# APPENDIX A

# Wireless Medical Telemetry Service / Television White Space Test Results

## Summary for Inova Mount Vernon Hospital

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**Preparation date:** 04-FEB-2015

| REVISIONS | |
|---|---|
| **Revision** | **Sections Changed in the Current Revision and Reason for the Change** |
| 1 | Initial Release |

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# 1. EXECUTIVE SUMMARY

Test results at Inova Mount Vernon Hospital show that the operation of an unlicensed device with a power level, separation distance and height consistent with the proposed rules in the FCC's Part 15 NPRM can cause significant harmful interference to existing Wireless Medical Telemetry Service ("WMTS") systems.[1] The protection criteria for WMTS systems currently proposed in the FCC Part 15 NPRM must be greater to avoid harmful interference. Furthermore, a more rigorous analysis and field measurement exercise would be required to establish actual boundaries sufficient for safe operation under all real-world scenarios.

# 2. INTRODUCTION

The FCC has proposed to make available Channel 37 (*i.e*., 608 – 614 MHz) for use by unlicensed devices. Through its rulemaking process, the FCC seeks comments from interested parties to determine the rules for such unlicensed device operations.

To assist the FCC in its efforts, GE Healthcare ("GEHC"), with assistance from Comsearch, conducted real-world testing, including gathering empirical data, at Inova Mount Vernon Hospital.[2] The testing was conducted pursuant to an FCC authorization for Special Temporary Authority ("STA"),[3] and was limited to unused WMTS frequencies.

The primary goals of this testing were to: (i) determine whether harmful interference is possible at FCC-prescribed Television White Space ("TVWS") distances, antenna heights, and power levels; (ii) validate path loss models used for WMTS protection; and (iii) avoid interfering with existing WMTS users at Inova Mount Vernon and other hospitals in the surrounding area.

# 3. SETUP

All test equipment used was powered up and allowed the appropriate time to warm-up to a stable operating temperature.

## 3.1 HOSPITAL BACKGROUND

Inova Mount Vernon Hospital in Alexandria, VA is the first site where TVWS/WMTS testing was performed by GEHC and Comsearch.[4] The hospital is six stories tall, has WMTS coverage on all floors, and has over 200 WMTS antennas installed with three antenna fields aggregated back to a central location on the 6th floor via the WMTS Distributed Antenna System ("DAS"). Additionally, there are multiple instances of WMTS antennas located in patient rooms with windows on any given floor.

## 3.2 SITE CHECKOUT

Several system checkout procedures were executed to ensure that the WMTS DAS was configured and performing per specification. Noise floor was measured on each antenna field to see if any interfering signals were present in the 608-614 MHz band, as well as to determine which telemetry transmitter frequencies were in use. This was necessary to program the victim transmitters to frequencies that would not interfere with the existing telemetry transmitters in use at the hospital. Marker 1 ("M1") in Figures 1-3 shows the noise floor measurement value at the main antenna field aggregation point, prior to fan out to

[1] *Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37; Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap; Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Notice of Proposed Rulemaking, 29 FCC Rcd 12248 (2014) ("Part 15 NPRM").
[2] The hospital is located at 2501 Parkers Lane, Alexandria, VA 22306. Additional information regarding the facilities is available at http://www.inova.org/patient-and-visitor-information/facilities/inova-mount-vernon-hospital/index.jsp.
[3] *See* Call Sign WI9XAF, ELS file no. 1026-EX-ST-2014 (granted Nov. 18, 2014).
[4] GEHC intends to conduct additional tests at other sites and will supplement the record after completion of those tests.

the receivers. A value of -74 dBm/10 kHz or less is considered acceptable when measured at this point of the WMTS DAS. The other peaks are telemetry transmitters in use.

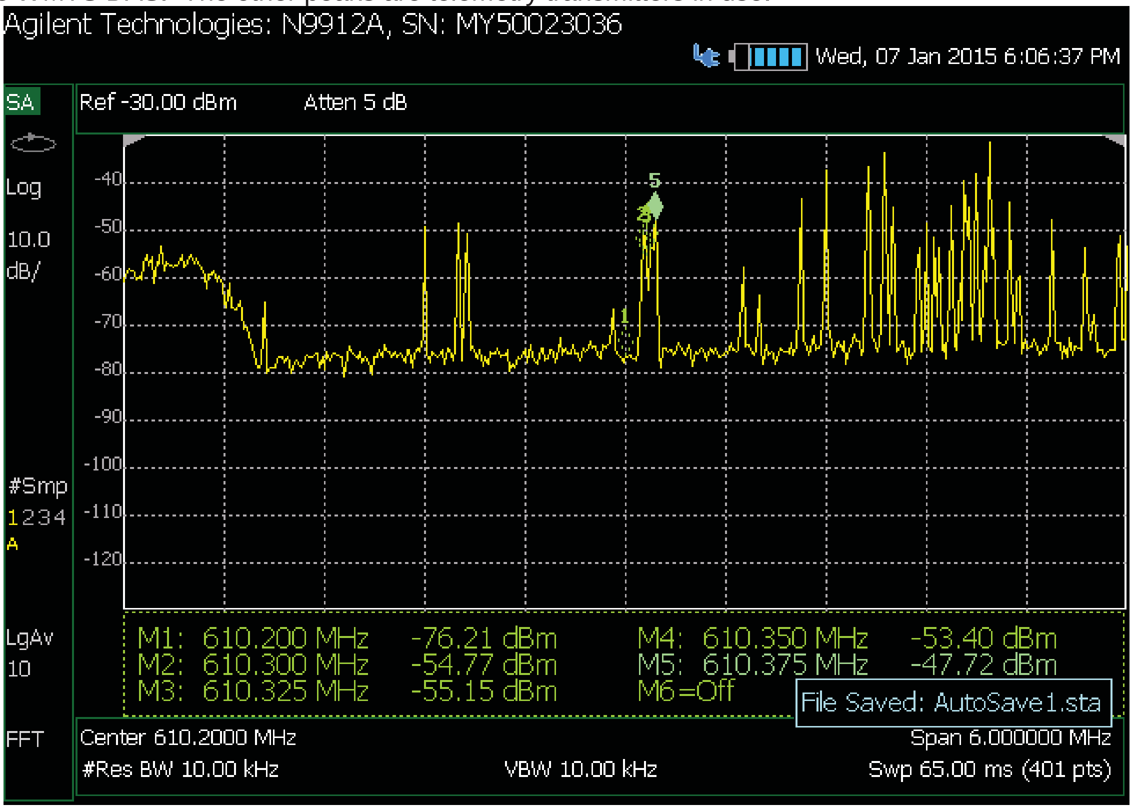


**Figure 1:** Noise Floor A Antenna Field

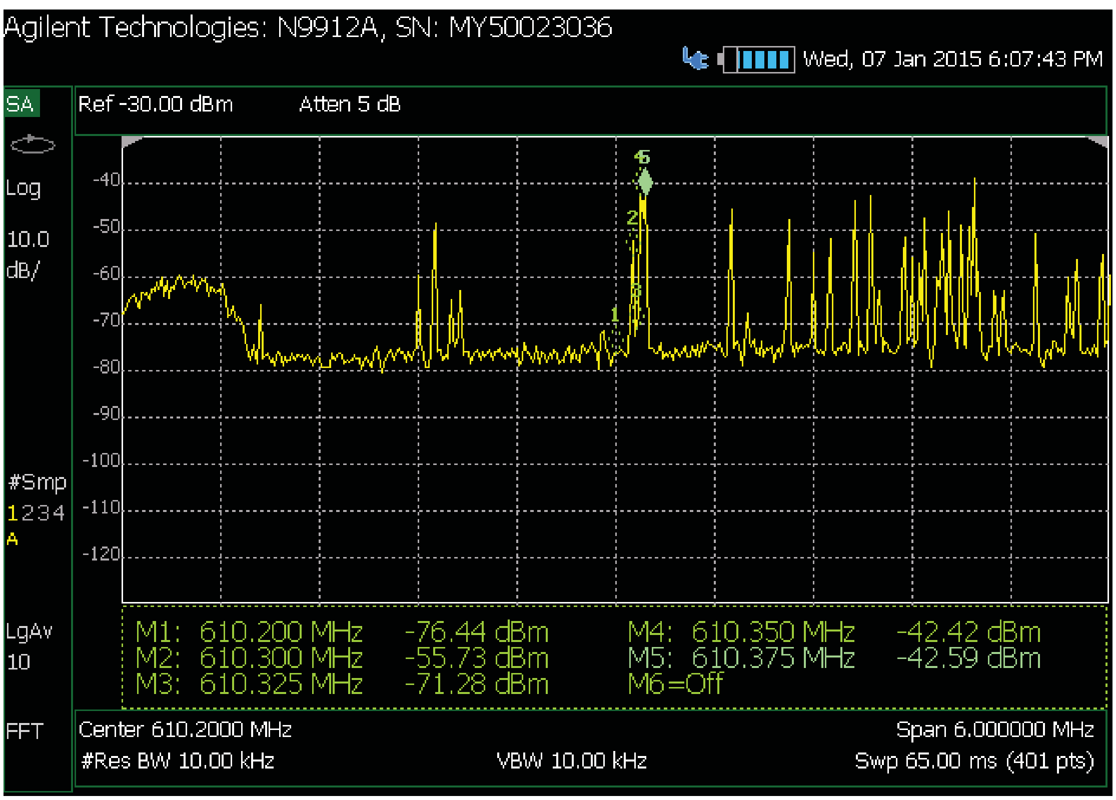


**Figure 2:** Noise Floor B Antenna Field

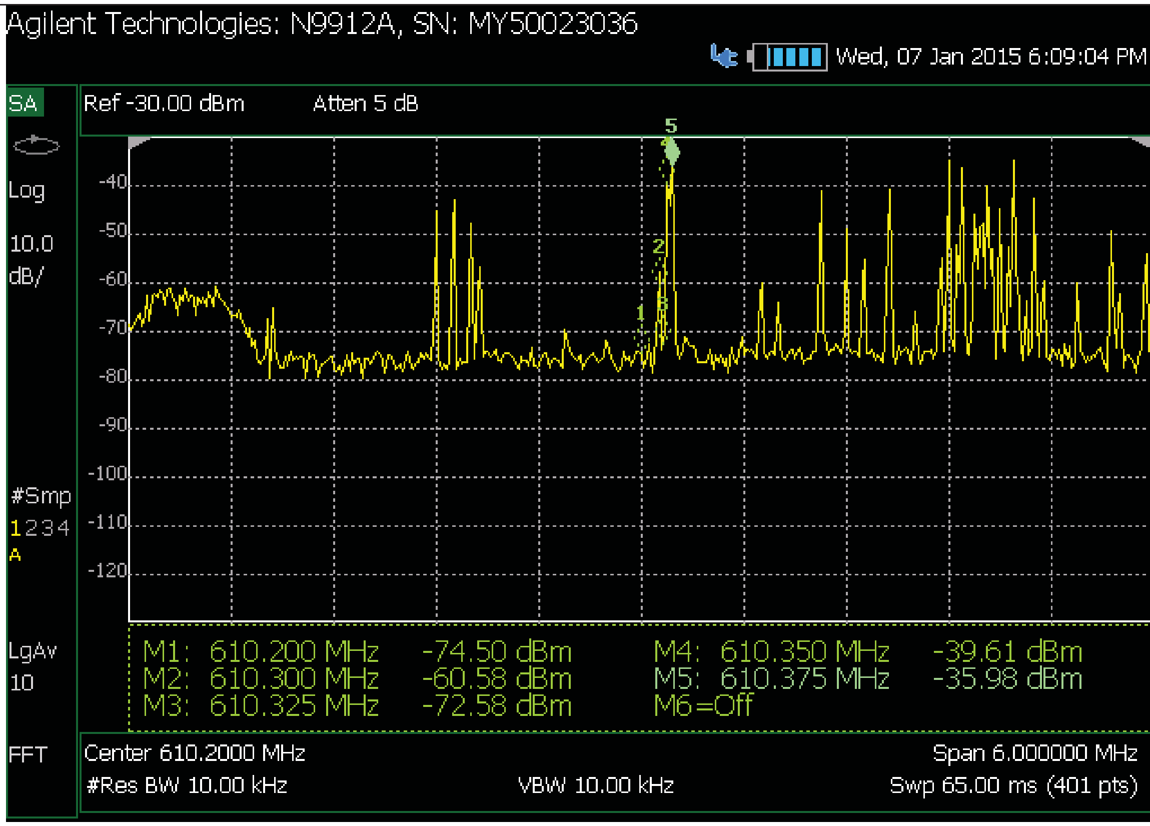


**Figure 3:** Noise Floor C Antenna Field

Additionally, each configurable component in the WMTS DAS was checked to verify all settings matched specifications, ensuring that the WMTS DAS was not over or under amplified for a given wireless coverage area and antenna field. Lastly, a telemetry transmitter was taken to the 5th and 6th floors of the WMTS coverage area to allow GEHC personnel to walk underneath a sample of WMTS antennas and confirm that they were connected and receiving the signal, per specification.

## 3.3 VICTIM TRANSMITTER PLACEMENT

Four test telemetry transmitters (the “victim transmitters”) were programmed to 610.3 MHz (TTXID 8612), 610.325 MHz (TTXID 8613), 610.35 MHz (TTXID 8614), and 610.375 MHz (TTXID 8615) and placed at different locations within the intended WMTS coverage area. Locations were selected such that at least one of the 3 receiver antenna fields was receiving the victim transmitter signal at 10 dB or more above the specified receive sensitivity of -95 dBm.

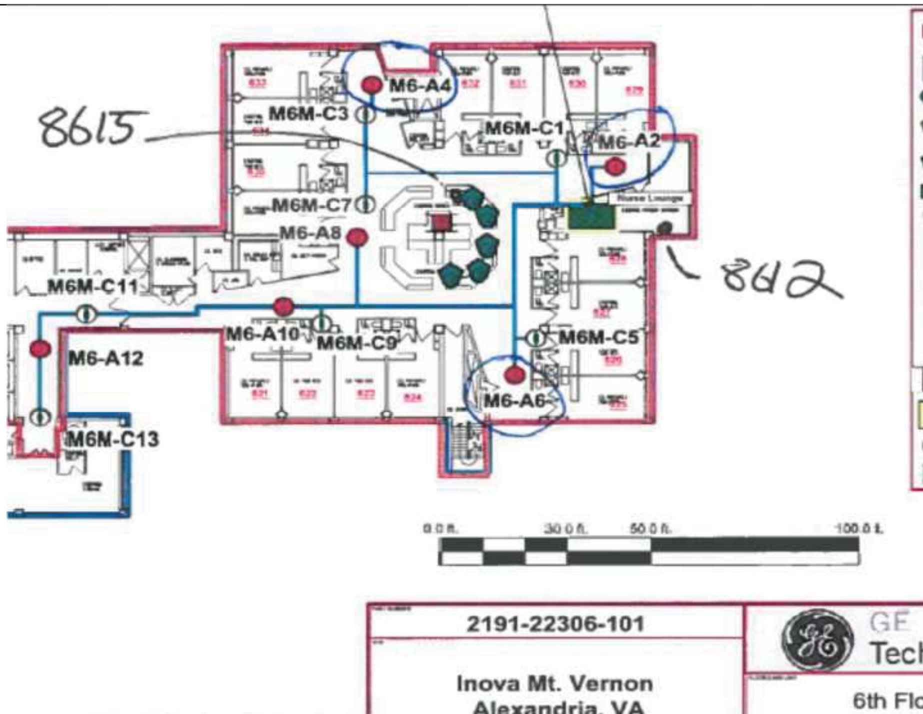


**Figure 4:** 6th Floor Victim Transmitter Locations (TTXID 8612 & 8615)

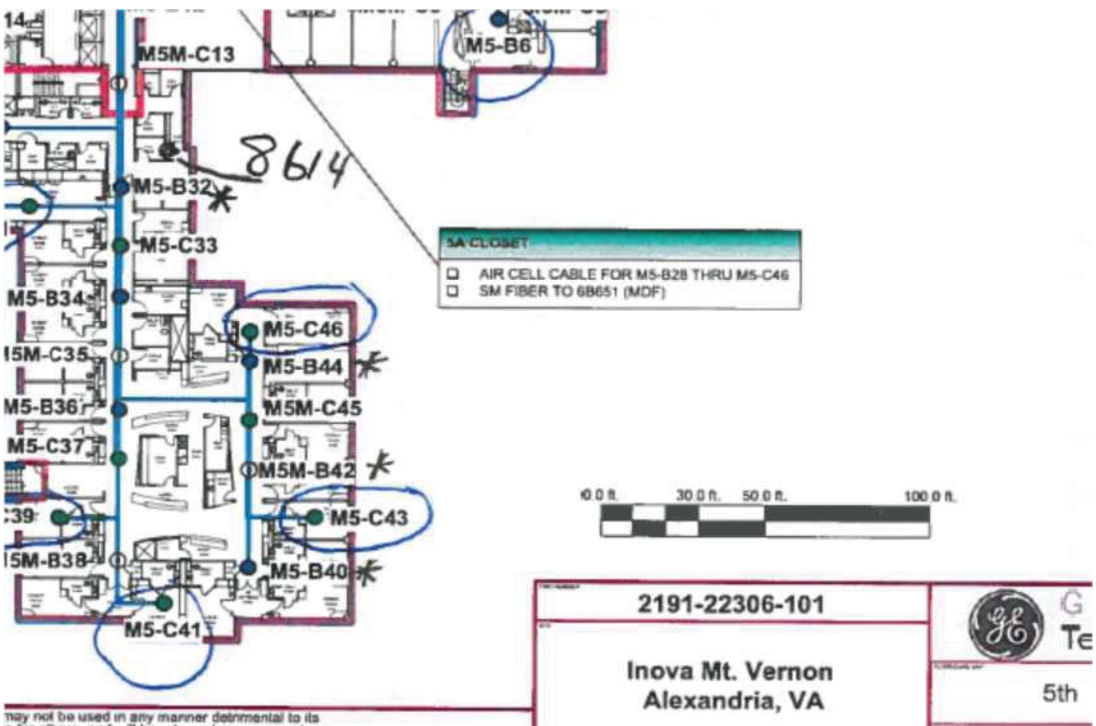


**Figure 5:** 5th Floor Victim Transmitter Locations (TTXID 8614)

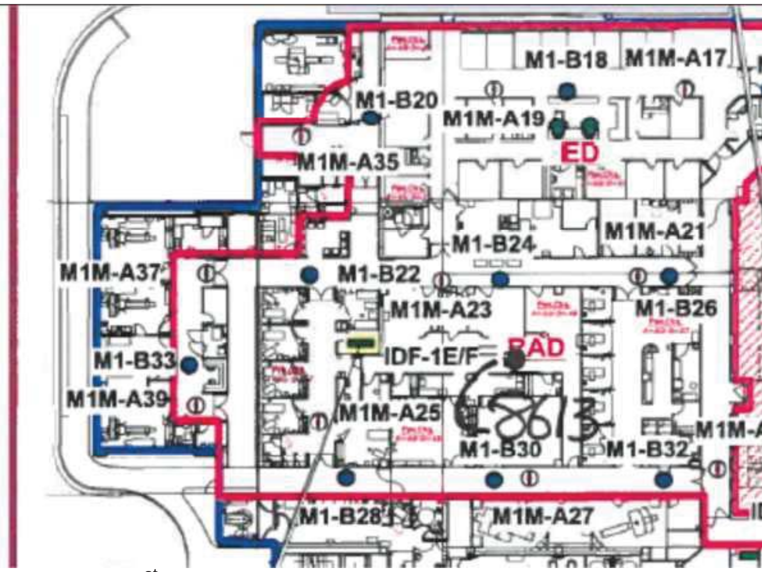


**Figure 6:** 1st Floor Victim Transmitter Locations (TTXID 8613)

## 3.4 CLINICAL INFORMATION CENTER AND SUPPORTING APEXPRO EQUIPMENT

A test Clinical Information Center ("CIC") display that renders ECG telemetry waveforms from the victim transmitters, an ApexPro Telemetry Server, and an ApexPro Receiver Subsystem were set up and connected to the antenna field expansion ports of the WMTS DAS. This allowed for historical capture of streaming ECG waveforms throughout the duration of testing.

## 3.5 SPECTRUM ANALYZER

An Agilent Field Fox spectrum analyzer (Model N9912A, Serial Number MY50023036) was connected to a given antenna field to measure the signal level of the interfering signal received by the WMTS DAS.

## 3.6 INTERFERING SIGNAL

Two types of interference signals were used during testing for a given test location. A continuous wave ("CW") signal was set at 610.2 MHz and used to record path loss measurement values. A 100 kHz wide IEEE802.11 OFDM modulated signal was used to record potential interference with the victim telemetry transmitters on a WMTS DAS. The power levels of the 100 kHz signals were based on paragraph 42 of the FCC Part 15 NPRM with necessary reduction to provide equivalent power spectral density within the smaller occupied bandwidth of the test signal (see Table 1 below for values used per test location distance). The modulated signal was first set to a frequency of 610.2 MHz, which is lower than the frequency from the victim telemetry transmitters to measure channel power of the modulated interfering signal. Then, the frequency of the modulated signal was shifted to 610.3375 MHz, which is in the middle of the 610.3-610.375 MHz band used by the four victim telemetry transmitters.

| | EIRP (dBm) | | | | Conducted |
|---|---|---|---|---|---|
| Distance for 3m TX Antenna Height | in 6MHz | in 100kHz | -10dBi Ant | Cable Loss (dB) | At Signal Generator (dBm) |
| 300m | 16 | -1.40 | -11.40 | 1.47 | -9.93 |
| 400m | 20 | 2.60 | -7.40 | 1.47 | -5.93 |
| 500m | 24 | 6.60 | -3.40 | 1.47 | -1.93 |
| 600m | 28 | 10.60 | 0.60 | 1.47 | 2.07 |
| 800m | 32 | 14.60 | 4.60 | 1.47 | 6.07 |
| 1000m | 36 | 18.60 | 8.60 | 1.47 | 10.07 |

**Table 1:** 100 kHz Power Level Adjustment Values

Additional information on the test setup of the interfering signal is provided in the “Radio Frequency Measurement Report” prepared by Comsearch, which is attached as Appendix B to the GEHC Comments.

## 3.7 TEST LOCATIONS

Figures 7 and 8 show where the interfering signal was placed outside of Inova Mount Vernon Hospital. Please refer to the “Radio Frequency Measurement Report” prepared by Comsearch for additional information and photos of the test locations.

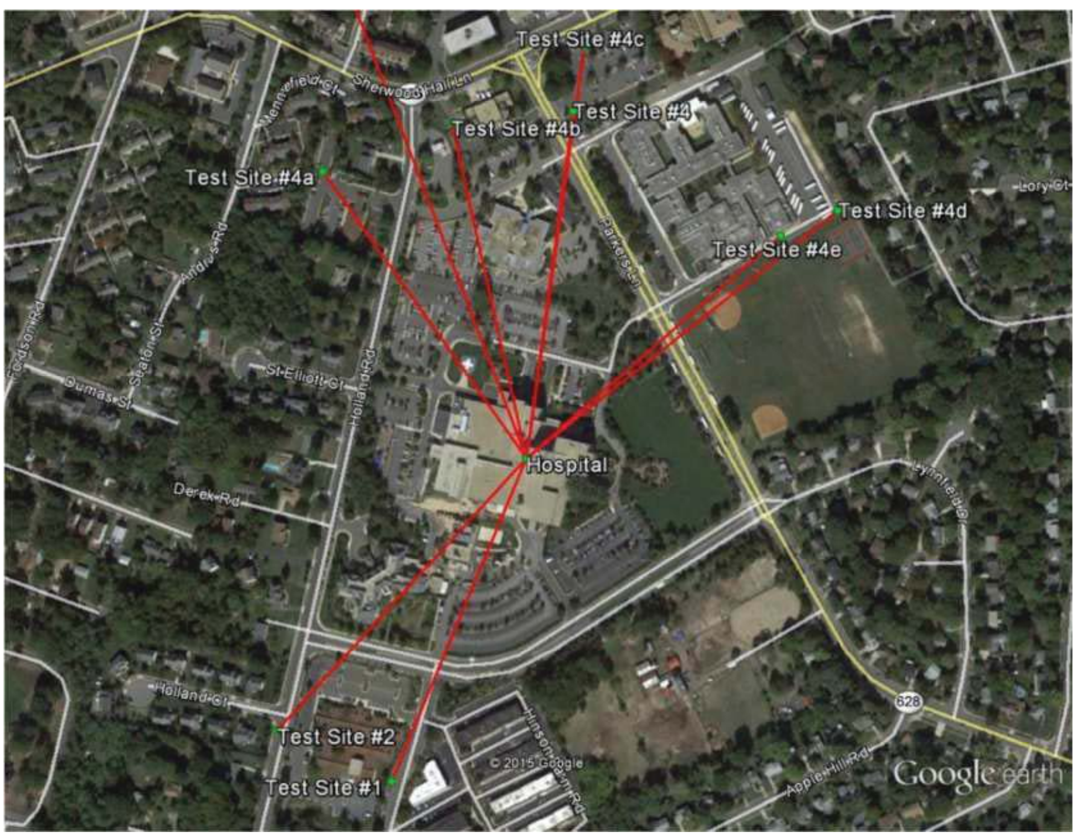


**Figure 7:** Close-up of Test Locations

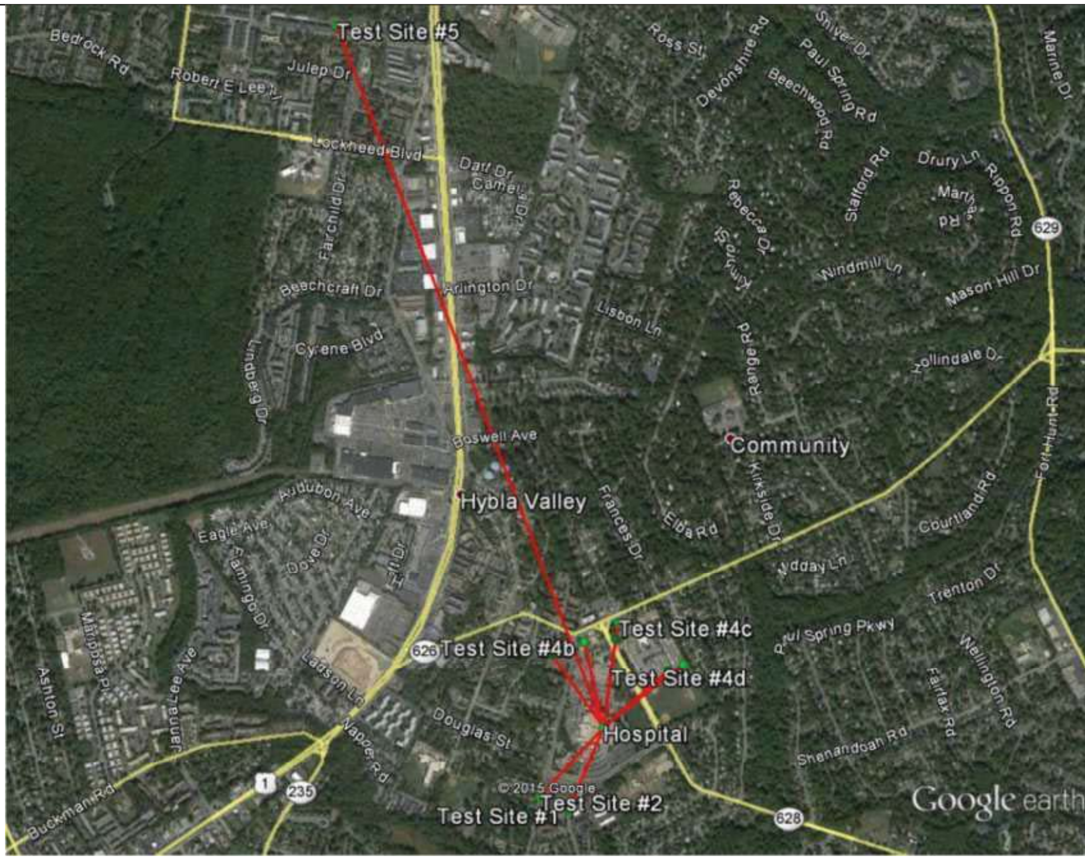


**Figure 8:** All Test Locations

## 4. PROCEDURE

For a given test location, several measurements were taken to quantify and qualify the impact of the interfering signal received by the WMTS DAS: 1) CW signal at 610.2 MHz; 2) 100 kHz modulated signal at 610.2 MHz; and 3) 100 kHz modulated signal at 610.3375 MHz.

### 4.1 CW SIGNAL AT 610.2 MHZ

1. For a given test location, taking into account HAAT, set the power level at the signal generator per Table 1.
2. Turn the signal generator RF on.
3. Connect the spectrum analyzer to the A antenna field of the WMTS DAS.
4. Take a screen shot of the measured interfering signal.
5. Repeat steps 3 & 4 for the B and C antenna fields.

### 4.2 100 KHZ MODULATED SIGNAL AT 610.2 MHZ

1. Turn modulation on at the signal generator.
2. Connect the spectrum analyzer to the A antenna field of the WMTS DAS.
3. Take a screen shot of the measured interfering signal.
4. Repeat steps 2 & 3 for the B and C antenna fields.

### 4.3 100 KHZ MODULATED SIGNAL AT 610.3375 MHZ

1. At the CIC, turn marker flags on to highlight when RF dropout occurs.
2. If ECG waveform dropout is not observed, increase the signal generator power level by 3 dB until observed or when the STA power limit is achieved.

3. If ECG waveform dropout is observed, decrease power level by 3 dB until dropout disappears.

## 5. RESULTS

Below are the results for each test procedure from TVWS interference testing at Inova Mount Vernon.

### 5.1 CW SIGNAL AT 610.2 MHZ

Detailed test results for the path loss measurements using this setup are provided in Table 4.1-1 of the "Radio Frequency Measurement Report" prepared by Comsearch, which is attached as Appendix B to the GEHC Comments. A sample data set is shown below in Table 2 to highlight differences between calculated free space loss, measured path loss outside of the hospital (*i.e*., ground clutter only), and measured loss inside of the hospital (*i.e*., ground clutter plus building penetration attenuation).

| Test Location | Calculated Free Space Loss (dB) | Measured Path Loss Outside (dB) | Delta From Free Space (dB) | Measured Path Loss Inside (dB) | Delta From Outside (dB) |
|---|---|---|---|---|---|
| 1 | 78.8 | 88.6 | 9.8 | 104.4 | 15.8 |
| 2 | 79.2 | 88.6 | 9.4 | 105.8 | 17.2 |
| 4 | 78.8 | 83.1 | 4.3 | 99.1 | 16.0 |
| 4a | 78.8 | 81.1 | 2.3 | n/a | n/a |
| 4b | 78.6 | 84.1 | 5.5 | 96.8 | 12.7 |
| 4c | 80.3 | 84.6 | 4.3 | 95.2 | 10.6 |
| 4d | 79.9 | 80.1 | 0.2 | 99.7 | 19.6 |
| 4e | 78.5 | 83.6 | 5.1 | 101.1 | 17.5 |
| 5 | 97.2 | 99.6 | 2.4 | 116.9 | 17.3 |

**Table 2:** Path Loss Results

The results in Table 2 show that path loss for several test locations approaches free space loss and that building attenuation at this site ranged between 10 dB and 20 dB. Given the wide variety of materials used in a hospital construction, it is expected that actual building loss values at other hospitals will vary beyond the range of data collected at Inova Mount Vernon.

### 5.2 100 KHZ MODULATED SIGNAL AT 610.2 MHZ

Channel power measurements were made to show the total power of the 100 kHz interfering signal received by the WMTS DAS. The channel power measurements also show if the interfering signal is above the noise floor or not.

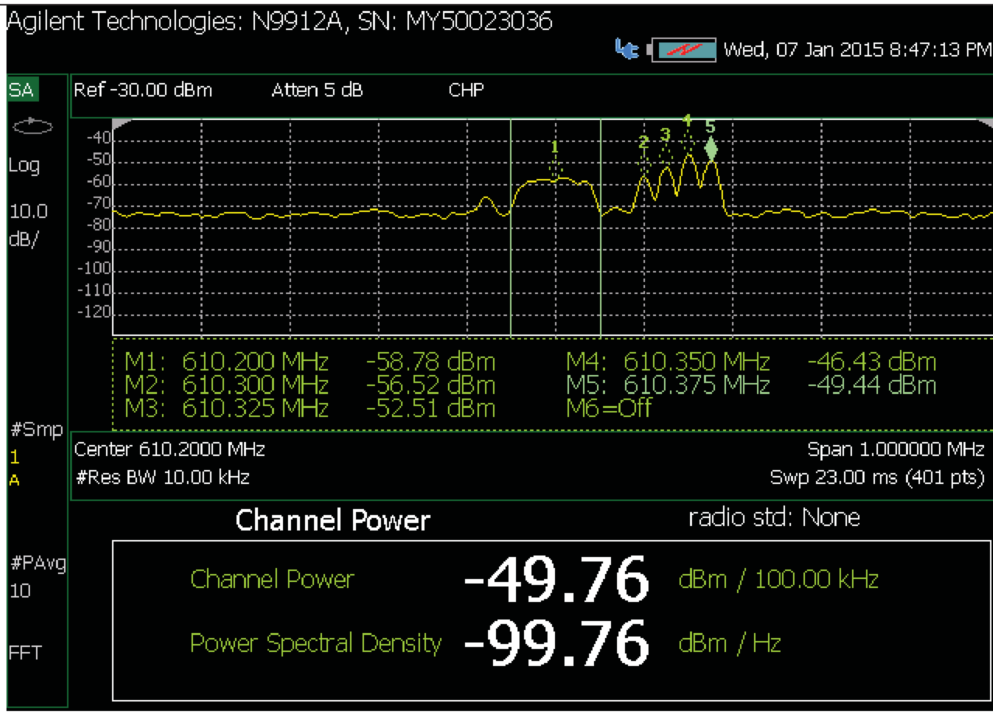


**Figure 9:** Test Location 4, B Antenna Field

Figure 9 is an example of an interference measurement recorded at the main antenna field aggregation point, prior to fan out to the receivers on the WMTS DAS. Markers (“M2-M5”) show the signal level of the victim telemetry transmitters with respect to the interfering signal and how little signal-to-noise margin is left when the interfering signal is present.

| | A Antenna Field | | B Antenna Field | | C Antenna Field | |
|---|---|---|---|---|---|---|
| Test Location | Channel Power (dBm / 100kHz) | Above Noise Floor Spec | Channel Power (dBm / 100kHz) | Above Noise Floor Spec | Channel Power (dBm / 100kHz) | Above Noise Floor Spec |
| 1 | -59.3 | Y | -64.2 | Y | -63.3 | Y |
| 2 | -63.8 | Y | -64.5 | Y | -62.9 | Y |
| 4 | -50.5 | Y | -49.8 | Y | -49.7 | Y |
| 4a | not recorded | not recorded | not recorded | not recorded | not recorded | not recorded |
| 4b | -57.6 | Y | -58.5 | Y | -58.6 | Y |
| 4c | -49.3 | Y | -47.1 | Y | -50.2 | Y |
| 4d | -54.7 | Y | -58.0 | Y | -55.8 | Y |
| 4e | -59.5 | Y | -58.4 | Y | -59.2 | Y |
| 5 | -62.4 | Y | -63.5 | Y | -61.2 | Y |

**Table 3:** Channel Power & Noise Floor Measurements

Table 3 shows multiple cases where the 100 kHz signal was measured above the noise floor at this particular point of the WMTS DAS. This constitutes a WMTS DAS design specification violation, that at best, would require changes to the site’s infrastructure, which are typically costly and invasive and would likely reduce wireless coverage area, or at worst would render the WMTS system unusable.
For test location 4a, the results were not recorded because the interfering signal levels were similar to test location 2.

## 5.3 100 KHZ MODULATED SIGNAL AT 610.3375 MHZ

Results from this test are shown in Table 4 below. The “Interference Free EIRP in 100 kHz (dBm)” column indicates the maximum power level where outages were not observed (*i.e.*, any power level higher caused ECG waveform dropout). In one case, the interfering EIRP had to be adjusted down due to positive HAAT.

| Test Location | Distance From Hospital (m) | Interfering Signal HAAT (m) | Part 15 NPRM EIRP in 100 kHz (dBm) | Interference Free EIRP in 100 kHz (dBm) |
|---|---|---|---|---|
| 1 | 338 | -23 | -1.4 | 4.6 |
| 2 | 357 | -24 | -1.4 | 11.5 |
| 4 | 338 | -23 | -1.4 | -10.4 |
| 4a | 341 | -23 | -1.4 | not recorded |
| 4b | 332 | -23 | -1.4 | -4.4 |
| 4c | 402 | -23 | 2.6 | -6.4 |
| 4d | 385 | -23 | -1.4 | -1.4 |
| 4e | 327 | -23 | -1.4 | -1.4 |
| 5 | 2836 | 18 | 14.6 | 26.0* |

**Table 4:** Interference Free Levels

Table 4 shows several cases (test locations 4, 4b, and 4c) where the power level had to be reduced in order to avoid interfering with the WMTS DAS and causing ECG waveform dropout. At test locations 4, 4b, and 4c with the interfering signal set to the value shown in the “Part 15 NPRM EIRP in 100 kHz (dBm)” column of Table 4, ECG waveform dropout ranged from a complete outage to modest pixelization. Regardless of the duration of the ECG waveform dropout, automatic arrhythmia detection, which is a critical feature relied upon by hospitals to continually monitor hundreds of patients, would be interrupted. This interruption would cause, at best, delays to alarm generation and clinical response during arrhythmia events or, at worst, obfuscation of the arrhythmia event causing it to be completely missed.

Furthermore, for the cases with a negative HAAT, the interfering transmit signal could have been placed higher, which would likely have resulted in more line-of-sight (LOS) scenarios, less path loss, and even more interference.

* For test location 5, which was 2836 m from the hospital, even at the maximum allowed power level per the STA, there was no observed ECG waveform dropout.

# 6. SUMMARY

Test results at Inova Mount Vernon Hospital show that the operation of an unlicensed device with a power level, separation distance and height consistent with the proposed rules in the FCC Part 15 NPRM can cause significant harmful interference to existing WMTS systems. In several cases, the interfering signal needed to be reduced by at least 3 dB, and up to 9 dB, to avoid ECG waveform dropout. Furthermore, there were multiple test locations where the interfering signal could not be increased meaning there was little to no margin left to protect the WTMS DAS from harmful interference.

It should be noted that the conditions in this test do not fully reflect realistic worst-case scenarios in several respects. For example, only a single interferer was simulated and the victim telemetry transmitters were not positioned at the true outer limit of coverage area. If interference was aggregated from multiple interferers and/or if the victim telemetry transmitters were placed exactly at the -95 dBm receive sensitivity limit rather than 10 dB above, the interferer EIRP would likely need to be reduced (or separation distance increased) even more to avoid prevent harmful interference.

It is also important to note that antenna diversity due to WMTS DAS field redundancy likely greatly limited the impact from interference observed in this test. However in practice this cannot be relied upon because the primary purpose of DAS field redundancy is to mitigate single-point failures in DAS hardware and allow the system to continue to operate safely and effectively until such failure can be corrected. If interference were allowed to degrade system margin on the backup field, sudden and severe outages would be expected to occur in the event of hardware failure on the primary field.

Lastly, when looking at the path loss results, it is possible that free space or near free space path loss can be expected from unlicensed devices located outdoors at near ground level to the perimeter of a hospital.

Based on this testing, the protection criteria for WMTS systems currently proposed in the FCC Part 15 NPRM must be greater to avoid harmful interference. Furthermore, a more rigorous analysis and field measurement exercise would be required to establish actual boundaries sufficient for safe operation under all real-world scenarios.