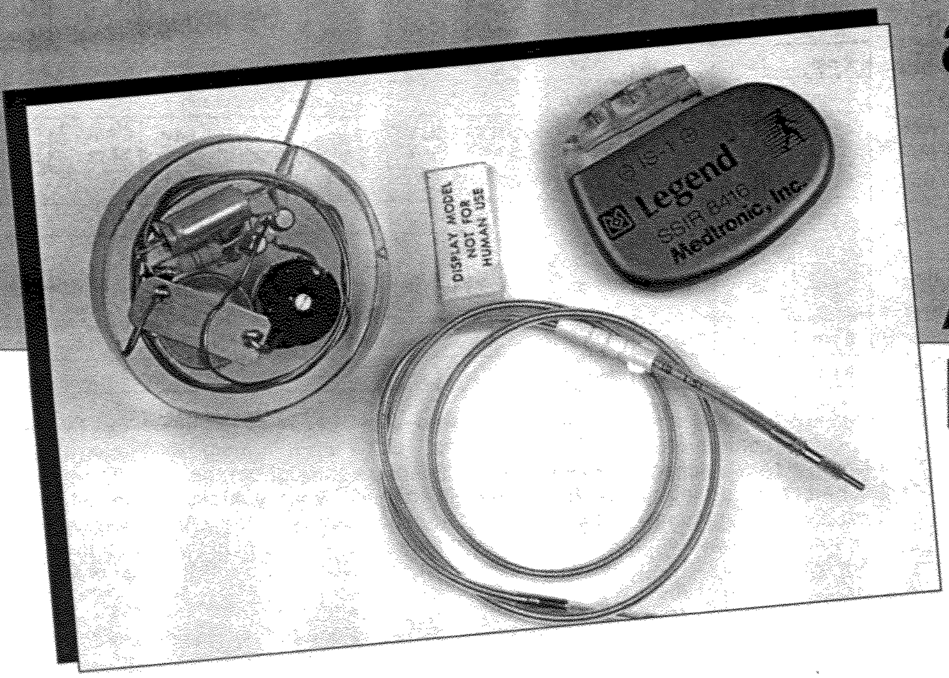
Pacemakers, Interference and Amateur Radio



Can hams who use pacemakers safely pursue Amateur Radio? And if they can, what safety precautions should they take?

By Fred Weber, MD, AA2KI
145 E Atlantic Blvd
Ocean City, NJ 08226

Photo by Kirk Kleinschmidt, NTØZ

Pacemakers—old and new. The large round pacemaker—the one that looks as though it were made in someone's home electronics shop—is a very early model. The smaller unit is representative of today's compact pacemakers. Note the coiled lead.

It's safe to assume that hams who come home from the hospital with shiny new pacemakers implanted in their chests are at least a little bit worried about turning on their rigs. It doesn't matter how much they've been counseled by their surgeons, or how much literature they've read. All of that stuff was about *someone else*! They're turning on their radios now, and they want to know that they're not jeopardizing their lives by pushing the PTT or twitching the key.

Although pacemaker experts and various informal studies and user histories agree that normal Amateur Radio environments pose minimal danger to pacemaker users, it's a good idea for *everyone* to reduce their exposure to high-level RF and electric fields.

Before we explore specific safety recommendations for hams who have pacemakers, let's take a look at pacemakers themselves, and how they work.

Cardiac pacemakers—lifesaving devices used to increase or regulate heartbeat—were introduced in 1957, and many active hams have these devices in place. By understanding their principles, safe station operation can be assured.

In this article, we'll look at pacemaker hardware, function, the ways pacemakers can fail, history, interference problems and how pacemakers interact with devices and situations in our modern world.

How Pacemakers Work

The response of muscle to electrical stimulation is well known. In 1768, Galvani, using a voltaic pile, described frog muscle contraction in response to an applied voltage. Pacemakers use this method to induce heartbeats in the human body.

The pacemaker's transmit mode is called pacing, and the receive mode is called sensing. In the pacing mode, the pacemaker sends a signal to the heart. In the sensing mode, the pacemaker receives a signal from the heart.

The pacing mode results in the contraction of the heart muscle. During the sensing (listening) mode, the pacemaker receives signals indicating whether a normal heartbeat has occurred (that is, whether the patient's heart provided its own properly timed beat).

After the unit hears a normal heartbeat (and after a short blanking period), the pacemaker is switched again to receive mode. If another heartbeat is heard, the system is cycled and the pacemaker begins to listen again. The pacemaker listens to every heartbeat.

If no heartbeat is detected at the end of a set interval, the unit is switched to transmit mode, which sends a 0.5-ms, 5-V pulse to the heart. The heart muscle contracts and a heartbeat is formed. The pacemaker again switches to the receive mode and listens. It is during sensing (receive mode) that the system is most vulnerable to RF interference.

How Pacemakers are "Installed"

During the implantation surgery, an electrical connection is made between the pacemaker and the heart. The pacemaker lead is inserted into the heart through a small vein in the upper chest.

After the lead and the pacemaker are firmly in place, the electrical connection to the heart is analyzed. First, the threshold of stimulation (in volts) is found (the level required to cause the heart muscle to contract) and current flow at that voltage is measured. Typical values are 0.5 V at 1 mA.

Finally, the pacemaker's sensing characteristics are examined. The voltage generated by a normal heartbeat is measured; it must be above 6 mV to assure proper pacemaker operation.

After a final hardware check, the incision is closed.

Possible Problems

There are many ways for pacemakers to fail, the most common being dead batteries! The lithium-iodine batteries used provide about 1 Ah of capacity (normal battery life is seven years).

The insulation on the lead running from the pacemaker to the heart may fail, creating a short circuit. If this happens, the pacemaker may operate intermittently, or the short circuit may drain the unit's battery.

Because the heart is in constant motion, the lead may become dislodged or even poke through the heart muscle. This can cause hiccoughs (at the paced rate!) or other involuntary muscle contractions.

In some patients, scar tissue builds up at the lead tip, increasing the circuit's resistance and the stimulation threshold.

Pacemakers are also susceptible to interference from electric and RF fields. As hams we know that subjecting a wire to an electromagnetic field causes a current to flow in the wire. This is how radio receiving antennas work. The pacemaker lead is such a wire, and it can act as an antenna, receiving unwanted electromagnetic signals that can potentially interfere with normal operation.

Smaller induced currents may not be large enough to cause stimulation or damage, but they may be strong enough to fool the pacemaker into thinking it's heard a normal heartbeat. Thinking that a normal heartbeat has occurred, the pacemaker produces no pacing pulse.

As long as the interfering signal exists and continues to blank the pacemaker's "receiver," no pacing pulses will be sent to the heart muscle. Blackout and death can occur.

In addition to magnetically coupled interference (discussed above), interference can enter the body and influence pacemakers via galvanic coupling—when a voltage or current source is applied to the body and current flows through all or part of it.

Ham Radio Test Case

Ten days after I implanted a pacemaker in Charles Gilbert, W3YJM, a continuous 24-hour recording of his heart's activity was made as he went about his normal daily activities. Three on-air operating sessions (in his shack) were recorded.

Charles fed 100 W to several antennas on several bands. The first session involved contacts on 20 meters using a half-wave dipole. Later, operation was switched to 40 meters, also using a dipole. Finally, Charles keyed up on 80 meters using an inverted-V antenna.

No discernible effect on pacemaker activity was noted.

Although this study was not comprehensive, nor did it have scientific "controls," it does illustrate that hams who have pacemakers can expect to safely use their stations.

—AA2KI

The History of Pacemakers

Throughout history, physicians have experimented with applying voltage and passing current through the human body. In 1788, Kite reported an attempt at reviving a patient with dc voltage. This is the same principle as modern defibrilation.

In 1925, the first successful treatment using a pacemaker took place in Australia. A stillborn infant was resuscitated and was alive and well four years later.

The first adult application of pacemaker technology was made by a New York cardiologist who built a spring-wound, "three-speed" pacing device (it was good for six minutes). Informally, the device was reported as successful, but resistance to invasive medical treatments and a cruel stroke of fortune doomed the device.

In 1931, a few months before the announcement of the new mechanical pacer, the movie *Frankenstein* was released. Because this science fiction horror also featured electrical resuscitation, unfortunate comparisons were made and the unit never came into general use.

In 1952, doctors achieved control of cardiac rhythm with electrodes placed on the front and back of the chest. Because the voltage necessary for stimulation was between 30 and 150 V, it was quite uncomfortable and not suitable for long-term use.

In 1958, the first self-contained pacemaker was implanted by surgeons in Stockholm, Sweden. The implant lasted three hours, was replaced, and thereafter lasted eight days. The patient survived and did not require further pacing.

This initial approach required major surgery; an alternative was developed in the US that placed the lead inside the heart without major surgery and major risk. This is how pacemakers are implanted today.

Hazards

These wonderful devices were, however, not free of risk. Reports of unwanted interactions between pacemakers and electrical devices began to appear.

Less than five years after the first self-contained pacemaker was implanted, an electric shock from poorly grounded hospital equipment disrupted pacemaker function in another patient and caused abnormal heart rhythms. The patient died.

Shortly thereafter, RF interference was encountered. Diathermy—an obsolete RF tissue-heating treatment that has largely been replaced by ultrasound—provided a graphic illustration.

Diathermy machines used RF transmitters that were connected to hand-held radiators that were placed over the area of the body requiring treatment. The transmitters were tuned to various high frequencies—popular bands included 13.5 and 27 MHz. The tissues under the antenna were warmed. Severe pacemaker interference often resulted, however, and the use of diathermy in pacemaker patients was quickly discontinued.

By 1968, interference problems had become significant. The first step toward alleviating interference problems came via techniques used to place pacemaker leads during implantation. By placing the electrodes closer together in the heart, inter-ference was dramatically reduced.

The second change was in pacemaker software. After pacemakers reportedly malfunctioned near active microwave ovens, the logic circuits were redesigned to differentiate between discrete and continuous interference. With this new ability, pacemakers could revert to fixed-rate pacing if interference was detected. The problem of pacemaker function near poorly shielded microwave ovens was overcome.

There are many potential hazards for pacemaker patients in our electrical world. Many devices encountered in daily life produce electric and magnetic fields. Here are some examples:

Our houses are rich in electric and magnetic fields, which vary from day to night, possibly reflecting appliance use. The fields from household electrical appliances, however, don't disturb pacemaker function.

In related tests, the electric field strengths in aircraft (at HF, VHF and microwaves) have also been measured. Patients experienced no change in pacemaker function.

A new antitheft technology known as electronic article surveillance (EAS) is in general use in many stores today. A tag is placed on the protected article, and devices near the store exits "scan" for the tags with RF or magnetic sensors. RF EAS systems didn't influence pacemaker wearers, but magnetic systems caused interference and pacemaker malfunction in two patients.

Weapons-detector gates commonly seen at airport security checkpoints had no effect on pacemaker function.

Work environments may produce significant amounts of electromagnetic interference. Recently, several potentially hazardous areas were studied. These extremes aren't usually encountered by most pacemaker patients (see Table 1).

Pacemaker failure as a result of radiation therapy for breast cancer has also been reported. At the end of therapy, the pacemaker was behaving irregularly. The unit was replaced and examined, and the doctors found that one of the unit's IC chips had been damaged.

Probably the most hostile environment for pacemaker patients is found within magnetic-resonance imaging (MRI) scanners, which are now in common use. Today's MRI devices produce extremely strong magnetic and RF fields. Needless to say, this situation is very dangerous, and the benefits of scanning must be carefully weighed against risks to the patient. An MRI scanner produces fields that are many times greater than those found in even high-power ham stations.

Tips for Safe Operation

When estimating potential dangers to pacemaker users, take steps not to generalize about pacemaker models, configurations, lead systems, and so on. Each patient is unique, and all variables must be carefully evaluated. Safe operation of a particular unit in a particular environment does not guarantee safe operation of that device in another.

So, what about hams who have pacemakers? Can they safely operate their stations without worry? The answer is straightforward: As long as accepted safety practices are maintained—the same practices recommended for all hams when it comes to electrical and RF safety—there is no increased danger. As the sidebar illustrates, interference to hams who use pacemakers (in Amateur Radio environments) is not expected with modern pacemakers.

Excellent discussions of RF exposure and recommended safety practices are found in the *ARRL Antenna Book* and in the *ARRL Handbook*.

One final precaution involves antennas. Most hams use external antennas that limit their exposure to RF energy. Everyone is encouraged to do this—especially hams with pacemakers. The increasing use of indoor loops and attic wires, however, brings RF closer to the shack, sometimes even bathing it in RF. As a precaution, hams with pacemakers should avoid these types of antennas.

Table 1
Pacemaker EMI Source Characteristics

EMI Source	*Output (max value)*
Spot-weld machine	1500 A
Arc welding machine	225 A
Industrial welder	300 A
Submerged arc welder	1000 A
TIG welder	220 A
Neon sign test room	4000 V
Electrical substation	138 kV
CRT assembly area	Magnetic field
Degaussing coil	Magnetic field
Jet engine plant	Magnetic field

Table values are from D. Marco, *PACE*, 15:2020 (1992).

Bibliography

M. A. Warnowicz, "The Pacemaker Patient and the Electromagnetic Environment," *Clinical Progress in Pacing and Electrophysics*, 1:166 (1983).

S. G. Hazwan, "The Effect of Power-Frequency High-Intensity Electric Fields on Implanted Cardiac Pacemakers," *PACE*, 6:1282 (1983).

W. Inrich, "Interference in Pacemakers *PACE*, 7:1021 (1984).

J. Erlebacher, "Effect of Magnetic Resonan Imaging on DDD Pacemakers," *Americ Journal of Cardiology*, 57:437 (1986).

Y. Cooperman, "The Effect of Metal Detect Gates on Implanted Permanent Pacemakers *PACE*, 11:1386 (1988).

G. Alastair, "Hazards in the Aircraft—T Development of a system for the evaluation electromagnetic interference with pacemak function," *Journal of Medical Engineeri and Technology*, 13:161 (1989).

D. Marco, "Testing of Work Environments f Electromagnetic Interference," *PAC* 15:2016 (1992).

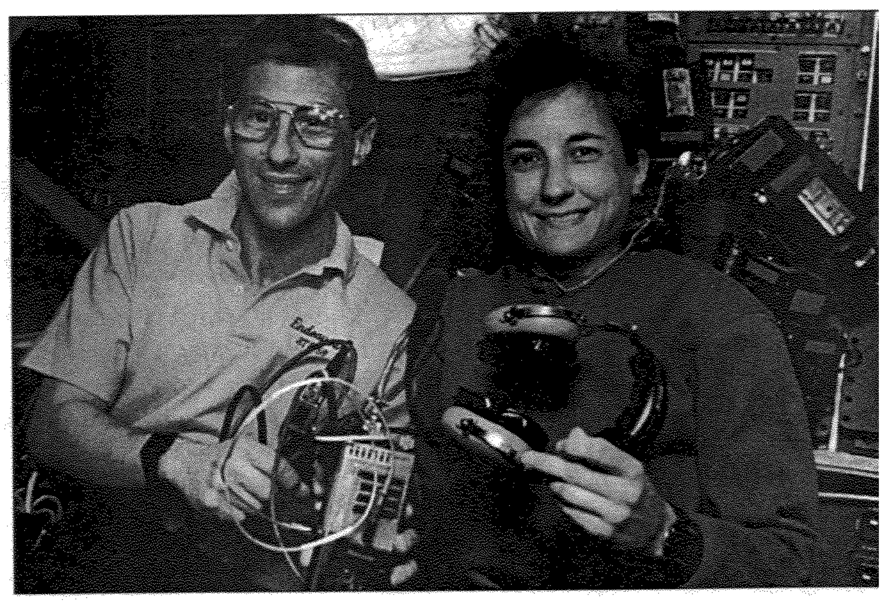
K. Jeffery, "The Invention and Re-inventi of Cardiac Pacing," *Cardiology Clini* 10:561 (1992).

B. Dodinot, "Electronic Article Surveillanc A Possible Danger for Pacemaker Patients *PACE*, 16:46 (1993).

G. Nelson, "A Brief History of Cardiac Pa ing," *Texas Heart Institute Journal*, 20: (1993).

Fred Weber, AA2KI, practices Thoracic surge (and Amateur Radio) in the Atlantic City, N Jersey, area.

Strays



Shuttle Successes

The Shuttle Amateur Radio EXperiment (SAREX), once again thrilled thousands of ha during the April STS-59 mission, operated by Mission Specialist Jay Apt, N5QWL, and Payload Commander Linda Godwin, N5RAX. The primary payload, a three-frequency imaging radar, mapped over 70 million square kilometers of the Earth's surface—represe ing 6,480 gigabytes of data about soil erosion, deforestation, volcanism and tectonic activity, among other things. Crew members used the SAREX payload to make 1,674 pa contacts, dozens of voice QSOs, and to speak with students from nine schools.

Jay Apt said, "It was a real thrill for me to be able to operate from low Earth orbit for th third time. It really makes me feel connected with the people I'm flying over to work them two meters. My biggest thrill was talking to my old crew mate Ken Cameron, R3/KB5AW Star City, Russia, where he and cosmonauts talked to us with a 5-9 signal."

"Talking to hams fit right in with our purpose for being in space," reported Linda Godwi "Our project, *Mission to Planet Earth*, was to study people and science."—*Rosalie White, WA1STO*