Cabling

Choose yourself and new technologies

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Wrocław University of Technology
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References

Basic:
Ott H. W., *Electromagnetic Compatibility Engineering*, Wiley, Hoboken, NJ, 2009

Additional:
Williams T., *EMC for Product Designers*, Elsevier-Newnes, 4-th ed., Oxford, 2007

Source of illustrative materials

All the illustrative materials have been taken from:
Ott H. W., *Electromagnetic Compatibility Engineering*, Wiley, Hoboken, NJ, 2009

Cabling

Cables are important because they are usually the longest parts of a system and therefore act as efficient antennas that pick up and/or radiate noise.

Assumptions:
- Shields are made of nonmagnetic materials
- Cables are short compared with a wavelength

Considered types of couplings are:
- Capacitive or electric coupling.
- Inductive, or magnetic coupling.

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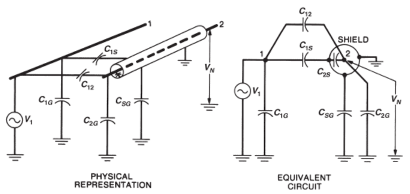
EFFECT OF SHIELD ON CAPACITIVE COUPLING

In many practical cases, the center conductor does extend beyond the shield, and the situation becomes that of the figure below



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EFFECT OF SHIELD ON CAPACITIVE COUPLING

For good electric field shielding, it is necessary
(1) to minimize the length of the center conductor that extends beyond the shield and
(2) to provide a good ground on the shield.

A single ground connection makes a good shield ground, provided the cable is not longer than one twentieth of a wavelength.
On longer cables, multiple grounds may be necessary.

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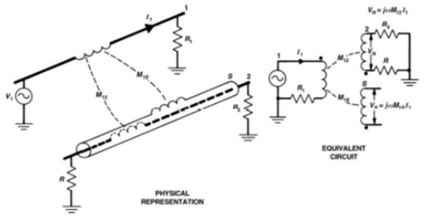
EFFECT OF SHIELD ON MAGNETIC COUPLING

If an ungrounded and nonmagnetic shield is placed around conductor 2(***M1s*** is the mutual inductance), the circuit becomes that of the figure below



EFFECT OF SHIELD ON MAGNETIC COUPLING

The shield pick up a voltage because of the current in conductor 1:

$$V_S = j\omega M_{1S} I_1$$

Note that mutual inductance $\boldsymbol{M_{1S}}$ *from conductor 1 to the shield is equal to the mutual inductance* $\boldsymbol{M_{12}}$ *from conductor 1 to conductor 2*

A nonmagnetic shield placed around a conductor and **ungrounded or grounded at one end** has no effect on the magnetically induced voltage in that conductor.

EFFECT OF SHIELD ON MAGNETIC COUPLING
Magnetic Coupling - Open Wire to Shielded Conductor

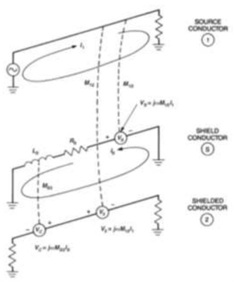
If the shield is **grounded at both ends**, the shield current flows and induces a voltage into conductor 2.

The total noise voltage induced into conductor 2 is

$$V_N = V_2 - V_c$$

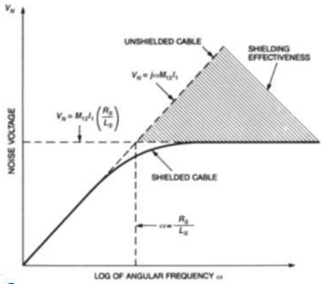
Note that ***these two voltages are of opposite polarity.***

$$V_N = j\omega M_{12} I_1 \left[\frac{R_S/L_S}{j\omega + R_S/L_S}\right]$$



Magnetic Coupling - Open Wire to Shielded Conductor

The equation for V_N is plotted in the figure



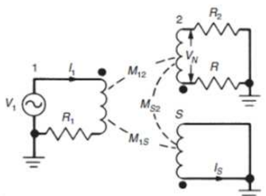
EFFECT OF SHIELD ON MAGNETIC COUPLING

At low frequencies, the noise pickup in the shielded cable is the same as for an unshielded cable; however, at frequencies above the shield cutoff frequency, the pickup voltage stops increasing and remains constant.

Magnetic Coupling - Open Wire to Shielded Conductor

Figure below shows a transformer analogy equivalent circuit for the magnetic coupling to a shielded cable when shield is grounded at both ends. (Remember that the mutual inductances $\mathbf{M_{12}}$ and $\mathbf{M_{1S}}$ are equal.)

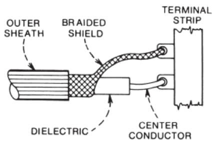
$$V_N = j\omega M_{12} I_1 - j\omega M_{12} I_1$$



SHIELD TERMINATIONS

Pigtails

For maximum protection, the shield should be terminated uniformly around its circumference. This can be accomplished by using coaxial connectors such as BNC or Type N. A pigtail connection causes the shield current to be concentrated on one side of the shield and strongly degrades the shield performance.



Grounding of Cable Shields

High-Frequency Cable Shield Grounding

At frequencies above about 100 kHz, or where cable length exceeds one twentieth of a wavelength, it becomes necessary to ground the shield at both ends.

Another problem develops at high frequency; stray capacitance tends to complete the ground loop, as shown in the figure below, which makes it difficult or impossible to maintain ground isolation at the unterminated end of the shield.