Radio Frequency (RF) Spectrum Study

for the Colorado Wireless Communities – Thornton

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Prepared by:

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1. Introduction

The report includes the methodology, observations and recommendations in relation to pre-installation analysis of the radio frequency (RF) spectrum for the deployment of a city-wide Wi-Fi network for Thornton. The test team collected signals throughout Thornton, which is referred to as the "test area" in this report.

2. Test Team

The test team consisted of the following members:

James T. Geier
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Eric W. Geier
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Refer to Appendix A for test team member biographies.

3. Data Collected

Wireless-Nets collected RF data within the test area September 8-11, 2006. The data collected consisted of RF spectrum scans and wireless LAN scans. This data offers a basis for determining the impact of existing signals on the operation of a city-wide Wi-Fi network.

3.1 RF Spectrum Scans

Spectrum scans involved the use of a spectrum analyzer to measure signal activity in the 2.4-2.5GHz and 5-6GHz frequency bands at locations throughout the test area.

Numerous spectrum scans were done using an AirMagnet Spectrum Analyzer Card inserted into a laptop running AirMagnet's Survey software. This spectrum analyzer used an external omni-directional antenna. The software automatically captured a spectrum scan every five seconds while the test team drove throughout the test area. The software plotted the location of each spectrum scan on a map (Microsoft MapPoint) based on coordinates obtained through a GPS, with external antenna for better position accuracy. The test team drove throughout the test area in a manner to capture multiple spectrum images of the 2.4-2.5GHz and 5.0-6.0GHz frequency throughout the test area.

Refer to Appendix B for the identification of chosen spectrum image locations and resulting spectrum images.

3.2 Wireless LAN Scans

The wireless LAN scans were done through the use of AirMagnet Survey software interfaced with an 802.11a/b/g radio card and a GPS. The software automatically recorded the SSID (Service Set Identifier), RF channel setting, signal strength and noise levels of wireless LAN access points while the test team drove throughout the entire test area in approximately 1 to 1.5 mile increments. This provides a sample of the wireless LANs active within the test area.

Refer to Appendix C for images that depict the routes driven throughout the test area and maps indicating average noise and access point signal amplitudes.

4. Observations

This section of the report discusses various observations based on the spectrum scans, wireless LAN scans, and notes made while visiting the test area.

4.1 Existing Signal Levels

The existing signals shown in the spectrum images and wireless LAN scans in Appendix B and Appendix C, respectively, will offer a limited level of noise to a municipal Wi-Fi network. These existing signals are emanating from wireless LANs and radio equipment currently operating throughout the City.

The average noise levels are below -90dBm throughout the test area in the 2.4-2.5GHz and 5.0-6.0GHz bands (refer to Appendix C, Figures C-3 and C-6). This consistent average noise does not pose significant potential problems to the use of these frequencies for supporting mesh nodes within the City. It's comparable to other cities successfully implementing city-wide Wi-Fi networks.

There are existing signals indicated in the spectrum scans in the 2.4-2.5GHz band at that will require careful design to avoid the impacts of RF interference and optimize the performance of a city-wide Wi-Fi network. The max signal levels in the 2.4-2.5GHz frequencies are moderately high (above -80dBm) in parts of the band at some locations, such as locations 1 and 4 in northern Thornton (depicted in Appendix B). These signals are likely emanating from existing Wi-Fi access points. In most cases, it will be possible, though, to tune the mesh nodes of the city-wide Wi-Fi network in the applicable locations to frequencies that will significantly reduce the interference.

Despite the presence of these existing signals, the proper design and deployment of the network should allow effective operation of the system.

4.2 Existing Wireless LANs

The wireless LAN scans shown in Appendix C indicate that there are numerous wireless LANs operating throughout the test area. The AirMagnet Survey software captured approximately 840 wireless LAN access points as the test team drove along the test route show in Appendix C, Figure C-1. This constitutes a sample of the total number of existing wireless LANs based on the drive route taken by the test team.

Even though there are many wireless LAN access points currently operating within the City, the signal levels from these existing networks are relatively low when measured outdoors, where the city-wide network will be operating. The vast majority of these existing wireless LANs are installed inside buildings, which attenuate the signals as they propagate outside to levels that will likely have minimal impacts on the city-wide network.

As shown in Appendix C, the signal strength of the existing 802.11b/g wireless LAN access points (measured outdoors) is mostly between -85dBm and -60dBm. The largest percentage (43 percent) of the existing access points are operating on channel 6, the common default channel. By setting the city-wide Wi-Fi mesh nodes to non-overlapping channels in relation to channel 6 (such as channel 1 or channel 11), the majority of the interference from existing access points can be avoided. Only 0.83 percent of the access points found by the AirMagnet Survey software were 802.11a access points operating in the 5GHz bands. Thus, the impact of existing 802.11a access points is insignificant.

4.3 Environmental Concerns

There are no major environmental issues. Most buildings in Thornton are less than three stories high, and there is only moderate tree coverage.

4.4 Mounting Assets

In some parts of Thornton, especially the commercial areas, there are sufficient traffic light poles and city-owned buildings for installing mesh nodes and backhaul equipment. Water tanks within the city also exist that can provide headend and backhaul relay points. These mounting assets are indicated on the maps provided by the City. These mounting assets alone, however, will not provide enough mounting points for mesh nodes in order to facilitate city-wide signal coverage. The use of street light poles will be necessary, especially within residential areas, in order to provide full coverage.

Thornton has two primary types of light poles. One type of light pole found on nearly all main streets and thoroughfares in Thornton are the light poles having a horizontal arm. These are conventional light poles found in most other cities. There should be no problems installing mesh nodes on these types of poles. Thornton also has non-conventional vertical light poles which are found on many of the interior residential streets. The light pole shown in Figure 1 is characteristic of this type of light pole. At this time it’s not known whether these poles will meet the weight and electrical power requirements of mesh nodes. In addition, these poles appear to be of a decorative type, and Thornton may encounter resistance from neighborhoods if installing mesh nodes on these poles.

Figure 1. Non-Conventional Light Pole

5. Recommendations

Based on the observations, the following are recommendations for deploying a municipal Wi-Fi wireless network throughout the City:

5.1 SNR Values

The SNR (signal-to-noise ratio) in all areas of the city-wide Wi-Fi network should be at least 15dB SNR to enable stable connections. In addition, signal levels of the Wi-Fi network should be high enough in all areas to provide required data rates as indicated in the technical specifications of the client radio cards that the City decides to support. If the wireless network will be supporting voice applications, then the SNR will likely need to be higher based on the specifications of the supported wireless voice handsets. For example, Cisco recommends a minimum of 25dB SNR for the Cisco 7920 Wireless IP Phone. The installation of the network should adhere to these values to ensure that existing noise levels doesn't limit range and performance of the municipal wireless network. In addition, it's important to understand that these minimum SNR values must be present at the location of the wireless user device and the mesh node to ensure effective two-way communications.

5.2 Back Haul Frequencies

In order to reduce RF interference between backhaul and existing systems operating in the 2.4-2.5GHz band, the backhaul frequencies should be in the 5.0-6.0GHz band. This avoids excessive retransmissions and potential lower performance that may occur in the 2.4-2.5GHz bands.

5.3 Client Access Frequencies

As mentioned before, many (43 percent) of the existing wireless LANs operating in the 2.4-2.5GHz band are set to channel 6. As a result, the mesh nodes of the city-wide Wi-Fi network should be set to channels that don't conflict with channel 6 (such as channel 1 or channel 11).

5.4 Dynamic RF Channel Selection

The continual proliferation of wireless LANs and other radio frequency equipment throughout the City will introduce additional sources of potential interference in the future. As a result, the use of access points or mesh nodes that dynamically choose the least congested channel may improve the performance of a city Wi-Fi network. Keep in mind that static channels should be chosen, however, if the wireless network will be supporting wireless voice applications. Most Wi-Fi phone specifications recommend using static channels to avoid excessive handset roaming and resulting dropped calls.

5.5 Mounting Assets

The following are mounting asset recommendations for deploying a municipal Wi-Fi wireless network throughout the City:

- **Mesh node installation locations**. The City should mount mesh nodes on the arm of light poles and traffic light poles, with the node as close to the center of the road as possible rather than along the side of the road. This generally maximizes signal propagation. The mounting assets should be clear of trees if possible. In addition, mesh nodes should be installed on mounting assets that are located ideally at street intersections. This makes best use of the mesh node for covering larger areas. If only straight poles (no arms) are available, then it's best to stagger installation of the nodes on poles along both sides of the street. It's important to not use mounting assets for wireless mesh nodes that are higher than the structures surrounding them. This avoids existing wireless LAN signals and RF noise from impacting the operation of the node and the users it supports.

- **Gateway/backhaul installation locations**. The location of gateways and backhaul components should be installed on mounting assets offering unobstructed line of sight with the headend or a relay point. The City has access to several sites, such as water tanks, that can be used to provide a radio relay point between the mesh gateways and the headend of the system. It may also be necessary to erect a tower on top of a centralized building in order to make LOS communications possible with the headend of the system.

Appendix A – Test Team Biographies

The following are biographies of the test team:

James T. Geier

Jim Geier is the founder of Wireless-Nets, Ltd. and the company's principal consultant. His 25 years of experience includes the analysis, design, software development, installation, and support of numerous wireless network-based systems for municipalities, enterprises, airports, homes, retail stores, manufacturing facilities, warehouses, and hospitals worldwide. Jim is the author of several books, including *Deploying Voice over Wireless LANs* (Cisco Press), *Wireless LANs* (SAMS), *Wireless Networks – First Step* (Cisco Press), *Wireless Networking Handbook* (Macmillan), and *Network Reengineering* (McGraw-Hill). He is the author of numerous tutorials for www.Wi-FiPlanet.com and other publications. Jim has been active within the Wi-Fi Alliance, responsible for certifying interoperability of 802.11 (Wi-Fi) wireless LANs. He has also been an active member of the IEEE 802.11 Working Group, responsible for developing international standards for wireless LANs. He served as Chairman of the IEEE Computer Society, Dayton Section, and Chairman of the IEEE International Conference on Wireless LAN Implementation. Jim is an advisory board member of several leading wireless LAN companies. Jim's education includes a bachelor's and master's degree in electrical engineering and a master's degree in business administration. Jim has completed training for various municipal Wi-Fi system solutions focused on designing, installing, testing, and troubleshooting municipal wireless networks.

Eric W. Geier

Eric Geier is a consultant of Wireless-Nets, Ltd., where he performs radio frequency surveys and wireless system testing for clients. He is also founder and President of Sky-Nets, Ltd., a company deploying Wi-Fi hotspots at airports throughout the U.S. Eric is a Certified Wireless Network Administrator (CWNA) and has completed numerous wireless LAN protocol and RF propagation tests as part of the development of the Certified Wireless Analysis Professional (CWAP) Study Guide published by Planet3 Wireless. Eric has developed computer-based training on wireless LAN topics and is the author of several books, including *Wi-Fi Hotspots* (Cisco Press), *Wireless Networks – 5 Minute Fixes* (Wiley) and *PCs – 5 Minute Fixes* (Wiley). Eric has completed training for various municipal Wi-Fi system solutions focused on designing, installing, testing, and troubleshooting municipal wireless networks.

Appendix B – RF Spectrum Scans

The following sections include RF spectrum scans captured in the 2.4-2.5GHz and 5.0-6.0GHz frequency bands at various locations throughout the City.

The spectrum scan images show the following signal values for each specific location:

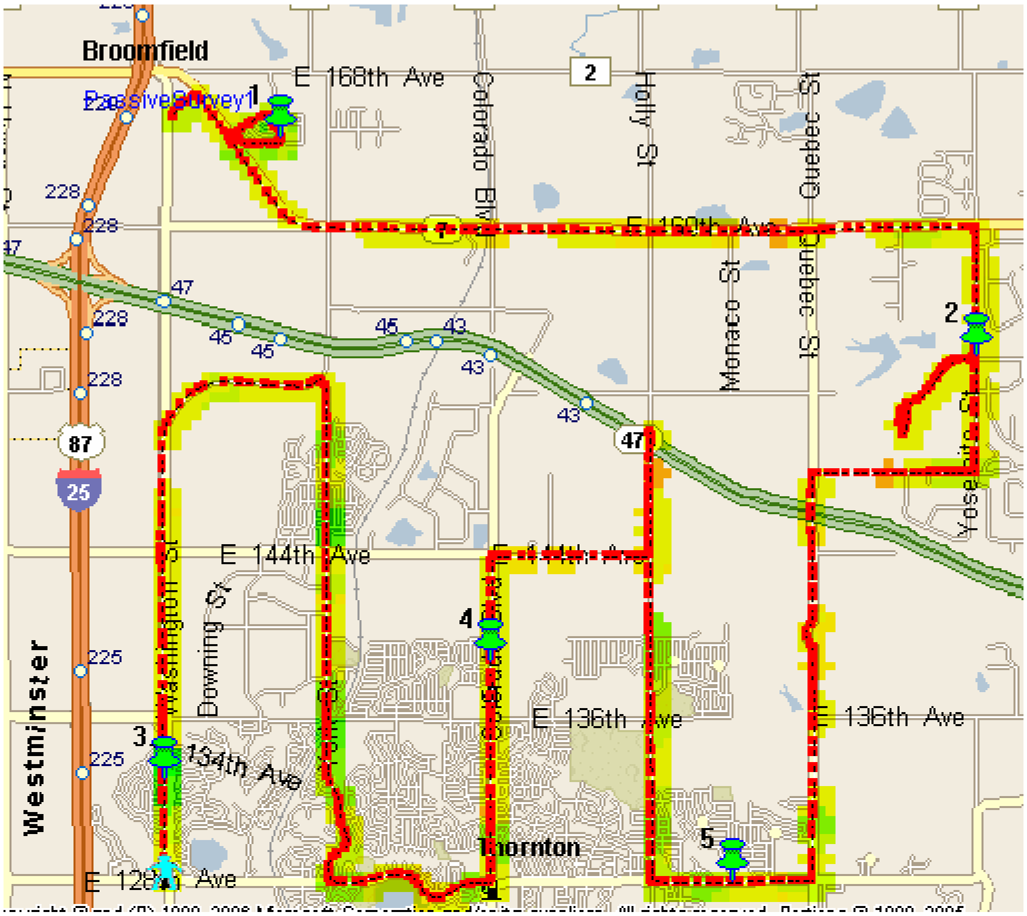
- Average Signal (blue line). This indicates the average signal amplitude captured at a specific location, which is a statistical average of the signals captured during the scan at that location.
- Max Signal (yellow color): This indicates the maximum signal amplitudes captured at a specific location during the scan at that location.
- Max Hold Signal (magenta line): This indicates the maximum signal amplitudes found while the spectrum analyzer was active. As a result, the max hold signal levels may appear the same in some of the spectrum images.

The spectrum scans offer insight into the presence of existing radio signals that may interfere with a city-wide Wi-Fi system. In locations where the average signal value is -100dBm or lower, then there is likely no significant interference. This is the case in nearly all of the spectrum scans. If the average signal value is higher than -100dBm, then interference may have some impact on the performance of a city-wide Wi-Fi system if the max signal levels are higher than -75dBm.

RF Spectrum Scans

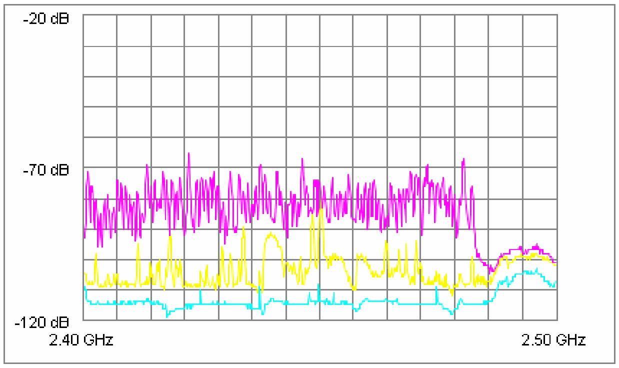
The following maps and spectrum scan images correspond to the spectrum scans:

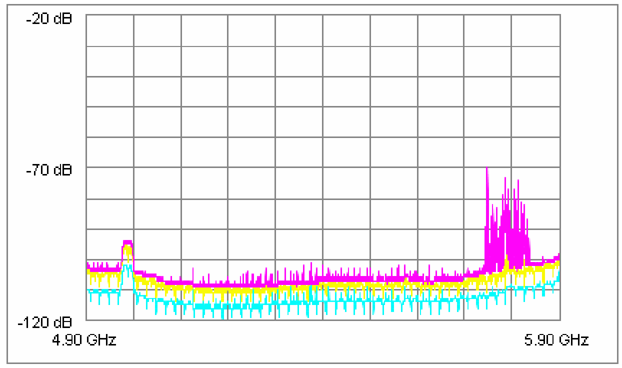
The map below identifies the location of each spectrum image for the northern portion of Thornton:



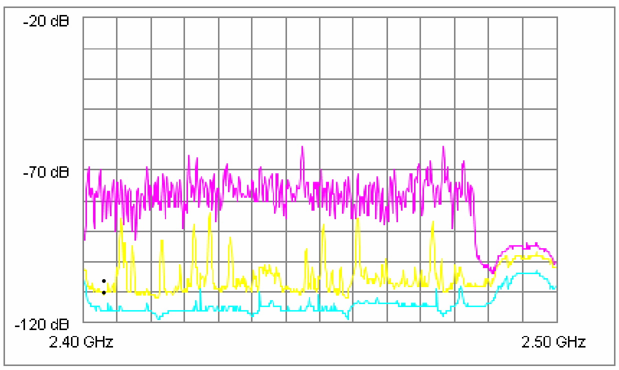
The following are the spectrum images:

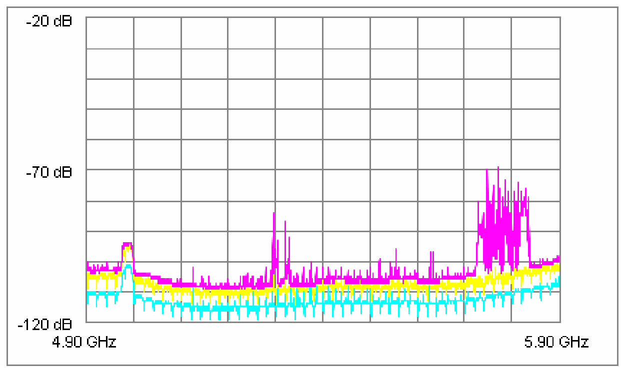
Location 1 – Northern Area



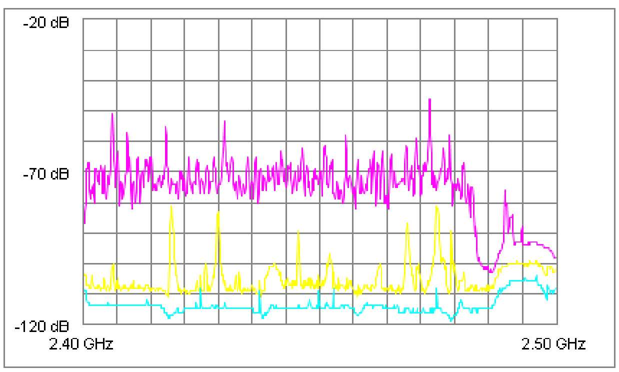


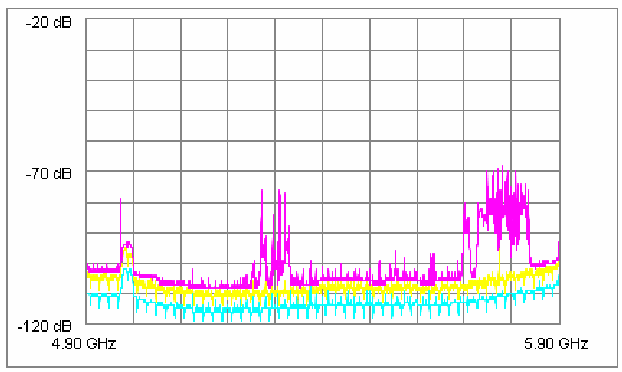
Location 2 – Northern Area



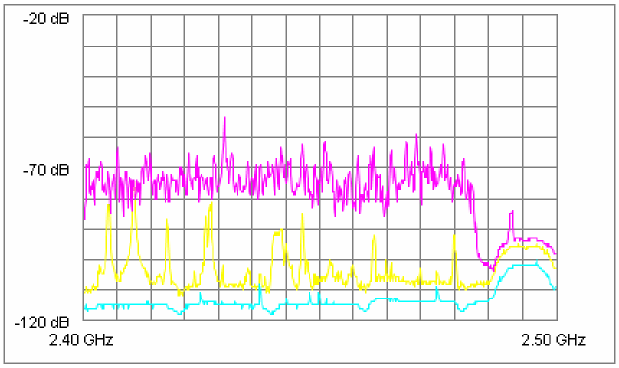


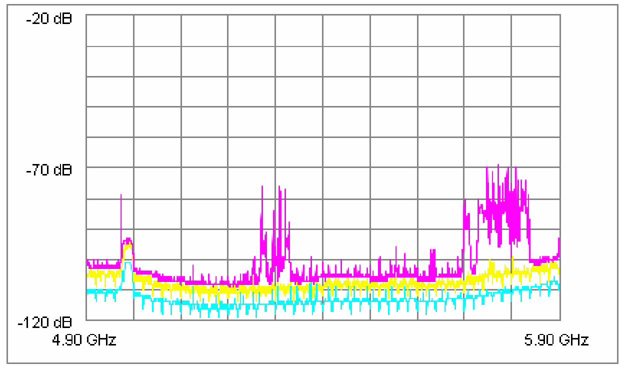
Location 3 – Northern Area



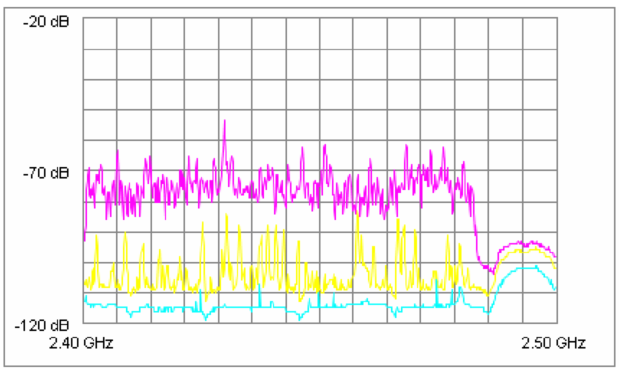


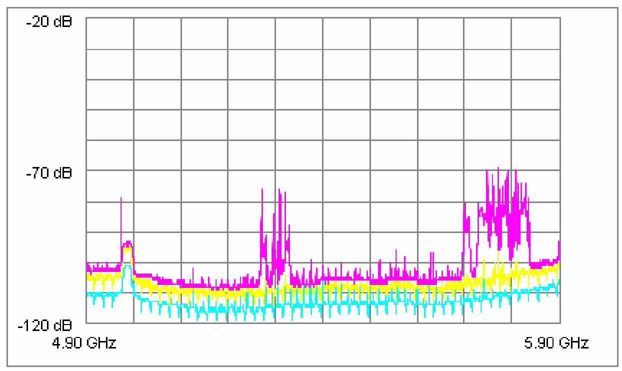
Location 4 – Northern Area



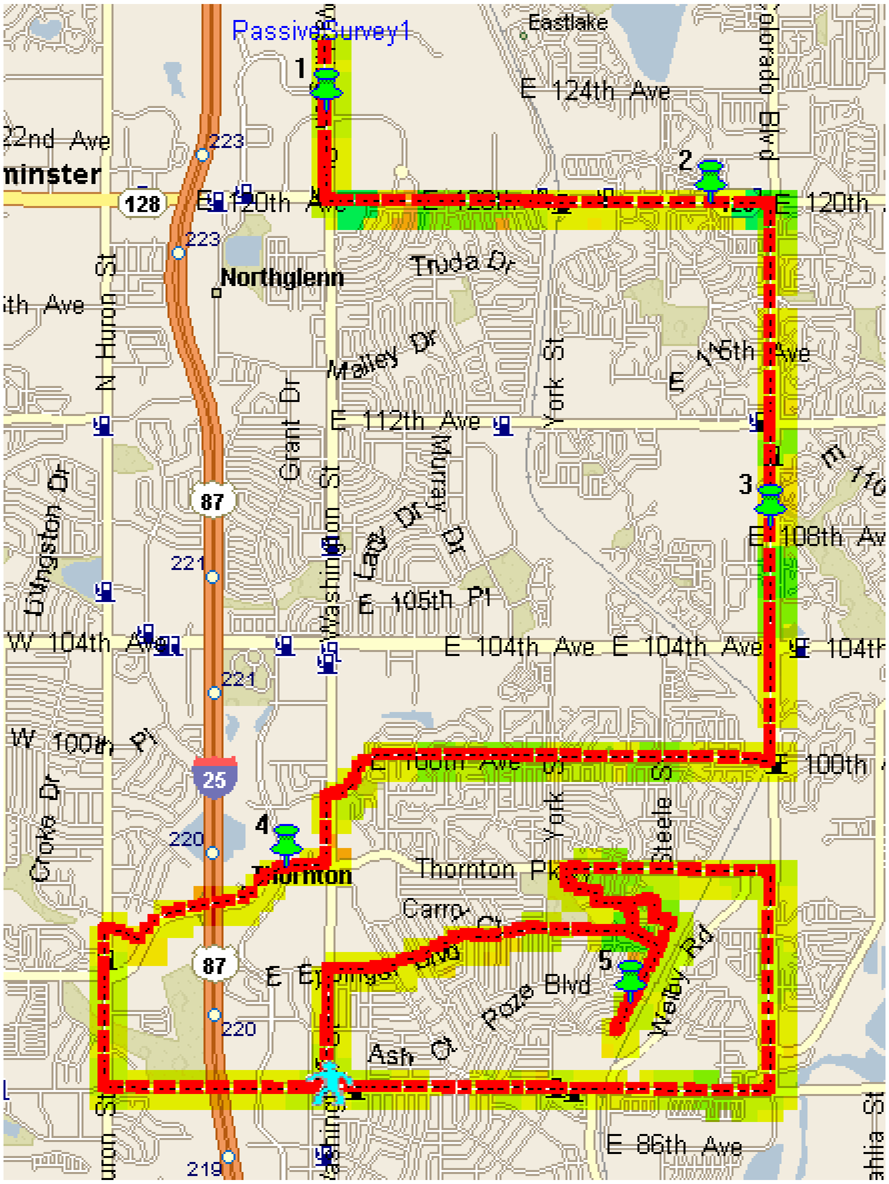


Location 5 – Northern Area



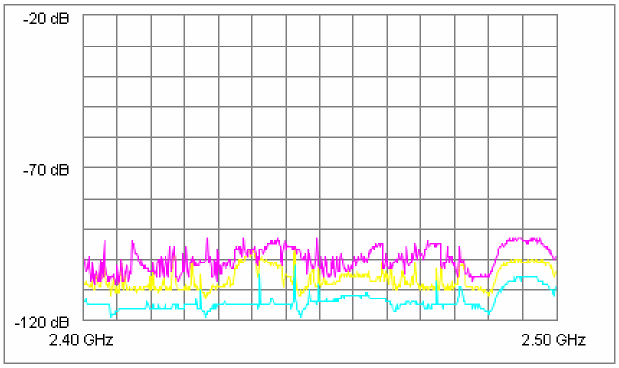


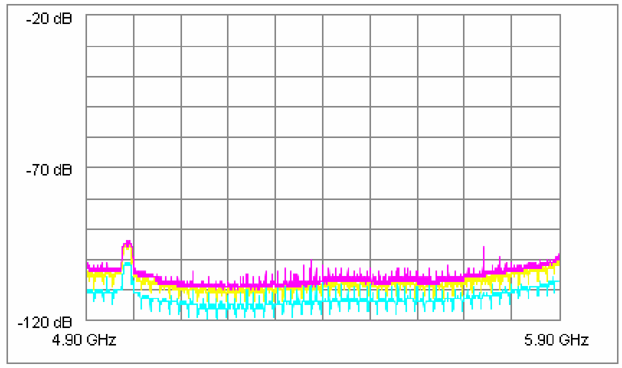
The map below identifies the location of each spectrum image for the southern portion of Thornton:



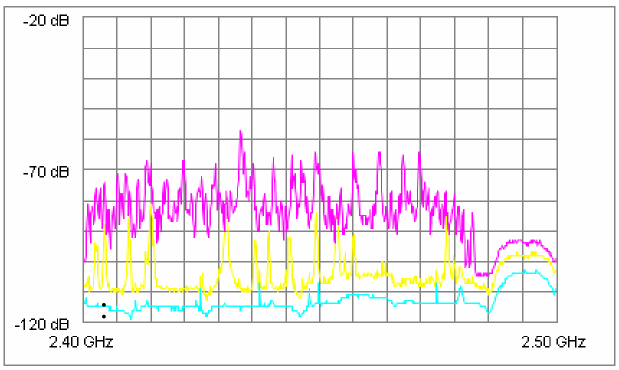
The following are the spectrum images:

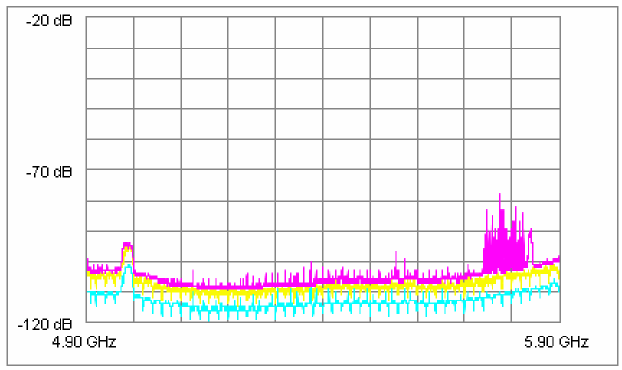
Location 1 – Southern Area



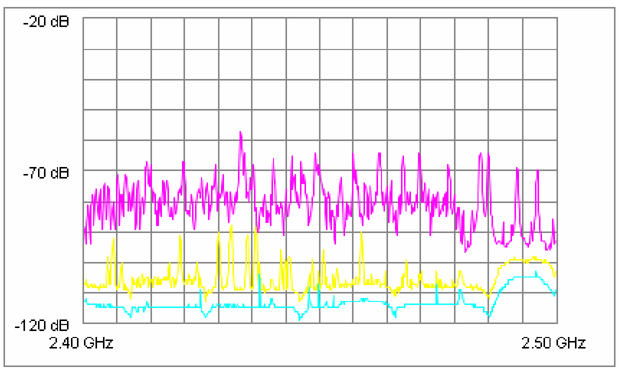


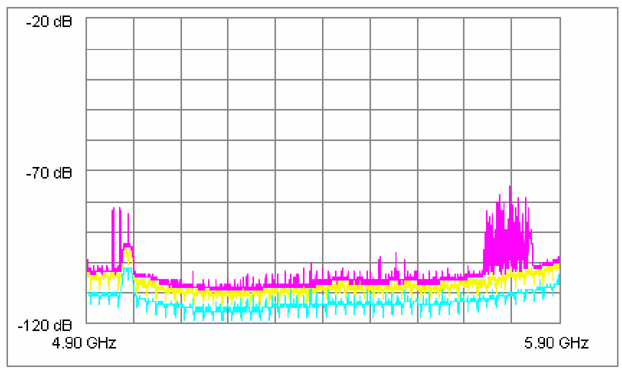
Location 2 – Southern Area



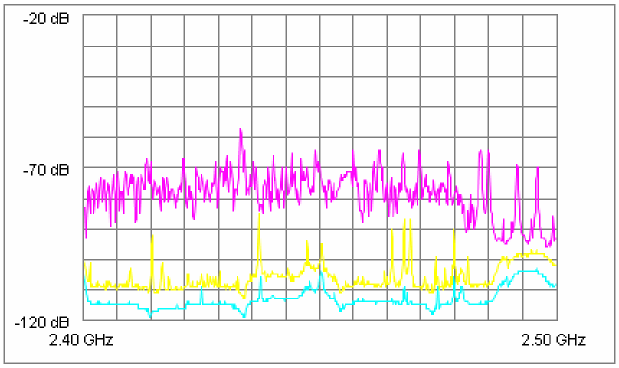


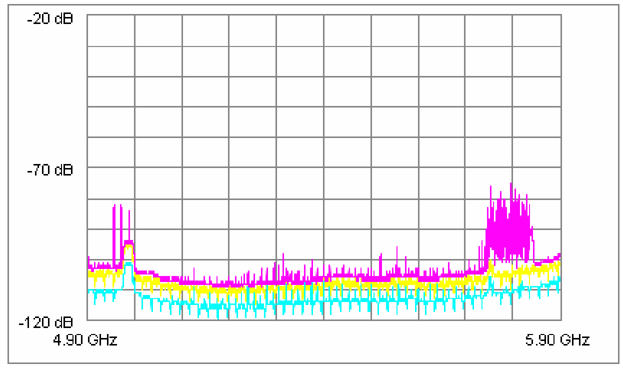
Location 3 – Southern Area



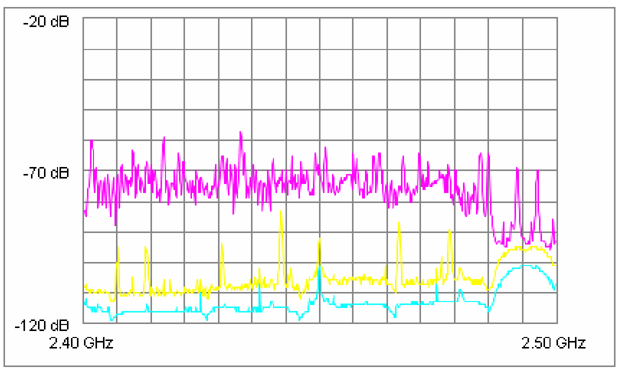


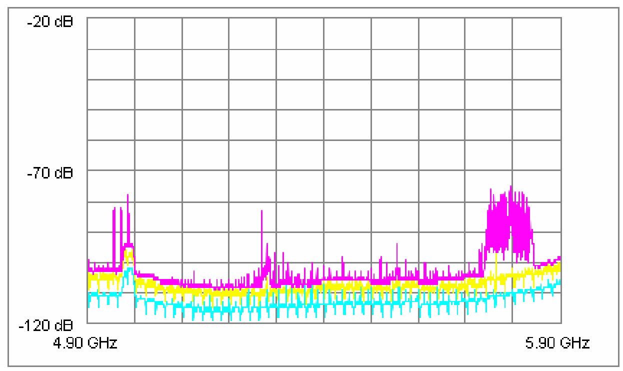
Location 4 – Southern Area





Location 5 – Southern Area





Appendix C – Wireless LAN Scans

The map in Figure C-1 identifies the route driven by the test team when collecting wireless LAN data in the northern portion of Thornton:

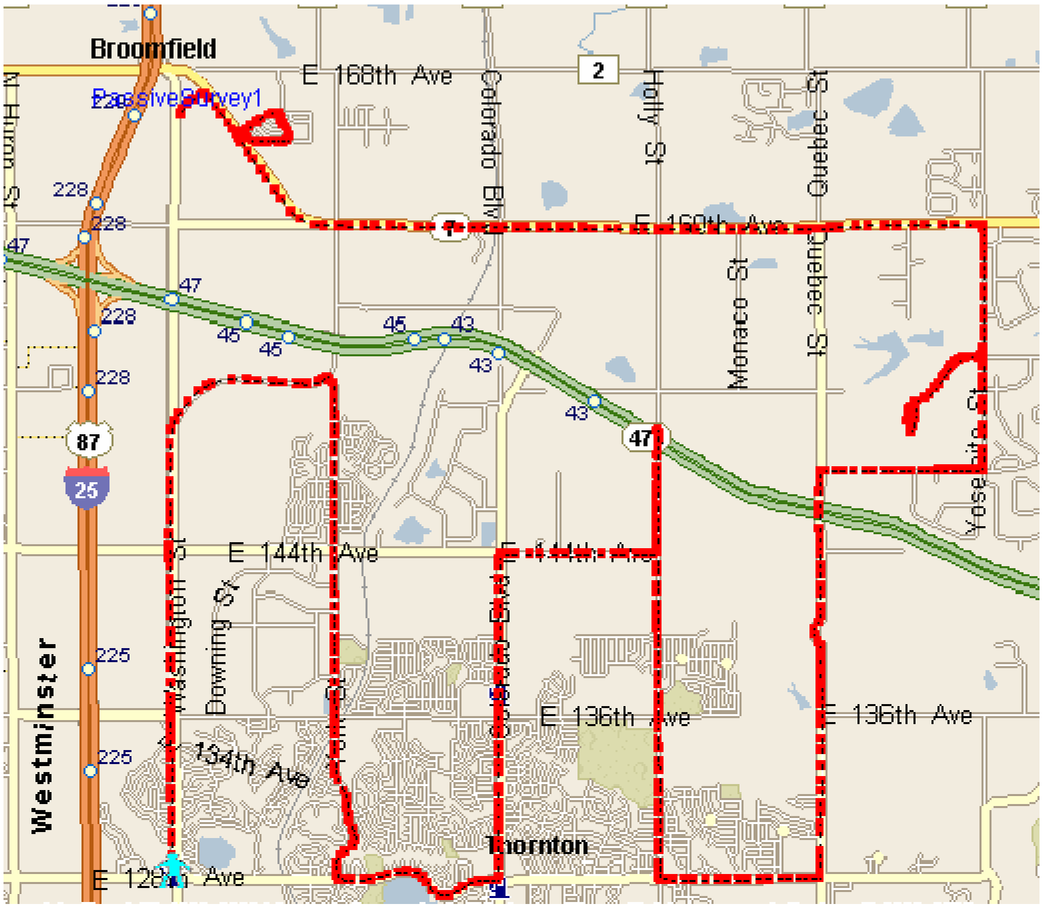


Figure C-1. Route Driven by the Test Team – Northern Thornton

The map shown in Figure C-2 indicates the signal strengths of access points found throughout the test area along the route driven by the test team in the northern portion of Thornton:

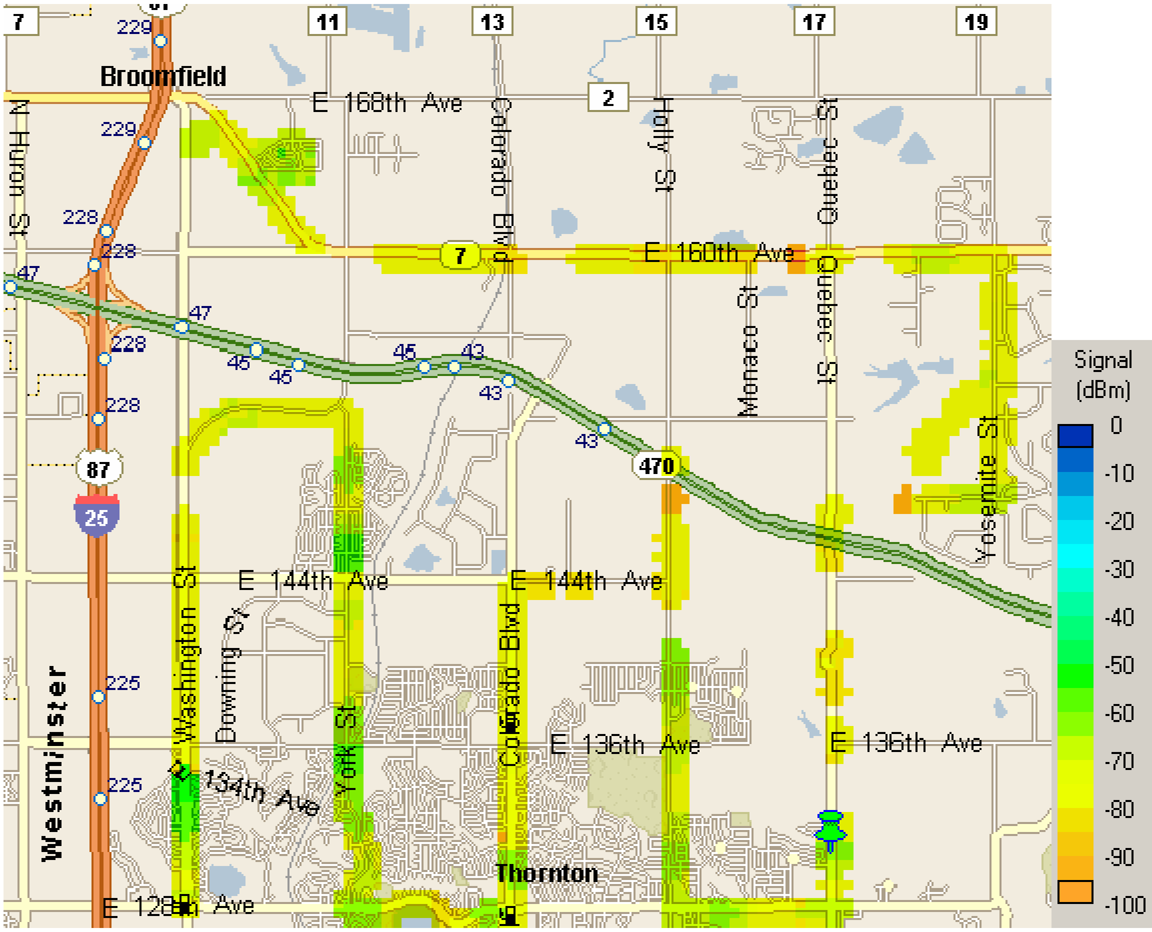


Figure C-2. Signal Strengths of Existing Access Points along the Test Route – Northern Thornton

The map shown in Figure C-3 indicates the average noise levels found throughout the test area along the route driven by the test team in the northern portion of Thornton:

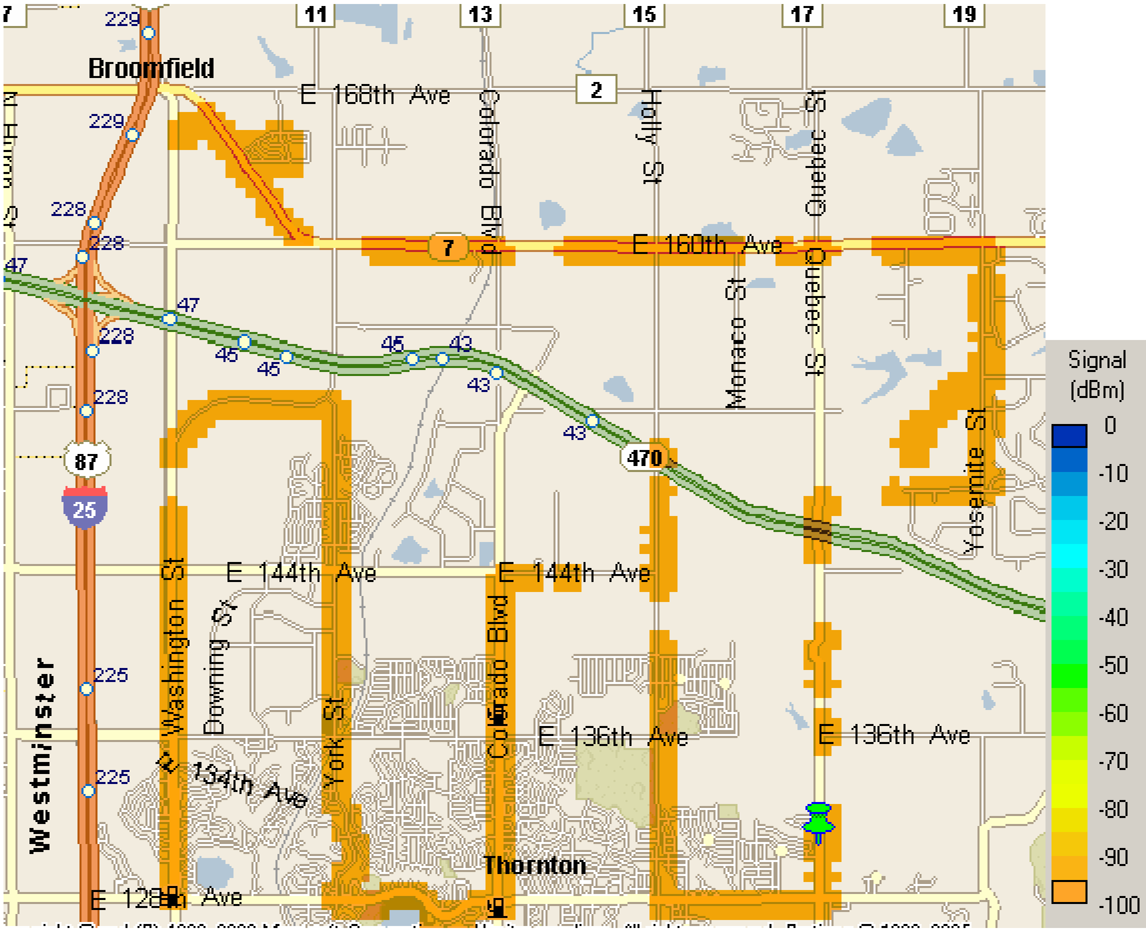


Figure C-3. Average Noise along the Test Route – Northern Thornton

The map in Figure C-4 identifies the route driven by the test team when collecting wireless LAN data in the southern portion of Thornton:

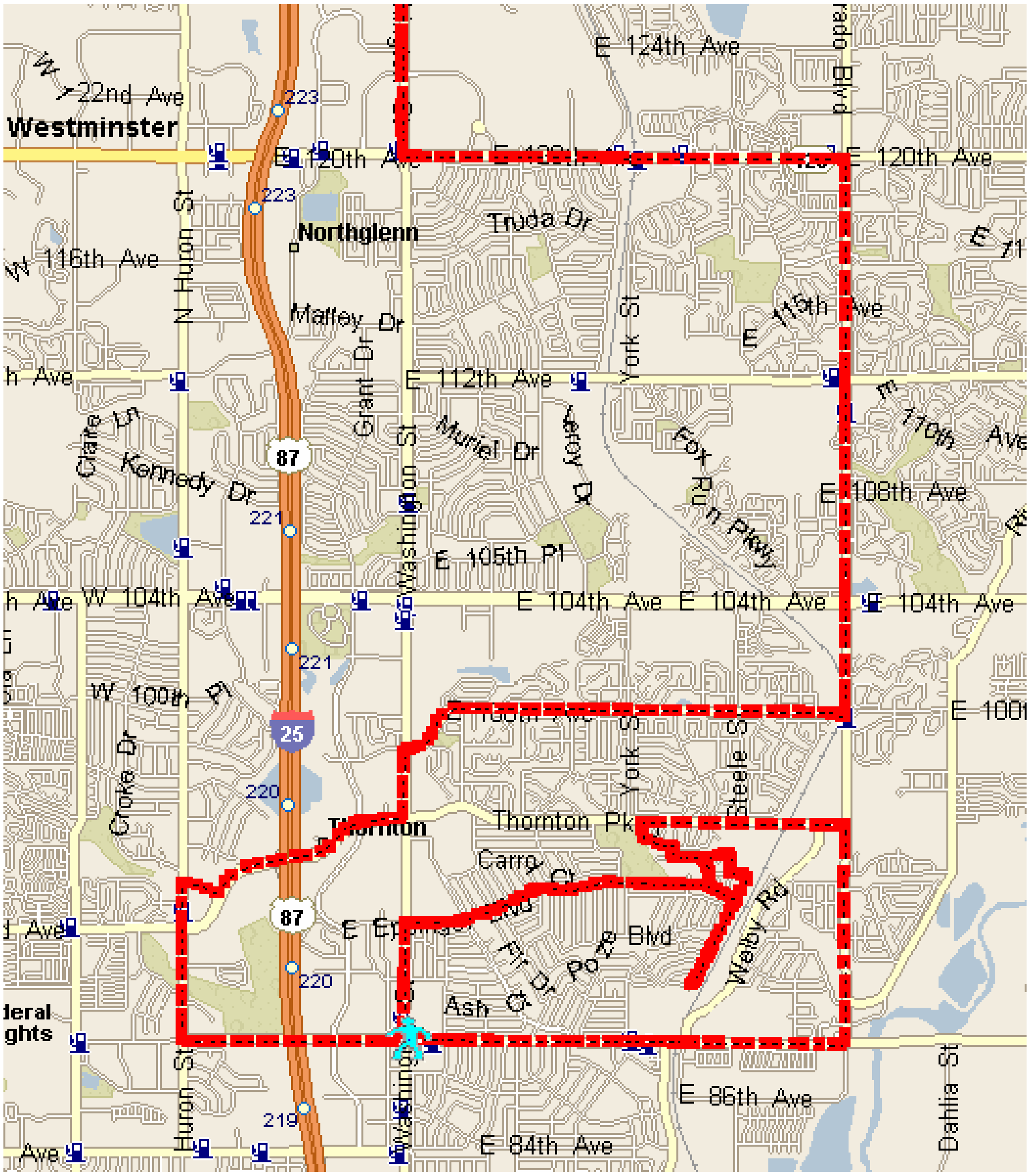


Figure C-4. Route Driven by the Test Team – Southern Thornton

The map shown in Figure C-5 indicates the signal strengths of access points found throughout the test area along the route driven by the test team in the southern portion of Thornton:

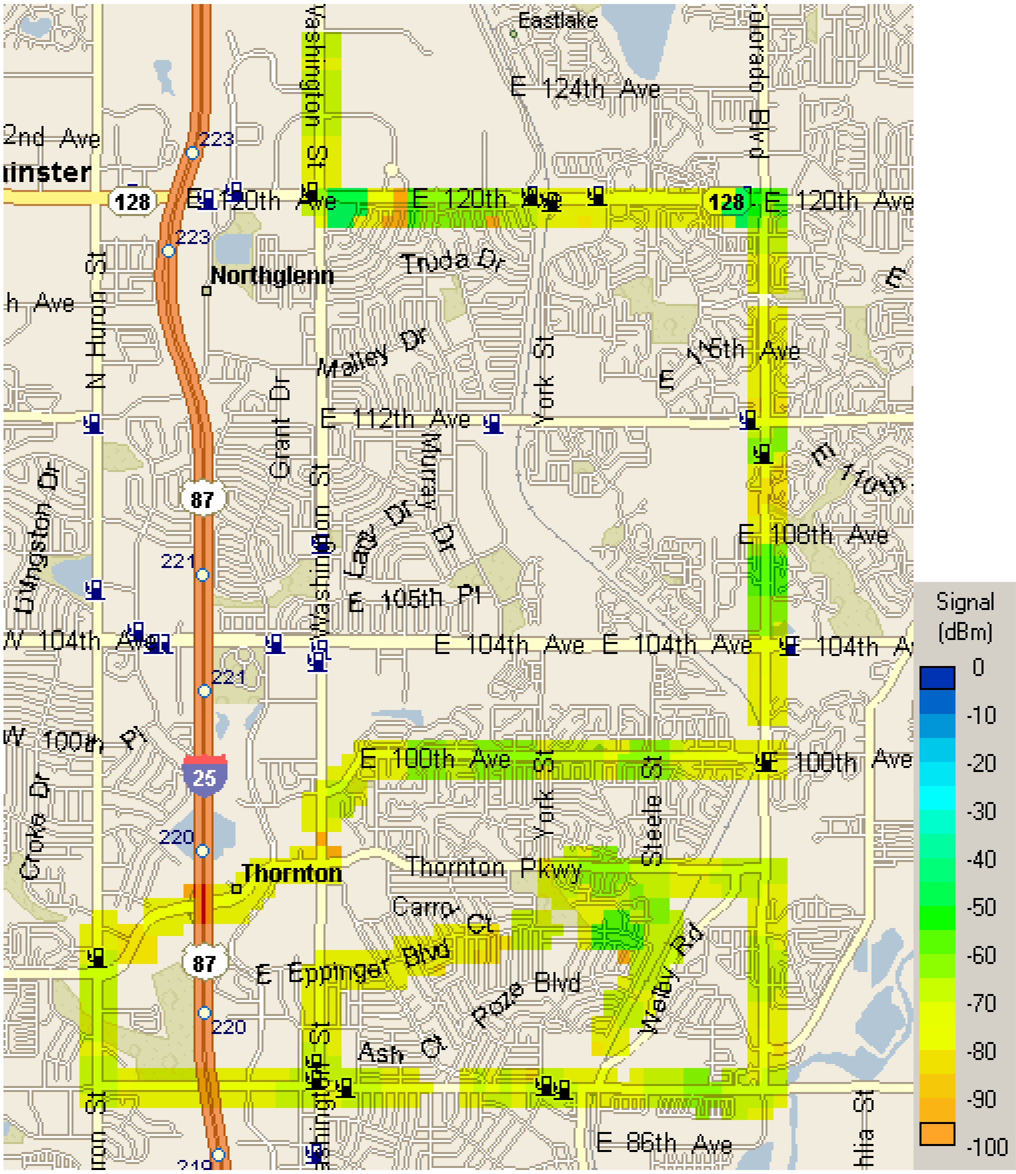


Figure C-5. Signal Strengths of Existing Access Points along the Test Route – Southern Thornton

The map shown in Figure C-6 indicates the average noise levels found throughout the test area along the route driven by the test team in the northern portion of Thornton:

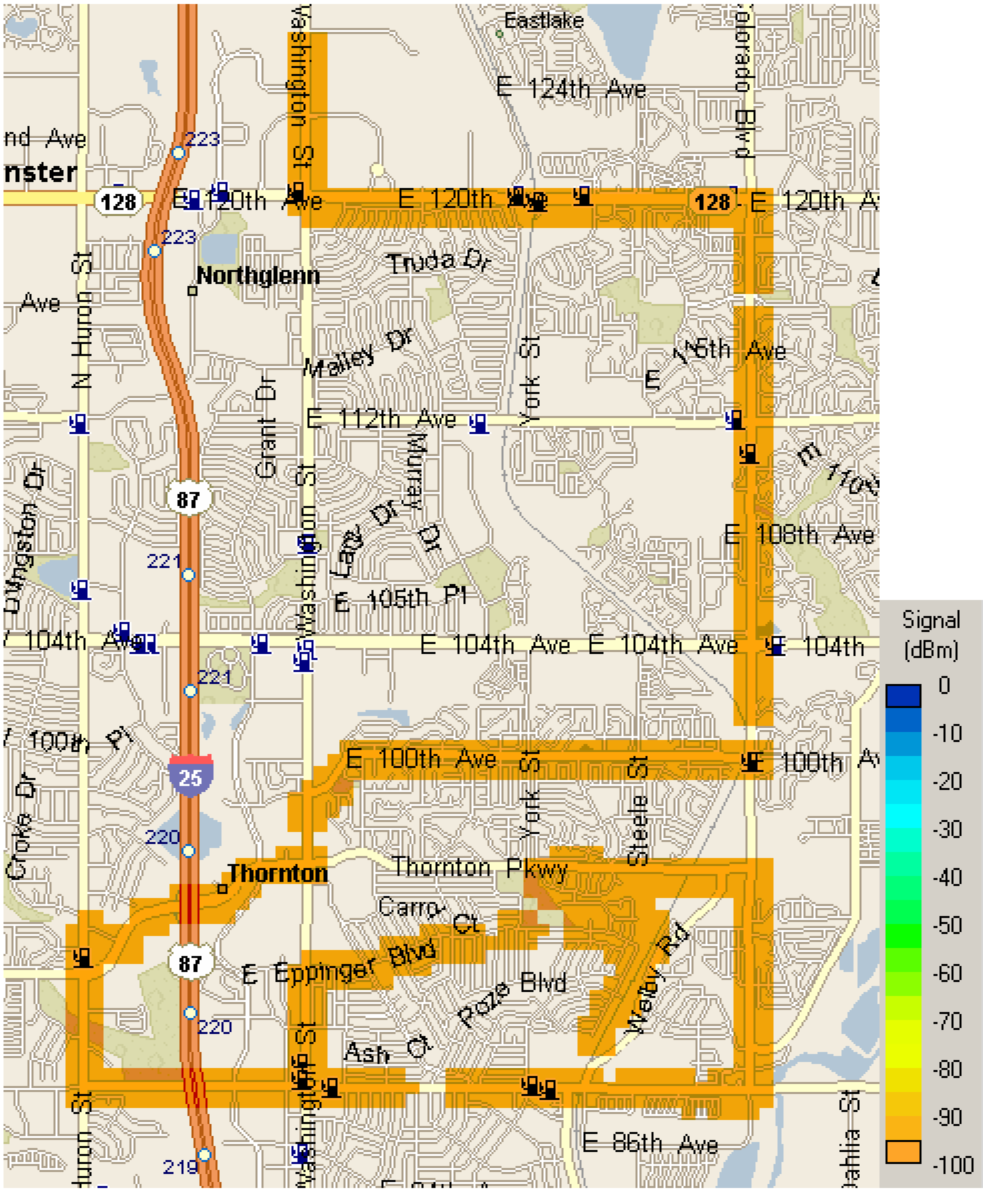


Figure C-6. Average Noise along the Test Route – Southern Thornton