April 7, 2016

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Background: I am a retired career U.S. Government scientist (Ph.D., Applied Physics, Harvard University, 1975). During my Government career, I worked for the Executive Office of the President, the National Science Foundation, and the National Institute of Standards and Technology. For those organizations, respectively, I addressed Federal research and development program evaluation, energy policy research, and measurement development in support of the electronics and electrical-equipment industries and the biomedical research community. I currently interact with other scientists and with physicians around the world on the impact of electromagnetic fields on human health.

Statement on conflicts of interest: I do not work for, or receive any funding from, any company or organization designing, manufacturing, marketing, installing, or servicing wireless devices, or promulgating exposure limits for such products. I was a member of the Institute of Electrical and Electronics Engineers (IEEE) for many years, and the IEEE does promulgate exposure limits for wireless devices. I worked for the National Institute of Standards and Technology (NIST) for 23 years before retiring. While I was employed there, NIST did not promulgate exposure limits or conduct studies of the biological effects of electromagnetic fields, and, to my knowledge, has not done so since. NIST's mission includes the development of measurement capability to assure the accuracy of measurements of electromagnetic fields. That measurement capability supports other organizations that work with electromagnetic fields to develop and calibrate instrumentation for making accurate measurements of such fields, to develop and market products that employ such fields or that might be exposed to such fields, and to study the biological effects of those fields, among many other applications. I am supportive of the development of new and more protective exposure limits for electromagnetic fields that are based on the scientific research of the international biomedical research community and that evolve with that research to assure the protection of all life from harm on a continuing basis.

Subject: Transmittal of
Review of the AECOM Report
"Radiofrequency (RF) Monitoring Summary Report: Montgomery County Public Schools"

Review of the AECOM Report

"Radiofrequency (RF) Monitoring Summary Report: Montgomery County Public Schools"

Prepared for the Montgomery County Public Schools

by Ronald M. Powell, Ph.D.

April 7, 2016

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CONCLUSIONS OF THIS REVIEW OF THE AECOM REPORT

No Credible Guidance

The AECOM Report provides measurements of the electric and magnetic fields produced by selected Wi-Fi Access Points[1] and by selected wireless Laptop Computers (Chromebooks) in 12 schools within the Montgomery County Public Schools (MCPS). The Report analyzes the measurement data and compares the analyzed data to the exposure limits suggested by several organizations. The comparisons made in the Report's "Conclusions" [2] imply that the electromagnetic fields at the schools do not present a health risk, without explicitly saying so.

Unfortunately, none of above tasks is accomplished adequately in the AECOM Report, in my view. I cite multiple concerns in this review to support this conclusion. These concerns include incorrect selection of measurement equipment (probes[3]), incorrect or non-optimal use of measurement equipment, and incorrect methods of data analysis, among other concerns. In my view, these concerns invalidate all of the analyzed data in the four tables that contain the principal results of the AECOM Report (Tables 7-2, 7-3, 7-4, and 7-5).[4] The result is the absence of valid analyzed data for comparison with any of the exposure limits, whatever the validity of the exposure limits themselves, some of which I also question.

For these reasons, it is my opinion that the AECOM Report is unable to provide credible guidance about whether the electromagnetic fields in the MCPS pose a health risk or not, no matter how good the intentions of those who prepared the Report.

Credible Guidance is Available

However, credible guidance is available from the sum total of thousands of biomedical research publications from the world's leading scientists and doctors conducting research on the biological effects of electromagnetic fields. These fields include the types and levels of electromagnetic fields emitted by the Access Points and the Laptop Computers (Chromebooks) which comprise the Wi-Fi system of the MCPS.

That guidance is documented in analytical reviews that pull together the key findings and draw important conclusions. That guidance indicates that precautionary action is needed now to protect human health from such electromagnetic radiation. In light of this guidance, there is no scientific or ethical justification for continuing to force children, teachers, and staff to be exposed to electromagnetic radiation for which the outcome is already known to be tragic. That does not mean that all questions about the biological effects of electromagnetic fields have been answered – far from that. But it does mean that more than enough is already known to justify taking precautionary action now.

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[1] The Access Points are electronic devices that communicate wirelessly (*via* "Wi-Fi") with the Laptop Computers (Chromebooks) to provide those computers with access to a network, without the need for wired connections to the computers.
[2] AECOM Report, Section 8.1, Conclusions, page 8-1.
[3] The probes are antennas that pick up the electromagnetic fields that are to be measured by a measurement instrument.
[4] AECOM Report, Section 7.2.1.1, Access Points, Table 7-2, Access Point Analysis, page 7-5.
AECOM Report, Section 7.2.1.2, Chromebooks, Table 7-3, Chromebook Analysis, page 7-8.
AECOM Report, Section 7.2.2.1, Access Points, Table 7-4, Maximum Instantaneous Power Density from Aps, Page 7-11.
AECOM Report, Section 7.2.2.2, Chromebooks, Table 7-5, Maximum Instantaneous Power Density from Chromebooks, Page 7-12.

Locating the Credible Guidance

For an overview of the big picture, and for pointers to the extensive biomedical research literature on the health risks of exposure to electromagnetic fields, please see the paper "Message to Schools and Colleges about Wireless Devices and Health"[5] and its many included references. Note, in particular, the BioInitiative Report of 2012[6] (which is referenced in the AECOM Report). For further motivation to investigate this issue, please see the "International EMF Scientist Appeal: Scientists Call for Protection from Non-Ionizing Electromagnetic Field Exposure"[7] submitted to the United Nations and the World Health Organization in May, 2015. Both of these documents name *Wi-Fi*, in particular, as a radiation source of concern to health; and both are addressed later in this document.

Responding to the Credible Guidance

In the MCPS setting, the protection needed by students, teachers, and staff can be implemented by replacing the wireless connectivity currently provided by Wi-Fi systems with wired connectivity that is non-radiating. That means using cable technologies, such as shielded Ethernet cable, or coaxial cable that is inherently shielded, or optical-fiber cable that needs no shielding. Even if replacement cannot be made now, it is still best to shut down all Wi-Fi connectivity to protect the health of all. No doubt that will disrupt the educational process, and will require some inventive management. But that is far better than continuing to put the health of all at risk.

The Challenge Facing the Montgomery County Public Schools

MCPS, like so many organizations around the world, faces a major challenge. Powerful forces are promoting the expansion of wireless technology, virtually without end, and with no regard for its impact on human health, and certainly not on children's health. For that expansion to continue unimpeded, it is vital that the current excessively permissive and outdated guidance on radiation exposure limits be continued. In the United States, the principal promulgator of that outdated guidance is the Federal Communications Commission (FCC), an agency of the U.S. Government. The current Chairman[8] of the FCC was appointed by the President in 2013. Prior to his appointment, he was the head of the CTIA – The Wireless Association. In that capacity he was the chief lobbyist for the wireless industry.[9]

Despite assurances of safety from the FCC and the wireless industry, the international biomedical research community is showing, in study after study, that current exposure limits are not even close to being protective of living things. The limitations of that guidance have been highlighted by agencies of the U.S. Government and by medical organizations. Among the agencies and organizations expressing concern are the Environmental Protection Agency, the Department of the Interior, the American Academy of Environmental Medicine, and the American Academy of Pediatrics, as described later in this document (page 41).

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[5] Ronald M. Powell, Ph.D., Message to Schools and Colleges about Wireless Devices and Health (http://www.scribd.com/doc/289778053/).

[6] BioInitiative Working Group, Cindy Sage and David O. Carpenter, Editors, BioInitiative Report: A Rationale for Biologically-based Public Exposure Standards for Electromagnetic Radiation, December 31, 2012 (http://www.bioinitiative.org).

[7] As of February 10, 2016, 220 scientists from 42 countries have signed this international appeal to the United Nations and to the World Health Organization. These scientists seek improved protection of the public from harm from the radiation produced by many wireless sources, including "cellular and cordless phones and their base stations, Wi-Fi, broadcast antennas, smart meters, and baby monitors" among others. Together, these scientists have published over 2000 peer-reviewed research papers on this subject. (https://www.emfscientist.org/index.php/emf-scientist-appeal).

[8] Wikipedia, Tom Wheeler (https://en.wikipedia.org/wiki/Tom_Wheeler).

[9] Wikipedia, CTIA – The Wireless Association (https://en.wikipedia.org/wiki/CTIA_%E2%80%93_The_Wireless_Association).

The MCPS is going to have to decide whom to believe. For you who are MCPS managers, that decision requires at least some familiarity with the massive amount of biomedical research literature available on this topic. Acquiring that familiarity will take some effort. But the stakes are so high for everyone in your schools, including yourselves, that a considerable effort is justified. I hope that you, as educators, will show the persistence that you would want your students in math, biology, chemistry, and physics to show in their forthcoming careers.

If you find yourself in doubt about what to do, despite the overwhelming evidence of risk in the international biomedical research literature, I urge you to side with the safety of everyone in your schools by taking precautionary action now. But whatever you do, resist the urge to use the outdated FCC exposure limits [called the Maximum Permissible Exposure (MPE) Limits] as an excuse for inaction. Our Government doesn't always get it right. And, sadly for all of us, our Government is failing us terribly in this case.

GENERAL CONCERNS

What follows are key examples of my concerns about the AECOM Report. I have not attempted to describe all of the concerns. There are simply too many of them to make that practical here. Some of the concerns arise early in the approach employed in the AECOM Report and invalidate downstream data. However, when this occurs, I continue to evaluate the downstream processes in order to provide a more complete picture of the full Report.

Sections called *"Background"* are inserted in this document to provide information helpful in understanding the concerns. Footnotes throughout this document point to specific statements of relevance in the AECOM Report or in external documents.

I have not attempted to review the AECOM Report's assessment of the biomedical research literature. That assessment is surpassed by more comprehensive, and updated, assessments conducted by teams of the world's leading experts on the biological effects of electromagnetic fields. It would be very difficult, if not impossible, for most organizations to assemble such teams. Here is just one example of the understandable limitations of the assessment of the biomedical research literature presented in the AECOM Report: The AECOM Report was published in July 2015 but contains no references to the substantial amount of research literature on the biological effects of electromagnetic fields published in any of the years 2013, 2014, or 2015.

Concern 1: No stated authors, no stated qualifications

The AECOM Report does not name the authors, nor state their qualifications for the work that they have undertaken. Further, the AECOM Report does not indicate if the authors are the same individuals who made the measurements. Nor does the AECOM Report indicate if the authors are even employees of AECOM. Rather, these personnel are referred to simply as "AECOM Representatives",[10] so I shall use that term throughout this document. Yet the AECOM Report purports to accomplish two tasks that require individuals with considerable qualifications:

Task 1: Measure the electromagnetic fields and analyze the results, which requires

(a) knowledge of the nature electromagnetic fields and their propagation (at the level of electrical engineers or physicists)

[10] AECOM Report, Section 5.2, Schools Surveyed, page 5-1.

(b) knowledge of the methods and instrumentation used for measuring electromagnetic fields (again, at the level of electrical engineers or physicists).

Task 2: Assess the health impact of the measured fields, which requires

(a) knowledge of the thousands of archival biomedical research publications that have contributed to our current knowledge about the biological effects of electromagnetic fields (at the level of biomedical scientists and physicians)

(b) knowledge of the meanings, the limitations, and the proper application of the various exposure limits promulgated by the U.S. Government and by private organizations.

With no information about the identity or the qualifications of the AECOM Representatives, there is no way to judge those qualifications. Rather, the reader of the AECOM Report is left to infer those qualifications from the content of the AECOM Report itself. Unfortunately, the AECOM Report raises too many concerns to make that inference a reassuring one.

Concern 2: No statement about conflicts of interest

The AECOM Report provides no statement about conflicts of interest, either for AECOM as a company or for its unspecified AECOM Representatives. That leaves unanswered the question of whether AECOM as a company, or the AECOM Representatives, in particular, have any conflicts of interest, through connections to the wireless industry or to standards-setting bodies, which might complicate their impartiality.

Concern 3: No detailed plan for characterizing the electromagnetic environment

The AECOM Report contains no plan for characterizing the electromagnetic environment that is detailed enough to enable evaluation before, or after, conducting the measurements and the associated analyses. For example, the following information is missing from the report:

- the layout of the classrooms measured
- the numbers and the positions of the Access Points and the Laptop Computers (Chromebooks) in the classrooms
- the presence or absence of other wireless devices in the classrooms, such as cell phones or tablet computers , and whether they were in operation when measurements were being made, and on what frequencies
- the locations and positions of the measurement instrumentation among the wireless equipment
- the directions from the Access Points along which the measurement probes were moved when measurements were made at successive distances, and whether those positions were collinear[11]
- the directions from the Laptop Computers (Chromebooks) along which the measurements probes were moved when measurements were made at successive distances, and whether those positions were collinear[11], and whether those directions were toward or away from the student using the Laptop Computers (Chromebooks)

[11] AECOM Report, Section 6.4.4, Perform the Study – Room Survey, page 6-4 provided additional information as follows: "Locations should include the following if possible: – Location representing the worst case between AP units or in front of AP units, experience has shown highest levels are found at a location that forms the corner of an isosceles triangle at the height of the AP units. – Location within 8 inches of the back of an individual student actively running an application. – Location where a table or group of students are working together." Apparently, these locations did not prove possible, because there is no reference to such locations in any of the data actually collected, as far as I can determine.

- clear definitions of the terminology that the AECOM Representatives use throughout their Report to represent a variety of measured and calculated quantities
- the basis for the selection of the measurement instrument and its associated probes (antenna sensors)
- the settings for the measurement instrument, the reasons for those settings, and which settings will be used consistently for all schools, and which must be adjusted for the local electromagnetic environment, since all affect the comparison of data from school to school and the comparison of data with the exposure limits.
- the overall strategy for the data analysis used to transform measured data into meaningful data for comparison with exposure limits.
- the motivations for measuring both electric fields and magnetic fields, but over different frequency ranges, and what differing roles were contemplated for them when comparisons were made with the exposure limits.

Finally, there is no detailed description of the activities of the Wi-Fi Access Points and the wireless Laptop Computers (Chromebooks) during the measurement period which greatly affects all measured values. For example, were the Laptop Computers (Chromebooks) to be measured while downloading data-intensive content, such as videos, or data-light content, such as text? The AECOM Report says only "All the measured field strengths were collected while students were actively using their Chromebook devices".[12]

Note that Section 6.4, Monitoring Protocol, of the AECOM Report does not constitute a plan for characterization of the electromagnetic environment, although some useful information is provided there.[13]

MEASUREMENT CONCERNS

This section describes concerns that relate to measurement equipment and it use. Again, sections called *"Background"* are inserted to provide information believed helpful in making the concerns more understandable.

Background: Overview of the approach in the AECOM Report

Since the AECOM Report did not contain a detailed plan for the work to be done at participating MCPS schools, no simple statement of the principal aim of the work was provided. Also the key steps to be followed during the pursuit of that aim were not outlined. Rather the aim and the key steps had to be divined from the full Report. Here is my attempt to fill that gap, so that the discussion that follows will be more understandable.

Principal Aim of the AECOM Representatives

Best I can tell, the principal aim of the AECOM Representatives had two major parts:

[12] AECOM Report, page 1-1. Similar descriptions appear elsewhere in the AECOM Report: (1) "Monitoring was conducted while Chromebooks and access points were in use. Data were collected for six minutes while students were actively engaged in using their Chromebook devices. AECOM Report, Section 6.1, Duration of Monitoring Events, page 6-1. (2) "Each measurement was collected at a specific location for a six-minute interval, while students were actively engaged in activities that required them to access the AP on their Chromebooks." AECOM Report, Section 6.5, Equipment, page 7-1.

[13] AECOM Report, Section 6.4, Monitoring Protocol, page 6-2.

- to develop two types of data (described below) on the power density of the electromagnetic fields in the classrooms of the MCPS, requiring multiple measurements of the electric fields in those classrooms and associated data analysis to produce the resulting data

- to compare the resulting data on power density with the existing exposure limits, also expressed as power density, provided by multiple organizations (the "Organizational Levels"), to see if those resulting data were below or above those exposure limits.

The two types of power density data developed were the following:

- The highest time-average power density of the electromagnetic radiation, subject to these qualifications:

    - in a single classroom per school, with one exception where two classrooms in the same school were measured
    - close to a single Access Point, and separately close to a single Laptop Computer (Chromebook) in the same classroom, with three exceptions:
        - a first exception where the Access Point and the Laptop Computer (Chromebook) were in different rooms
        - a second exception where only the Access Point was measured,
        - a third exception where only the Laptop Computer (Chromebook) was measured.
    - based on measurements over a frequency range of 2.4 GHz to 6 GHz, which was inclusive of all frequencies at which the Access Points and the Laptop Computers (Chromebooks) operate, in all of the MCPS schools
    - based on measurements at four distances (from 1 to 24 inches) or five distances from (1 to 36 inches) with the highest value found at any of those distances selected for direct comparison with the exposure limits.
    - based on 6 minutes of operation of the measurement instrument at each distance addressed.

- The highest instantaneous power density of the electromagnetic radiation, subject to qualifications similar to the above qualifications for the time-average power density

Quantities employed in the AECOM Report

In pursuit of the above aim, the AECOM Representatives produced a multitude of quantities with a variety of names, not all of which are immediately understandable or distinguishable. Those names are shown in quotation marks in Table A, with the exact abbreviations and punctuation used by the AECOM Representatives. I shall use those exact names when I refer specifically to those quantities in the text of this document, so that they can be more readily identified as the quantities used by the AECOM Representatives, as distinguished from related quantities that I introduce. The quantities in the AECOM Report will be introduced and explained where needed in the rest of this review.

Table A: Key Quantities Used in AECOM Report

Name of Quantity	Found in	Type of Quantity	Units of Measure	
			full name	abbreviation
"Average"	Appendix C	electric field	volts per meter	V/m
"Max Avg."	Appendix C	electric field	volts per meter	V/m
"Absolute Max"	Appendix C	electric field	volts per meter	V/m
"Max E"	Appendix D	electric field	volts per meter	V/m
"Max Power Density"	Appendix D	power density	milliwatts per square centimeter	mW/cm^2
"Avg E"	Appendix D	electric field	volts per meter	V/m
"Avg Power Density"	Appendix D	power density	milliwatts per square centimeter	mW/cm^2
"Maximum Average Power Density"	Tables 7-2 and 7-3	power density	microwatts per square centimeter	$\mu W/cm^2$
"Maximum Instantaneous Power Density"	Tables 7-4 and 7-5	power density	microwatts per square centimeter	$\mu W/cm^2$
Other Quantities				
frequency	Appendix B	frequency	hertz	Hz
frequency	text	frequency	gigahertz	GHz
Conversion Factors				
1 watt (W) = 1000 milliwatts (mW)		1 milliwatt (mW) = 1000 microwatts (µW)		
1 meter = 100 centimeters (cm)		1microwatt (µW) = 1000 nanowatts (nW)		
1 gigahertz (GHz) = 1,000,000,000 hertz (Hz)		1 square meter (m^2) = 10,000 square centimeters (cm^2)		

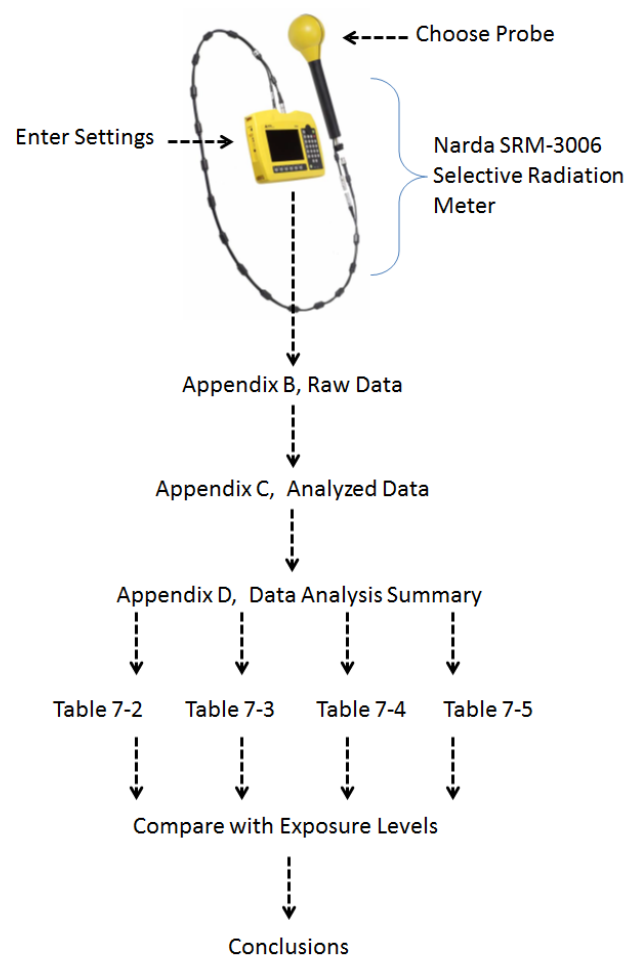
Flow of information in the AECOM Report

Figure 1 provides an overview of the flow of information in the AECOM Report, beginning with the setup of the measurement instrument, followed by the extraction of the measured data from the instrument, and then the movement of data through the various parts of the AECOM Report where it is aggregated and analyzed, until it finally emerges in four key tables (7-2, 7-3, 7-4, and 7-5) which provide the principal results of the AECOM Report. There the data are compared with the exposure limits of several organizations to enable drawing conclusions.

With that overview in mind, the following list describes the flow of information in the AECOM Report in more detail. In the rest of this review, I will discuss the steps in the information flow in the order shown here, and I will raise selected concerns where they occur.

- Choose the measurement instrument and the associated probes (antenna sensors).
- Select and enter the settings to be used with the measurement instrument.

Figure 1: Flow of Information in AECOM Report



- Measure the electric and magnetic fields at several distances close to the Access Points and the Laptop Computers (Chromebooks) at the MCPS Schools, and store the results in tables in Appendix B, Raw Data.
- Aggregate the data from Appendix B, by individual Access Point or Laptop Computer (Chromebook), and for a given set of test conditions, into individual tables in Appendix C, Analyzed Data.
- Perform first steps of analysis of the aggregated data in the tables in Appendix C.
- Aggregate the analyzed data from Appendix C, by individual Access Point or Laptop Computer (Chromebook), and for a given school, into individual tables in Appendix D, Data Analysis Summary.
- Transfer selected data from Appendix D into the main body of the Report, for all schools in which the relevant measurements were made, into four tables that represent the principal findings of the AECOM Report. Those tables are listed here with expanded titles for clarity:
  - Table 7-2: "Maximum Average Power Density" produced by the Access Point Analysis[14]
  - Table 7-3: "Maximum Average Power Density" produced by the Laptop Computer (Chromebook Analysis)[15]
  - Table 7-4: "Maximum Instantaneous Power Density" from Aps (Access Points)[16]
  - Table 7-5: "Maximum Instantaneous Power Density" from Chromebooks[17]
- Compare the analyzed data in Table 7-2 and Table 7-3 explicitly with selected exposure limits provided by several organizations. Provide the reader with the opportunity to compare the analyzed data in Tables 7-4 and 7-5 implicitly with the exposure limits.
- Draw conclusions and report on them, based on the comparison of the analyzed data in Table 7-2 and Table 7-3 with the exposure limits.

Background: Access Points and Laptop Computers (Chromebooks) at the MCPS schools addressed by AECOM

Access Points

According to the AECOM Report, the Access Points (APs) measured in the MCPS schools were predominantly the Cisco Aironet Series 2600 and secondarily the Aerohive AP230. The AECOM Report indicates the following: "Both models of APs are dual band and follow the IEEE 802.11n standard. The IEEE 802.11n standard operates in the RF band of the EM spectrum, between 2.4 and 2.5 GHz and 5.150 and 5.950 GHz."[18]

Laptop Computers (Chromebooks)

Again, according to the AECOM Report, "MCPS currently provides Acer C720 Chromebooks for student use in classrooms." [19] (Acer indicates that the Acer C720 Chromebooks are "laptop" computers.[20]) Since these Chromebooks are capable of supporting the IEEE 802.11n standard, which matches the capability of the Access Points, I assume that all Laptop Computers (Chromebooks) in all schools were operating under that standard for all measurements made by the AECOM Representatives. [21]

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[14] AECOM Report, Section 7.2.1.1, Access Points, Table 7-2, Access Point Analysis, page 7-5.
[15] AECOM Report, Section 7.2.1.2, Chromebooks, Table 7-3, Chromebook Analysis, page 7-8.
[16] AECOM Report, Section 7.2.2.1, Access Points, Table 7-4, Maximum Instantaneous Power Density from Aps, Page 7-11.
[17] AECOM Report, Section 7.2.2.2, Chromebooks, Table 7-5, Maximum Instantaneous Power Density from Chromebooks, Page 7-12.
[18] AECOM Report, Section 5.1, MCPS Equipment, page 5-1.
[19] AECOM Report, Section 5.1, MCPS Equipment, page 5-1.
[20] C720, The most powerful 11" Chromebook (http://us.acer.com/ac/en/US/content/series/c720).
[21] AECOM Report, Section 5.1, MCPS Equipment, page 5-1.

Background: Electric and magnetic fields measured, and not measured, at participating MCPS schools

The AECOM Representatives set out to measure electric fields in the frequency range from 2.4 GHz to 6 GHz, apparently with the intention of converting the measured values into power densities (power per unit area passing through a plane perpendicular to the direction of the radiation) for ready comparison with the radiation exposure limits of several organizations that are also expressed as power densities. However, no rationale was presented in the AECOM Report for the measurements the AECOM Representatives made of the magnetic fields over a different and lower frequency range. Nor was any use made of the magnetic field data in the AECOM Report, beyond the first step of the data analysis. For example, magnetic field data were not used to support the conclusions of the AECOM Report. Hence, I focus here on the measurements of the electric fields, and mention only briefly the measurements of the magnetic fields.

The AECOM Report describes measurements made at 12 schools and 13 locations. (Two of the locations were at one of the schools, the Bells Mill Elementary School.) Nearly all of those locations were described as "classrooms".

Four types of measured information, at the most general level, were developed for classrooms.

- electric field measurements near the Access Points (routers)
- electric field measurements near the Laptop Computers (Chromebooks)[22]
- magnetic field measurements near the Access Points (routers)
- magnetic field measurements near the Laptop Computers (Chromebooks)[22]

In addition, two types of measured information were developed for a "Charging Station" in one school, the William Wims Elementary School:

- electric field measurements near the "Charging Station"
- magnetic field measurements near the "Charging Station"

The nature of the Charging Station was not explained in the AECOM Report which merely stated that "AECOM personnel were specifically requested to collect data on the charging station as part of this study."[23]

For reasons not explained in the AECOM Report, the unnumbered table at the beginning of the Report,[24] and Table 5-1 of the Report,[25] indicate that some of the measurements described above were omitted at some of the schools. No reasons for these omissions are provided in the AECOM Report:

- The electric and magnetic fields from the Access Points in the Little Bennett Elementary School were not measured.
- The electric and magnetic fields from the Laptop Computers (Chromebooks) in the Goshen Elementary School were not measured.

[22] The Acer 720 Chromebooks, which the AECOM Report indicates were employed in all the classrooms where measurements were conducted, are described by the manufacture, Acer, as Laptops, so that term will be used in this document (http://www.acer.com/ac/en/US/content/series/c720).
[23] AECOM Report, Section 7.2.3 Charging Station, page 7-12.
[24] AECOM Report, Section 1, Executive Summary, page 1-1.
[25] AECOM Report, Section 5.2, Schools Surveyed, Table 5-1, page 5-1.

- The electric and magnetic fields from both the Access Points and the Laptop Computers (Chromebooks) in the William Wims Elementary School were not measured, although the electric fields and the magnetic fields of the "Charging Station" were measured.

Also observed was the following oddity, for which no explanation was given:

- In the Wootton High School, the Access Point was measured in one room (154), and the Laptop Computers (Chromebooks) were measured in a different room (162).

Additional measurements were made of outdoor electric fields and magnetic fields in the parking lots of the schools, to gauge background radiation levels, but I will not discuss those here. Rather, the focus here will be the measurements of the electric fields made inside the classrooms.

Background: Narda SRM-3006 Selective Radiation Meter (the "measurement instrument")

The instrument used for all measurements reported in the AECOM Report was the Narda SRM-3006 Selective Radiation Meter.[26] Throughout this review, I refer to this instrument as the "measurement instrument". This measurement instrument is pictured in Figure 1 with one of its field "probes" attached. (The field probes are also called "antennas"; they are the sensors that pick up the electric fields, or the magnetic fields, to be measured.) This measurement instrument can measure electric fields when equipped with any one of several electric field probes. And the measurement instrument can measure magnetic fields when equipped with any one of several magnetic field probes. The measurement instrument has several operating modes with very different capabilities. As far as I can tell, the mode used for all measurements in the AECOM Report was the Spectrum Analysis Mode,[27] although no rationale for the use of this mode was presented in the AECOM Report. The operation of the measurement instrument in this mode will be described further below.

Background: Organization and Content of the AECOM Report

The AECOM Report is organized in five parts:

Body of the report, in 10 sections
Appendix A Certificates of Calibration
Appendix B Raw Data
Appendix C Data Analysis
Appendix D Data Analysis Summary

Content of the body of the report, Appendix A, and Appendix D

Initially, on about November 20, 2015, the MCPS published three of the five parts of the AECOM Report on the MCPS web site.[28] Those three parts were the body of the report, Appendix A, and Appendix D. Those three

[26] Narda Safety Test Solutions GmbH, SRM-3006, Selective Radiation Meter, key documentation:
(1) Introduction (http://www.narda-sts.us/products_highfreq_srm.php);
(2) Brochure (STS-SRM-022013) (http://www.narda-sts.us/pdf_files/Brochure/SRM3006_Brochure.pdf);
(3) Data Sheet (http://narda-sts.us/pdf_files/DataSheets/SRM3006_DataSheet.pdf);
(4) Operating Manual (2010) (http://www.narda-sts.us/pdf_files/OperatingManuals/SRM3006_Manual.pdf);
(5) Helmut Keller, Principles and Applications of the Selective Radiation Meter SRM-3000, Application Note AN_HF_1000_E_Principles SRM_2006-06, page 16 (2006). The SRM-3006 extends the top frequency of the SRM-3000 to 6 GHz. (Document not posted online.)
[27] AECOM Report, Section 6.4.2, Perform the Study - Adjust Settings, page 6-3.
[28] AECOM, Radiofrequency (RF) Monitoring Report: Montgomery County Public Schools, Project No. 60429211 (July 8, 2015) (http://www.montgomeryschoolsmd.org/uploadedFiles/departments/technology/MCPS%20RF%20Monitoring%20Report%20FINAL.pdf).

parts were likely selected for publication because they were printable parts, that is, they could be rendered as ordinary pages of text, in either hardcopy or electronic form. Also, the body of the report and Appendix D were the more general parts; that is, they contained the highest level of aggregation of the data presented. And the body of the report, of course, contained the conclusions of the AECOM Report. For all of these reasons, they were likely judged more accessible and more important to most readers. Appendix A contained the certificates of calibration for the instrumentation employed.

But to understand the data published in the AECOM Report, access to Appendix B and Appendix C proved necessary.

Content of Appendix B and Appendix C

Appendix B and Appendix C were published on about February 9, 2016 on the MCPS web site.[29] Both of these appendices were in the form of spreadsheet files.

Appendix B contained the raw data files generated by the measurement instrument as the measurements progressed. Each file in Appendix B contained all measured values collected on a single "sweep" of the measurement instrument throughout the frequency range for which it was set. At the top of each of these files were the settings of the measurement instrument at the time that instrument generated all of the measured data within that file.

Appendix C contained files that aggregated the measured data from related files in Appendix B. Each file in Appendix C contained all data from a given school, for a given location within that school, for a given source [either an Access Point or a Laptop Computer (Chromebook)], for a given measured quantity (electric field or magnetic field), and for a given distance from the source. The files in Appendix C also contained embedded formulas that showed how the first steps of the data analysis had been conducted.

Concern 4: Incomplete explanation of the settings of the measurement instrument

What the measurement instrument actually measures is very much affected by its many settings. Unfortunately, the AECOM Report did not provide the rationale for the measurement instrument settings. That left a lot of questions unanswered, and led to several concerns. But, first, some background information is needed.

Background: Settings used for the measurement instrument, and their implications

An example of the key settings that the AECOM Representatives used with the measurement instrument when measuring electric fields is provided in Table B on page 12. That example shows the settings used when measuring the electric field of the Access Point at the Beverly Farms Elementary School at a distance of 12 inches.[30] As noted above, the measurement instrument writes its settings into the raw data files that it generates; and those data files were included in Appendix B, Raw Data, in the AECOM Report. This particular example was chosen because the AECOM Representatives used it as an example to create Figure 7-1 and Figure 7-2 in the AECOM Report.[31]

[29] Montgomery County Public Schools: Radiofrequency Monitoring (http://mcpsmd-public.sharepoint.com/radiofrequency).
[30] AECOM Report, Appendix B, Raw Data, 2015-06-08_Beverly Farms Elementary School, Room 252 – access point, Electric, one foot, D-0151_00003_00001.
[31] AECOM Report, Section 7.2, In School Evaluations, Figure 7-1 and Figure 7-2, page 7-4.

Table B: Selected Settings for Narda SRM-3006 for Measurements at Beverly Farms Elementary School, Room 252, Access Point, Electric Field, 12 Inches Distance

Name	Value or Choice	Explanation
Mode	Spectrum Analysis Mode	Measures the electric or magnetic field produced by narrow frequency segments, each centered on an individual frequencies within a larger frequency range through which the instrument "steps". Each such passage through the entire frequency range is a "sweep".
F_{min}[Hz]	2,400,000,000 Hz (2.4 GHz)	Low end of the frequency range for each sweep.
F_{max}[Hz]	6,000,000,000 Hz (6.0 GHz)	High end of the frequency range for each sweep.
df[Hz]	156,250 Hz	The spacing (step size) between the discrete frequencies at which measurements are made throughout the frequency range.
RBW[Hz]	300,000 Hz	Resolution Bandwidth is the minimum frequency separation that two signals with the same amplitude, but on different frequencies, must have for the instrument to be able to distinguish between them.[32]
Number Values	23,041	The number of discrete frequencies in the frequency range at which measurements are made: (Fmax – Fmin)/df +1
Antenna	Three-axis (electric field) Antenna 420MHz - 6GHz	A three-axis antenna (probe) can measure X, Y, and Z field components for combination by the measurement instrument into a single value. But the components are measured sequentially, not simultaneously, so the three-axis capability is not suitable for measuring pulses accurately.
Axis	RSS	Three-axis antenna was used in its three-axis mode (not a single axis mode).
MR [V/m]	1.1	Measurement Range controls an attenuator that reduces the incoming signal level. If set too low (too sensitive), the strongest signal encountered may overload the input of the instrument. If set too high (too insensitive), the incoming signal may be suppressed so greatly that it disappears into the electrical noise of the instrument and thus becomes unmeasurable.
Time Avg. (s)	360 seconds	The total time allowed for the measurements. Determines the number of sweeps that will be made.
Sweep Time (ms)	1043 ms	The time to sweep throughout the entire frequency range one time, beginning at F_{min} and advancing by df (step size) each time until F_{max} is reached, making measurements at each frequency in the process.
Number of Sweeps	260	Determined indirectly by the total time that the instrument spends sweeping, which in this case is 360 seconds, or six minutes. One data file is produced for each sweep and holds all 23,041 ("Number Values") measurements reported for that sweep.

Values calculated by me, based on the above settings, as estimations.

Name	Value	Explanation
Time per Frequency Segment per Sweep[33]	0.045 ms	(Sweep Time) / (Number Values) = (1043 ms)/23,041 = 0.0453 ms. However, the actual time spent measuring may be less because of so-called "blind" time at each measurement frequency.[34]
Time per Frequency Segment for All Sweeps[33]	11.8 ms	(Time per Frequency Segment per Sweep) x (Number of Sweeps) = (0.0453 ms) x 260 = 11.8 ms. However, the actual time spent measuring may be less because of so-called "blind" time at each measurement frequency.[34]

[32] Narda Safety Test Solutions GmbH, SRM-3006, Selective Radiation Meter: Operating Manual, Section 6.2 Setting the resolution bandwidth (RBW), page 71 (2010).

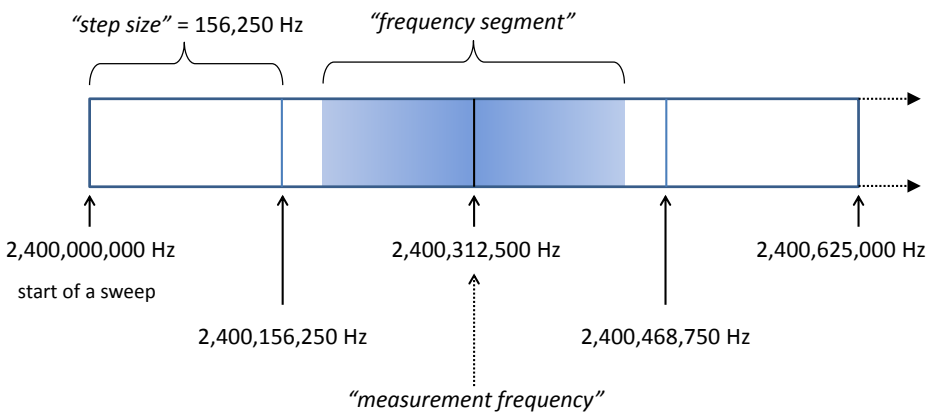
[33] This parameter was defined and calculated by author, not by the Narda 3006-SMR instrument, for use in explanations in this document. No time was deducted for calculation or data recording, so the characteristic measurement time may be somewhat less than this amount.

[34] Helmut Keller, Narda Safety Test Solutions, Principles and Applications of the Selective Radiation Meter SRM-3000, Application Note AN_HF_1000_E_Principles SRM_2006-06, page 16 (2006). 'The SRM can likewise only roughly record the time structure of the real spectrum because of the frequency synthesizer settling time needed for each tuning step and the processing time needed to evaluate the signal after each result is recorded. Just like a classical spectrum analyzer, the SRM is "blind" for most of the time at a given tuning [measurement] frequency.' The SRM-3006 is very similar to the SRM-3000 with the top frequency increased to from the 3 GHz of the SRM-3000 to the 6 GHz of the SRM 3006.

To put the measurement instrument into use, a probe for measuring either electric fields or magnetic fields must be attached; and the desired settings must be entered into the instrument. In this case, the AECOM Representatives set the "Mode" of the instrument to "Spectrum Analysis Mode", as shown in Table B. In the Spectrum Analysis Mode, the instrument increases ("sweeps") the frequency at which it is making a measurement, in "steps", from a minimum frequency (F_{min}) of 2.4 GHz to a maximum frequency (F_{max}) of 6 GHz. Figure 2 on page 13 provides a snapshot of the measurement process soon after it has started.

Figure 2 also shows the terminology that will be used here to describe that process. Each step increase in the frequency is the same size and is called here the "step size", which is 156,250 Hz, as shown in Table B. That is, each successive frequency at which a measurement is made is 156,250 Hz higher than the preceding frequency at which a measurement was just made. The frequency at which a measurement is currently being made is called here the "measurement frequency". So Figure 2 shows the measurement process *after* the measurement at 2,400,000,000 Hz (2.4 GHz) has been completed, and *after* the measurement at 2,400,156,250 Hz has also been completed, and *while* the measurement at 2,400,312,500 Hz is underway. So at the time that the snapshot in Figure 2 was taken, the measurement frequency was 2,400,312,500 Hz.

Figure 2: Snapshot of Beginning of a Measurement Sweep in Spectrum Analysis Mode, and Associated Terminology



The measurement made at each measurement frequency reflects all of the radiation present within the "frequency segment" centered on that measurement frequency. As the measurement instrument steps through the entire frequency range from 2.4 GHz to 6 GHz, it produces 23,041 measurements, one at each of 23,041 frequencies that are spaced the one step size apart. Because the frequency segment can be set to a value different from the step size, a correction factor must be applied when combining the radiation levels from adjacent frequency segments, basically to account for the possibility of double counting the contributions from overlapping adjacent frequency segments.[35] (The frequency segment is a function of a setting called the "Resolution Bandwidth", or "RBW"; and the correction factor is a mathematical function of the RBW and the step size.)[36]

Concern 5: Incorrect or non-optimal instrument settings

The accuracy of all of the measurements of pulsed signals reported in the AECOM Report is in question because of incorrect or non-optimal instrument settings without explanation or justification. I describe here three examples and will refer to them, as appropriate, later in the context of other concerns.

[35] Helmut Keller, Narda Safety Test Solutions, Principles and Applications of the Selective Radiation Meter SRM- 3000, Application Note AN_HF_1000_E_Principles SRM_2006-06, page 16 (2006). The SRM-3006 extends the top frequency of the SRM-3000 to 6 GHz. (Document not posted online.)

[36] Helmut Keller, Narda Safety Test Solutions, Principles and Applications of the Selective Radiation Meter SRM-3000, Application Note AN_HF_1000_E_Principles SRM_2006-06, Equation 3.3.1, page 20 (2006). The SRM-3006 extends the top frequency of the SRM-3000 to 6 GHz (not posted online).

Spectrum Analysis Mode

The mode used throughout the AECOM effort was the "Spectrum Analysis Mode". However, this mode was not always the best choice for the particular purpose being undertaken. Other more suitable modes of the multimode measurement instrument were available. Narda explains that the Spectrum Analysis Mode of the measurement instrument is intended for measuring electromagnetic fields with "quasi-stationary characteristics". [37] The fields generated by the Access Points and the Laptop Computers (Chromebooks) are pulsed and thus are not quasi-stationary. A key reason for this limitation is that the measurement times, at any given measurement frequency, are very short, as shown by the estimated times at the bottom of Table B.

Those short measurement times mean that the measured values may not be fully representative of pulsed signals even when the measurement data from multiple sweeps of the entire frequency range of interest have been collected. The pulses that do occur at a given measurement frequency simply may not occur during the very short times that the measurement instrument is addressing that frequency.

However, as the instrument manufacturer, Narda, indicates, another mode of the instrument, called the "Scope Mode", which was not employed by the AECOM Representatives, can "determine the peak value and the average value of the input power level within the selected frequency range for any type of input signal."[37]

Three-Axis Antenna (Probe)

The AECOM Representatives employed three-axis probes, operating in three-axis (isotropic) mode, for all measurements, as far as I can determine. (The three-axis probes can also be used in a single-axis mode.) The use of the three-axis (isotropic) mode is indicated in Table B by the "Axis" setting of "RSS". RSS stands for "root sum square", which is the mathematical method that the measurement instrument uses to combine the measurements of the three axes into a single value.

These three-axis probes, when used in the three-axis (isotropic) mode, have the advantage that they can measure each of the three directional components of the electric (or magnetic field), X, Y, and Z, separately. The measurement instrument then combines the three measurements into a single value. But the three-axis probes have the limitation that the three axes are measured sequentially, not simultaneously. As the Narda operating manual indicates: "All three axes are measured, one after the other[,] and the isotropic result calculated and displayed by the SRM-3006."[38]

The three-axis (isotropic) mode of the probes complicates the measurement of pulsed signals because those signals change so quickly in time that they may have one value when the first axis is measured, a different value when the second axis is measured, and a third value when the third axis is measured. As a result, the combining of the three axes may not produce a proper characterization of the pulse. The types of signals issued by the Access Points and the Laptop Computers (Chromebooks) are pulsed signals.

So both the Spectrum Analysis Mode and the Three-Axis Antennas (Probes), when used in their three-axis (isotropic) mode, engender timing- related concerns that complicate the proper measurement of pulsed signals of the type under consideration at the MCPS.

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[37] Helmut Keller, Narda Safety Test Solutions, Principles and Applications of the Selective Radiation Meter ARM-3000, Application Note AN_HF_1000_E_Principles SRM_2006-06, Section 3.5 "Time Analysis" operating mode, since renamed "Scope" operating mode, page 23 (next to last paragraph).

[38] Narda Safety Test Solutions GmbH, SRM-3006, Selective Radiation Meter, Operating Manual (2010), Section 6.6.1, Measurement using a three axis antenna, page 85 (http://www.narda-sts.us/pdf_files/OperatingManuals/SRM3006_Manual.pdf).

Measurement Range

The setting called "Measurement Range (MR)" determines the input sensitivity of the measurement instrument. It controls an internal input attenuator. The higher the value of the Measurement Range, the greater is the amount of attenuation applied. The Measurement Range has units of electric field (V/m) and should be set to the lowest value (most sensitive setting) that is sufficient to keep the input of the measurement instrument from experiencing an overload. If the Measurement Range is set too high, the attenuator can reduce the strength of the incoming signal so much that it disappears into the inherent internal electrical noise of the measurement instrument.

Concerns about the settings for the Measurement Range used by the AECOM Representatives came into question when inspecting Figure 7-2 in the AECOM Report, and were reinforced when inspecting other similar figures in Appendix C made from the data on some other Laptop Computers (Chromebooks) measured for the AECOM Report. Figure 7-2 is reproduced, with annotations, in the Appendix to this document as Figure 5 on page 49 for convenient reference. That figure may be more easily understood after the rest of this review has been read. But the important feature to note in Figure 5 is that is shows no peaks in radiation throughout the entire frequency range covered, 2.4 GHz to 6 GHz. This lack of peaks was true for all four distances at which this Laptop Computer (Chromebook) was measured: 1, 6, 12, and 24 inches. Compare this lack of peaks with the presence of peaks in Figure 7-1 from the AECOM Report, which is also reproduced in the Appendix to this document as Figure 4 on page 49. That figure shows the results of measurements made of the Access Point, at a distance of 12 inches, in the same classroom.

The AECOM Report provides its own explanation, in the caption to Figure 7-2, as to why no signal was seen from the Laptop Computer (Chromebook) associated with that figure: "Note that the average values result in a relatively flat line, as the amount of time that the Chromebook spends interacting with the AP is actually quite low." This seems to me to be the least likely explanation, since the signals from wireless laptops should be quite strong, especially at such close range (12 inches), and should thus be easily detectable. Here are two alternate explanations that seem more likely.

- As shown in the annotations that I have added to Figure 5 on page 49, the Measurement Range was set to 28 V/m when the measurements were made, at a distance of 12 inches from the Laptop Computer (Chromebook), to produce Figure 7-2. That value for the Measurement Range is 193 times greater than the highest value of the electric field measured for any single frequency segment on any sweep (that is, the "Absolute Max") under the conditions described in the caption for Figure 7-2. Such a high level of attenuation may have driven any signal present into the inherent electrical noise of the measurement instrument.

  How might such a high value for the Measurement Range have been selected? Here are some possibilities:

  - The operating manual for the measurement instrument indicates that the Measurement Range should be set manually (not automatically) when measuring pulsed signals,[39] that is, signals like those produced by the Access Points and the Laptop Computers (Chromebooks). So, if the AECOM Representatives used the automatic option to set the Measurement Range, then that range might have been set incorrectly by that automatic feature.

[39] Narda Safety Test Solutions, SRM-3006 Selective Radiation Meter, Operating Manual, Section 6.3.1, Manual measurement range selection, p. 73.

- If the AECOM Representatives did set the Measurement Range manually, perhaps they did not understand its effect on the measured data, and set it very high, "just to be safe", that is, to assure protecting the measurement instrument from overload.

- If there was another source of electromagnetic fields in the classroom that was transmitting outside of the range being measured, 2.4 GHz to 6 GHz, then a very high setting of the Measurement Range might have been needed to protect the measurement instrument from the dominant source of radiation in the classroom. But, if such an extreme condition did occur, it should have been reported in the AECOM Report.

- The Laptop Computer (Chromebook) was not transmitting at all for some reason not described in the AECOM Report:
  - It was not turned ON.
  - It was turned ON, but it was not transmitting when the measurements were made.

This last bullet may seem unlikely at first glance; but consider the time of day at which the measurements of this Laptop Computer (Chromebook) were made at all four distances, as shown in Table C. Those times were embedded in the raw data files recorded automatically by the measurement instrument itself, and were included in Appendix B of the AECOM Report. The measurement instrument appears to be reporting time in its 24-hour format, because no "a.m." or "p.m." is specified. That means that the measurements were made between 5 a.m. and 6 a.m., assuming that the measurement instrument's clock was set correctly. At such an hour it seems unlikely that the students of the Beverly Farms Elementary School would have been present. [40] That brings into question the validity of the statement in the AECOM's Report: "All the measured field strengths were collected while students were actively using their Chromebook devices".[41] So perhaps the Laptop Computer (Chromebook) being measured was not in use by a student (or by anyone) when its electric field was measured.

Table C: Measurement Times and Measurement Range at Beverly Farms Elementary School, Room 252, Laptop Computer (Chromebook), Electric Field, at Four Distances

Measurement Distance (inches)	Measurement Times on June 8, 2015		Measurement Range (V/m)
	Start Time of First Sweep (hours:minutes:seconds)	Start Time of Last Sweep (hours:minutes:seconds)	
1	5:32:29	5:38:28	16
6	5:40:14	5:46:13	28
12 (Figure 7-2)	5:47:56	5:53:54	28
24	6:12:26	6:18:25	63

References in AECOM Report, Appendix B Raw Data, 2015-06-08_Beverly Farms Elementary School, Room 252, Chrome Book, Electric Field

Distance	First Sweep Filename	Last Sweep Filename
1 inch	K-0098_00001_00001.csv	K-0098_00001_00257.csv
6 inches	K-0098_00002_00001.csv	K-0098_00002_00257.csv
12 inches	K-0098_00003_00001.csv	K-0098_00003_00249.csv
24 inches	K-0098_00001_00001.csv;	K-0098_00001_00259.csv

[40] If the clock was in 12-hour mode, with no "a.m." or "pm." indicator expressed, the time might have been 5 to 6 p.m., which seems an equally unlikely time for the students at the Beverly Farms Elementary School to be present.

[41] AECOM Report, page 1-1. Similar descriptions appear elsewhere in the AECOM Report: (1) "Monitoring was conducted while Chromebooks and access points were in use. Data were collected for six minutes while students were actively engaged in using their Chromebook devices." AECOM Report, Section 6.1, Duration of Monitoring Events, page 6-1. (2) "Each measurement was collected at a specific location for a six-minute interval, while students were actively engaged in activities that required them to access the AP on their Chromebooks." AECOM Report, Section 6.5, Equipment, page 7-1.

Concern 6: Probe used for all magnetic measurements incorrectly identified and incorrectly specified.

Table 6-1 in AECOM Report indicates that the probe used for magnetic field measurements was the Narda Model 3531/02.[42] But this probe is not a magnetic field probe. Rather, this probe is an electric field probe. Later in the AECOM Report, the probe used for magnetic field measurements is again identified as the Model 3531/02.[43] Further, there is no mention anywhere in the body of the AECOM Report (that is, prior to the appendices) of any other probe used for magnetic field measurements.

Checking the calibration certificates in Appendix A of the AECOM Report indicates that no Certificate of Calibration was provided for the Model 3531/02 probe. However, there was a Certificate of Calibration provided for another probe that is a magnetic field probe, the Narda Model 3581/02. Based on data embedded in the data files in Appendix B by the measurement instrument, it appears that the Model 3581/02 probe was the one used for all magnetic field measurements, based on its description and serial number. [44] Assuming that is so, then the frequency range of the probe shown in Table 6-1 in the AECOM Report is also incorrect and should be 9 kHz to 250 MHz,[45] instead of the 9 kHz to 300 MHz shown.[46]

Assuming, again, that the Model 3581/02 probe is the one used for all magnetic measurements, the AECOM Report indicates that the frequency range surveyed was set to "capture the full spectrum of the probe for magnetic fields".[47] Actually, a spot check of the data files in Appendix B for the Beverly Farms Elementary School indicates that the frequency range actually surveyed was 9 kHz to 200 kHz, [48] not 9 kHz to 250 kHz.

The AECOM Report offers no explanation for these several inconsistencies.

Strangely, even though the AECOM Report included many magnetic measurements, the Report draws no conclusions from them, leaving the reader wondering why these measurements were made at all, especially when those measurements fall outside of the frequency range of interest for the Access Points and the Laptop Computers (Chromebooks), 2.4 GHz and 6 GHz. While I can guess at some possible reasons, I am not clear on what was in the minds of the AECOM Representatives. Accordingly, I have not addressed magnetic measurements in this review, except peripherally.

Concern 7: Incorrect probe used for all electric field measurements in 5 of the 12 schools (and, thus, in 6 of the 13 classrooms).

Table 6-1 in the AECOM Report indicates that two different probes were used for electric field measurements:[49]

- One of those electric field probes is the Narda Model 3501/03. This probe was used in 5 of 12 MCPS schools (and thus in 6 of the 13 rooms), as shown in Table 6-3 of the AECOM Report.[50] This probe

[42] AECOM Report, Section 6.2 Monitoring Equipment, Table 6-1, Probes Used, page 6-1,
[43] AECOM Report, Section 6.5, Equipment, Table 6-3, Electric Probes Used, page 6-5.
[44] AECOM Report, Appendix B, Raw Data, 2015-06-08_Beverly Farms Elementary School, Room 262 – access point, Magnetic, one foot, D-0151_00002_00001.csv. "Three-axis probe 9 kHz - 250 MHz", and Serial No. "AA-0249".
[45] Narda Safety Test Solutions, SRM3006 Selective Radiation Meter, Operating Manual (2010), page 197. (http://www.narda-sts.us/pdf_files/OperatingManuals/SRM3006_Manual.pdf).
[46] AECOM Report, Section 6.2, Monitoring Equipment, Table 6-1, Probes Used, page 6-1.
[47] AECOM Report, Section 6.4.2.3, Frequency, page 6-4.
[48] AECOM Report, Appendix B, Raw Data, 2015-06-08_Beverly Farms Elementary School, Room 262 – access point, Magnetic, one foot, D-0151_00002_00001.csv.
[49] AECOM Report, Section 6.2, Monitoring Equipment, Table 6-1, Probes Used, page 6-1.

covers the frequency range from 2.4 GHz to 3 GHz. But this is only part of the frequency range that the rest of the AECOM Report indicates was measured: 2.4 to 6 GHz. This suggests that the balance of the frequency range, from 3 GHz to 6 GHz, was not measured at any school at which this probe was used. That means that all measurements of the electric field made in those 5 schools (and those 6 rooms) are invalid. Those schools are Wootton High School, Gaithersburg High School, Cabin John Middle School, Churchill High School, and Bells Mill Elementary School (two classrooms).

- The second of those electric-field probes is the Narda Model 3502/01. This probe covers the frequency range of 420 MHz to 6 GHz and thus does include the entire frequency range that the AECOM Report indicates was measured: 2.4 GHz to 6 GHz. This probe was used in 7 of 12 MCPS schools (and thus in 7 of the 13 rooms). The schools are Fallsmead Elementary School, Beverly Farms Elementary School, Little Bennett Elementary School, William Wims Elementary School, Arcola Elementary School, Goshen Elementary School, and Strawberry Knoll Elementary School.

The use of the wrong probe for the measurements in 5 of the 12 schools, and in 6 of the 13 rooms in those 12 schools, is rationalized in the AECOM Report in the first paragraph of Section 6.5 with this statement:

> "Different equipment was available over the course of the study. While the same magnetic field probe (3531/02) was available for the duration of the study, different electric field probes were available."[51]

So the AECOM Representatives apparently determined which electric field probes to use based on which probes "were available" and not based on which probes were right for the task. (At the same time, the 3531/02 probe is identified, as already noted above, as the one used for magnetic field measurements when that probe is for electric field measurements only.)

The likely effect of using the wrong electric field probe in 5 of the 12 schools is to understate the radiation levels measured in those schools, which may explain the following:

- For the Access Points, the 3 schools reported to have the lowest power density values in Table 7-2 of the AECOM Report[52] were measured with the wrong electric field probe, one that would tend to understate the radiation levels.

- For the Laptop Computers (Chromebooks), 3 of the 4 schools reported to have the lowest power density values in Table 7-3 of the AECOM Report[53] were measured with the wrong electric field probe, one that would tend to understate the radiation levels.

Concern 8: Improper use of electric and magnetic field probes for all measurements made at distances less than 4.7 inches from the source

As shown in Table 6-2, the probes were used for measurements at distances of 1 inch, 6 inches, 12 inches, 24 inches, and, occasionally, 36 inches from the Access Points and from the Laptop Computers (Chromebooks)[54]. The longest distance, of 36 inches, was included only if the AECOM Representatives judge

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[50] AECOM Report, Section 6.5, Equipment, Table 6-3, Electric Probes Used, page 6-5.
[51] AECOM Report, Section 6.5, Equipment, page 6-5.
[52] AECOM Report, Section 7.2.1.1, Access Points, Table 7-2, Access Point Analysis, pages 7-5 to 7-6.
[53] AECOM Report, Section 7.2.1.2, Chromebooks, Table 7-3, Chromebook Analysis, pages 7-8 to 7-9.
[54] AECOM Report, Table 6-2, Measurement Distances from APs [Access Points] and Chromebooks, page 6-1

that "noticeable levels were present" at that longer distance.[55] Those "noticeable levels" were not defined in the AECOM Report.

Narda, the manufacturer of the probes and the measurement instrument, indicates that the probes must be used at distances greater than one "probe diameter" from the source of the radiation. The diameters of all of the probes described in the AECOM Report are 120 millimeters (4.7 inches).[56] Specifically, that is true for the two models used for electric field measurements (Models 3501/03 and 3502/01) and the one model used for magnetic field measurements (mistakenly shown as the Model 3531/02, but believed to be the Model 3581/02, as described above). So all measurements of electric fields, and all measurements of magnetic fields, made at a distance of 1 inch are invalid because they are within one probe diameter (4.7 inches) of the source. The reason for this restriction is that a meaningful measurement cannot be made when the probe is positioned less than one probe diameter from the source, because the electromagnetic fields vary greatly over the dimensions of the probe itself.

DATA ANALYSIS CONCERNS

Background: AECOM's "Raw Data" in Appendix B (as illustrated here in Table D)

AECOM's Representatives measured the electric and magnetic fields at the selected MCPS schools in several steps. They connected selected probes to the measurement instrument and measured and recorded the electric and magnetic fields at distances of 1, 6, 12, 24, and occasionally 36 inches (as noted above), from one Access Point and from one Laptop Computer (Chromebook) in each designated classroom, or other designated room, in each designated school. There was one exception: In the Bell's Mills Elementary School, measurements were made in two rooms. An example of the type of data file produced by the measurement instrument is shown in Table D. The Beverly Farms Elementary School is, again, used as an example.

Table D: From AECOM Report Appendix B for Beverly Farms Elementary School, Room 252, Access Point, Electric Field, 12 Inches Distance

23,041 frequencies, spaced an equal 156,250 Hz apart and extending from 2.4 GHz to 6.0 GHz, which is 2,400,000,000 Hz to 6,000,000,000 Hz.

Frequency [Hz]	Electric Field [V/m] Sweep 1
2,400,000,000	0.0007530
2,400,156,250	0.0006410
2,400,312,500	0.0005083
•••	•••
•••	•••
6,000,000,000	0.0029140

Reference: AECOM Report, Appendix B, Raw Data, File 2015-06-08_Beverly Farms Elementary School, Room 252, access point, Electric, one foot, D-0151-00003_00001

23,041 measurements of the Electric Field, one attributable to each frequency segment

This table contains 23,041 rows of data, one row for each frequency at which the electric field was measured, so it is a very long table. Shown here are just the first three rows and the last row to illustrate the structure and some of the actual content of that file. No data analysis was done by the AECOM Representatives in this

[55] AECOM Report, Section 6.3, Monitoring Distances, Table 6-2, Measurement Distances from APs and Chromebooks, pages 6-2 to 6-2.
[56] Narda,SRM-3006 Selective Radiation Meter (Data Sheet), page 55 (http://narda-sts.us/pdf_files/DataSheets/SRM3006_DataSheet.pdf). The probe labeled "Three Axis E-Field (Supplied)"on the Data Sheet is the Model 3501/03. The other probes in the text above are labeled as they are on the Data Sheet.

file which appears in Appendix B, Raw Data. Note that the first few frequencies shown match those in Figure 2 on page 13, as they should.

In the actual tables in Appendix B, the title "Value [V/m]" is used at the top of the right column. Since that title is especially vague, I have substituted the title "Electric Field [V/m]" in Table D, and I have added the subtitle "Sweep 1" to facilitate tracking the data in that column to Table E.

Background: AECOM's "Analyzed Data" in Appendix C (as illustrated here in Table E)

AECOM's Representatives created the electronic files in Appendix C by aggregating related sets of sweeps together into individual files, as shown by the real example in Table E. There, the data from all of the 260 sweeps made of the Access Point at the Beverly Farms Elementary School, for measurement of the electric field at a distance of 12 inches, were assembled together. Each of these aggregated files contained the same number of rows of data as the files in Appendix B, 23,041, and the same number of columns as there are sweeps, 260.

Table E: From AECOM Report Appendix C for Beverly Farms Elementary School, Room 252, Access Point, Electric Field, 12 Inches Distance

Each of the 260 columns corresponds to a different sweep of the SRM-3006 and contains 23,041 measurements of the electric field, each measurement associated with one frequency segment.

Each of the 23,041 rows corresponds to one of 23,041 frequency segments, spaced 156,250 Hz apart. Together, the frequency segments, cover the frequency range from 2.4 GHz to 6 GHz, which is 2,400,000,000 Hz to 6,000,000,000 Hz. Each row contains 260 measurements of the electric field, all made of the same frequency segment, but on successive sweeps.

Frequency [Hz]	Electric Field [V/m]				
	Sweep 1	Sweep 2	•••	Sweep 260	Average
2,400,000,000	0.0007530	0.0005583	•••	0.0003828	0.0004737
2,400,156,250	0.0006410	0.0007083	•••	0.0006972	0.0004688
2,400,312,500	0.0005083	0.0006283	•••	0.0006994	0.0004587
•••	•••	•••	•••	•••	•••
•••	•••	•••	•••	•••	•••
6,000,000,000	0.0029140	0.0021860	•••	0.0016570	0.0027091
		Absolute Max		0.3169	
		Max Avg.			0.0206264

Reference: AECOM Report, Appendix C, Analyzed Data, Filename Gayle-Sarah Ault-Beverly Farms Elementary-Room 252 - access point-Electric-one foot.xlsx

Each value in this column is the average (the arithmetic mean) of all electric field values on the same row (that is, of all measurements of the electric field for the same frequency segment) from the "Sweep 1" column to the "Sweep 260" column.

The "Max Avg." is the largest of the average (arithmetic mean) values of the electric field in this "Average" column.

The "Absolute Max" is the single largest electric field value in any column, from Sweep 1 to Sweep 260, and in any row, and thus for any frequency segment.

In these aggregated files, the AECOM Representatives calculated three types of numbers, each marked by an arrow and an associated note in Table E:

- The average (arithmetic mean) of all electric field values measured at a given frequency from all 260 sweeps, which the AECOM Representatives placed in the "Average" column in Table E.

- The largest of those values in the "Average" column for any frequency, which the AECOM Representatives labeled the "Max Avg." and which, apparently, was intended to mean the maximum time average electric field, arising from the frequency segment associated with any single frequency.

- The single largest value of the electric field measured during any sweep and at any frequency, which the AECOM Representatives labeled "Absolute Max" and which apparently was intended to mean the

absolute maximum instantaneous electric field encountered over all 260 sweeps of all 23,041 frequencies.

Background: The radiation associated with one frequency segment cannot characterize the radiation throughout the frequency range of interest, 2.4 GHz to 6 GHz.

The AECOM Representatives employed several methods of analysis that contributed to Concerns 9, 10, and 11 that will be discussed below. Those methods had a common theme: the attempt to utilize the radiation associated with a single frequency segment, as a substitute for the radiation produced by all frequency segments in the frequency range of interest, 2.4 GHz to 6 GHz. That was true whether that radiation was produced by all sweeps of a given source of radiation (Concerns 9 and 10), or by a single sweep of the source of radiation (Concern 11). I describe the problem in general terms in this background section of this review and then apply that description to the three concerns.

Any person in the classrooms of the schools at the MCPS is exposed, simultaneously, to the radiation from all of the wireless sources at all frequencies at which those sources are operating, whether they are Access Points, Laptop Computers (Chromebooks), or other wireless devices that may be present.

But the measurement instrument, when operating in the Spectrum Analysis Mode used by the AECOM Representatives, can measure the radiation in only one frequency segment at a given time because each frequency segment is measured sequentially; that is, each is measured at a slightly different time. That is why the Spectrum Analysis Mode is recommended by the manufacturer for quasi-stationary signals, not for the pulsed type of signals being measured at the MCPS.[57] So, determining accurately two key quantities of interest here is a bit complicated: the root-mean-square time-average electric field, or the peak electric field. That is one reason why the measurement instrument offers multiple modes.

To illustrate this point further, see the data at the bottom of Table B on page 12 for the example of the Beverly Farms Elementary School, Room 252, Access Point, electric field, 12 inches distance. In Spectrum Analysis Mode, the measurement instrument moves very quickly from one measurement frequency to the next. In the process it spends only 0.045 milliseconds at each measurement frequency before moving to the next one. Thus, if the instrument visits each measurement frequency one time for each of 260 sweeps over a 6 minute period, then it spent a total time of only 11.8 milliseconds at each measurement frequency. That is a very short total time to develop a time-average value truly characteristic of what a person in a classroom experiences over the course of 6 minutes, let alone a day. It is for this reason, among others, that the measurement instrument provides several modes of operation, not just the Spectrum Analysis Mode.

Possible origin of the misunderstanding

I wondered if this misunderstanding could have been sourced in a misunderstanding of the thermally based exposure limits, like those of the Federal Communications Commission, that are discussed in the section "Thermally based exposure limits" that begins on page 39. These exposure limits are based on all of the radiation, at all frequencies, in the environment being tested. But those exposure limits are described by their supporting organizations as varying with frequency; that is, they are weighted according to frequency because some frequencies are more readily absorbed by the body than others. Fortunately, the FCC exposure limit [called the Maximum Permissible Exposure (MPE) Limit] has a single value, a power density of 1 mW/cm^2,

[57] Helmut Keller, Narda Safety Test Solutions, Principles and Applications of the Selective Radiation Meter SRM- 3000, Application Note AN_HF_1000_E_Principles SRM_2006-06, page 23 (2006). The SRM-3006 extends the top frequency of the SRM-3000 to 6 GHz. (Document not posted online.),

throughout the frequency range of interest here, 2.4 GHz o 6 GHz. That description has this meaning: If all of the radiation in the environment were present at a single frequency, the MPE is the highest value of the time-average power density that would be compliant with the MPE at that frequency. But that does not mean that the same stated exposure limit applies *simultaneously and independently* to each different incremental frequency. Here are two illustrations of the application of this fact in the classroom environment under consideration here, using, as an example once again, the Beverly Farms Elementary School, Room 252, Access Point, Electric Field, 12 Inches Distance:

> If the time-average power density, attributable to a given frequency segment and averaged over the maximum averaging time (such as 30 minutes), exceeds the exposure limit, then that exposure limit has been exceeded, no matter what contributions to the total time-average power density might be made by the other frequency segments in the frequency range of interest (2.4 GHz to 6 GHz), even if they are zero.
>
> If the time-average power density, attributable to a given frequency segment, as averaged over the maximum averaging time (such as 30 minutes), has not exceeded the exposure limit, that fact is insufficient to say that the exposure limit has not been exceeded over the frequency range of interest, even if the frequency segment selected has the highest time-average power density of any of the 23,041 frequency segments in the frequency range of interest.

Implications of the misunderstanding

Suppose that the thermally based exposure limits were applied independently to each frequency segment, and consider the implications. That would amount to no limit at all, because the size of the frequency segment is not a characteristic of the environment. Rather, it is determined entirely by the settings made to the measurement instrument. That is, the following situations would result:

> If those settings were changed to make the frequency segments smaller, so that more frequency segments could be fit into the frequency range of interest, then the total power density compliant with the exposure limit would increase.
>
> Conversely, if the settings were changed to make the frequency segments larger, so that fewer frequency segments could be fit into the frequency range of interest, then the total power density compliant with the exposure limit would decrease.

The result would be that a given electromagnetic environment could be found compliant or non-compliant based on the settings of the measurement instrument that affect the size of the frequency segment. In effect, there would be no meaningful exposure limit at all.

Concern 9: Incorrect method for determining the time-average electric field, as reflected in the "Average" electric field in Appendix C (as illustrated here in Table E)

As indicated above, the tables in Appendix C are illustrated here by Table E, where the "Average" electric field values appear in the column on the right. There are two aspects to the concern that arises there about the "Average" electric field values.

First, each of the values in the "Average" column of Table E is dependent on instrument settings that affect the size of the frequency segment. That fact alone assures that each value of the "Average" electric field is

not characteristic solely of the electromagnetic environment in the frequency range from 2.4 GHz to 6 GHz, as explained in the "Background" section above.

Second, the equations embedded in the tables in Appendix C indicate that the method used to calculate the values in the "Average" column is not correct for the purpose for which the AECOM representatives subsequently used those calculated values. Specifically, the AECOM Representatives use those calculated "Average" values to determine a value for a time-average power density, as explained below. But the power density is a function of the square of the electric field. For that reason, the AECOM representatives should have calculated the root-mean-square of the electric fields values in each row of Table E. Instead they calculated the arithmetic mean. The comparison below shows the difference between these two methods of calculation, using just three values of the electric field (E_1, E_2, and E_3) for simplicity, instead of the 260 values which would be needed to calculate the root mean square of each row of electric field values in Table E.

$$arithmetic\ mean\ of\ electric\ field\ values = \frac{E_1 + E_2 + E_3}{3}$$

$$root\ mean\ square\ of\ electric\ field\ values = \left[\frac{{E_1}^2 + {E_2}^2 + {E_3}^2}{3}\right]^{½}$$

Unfortunately, the use of the wrong method for calculating the "Average" electric field in Table E means that every time-average electric field value in the AECOM Report is invalid; and, therefore, so is every time-average power density value calculated from those invalid time-average electric field values. [The same mistake was made in calculating the time-average magnetic field values, which ultimately led to invalid "Avg H" values in Appendix D, which is illustrated in this review in Table G on page 26.]

The implication of the factors contributing to Concern 9 is that all of the "Average" electric field values in the AECOM Report are invalid for all measurements made of all of Access Points and all of Laptop Computers (Chromebooks) at all schools. Even so, I will continue to evaluate the downstream processes that the AECOM Representatives employed.

Concern 10: Incorrect method for determining the maximum time-average electric field, as reflected in the "Max Avg." electric field in Appendix C (as illustrated here in Table E)

The equations embedded in the tables in Appendix C also show the method that the AECOM Representatives used to determine what they call the "Max Avg." electric field from the "Average" electric field values. Again, the Beverly Farms Elementary School table from Appendix C is illustrated in Table E. The method used to determine the "Max Avg." electric field was to select the largest of the individual values in the "Average" column in Table E. Thereafter, the "Max Avg." is used as if it represents the highest time-average electric field produced under the test conditions. But this method cannot represent the time-average electric field present in the classroom because it is based on the contributions made by only one frequency segment, out of 23,041, even if that frequency segment in the largest single contributor in the frequency range of interest (2.4 to 6 GHz).

A better approach

The AECOM Representatives could have employed a different approach that would have been better, although still limited by the use of the Spectrum Analysis Mode. The measurement instrument contains an

internal function called "Integration over Frequency Band". [58] It will sum up (integrate) the contributions of the electric fields at all frequencies, that is, from all frequency segments in the frequency range of interest, 2.4 GHz to 6 GHz, and convert that summation to a time-average power density. In the process, that internal function applies a correction factor required to account for the relative sizes of the frequency segment and the step size. [59] That internal function is entirely different from the process that the AECOM Representatives employed here to calculate "Max Avg.". However, even if this internal function had been employed, the result obtained would reflect the limitations that are inherent in the use the Spectrum Analysis Mode to produce time-average values in pulsed fields where each frequency segment is visited so infrequently and so briefly over a total measurement time of 6 minutes. As noted above, the measurement instrument has other modes available.

Concern 11: Incorrect method for determining the maximum electric field, as reflected in "Absolute Max" electric field in Appendix C (as illustrated here in Table E).

Table E on page 20 also shows that the method used to determine the "Absolute Max" electric field is incorrect. This value was determined by selecting the highest value of the electric field found for any frequency segment (that is, at any measurement frequency) over the entire frequency range of interest, from 2.4 GHz to 6 GHz, and in any of the 260 sweeps made of that frequency range. That approach raises concerns which bear important similarities to those expressed above.

- The students in the classroom experience the combined radiation from all frequencies present, not just from one frequency segment. So selecting just one frequency segment from one sweep as the one of interest, even if it is the one with the highest electric field, does not guarantee that the true maximum electric field has been determined.

- In Spectrum Analysis Mode, the total time spent at each frequency segment is only 11.8 milliseconds out of 6 minutes as shown at the bottom of Table B on page 12. When measuring pulsed signals, like those produced by the Access Points and the Laptop Computers (Chromebooks), that means that the probability that the measurement instrument is measuring a given frequency segment just at the moment when the maximum electric field is occurring within that segment is very small. And, if the maximum electric field has contributions from frequencies that fall in more than one frequency segment, then the probability of capturing the maximum electric field is zero, since only one frequency segment is measured at a time in the Spectrum Analysis Mode. It is for this reason, among others, that the measurement instrument provides several modes of operation, not just the Spectrum Analysis Mode.

- When using a Three-Axis Antenna (Probe) in its isotropic (three-axis) mode, as used in the AECOM Report, the contributions of each axis are measured sequentially, not simultaneously, so the probability of capturing all of the components of the true maximum value is greatly reduced when measuring pulsed signals.

[58] Narda Safety Test Solutions, SRM-3006 Selective Radiation Meter: Operating Manual, Section 8.3.2, Integrating measured values (Integration), page 112.

[59] Helmut Keller, Narda Safety Test Solutions, Principles and Applications of the Selective Radiation Meter SRM-3000, Application Note AN_HF_1000_E_Principles SRM_2006-06, Equation 3.3.1, page 20 (2006). The SRM-3006 extends the top frequency of the SRM-3000 to 6 GHz (not posted online).

For these reasons, the "Absolute Max" values reported in Appendix C, and illustrated in Table E, are so unlikely to represent the true maximum electric field (often referred to as the "peak" value) that they must all be considered invalid.

Background: AECOM's "Data Analysis Summary" in Appendix D (as illustrated here in Table G)

The AECOM Representatives aggregated the most important calculated values from Appendix C into tables in Appendix D to prepare for further data analysis. One table was created in Appendix D for each school. As an example, the table created in Appendix D for the Beverly Farms Elementary School is shown here as Table G on page 26.

But as the AECOM Representatives moved data from Appendix C to Appendix D, they changed the terminology and the numeric notation that they employed. Table F will aid in tracking those changes for the electric field values.

Table F: Changes of Parameter Names and Numeric Notation for Data Moved from Appendix C to Appendix D for Beverly Farms Elementary School, Room 252, Access Point, Electric Field, 12 inches Distance

In Appendix C				In Appendix D			
Parameter Name	**Units of Measure**	**Numeric Notation[60]**	**Actual Example**	**Parameter Name**	**Units of Measure**	**Numeric Notation[61]**	**Actual Example[62]**
"Max Avg."	V/m	Number	0.0206264	"Avg E"	V/m	Scientific	2.06E-02
"Absolute Max"	V/m	Number	0.3169	"Max E"	V/m	Scientific	3.17E-01

Continuing with the Beverly Farms Elementary School as an example, the data transferred from Appendix C to Appendix D in the AECOM Report are circled in Table E on page 20. And the same data, arriving in Table G on page 26, after the changes made in Table F have been implemented, are similarly circled. All data on electric fields from Table E enter Table G through columns D ("Max E") and F ("Avg E"). From the data called "Max E" in column D of Table G, the AECOM Representatives calculated the "Max Power Density" in column E. Similarly, from the data called "Ave E" in column F of Table G, the AECOM Representatives calculated the "Avg Power Density" in column G.

Arrows in Table G point to four numbers. Each is the highest value (the "Max") in that column determined either for the Laptop Computer (Chromebook), or for the Access Point, for any distance from that named device for which a measurement was made. The inserted text boxes describe each such number further. The four numbers pointed to by the arrows were then transferred, one each, into four tables in the body of the AECOM Report. The first two of these tables, Table 7-2,[63] Table 7-3,[64]provide the basis for the conclusions drawn by the AECOM Report. The second two of these tables, Table 7-4[65] and Table 7-5,[66] were apparently meant as reinforcement of those conclusions. All four of these tables will be discussed further below.

[60] Appendix C was rendered in a Microsoft Excel compatible format (*.CSV), so Microsoft terminology for Numeric Notation were used here.
[61] Appendix C was rendered in a Microsoft Excel compatible format (*.CSV), so Microsoft terminology for Numeric Notation were used here.
[62] Data in Appendix D were rounded to three figures.
[63] AECOM Report, Section 7.2.1.1, Access Points, Table 7-2, page 7-5.
[64] AECOM Report, Section 7.2.1.2, Chromebooks, Table 7-3, page 7-8.
[65] AECOM Report, Section 7.2.2.1, Access Points, Table 7-4, page 7-11.
[66] AECOM Report, Section 7.2.2.2, Chromebooks, Table 7-5, page 7-12.

Table G: Data for Beverly Farms Elementary School, Room 252, from Appendix D

The largest of the "Max Power Density" values at each of four distances (1, 6, 12, and 24 inches) from the Chromebook, is deemed the "Maximum Instantaneous Power Density" for that Chromebook at the Beverly Farms Elementary School and is transferred to Table 7-5 on page 7-12 in the AECOM Report after changing units from 2.83E-05 mW/cm^2 to 2.83E-02 µW/cm^2 written as 2.83 x 10-2 µW/cm^2.

The largest of the "Avg Power Density" values, at each of four distances (1, 6, 12, and 24 inches) from the Chromebook, is deemed the "Maximum Average Power Density" for that Chromebook at the Beverly Farms Elementary School and is transferred to Table 7-3 on page 7-8 in the AECOM Report after changing units from 7.36E-06 mW/cm^2 to 7.36E-03 µW/cm^2 written as 7.36 x 10^{-3} µW/cm^2.

	A	B	C	D	E	F	G	H	I
1	**Room**	**Measurement Type**	**Distance (in)**	**Max E (V/m)**	**Max Power Density (mW/cm^2)**	**Avg E (V/m)**	**Avg Power Density (mW/cm^2)**	**Max H (A/m)**	**Avg H (A/m)**
2	252	Chrome Book	1	2.02E-01	1.08E-05	5.01E-02	6.65E-07	7.80E-02	2.70E-05
3	252	Chrome Book	6	1.51E-01	6.08E-06	8.40E-02	1.87E-06	5.57E-02	2.03E-05
4	252	Chrome Book	12	1.45E-01	5.61E-06	8.33E-02	1.84E-06	2.12E-01	7.20E-05
5	252	Chrome Book	24	3.27E-01	2.83E-05	1.67E-01	7.36E-06	4.95E-02	1.95E-05
6		Parking Lot	Background	6.15E-02	1.00E-06	2.58E-02	1.76E-07	6.21E-02	2.31E-05
7	252	Access Point	1	3.49E-01	3.23E-05	1.32E-02	4.60E-08	9.85E-03	4.64E-03
8	252	Access Point	6	2.58E-01	1.76E-05	1.28E-02	4.31E-08	1.10E-02	5.00E-03
9	252	Access Point	12	3.17E-01	2.66E-05	2.06E-02	1.13E-07	8.42E-03	4.56E-03
10	252	Access Point	24	6.08E-01	9.81E-05	3.07E-02	2.51E-07	9.18E-03	5.00E-03
11	252	Access Point	36	9.47E-01	2.38E-04	2.98E-02	2.35E-07		
12									
13			Maximums		2.38E-04		7.36E-06		
	Reference: AECOM Report, Appendix D, Data Analysis Summary, Beverly Farms Elementary School, page 6.								

The largest of the "Max Power Density" values, at each of five distances (1, 6, 12, 24, and 32 inches) from the Access Point, is deemed the "Maximum Instantaneous Power Density" for that Access Point at the Beverly Farms Elementary School and is transferred to Table 7-4 on page 7-11 in the AECOM Report after changing units from 2.38E-04 mW/cm^2 to 2.38E-01 µW/cm^2 written as 2.38 x 10^{-1} µW/cm^2.

The largest of the "Avg Power Density" values, at each of five distances (1, 6, 12, 24, and 36 inches) from the Access Point, is deemed the "Maximum Average Power Density" for that Access Point at the Beverly Farms Elementary School and is transferred to Table 7-2 on page 7-5 in the AECOM Report after changing units from 2.51E-07 mW/cm^2 to 2.51E-04 µW/cm^2 written as 2.51 x 10^{-4} µW/cm^2.

Concern 12: Incorrect method for determining the power density from the electric field for all measurements made at distances less than 9.8 inches from the source, affecting both "Max Power Density" and "Avg Power Density" in Appendix D (as illustrated here in Table G)

When radiation levels are compared to the exposure limits for human subjects at the frequencies of interest here, 2.4 to 6 GHz, that comparison is made in terms of the power density.[67] So the AECOM Representatives converted the electric field values they measured to power density levels. Power density reflects the power per unit area flowing through a surface perpendicular to the direction of travel of the radiation at a given location.

The equation, and associated text, on page 7-1 of the AECOM Report shows how the AECOM Representatives converted the electric field values they measured to power density values, as quoted here:

> "Note that all electric field measurements were collected in V/m. These measurements were then converted into power density using the following equation:
>
> $$PD = (E)^2/Z_o$$
>
> where
>
> P_D = Power Density, in W/m^2
> E = Electric field, in V/m
> Z_o = Characteristic impedance of free space, 377 Ohms"

Unfortunately, this equation is valid for use only in the "far field" of the source of the radiation where the electric field and the magnetic field assume a known relationship to each other that is implicit in the above equation. At distances closer to the source of the radiation than the onset of the far field, the relationship between the electric and magnetic fields is very complicated and is not reducible to such a simple equation.

The distance from the source (whether an Access Point or a Laptop Computer) to the beginning of the far field is dependent on the size of the largest dimension of the antenna of the source, compared to a wavelength. If the largest dimension of the antenna of the source is small (about ½ wavelength or less), the far-field begins about 2 wavelengths from the source. If the largest dimension of the antenna in the source is larger than ½ wavelength, then the far field begins even farther from the source; and that distance increases as the size of the largest dimension of the antenna of the source increases.

If we make the most forgiving assumption possible, that the largest dimensions of the antennas in the Access Points and in the Laptop Computers (Chromebooks) are ½ wavelength long or less, then consider the following reasoning:

- A distance of two wavelengths is 25 centimeters (9.8 inches) at 2.4 GHz, which is the low end of the frequency range scanned.
- A distance of two wavelengths is 10 centimeters (3.9 inches) at 6 GHz, which is the high end of the frequency range scanned.

[67] Federal Communications Commission, Office of Engineering & Technology, OET Bulletin 65, Edition 97-01, (August 1977), Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, Appendix A, Summary of RF Exposure Guidelines, Table 1. (B) Limits for general Population/Uncontrolled Exposure, Frequency Range (MHz), 1500-100,000, Power Density (S) 1.0 (mW/cm2). Page 67 (http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf).

- So the closest approach of the electric field probes to the source, in order for the power density formula to be valid throughout the frequency range scanned (2.4 to 6 GHz), is the longer of these two distances, or 25 centimeters (9.8 inches).

So the conversion that the AECOM Representatives made from electric field to power density is invalid for all measurements made at distances less than 9.8 inches, that is, for all measurements made at distances of 1 inch and 6 inches, whether for Access Points or Laptop Computers (Chromebooks). Unfortunately, it is these shortest distances that are likely to be the most important to health effects because radiation levels are generally higher closer to the source than farther from the source. So the closest, and thus the most important, of all of the reported power densities in the AECOM Report are the ones most assuredly invalid, based on this concern alone.

If the largest dimension of the antenna in the Access Points, or of the antenna in the Laptop Computers (Chromebooks), is greater than ½ wavelength, then the conversion that the AECOM Representatives made of the electric field values to power density values will be invalid at greater distances as well. But, since the AECOM Representatives did not report on the size of the antennas in the Access Points or in the Laptop Computers (Chromebooks), we cannot know at what greater distance the conversion from electric field to power density might be invalid.

Concern 13: "Maximum Average Power Density" is unknowable for all schools in Appendix D

As noted above, the AECOM Report focuses on the "Maximum Average Power Density" values determined for the Access Points and the Laptop Computers (Chromebooks) for each school as the principal outcome of the Report. The Report compares those values with the exposure limits of several organizations (the "Organizational Levels") to indicate whether the power density levels at the schools are compliant.

The "Maximum Average Power Density" is a maximum in this sense: It is the highest of the "Avg Power Density" values at a distance of 1, 6, 12, 24, and, if included, 36 inches, from the source, whether that source is an Access Point or a Laptop Computer (Chromebook), from Appendix D, as illustrated in Table G.

Unfortunately, if the value determined at any one of these distances is invalid for any reason, then the "Maximum Average Power Density" is unknowable. That is, if you want to say at what distance the "Avg Power Density" is a maximum, but you do not have valid determinations of the "Avg Power Density" at one or more of the distances to be considered, then you cannot say at what distance the maximum occurs or what value that maximum assumes, which is the present case.

Concern 14: "Maximum Instantaneous Power Density" is unknowable for all schools in Appendix D

As noted above, the AECOM Report offers values of the "Maximum Instantaneous Power Density" determined for the Access Points and the Laptop Computers (Chromebooks) for each school as the second most important outcome of the Report.

The "Maximum Instantaneous Power Density" is a maximum in this sense: It is the highest of the "Max Power Density" values at a distance of 1, 6, 12, 24, and, if included, 36 inches from a source, whether that source is an Access Point or a Laptop Computer (Chromebook), from Appendix D, as illustrated in Table G.

Unfortunately, if the value determined at any one of these distances is invalid for any reason, then the "Maximum Average Power Density" is unknowable, for the same reason just cited in Concern 13 above, which is the present case.

CONSEQUENCES OF THE CONCERNS FOR TABLES 7-2 AND 7-3 ("Maximum Average Power Density")

The consequences of the multiple concerns that affect the "Maximum Average Power Density" are summed up in the two tables that follow. Table H is for the Access Points and relates to Table 7-2[68] in the AECOM Report. Table I is for the Laptop Computers (Chromebooks) and relates to Table 7-3[69] in the AECOM Report.

Access Point Analysis

The first of the two tables, Table 7-2, purports to show the "Maximum Average Power Density" of the radiation coming from each of 11 Access Points in 10 schools. For the Bells Mill Elementary School, two different Access Points, each in a different room, were addressed (AP Rm 149, and AP Rm 223).

Table H on page 30 captures, for each classroom at each school, the "Maximum Average Power Density" values, from Table 7-2, and the distance for which that particular value was determined from Appendix D. Table H also shows, with checkmarks (✓), which of several concerns apply to a particular value of the "Maximum Average Power Density". These concerns are particularly serious, because the occurrence of any one of them is sufficient to make a given value of the "Maximum Average Power Density" invalid.

Note that all 11 reported values for the "Maximum Average Power Density" in Table H were judged invalid. Each gave rise to at least 3 concerns, and one gave rise to all 6 concerns.

Note that the "Maximum Average Power Density" was found to occur at five different distances from the Access Points for the different schools: 1, 6, 12, 24, and 36 inches. This variation may be explained in part by the multiple concerns that were applicable to each reported value. But other factors could have been in play as well, especially in a classroom setting where so many sources of radiation were in operation.

So, of the 11 values reported in Table 7-2 in the AECOM Report,[70] none can be known to represent what they are purported to be -- the "Maximum Average Power Density" -- at any of the distances at which the original measurements were made.

[68] AECOM Report, Section 7.2.1.1, Access Points, Table 7-2, Access Point Analysis, page 7-5.
[69] AECOM Report, Section 7.2.1.2, Chromebooks, Table 7-3, Chromebook Analysis, page 7-8.
[70] AECOM Report, Section 7.2.1.1, Access Points, Table 7-2, Access Point Analysis, page 7-5.

Table H: Access Point Analysis (relates to Table 7-2 in AECOM Report)

School	"Maximum Average Power Density" ($\mu W/cm^2$)	Distance of Probe from Access Point (inches)	Reported "Maximum Average Power Density" is invalid because . . .						Conclusion about "Maximum Average Power Density"
			Incorrect electric field probe used in 5 of 12 schools and thus 6 of 13 classrooms. Concern 7	Improper use of electric field probe at distances less than 4.7 inches. Concern 8	Incorrect method for determining time-average electric field as reflected in "Average" electric field in Appendix C. Concern 9	Incorrect method for determining maximum time-average electric field as reflected in "Max Avg." electric field in Appendix C. Concern 10	Incorrect method for determining power density from electric field data derived from measurements originally made at distances less than 9.8 inches in Appendix D. Concern 12	"Maximum Average Power Density" unknowable for all schools in Appendix D. Concern 13	
Wootton High School	1.24×10^{-4}	1	✓	✓	✓	✓	✓	✓	Invalid
Gaithersburg High School	1.27×10^{-5}	6	✓		✓	✓	✓	✓	Invalid
Cabin John Middle School	1.14×10^{-5}	36	✓		✓	✓		✓	Invalid
Churchill High School	9.72×10^{-4}	24	✓		✓	✓		✓	Invalid
Bells Mill Elementary School AP Rm 149	8.50×10^{-4}	36	✓		✓	✓		✓	Invalid
Bells Mill Elementary School AP Rm 223	1.40×10^{-4}	6	✓		✓	✓	✓	✓	Invalid
Fallsmead Elementary School	6.83×10^{-5}	36			✓	✓		✓	Invalid
Beverly Farms Elementary School	2.51×10^{-4}	24			✓	✓		✓	Invalid
Arcola Elementary School	3.62×10^{-3}	24			✓	✓		✓	invalid
Goshen Elementary School	7.37×10^{-4}	12			✓	✓		✓	invalid
Strawberry Knoll Elementary School	2.22×10^{-3}	1		✓	✓	✓	✓	✓	Invalid

Chromebook Analysis

The second of the two tables, Table 7-3, purports to show the "Maximum Average Power Density" of the radiation coming from each of 11 Laptop Computers (Chromebooks) in 10 schools. For the Bells Mill Elementary School, two different Laptop Computers (Chromebooks), each in a different room, were measured (AP Rm 149, and AP Rm 223).

Table I on page 32 captures for each classroom at each school the "Maximum Average Power Density" values from Table 7-3, and the distance at which that particular value was determined from Appendix D. For the Gaithersburg High School, the maximum value was incorrectly identified in Appendix D. That value has been crossed out, and the correct value has been substituted.

Table I also shows, with checkmarks (✓), which of several concerns apply to a particular value of the "Maximum Average Power Density". These concerns are particularly serious, because the occurrence of any one of them is sufficient to make a given value of the "Maximum Average Power Density" invalid.

Note that all of the 11 reported values for the "Maximum Average Power Density" in Table I were judged invalid. Each gave rise to at least 3 concerns, and three gave rise to all 6 concerns.

Note that the "Maximum Average Power Density" was found to occur at four different distances from the Laptop Computers (Chromebooks) at the different schools: 1, 6, 24, and 36 inches. This variation may be explained in part by the multiple concerns that were applicable to each reported value. But other factors could have been in play as well, especially in a classroom setting where so many sources of radiation were in operation.

So, of the 11 values reported in Table 7-3 in the AECOM Report,[71] none can be known to represent what they are purported to be --the "Maximum Average Power Density" -- at any of the distances at which the original measurements were made.

Conclusion about the Data Reported in Table 7-2 and Table 7-3

In conclusion, none of the 22 values reported as the "Maximum Average Power Density" in Table 7-2 and Table 7-3 in the AECOM Report are valid. As a result, there are NO valid "Maximum Average Power Density" values in those tables to compare with the exposure limits (referred to as "Organizational Levels" in the AECOM Report), even before considering the validity of the exposure limits themselves.

[71] AECOM Report, Section 7.2.1.2, Chromebooks, Table 7-3, Chromebook Analysis, page 7-8.

Table I: Laptop Computer (Chromebook) Analysis (relates to Table 7-3 in AECOM Report)

School	"Maximum Average Power Density" ($\mu W/cm^2$)	Distance of Probe from Chrome-book (inches)	Reported "Maximum Average Power Density" is invalid because . . .						Conclusion about "Maximum Average Power Density"
			Incorrect electric field probe used in 5 of 12 schools and thus 6 of 13 classrooms. Concern 7	Improper use of electric field probe at distances less than 4.7 inches. Concern 8	Incorrect method for determining time-average electric field as reflected in "Average" electric field in Appendix C. Concern 9	Incorrect method for determining maximum time-average electric field as reflected in "Max Avg." electric field in Appendix C. Concern 10	Incorrect method for determining power density from electric field data derived from measurements originally made at distances less than 9.8 inches in Appendix D. Concern 12	"Maximum Average Power Density" unknowable for all schools in Appendix D. Concern 13	
Wootton High School	1.54×10^{-3}	1	✓	✓	✓	✓	✓	✓	Invalid
Gaithersburg High School	3.51×10^{-5} ~~3.45×10^{-5}~~	36	✓		✓	✓		✓	Invalid
Cabin John Middle School	7.21×10^{-5}	1	✓	✓	✓	✓	✓	✓	Invalid
Churchill High School	1.79×10^{-3}	1	✓	✓	✓	✓	✓	✓	Invalid
Bells Mill Elementary School Rm 149	1.99×10^{-4}	36	✓		✓	✓		✓	Invalid
Bells Mill Elementary School Rm 223	3.44×10^{-3}	6	✓		✓	✓	✓	✓	Invalid
Fallsmead Elementary School	7.41×10^{-4}	1		✓	✓	✓	✓	✓	Invalid
Beverly Farms Elementary School	7.36×10^{-3}	24			✓	✓		✓	Invalid
Little Bennett Elementary School	1.21×10^{-3}	6			✓	✓	✓	✓	invalid
Arcola Elementary School	1.23×10^{-2}	1		✓	✓	✓	✓	✓	invalid
Strawberry Knoll Elementary School	7.70×10^{-4}	1		✓	✓	✓	✓	✓	Invalid

CONSEQUENCES OF THE CONCERNS FOR TABLES 7-4 AND 7-5 ("Maximum Instantaneous Power Density")

The consequences of multiple concerns for the "Maximum Instantaneous Power Density" are summed up in the two tables that follow. Table J is for the Access Points and relates to Table 7-4[72] in the AECOM Report. Table K is for the Laptop Computers (Chromebooks) and relates to Table 7-5[73] in the AECOM Report.

Access Point Analysis

The first of the two tables in the AECOM Report, Table 7-4, purports to show the "Maximum Instantaneous Power Density" of the radiation coming from each of 11 Access Points in 10 schools. For the Bells Mill Elementary School, two different Access Points, in different rooms, were addressed (AP Rm 149, and AP Rm 223).

Table J on page 34 captures for each classroom at each school the "Maximum Instantaneous Power Density" values from Table 7-4, and the distance at which that particular value was determined from Appendix D. However, the first two of those "Maximum Instantaneous Power Density" values, for Wootton High School and for Gaithersburg High School, were reported incorrectly. I have recovered the correct data from Appendix D, and have reflected those corrected data in Table J by crossing out the incorrect values and replacing them with the correct values.

Table J also shows, with checkmarks (✓), which of several concerns applies to a particular value of the "Maximum Instantaneous Power Density". These concerns are particularly serious because the occurrence of any one of them is sufficient to make a given value of the "Maximum Instantaneous Power Density" invalid.

Note that all 11 reported values for the "Maximum Instantaneous Power Density" in Table J were judged invalid. Each gave rise to at least 2 of these concerns, and one gave rise to all 5 of these concerns.

Note that the "Maximum Instantaneous Power Density" was found to occur at four different distances from the Access Points at the different schools: 1, 6, 24, and 36 inches. This variation may be explained in part by the multiple concerns that were applicable to each reported value. But other factors could have been in play as well, especially in a classroom setting where so many sources of radiation were in operation.

So, of the 11 values reported in Table 7-4 in the AECOM Report,[74] none can be known to represent what they are purported to be --the "Maximum Instantaneous Power Density" -- at any of the distances at which those measurements were made.

[72] AECOM Report, Section 7.2.2.1, Access Points, Table 7-4, Maximum Instantaneous Power Density from APs, page 7-11.
[73] AECOM Report, Section 7.2.2.2, Chromebooks, Table 7-5, Maximum Instantaneous Power Density from Chromebooks, page 7-12.
[74] AECOM Report, Section 7.2.2.1, Access Points, Table 7-4, Maximum Instantaneous Power Density from APs, page 7-11.

Table J: "Maximum Instantaneous Power Density" from APs (relates to Table 7-4 in AECOM Report)

School	"Maximum Instantaneous Power Density" ($\mu W/cm^2$)	Distance of Probe from Access Point (inches)	Reported "Maximum Instantaneous Power Density" is invalid because . . .					Conclusion about "Maximum Instantaneous Power Density"
			Incorrect electric field probe used in 5 of 12 schools and thus 6 of 13 classrooms. Concern 7	Improper use of electric field probe at distances less than 4.7 inches. Concern 8	Incorrect method for determining maximum electric field as reflected in "Absolute Max" electric field in Appendix C. Concern 11	Incorrect method for determining power density from electric field data derived from measurements originally made at distances less than 9.8 inches in Appendix D. Concern 12	"Maximum Instantaneous Power Density" unknowable for all schools in Appendix D. Concern 14	
Wootton High School	1.32×10^{-2} ~~1.95×10^{-2}~~	1, 6 (tied)	✓	(✓)[75]	✓	✓	✓	Invalid
Gaithersburg High School	1.95×10^{-2} ~~1.05×10^{-2}~~	24	✓		✓		✓	Invalid
Cabin John Middle School	2.67×10^{-2}	36	✓		✓		✓	Invalid
Churchill High School	2.45×10^{-1}	24	✓		✓		✓	Invalid
Bells Mill Elementary School AP Rm 149	7.50×10^{-2}	24	✓		✓		✓	Invalid
Bells Mill Elementary School AP Rm 223	1.65×10^{-2}	24	✓		✓		✓	Invalid
Fallsmead Elementary School	4.20×10^{-1}	36			✓		✓	Invalid
Beverly Farms Elementary School	2.38×10^{-1}	36			✓		✓	Invalid
Arcola Elementary School	5.69×10^{0} (= 5.69)	1		✓	✓	✓	✓	invalid
Goshen Elementary School	5.42×10^{-2}	24			✓		✓	invalid
Strawberry Knoll Elementary School	2.33×10^{0} (= 2.33)	1		✓	✓	✓	✓	Invalid

[75] Parentheses surround the checkmark, (✓), because Concern 8 applies to the measurement made at 1 inch from the Access Point at the Wooton High School, but to the measurement made at a distance of 6 inches from the Access Point at the Wootton High School.

Laptop Computer (Chromebook) Analysis

The second of the two tables, Table 7-5, purports to show the "Maximum Instantaneous Power Density" of the radiation coming from each of 11 Laptop Computers (Chromebooks) in 10 schools. For the Bells Mill Elementary School, two different Laptop Computers (Chromebooks), each in a different room, were measured (AP Rm 149, and AP Rm 223).

Table K on page 36 captures, for each classroom at each school, the "Maximum Average Power Density" values from Table 7-5, and the distance at which that particular value was determined from Appendix D. However, the first two of those "Maximum Instantaneous Power Density" values, for Wootton High School and for Gaithersburg High School, were reported incorrectly. I have recovered the correct data from Appendix D, as shown in Table J by crossing out the incorrect values and replacing them with the correct values.

Table K also shows, with checkmarks (✓), which of several concerns applies to a particular value of the "Maximum Instantaneous Power Density". These concerns are particularly serious, because the occurrence of any one of them is sufficient to make a given value of the "Maximum Instantaneous Power Density" invalid.

Note that all of the 11 reported values for the "Maximum Instantaneous Power Density" in Table K were judged invalid. Each gave rise to at least 2 concerns, and one gave rise to all 5 concerns.

Note that the "Maximum Instantaneous Power Density" was found to occur at four different distances from the Laptop Computers (Chromebooks) at the different schools: 1, 6, 12, and 24 inches. This variation may be explained in part by the multiple concerns that were applicable to each reported value. But other factors could have been in play as well, especially in a classroom setting where so many sources of radiation were in operation.

So, of the 11 values reported in Table 7-5 in the AECOM Report,[76] none can be known to represent what they are purported to be --the "Maximum Instantaneous Power Density" -- at any of the distances at which those measurements were made.

Conclusion about the Data Reported in Table 7-4 and Table 7-5

In conclusion, none 22 of the values reported as the "Maximum Instantaneous Power Density" in Tables 7-4 and 7-5 in the AECOM Report are valid. As a result, there are NO valid "Maximum Instantaneous Average Power Density" values in those tables to compare with the exposure limits (referred to as "Organizational Levels" in the AECOM Report), even before considering the validity of the exposure limits themselves.

[76] AECOM Report, Section 7.2.2.2, Chromebooks, Table 7-5, Maximum Instantaneous Power Density from Chromebooks, page 7-12.

Table K: "Maximum Instantaneous Power Density" from Chromebooks (relates to Table 7-5 in AECOM Report)

School	"Maximum Instantaneous Power Density" ($\mu W/cm^2$)	Distance of Probe from Chromebook (inches)	Reported "Maximum Instantaneous Power Density" is invalid because . . .					Conclusion about "Maximum Instantaneous Power Density"
			Incorrect electric field probe used in 5 of 12 schools and thus 6 of 13 classrooms. Concern 7	Improper use of electric field probe at distances less than 4.7 inches. Concern 8	Incorrect method for determining maximum electric field as reflected in "Absolute Max" electric field in Appendix C. Concern 11	Incorrect method for determining power density from electric field data derived from measurements originally made at distances less than 9.8 inches, in Appendix D. Concern 12	"Maximum Instantaneous Power Density" unknowable for all schools in Appendix D. Concern 14	
Wootton High School	1.36×10^{-1} ~~1.95×10^{-2}~~	6	✓		✓	✓	✓	Invalid
Gaithersburg High School	4.77×10^{-3} ~~1.36×10^{-1}~~	6	✓		✓	✓	✓	Invalid
Cabin John Middle School	4.01×10^{-3}	24	✓		✓		✓	Invalid
Churchill High School	1.26×10^{-2}	1	✓	✓	✓	✓	✓	Invalid
Bells Mill Elementary School Rm 149	2.10×10^{-2}	6	✓		✓	✓	✓	Invalid
Bells Mill Elementary School Rm 223	1.18×10^{-2}	6	✓		✓	✓	✓	Invalid
Fallsmead Elementary School	8.10×10^{-2}	6			✓	✓	✓	Invalid
Beverly Farms Elementary School	2.83×10^{-2}	24			✓		✓	Invalid
Little Bennett Elementary School	3.98×10^{-2}	12			✓		✓	invalid
Arcola Elementary School	7.92×10^{-2}	6			✓	✓	✓	invalid
Strawberry Knoll Elementary School	4.81×10^{-2}	1		✓	✓	✓	✓	Invalid

EXPOSURE LIMITS CONCERNS

Background: Exposure limits for comparison with the AECOM data

The AECOM Report compares the power density levels determined by the AECOM Representatives to the exposure limits, also expressed as power density levels, provided by several organizations. The AECOM Representatives refer to these exposure limits as "Organizational Levels" which reflects the origin of those exposure limits in different organizations. Those exposure limits are referred to by somewhat different names by their developing organizations and have somewhat different meanings. The purpose of the comparison was to indicate whether the power density levels found by the AECOM Representative present a health risk or not, and according to which of the exposure limits. Even though all of the power density levels found by the AECOM Representatives have been shown to be invalid, I continue anyway with this discussion of the exposure limits. My purpose is to show that there are challenges not only in making meaningful determinations of the radiation in a given environment but also in identifying meaningful exposure limits to use for comparison.

Five exposure limits from four organizations were addressed in the AECOM Report. One organization provided two of the exposure limits, one replacing the other as more was learned from new research by the international biomedical research community. The five exposure limits fall into two categories: (1) three thermally based levels; and (2) two biologically based levels. The thermally based levels reflect the harm that radiation does by heating body tissue, that is, by "thermal" effects even for relatively short periods of time. In contrast, the biologically based levels reflect the harm that radiation does by any mechanism, whether thermal or non-thermal, particularly when the exposure is "chronic", that is, when it continues for long periods of time.

Table L on page 38 shows the exposure limits currently recommended by each of the four principal organizations mentioned in the AECOM Report. (One historical limit is also shown for comparison, as is explained below.) The information in Table L is drawn directly from documentation of those organizations, not from the AECOM Report, because there are several errors in the representation of those levels in the AECOM Report. The extensive footnotes point to the source documents.

Table L applies only to the frequency range of interest in the AECOM Report (2.4 GHz to 6 GHz). Each of the recommended exposure limits is expressed as a power density, that is, as the power per unit area passing through a surface perpendicular to the direction of travel of the radiation. However, each power density is expressed equivalently in four different sets of units to facilitate comparison with the data in different parts of the AECOM Report and in other documents. The two most important units of measure for comparison with values in the AECOM Report are milliwatts per square centimeter (mW/cm^2) and microwatts per square centimeter ($\mu W/cm^2$). The two other units of measure are nanowatts per square centimeter (nW/cm^2) and watts per square meter (W/m^2). Conversion factors are shown at the bottom of Table L.

Table L also shows the span of years for which each recommended exposure limit has been, or is currently, applicable. Updates to the exposure limits of a given organization that did not change the exposure limits for the frequency range of interest here (2.4 GHz to 6 GHz) are not reflected. Note that, for the FCC, the path to the adoption of the exposure limit shown, as an official FCC guideline, is complicated, involving many organizations over many years, and can better be explored through the reference in Footnote 77. (The footnotes for Table L begin on page 38 and continue on the following page because of the limitations of space on the page 38 where the table appears.)

Table L: Exposure Limits for 2.4 GHz to 6 GHz

Basis	Organization	Exposure Limits Expressed as Power Density (in equivalent units)				Maximum Averaging Time	Years of Applicability	Description of Exposure Limits
		mW/cm^2	$\mu W/cm^2$	nW/cm^2	W/m^2	minutes		
Thermal	Federal Communications Commission (FCC)	1	1000	1,000,000	10	30	1996[77] to present,[78] but based on NCRP limits of 1986[79]	"Limits for Maximum Permissible Exposure (MPE)" for "General Population/Uncontrolled Exposure"[78] (time-averaged)
Thermal	International Commission on Non-Ionizing Radiation Protection (ICNIRP)	1	1000	1,000,000	10	6	1998[80] to present[81,82]	"Reference levels for general public exposure to time-varying electric and magnetic fields (unperturbed rms values)"[80] (time averaged)
Thermal	Institute of Electronic and Electrical Engineers (IEEE)	1	1000	1,000,000	10	30-25[83]	2005[84] to present[85]	"Action level (MPE for the general public when an RF safety program is unavailable)"[84] (time-averaged)
Biological	BioInitiative Report 2007	0.0001	0.1	100	0.001	(none) chronic exposure	2007 to 2012[86]	Precautionary Action Level based on chronic exposure to pulsed radiofrequency radiation
Biological	BioInitiative Report 2012	0.0000003-0.0000006	0.0003-0.0006	0.3-0.6	0.000003-0.000006	(none) chronic exposure	2012 to present[86]	Precautionary Action Level based on chronic exposure to pulsed radiofrequency radiation
Conversion Factors								
$1\ W/m^2 = 0.1\ mW/cm^2$					$1\ mW/cm^2 = 1000\ \mu W/cm^2$			
$1\ W/m^2 = 100\ \mu W/cm^2$					$1\ \mu W/cm^2 = 1000\ nW/cm^2$			

[77] Federal Communications Commission, Office Engineering & Technology, Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, OET Bulletin 65, Edition 97-01, page 65 (August 1997). See first paragraph under heading "FCC Guidelines for Evaluating Exposure to RF Emissions" (http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf).

[78] FCC, Electronic Code of Federal Regulations; Title 47, Telecommunications; Subchapter A; Part 1, Practice and Procedure; Subpart I, Procedures Implementing the National Environmental Policy Act of 1969; §1.1310, Radiofrequency radiation exposure limits; Table 1, Limits for Maximum Permissible Exposure; Part (B), Limits for General Population, Uncontrolled Exposure; Frequency range (MHz): 1,500 to 100,000 (http://www.ecfr.gov/cgi-bin/text-idx?SID=121340a258bfa53768f89497ff4ef876&mc=true&node=se47.1.1_11310&rgn=div8).

[79] Originally promulgated in NCRP (National Council on Radiation Protection and Measurements) Report No. 86: Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields, Recommendations of the National Council on Radiation, April 2, 1986. See the applicable frequency range in Figure 17.2, Criteria for Exposure to RFEM fields, on page 280. Report No. 86 is sold by the NCRP for $56 in downloadable PDF format (http://www.ncrppublications.org/Reports/086). For further information see Federal Communications Commission, Office Engineering & Technology, Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, OET Bulletin 65, Edition 97-01, page 7 and footnote 6 on that page (August 1997) (http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf).

[80] ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (Up to 300 GHz), Table 7, Reference levels for general public exposure to time-varying electric and magnetic fields (unperturbed rms values) and footnote 3 to that table, as published in Health Physics 74(4), page 511 (1998) (http://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf).

[81] As of 2009, ICNIRP stated: "Therefore, ICNIRP reconfirms the 1998 basic restrictions in the frequency range 100 kHz–300 GHz until further notice." ICNIRP Statement on the "Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (Up to 300 GHz), as published in Health Physics 97(3), page 257 (2009) (http://www.icnirp.org/cms/upload/publications/ICNIRPStatementEMF.pdf).

[82] ICNIRP has not issued a revision of its exposure guidelines from 2009 to the present, making the original guidelines issued in 1998 still the current ones (http://www.icnirp.org/en/publications/article/hf-review-2009.html).

[83] 30 minutes from 2.4 GHz to 5.0 GHz, 25 minutes at 6.0 GHz, and governed by the formula $150/f_G$ from 5.0 GHz to 6.0 GHz, where f_G is the frequency in GHz. See reference in footnote 84.

[84] IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, IEEE Std C95.1™-2005 (Revision of IEEE Std C95.1-1991), Table 9, Action level (MPE for the general public when an RF safety program is unavailable), page 25 (19 April 2006) (http://standards.ieee.org/findstds/standard/C95.1-2005.html).

[85] IEEE C95.1-2005 is listed with the "Status" of "Active Standard" by IEEE, indicating that it is still the current standard at the present time (http://standards.ieee.org/findstds/standard/C95.1-2005.html).

[86] BioInitiative Working Group, Cindy Sage and David O. Carpenter, Editors, BioInitiative Report: A Rationale for Biologically-based Public Exposure Standards for Electromagnetic Radiation, December 31, 2012 (http://www.bioinitiative.org).

Thermally based exposure limits

The thermally based exposure limits come from the following three organizations:

- Federal Communications Commission, an independent agency of the U.S. Government founded in 1934.[87]
- Institute of Electrical and Electronics Engineers (IEEE), a U.S. professional association for electrical and electronic engineers, founded in 1963[88] by the merger of earlier organizations
- International Commission on Non-Ionizing Radiation Protection (ICNIRP), which is an "independent non profit scientific organization chartered in Germany." ICNIRP was founded in 1992.[89]

Of these three organizations, the most important one for the United States is the Federal Communications Commission (FCC), as an independent agency of the U.S. Government. The FCC sets several types of exposure limits. The one invoked in the AECOM Report is the FCC Maximum Permissible Exposure (MPE) Limit, so I will focus on that one here.

The FCC continues to define two categories of Maximum Permissible Exposure (MPE) Limits as follows:

- "Occupational/controlled exposure limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure." [90]

- "General population/uncontrolled exposure limits apply in situations in which the general public may be exposed, or in which persons who are exposed as a consequence of their employment may not be fully aware of the potential for exposure or cannot exercise control over their exposure." [91]

According to the FCC, the category applicable to the Wi-Fi systems in schools is the "General Population/Uncontrolled Exposure"; so the data from that category are included in Table L. The analogous categories from the ICNIRP and the IEEE, with the specific names that apply to them, are also shown in Table L.

The thermally based limits have not changed much over time. According to the FCC, the current FCC Maximum Permissible Exposure (MPE) Limits are based primarily on a 1986 publication of the National Council on Radiation Protection and Measurements (NCRP):[92, 93] "Report No. 86 - Biological Effects and Exposure

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[87] Federal Communications Commission, About the FCC (https://www.fcc.gov/consumers/guides/about-fcc).
[88] Institute of Electrical and Electronics Engineers, History of the IEEE, The societies converge and merge (http://www.ieee.org/about/ieee_history.html).
[89] International Commission on Non-Ionizing Radiation Protection, Wikipedia (https://en.wikipedia.org/wiki/International_Commission_on_Non-Ionizing_Radiation_Protection).
[90] Electronic Code of Federal Regulations, Title 47, Chapter I, Subchapter A, Part 1, §1.310, dated January 6, 2016 (http://www.ecfr.gov/cgi-bin/text-idx?SID=a0b1a8235d32fe7176edd9706e8a2712&mc=true&node=se47.1.1_11310&rgn=div8).
[91] Electronic Code of Federal Regulations, Title 47, Chapter I, Subchapter A, Part 1, §1.310, dated January 6, 2016. (http://www.ecfr.gov/cgi-bin/text-idx?SID=a0b1a8235d32fe7176edd9706e8a2712&mc=true&node=se47.1.1_11310&rgn=div8).
[92] NCRP (National Council on Radiation Protection and Measurements) Report No. 86: Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields, Recommendations of the National Council on Radiation, April 2, 1986. See the applicable frequency range in Figure 17.2, Criteria for Exposure to RFEM fields, on page 280. Report No. 86 is sold by the NCRP for $56 in downloadable PDF format (http://www.ncrppublications.org/Reports/086). For further information see Federal Communications Commission, Office Engineering & Technology, Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, OET Bulletin 65, Edition 97-01, page 7 and footnote 6 on that page (August 1997).
[93] The National Council on Radiation Protection and Measurements has this history: (1) in 1929, formed as the U.S. Advisory Committee on X Ray and Radium Protection; (2) in 1946, renamed as the National Committee on Radiation Protection and Measurements; (3) in 1964, chartered by the U.S. Congress and renamed as the National Council on Radiation Protection and Measurements (https://en.wikipedia.org/wiki/National_Council_on_Radiation_Protection_and_Measurements).

Criteria for Radiofrequency Electromagnetic Fields".[94] That document is now 30 years old, and the current FCC exposure limits for the frequency range of interest here (2.4 GHz to 6 GHz) are the same as in that document, so those limits are also 30 years old. The current ICNIRP and the IEEE limits have also changed little over time, and the limits of all three organizations have largely converged over the years. In fact, as shown in Table L, the power density levels, for the frequency range of interest here (2.4 GHz to 6 GHz), are the same for all three organizations. The difference is that the averaging time for the power density is 6 minutes for the ICNIRP but 30 minutes for the FCC and 30-25[95] minutes for the IEEE. The averaging time is the maximum time over which the power density may be averaged to determine if it complies with the exposure limit. Averaging enables times when the power density is above the exposure limit to be offset by times when the power density is below the exposure limit. Averaging facilitates achieving compliance even when power density levels are far above the exposure limit but for an adequately short period of time. The longer the averaging time, the more forgiveness is provided for periods of time above the exposure limit.

Concern 15: Incorrectly stated thermal exposure limits

The three thermal exposure limits (FCC, IEEE, and ICNIRP) are stated correctly, as 1000 μW/cm^2, in the AECOM Report where they are first introduced.[96] But, strangely, those thermal limits are stated incorrectly, as 10,000 μW/cm^2, when they are compared with the analyzed data on the schools. Here are the specifics:

- In Tables 7-2 and 7-3, where the principal findings of the AECOM Report are shown, the IEEE and the ICNIRP exposure limits are stated explicitly and incorrectly as 10,000 μW/cm^2.[97] Oddly, the FCC exposure limit is not included in those tables, even though it is the only exposure limit from a U.S. Government agency.

- In the text accompanying Tables 7-2 and 7-3, the FCC exposure limit is stated implicitly and again incorrectly, as 10,000 μW/cm^2, by comparison to the IEEE exposure limit in this statement: "Note that the only regulatory agency in the United States for RF exposure is the FCC, which has adopted the IEEE MPE standard in the table above."[98]

- In Figures 7-3 and 7-4, which compare the analyzed data from the schools to the exposure limits ("Organizational Levels") in graphical form, the IEEE exposure limit is again shown incorrectly as 10,000 μW/cm^2. The ICNIRP exposure limit is included in the key for both figures but does not appear explicitly in the figures, presumably because it is covered up by the IEEE limit, and thus appears, at best, implicitly and incorrectly, in both figures as 10,000 μW/cm^2.[99] Oddly, the FCC exposure limit does not appear at all in either of the two figures.

The correct thermal exposure limits of all three of these organizations (1000 μW/cm^2) are very high and thus are very permissive, even if they are factor of 10 below the incorrectly stated thermal exposure limits (10,000 μW/cm^2) in the AECOM Report.

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[94] NCRP Report No. 86: Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields, Recommendations of the National Council on Radiation, April 2, 1986. See the applicable frequency range in Figure 17.2, Criteria for Exposure to RFEM fields, on page 280.
[95] See Footnote 83 for an explanation of this range of times. This document is sold by the NCRP for $56 in downloadable PDF form (http://www.ncrppublications.org/Reports/086).
[96] AECOM Report, Section 3.1, State and National, pages 3-2 to 3-3.
[97] AECOM Report, Section 7.2.1.1, Access Points, Table 7-2, Access Point Analysis, page 7-5.
AECOM Report, Section 7.2.1.2, Chromebooks, Table 7-3, Chromebook Analysis, page 7-8.
[98] AECOM Report, Section 7.2.1.1, Access Points, page 7-6, and AECOM Report, Section 7.2.1.2, Chromebooks, page 7-9.
[99] AECOM Report, Section 7.2.1.1, Access Points, Figure 7-3, Comparison of Access Point Values to Organizational Values, page 7-7.
AECOM Report, Section 7.2.1.2, Chromebooks, Figure 7-4, Comparison of Tablet Values to Organizational Levels, page 7-10.

Expressed concerns about the outdated and overly permissive thermal exposure limits

Agencies of the U.S. Government and medical organizations have expressed concern that the thermal limits are outdated and need to be updated to provide adequate protection of human beings, especially children, and other living things. Here is just a sampling of those views.

U.S. Environmental Protection Agency

The limitations of the thermal exposure limits of the FCC, the IEEE, and the ICNIRP, were described by the Environmental Protection Agency (EPA) in 2002 as follows:[100]

> "The FCC's current exposure guidelines, as well as those of the Institute of Electrical and Electronics Engineers (IEEE) and the International Commission on Non-ionizing Radiation Protection [ICNIRP], are thermally based, and do not apply to chronic, nonthermal exposure situations…. The FCC's exposure guideline is considered protective of effects arising from a thermal mechanism but not from all possible mechanisms. Therefore, the generalization by many that the guidelines protect human beings from harm by any or all mechanisms is not justified."
>
> "Federal health and safety agencies have not yet developed policies concerning possible risk from long-term, nonthermal exposures. When developing exposure standards for other physical agents such as toxic substances, health risk uncertainties, with emphasis given to sensitive populations, are often considered. Incorporating information on exposure scenarios involving repeated short duration/nonthermal exposures that may continue over very long periods of time (years), with an exposed population that includes children, the elderly, and people with various debilitating physical and medical conditions, could be beneficial in delineating appropriate protective exposure guidelines."

So, the EPA explains above the following: (1) the FCC thermal exposure guidelines do NOT protect against all harm, only the harm caused by too much heating; (2) the FCC thermal exposure guidelines do not apply to "chronic, nonthermal exposure", which is the type of exposure generated by the Access Points and Laptop Computers (Chromebooks) at the MCPS; and (3) when new FCC guidelines are developed for chronic nonthermal exposures, they must accommodate "children", among other high risk groups because those groups are not accommodated now.

U.S. Department of the Interior

The limitations of the FCC thermal exposure guidelines were described in a totally different way by the U.S. Department of the Interior (Fish and Wildlife Service) in 2014. The Interior Department was motivated principally by multiple adverse effects of radiation on the health, and the life, of birds, particularly in connection with cell towers. [101] [Cell towers, of course, are increasingly being placed on school grounds.]

> "However, the electromagnetic radiation standards used by the Federal Communications Commission (FCC) continue to be based on thermal heating, a criterion now nearly 30 years out of date and inapplicable today."

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[100] Letter from Frank Marcinowski, Director, Radiation Protection Division, EPA, and Norbert Hankin, Center for Science and Risk Assessment, Radiation Protection Division, EPA, to Janet Newton, President, the EMR Network, with copies to the FCC and the IEEE, and dated July 16, 2002. (http://www.emrpolicy.org/litigation/case_law/docs/noi_epa_response.pdf).

[101] Letter from Willie R. Taylor, Director, Office of Environmental Policy and Compliance, Office of the Secretary, United States Department of the Interior to Mr. Eli Veenendaal National Telecommunications and Information Administration U.S. Department of Commerce, dated February 7, 2014 (https://www.ntia.doc.gov/files/ntia/us_doi_comments.pdf).

American Academy of Environmental Medicine

The American Academy of Environmental Medicine (AAEM), which trains physicians in preparation for Board Certification in Environmental Medicine, states the following:

> "The AAEM strongly supports the use of wired Internet connections, and encourages avoidance of radiofrequency such as from WiFi, cellular and mobile phones and towers, and 'smart meters'."
>
> "The peer reviewed, scientific literature demonstrates the correlation between RF *[radiofrequency]* exposure and neurological, cardiac, and pulmonary disease as well as reproductive and developmental disorders, immune dysfunction, cancer and other health conditions. The evidence is irrefutable."
>
> "To install WiFi in schools plus public spaces risks a widespread public health hazard that the medical system is not yet prepared to address."[102]

American Academy of Pediatrics

The American Academy of Pediatrics (AAP), whose 60,000 doctors care for our children, supports the development of more restrictive standards for radiofrequency radiation exposure that would better protect the public, particularly the children. The AAP, in a letter to the Federal Communications Commission (FCC) and the Food and Drug Administration (FDA), dated August 29, 2013, states that the following:

> "Children are not little adults and are disproportionately impacted by all environmental exposures, including cell phone radiation. Current FCC standards do not account for the unique vulnerability and use patterns specific to pregnant women and children. It is essential that any new standard for cell phones or other wireless devices be based on protecting the youngest and most vulnerable populations to ensure they are safeguarded throughout their lifetimes."[103]

The reference to "other wireless devices" above includes, of course, Wi-Fi.

Thermally based exposure limits survive by dismissing decades of the world's research on the biological effects of electromagnetic fields.

Unfortunately, all three of the organizations that are still promulgating thermally based exposure limits (FCC, IEEE, and ICNIRP) have rejected virtually *all* of the research conducted worldwide in the past 30 years as persuasive of a need for *any* significant change in either the level of the exposure limits or their thermal-only basis.

Since the thermal basis for exposure limits was established in 1986, a world of new wireless products has emerged, employing digital radiofrequency/microwave technology. And the radiation that these microwave wireless products are emitting into the environment has grown exponentially, raising concerns about adverse health effects. In response, the international biomedical research community has published thousands of papers in biomedical research journals that have contributed to our understanding of those health effects.

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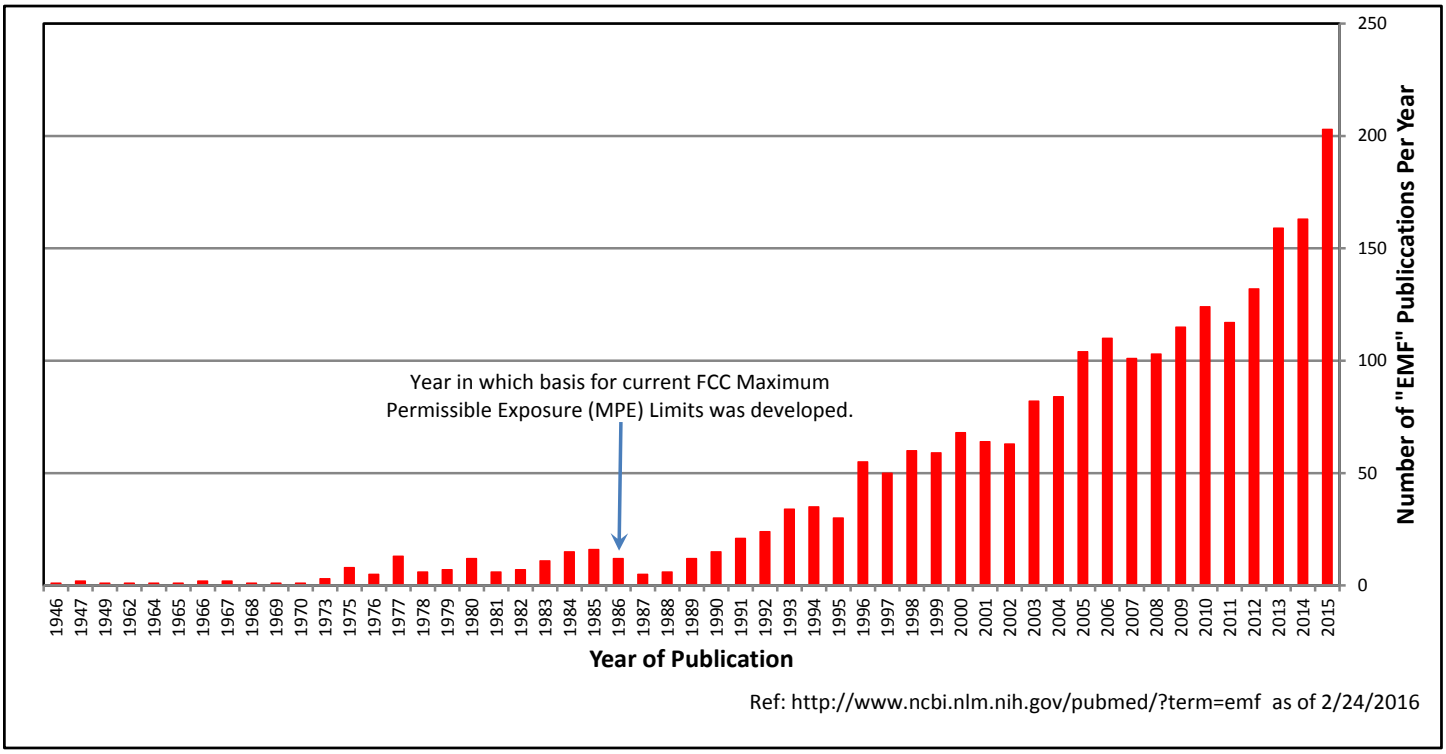
[102] American Academy of Environmental Medicine, Wireless Radiofrequency Radiation in Schools, November 14, 2013 (http://www.aaemonline.org/pdf/WiredSchools.pdf).

[103] American Academy of Pediatrics, letter dated August 29, 2013 addressed to The Honorable Mignon L. Clyburn, Acting Commissioner Federal Communications Commission and The Honorable Dr. Margaret A. Hamburg, Commissioner, U.S. Food and Drug Administration (http://apps.fcc.gov/ecfs/document/view?id=7520941318).

Many of those health effects have been found to occur at levels of radiation many orders of magnitude (many factors of 10) below the thermal levels that have been the focus of interest in the past.

That growth in the biomedical research literature is illustrated in Figure 3. The figure was created automatically by PubMed to show the number of biomedical research publications found using "EMF" (electromagnetic fields) as the search term. PubMed[104] is maintained by the National Institutes of Health and is the world's most comprehensive index to the biomedical research literature. Figure 3 indicates the number of biomedical research publications published in each year from 1946 to 2015 under the heading "EMF".

Figure 3: Number of EMF Publications per Year Listed by NIH's PubMed Database



The data for this figure indicate the following:

- In 1986, when the basis for the current FCC thermally based exposure limits was developed, there were 135 publications in the PubMed index addressing "EMF" for the period 1946 to 1986.
- Since then, that is, for the years 1987 through 2015, an additional 2198 publications have been added to the PubMed index, representing 94 percent of all of the publications addressing "EMF" since 1946.
- In just the last three years of 2013, 2014, and 2015, a total of 525 papers addressing "EMF" have been published, representing 23 percent of all papers published since 1946.
- And in the most recent year that is now fully indexed, 2015, the number of publications addressing "EMF" shows a striking 25 percent increase relative to the preceding year of 2014, reflecting a significant increase in the focus of the international biomedical research community on the relationship between "EMF" (electromagnetic fields) and health.

It seems reasonable to suspect that something important enough to cause a significant change in the thermally based exposure limits has been learned since 1986. But the FCC, the IEEE, and the ICNIRP have, in

[104] PubMed, National Institutes of Health (http://www.ncbi.nlm.nih.gov/pubmed).

effect, found *all* of those publications insufficient to justify any significant change in the thermally based exposure limits under discussion here (those applicable to the frequency range 2.4 GHz to 6 GHz).

As noted above, the publications in Figure 3 were found in NIH's PubMed with just a single search term, "EMF". It would take many such search terms to capture *all* of the publications of relevance to the biological effects of electromagnetic fields, so there will be many more publications of relevance than those shown in Figure 3. The purpose here is to show the rate of growth for a readily definable segment of the international biomedical research literature on the effects of electromagnetic fields on health.

Can we expect change in the thermally based exposure limits of the FCC in the near future?

In a word: No. The reason is that the FCC is too tightly controlled by the wireless industry that it is supposed to regulate.

The FCC has acted in partnership with the wireless industries by permitting wireless radiation levels far higher than the biomedical research literature indicates are causing biological effects. The success of the wireless industries in capturing the FCC, the committees in the U.S. Congress that oversee the FCC, and the Executive Branch is detailed in a new monograph from the Center for Ethics at Harvard University. [105] As an example of that capture, the President recently appointed, as head of the FCC, the former head of the CTIA - The Wireless Association, which is the major lobbying organization for the wireless industry. This, of course, is the infamous "revolving door".

The implication is this: If the MCPS wants to protect its students, teachers, and staff from exposure to harmful levels of electromagnetic fields, it will have to act on its own. The good news is that the MCPS *can do so*.

Biologically based exposure limits

In contrast to the above three organizations (FCC, IEEE, and INCIRP) that have been setting thermally based exposure limits, another organization, The BioInitiative Working Group recommends "biologically based" exposure limits. The biologically based limits consider all biological effects, no matter what level of radiation has produced them. The biologically based exposure limits are informed by *all* of the international biomedical research literature published up to the time that each supporting analysis was conducted by the BioInitiative Working Group.

Two such analyses have been produced so far, one in 2007 (BioInitiative Report of 2007) and one in 2012 (BioInitiative Report of 2012). The latter is the most recent of the most comprehensive analyses of the biological effects associated with exposure to electromagnetic fields. That analysis was prepared by 29 experts from 10 countries around the world, heavy in Ph.D.s and M.D.s, with the largest contingent (10) from the United States. The biologically based exposure limits recommended in these two documents are included in Table L on page 38. Those exposure limits are described as "Precautionary Action Level based on chronic exposure to pulsed radiofrequency signals". The use of the word "precautionary" is intended to reflect the fact that enough information has been learned that we should act, on a precautionary basis, to lower radiation levels whenever they exceed the "Precautionary Action Level". That does not mean that everything has been learned that would be desirable to know. Rather, it means that enough has been learned to justify taking precautionary action *now*, especially when so many people are potentially affected in such a multitude of

[105] Norm Alster, Captured Agency: How the Federal Communications Commission is Dominated by the Industries It Presumably Regulates (2015) (http://ethics.harvard.edu/news/new-e-books-edmond-j-safra-research-lab).

ways. The BioInitiative Report of 2012 leaves the door open to future changes in the Precautionary Action Level as more is learned by the international biomedical research community.

Comparing exposure limits to each other

It is instructive to compare the exposure limits in Table L. But note that the limits are not strictly comparable. For example, the ICNIRP limit reflects the power density time averaged over an interval as long as 6 minutes. But the FCC and IEEE limits reflect the power density time averaged over much longer time intervals, as long as 30 minutes. Longer averaging times permit exposure to higher peak levels, because there is more time available for exposure at lower levels to pull down the time-average exposure.

The biologically based Precautionary Action Levels are specifically for "chronic exposure to pulsed RFR [radiofrequency radiation]." [106] ("Chronic" means continuing for long periods of time, not just for periods of 6 minutes or 30 minutes.) Chronic exposure to pulsed radiofrequency radiation is the type of exposure that students, teachers, and staff experience at the MCPS schools when exposed to wireless signals from Access Points and Laptop Computers (Chromebooks), every school day for years. Hence, the Precautionary Action Levels are particularly important for the MCPS population considered here.

Although the biologically based exposure limits are expressed in a manner that is not entirely comparable to the thermally based exposure limits, the biologically based exposure limits are so much lower that the difference is worth noting. And the exposure limits in the BioInitiative Report of 2012 are very much lower than the exposure limits in the BioInitiative Report of 2007. That difference reflects the fact that the BioInitiative Working Group is continually learning from the new biomedical research literature being published, and much was learned from the literature published in the five years that passed between the issuance of these two reports. As stated in the BioInitiative Report of 2012:

> "Roughly, 1800 new studies have been published in the last five years [that is, since the publication of the BioInitiative Report of 2007] reporting effects at exposure levels ten to hundreds or thousands of times lower than allowed under safety limits in most countries of the world. Yet, no government has instituted comprehensive reforms." [107]

Specifically, the BioInitiative Report of 2007 recommended a Precautionary Action Level of 0.1 $\mu W/cm^2$ for chronic exposure to pulsed radiofrequency radiation.[108] The 1800 new studies published since the publication of the BioInitiative Report of 2007 led to a more restrictive recommended Precautionary Action Level of 0.0003 to 0.0006 $\mu W/cm^2$ for chronic exposure to pulsed radiofrequency radiation. So, the 2012 level is 167 to 330 times lower (more protective) than 2007 level. The BioInitiative Report of 2012 also indicated the following:

> "These levels may need to change in the future, as new and better studies are completed. We leave room for future studies that may lower or raise today's observed 'effects levels' and should be prepared to accept new information as a guide for new precautionary actions."

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[106] BioInitiative Working Group, Cindy Sage and David O. Carpenter, Editors, BioInitiative Report: A Rationale for Biologically-based Public Exposure Standards for Electromagnetic Radiation, December 31, 2012 (http://www.bioinitiative.org). See last section of Conclusions (http://www.bioinitiative.org/conclusions/).

[107] BioInitiative Working Group, Cindy Sage and David O. Carpenter, Editors, BioInitiative Report: A Rationale for Biologically-based Public Exposure Standards for Electromagnetic Radiation, December 31, 2012 (http://www.bioinitiative.org). See Section i, Preface 2012, page 2.

[108] BioInitiative Working Group, Cindy Sage and David O. Carpenter, Editors, BioInitiative Report: A Rationale for Biologically-based Public Exposure Standards for Electromagnetic Radiation, December 31, 2012 (http://www.bioinitiative.org). See last section of Conclusions (http://www.bioinitiative.org/conclusions/).

With the published international biomedical research literature continuing to grow so rapidly, changes in the biologically based exposure limits are to be expected periodically. This situation contrasts starkly with the thermally based exposure limits which have shown virtually no change for 30 years for the frequency range of interest here, 2.4 GHz to 6 GHz.

Concern 16: Conclusions of the AECOM Report

The data on the "Maximum Average Power Density" reported in Table 7-2[109] for the Access Points, and in Table 7-3[110] for the Laptop Computers (Chromebooks), is the data used to support the conclusions of the AECOM Report. Those data are presented not just in those two tables, but also graphically for the 12 schools in Figure 7-3[111] and Figure 7-4,[112] respectively. All of those data show values lower than the exposure limits (the "Organizational Levels") of the FCC, the IEEE, the ICNIRP, and the BioInitiative Report 2007. The implied conclusion in the AECOM Report, although never explicitly stated, is that those radiation levels are safe.
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The concerns about the "Maximum Average Power Density" data in the "Conclusions"[113] of the AECOM Report are these:

- As shown in Table H and Table I, all of the data on "Maximum Average Power Density" in Table 7-2 and Table 7-3 in the AECOM Report are invalid for multiple reasons; so it really makes no difference to which exposure limits ("Organizational Levels") those data are compared. **It is not possible to develop any conclusions from invalid data, one way or the other, about the associated health risks.**

- The most striking omission from Figure 7-3 and Figure 7-4 is the most recent exposure limit, the biologically based Precautionary Action Level from the BioInitiative Report 2012. This document provides the most recent of the comprehensive analyses of the international biomedical research literature. This level was included in Table 7-2 and 7-3, to the credit of the AECOM Representatives. The rationale given for the omission of this exposure limit from Figure 7-3 and Figure 7-4 was this:

  > "Since background RF EMF levels are above the 2012 BioInitiative Report precautionary level, this level is unrealistic and unattainable. Background sources include man-made sources, like television, cellular and radio signals, as well as natural sources, like cosmic radiation and the sun."

  Note that lumping "natural sources, like cosmic radiation and the sun" in with manmade sources, like "television, cellular and radio signals" is misleading. These two categories of radiation operate at very different frequencies and have very different roles in biology. All living things on earth evolved in the presence of the natural sources, and have adapted to them over eons. But the manmade sources are new and are expanding too fast to enable adaptation. Further, adaptation by evolution may be natural, but it is also brutal (survival of the fittest). Should we be adopting technology that forces all living things to adapt to it, or should we be adapting technology to all living things?

[109] AECOM Report, Section 7.2.1.1, Access Points, Table 7-2, Access Point Analysis, page 7-5.
[110] AECOM Report, Section 7.2.1.2 Chromebooks, Table 7-3, Chromebook Analysis, page 7-8.
[111] AECOM Report, Section 7.2.1.1, Access Points, Figure 7-3, Comparison of Access Point Values to Organizational Values, page 7-7.
[112] AECOM Report, Section 7.2.1.2, Chromebooks, Figure 7-4, Comparison of Tablet Values to Organizational Levels, page 7-10. (The reference to "Tablet Values" is apparently an error. This reference should have read "Chromebook Values" or "Laptop Computer Values", as no measurements of the radiation from tablets at the MCPS were referenced in the AECOM Report.)
[113] AECOM Report, Section 8.1, Conclusions, page 8-1.

But it is true that the *manmade* background radiation, that is, radiation from sources other than those of current focus, can exceed the Precautionary Action Level recommended in the BioInitiative Report 2012. For example, if the current focus is on Access Points and the Laptop Computers (Chromebooks) with which they communicate, then cell phones, and the cell towers with which they communicate, can be considered contributing to the manmade background radiation. And those contributors, by themselves, can easily exceed the Precautionary Action Level recommended in the BioInitiative Report of 2012. But that is no reason for omitting that Precautionary Action Level from Figures 7-3 and 7-4. Rather, that is a reason for highlighting the Precautionary Action Level, because any addition of radiation in such an environment makes an already bad situation even worse.

The data on the "Maximum Instantaneous Power Density" reported in Table 7-4 for the Access Points and in Table 7-5 for the Laptop Computers (Chromebooks) is not explicitly referenced in the "Conclusions" [114] of the AECOM Report. However, if the intent of the AECOM Representatives was to include these data by implication, than that would raise this concern:

- As shown in Table J and Table K, all of the data on "Maximum Instantaneous Power Density" in Table 7-4 and Table 7-5 in the AECOM Report are invalid for multiple reasons, so it really makes little difference to what exposure limits ("Organizational Levels") those data are compared. **It is not possible to develop any conclusions from invalid data, one way or the other, about the associated health risks.**

CLOSING

The many concerns, described above, about the AECOM Report mean that it cannot be used to establish whether the radiation levels produced by the Access Points and the Laptop Computers in the MCPS are safe or unsafe. But even if the AECOM Report had been flawless, it would not have been the best source of information available for this purpose anyway. Rather, the extensive peer-reviewed literature, published by the international biomedical research community, and the statements by that community, provide the best guidance available about the health risks.

The BioInitiative Report of 2012 is the most recent of the comprehensive reviews of the international biomedical research literature on the biological effects of chronic exposure to radiofrequency radiation. In the "Conclusions" of the BioInitiative Report 2012, [115] "Wi-Fi" is noted as a concern four times, and children, and their special vulnerabilities to harm from radiation, are mentioned 18 times. Specifically the BioInitiative Report of 2012 concludes:

> "Bioeffects are clearly established and occur at very low levels of exposure to electromagnetic fields and radiofrequency radiation. Bioeffects can occur in the first few minutes at levels associated with cell and cordless phone use. Bioeffects can also occur from just minutes of exposure to mobile phone masts (cell towers), Wi-Fi, and wireless utility 'smart' meters that produce whole-body exposure. Chronic base station level exposures can result in illness."

The warning of the world's scientists conducting research on the biological effects of the radiation from wireless devices was recently made very explicit. As of February 10, 2016, 220 scientists from 42 countries

[114] AECOM Report, Section 8.1, Conclusions, page 8-1.
[115] BioInitiative Working Group, Cindy Sage and David O. Carpenter, Editors, BioInitiative Report: A Rationale for Biologically-based Public Exposure Standards for Electromagnetic Radiation, December 31, 2012 (http://www.bioinitiative.org). Conclusions (http://www.bioinitiative.org/conclusions/).

have signed an international appeal to the United Nations and to the World Health Organization. That appeal was first introduced in May 2015[116] and continues to gain support. These scientists seek improved protection of the public from harm from the radiation produced by many wireless sources, including explicitly "cellular and cordless phones and their base stations, Wi-Fi, broadcast antennas, smart meters, and baby monitors" among others. Together, these scientists have published over 2000 peer-reviewed research papers on this subject. They state the following:

> "Numerous recent scientific publications have shown that EMF affects living organisms at levels well below most international and national guidelines. Effects include increased cancer risk, cellular stress, increase in harmful free radicals, genetic damages, structural and functional changes of the reproductive system, learning and memory deficits, neurological disorders, and negative impacts on general well-being in humans. Damage goes well beyond the human race, as there is growing evidence of harmful effects to both plant and animal life."

If your search for the truth about the impact of the electromagnetic radiation from wireless devices on all living things has not yet begun in earnest, I hope it will begin now.

Please protect your students, teachers, and staff from the harm caused by the electromagnetic radiation from wireless devices. Replace the current wireless connectivity in the MCPS schools with much safer wired connectivity as soon as possible and avoid introducing other wireless devices into your schools.

[116] International Appeal: Scientists call for Protection from Non-ionizing Electromagnetic Field Exposure (https://www.emfscientist.org/) and (https://www.emfscientist.org/index.php/emf-scientist-appeal).

APPENDIX: Selected Graphs from Appendix C of the AECOM Report (Annotated)

Figure 4: "Average" Electric Field of Each Frequency Segment for Access Point at 12 Inches Distance at Beverly Farms Elementary School (as in Figure 7-1 in AECOM Report)

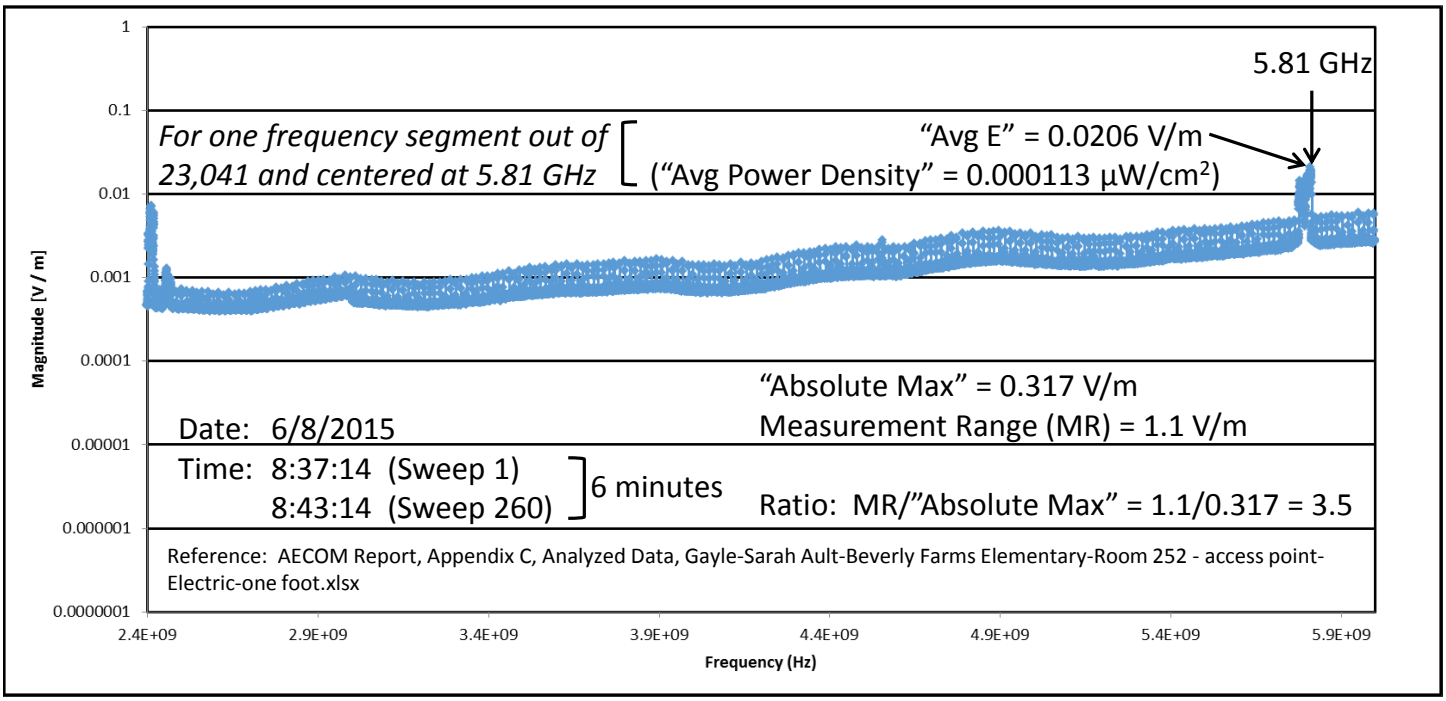
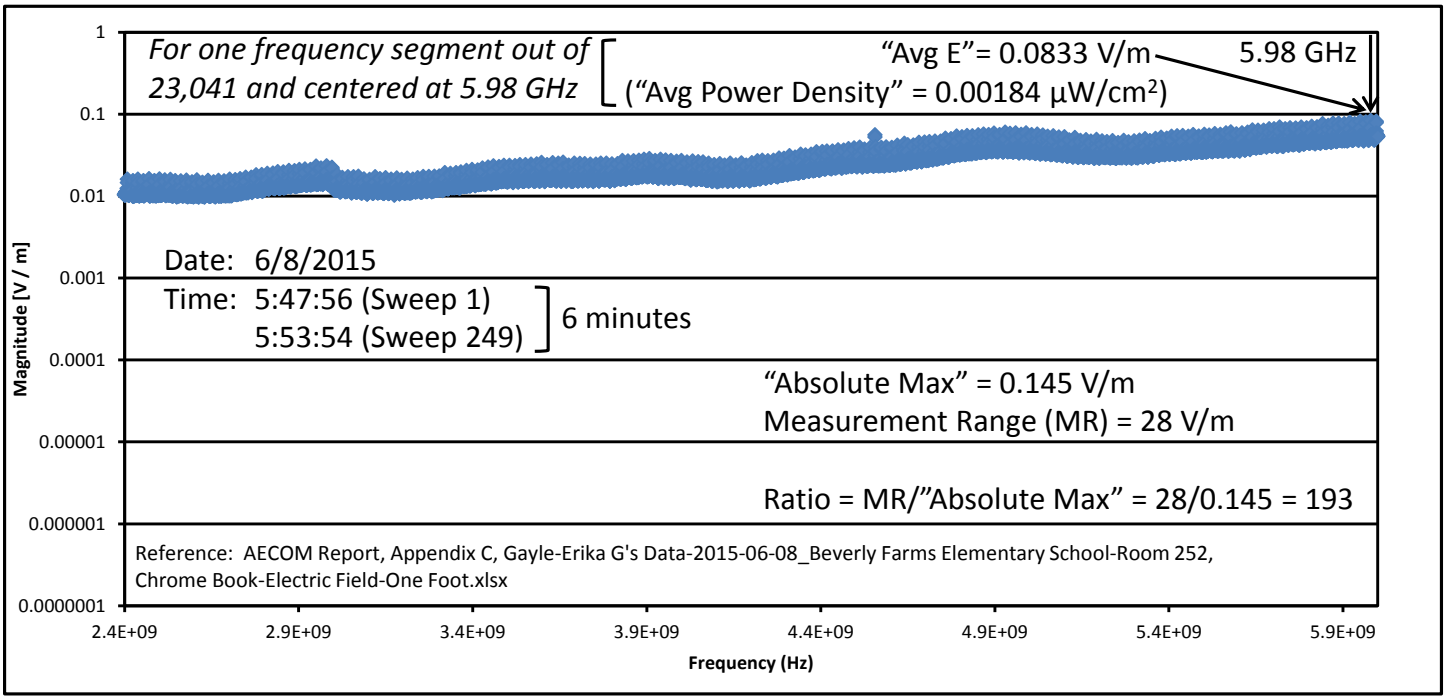
Figure 5: "Average" Electric Field of Each Frequency Segment for Laptop Computer (Chromebook) at 12 Inches Distance at Beverly Farms Elementary School (as in Figure 7-2 in AECOM Report)