FHWA-NJ-2017-007

Worker Safety Issues of Wi-Fi Devices

FINAL REPORT
December 2016

Submitted by

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In cooperation with

New Jersey
Department of Transportation
Bureau of Research
And
U.S. Department of Transportation
Federal Highway Administration

DISCLAIMER STATEMENT

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. 2014-5-04	2.Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Worker Safety Issues of Wi-Fi Devices		5. Report Date December 2016 6. Performing Organization Code
7. Author(s) Dr. Allen Katz, Prof. Joseph Jesson, and Dr. Thomas M. Brennan		8. Performing Organization Report No.
9. Performing Organization Name and Address The College of New Jersey PO Box 7718 Ewing, NJ 08628-0718		10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address New Jersey Department of Transportation PO 600 Trenton, NJ 08625		13. Type of Report and Period Covered 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The application of wireless devices for the transmission and reception of electromagnetic (E&M) energy is rapidly expanding. These devices use new protocols such as Bluetooth, Bluetooth Low Energy (BLE), cellular Long-Term Evolution (LTE), and Wi-Fi standards (802.11n and 802.11a) and produce measurable E&M power densities that add to already existing radiated Radio Frequency (RF) Spectrum. Radio Frequency Electromagnetic Field (RF-EMF) exposure occurs from the use of these devices. The New Jersey Department of Transportation (NJDOT) uses Bluetooth sensors to collect data for travel times on the State roadway systems and transmits this data to provide accurate real-time information to the motoring public. The research documented in this report answers questions related to the use and repair of these transmitters: (1) What are the RF-exposure health risks to NJDOT employee? (2) What steps can be taken to mitigate any risks from RF transmitted sources? This research also goes beyond Bluetooth and Bluetooth LE, and considers the risk from second generation (2G) and 3G cellular radiators and other 801.11 standards equipment now in production. In all cases the levels measured were well below the safe exposure levels established in the United States of America and international standards. Nevertheless, the effects of this exposure on worker health and safety are considered and how to mitigate any possible negative effects discussed.

17. Key Words E&M Safety, RF-exposure health risks, WiFi, Cellular US & European Standards, Bluetooth, Specific Absorption Rate, IEEE/ANSI C-95	18. Distribution Statement		
19. Security Classif (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No of Pages 48	22. Price

Form DOT F 1700.7 (8-69)

ACKNOWLEDGEMENTS

The author wishes to thank the New Jersey Department of Transportation for their assistance and support, particularly Giri Venkiteela, whose aid was essential to the success of this research. The author also wishes to thank TCNJ student Mehdi Benmassaoud for his support of this research, and Dr. Brett BuSha, Associate Professor, Department of Biomedical Engineering for his contributions, especially in the field of human physiology.

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EXECUTIVE SUMMARY:

Wireless-based devices, each of which is transmitting and receiving electromagnetic (E&M) energy at a measurable Power Density, and new protocols such a Bluetooth, Bluetooth Low Energy (BLE), and cellular Long-Term Evolution (LTE), and new Wi-Fi standards (802.11n, 802.11a) continue to be added to the radiated Radio Frequency (RF) Spectrum. Radio Frequency Electromagnetic (RF-E&M) Field exposure occurs from the use of various RF-enabled devices, e.g., the New Jersey Department of Transportation has Bluetooth sensors used to collect data for travel times on State roadway systems and these data are used to transmit accurate real-time information to the motoring public. The new research documented in this report answers the questions related to the repair of these Bluetooth transmitters: (1) What are the RF-exposure health risks to the employee? (2) What steps can be taken to mitigate any risks from RF transmitted sources? This research also goes beyond Bluetooth and Bluetooth LE, and considers the risk from second generation (2G) and 3G cellular radiators and other 801.11 standards equipment now in production.

In all cases the levels measured were well below the safe exposure levels established in the United States of America. Nevertheless, the effects of this exposure on worker health and safety are considered and how to mitigate any possible negative effects discussed.

The objectives of this study were to:

1. Examine, and analyze the employed and serviced NJDOT's wireless devices in use today, and planned devices, to identify the existing and future planned E&M emitter sources. **Expanded E&M Sources investigated included:**
    a. **Wi-Fi (802.11a, 802.11b, 802.11n Standards)**
    b. **Bluetooth & the Newer Low-Power Bluetooth LE Transmitters, and**
    c. **Cellular US & European Standards (including the new LTE Protocol Standards).**
2. Measure, analyze, and document the E&M Radiation Signal Power Density (PD), in mW/cm^2 units, NJDOT employees are exposed to while repairing and working in proximity to transmitting equipment, e.g., repairing Bluetooth-enabled collection devices. **Measurements were made on multiple sites around New Jersey**.
   Map the results of the exposed levels by frequency and amplitude to the findings of the Literature Search and compare and contrast the latest risk levels as defined by individual country's RF risk standards. **All USA and international standards were considered.**
3. Recommend and document the maximum RF levels of exposure that the NJDOT employee should not exceed. **This level was based upon researching, and identifying quality, replicated studies, which set determined standards.**
4. Determine existing wireless hardware, which exceeds these levels and, if required, develop a remediation plan, which may include recommending exposure time limits. **In all cases the levels measured were well below the safe exposure levels established in the United States of America and internationally. Nevertheless, the effects of this exposure on worker health and safety are considered and how to mitigate any possible negative effects discussed.**
5. Document any equipment purchase specification standard, which would assure that new purchased equipment would not exceed the determined limits. **Equipment recommendations were made.**

6. Develop a systematic plan for the implementation of the periodic monitoring of E&M strength (level & frequency) **in order to insure published standards are met.**
   A detailed plan was formulated. **All objectives were achieved.**

1. Background

The proliferation of wireless-based sensors, each of which is transmitting E&M energy at a certain Power Density, and new protocols such a Bluetooth, Bluetooth Low Energy (BLE), and cellular Long-Term Evolution (LTE), and new Wi-Fi standards (802.11n, 802.11a) continue to be added to the radiated Radio Frequency (RF) Spectrum. Radio Frequency Electromagnetic Field (RF-EMF) exposure certainly occurs from the use of these additional protocols from the use of various RF-enabled sensors, e.g., the New Jersey Department of Transportation has Bluetooth devices used to collect data for travel times on State roadway systems and these data are used to transmit accurate real-time information to the motoring public. During the repair of these Bluetooth transmitters, the specific questions are: (1) What are the health risks to the employee? (2) What steps can be taken to mitigate any risks from RF transmitted sources? New research beyond the second generation (2G) and 3G cellular risks need to be performed related to these two questions as Bluetooth, Bluetooth LE, and other 801.11 standards are in production. Therefore, there is a need to understand the effects of this exposure on worker health and safety and how to mitigate any negative effects it may have.

2. Project Goals

The objectives of this study were to:

1. Examine, and analyze the employed and serviced NJDOT's wireless devices in use today, and planned devices, to identify the existing and future planned E&M emitter sources.

   Expanded E&M Sources investigated included:
   a. **Wi-Fi (802.11a, 802.11b, 802.11n Standards)**
   b. **Bluetooth & the Newer Low-Power Bluetooth LE Transmitters, and**
   c. **Cellular US & European Standards (including the new LTE Protocol Standards).**

2. Measure, analyze, and document the E&M Radiation Signal Power Density (PD), in mW/cm^2 units, NJDOT employees are exposed to while repairing and working in proximity to transmitting equipment, e.g., repairing Bluetooth-enabled collection devices.

   Measurements were made on multiple sites around New Jersey, see:
   Appendix II DOT Field Measurement Data, Compared to Safety Standards

3. Map the results of the exposed levels by frequency and amplitude to the findings of the Literature Search and compare and contrast the latest risk levels as defined by individual country's RF level risk standards.

   All known USA and international standards were considered.

4. Recommend and document the maximum RF levels of exposure that the NJDOT employee should not exceed.

   This level was based upon researching, and identifying quality, replicated studies, which set determined standards. An extensive literature search was conducted on the health effects of E&M radiation in all forms with 124 references listed.

5. Determine existing wireless hardware, which exceeds these levels and, if required, develop a remediation plan, which may include recommending exposure time limits.

   In all cases the levels measured were well below the safe exposure levels established in the United States of America and internationally. Nevertheless, the effects of this exposure on worker health and safety are considered and how to mitigate any possible negative effects discussed.

6. Document any equipment purchase specification standard, which would assure that new purchased equipment would not exceed the determined limits.

   Equipment recommendations were made.

7. Develop a systematic plan for the implementation of the periodic monitoring of E&M strength (level & frequency) in order to insure published standards are met.

   A detailed plan was formulated.

All objectives were achieved.

3. Biological Risk to Personnel in an RF Environment

An extensive literature search was conducted on the health effects of E&M radiation in all forms. The bibliography generated as result of this search is shown in appendix I. The searched biomedical and medical databases included professional IEEE Xplore document databases, which includes a massive library of all the IEEE societies and special-interest groups (SIGs). IEEE Xplore and cross-SIG (Global Biomedical-Microwave papers online library) databases were leveraged to obtain what is believed to be a nearly comprehensive list. The results of the literature search were classified by quality; data supported (thermal model) papers and by non-data/science supported papers and books, which describe extraordinary risks. Examples of high and poor quality papers are illustrated in Figures 1 and 2. During the duration of this project, online alerts were defined in order to detect any discoveries that would conflict with any of the identified documents and their risk conclusions. While this alert was triggered 4 times during this work, upon closer investigation, it was determined that the findings were all dubious and not replicated or peer-reviewed quality findings [15], [34], [36]. Study frequencies were not documented in these reports and they often lacked a control group; hence we could not confirm microwave emitting sources, or power and exposure levels.

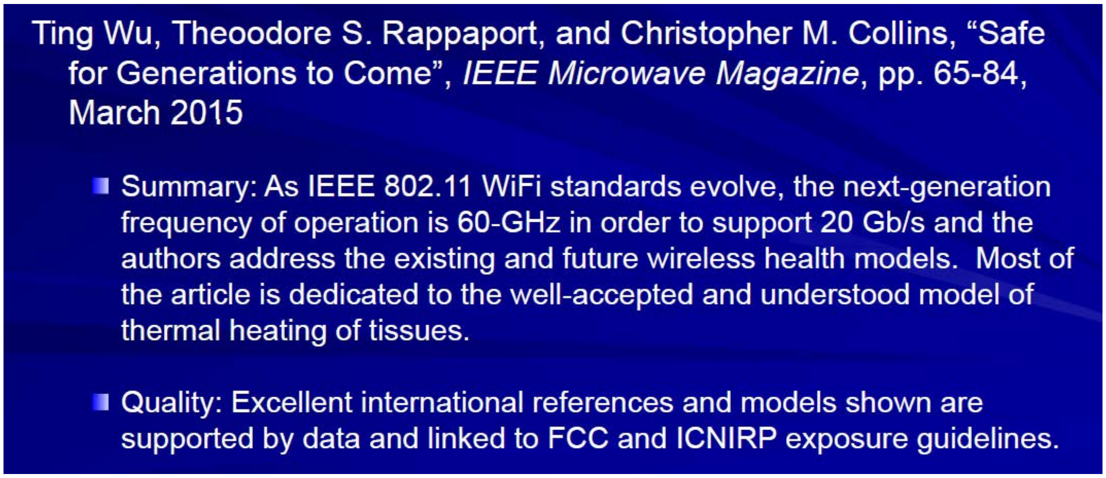

Figure 1. Example of highly rated paper

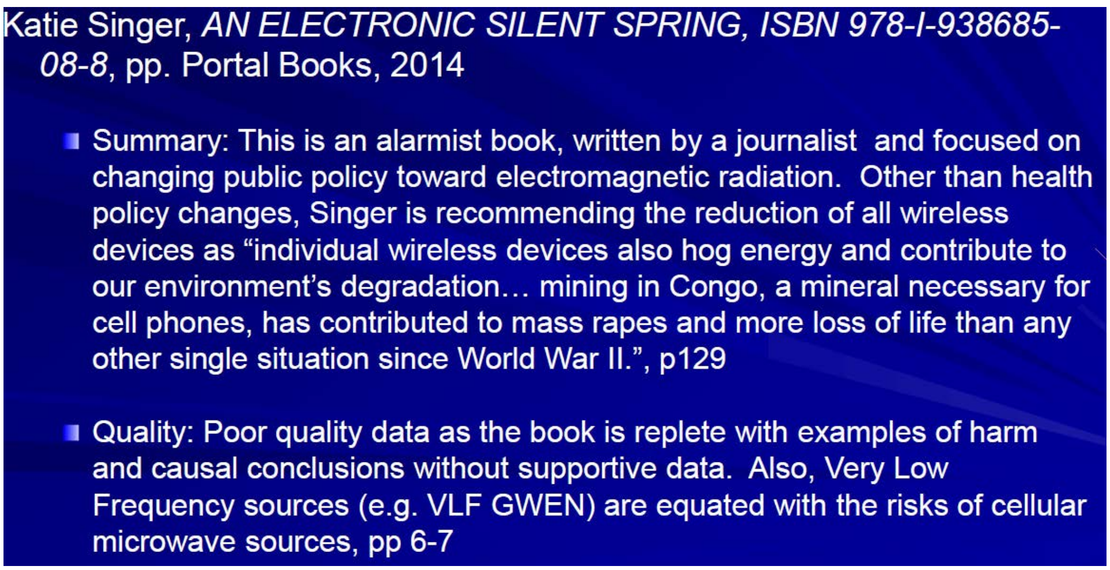

Figure 2. Example of poorly rated paper

Many papers describe the three-layer model of human tissue, as described in Figure 3.

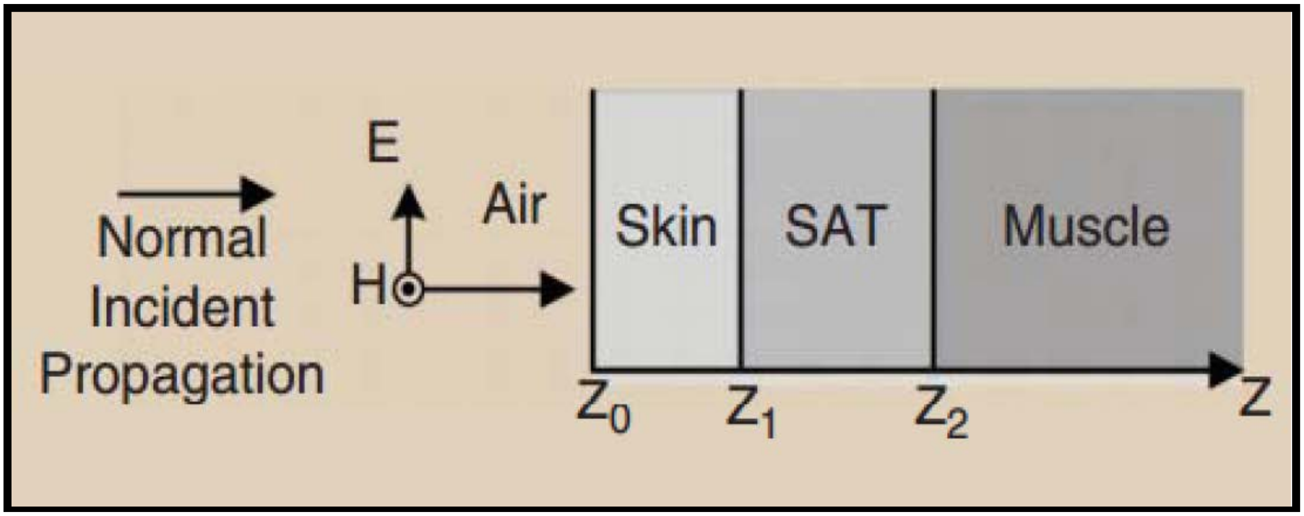

Figure 3. Three-layer model of human tissue where Z's are wave impedances and 'SAT' refers to subcutaneous adipose tissue

The penetration depth in the human skin decreases as the exposure frequency increases. At <30 MHz, frequencies, most of the RF Energy passes through human tissues with little absorption. At 1,500 MHz and above approximately 80 percent of the RF energy is reflected off the skin, and 20 percent is absorbed. This study referenced in Figure 1 focuses on WiFi and Bluetooth Industrial frequencies of 2399.5 MHz to 2484.5 MHz, 5.250–5.350 GHz and 5.470–5.725 GHz. Figure 4 shows the effect of frequency on penetration depth into the body.

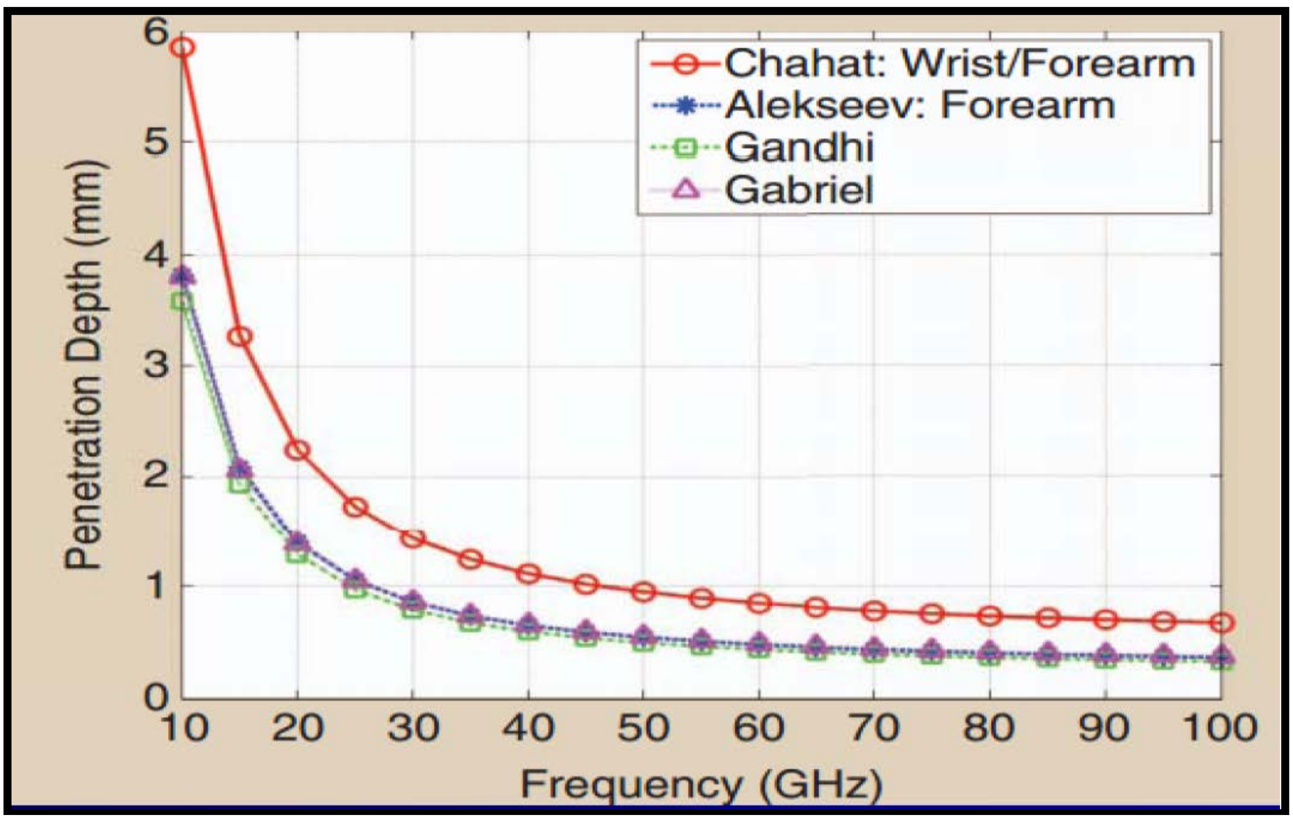

Figure 4. Skin penetration depth as a function of exposure frequency

The largest number of reference documents overwhelmingly support the thermal risk model of microwave, non-ionizing, emitted radiation, Refs [1] - [114]. They describe the principle RF Energy effect using a thermal model. The thermal model indicates that the most susceptible part of the body to RF heating is the eyes, where cataract formation is a risk. Also, a significant reduction in sperm motility (decreased fertility) was observed and measured. Specific replicated sperm motility risks of levels >30 mW/cm^2 is found at [108], eye cataract risks, human and rabbit, referenced in [45], [46], [47], [48], [49], [50], [51] and tissue heating risks documented in [24], [68], [70], [71].

A majority subset of the literature search also supported the international IEEE microwave health Standard C95.1 2005, including 1 mW/cm^2 Ref [10] and for limited exposures <40 minutes; the levels of 1 mW/cm^2 are also supported by the International ICNIRP standards group [16], [115]. When the IEEE microwave health Standard C95.1 1992 [9] was compared and contrasted with the newest (2005) IEEE microwave health Standard, changes to the low-frequency section of the graph (lower-risk defined) were found, but no changes to the microwave limit defined as 1 mW/cm^2. The American National Standards Institute (ANSI), in 1966, was the initial US standards body that defined a RF radiation exposure standard. It recommended that exposure be limited to field levels <= 10 mW/cm^2. In the 1982 version, ANSI C95.1–1982, the first Specific Absorption Rate (SAR) human exposure standard in the world was established. This standard was based upon localized body heating and electrostimulation. It is similar to the original. The ANSI standard was adopted as a IEEE standard and became truly international in scope. The next update of the standard was IEEE C95.1–1991. It was also ratified by ANSI a year later.

Microwave ovens, researched as a control source for Microwave emission, also must meet the 1 mW/cm^2 standard above for newly manufactured Microwave ovens, but a serviced microwave oven only need meet the OSHA safety published microwave standard of 5 mW/cm^2, Ref [118], [120], [124], and [121]. References on the test equipment, specifically the Narda 8700-series RF microwave power meter, used for measurements in this study, instrument setup, and calibration is found at [117] and specific microwave transmitter modules found in the NJDOT network are found at [122], and [123].

4. Research and Inventory of Transmission Equipment

An inventory of the WiFi, Bluetooth, Microwave and Cellular NJDOT emitters was compiled, which included model #, labeled FCC ID number, and location – see appendix 2. This inventory was used to decide on sites to be visited and equipment to be evaluated. WiFi equipment sites were the first to be visited and to have E&M radiation levels measured. Figure 5 shows one of the NJDOT WiFi sites that were visited.

Figure 5. Example of a Bluetooth/Cellular Wireless Sensor visited by the research team

Figure 6 shows information on one of the sights evaluated that houses both a Bluetooth data tracker and cell telephone sources.

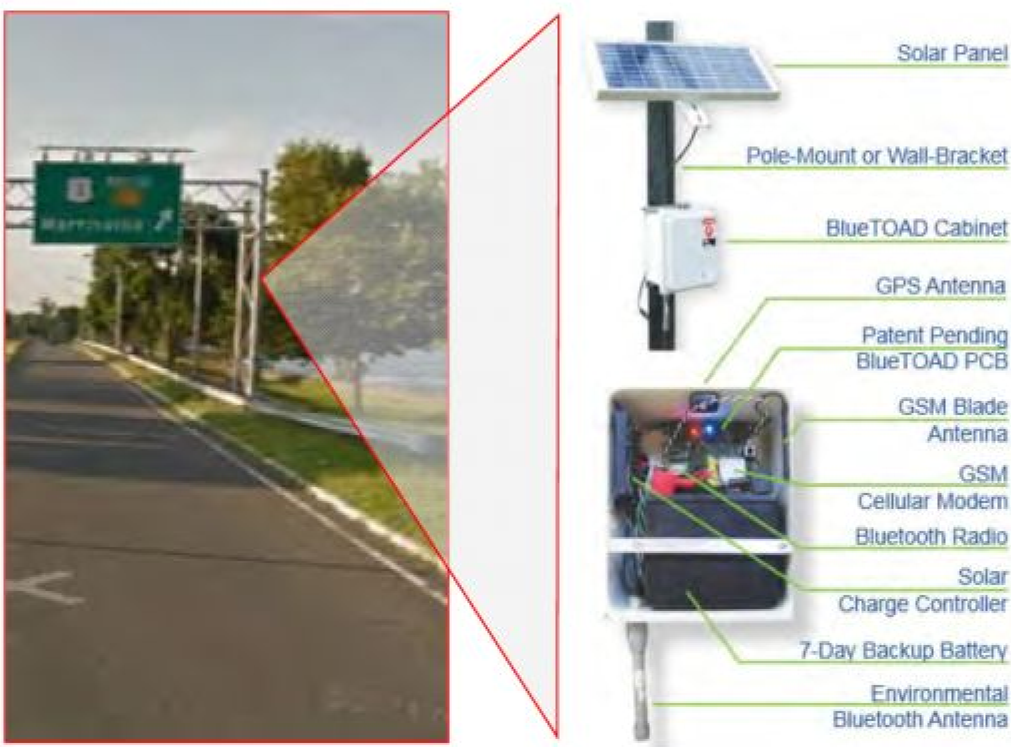

Figure 6. Potential radiation evaluation site with cellular and Bluetooth radio sources

The project team, in parallel with its site measurements, collected information from public databases – the FCC-certified lab RF measurements made by the vendor in order to comply with FCC Part 15 A/B legal requirements. Figure 7 shows a type of WiFi sensor similar to those used by NJDOT. Table I lists radiation levels produced in association with such devices. Links into the FCC data that show the RF measurements made by the device/module manufactures can be found at https://fccid.io/.

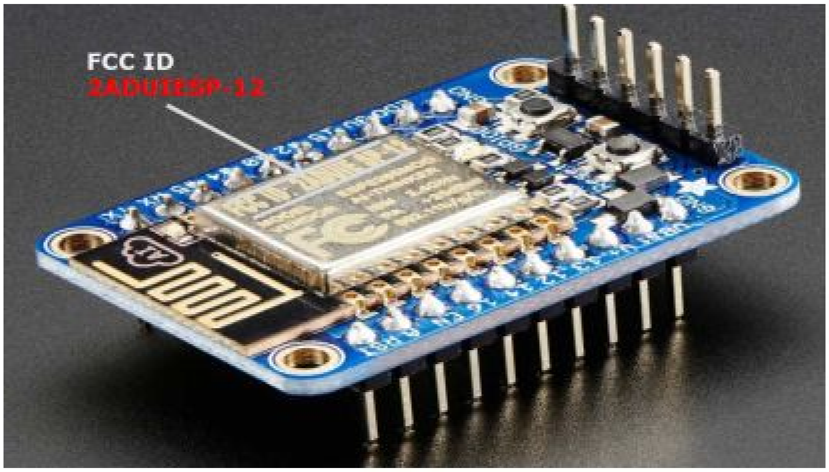

Figure 7.Example of WiFi sensor similar to those used by NJDOT

Table I - Emission Level and Frequency of FCC Part 15 Devices

Normal Voltage							
Polar (H/V)	Frequency (MHz)	Meter Reading (dBuV)	Factor (dB)	Emission Level (dBuV/m)	Limits (dBuV/m)	Margin (dB)	Detector Type
Mid Channel (2412 MHz)							
Vertical	1187.688	79.85	-18.27	61.58	74	-12.42	Pk
Vertical	1433.535	78.51	-17.12	61.39	74	-12.61	Pk
Vertical	1636.784	75.77	-16.06	59.71	74	-14.29	Pk
Vertical	4824	61.7	-3.6	58.1	74	-15.90	Pk
Vertical	4824	45.58	-3.6	41.98	54	-12.02	Pk
Horizontal	1187.688	77.03	-18.27	58.76	74	-15.24	Pk
Horizontal	2095.928	73.88	-11.88	62.00	74	-12.00	Pk
Horizontal	2412	73.83	-12.97	60.86	74	-13.14	Pk
Horizontal	2791.777	74.68	-11.65	63.03	74	-10.97	Pk
Horizontal	4824	70.77	-3.6	67.17	74	-6.83	Pk
Horizontal	4824	50.47	-3.6	46.87	54	-7.13	AV
Mid Channel (2437 MHz)							
Vertical	1187.688	82.02	-18.27	63.75	74	-10.25	Pk
Vertical	1433.535	78.48	-17.12	61.36	74	-12.64	Pk
Vertical	1636.784	75.81	-16.06	59.75	74	-14.25	Pk
Vertical	4874	66.4	-3.64	62.76	74	-11.24	Pk
Horizontal	1187.688	78.06	-18.27	59.79	74	-14.21	Pk
Horizontal	2099.687	72.59	-11.84	60.75	74	-13.25	Pk
Horizontal	2502.727	74.90	-12.73	62.17	74	-11.83	Pk
Horizontal	4874	70.19	-3.64	66.55	74	-7.45	Pk
Horizontal	4874	51.12	-3.64	47.48	54	-6.52	AV

5. Relate RF Levels to Risk

In order to understand the NJDOT personnel risk, the maximum permissible exposure (MPE) over a 6 minute period as defined by the IEEE/ANSI C-95 standards documentation were both measured and calculated. The IEEE/ANSI C-95 standards documentation sets the RF exposure standards for OSHA, NIOSH, and the DOD. The MPE in the United States (US) is power density of 10 W/m^2. It should be noted that many countries have lower MPE or power density (PD) than the United States.

Much of the European Union, Russia and China use a level that is one percent of the level used in the US. Table II shows the limits of a sampling of different countries.

Table II Exposure Limits to RF Radiation by Country

Country/Guidelines	PD Restrictions for the General Public in W/m²	PD Restrictions for the General Public in mW/cm²	Frequency Range (GHz)	Basis
ICNIRP [17] (1998)	10	1	2–300	Science based
FCC [16] (1996)	10	1	1.5–100	Science based
China [32] (1987)*	0.1	0.01	0.3–300	Science based
Russia [33] (2003)	0.1	0.01	0.3–300	Science based
Switzerland [34] and [35] (2000)*	0.1	0.01	1.8–300	Precautionary
Italy [36] (2003)*	0.1	0.01	0.0001–300	Precautionary
Typical maximum exposure from cellular base station mounted on 50-m tower (assuming a total effective radiated power of 2,500 W in each sector, summed over all channels)	0.01	0.001	1–2	Example from [29]

*These restrictions only apply to sensitive areas, such as school, hospital, or rooms in buildings, where they are regularly occupied by persons for prolonged periods.

Measurements were made onsite at actual NJDOT locations in the field and compared to the ICNIRP/C95.1/OSHA/FCC Part 15 Standards. Two different sets of equipment were used to measure and verify radiation levels. One method used standardized commercially available radiation meters. Two radiation meters from different manufactures were available for the testing. A Narda 8611 was the instrument used in the majority of our DOT field tests, and is illustrated in Figure 8.

Figure 8. One instrument used to evaluate radiation levels of element under test (EUT)

The second method used a calibrated standard horn and high quality laboratory microwave test instrumentation as illustrated in Figure 9. This is the method normally used by the Federal

Communications Commission (FCC) to measure radiations levels. The horn's frequency of operation was centered on the WiFi frequency band (2.4 GHz). Each component of the system and the overall system performance were evaluated. The standard horn was designed, fabricated and calibrated at TCNJ. Details of its design and construction are discussed in appendix III.

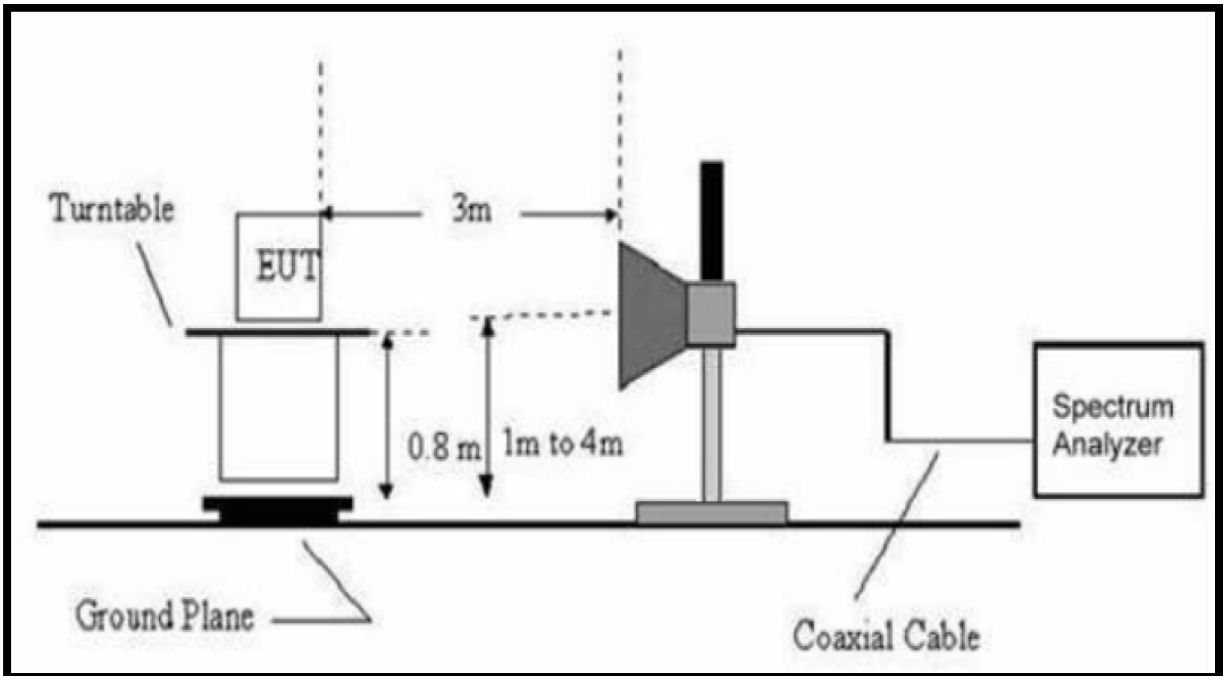

Figure 9. FCC method for evaluating radiation levels of EUT

Pictures and details of site visits are shown in Figures 10 through 13. Figure 10 shows details of a 2.45 GHz Bluetooth (BT) discussed earlier this report. Figure 11 illustrates a BT radiation measurement using the standardized horn and its related spectrum. Testing with the standard horn antenna and a spectrum analyzer allows specific frequencies of interest to be identified. This was just one of several measurement techniques employed. Figure 12 shows the same measurement taken with a Techtronic's broadband radiation detector. There was also cell telephone radiation at this location that was evaluated as well. Figures 13 and 14 show the cell telephone testing and the resulting spectrum, and respectively broadband detector results.

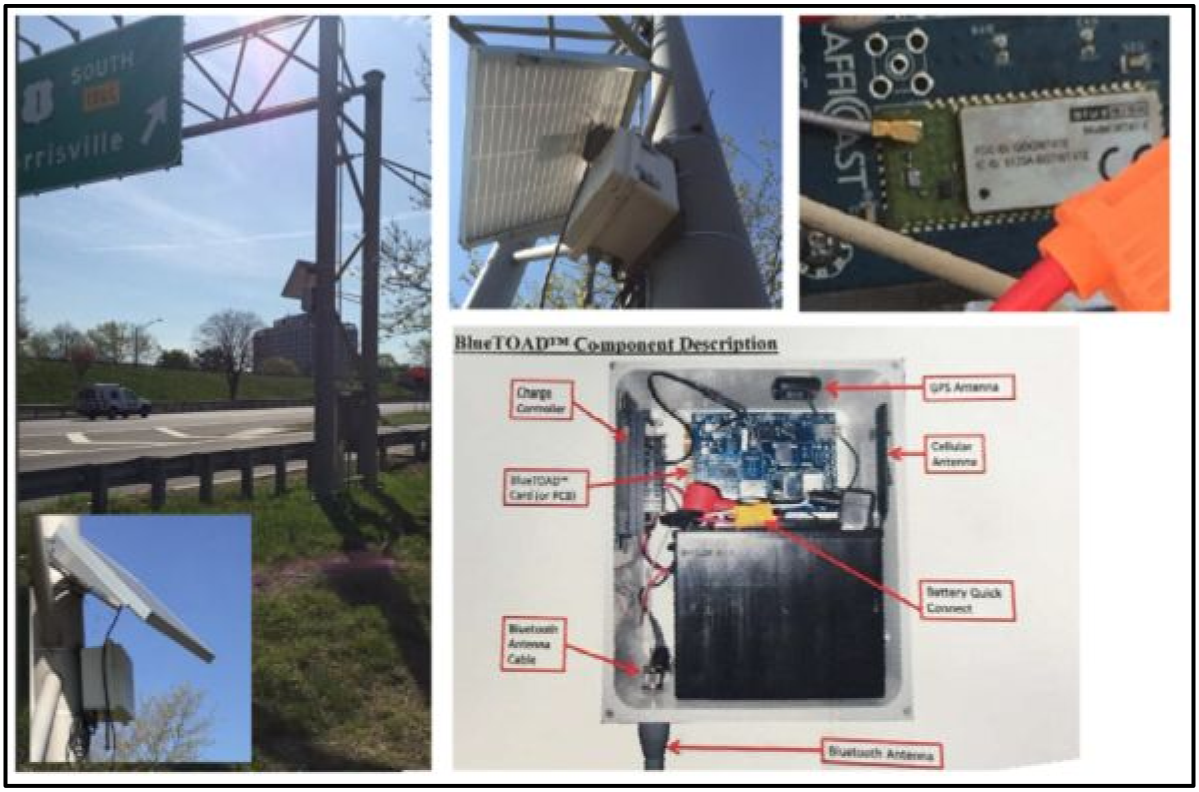

Figure 10. Bluetooth radiation source test site and related equipment details

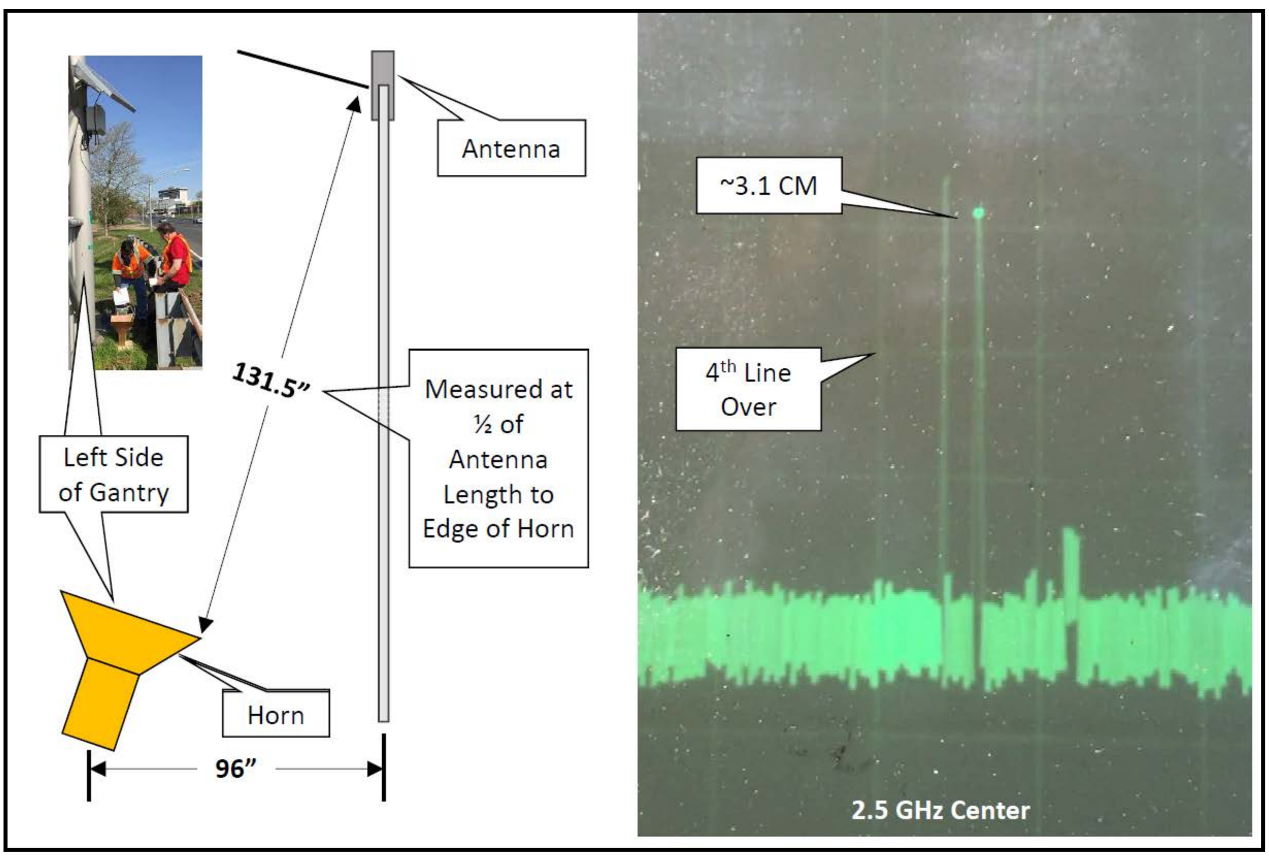

Figure 11. Bluetooth radiation measurement using standardized horn and related spectrum

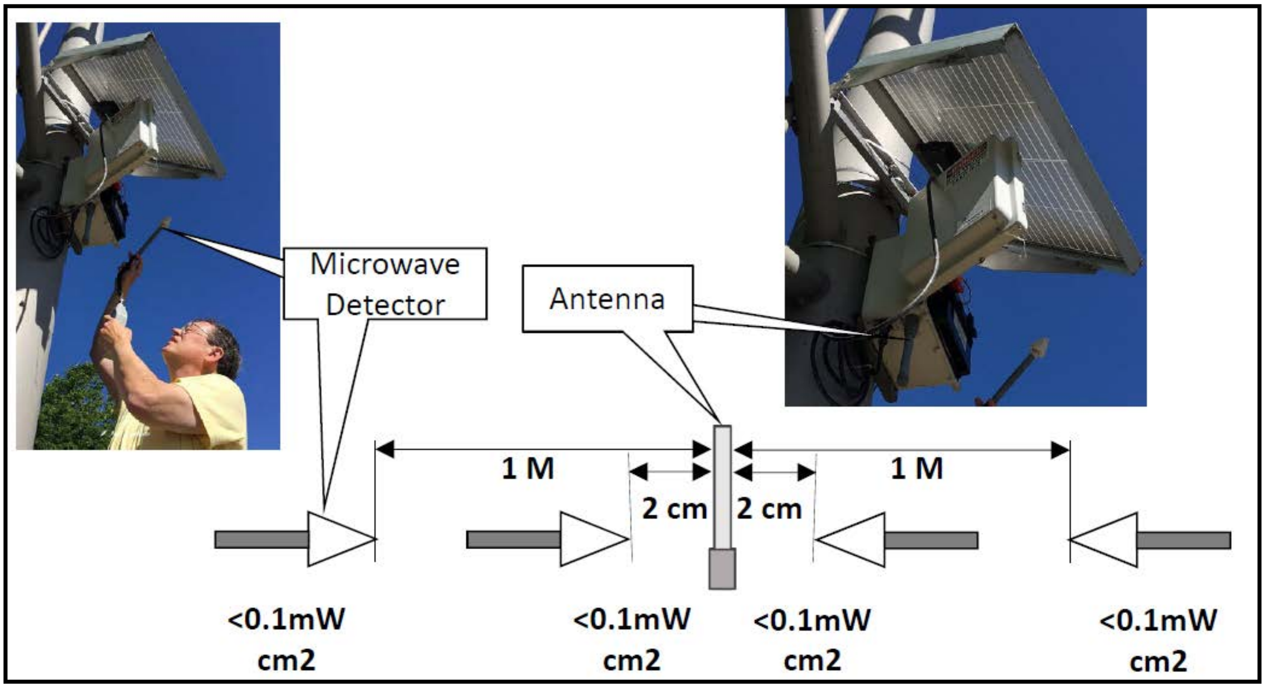

Figure 12. Testing with a broadband radiation detector

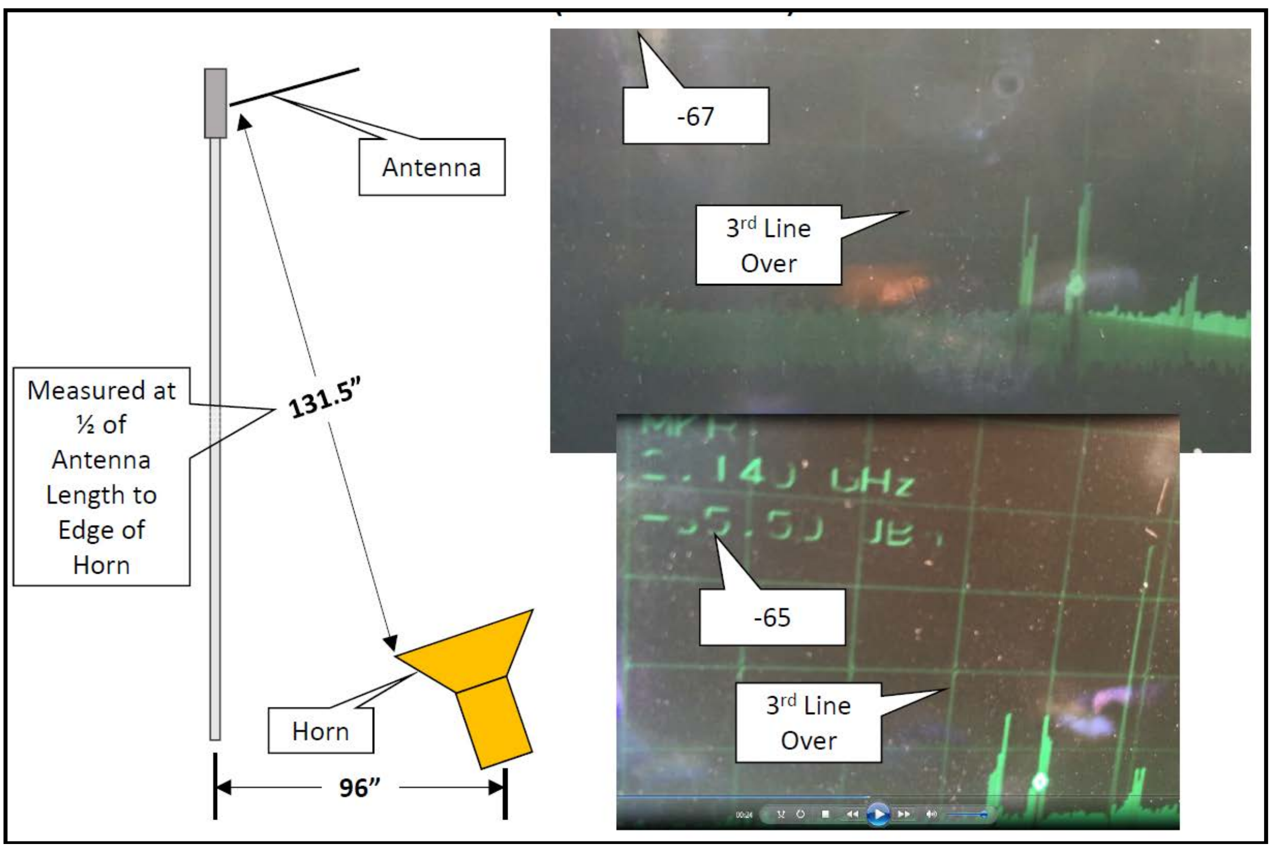

Figure 13. Measurement of cell telephone radiation levels; using the standard horn antenna and spectrum analyzer allows specific frequencies of interest to be identified

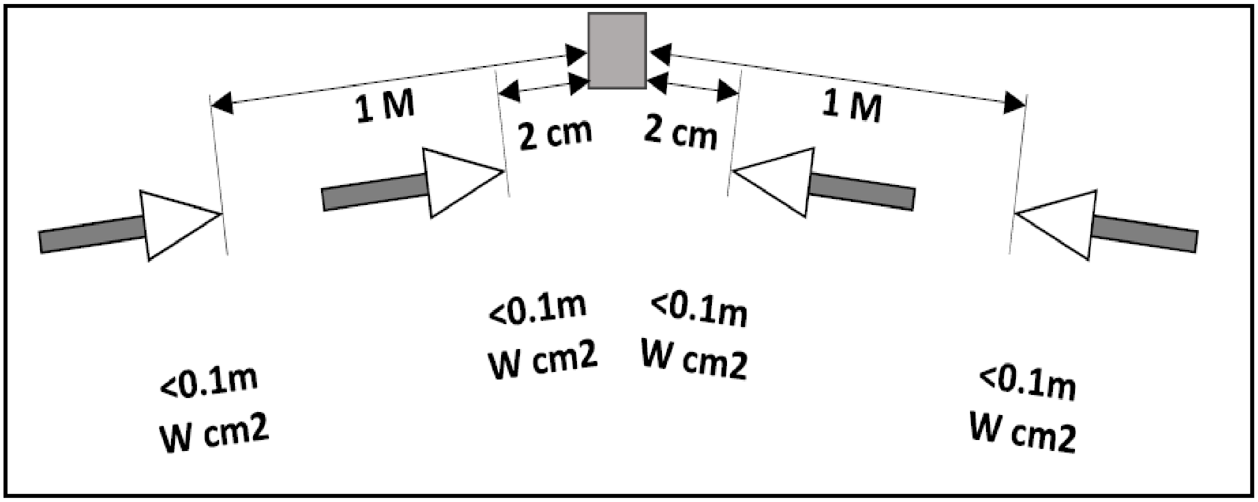

Figure 14. Results of measurement of cell telephone radiation levels using the standard horn antenna and broadband detector

One of the complications encountered is the absence of WiFi *hotspots* at the NJDOT headquarters. As the evaluation of WiFi radiation was a specific objective of this study, it was decided to make measurement at WiFi locations at The College of New Jersey (TCNJ). Figure 15 shows WiFi hotspot measurements being conducted in the electrical lab at TCNJ.

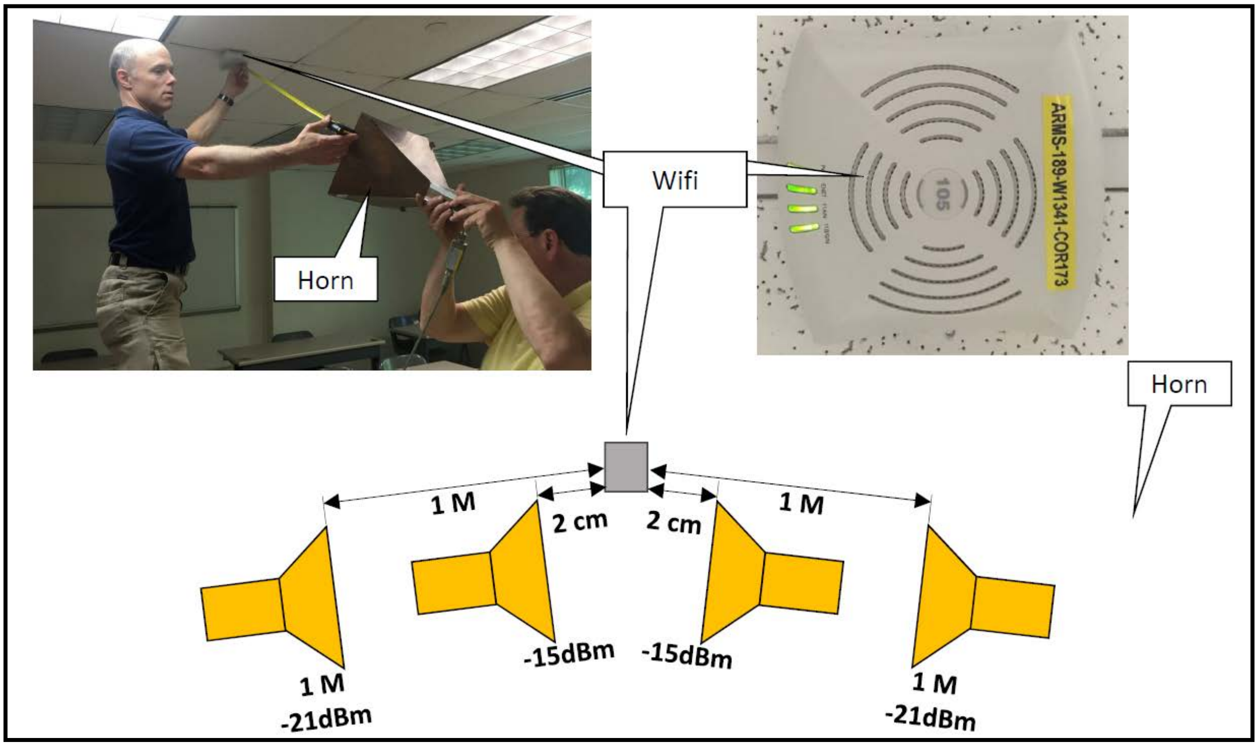

Figure 15. Measurement of WiFi radiation levels at TCNJ using the standard horn antenna

As a related addition, we investigated the radiation safety of microwave ovens located at NJDOT facilities and elsewhere, and compared these results to the FDA microwave oven standards and to the IEEE RF Standards.

6. Correlate Results and Recommendations

A Map of the worst case results of the measured exposed levels by frequency and amplitude compared to the risk levels as defined by the RF exposure standards is shown table III.

Table III - Measured Exposure Levels by Frequency and Amplitude

RF ELECTROMAGNETIC SAFETY TRAINING

RF LEVEL

MICROWAVE RF LEVEL in mW/cm^2	DOCUMENTED HEALTH EFFECTS	NATIONAL and INTERNATIONAL STANDARDS	MEASURED NJDOT EXPOSURE LEVELS
5,000.00	Burning and Cooking		
1,000.00	Pain is Induced		
100.00	Eye Cataracts Develop Decreased Sperm Motility		
30.00	Eye Cataracts Develop		
10.00	None[1]	OSHA worker safety standard of the 1970's is 10 mW/cm^2	
5.00	None[1]	OSHA, FDA, Microwave Ovens (Repaired Limit) 5.0 mW/cm^2	
1.00	None[1]	OSHA, IEEE Std C95.1™ - 2005 Compliance Specifications:ICNIRP (International Standard) 1.0 mW/cm^2	DOT SENSORS
0.10	None[1]		
0,01	None[1]	[1] Russia, Switzerland, China, Italy have EMF standards based upon Continuous. Indoor, e.g. Hospital, Exposure	0.12 – 0.18 mW/cm^2

In no case was a radiation level measured that exceed the safe level as documented in IEEE/ANSI C-95 standard, which sets the RF exposure standards for OSHA, NIOSH, ICNIRP and the DOD [10 mW/cm^2]. In fact, no level was measured that came close to unsafe at a peak measurement of 0.18 mW/cm^2 (Rt. 36 at 4 mile marker).

With regard to the purchasing of new equipment containing RF emitters, it is recommended that all sensors with embedded interface electronics comply with FCC Part 15 regulations. The related FCC ID is located both in the sensor specifications document. The manufacturer is also required to place FCC ID labeling on the exterior housing, see Ref: 125, https://www.fcc.gov/oet/info/rules. Traffic sensors in the NJ DOT network, the BlueToad™, appendix V, DOT Wireless Sensor Analysis BlueTOAD™, see ref. [122], were found not to comply with this FCC requirement. Vendors are not allowed to market products without the FCC Part 15 ID compliance labels.

With regard to the periodic monitoring of E&M signal strength, based on the low level of RF emissions observed, such monitoring does not appear necessary at this time. The peak measured level of all measurements conducted was found to be less than 1/3 the standard [0.3 mW/cm^2]. There is no reason for these levels to increase with time. It should be noted that the standard is for extended exposure over time. For repair and maintenance, the exposure should be over a limited time period. However, when purchasing new equipment, the equipment should be reviewed to insure it has passed the FCC Part 15 certification (published in the open FCC database).

It is recommend that the NJ DOT purchase a commercial radiation monitor as Narda model 8611 portable radiation monitor used among other instruments in this research study. Thus if a question should arise in the future, this instrument could be used to evaluate if a risk exists. This option will be discussed further in the training material in Appendix VII.

7. RF Device Safety Training Program

A seminar/training session for NJDOT personnel on RF/microwave radiation safety will be presented. Basic E&M concepts and related safety principles will be presented. The results of this study will be discussed and procedures to insure employee safety covered. The specific presentation dates/times remain to be set in conjunction with NJDOT. A copy of the presentation slides is shown in appendix VII.

8. Conclusion

All objectives of this study have been achieved.

The objectives of this study were to:

1. Examine, and analyze the employed and serviced NJDOT's wireless devices in use today, and planned devices, to identify the existing and future planned E&M emitter sources.

   Expanded E&M Sources investigated included:

   a. **Wi-Fi (802.11a, 802.11b, 802.11n Standards)**
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2. Measure, analyze, and document the E&M Radiation signal Power Density (PD) that NJDOT employees are exposed to while repairing and working in proximity to transmitting equipment, e.g., repairing Bluetooth-enabled collection devices.

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This level was based upon researching, and identifying quality, replicated studies, which set determined standards. An extensive literature search was conducted on the health effects of E&M radiation in all forms with 124 references listed.

5. Determine existing wireless hardware, which exceeds these levels and, if required, develop a remediation plan, which may include recommending exposure time limits.

In all cases the levels measured were well below the safe exposure levels established in the United States of America and generally accepted internationally. Nevertheless, the effects of this exposure on worker health and safety are considered and how to mitigate any possible negative effects discussed.

6. Document any equipment purchase specification standard, which would assure that new purchased equipment would not exceed the determined limits.

Equipment recommendations were made.

7. Develop a systematic plan for the implementation of the periodic monitoring of E&M strength (level & frequency) in order to insure published standards are met.

Periodic monitoring was not recommended because of the low levels observed. However, recommendations were made and a plan presented.

Appendix I Bibliography of Electromagnetic Safety Issues

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[115] http://www.emf.ethz.ch/archive/var/ICNIRP_effekte_RFReview.pdf

[116] http://www.gruppompb.com/public/upload/NOTA-APPLICATIVA-09-04-2009.pdf

[117] http://www.mhzelectronics.com/ebay/manuals/narda_8700-series_rf_radiation_test_set_manual.pdf.

[118] https://www.osha.gov/SLTC/radiofrequencyradiation/standards.html.

[119] https://www.osha.gov/SLTC/radiofrequencyradiation/standards.html.

[120] FDA Microwave Oven Calibration Guide http://www.fda.gov/downloads/medicaldevices/deviceregulationandguidance/guidancedocuments/ucm095321.pdf.

[121] FCC Part 15 Filing for a Samsung Microwave Oven, https://fccid.io/document.php?id=235087.

[122] Bluetoad Traffic Sensor: http://www.trafficcast.com/index.html.
[123] Bluetooth Module WT41-E RF Test setup photos, Reports, and Data: https://fccid.io/QOQWT41E.

[124] OSHA Standards https://www.osha.gov/SLTC/radiofrequencyradiation/electromagnetic_fieldmemo/electromagnetic.htm.

Appendix II DOT Field Measurement Data, Compared to Safety Standards:

DOT Location mile marker	**Measured Level** mW/cm^2 Nanda 8611 meter	**w/ Probe Calibration** Model 70035 probe 0.6160x @ 2.45 GHz =	**Safe Limit** mW/cm^2
(1) Rt. 29 Trenton	0.2	0.12	1.0
(1) Rt 36. 2 mile mkr	0.2	0.12	1.0
(1) Rt 36. 4 mile mkr	0.2	0.12	1.0
(1) Rt 36. 5.8 mile mkr	0.2	0.12	1.0
(1) Rt 36. 9.4 mile mk	0.2	0.12	1.0
(2) Rt. 29 Trenton	0.2	0.12	1.0
(2) Rt 36. 2 mile mkr	0.2	0.12	1.0
(2) Rt 36. 4 mile mkr	0.3	0.18	1.0
(2) Rt 36. 5.8 mile mkr	0.2	0.12	1.0
(2) Rt 36. 9.4 mile mk	0.2	0.12	1.0
(3) Rt. 29 Trenton	0.2	0.12	1.0
(3) Rt 36. 2 mile mkr	0.2	0.12	1.0
(3) Rt 36. 4 mile mkr	0.3	0.18	1.0
(3) Rt 36. 5.8 mile mkr	0.2	0.12	1.0
(3) Rt 36. 9.4 mile mk	0.2	0.12	1.0

Field test results by location and measured RF Level
At each location, the measurement was taken x3 times, sampled by intervals of 5 minutes. The only location exceeding 0.12 mW/cm^2, was the Rt 36, 4-mile marker location, which on the 2nd & 3rd sample period measured 0.18 mW/cm^2, well under the safe limit of 1.0 mW/cm^2.

The Rt 36, 4-mile marker location sensor and in close proximity (~200m) is a local Base-Station tower. This adjacent cellular tower explains the difference in sensor radiation levels.

Appendix III Microwave Oven Field Measurement Data, Compared to FDA/OSHA/FCC Safety Standards:

Microwave Oven Manufacture	**Measured Level** mW/cm^2 Nanda 8611 meter	**w/ Probe Calibration** Model 70035 probe 0.6160x @ 2.45 GHz =	**Safe Limit** mW/cm^2
(1) Magic Chef Model mcm1110w	0.2	0.12	1.0 new / 5.0 repaired
(1) GE Profile Model 012TAGH00191	0.1	0.06	1.0 new / 5.0 repaired
(1) Goldstar Multiwave Model ma - 1164M	0.1	0.06	1.0 new / 5.0 repaired
(2) Magic Chef Model mcm1110w	0.2	0.12	1.0 new / 5.0 repaired
(2) GE Profile Model 012TAGH00191	0.1	0.06	1.0 new / 5.0 repaired
(2) Goldstar Multiwave Model ma - 1164M	0.1	0.06	1.0 new / 5.0 repaired
(3) Magic Chef Model mcm1110w	0.2	0.12	1.0 new / 5.0 repaired
(3) GE Profile Model 012TAGH00191	0.1	0.06	1.0 new / 5.0 repaired
(3) Goldstar Multiwave Model ma - 1164M	0.1	0.06	1.0 new / 5.0 repaired

Microwave Oven Emission Testing Procedure

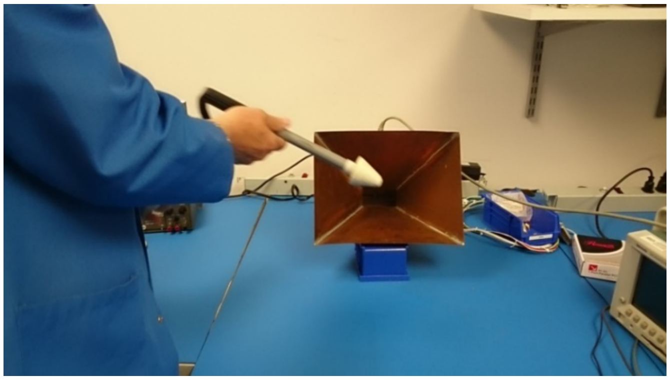
- A 700-ml water load is placed in the center of the oven.
- The power setting was set to maximum power.
- While the oven was operating, the Microwave Survey Meter probe was moved slowly around the door seams (A, B, and C location) to check for leakage

FCC filing, https://fccid.io/document.php?id=235087, for a Samsung Microwave Oven with a label: FCC ID: A3LBT3000

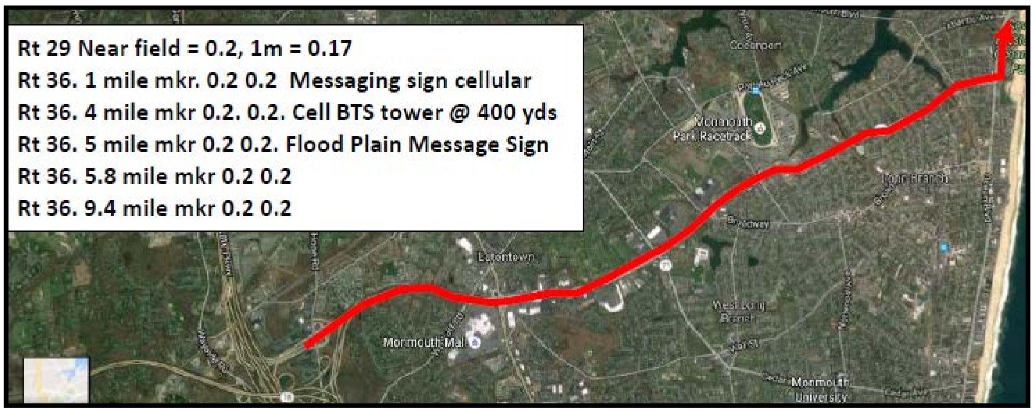
Appendix IV DOT Field Measurement Instrument, Specifications, and Calibration:

Narda model 8611 Portable Radiation Monitor
With 70035 0.3-18 GHz 200 mW/cm^2 probe

1. Frequency Range, 300 MHz to 18 GHz
2. Dynamic Range, 30 dB
3. Meter Scale Range, Linear 0.2, 2 and 20 mW/cm^2
4. Instrument Accuracy, +-3%
5. Operating Temperature, 0-50º C



Appendix V DOT Device Inventory and Test Locations



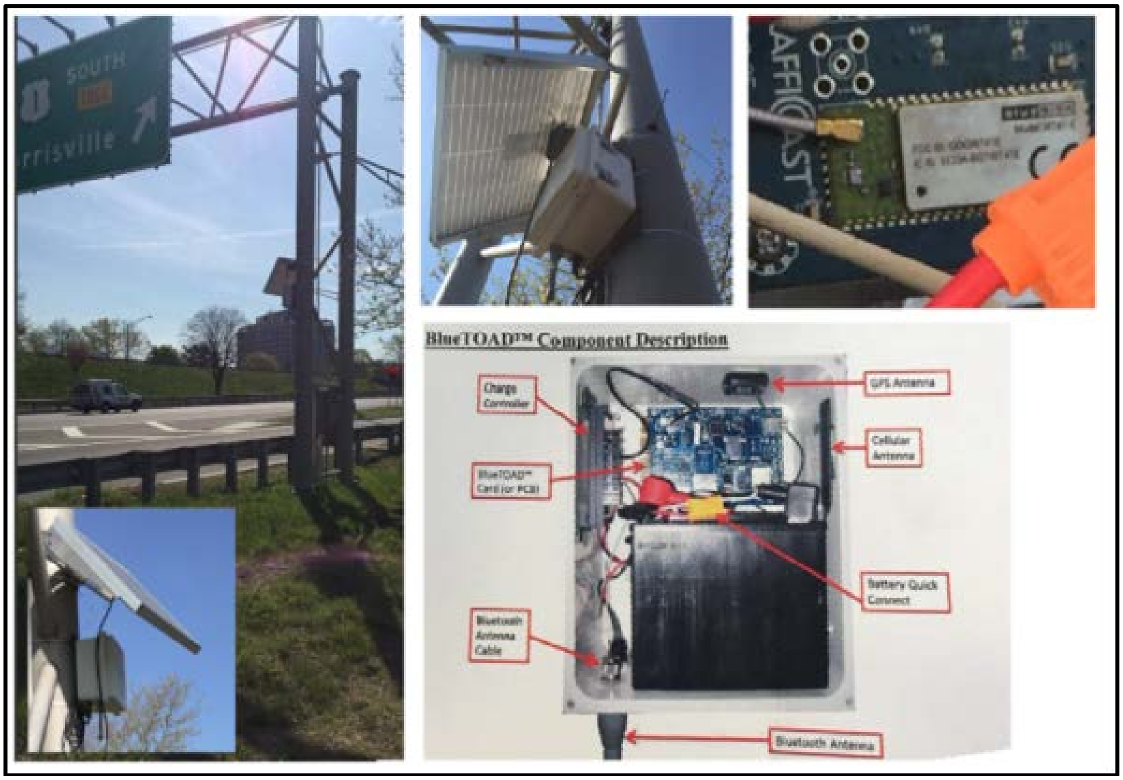
DOT Field Sensor Locations, General Information and RF Emissions

DEVICE	1360	00000036_	00000036_	South to North	6.15	6.15	Long Branch City	Monmouth	TTSC	NJDOT	EXISTING	South - 961654 - 011961654 - - - Jacobs -	TTSC
DEVICE	1361	00000036_	00000036_	South to North	13.18	13.18	Middletown Twp	Monmouth	TTSC	NJDOT	EXISTING	South - 961654 - 011961654 - - - Jacobs -	TTSC
DEVICE	2354	00000036_	00000036_	South to North	24.12	24.12	Keyport Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - TOCN -	TTSC
DEVICE	2355	00000036_	00000036_	South to North	17.79	17.79	Middletown Twp	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - TOCN -	TTSC
DEVICE	2356	00000036_	00000036_	South to North	15.4	15.4	Middletown Twp	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - TOCN -	TTSC
DEVICE	2357	00000036_	00000036_	South to North	13.14	13.14	Middletown Twp	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - TOCN -	TTSC
DEVICE	2358	00000036_	00000036_	South to North	20.42	20.42	Keansburg Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - TOCN -	TTSC
DEVICE	2359	00000036_	00000036_	South to North	22.61	22.61	Union Beach Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - TOCN -	TTSC
DEVICE	2701	00000036_	00000036_	South to North	11.4	11.4	Sea Bright Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2702	00000036_	00000036_	South to North	9.4	9.4	Sea Bright Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2703	00000036_	00000036_	South to North	7.7	7.7	Monmouth Beach Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2704	00000036_	00000036_	South to North	5.8	5.8	Long Branch City	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2705	00000036_	00000036_	South to North	4	4	Long Branch City	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2708	00000036_	00000036_	South to North	0	0	Eatontown Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2706	00000036_S	00000036_	North to South	2	2			TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2707	00000036_S	00000036_	North to South	0.5	0.5			TTSC	NJDOT	EXISTING	South - - - - - -	TTSC

Appendix VI DOT Wireless Sensor Analysis BlueTOAD^{tm}, see ref [122]

BlueTOAD^{tm} Traffic Sensor

This requires an FCC Part 15 (All electronics with a processor and clock) RF level certification or a PTCRB (all cellular products, including AT&T, require PTCRB certs) levels. FCC Part 15 requires visible stickers identifying their cert numbers.



BlueTOAD^{tm} Traffic Sensor

Includes Embedded Bluetooth and Cellular RF XMIT Modules

Bluetooth Module in FCC Part 15 Database:

Bluetooth Module WT41-E RF Exposure Info Microsoft Word -
RF EXPOSURE ANALYSIS_WT41-E_9.9.2011 Silicon Laboratories Finland
(Power Density of 0.021 mW/cm2 measured @ 20cm @ 2.45 GHz)
Bluetooth Module WT41-E RF Test setup photos, Reports, and Data: [https://fccid.io/QOQWT41E]

GSM Quad-band Cellular Module in FCC Part 15 Database:

Telit Communications UC864G Module
RF Test setup Photos, Reports, and Data: [https://fccid.io/RI7UC864G]

Appendix VI.1 DOT Wireless Sensor Analysis BlueTOAD^{tm}, Bluetooth Module: see ref [123]

Product	**FCC ID**	**IC number**
Bluetooth module	QOQWT41E	5123A-BGTWT41E

WT41-E is a class 1 Bluetooth module containing all the necessary elements from Bluetooth® radio to antenna and a fully implemented protocol stack. Therefore WT41 provides an ideal solution for developers who want to integrate Bluetooth technology into their design. Module can be operated with batteries or DC power supply.

Analysis for FCC

The equipment transmits in the 2 402 – 2 480 MHz frequency range and therefore the applicable threshold is calculated as stated in FCC document KDB 447498 by using the formula $60/f$ (where f is a highest frequency in used) $60/2.48 = 24.19 mW$

Output power considerations:

Max. E.I.R.P value: 18.08 dBm = 64.3 mW
(Value is taken from the test report number: 264152-11. Value contains conducted output power and antenna gain.)

RF exposure evaluation:

$$S = \frac{P * G}{4\pi R^2} = \frac{E.I.R.P}{4\pi R^2}$$

E.I.R.P (dB)	E.I.P.R (mW)	Evaluation distance (cm)	S – power density (mW/cm^2)
18.08	**64.3**	**20**	**0.021**

Analysis for IC

According to standard RSS-102, RF exposure analysis is required for devices operating at or above 1.5 GHz if the maximum E.I.R.P. of the device is 5.0 W or more. Therefore RF exposure analysis is not required for this device.

Result:

Equipment complies with the FCC and IC limits for maximum permissible exposure

Appendix VII, US and International RF Microwave Standards:

The main agencies involved in these measurements are next:

- IEEE, Institute of Electrical and Electronics Engineers, IEEE C95.3-2002
- ANSI, American National Standards Institute
- ICNIRP, International Commission on Non-Ionizing Radiation Protection
- NCRP, National Council on Radiation Protection and Measurements
- FCC, Federal Communications Commission.

IEEE INTERNATIONAL COMMITTEE ON ELECTROMAGNETIC (SCC39)
OSHA, ANSI C95.1 - 2005 IEEE Std C95.1™ - 2005 Compliance Specifications:
Ref: http://emfguide.itu.int/pdfs/C95.1-2005.pdf

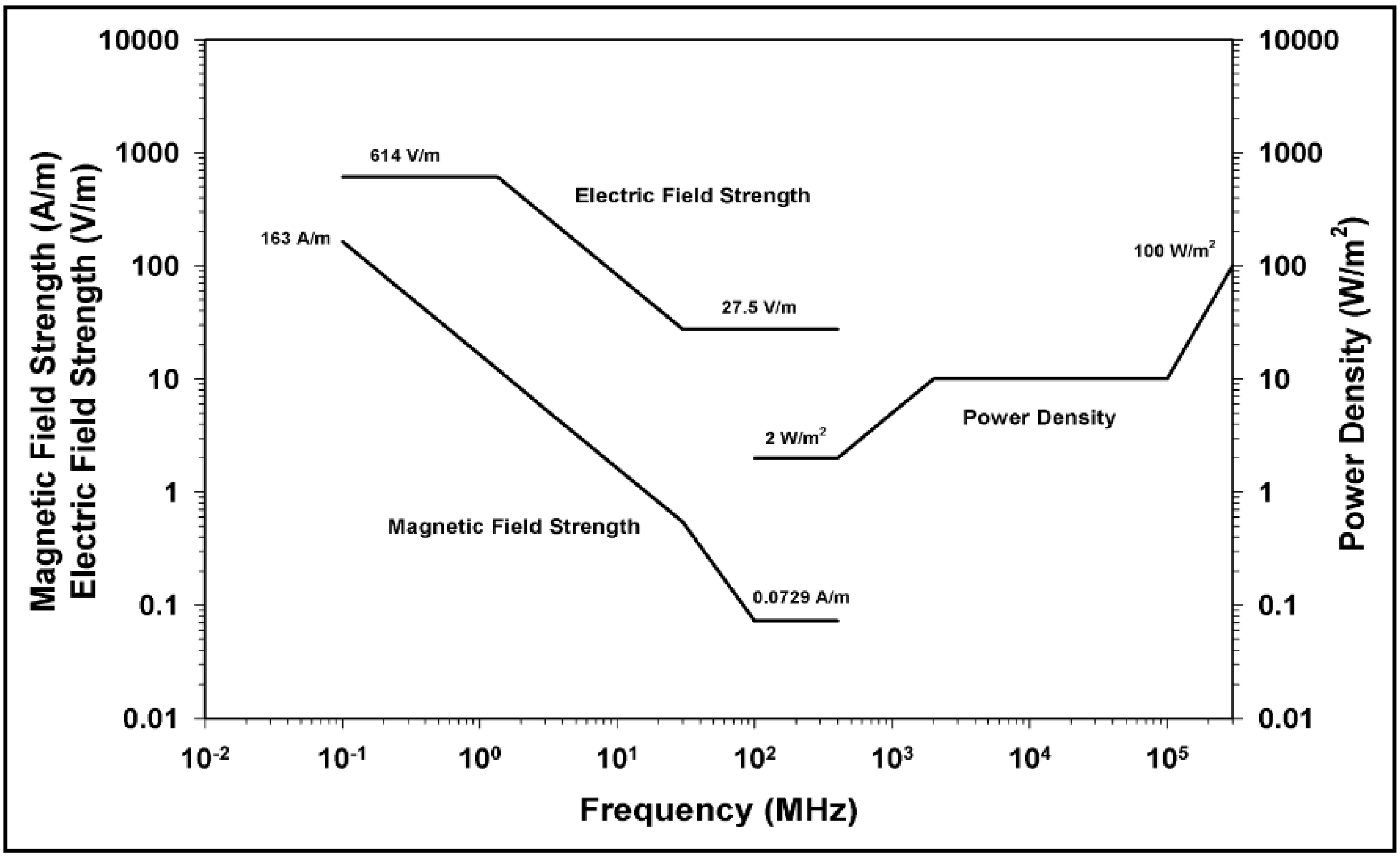


Fig. A6-1 – Permissible E&M levels as published in IEEE Std C95.1

Note: 10 W/m^2 = 1 mW/cm^2

ICNIRP - INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION
Ref: http://www.icnirp.org/

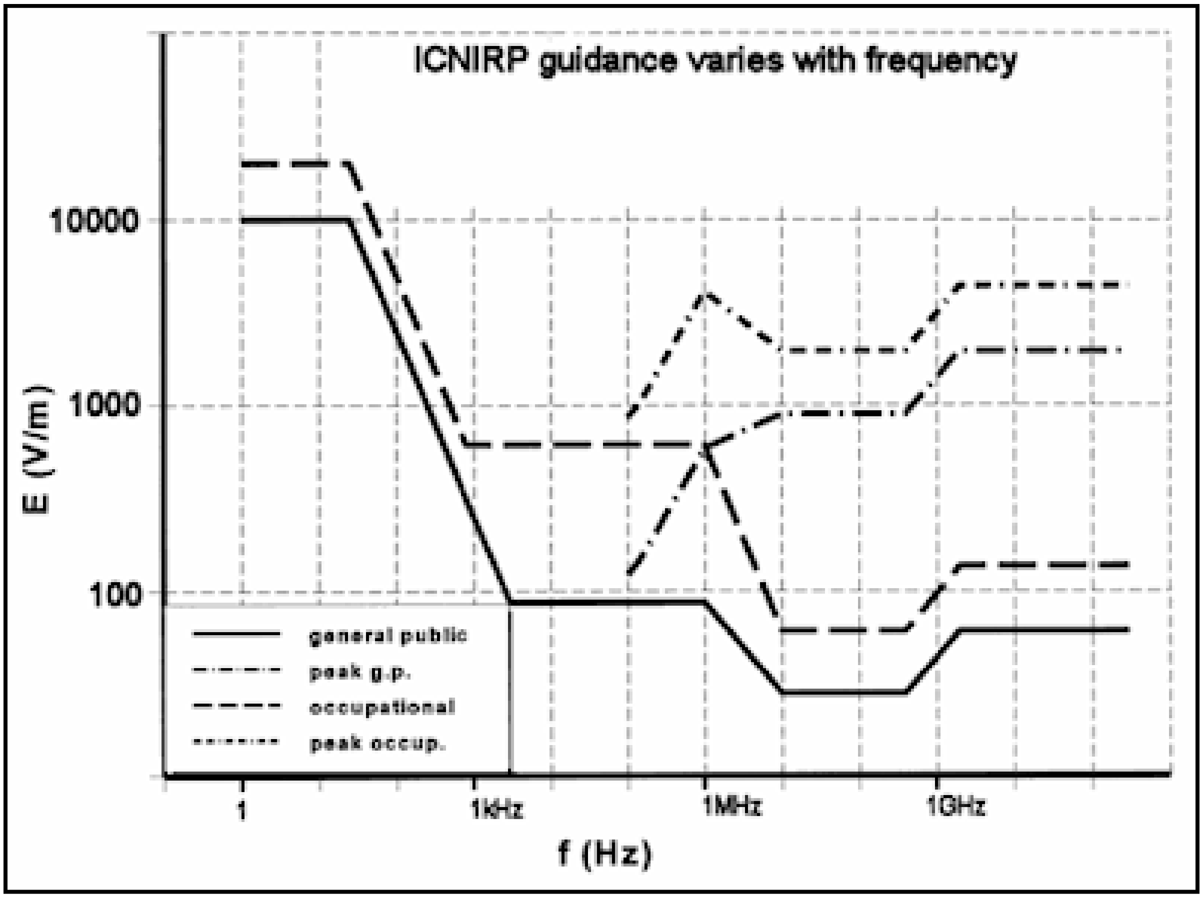
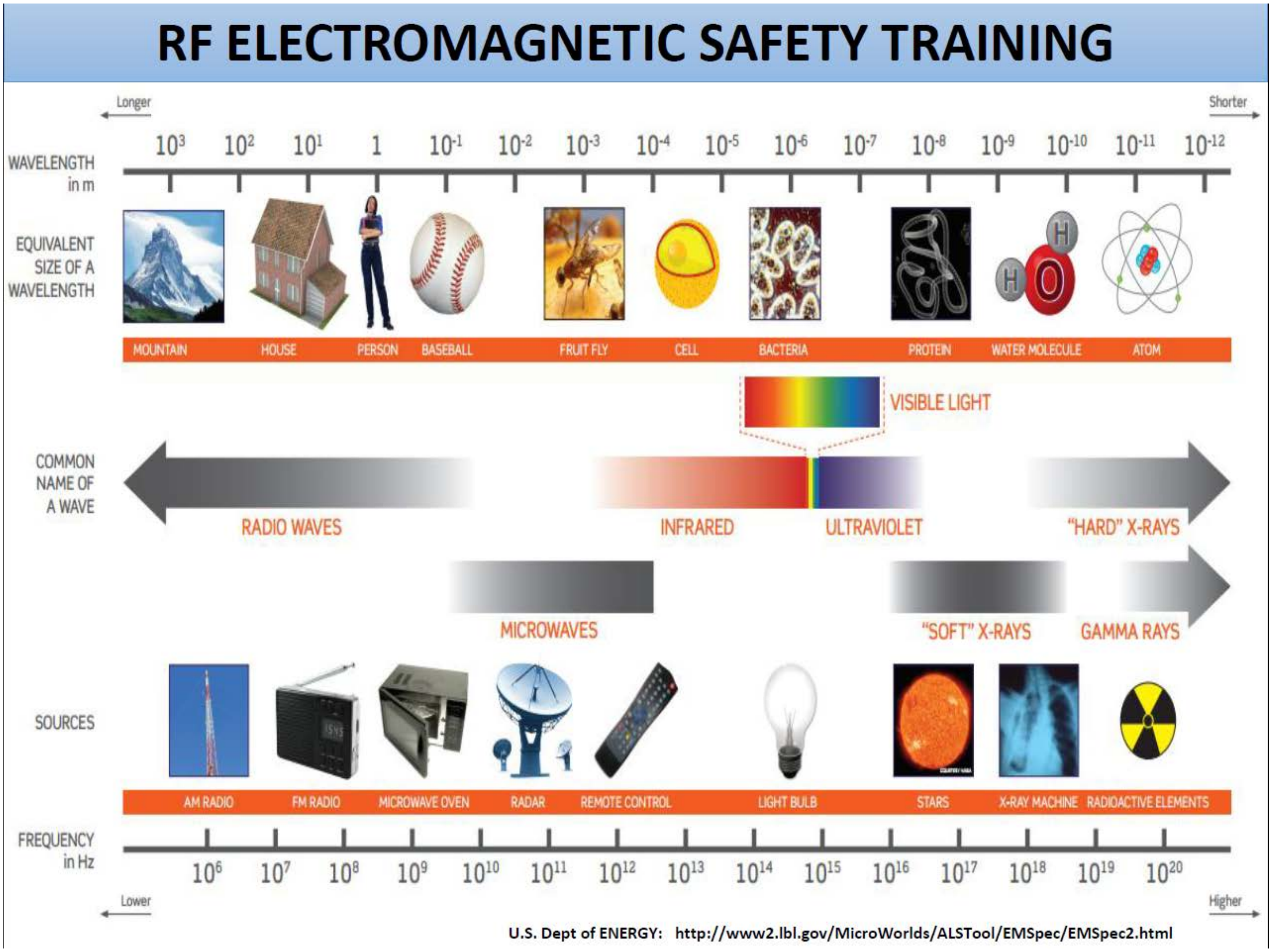
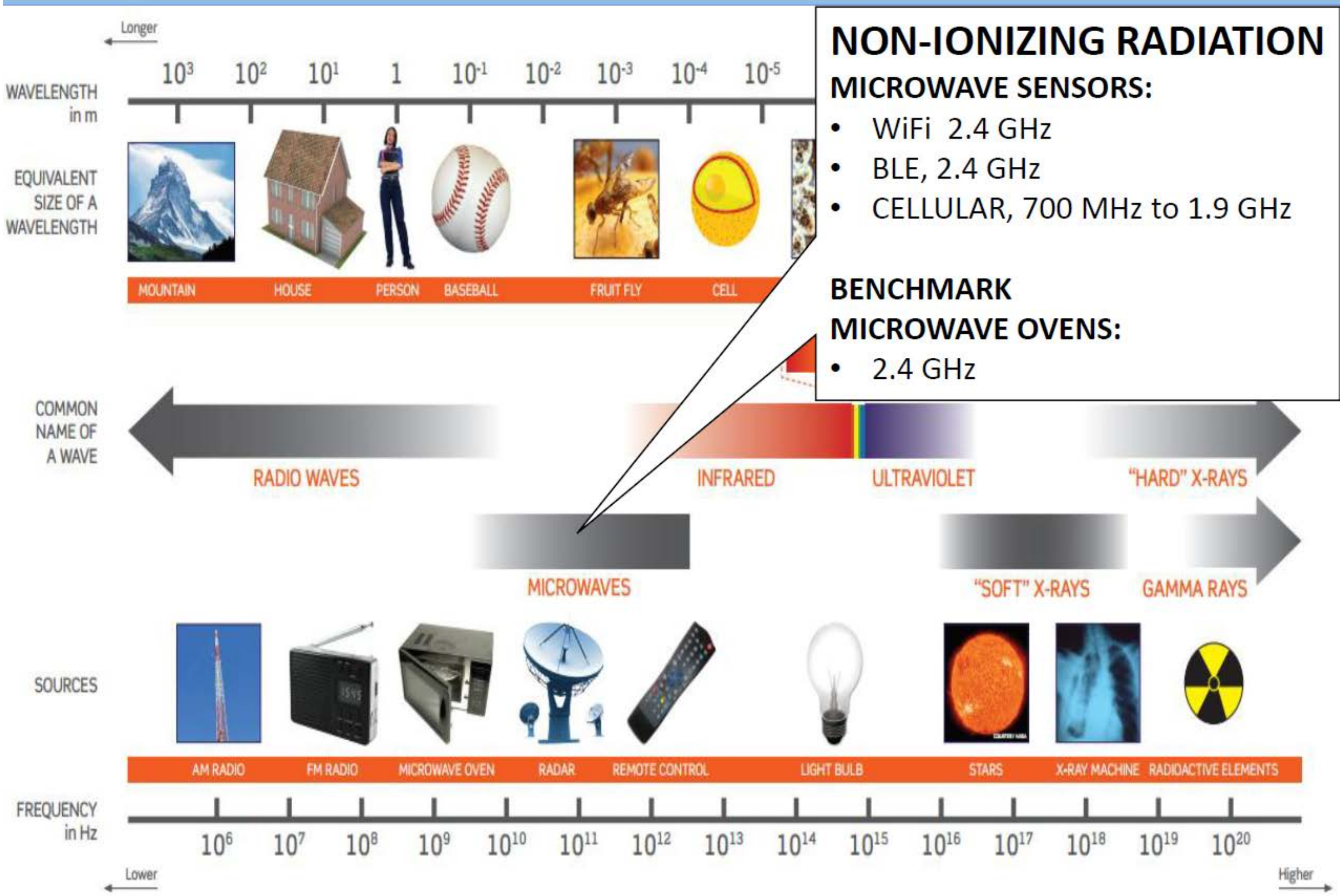


Fig. A6-1 – Permissible E&M levels as published in ICNIRP Std.

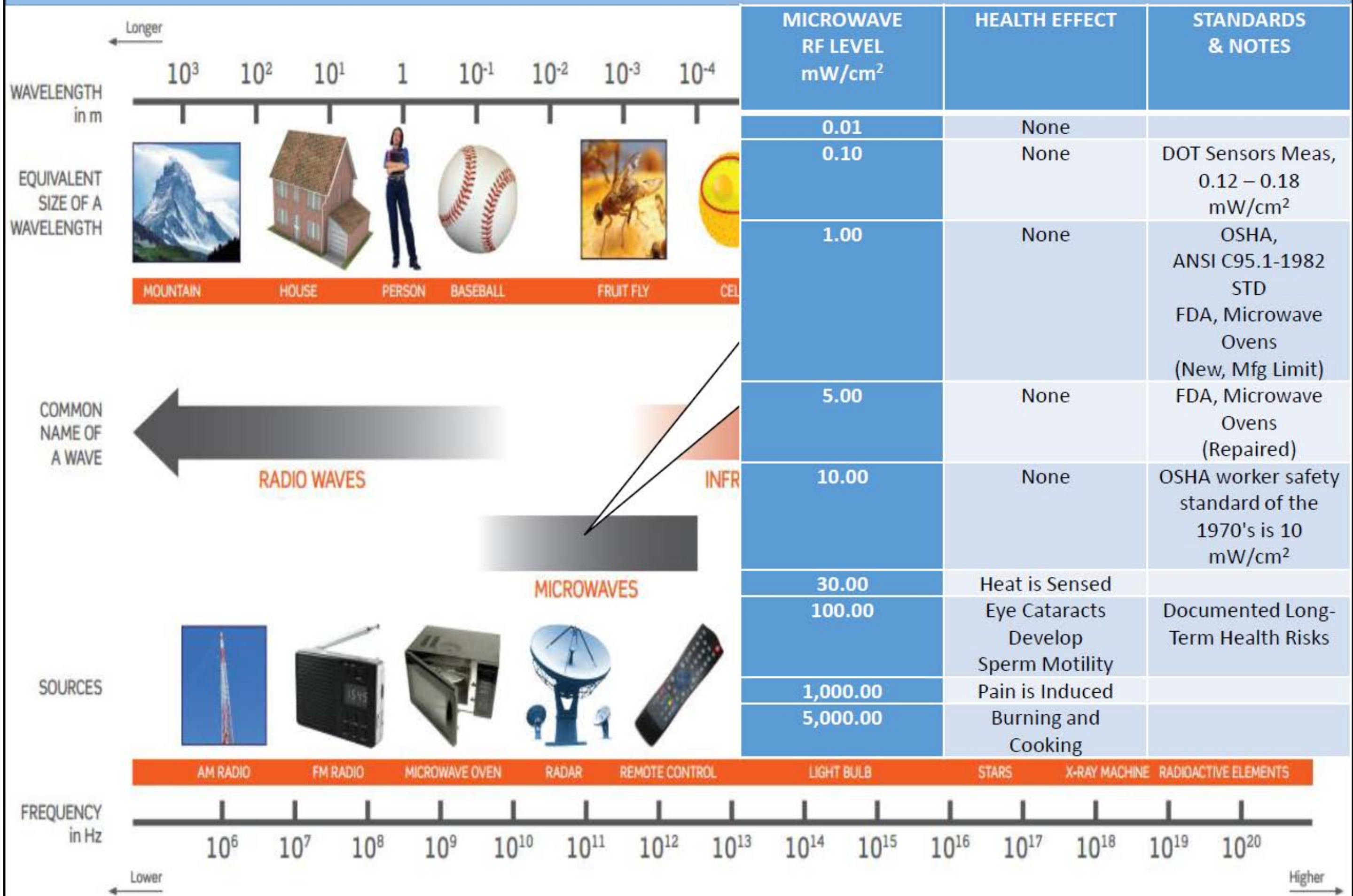
Appendix VIII Training Program Presentation Slides



RF ELECTROMAGNETIC SAFETY TRAINING



RF ELECTROMAGNETIC SAFETY TRAINING



MICROWAVE RF LEVEL mW/cm^2	HEALTH EFFECT	STANDARDS & NOTES
0.01	None	
0.10	None	DOT Sensors Meas, 0.12 – 0.18 mW/cm^2
1.00	None	OSHA, ANSI C95.1-1982 STD FDA, Microwave Ovens (New, Mfg Limit)
5.00	None	FDA, Microwave Ovens (Repaired)
10.00	None	OSHA worker safety standard of the 1970's is 10 mW/cm^2
30.00	Heat is Sensed	
100.00	Eye Cataracts Develop Sperm Motility	Documented Long-Term Health Risks
1,000.00	Pain is Induced	
5,000.00	Burning and Cooking	

RF ELECTROMAGNETIC SAFETY TRAINING

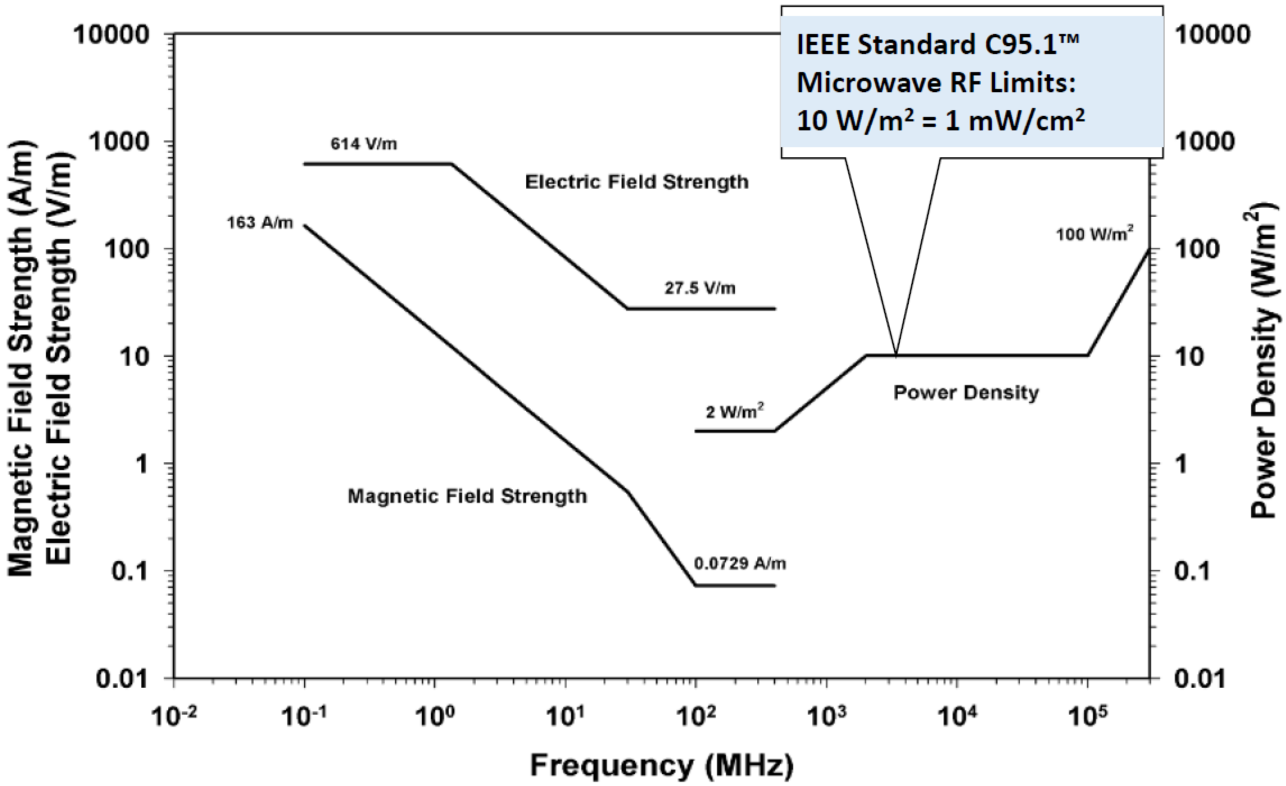
RF LEVEL

MICROWAVE RF LEVEL in mW/cm^2	DOCUMENTED HEALTH EFFECTS	NATIONAL and INTERNATIONAL STANDARDS	MEASURED NJDOT EXPOSURE LEVELS
5,000.00	Burning and Cooking		
1,000.00	Pain is Induced		
100.00	Eye Cataracts Develop Decreased Sperm Motility		
30.00	Eye Cataracts Develop		
10.00	None[1]	OSHA worker safety standard of the 1970's is 10 mW/cm^2	
5.00	None[1]	OSHA, FDA, Microwave Ovens (Repaired Limit) 5.0 mW/cm^2	
1.00	None[1]	OSHA, IEEE Std C95.1™ - 2005 Compliance Specifications:ICNIRP (International Standard) 1.0 mW/cm^2	**DOT SENSORS**
0.10	None[1]		
0,01	None[1]	[1]Russia, Switzerland, China, Italy have EMF standards based upon Continuous. Indoor, e.g. Hospital, Exposure	0.12 – 0.18 mW/cm^2

RF ELECTROMAGNETIC SAFETY TRAINING

IEEE INTERNATIONAL COMMITTEE ON ELECTROMAGNETIC (SCC39)

OSHA, ANSI C95.1 - 2005 IEEE Std C95.1™ - 2005 Compliance Specifications:



IEEE Std C85.1 http://emfguide.itu.int/pdfs/C95.1-2005.pdf

The Human Body Heat Engine

- Absorption of RF Power causes heating
- Specific Absorption Rate (SAR) Watts/kg
- A SAR produces same heating regardless of frequency
- A human at rest produces about 1 Watt/kg
- A SAR of 4 W/kg will raise tissue temp. 1 degree – same as a brisk walk
- Avg. 4 W/kg or PK 20 W/kg in limbs safe.

Living Human Properties

- The human body is a marvel at regulating its internal temperature through blood circulation and perspiration.
- Sperm in the testes are very temperature sensitive.
- The lens of the eye lacks blood flow to keep it cool. If "cooked" at high temperature, cataracts will form.

RF Field Strength

- Electric E Field is in Volts per meter
- Magnetic H Field is in Amperes per meter
- Power Density, S is Watts per square meter
- $S = E \times H = E^2/377 = 377\ H^2$ Watts/sq. meter
- 10 Watts/sq. m = 1 milliwatt/sq. cm
- For a point source, $S = \text{Power} / 4\pi d^2$

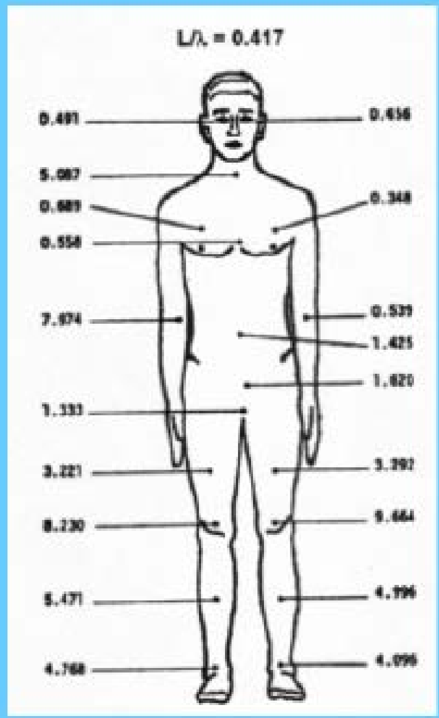
Field Strength Examples

- For a point source, $S = \text{Power} / 4\pi d^2$

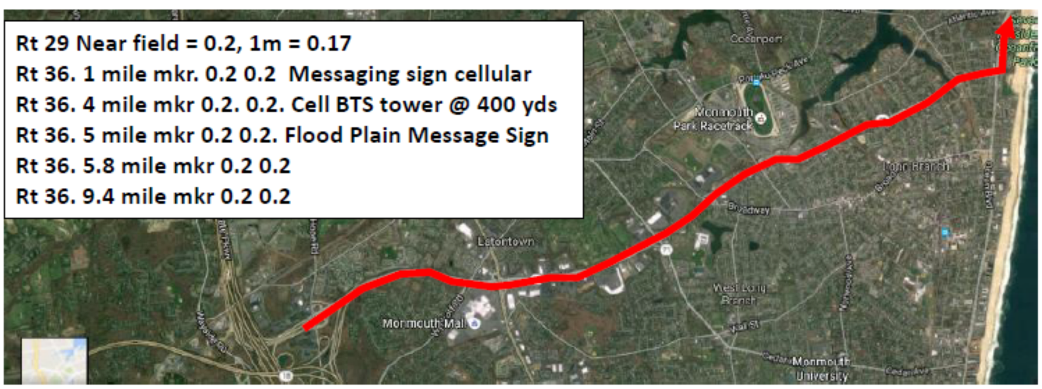
Eff. Rad. Power	Distance, d	Strength, S
1250 Watts	1.0 Meter	10 mW/sq. cm
125 watts	1.0 meter	1 mW/sq. cm
125 watts	0.1 meter	100 mW/sq. cm
125 Watts	10 Meters	.01 mW/ sq. cm

Conversion from SAR to RF Field Strength

- Exposing a human body to 10 mW/sq. cm
- Frequency of maximum absorption (about 70 mHz)
- Localized SAR values
- Average SAR is 1.88 W/kg
- From Proc. IEEE 68:27, 1980



July 28, 2016 Field Visit
SR 29
SR 36



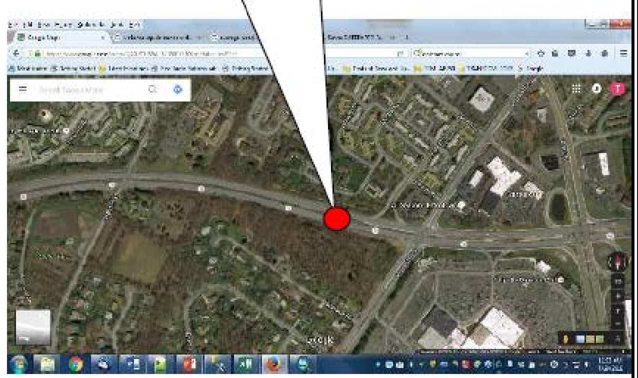
DEVICE	1360	00000036_	00000036_	South to North	6.15	6.15	Long Branch City	Monmouth	TTSC	NJDOT	EXISTING	South - 961654 - 011961654 - - - Jacobs -	TTSC
DEVICE	1361	00000036_	00000036_	South to North	13.18	13.18	Middletown Twp	Monmouth	TTSC	NJDOT	EXISTING	South - 961654 - 011961654 - - - Jacobs -	TTSC
DEVICE	2354	00000036_	00000036_	South to North	24.12	24.12	Keyport Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - TOCN -	TTSC
DEVICE	2355	00000036_	00000036_	South to North	17.79	17.79	Middletown Twp	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - TOCN -	TTSC
DEVICE	2356	00000036_	00000036_	South to North	15.4	15.4	Middletown Twp	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - TOCN -	TTSC
DEVICE	2357	00000036_	00000036_	South to North	13.14	13.14	Middletown Twp	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - TOCN -	TTSC
DEVICE	2358	00000036_	00000036_	South to North	20.42	20.42	Keansburg Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - TOCN -	TTSC
DEVICE	2359	00000036_	00000036_	South to North	22.61	22.61	Union Beach Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - TOCN -	TTSC
DEVICE	2701	00000036_	00000036_	South to North	11.4	11.4	Sea Bright Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2702	00000036_	00000036_	South to North	9.4	9.4	Sea Bright Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2703	00000036_	00000036_	South to North	7.7	7.7	Monmouth Beach Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2704	00000036_	00000036_	South to North	5.8	5.8	Long Branch City	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2705	00000036_	00000036_	South to North	4	4	Long Branch City	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2708	00000036_	00000036_	South to North	0	0	Eatontown Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2706	00000036_S	00000036_	North to South	2	2			TTSC	NJDOT	EXISTING	South - - - - - -	TTSC
DEVICE	2707	00000036_S	00000036_	North to South	0.5	0.5			TTSC	NJDOT	EXISTING	South - - - - - -	TTSC

Bluetooth Device (Same as 29) **And Microwave Detector**

Rt 36. 5.8 mile mkr 0.2 0.2

Cell Antenna on top of Traffic Cabinet

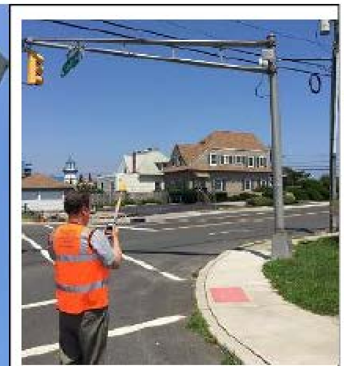
Rt 36. 1 mile mkr. 0.2 0.2 Messaging sign cellular

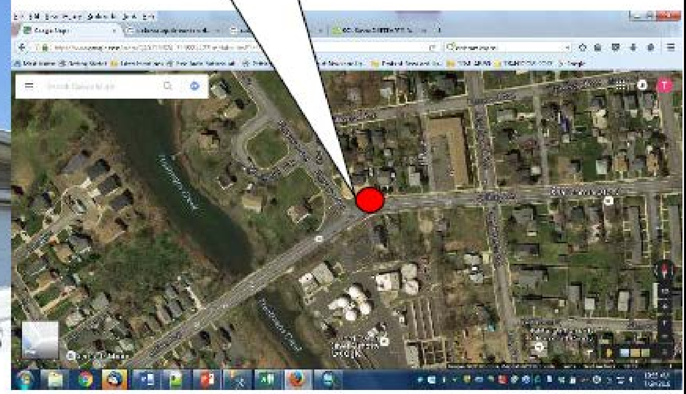


Bluetooth Device (Same as 29)

And Microwave Detector

Rt 36. 5.8 mile mkr 0.2 0.2



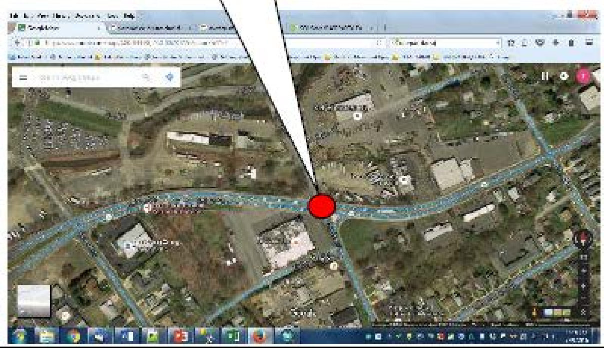



Antenna on top of Flood Plain Sign
Rt 36. ~5 mile mkr. 0.2 – Flood Plain Message Sign
URGENT
WHEN FLASHING
ROADWAY FLOODED
DO NOT PROCEED

Bluetooth Device (Same as 29)

And Microwave Detector

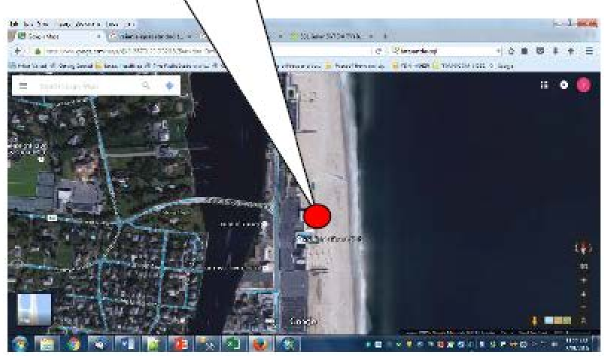
Rt 36. 4 mile mkr 0.2. 0.2. Cell BTS tower @ 400 yds



Bluetooth Device (Same as 29)

And Microwave Detector

Rt 36. 9.4 mile mkr 0.2 0.2



DOT Field Sensor Locations, General Information and RF Emissions

DEVICE	1360	00000036_	00000036_	South to North	6.15	6.15	Long Branch City	Monmouth	TTSC	NJDOT	EXISTING	South - 961654
DEVICE	1361	00000036_	00000036_	South to North	13.18	13.18	Middletown Twp	Monmouth	TTSC	NJDOT	EXISTING	South - 961654
DEVICE	2354	00000036_	00000036_	South to North	24.12	24.12	Keyport Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - T
DEVICE	2355	00000036_	00000036_	South to North	17.79	17.79	Middletown Twp	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - T
DEVICE	2356	00000036_	00000036_	South to North	15.4	15.4	Middletown Twp	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - T
DEVICE	2357	00000036_	00000036_	South to North	13.14	13.14	Middletown Twp	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - T
DEVICE	2358	00000036_	00000036_	South to North	20.42	20.42	Keansburg Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - T
DEVICE	2359	00000036_	00000036_	South to North	22.61	22.61	Union Beach Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - T
DEVICE	2701	00000036_	00000036_	South to North	11.4	11.4	Sea Bright Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -
DEVICE	2702	00000036_	00000036_	South to North	9.4	9.4	Sea Bright Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -
DEVICE	2703	00000036_	00000036_	South to North	7.7	7.7	Monmouth Beach Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -
DEVICE	2704	00000036_	00000036_	South to North	5.8	5.8	Long Branch City	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -
DEVICE	2705	00000036_	00000036_	South to North	4	4	Long Branch City	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -
DEVICE	2708	00000036_	00000036_	South to North	0	0	Eatontown Boro	Monmouth	TTSC	NJDOT	EXISTING	South - - - - - -