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Construction Practices and Tips

Contents

RF Exposure Guidelines

By The ARRL Bio Effects Committee

(From *The ARRL Handbook*)

Although Amateur Radio is basically a safe activity, in recent years there has been considerable discussion and concern about the possible hazards of electromagnetic radiation (EMR), including both RF energy and power frequency (50-60 Hz) electromagnetic fields. Extensive research on this topic is underway in many countries. This section was prepared by members of the ARRL Committee of the Biological Effects on RF Energy ("Bio Effects" Committee) and coordinated by Wayne Overbeck, N6NB. It summarizes what is now known and offers safety precautions based on the research to date.

All life on Earth has adapted to survive in an environment of weak, natural low-frequency electromagnetic fields (in addition to the Earth's static geomagnetic field). Natural low-frequency EM fields come from two main sources: the Sun, and thunderstorm activity. But in the last 100 years, man-made fields at much higher intensities and with a very different spectral distribution have altered this natural EM background in ways that are not yet fully understood. Much more research is needed to assess the biological effects of EMR.

Both RF and 60-Hz fields are classified as *nonionizing radiation* because the frequency is too low for there to be enough photon energy to ionize atoms. Still, at sufficiently high power densities, EMR poses certain health hazards. It has been known since the early days of radio that RF energy can cause injuries by heating body tissue. In extreme cases, RF-induced heating can cause blindness, sterility and other serious health problems. These heat-related health hazards are called *thermal effects*. But now there is mounting evidence that even at energy levels too low to cause body heating, EMR has observable biological effects, some of which may be harmful. These are *athermal effects*.

In addition to the ongoing research, much else has been done to address this issue. For example, the American National Standards Institute, among others, has recommended voluntary guidelines to limit human exposure to RF energy. And the ARRL has established the Bio Effects Committee, a committee of concerned medical doctors and scientists, serving voluntarily to monitor scientific research in the fields and to recommend safe practices for radio amateurs.

THERMAL EFFECTS OF RF ENERGY

Body tissues that are subjected to very high levels of RF energy may suffer serious heat damage. These effects depend upon the frequency of the energy, the power density of the RF field that strikes the body, and even on factors such as the polarization of the wave.

At frequencies near the body's natural resonant frequency, RF energy is absorbed more efficiently, and maximum heating occurs. In adults, this frequency usually is about 35 MHz if the person is grounded, and about 70 MHz if the person's body is insulated from the ground. Also, body parts may be resonant; the adult head, for example is resonant around 400 MHz, while a baby's smaller head resonates near 700 MHz. Body size thus determines the frequency at which most RF energy is absorbed. As the frequency is increased above resonance, less RF heating generally occurs. However, additional longitudinal resonances occur at about 1 GHz near the body surface.

Nevertheless, thermal effects of RF energy should not be a major concern for most radio amateurs because of the relatively low RF power we normally use and intermittent nature of most amateur transmissions. Amateurs spend more time listening than transmitting, and many amateur transmissions such as CW and SSB use low-duty-cycle modes. (With FM or RTTY, though, the RF is present continuously at its maximum level during each transmission.) In any event, it is rare for radio amateurs to be subjected to RF fields strong enough to produce thermal effects unless they are fairly close to an energized antenna or unshielded power amplifier. Specific suggestions for avoiding excessive exposure are offered later.

ATHERMAL EFFECTS OF EMR

Nonthermal effects of EMR, on the other hand, may be of greater concern to most amateurs because they involve lower-level energy fields. In recent years, there have been many studies of the health effects of EMR, including a number that suggest there may be health hazards of EMR even at levels too low to cause significant heating of body tissue. The research has been of two basic types: epidemiological research, and laboratory research into biological mechanisms by which EMR may affect animals or humans.

Epidemiologists look at the health patterns of large groups of people using statistical methods. A series of epidemiological studies has shown that persons likely to have been exposed to higher levels of EMR than the general population (such as persons living near power lines or employed in electrical and related occupations) have higher than normal rates of certain types of cancers. For example, several studies have found a higher incidence of

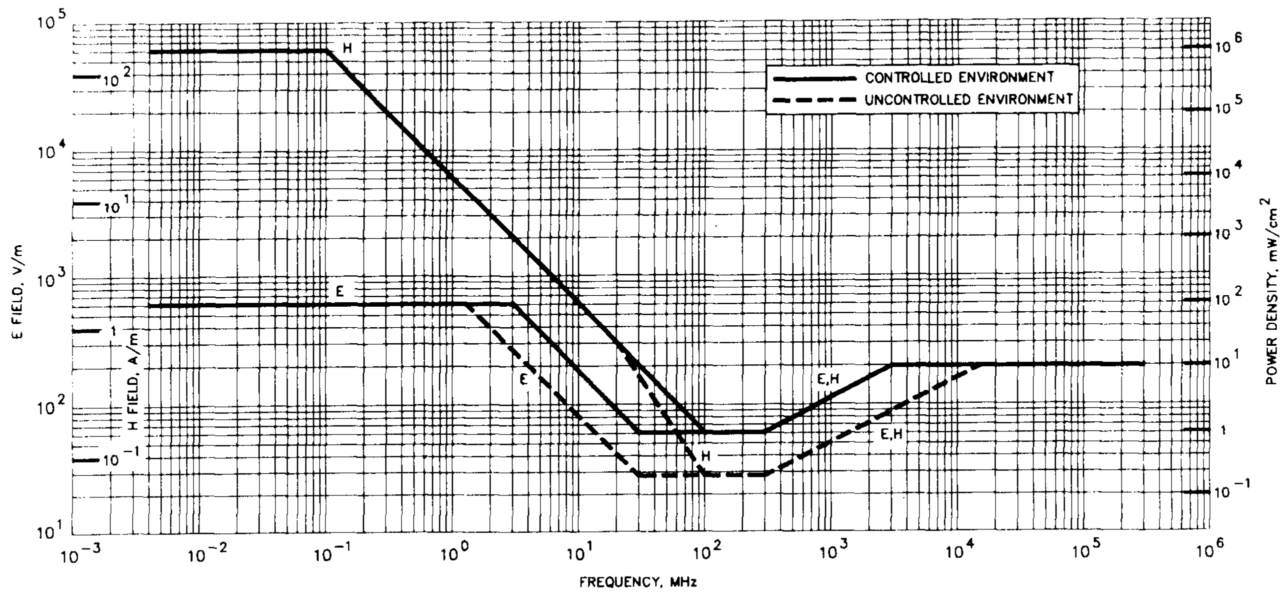

Fig 1—IEEE RF protection guidelines for body exposure of humans.

leukemia and lymphatic cancer in children living near certain types of power transmission and distribution lines and near transformer substations than in children not living in such areas. These studies have found a risk ratio of about 2, meaning the chance of contracting the disease is doubled. (The bibliography at the end of this chapter lists some of these studies. See Wertheimer and Leeper, 1979, 1982; Savitz et al, 1988.)

Parental exposures may also increase the cancer risk of their offspring. Fathers in electronic occupations who are also exposed to electronic solvents have children with an increased risk of brain cancer, and children of mothers who slept under electric blankets while pregnant have a 2.5 risk ratio for brain cancer.

Adults whose occupations expose them to strong 60-Hz fields (for example, telephone line splicers and electricians) have been found to have about four times the normal rate of brain cancer and male breast cancer. Another study found that microwave workers with 20 years of exposure had about 10 times the normal rate of brain cancer if they were also exposed to soldering fumes or electronic solvents (Thomas et al, 1987). Typically, these chemical factors alone have risk ratios around 2.

Dr. Samuel Milham, a Washington state epidemiologist, conducted a large study of the mortality rates of radio amateurs, and found that they had statistically significant excess mortality from one type of leukemia and lymphatic cancer. Milham suggested that this could result from the tendency of hams to work in electrical occupations or from their hobby.

However, epidemiological research by itself is rarely conclusive. Epidemiology only identifies health patterns in groups — it does not ordinarily determine their cause. And there are often confounding factors: Most of us are exposed to many different environmental hazards that may affect our health in various ways. Moreover, not all studies of persons likely to be exposed to high levels of EMR have yielded the same results.

There has also been considerable laboratory research about the biological effects of EMR in recent years. For example, it has been shown that even fairly low levels of EMR can alter the human body's circadian rhythms, affect the manner in which cancer-fighting T lymphocytes function in the immune system, and alter the nature of the electrical and chemical signals communicated through the cell membrane and between cells, among other things. (For a summary of some of this research, see Adey, 1990.)

Much of this research has focused on low-frequency magnetic fields, or on RF fields that are keyed, pulsed or modulated at a low audio frequency (often below 100 Hz). Several studies suggested that humans and animals can adapt to the presence of a steady RF carrier more readily than to an intermittent, keyed or modulated energy source. There is some evidence that while EMR may not directly cause cancer, it may sometimes combine with chemical agents to promote its growth or inhibit the work of the body's immune system.

None of the research to date conclusively proves that low-

Table 1

Typical 60-Hz Magnetic Fields Near Amateur Radio Equipment and AC-Powered Household Appliances

Values are in milligauss.

Item	*Field*	*Distance*
Electric blanket	30-90	Surface
Microwave oven	10-100	Surface
	1-10	12"
IBM personal computer	5-10	Atop monitor
	0-1	15" from screen
Electric drill	500-2000	At handle
Hair dryer	200-2000	At handle
HF transceiver	10-100	Atop cabinet
	1-5	15" from front
1-kW RF amplifier	80-1000	Atop cabinet
	1-25	15" from front

(Source: measurements made by members of the ARRL Bio Effects Committee)

Table 2

Typical RF Field Strengths Near Amateur Radio Antennas

A sampling of values as measured by the Federal Communications Commission and Environmental Protection Agency, 1990.

Antenna Type	*Freq, MHz*	*Power, Watts*	*E Field, V/m*	*Location*
Dipole in attic	14.15	100	7-100	In home
Discone in attic	146.5	250	10-27	In home
Half sloper	21.15	1000	50	1 m from base
Dipole at 7-13 ft	7.14	120	8-150	1-2 m from earth
Vertical	3.8	800	180	0.5 m from base
5-element Yagi at 60 ft	21.2	1000	10-20	In shack
			14	12 m from base
3-element Yagi at 25 ft	28.5	425	8-12	12 m from base
Inverted V at 22-46 ft	7.23	1400	5-27	Below antenna
Vertical on roof	14.11	140	6-9	In house
			35-100	At antenna tuner
Whip on auto roof	146.5	100	22-75	2 m from antenna
			15-30	In vehicle
			90	Rear seat
5-element Yagi at 20 ft	50.1	500	37-50	10 m from antenna

level EMR causes adverse health effects. Although there has been much debate about the meaning and significance of this research, many medical authorities now urge "prudent avoidance" of unnecessary exposure to moderate or high-level electromagnetic energy until more is known about this subject.

SAFE EXPOSURE LEVELS

How much EM energy is safe? Scientists have devoted a great deal of effort to deciding upon safe RF-exposure limits. This is a very complex problem, involving difficult public health and economic considerations. The recommended safe levels have been revised downward several times in recent years — and not all scientific bodies agree on this question even today. A new Institute of Electrical and Electronic Engineers (IEEE) guideline for recommended EM exposure limits went into effect in 1991 (see Bibliography). It replaced a 1982 American National Standards Institute guideline that permitted somewhat higher exposure levels. ANSI-recommended exposure limits before 1982 were higher still.

This new IEEE guideline recommends frequency-dependent and time-dependent maximum permissible exposure levels. Unlike earlier versions of the standard, the 1991 standard recommends different RF exposure limits in *controlled environments* (that is, where energy levels can be accurately determined and everyone on the premises is aware of the presence of EM fields) and in *uncontrolled environments* (where energy levels are not known or where some persons present may not be aware of the EM fields).

The graph in Fig 1 depicts the new IEEE standard. It is necessarily a complex graph because the standards differ not only for controlled and uncontrolled environments but also for electric fields (E fields) and magnetic fields (H fields). Basically, the lowest E-field exposure limits occur at frequencies between 30 and 300 MHz. The lowest H-field exposure levels occur at 100-300 MHz. The ANSI standard sets the maximum E-field limits between 30 and 300 MHz at a power density of 1 mW/cm^2 (61.4 volts per meter) in controlled environments — but at one-fifth that level (0.2 mW/cm^2 or 27.5 volts per meter) in uncontrolled environments. The H-field limit drops to 1 mW/cm^2 (0.163 ampere per meter) at 100-300 MHz in controlled environments and 0.2 mW/cm^2 (0.0728 ampere per meter) in uncontrolled environments. Higher power densities are permitted at frequencies below 30 MHz (below 100 MHz for H fields) and above 300 MHz, based on the concept that the body will not be resonant at those frequencies and will therefore absorb less energy.

Table 3

RF Awareness Guidelines

These guidelines were developed by the ARRL Bio Effects Committee, based on the FCC/EPA measurements of Table 2 and other data.

- Although antennas on towers (well away from people) pose no exposure problem, make certain that the RF radiation is confined to the antenna radiating elements themselves. Provide a single, good station ground (earth), and eliminate radiation from transmission lines. Use good coaxial cable, not open wire lines or end-fed antennas that come directly into the transmitter area.
- No person should ever be near any transmitting antenna while it is in use. This is especially true for mobile or ground-mounted vertical antennas. Avoid transmitting with more than 25 watts in a VHF mobile installation unless it is possible to first measure the RF fields inside the vehicle. At the 1-kilowatt level, both HF and VHF directional antennas should be at least 35 feet above inhabited areas. Avoid using indoor and attic-mounted antennas if at all possible.
- Don't operate RF power amplifiers with the covers removed, especially at VHF/UHF.
- In the UHF/SHF region, never look into the open end of an activated length of waveguide or point it toward anyone. Never point a high-gain, narrow-beamwidth antenna (a paraboloid, for instance) toward people. Use caution in aiming an EME (moonbounce) array toward the horizon; EME arrays may deliver an effective radiated power of 250,000 watts or more.
- With hand-held transceivers, keep the antenna away from your head and use the lowest power possible to maintain communications. Use a separate microphone and hold the rig as far away from you as possible.
- Don't work on antennas that have RF power applied.
- Don't stand or sit close to a power supply or linear amplifier when the ac power is turned on. Stay at least 24 inches away from power transformers, electrical fans and other sources of high-level 60-Hz magnetic fields.

In general, the IEEE guideline requires averaging the power level over time periods ranging from 6 to 30 minutes for power-density calculations, depending on the frequency and other variables. The ANSI exposure limits for uncontrolled environments are lower than those for controlled environments, but to compensate for that the guideline allows exposure levels in those environments to be averaged over much longer time periods (generally 30 minutes). This long averaging time means that an intermittently operating RF source (such as an Amateur Radio transmitter) will show a much lower power density than a continuous-duty station for a given power level and antenna configuration.

Time averaging is based on the concept that the human body can withstand a greater rate of body heating (and thus, a higher level of RF energy) for a short time than for a longer period. However, time averaging may not be appropriate in considerations of nonthermal effects of RF energy.

The IEEE guideline excludes any transmitter with an output below 7 watts because such low-power transmitters would not be able to produce significant whole-body heating. (However, recent studies show that handheld transceivers often produce power densities in excess of the IEEE standard within the head).

There is disagreement within the scientific community about these RF exposure guidelines. The IEEE guideline is still intended primarily to deal with thermal effects, not exposure to energy at lower levels. A growing number of researchers now believe athermal effects should also be taken into consideration. Several European countries and localities in the United States have adopted stricter standards than the recently updated IEEE standard.

Another national body in the United States, the National Council for Radiation Protection and Measurement (NCRP), has also adopted recommended exposure guidelines. NCRP urges a limit of 0.2 mW/cm^2 for nonoccupational exposure in the 30-300 MHz range. The NCRP guideline differs from IEEE in two notable ways: It takes into account the effects of modulation on an RF carrier, and it does not exempt transmitters with outputs below 7 watts.

Low-Frequency Fields

Recently, much concern about EMR has focused on low-frequency energy rather than RF. Amateur Radio equipment can be a significant source of low-frequency magnetic fields, although there are many other sources of this kind of energy in the typical home. Magnetic fields can be measured relatively accurately with inexpensive 60-Hz dosimeters that are made by several manufacturers.

Table 1 shows typical magnetic fields intensities of Amateur Radio equipment and various household items. Because these fields dissipate rapidly with distance, "prudent avoidance" would mean staying perhaps 12 to 18 inches away from most Amateur Radio equipment (and 24 inches from power supplies with 1-kW RF amplifiers) whenever the ac power is turned on. The old custom of leaning over a linear amplifier on a cold winter night to keep warm may not be the best idea!

There are currently no national standards for exposure to low-frequency fields. However, epidemiological evidence suggests that when the general level of 60-Hz fields exceeds 2 milligauss, there is an increased cancer risk in both domestic environments (Savitz et al, 1988) and industrial environments (Matanoski et al, 1989; David and Milham, 1990; Garland et al, 1990). Typical home environments (not close to appliances or power lines) are in the range of 0.1-0.5 milligauss.

Determining RF Power Density

Unfortunately, determining the power density of the RF fields generated by an amateur station is not as simple as measuring low-frequency magnetic fields. Although sophisticated instruments can be used to measure RF power densities quite accurately, they are costly and require frequency recalibration. Most amateurs don't have access to such equipment, and the inexpensive field-strength meters that we do have are not suitable for measuring RF power density. The best we can usually do is to estimate our own RF power density based on measurements made by others or, given sufficient computer programming skills, use computer modeling techniques.

Table 2 shows a sampling of measurements made at Amateur Radio stations by the Federal Communications Commission and the Environmental Protection Agency in 1990. As this table indicates, a good antenna well removed from inhabited areas poses no hazard under any of the various exposure guidelines. However, the FCC/EPA survey also indicates that amateurs must be careful about using indoor or attic-mounted antennas, mobile antennas, low directional arrays, or any other antenna that is close to inhabited areas, especially when moderate to high power is used.

Ideally, before using any antenna that is in close proximity to an inhabited area, you should measure the RF power density. If that is not feasible, the next best option is make the installation as safe as possible by observing the safety suggestions listed in Table 3.

It is also possible, of course, to calculate the probable power density near an antenna using simple equations. However, such calculations have many pitfalls. For one, most of the situations in which the power density would be high enough to be of concern are in the near field — an area roughly bounded by several wavelengths of the antenna. In the near field, ground interactions and other variables produce power densities that cannot be determined by simple arithmetic.

Computer antenna-modeling programs such as *MININEC* or other codes derived from *NEC* (Numerical Electromagnetics Code) are suitable for estimating RF magnetic and electric fields around amateur antenna systems. (See the Propagation chapter for more information about *MININEC*.) And yet, these too have limitations. Ground interactions must be considered in estimating near-field power densities. Also, computer modeling is not sophisticated enough to predict "hot spots" in the near field — places where the field intensity may be far higher than would be expected.

Intensely elevated but localized fields often can be detected by professional measuring instruments. These "hot spots" are often found near wiring in the shack and metal objects such as antenna masts or equipment cabinets. But even with the best instrumentation, these measurements may also be misleading in the near field.

One need not make precise measurements or model the exact antenna system, however, to develop some idea of the relative fields around an antenna. Computer modeling using close approximations of the geometry and power input of the antenna will generally suffice. Those who are familiar with *MININEC* can estimate their power densities by computer modeling, and those who have access to professional power-densities meters can make useful measurements.

While our primary concern is ordinarily the intensity of the signal radiated by an antenna, we should also remember that there are other potential energy sources to be considered. You can also be exposed to RF radiation directly from a power amplifier if it is operated without proper shielding. Transmission lines may also radiate a significant amount of energy under some conditions.

SOME FURTHER RF EXPOSURE SUGGESTIONS

Potential exposure situations should be taken seriously. Based on the FCC/EPA measurements and other data, the "RF awareness" guidelines of Table 3 were developed by the ARRL Bio Effects Committee. A longer version of these guidelines, along with a complete list of references, appeared in a *QST* article by Ivan Shulman, MD, WC2S (see bibliography).

QST carries information regarding the latest developments for RF safety precautions and regulations at the local and federal levels. You can find additional information about the biological effects of RF radiation in the publications listed in the bibliography.

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An excellent and timely document is available on the Internet by an anonymous FTP from: rtfm.mit.edu, /pub/usenet-by-group/news.answers/powerlines-cancer-faq/part1 and part2.

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Make Etching Patterns with a Hobby Knife and Transparent Tape

By Dave Mascaro, WA3JUF

Anyone can reproduce a microstrip printed-circuit board without using photosensitive boards and negatives. The copper is etched off, so this method is neater than simply using a hobby (X-Acto) knife to cut away the copper. Transparent tape is used as the resist material. I use 4-inch-wide tape, available at stationery stores. Here's how I do it:

1. Cut the board to size and clean the foil so it's shiny.
2. Draw the artwork on the board with a pencil.
3. Cover the board with tape, making sure there are no bubbles.
4. Using a hobby knife, cut the tape along the pencil lines, with the aid of a straight edge if necessary.
5. Remove the tape from the board where you want the copper to be removed.
6. Press the remaining tape firmly against the board.
7. Etch the board in ferric-chloride solution. I put the board and ferric chloride in a plastic bottle with a lid. Then I agitate the bottle in a bucket of hot water.
8. After rinsing the board, remove the tape and clean the board with steel wool.
9. Plate the board with solder and a flat-bladed soldering tip. Use liquid flux so the solder flow is even and thin.

A Milled Brass Amplifier Case

By Dave Mascaro, WA3JUF

Refer to Figs 1, 2 and 3. The amplifier housing is milled from brass stock 1.5" wide by 0.5" thick. Cut the piece 0.30" longer than the printed-circuit board to be installed. Square off the stock on the milling machine. Then hog out inside material to a depth of 0.30". Take out the corners to clear the board. Then mill out the slot for the transistor flange. Drill and tap necessary holes.

The SMA connectors can be secured with machine screws, or sweat soldered in place after the board is installed. Cut a hole in the PC board the size of the transistor flange. Sweat solder the board (and connectors, if desired) by heating the brass on a hot plate or stove burner. The feedthrough capacitor is a Spectrum Control Inc. (SCI) 729-303 or equivalent.

Spread a thin coating of silicone grease on the housing surface that mates with the heat sink.

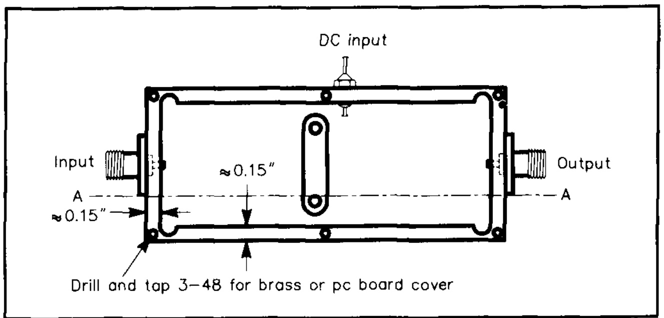

Fig 1—Top view of the brass amplifier case used by WA3JUF, before the PC board is installed. The bottom of the case is milled out to clear the device mounting flange.

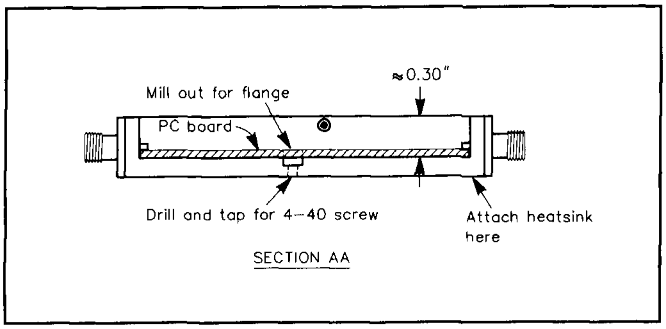

Fig 2—Side view of the brass case. The SMA connectors can be secured with machine screws or sweat soldered (see text). A heat sink is secured to the bottom of the case.

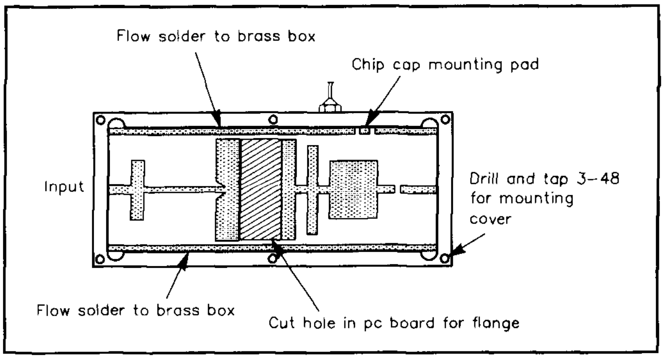

Fig 3—Top view of the case with a board installed. Run a continuous bead of solder around the perimeter of the board to provide a good RF ground. A hole cut in the center of the board provides clearance for the device mounting flange. A piece of copper-clad board or thin, sheet copper can be used as a cover.

Microwave Layout Tips

By Dave Mascaro, WA3JUF

Here's an example of a typical microwave amplifier layout using the end-launcher method. The PC board is soldered to the connectors on the groundplane side of the board, to provide a continuous RF ground. Rivets are used at all RF and dc grounds. A cover or box can be fabricated of scrap pieces of PC board. A U-shaped piece of copper foil is soldered to the bottom of the PC board beneath the device flange. When the device is secured to the heat sink, the foil provides a good RF ground.

Power-supply bypassing is important when several microwave stages are powered from the same source. I recommend series-resonant feedthrough capacitors, like the Spectrum Control Inc. 729-303.

Fig 4 shows a typical layout from the top. Ferrite beads, lumped-constant RF chokes and chip bypass capacitors are used liberally to decouple the power supply. Fig 5 shows the same layout from the side. The heat sink is milled out to just clear the device flanges. You can use a milling machine, or a milling bit in a Dremel drill. (Caution: Wear safety glasses.) The PC board should be secured to the heat sink in several places. The heat sink can be drilled and tapped to receive machine screws, or you can simply rivet the board to the heat sink.

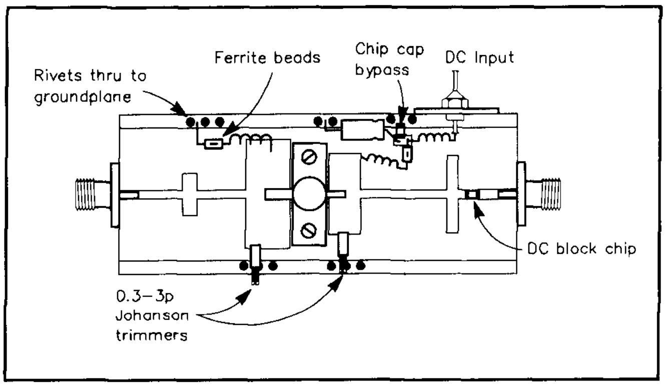

Fig 4—Typical microwave layout. Liberal use of ferrite beads, RF chokes and chip capacitors is recommended to prevent RF coupling through power leads.

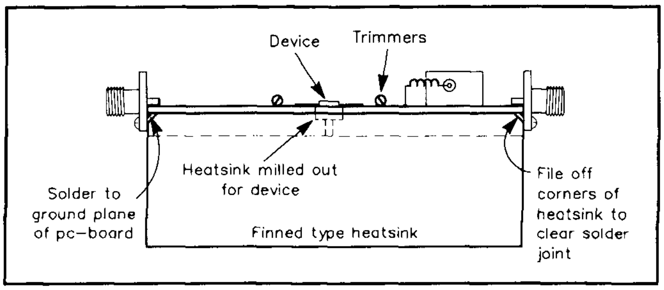

Fig 5—Side view, showing attention to RF grounding. Good layout practice makes for more-reliable operation—especially important for portable operation.

How to Safely Handle FETs

By Dick Jansson, WD4FAB

The safe handling of very-high-impedance FET devices requires great preparation to avoid destroying the device with stray static charges. When I was a practicing engineer, I had the use of an anti-static bench and floor mats (the operator was also grounded to this system). I don't have this type of equipment at home, yet I've been successfully working with GaAsFET devices using the simple grounding system described here. Since these devices are important to the quality and performance of low-noise UHF and VHF receivers, you may want to practice some of these safety techniques.

My grounding system starts with the use of a *grounded* (and transformer isolated) soldering iron (a Weller model W-TCP, in my case). Since this iron has a three-prong plug, I use the ground of an adjacent duplex outlet as an additional common ground connection. A banana plug which has been "fattened" a bit to make contact in the ground socket is connected to several limber wires of suitable length. Each wire has an alligator clip on the free end.

A length of ball chain is formed into a loop and slipped over one of the operator's wrists and clipped to one of the ground wires. Another wire is clipped to the chassis ground of the device being assembled. I usually ground the vice that the chassis is clamped in. Finally, the package containing the FET should be made of conductive material (black foam or foil-lined envelopes). This material should be connected to ground before you extract the device for installation. I tear back one corner of the envelope and connect the ground wire. Granted, this system is not up to commercial standards, but it seems to work well, and it certainly protects the FETs better than doing nothing.

Caveats For Choosing Microwave Capacitors

By Bob Atkins, KA1GT

(From *QST*, August 1989)

Physically, chip capacitors are simply small, leadless capacitors. But all physically small, leadless capacitors are not necessarily microwave-quality components. Very small chip capacitors have become much more common as a result of their use in miniaturized circuits. Circuits that operate at only a few megahertz (or tens of megahertz) can get by using inexpensive chip capacitors; the problem is that the dielectric materials used in inexpensive chip capacitors show very low loss at VHF/ UHF, but are entirely unusable at 10 GHz.

One necessary characteristic of microwave-rated components is low dielectric loss at microwave frequencies. A second characteristic of all capacitors—including chip versions—that comes into play is the presence of undesired series and parallel inductances that result from the device packaging. These inductances not only have reactances; they also result in series and parallel device resonances. Where capacitors are used as bypass or dc-blocking devices, series resonances aren't a problem because impedance is minimized. Parallel resonances, however, can be highly detrimental to circuit performance. A third consideration when chip capacitors are used in microstripline circuits is that they create physical discontinuity, and cause some reflection of incident power as a result. This, too, can give rise to losses. Well-designed circuits use capacitors that cause minimal impedance discontinuities.

When a circuit calls for a particular type and value of capacitor, use of the specified component may be critical to circuit performance. Thorough designers take into account the factors discussed above, and select capacitors with low loss when designing equipment.

Loss data on a capacitor can be obtained by testing its effect when used as a dc block in a microstripline circuit. To do this, etch a board with a microstripline of the desired impedance, and leave a small gap in the line. The gap can be bridged by either the capacitor under test or a length of copper foil. First measure the circuit loss when the gap is bridged by the copper foil; then with the capacitor in place of the foil. The difference in attenuation is the additional loss caused by the capacitor.

Loss data for one line of commercial microwave chip capacitors rated for use at frequencies up to 4.2 GHz shows that one particular 120-pF capacitor has a loss of almost 0.4 dB at 3 GHz. A 100-pF capacitor from the same series shows less than 0.05 dB loss at that frequency. In this case, substitution of the 120-pF capacitor for the 100-pF capacitor would result in considerable performance degradation in a 3-GHz circuit—not from the change in capacitance, but from associated packaging effects. This also applies to nominally equivalent capacitors from different manufacturers. If you make substitutions without knowledge of these factors, you may find yourself in unexpected trouble.

Further references to microwave components and microstrip circuitry can be found in the "New Frontier" columns in January 1981, December 1981, April 1982 and June 1988 *QST*.

Surface-Mount Soldering

By Paul D. Husby, WØUC

(From *QST*, June 1991)

Surface-mount devices and boards are a great invention and a joy to work with once you get comfortable handling and soldering the tiny devices. My soldering routine is slightly different from that suggested by Bryan Bergeron, NU1N[1]. Tinning both pads may lead to an installation in which the device is not flat and close to the board. Or, worse, a fragile chip device may be left physically stressed. I prefer this routine:

- Tin only one of the pads, and let it cool.
- Set the device in place. While pressing the device very slightly with a toothpick, reheat the tinned pad until the device sinks flat to the board. Allow the connection to cool. Solder the second terminal, touching the iron only to the pad.
- After the device has again cooled, touch up the first solder joint as necessary.
- Use silver solder.

With this method, I get a 100% success rate of devices that are flat, straight and well-soldered.

Finding silver solder can be a problem in some locations. (Radio Shack carries 62/36/2 solder [RS 64-013].)

[1] B. Bergeron, "A Surface-Mount Technology Primer—*Part 2*," *QST*, Jan 1991, pp 27-30; see p 29, Fig 12.