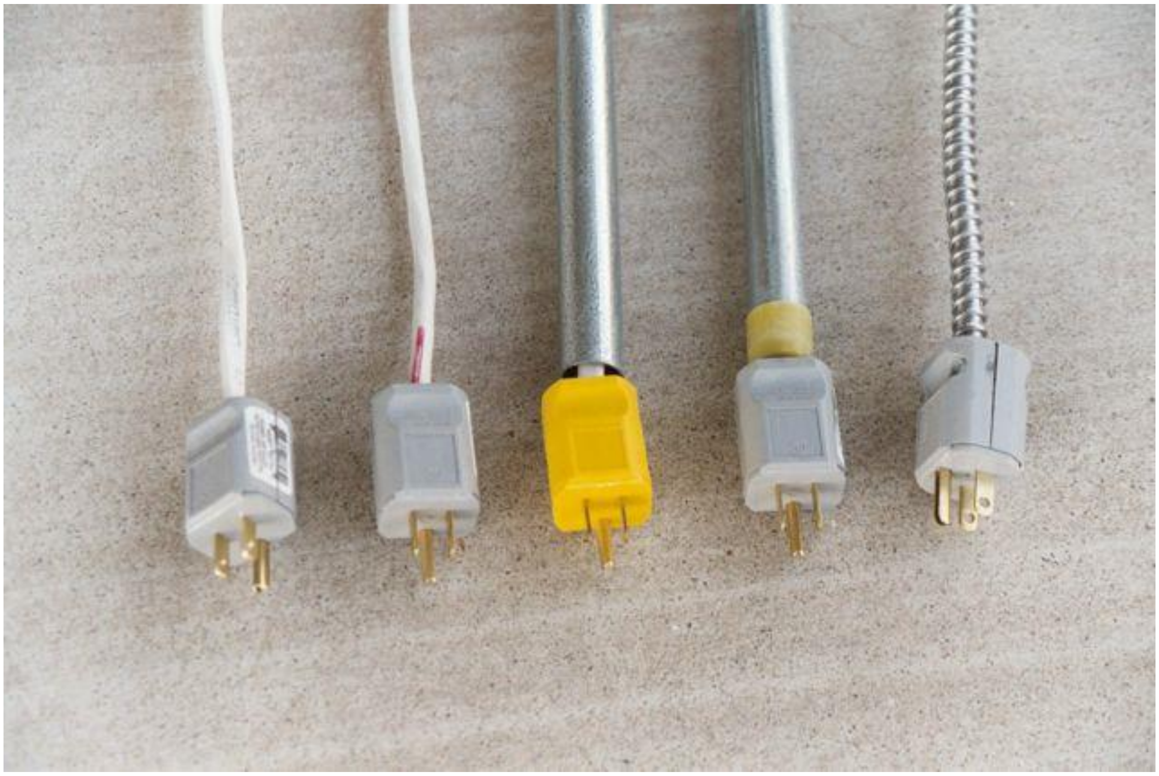
Choosing household wiring for low EMF



We tested five ordinary electrical cables and conduits to see which one emits the lowest magnetic field. We found that twisted wires are an effective and low-cost way to dramatically lower the radiation level. For best results, combine twisted wires with a steel conduit.

Keywords: EMF, shielded cables, shielding, magnetic field

The picture above shows from left to right: ROMEX 12/2, ROMEX 12/3, EMT conduit, IMC conduit, MC 12/2.

Modern buildings have electrical wiring in all walls, and often in ceilings and under the floors as well. As electricity runs through the cables to be consumed elsewhere, an AC magnetic field (EMF) is generated. This field surrounds the cable in its entire length and becomes weaker with increasing distance to the cable. Magnetic fields are bothersome to some individuals and can be measured by a gaussmeter.

Power cables are also surrounded by an electrical field. This field depends on the voltage and is the same whether electricity (amps) passes through the cable or not.

The electric field is shielded by any metal. In this test we looked only at the magnetic field.

When wiring a new building, or upgrading an existing building, it may be prudent to choose a type of cable that emits less EMF, but which one to choose?

To find out, we purchased a selection of cables and metal conduits that are widely available and in general use in the United States. The cables tested were:

- ROMEX 12/2 (2-conductor, AWG 12)
- ROMEX 12/3 (3-conductor, AWG 12)
- MC 12/2 (flexible metal-clad, 2-conductor, AWG 12)

The conduits tested were:

- EMT - lightweight steel conduit
- IMC - heavy steel conduit

The AWG 12 thickness of the wires was chosen, as they are used for typical household wiring carrying up to 20 amps.

A wiring primer

In the electrical trade, the grounding wire is always present in a cable and is not counted as a conductor. A "2-conductor cable" thus has three wires inside – a black one for the phase, a white for the neutral, and a bare copper wire for the ground. In some cases, the ground wire is green instead of bare. (Other countries may have different color schemes.)

A 3-conductor cable has one additional wire, which is usually red. This type of cable is commonly used for bringing two-phase (230 volt) electricity to electrical stoves, clothes dryers and water heaters. It can also be used for lighting circuits with two switches, such as at each end of a hallway.

Test setup

We tested a combination of cables and metal conduits under identical conditions. To provide a test load, a 1380-watt space heater of brand Intertherm (now SoftHeat) was placed approximately 20 feet away.

The metal conduits tested were sold in 10-foot sections, but we used six-foot samples due to transportation restrictions. The measurements were done at the middle of the conduit, which was simply sleeved over the cable. In all tests, the ground wire in the cable was connected to the ground in the wall outlet, as it normally would be.

The ROMEX 3-conductor cable was tested without connecting the red extra wire to anything.

To limit outside interference with the test, a specially shielded outlet was used, while the breakers were off to all the other outlets within twenty feet (6 meters). The outlet used had wiring inside EMT metal conduit, which went all the way back to the breaker box.

The magnetic levels were measured by a gaussmeter of the TriField brand, produced by Alpha Labs in Utah. The TriField meter was outfitted with the optional external probe that makes it one hundred times more sensitive and able to pick up magnetic radiation down to 0.001 milligauss (0.1 nanotesla).

The 120-volt AC power in the building did have some overlying static ("dirty electricity") which could be picked up with an AM radio. This static was present whether any current was running or not (i.e., it was a fluctuation of the line voltage). It appeared to come from the outside of the building and this was deemed not to be a problem for this comparison.

Results

The results from the gaussmeter readings are shown in Table 1. It is clear that the 3-conductor ROMEX wire (ROMEX 12/3) is vastly superior to the 2-conductor (ROMEX 12/2). This is due to the fact that the individual wires inside the cable happen to be twisted around each other. This effect is used in wires for computer networks and long telephone cables, so it was not a surprise that it also worked well here.

It was a surprise that the twisted ROMEX 12/3 cable was also superior to untwisted wires inside metal sleeves (MC, EMT and IMC).

When the ROMEX 12/3 cable was further shielded by EMT conduit, the radiation level became so low that it only measured 0.4 milligauss directly on the surface of the conduit.

Table 1: Distance in inches from cable for specific EMF levels (1380 watt load)

	1 milligauss (0.1 microtesla)	0.2 milligauss (0.02 microtesla)	0.01 milligauss (1 nanotesla)
ROMEX 12/2	10.5	18.5	37

ROMEX 12/2 in EMT	3	6.5	25
ROMEX 12/2 in IMC	2	5	15
ROMEX 12/3	0.6	1.7	3.3
ROMEX 12/3 in EMT	--	0.7	2
MC 12/2	1.5	2.3	3.7

Discussion and conclusion

If wanting to wire a house for lower magnetic levels, using the 3-conductor twisted ROMEX 12/3 (or any other suitable AWG size) is clearly a good choice. It is about ten times as good as the standard 2-conductor ROMEX wiring.

The extra cost of using a 3-conductor cable is minor; it just costs somewhat more due to having more copper in it. The price was very close to the cost of the metal-clad MC cable, and much cheaper than using the rigid metal conduits (EMT and IMC) as they are much more labor intensive to install.

The extra (red) wire in the cable cannot be used for anything without violating the National Electrical Code (NEC). Just make sure it cannot accidentally become energized.

It is only when combining the 3-conductor cable with a metallic conduit that even better results are possible. Whether going this route is cost-justifiable depends on the project; in most cases it probably is not. In practice, it may be better to use individual wires, which are twisted manually before pulled through the conduit.

A reason to use metallic conduit could be to shield the electrical field, which is not shielded by twisted wires. This may especially be warranted if the wiring carries high-frequency dirty electricity or microwave frequencies. However, metal conduits have in some cases made that situation worse.[1]

We expect that the MC flexible metal will be more leaky of radio-frequency signals than the rigid EMT and IMC conduits, but we do not have the facilities to test that, and how much of a difference it might make.

The tested 3-conductor ROMEX cable had a full turn of the wires inside it for every four inches (10 centimeters) of running cable. Cables of other brands may have a tighter or looser twist ratio, which may affect the shielding effect. Some brands may not have any twisting.

If twisted cables are not available, it may be possible to make them yourself.[2]

This test was done as a laboratory setup, so the various combinations could be tested under identical conditions. The cables and conduits were straight and not attached to anything. The conduits were also not grounded, which they must be in a real installation.

ROMEX is usually not used inside conduit. Loose wires are commonly used instead, which means there may be a greater distance between the conductors, unless the wires are attached to each other by twisting them. A real-life steel conduit with loose wires may thus perform more poorly than in this controlled experiment.

Three-conductor ROMEX, which happens to be twisted inside the sleeve. The twisting can be seen through the outer sleeve.

Applying this information to real life

This information can be useful in the construction or renovation of homes, apartments, medical facilities, offices, etc. Decisions on the practical implementation of this information should be made together with professionals who are familiar with local codes and practices.

Building professionals are often, for good reasons, rather conservative in their methods and may need to think about the implications. However, some may simply be uncomfortable with the unfamiliar and decline the job.

End notes

(1) The reason for these problems is not clear. It may be because common practice is to connect the conduit to ground at both ends, i.e. to both a grounded steel wall box and the steel breaker box. Such multi-point grounding is specifically listed as a “don’t” in many EMC textbooks.

(2) If a suitably twisted ROMEX cable is not available, it is possible to manually twist a 2-conductor ROMEX cable, using a variable speed power drill. This has successfully been done in some cases. Care must be taken not to twist the cable so tightly that the plastic insulation becomes much thicker. A thicker insulation could make a cable carrying a high current overheat, which is a fire hazard. Discuss this with a professional in the field.

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