GE Healthcare

# Wireless Medical Telemetry Service ("WMTS") / Television White Space ("TVWS") Test Results

## Summary for Froedtert Community Memorial Hospital

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| 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 Froedtert Community Memorial show that significant harmful interference can be caused to existing WMTS systems from even a single unlicensed device with power level, separation distance and height consistent with the proposed rules in the FCC Part 15 NPRM. 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.[1] Through its rulemaking process, the FCC seeks comments from interested parties to determine the rules for such unlicensed operations.

To assist the FCC in its efforts, GE Healthcare, with assistance from Comsearch, conducted real-world testing, including gathering of empirical data, at Froedtert Community Memorial 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 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 Froedtert Community Memorial 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

Froedtert Community Memorial Hospital in Menomonee Falls, WI is the second site where TVWS/WMTS testing was performed by GEHC and Comsearch.[4] This site is five stories tall, has WMTS coverage on all floors, and has over 130 WMTS antennas installed with four antenna fields aggregated back to a central location on the 2nd floor via the WMTS Distributed Antenna System ("DAS"). Additionally, there are multiple instances of a WMTS antenna located in a patient room 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 1-4 shows the noise floor measurement value after fan out to the receivers. A value of -95dBm/10kHz or less is considered acceptable when measured at this point of the WMTS DAS. The other peaks are actual telemetry transmitters in use in the hospital.

[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) (NPRM).
[2] The hospital is located at W180 N8085 Town Hall Road, Menomonee Falls, WI 53051. Additional information regarding the facilities is available at http://www.froedtert.com/community-memorial.
[3] FCC STA grant for GE: Call Sign = WI9XAF, File # = 1026-EX-ST-2014.
[4] GE Healthcare has conducted tests at a total of three sites as of the date of this test report.

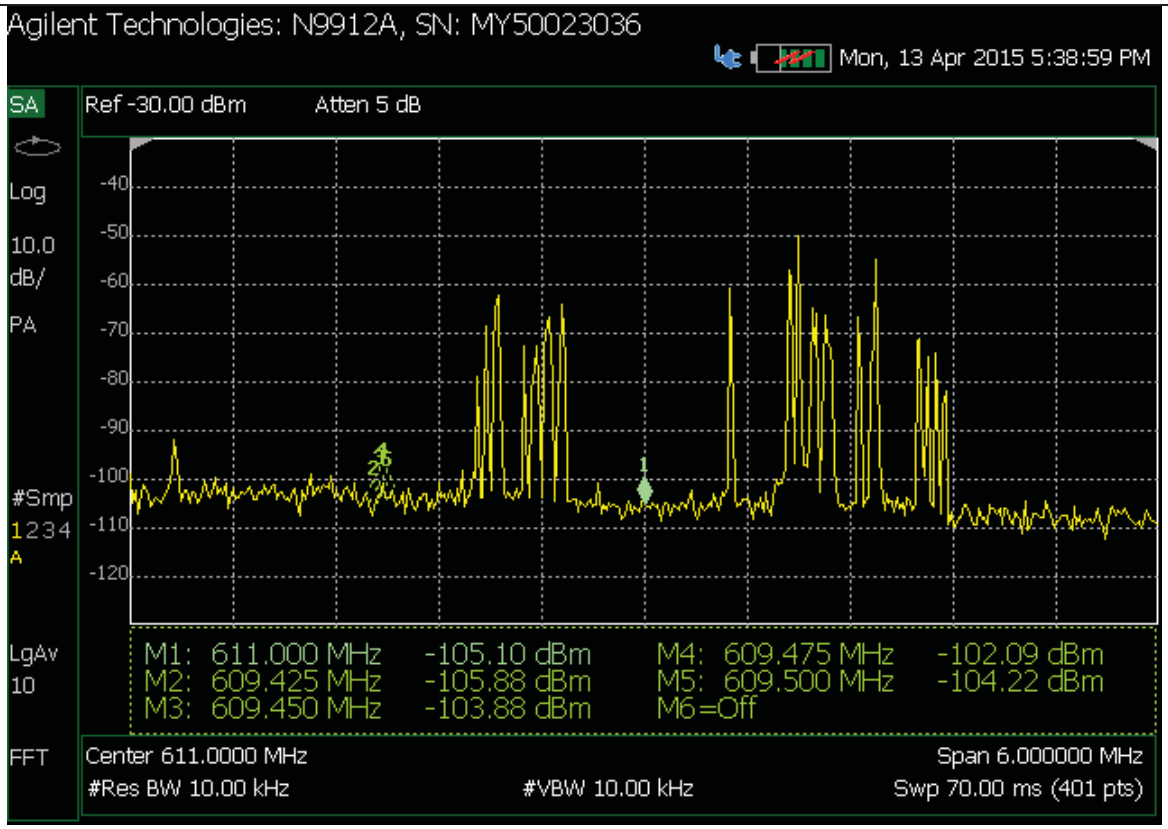


**Figure 1:** Noise Floor A Antenna Field

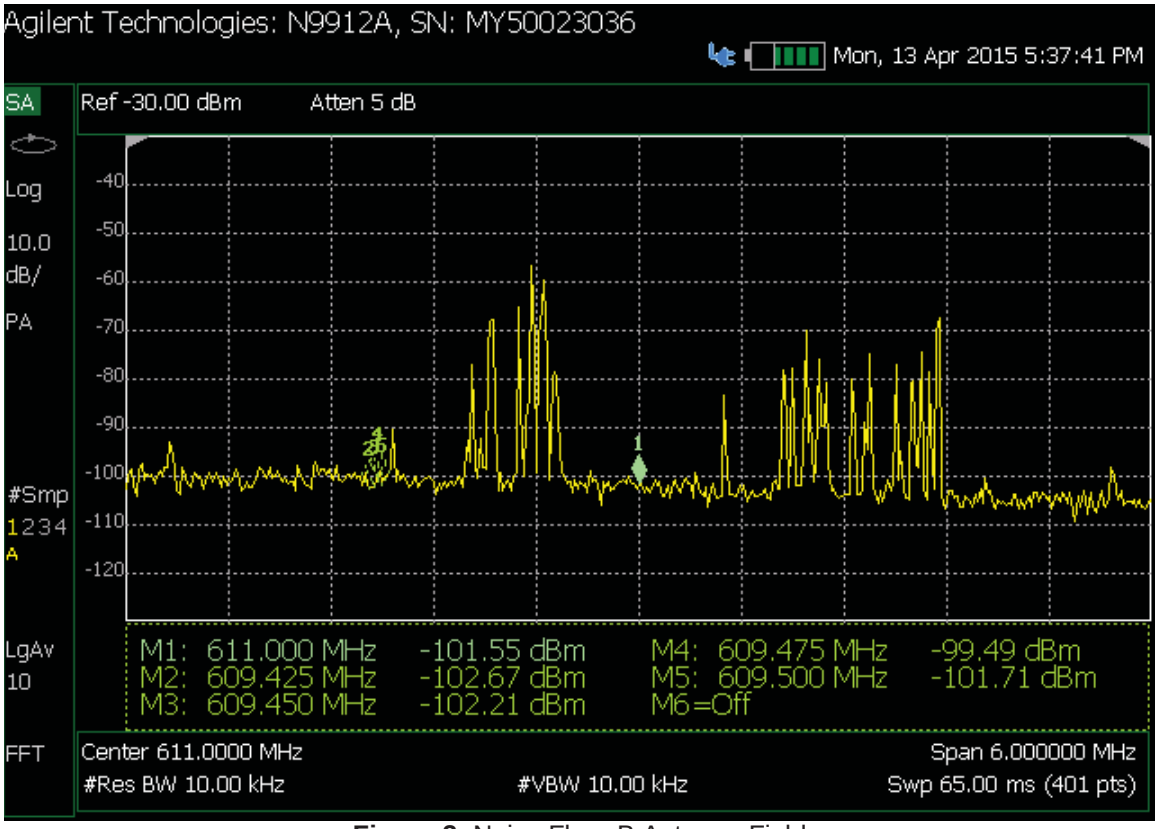


**Figure 2:** Noise Floor B Antenna Field

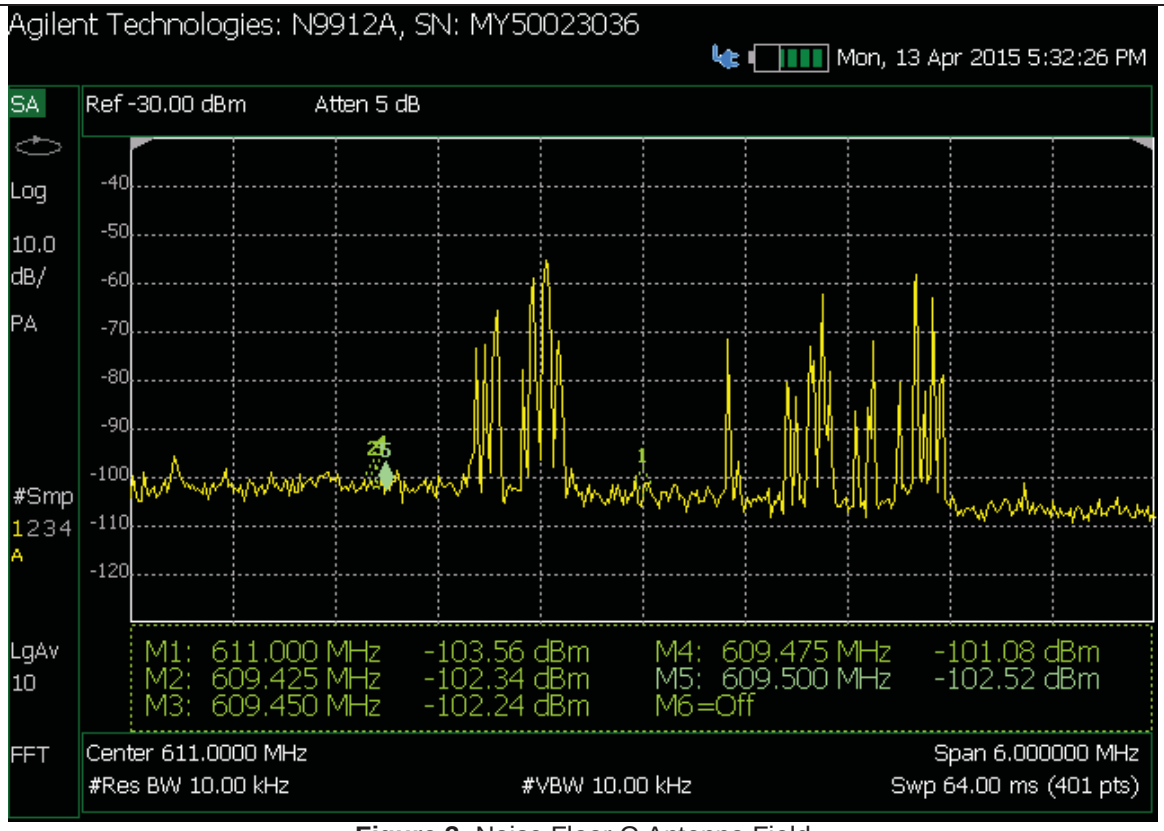


**Figure 3:** Noise Floor C Antenna Field

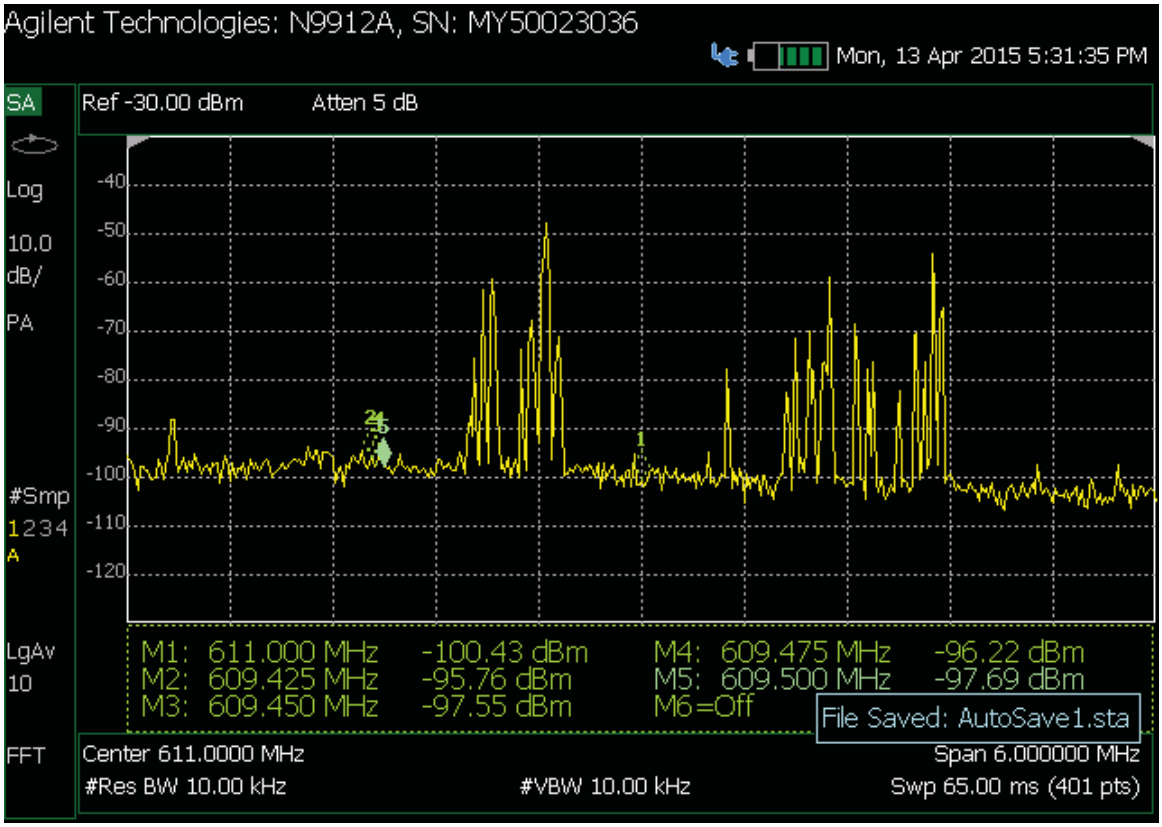


**Figure 4:** Noise Floor D Antenna Field

Additionally, a telemetry transmitter was taken to the 4th and 5th floors of the WMTS coverage area such that GEHC personnel could walk underneath a sample of WMTS antennas to ensure that they were connected and receiving signal per specification.

## 3.3 VICTIM TRANSMITTER PLACEMENT

Four victim telemetry transmitters were programmed to 609.425 MHz (TTXID 8577), 609.450 MHz (TTXID 8578), 609.475 MHz (TTXID 8579), and 609.500 MHz (TTXID 8580) and placed at different locations within the intended WMTS coverage area. Locations were selected such that at least one of the four receiver antenna fields was receiving the victim transmitter signal at 10 dB or more above the specified receive sensitivity of -95 dBm (see Table 1 below).

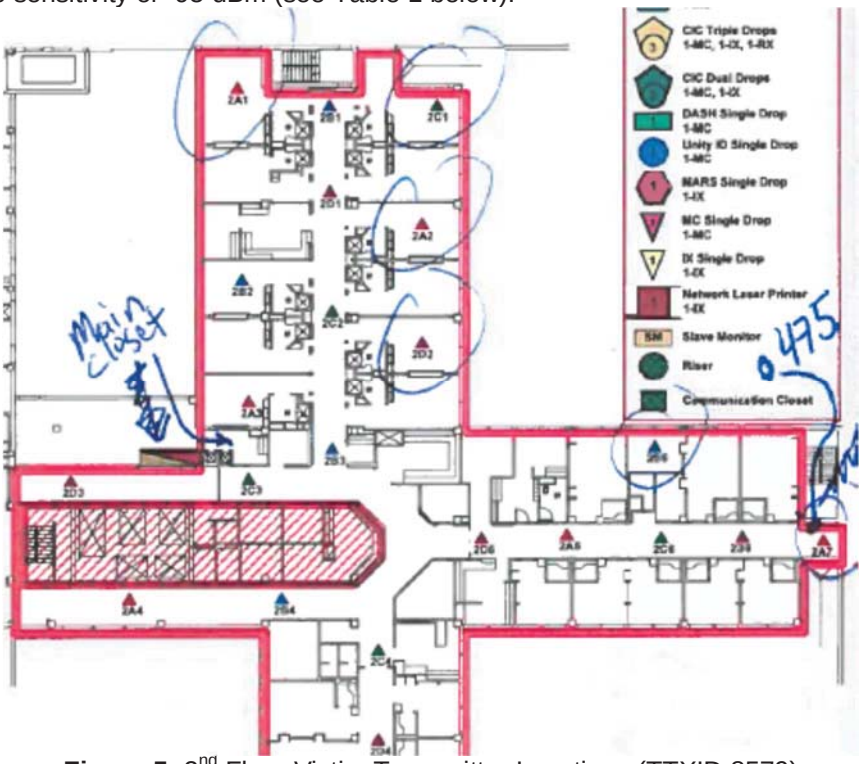


**Figure 5:** 2nd Floor Victim Transmitter Locations (TTXID 8579)

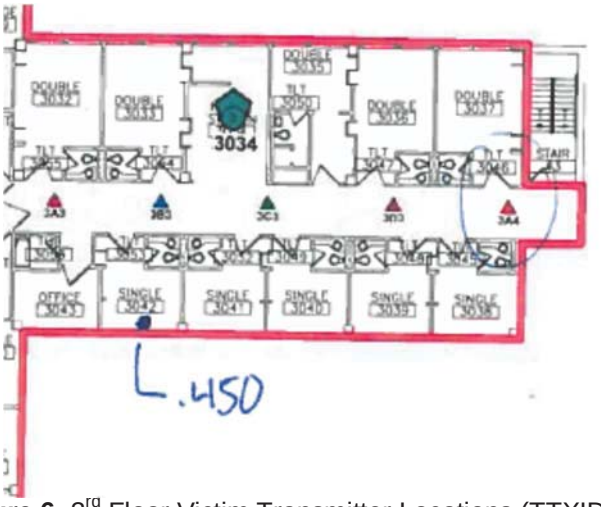


**Figure 6:** 3rd Floor Victim Transmitter Locations (TTXID 8578)

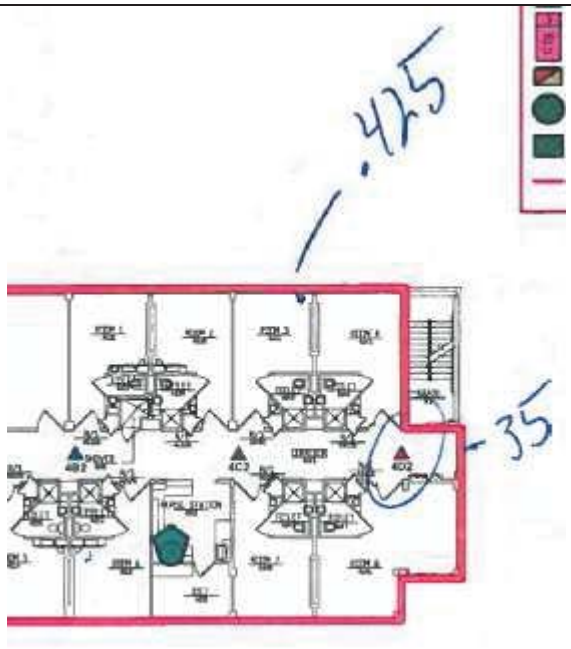


**Figure 7:** 4th Floor Victim Transmitter Locations (TTXID 8577)

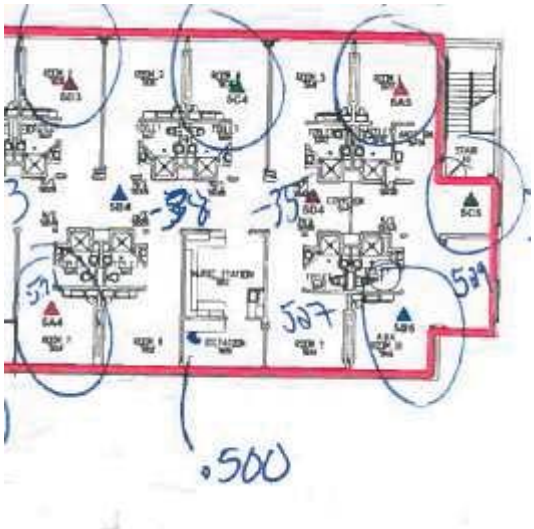


**Figure 8:** 5th Floor Victim Transmitter Locations (TTXID 8580)

| TTX | Field | Signal Level (dBm) |
|---|---|---|
| 8577 | A | -76 |
| | B | -64 |
| | C | -68 |
| | D | -60 |
| 8578 | A | -80 |
| | B | -80 |
| | C | -88 |
| | D | -87 |
| 8579 | A | -80 |
| | B | -91 |
| | C | -79 |
| | D | -77 |
| 8580 | A | -64 |
| | B | -61 |
| | C | -62 |
| | D | -89 |

**Table 1:** Victim Transmitter Received Signal per Antenna Field

## 3.4 CLINICAL INFORMATION CENTER AND SUPPORTING APEXPRO EQUIPMENT

A Clinical Information Center ("CIC") display that renders ECG telemetry waveforms from the victim transmitters, ApexPro Telemetry Server, and ApexPro Receiver Subsystem were set up and connected to the antenna field expansion ports of the existing WMTS DAS installed at Froedtert Community Memorial Hospital. This allowed for measurements on a live WTMS DAS in use for patient monitoring and historical capture of streaming ECG waveforms throughout the duration of testing without effecting clinical workflow at Froedtert Community Memorial Hospital.

## 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 609.350 MHz and used to record path loss measurement values between a simulated TVWS transmitter located outside of the hospital at a specified test location and a receive antenna provided by Comsearch located inside of the hospital in close proximity to the location of an existing WTMS DAS antenna[5]. A 100 kHz wide IEEE802.11 OFDM modulated signal was used to record potential interference with the victim telemetry transmitters on a live 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 2 below for values used per test location distance). The modulated signal was first set to a frequency of 609.350 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

[5] Please refer to "Radio Frequency Measurements Report" for Froedtert Community Memorial Hospital generated by Comsearch for the WMTS Coalition, Figures 3.5-4 and 3.5-6, for examples of the path loss measurement setup outside and inside the hospital respectively.

was shifted to 609.4625 MHz, which is in the middle of the 609.425-609.500 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 |
| 1km | 36 | 18.60 | 8.60 | 1.47 | 10.07 |

**Table 2:** 100kHz Power Level Adjustment Values

Please refer to "Radio Frequency Measurements Report" for Froedtert Community Memorial Hospital generated by Comsearch for the WMTS Coalition for additional information on test setup of the interfering signal.

## 3.7 TEST LOCATIONS

Figures 9 and 10 show where the interfering signal was placed outside of Froedtert Community Memorial Hospital. All test locations were outside with the exception of test location 3 which was inside another building (i.e. in building to in building path loss). Please refer to "Radio Frequency Measurements Report" for Froedtert Community Memorial Hospital generated by Comsearch for the WMTS Coalition for additional information and photos of the test locations.

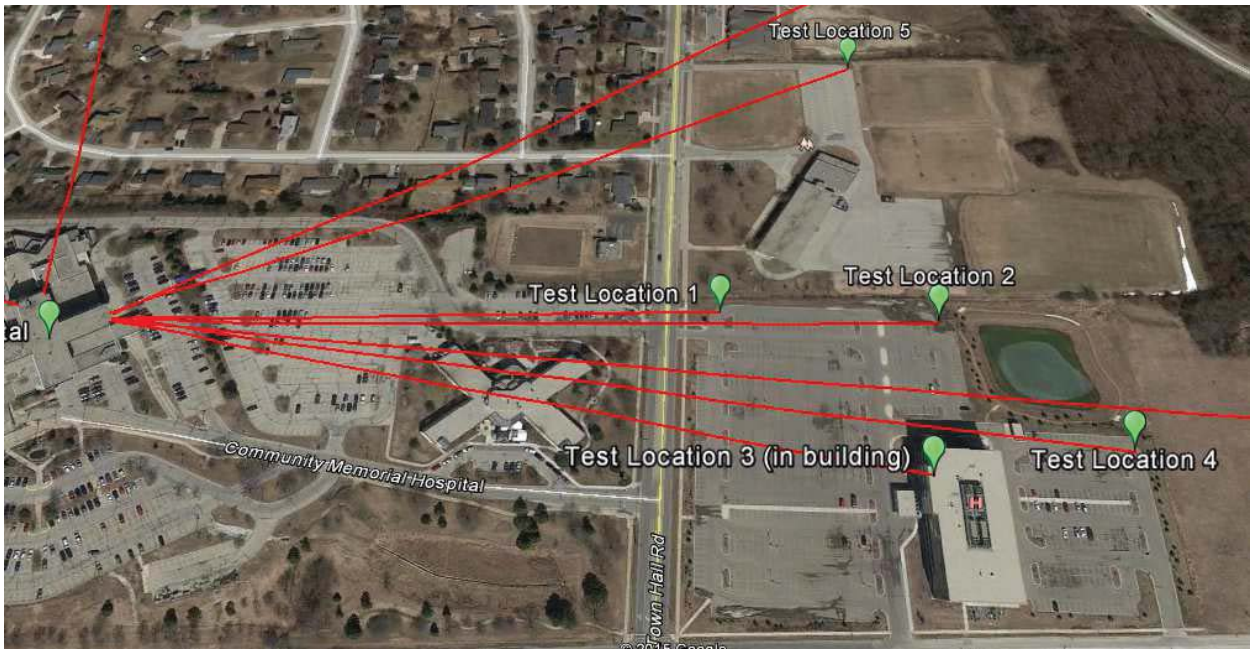


**Figure 9:** Close-up of Test Locations

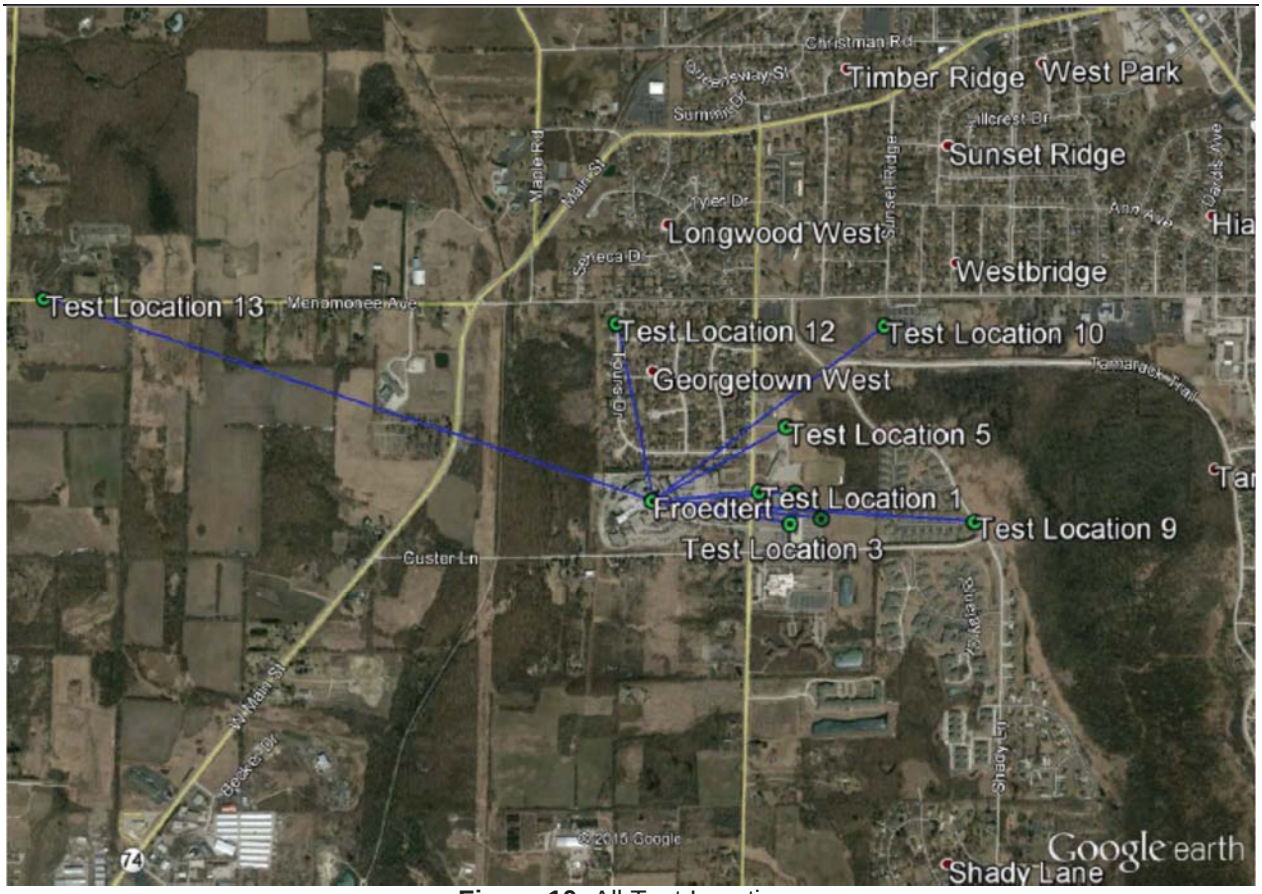


**Figure 10:** All Test Locations

## 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 609.350 MHz; 2) 100kHz modulated signal at 609.350 MHz; and 3) 100 kHz modulated signal at 609.4625 MHz.

### 4.1 CW SIGNAL AT 609.350MHZ

1. For a given test location, set the power level at the signal generator per Table 2.
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, C, and D antenna fields.

### 4.2 100 KHZ MODULATED SIGNAL AT 609.350MHZ

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, C, and D antenna fields.

### 4.3 100 KHZ MODULATED SIGNAL AT 609.4625MHZ

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 Froedtert Community Memorial.

### 5.1 CW SIGNAL AT 609.350MHZ

Detailed test results for the path loss measurements using this setup are shown in Table 4-1-1 of the "Radio Frequency Measurements Report" for Froedtert Community Memorial Hospital generated by Comsearch for the WMTS Coalition. For clarity, a reduced data set is shown below in Table 2 to highlight differences between calculated free space loss and measured loss inside of the hospital (i.e. includes ground clutter, building penetration attenuation, antenna polarization mismatches, etc.).

| Test Location | Distance From Hospital (m) | Calculated Free Space Loss (dB) | Measured Path Loss Inside (dB) | Delta From FSPL (dB) |
|---|---|---|---|---|
| 1 | 314 | 78.1 | 95.4 | 17.3 |
| 2 | 429 | 81.5 | 95.5 | 14.0 |
| 3 | 421 | 81.2 | >122.4 | >41.2 |
| 4 | 518 | 82.9 | 96.6 | 13.6 |
| 5 | 455 | 82.0 | 82.2 | 0.2 |
| 9 | 1003 | 88.5 | 104.5 | 16.0 |
| 10 | 895 | 87.6 | 89.1 | 1.6 |
| 12 | 538 | 83.3 | 99.5 | 16.1 |
| 13 | 2006 | 94.4 | 101.6 | 7.3 |

**Table 2:** Path Loss Results

The results in Table 2 show that path loss for several test locations approaches free space loss and that deviations above free space loss ranged from 0 dB to 17 dB. For test location 3, the signal was not measurable above the noise floor. If the measured signal was right at the noise floor, the in-building to in-building loss would be greater than 40dB. 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 Froedtert Community Memorial Hospital.

### 5.2 100 KHZ MODULATED SIGNAL AT 609.350MHZ

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.

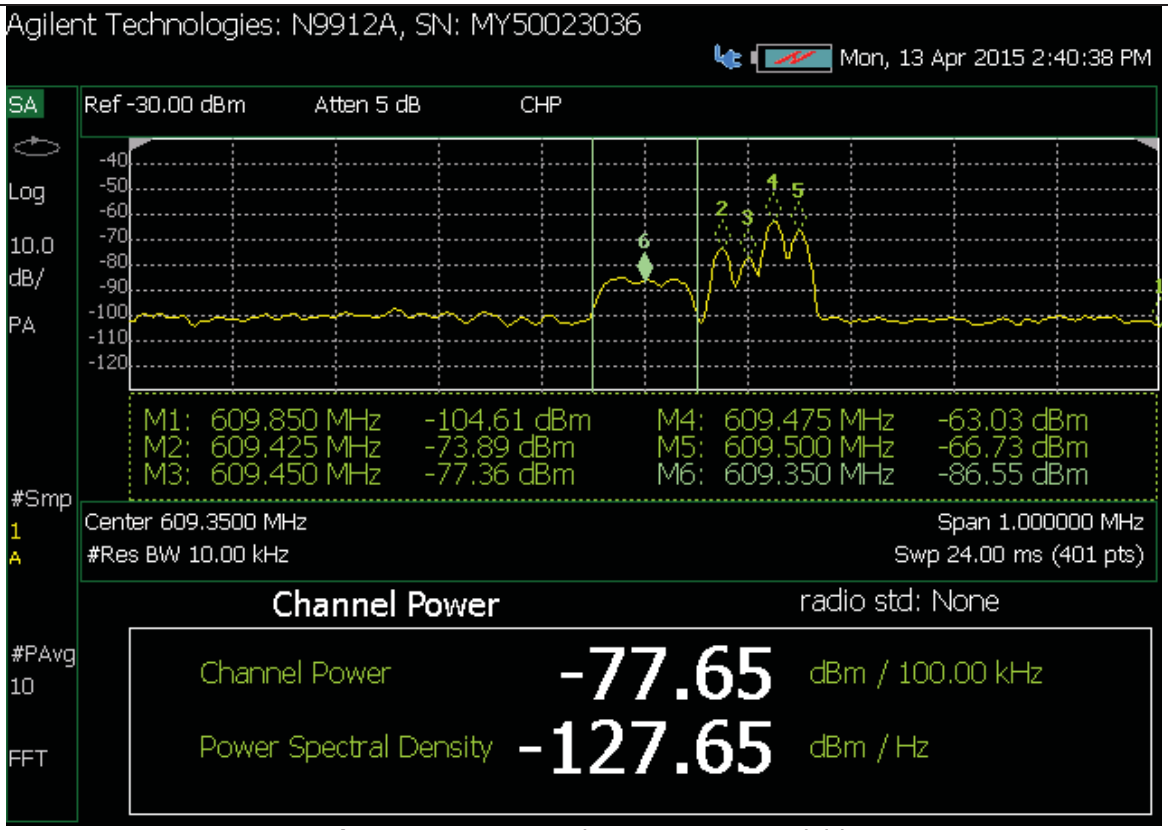


**Figure 11:** Test Location 5, A Antenna Field

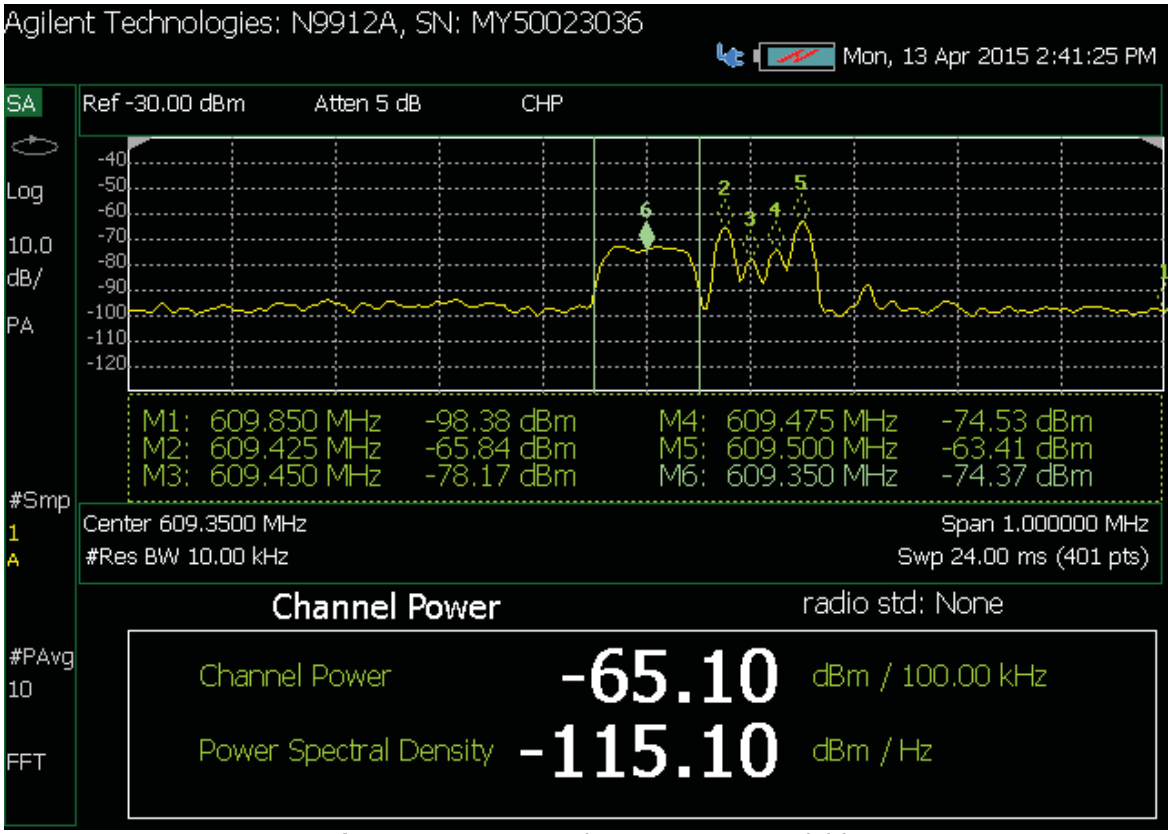


**Figure 12:** Test Location 5, B Antenna Field

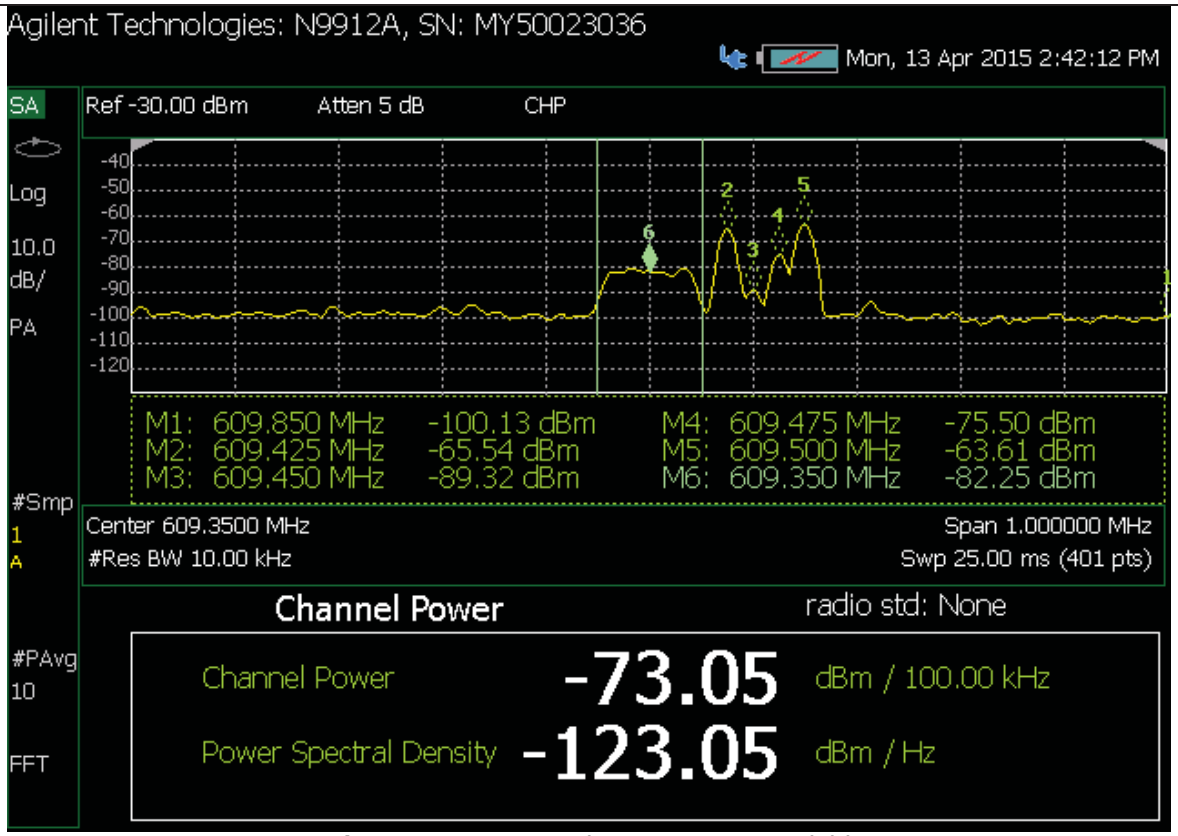


**Figure 13:** Test Location 5, C Antenna Field

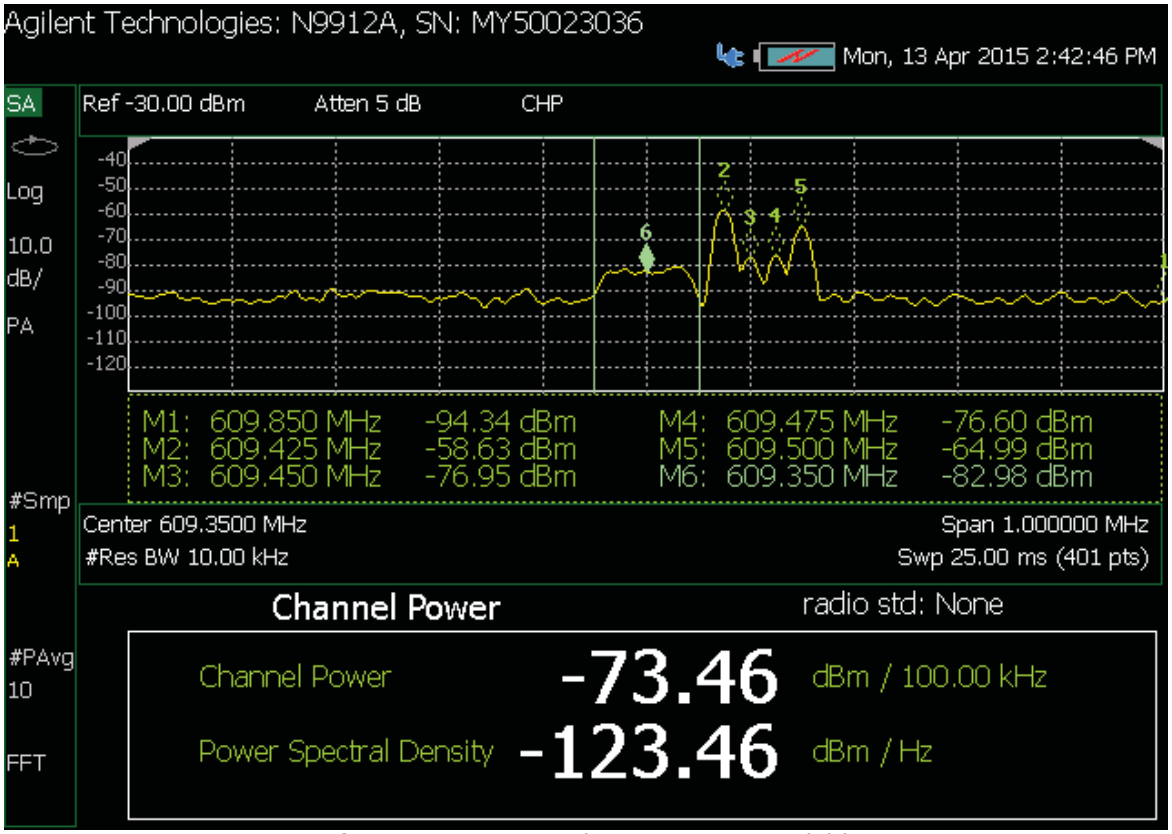


**Figure 14:** Test Location 5, D Antenna Field

Figures 11 through 14 are examples of interference measurements recorded after 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, if any, signal to noise margin is left when the interfering signal is present.

| | A Antenna Field | | B Antenna Field | | C Antenna Field | | D 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** | **Channel Power (dBm / 100kHz)** | **Above Noise Floor Spec** |
| 1 | -81.9 | Y | -72.8 | Y | -77.5 | Y | -73.1 | Y |
| 2 | -73.0 | Y | -64.3 | Y | -81.8 | Y | -71.1 | Y |
| 3 | not recorded | N | not recorded | N | not recorded | N | not recorded | N |
| 4 | -86.1 | Y | -75.7 | Y | -82.3 | Y | -74.4 | Y |
| 5 | -77.7 | Y | -65.1 | Y | -73.1 | Y | -73.5 | Y |
| 9 | -77.5 | Y | -62.9 | Y | -79.4 | Y | -72.0 | Y |
| 10 | -69.3 | Y | -62.8 | Y | -69.1 | Y | -64.5 | Y |
| 12 | -86.1 | Y | -75.3 | Y | -84.1 | Y | -78.2 | Y |
| 13 | -79.4 | Y | -72.7 | Y | -84.2 | Y | -75.7 | 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.

Note: for test location 3, results were not recorded as interfering signal levels were not observed above the noise floor.

## 5.3 100 KHZ MODULATED SIGNAL AT 609.4625MHZ

Results from this test are shown in Table 4 below. The "Min Power that Causes Interference (dBm)" column indicates the minimum power level where outages were observed (i.e. any power level lower resulted in no ECG waveform dropout).

| Test Location | Distance From Hospital (m) | Max Permitted Transmit Power from Rules (dBm) | Min Power that Causes Interference (dBm) | Margin (dB) |
|---|---|---|---|---|
| 1 | 314 | 16 | 19.0 | 3.0 |
| 2 | 429 | 20 | 19.0 | -1.0 |
| 3 | 421 | 20 | interference not detected* | n/a |
| 4 | 518 | 24 | 24** | 0.0 |
| 5 | 455 | 20 | 9.0 | -11.0 |
| 9 | 1003 | 36 | 31.0 | -5.0 |
| 10 | 895 | 32 | 21.0 | -11.0 |
| 12 | 538 | 24 | interference not detected*** | n/a |
| 13 | 2006 | 36 | 36.0 | 0.0 |

**Table 4:** Interference Margin

Table 4 shows several cases (test locations 2, 5, 9, and 10) where the power level had to be reduced in order to avoid interfering with the WMTS DAS and causing ECG waveform dropout. At those test locations, with the interfering signal set to the value shown in the "Max Permitted Transmit Power from Rules (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 causing, at best, delays to alarm generation and clinical response during arrhythmia events or at worst, completing missing arrhythmia events.

Note: for test location 4, interference was detected with interfering signal level at Maximum Permitted Transmit Power, but the interfering signal level was not reduced to determine margin.

Note: for test location 3 and 12, interference was not detected with interfering signal level at Maximum Permitted Transmit Power, but the interfering signal level was not increased to determine margin.

## 6. SUMMARY

Test results at Froedtert Community Memorial show that significant harmful interference can be caused to existing WMTS systems from even a single unlicensed device with power level, separation distance and height consistent with the proposed rules in the FCC Part 15 NPRM. In several cases, the interfering signal needed to be reduced by at least 1 dB and up to 11 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.