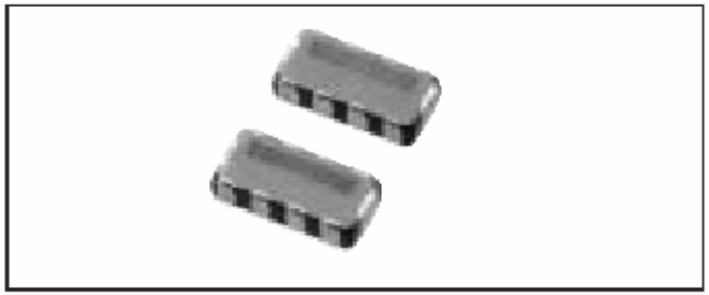
- Display (2)
  - The case 1. mentioned before is the worst case: the signals of the memory bus are present on the display and are active whenever the microprocessor acceses the external memory and every other bus controlled peripherals. Especially if the display is not shielded and there is a long flex connection some EMI suppressor are required. There are several type of components suitable for this task, starting from simple discrete RC filtering, up to a large variety of suppressors available in single package and arrays, some examples of which are shown in the next slides.

Radiated digital signals spurs (7)

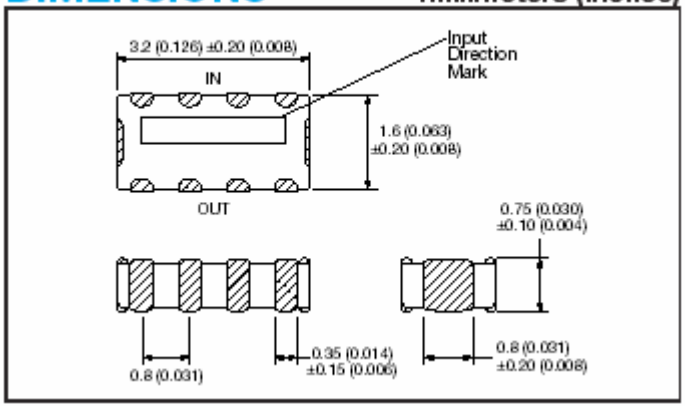
Here an example of EMI suppressors array from AVX is shown

EMI Filter Array

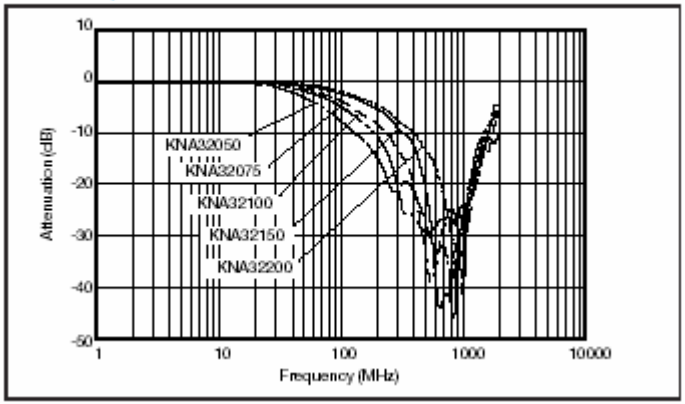
KNA Series



DIMENSIONS millimeters (inches)



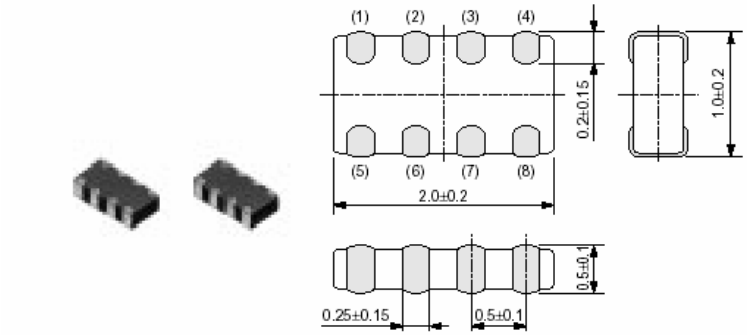
FREQUENCY CHARACTERISTICS

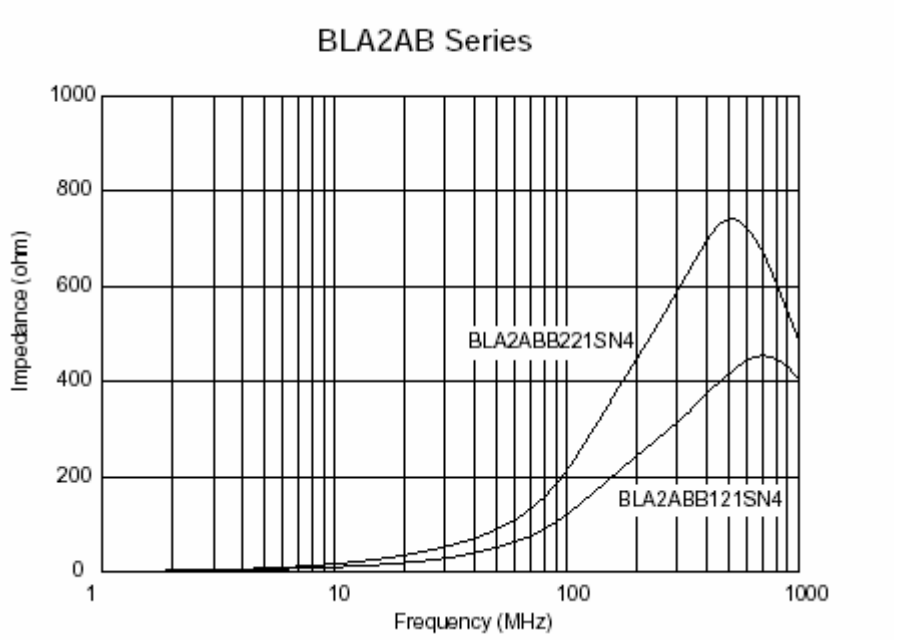


Radiated digital signals spurs (8)

Here another example from Murata

BLA2AA/BLA2AB Series

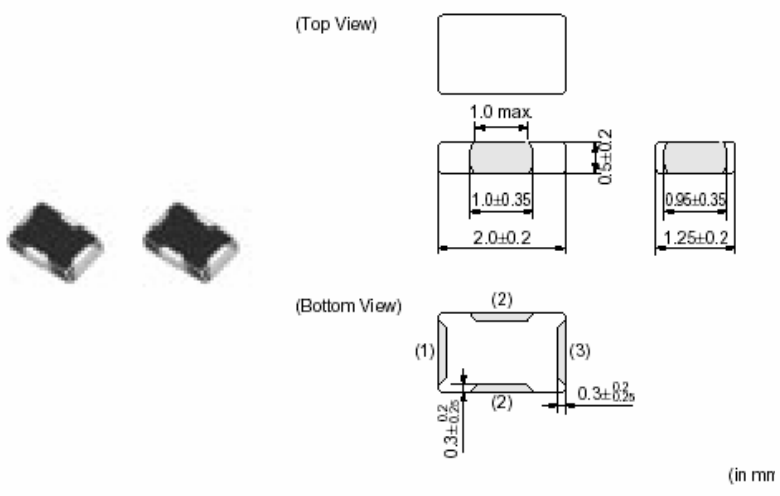


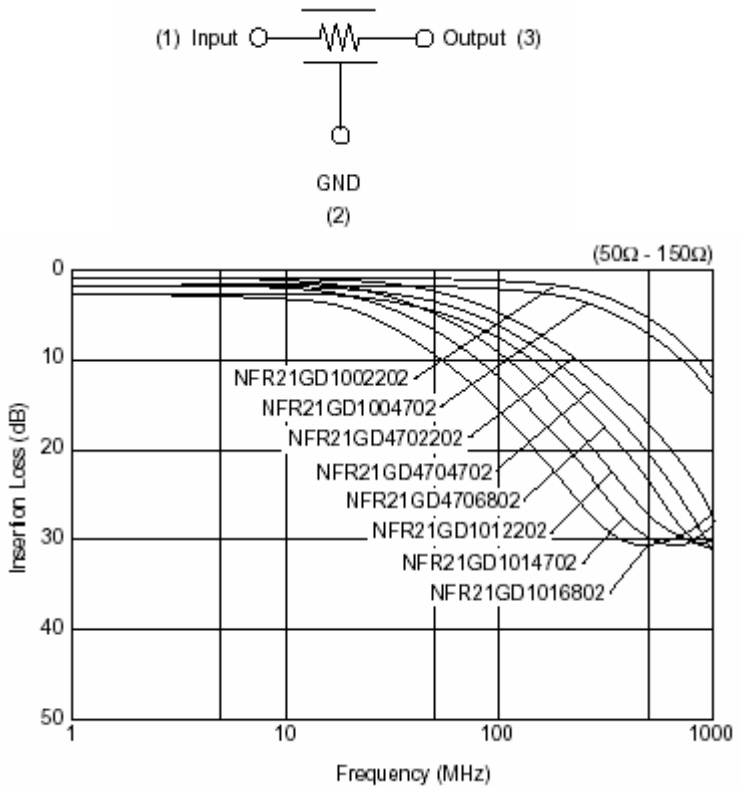


Radiated digital signals spurs (9)

Here there is another Murata example for a more complex structure EMI suppressor

Chip EMIFIL® RC Combined Type NFR21G Series





Radiated digital signals spurs (10)

- Display (3)
  - The case 2. and 3. mentioned before are instead less critical even if the display is not shielded: the level translator or companion chip will stop all the bus activity except from the one direct involving the display itself. The degradation of the receiver performances will have a very low probability dependent by the software architecture: most likely the display refresh is cosidered a very low priority task if compared to the network related activities, so the data lines controlling the display will stay inactive when the receiver, equalizer and protocol code will run. Moreover the display refresh is an activity with an average frequency of seconds and a duration of tens of milliseconds, asyncronous to the GSM activity, so only seldom the receiver is on when the display is refreshed.

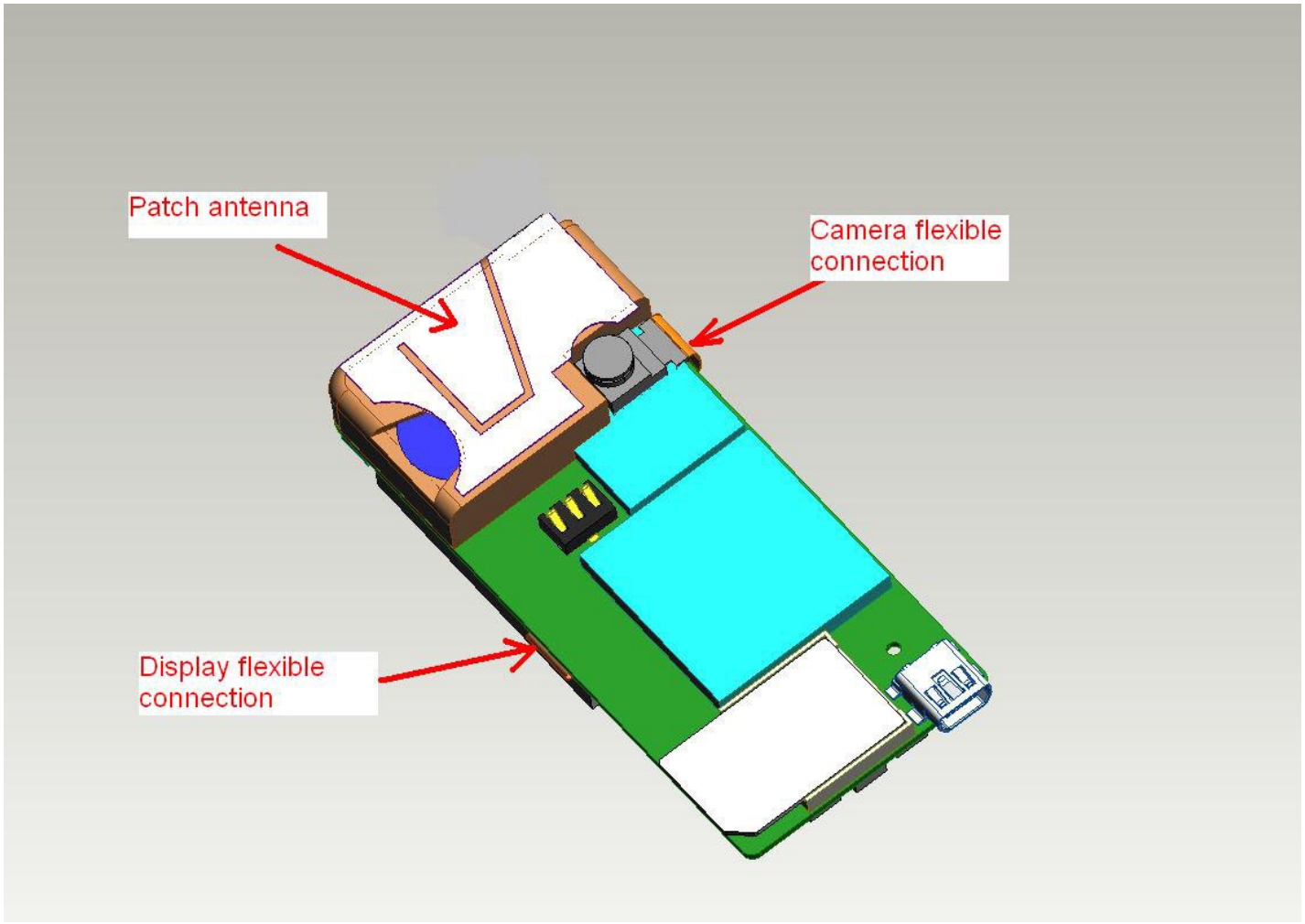
Radiated digital signals spurs (11)

- Display (4)
  - Last case (4.) is a serially driven display: this case is not critical as 2. and 3., because the serial lines are not accessing memories and so the possible interferences are few, as explained in the preceding slide. The only difference is the speed: to have a refresh of the display lasting the same time the serial lines have to be 8 or 16 times faster than the parallel ones, so the level of the radiated spurs will be higher. If the activities are not occurring at the same time, however, there will be no issue.

Radiated digital signals spurs (12)

- Camera (1)
  - As for the display the camera can be controlled in several ways, but the considerations previously written for the display itself are no more valid, since when a subsysytem camera + display is running in view-finder mode, there will be a huge amount of data, which size will be related to display size, frame rate and number of colours, flowing from the camera to the display, so companion chip, level translator or serial connection will not avoid the interference to GSM receiver caused by the digital signal.
  - To minimize the problem the coupling between antenna and camera and display flexible connection has to be reduced as much as possible with distance and shielding. In the next slide there is an example of possible architecture, adopted for GLOBE2, in which the display connection and patch antenna have been kept on the opposite side of the PCB, while the camera connection crosses the PCB.

Radiated digital signals spurs (13)



Radiated digital signals spurs (14)

- Camera (2)
  - Other ways to minimize the inteference are to use metal shileding of conductive paintings in order to block the spurs and prevent their feeding into the antenna. It can be easier for clam shell design, where the upper part can be all shielded and can be the container of display + camera subsystem
  - Less is the help that can be given by the EMC suppressor mentioned in display section, because in viewfinder mode the source of digital data is the camera and the filter can be inserted only on the PCB, after the flexible camera connection, thus the spurs of the digital signal on this connection will be unaffected by the filtering and radiated into the antenna.

Conducted high frequency coupling (1)

- PA fundamental and harmonics
  - In the GSM mobile phone design a potentially big issue can be the leakage of RF from the power amplifier that through the power supplies can be coupled to several part of the board, with big consequences. A fundamental way to be followed is a careful layout of the bypassing structure to properly block the RF coming from PA power supply. A good layout for the bypass capacitor is the one that reduces the lenght of the connection from the power supply trace to the capacitor and from capacitor to ground in order to minimize the inductance indroduced with the routing. In the following page an example of layout for the bypass of the power supply of the PA.

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Conducted high frequency coupling (2)