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A vehicle-mounted radiotelemetry antenna system design

Todd J. Brinkman, Christopher S. DePerno, Jonathan A. Jenks, John D. Erb, and Brian S. Haroldson

In the early 1960s, radio-tracking techniques were developed to remotely monitor movements and activities of free-ranging animals (LeMunyan et al. 1959, Cochran and Lord 1963). Through the years, several designs have been devised to mount antenna(s) on vehicles to increase mobility and accuracy of data collection (Bray et al. 1975, Kolz and Johnson 1975, Hegdal and Gatz 1987, Joynt 1997, Mechlin and Sapp 1997). However, no single radio-tracking system has been devised that will work in every situation. Consequently, radio-tracking systems must be designed individually to meet the requirements of each study (White and Garrott 1990).

When tracking mobile, radio-marked animals, vehicle-mounted receiving systems allow investigators to cover large geographic areas in short periods of time and remain relatively close to monitored animals (White and Garrott 1990). Vehicles also can be equipped with heavier and more powerful antennas than can be carried on foot, which may improve accuracy of data collection (Kenwood 1987).

There are problems with vehicle-mounted systems that must be considered. First, in addition to risking damage from low branches, cables, and other obstacles, many vehicles equipped with receiving antennas must be stopped to rotate the antenna while taking bearings (Kenwood 1987). Second, because mobile units are moved from one location to another, a problem arises in determining bearing relative to true north (White and Garrott 1990). Even if vehicles are equipped with a rosette compass and pointer, the position of the rosette relative to north changes with each movement of the vehicle. Third, vehicle-mounted antenna systems often require major modifications to the vehicle or require the operator or driver to leave the seated position or assume an awkward position while manipulating the antenna (Mechlin and Sapp 1997). We describe a vehicle-mounted telemetry system design that overcomes limitations of some previous designs.

Antenna design and system evaluation

Our vehicle-mounted antenna system was a Null-Peak design with a matched array of 2 4-element

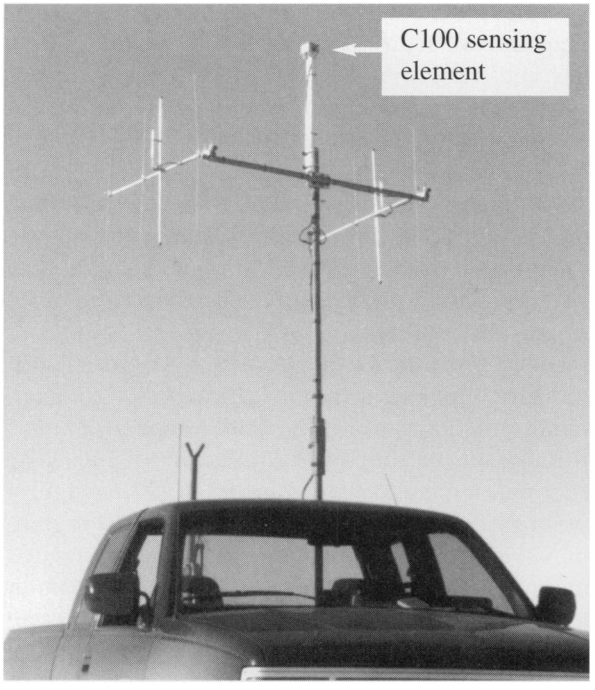

Figure 1. A vehicle-mounted Null-Peak antenna system used for tracking radiocollared animals.

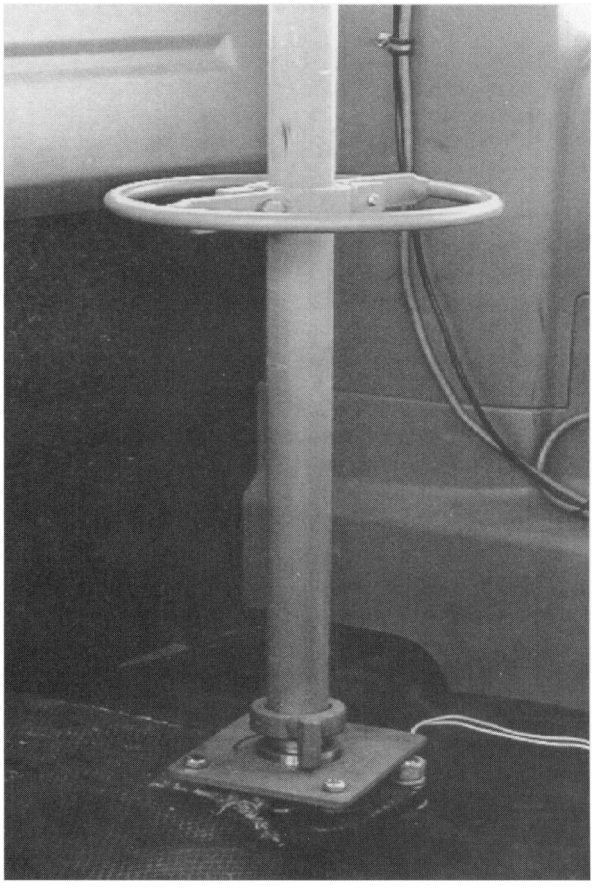

Figure 2. Floor mount and vehicle interior portion of antenna mast equipped with steering wheel for a vehicle-mounted Null-Peak antenna system.

Yagi antennas positioned 1.5 m apart on a horizontal boom (Figure 1). The manufacturer (Advanced Telemetry Systems, Isanti, Minn.) recommended a distance of 1.5 m between the Yagi antennas for frequency range 162–174 MHz. With a Null-Peak system, a switch box is used to feed signals from the two antennas exactly in-phase or out-of-phase. When each antenna is pointing directly at a transmitter, the incoming signal phases out, producing a sharp "null" (Kenwood 1987). A toggle switch can be added to make the antenna a peak system, in which an optimum gain is produced by feeding the signals exactly in-phase.

The system mast was constructed using 3.2 m of 3.2-cm-inner-diameter iron pipe. The mast was machined in 2 locations to allow insertion of 2 4.1-cm bearings that assist rotation with minimal friction. The bottom bearing was housed in a square cast-iron flange mount that was bolted to the floor of the cab behind the driver's seat (Figure 2). A 14.0-cm square steel plate with a hole cut in the center was fit over the floor mount on the lower bearing. Two bolts in this plate act as a stop when they contact bearing mount bolts. This restricts mast rotation to 388° (1.08 revolution), preventing antenna cables from wrapping around the mast. To assist in rotating the mast, a 25.4-cm-diameter iron wheel was attached about 46 cm above the floor (Figure 2). This wheel can be adjusted for operator comfort and was easily accessible to the driver when seated (Figure 3). The second bearing had a stamped steel

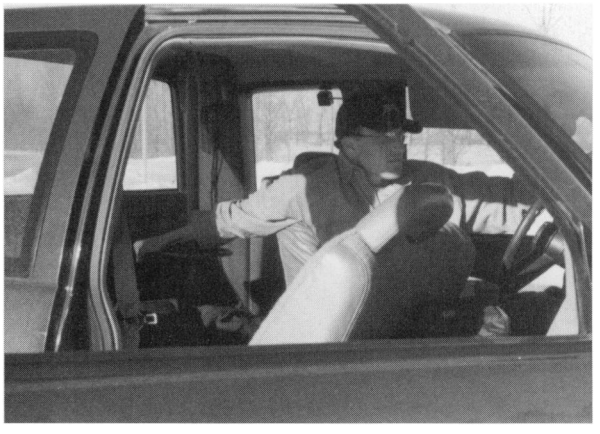

Figure 3. Driver operates mast steering wheel for a vehicle-mounted Null-Peak antenna system.

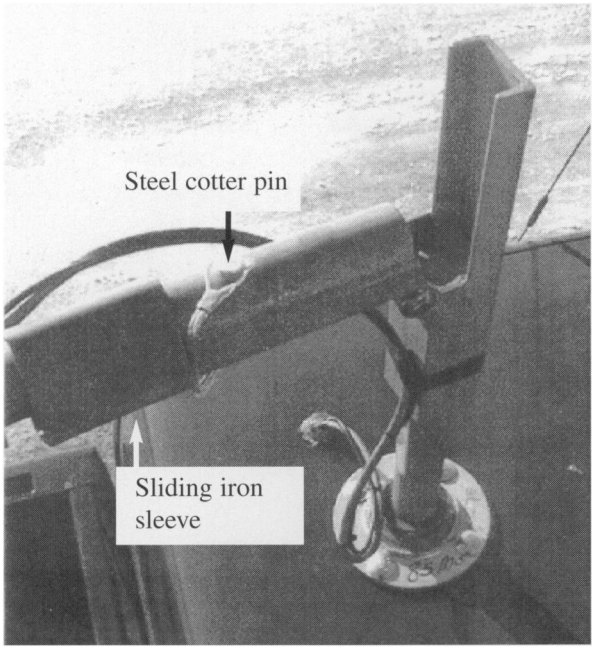

Figure 4. Folding hinge and antenna-mast mount on the roof of the vehicle.

flange mount bolted to the truck roof (Figure 4). The diameter of the hole cut in the roof was 10 cm. Silicon caulk was applied to prevent water from entering the vehicle through the roof mount.

The mast extended 2.72 m above roofline to minimize interference caused by vehicle metal and enhance radio-signal reception (Samuel and Fuller 1990). The mast was hinged 53.3 cm above roofline, allowing it to travel in a folded position (Figure 5). This design reduced the risk of damage to antennas from overhanging branches, utility lines, and other obstructions, and decreased wind drag and wear during transit. When folded, antennas and mast were supported by a padded yoke attached to a tripod mounted in the bed of the pickup (Figures 5 and 6). Metal eyebolts attached to the mast and antenna boom served as lashing points for rubber bungee cords to stabilize the system during transport. When the mast was returned to a vertical position, it was secured in place using a steel cotter pin and iron sleeve that slides over the hinge assembly (Figure 4).

An electronic C100 Compass Engine (KVH Industries, Inc. Middletown, R.I.) was used to determine directional bearings. The compass operates through tilt (i.e., pitch and roll) ranges of ±16°. The sensing element of the compass was the highest point of the antenna mast when in the erect position (Figure 1). The manufacturer recommended mounting the sensing element of the compass at least 30.5 cm from any magnetic material. Therefore, we attached the sensing element to the end of a 70.0-cm aluminum rod using brass screws and bolted the aluminum rod to the top of the central mast with 2 U-bolts (Figures 1 and 6). With this design, the sensing element extended 60.0 cm beyond the steel material of the mast.

Figure 5. Antenna in folded position rests on a tripod mounted to the bed of the pickup.

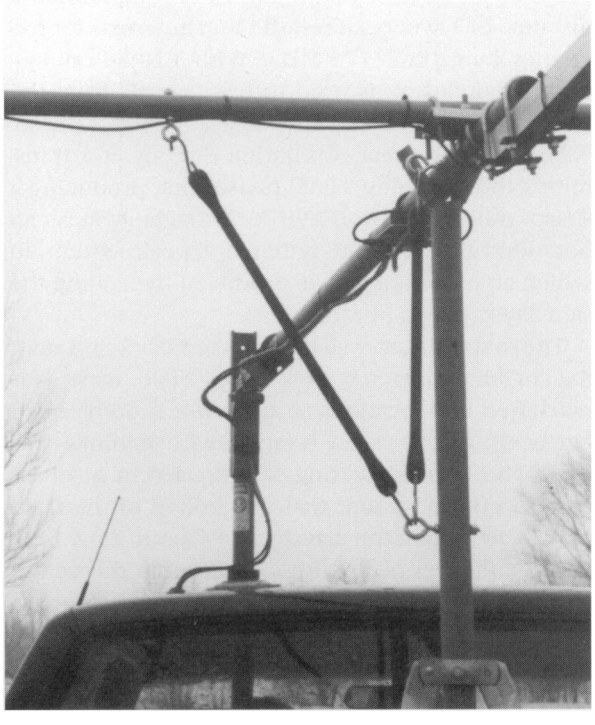

Figure 6. Bungee-cord attachments stabilize the folded antenna mast during transit.

A digital display indicating antenna directional bearing was mounted on the vehicle dashboard. A menu-driven software program (KVH Industries, Inc. Middletown, R.I.) allowed users to specify data collection parameters (e.g., heading type, baud rate). For example, setting the heading type to true north eliminated the need to compensate for magnetic declination. Because the electronic compass can deliver output to the digital interface with true rather than magnetic heading bearings, movement or repositioning of the vehicle did not affect accuracy of bearings relative to true north. Vehicle orientation was relevant only when using a compass rosette attached to the seat. In our system, the compass was attached directly to the mast, independent of vehicle direction. Once calibrated, compass accuracy of $\pm 0.5^{o}$ could be expected under conditions with low magnetic interference. Prior to field use, compass calibration was necessary to adjust for magnetic interference near the sensing element.

Twenty-eight labor hours were required for installation of the antenna system. Cost of the C100 compass engine was $1,200 (including digital interface and software program). The 2 Yagi antennas cost $300 total, and hardware components (e.g., tripod, masts, mounts, bearings, nuts, bolts, steering wheel) totaled $250.

To test the system, 4 radiocollars were placed in different locations in a study area with low vegetation, a flat topography (0.5–1% slope), and minimal magnetic interference. Collars were placed approximately 1 m above ground on wooden posts or barren saplings. Three directional bearings were estimated from 10 different telemetry stations (120 bearings total) approximately 1.6 km from each radiocollar. After directional bearings were estimated, a global positioning system (GPS) (GARMIN International Inc., Olathe, Kans.) was used to find Universal Transverse Mercator (UTM) coordinates of the 4 radiocollars and 10 telemetry stations. Actual directional bearings were compared to those estimated using the antenna system. UTM coordinates of the radiocollars and telemetry stations were checked by plotting points on USGS 3-m Digital Orthophoto Quadrant maps using the software program ArcView 3.2 (ESRI, Redlands, Calif.). Accuracy of the system under these conditions was $\pm 1.0^{o}$. The antenna system was tested again after >500 hrs of field use with no decline in accuracy.

Discussion and recommendations

We believe use of this system maximized efficiency and accuracy in locating radio-marked animals. The antenna operator was required to leave the vehicle only to fold or extend the mast. Therefore, elapsed time between determining directional bearings was minimized. Accurate digital compass bearings were continuously displayed regardless of vehicle movement and orientation. The folding capability of this system design also reduced the chance of damage to antenna(s). When the mast was extended, iron construction of the system provided sturdiness, while bearings facilitated quick and easy rotation and operation of the mast. Weight of the mast at lifting point was 13.6 kg, allowing the operator to raise and lower the mast with minimal effort.

The central mast of the antenna system should be mounted in the middle of an extended-cab vehicle rather than behind the driver's seat. In this location, both antennas fold into the bed of the pickup with no overhang outside the bed. Furthermore, mounting the mast in the center facilitates access to the antenna from the passenger seat. Last, eyebolts, which served as lashing points for the rubber bungee cords, should be mounted to the boom on both sides of the tripod rather than 2 on 1 side of the tripod (Figure 6). This modification would help to evenly distribute weight of the mast when placed in the folded position.

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