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Road Testing Cell Phone Amplifiers

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Signal amplifiers (also known as boosters) for cell phones are relatively inexpensive. Mobile signal amplifiers with magnet-based car roof antennas cost $250 to $450. Cell phones can be coupled with an amplifier to extend coverage while traveling through rural areas with limited cellular service. Increasing the range of cell phones can improve safety for Forest Service employees.

Highlights...

- Hand-held radios allow limited conversations that may require intermediaries with phones to forward a message. Cell phones provide direct communications—but only when cell phones have coverage.
- MTDC conducted mobile tests with an LG Model VX3450L cell phone and two Wilson Electronics, Inc., amplifiers.
- Cell phone amplifiers can extend the range of cell phones from several miles to 10 miles or more in flat terrain.

Physics and Cell Phone Transmissions

The limited range of cell phones is based on two factors: operating frequencies in the UHF (Ultra High Frequency, 300 to 3,000 megahertz) radio spectrum and the limited transmission power of cell phones. The operating frequencies of contemporary cell phones (800 and 1,900 megahertz) limit communications to line-of-sight between the cell phone and a cell tower. When the distance between the tower and cell phone is relatively short, the line-of-sight limitation may be overcome by signals reflected off buildings or rock walls or by "knife-edge" refraction (bending) over ridges. Such indirect signal paths typically allow a range of a few miles, while line-of-sight signal paths permit connections for many miles.

The other factor that affects the communication range of cell phones is the power of the transmitted signal. Federal Communications Commission rules restrict the amount of RF (radio frequency) power a cell phone may transmit. While battery size does not limit the power of radio transmissions in cell phone towers, the small batteries in cell phones do limit the power of the phones' transmissions. A cell phone's operating life on a single battery charge is determined by the transmitter's power and the length of time the cell phone is broadcasting (someone is speaking into the cell phone). The transmission power of a cell phone is about a quarter of a watt.

The range of cell phones also is affected by the location and shape of the antenna. For maximum range, a cell phone's antenna should be outside the handset, not built into it.

Cell Phone Amplifiers

A cell phone amplifier can increase the range of a cell phone.

The amplifier:

- Is powered by a vehicle's electrical system, so the amplifier's operating life is not tied to the cell phone's internal battery.

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- Has two RF amplifiers: one to boost the signal the phone receives from a cell tower and the other to boost the signal the cell phone transmits to the tower. The power of the cell phone's transmission is amplified to about 2 watts.
- Is used with an antenna that may be mounted on the roof of a vehicle (an optimal location). The size and design of the external antenna improve the effectiveness of the system. Some external antennas attach with magnets so they can be transferred easily to other vehicles.

Three methods of coupling cell phones to amplifiers are:

- A cable and plug for a cell phone with an external antenna jack.
- A contact antenna that can be attached to the back of a cell phone (figure 1).
- A repeater antenna that can be mounted inside the vehicle 1 to 2 feet away from the cell phone (figure 2).

Few cell phones have external antenna jacks, so the Missoula Technology and Development Center (MTDC) decided to evaluate how well the contact antenna and repeater antenna would work with amplifiers. MTDC used Wilson Electronics, Inc., products for the evaluation because the products are available in kits that can be assembled to suit specific applications.

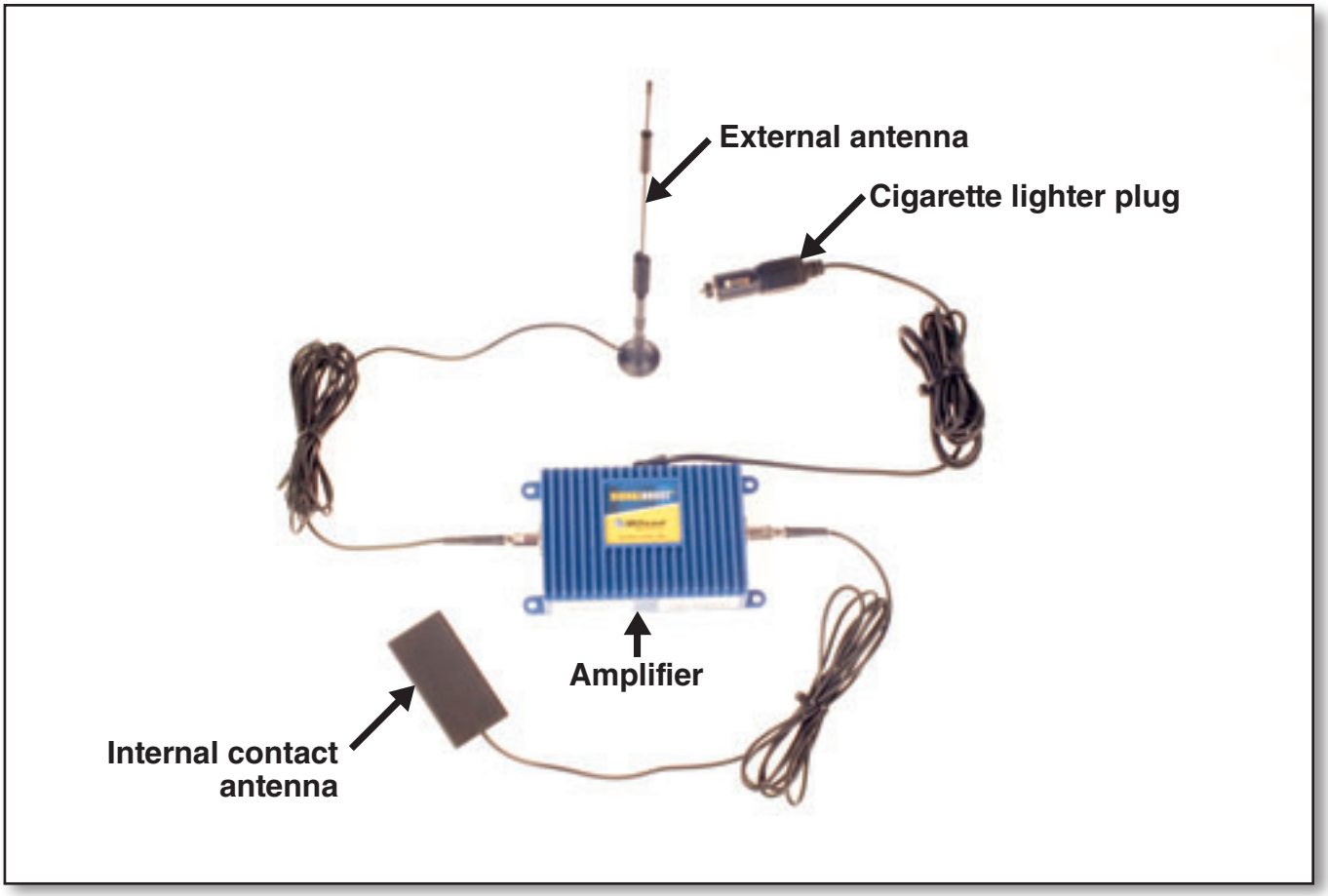

Figure 1—This system uses a contact antenna mounted to the back of a cell phone, an amplifier, and an external roof-mounted antenna to boost the range of cell phone transmissions.

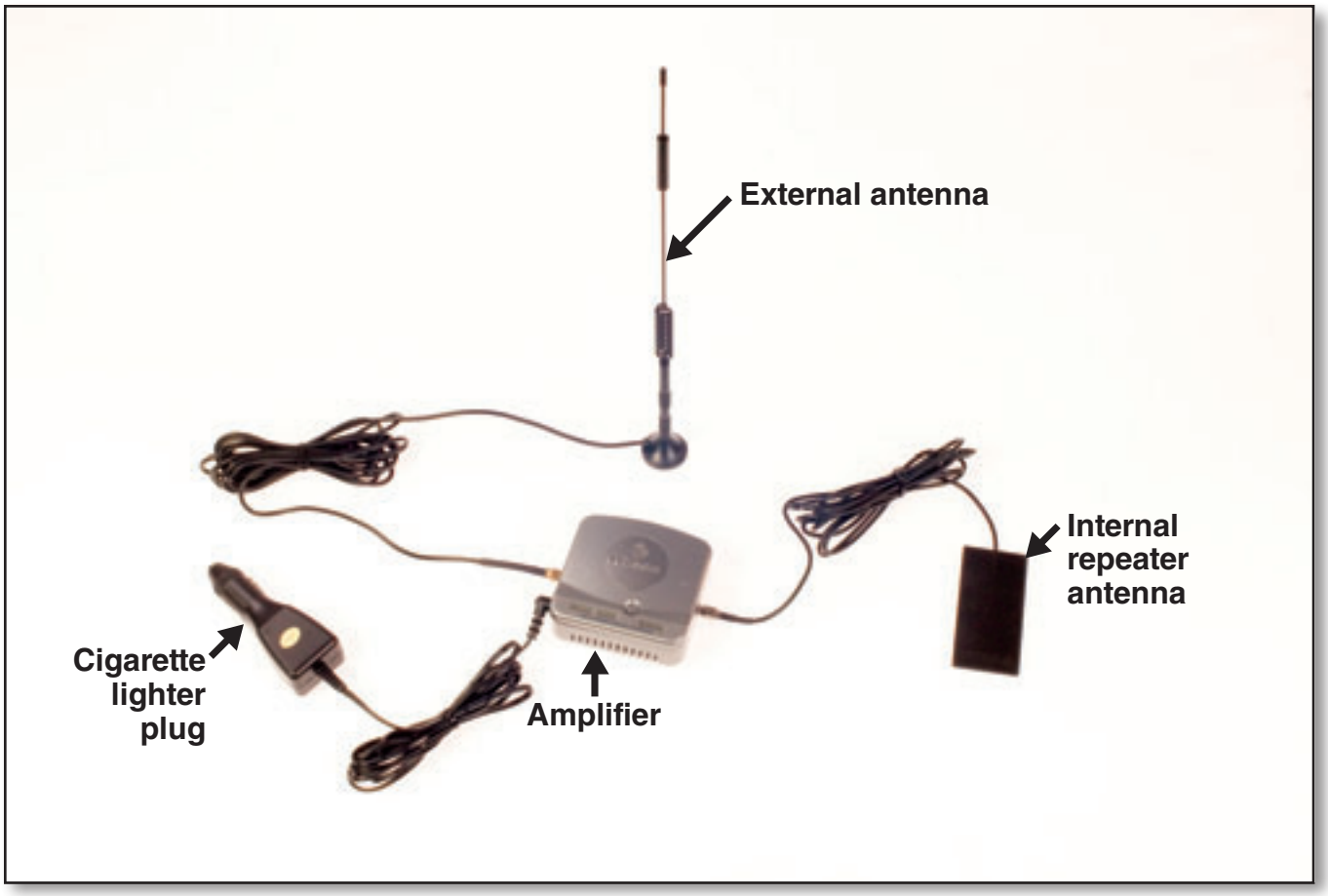

Figure 2—This system uses an internal repeater antenna, an amplifier, and an external roof-mounted antenna to boost the range of cell phone transmissions.

Products That Were Selected for the Driving Tests

The Wilson Electronics Model 811210 and 801230 amplifiers use 6-volt power sources. Cigarette lighter power plugs that came with the Wilson amplifier kits contain voltage regulators that lower the 12-volt car voltage to 6 volts as required for the amplifiers. The amplifiers were evaluated with 12-inch external antennas mounted with magnets on the vehicle's roof and with antennas inside the vehicle that were coupled to the cell phones directly or indirectly.

Driving Test Results

MTDC performed driving tests with a Ford Escape hybrid in and near six national forests in Montana. The external antenna was mounted with magnets in the center of the roof. MTDC performed most of the tests with the internal contact antenna (Model 811210). The amplifier and internal repeater antenna (Model 801230) produced similar results if the antenna was within a foot of the cell phone. Performance dropped off with increasing distance, but even when the cell phone was 2 feet away from the internal repeater antenna, reception and transmissions were still improved.

The cell phone used for mobile tests was an LG Model VX3450L. The cell phone featured a diagnostic screen (figure 3) that displayed received signal strength in dBm (decibels relative to 1 milliwatt of power) and signal quality (a data error rate listed as "EC/IO"). The cell phone was equipped for Verizon wireless service, which is widely available in western Montana.

The tests were performed either in a parked vehicle or by the passenger in a moving vehicle. The Forest Service's Health and Safety Code Handbook 6709.11, section 12.34, prohibits using two-way radios and hand-held cell phones while driving.

Figure 3—Diagnostic screens found on some cell phones offer a more accurate way of determining when a cell phone can complete transmissions than the bars most cell phones display.

In many areas of western Montana, small towns with cellular service are 20 to 30 miles apart. Without a cell phone amplifier, someone driving between those towns would be out of service for 10 to 15 miles. With the amplifier, continuous coverage was available. In similar situations, amplifiers could allow continuous cell phone coverage on hundreds of miles of highways between towns where coverage would not be available otherwise.

In areas where a town was the sole source of cellular coverage for many miles, coverage outside town was extended on average by 7 miles, frequently doubling the range of an unamplified cell phone. If the road into town was relatively straight, often coverage was extended by more than 10 miles. If the road took a sharp turn into a steep drainage, typically the coverage was extended just 2 to 3 miles. If the road followed rolling hills, coverage would be lost in the dips of the road and recovered near the ridges.

If a cell phone user has the opportunity to seek out a high ridge or hilltop that provides line-of-site access to a cell tower, cell phone service often can be obtained in relatively remote locations.

More Details

At several points during each test, calls were placed to an office and voice mail messages were left to record the audio quality of the cell phone connection. Using the diagnostic screen on the LG cell phone, calls could be placed when the unamplified cell phone registered received signal strength of -104 dBm. The cell phone would not register signals below -106 dBm. When the amplifier was turned on, the received signal strength would typically increase about 26 dBm; an unamplified received signal registering -100 dBm would increase to about -74 dBm when the amplifier was on.

With the amplifier on, the received signal strength level had to be about -92 dBm to make a call. The amplifier can provide more boost to signals it receives from cellular towers than it can to signals it sends to those towers—the amplifier can detect tower signals beyond its range for responding.

The EC/IO value the phone displayed was a good indicator of whether a call could be placed, regardless of the received signal strength. Values down to -10 appeared to be associated with calls with good voice quality. Voice quality was poor or the phone could not connect when the EC/IO value was less than about -10.

Conclusions

Cell phone coverage in national forests is not likely to match the communication coverage available through the Forest Service's VHF (Very High Frequency, 30 to 300 megahertz) repeater network. However, adding cell phone amplifiers to Forest Service vehicles can extend the range of cell phone coverage, reducing instances when employees are forced to radio their dispatcher to ask for help in forwarding a message by phone.

With the decreasing availability of external antenna jacks on cell phones, the contact antenna is the most effective method MTDC tested for coupling a cell phone to an amplifier. An in-car signal coupling option that wasn't investigated for this project is a cell phone "cradle" that contains a contact antenna behind the cell phone. Because the cradle would have to be mounted on the dash or the center console, the cell phone would have to be used with a headset plugged in or in speaker mode. Considering the noise in a vehicle, a headset would provide clearer audio.

A cell phone amplifier installed permanently in a vehicle should be mounted in an out-of-the-way location, such as under the passenger seat, where there is good ventilation. The power and antenna cables should be routed to avoid tripping, snagging, and damage.

About the Author

Ted Etter joined MTDC in 2002 as an electronics engineer and project leader. He has 20 years' experience working for private industry in the design of test equipment, display devices, and medical instrumentation. For 6 years before he joined MTDC, Etter taught courses in the electronics technology program at the University of Montana College of Technology, Missoula, MT. His work at MTDC includes projects in wireless communications, alternative energy sources, instrumentation, and process control. Etter received a bachelor's degree in mathematics from the University of Oregon and a master's degree in teacher education from Eastern Oregon State University.

Library Card

Etter, Ted. 2009. Road testing cell phone amplifiers. Tech Tip 1066–2320P–MTDC. Missoula, MT: U.S. Department of Agriculture Forest Service, Missoula Technology and Development Center. 6 p.

Forest Service employees are often out of cell phone range when working in rural areas. Although the Forest Service has its own radio network to help employees stay in touch, cell phones are a widely used alternative. Small amplifiers plugged into vehicle cigarette lighters can increase the strength of the signal received from cell phone towers and increase the strength of cell phone transmissions to the towers, extending the range of cell phone coverage by several miles to an additional 10 miles or more in flat terrain. This tech tip discusses tests of two amplifiers made by Wilson Electronics, Inc.

Keywords: antennas, cell phone coverage, rural areas, telecommunications, Wilson Electronics

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Electronic copies of MTDC's documents are available on the Internet at:

http://www.fs.fed.us/eng/t-d.php

For additional information about cell phone amplifiers, contact Ted Etter at MTDC:

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