Fighting Antenna Corrosion

Yesterday your antenna was working fine—today it's on the fritz. The problem could be quite obvious, or caused by something you may not suspect.

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Here's an assortment of readily available corrosion-fighting compounds. Most of the brand names can be read; the item second from the left is ALUMA-SHIELD.

At Christmastime, *Santa Claus* is supposed to be on rooftops—*I'm not!* But there I was, dismantling my antenna. Don't misunderstand—I enjoy working on antennas, and the winter weather in Southern California makes rooftop work far less arduous than in the New England or more northerly climes. But I had installed my antenna only six months earlier and was hoping to spend my holiday vacation time *operating!* Unfortunately, my otherwise trusty Butternut vertical had ceased to work—*right in the middle of the ARRL 10-Meter Contest a few weeks earlier!* One day it was fine; the next day, it simply wouldn't load properly.

At first, I suspected something simple: a broken connector, maybe. Substituting a dummy antenna for the vertical quickly showed the problem was at the antenna. As I dismantled the vertical, I noticed a fine, white powder at each joint. Apparently, over the six months since I'd installed the antenna, corrosion had crept into every connection. I hadn't anticipated this! I live in an inland part of San Diego County, where the climate is typically dry. I had tightened each clamp and bolt securely. But, my reliance on clean joints and joint pressure alone to ensure good and lasting electrical connections was obviously lacking. Murphy set the timing; Mother Nature had done the work. I was off the air until I solved my corrosion problem.

Simplified Corrosion Physics

In geologic terms, we only borrow metal for a while. After all, metal is usually found as ore, locked up in rocks in compounds of one kind or another. The extraction of metal from ore and the subsequent processing can be viewed as adding energy. This energy is just waiting to be released under the right circumstances.[1] In the long run, metal returns to its natural, corroded state.

My antenna, like most antennas, is made almost entirely of aluminum. Relative to other metals, aluminum needs *lots* of energy to extract it from ore. In the atmosphere, aluminum oxidizes readily, forming a surface oxide with the chemical name Al_2O_3—aluminum oxide: This is the fine, white powder that I found on my antenna.

Bimetallic Corrosion

Bimetallic corrosion also causes a great deal of trouble. It occurs when two metals with the right properties are brought into contact, and an electrolyte is present. It's the same chemical process that occurs in batteries. Specifically, electrons from one metal (called the *anodic* metal) flow across the junction to the other metal (called the *cathodic* metal), as shown in Fig 1. Gaseous hydrogen forms at the surface of the cathodic metal near the junction. The positive ions left in the anodic metal oxidize, either flowing into the solution, or forming an oxide layer at the junction. In bimetallic junctions, the more anodic metal is always the one that corrodes.

The electrolyte is typically some kind of salt or other compound dissolved in water, making the solution conductive. The metals need not be immersed in the electrolyte. Morning dew, or dissolving salts from fingerprints are sufficient for bimetallic corrosion to start. Acid rain is an electrolyte formed when sulfur compounds in air pollution mix with atmospheric moisture.

Galvanic Incompatibility

Metals that readily corrode when in contact with other metals are said to be *galvanically incompatible* because of their relative positions on the galvanic chart (see Table 1). This table relates the *electropotential* of metals, or metal alloys, in sea water, because sea water is a common electrolyte. The

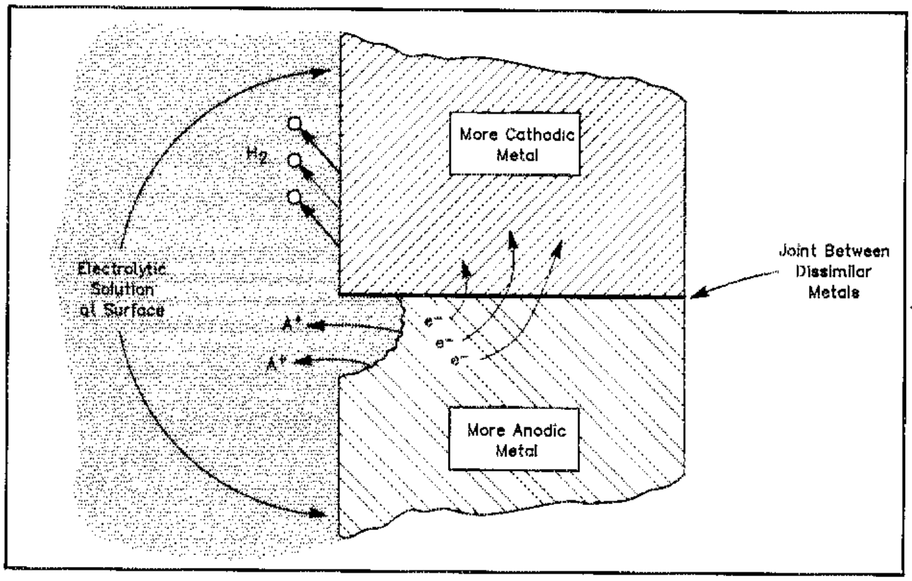


Fig 1—Bimetallic corrosion. When two dissimilar metals are joined in the presence of an electrolyte, the more anodic metal will corrode by releasing positive ions (A^+). This frees electrons (e^-) that move across the junction, forming hydrogen bubbles (H_2) at the cathode. This is the same reaction that batteries use, except the electrons flow through a circuit.

[1]Notes appear on page 26.

A recently disassembled, partially oxidized interior joint. The short, formerly telescoped tubing section looks much better than the adjoining element section that has been continually exposed to the elements. Nevertheless, it has oxidized.

metals in Table 1 are listed in order of decreasing potential, from most anodic to most cathodic. In practice, when mating metals, it's best to choose those that are close together on the galvanic chart.

Tin and gold are metals that illustrate how troublesome bimetallic corrosion can be. Both metals are commonly used to coat electrical connectors. As you can see in Table 1, these metals are galvanically remote. Sometimes, connectors with pins coated with these metals are inadvertently attached to each other. If the contact pressure is insufficient to keep out moisture, or if the metals are used in an environment where electrolyte forms easily, the tin surface oxidizes. I've seen this happen in personal computers, where plug-in cards with gold-plated edge connectors are plugged into tin-plated motherboard connectors. The resulting problems are usually intermittent and difficult to localize. Simply removing a card and reinserting it may remove enough oxide that the problem disappears—temporarily, at least. After awhile, the oxide reforms and the problem returns.

Ensuring Good Electrical Joints

Making and keeping good electrical connections in antennas is really simple—as long as you pay attention to the basics. The best way to make good electrical connections is to start with galvanically compatible metals, then clean all connections well before assembly (refer to the accompanying photos). To make sure these connections *stay* good, seal all contact points so moisture can't enter the joint to form an electrolyte and start corrosion. In my case, I had done the first, but not the second.

Electrical contact at mating surfaces occurs between microscopic bumps and points where the metals meet. Joint impedance is proportional to the number of points in contact. A smooth, clean surface ensures that there will be lots of these points and little between them to get in the way. For antennas, I've found it's best to first buff all joining parts with steel wool, emery cloth or a wire brush, then with a nylon scouring pad (ScotchBright or equivalent). For metal tubing, it's important not to forget to clean the *inside surfaces* of telescoping parts. I wrap steel wool around a pencil or form it into a pencil-like shape so I can get to the tubing's inside surface. Finally, I use a clean rag to wipe off any powdered metal and oxide. I do my best to refrain from touching the mating surfaces and contaminating them with body oils. (Using cotton gloves during antenna assembly is a good idea.)

Mating-Surface Pressure

Pressure between mating surfaces is important. Oxides start to form immediately, so there must be enough pressure to break through the oxide layer. Furthermore, contact pressures must be high enough to ensure joints are stable and tight during normal flexing. A phenomenon called *fretting corrosion*[2] occurs when a connection is repeatedly opened and closed. (See the sidebar, "Fretting Corrosion.") The closure breaks through a fresh surface oxide, so fresh metal is in contact with fresh metal. However, when the contact opens, this fresh metal is again subject to oxidation. With time, the oxidation builds up. Eventually, the contact pressure isn't enough to break through the oxide layer and the connection fails.

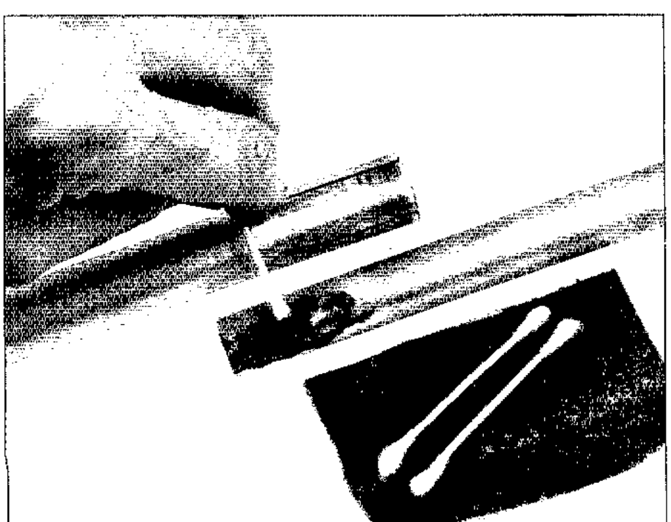
Table 1
Relative Galvanic Series in Sea Water

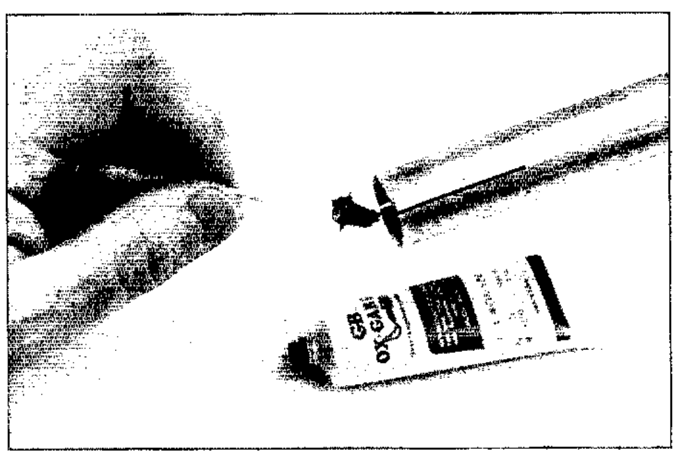
*** Anodic End ***
Magnesium
Zinc
Aluminum
Mild steel
Iron
50-50 lead/tin solder
Stainless steel (type 304 & 316)
Tin
Nickel (active)
Brass
Aluminum-bronze
Copper
Nickel (passive)
Silver
Gold
*** Cathodic End ***

Minimizing Corrosion

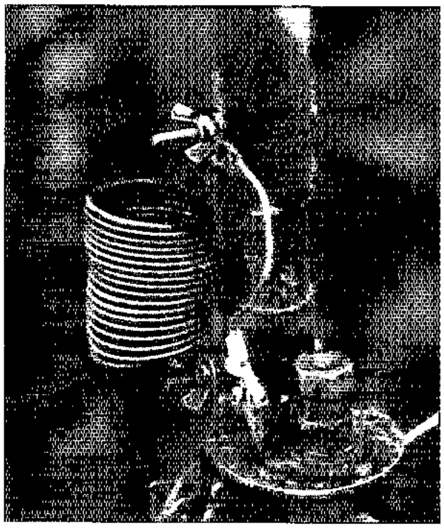
Galvanic Similarity

To minimize bimetallic corrosion at contact points, use parts that are galvanically similar. Then, too, assemble them for minimum galvanic differences. For example, aluminum and copper are not very compatible because they are far apart on the galvanic table (see Table 1). Yet, the connection of a copper wire to an aluminum antenna part is often needed. So, tin or solder-plate the copper wire, forming a gas-tight seal between the copper and plating. Then, use stainless-steel hardware[3] to secure the connection. Stainless steel is galvanically close to both tin and aluminum, and won't rust like other steel hardware. Use a stainless-steel washer between an aluminum surface and a tinned wire, or lug, connected to it. This is because the galvanic difference between tin and stainless steel—or aluminum and stainless steel—is less than tin and aluminum. This should help the joint last even longer if (or when) an electrolyte gets into the joint.





After scrubbing the aluminum to remove the oxide, an antioxidant (Ox Gard, in this case) is applied to both sections of the telescoping tubing. *(photos by Kirk Kleinschmidt, NT0Z)*



After assembly, this section of an antenna was painted. I used a brightly colored paint; in this case, red. Painting is especially useful where plastic tape is difficult to apply, or where an impracticably large amount of tape would be needed. When you need to disassemble a joint for cleaning, the bright color makes it easier to see if you've removed all the paint. (*photo by the author*)

Fretting Corrosion

Fretting corrosion occurs whenever there is a small repetitive or cyclical motion at a metal-to-metal joint or seam. This motion can be either a make-break or sliding action. Basically, joint flexing or sliding exposes clean, fresh metal to the air, and an oxide begins to form. This oxide is broken or scraped away with each reconnection or flex, but begins to reform when it is exposed again. Over time, the oxide builds up at the joint, and eventually the reconnection or scraping won't remove all the oxide at the point of contact. Joint resistance gradually increases, and the joint eventually becomes intermittent. How long a joint or contact lasts before it becomes a problem depends on joint pressure. It also depends on how oxidation-prone the metals at the joint are, and other conditions such as temperature, humidity and the existence of surface contaminants.

For example, automotive engineers are concerned about tin-plated connector pins used in automobiles because of fretting corrosion.* The trend in automotive connectors is to use more pins (more things to go wrong), make them smaller (with smaller contact surfaces), and to use lower insertion force to make assembly easier. These connectors are also subject to vibration, elevated temperatures and rain or salty mud in some locations. All these things aggravate the fretting corrosion problem.

Over time, normal antenna flexing in the wind can cause fretting corrosion at joints if they're not assembled correctly and well protected. To minimize fretting corrosion at antenna joints:

- Design the joints to have large contact-surface areas.
- Thoroughly clean mating surfaces before assembly.
- Securely fasten joints to minimize flexing.
- Use the highest practical contact force.
- Use oxide-inhibiting lubricants or pastes.
- Protect finished joints from the atmosphere with paint, tape, or other overcoatings.

*M. Lee, A. Mao, and M. S. Mamrick, "Fretting Corrosion of Tin at Elevated Temperatures," *Proc. 34th Meeting of IEEE Holm Conference on Electrical Contacts*, San Francisco, Sep 26-29, 1988, pp 87-91.

Use Star Washers

Another way to form a gas-tight seal with hardware is to use star washers. Star washers break through oxides and cut into the mating surfaces under the pressure of the screw and nut used to hold them in place, so that fresh metal is in contact with fresh metal. In some cases, you can get the same effect using sheet-metal screws (again, I prefer stainless-steel screws). This technique works best for hardware that is to go on once, or at most, only a few times. Repeated assembly can damage a surface, possibly providing a path for moisture to enter the joint.

Joint Compounds

Special pastes, fluids, and other joint compounds help seal joints and inhibit electrolyte action.[4] These compounds are squeezed away from the microscopic points of contact by mating pressure, but fill in around the points of contact to inhibit air and moisture passage. For aluminum antennas, I use pastes available for aluminum electrical wiring. These pastes are available at electrical-supply houses, hardware stores and building-supply outlets. A *few* antenna manufacturers provide an antioxidant compound with their antennas.[5] The joint compound can be spread with a cotton-tipped applicator. Wire-brushing the surface after compound application helps ensure all quickly formed oxide is broken down and prevents a new layer from forming. Tooth-brush-size wire brushes are available from most hardware stores.

Joint compounds, unfortunately, don't last forever. They harden and crack, or with time and temperature, simply flow away from joints. For this reason, some sort of finishing barrier or overcoat is needed, such as plastic tape, paint, or silicone rubber sealant (bathtub caulking). Choose a material that is flexible and resistant to ultraviolet light. Many paints and plastic tapes eventually harden and become brittle from exposure to ultraviolet light. Normal antenna flexing in the wind cracks them, and moisture seeps in through these cracks. On the other hand, this also argues for regular maintenance. Plastic tape is easy to remove and replace. If you use paint, use a bright color: red or yellow. If you need to disassemble a joint for cleaning, the bright color is easier to see so you can tell if you've removed it all.

Summary

All this probably sounds like a great deal of trouble to go through to keep an antenna working. It is—especially when the antenna is new and you want to get it on the air in a hurry! The key to antenna longevity is to do *all*, not just some, of what I've told you about. The effort ensures reliable and long-lasting antenna-element joints and connections. My vertical antenna is still working fine after two years.

Antenna work is fun, but I'd much rather build new ones than rebuild an old one again and again, wouldn't you?

Notes

[1] L. Van Delinder, ed., *Corrosion Basics*, from the National Association of Corrosion Engineers, 1440 South Creek Dr, Houston, TX 77084, pp 23-32.

[2] J. Whitley, "Investigation of Fretting Corrosion Phenomena in Electric Contacts," *Proceedings 8th International Conference on Electric Contact Phenomena*, Tokyo, Japan, Aug 22-26, 1976. (Copies of this paper can be obtained from Amp, Inc, PO Box 3608, Harrisburg, PA 17105, tel 717-564-0100, as their publication #82418.)

[3] Stainless-steel hardware is available from Small Parts, 13980 NW 58th Ct, PO Box 4650, Miami Lakes, FL 33014-0650, tel 305-557-8222, fax 800-423-9009. (If you buy stainless-steel hardware locally—especially hose clamps—ensure the *entire* clamp is made of stainless steel! There are "stainless-steel" hose clamps of which only the *band*—not the screw mechanism—is made of stainless steel.—*Ed.*)

[4] S. Leibson, "Fluids Vanquish Intermittent Contacts," *EDN*, Mar 14, 1991, pp 59-64.

[5] An extensive list of corrosion-fighting compounds is available free from the ARRL. Address your request for the ARRL LAB's ANTIOXIDANTS TEMPLATE to: Technical Department Secretary, ARRL, 225 Main St, Newington, CT 06111. Please be sure to enclose a business-size SASE.

Scott Roleson was first licensed as a Novice (WA2NYR) in 1965. He earned his Advanced class license while living in Arizona in the early 1980s. Scott's ham radio interests include antennas and the occasional—and all too infrequent—casual ragchew. Scott credits his becoming an engineer to having his ham radio hobby get out of control!

Before getting his BSEE from Arizona State University and his MSEE from the University of Arizona, Scott worked for Motorola as an electronics technician on RF communications and radar equipment, and in radiation-effects testing at Bell Telephone Laboratories. He has over 10 years experience in Electromagnetic Compatibility (EMC) engineering and works at Hewlett-Packard's San Diego facility. Scott has published many technical papers and articles, mostly on EMC subjects. He is a member of the IEEE and the IEEE EMC and Antennas & Propagation societies.