Evaluation of Datacasting in the Mobile Environment

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Abstract— **Datacasting employs the excess bandwidth from digital television signals for use in one-way data transmission, and it is being used successfully for high-speed downloads at fixed locations. There is considerable interest in extending datacast usage to mobile users, although there are reception challenges in the mobile environment that can significantly impact system performance. To explore the feasibility of using datacasting in this environment, datacasting receivers and data logging equipment have been installed in 10 emergency vehicles to record performance characteristics over a wide range of operational conditions. Summary conclusions from that study are described in this paper along with details about the equipment used to make the test and the environmental factors that were found to have the greatest impact on system performance.**

The use of the low-speed (9600 baud) VHF, emergency-band data channel in conjunction with the datacast channel to provide two-way data transmission is also evaluated and discussed for the mobile environment.

Index Terms—Datacasting, Mobile, Antenna, UHF, Rain Effects, 8VSB modulation

I. Introduction

Datacasting is the term used to describe the transmission of data that is contained in the excess bandwidth from digital television signals. Bandwidth is left over when the video being transmitted does not occupy the entire allotted bandwidth for the channel, and this generally occurs when the television image does not contain a high degree of motion. Download data rates of up to 1.5 Mb/sec are attainable, and the data can be retrieved using relatively low-cost equipment from within the television station coverage area. Data carried via datacasting can be encrypted and sent only to targeted receivers, making this form of data transmission desirable for a range of commercial and government applications.

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Datacasting is being used increasingly for one-way, point-to-point data transmission to fixed locations; the work reported here involves the practical considerations associated with using datacasting in mobile environments, and in particular emergency vehicles. These practical considerations include the relationship between receiving equipment (viz., the antenna, pre-amp and receiver) and reception for a variety of operational conditions. Further, the use of the 9600 baud VHF police-band data channel to provide two-way (low-speed uplink, high-speed downlink) data transmission is being investigated.

The mobile datacast evaluation effort described in this paper is currently ongoing and is being carried out in the state of New Hampshire in the USA. To measure datacast performance, 10 State Police vehicles have been outfitted with hardware that records parameters pertinent to one and two-way datacast reception. The result of this work affords a quantitative assessment of the capabilities and limitations of datacasting in the mobile environment for a wide range of operational conditions. Data have been and will be collected over different terrain types (New Hampshire varies from relatively flat, sea-level terrain to rugged mountains containing the highest peak in the Northeast USA) and different weather conditions (data collection will span the New England summer, fall and winter seasons). Through the mining of the extensive data collected as part of this effort, it is becoming clear as to the exact conditions where datacasting will and will not provide a robust and dependable data link for the mobile receiver.

II. Selecting Equipment for Measurements

One of the guiding principles used in selecting equipment for the measurements was to use off-the-shelf items, and to keep costs as reasonable as possible. Further, there should be a standard equipment configuration that will enable reception over the entire UHF television band. This latter constraint mandated the use of a broadband antenna, which eliminated the possibility of using smart antennas to boost gain and lessen noise. Consequently, one of the challenges in identifying antennas for this application was to find ones that would cover the entire UHF television band (≈200 MHz to 1 GHz). One of the drawbacks to this is that broadband antennas tend to have a lower output which necessitates the use of a preamplifier, and preamplifiers always introduce some degree of noise.

Another challenge in selecting antennas is that the datacast signal is horizontally polarized, which makes it more difficult to achieve the desired azimuthally-isotropic radiation pattern. An isotropic pattern is desirable for this application so that reception will not vary with vehicle heading. If the signal were vertically polarized, a simple, electrically-short whip antenna would be the obvious solution.

Two of the few low-cost antenna designs that will operate over a wide bandwidth and provide a nearly isotropic radiation pattern for horizontal polarization are a short folded dipole and a magnetic loop antenna. These are the two designs used for this study, the electric-field antenna being an off-the-shelf product and the magnetic-field antenna being custom made for this application. Half of the installations for this study were made using one of the two designs, which are pictured in Figure 1. The off-the-shelf antenna [1] is intended for mobile TV reception and costs around $100 USD including preamplifier.

Figure 1. Electric and Magnetic Field Antennas Mounted on Police Vehicles. The H-Field Antenna Is Positioned Just in Front of the Vertical Whip.

A final challenge in selecting antennas has been to identify ones that will stand up to the rigors of the mobile environment. Specifically, an antenna should be mechanically strong so that it will not be susceptible to damage in normal operation and so that it will not be an easy target for vandals. Appearance and ease of installation were also considerations in selecting antennas.

At this point in the study, both the electric and magnetic field antennas demonstrate similar reception characteristics, although the size of the magnetic field antenna makes it preferable from an installation perspective.

As noted above, a preamplifier is typically needed for electrically short antennas such as the ones used for this study. Since the noise added by the preamplifier (noise figure) reduces the signal-to-noise ratio, and hence reception coverage area, the noise figure was evaluated for several off-the-shelf preamps. Figure 2 plots the noise figure measured in this study against manufacturer specifications and includes the preamp cost. Given the desire to contain costs, a preamplifier with a noise figure of approximately 2 dB was selected, although a quieter preamplifier can always be used in fringe reception areas. To enable an unbiased assessment of antenna performance, both use the same preamplifier for the signal measurements reported here.

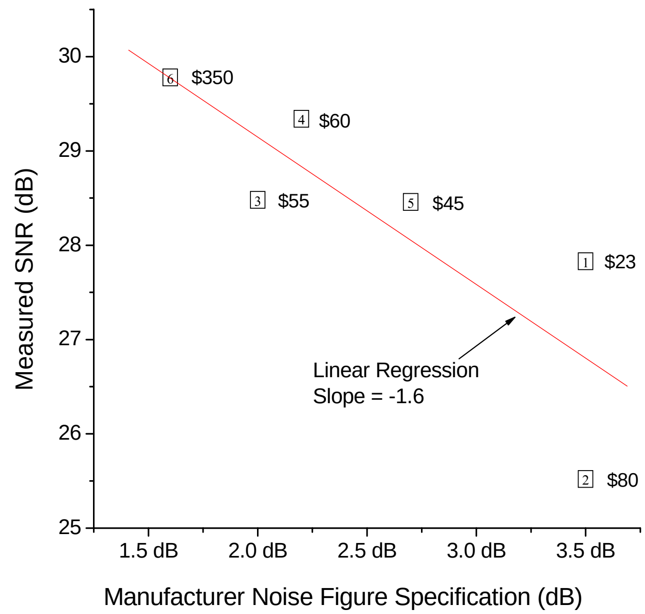

Figure 2. Plot of Measured versus Advertised Noise Figure for Variously Priced Preamplifiers

The receiver selected for this study was the Broadband Technologies AirStar 5th generation datacast receiver, available through Triveni [2] at a cost of around $170 USD. This receiver was selected primarily due to the researchers' past experience using it and its earlier version.

The total cost to install datacasting capability into a vehicle for this study is in the neighborhood of $300 USD, and that cost will likely decrease for large quantities.

III. Rain Effect on Datacast Reception

Conventional wisdom suggests that rain effects will not appreciably degrade radio reception at UHF [3], and hence it might be assumed that rain will not affect datacast performance. Accordingly, while a lot of work has been performed to characterize rain effects for earth-satellite links and microwave terrestrial links (for example [4]), very little documentation exists regarding rain and relatively-short, UHF terrestrial links such as the datacast link. However, in the early part of this study, datacast reception outages were observed to coincide with heavy rainfall. These observations are surprising at 731 MHz (Channel 57), particularly considering that some of the outages occurred for propagation paths under 20 km. Because the overall objective of this study is to investigate the capabilities and limitations of the datacast system, gaining an understanding of the rain-related outages is considered to be a priority.

There are two points worth noting here: 1) the rain outages were observed mostly while using older Generation 1 receivers and 2) the signal strength often remained at above-reception levels while the signal-to-noise ratio dropped below the reception threshold. It is recognized that the Generation 1 receivers are quite sensitive to multipath when compared to the now-available Generation 5 receivers.

Although the Generation 5 receivers have been shown to be less susceptible to rain than the Generation 1 receivers, rain effects remain a concern. To better understand those effects, a fixed datacast monitor has been installed in addition to the mobile installations to enable rain effects to be documented explicitly. Key parameters defining datacast signal robustness, signal strength and signal-to-noise ratio, are being recorded every second, and radar display information along the propagation path are being recorded every five minutes, the rate at which they are updated on the web site from which they are being collected [5] .

An example of a rain-induced drop in signal-to-noise ratio is evident in Figure 3. The data in Figure 3 were collected by a Generation 5 receiver during heavy rainfall which was color coded on radar to have an intensity of 50 dBZ as seen in Figure 4. The color coding on the map represents dBZ, which is an indication of equivalent reflectivity measured by the weather radar system. 50 dBZ corresponds to a rainfall rate of at least 1.75 inches per hour.

The pronounced dip in SNR is significant, particularly considering the short distance between the transmitter and receiver (≈20 km). This degree of signal degradation is sufficient to make datacast reception unavailable at most receiver locations.

Reception using Generation 5 receives does not appear to be affected measurably by storms with less than 40 dBZ readings (less than 0.4 inches/hour rainfall). It should also be noted that heavy snowfall (≈40 dBZ) does not appear to measurably impact reception.

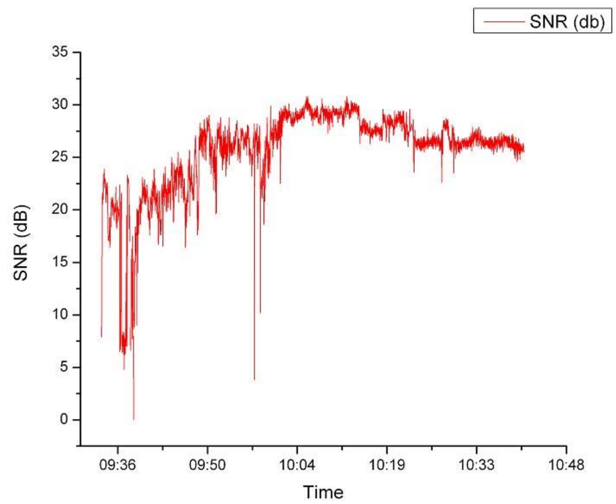

Figure 3. Datacast Signal-to-Noise Ratio Measured During a Heavy Rain Event (50 dBz) on July 11, 2006 by a Generation 5 Receiver

A preliminary conclusion that can be made from the data that have been collected to date is that both Generation 1 and 5 receivers are susceptible to heavy rainfall (>40 dBz), while neither appear to be affected by light rainfall (<30 dBz). The assumed cause of the outages is the Doppler shift and/or multipath interference created by regions of intense and moving rainfall. From the observations made to date, only rainfall amounts in excess of around 50 dBZ will create outages for Generation 5 receivers, while lesser amounts do not appear to measurably affect system performance.

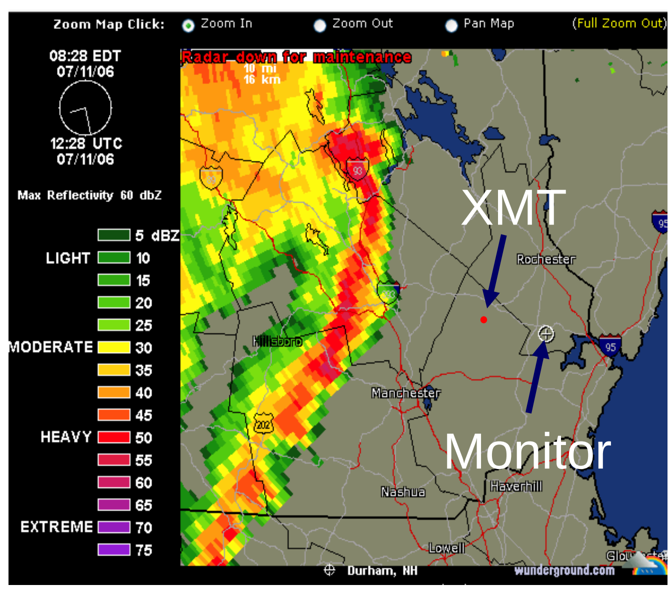

Figure 4 Radar Image Showing Rainfall between Transmitter and Receiver at 06:39 on August 25, 2006. Storm Movement is West to East

Data collection on rain effects will continue until rain effects on datacast reception are more clearly understood.

IV. Datacast Reception in the Mobile Environment

Datacast installations, using the equipment described in Section II, have been made in 10 New Hampshire State Police vehicles. Those vehicles had already been outfitted with computer and networking equipment developed as part of an effort known as Project54 [6]. Project54 equipment enables electronics within a vehicle to be controlled by a single computer, which affords options such as voice-activation, device coordination and data logging. Since most of the networking and computing infrastructure was already in place, adding the datacasting equipment and making the necessary modifications to the data logging software was straightforward.

The datacast signal is provided by New Hampshire Public Television on Channel 57 (ERP = 598 KW from an antenna height of 45 meters AGL). An IP encapsulator was installed at the station to embed digital data into the transmitted signal. The installed datacasting equipment also enables two-way data transmission by handling TCP/IP-type handshake commands coming through available channels, such as the VHF data channel.

The data logged in the vehicles provide detail as to where and when the datacast and VHF channels are available. Position data are given by GPS, and datacast robustness is determined by signal-to-noise ratio. Files of varying size and type (ASCII, audio and streaming video) are periodically sent to all vehicles in the study to assess channel throughput.

Determining VHF channel coverage is somewhat problematic, since the signal is not continuously available. Because a VHF channel could not be dedicated for this study, signal availability is determined from regular police broadcasts. This requires having a separate fixed monitor to determine when the transmissions are made and by whom, and that log is compared with vehicle-logged data to determine if the transmissions were received.

The final results of the data logging effort are maps showing where datacast reception is possible. Importantly, because data are collected repeatedly by different vehicles and under different operational conditions, a realistic assessment of channel reliability is afforded.

Coverage maps can be generated in a wide range of formats. For example, Figure 5 shows datacast coverage from the Channel 57 transmitter for most of the state of New Hampshire. As expected, the location of data points corresponds to the major roadways patrolled by the cruisers, and each point plotted represents a location where the averaged signal-to-noise ratio collected at that location was either above an empirically-derived reception threshold (green dot) or below it as indicated by the failure of the receiver to lock (red-dot).

The signal-to-noise ratio values used in generating the coverage maps often come from measurements over time by a single vehicle, and/or from multiple vehicles collecting data at the same location (within the 11 meter resolution of the GPS equipment used in this study). Consequently, each dot on the map may represent the average of many individual measurements. As this study continues, and more data becomes available, the statistical likelihood of reception at many locations will be calculated and coded in a greater spectrum of colors than presented here.

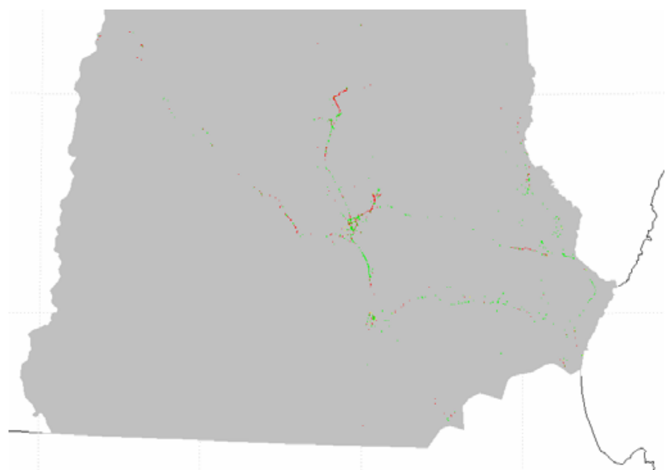

Figure 5 Datacast Coverage Map for Southern New Hampshire

Figure 6 plots estimated television coverage for the entire state. The estimate values plotted were obtained from the Longley-Rice propagation model and give a reasonable approximation of coverage area for stationary television viewers. Referring to Figures 5 and 6, it is evident that the coverage area for mobile users is generally less than the predicted coverage area. There are two fundamental reasons why mobile datacast coverage using low-cost equipment will be less than stationary television coverage. The first reason is that stationary reception is generally obtained using directional antennas with gains of 5- 15 dBi which are elevated so as to provide line-of-sight propagation paths. The non-directional datacast antennas elevated at trunk height are not as conducive to good reception.

The second reason that datacast coverage area tends to be less than television coverage area is that multipath interference can make the datacast channel unusable, while it can cause ghosting in television reception. Ghosting can typically be minimized for television by aiming the directional antenna away from the multipath, an option not available with the non-directional datacast antenna.

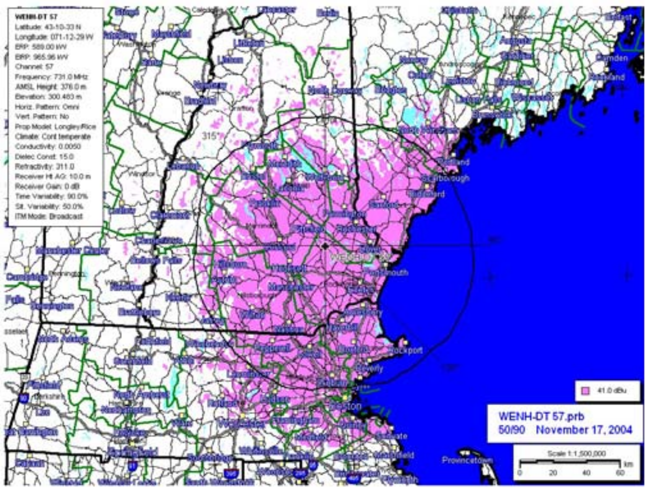

Figure 6. Computer Model (Longley-Rice) Generated Coverage Map for Channel 57.

Figure 7 is an example of how measured datacast reception data can be overlaid on satellite photos. These types of plots can be zoomed in to show even more precisely the locations where reception is possible. The location shown is particularly challenging from a reception perspective because of multiple shadowing terrain features.

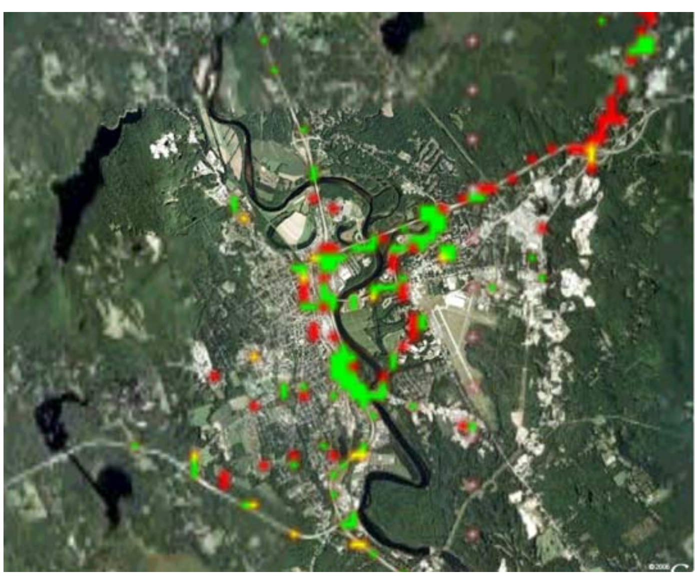

Figure 7 Datacast Reception Superimposed on Satellite Photo for the Vicinity of Concord, New Hampshire

V. Conclusions

Datacasting can provide a high-speed downlink channel to mobile users with reasonably-priced in-vehicle equipment. Preliminary indications are that the signal is available in a sufficient region of a television transmitter coverage area to enable it to be a useful tool for disseminating large quantities of data.

Future work will concentrate on calculating statistical assessments of channel performance, and on connecting an uplink channel so as to provide two-way data transmission.

VI. Acknowledgements

The work reported here was funded by the National Institute of Justice under Contract 2001-LT-BX-K010.

VII. References

[1] The antenna model is a Wintenna Silhouette 747A, available from Wintenna, Inc., 113 E. Shockley Ferry Road Anderson, South Carolina 29621, USA

[2] Triveni, Inc., 40 Washington Rd., Princeton Junction, New Jersey 08550, USA

[3] Donald Fink, *Electronics Engineers' Handbook*, McGraw-Hill, 1975, Section 18-90. The plot of rain attenuation comes from CCIR Report 234-2.

[4] Frigyes, I. Horvath, P.,"Mitigation of Rain-Induced Fading: Route Diversity vs Route-Time Coding," Antennas and Propagation, 2003. (ICAP 2003). Twelfth International Conference on (Conf. Publ. No. 491)

[5] www.weatherunderground.com

[6] www.project54.unh.edu