Deployment of TV White Space Technology
## In El Dorado County, California

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Background:

In April 2013, Cal.net, Inc., a wireless Internet Service Provider, initiated a project to deploy and test TV White Space ("TVWS") technology in portions of its service area for the purpose of determining the efficacy of the technology for delivering quality broadband Internet services to residents and businesses situated in challenging locations. These prospective recipients are located in areas where no wire-line broadband service exists, where cellular telephony service is spotty or nonexistent, and where line-of-sight wireless communications technologies are ineffective due to dense forests and/or rugged terrain. The products used for this TVWS trial were manufactured by Carlson Wireless Technologies[1] and were deployed under a Special Temporary Authority from the FCC for the duration of the test phase, which ran through the remainder of the year 2013.

Evaluation:

In order to judge the ability of TVWS to perform in contrast to other common fixed-wireless broadband solutions, initial testing began at a single site where a point-to-multipoint TVWS base station transceiver was installed on a tower alongside existing base stations utilizing other frequency bands – namely 5.8 GHz, 3.65 GHz, and 900 MHz. Extensive nomadic field testing at 26 remote field locations was conducted to measure the performance and establish the limitations of TVWS in comparison with the other equipment. The results unequivocally established the viability of the technology to deliver on its promise of providing good quality terrestrial broadband service to otherwise unserviceable locations.
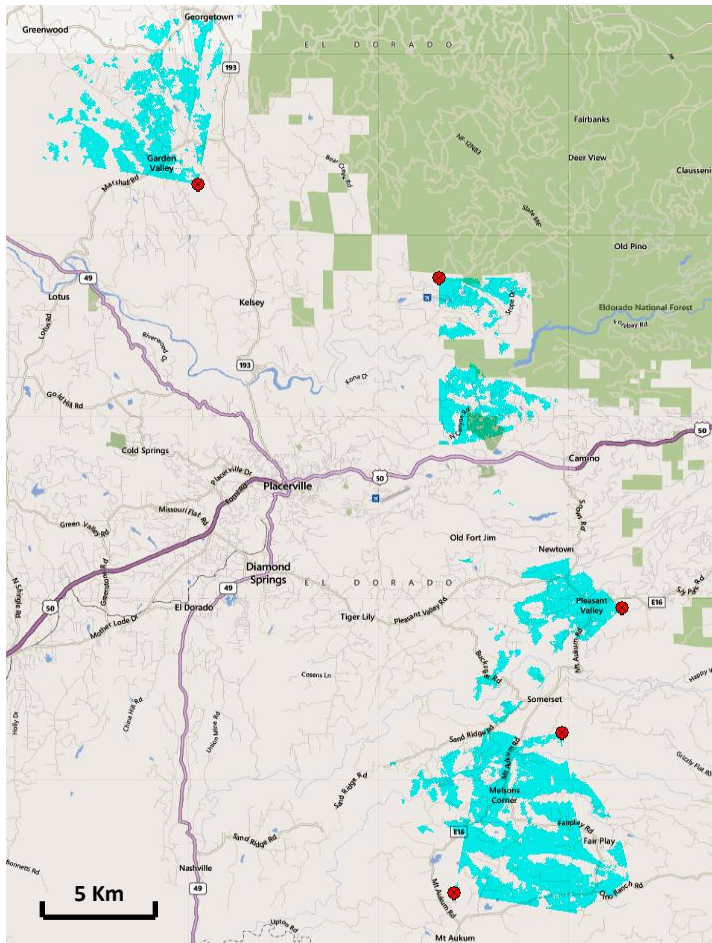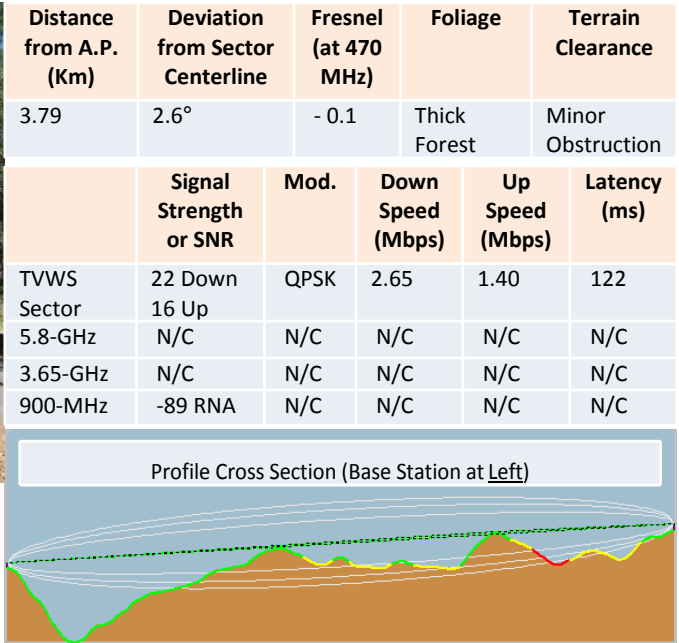

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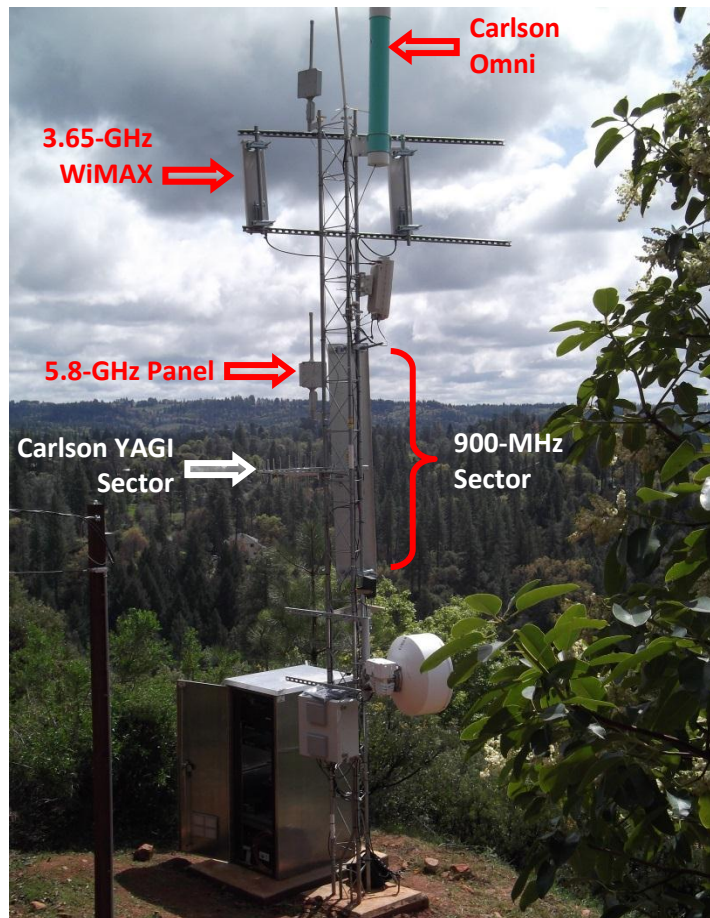
[1] Full disclosure: the author holds a seat on the Board of Directors of Carlson Wireless Technologies, Inc. Despite that fact, this evaluation was conducted with complete objectivity solely for the benefit of the author's employer, Cal.net, Inc., without intent for publication of the results at the time of this testing.

A representative example of one of the nomadic remote test sites is illustrated below. This location was able to establish a strong connection at a distance of several kilometers from the TVWS base station through multiple very-thick patches of trees and over a mild terrain obstruction. None of the other technologies were able to connect, and in fact, only the 900-MHz equipment was able to detect any kind of signal at all from its base station.

View Toward Base Station

Distance from A.P. (Km)	Deviation from Sector Centerline	Fresnel (at 470 MHz)	Foliage		Terrain Clearance
3.79	2.6°	- 0.1	Thick Forest		Minor Obstruction

	Signal Strength or SNR	Mod.	Down Speed (Mbps)	Up Speed (Mbps)	Latency (ms)
TVWS Sector	22 Down 16 Up	QPSK	2.65	1.40	122
5.8-GHz	N/C	N/C	N/C	N/C	N/C
3.65-GHz	N/C	N/C	N/C	N/C	N/C
900-MHz	-89 RNA	N/C	N/C	N/C	N/C

Profile Cross Section (Base Station at <u>Left</u>)

Long-Term Testing:

Upon conclusion of the initial evaluation phase, TVWS base stations were then deployed in four additional locations spread over a distance of about 40 km as illustrated in the adjacent map (blue shades indicate coverage areas of each base station). Up to nine long-term test subscribers were then provisioned for each of the five base stations. These test users were chosen not only at locations offering highly optimal connections, but also deliberately at some marginal locations in order to analyze the effects of environmentally-induced temporal variability.

Observations:

While no technology is a panacea, TVWS has definitely proven itself a viable means of delivering broadband

service to rural subscribers who have no alternatives available (other than satellite). Excluding the few end users deliberately provisioned with marginally-acceptable service as noted above, most have been delighted with the results that have been achieved. As a result of these long term tests, it was determined that the optimal quality of service can be achieved by conforming to these limitations:

- QPSK is the minimal acceptable modulation

- Avoid a wide range of modulations among the subscribers on any one base station

- Limit the distance through trees to no more than 7.5 kilometers

Additionally, at least two very important caveats were discovered in this process:

- The TVWS ecosystem was designed to protect the incumbent licensed users of the band from the unlicensed users, but the converse is _not at all true_. Just because a location is deemed eligible for use by the TVWS databases, does not mean that the location is feasible for use in all allowable channels. The noise floor on any given allowable channel may simply be too high for viable broadband communications. Furthermore, just because a given channel in a specific location may be very suitable upon initial deployment, that does not imply that this condition will remain static over time – a licensed user may upgrade, reconfigure, or relocate their transmitter without warning, rendering useless what was once a very-usable TVWS channel, _even without making the channel ineligible_ (because the TVWS site in question still remains outside the newly-revised protected contour).

- There can be significant daily variation of the noise floor in some channels. Consequently, marginally acceptable connections during installation should be avoided.

Markets:

El Dorado County is one small but highly representative example of a significant market opportunity in the United States. Because of the combination of population density, topography, and tree cover, thousands of households there have no access to traditionally-delivered broadband services. TV White Space provides the only viable means of reaching these users with acceptable levels of service. And similar conditions exist in hundreds, if not thousands, of rural locales throughout the United States. The stabilization and maturing of the TVWS industry will be paramount in providing a means to service a significant proportion of the millions of rural residents in this country still without access to high quality broadband services.

Now that Carlson Wireless TVWS equipment has been certified by the FCC, Cal.net will commence commercial deployment in its service area in March, 2014. Within a year, several dozen base stations will be deployed, and hundreds of end users will be provisioned. When available, equipment from other manufacturers – not just Carlson – will be part of the mix. Cal.net eagerly awaits the certification of Adaptrum's product, and with it the start of a competitive supplier market for rural broadband TVWS equipment.

And as important as rural broadband is for personal and business uses, there are also industrial machine-to-machine types of applications where TVWS will play a significant role. Low-bandwidth telemetry, such as that enabled by KTS Wireless' TVWS equipment, is one such example. High-bandwidth equipment monitoring for use in certain vertical markets such as oil and gas, exemplified by the new Redline TVWS product, is another such example. Together, these

types of applications are but the tip of the iceberg for a burgeoning new industry, which must be intelligently nurtured by the world's various regulatory agencies to enable it to reach its potential.