Use of Coded Transmitter Schemes to Overcome Radio Frequency Spectrum Constraints in Terrestrial Wildlife Tracking.

Joseph Allen
Advanced Telemetry Systems, Inc., Isanti, MN 55040

Agencies and institutions engaged in terrestrial-based wildlife research have increasingly had their telemetry operations constrained due to frequency spectrum congestion. This includes operational and administrative limits on which portions of the VHF band they may utilize. This paper will explain this situation from the researchers standpoint, and help those planning future projects by offering a solution using technologies now available.

Problem Definition and Background:

Frequency congestion, too few available radio frequencies, has become an increasing problem for today's researcher utilizing VHF radio telemetry techniques to collect data and successfully complete projects.

Conventional telemetry as carried out by today's researcher is simple enough. Each animal, and therefore each VHF radio tag, is identified by assigning a single frequency, within a defined frequency range, e.g., between 152.000 megahertz, and 152.400 megahertz (MHz). For reasons we will discuss below, assume that this researcher is limited to using only frequencies available within the very narrow bandwidth described above. A scientist working within that frequency range would be able to tag up to 40 animals, using standard 10 kilohertz (kHz) spacing. See Figures 1 and 2. This constraining factor will limit a researcher's work if, optimally, a study requires the tagging and tracking of 80 animals.

152.000	152.100	152.200	152.300
152.010	152.110	152.210	152.310
152.020	152.120	152.220	152.320
152.030	152.130	152.230	152.330
152.040	152.140	152.240	152.340
152.050	152.150	152.250	152.350
152.060	152.160	152.260	152.360
152.070	152.170	152.270	152.370
152.080	152.180	152.280	152.380
152.090	152.190	152.290	152.390

Figure 1. CONVENTIONAL TELEMETRY FREQUENCY ASSIGNMENTS.
Range 152.000-152.400 MHz, 40 frequencies, one frequency per animal, 10 kHz spacing between frequencies.

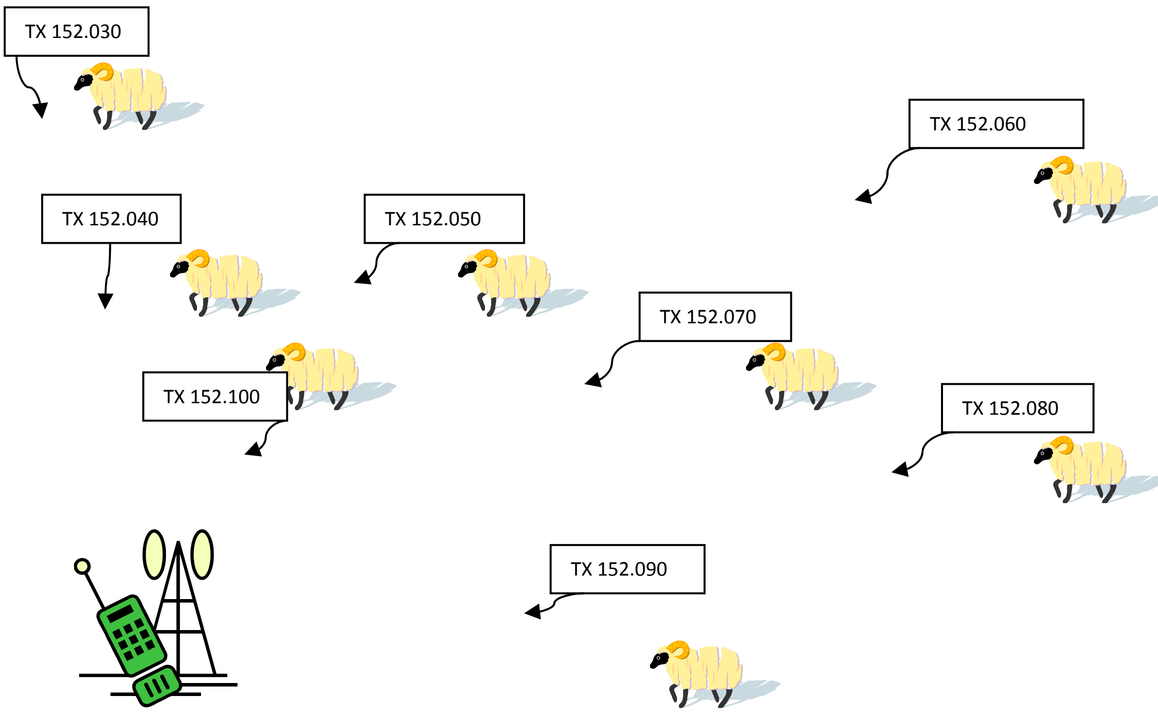


Figure 2.
TRADITIONAL TELEMETRY SCHEME.
One frequency (or channel) per animal.

Further, if the receiver being used is set for a dwell time (the number of seconds the receiver "sits" on each of the frequencies being scanned) of eight seconds, it would take 320 seconds, or a little over five minutes, to scan through all 40 frequencies. This may present some problems, particularly in tracking from aircraft where the aircraft may fly past and go beyond the range of the transmitter before the entire list is scanned. Problems may also occur if the animals being tracked are moving together ("clumped" together), as in a herd, or if they are moving quickly. One could easily miss identifying some animals, leading to faulty data.

Other obstacles posed to conventional telemetry due to frequency congestion:

a. Other researchers, or the same researcher, working in the same vicinity, and on a similar frequency range, which limits available frequencies for new research.
b. Agency administrative and licensing restrictions as to which frequencies the researcher may use. There are several states which are known to be problematic to researchers, such as California, Texas, and Colorado, and along areas of the U.S. East Coast.
c. Receiving equipment limitations. Many older receivers only cover a 2 MHz range (e.g. 160.000-161.999). Newer receivers might cover a 4 or 8 MHz range.

Coded System Development:

For many years now, fish researchers have been using coded tracking systems in their work. The requirement to use coded schemes came about due to large numbers of fishes in river systems passing stationary receive sites in as little as 10 seconds. Optimally, every fish was required to be logged by the detection equipment as it passed abeam the receiving antennas. Up to 100 fish might pass by the riverside station in a short span of time, as little as ten seconds. Beginning around 1990, a new system evolved, which would allow researchers to accurately detect the fish, given these high population, high velocity movements. That system is known as a coded VHF fish detection system.

Coded System Characteristics

Coded tag systems utilize transmitters where a *pulse code burst* identifies individual tags, allowing multiple transmitters to transmit on a single frequency, in effect "sharing" that frequency. This system also requires use of a specialized receiver capable of decoding and logging individual tag detections to memory. See Figure 3.

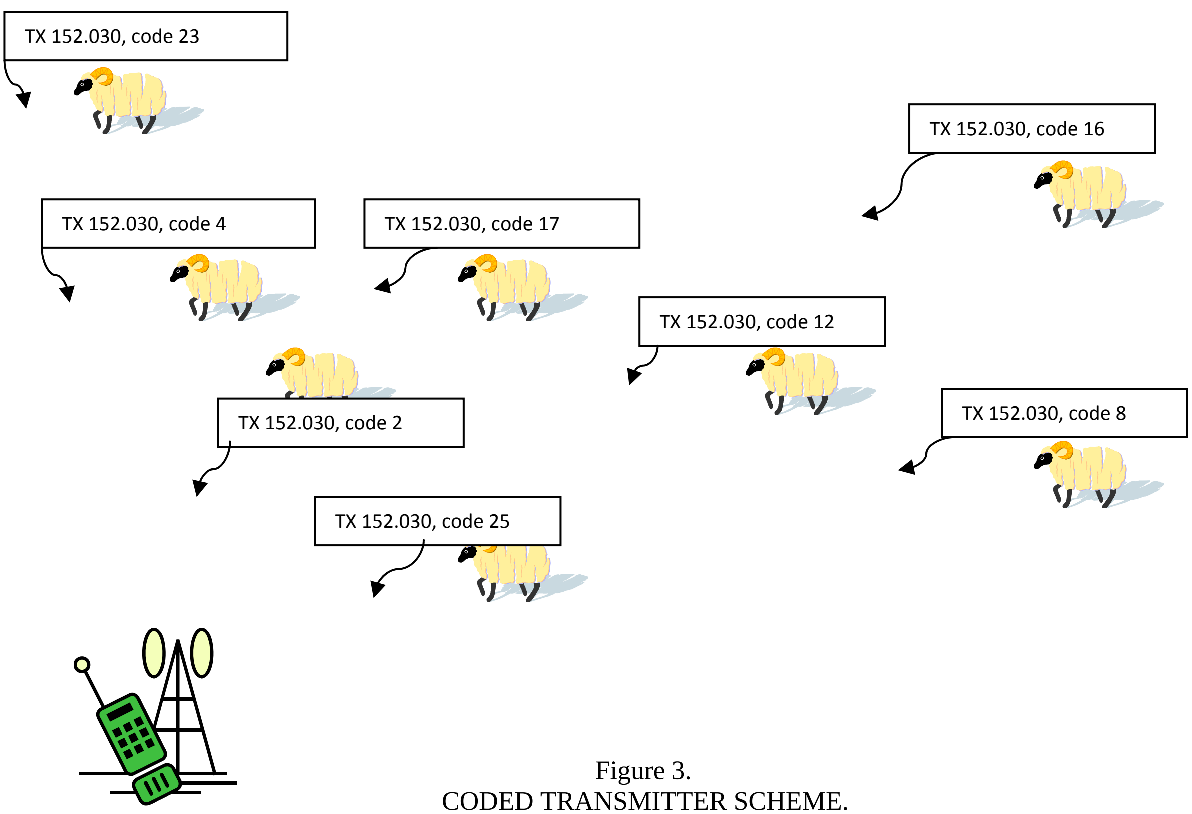


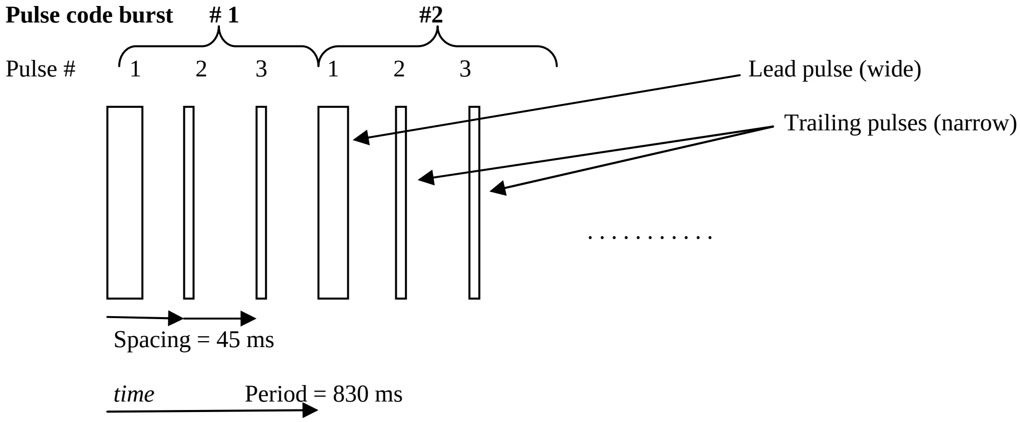
Figure 3.
CODED TRANSMITTER SCHEME.
Up to 25 tags per frequency channel.

Various encoding schemes have been designed by telemetry manufacturers, some more robust than others. Generally, whereas a standard tagging scheme emits a single pulse (or beep) on one discrete frequency, in a coded scheme, three or more distinct pulses, instead of one, are emitted, in order to transmit a unique code. The time between the individual pulses is varied slightly, and these differences are measured by the receiver in order to decode them.

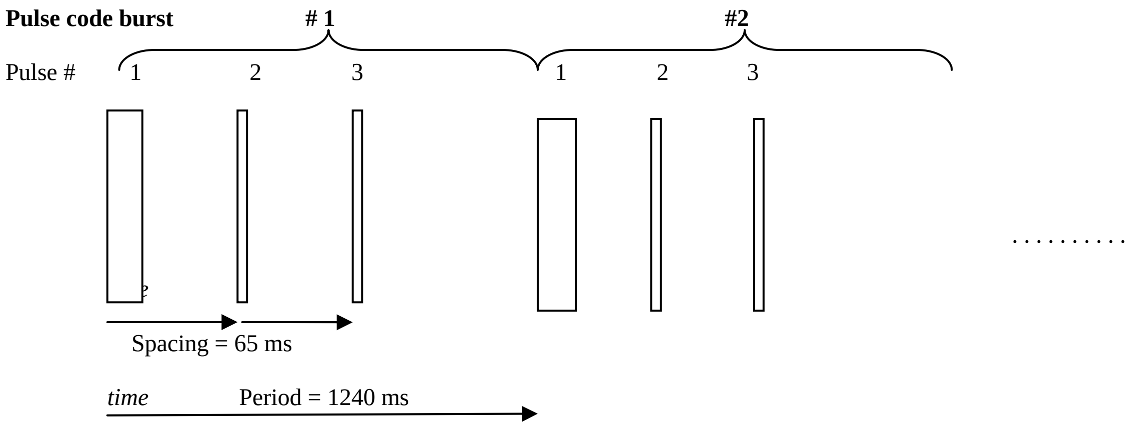
An on-board micro-processor is necessary to precisely control the varying pulse rates and widths comprising each tag's code. Since a greater number of pulses are being transmitted, coded tagging systems- will have shorter operating lives. Coded tag lives are approximately 50% shorter than standard tags, for any given battery type/size.

In a typical coding scheme, the beep pattern consists of a lead pulse, followed by two shorter pulses. By altering the exact spacing between these pulses, unique identification of each of the transmitters is accomplished. Additionally, the actual pulse rate of the initial pulse is varied. This is done by defining a subset of transmitters and varying the pulse rates of the initial, or lead, pulse. If two separate transmitters transmit at the same time (transmitter overlap), because their individual pulse rates are slightly different (e.g. one is at 51 pulses per minute, versus another at 60 ppm), they will quickly pulse at different times, preventing them from being "stepped-on" by one another, and to be correctly identified.

Today there are coded systems operating which have the ability to encode and decode 100 or more different transmitters on a single frequency, or channel. See Figure 5. Of course, the human ear is unable to identify and differentiate these coded pulses, though they are audible. A special receiver which is capable of digital signal processing is needed to decode the transmitter's pulse code burst, and for a user to detect and hear only one tag in a group of tags.



Freq. 154.010, code 0 (830ms period/45ms spacing)



Freq. 154.010, code #97 (1240 ms period/65 ms spacing)

Figure 5.
VARYING BEEP PATTERNS ON ONE FREQUENCY TO ENCODE TRANSMITTERS. Transmitters are differentiated by varying the time period between two lead pulses, and by varying the time spacing between two trailing pulses.

One drawback to coded systems is that there will be some amount of collision of the transmitter's signal, since many transmitters may all be present in a confined location, all within range of the receiving equipment. Also, the period of time that a transmitter will be within detection range of the receiving station is a critical factor. If any one transmitter will be within reception range for, say 10 minutes, then all of the possible frequencies used in the project must be scanned within that time.

Use of Coded Tags in the Terrestrial Tracking Environment

Researchers are now beginning to adopt coded tag systems to study terrestrial animals, especially ungulates, which may translocate while in packs or herds. This is due to large numbers of animals needing to be located during tracking operations, while only a minimum of frequencies are available to complete the project.

Assume that for one hypothetical project, only 20 discrete frequencies are available, but that this study would optimally include tagging and tracking 100 animals. The researcher would then plan to deploy 100 tags, where each of the twenty frequencies would have five different codes assigned to them. Using this coded tag scheme, the time required to complete a scan to locate all 100 tags is significantly reduced, compared to standard frequency tags, since only 20 frequency channels, instead of 100, need to be scanned. If the “dwell time” (the amount of time the receiver stays on each frequency while it “listens” for tags within range) is set by the user to 5 seconds, the total time required to complete a scan for all 100 tags is just 100 seconds. Using standard transmitters, the time required would be 100 tags, times 5 seconds, or 8 1/3 minutes. Therefore, use of coded systems will save significant time and fiscal resources.

As mentioned, coded tag systems require a receiver capable of decoding the individual codes of the transmitters. The receiver may optionally also log that information into memory, typically including date, time, and signal strength of the located tag. Since each manufacturer has designed and implemented a particular method of encoding tags, it is usually not possible to deploy tags of a given manufacturer without also using receivers from that same manufacturer.

Operational Scenarios

Certain models of coded receivers in use for terrestrial tracking feature the ability to quickly and accurately search for one particular targeted animal, out of a group of animals. Whereas use of a standard tracking system lengthens the time required to do this, an advantage of coded tags is that the coded receiver is capable of detecting up to 25 transmitters simultaneously, and of displaying all codes, or animals, that have been detected. Thus it is quickly and easily determined which animals are present.

During tracking, a researcher using coded transmitters and a coded receiver is now able to select one of three audio output options at any one time. They are: select all, select none, or select one. A typical operation would have the researcher tracking on the ground or in the air, attempting to locate a group of animals, and subsequently attempting to locate certain individuals within the group.

This scenario would begin with the researcher activating the receiver and selecting the option to listen to all codes. This will allow him to “home” in on the group. The receiver will display all individual codes as it detects and decodes them (and display all of the last nine codes detected). The receiver will also log the detected codes to memory. Assume that the group has been located, and now the researcher wishes to locate an individual, e.g. an animal transmitting code #97. The researcher would then choose the “select one” option on the receiver and enter the code number. Now only the beep pattern from this single tag will be audible, if it is present and within reception range. Normal tracking techniques may now be used to "home" in on the animal.

Taking the scenario one more step, assume now that the researcher wishes to detect only codes not previously detected. They may choose "select none," in order to determine if any other animals have since moved within range of the receiving equipment.

Another advantage to using coded tag systems is the increased sensitivity, and so increased detection range, of the receivers. This is due to digital signal processing techniques.

Summary

Coded tag systems offer several advantages over conventional telemetry systems.

1. Increased detection range due to digital signal processing technology.
2. Minimal use of radio spectrum (up to 1/25th savings).
3. Conventional radio tracking characteristics and methods remain available.

The trade-offs are minimal:

1. Increased equipment costs, approximately 10-20% overall.
2. Increased system complexity and learning curve.

References

1. R4520C Receiver/Datalogger Operating Manual, *Advanced Telemetry Systems, Inc., Isanti, MN 55040*