Trilogy of Magnetics

Applications

Design Guide

for EMI Filter Design,

SMPS & RF Circuits

1 Filter Circuits (Including ESD)

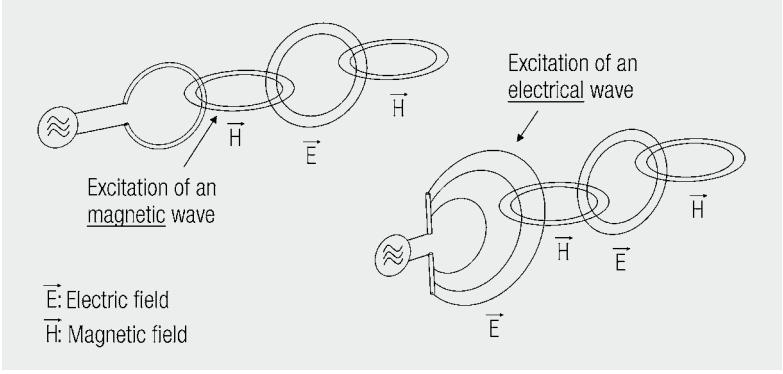
1.1 Use of filters in interface applications

Filters may be constructed in different ways. Not only parameters describing the effectiveness of filter components, such steepness, impedance, attenuation etc. may be measured on the laboratory test bench or ascertained with simulation programs, but also system specific parameters, such as source impedance, sink impedance, layout, positioning of the filter in the system, positioning of filter components etc.

Magnetic wave

Electrical wave

Peripheral cables (cables from one device to another, e.g. from PC to keyboard) are conductor configurations, which have the ability to radiate electro magnetic waves. In principle, two possible waves may be excited. Figure 3.1 illustrates the principles: In one case a magnetic wave is excited from a wire winding, in the other case, from bowed parallel wire conductor, the dipole, an electrical wave.



Wave excitation

Fig. 3.1: Two possibilities of wave excitation (simplified near-field representation)

Dipole electric field

The dipole electric field is symmetrical to the surface passing perpendicular through the dipole axis. As this plane is symmetrical to both halves of the dipole, it has the property of being a zero potential surface or ground surface; it can be replaced by a metal surface without changing the dipole field (Figure 3.2).

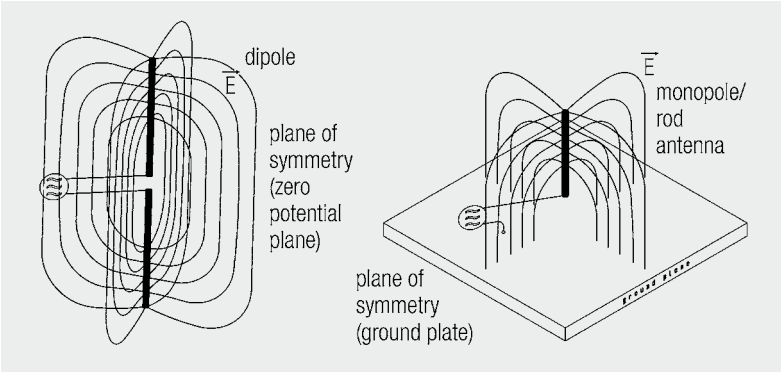


Fig. 3.2: Conversion of the symmetrical dipole to a rod antenna

Rod antenna
Peripheral cable

If one of the dipole-halves is omitted and is instead fed into the metal plane of symmetry, a configuration is obtained consisting of a vertical rod above a conducting plane, a rod antenna. The electric field of a rod antenna corresponds to that of a dipole, but just in half the space; the ground plane shades the other half. The link to the peripheral cable becomes apparent. Figure 3.3 illustrates this relationship.

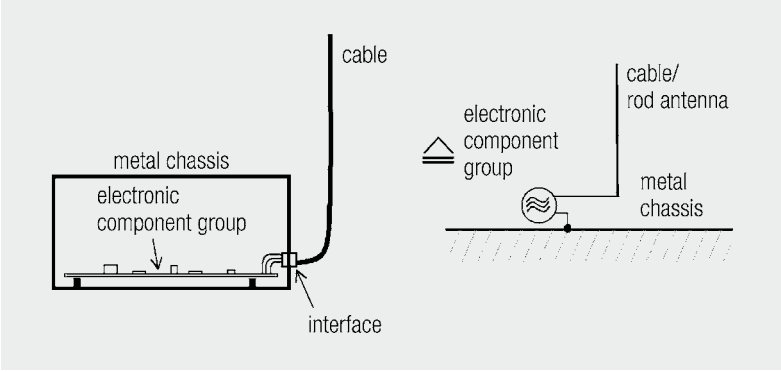


Fig. 3.3: Relationship between peripheral cable and rod antenna

Impedance

The impedance of the rod antenna is twice as high as that of the dipole, the equivalent circuits of the rod antenna correspond to that of the dipole.

Equivalent circuit

Figure 3.4 shows that the equivalent circuit of the rod antenna varies depending on its length.

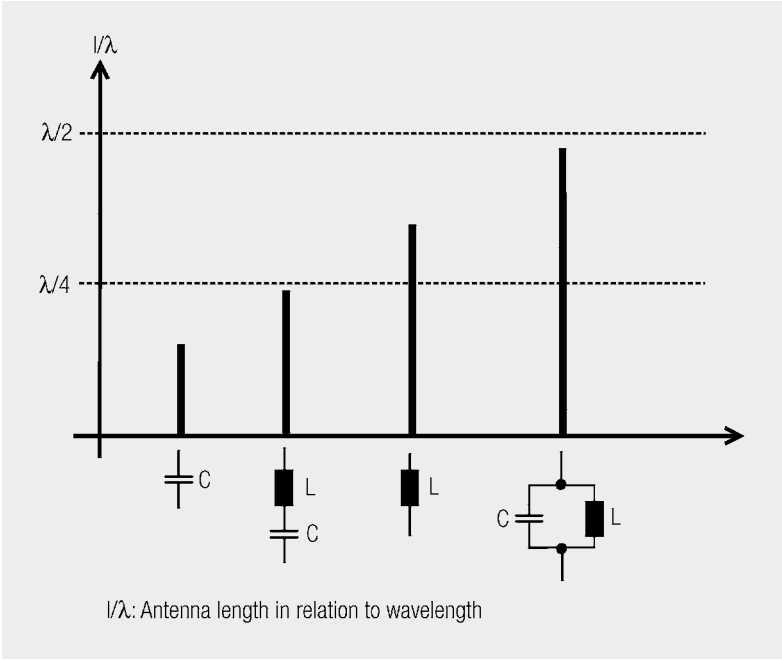


Fig. 3.4: Equivalent circuit of the rod antenna is dependent on the antenna length

Input impedance

Impedance bandwidth

The input impedance of the rod antenna – the peripheral cable – changes with length. In practice, the antenna or cable length of course remains constant, which means the antenna does not have a defined effective frequency, but a whole interference frequency spectrum available to radiate. The impedance bandwidth of such a cable configuration is between approx. 40 Ω and several 1000 Ω and depends also on parameters such as cable thickness and type and degree of area coverage and possibly the cable shield used. In practice, cable shield impedances of over 100 Ω can be expected.

Antenna impedance

The interface filters must reduce the interference energy normally fed to the cable or rod antenna by frequency dependent voltage division (see Chapter III/1.1 The principle of filtering). It is clear that only certain filter circuits may be used when considering the antenna impedance. The output impedance of the filter must be low to achieve high attenuation as the rod antenna has high input impedance. Figure 3.5 illustrates the relationships.

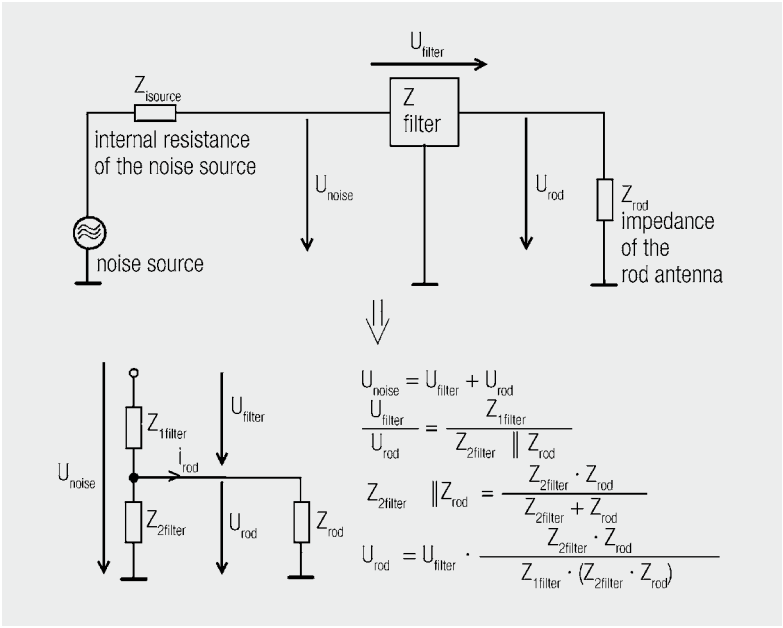


Fig. 3.5: Impedance relationships at the peripheral cable interface

Impedance relationships

According to the relationships presented in Figure 3.5 this means that

- $Z_{2filter}$ must be as small as possible
- $Z_{3filter}$ must be as large as possible

to keep U_{rod} as small as possible and therefore to achieve a high attenuation of the noise voltage U_{noise}. Therefore only filter circuits of the type shown in Figure 3.6 are worth considering.

Filter attenuation

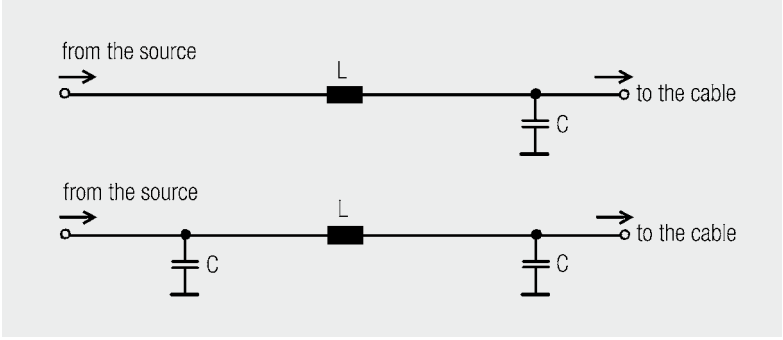


Fig. 3.6: Interface filter circuit versions (common-mode versions not considered)

If the capacitor on the cable end were omitted, the impedance of the inductor has to be very high in the required frequency range. To achieve an attenuation of 10 dB, the cable impedance would have to be 1 kΩ and the impedance of the inductor 4 kΩ!

Capacitor