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Subject: EMI/RFI Site Survey Report – Florida State University Interdisciplinary Science Research Building Recommendations and Mitigation Strategies

Dear Mr. Martin:

Vitatech Electromagnetics, LLC was commissioned by Wilson Architects to perform a comprehensive full-spectrum EMI/RFI site survey at two (2) Southwest Campus locations for the Interdisciplinary Science Research Building project at Florida State University (FSU) in Tallahassee, Florida: Lots 3C, 4C and 5C & Lot 4B as shown below in Diagram #1:

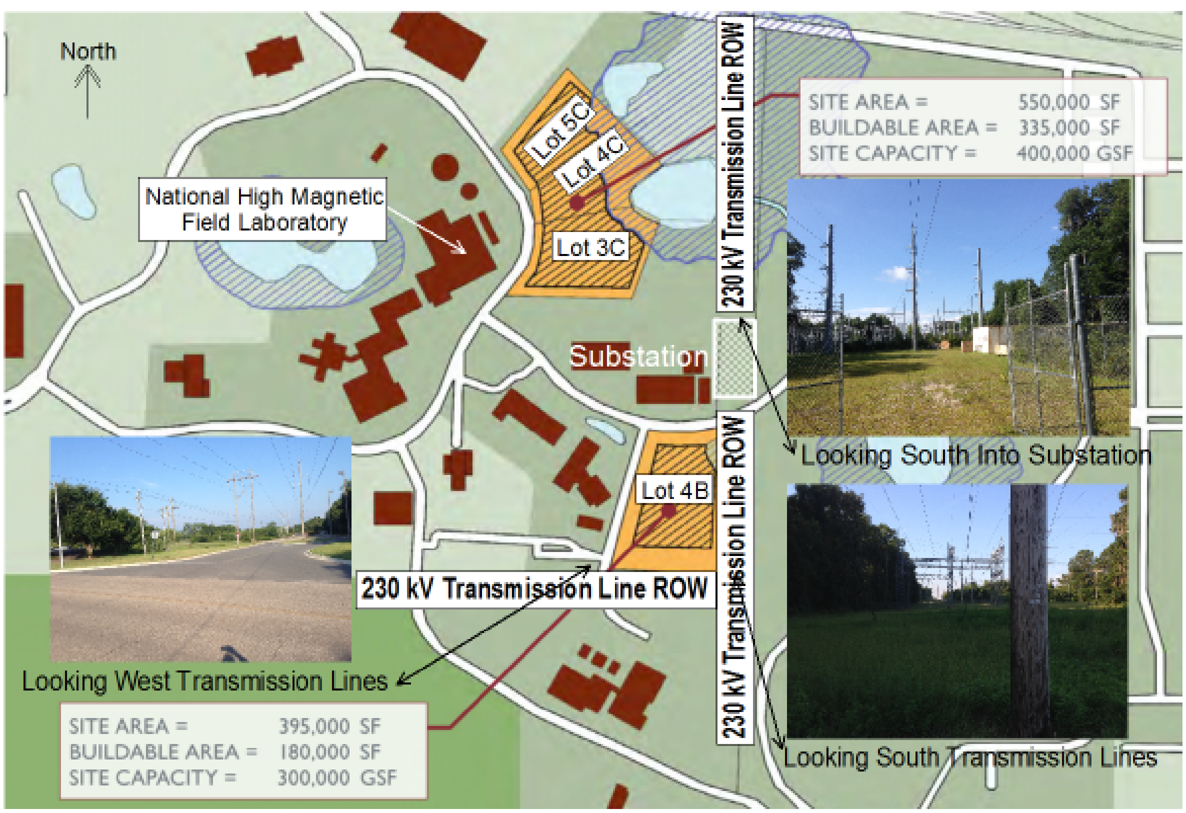


Diagram #1, Lot 4B, Lots 2C, 4C & 5C With 230 kV Transmission Lines & Substation

These are two (2) complicated EMI building sites under consideration. Lot 4B has three (3) overhead 230 kV transmission lines running north-south connecting to a common substation and two (2) interconnecting overhead 230 kV transmission lines running east-west as shown on Diagram #1. Lots 3C, 4C and 5C have underground distribution lines traveling along Paul Dirac Drive several feet inside the curb and along the perimeter of Lot 3C to a nearby smaller substation and the main 230 kV substation. There are also three (3) 230 kV transmission lines traveling north from the main substation as shown in Diagram #1. Finally, there is the National High Magnetic Field Laboratory on Paul Dirac Drive directly across the street from Lots 3C, 4C and 5C. I am almost certain (unless there is evidence to the contrary) that elevated and high magnetic field emissions (i.e., transients, EMPs and other emission types) will emanate from the research facility due to experiments and / or high power demands from the National High Magnetic Field Laboratory and the nearby underground electrical distribution feeders adjacent to Lot 3C during high current experiments.

Vitatech recorded lateral and perimeter mapped AC 60 Hz magnetic flux density levels around both potential sites, recorded quasi-static DC magnetic data near Lot 3C, predicted quasi-static DC emissions due to traffic on nearby roads and recorded 75 MHz to 3 GHz RF electric field strength levels at both sites. Vitatech shall evaluate the impact of the recorded and predicted EMI/RFI data, recommend acceptable EMI/RFI levels for research tools, presents EMI emission thresholds and discuss critical EMI issues required to achieve full compliance and performance in this report with recommended EMI mitigation strategies.

Electromagnetic Interference (EMI) & Recommended EMI Levels
Electromagnetic induction occurs when time-varying AC ELF (extremely low frequency (3 Hz to 3000 Hz) magnetic fields couple with any conductive object including wires, electronic equipment and people, thereby inducing circulating currents and voltages. In unshielded (susceptible) electronic equipment (computer monitors, video projectors, computers, televisions, LANs, diagnostic instruments, magnetic media, etc.) and signal cables (audio, video, telephone, data), electromagnetic induction generates electromagnetic interference (EMI), which is manifested as visible screen jitter in displays (shifting for quasi-static DC and pulses), hum in analog telephone/audio equipment, lost sync in video equipment and data errors in magnetic media or digital signal cables.

Large and small ferromagnetic masses in motion such as elevators, cars, trucks, and metal doors produce geomagnetic field perturbations in the sub-extremely low frequency (SELF) 0 – 3 Hz band that radiate (similar to throwing a pebble in a pond) from the source generating DC electromagnetic interference (EMI) in sensitive scientific tools and instruments. The magnitude of the geomagnetic field perturbation and radiated distance from the source depends on the size, mass and speed of the moving ferromagnetic object. Theoretically, DC magnetic emissions sources (i.e., ferromagnetic objects, magnets, etc.) decay according to the inverse cube law, in practice the decay rates are not ideal. Other problematic DC EMI sources include electromagnetic pulse (EMP) devices (i.e., National High Magnetic Field Laboratory), subways, trolleys, NMRs, and MRIs. Electron microscopes (SEMs, TEMs, STEMs), Focus Ion Beams (FIB) writers and E-Beam writers are also very susceptible to DC EMI emissions and require clean and low DC environments less than 1 mG p-p. *Furthermore, to ensure a safe working environment around MRIs and NMRs, adequate signage must be posted at 5 and 10 Gauss lines to warn staff and visitors with implantable devices and to minimize inadvertent data corruption (coercivity) of credit cards and other valuable magnetic media.* A list of DC EMI Thresholds in Gauss that will impact CRT displays, electronic instruments and magnetic media:

DC EMI Thresholds - CRT screen shift, noise & coercivity (data errors)
0.001 Gauss & Less SEMs, TEMs E-Beam/FIB Writers
0.75 Gauss CRT Monitors & Electronic Instruments
5 Gauss Cardiac Pacemakers & Implantable Devices Warning Sign
10 Gauss Credit Cards & Magnetic Media Warning Sign
300 Gauss Low Coercivity Mag-Stripe Cards
700 Gauss High Coercivity Mag-Sripe Cards & Video Tapes
1000 milligauss (mG) = 1 Gauss (G) & 1 mG = 0.001 G = 0.1 uT (microtesla)

Placement of each scientific tool and instrument depends on the actual EMI susceptibility under defined thresholds, which are often not easy to ascertain from the manufacturer's performance criteria. Magnetic flux density susceptibility can be specified in one of three terms: Brms, Bpeak-to-peak (p-p) and Bpeak (p) according to Equation 1 below:

$$\text{Equation 1:} \quad Brms = \frac{Bp-p}{2\sqrt{2}} = \frac{Bp}{\sqrt{2}}$$

Using the recorded data and resultant emission profiles within this report and the correct conversion formula, it is possible to identify the appropriate levels acceptable for each tool *if the correct EMI susceptibility figure can be ascertained from the manufacturer's specifications. Therein, lies the real EMI challenge.*

Recommended EMI Thresholds Research & Scientific Instruments & Labs

Vitatech presents our recommended list of EMI sensitive Tool Thresholds for time-varying ELF (extremely low frequency) magnetic fields ranging from 3 Hz to 3000 Hz including 60 Hz electrical sources and harmonic components. The SELF band ranges from 0 Hz to 3 Hz and includes DC Static and DC quasi-static emissions from moving vehicles, elevators, and potential DC EMI emissions emanating from the National High Magnetic Field Laboratory could be a serious problem for EMI sensitive research tools in the future Interdisciplinary Science Research building.

AC ELF EMI Peak-to-Peak (RMS) Typical Research Tool Thresholds
14.0 mG p-p (5.0 mG rms) high resolution CRT monitors and audio/video analogue cables
3.0 mG p-p (1.0 mG rms) magnetic imaging & electrophysology tools (i.e., MRIs, NMRs, EEGs, EKGs, etc.)
0.8 mG p-p (0.3 mG rms) typical electron imaging tools (i.e., SEMs, E-Beams, FIBs, etc.)
0.3 mG p-p (0.1 mG rms) improved performance electron imaging tools (i.e., SEMs, E-Beams, FIBs, etc.)
0.1 mG p-p (0.04 mG rms) high performance electron imaging tools (i.e., TEMs, STEMs, research EEGs, etc.)

For occupied Interdisciplinary Science Research Building (i.e., offices, hallways, work areas, cafes, conference rooms, etc.) not considered research EMI sensitive areas, I recommend a maximum Br resultant long-term human exposure threshold of 10 mG RMS (28.3 mG p-p) and 5 mG RMS (14 mG p-p) for CRT high resolution monitors (assuming anyone has a CRT anymore), computer equipment (i.e., laptops, servers, hubs, IT equipment, etc.) and industrial audio/video analogue signals. This is generally achievable without applying AC ELF (extremely low frequency) magnetic shielding unless the occupied areas are adjacent to the main switchgear room, electrical closet, transformer and primary (12 kV) building feeder. Adequate separation distances between the various high current electrical sources and occupants should ensure a Br resultant of 10 mG RMS (28.3 mG p-p). It should be noted that unshielded single-end (non- balanced) microphone / guitar pickup / high performance audio cables including mixers, preamplifiers and other EMI sensitive audio equipment has an EMI threshold of less than 1 mG RMS (3 mG p-p).

EMI/RFI Site Survey & Assessment

Vitatech recorded the ambient magnetic and electric field conditions including 60 Hz magnetic fields, quasi-static DC magnetic fields, and radiofrequency (RF) levels, which was performed in preparation for the various laboratory and other EMI-sensitive areas proposed for the Interdisciplinary Science Research building. The EMI/RFI site survey was conducted over three very hot summer days between July 8th and July 10th in 2014 by Lou Vitale.

Mapped 60 Hz Magnetic Field Levels

Vitatech recorded mapped AC ELF magnetic flux density levels at the two (2) future Interdisciplinary Science Research proposed sites at 1-meter above the grade with a Dexsil Fieldstar 1000 three-axis 60 Hz gaussmeter and survey wheel. It should be noted that all mapped AC magnetic flux density levels were recorded in units of milligauss RMS (root-means-square) at 1-foot intervals. An assessment of the recorded magnetic flux density data is presented as Hatch and Profile Plots as follows: Lot 4B in Figure #1 and Lots 3C, 4C and 5C in Figures #2 and #2A.

<u>Figure #1, Lot 4B AC 60 Hz Magnetic Field Assessment</u>

Figure #1 shows three (3) Hatch plots (left section) overlaid on a scaled Google site map with the associated three (3) Profile plots (right section) recorded on Friday, 8 August 2014, during hot summer morning representing peak summer loads on the 230 kV transmission lines. Hatch and Profile plots identified as Rec 35 show the lateral plots from Engineer Drive across the field through the transmission line ROW (Right-Of-Way) past the last transmission line. A peak spot of 13 mG RMS was recorded under the transmission line most west of the three (3) with a low of 0.04 mG RMS (noted as No Hatch Marks) along a ~180 ft. path starting ~50 ft. from Engineers Road to the first blue Hatch mark.

Hatch and Profile plots identified as Rec #36 run north from the Bush/Tree Area to Point A averaging 0.16 mG RMS, along Levy Avenue averaging 0.24 mG RMS to Point B and south along Engineer Drive with levels ranging from 0.12 to 0.32 mG

RMS until the peak spot of 20.4 mG RMS under the East-West 230 kV transmission lines. The Grassy Area Hatch and Profile plots from the Start to Point A in Rec #36 had low levels of 0.16 mG RMS.

Finally, Rec 38 Hatch and Profile plots show levels recorded showed a 21.7 mG RMS spike on Engineer Drive from an underground distribution line rapidly decaying to 0.04 mG RMS and less 50 feet away slowly increasing to 0.88 mG RMS due to 230 kV transmission lines at Point A decaying slightly to 0.64 mG RMS at Point B and decaying to 0.04 mG and less for another ~200 feet until increasing to 0.12 mG RMS at Engineer Drive.

<u>Conclusions & Recommendations Figure #1, Lot 4B</u>
Based upon the Lot 4B recorded peak summer load 230 kV transmission line magnetic flux density data, the levels are reasonable low from 0.04 mG RMS (0.11 mG p-p) 50 feet east of Engineer Drive, 50 feet south of Levy Avenue and 0.50 mG RMS (1.4 mGp-p) 250 feet east of Engineer Drive. Within this region the AC 60 Hz and higher harmonic magnetic fields emanating from the 230 kV transmission lines and underground distribution lines are of reasonable magnitude and can be mitigated with electromagnetic shielding and supplemental Active Compensation System (ACS) technology within the EMI sensitive TEM/SEM areas with ion beam imaging equipment and magnetic imaging (NMR and /or MRI) systems.

<u>Figures #2 & 2A, Lots 3C, 4C & 5C AC 60 Hz Magnetic Field Assessment</u>
The Hatch Plots are shown in Figure #2 and the Profile Plots in Figure #2A. Rec #3 shows the perimeter Paul Dirac Drive data that ranges from an average of 2.5 mG RMS to a peak of 22.7 mG RMS directly above the underground distribution lines supplying the National High Magnetic Field Laboratory. Rec #40 is a lateral from the driveway/parking area to the transformer across the Paul Dirac Drive with a peak of 5.96 mG near the transformer / underground feeder. A ground current was noted (Bz direction) in Rec #40 between the underground distribution line traveling along the street and the National High Magnetic Field Laboratory (this is usually due to a N.E.S.C. violation.

Rec #8 shows only the Hatch plot of the magnetic field emissions along the underground distribution line adjacent to Lot 3C ranging from an average of 10.8 mG RMS to a peak of 25.8 mG RMS. Rec 5 starts in the parking lots intersecting the underground distribution line shown in Rec 8 and continues into Lot 3C for 250 feet ranging from 0.12 mG RMS down to 0.04 mG RMS the last 200 feet. Rec #6 starts on the trail with low levels of 0.04 mG RMS for 150 feet intersecting Rec #5, increasing to 0.12 mG RMS for another 100 feet before elevated levels greater than 10 mG indicates the underground distribution feeder at 13 mG RMS and remains elevated all another 400 feet until the 230 kV transmission lines appear with at 16 mG RMS peak. Finally, Rec #9 starts in the parking lot and travels above the underground distribution line adjacent to Lot 3C with an average of 2.8 mG RMS and a peak of 20.4 mG RMS directly over the underground distribution line.

Conclusions & Recommendations Figure #2 & #2A, Lots 3C, 4C & 5C

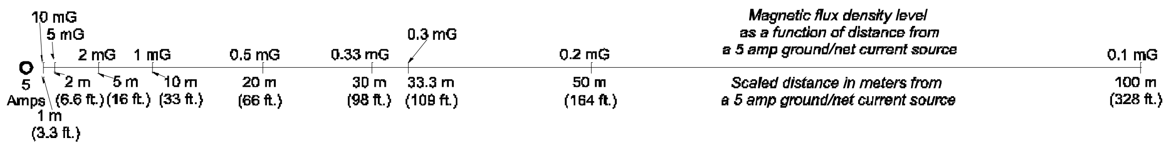
Based upon the Lots 3C, 4C and 5C recorded peak summer load 230 kV transmission line and underground distribution line magnetic flux density data, the levels are reasonable low from 0.04 mG RMS (0.11 mG p-p) 100 feet east of Paul Dirac Drive due to the underground distribution line along the road, 0.04 mG RMS 125 feet north of underground distribution line and less than 0.12 mG RMS 100 feet west of the 13 mG RMS peak emanating from underground distribution line shown in Rec #6. Within this region the AC 60 Hz and higher harmonic magnetic fields emanating from the underground distribution lines, small substation, main substation and 230 kV transmission lines are of reasonable magnitude and can be mitigated with electromagnetic shielding and supplemental Active Compensation System (ACS) technology within the EMI sensitive TEM/SEM areas with ion beam imaging equipment and magnetic imaging (NMR and /or MRI) systems. However, due to the close proximity to the National High Magnetic Field Laboratory and underground distribution feeders that supply the facility issues regarding magnetic field transients, EMPs and other magnetic field emissions including Static DC and Quasi-Static DC magnetic field sources may compromise the future Interdisciplinary Science Research tools regardless of the mitigation strategies applied to control potential EMI threats.

Net/Ground Current Issues

Ground and net currents are due to electrical code violations (i.e., grounded neutrals, wiring errors, etc.) in the electrical service, distribution and grounding systems of a building and utility code violations (i.e., grounding problems, etc.) on distribution and transmission lines. Unbalanced phases on medium voltage distribution lines and 480/277V low-voltage feeders generate zero-sequence currents, which return on the neutrals and grounding conductors. Most utilities maintain 5% and less unbalanced phases on high voltage transmission lines and 10-15% unbalanced phases on distribution lines (power quality issues) except in local neighborhoods where unbalanced phases may exceed 20%. A percentage of the zero-sequence neutral currents on distribution lines travel along other electrically conductive paths (i.e., underground water pipes, earth channels, grounded guy wires, building neutrals/grounding systems, etc.) back to the substation. If all the zero-sequence currents were to return via the multi-ground neutral system (MGN) wire mounted on the pole under the three phase conductors (sum of all phase and neutral currents are zero), then the magnetic fields would decay at the normal inverse square rate ($1/r^2$ in meters) from the single-circuit distribution line (same for transmission lines and low-voltage feeders). However, if only a fraction of the zero-sequence current returns on the MGN system or low-voltage neutral conductor, then there is a net current missing (amount of current returning via other paths) – this net current emanates a magnetic field similar to a ground current (electrical current of low voltage returning on a ground wire, water pipe or other conductive path) that decays at a linear 1/r (in meters) rate based upon the following formula:

BmG = 2(I)/r where I is amps and r meters

Magnetic fields from ground and net (zero-sequence) currents decay at a slow, linear rate illustrated below, using a 5 amp ground/net current source: 10 mG is 1m away, 1 mG is 10 m away, 0.5 mG is 20 m away and 0.1 m is 100 m away:



Since there is a proportional relationship between current load and magnetic flux density levels, the above chart can be used to predict the emission levels based upon ground/net current loads. Using 2.5 amps of ground/net current, the levels above the selected decay distance are calculated by dividing by 2, which is 50% of 5 amps. The ground/net current decay chart is indispensable in ascertaining the acceptable operating distance from ground and net (zero sequence) currents based upon a specified instrument performance criteria (i.e., 1 mG, 0.1 mG or 0.01 mG). Ground and net current magnetic field emissions are difficult to shield using flat or L-shaped ferromagnetic and conductive shields -- the most effective shielding method for AC ELF ground/net current emissions requires a six-sided, seam welded aluminum plate shielding system with a waveguide entrance. *Finally, low ambient magnetic field levels can be achieved inside a research laboratory or imaging suite by adhering to the electrical code and good wiring practices. However, these low levels can only be achieved under the most pristine conditions and without any circulating ground/net currents present on the primary electrical distribution system outside of the building, low-voltage distribution feeders and branch circuits inside the building systems and the grounding system otherwise AC ELF magnetic shielding is required to obtain the performance objectives.*

Quasi-Static DC Magnetic Field Issues –Vehicles & Elevators

Timed quasi-static DC (0 Hz to 10 Hz) data was recorded at 0.2 second intervals 1-meter above grade at the driveway adjacent to the National High Magnetic Field Laboratory as shown in Figures #2 & #3 and Diagram #2 below:

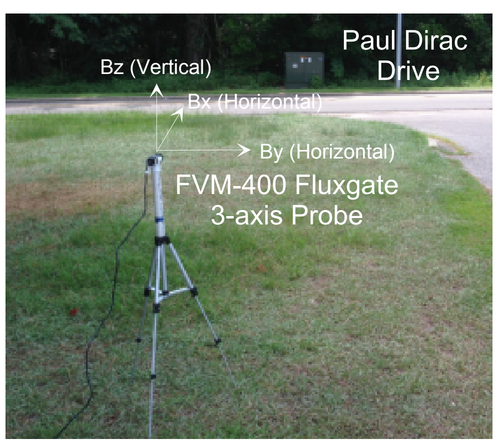
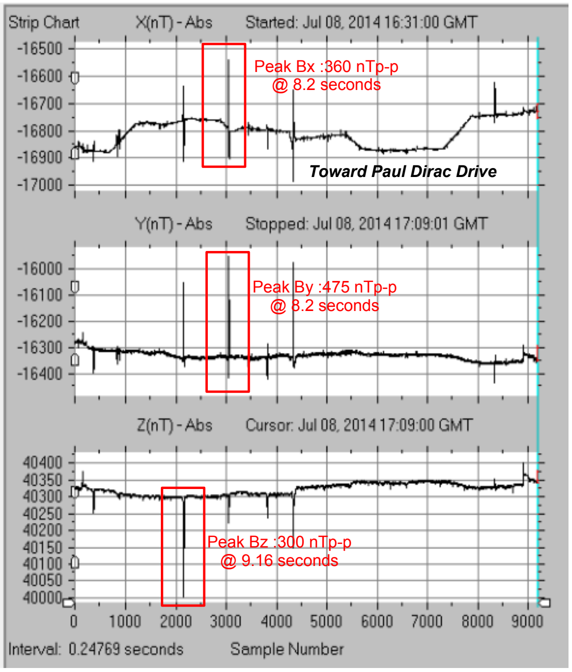
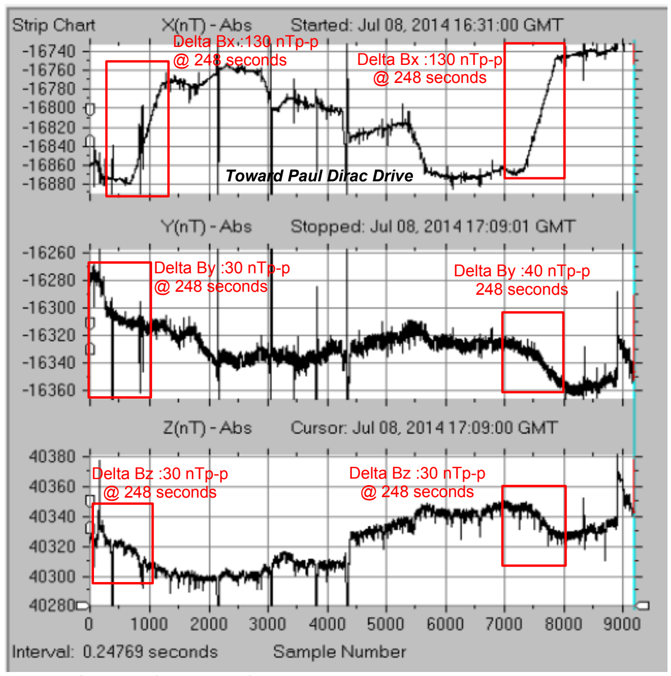


Diagram #2, MEDA FVM-400 & Fluxgate Probe

It should be noted that all DC EMI magnetic flux density levels were recorded in units of milligauss RMS (root-means-square). The fluxgate probe was 80 ft (24 meters) from Paul Dirac Drive. Figure #3 is presented below for EMI assessment:



Quasi-Static DC Magnetic Flux Density Data
Vehicles Passing Fluxgate Probe



Quasi-Static DC Magnetic Flux Density Data
DC Static Changes Fluxgate Probe (Not Spikes)

Timed DC magnetic flux density levels recorded with MEDA FVM-400 three-axis fluxgate magnetometer. Data sampled at 0.2 sec, bandwidth DC - 10 Hz, 0.01 mG (1 nT) resolution, 1200 mG maximum.

Recorded Timed DC EMI Emission Data
Driveway & 80 ft. to Paul Dirac Drive (peak-to-peak)

Axis	Delta Range	Peak
Bx	130 nT	360 nT
By	30 to 40 nT	475 nT
Bz	30 nT	300 nT

Figure #3, Lots 3C, 4C & 5C Southwest Campus
Timed Quasi-Static DC Magnetic Flux Density @ 1-m
FSU Interdisciplinary Science Research Building Study
Florida State University (FSU), Tallahassee, Florida

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On the left side panel the spikes represent cars passing on driveway which are indicated by higher peaks in the By axis facing the driveway towards the ferromagnetic vehicles (this is due to the geomagnetic field). The moving vehicles required 4 to 4.5 seconds to reach the peak as noted in the Bx, By and Bz axis and about 4 to 4.5 seconds to pass to Paul Dirac Drive. The right side panels show a scaled up version of the right panel data where the delta indicates changes in the geomagnetic magnetic field from passing vehicles which is lower than the peak spikes. The objective was to record the DC static and Quasi-Static DC magnetic fields near the driveway and the National High Magnetic Field Laboratory for 36 minutes to document the environment and potential DC EMI issues.

<u>Conclusion Static & Quasi-Static DC Magnetic Field Issues</u>
I am very concerned with the National High Magnetic Field Laboratory on Paul Dirac Drive directly across the street from Lots 3C, 4C and 5C. I am almost certain (unless there is evidence to the contrary) that elevated and high magnetic field emissions (i.e., transients, EMPs and other emission types) will emanate from the

research facility due to experiments and / or high power demands from the National High Magnetic Field Laboratory and the nearby underground electrical distribution feeders adjacent to Lot 3C during high current experiments. *If this site is selected, then I must meet with the Director of the National High Magnetic Field Laboratory to discuss "containment and control" of spurious electric and magnetic field emissions due to experiments. Furthermore, I must also record 24 to 48 hour timed AC ELF and static/quasi-static EMI data at the proposed EMI sensitive research laboratory locations in the future Interdisciplinary Science Research Building to ensure optimal low levels depending on the recommended mitigation solutions such as magnetic or electric field shielding and / or Active Compensation System (ACS) technology. We must be absolutely certain that the future in close proximity to the National high Magnetic Field Laboratory will not compromise the research proposed for this new facility under any circumstances.*

Moving Vehicle Quasi-Static DC Magnetic Fields

Vitatech recorded timed DC EMI data from moving vehicles at the University of Florida future Nanotechnology Research Center in Gainesville, Florida, nearly a decade ago. Calculated U.S. car and bus vehicle profiles were generated by applying the decay data to Curve Fitting software. The average mass of a U.S. car is 3,000 lbs and of a large U.S. bus is 30,000 lbs (DOT information). Comparing the car and bus EMI emission data, the below chart presents the EMI decay rates based upon the predicted U.S. vehicle mass formulas shown below in Table #1:

Calculated Vehicle Profiles

Distance	Car	Bus
1 m	3.50 mG	30.0 mG
6 m	0.48 mG	2.6 mG
12 m	0.22 mG	1.0 mG
18 m	0.15 mG	0.59 mG
24 m	0.11 mG	0.40 mG
30 m	0.08 mG	0.30 mG
36 m	0.07 mG	0.23 mG
40 m	0.06 mG	0.20 mG

Special Note: magnetic fields decay more rapidly after 30 meters than the calculated levels indicate.

Table #1, U.S. Vehicle Predicted DC EMI Emission Profile

Since the University of Florida (UF) and Florida State University (FSU) are in reasonable close proximity, the UF vehicle data will apply to the Interdisciplinary Science Research sites. Typically, DC magnetic interference is caused by perturbations in the geomagnetic field of the earth from moving ferromagnetic objects (i.e., vehicles, subways, elevators, metal carts, etc.) – something like a pebble in the pond. These perturbations are captured by the fluxgate magnetometer and presented as differential peak-to-peak changes in the recorded timed geomagnetic field data. While recording the quasi-static DC data several large campus busses and delivery trucks passed site. Therefore, I recommend at least 50 meters (164 ft.) separation distance from all adjacent road curbs to any EMI sensitive ion beam imaging laboratories (i.e., TEMs, SEMs, STEMs, FIBs, E-Beams, etc.) and magnetic imaging tools (NMRs, SQUIDS, MRIs, etc.).

Predicted Elevator Recorded Quasi-Static DC Magnetic Fields

Vitatech and the University of Alberta in Edmonton, Canada, collaborated on measuring (and quantifying by curve fitting software) the quasi-static DC magnetic flux density level changes in magnetic flux over time (nanotesla - nTpeak-to-peak) from a moving ThyssenKrupp passenger elevator in the Engineering Building. The ThyssenKrupp passenger elevator specifications are as follows: Type: Overhead Traction; Capacity: 4500 lbs.; Car Weight: 5290 lbs.; and, Counter Weight: 7540 lbs. Vitatech shows the elevator DC EMI emission formula solved in units of milligauss (mG) peak-to-peak as a function of distance (d) in meters from the center:

$$\mathbf{mG_{(passenger)} = 647(d)^{-2.65}}$$

Table #2 shows the predicted Br resultant peak-to-peak magnetic emission profile of the overhead traction passenger elevator recorded at the University of Alberta. Radial distances in meters/feet from the center of the passenger elevator were solved for six thresholds: 10 mG, 5 mG, 1 mG, 0.5 mG, 0.2 mG and 0.1 mG.

Predicted Passenger Elevator DC Emission Profile

Level	Distance From Center
10.0 mG	4.82 m (15.8 ft.)
5.0 mG	6.27 m (20.6 ft.)
1.0 mG	11.50 m (37.7 ft.)
0.5 mG	14.94 m (49.0 ft.)
0.2 mG	21.11 m (69.3 ft.)
0.1 mG	27.42 m (89.9 ft.)

Table #2, University of Alberta Passenger Elevator DC EMI Profile

Vitatech recommends locating EMI sensitive instruments and tools at the appropriate separation distance from the passenger elevator (add 6 meters or 20 feet for service/freight elevators) to avoid the need for DC mitigation (i.e., shielding / active cancellation elevator or active cancellation of EMI impacted laboratory).

Radiofrequency Interference (RFI)

In the United States, the Federal Communications Commission (FCC), not the local municipal zoning authorities or law enforcement, has legal jurisdiction over radiofrequency interference (RFI). Simply stated, RF devices (intentional and unintentional emitters) are not permitted to cause interference within other radio or television services, electronic equipment and systems. At present, there are no mandated radiofrequency interference (RFI) susceptibility government standards in the United States. The only equipment susceptibility standards that exist are unique to equipment (quality control) internal standards written by equipment manufacturers based on radiated emission standards for intentional radiators set forth by FCC. In other words, equipment manufactured within the United State must be designed to function properly within a radiated emission field level from intentional radiators.

In Europe, there are susceptibility (radiated immunity) standards, such as the EN 61000-6-1 states 3 V/m level for residential electronic equipment, while 10 V/m is standard for industrial electronic equipment in the EN 61000-6-2. Engineers in the United States utilize the European susceptibility standards as a guideline. Vitatech recommends 3 V/m as the industrial RFI threshold and 1 V/m for the medical/scientific instrument RFI threshold for maximum performance.

RFI Electric Field Strength Site Assessments & Conclusions
RF spectral electric field strength data in volts-per-meter (V/m) was recorded with the SRM-3000 spectrum analyzer at the center of Lot 4B and the woods in the center of Lots 3C and 4C along the cut path. The RFI data was collected as sweeping samples within the spectral range of 75 MHz to 3 GHz. The RF electric field strength data collected is presented in Diagrams #3 and #4 below:

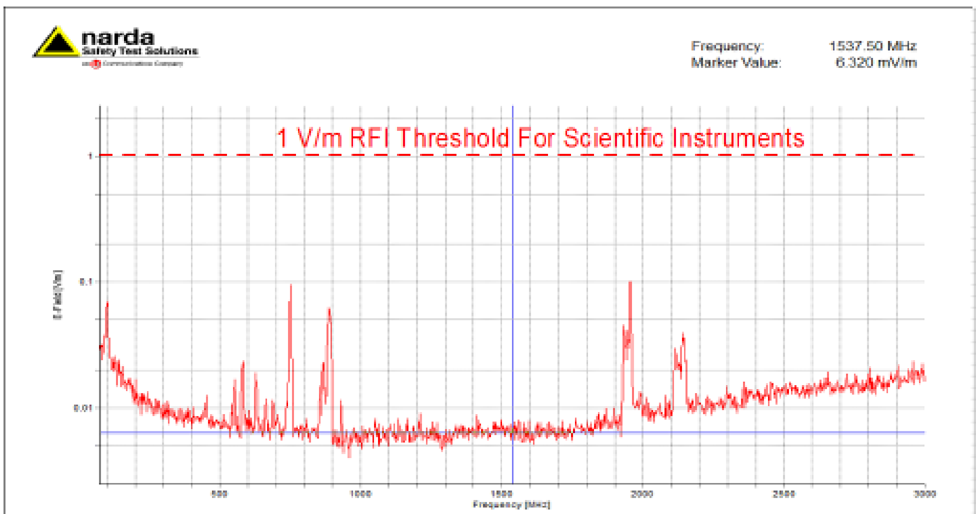


Diagram #3, Lot 4B RFI Data: 75 MHz to 3 GHz
SRM-3000 Isotropic Spectrum Analizer

Index	Frequency		Level	
1	1955.1	MHz	102.6	mV/m
2	751.13	MHz	101.8	mV/m
3	100.6	MHz	70.92	mV/m
4	886.08	MHz	65.35	mV/m
5	888.04	MHz	60.92	mV/m
6	1932.8	MHz	45.56	mV/m
7	1945.3	MHz	41.24	mV/m
8	2140.7	MHz	40.38	mV/m
9	90.74	MHz	38.59	mV/m
10	2146.6	MHz	37.31	mV/m
11	81.5	MHz	32.73	mV/m
12	2117.1	MHz	30	mV/m
13	127.6	MHz	25.98	mV/m
14	111.25	MHz	25.48	mV/m
15	122.26	MHz	25.26	mV/m
16	2151.5	MHz	24.96	mV/m
17	581.55	MHz	24.75	mV/m
18	886.48	MHz	24.31	mV/m
19	142.16	MHz	24.26	mV/m
20	134.5	MHz	23.7	mV/m
21	2957.3	MHz	23.47	mV/m
22	2128	MHz	23.09	mV/m
23	2989.9	MHz	22.45	mV/m
24	2901.9	MHz	22.11	mV/m
25	155.13	MHz	21.63	mV/m
26	2802.1	MHz	21.1	mV/m
27	2943.2	MHz	20.51	mV/m
28	2994.4	MHz	20.23	mV/m
29	2968.2	MHz	20.08	mV/m
30	148.94	MHz	19.84	mV/m
31	2975.5	MHz	19.71	mV/m
32	2878	MHz	19.15	mV/m
33	2963.6	MHz	19.15	mV/m
34	2854.8	MHz	19.15	mV/m
35	627.91	MHz	19.1	mV/m
36	2753	MHz	18.85	mV/m
37	2722.3	MHz	18.57	mV/m
38	2890.3	MHz	18.34	mV/m
39	2832.4	MHz	18.18	mV/m
40	2924.9	MHz	18.01	mV/m
41	2913.6	MHz	17.97	mV/m
42	2839.8	MHz	17.91	mV/m
43	2852.7	MHz	17.54	mV/m
44	2815.4	MHz	17.51	mV/m
45	2808	MHz	17.43	mV/m
46	176.76	MHz	17.38	mV/m
47	184.77	MHz	17.28	mV/m
48	2645	MHz	17.27	mV/m
49	552.31	MHz	16.99	mV/m
50	199.81	MHz	16.95	mV/m

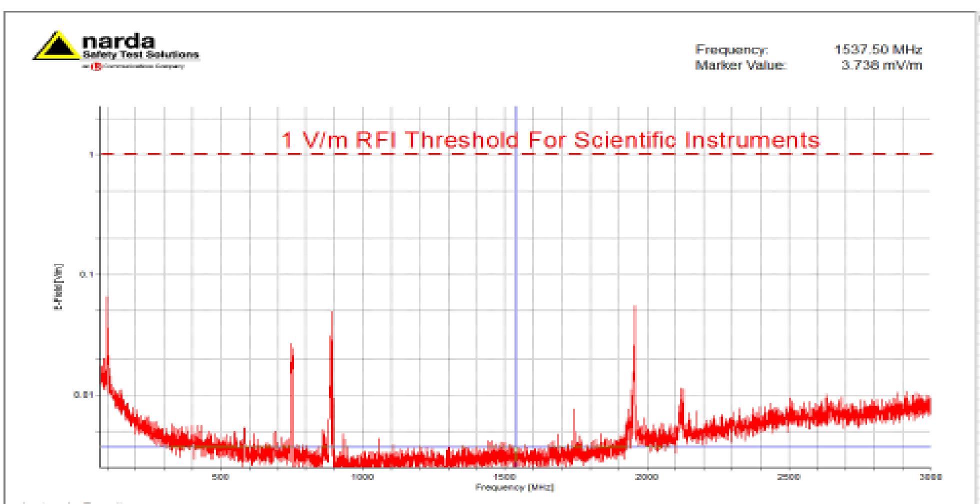


Diagram #4, Lots 3C / 4C RFI Data: 75 MHz to 3 GHz
SRM-3000 Isotropic Spectrum Analizer

Index	Frequency		Level	
1	98.9	MHz	66.41	mV/m
2	1957.5	MHz	55.21	mV/m
3	888.11	MHz	50.62	mV/m
4	889	MHz	43.68	mV/m
5	102.25	MHz	37.96	mV/m
6	887.14	MHz	32.21	mV/m
7	893.01	MHz	28.67	mV/m
8	749.52	MHz	27.12	mV/m
9	751.15	MHz	24.7	mV/m
10	752.45	MHz	24.43	mV/m
11	748.37	MHz	21.62	mV/m
12	753.91	MHz	21.49	mV/m
13	746.72	MHz	20.79	mV/m
14	89.76	MHz	20.66	mV/m
15	886.17	MHz	19.41	mV/m
16	93.06	MHz	17.93	mV/m
17	79.46	MHz	17.33	mV/m
18	82.5	MHz	17.31	mV/m
19	107.43	MHz	16.79	mV/m
20	90.79	MHz	16.49	mV/m
21	106.59	MHz	16.48	mV/m
22	1953.8	MHz	16.01	mV/m
23	1952.6	MHz	15.57	mV/m
24	81.72	MHz	15.39	mV/m
25	1955	MHz	15.32	mV/m
26	83.89	MHz	15.32	mV/m
27	93.92	MHz	15.21	mV/m
28	78.44	MHz	14.54	mV/m
29	112.99	MHz	14.41	mV/m
30	1951.1	MHz	14.37	mV/m
31	95.91	MHz	14.28	mV/m
32	78.25	MHz	14	mV/m
33	84.82	MHz	13.78	mV/m
34	87.87	MHz	13.24	mV/m
35	108.49	MHz	13.1	mV/m
36	109.51	MHz	12.83	mV/m
37	97.16	MHz	12.62	mV/m
38	116.45	MHz	12.33	mV/m
39	114.98	MHz	12.21	mV/m
40	85.95	MHz	12.06	mV/m
41	882.15	MHz	12	mV/m
42	884.88	MHz	11.95	mV/m
43	110.87	MHz	11.7	mV/m
44	105.31	MHz	11.66	mV/m
45	122.16	MHz	11.62	mV/m
46	2119.6	MHz	11.5	mV/m
47	2128.1	MHz	11.35	mV/m
48	112.03	MHz	11.18	mV/m
49	1946	MHz	11.12	mV/m
50	148.08	MHz	11.09	mV/m

Final RFI Conclusion: Lot 4B of Diagrams #3 and Lots 3C/4C from Diagram #4 fully comply with the recommended 1 V/m electric field strength threshold for scientific and medical equipment between 75 MHz to 3 GHz RF bandwidth. Vitatech also measured from 100 kHz to 300 MHz these RFI levels also fully complied with the 1 V/m electric field strength threshold at both sites. Given that the peak electric field strength levels were below 1 V/m from 100 kHz to 3 GHz throughout the two (2) tested sites, Vitatech would conclude that the footprint reserved for the future Interdisciplinary Science Research Building RF levels are acceptable for scientific and medical instruments.

It should be noted that the typical attenuation for building construction materials such as the below grade research EMI / RFI sensitive rooms range from -30 to -40 dB depending on the concrete thickness, types of materials, paints and other parameters that impact the properties of reflection, absorption and transmission besides radiated power. For example an external 1 V/m RF source would be attenuated from 0.032 V/m to 0.01 V/m assuming -30 dB to -40 dB of attenuation from the building due to absorption and reflection. The recorded levels at both sites were less than 0.1 V/m, and the future Interdisciplinary Science Research building levels would be attenuated down to 0.003 V/m to 0.001 V/m.

Construction Recommendations

It is absolutely critical that a well-qualified, highly skilled electrical contractor with licensed electricians be selected to perform the electrical installation work. **The electrical contractor must test every neutral (feeders, branch and lighting circuits) in the building during construction to guarantee electrical isolation from the grounding system.** The neutral-grounding system isolation test must be documented and submitted to the EMI Consultant for review. If the electrical distribution system is fully compliant with the N.E.C., then there will be minimal circulating ground currents except due to leakage currents (i.e., transformers, refrigerator compressors, etc.) returning along the various conductive paths and a steel frame and/or concrete reinforced building with uncoated steel rebar back to the switchgear room ground bonding point and/or to the primary building transformer grounds. Nevertheless, Vitatech recommends fiberglass rebar in the concrete slabs of all EMI sensitive research tools to guarantee that any returning ground currents do not travel beneath the tools. Vitatech highly recommends that all electrical contractors follow the Required Practices for Mitigating AC ELF Magnetic Fields:

<u>Required Practices for Mitigating AC ELF Magnetic Fields</u>

1) Each single phase circuit, including all lighting circuits, must have a dedicated neutral with each phase to ensure maximum magnetic field cancellation along the conduit paths.
2) All neutral conductors must be tested for unintentional grounding – final testing report must be submitted to the EMI Consultant for review.
3) In EMI sensitive areas, including the hallways, all circuit conductors (phases, neutral and any grounding) must be twisted for maximum

magnetic field cancellation. It is recommended to use nylon wire ties in switchboards, pull boxes, wire-ways, surface metal raceways and equipment to minimize conductor separation in the EMI sensitive research areas.

4) Do not route any circuits (power, signal or telecommunications) above or below EMI sensitive laboratories, except those circuits required for the specific use of the laboratory. All conduits (power, signal or telecommunications) must travel in the center hallway ceiling (none should be below the laboratory floor providing the maximum separation distance from future EM tool column and power conduits. All branch and lighting circuits must have dedicated neutrals that follow each phase conductor.
5) All primary feeders within 50 feet and inside of the building must be in RGS conduits. All 480//277V and similar high current feeders within 50 feet and inside of the building must be shielded. Twisting the phase and neutral conductors will also decrease the magnetic field emission profiles.
6) Electrical equipment should not be located within 16.4 feet (5 meters) of the EMI sensitive tool columns or instruments. Electrical feeders 100 amps and higher must be shielded and routed to ensure maximum separation distance from the EMI sensitive tools.
7) Vitatech does not recommend the use of busways of any size in scientific and research building unless the busway EMI emissions are simulated and the appropriate distance to EMI sensitive tools defined. If busways are specified, it will be necessary to install magnetic shielding systems around the electrical room walls to attenuate the magnetic field emissions in adjacent EMI sensitive laboratories and offices.

Electrical Room 60 Hz EMI Emissions

Typically, Vitatech recommends at least 5 meters of separation distance between unshielded electrical rooms and 20 meters from unshielded Main Switchgear Rooms to EMI sensitive research areas and laboratories.

Doors & Hardware Options For EM & TEM Rooms Extremely Important

Vitatech recommends non-ferrous and/or wooden doors where possible to minimize the DC EMI impact. Doors will have a minimal EMI impact on EM tools if they are composed of nonferrous materials such as aluminum or wood. A glass door with a steel frame is acceptable in clean rooms. Aluminum and/or wooden doors are acceptable for imaging laboratories with steel hinges and locking hardware. Special non-ferrous doors should not be fabricated unless within 6 meters of any EMI sensitive tools. Therefore, using steel hardware (only hinges and locks) is acceptable in non-ferrous doors for security and safety, and therefore should not present a serious EMI impact. The University of Alberta study examined the impact of steel doors on DC EMI magnetic field emissions and concluded as follows

> *The effect of moving metallic objects in the Earth's geomagnetic field were observed to significantly perturb magnetic field levels. Specifically, (steel) doors were found to perturb magnetic field levels above the acceptable range of*

5 nT over distances as great as 6m. It is recommended to keep (steel) doors away from sensitive areas by at least 6m, and if possible, 12m to be safe. It was found that a measurable difference in the functional behavior of the fall-off of the magnetic field perturbations existed between rebar reinforced concrete structures and steel frame structures. Specifically, it was observed that perturbations in steel frame structures, both due to doors and elevators, fell off more rapidly than in reinforced concrete structures. This was attributed to a higher concentration of steel in steel frame structures which essentially tended to shield the perturbations.

Concrete Verses Steel Building Structural Frame Discussion

In all building types, the circulating ground currents due to electrical code violations (i.e., grounded neutrals, wiring errors, etc.) in the electrical distribution system traveling on the conductive steel structures such as rebar, steel beams, and metallic pipe/duct systems generate the most serious EMI problems for high resolution imaging tools (i.e., STEMs, SEMs, TEMs, FIBs, E-Beams, NMRs, MRIs, etc.). These conductive paths are part of an unintentional electrical circuit for ground currents seeking a return path to the secondary grounded-wye of the source transformer.

A ground current of 1 amp on a conductive path (steel rebar and/or steel beam) will generate a magnetic field of 2 mG at one-meter separation distance that diminishes at a linear decay rate (1/r in meters) from the conductive path according to the following formula:

B rms = 2(I in amps)/r in meters

But why should a new code-compliant high-tech building with a well inspected electrical distribution system have circulating ground currents? Not easy to answer -- but simply stated -- if there are electrical code violations (i.e., grounded neutrals, wiring errors, etc.) in the low-voltage electrical distribution system, then circulating ground currents will return via the steel rebar and building steel presenting a possible AC ELF EMI problem in the EMI sensitive Imaging Areas and Cleanroom tool areas.

In concrete buildings, steel rebar is used to reinforce the vertical columns and horizontal floor slabs of the structure. Since the steel rebar in the columns and floor slabs are tied together with metal wire before the concrete is poured, the building frame is essentially a continuous metallic structure similar to a steel building, but with significantly higher resistive impedance (steel buildings are lower impedance structures by nature of the interlocking, bolted and welded steel frame). There are several types of rebar that can be used as reinforcement: uncoated steel, epoxy coated, non-magnetic stainless steel and fiberglass. Uncoated steel rebar is used in most building construction except where salt intrusion can corrode and compromise structural integrity, then epoxy coated rebar is more effective. In recent years, several research facilities have been constructed using epoxy coated rebar to minimize circulating ground currents inside the reinforced columns and slab.

First, let's discuss the use of epoxy coated reinforcing steel in the slab on grade -- although the epoxy coating will theoretically minimize ground current circulation on the steel rebar, there are still issues regarding electromagnetic induction and magnetic flux reticulating along the steel rebar path beneath the tool from time-varying DC and AC magnetic fields. A simple solution is to replace the steel rebar in the on grade concrete floor slabs with fiberglass reinforcement (does not apply to columns and floors not on grade): now potential DC and AC EMF EMI emissions problems are eliminated inside the imaging rooms beneath the tool, but this only works for on-grade slabs.

Achieving less than 1 mG down to 0.01 mG peak-to-peak in the Imaging Areas is the real objective and depends on the magnitude of the magnetic emission source (time-varying AC or DC magnetic flux), polarization of the field (direction) and the permeability of the steel rebar plus the influence (mutual inductance, etc.) of other nearby ferromagnetic objects. A local time-varying AC ELF magnetic field source (i.e., primary/secondary feeders, transformers, electric panels, distribution transformers, conduits, etc.) will induce magnetic fields (electromagnetic induction) in any nearby ferromagnetic materials (steel rebar, I-beams, etc.) generating an opposing AC ELF magnetic field (Lenz's Law) in the steel rebar from the localized external electromagnetically induced time-varying source, which is usually small in size compared to the magnetically coupled steel rebar frame. The AC ELF EMI induced fields are localized and rapidly diminish from the inducing source. Therefore, circulating ground currents due to electrical code violations in the electrical distribution system traveling on conductive return paths such as uncoated rebar and building steel present the greatest EMI threat to sensitive imaging tools, not the magnetically induced time-varying currents within the ferromagnetic materials from nearby electrical sources (the difference is very important).

An EMI Study performed by the University of Alberta and Vitatech Engineering examined the response of steel rebar to DC induced magnetic fields and circulating ground currents – the following Conclusion was presented:

> *Rebar was investigated to determine if it coupled magnetic fields. It was found to be ferromagnetic. That it becomes permanently magnetized is not a serious problem… The rebar does, however, couple strongly with the magnetic field along its length. Again, this does not pose a significant problem, as it was also found that field levels fall off exponentially from the end of the rebar. So long as a reasonable distance (minimum of 1m, preferably 2m) is maintained between rebar and sensitive areas, the coupling is likely not to be a concern. It was also found that rebar is highly conductive, which may pose a significant problem in the future, if net currents are to develop in them. In this case, a ground current flowing along the rebar would only fall off as 1/r, and hence may cause serious problems. Based on these measurements, it can*

> *be concluded that rebar may not cause problems with magnetic field levels as demonstrated in the shielding effect of rebar reinforced concrete structures and steel frame structures, and the exponential decay of the coupling of a magnetic field along its length, however, care should be exercised in using rebar due to its high conductivity that may cause problems in the future.*

However, the University of Alberta study discovered DC EMI differences caused by moving elevators and doors in concrete reinforced and steel frame buildings, which are presented in the same Conclusion:

> *The effects of moving metallic objects in the Earth's geomagnetic magnetic field were observed to significantly perturb magnetic field levels. Specifically, doors were found to perturb magnetic field levels above the acceptable range of 5nT over distances as great as 6m. It is recommended to keep doors away from sensitive areas by at least 6m, and if possible, 12m to be safe. Elevators were also found to significantly perturb magnetic field levels. It was found that to reach 5nT, distances as great as 38m had to be achieved. It is recommended that elevators be kept as far away as possible, at least 38m, and if possible, further to be safe. It was found that a measurable difference in the functional behavior of the fall-off of the magnetic field perturbations existed between rebar reinforced concrete structures and steel frame structures. Specifically, it was observed that perturbations in steel frame structure, both due to doors and elevators, fell off more rapidly than in reinforced concrete structures. This was attributed to a higher concentration of steel in steel frame structures which essentially tended to shield the perturbations.*

According to the University of Alberta study, the DC EMI emissions inside steel frame buildings caused by moving ferromagnetic objects (i.e., elevators, doors and vehicles) were lower because the thick steel beams appear to provide shielding (or rather absorb more magnetic flux) compared to the reinforced concrete steel. However, there is an EMI AC ELF emission higher risk from circulating ground currents in a steel frame building and uncoated steel rebar building than in an epoxy coated steel rebar reinforced concrete building. Therefore, the basement level TEM suites should use fiberglass reinforced rebar, not steel or epoxy coated rebar, to eliminate circulating ground currents under the tools over the life of the building. Steel rebar and/or steel beams can be used in the columns; however, using epoxy coated rebar for the columns would minimize circulating ground currents in a reinforced concrete structure. Unfortunately, during construction the epoxy insulation on the coated rebar can be compromised as installed and formed, so each section must be tested for electrical isolation to minimize conductive paths ensuring compliance (Quality Control Issue), which is very time consuming.

In conclusion, the DC magnetic emissions from moving ferromagnetic objects (i.e., elevators, vehicles and other objects) appear to emanate further in concrete reinforced building with steel rebar (epoxy coated or uncoated) rather than in steel frame building according to the University of Alberta study. However, circulating ground current AC ELF magnetic emissions due to electrical code violations in the electrical system would travel along the low impedance path of the steel frame structure, and to a lesser effect, on the higher impedance uncoated steel rebar structure, back to the source transformer wye grounded neutral point (usually the 415/240 V source). An epoxy coated rebar structure field tested for electrical isolation would not permit return ground currents to return inside the structure; however, the ground return currents would return on the metal conduits, pipes, HVAC ducts, unistrut supports and any other conductive paths back to the main building grounds.

Therefore, it is critical that a well-qualified, highly skilled electrical contractor with licensed electricians be selected to perform the electrical installation work. The contractor should test every neutral (feeders and branch circuits) in the building during construction to guarantee electrical isolation from the grounding system. If the electrical distribution system is fully compliant with the electrical code, then there will be very low circulating ground currents typically caused by leakage currents returning along the various conductive paths and a steel frame and/or concrete reinforced building with uncoated steel rebar would have very similar AC EMI effects on the nearby high resolution imaging tools.

<u>Additional Comments Using Metal Rebar Beneath TEM Imaging Labs</u>
Vitatech typically recommends the use of carbon fiber rebar or fiberglass fill under EM Imaging Areas rather than non-magnetic stainless steel (very expensive) and/or epoxy coated rebar to avoid circulating ground currents on stainless steel or rebar directly below EMI sensitive research tools.

However, epoxy coated rebar can be used in the EM inertia slabs and concrete under slabs as long as the epoxy coating is not compromised during installation and all the epoxy coated rebar is electrically isolated (verified by on-site continuity testing) from the other epoxy coated rebar and electrically isolated from any steel rebar and grounding system in the building so ground/net currents cannot travel on the epoxy coated rebar beneath the EM tools compromising the image quality from ground current magnetic field emissions. The EM shielded floor shield should be located beneath the EM inertia slabs to avoid transferring vibrations into the inertia slabs and EM tool. *However, Vitatech prefers the use of fiberglass fill and/or carbon fiber rebar in the concrete spaces directly beneath EM tools to completely eliminate any potential EMI problems with circulating currents on electrically compromised epoxy coated rebar due to nicks in the epoxy coating or unknown problems that compromised electrical isolation occurred during construction.* It should be noted that epoxy coated non-magnetic stainless steel (Grades 310 and 316 only) rebar has the same electrical isolation challenges as epoxy coated rebar, not magnetic and significantly more costly than epoxy coated steel rebar (Vitatech does not recommend this as a solution unless cost is not an issue). Finally, DC magnetic field magnetization due to moving steel rebar and epoxy coated steel rebar with electromagnets in the mill and transport will not seriously impact the EM tools and can shimmed into calibration during tool calibration.

Non-magnetic stainless steel, also known as austenitic, has very low magnetic permeability and almost no response to a magnet when in the annealed condition. However, when these steels have been cold worked by wire drawing, rolling or even center less grinding, shot blasting or heavy polishing the non-magnetic properties change. After substantial cold working, Grade 304 may exhibit a strong response to a magnet, whereas Grades 310 and 316 will in most instances still be almost totally non-responsive. In general, the higher the nickel-to-chromium ratio the more stable is the austenitic structure and the less magnetic response that will be induced by cold work. Therefore, Vitatech does not normally recommend using non-magnetic stainless steel unless it can be guaranteed to be the non-magnetic grade, which also requires field testing all pieces with a fluxgate magnetometer to ensure using the non-magnetic grade before installation.

Metal Stud Framing & PVC Conduit Discussion

Metal stud framing and metal conduits can present an AC ELF EMI problem when circulating ground currents due to electrical code violations (i.e., grounded neutrals, wiring errors, shorts, etc.) are present in the electrical distribution system and travel on the steel stud walls and metal conduits adjacent to sensitive imaging suites. Several research facilities such as Oak Ridge National Labs, Duffield Hall (Cornell University) and Argonne National Labs (SAMM Building) have used wooden studs and PVC conduits with twisted conductors in the high resolution imaging labs to minimize potential DC and AC ELF EMI problems. It should be noted that the Argonne SAMM Building is located more than 100 meters from the nearest road and any elevators to minimize quasi static DC EMI problems. *The University of Sydney AIN Building is located in the center of a busy campus surrounded by multiple access roads and a freight elevator within an affective proximity of the Imaging Area and sensitive instrument locations. Furthermore, the predicted DC EMI data near selected imaging labs will directly vary with the elevator and adjacent traffic emissions so it is not possible to have a pristine DC EMI environment like the SAMM site. Therefore, wooden stud framing will not benefit the EM labs. Also, Vitatech does not recommend PVC conduits in EM tool rooms because the electrical code in the United States requires metal conduits to be code compliant and there is a potential liability issue if someone is accidently electrocuted. The EMI advantage using PVC conduits is minimal and not worth the risk. Vitatech recommends metal conduit with twisted conductors for low current circuits under 100 amps in the Imaging Labs. The client must issue a "hold harmless" if PVC conduits and twisted conductors are recommended for the Imaging Areas.*

Time-Varying AC ELF & Quasi-Static DC Mitigation Strategies

Eliminating AC ELF (power frequency) and quasi-static DC magnetic field emissions is challenging due to the plethora of primary / secondary sources, underground feeders, adjacent buildings, and even the support equipment for tools themselves. However, *reducing* the magnetic field levels to acceptable (optimal performance) levels for specific instruments can be accomplished through a variety of tactics.

First and foremost, it is critical that separation distance be viewed as the primary method to providing the best EMI environment for a sensitive tool. Placing instruments and labs away from AC ELF power frequency and quasi-static DC (i.e., roads with moving vehicles, loading docks, elevators, etc.) sources is not only suggested but *encouraged*, provided it is an available option for a specific site. This includes providing the greatest distance between the instrument and the following: transmission lines, underground feeders, transformers, electrical rooms, electrical panels, electrical equipment and roads, train tracks, subways (both above and below grade), elevators, roads, loading docks, parking garages, etc. How much separation distance is required is dependent upon two factors: the nature of the surrounding sources, and the EMI sensitivity of the instrument.

After all reasonable solutions regarding applicable separation distance have been exhausted and/or considered, there are two methods for reducing magnetic field levels within an area.

The second and most effective method to attenuate time-varying 60/50 Hz and higher harmonic magnetic fields within a microscopy lab is to design and install a six-sided AC ELF (3 Hz to 3000 Hz) magnetic shielding system composed of highly conductive, seam welded thick aluminum plates. This is the preferred solution when elevated AC ELF magnetic fields up to 6 mG p-p must be attenuated down to very low 0.1 mG p-p (10 nT p-p) and less levels in the Bx, By and Bz axis measured at the tool column as required for TEMs and STEMs from circulating ground/net currents due to N.E.C. violations (i.e., grounded neutrals, wiring errors, etc.) in the electrical distribution system and traveling on conductive metallic paths (i.e., water/gas pipes, HVAC ducts, metal studs, etc.).

Attenuating the impact from quasi-static magnetic field sources (i.e., elevators, traffic, trains, subways, etc.), DC magnetic shielding is applied on six-sides to lower the ambient geomagnetic fields at the column which enhances the overall performance of DC ACS systems (see next paragraph for details). Magnetic shielding can be implemented in one of two ways: by shielding the source itself (i.e., shielding an electrical room), or by shielding the instrument or room housing the instrument (i.e. shielding an entire lab). The method recommended for a location depends on the sources surrounding the area and sizes of the labs, but multiple factors determine the proper shielding recommended for any instruments. Shielding of the utilities (i.e., primary feeders, substation vaults, etc.) is indeed possible, but will require an advanced knowledge of the physical locations of the conduits (and preferably, the current on each circuit) to ensure proper mitigation is enabled.

The third method to mitigate AC ELF and quasi-static DC magnetic field emissions is the application of active compensation system (ACS) technology. As the name suggests, ACS technology actively senses the incident magnetic field at the tool column where the fluxgate magnetometer probe is located, sending the Bx, By and Bz magnetic field signal to the ACS processor that generates an equal and opposite

(180 degree) magnetic field signal. The Bx, By and Bz magnetic signals are amplified and supplied to six (6) orthogonal Helmholtz coils installed around the tool or room with one loop pair per axis canceling the incident magnetic field emission, thus attenuating the magnitude of the magnetic field at the tool column. This is especially pertinent to areas with traffic surrounding the site on all sides (for example, Engineering Building #4 upon UCLA's campus). *This method has its limitations due to the ACS response times, number of external EMI sources and other challenges that impact the overall attenuation characteristics and performance, so selecting the proper model, manufacturer and installation solution (i.e., coils around the room vs. the tool) is absolutely essential for optimal ACS performance.*

Vitatech has successfully designed and installed AC ELF, DC and quasi-static DC magnetic shielding and RF shielding systems for research, medical and engineering facilities in the United States and around the world. We will design and recommend the most cost-effective mitigation solutions for EMI/RFI sensitive research tools for this project based upon more than 20 year of professional experience.

AC ELF, DC & RF Test Instruments

<u>FieldStar 1000 Gaussmeter - AC ELF Magnetic Flux Density</u>

Vitatech recorded the AC ELF magnetic flux density data using a FieldStar 1000 gaussmeter with a NIST traceable calibration certificate manufactured by Dexsil Corporation. The FieldStar 1000 has a resolution of 0.04 mG in the 0 - 10 mG range, 1% full-scale accuracy to 1000 mG and a frequency response of 60 Hz (55 - 65 Hz @ 3dB). Three orthogonal powdered-iron core coils are oriented to reduce interference to less than 0.25% over the full dynamic range. The three coils are arranged inside the unit holding horizontal with the display forward: Bx horizontal coil points forward, By horizontal coil points to the right side, and Bz vertical coil points upward. The microprocessor instantly converts the magnetic field to true RMS magnetic flux density (milligauss) readings of each axis (Bx, By, Bz) and simultaneously calculates the resultant R_{rms} (root-means-square) vector according to the following formula:

$$R_{rms} = \sqrt{Bx^2 + By^2 + Bz^2}$$

When collecting contour path data, a nonmetallic survey wheel is attached to the FieldStar 1000 gaussmeter and the unit is programmed to record mapped magnetic flux density data at selected (1-ft., 5-ft., 10-ft. etc.) intervals. The FieldStar 1000 is exactly 39.37 inches (1 meter) above the ground with the survey wheel attached. Along each path the distance is logged by the survey wheel and the relative direction (turns) entered on the keyboard. Up to 22,000 spot, mapped and timed data points can be stored, each containing three components (Bx, By & Bz), event markers and turn information. After completing the path surveys, magnetic flux density data is uploaded and processed. All plots display a title, time/date stamp, ID path number, and the following statistical data (in milligauss) defined below:

Peak - maximum magnetic field (flux) value measured in group.
Mean - arithmetic average of all magnetic field (flux) values collected.

The following is a quick description of the Hatch, Profile and 3-D Contour plots presented in the figures of this report:

Hatch Plot - data is represented by four difference hatch marks (0.1 mG, 0.25 mG, 0.5 mG and 1.0 mG thresholds) based on width and color as a function of distance along the survey path that shows 90 and 45 degree turns. Note: the site drawing and all Hatch Plots were scaled in feet to verify actual recorded distances and correct survey locations.

Profile Plot - data shows each recorded component (Bx, By, Bz) axis and the resultant (Br) levels as a function of distance: Bx (red) is the horizontal component parallel to the survey path, By (green) is the horizontal component normal (perpendicular) to the survey path, and Bz (blue) is the vertical component with the computed Br resultant RMS (root-means-square) summation of the three components.
3-D Contour Plot - displays the magnitude of the computed resultant Br in the vertical direction (peaks and valleys) using eight threshold color ranges from 0.1 to 2-mG. Letter markers are included on the 3-D Plots to reference turns on the Hatch Plots.

<u>MEDA FVM-400 DC Three-Axis Magnetometer</u>
timed three-axis DC magnetic flux density levels were recorded from the elevators and moving vehicles with a three-axis fluxgate magnetometer at 1 second intervals over a 10-minute periods. The MEDA FVM-400 three-axis fluxgate magnetometer has 1 nT (0.01 mG) resolution and 1.2 Gauss (1,200 mG) maximum range with 1% full scale accuracy from 0-10 Hz. Data is downloaded directly to a computer during data collection and processed for graphical presentations.

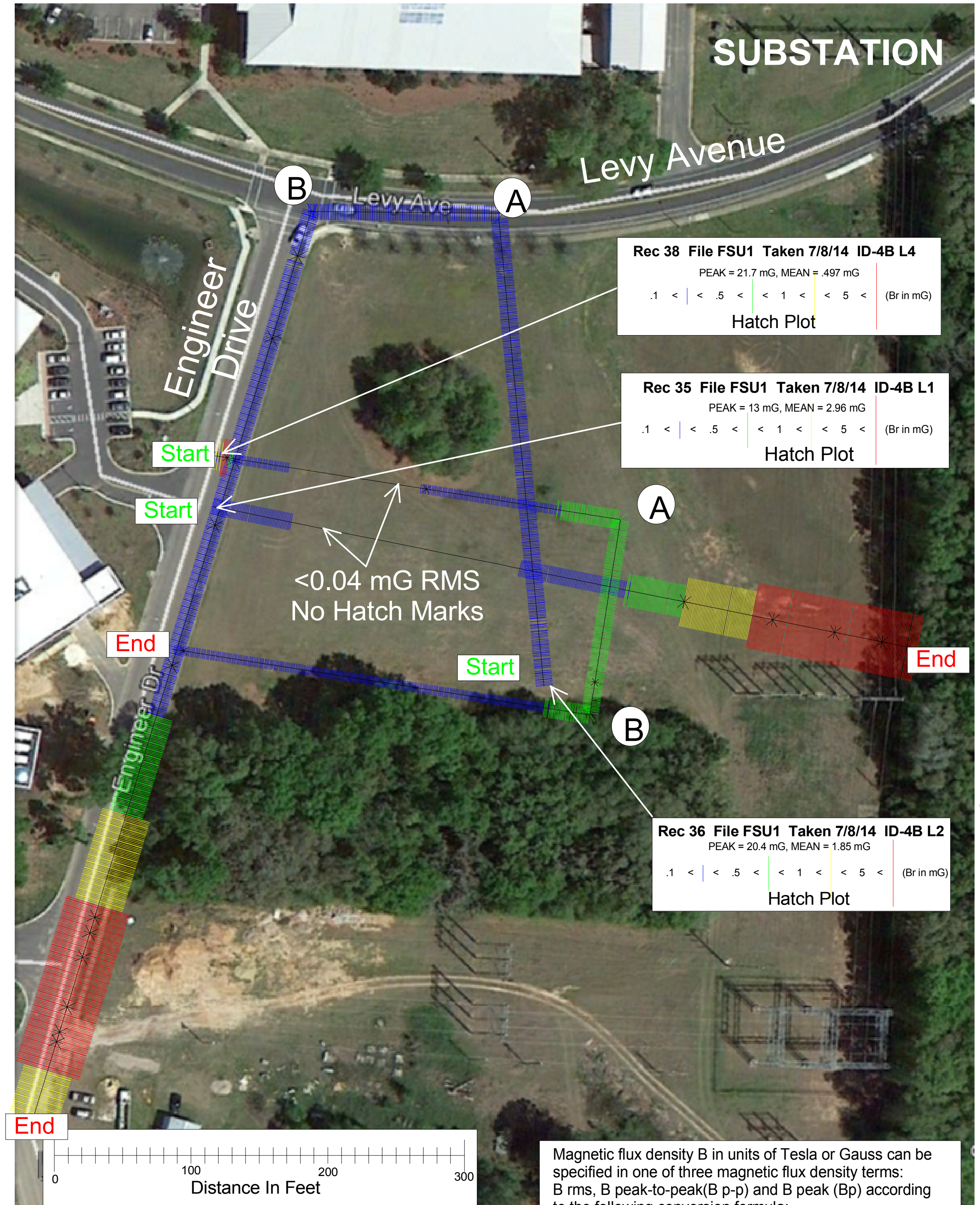
<u>SRM-3000 RF Spectrum Analyzer - Electric Field Strength Data 100 kHz - 3 GHz</u>
The state-of-the-art SRM-3000 Spectrum Analyzer is a radio-frequency (RF) electric field strength meter for broadband measuring and monitoring from 100 kHz to 300 MHz with a single axis active antenna and 75 MHz to 3 GHz with an isotropic active antenna. Each antenna attached to the top of the device records spectral data in Volts-per-meter (V/m) and simultaneously visually arranges it for immediate use. It records average, maximum and peak data while recording each of its timed "samples" at an average rate of 1 sample per second. In addition, safety analyses can be performed, which record the RF electric field strength levels in comparison to the recommended exposure limits expressed in percentile ratio.

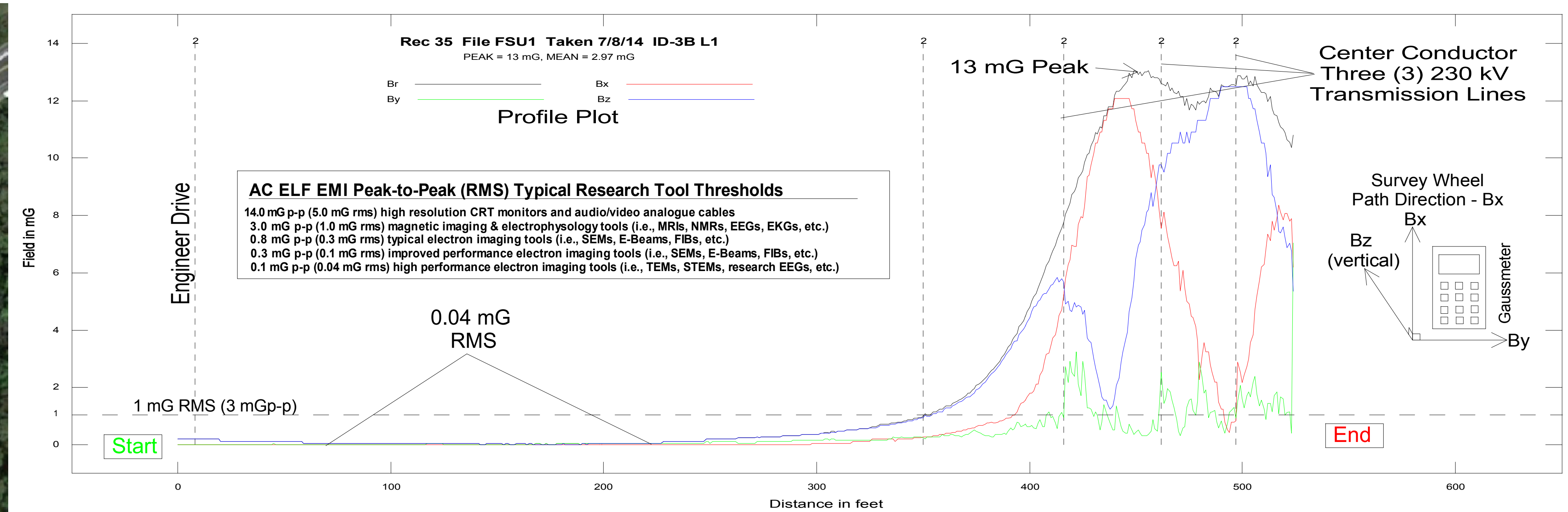
This completes the *EMI/RFI Site Survey Report – Florida State University Interdisciplinary Science Research Building Recommendations and Mitigation Strategies. The contents of this report are intended for the exclusive use of the Florida State University and Wilson Architects.*

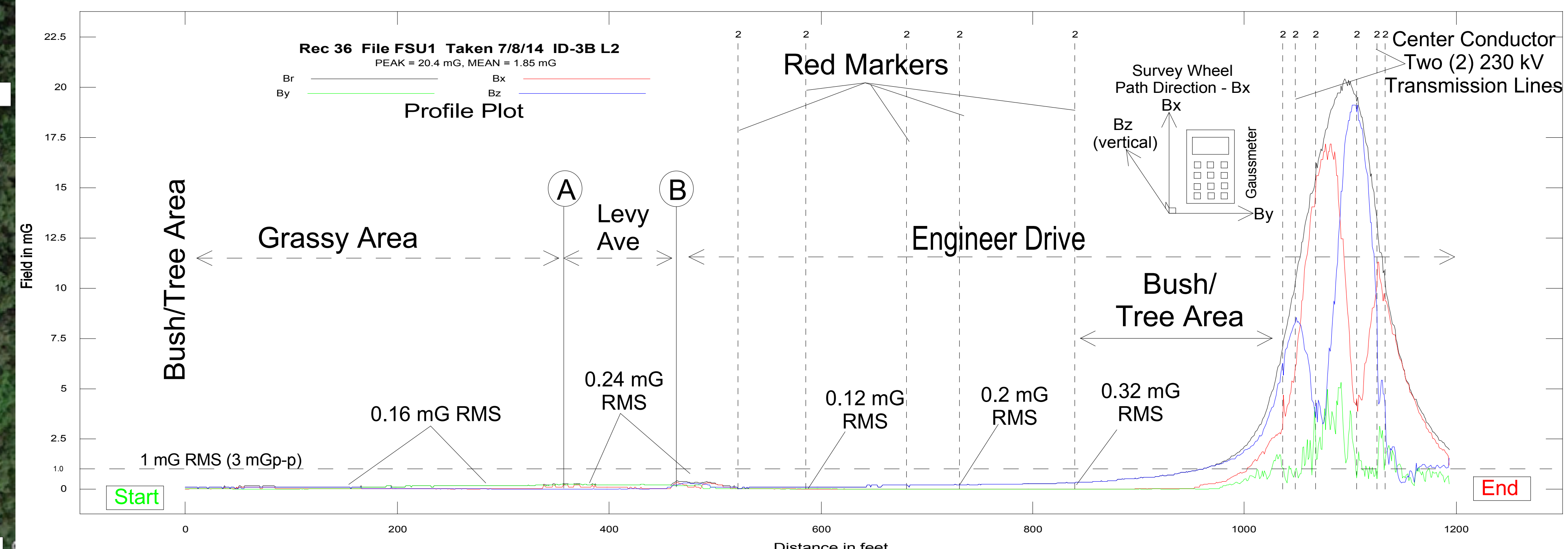
Best regards,

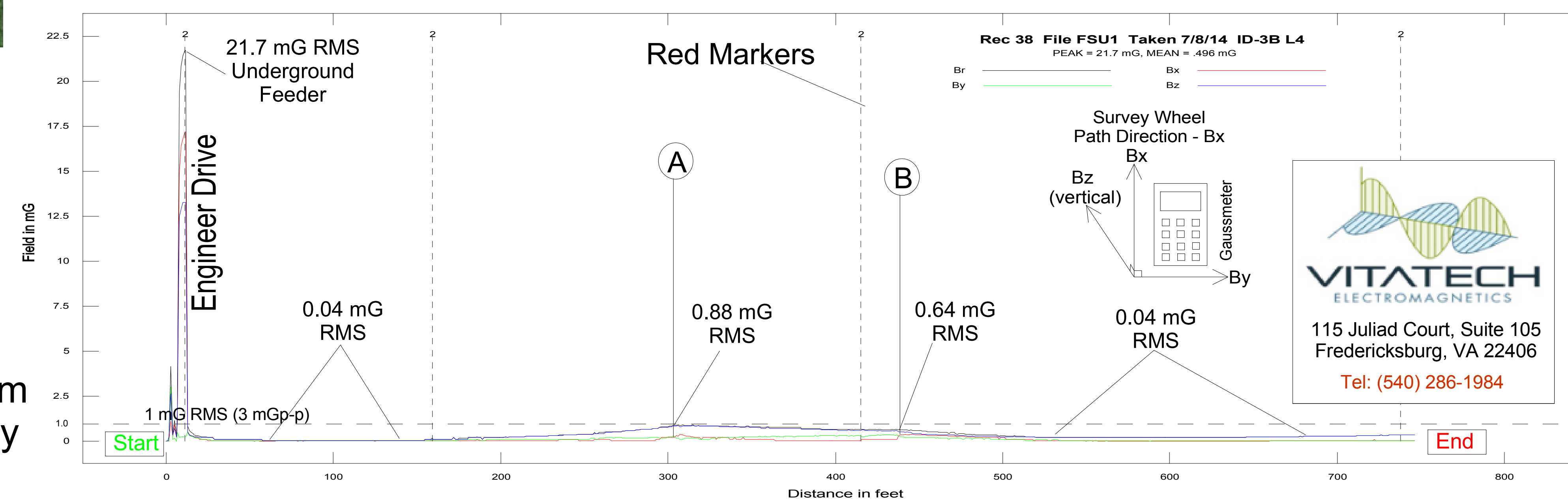
Louis S. Vitale, Jr.
Chief Engineer & Founder

Attachments: Figures #1 - #3 (total of four figures)









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Magnetic flux density B in units of Tesla or Gauss can be specified in one of three magnetic flux density terms: B rms, B peak-to-peak(B p-p) and B peak (Bp) according to the following conversion formula:

$$B_{rms} = \frac{Bp-p}{2\sqrt{2}} = \frac{Bp}{\sqrt{2}}$$

Magnetic field strength (A/m) in SI units can be converted to units of milligauss (mG) according to the following conversion formula:

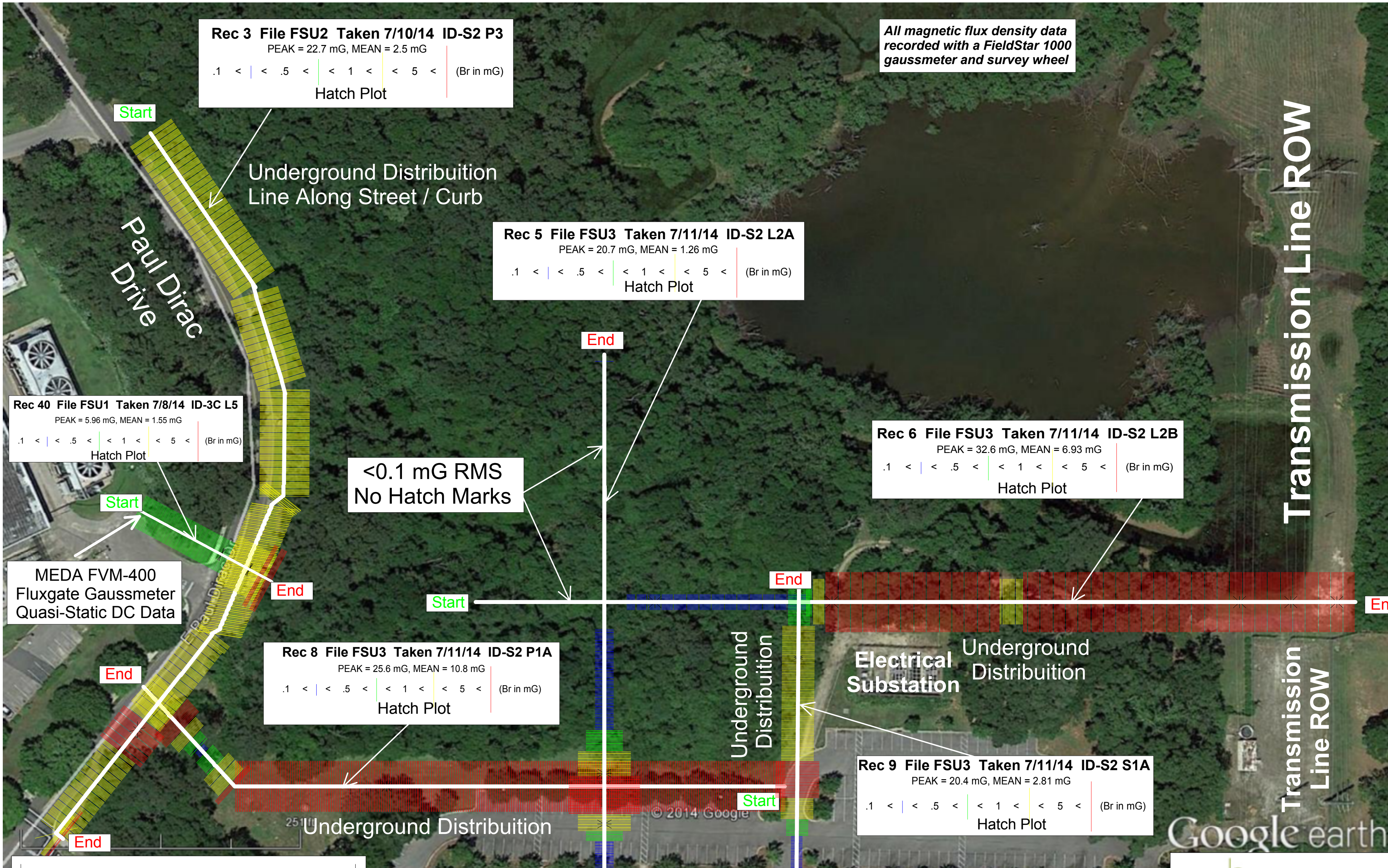
$$\text{mG} = 4\pi(\text{X A/m})$$

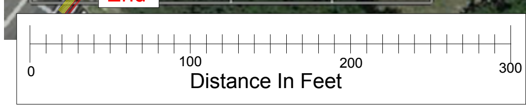
SI & CGS Unit Conversion Chart
Magnetic Flux Density

Tesla (T):	1 T =	10,000 Gauss (G)
milliTesla (mT):	1 mT =	10 Gauss (G)
microTesla (uT):	1 uT =	10 milliGauss (mG)
nanoTesla (nT):	1 nT =	0.01 milliGauss (mG)

All magnetic flux density data recorded with a FieldStar 1000 gaussmeter and survey wheel

Figure #1, Lot 4B, Southwest Campus
Hatch & Profile Laterals - Magnetic Flux Density @ 1-m
FSU Interdisciplinary Science Research Building Study
Florida State University (FSU), Tallahassee, Florida





Profile Plots Refer To Figure #2A.

Figure #2, Lots 3C, 4C & 5C Southwest Campus
Hatch Laterals - Magnetic Flux Density @ 1-m
FSU Interdisciplinary Science Research Building Study
Florida State University (FSU), Tallahassee, Florida

Magnetic flux density B in units of Tesla or Gauss can be specified in one of three magnetic flux density terms: B rms, B peak-to-peak(B p-p) and B peak (Bp) according to the following conversion formula:

$$B_{rms} = \frac{Bp-p}{2\sqrt{2}} = \frac{Bp}{\sqrt{2}}$$

Magnetic field strength (A/m) in SI units can be converted to units of milligauss (mG) according to the following conversion formula:

$$\mathrm{mG} = 4\pi(\mathrm{X\ A/m})$$

SI & CGS Unit Conversion Chart
Magnetic Flux Density

Tesla (T):	1 T =	10,000 Gauss (G)
milliTesla (mT):	1 mT =	10 Gauss (G)
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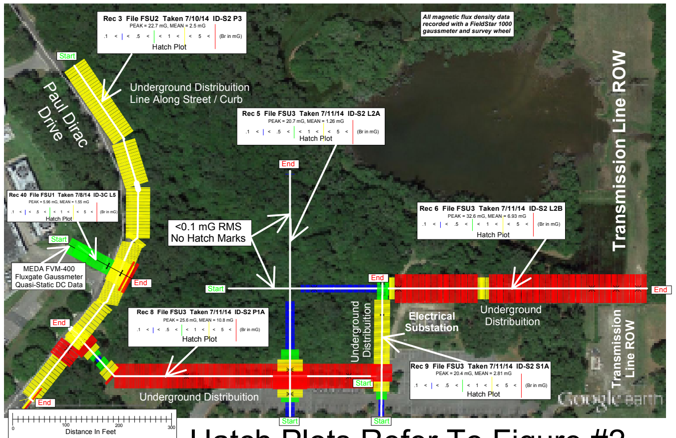
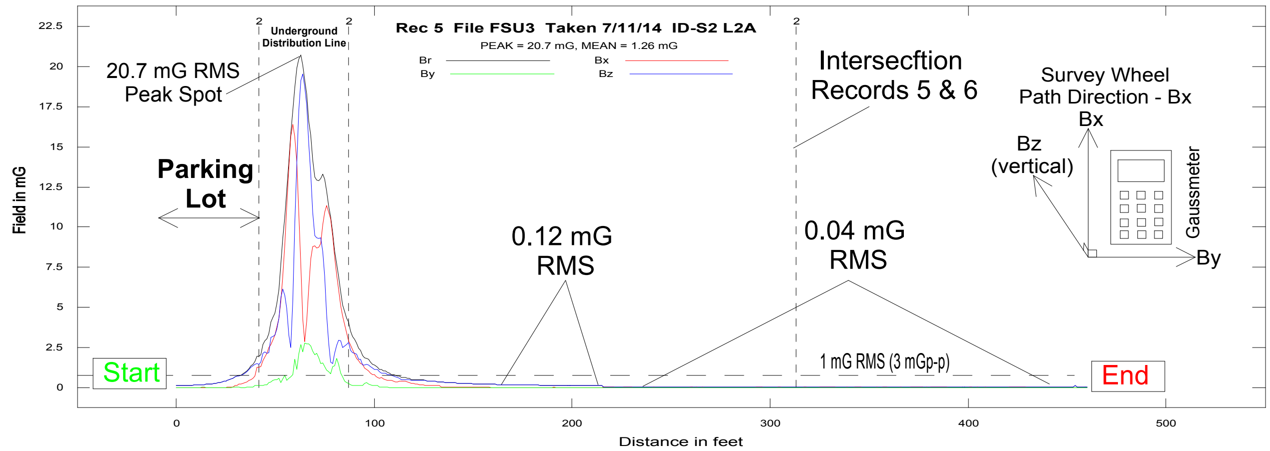
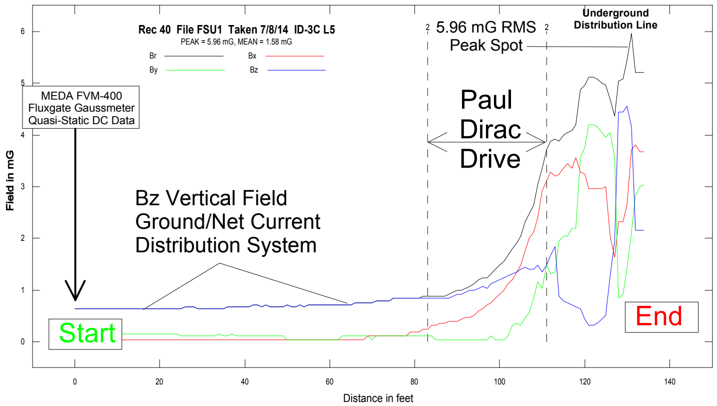
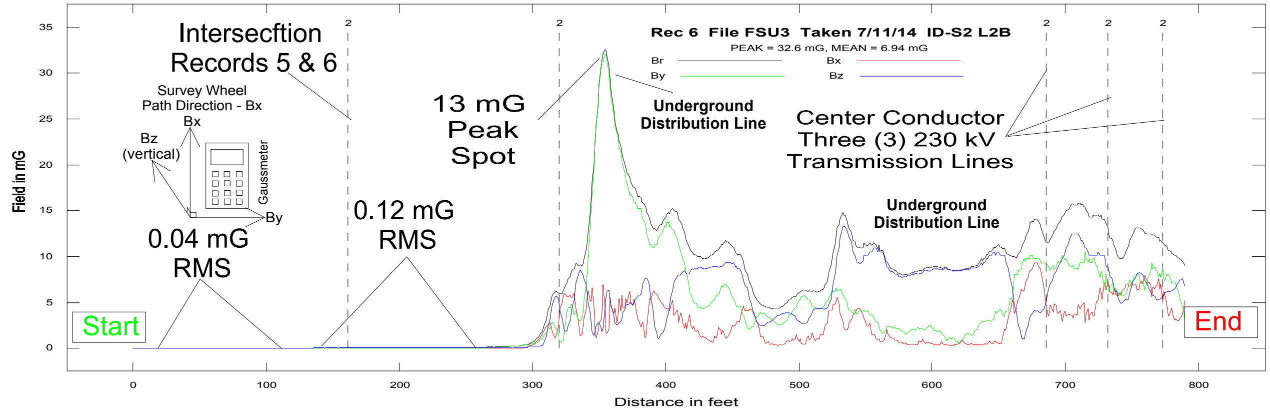
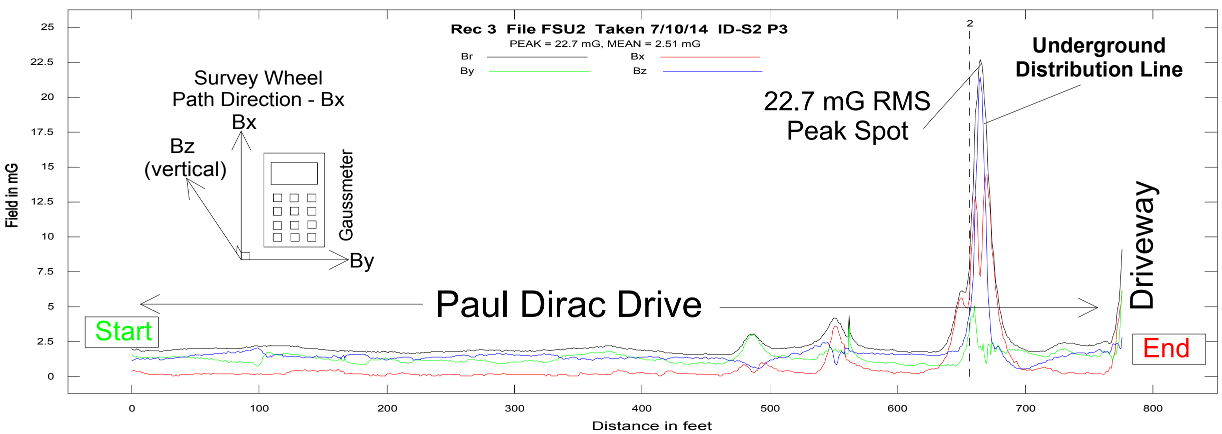


Hatch Plots Refer To Figure #2.









AC ELF EMI Peak-to-Peak (RMS) Typical Research Tool Thresholds

- **14.0 mG p-p (5.0 mG rms) high resolution CRT monitors and audio/video analogue cables**
- **3.0 mG p-p (1.0 mG rms) magnetic imaging & electrophysiology tools (i.e., MRIs, NMRs, EEGs, EKGs, etc.)**
- **0.8 mG p-p (0.3 mG rms) typical electron imaging tools (i.e., SEMs, E-Beams, FIBs, etc.)**
- **0.3 mG p-p (0.1 mG rms) improved performance electron imaging tools (i.e., SEMs, E-Beams, FIBs, etc.)**
- **0.1 mG p-p (0.04 mG rms) high performance electron imaging tools (i.e., TEMs, STEMs, research EEGs, etc.)**

Figure #2A, Lots 3C, 4C & 5C Southwest Campus Profile Laterals - Magnetic Flux Density @ 1-m FSU Interdisciplinary Science Research Building Study Florida State University (FSU), Tallahassee, Florida

Magnetic flux density B in units of Tesla or Gauss can be specified in one of three magnetic flux density terms: B rms, B peak-to-peak(B p-p) and B peak (Bp) according to the following conversion formula:

$$B_{rms} = \frac{Bp-p}{2\sqrt{2}} = \frac{Bp}{\sqrt{2}}$$

Magnetic field strength (A/m) in SI units can be converted to units of milligauss (mG) according to the following conversion formula:

$$\text{mG} = 4\pi(\text{X A/m})$$

SI & CGS Unit Conversion Chart
Magnetic Flux Density

Tesla (T):	1 T =	10,000 Gauss (G)
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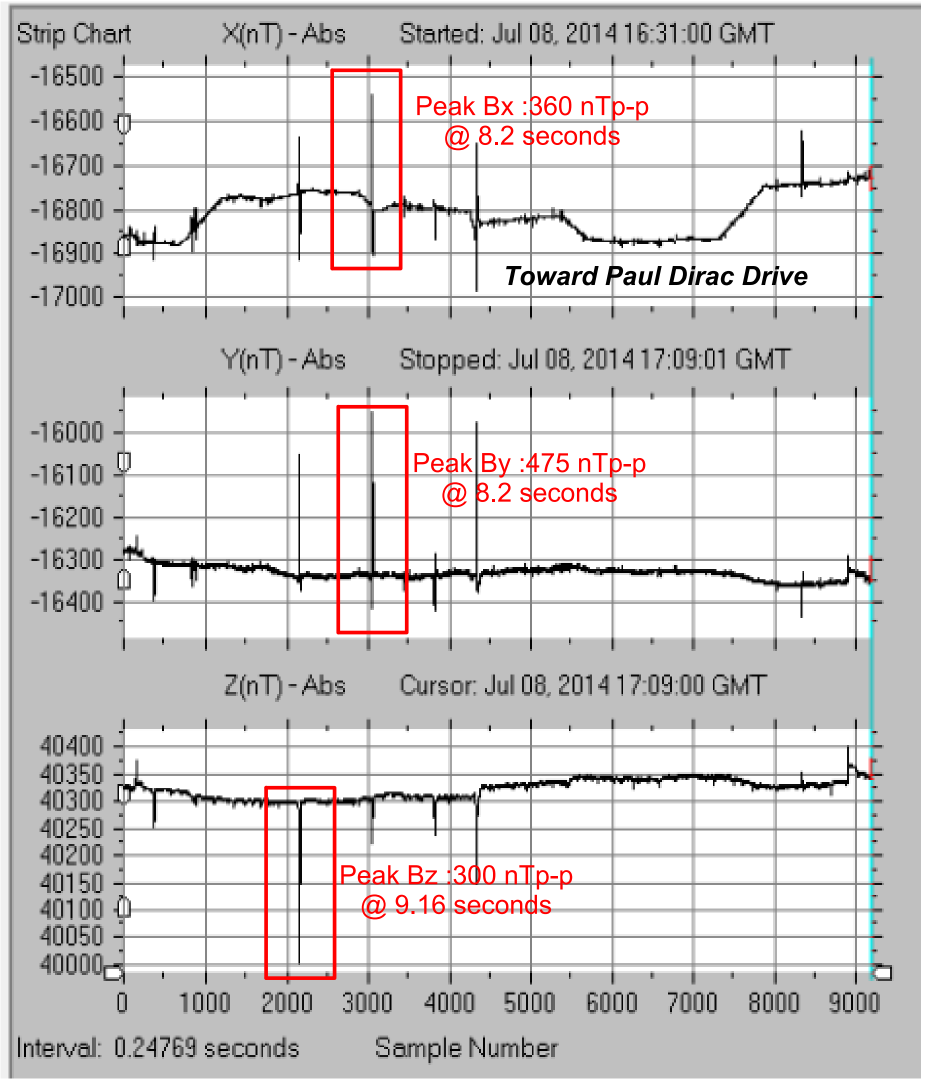
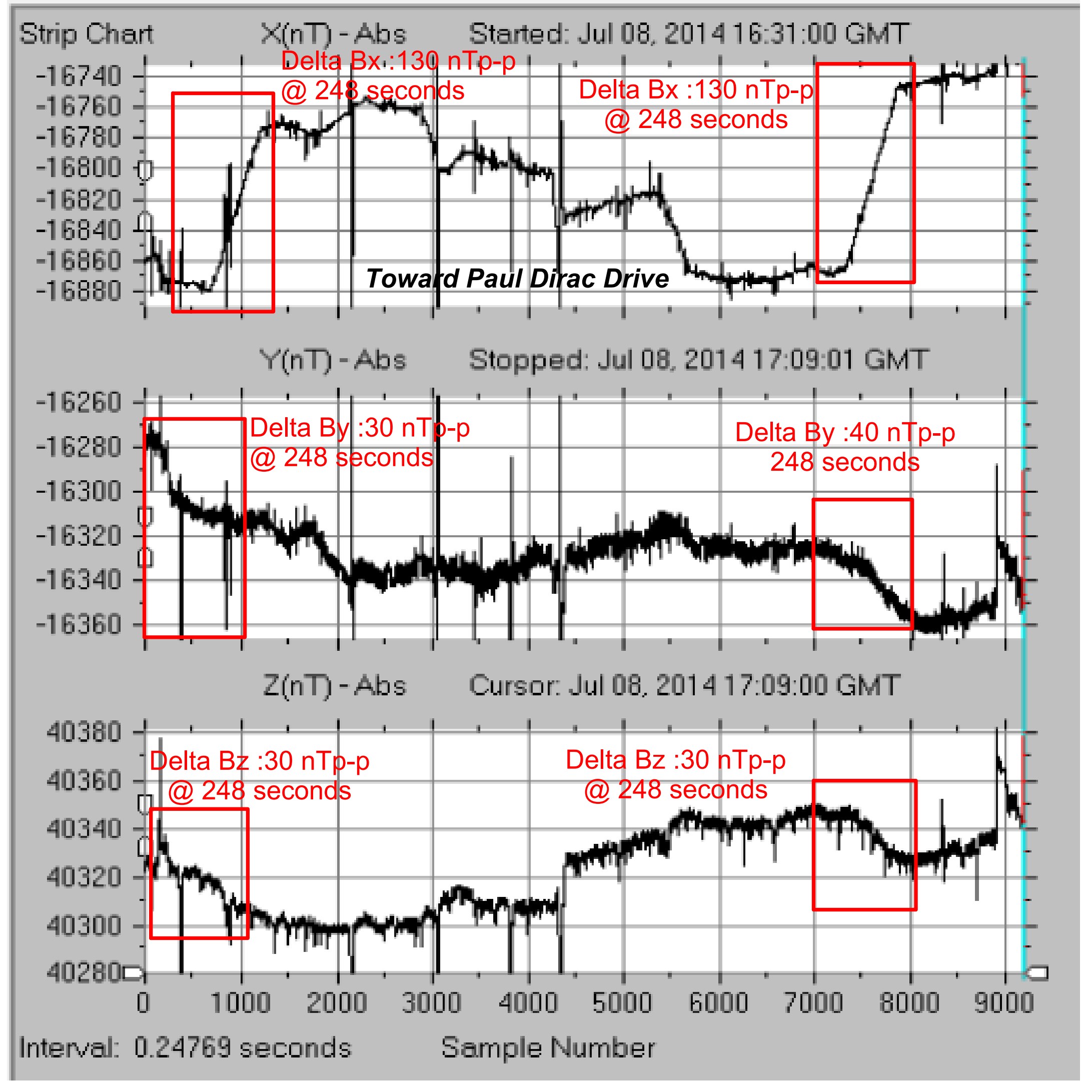


Quasi-Static DC Magnetic Flux Density Data
Vehicles Passing Fluxgate Probe



Quasi-Static DC Magnetic Flux Density Data
DC Static Changes Fluxgate Probe (Not Spikes)

Timed DC magnetic flux density levels recorded with MEDA FVM-400 three-axis fluxgate magnetometer. Data sampled at 0.2 sec, bandwidth DC - 10 Hz, 0.01 mG (1 nT) resolution, 1200 mG maximum.

Recorded Timed DC EMI Emission Data
Driveway & 80 ft. to Paul Dirac Drive (peak-to-peak)

Axis	Delta Range	Peak
Bx	130 nT	360 nT
By	30 to 40 nT	475 nT
Bz	30 nT	300 nT

**Figure #3, Lots 3C, 4C & 5C Southwest Campus
Timed Quasi-Static DC Magnetic Flux Density @ 1-m
FSU Interdisciplinary Science Research Building Study
Florida State University (FSU), Tallahassee, Florida**

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