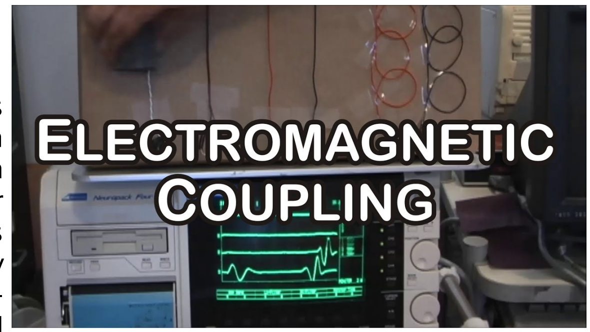
Brass Tacks

An in-depth look at a radio-related topic

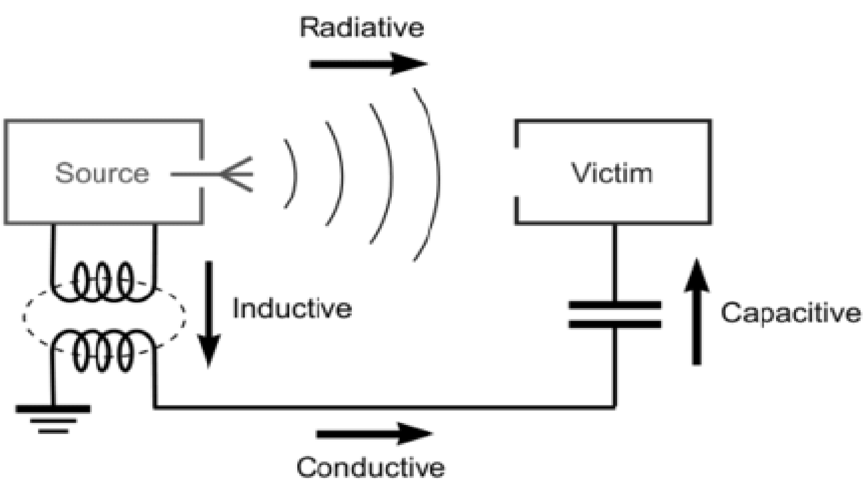
Coupling



An RF (radio frequency) signal can be present as electrical AC (alternating current) in a wire or an EM (electromagnetic) signal transmitted through space. Transferring this energy between two or more circuits can be done by wiring the circuits together, known as *conductive coupling*, or by "connecting" them wirelessly. This discussion focuses on the RF connection made through EM fields, the wireless method.

EM coupling is a phenomenon that's both indispensable to the workings of amateur radio, and at times an unintended, interfering nuisance. It's manifested in at least two different effects, known as *inductive coupling* and *capacitive coupling*, but for the purposes of amateur radio, I'll treat them the same, and simply call them both ***coupling***. To save you the headache of reading through the physics of wireless coupling, I've inserted a few paragraphs on the details near the end of this article, for those who really want to understand the fundamentals behind it.

For completeness, yet also not part of this discussion, one more type of EM coupling, *radiative coupling*, in a way connects your radio antenna with that of another radio, allowing wireless communication between stations. Furthermore, publications that address classical EM coupling often refer to a *source* circuit to identify the origin of an interfering signal, and a *victim* circuit or conductor as the recipient of the signal, to describe their interaction.



The four major types of coupling illustrated

The reason you need to know all this is because ***the objects that get coupled with your antenna become part of your antenna system***. Once you start grasping the idea of coupling, the better you can envision the effects of antenna placement, transmission line shielding, and some causes of impedance mismatch (resulting in high SWR) in your antenna system.

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Antenna element proximity

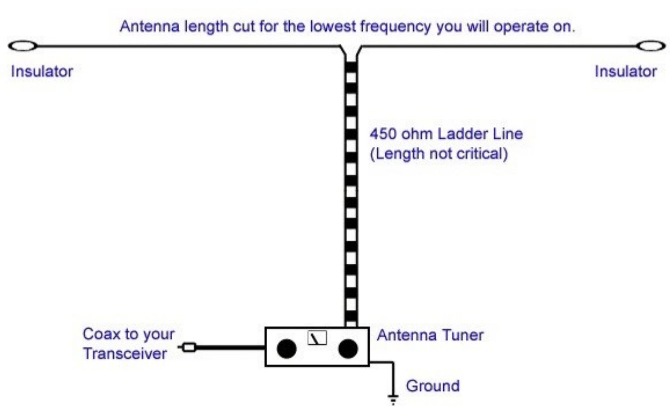
One day a local ham proudly showed me a photo of his newly installed Pockrus J-pole, but added that it didn't seem to work very well. Indeed, his antenna was more than twenty feet up in the air, but he said people on line-of-sight repeaters had complained about his signal. Glancing at the photo, it was fairly obvious what was going on. He had bolted the metal angle bracket to the aluminum siding of his house, which placed the three vertical elements less than an inch from the siding.

I told him that he had effectively coupled his antenna with his house, making the aluminum exterior an extension of his antenna, essentially turning his house into a huge, non-resonant antenna at VHF frequencies. He noted that he had gone through great pains to mount it where it was, and asked whether I was certain that the antenna's proximity to his siding was the reason for the bad signal reports. I told him that, if everything else was working as they should be, I believed that to be the case.

After a few more trips up his ladder, my friend installed a mast on the side of the house, and mounted his J-pole to the mast, clear of any metal, and said that people now gave him great reports, even on simplex much farther away. So, the two lessons learned here were that a) it's good to know which part of an antenna is responsible for radiating a signal, and b) to make sure and keep that part of the antenna away from anything conductive.

Ladder line proximity

Coax (coaxial cable) is a wonderful invention, in that its proximity to surrounding metal objects will not affect its characteristics much. I say "much" because there are a few exceptions, such as its use in an RF choke.



Doublet antenna, which uses a matching ladder

On the other hand, ladder line (including window line, ribbon-line, and open-wire line) is very susceptible to behavior change due to coupling with nearby conductors. Take precautions to keep ladder line, whether it's used as a feedline or a matching section, away from anything metal.

More than once, I've visited the home of a G5RV or Zepp or doublet owner who has complained about his signal or SWR, only to see the ladder section partially lying on the ground or draped against aluminum siding.

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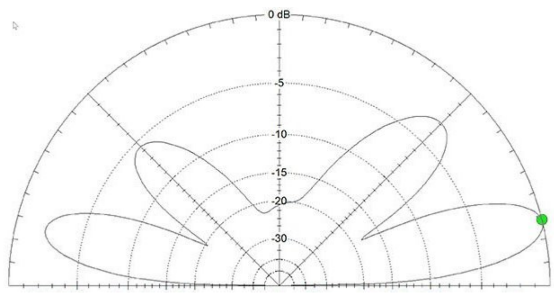
How close is *close*

Ok, so now you know that you should not mount your antenna close to anything conductive unless your design calls for it. But just how close is *close*? There's no easy answer, because the proximity is frequency-dependent and pattern-dependent. To arrive at a concrete answer, I've had to ask myself how close I want the antenna to a metal object if I *wanted* them to couple, and then try to remain clear of that distance.

Quite a lot of research (electronic simulations, calculations, plus real-life measurements) has gone into locating that perfect separation between the driven element and reflector of a Yagi antenna, for example, and many findings agree that a quarter-wavelength seems to be nearly ideal. Using this "quarter-wavelength" spacing is far from a perfect ruler, but does offer some guidance that can be used somewhat generally.

Radiation patterns



If you're aware of your antenna's radiation pattern, it's possible to mount your antenna, such that nearby conductive materials fall outside the *effective space*, or the lobes of the antenna pattern, and in the *nulls* instead. The term "effective space" is something I made up, but I'm using it to mean that space in which the coupling effects are *noticeable*, due to the relative proximity of the conducting materials in or near one of the lobes, as displayed by the antenna pattern. (My "effective space" term is not to be confused with *effective area* or *aperture*, a receiving antenna concept.) For example, in the above sample pattern, if I had to mount my antenna near a metal light fixture, I might want to install it so that the fixture is about 30˚ up from the antenna, to minimize the coupling effects with that light fixture.

A Yagi antenna works on the principle that its parasitic elements lie within the effective space of the driven element. The driven element of a Yagi antenna is *intended* to couple with its reflector, which actually extends the effective space around the antenna to include that longer element, elongating the main lobe, increasing the antenna's gain.

Conductive materials

Vegetation (trees, shrubs, tall grass) can also be subject to coupling, but it's more of a radiative obstruction than a coupling concern, and can often be dismissed. Even nearby or attached trees possess little ability to couple with an antenna, HF or VHF. A ground-mounted vertical antenna will much more readily couple with a metal shed a few feet away than with a tree a few inches away.

Weather can turn some non-conductive things (tree limbs, vinyl fences, wooden sheds) into conductive ones, which can be subject to some amount of minor coupling. Also, moisture (rain, snow, dew) from the weather can coat your coax, PVC pipes, and other nearby objects that are normally non-conductive. But their coupling capability also remains low.

Metal siding, stucco, the dirt, a swing set, rain gutters and downspouts, ductwork, metal soffits, house wiring, and copper pipes, on the other hand, can all conduct electricity to one extent or another, and can therefore couple with an antenna element if it's installed nearby.

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Taking an example from the Yagi antenna once again, conductive materials can use radiative coupling to capture a portion of the wireless signal, and re-radiate it. If the re-radiated signal is close enough to your antenna (the source), it can alter your transmitted signal through destructive interference. If the re-radiated signal is not close enough to your transmitting antenna to affect the transmitted signal, it can still affect what is received from you by others, due to multi-path.

How you can know

Now that you know what can cause coupling, and why it might not be a good thing, how would you know that your antenna is coupling with something, and what can you do about it? My antenna analyzer, a RigExpert AA-170, can display real-time SWR at a selected frequency as I move my antenna around, allowing me to "see" the coupling effects nearby objects have on my antenna. And when I do find an exception to some of the unlikely coupling situations I mentioned, I can often use a tuner to compensate for the mismatch or coupling, especially on HF.

If you really want to know

DC current flowing in a wire will result in a steady magnetic field around the wire (Biot-Savart Law). If the wire carrying the DC current is then brought close to a second wire, one that's not carrying a current, the first wire won't have much of an effect on the second wire. AC current (one that changes polarity every fraction of a second) flowing in the first wire will result in a *changing* magnetic field around the first wire (Ampere's Law). If the wire carrying the AC current is then brought close to the second wire, the same one that's not carrying any current, the second wire will now have an AC voltage induced across it (Faraday's Law).

So, we can gather a couple of conclusions from this. First, even though the two wires are not electrically connected to each other, the second wire ended up with a voltage across it. Second, this coupling action could only occur by AC, not DC, electricity. These two conclusions form the basis of how inductive coupling works, and forms the foundation of electric motors, generators, transformers, and other devices that use tightly wound coils to achieve their purposes.

A capacitor is a (typically) two-conductor component that prevents the flow of DC current between a circuit connected to one capacitor lead and a second circuit connected to the other. However, AC current can *seem* to flow through a capacitor connected between the two circuits, depending on the frequency. In a capacitor, the energy is transferred by means of its electric field, which can be modified (enhanced or degraded) by the physical material (dielectric) between its two conductors.

Summary

Wireless coupling is the connection between two wires or circuits by radio waves or changing magnetic or electric fields. For amateur radio, it's both necessary and can be a problem. When the effects are desirable, you can take steps to enhance the coupling, and help your antenna work better. When the effects are unwanted, you can take steps to eliminate or at least minimize the coupling, and improve your station's performance.

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