Technical Notes On Receivers

Or, Romans,
Lend Us Your Ears

Many of us engaged in field research over the past 25 years have relied on radio receivers as virtual extensions of our senses. It's interesting and helpful to look back in time to better understand our current technology.

Thousands of years ago, field personnel (Roman herdsmen) devised systems to aid in animal locating activities utilizing technology readily at hand. The systems took the form of what is now our 19/20th century cowbell. The bell functioned as the "emitter," and was utilized in conjunction with a receiving system already owned and operated by most people.

The receiver consisted of a reasonably efficient directional antenna system which provided a means of differential comparison between the amplitude of audible signals reaching the two ears of the observer, coupled with a receiver/data processing system comprised of the human auditory system and brain. The performance of the system formed was respectable to say the least and when the wind was right, operating ranges exceeded a mile — not bad for no batteries!

Operating power requirements were satisfied by direct biological/mechan-ical conversion processes. The animal provided the energy to ring the bell, resulting in operating ranges adequate for the task at hand. It is lamentable that today we require greatly increased complexity in order to improve significantly upon these early systems.

Although modern biomedical telemetry systems appear overly complex, they are little more than logical extensions of the tools utilized by the early Roman livestock "managers." The cow bell emitter has been replaced with devices which transmit at higher frequencies. This provides better range and more reliable operation than could be obtained with signals in the audible range. Moving outside the range of frequencies monitored by a large percentage of the animal kingdom also means that predators (of all types) can no longer eavesdrop on prey.

Modern "radio" signals are largely electromagnetic in nature because of the relatively higher frequencies employed (typically in the VHF range). Due to a few elemental laws of physics, electromagnetic propagation of radio waves in specific regions of the VHF range are not subject to significant influence by air currents, and they pass reasonably well through dry vegetation. This is a distinct advantage as dense, dry growth significantly attenuated the audible frequencies utilized in the early cowbell systems.

On the down side, there is no naturally occurring receiving system which is satisfactory for radio frequencies. Modern radio emissions are now within frequency ranges well beyond the auditory perceptions of both humans and animals (insofar as is currently known). A means is therefore required to recover, selectively amplify, and translate the signals down to an audible range. These three seemingly simple tasks are the primary functions of modern antennas and telemetry receivers. The compatible receiving system thus formed is essentially placed in front of the human ear in order to make radio signals perceptible to us. In accomplishing these tasks, modern antenna/receiver systems can be made selectable with regard to which frequencies existing in the environment are intentionally amplified and translated downward for human utilization. In actual practice, the signals are extremely weak and must be selectively amplified to process properly.

As shown in the diagram, a directional antenna replaced the ear as a means of capturing signals traveling in the ether (air, water, etc.) for further processing by the balance of the receiving system. The antenna functions as a frequency selective impedance transformer, reducing the virtually infinite impedance of the air to the 50 ohm impedance standard required by modern convention. The signals captured are "passed" through a coaxial cable transmission line which (hopefully) exhibits and maintains the characteristic 50 ohm impedance to a tuned amplifier.

The amplifier further selects the desired range of frequencies from which signals are to be extracted, segregating them from among many others which exist naturally and as a result of man-made interference in the environment. The desired signals are then amplified to a workable level before coupling them to a device called a "mixer."

Acting as a frequency translator, the mixer converts selected radio signals occurring at rates of millions of cycles per second down to frequencies in the range of hundreds of cycles per second — which are perceptible to the human ear. This process is accomplished within tiny semiconductor devices by algebraically summing the incoming frequencies with a specific "mixing" frequency generated by a stable oscillator within the receiver. The mixing frequency is mathematically related to the desired signal, and is selected by the operator in the process of tuning the receiver. Using simple math, the output of the mixer is the difference between the incoming frequencies and the internal oscillator frequency. Subsequent circuitry simply selects the desired output of the mixer.

This type of receiver design is dubbed "superheterodyne" due to the mixing or "heterodyning" action by which a resultant "product" (output) frequency is derived. The tuning controls on the front panel allow us to tune the receiver by changing the frequency of the internal oscillator signal. The resultant audio product frequencies are then coupled to the ear of the observer by means of some impedance matching transducer (a pair of earphones), or by direct connection to other processing equipment.

Although theoretically fundamental, in actual practice the process of radio telemetry signal acquisition requires substantial engineering in order to achieve reliable functionality in the field. I must admit that, at times, we have been slightly envious of the simplicity of the cowbell system...

Dave Beaty

What Happened To Cat #12? Equipment Analysis Helps Reconstruct Events

It has always been our policy at Telonics to work closely with field researchers and in the case of the Florida panther study, we have been providing radio telemetry equipment since 1981. Recently, an extremely interesting case study arose.

A radio collar had apparently failed after being placed on a Florida panther (Felis conclor coryi). Identified as #12, the animal was a 130 lb. adult male located in Collier County, Florida. By compiling our respective data, we were able to piece together a probable sequence of events.

The transmitter deployed on Panther #12 was a MOD-500 configuration with an X-1 high shock option, S6A mortality sensor, and S9 activity switch. Mounted on a CLM collar with a CAST-1 casting option, the unit was final tested on 3 October, 1986. It was properly stored and exercised over the ensuing months, and then deployed on 31 January, 1988.

After functioning normally for almost ten months, the transmitter pulse rate was recorded at an abnormally slow 40 pulses per minute on 26 November, 1988. It should be noted that the pulse rate of a mortality/activity transmitter remains at one of three set pulse rates (e.g. animal's head up at 54 PPM, head down at 68 PPM, inactivity at 135 PPM after a 2 hour delay), or it fluctuates between head up and head down depending on activity. In the case of Panther #12, the pulse rate continued to slow through 9 December, although the activity switch was apparently still functioning. On 13 December, the signal was not received during a routine flight, nor during subsequent air tracking efforts.

Panther #12 was recaptured within his known home range on 15 January, 1989. Examination of the 8-9 year old cat revealed recently healed sores and a 10" scar along the right rib cage. The left front foot was also healing from a severe dislocation or fracture.

When the transmitter was examined in the field, a large dent with a small puncture hole was discovered in the external casting. Removal of the casting revealed a 1/8" diameter hole and a dent 4.5 cm to the left of the hole. Comparisons with skulls in an office collection indicated that the damage was probably caused by the upper canines of an adult male Florida panther. The unit was then scheduled for a complete evaluation.

Initial lab testing verified that the transmitter had no signal output and the canister was severely damaged. The subsystem was disassembled with an internal visual examination revealing that the puncture hole was 1/16" away from the printed wiring board. While the hole did not directly damage the internal contents (all leads and structural materials were still in place), it did allow moisture to leak, causing internal corrosion. Electrical tests determined that the battery was exhausted and the printed wiring board shorted from corrosion build-up. It appeared that when the transmitter canister was damaged, the external polymer had partially resealed the puncture hole. Moisture slowly penetrated and caused the change in pulse rate with an increase in battery current consumption. The transmitter functioned until the elevated current drain exhausted the battery.

Further evaluation of the location data revealed that the only other radio-collared adult male panther overlapping ranges with Panther #12 was Panther #25, a younger cat of similar proportions. Panther #25 was found dead on 26 August, 1988. Death apparently was caused by a severe bacterial infection from puncture wounds inflicted by another cat. It was noted from telemetry data that Panther #12 passed through the general area frequented by Panther #25 on two occasions, once before #25's death and once immediately afterwards. Although the two panthers were not actually found together at any time, it is speculated that they engaged in a fight, resulting in the death of #25 and in serious injuries to #12. The damage to the radio collar may have occurred at this time, and may have prevented more serious injury to #12 by protecting his throat.

While it is not unusual for a unit to be returned with bite marks, this was the first transmitter in our experience to ultimately go off the air due to a bite from a large cat. The opportunity to analyze field equipment is valuable because it helps us make design changes which can minimize future problems. In addition, our close relationship with researchers helps to reconstruct events in the lives of collared wildlife which might otherwise be lost. Sharing data may help to explain the disappearance of some instrumented study animals, or it may provide some other kind of biologically important information.

Finally, transmitting subsystems are often subjected to intense environmental stresses and must meet rigorous performance standards. Cooperation between the laboratory and the field helps to improve performance, and can affect future generations of transmitter subsystems.

Dave Maehr and Dan Decker

David S. Maehr is a Wildlife Biologist with the Florida State Game and Fresh Water Fish Commission. In addition to panther research, his other telemetry experiences include studies of white-tailed deer, black bears and bobcats.

Transmitter Batteries Proper Selection Is A TradeOff

In a recent issue, building smaller transmitter electronics by employing "chip and wire bond" or hybrid circuit technology was discussed. The benefits of such a design to the complete transmitting subsystem cannot be considered complete without examining the power source, usually a battery.

Although technically a battery is two or more cells connected in some manner, for this discussion we will include the use of a single cell as a means of providing the power for a transmitting subsystem. Batteries are also available in a wide variety of sizes, shapes and capacities, and they utilize a number of different chemical systems to generate the desired electrical output. There are primary cells that are not rechargeable, and secondary cells that can be recharged. This discussion, however, is limited to primary cells as they are the most widely used.

Battery capacity is specified in ampere-hours for larger cells and in milliampere-hours for smaller cells. For example, a cell with a 500 milliampere-hour (mAH) capacity is capable of supplying a current of 1 milliampere (mA) for 500 hours, 10 mA for 50 hours, 100 microamperes (uA) for 5000 hours, etc. The length of time a transmitting subsystem will operate is directly related to this capacity.

Each cell, depending on its chemical system, has a corresponding terminal voltage which ranges from as low as 1.2 volts to over 3.5 volts. The transmitter's output power and the resultant range of the system is directly (not linearly) linked to the battery voltage. Higher voltages are obtained by connecting cells in series, while greater capacity can be obtained by connecting two or more cells in parallel, using suitable isolation techniques.

When voltage is multiplied by capacity, the power capacity of a given cell is expressed in watt-hours. The higher the capacity, the more energy the cell is capable of delivering to a transmitter throughout its operating life. When this figure is related to the volume of the cell, the cell's energy density can be measured in watt-hours per cubic centimeter. The most desirable cell for our purpose would then have the highest energy density.

After considering these ratings, a series of questions must be answered to determine whether a particular cell type is suitable for use in a given telemetry system:

- How does the cell perform over the kinds of temperature extremes that are frequently encountered in our work?
- Is the battery capable of delivering energy in short, high current bursts?

Just because a cell has a rating of 1000 mAH does not necessarily guarantee that it can perform satisfactorily in a pulsed current mode. This is especially true of smaller cells.

- Since many transmitting subsystems are not deployed immediately upon receipt, how well will the cell perform after a prolonged period of storage?
- Is the cell sufficiently rugged to withstand the physical abuse encountered when attached to an animal?
- Is the size and weight of the transmitting subsystem appropriate for the animal, while still providing sufficient operating life and range?

Clearly, battery selection is based on rigorous physical and electrochemical criteria. The physical configuration for a transmitting subsystem is critically important, and most of the weight and volume should be allocated to the battery or power source.

The Table compares several of the transmitters and battery combinations that are used in standard Telonics subsystems, and illustrates how volume and weight are distributed between transmitter electronics and battery.

Historically, transmitters were designed with wire-leaded components, usually soldered to circuit boards, and the MOD-400, 500 and 600 fall in this category. To produce smaller units with the same operating range and options, we had to reduce the size of either the battery and/or the transmitter.

Transmitter size was initially reduced 15-25 years ago by utilizing miniature leaded components. While this reduced the required volume by 75%, it nearly doubled the transmitter cost. The development of surface mount techniques made it possible to produce small transmitters more economically, and the MOD-090, 070 and 040 are representative.

To further reduce the size and volume of the transmitter requires "chip and wire" techniques. Although Telonics has the capability, the technology is only being used experimentally. The start up costs are high, involving expensive equipment and components in addition to highly trained personnel.

Reducing battery size has the greatest impact on overall size and weight. The operating life of the subsystem can be maintained if we're willing to accept a significantly reduced output power, with a consequent reduction in operating range. This is normally accomplished by utilizing a lower voltage battery and it's been done successfully with the CHP-1H.

Transmitting subsystems have been optimized to balance all the various factors including size, weight, operational life, operating range of the overall system, and cost. While most of the weight and volume of a transmitting subsystem is devoted to the power source, the electronics are designed to be physically compatible while consuming a relatively small portion of the total volume. Only when the weight or volume of the transmitter becomes a significant part of the total is a smaller (and more expensive) transmitter merited.   Boyd Hansen

Innovations In Collar Assembly

In the early days of wildlife telemetry, collars were made in the field by individual scientists. The technology was very experimental and by the mid-70's our laboratory was receiving so many requests from the field that we began developing collars as an integral part of the transmitting subsystem. We've been committed to collar development ever since and our capabilities have evolved tremendously.

Some of the changes have occurred because of new equipment. When collar production first began at Telonics, we sat around a table with hand-held leather punches and then, as production increased, we automated with bench-mounted punches. This helped to accelerate production and ensure quality. Initially, we used hand-held riveters and aluminum rivets, but soon realized that aluminum corrodes and breaks, separating the transmitter electronics, battery, and housing from the collar. With pneumatic riveters, we were able to use stainless steel rivets which do not degrade in the environment and which ensure the mechanical integrity of the collar. Since all our collar sewing was originally "farmed out" to a local cobbler, the purchase of industrial sewing machines was another major step. In-house machinery allowed us to move production smoothly through all the various phases.

Other changes have occurred in polymeric processes. We started with urethanes fifteen years ago and had problems with slow curing times and bubbles trapped in the casting. We briefly experimented with epoxies and while they cured more rapidly, they also presented an unacceptable level of shock transfer. Since the goal is always quality and biological compatibility, we went back to urethanes and set out to perfect the process. Urethanes exhibited all the right qualities (no chipping, great shock protection, retention of qualities over wide temperature ranges), but we needed to accelerate the curing time. A special polymer curing oven was built and we added a vacuum chamber to evacuate air from the urethane, thus eliminating any bubbles in final castings. Over the past fifteen years our processes have become standardized.

Despite all the changes, our collars are still handcrafted. We take great pride in them and are constantly testing new equipment and materials to enhance performance.   Bob Carroll

Lab Notes

A Few Helpful Hints

- Try to avoid pulling (or jerking) the coaxial cable attached to the receiver. Such treatment can cause the ground braid to separate at the connector.

- If you have lost directionality from a "YAGI" or H-antenna while tracking, check to see if the cable's ground braid is broken or detached from the cable connectors.

- Increasing the volume-gain setting of a telemetry receiver beyond a comfortable listening level is not advisable. Doing so may actually "mask" weak signals.

- When searching for lost animals, try programming in neighboring 1 KHz steps on your TS-1 scanner. If you do not have a scanner, adjust the fine tune on your TR-2.

- For the RA-NS system to function properly, the cables from the antennas to the TAC combiner must be in good shape and exactly (within 0.25 inches) the same length.

- Do not close a door or window on coaxial cables. Deforming cables can destroy the performance of many antenna systems.

• If you are not using headphones, you are not really tracking. Unless, of course, you find all your animals this way; in which case, we stand corrected. In all fairness, most folks need headphones to work optimally.

P.S. You do not have to talk louder when you use headphones.

• When it rains, protect your receiver as you would protect other electronic equipment.

• If you lose directionality and range while using a RA-2AK (H-ANT), check to see if you have inadvertently installed elements from an antenna tuned to another frequency band.

• To avoid static damage to the receiver's front end, always discharge any static buildup. Ground yourself prior to touching the antenna and/or antenna input connector.

• Take the magnet off the transmitter before deploying the unit on an animal, and check the transmitter operation on your receiver. If you forget, the tape holding the magnet may take months to come loose, moving your data collection period into the next fiscal year.

• When storing transmitters, don't allow the shut-off magnets to get too close together or touch. This could cancel the magnetic field and activate the transmitter. The same thing can happen if the units are allowed to rest on metal shelves, or on a metal truck box with the magnet touching metal.

• Graduate students should not have to do all the work.

Anon and Others

As always, we encourage you to write or call us at (602) 892-4444. Your questions, field tips and suggestions for topics are always welcome and we enjoy hearing from you.