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January 27, 2012

VIA ELECTRONIC FILING

Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: Progeny LMS, LLC
Demonstration of Compliance with Section 90.353(d) of the Commission's Rules
WT Docket No. 11-49

Dear Ms. Dortch:

Progeny LMS, LLC, by its counsel and pursuant to Section 90.353(d) of the Commission's rules, hereby submits its demonstration that its Multilateration Location and Monitoring Service ("M-LMS") network does not cause unacceptable levels of interference to Part 15 devices.[1] Progeny's demonstration was prepared by an independent third party testing firm, Spectrum Management Consulting Inc. ("SMC"), which conducted extensive field tests using a number of Part 15 devices and Progeny's initial M-LMS network deployment in Santa Clara County, California.[2]

The Commission recently granted Progeny two waivers of the Commission's rules permitting Progeny to construct an M-LMS network that the Commission acknowledged "offers the potential for significantly improved location based services" and also "takes the goal of minimizing interference to other users into account."[3] The Commission elaborated in its order on Progeny's obligations pursuant to Section 90.353(d), explaining that, once it has completed

[1] *See* 47 C.F.R. § 90.353(d).

[2] Progeny's initial M-LMS network deployment was constructed and is operated by Progeny's sister company, Commlabs, Inc., pursuant to FCC experimental license call sign WF2XLW and is consistent with the network architecture that will be used throughout the United States.

[3] Request by Progeny LMS, LLC for Waiver of Certain Multilateration Location and Monitoring Service Rules, *Order*, DA 11-2036, ¶¶ 18 and 26 (Dec. 20, 2011) ("*Waiver Order*") (granting conditional waivers of Sections 90.155(e) and 90.353(g) of the Commission's rules).

the design of its M-LMS system but prior to commencing commercial operations, Progeny shall file a report that:

- provides details on its M-LMS system design (*e.g.*, proposed transmit bandwidth, power levels and power controls, duty cycle, sharing techniques, etc.), and

- describes the process by which it carried out field testing, including the particular types of Part 15 devices tested, and demonstrates that its M-LMS system will not cause unacceptable levels of interference to Part 15 devices that operate in the 902-928 MHz band.[4]

Progeny's report providing the details of its M-LMS system design is included as Attachment 1 to this letter. Progeny's report on the field tests conducted by SMC and the resulting demonstration is included as Attachment 2 to this letter.

As indicated in Attachment 2, not only does Progeny's M-LMS network refrain from causing unacceptable interference to Part 15 devices, but, in the vast majority of cases, Part 15 devices are unable to detect the signals from Progeny's M-LMS network. The absence of interference to Part 15 devices results from a number of factors.

First, many Part 15 devices employ automatic frequency selection capabilities, which prompt the device to switch channels in order to identify a channel that is not being used by other nearby Part 15 devices. This capability causes Part 15 devices to switch to a channel that is not being used for M-LMS transmissions in those limited cases in which a Part 15 device is able to detect the M-LMS signal on a channel. Those Part 15 devices that include manual, user-control channel selection capabilities also enable users to avoid M-LMS signals that are detected by switching to another channel.

Second, an increasing number of Part 15 devices include frequency hopping technology that, pursuant to Commission rules, employs a very short dwell time on any particular channel. When considered together with the low duty cycle of Progeny's M-LMS service, such Part 15 devices are statistically highly unlikely to operate on the same channel at the same time as the M-LMS transmission and, even if they did, any potential impact on the Part 15 signal would be isolated and brief.

Third, when Part 15 devices are forced to operate on the same channel as the M-LMS transmission, nearly all of the Part 15 devices that SMC could test in this manner (some could not be forced) still could not detect the M-LMS signal in most typical test scenarios (*i.e.*, at least 50 feet from an M-LMS base station). When the Part 15 devices were placed unusually close to an M-LMS base station (within 50 feet) and forced to operate on the same channel, some of the Part 15 devices still could not detect the M-LMS transmission.

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[4] *Id*, ¶ 29.

Fourth, in nearly all cases in which a Part 15 device was able to detect an M-LMS transmission, the signal of only one M-LMS base station was detected, resulting in a brief “shh” or “beep” sound at one second intervals (corresponding with the very low duty cycle of Progeny’s service, discussed below). Despite the presence in some cases of an M-LMS signal artifact, the Part 15 device continued to operate, sending and receiving desired signals, and the ability to recognize speech was unchanged by the beacon signal. Further, moving the Part 15 transmitter and receiver closer together diminished or eliminated the M-LMS signal artifact.

Similar findings resulted from the testing of Part 15 devices utilized in commercial, industrial, and utility applications. SMC found that the M-LMS transmission had no material impact on their operation. When the M-LMS signal was present, these Part 15 devices continued to transmit the desired data over distances consistent with what could otherwise be achieved when an M-LMS signal was not present. The results of the SMC study demonstrate that Progeny’s M-LMS network does not cause unacceptable levels of interference to Part 15 devices and therefore Progeny’s service can co-exist with Part 15 equipment.

The test results documented by SMC provide further evidence that Progeny has engaged in significant efforts to minimize the potential for interference to other users of the 902-928 MHz band. Progeny is employing a number of spectrum sharing techniques that enhance the capability of its service to co-exist with Part 15 devices. Specifically identified measures include:

- Refraining from using return path transmissions from user devices,
- Employing a very low bit data rate stream,
- Minimizing the necessary base station density, and
- Employing a maximum duty cycle of 20 percent.

Perhaps the most significant of the above-identified measures to minimize interference to Part 15 devices is Progeny’s use of handset-based location technology to eliminate the return transmissions from mobile terminals using Progeny’s M-LMS service. As the Commission recognized when it created M-LMS, “reverse link transmissions could present significant problems to Part 15 operations depending on the power levels, duty cycles and density of mobile units.”[5] The interference potential from return path transmissions is heightened by the fact that M-LMS user terminals are mobile and ubiquitously deployed, potentially operating immediately adjacent to Part 15 receivers. By eliminating these return transmissions, Progeny has resolved the single greatest source of potential interference to Part 15 devices.

Another measure Progeny has employed that minimizes the potential for interference to Part 15 devices is the use of a very low bit rate, which results in higher processing gain, enabling reception at greater distances and indoors without the need for additional transmitters. Progeny therefore can employ fewer base stations than would be needed in a normal M-LMS network.

[5] Amendment of Part 90 of the Commission’s Rules to Adopt Regulations for Automatic Vehicle Monitoring Systems, *Report and Order*, 10 FCC Rcd 4695, ¶ 77 (1995).

Two other characteristics of Progeny's network have also reduced the number of base stations that will be needed. First, Progeny's M-LMS base stations each transmit a common broadcast signal to all mobile devices, rather than a unique communication to each device. This eliminates the need for additional base stations to increase capacity as the number of users increases. Second, Progeny's elimination of return link transmissions from mobile devices alleviates the need for sufficient base station density to receive the relatively weak return signals from mobile units. Each of these factors contributes to a reduction in M-LMS base station locations as compared to a normal M-LMS network.

An additional measure that Progeny has employed to enhance co-existence with Part 15 devices is the use of a transmitter duty cycle of no more than 20 percent. Because of this low duty cycle, a Part 15 device that detects the signal from an M-LMS base station experiences only the addition of a brief M-LMS signal artifact in its audio or data transmission stream, which does not impair the ability of the Part 15 device to continue to transmit and receive its desired signals.

When all of these elements are considered together, Progeny's M-LMS network provides an optimal co-existence opportunity for the 902-928 MHz band. Progeny's M-LMS signals are not detected by most Part 15 devices operating in typical operating conditions. Even in those limited cases when Progeny's service is detected, the M-LMS signal artifact does not impede the ability of the Part 15 device to transmit voice or data communications.

As the Commission has recognized, Progeny's M-LMS service offers the potential to provide "highly accurate location determinations, including more precise location information that can improve delivery of E911 emergency services."[6] In light of the "substantial public interest benefits" of Progeny's M-LMS service,[7] Progeny urges the Commission to help make its position location service expeditiously available to the public by promptly concluding that Progeny may commence commercial operations.[8]

Sincerely,

Bruce A. Olcott
Counsel to Progeny LMS, LLC

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[6] *Waiver Order*, ¶ 1.

[7] *Id.*, ¶ 19.

[8] *See id.*, ¶ 29.

ATTACHMENT 1

Wide Area Positioning System Network Description

Wide Area Positioning System

Network Description

NextNav Holdings LLC, through its wholly-owned subsidiaries Progeny LMS, LLC and NextNav LLC (together, "NextNav"), is deploying a wide-area positioning system ("WAPS") to provide high-precision location services in areas where the Global Positioning System ("GPS") does not work reliably, particularly indoors and in urban canyons. The GPS system is satellite-based with low signal strength at the Earth's surface, resulting in relatively low accuracy and yield in urban and indoor environments. Rather than surround the Earth with satellites, NextNav transmitters (beacons) surround a given market, using spectrum allocated to the Multilateration Location and Monitoring Service ("M-LMS") in the 902-928 MHz band. These characteristics provide wide-area network coverage and significantly more link margin for urban service and building penetration.

Overview

The NextNav system consists of a number of beacons that, like GPS, transmit a signal to a receiver in a car, portable device or suitably equipped cell phone. The signals from each beacon include such information as the beacon's location and other local information. The receiver measures the time difference of arrival ("TDOA") from three or more beacons and applies the laws of trigonometry to determine its position.[1]

The NextNav system does not have a return link from the receiver to a beacon. If a receiver needs to send its position information to another location, it uses a communications network such as Wi-Fi or cellular and a protocol such as Secure User-Plane Location ("SUPL") for this purpose.

Operating the NextNav system in this "broadcast mode," reduces interference to other users in the 902-928 MHz band. In addition, each NextNav beacon transmits no more than 200 milliseconds during each second. This 20 percent duty cycle further reduces the potential for interference to other spectrum users.

Each beacon also transmits its local barometric pressure. This information allows devices equipped with pressure sensors to compute their height very accurately. In many indoor environments, this is sufficient to estimate the floor where a receiver is located.

Network

Figure 1 illustrates the NextNav network concept. NextNav's beacons transmit at up to 30 watts ERP per channel and are preferably placed at the highest available points on existing broadcast, paging or cellular towers. NextNav is deploying its system primarily using omnidirectional antennas to cover as much area as possible with as few sites as possible. This contrasts with

[1] Time-difference-of-arrival techniques allow the receiver to estimate the distance from a given transmitter using the difference in time between the reception of two signals. Combining multiple differences allows a receiver to perform a multilateration or trilateration calculation.

cellular and other two-way systems that seek to transmit and receive as much energy as possible into a given area without causing self-interference. Because NextNav operates a broadcast-only network, it will not require additional sites to increase capacity as the number of users increases.

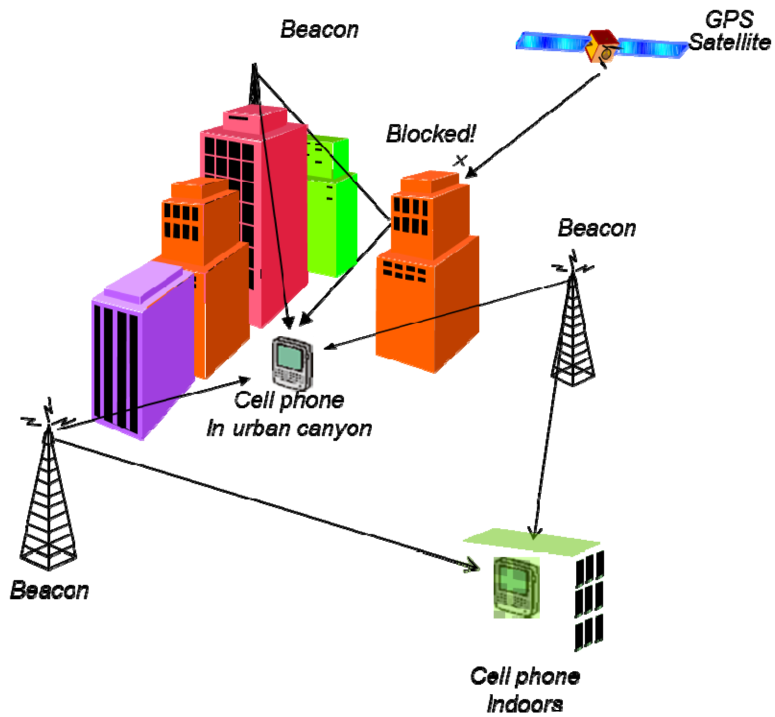

Figure 1

Beacon Transmitter

NextNav has completed certification and compliance testing for its beacon transmitters and is currently awaiting final FCC type approval for the equipment from NTS Corporation. Figure 2 illustrates the NextNav signal and the relevant emissions mask in which it must fit.

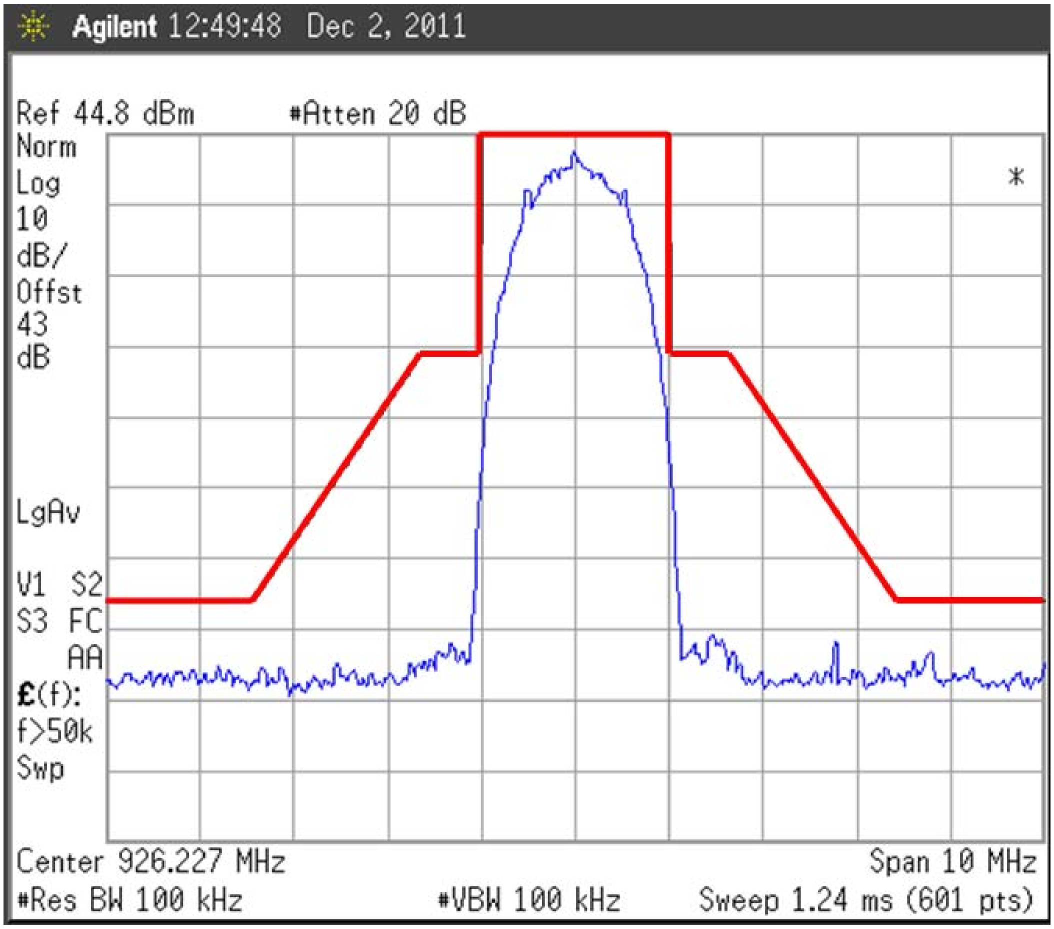

Figure 2

As shown, NextNav exceeds the out-of-band emissions requirement of -66 dBc at the upper band edge by approximately 15 dB, and achieves this result at approximately 0.5 MHz from band edge. The signal itself is required to meet a stability requirement of 2.5 ppm. In testing this figure was found to be -0.4 ppm, significantly exceeding the established standard. Figure 3 is a block diagram summarizing NextNav's beacon design.

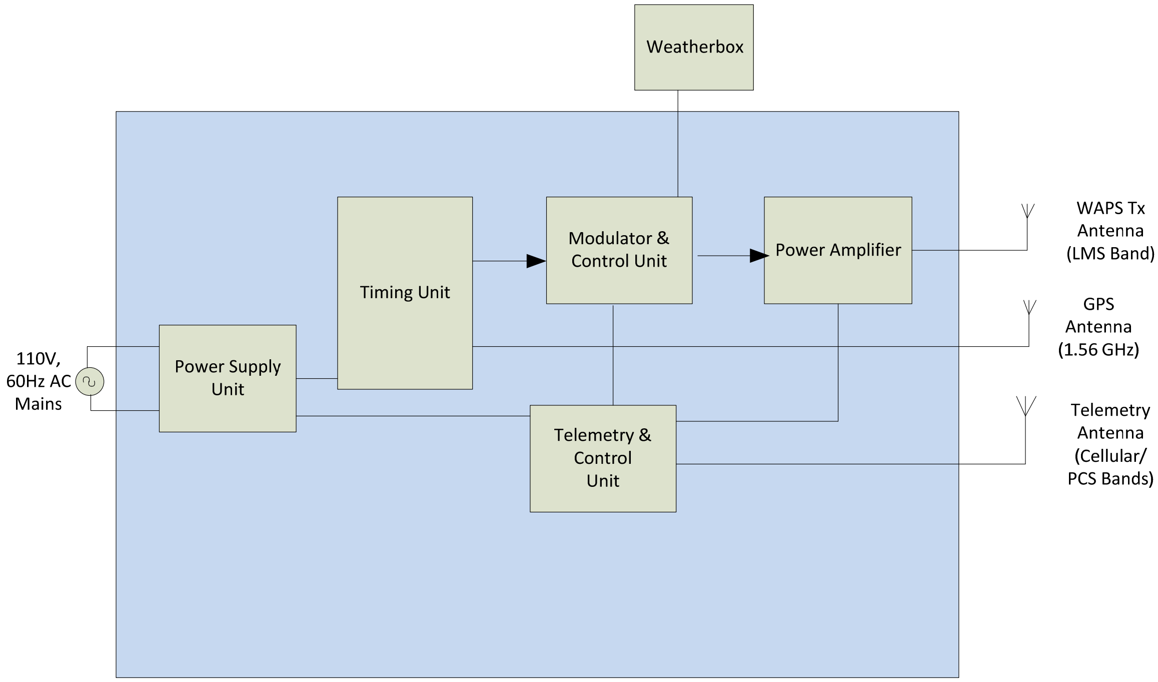

Figure 3

The core of the NextNav transmitter is its timing synchronization system. NextNav primarily relies on GPS for the coarse timing synchronization across its transmitters, although we are developing the capability for the network to self-synchronize in order to maintain the availability of the WAPS service in the absence of GPS. NextNav also uses proprietary techniques to ensure that its transmitters are synchronized to within nanoseconds of each other.

In addition to timing data, the transmitters collect barometric pressure and other relevant weather data and include this information in the data transmission. The system is designed to be run on standard 110/120 V, 60 Hz power. The system is monitored, and can be actively managed either through a wireless modem or POTS telephone line connected to NextNav's network operating center ("NOC").

Beacon Signal

The NextNav beacon signal is designed to replicate the GPS signal as much as possible, employing a low-data-rate, spread spectrum signal modulated across an identical bandwidth, and delivered in a broadcast manner. The similarity to GPS contributes to NextNav's higher receive sensitivity, which in turn permits the construction and operation of a network that utilizes lower-power and lower-site density than typical cellular systems. The broadcast architecture also reduces power consumption at the receivers (since they do not need to transmit in the return path) and minimizes interference to other users.

The spread-spectrum signal uses Gold codes at a 1.023 Mcps chipping rate, resulting in a 2.046 MHz null-to-null channel bandwidth. This is identical to GPS and minimizes the cost and effort required to implement NextNav's technology on a GPS chipset and subsequently a cellular, automotive or other consumer electronics devices.

NextNav's network uses two identical signals, one with a center frequency at 926.227 MHz and one with a center frequency at 920.773 MHz. Using two channels provides frequency diversity, enabling a more robust service. The NextNav signal is divided into 100ms time slots and each transmitter will use up to two slots in any given second. The time slots used by a transmitter may be contiguous, resulting in a 200 millisecond transmission, or discontinuous, resulting in two 100 millisecond transmissions. Figure 4 below illustrates this technique.

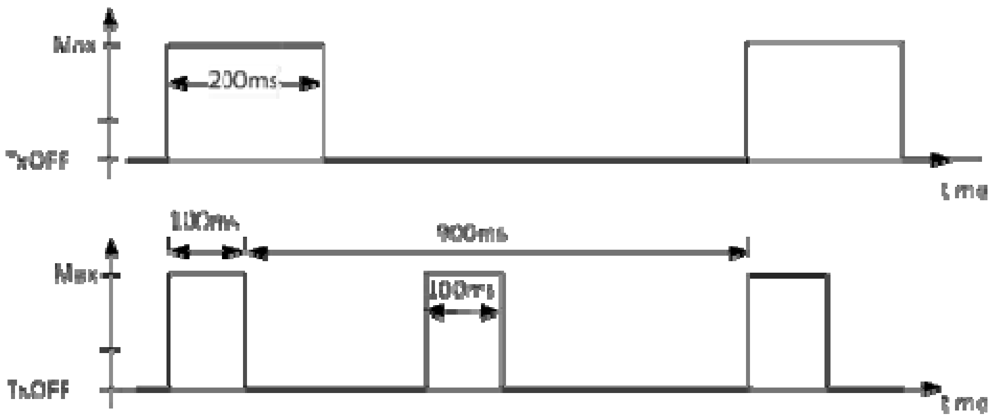

Figure 4

As noted above, the NextNav's beacons broadcast all of the necessary information for handset-based ranging and positioning of the receiver. NextNav transmits this information at 50 bits per second, using a BPSK modulation scheme. This further commonality with GPS results in similarly high receiver sensitivity, typically –120dBm in a handheld device implementation. Table 1 provides an overview of the link budget. Details of the receiver design vary depending on the application, *i.e.*, vehicular, cellular, or other portable device.

Table 1

Description	Units	Value
Transmit PA Power	W	10
Loss from PA to antenna	dB	4.2
Transmit Antenna gain	dBd	8.9
Transmit Power ERP	W	30
Receive sensitivity at chipset input	dBm	-128
Antenna, and Filter losses + LNA Noise Figure	dB	-8
Receive sensitivity at antenna input	dBm	-120
Allowed link loss	dB	165

Network Architecture

Unlike cellular networks, which are optimized for coverage and capacity, and tend to "fill" a given location with transmitters, the NextNav system is optimized for location identification. An optimal network configuration would tend to "surround" a service area to maximize the geometric diversity of the received signals, resulting in a more precise location computation.[2] This is done using a location metric called "GDOP", or geometric dilution of precision. The GDOP of a location effectively measures how evenly it is surrounded by beacons. In urban areas and in locations of heavy use, these surrounding beacons may be supplemented by additional beacons positioned on tall structures overlooking the urban core to produce increased yield and accuracy.

Pursuant to the Commission's rules for M-LMS, multilateration takes place when a mobile device is able to receive the signals from three or more M-LMS transmitters. Position accuracy is increased further when four or more beacons are visible to the receiver. For this reason, NextNav ensured that all of the locations used for the Part 15 tests were able to receive signals from at least four beacons with a GDOP calculation of 2 or lower.[3] Once GDOP and coverage requirements have been satisfied, each transmitter is sited and carefully surveyed to establish its exact latitude, longitude and altitude, and the altitude at which pressure measurements are being recorded is likewise surveyed.

NextNav's network configuration in Santa Clara County, where Progeny's Part 15 tests were conducted, is representative of a commercial network installation. Figure 5 depicts this coverage for Santa Clara County with the transmitters identified by red (numbered) points and the test locations identified by yellow (lettered) points. The different background colors indicate the overall quality of the position fix available based on GDOP calculations. The areas depicted in blue, green, and yellow have a GDOP of two or less and therefore provide sufficient beacon coverage for a reliable and accurate position fix. The orange and red areas indicate areas where the position fix may be compromised. The GDOP calculations were conducted using beacon transmitters that were projected to have sufficient signal strength to provide service in suburban buildings as well as in vehicles in the covered area.

[2] Although beyond the scope of this paper, NextNav has also developed sophisticated proprietary algorithms to mitigate the effects of multi-path on its range estimates.

[3] The precision of a three-transmitter solution is limited by the accuracy of the clock on the receiver. A four-transmitter solution can estimate clock error, permitting a more precise position estimate.

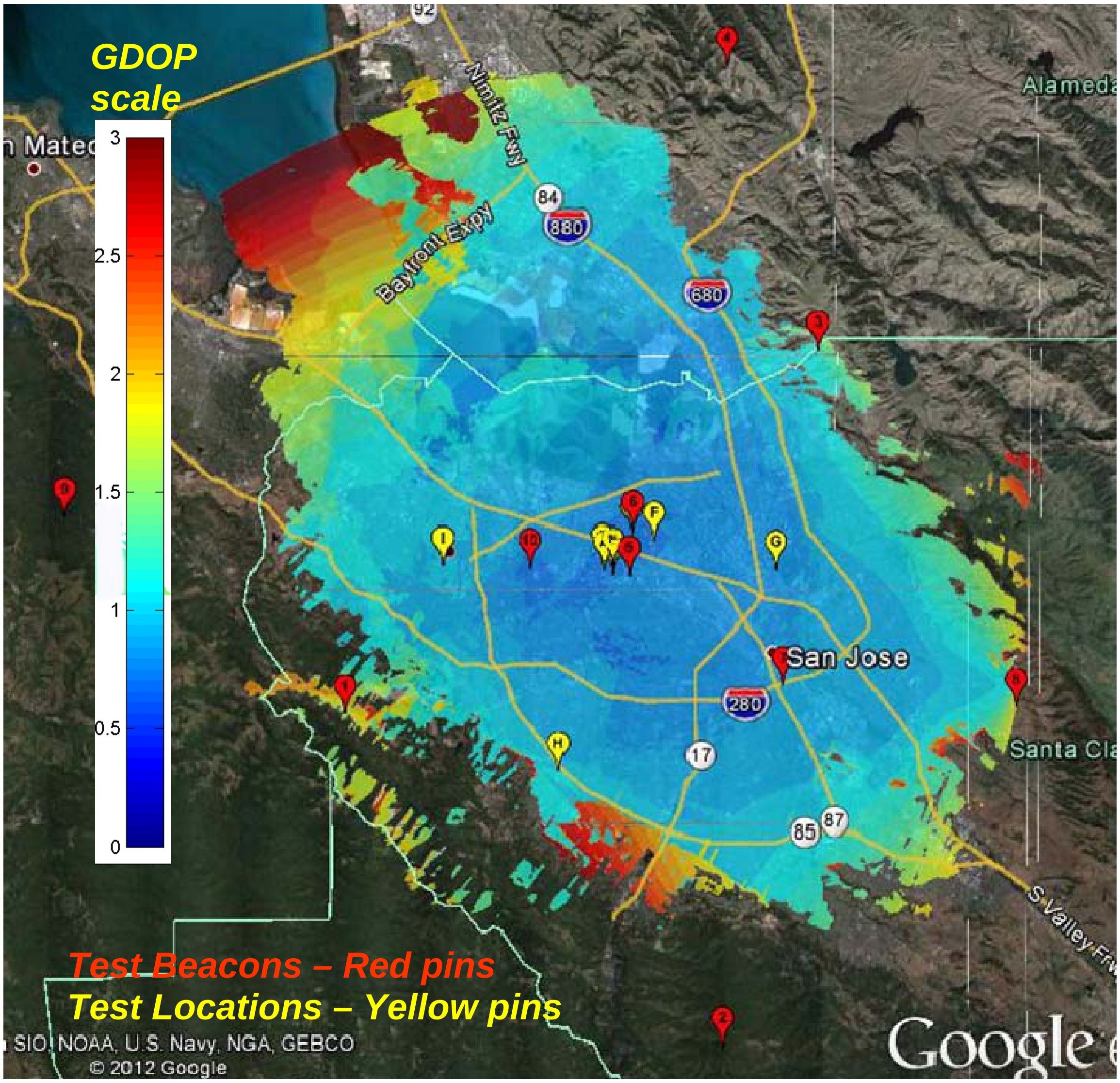

Figure 5

Interference Mitigation

Although Progeny's M-LMS license permits two-way operations, NextNav is not conducting reverse-link operations in its broadcast deployment. The technical choice to implement a GPS-like broadcast system, rather than a two-way system, will result in significantly fewer transmission sources within a given service area.

NextNav is also refraining from exercising its authority under Progeny's M-LMS license to broadcast continuous transmissions. Instead, NextNav is employing a duty cycle of no more than 20 percent. By limiting its operations from a given transmitter to up to 20 percent utilization of any second of time, the probability of interference occurring is significantly reduced, and the impact of any potential interference is limited in duration.

NextNav's network architecture is oriented around minimizing the number of sites required to provide a high-precision location solution. That means that NextNav often will preferentially select the highest available positions on existing tower facilities, placing the source of its transmission at a considerable physical distance from most typical uses of Part 15 devices. A NextNav transmitter will be in close proximity to a device employing the 902-928 MHz band only in very unusual circumstances.

Because NextNav uses a very low data rate, its link margin is substantially higher than other data services. This, combined with NextNav's optimization of its deployment for forward-link operations, results in far fewer transmitters than cellular or other two-way wide-area systems that rely on reverse-link transmissions or high data rates. Further, NextNav will not need to add additional sites to increase network capacity through frequency reuse.

Taken together, NextNav's technology and network architecture result in a relatively benign signal environment that will not result in unacceptable levels of interference to other users of the 902-928 MHz band.

Performance

The NextNav solution is highly accurate. In initial testing across approximately 240 square kilometers in Santa Clara County, NextNav has achieved accuracy of better than 25 meters, 67 percent of the time.[4] NextNav has also demonstrated height accuracy to within 1 to 2 meters,[5] which provides a distinct benefit in multi-level structures.

The NextNav link provides not only superior in-building performance, but also provides a very rapid time-to-first-fix ("TTFF"). A NextNav receiver can compute a position fix typically within 5 seconds. Standalone GPS can take as long as 12 minutes, while Assisted GPS ("A-GPS") typically requires approximately 30 seconds.[6]

Applications

NextNav is deploying its network to meet urgent public safety and commercial market needs. Wireless E911, particularly from mobile handsets, has become a predominately indoor service, while many modes of mobile communication increasingly rely on location information to provide consumer value. NextNav's system has the potential to offer service improvements to location

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[4] Based on testing conducted by NextNav at a grid of 128 separate indoor and outdoor locations in Santa Clara County in which 32,000 measurements were recorded.

[5] Based on initial testing conducted by NextNav in structures in San Francisco and Sunnyvale, California.

[6] These estimates are based on cold-start determinations. "Cold start" means that the receiver has no information about the transmitter locations, which transmitters are in view when the device is powered on, and no access to off-board information about where to look for the appropriate signals.

accuracy that could impact not only quality of life, but safety of life, in places where other positioning systems lack coverage, precision or reliability.

E911 Location Accuracy

The FCC has mandated that, when an E911 call is made from a mobile phone, the location of that handset must be made available to emergency responders. Current E911 location accuracy standards, however, are based on outdoor performance. The existing requirements do not mandate useful indoor location performance and have no provision for vertical accuracy, which is critical in multi-level structures. There are various technologies in the market that have been developed in an effort to address these shortcomings. None of them, however, has been demonstrated to be as accurate and consistent as NextNav's WAPS technology. Further, NextNav's technology is the only wide area solution that precisely addresses the 'Z' axis problem providing meter level accuracy.

Commercial and Automotive Markets

There is, likewise, a compelling commercial market need for greater location accuracy, particularly in urban areas. Vehicles are frequently operated in more complex environments than open highways, and vertical location can become a critical factor in both navigation and emergency response, for example in the case of a roadway extending over another roadway. A vehicle that enters an urban area could experience GPS service interruption, and this possibility extends to a near certainty in the case of a parking garage.

For mobile devices, there are a multitude of applications that could benefit from the NextNav system, including those with significant safety implications. Location-based "child finder" services could improve their performance from today's quarter mile accuracy to 25 meters or better, swiftly locating a family member within visual distance. Other services could include indoor navigation, more effective mobile advertising, social networking and more useful local search.

ATTACHMENT 2

Part 15 Test Report

Coexistence of M-LMS Network and Part 15 Devices

FINAL

SPECTRUM MANAGEMENT CONSULTING INC

January 2012

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List of Acronyms

CFR	Code of Federal Regulations
dB	Decibels – the common logarithm of a number multiplied by ten
dBm	milliWatts of power, expressed in dB
DSSS	Direct Sequence Spread Spectrum
EAS	Equipment Authorization System
EIRP	Equivalent/Effective Isotropic Radiated Power
ERP	Equivalent Radiated Power
FCC	Federal Communications Commission
FHSS	Frequency-Hopped Spread Spectrum
FM	Frequency Modulated
GPS	Global Positioning System
LMS	Location and Monitoring Service
M-LMS	Multilateration Location and Monitoring Service
OEM	Original Equipment Manufacturer
TDMA	Time Division Multiple Access
WAPS	Wide Area Positioning System

Executive Summary

NextNav Holdings LLC, ("NextNav") through its wholly-owned subsidiaries, Progeny LMS, LLC ("Progeny") and NextNav LLC ("NextNav"), is building a near-nationwide network to improve the ability to locate accurately mobile devices such as cell phones indoors. The technology, named Wide Area Positioning System ("WAPS"), uses signals from beacon stations operating in the Multilateration Location and Monitoring Service ("M-LMS") in the 902-928 MHz band. M-LMS is a licensed service, but unlicensed devices[1] also operate in this band. For this reason, the FCC's rules require M-LMS operators to "demonstrate through actual field tests that their systems do not cause unacceptable levels of interference to [Part 15] devices."[2]

Spectrum Management Consulting, Inc ("SMC") was contracted by NextNav to conduct field tests of how an operating WAPS network potentially affects the operation of Part 15 devices. More specifically the work performed by SMC had the objective to:

1) Determine whether a network of WAPS beacons would impact the operation of a variety of Part 15 devices, and if so:
   a) under what conditions,
   b) the type of impact and impairment that occurred, and
   c) whether different device types were impacted differently.
2) Assess the efficacy of interference mitigation techniques employed by the WAPS network in minimizing interference to Part 15 devices, and
3) Evaluate how the operating characteristics of a Part 15 device, such as its ability to sense interference and re-tune channels, can alleviate or eliminate the impact of a WAPS beacon in those cases in which an impact was detected.

This report details the findings of this work together with the methodology, field testing, and analysis employed in deriving these findings.

Methodology

The coexistence scenario between Part 15 and WAPS uses is complex and governed by a number of factors including:

- intended Part 15 device applications: residential, commercial, industrial;

[1] Specifically, devices operating under Part 15 of the Commission's Rules, which are therefore sometimes called "Part 15" devices.

[2] 47 C.F.R. 353(d).

- technology used in both the Part 15 and WAPS beacon: frequency of operation, modulation scheme, useable range, interference avoidance; and
- other characteristics of the Part 15 devices and WAPS beacons particularly the surrounding environment and when and where they are used.

The testing performed by SMC had three segments. The first segment involved testing in a typical or normal operating environment. We tested a large number of devices under these conditions, including industrial, commercial, and residential/consumer devices that use varying technologies such as FM analog and frequency hopping capabilities. The devices were set up in a manner that was consistent with how a typical user would operate the device. For example, when testing cordless phones and similar consumer devices, the transmitter and receiver units were placed in different rooms often some distance from each other, but within the same building, or with the transmitter inside the building and the receiver just outside the building. If the device had multiple selectable operating channels, it was tuned to a channel not used by the WAPS beacons.

The operating environment of the Part 15 receive locations was always within the operational area of the WAPS network. For purposes of these tests, the operational area of the WAPS network was defined as any location where at least four WAPS beacons could be detected at sufficient signal strength and angular diversity to obtain a position "fix." The receive locations in the typical operating environment were positioned at distances to the beacons varying from 500 feet to 6.5 miles with the preponderance of receive locations positioned within one mile or less of the nearest WAPS beacon. For this reason, even in what we are describing as a "typical operating environment" the average distance to the nearest WAPS receiver was shorter than can be expected once the WAPS network is deployed.

In the first segment, the typical operating environment, the Part 15 device under test almost never detected the WAPS network. Therefore, a second test segment was employed in which Part 15 consumer devices were tested in atypical operating conditions. The test environment for the atypical conditions was the same as in the typical test environment. In the atypical conditions, however, Part 15 devices always operated on the same frequency with a WAPS beacon. This was done either by intentionally employing the same channel setting on the Part 15 device as the WAPS beacon even if other channels were available, or by physically preventing, if possible, a Part 15 device from automatically shifting to a non-WAPS channel.

Even under atypical operating conditions, most Part 15 devices did not detect the WAPS beacon in most of the test environments. For this reason, a third set of test conditions was created that was intended to represent a worst case operating environment, referred to herein as the "break case." In the break case, Part 15 consumer devices were tested within 50 feet of a WAPS beacon. Depending on the capabilities of the Part 15 consumer devices, the devices were tested both off channel from the WAPS beacon and on an overlapping frequency with the WAPS beacon.

SMC used two groups of Part 15 devices to ensure that a representative range of devices were investigated:

- Consumer devices such as cordless phones and baby monitors that could be purchased at retail outlets or online.
- Commercial devices including devices intended for more specialized commercial, industrial, and utility applications including wireless remote control systems, RFID tag readers, and utility meter reading systems.

A total of 17 devices, 12 consumer devices and 5 commercial devices were selected for use in testing in the presence of an operational WAPS system. Several techniques were used to help identify this representative sample of Part 15 devices. The FCC's Equipment Authorization System ("EAS") database was initially used to obtain information for different devices including the technology type (analog FM, FHSS, etc.), the frequency band of operation, and the specific section under the Part 15 rules governing their operation. This information was used to filter the devices under consideration to those that operate within, or immediately adjacent to, the M-LMS band, thus identifying the device types most susceptible to impact from the WAPS transmission.

Testing and Analysis

The primary objective for field testing was to examine the coexistence of Part 15 devices with WAPS in a normal or typical operating environment. Part 15 devices operate in dynamic RF conditions in the 902-928 MHz band. The effects that Part 15 devices have on each other and how Part 15 devices mitigate the potential interference from other Part 15 devices is relevant to the testing of M-LMS use in the band. This is because Part 15 devices must operate in an uncontrolled environment in which other Part 15 devices are present. Interference is a fact of life in this environment and unlicensed devices are designed to tolerate or avoid this interference. Part 15 devices use a variety of means to mitigate or avoid interference. Examples include the use of multiple channels, frequency hopping or direct sequence spread spectrum transmissions.

The basic approach for the field testing was as follows:

- Create a test network where WAPS beacons operate as they would in commercial operation.
- Identify a set of test locations that would (a) permit use of Part 15 devices in their intended environment, and (b) be covered with signal levels from a sufficient number of WAPS beacons to provide a "fix."
- Conduct tests with the WAPS network operated in two states, first "OFF" and then "ON."
- Listen to and often record audio or data files that could be used to identify any changes in behavior between tests.

The audio files recorded in the field were repeatedly listened to after the tests to determine whether a beacon could be detected. For expediency, measurements corresponding to typical and atypical conditions were done at the same time. For example, some of the normal cases involved operating the Part 15 device first in an unused portion of the WAPS band ("off-channel"), while the atypical environment involved re-tuning so the Part 15 device was co-channel to the WAPS beacon. In addition, measurements that involved placing the Part 15 devices at different ranges to simulate the different environments were carried out together.

Measurement data was analyzed to look at:

- Whether the beacon had an effect on Part 15 devices.
- How this effect manifested in the measurements. (For example, whether one or more beacons could be detected).
- What impact, if any, the beacon artifact had on Part 15 device operations and the role of the interference mitigation measures employed by the WAPS beacon network on that impact.

The test environment consisted of ten WAPS beacons in Santa Clara County, California. The beacons were deployed on tower facilities and building rooftops in a manner consistent with what would be desired for an operational system. The WAPS beacons used in the tests operated under an experimental license issued by the Commission. NextNav has represented to us that the transmitter beacons and test network employed in the tests are representative of those that NextNav will deploy throughout the country for its operational network, using, for example, the same power level, bandwidth and waveform as the operational WAPS system.[3] Specifically, the beacons operated at a power level of 30 Watts ERP, which is the maximum power level authorized for M-LMS transmissions in the 919.75-927.25 portion of the M-LMS spectrum bands.[4] Each beacon transmitted two signals, each with an occupied bandwidth of 2.046 MHz (with a 99 percent power bandwidth of approximately 1.56 MHz), one at the lowest portion of Progeny's authorized M-LMS spectrum at 919.75-921.75 MHz and the other near the upper end of the M-LMS band at 925.25-927.25 MHz. We would anticipate that moving the beacon channels to a different portion of the M-LMS spectrum would produce essentially the same results as long as other factors remained constant, *i.e.*, transmit power, bandwidth, duty cycle, transmitter height and density.

Twelve unique sites, including single family homes, apartments, and office buildings, were selected for the field tests. The distance from the closest beacon to a given test site varied from 0 miles (*i.e.*, the test site was colocated with a WAPS beacon) to 6.5 miles. Eight of the test sites were within one mile of the closest beacon. Eight sites were used exclusively for testing the consumer devices, two locations were used exclusively for testing commercial and industrial devices, and at one location both types of devices were tested. Finally, a device intended for broadband wireless access was tested with its link established between a pair of outdoor sites in the middle of the test area.

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[3] *See* FCC Call Sign WF2XLW.

[4] The Commission's rules permit M-LMS network to employ power levels of up to 300 Watts ERP in the 927.25-928.0 MHz portion of the M-LMS band. *See* 47 C.F.R. 90.205(l). The testing conducted for this report did not include testing of M-LMS transmissions at power levels in excess of 30 Watts ERP and, therefore, the results of this test report are not applicable to M-LMS operations in excess of 30 Watts ERP.

Findings

SMC found that most Part 15 consumer devices, when used in a typical or expected manner, will never detect a WAPS beacon. This is because:

(1) they will switch to a channel that is outside the WAPS bandwidth – either automatically or through normal user action – when a WAPS signal is detected, or

(2) they are statistically unlikely to occupy the WAPS band as a result of the signal modulation they employ, such as frequency hopping technology, or

(3) when they operate on the same channel as a WAPS beacon, the Part 15 receiver does not detect the WAPS beacon signal because the WAPS signal is too weak or is overpowered by the desired signal from the Part 15 transmitter.

Even under conditions in which a Part 15 device detected a WAPS signal on a channel and the device remained on that channel, the Part 15 device continued to operate, transmitting and receiving the desired signal. Aside from the presence in some cases of a beacon artifact, the ability to recognize speech was unchanged by the beacon. More specifically, the testing of Part 15 consumer devices can be summarized as follows:

- Nearly all Part 15 devices, when operated at a typical distance from a WAPS Beacon (*i.e.*, greater than 50 feet) in a normal operational mode (*i.e.*, using a frequency not used by WAPS), do not detect a WAPS beacon signal and the device continues to function as if the WAPS system is off.

- Even when a Part 15 device is operated in an atypical co-channel state with the WAPS beacon (either through manual channel selection or by overriding the automatic selection function), nearly all of the nine Part 15 devices that we could operate in this manner (some could not be forced to do this) still could not detect the WAPS beacon in most test scenarios.

- In nearly every case in which a Part 15 consumer device was able to detect the WAPS beacon, the device detected the signal from only one WAPS beacon, which resulted in a brief "shhh" or "beep" sound once per second.

    - The WAPS beacon artifact, when detected, did not prevent the Part 15 device from continuing to send and receive its desired signals, and the ability to recognize speech was unchanged by the beacon.

As noted above, one of the objectives of the testing was to create a "break case" in order to observe the results when detection of the WAPS signal by a Part 15 device is most likely. To accomplish this, SMC situated an additional test location in the same building as a beacon transmitter and no more than 50 feet below the beacon's location on the roof. This is an unusual configuration because, in a normal high-rise building, the floor immediately below the roof is usually used to house utility, maintenance, elevator and telecom equipment, leading to additional separation and signal attenuation between a transmitter on the roof and public, commercial or residential areas. The results of the "break case" were as follows:

- In the normal mode, with the Part 15 devices operating on a different channel (if available) than the WAPS beacon, most of the Part 15 devices (7 out of 12) did not detect the WAPS beacon.
    - Of the 5 devices that did detect the WAPS beacon, all used older analog FM technology. One of the analog FM devices lacked a channel selection capability and had to operate co-channel with the WAPS beacon.
    - Two Part 15 consumer devices that employ FHSS or DSS technology could not be forced to operate consistently on the same channel as the WAPS beacon and did not detect the WAPS beacon in the "break case" test conditions.
- In the atypical break case mode, with the Part 15 device operating on the same channel as the WAPS beacon, of the 9 devices that could operate in this mode, 7 of the devices detected the WAPS beacon, but all of the devices continued to operate, transmitting and receiving their desired signals.

The findings of our tests (both the break case and the non-break case) are significant because they indicate that, apart from the audio artifact in some cases, the WAPS beacon did not otherwise impact Part 15 device operation. Instead, each device that was tested continued to operate, maintaining a communication link at the same range that it otherwise did when a WAPS beacon signal was not present.

In the non-break case test conditions, the detection of a WAPS beacon was a rare occurrence, usually requiring that the Part 15 device be operated co-channel with the WAPS beacon even when other communication channels were available. When the WAPS beacon was detected, the Part 15 device continued to operate, transmitting and receiving the desired signal, and the ability to recognize speech was unchanged by the beacon signal. Further, the audio artifact could be eliminated in nearly all cases (break case and non-break case) by changing the channel or moving the Part 15 transmitter and receiver closer together.

For Part 15 devices utilized in specialty commercial, industrial, or utility applications, SMC found that the WAPS signal also had no material impact on their operation. When the WAPS signal was present, these devices continued to operate and transmit the desired data at rates and over distances consistent with what could otherwise be achieved when a WAPS signal was not present.

The absence of a material impact on Part 15 devices used in commercial, industrial and utility applications is attributable in part to the use of robust communication technologies in such equipment.

For example, such devices tend to employ FHSS or DSS technology instead of the analog FM technology that is prevalent in older consumer devices. Commercial, industrial and utility devices also tend to transmit data, rather than audio signals, and are therefore more tolerant of other signals in the band because the transmitted data can be encoded or retransmitted if necessary.

The findings of our study indicate that Part 15 devices can co-exist with WAPS service in the M-LMS portions of the 902-928 MHz band.

Background

M-LMS Band

In 1974, the FCC created the Automatic Vehicle Monitoring ("AVM") service. The service was subsequently renamed the Location and Monitoring Service (LMS) and regulated under a new Subpart M starting at Section 90.350 of the Commission's rules. An LMS system utilizes non-voice radio techniques to determine the status and location of mobile units. The service is defined in two general categories of LMS technologies: multilateration and non-multilateration.

The M-LMS spectrum is defined as three frequency blocks within the 902-928 MHz band. Progeny is licensed on a near-nationwide basis in the M-LMS B and C-blocks, specifically 919.75-921.75 MHz and 921.75-927.25 MHz. along with the M-LMS B and C-block sub-bands at 927.25-927.50 MHz and 927.50-927.75 MHz.

M-LMS is authorized on a primary basis while Part 15 devices are authorized on a secondary basis. In order to ensure that Part 15 devices can continue to operate in the 902-928 MHz band, the FCC's rules require M-LMS operators to "demonstrate through actual field tests that their systems do not cause unacceptable levels of interference to [Part 15] devices."[5]

To address this requirement, SMC's approach was to capture the behavior of Part 15 devices in actual use and quantify the impact, if any, on the desired signal either with respect to the continued transmission of uninterrupted audio, or with respect to any change in the distance that the Part 15 device could successfully transmit and receive data.

Part 15 Devices

Part 15 (47 C.F.R. 15) contains the FCC's rules and regulations regarding unlicensed transmissions, which broadly encompasses everything from spurious emissions to unlicensed low-power broadcasting. Nearly every electronic device sold in the United States radiates some form of unintentional emissions, and must be reviewed to comply with Part 15 before it can be advertised or sold in the U.S. market.

[5] 47 C.F.R. § 90.353(d).

Devices that intentionally radiate must go through a formal FCC Equipment Authorization process to demonstrate that they comply with FCC rules to permit the coexistence of these devices in a non-exclusive, unlicensed manner.

Types of Devices

There are a number of types of devices regulated by Part 15, including:

- High-power intentional radiators: These devices are specifically authorized as intentional emitters and an Equipment Authorization must be secured authorizing their marketing, sale and use. Regulations addressing such technical parameters as the frequency band of use, transmit power, field strength, and/or modulation technology are imposed to reduce the interference potential to other devices.
- Low-power intentional radiators: These devices can operate on nearly any frequency and also require an Equipment Authorization to permit their marketing, sale or use. They are limited to specific field strengths that vary with frequency. The field-strength limits were identified by the Commission so that interference would not be expected under most circumstances.
- Unintentional radiators: This category encompasses nearly every electronic device (a common example of an unintentional radiator is a television or a personal computer). For unintentional radiators, the FCC imposes radiated emissions limits above 30 MHz and conducted emissions limits below 30 MHz. Devices must be verified to comply with the rules governing unintentional radiators but certification is not required.
- Incidental radiators: These include such devices as motors and power lines. Part 15 requires that the manufacturers of such devices employ good engineering and that such devices not cause harmful interference to radio services.

Device Classes

Part 15 rules also define two different device classes:

- Class A digital device: a digital device that is marketed for use in a commercial, industrial or business environment.
- Class B digital device: a digital device that is marketed for use in a residential environment primarily for use by the general public. Examples of such devices include, but are not limited to, cordless phones, baby monitors, personal computers. Class B equipment must meet much stricter RF emission limits than Class A devices in order to provide additional protection to relatively sensitive consumer equipment, such as broadcast television receivers.

Part 15 devices are all intended to cope with the interference environment of unlicensed operation. The most common coping mechanism is frequency agility. This can be as simple as providing multiple user-selectable channels or as complex as FHSS.

Typical Operation

The typical operation of a Part 15 device occurs when the device is operated on a channel where the interference is low enough that the device can be used for its intended purpose. This channel would presumably be one that is otherwise unoccupied and not in use by other Part 15 devices nearby.

Atypical Operation

Atypical operation of a Part 15 device occurs when the device is operated on a channel that experiences sufficient interference from other Part 15 uses to cause its performance to be degraded. The performance degradation can be something obvious to the user – such as a change in the voice quality or the addition of audio artifacts (static, buzzes, clicks, or swirling sounds mixed in with the audio) – or less apparent such as decreased range or an increase in bit error rate.

Coexistence Scenario

Figure 1 illustrates the basic scenario of sharing between Part 15 devices and M-LMS, shown here in terms of a residential cordless phone. Such a device has a base unit and a handset, which must be in range of each other to communicate. When they are within range, the quality of the signal will usually continue to improve as the base and handset are moved closer together.

The WAPS beacon is typically located on a high site some distance from both the base unit and the handset. The signal power from the beacon to the receiver, for instance the handset, depends on the distance between them as well as any obstructions, such as buildings or foliage. Further, the WAPS beacon is only one of many potential sources of undesired signals with which the receiver must contend. In particular, other, more proximately located Part 15 devices may affect the performance.

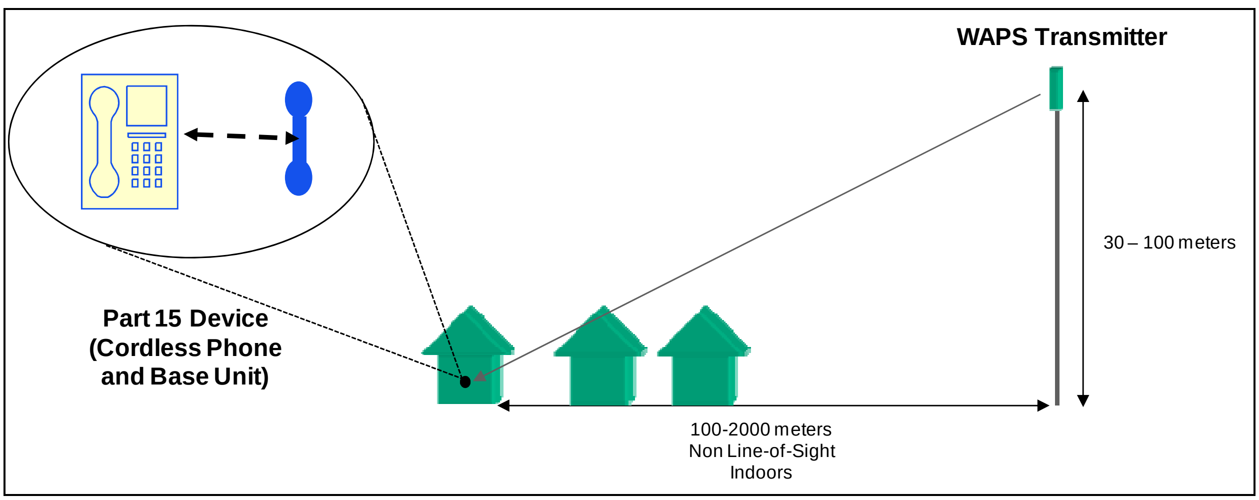

Figure 1: Transmission Paths Between Part 15 Device and WAPS

The coexistence scenario described above can be generalized to all Part 15 unlicensed devices. There is a transmitter and a receiver. If the transmitter/receiver pair operates on or near the frequency of the WAPS beacon, the beacon intermittently raises the noise floor at the receiver. The unlicensed device pair can employ various means to avoid or mitigate this additional noise such as rejecting the noise, switching to another frequency, or using a frequency agile architecture such as frequency hopping technology. There are five key factors that are relevant to the coexistence analysis:

1) The distance between the Part 15 transmitter and receiver.
2) The signal power from the WAPS beacon at the Part 15 receiver, which depends, among other things, on the beacon's power and distance.
3) The techniques employed by the WAPS beacon to minimize interference to Part 15 devices.
4) The interference power from other sources (the interference environment) at the Part 15 receiver.
5) The technology employed by the receiver to tolerate, mitigate or avoid interference.

This report details the study of the above factors in the presence of M-LMS operation. As a first step, the Part 15 devices were analyzed and categorized so that a manageable collection of representative devices could be obtained for further study.

Device Selection and Procurement Methodology

Considering the broad range of device types and device categories regulated under Part 15, a key aspect of this study was to identify a representative sample of Part 15 devices to apply in the coexistence study. More specifically, the goals were to ensure that devices were selected representing:

1) a broad range of user applications;
2) both Part 15 Class A and Class B device categories; and
3) different technologies such as analog FM, DSS and FHSS.

To select devices for further study, an extensive list of Part 15 devices was identified and categorized. Information for each device was obtained from FCC certification test reports and other publicly available manufacturer documentation including the technology type (analog FM, FHSS, etc.), the frequency band of operation, and the governing FCC rule section. This information was used to further filter the devices under consideration, specifically to those that operated within, or immediately adjacent to, the M-LMS portion of the 902-928 MHz band that is licensed to Progeny. The devices in this filtered list were then categorized according to their intended application. SMC then conducted a search to determine if these devices could reasonably be procured for use in the field testing. Further details on the selection and procurement methodology follows below and can be found in the Appendix.

The process began with a search of the FCC's Equipment Authorization System (EAS) database. A sample of 730 devices, certified by the Commission within the previous five or six years and therefore likely to be in use, was obtained from the EAS database.[6] The next step was to obtain technical details about the devices. To do this, a random sample of the devices was drawn and searched the EAS again

[6] The devices were all type approved since January 1, 2005 and hence represent more current technologies used by Part 15 devices. The Appendix contains additional information about how this sample was drawn.

using the device's FCC ID number. Also consulted were user manuals, test reports and any annexes, operational descriptions and similar material on file with the Commission describing the function and operation of the device.

The devices were categorized according to the technology employed, the governing FCC rule section, and the criterion of whether the device had the capability to operate within the M-LMS frequency blocks that would be utilized in the tests, specifically 919.75 to 921.75 MHz and 925.25 to 927.25 MHz.

The devices were also categorized according to their expected use and application, either (1) consumer or (2) commercial, industrial, or utility. The filtered list was then analyzed to determine the commercial availability of the products listed. Many of the devices listed could not easily be obtained:

- Many consumer devices were no longer available for sale, or had been replaced with an updated make/model that no longer operated in the 900 MHz Part 15 band;
- Many devices certified for commercial or industrial applications were Original Equipment Manufacturers ("OEM") modules and could not be readily sourced;
- Devices intended for utility applications could not easily be procured despite numerous attempts with the manufacturers and product dealers.

Despite the difficulties in obtaining certain Part 15 devices, SMC believes that it was successful in securing an adequate and representative sample of Part 15 devices, including devices using different technologies and devices intended for different user environments and applications. As a result of the vetting process, a total of 17 devices, 5 Class A devices and 12 Class B devices were selected for use in testing in the presence of the operational WAPS network. Table 1 provides further detail on the selected devices. (An additional eighteenth device was initially selected for testing, but later had to be removed from the testing process. The device, identified internally as Device 13, was a RF clock radio (Pyramid Technology "Clock in a box") that used a master controller to change the time. Unfortunately it took hours for the synchronization process to take place between the master controller and the clock therefore making it impractical for field testing.)

Table 1: Part 15 Devices Used in Field Study

Device Number	Equipment Class	Category	Device Description	FCC ID	Lowest Frequency (MHz)	Highest Frequency (MHz)	Number of channels	Channel Selection	Modulation
1	**B**	Consumer	Audio/Video Baby Monitor	PZK201AT	910	921	2	Manual	Analog FM
2	**B**	Consumer	Baby Monitor + Walkie Talkie	EHK900646RTRIA	925.2	926	2	Manual	Analog FM
3	**B**	Consumer	Baby Monitor	M6YA3929A3930	909.524	919.764	6	Manual	DSS digital modulation
4	**B**	Consumer	Cordless Phone	AK8SPPSS965	904.018	927.133	20	Automatic	DSS digital modulation
5	**B**	Consumer	Cordless Phone	AESUC226	925.610677	927.698745	20	Manual	Analog FM
6	**B**	Consumer	Cordless Phone	OG993	924.928	927.36	20	Manual	Analog FM
7	**B**	Consumer	Audio/Video Baby Monitor	MNJ08020T	908.5	927.5	2	Manual	Analog FM (audio)
8	**B**	Consumer	Wireless Headphones	DMORS03ABUS	926	928	3	Manual	Analog FM (stereo)
9	**B**	Consumer	Wireless Outdoor Speaker	S6LB-BROOKSTONE	925.8	927.4	3	Manual	Analog FM
10	**B**	Consumer	Wireless Telephone Pendant	TYD30911/ELG30911	925.3	927.2	20	Not Selectable	Analog FM
11	**A**	Commercial	Universal Remote Control	P4U-MNTA2	902	928	65	Automatic	FHSS
12	**B**	Consumer	PTT Radio/Wallkie-Talkie	IHDP56HJ1	902.575	927.475	500	Automatic	FHSS – 8FSK
14	**B**	Consumer	Cordless Phone	AK8SPPSS965	902	928	20	Automatic	DSSS
15	**A**	Industrial	Handheld RFID Reader	PJMMRU200	902	928	50	Automatic	FHSS
16	**A**	Industrial	Long Range RFID Reader	H9PMC906RC	902	928	50	Automatic	FHSS
17	**A**	Utility	AMR Meter System	NTAXMETER30	905.43	923.55	6	Automatic	DTS
18	**A**	Commercial	Broadband Wireless System	ABZ89FC5809	902	928	3	Manual	Digital

Technologies Represented

As noted previously, a key selection criterion was to ensure that a broad range of device technologies were represented. Table 2 below provides a breakdown of the technology employed by the devices selected for the testing.

Table 2: Part 15 Technologies Selected for Tests

Modulation	Residential Devices	Industrial Devices
Analog FM	9	0
DSS	2	4
DTSS	0	1
FHSS	1	0
Total	**12**	**5**

Frequency Hopped Devices

All FHSS devices operating in the 902-928 MHz band must follow a prescribed minimum hopping scheme set out in Section 15.247(a)(1)(i) of the Commission's Rules. Table 3 summarizes these requirements. As can be seen, the Rules require that systems with bandwidths narrower than 250 KHz operate on fifty channels with a duty cycle of no more than 2 percent.

Table 3: FCC Requirements for FHSS in 902-928 MHz

Channel Bandwidth or Hopping Spacing (kHz)	< 250	≥ 250
Minimum Number of Hopping Channels	50	25
Hopping Cycle Length(s)	20	10
Maximum Dwell Time per Channel	0.4	0.4
Duty Cycle	2%	4%

The frequency hopped device used in SMC's tests was documented as in compliance with the FCC's Rules, using 500 channels in aggregate and a hopping interval of 50 kHz. Spectrum occupancy was 25 MHz (902.525-927.475 MHz). The total overlap with the WAPS beacon bandwidths was 3.975 MHz (2 MHz in the M-LMS B-block and 1.975 in the M-LMS C-block). Hence the Part 15 device may be operating in the WAPS band 16 percent of the time (3.975 MHz/25MHz). Based on information retrieved from the EAS database, other devices with frequency-hopping capabilities have similar or slightly less spectrum overlap with WAPS.

The WAPS signal itself has a duty cycle of no more than 20 percent (*e.g.*, 0.2 seconds on and 0.8 seconds off). A channel conflict between an FHSS device and the WAPS signal can occur only if the two signals occupy a channel simultaneously, which has a probability of at most 3.2 percent (20% × 16% = 3.2%).[7] All other FHSS devices that comply with Section 15.247(a)(1)(i) should behave similarly.

This same general argument applies to FHSS devices with bandwidths above 250 kHz. Although the permissible duty cycle is doubled, the number of channels where interference may occur is halved. As a result, the overall probability of an overlap is only a few percent.

Moreover, because they are digital, FHSS devices are likely to have additional error detection or error correction built into them. Although intended to protect the communication link against interference from other Part 15 devices, error detection or correction will provide additional protection during the less than 2 percent of the time when there may be a co-channel WAPS signal. As such, the expectation is that FHSS devices are unlikely to experience WAPS beacon interference that the technology cannot mitigate.

Digital Devices

The digital devices selected can operate both within and outside of the WAPS band and some of those devices automatically avoid interference by changing frequencies if they detect interference. These and similar devices should not experience interference from WAPS under typical operating conditions. Moreover, as with FHSS devices, these digital devices are likely to use error correcting or error detecting techniques to mitigate interference.

Analog FM Devices

The analog FM devices selected for testing employ a narrow channel bandwidth and generally have a manual channel selection feature. Other than channel reselection, devices in this category do not use any technology that would otherwise mitigate interference from other Part 15 uses. As such, they are likely to be the most susceptible to interference.

Prior to 2005, consumer devices utilizing analog FM technology were quite prevalent, as measured in terms of new FCC Equipment Authorizations. In more recent years, the majority of Equipment Authorizations appear to be for devices using more robust FHSS or DSS technology.

Field Testing

The second phase of the process was to field test all of the devices. Except with respect to the break case, the test conditions and operational parameters of the Part 15 devices were structured in a manner that was intended to represent the normal or typical operating conditions for such devices.

[7] The probability that a FHSS device would experience interference from more than one WAPS beacon is negligible because the beacons are spaced miles apart.

Overview of Test Conditions

The test area was centered in Santa Clara County, California where NextNav subsidiary Commlabs operates a network of WAPS beacons under FCC Experimental Authority. The WAPS beacons are located on sites consistent with the design requirements of the commercial WAPS system, which include hilltops, tall buildings, and towers. The operating parameters of the beacons, including the transmitted waveform, radiated power, and duty cycle were also consistent with the requirements of the commercial system.

Locations representative of typical Part 15 use, that is residential, commercial, and industrial facilities, were selected for testing. These locations included single family homes, apartments, and office buildings as well as hotel rooms. Several criteria were considered in selecting specific test locations, the most important of those being in-building coverage from at least four WAPS beacons with sufficient angular diversity to achieve the targeted system accuracy.

Field Test Environment

The test area in Santa Clara County is at the southern end of the San Francisco Bay Area and is commonly known as Silicon Valley. With a population of more than 1.7 million, Santa Clara is the most populous county in the Bay Area region and is one of the most affluent counties in the United States. It was therefore expected that the concentration of Part 15 uses in the vicinity of the test location would be quite high.

A test network comprised of ten WAPS beacons was utilized for the testing. The WAPS beacons cover approximately 260 square miles of area centered on Santa Clara County. The WAPS beacon locations and general area served with in-building coverage from the WAPS beacons is depicted in Figure 2 below. As can be seen, six beacons are on mountains surrounding the valley. The other four are on high locations on the valley floor. The beacons were deployed in sufficient density to ensure that a unit being tracked by the network had a sufficiently high level of probability that it could receive signals from and calculate a location fix using multiple beacon locations.

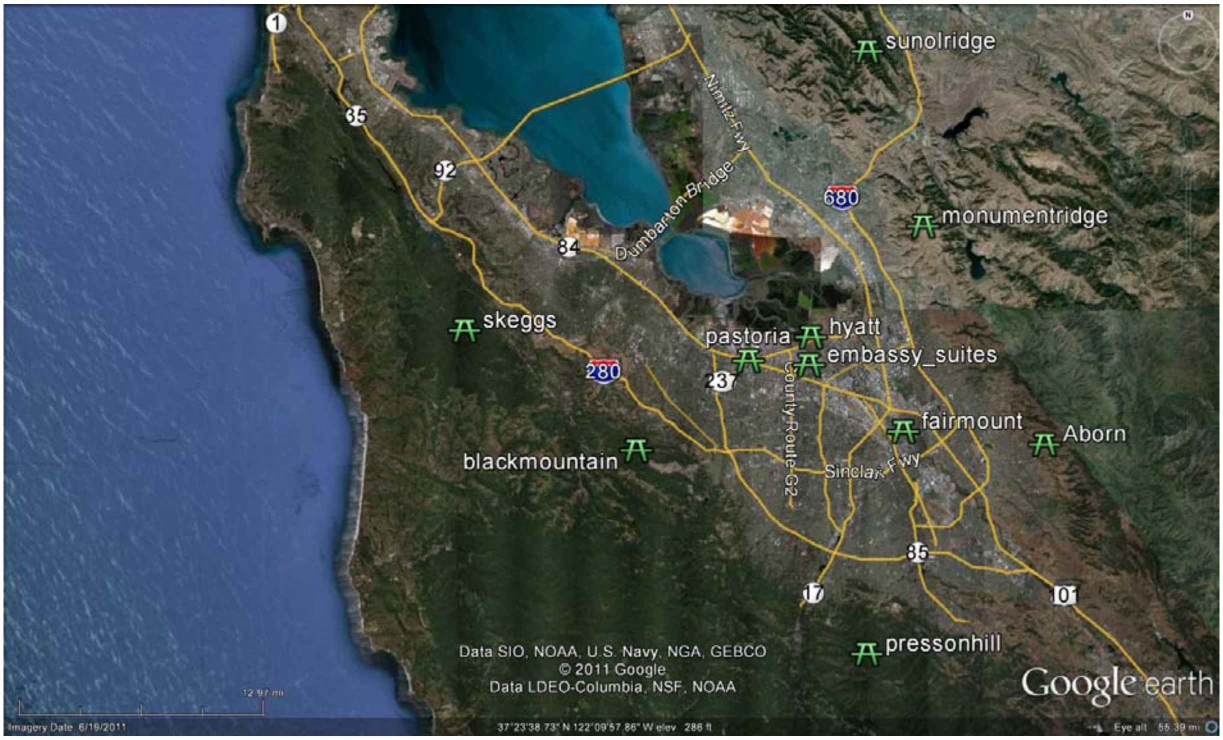

Figure 2: Area Served by WAPS Beacons in Santa Clara County

The area served by the WAPS beacons is generally flat with some rolling hills. The foliage is not dense and is typically 30 feet or less in height. Most buildings are two to five floors in height, with relatively few buildings ten floors or more in height. Considering the elevation of the WAPS beacon installations in relation to the service area, the propagation path from the beacons to a given test location is generally unobstructed by large amounts of foliage or dense buildings and applying generally accepted mobile propagation models should yield typical results for such tools.

Table 2 below lists the specifics of each of the sites used in the test network. Antenna gains varied between 8 to 12 dBi with the majority between 8 and 11 dBi. The test area has mountain ridges surrounding the basin of the Santa Clara area with elevations on the ridges where sites are placed in the 1000 to 3000 foot range above mean sea level (AMSL), with the majority in the 2000 to 2700 foot range. The actual height of the antenna sites on the ridges is low, with antenna placement heights ranging from 11 to 98 feet and the majority of the ridge sites around 60 feet. In contrast, the mean sea level (AMSL) in the basin is only in the 100 to 150 foot range, but the structures upon which beacon transmitters were placed in the basin range from 109 to 140 feet in height.

Beacon	Address	City	Beacon Latitude	Beacon Longitude	Ground Elevation AMSL (ft)	Antenna Height in feet on structure	Antenna Mfg	Antenna Model	Antenna Type
Pastoria	375 N. Pastoria	Sunnyvale	37.4	-122.0	101	44	Pacific Wireless	OD9-11	11 dBi/Omni
Embassy	2855 Lakeside	Sunnyvale	37.4	-122.0	142	136	Pacific Wireless	OD9-11	11 dBi/Omni
Hyatt	5101 Great America Pkwy	Santa Clara	37.4	-122.0	109	170	Amphenol	BCD-8707	8 dBi/Omni
Aborn	3903 Aborn Rd	San Jose	37.3	-121.8	1,022	60	Amphenol	BCD-8707	8 dBi/Omni
Black Mountain	1701 Montebello Rd	Palo Alto	37.3	-122.1	2,744	57	Amphenol	BCD-8707	8 dBi/Omni
Presson	15500 Soda Springs Rd	Los Gatos	37.2	-121.9	3,351	62	Decimal	DB806D-Y	8 dBi/Omni
Monument	3950 Weller Rd	Fremont	37.5	-121.9	2,521	42	Decimal	BCD87010	10 dBi/Omni
Skeggs	15300 Skyline Blvd	Woodside	37.4	-122.3	2,454	98	Decimal	BCD85010	12dBi / Omni
Sunol	37000 Palomares Rd	Sunol	37.6	-121.9	2,177	11	Pacific Wireless	OD9-11	11 dBi/Omni
Fairmont	170 S Market St	San Jose	37.3	-121.9	137	334	Decimal	BCD-8707	8 dBi/Omni

Table 4: WAPS Beacon Site Information

The beacon transmitter at each of the sites was adjusted to compensate for differences in equipment setup (such as variations in feederline length) so that the power output was as close to, but did not exceed, the FCC authorized power of 30 W ERP per channel. Each WAPS Beacon operates using two channels that correspond with the frequencies described above. At each site, the power was measured at the antenna port with a power meter to verify the output power presented in Table 5.

Beacon	B-Block PA Output Power dBm	C-Block PA Output Power dBm	Antenna Cable Loss	Antenna Gain dBi	B-Block Channel ERP Watts	C-Block Channel ERP Watts
Black Mountain	40.06	40.06	-1.23	8.00	29.31	29.31
Presson Hill	41.33	41.33	-2.50	8.00	29.31	29.31
Monument Ridge	39.73	39.73	-2.90	10.00	29.31	29.31
Sunol Ridge	38.33	38.33	-2.50	11.00	29.31	29.31
Hyatt	41.33	41.33	-2.50	8.00	29.31	29.31
Fairmount	39.33	39.33	-0.50	8.00	29.31	29.31
Aborn	40.83	40.83	-2.00	8.00	29.31	29.31
Skeggs	36.41	36.41	-1.58	12.00	29.31	29.31
Pastoria	36.93	36.93	-1.10	11.00	29.31	29.31
Embassy Suites	38.33	38.33	-2.50	11.00	29.31	29.31

Table 5: WAPS Beacon Power Settings

Field Test Locations

Test locations were selected by SMC, with the assistance of NextNav, as representing realistic locations for the actual use of the Part 15 devices. Further, the selected locations were chosen such that the distance to the WAPS beacons varied from 500 feet to 6.5 miles and the general surroundings included both light urban and suburban settings.

Although most consumer uses of Part 15 devices are expected to be indoors, locations were selected such that tests of some devices (such as baby monitors or cordless phones) could be conducted with the base station indoors and the receiver located at a reasonable location (*e.g.*, on a patio or backyard) outside the structure.

One test location was selected to permit testing under a break case condition – immediately below a roof-top mounted WAPS transmitter. Although such a location would likely result in atypical WAPS beacon signal levels and necessitate testing of Part 15 devices outside of normal uses or operating conditions, it was nonetheless considered a pertinent requirement. This location would not itself prove or disprove the ability of Part 15 and M-LMS to coexist, but would instead provide valuable insights into the mechanisms that govern coexistence (*i.e.*, under what conditions it might fail).

A total of 10 test locations were chosen as representative of the environment where Part 15 devices are typically used.[8] These included single family homes, apartments, and office buildings as well as hotel rooms.[9] The locations vary in terms the construction style and materials used. The test locations are summarized in Table 6, and an aerial photograph of all ten test locations is provided in Figure 3.

Table 6: List of Test Locations

Location	Description	Construction	Device Categories Tested
A	Office Suites	Reinforced concrete with atrium	Consumer, Commercial, Industrial
B	Commercial Office Building	Tilt-up	Commercial, Industrial
C	Apartments	Wood frame construction with stucco exterior	Consumer
D	High rise Hotel	Reinforced concrete	Consumer
E	Garden Hotel	Wood frame construction	Consumer
F	Single Family Home	Wood frame construction with stucco exterior	Consumer
G	Multistory Condominium	Wood frame construction with stucco exterior	Consumer
H	Single Family Home	Wood frame construction with stucco exterior	Consumer
I	Single Family Home	Wood frame construction	Consumer
J	High-rise Hotel	Reinforced concrete with glass exterior	Consumer

[8] A further pair of locations, used solely for testing the wireless broadband system, is described in the report below addressing those tests.

[9] Hotel rooms were chosen as a surrogate for residential Part 15 use cases and were particularly useful in the field test program given the proximity to WAPS beacons that could not otherwise be achieved with more typical residential sites.

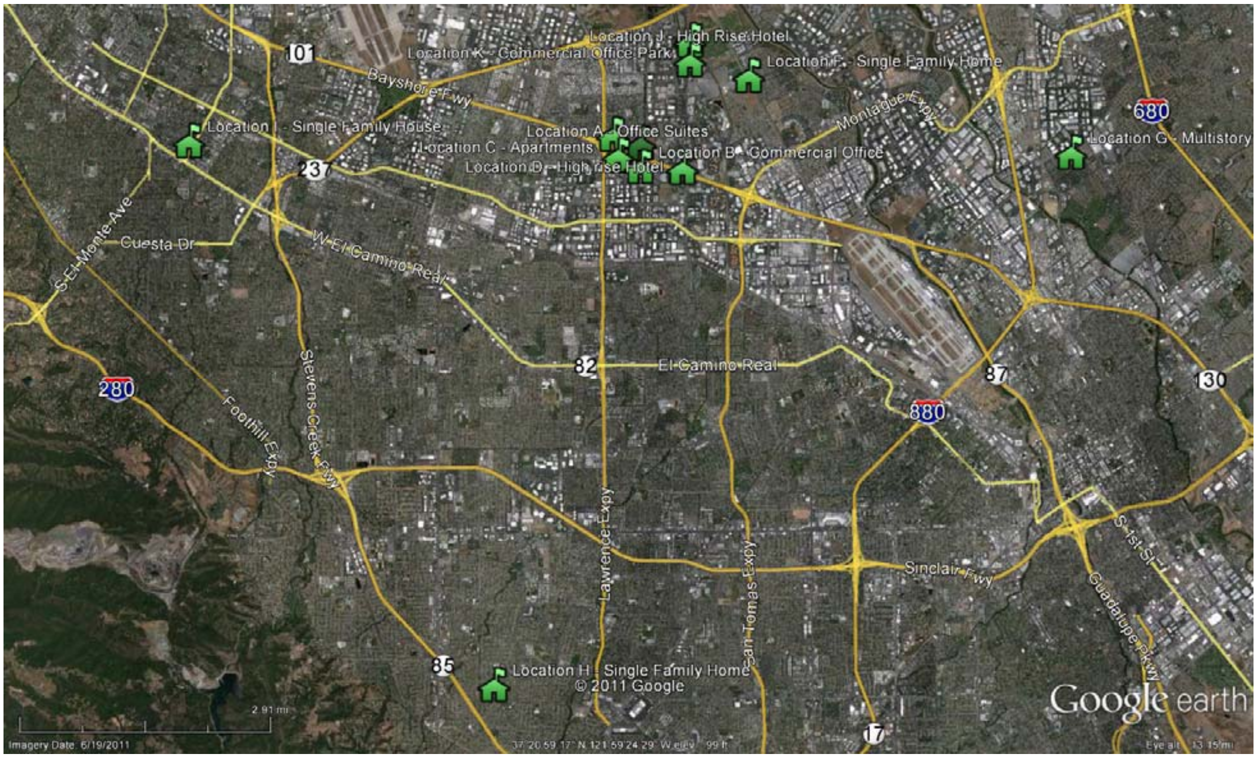

Figure 3: Part 15 Device Test Locations

A key criterion in selecting the test locations was to ensure that in-building WAPS beacon coverage was sufficient to provide a position determination using the WAPS beacon signals of at least four WAPS transmitters with adequate angular diversity. To verify this capability, NextNav performed a "GDOP" or geometric dilution of precision analysis. The GDOP of a location effectively measures how evenly it is surrounded by beacons. A network configuration with an optimal GDOP would tend to surround a service area to maximize the geometric diversity of the received signals, resulting in a more precise location computation.

Figure 4 depicts the GDOP coverage for the WAPS test network in Santa Clara County with the transmitters identified by red (numbered) points and the test locations identified by yellow (lettered) points. The different background colors indicate that overall quality of the position fix available based on the GDOP calculations. The areas depicted in blue, green, and yellow have a GDOP of less than two and therefore provide sufficient beacon coverage for a reliable and accurate position fix. The orange and red areas indicate areas where the position fix will be compromised.

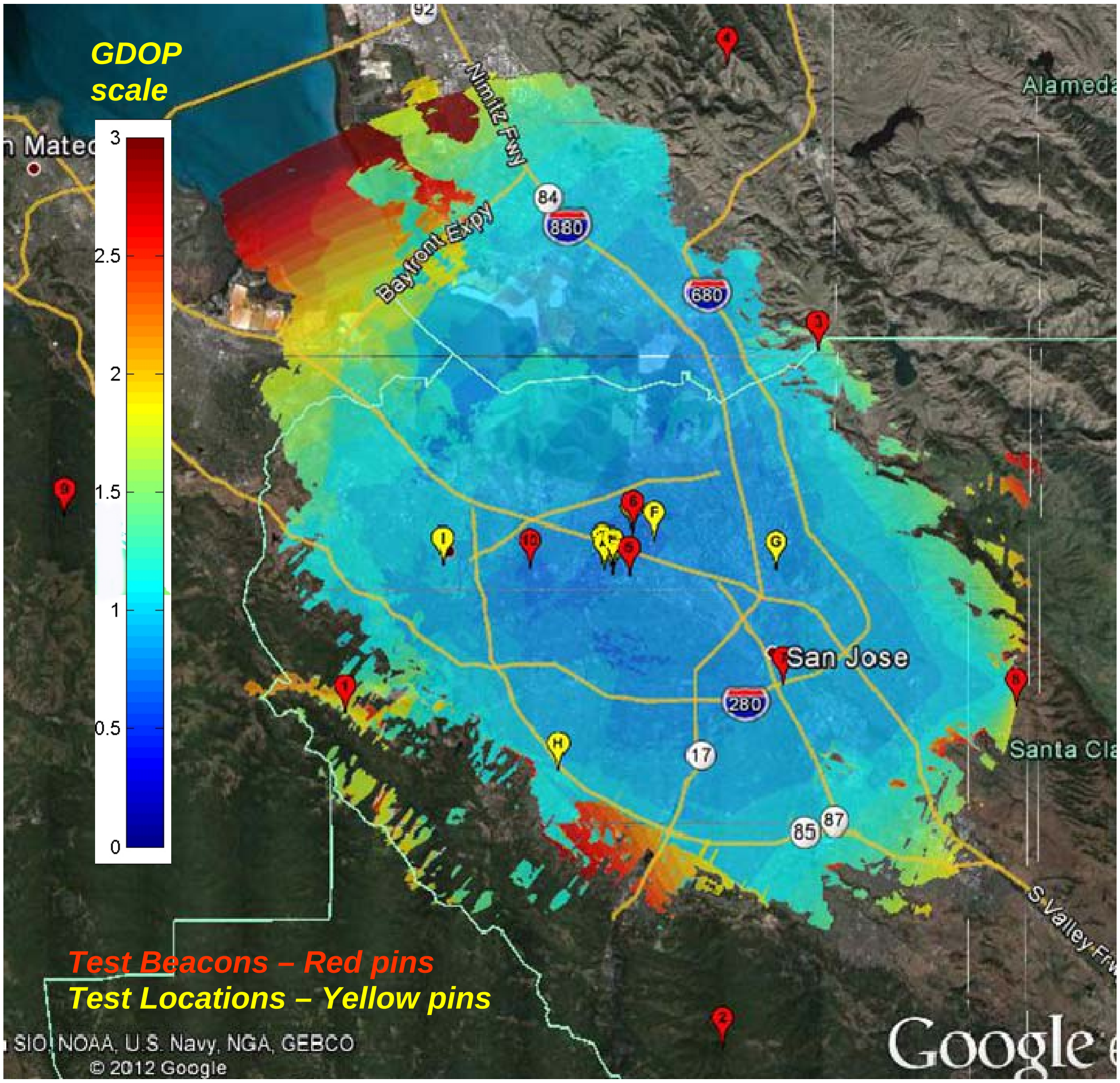

Figure 4: Calculated GDOP Coverage of WAPS Signals in Test Area

Table 7 summarizes the computed distances between the WAPS beacons and the test locations. As can be seen, the shortest distance from a test location to a beacon varies from 0 miles (the test location was colocated with a beacon installation) to 6.5 miles, with most test locations less than one mile from a beacon location.

Table 7: Distances from WAPS Beacons to Test Locations

	Beacon Distance to Test Location (miles)									
Beacon/Test Site	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Black Mountain	9.5	9.6	9.5	10.1	9.8	11.3	14.5	7.1	5.6	10.8
Presson Hill	15.6	15.4	15.8	15.3	15.6	16.2	15.3	10.1	17.7	16.5
Monument Ridge	9.7	9.6	9.6	9.3	9.4	7.9	7.1	15.7	13.8	8.3
Sunol Ridge	16.6	16.7	16.4	16.6	16.4	15.3	16.2	23.1	18.3	15.3
Hyatt	1.6	1.6	1.4	1.5	1.3	0.8	4.8	8.1	6.2	0.2
Fairmont	6.8	6.5	7.0	6.1	6.6	6.2	3.7	7.7	11.6	6.8
Aborn	13.8	13.5	13.9	13.0	13.6	12.7	8.8	14.7	18.8	13.4
Skeggs	17.4	17.6	17.3	18.1	17.6	18.9	22.8	17.7	12.2	18.1
Pastoria	2.4	2.7	2.3	3.2	2.7	4.1	7.9	6.5	2.8	3.4
Embassy Suites	0.8	0.5	0.9	0.0	0.6	1.4	4.7	6.6	6.0	1.3
Distance to Closest Beacon	0.8	0.5	0.9	0.0	0.6	0.8	3.7	6.5	2.8	0.2

The following subsections provide additional detail about each of the test locations.

Test Location A:

This location is a collection of office suites on the third floor of a multitenant office building. The building is constructed of pre-cast reinforced concrete.

Two Part 15 use case tests were conducted at this site. For one use case, the Part 15 transmitter and receiver were located in two separate and non-adjacent office suites. Several interior walls and other obstructions separated the transmitter and receiver. The approximate separation between the Part 15 transmitter and receiver was 55 feet. For the other use case, the Part 15 transmitter was moved outdoors to an open atrium area immediately outside of the office. The approximate separation between the Part 15 transmitter and receiver was 50 feet.

Test Location B:

This location is a large single floor commercial office of tilt-up construction with high ceilings and concrete and glass exterior. Within the building, offices line the exterior walls and these offices are adjacent to large open areas filled with cubicles. The center of the building is mostly framed construction for common areas (*e.g.*, break room, restrooms) and building facilities (*e.g.*, HVAC, plumbing, and electrical closets).

This location was used exclusively for testing commercial and industrial devices.

Test Location C:

This test location was a two bedroom apartment on the ground floor of a three-story apartment building. The apartment building is one of several buildings in a large modern apartment complex. The construction is wood frame with steel reinforcements. The exterior is stucco.

Two Part 15 use cases were conducted at this site. For one use case, the Part 15 transmitter and receiver were located in separate bedrooms. Two interior walls and a living/dining room area separated the transmitter and receiver and the approximate separation between the Part 15 transmitter and receiver was 34 feet. For the other use case, the Part 15 transmitter was moved outdoors to a patio area that adjoined the two bedrooms. The approximate separation between the Part 15 transmitter and receiver was 28 feet.

Test Location D:

This test location was a modern high rise hotel with a glass and concrete exterior. A WAPS beacon is installed on the roof of the building. For the tests, the Part 15 receiver was situated in a suite-style room located on the top (10^{th}) floor of the hotel. For most tests, the transmitter was located in the hotel hallway approximately 40 to 55 feet away from the receiver. Some additional tests were performed with the receiver and transmitter located within the hotel room, separated by 10 feet or less. For all tests, the WAPS beacon and Part 15 transmitter and receiver were separated only by the building rooftop (assumed to be corrugated steel and concrete construction, with a tar and gravel roof material) at a distance of 50 feet or less.

This specific test location was selected because it permitted testing in very close proximity to a WAPS beacon with a realistic (*e.g.*, indoors with some reasonable transmitter – receiver separation) Part 15 use case. This test location, however, is undoubtedly a worst case scenario for testing the potential impact of a WAPS beacon. It will be a scenario that is very infrequent in a commercial WAPS deployment.

Test Location E:

This test location consisted of two adjacent studio apartments that are part of an extended stay hotel. The units were located on the ground floor of the two-story apartment unit. The construction is typical wood frame materials as found throughout California. However, we believe there is a firewall between the units, which we speculate may be made of cinderblock.

The Part 15 receiver was placed in one apartment and the transmitter in the other. The approximate separation between the Part 15 transmitter and receiver was 21 feet.

Test Location F:

This test location was a two-story single family home located in a residential development. The wood frame construction with stucco exterior is very typical of homes throughout California. A small courtyard patio is located behind the home and is directly accessed through a set of sliding doors that connect to the kitchen and dining room areas.

The floor plan created a number of different Part 15 use cases to test. The test cases included a master bedroom to kitchen use case of approximately 38 feet in length; a master bedroom to dining room test path approximately 45 feet in length, a master bedroom to outdoor patio use case of approximately 60 ft. in length; and a kitchen to outdoor patio use case of approximately 17 feet in length. The indoor tests involving the master bedroom were further obstructed by a floor (*i.e.*, the master bedroom is on the second floor) and multiple interior walls.

Test Location G:

This test location was a three bedroom condominium on the second floor of a two-story building. The condominium building is one of several in a large modern complex and the construction is wood frame with steel reinforcements with stucco. Overall this test location was similar in character to that of Test Location C.

One Part 15 use case was conducted at this site. The Part 15 transmitter was located in the dining nook of the kitchen and the receiver was located in the adjacent bedroom. The propagation path was approximately 14 feet in length and one interior wall separated the devices.

Test Location H:

This test location was a one- and two-story single family home located in a residential development. Construction is wood frame materials with stucco exterior similar to Test Location F, however, this is a larger home with a more sprawling layout surrounding a courtyard. A large section of the home is only one floor in height.

A single Part 15 use case was conducted, with the transmitter and receiver separately placed in a bedroom at the front of the house and the kitchen. The propagation path traversed the outdoor courtyard and intersected both interior and exterior walls. The path length was approximately 60 feet for the DSS and FHSS devices. For the analog FM devices, a path length of approximately 48 feet was used in order to enable a reliable link between the Part 15 transmitters and receivers.

Test Location I:

This test location was a single story single family home located in a residential development. It was an older home typical of Craftsman or bungalow construction prevalent in California in the mid 1900's.

A single Part 15 use case was conducted, with the transmitter and receiver separately placed in kitchen at the back of the house and the basement. The propagation path was approximately 38 feet in length with the floor separating the kitchen from basement as the main blockage. The foundation was cinder block and concrete and several support columns and half walls were within the propagation path.

Test Location J:

Similar to Test Location D, this was a modern, high rise hotel constructed of steel and reinforced concrete with a tinted glass and stucco exterior. This location is approximately 500 feet from a WAPS beacon site that is installed on the roof of a nine story building across the street. The hotel room tower was rectangular in shape and rooms run across both of the longer dimensions. Two adjacent standard hotel rooms located near the midpoint of the longer building dimension and facing away from the WAPS beacon site were used for testing. The Part 15 transmitter was situated on a coffee table and the receiver was located in the adjacent room on a desk. The propagation path was approximately 12 feet in length with one intervening interior wall. The construction of the wall was not ascertained but is assumed to be metal stud with some fireproofing and/or soundproofing materials.

Table 8 below summarizes the test paths used for the testing.

Table 8: Summary of Test Configurations

	Test Location									
	A	B	C	D	E	F	G	H	I	J
Shortest Distance to WAPS Beacon (miles)	0.8	0.5	0.9	0.0	0.6	0.8	3.7	6.5	2.8	0.2
Walls/Ceilings Between Transmitter and Receiver	Numerous interior	1 Exterior	1 firewall & one interior or outer wall	2-3 interior likely firewalls	1 Firewall	1 window or 1 external wall or a ceiling and wall	1 interior	Interior and exterior walls	One Floor	1 wall likely firewall
Beacon LOS (to outside of building)?	No	No	No	Almost- only to roof of building	No	No	No	No	No	Almost- only to roof of building
Part 15 Setting for Use Case	Mixed	Mixed	Mixed	Interior	Interior	Mixed	Interior	Interior but propagation shortest path though exterior	Interior	Interior
Location Construction	Reinforced concrete	Reinforced concrete	Wood frame w/ steel reinforced	Reinforced concrete & Glass	Wood Frame	Wood Frame Stucco exterior	Wood frame w/ steel reinforced	Wood Frame Stucco exterior	Wood Frame	Reinforce d concrete & Glass
Part 15 Path Distance (meters)	17	Varies depending on device	9-10	2, 12,15	6	5 - 18	4	15-20	12	4
Number of Part 15 Use Cases Tested	2-interior & outside walkway	Typically 3	2-interior & outside Patio	2 main a few other trials	1	3	1	1	1	1

Consumer Devices

Test Criteria

The program for testing consumer Part 15 devices was developed to investigate the factors that influence the coexistence of these devices and M-LMS in a controlled and repeatable fashion. These factors include:

1. The distance between the Part 15 transmitter and receiver in typical use.
2. The signal power from the WAPS beacon at the Part 15 receiver, which depends, among other things, on the beacon's power and distance.
3. The effectiveness of the interference mitigation techniques employed by the WAPS beacon network.
4. The effectiveness of the technology employed by the Part 15 device to avoid, tolerate or mitigate interference.
5. The potential impact that the general interference environment from other Part 15 use has on the Part 15 receiver under examination.

To investigate these factors in real world conditions, a standard audio sample was transmitted over the Part 15 device and often recorded for subsequent evaluation and analysis. The use of audio samples simulated the real world use of these devices and serves as the most realistic indication of beacon impact as perceived by the consumer using the Part 15 device. The testing followed a conventional case control study so the "before and after" effects of the WAPS beacon operation could be evaluated.

The basic test approach was to test each of the devices at each test location, once with the WAPS network OFF and then again with it ON. For the ON state testing, an attempt was made to obtain data samples collected both when the Part 15 device is operated co-channel with a WAPS beacon as well as off-channel from a beacon.[10]

The basic flow of the evaluation process is provided in the figure below and is subdivided into the following steps: Device Selection & Test Plan Development, Field Testing, and Post Processing.

[10] Not all of the Part 15 devices tested have a user controlled tuning capability (*e.g.*, a channel selector or channel change button). In particular, the wireless telephone pendant device (device number 10) does not have a user controlled channel change feature and operates only co-channel with the WAPS beacon.

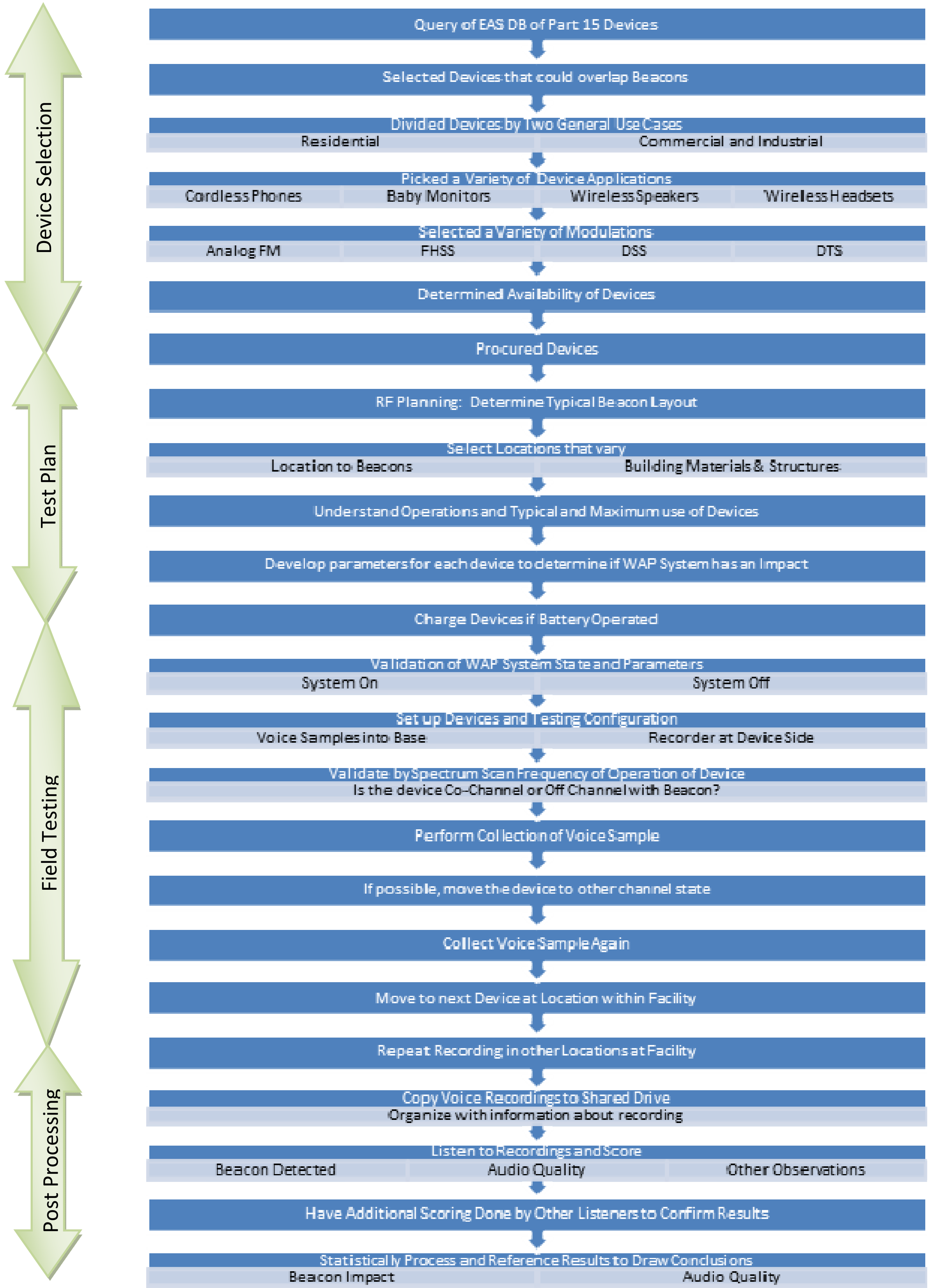

Figure 5: Process Flow for Part 15 Consumer Device Evaluation

Test Configuration and Setup

Figure 6 shows the general test setup, which included:

1. Multiple WAPS beacons.
2. A Part 15 device (*i.e.*, both a transmitter and receiver) capable of operating in those portions of the M-LMS band used by the WAPS beacon transmitters and positioned in conditions representative of normal operation with respect to range, indoors, number of walls, etc.
3. A standard audio sample injected into the Part 15 device transmitter and often recorded at the Part 15 device receiver with a compact recording device. [11]
4. A portable spectrum analyzer that could be used to capture a trace of the WAPS beacon if it was detectable and the Part 15 transmitter signals at the Part 15 receiver.

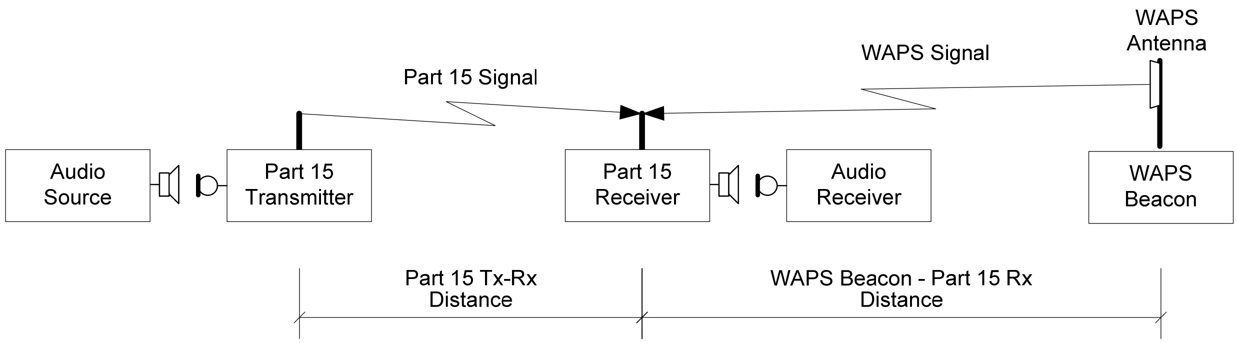

Figure 6: General Test Setup for Testing Consumer Devices

As discussed previously, the distance between the Part 15 receiver and the WAPS beacon was varied by using test locations at different distances from the beacons. The distance between the Part 15 transmitter and receiver varied depending on the specific Part 15 use case at the test location, and in some cases multiple use cases were tested.

Data Collection

Prior to the testing, measurements were performed to confirm that the WAPS beacons operated in the required band at the specified power and were sufficiently detectable to provider a location fix. All tests with the WAPS beacon ON employed two beacon carrier signals, each with bandwidth of approximately 2 MHz, positioned at the lower and upper ends of the M-LMS B-block and C-block, 919.75-921.75 MHz and 925.25-927.25 MHz, respectively.

The Part 15 devices were confirmed to be in working order. Before commencing the test program, a spectrum analyzer was used to confirm that the general operating parameters of the Part 15 device

[11] Most of the Part 15 devices tested, such as baby monitors or cordless phones, support two way communication, so transmitter and receiver terminology is used interchangeably to signify the terminal where the audio sample is injected, the transmitter, and the terminal where it is received. In practice, the transmitter for a two-way device like a cordless phone was the base station and the receiver was the handset.

corresponded to the information contained in the FCC Equipment Authorization. Specifically the channel selections necessary to operate the device in a co-channel or off-channel state was verified.

A standard audio sample to be played through each audio device was prepared. The standard audio sample consisted of 17 Harvard sentences (9 sentences in a female voice and 8 in a male voice) of good fidelity with brief periods of silence between sentences. A one-second tone signified the start and end of the audio sample to permit accurate and consistent recording. The total length of the audio sample was a little more than one minute.

To achieve the best audio fidelity without disassembling the Part 15 device[12], different techniques were used to inject the audio in to the Part 15 transmitter. The audio input technique used for each consumer device is described in Table 9 below.

Table 9: Audio Input Techniques Used for Each Part 15 Consumer Device

Device Number	Device Type	Audio Injection Technique
1	Baby Monitor	Headphone speaker affixed to Part 15 device microphone
2	Baby Monitor	Headphone speaker affixed to Part 15 device microphone
3	Baby Monitor	Headphone speaker affixed to Part 15 device microphone
4	Cordless Phone	Audio jack wired to standard RJ-11 terminal, connected to cordless phone base
5	Cordless Phone	Audio jack wired to standard RJ-11 terminal, connected to cordless phone base
6	Cordless Phone	Audio jack wired to standard RJ-11 terminal, connected to cordless phone base
7	Baby Monitor	Headphone speaker affixed to Part 15 device microphone
8	Wireless Headphones	Direct audio input into headphone base unit
9	Wireless Outdoor Speaker	Direct audio input into speaker base unit
10	Wireless telephone pendant	Base unit connected to phone line emulator (device required dial tone to operate). After connection is initiated, audio jack wired to standard RJ-11 terminal connected to emulator.
12	PTT Radio	Headphone speaker affixed to Part 15 device microphone
14	Cordless Phone	Base unit connected to phone line emulator (device required dial tone to operate). After connection is initiated, audio jack wired to standard RJ-11 terminal connected to emulator.

[12] Pursuant to the Commission's rules, a device is no longer Part 15 compliant if it is disassembled or broken into. *See*, *e.g.*, 47 C.F.R. § 15.21.

In preliminary testing it was observed that the specific placement of the microphone and/or speaker as well as the volume control settings had an impact on audio quality. This was particularly evident for the devices tested with both a speaker and microphone configuration given the multiple interfaces. Particular care was therefore taken to define controlled and repeatable audio level settings for each device. Microphones and speakers were affixed to devices with tape to ensure proper placement throughout the test. The microphones were also embedded into a flexible foam material to isolate them from other background and environmental noise. Of the three techniques used, the direct audio injection, as used for Devices 8 and 9, and the use of the RJ-11 interface with the cordless phones provided the highest quality audio input since no conversion (speaker-to-microphone) was necessary.

Even with these additional precautions, the audio quality among the devices varied and background or other non-WAPS environmental noise was evident in some of the collected samples. At each test location, the Part 15 transmitter was positioned so that it was not close to possible interference sources such as a microwave oven, television, computer, or other incidental radiator. The Part 15 receiver's batteries were charged and it too was positioned to avoid possible interference sources. Care was taken to ensure that other Part 15 devices to be tested were not operational and other apparent sources of Part 15 interference were turned off for test.

Control Case (WAPS beacon OFF)

A single test per device was performed with the WAPS beacons OFF and the Part 15 transmitter ON:

1. Proper operation of the device, placement of the microphone (and speaker as required), and volume control levels for the Part 15 device and test equipment were verified.
2. The operating frequency of the Part 15 device was selected with the aid of a spectrum analyzer. For devices with a tuning capability, the Part 15 device was set to operate in either the 919.75 to 921.75 MHz and/or the 925.25 to 927.25 MHz band.
3. The test technicians coordinated the start of the audio sample playback and the monitoring and recording process. Care was taken to minimize background noise during the tests and the Part 15 devices were held stationary.
4. During the test, the spectrum analyzer was used to obtain a sweep of the entire 902–928 MHz band. A screen capture of the spectrum analyzer plot was obtained for documentation.
5. The recording of the audio sample, if one was taken, was verified and measurement specifics (device, audio file index, etc.) and any unusual ambient conditions or other anomalies observed during the tests were recorded on a measurement log sheet.

Test Case (WAPS beacon ON)

Where possible, two tests, both a co-channel test and off-channel test, were performed with the WAPS beacons and the Part 15 transmitter both ON:

1. Proper operation of the device, placement of the microphone (and speaker as required), and volume control levels for the Part 15 device and test equipment were verified.

2. For devices with a tuning capability, the operating frequency of the Part 15 device was selected with the aid of a spectrum analyzer.
    a. Co-Channel: The Part 15 device was set to operate on a channel *within* either the 919.75-921.75 MHz or the 925.25-927.25 MHz bands. If the device had multiple co-channel alternatives, a channel near the center of the respective M-LMS channel bandwidth (*i.e.*, around 920.75 MHz or 926.25 MHz) was selected.
    b. Off Channel: The Part 15 device was set to operate on a channel *outside* of the 919.75-921.75 MHz and the 925.25-927.25 MHz band. If the device had multiple off-channel alternatives, the channel furthest from the M-LMS channel bandwidths was selected.
3. The test technicians coordinated the start of the audio sample playback and the monitoring and recording process. Care was taken to minimize background noise during the tests and the Part 15 devices under test were held stationary.
4. During the test, the spectrum analyzer was used to obtain a sweep of the entire 902-928 MHz band. A screen capture of the spectrum analyzer plot was obtained for documentation.
5. The recording of the audio sample, if one was taken was verified and measurement specifics (device, audio file index, etc.) and any unusual ambient conditions or other anomalies observed during the tests were recorded on a measurement log sheet. Specifically if a WAPS artifact, audible as a "shhh" or "beep" sound with a one-second period corresponding to the duty cycle of the WAPS beacon, was detected it was noted in the log sheet.

In a number of cases, certain of the tests were repeated on subsequent days, but with otherwise identical test conditions, in order to verify the results. This repetition was particularly helpful with respect to some of the tests in which the WAPS beacon was ON because the WAPS artifact was often very difficult to detect on the audio samples and additional samples were needed in order to verify that a sample either did, or did not, include the WAPS artifact. In making these determinations, we were guided by the following observations:

- In certain instances when the beacons were operational, an audible "shhh" or "beep" pulse was detected. Although the pulse could vary in sound and intensity, it had a regular period of one second. This audible pulse was not a normal part of the Part 15 device operation and attributed to beacon operation.

- Various other non-normal noise conditions (static, buzzes, clicks, swirls, pops, etc.) and blanking interference characteristic of Part 15 device operation could also be detected on many samples. Because these were equally present in both the beacon OFF state tests and the beacon ON state tests, they were attributed to Part 15 device operation.

Commercial/Industrial/Utility Devices

Test Criteria

Similar to the consumer device test, the methodology for Part 15 devices with commercial, industrial, or utility applications was developed to investigate the factors that influence coexistence between these devices and M-LMS use in a controlled and repeatable fashion. The primary difference between the two test programs was the evaluation method. Part 15 devices designed for commercial, industrial and utility applications are generally designed to transmit data, either as a part of a control system (such as a wireless remote), or to transfer information, such as a data acquisition system (utility meter or RFID tag read) or a broadband wireless access system.

The basic test methodology for devices used for commercial, industrial, and utility applications was to determine the maximum range at which a reliable communications link could be maintained with the WAPS network OFF and then again with it ON to see if WAPS beacon operation impacted this maximum range. For the ON state testing, an attempt was made to determine not only the maximum range but whether the link quality was impacted by the beacon signal.

Range was selected because it was simple to measure, easily understood and related directly to the effectiveness of the device for communication. Other possible figures of merit, such as bit error rate, signal to noise ratio and throughput, are hard to measure without physically breaking the device under test. Also, unlike the audio devices, there is no standard test signal or set of signals available that could be used to approximate an industry standard. (Given that the tests were conducted on everything from water meters to broadband devices, this is not surprising.)

In one case involving a fixed wireless broadband device, the throughput of a link with a fixed distance was used instead of the range because it was impractical, and not very meaningful, to move the device back and forth around the area where SMC was conducting testing.

The basic flow of the evaluation process is provided in the figure below.

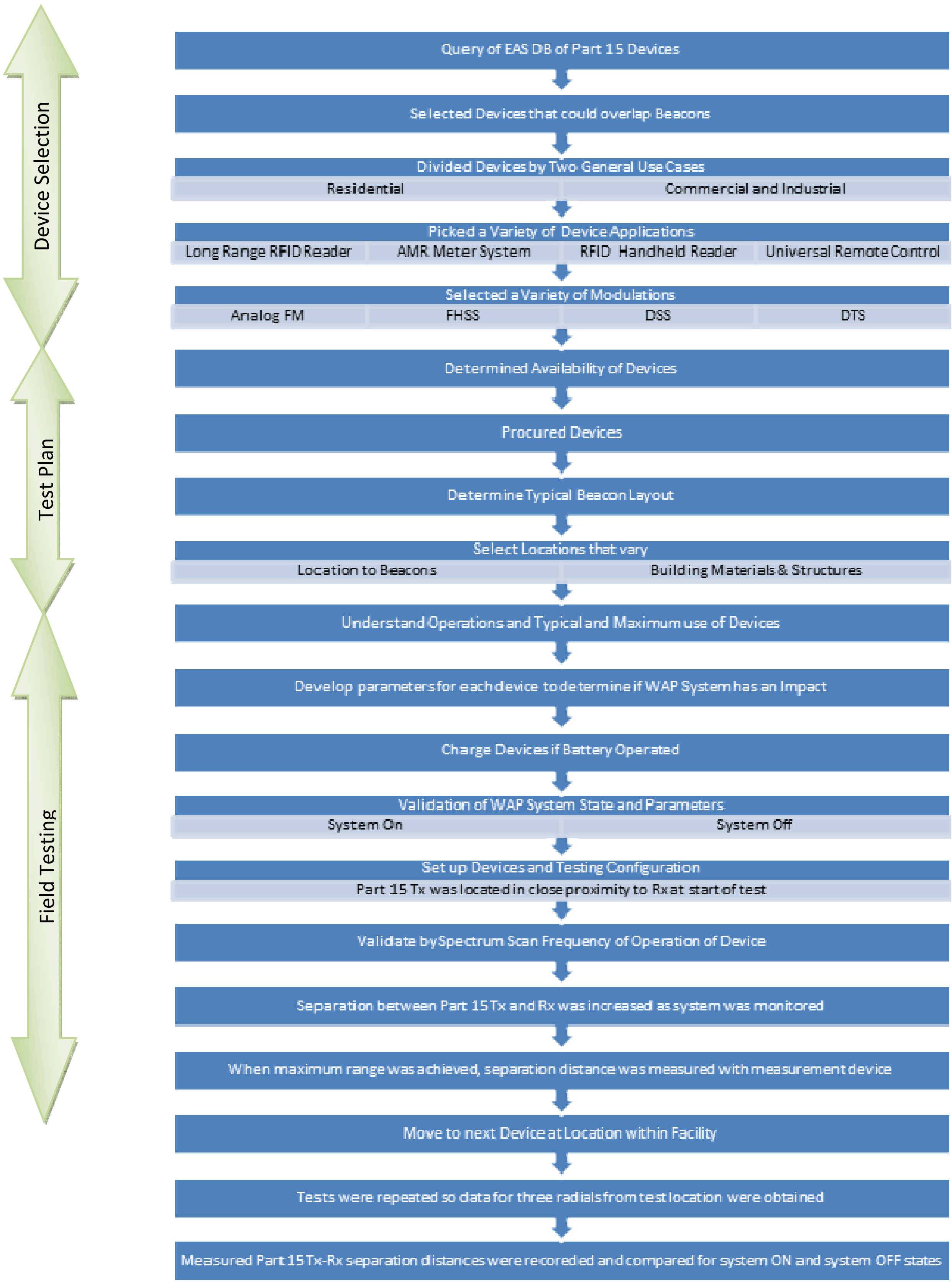

Figure 7: Process Flow for Part 15 Commercial, Industrial and Utility Device Evaluation

Test Configuration and Setup

Figure 8 shows the general test setup, which included:

1. Multiple WAPS beacons.
2. A Part 15 device (*i.e.*, both a receiver and transmitter) operating in the M-LMS band.
3. The Part 15 device situated at its maximum range, which was determined with the WAPS beacons turned both OFF and ON.
4. A portable spectrum analyzer was sometimes used to capture a trace of the WAPS beacon and the Part 15 transmitter signals at the Part 15 receiver.

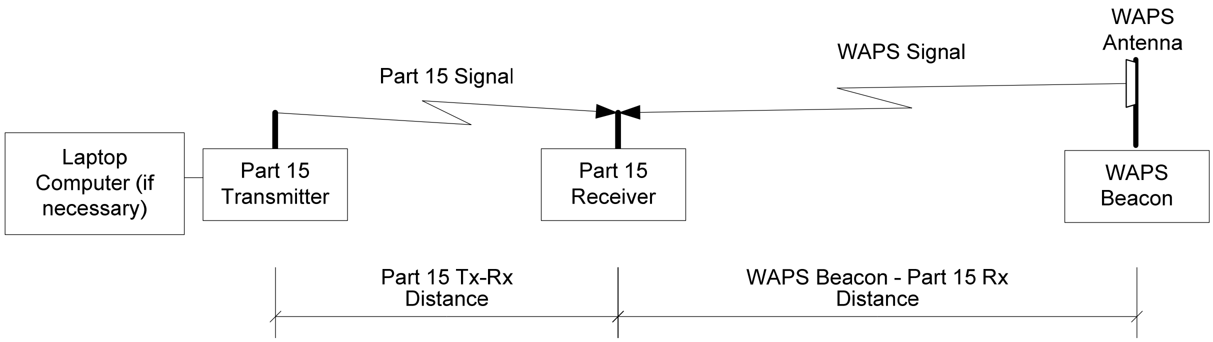

Figure 8: General Test Setup for Testing Commercial, Industrial, and Utility Devices

Tests were conducted at two locations that were both within 0.7 miles of a WAPS beacon. Given that these devices utilize more robust DSS or FHSS technology, testing at distances further away from the beacon was not deemed necessary. Figure 9 is a satellite image of the general test area. The test area is a commercial park characterized by generally flat terrain with buildings of one to five floors in height and some foliage 20 to 30 feet in height.

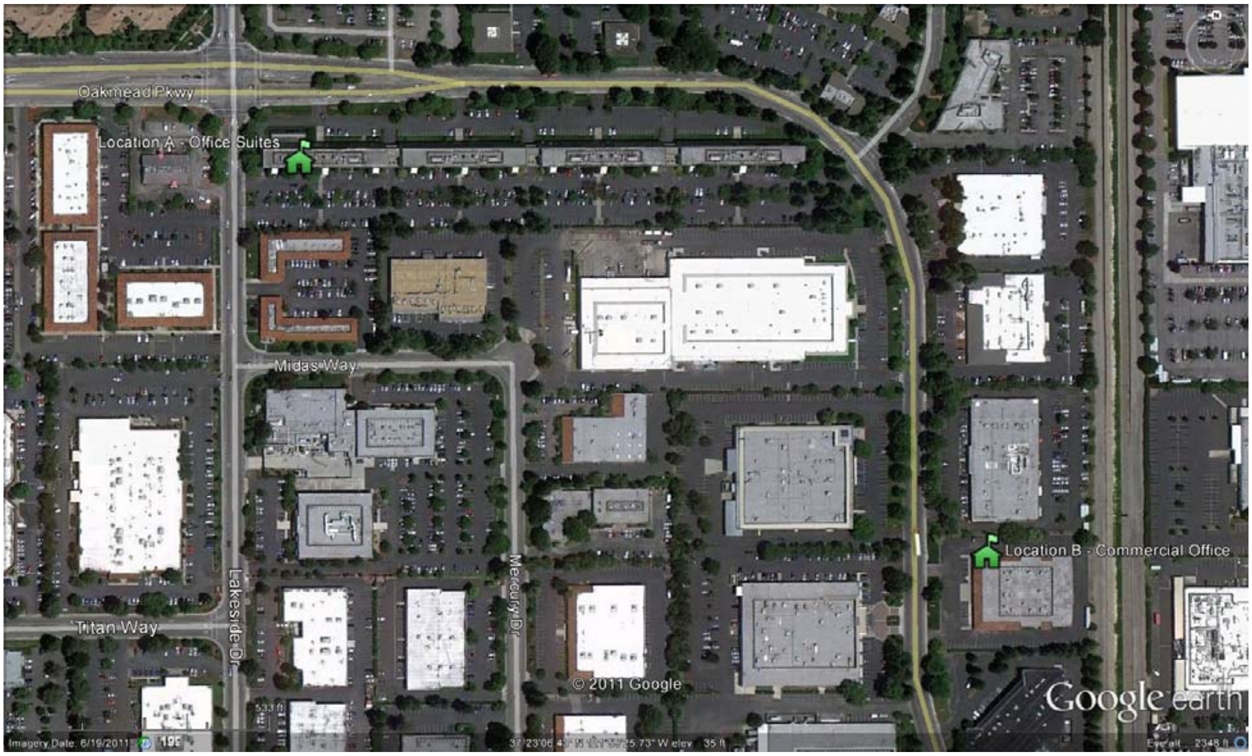

Figure 9: General Area Where Commercial, Industrial, and Utility Part 15 Devices Were Tested

For most measurements, the Part 15 transmitter and receiver were initially located in close proximity to each other and the distance separating them was slowly increased until the transmitter and receiver could no longer achieve reliable communications.[13] In the case of the wireless broadband system, the transmitter and receiver separation was fixed according to the locations where these units were installed and the communications link was evaluated by measuring the data throughput that could be achieved.

Further detail regarding the configuration of the various Part 15 systems is described below.

Broadband Wireless Access System

The transmitter and receiver for the broadband wireless access (BWA) system was installed on the rooftop of one building and the subscriber unit was installed on a tripod to allow us to test multiple locations. The link was tested twice at two locations 0.4 miles and 0.43 miles from the fixed panel antenna on the roof of the first building. The link was not a clear line of sight due to a corner of a building that was likely in the Fresnel zone and number of trees in the path.

[13] As will be seen in the data analysis, the usable range for this category of Part 15 devices varied substantially. RFID tag readers are intended for very short range, one-way communication while the useful range for the utility meter reader extended to almost a quarter of a mile.

RFID Tag Readers

Both a "short range" handheld RFID tag reader and "long range" laptop-operated RFID tag reader were tested. The tests were conducted indoors at both Test Location A and B and three different RFID tags were used.

Preliminary testing of both tag readers revealed that the devices were very sensitive to the orientation of both the RFID tag and the reader itself. Special care was taken during the testing to ensure that consistent measurement geometry was maintained. Tests were repeated several times to verify results.

Utility Meter Reader

The utility meter system consisted of a meter device and vehicle based transceiver. The meter device was a weatherized, self-contained battery operated transceiver designed as a "collar" for a water meter. The vehicle based transceiver consisted of an external magnetic mount antenna, transceiver unit, and RS-232 connection to a laptop. A software application on the laptop was used to both configure the system and acquire data.

As no diagnostic software was available, the system was tested by configuring it to perform reads at 6-second intervals. With each measurement, the software application would report whether a status measurement was successful or if it had failed.

Wireless Remote Control System

The wireless remote control system consisted of a handheld transmitter and a receiver that controlled multiple relays. To test the unit, an LED light was connected to one of the available relays such that pressing the control button on the remote transmitter caused the light to turn on.

Data Collection

The general data collection process was similar to the one used for testing consumer devices. Both system ON and system OFF tests were performed for the devices and the devices were tested in a controlled and repeatable fashion. The key difference is that, because the tests relied on a measurement of the useful link or coverage range of the Part 15 device, an audio measurement sample was not obtained. Instead, linear distances were measured and used for the "ON/OFF" type analysis that was performed.

Control Case (WAPS beacon OFF)

Multiple tests were performed for each device with the WAPS beacons OFF and the Part 15 transmitter ON:

1. A start location was established where the transmitter and receiver were in close proximity. For the wireless remote and utility meter technology this was a distance of 20-30 feet. For the RFID systems the distance was approximately 5 feet.
2. Proper operation of the device was verified at the start location.
3. With the system operating, the test technician would increase the separation distance between the Part 15 device transmitter and receiver.
4. Where appropriate, another text technician monitored the receiver to ensure that the device was operating normally. For example, in the case of the utility meter the configuration screen

was monitored to ensure that status measurements were received on a consistent 6-second interval.

5. When the criterion used to determine the edge of coverage was satisfied, the test technician moved about the location (left, right, front, and back) to ensure that the measurement actually corresponded to maximum range and not an effect of localized fading.
6. A rolling measurement device was used to measure the transmitter/receiver displacement. Any unusual ambient conditions or other anomalies observed during the tests were recorded on a measurement log sheet.

The procedure above was repeated along three different radials extending from the start location. One of these radials (Test Case 1) involved placing the Part 15 device at an elevated location with the receiver at ground level. The other two test cases each involved ground level tests using different radials from the state location to identify potential variations in local noise conditions and propagation paths.

Test Case (WAPS beacon ON)

The commercial, industrial, and utility devices did not have a manual channel selection feature. It was therefore not possible to separately test co-channel and adjacent-channel conditions. The data collection procedure used in the beacon ON condition was identical to that used for the corresponding system OFF test.

Multiple tests were performed for each device with the WAPS beacons ON and the Part 15 transmitter ON:

1. A start location was established where the transmitter and receiver were in close proximity. For the wireless remote and utility meter technology this was a distance of 20-30 feet. For the RFID systems the distance was approximately 5 feet.
2. Proper operation of the device was verified at the start location.
3. With the system operating, the test technician would increase the separation distance between the Part 15 device transmitter and receiver.
4. Where appropriate, another text technician monitored the receiver to ensure that the device was operating normally. For example, in the case of the utility meter the configuration screen was monitored to ensure that status measurements were received on a consistent 6-second interval.
5. When the criterion used to determine the edge of coverage was satisfied, the test technician moved about the location (left, right, front, and back) to ensure that the measurement actually corresponded to maximum range and not an effect of localized fading.
6. A rolling measurement device was used to measure the transmitter/receiver displacement.
7. Any unusual ambient conditions or other anomalies observed during the tests were recorded on a measurement log sheet.

The procedure above was repeated along the same three radials, extending from the start location, as was done in the system OFF tests.

Test Results

Consumer Devices in Typical Operation

As discussed in the Background section of this report, a Part 15 device in typical operating conditions will be used in such a manner that minimizes the impact of other Part 15 device transmissions on its communications. Results presented in this section focus on specific measurements corresponding to this condition. Specifically, for devices that have fixed, selectable channels, typical operation occurs when the device is operated on frequencies not used by the WAPS beacons.

Typical operation also encompasses Part 15 devices with FHSS technology or DSS devices that sense interference and automatically reselect the operating channel. Finally, typical operation encompassed one Part 15 device (the wireless pendant) that did not include channel selectivity and instead used only a single frequency that was co-channel with the WAPS beacon.

Data was collected for a total of 156 different measurement states[14] with the WAPS beacons ON, the Part 15 consumer device in its typical mode of operation, and the Part 15 consumer devices placed in test locations that are characteristic of the coexistence between Part 15 and M-LMS use. Another 156 states were measured with the system OFF or a total of 312 measurement states in both system states. Table 10 summarizes the measurements obtained and the corresponding results. There was no evidence of a WAPS beacon impact in the measurements obtained for typical Part 15 device operation, except for the wireless pendent, which could not operate on another channel. Note that the wireless pendant was able to detect the WAPS signal only at two locations where the WAPS beacon was relatively close, as indicated in Table 11. Further, even when the WAPS beacon could be detected, the device could still be used to transmit audio and the ability to recognized speech was unchanged.

Table 10: Tests of Consumer Devices in Typical Operation

(Beacon Detected/Total)	WAPS Beacon ON	WAPS Beacon OFF
Off Channel of Beacon	0/117	0/117
Non-Selectable Devices (FHSS or DSS)	0/26	0/26
Non Selectable Co-Channel Device	2/13	0/13
Total	**2/156**	**0/156**

[14] A state is one representative sample at one location, at one test path, with one device channel selected, in one system state.

Table 11: State Summary of Consumer Devices by Location in Typical Operation

Device Number			1	2	3	4	5	6	7	8	9	10	12	14	
Manufacture			Evenflo	Summer Infant	Safety 1st	Sony	Uniden	AT&T	Graco	Sennheiser	Brookstone	Logic Mark	Motorola	Sony	
Device Type			Baby Monitor	Audio/Video Baby Monitor	Audio/Video Baby Monitor	Cordless Phone	Cordless Phone	Cordless Phone	Baby Monitor	Wireless Headphones	Wireless Outdoor Speaker	Wireless E911 Pendant	PTT	Cordless Phone	
Modulation			Analog FM	Analog FM	Analog FM	Analog FM	Analog FM	Analog FM	DSS	Analog FM	Analog FM	Analog FM	FHSS	DSS	
Device Channel Selection			Off	Off	Off	Off	Off	Off	Off	Off	Off	Co	Auto	Auto	
Location Code	Distance to Nearest Beacon	Test Path													Total
A	0.8 mi	Office #303 - Office #306													0
A	0.8 mi	Office #303 - Outside													0
C	0.9 mi	Bedroom #1 - Bedroom #2													0
C	0.9 mi	Bedroom #1 - Patio													0
E	0.6 mi	Room - Room													0
F	0.8 mi	Kitchen													0
F	0.8 mi	Backyard										x			1
F	0.8 mi	Kitchen to Backyard													0
F	0.8 mi	Kitchen to Bedroom													0
G	3.7 mi	Bedroom - Kitchen													0
H	6.5 mi	Bedroom - Kitchen													0
I	2.8 mi	Kitchen													0
J	0.2 mi	Room - Room										x			1
Beacon Detected Total												2			2
Total States Tested			13	13	13	13	13	13	13	13	13	13	13	13	156

Consumer Devices in Atypical Operation

Atypical operation of a Part 15 device occurs when the device is prevented from automatically shifting to a more desirable channel or where multiple channels are available and the user intentionally operates the device using a less desirable channel. The data presented in this section focus on the results for specific measurements corresponding to this condition. Specifically for devices that have fixed, selectable channels, atypical operation occurs when the device is operated on an overlapping frequency within the WAPS beacon channels on a continuous basis despite the availability of other selectable channels.

A total of 117 measurements were collected with the WAPS beacons ON, the Part 15 consumer device in an atypical mode of operation, and the Part 15 consumer device placed in test locations that are characteristic of the coexistence between Part 15 and M-LMS use.[15] Table 12 summarizes the measurements obtained and the results. A WAPS beacon artifact was detected in 27 measurements.

Table 12: Consumer Devices in Atypical Operation

(Beacon detected/Total)	WAPS Beacon ON	WAPS Beacon OFF
Co Channel with Beacon	27/117	0/117
Total	**27/117**	**0/117**

[15] The total number of measurement states tested in atypical operating conditions is less than the total number of measurement states tested in typical operating conditions because some Part 15 consumer devices could not be made to operate in an atypical operating condition.

Table 13: Consumer Devices by Location in Atypical Operation

Device Number			1	2	3	4	5	6	7	8	9	
Manufacture			Evenflo	Summer Infant	Safety 1st	Sony	Uniden	AT&T	Graco	Sennheiser	Brookstone	
Device Type			Baby Monitor	Audio/Video Baby Monitor	Audio/Video Baby Monitor	Cordless Phone	Cordless Phone	Cordless Phone	Baby Monitor	Wireless Headphones	Wireless Outdoor Speaker	
Modulation			Analog FM	Analog FM	Analog FM	Analog FM	Analog FM	Analog FM	DSS	Analog FM	Analog FM	
Device Channel Selection			Co	Co	Co	Co	Co	Co	Co	Co	Co	
Location Code	Distance to Nearest Beacon	Test Path										Total
A	0.8 mi	#306								x	x	2
A	0.8 mi	Outside	x				x			x	x	4
C	0.9 mi	Bedroom #2								x		1
C	0.9 mi	Bedroom #1 - Patio								x		1
E	0.6 mi	Room - Room								x		1
F	0.8 mi	Kitchen						x		x	x	3
F	0.8 mi	Backyard	x				x				x	3
F	0.8 mi	Kitchen to Backyard	x							x	x	3
F	0.8 mi	Kitchen to Bedroom					x		x		x	3
G	3.7 mi	Bedroom - Kitchen								x		1
H	6.5 mi	Bedroom - Kitchen										0
I	2.8 mi	Kitchen								x		1
J	0.2 mi	Room - Room	x			x				x	x	4
Detected Total			4	0	0	1	3	1	1	10	7	27
Total States Tested			13	13	13	13	13	13	13	13	13	117

As shown in Table 13, even under atypical operation with the Part 15 device operating co-channel with the WAPS beacon, a beacon artifact was not detected in most instances. A total of 27 measurements, or 23 percent of all measured states obtained under atypical operation, had a beacon artifact present. Indeed, two of the devices were unable to detect the beacon signal when operated co-channel with a beacon for any of the locations tested. Three other devices were able to detect the beacon signal at only one of the test locations.

In nearly all cases in which a WAPS beacon signal was detected, the signal artifact of only one WAPS transmitter could be identified on the resulting audio sample. The cases in which two beacons were detected were rare and in no test case were more than two beacon signals detected. Based on the test results, it is reasonable to conclude that Part 15 receivers operating in typical conditions will not detect the WAPS beacon in most situations due to environmental signal attenuation such as physical obstructions, or because the more proximate transmissions from the associated Part 15 transmitter prevent such reception.

Break Case Beacon Impact

As noted above, measurements were obtained at a location colocated with a WAPS beacon, specifically on the top floor of a modern high rise hotel with a WAPS beacon installed on its rooftop (Location D). The less than 50 foot separation between the WAPS beacon and the general test location represents a break case scenario for coexistence. Although this scenario is not typical of a commercial or residential setting, it was nonetheless useful for testing as it provided insight into the mechanisms that govern coexistence.

A total of 24 measurements were collected at Location D for various combinations of WAPS beacon state (*i.e.*, ON or OFF) and Part 15 operating conditions (*i.e.*, typical or atypical). Results of the measurements obtained at Location D are summarized in Table 14 through Table 17 below.

Table 14: Measurement Results for Typical Part 15 Device Operation Obtained at Break Case Scenario for Coexistence

(Beacon detected/Total)	WAPS Beacon ON	WAPS Beacon OFF
Off Channel of Beacon	4/9	0/9
Non Selectable Devices (FHSS or DSS)	0/2	0/2
Non selectable co-channel device	1/1	0/1
Total	**5/12**	**0/12**

Table 15: State Summary of Consumer Devices by Location in Typical Operations at Break Case Scenario for Coexistence

Device Number			1	2	3	4	5	6	7	8	9	10	12	14	
Manufacture			Evenflo	Summer Infant	Safety 1st	Sony	Uniden	AT&T	Graco	Sennheiser	Brookstone	Logic Mark	Motorola	Sony	
Device Type			Baby Monitor	Audio/Video Baby Monitor	Audio/Video Baby Monitor	Cordless Phone	Cordless Phone	Cordless Phone	Baby Monitor	Wireless Headphones	Wireless Outdoor Speaker	Wireless Pendant	PTT	Cordless Phone	
Modulation			Analog FM	Analog FM	Analog FM	Analog FM	Analog FM	Analog FM	DSS	Analog FM	Analog FM	Analog FM	FHSS	DSS	
Device Channel Selection			Off	Off	Off	Off	Off	Off	Off	Off	Off	Co	Auto	Auto	
Location Code	Distance to Nearest Beacon	Test Path													Total
D	0.0 mi	10th Floor	x				x			x	x	x			5
Beacon Detected Total			1				1			1	1	1			5
Total States Tested			1	1	1	1	1	1	1	1	1	1	1	1	12

Table 16: Measurement Results for Atypical Part 15 Device Operation Obtained at Break Case Scenario for Coexistence

(Beacon detected/Total)	WAPS Beacon ON	WAPS Beacon OFF
Co Channel with Beacon	7/9	0/9
Total	**7/9**	**0/9**

Table 17: Measurement Results for Atypical Part 15 Device by Locations Obtained at Break Case Scenario for Coexistence

Device Number			1	2	3	4	5	6	7	8	9	
Manufacture			Evenflo	Summer Infant	Safety 1st	Sony	Uniden	AT&T	Graco	Sennheiser	Brookstone	
Device Type			Baby Monitor	Audio/Video Baby Monitor	Audio/Video Baby Monitor	Cordless Phone	Cordless Phone	Cordless Phone	Baby Monitor	Wireless Headphones	Wireless Outdoor Speaker	
Modulation			Analog FM	Analog FM	Analog FM	Analog FM	Analog FM	Analog FM	DSS	Analog FM	Analog FM	
Device Channel Selection			Co	Co	Co	Co	Co	Co	Co	Co	Co	
Location Code	Distance to Nearest Beacon	Test Path										Total
D	0.0 mi	10th Floor	x	x		x	x	x		x	x	7
Beacon Detected Total			1	1		1	1	1		1	1	7
Total States Tested			1	1	1	1	1	1	1	1	1	9

Note that only the analog FM devices detected the beacon in each of the break case test states. These are the same six analog FM devices that detected the beacon in the atypical use scenario along with one analog FM devices. The DSS device did not detect the beacon in atypical use in the break case test.

In each instance in which a WAPS beacon was detected in the break case test conditions, the Part 15 device continued to operate, transmitting and receiving its desired signal. The Part 15 device could still be used for its intended purpose and the WAPS beacon audio artifact could be eliminated in nearly all cases by changing the channel or moving the Part 15 transmitter and receiver closer together.

Commercial/Industrial Devices

AMR, Wireless Remotes and RFID Devices

Four commercial, industrial and utility devices were tested under the first test scenario identified for such devices, while the broadband wireless access (BWA) system was subjected to its own test scenario. As seen in Table 18, the tests showed no material differences for any of the devices when the WAPS beacon was ON and when it was OFF. Differences that are evident in the test results appear to be caused by variations in the orientation between the RFID tag and the readers, or by slight errors introduced through the use of the distance measuring wheel (Figure 10) on uneven surfaces.

Figure 10: Distance Measuring Wheel

Table 18: Summary of Measurements for Commercial/Industrial/Utility Devices

Test Location A	System Off (Distance in feet)			System On (Distance in feet)		
	Test Case 1	Test Case 2	Test Case 3	Test Case 1	Test Case 2	Test Case 3
AMR Meter System	354.3	997.0	658.0	354.0	982.0	661.0
Universal Remote Control	78.0	201.0	89.0	81.0	201.0	80.0
Long Range RFID Reader	21.0	18.3	3.0	22.0	19.0	2.8
Handheld RFID Reader	21.5	17.0	8.0	23	18.0	8.0

Test Location B	System Off (Distance in feet)			System On (Distance in feet)		
	Test Case 1	Test Case 2	Test Case 3	Test Case 1	Test Case 2	Test Case 3
AMR Meter System	447.0	369.0	747.7	467.0	376.0	747.7
Universal Remote Control	317.0	189.0	291.0	298.0	180.0	294.0
Long Range RFID Reader	20.0	19.7	3.7	20.0	19.7	3.4
Handheld RFID Reader	60.0	36.0	7.5	60.0	36.0	7.5

The three Test Cases come from testing the devices along three different radials extending from the start location in order to identify any variables (such as the impact of ambient noise) at the test location.

Broadband Wireless Access System

In a manner similar to that used in setting up the operating conditions for the consumer devices, we determined a typical use case for a Broadband wireless Access (BWA) system, and set the device under test to meet those conditions. The BWA system used in this case was a Motorola Canopy system. This system consists of an Access Point (AP), which performs in a manner similar to a Wi-Fi AP, and subscriber units which are associated with the customer end user equipment. The Canopy system is designed to be professionally installed on towers and building rooftops, with data connectivity to the customer provided by way of an Ethernet (RJ45) connection. The Canopy system is designed as a Point-to-Multipoint system, so multiple subscriber units share the capacity provided by a single AP.

In order to emulate a typical installation and customer use, we first determined a throughput requirement. Since we have seen many instances of such BWA systems being used for the transmission of multiple applications we decided to test a range of throughputs as the baseline throughput requirements at 500 kbps, 750 kbps and 1000 kbps rates.

The test location was selected in part because it permitted us to set up the BWA system so that it could achieve the baseline throughput levels with the WAPS beacon OFF. The test link had the AP on the roof of one building and the subscriber unit installed on a tripod to allow us to test using multiple locations. The signal was generated from the subscriber unit to the AP (uplink path). The link was tested twice at two locations 0.4 miles (red path) and 0.43 miles (yellow path) from the building fixed panel antenna on the roof. The link was not a clear line of sight due to a corner of a building likely being in the Fresnel zone and number of trees in the path. As indicated in Figure 11, the nearest WAPS beacon was located on the adjacent building to the test location of the AP (which was acting as the receiver for test purposes), or 0.10 miles away.

Figure 11: Location of BWA Links and Closest WAPS Beacon

The BWA subscriber device includes a software tool provided by the manufacturer to help the installer find the best link. It is unclear whether this RSSI measurement was associated only with the signal transmitted by the AP or whether the reported RSSI included power being received from other Part 15 sources. The reported received signal strengths in the -55 to -84 dBm range.

As noted, the BWA system is capable of operating on a number of different frequencies, ranging from a center frequency of 906 MHz to a center frequency of 924 MHz, permitting the installer to select the most desirable frequency in a particular location. Most of the available operating frequencies for the BWA system are below the frequency range licensed to Progeny. For the throughput tests, we operated the BWA system with a center frequency of 906 MHz and 920 MHz, each with the WAPS system ON and the WAPS system OFF, and noted whether the system delivered the desired test throughput levels of service. The 920 MHz band was selected because it provided the most significant overlap between the 2 MHz WAPS signal centered at 920.75 MHz and the 8 MHz BWA signal centered at 920 MHz.

When the WAPS network was turned ON, the spectrum analyzer tool reported a one (1) dB rise in signal strength at Location 1. As shown in Figure 11, the nearest beacon was located about 0.43 miles from Location 1. The result was basically identical at Location 2: the tool reported no difference in noise when co-channel with the WAPS network, whether it was ON or OFF. The summary of the results are shown in Table 19.

Table 19: Broadband Wireless Throughput at Different Center Frequencies

Average Measured Throughput (kbps)					
			Throughput Test Rate (kbps)		
WAPS Status	Location	Frequency (MHz)	500	750	1,000
OFF	**1**	**906**	500.00	750.55	1,000.45
ON	**1**	**906**	500.00	749.95	1,000.35
Percent throughput reduction with WAPS ON			0.0%	<0.08%	<0.01%
OFF	**1**	**920**	500.00	746.75	999.80
ON	**1**	**920**	499.90	749.95	940.15
Percent throughput reduction with WAPS ON			0.02%	0.0%	5.97%
OFF	**2**	**906**	500.00	750.50	1,000.35
ON	**2**	**906**	500.00	750.50	999.85
Percent throughput reduction with WAPS ON			0.0%	0.0%	<0.05%
OFF	2	920	500.00	749.90	1,000.40
ON	2	920	500.00	750.50	997.35
Percent throughput reduction with WAPS ON			0.0%	0.0%	0.3%

As summarized in Table 19, operation of the WAPS system did not affect the performance of the link even when the link was operating at 920 MHz with nearly the same center frequency as the WAPS beacon. As can be seen, the difference in throughput with the WAPS system ON and OFF was not meaningful.

Coexistence of M-LMS Network and Part 15 Devices

APPENDIX

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Appendix

Part 15 Devices

EA Database for Part 15 Devices

The FCC's Office of Engineering and Technology (OET) maintains an on-line database of equipment authorizations (type approvals or type acceptances) known as the Equipment Authorization System (EAS). The EAS lets manufacturers and OET electronically file information regarding devices that are to be marketed in the United States. Members of the public may consult the EAS for information about the equipment.

Ideally, NextNav would select Part 15 devices based on their prevalence in the marketplace. However, NextNav found that product-level data on device sales or market share was proprietary and closely held by manufacturers. The EAS offered a way to determine what types of unlicensed devices were likely to be in the marketplace. However, information in the EAS cannot distinguish between widely used and rarely used items.

NextNav used the following process to access the database. These steps were intended to be sure that a comprehensive list of devices was pulled, before sampling.

1. All searches were performed on April 13, 2010 at Equipment Authorization Search https://fjallfoss.fcc.gov/oetcf/eas/reports/GenericSearch.cfm
2. A separate search was done for each Equipment Class. The search range was: 902 – 928. The "Exact Match" box was not checked
3. Search results were copied from the browser page and pasted into spreadsheet tabs in Microsoft Excel.
4. Each tab was sorted to remove extra lines and a heading row was added
5. Sequence numbers were added to preserve the original order of each search return
6. A column with the Equipment Class code was added
    a. Steps 5. and 6. ensure that no information is lost when the search results are pooled.
7. Data for all equipment classes except LMS were pooled on a single spreadsheet tab.
8. Duplicates were removed as follows:
9. Sort the data by: FCC ID > Lowest Frequency > Highest Frequency > Date Filed
10. If a record's FCC ID is unique, we recorded it.
11. If two records had the same FCC ID but different dates, we recorded the most recent one.
12. If two records had the same date and ID, but one included the frequency and the other did not, we did not record the one with the missing frequencies. (This step is necessary because sometimes a two-way device has two records with the same FCC ID, one for base and the other for handset.)
13. Records with frequencies outside 902-928, such as 2.4 and 5.8 MHz bands, were removed.

14. We then added a column of uniformly distributed [0, 1] random numbers to facilitate sub-sampling.

As can be seen from Table 1, this process yielded 5,216 records. In order to ensure that the devices to be sampled were (a) likely to be on the market and (b) might be subject to interference, the sample itself was drawn only from a subset of these records, consisting of devices registered after January 1, 2005 and with frequencies that included the M-LMS spectrum As can be seen, there were 867 records that met these criteria, about 16% of the total.

Even though there are ten possible equipment classes, it is interesting to note in Table 1 that by 2005 only four of them are in regular use. However, just because the Equipment Code for a "Cordless Telephone System" is no longer used does not mean that cordless telephones are no longer being registered. It turns out that cordless phones and other consumer devices that use digital modulation and are registered under §15.247 are listed as Spread Spectrum Transmitters or Digital Transmission Systems.

Part 15 Types	Entire database	In M-LMS spectrum and registered since 1/1/2005	Random Sample
Part 15 Security/Remote Control Transmitter	61	1	0
Part 15 Remote Control/Security Device Transceiver	23	0	0
Part 15 Spread Spectrum Transmitter	1665	535	12
Digital Transmission System	303	108	2
Part 15 Low Power Transceiver, receiver Verified	1085	79	3
Part 15 Low Power Communication Device Transmitter	1893	144	3
Part 15 Automatic Vehicle Identification System	1	0	0
Part 15 Cordless Telephone System	134	0	0
Part 15 Anti-Pilferage Device	7	0	0
Part 15 Field Disturbance Sensor	44	0	0
Total	**5216**	**867**	**20**

Table 1: EAS Database by Equipment Type

Finally, a sample of twenty devices was drawn by taking the devices with the smallest random numbers assigned in Step 10 above.

Inspection of the sample revealed that almost all the devices were commercial, not consumer devices. NextNav therefore collected additional devices. This second group of devices includes cordless phones and baby monitors labeled as "900 MHz" and bought at retail outlets and on-line. Note that these additional units were not selected in a random process.

The next step was to obtain technical details about the identified devices. To do this, the EAS was searched again using to the FCC ID number for each device. NextNav then consulted the materials on file with the FCC, including user manuals, test reports and any annexes, operational descriptions and similar material describing the function and operation of the device.

Table 2 and Table 3 show two breakdowns of the random and non-randomly selected device groups. The groups are quite different. For example, 15 of the 21 operating modes in the random group use some form of digital modulation. Only 4 of the 15 devices in the non-random do this.

Technology	Random Group	Noon-Random Group
FHSS	12	0
DTS	1	4
TDMA	2	0
Analog FM	5	11
Other / unstated	1	0
Total	**21**	**15**

Table 2: Technologies Identified In Groups

Note: One device in the random group is counted twice because it could operate in either FHSS or DTS modes.

FCC Rule Part	Random Group	Non-Random Group
15.247	13	4
15.249	6	11
Other / unstated	1	0
Total	**20**	**15**

Table 3: FCC Rule Parts for Groups

Test Setup

Figure 1: Typical setup of Transmitter End of Part 15 Devices

Figure 2: Typical Receiver End of Part 15 Devices

Test Locations

The following pictures show the typical surroundings of test locations, residential and semi commercials where these devices are used.

Embassy suites

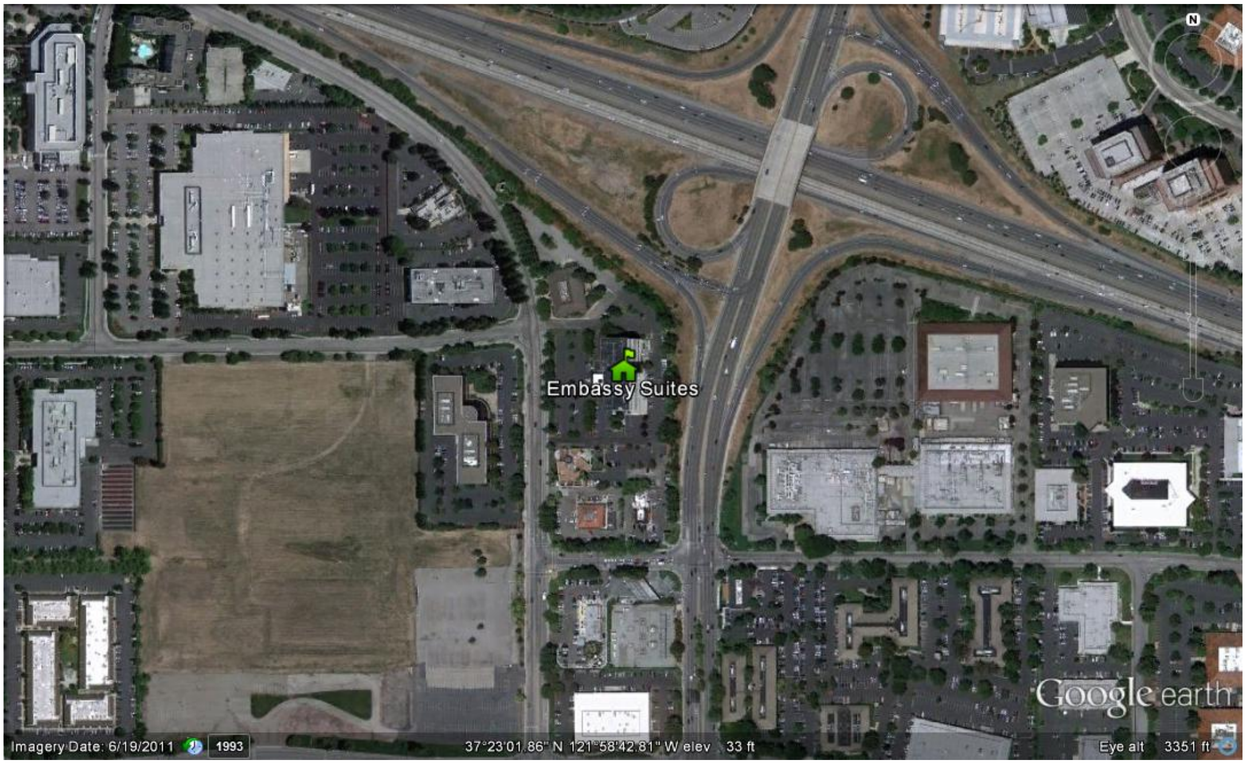

Figure 3: Embassy Suites

Hilton Hotel

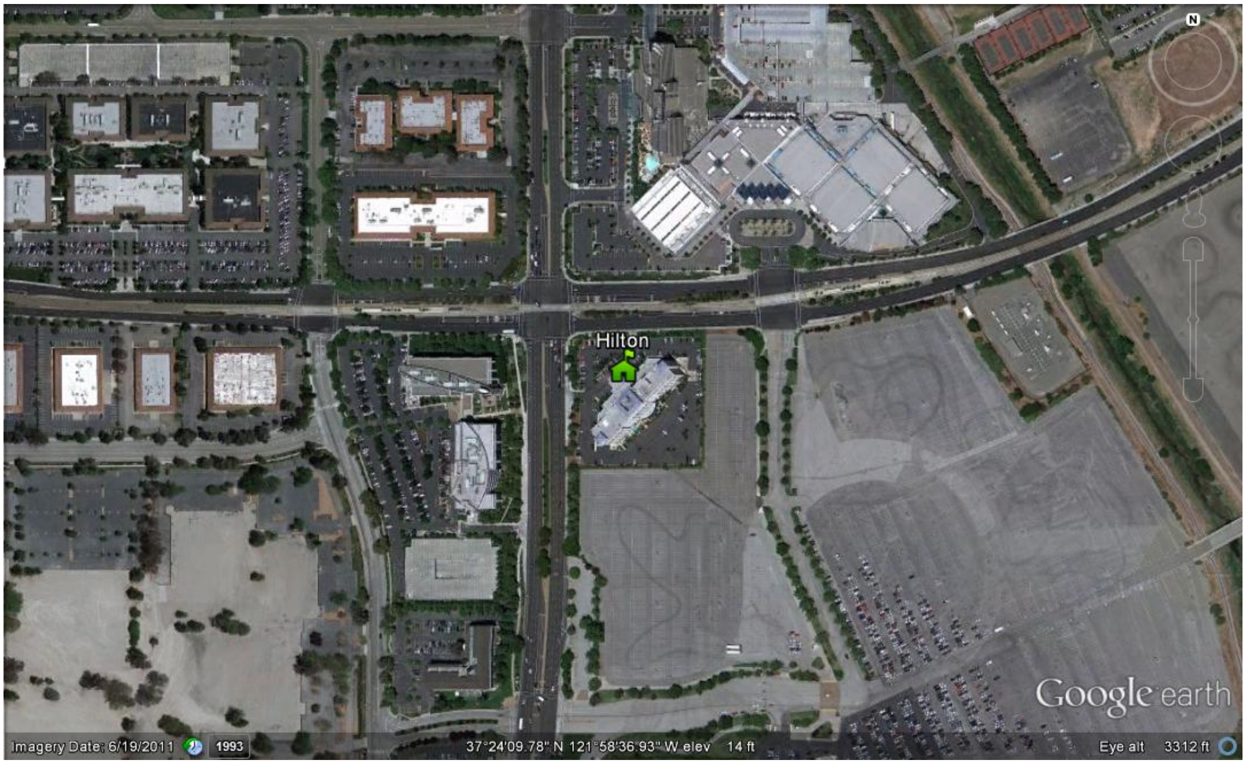

Figure 4: Hilton Hotel

Commlabs Offices (1)

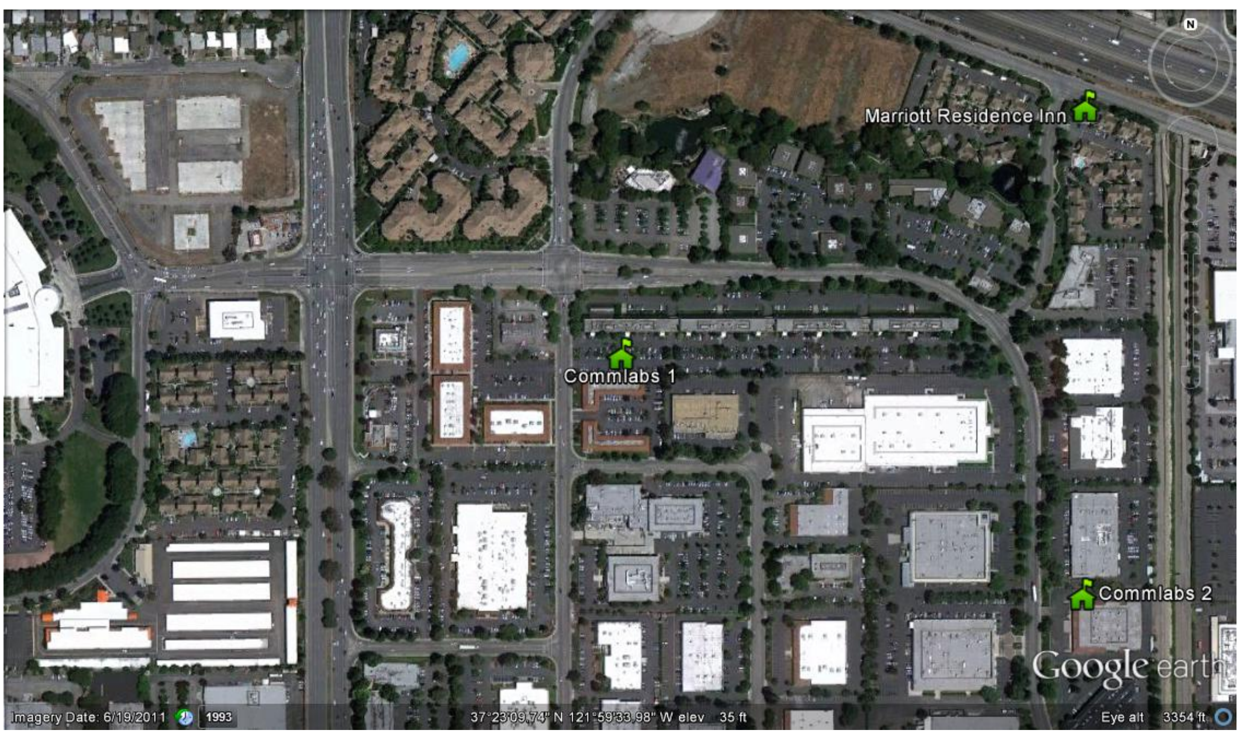

Figure 5: Commlabs Offices (1)

Commlabs Offices (2)

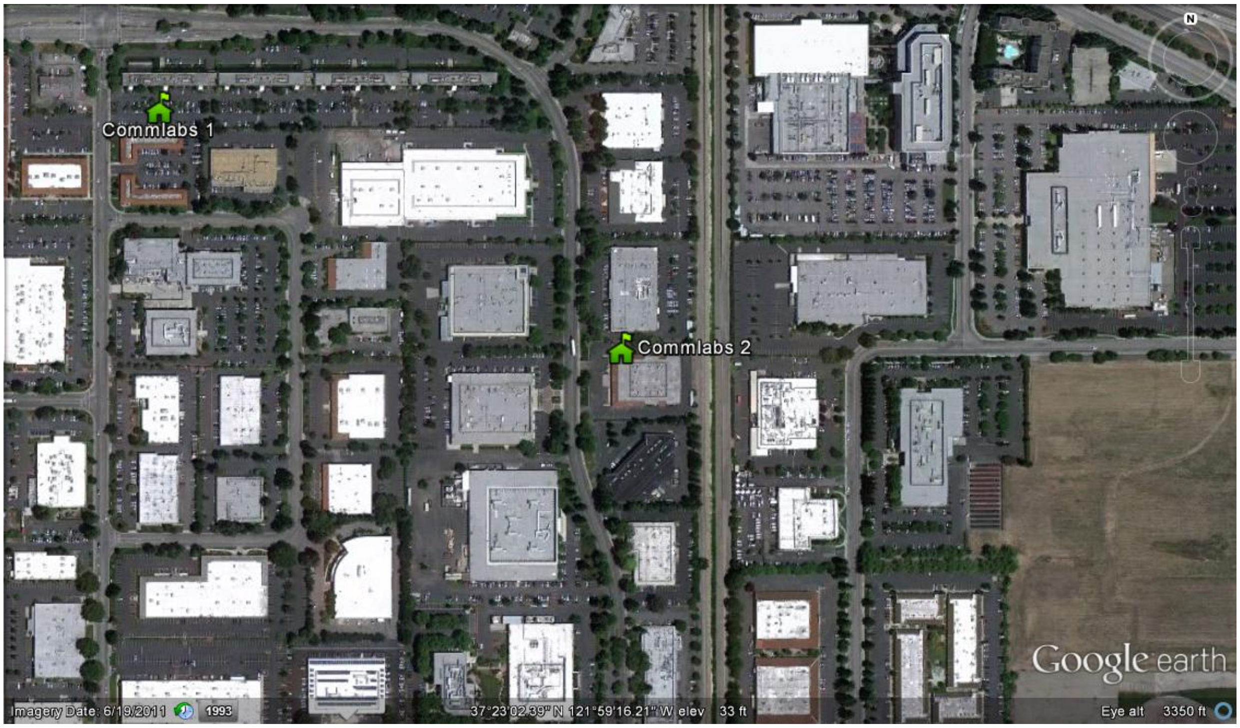

Figure 6: Commlabs Offices (2)

Avalon Corporate Apartments

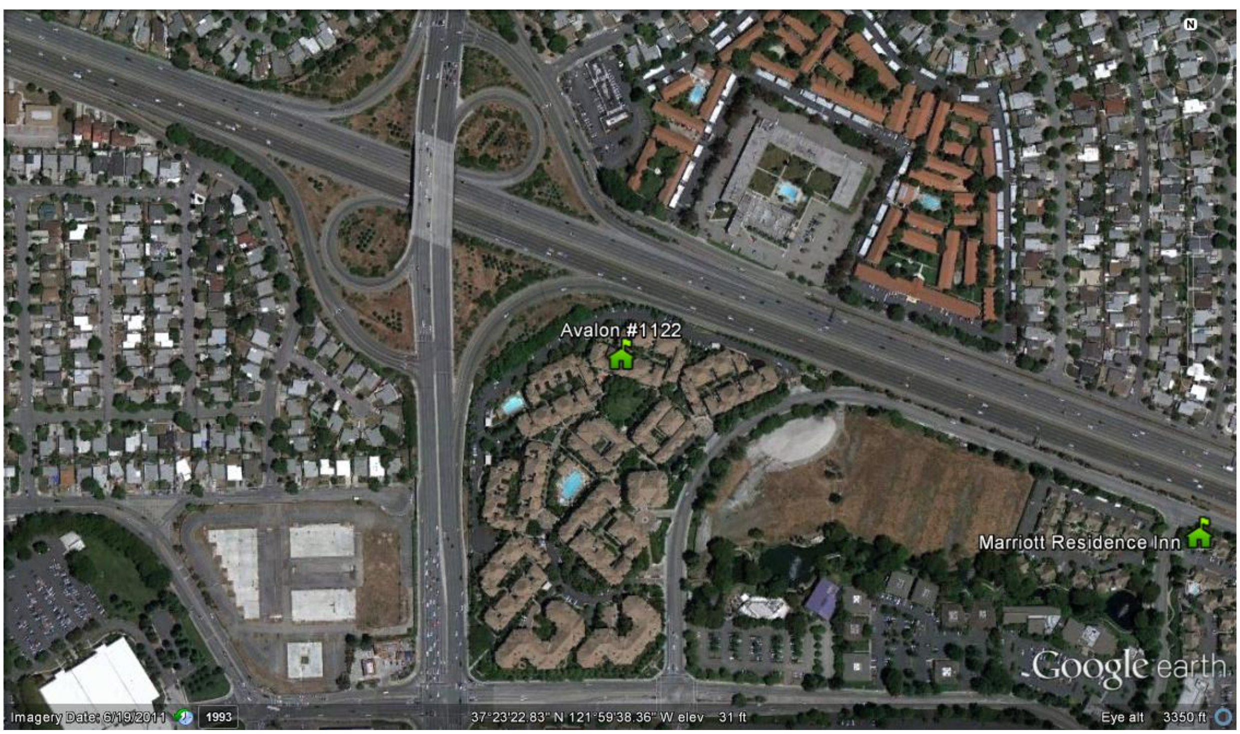

Figure 7: Avalon Corporate Apartments

Figure 8: Transmitter Setup at Avalon Apartments

Marriott Residence Inn

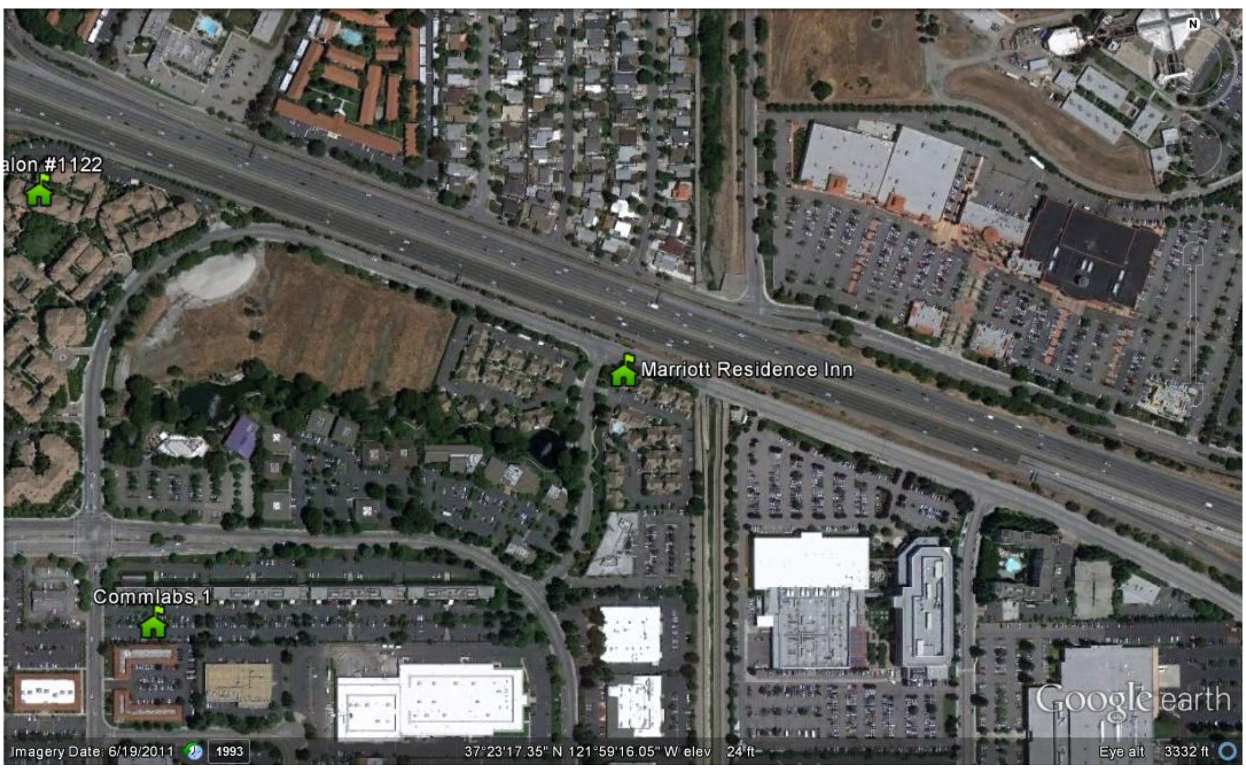

Figure 9: Marriott

Figure 10: Two Rooms at Marriott Used for Testing

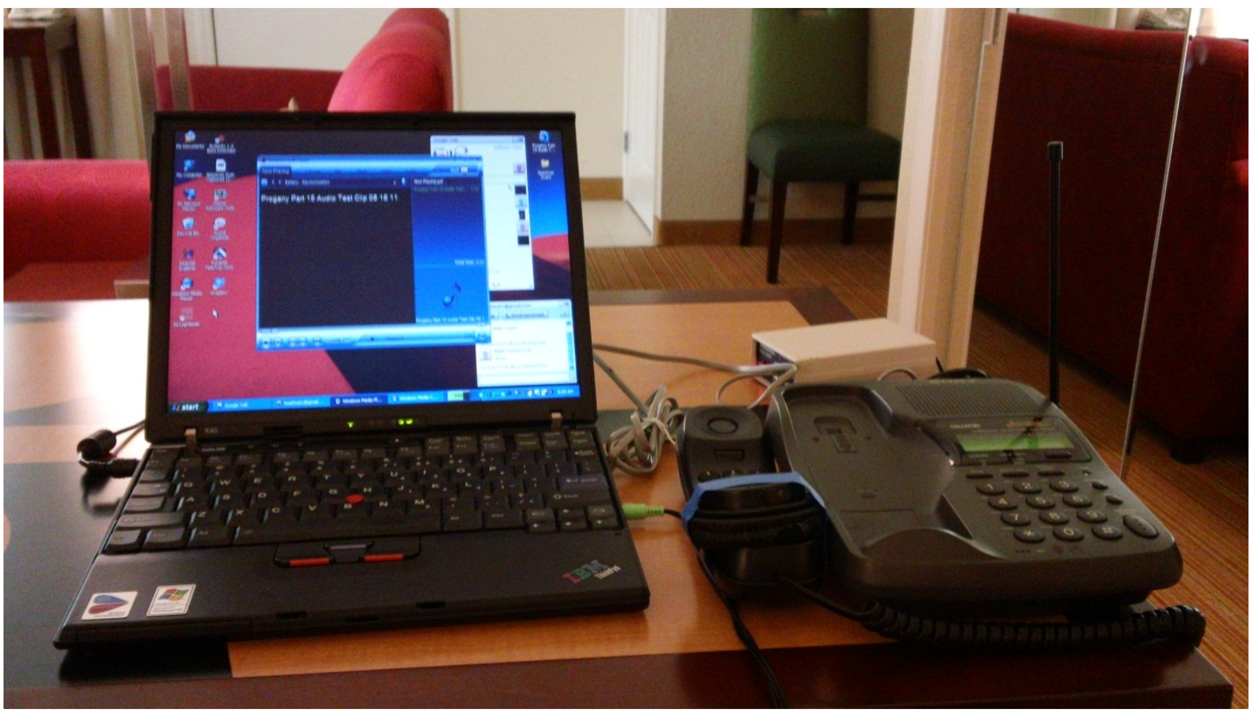

Figure 11: Transmitter Setup at Marriott

Techmart Office

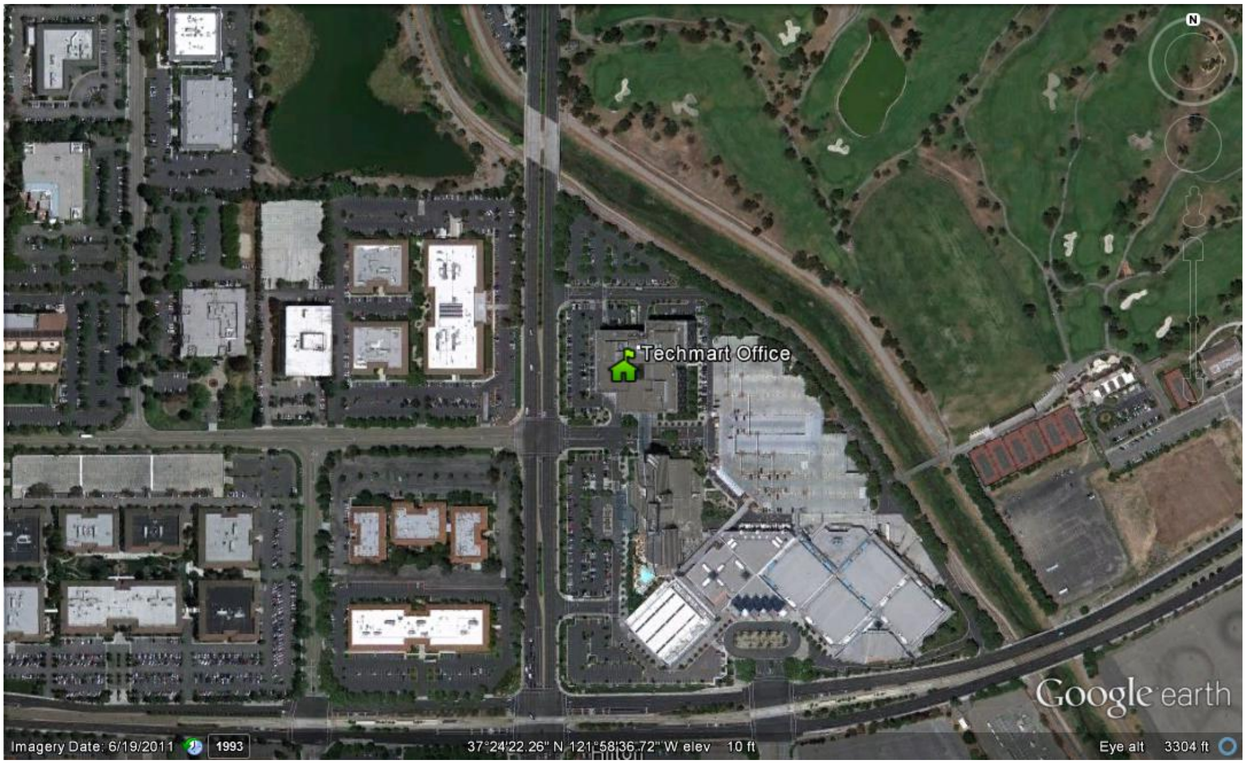

Figure 12: Techmart

Location F - Home

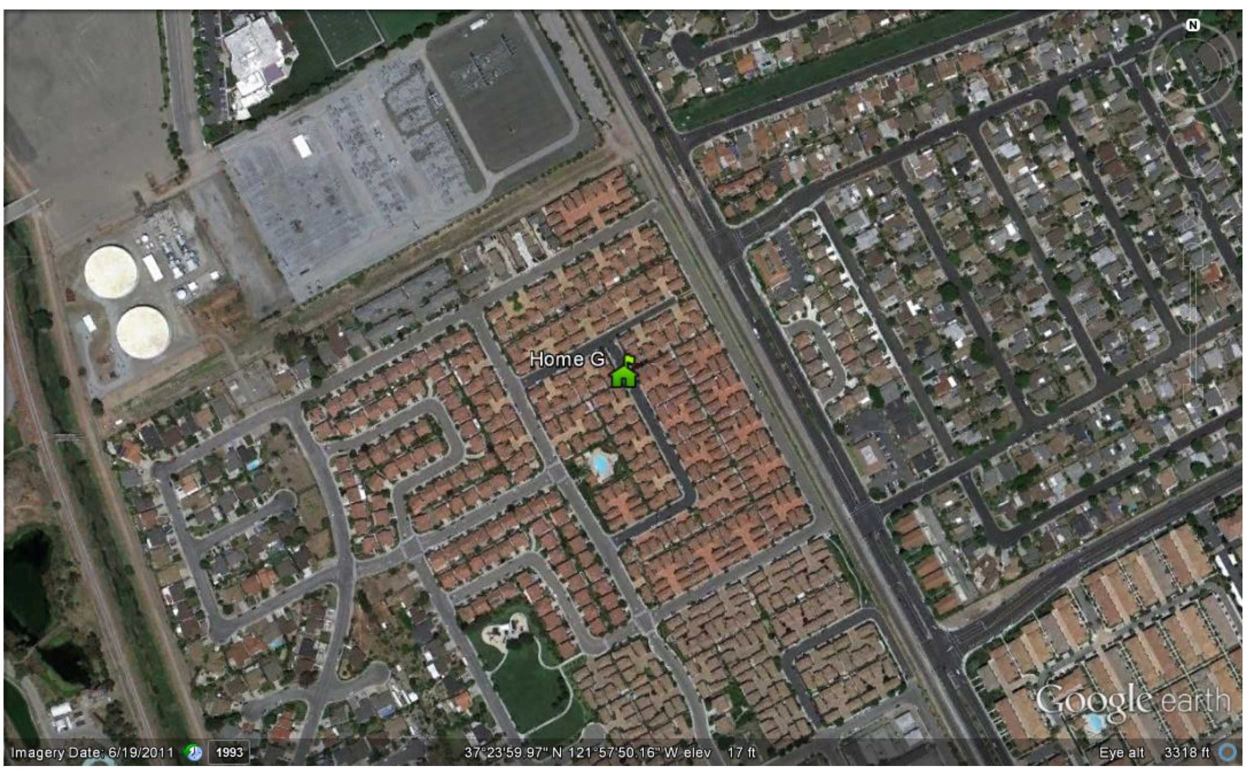

Figure 13: Location F - Home

Location G - Home

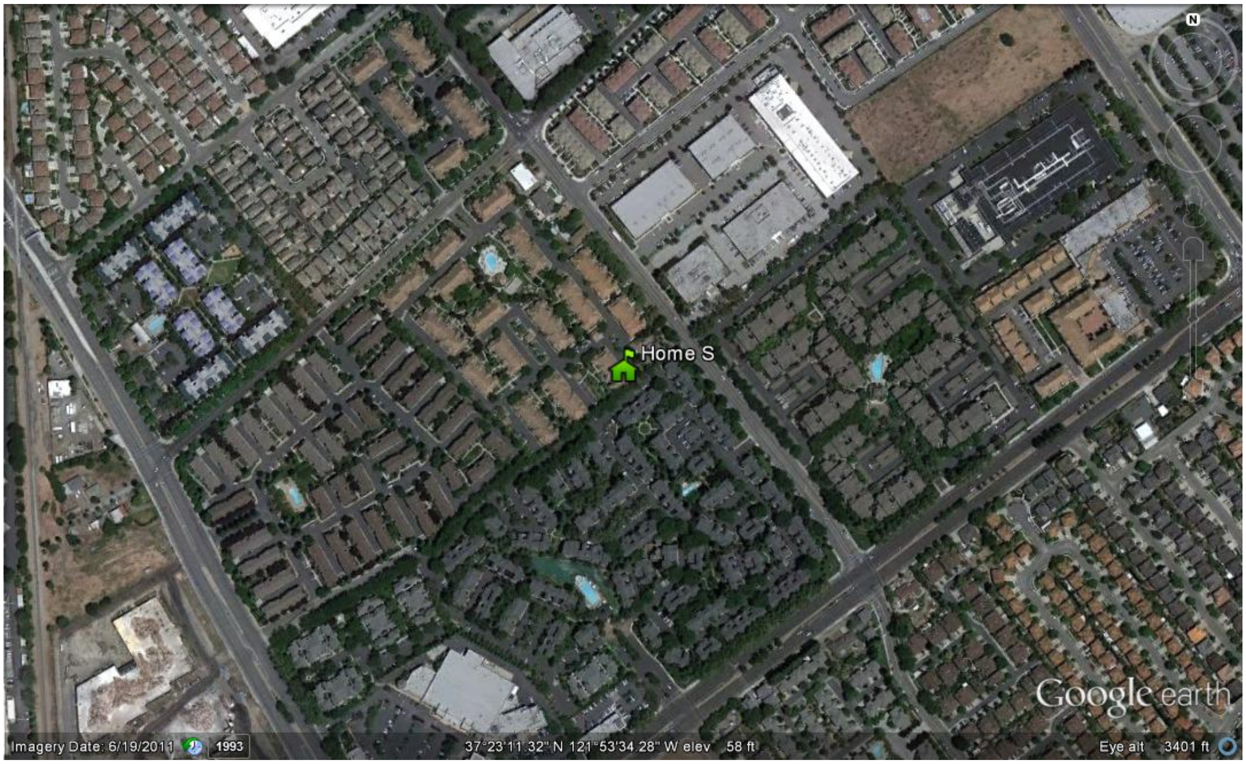

Figure 14: Location G - Home

Figure 15: Test Setup at Location G

Location H - Home

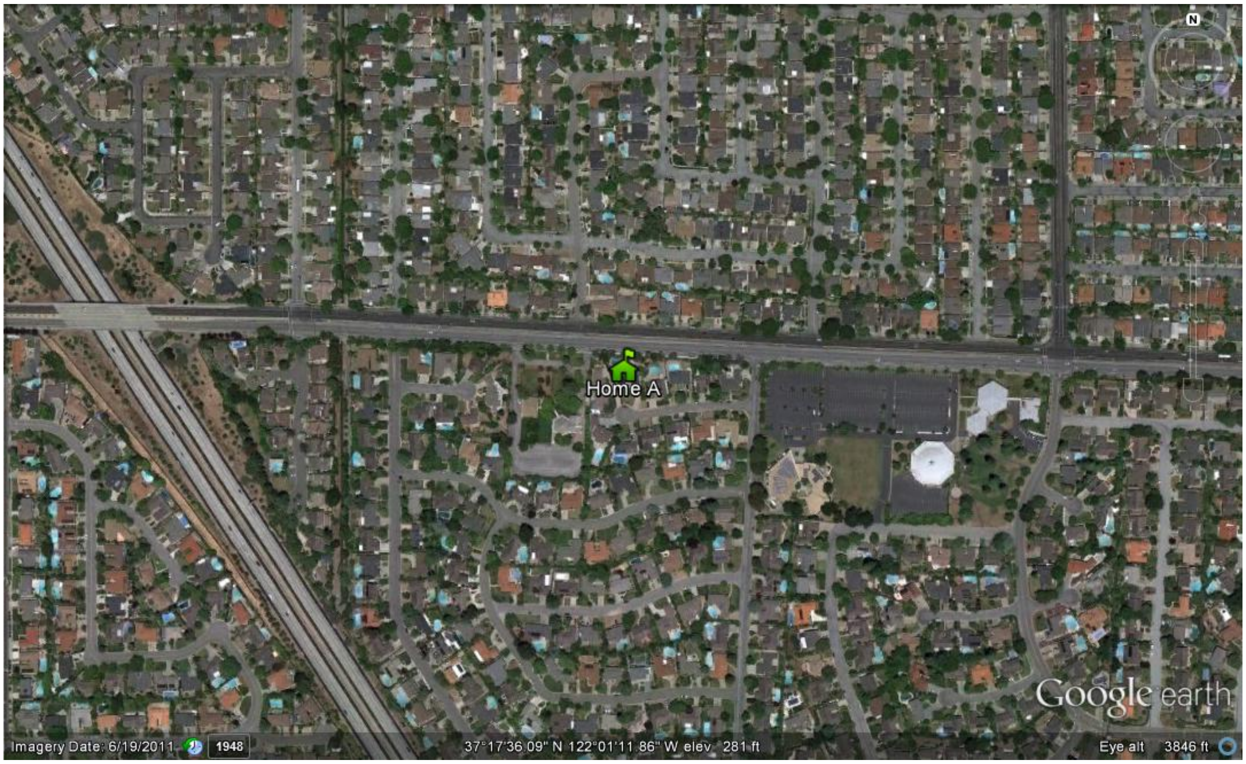

Figure 16: Location H - Home

Figure 17: Transmitter in Bedroom at Location H

Figure 18: Receiver in the Kitchen at Location H

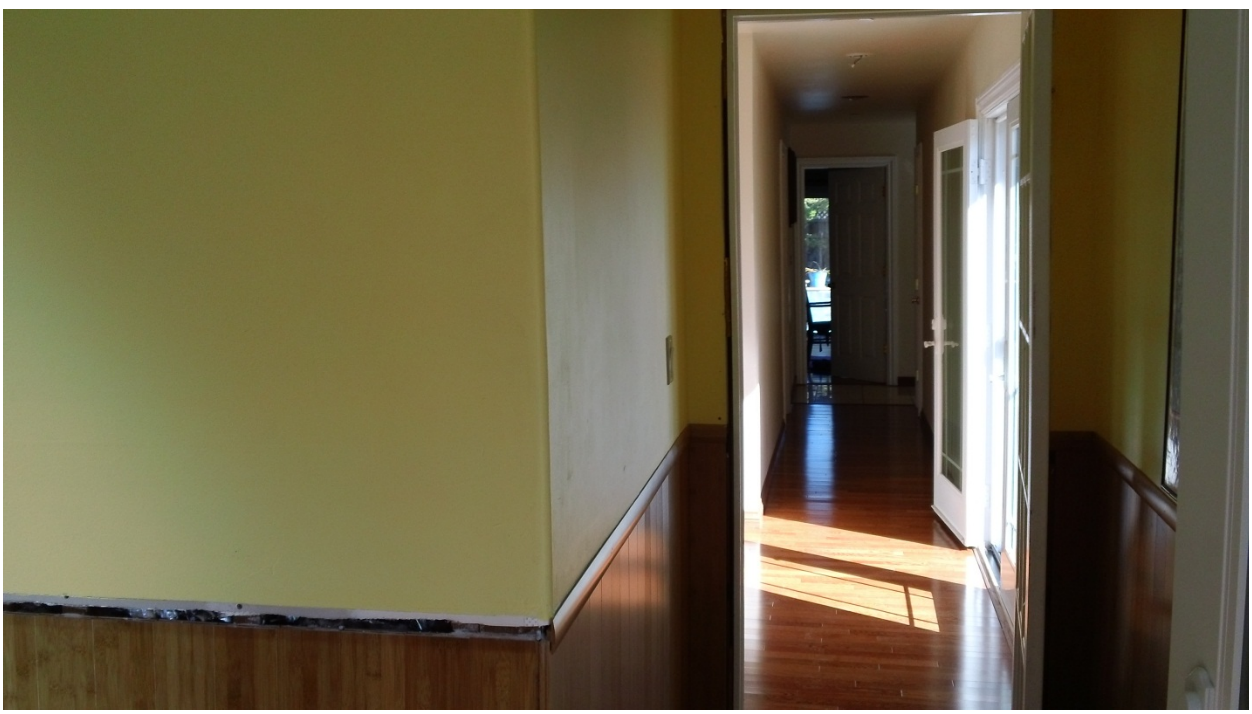

Figure 19: Corridor between Part 15 Transmitter and Receiver Ends at Location H

Location I - Home

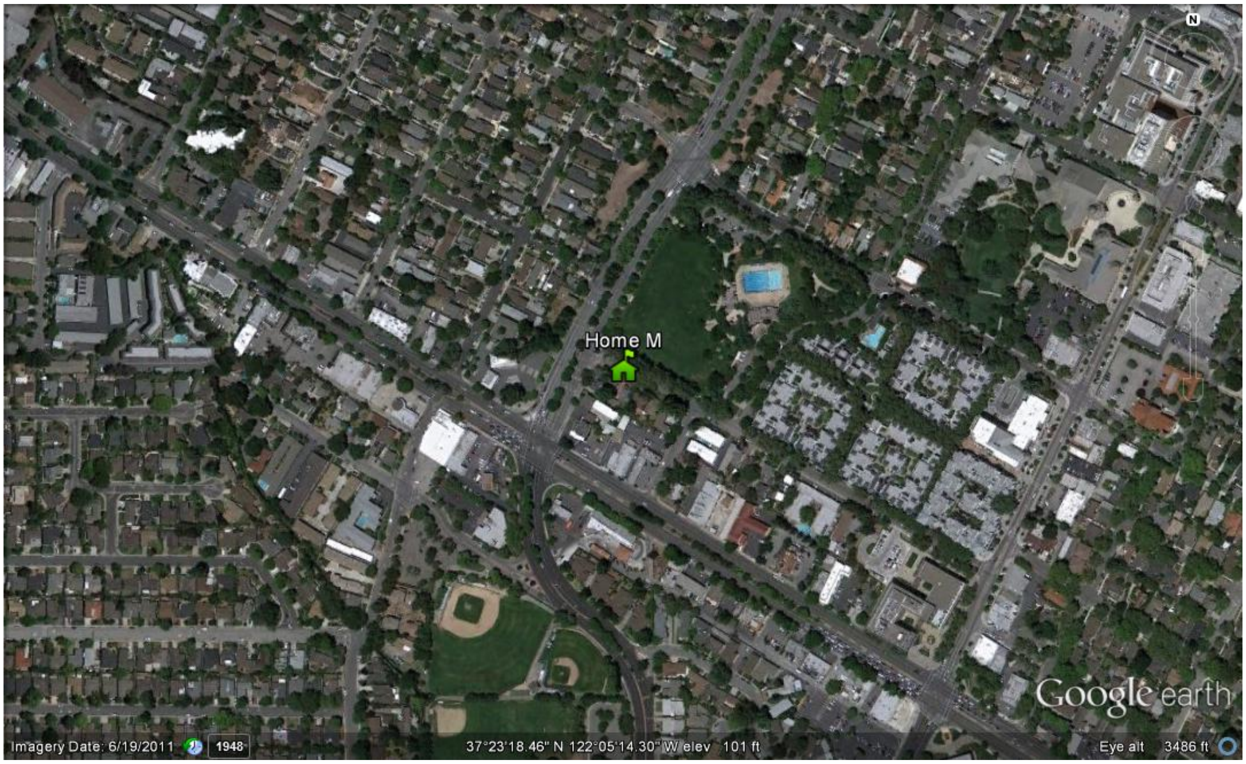

Figure 20: Location I - Home

Figure 21: Receiver at Location I in the Kitchen (on Main Level)

Figure 22: Transmitter at Location I in the Basement