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ACS & EM Tool Interaction

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Active Compensation System (ACS) technology is a very powerful mitigation tool. ACS technology can reduce 50/60 Hz and quasi-static DC magnetic fields in an empty volume of space up to -60 dB (1000 times reduction). But -60 dB attenuation is the theoretical maximum. Actual reduction levels range between -15 to -30 dB (5 to 31 times field reduction) for most ACS vendors and between -30 dB to -50 dB (30 to 316 times field reduction) for the Stefan Mayer FAST MR-3 ACS. Why such a disparity? Coil design (number of turns), coil amplifier (current pump verses voltage amplifier), coil placement (perimeter walls, horizontal X-Y off-set, Merritt, etc.), and ACS signal processing capabilities. Vitatech has already shown that poor perimeter coil layout shown in Figure #1 below can create as much as 80nT variation over 2m elevation of a TEM column. But there are several other critical factors that can degrade attenuation as well.

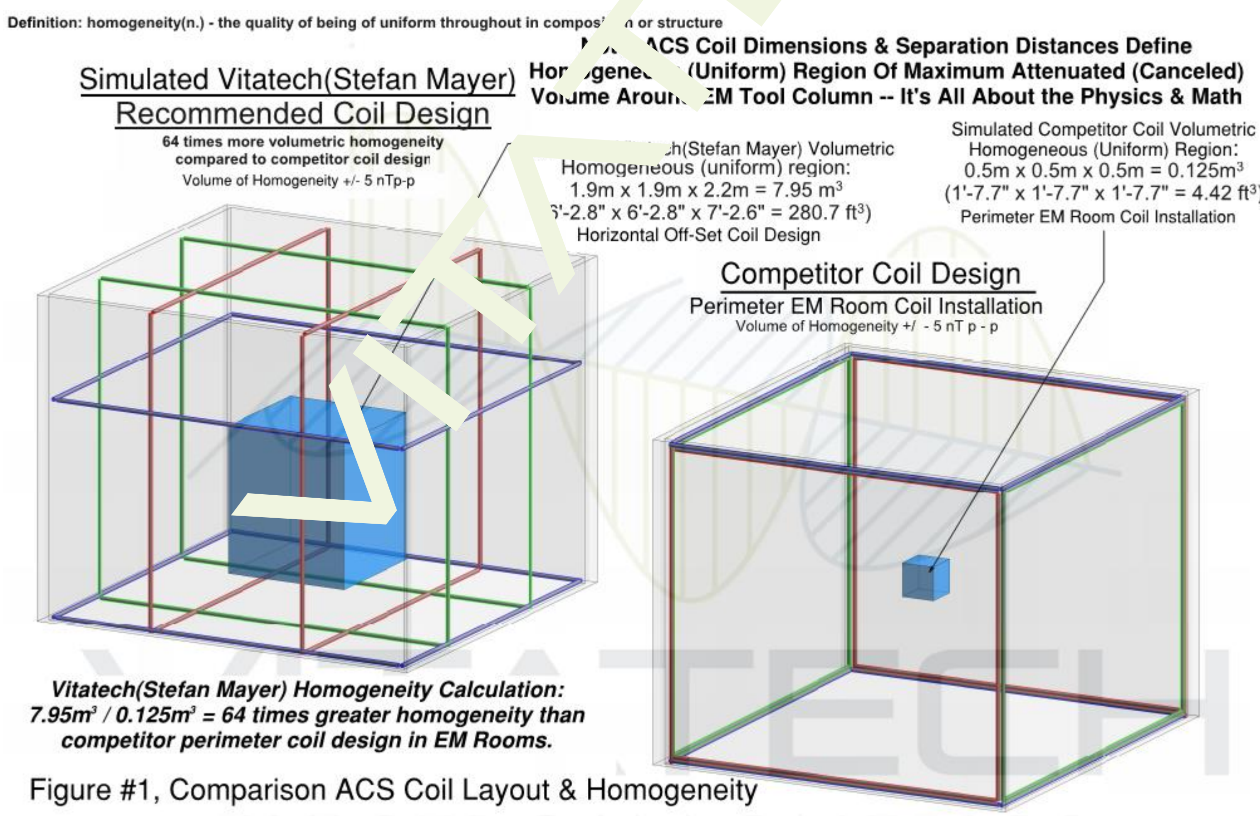


Figure #1, Comparison ACS Coil Layout & Homogeneity

First, the EM fields to be canceled are rarely homogenous (uniform). Most power frequency 50/60 Hz magnetic fields are localized, and as such have significant gradients. In addition, there are multiple 50/60 Hz sources (i.e., switchgears, feeders, transformers, panels, motors, etc.) with gradient fields. Magnetic fields add and subtract as vectors in complex ways that have localized three dimensional components. It is essentially impossible to cancel complex gradient fields with a single sensor position and three (3) pair Helmholtz coil axis ACS system. If fact, only uniform magnetic fields can be effectively ACS cancelled such as distant vertical Bz quasi-static DC sources from electrified trains and subways; and, uniform ground/net current magnetic fields from N.E.C. code violations (i.e., grounded neutrals, wiring errors, etc.) each of which generates highly uniform fields. But there is more.

The most magnetically sensitive location in the EMs are within the tool column. Particularly along the electron beam line in the free field regions. Obviously, it is not practical to place the sensor inside the tool column. The sensor must be placed outside the column, far enough away that the electron lens stray flux does not saturate the fluxgate detector. Any exterior column sensor position is a compromise. There are still more detrimental factors…

The homogeneity of the controlling fields in an ACS system are predicated on the uniform permeability of the volume of controlled space. Air has a relative magnetic permeability of essentially one. Electron optics columns are made from iron, steel and frequently have Mμ-metal or Permalloy covers. The outside of the EM may have a relative permeably of several thousand. What does this mean? The discontinuity in permeability between the air and the column distorts the flux lines in and around the column. The flux follows the path of least *reluctance*. To put it another way, the magnetic flux lines are “sucked” into the column. The Figure #2 below shows a two-dimensional FEA model of this effect.

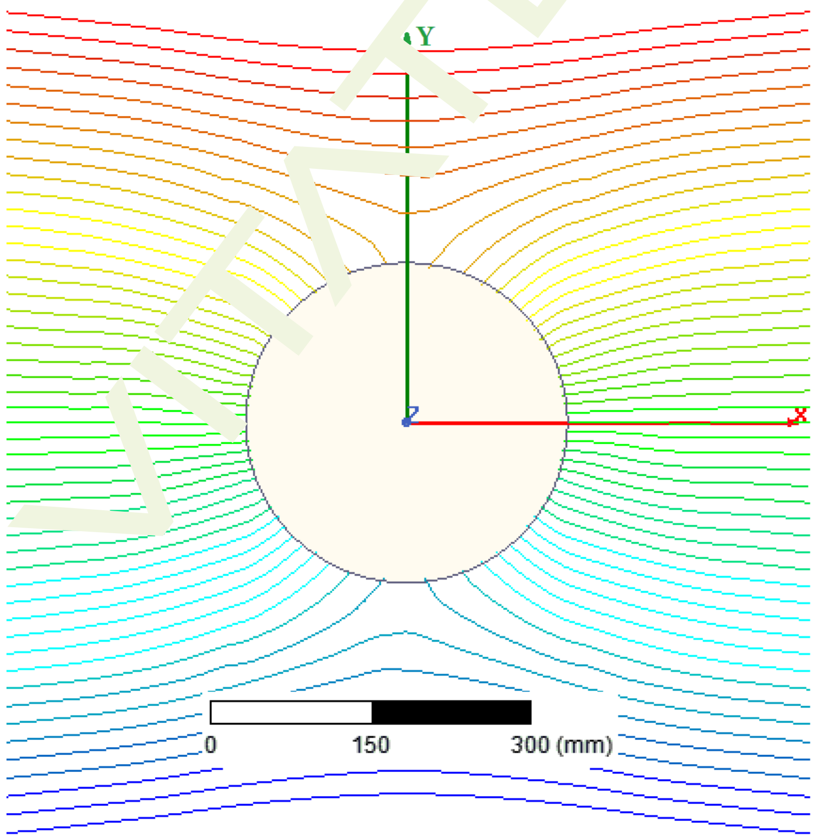


Figure #2

Why does this make a difference? The distorted flux lines can alter the virtual sensor orientation. For best performance, the sensor should only respond to signals in the intended axis. Response to other axes causes crosstalk between the axes that limits effective gain and therefore noise reduction. Figure #3 shows the sensor placed in two locations, Position 1 the sensor accurately responds to the X flux, Position 2 causes the X flux to be detected in both the X and Y sensors. This splitting of the signal leads to crosstalk. If individual X, Y and Z sensors are implemented, they can be adjusted to follow the localized flux lines. If the sensor is a single three axis sensor, no single position can have virtual orthogonality in all three axes. The only way to reduce this effect is to move the sensor away from the column. In moving the sensor away, you are moving away from the ideal location, inside the column space. One partial solution is to use two separate three axis sensors. When placed outside the distorted region, blending the two sensors signals can create a virtual sensor that approximates the location inside the column.

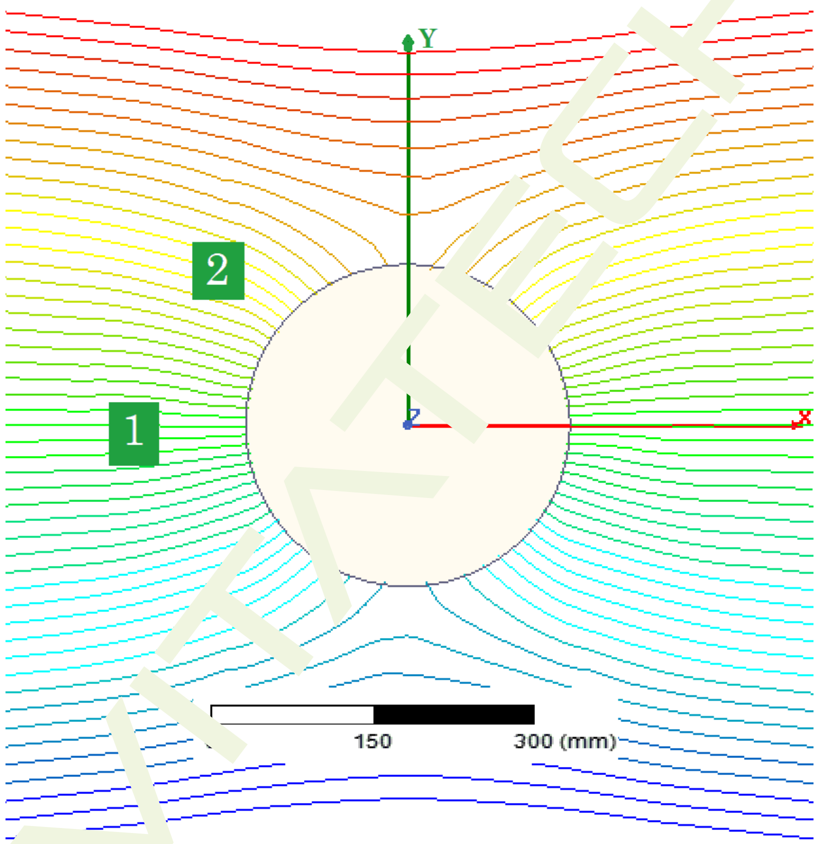
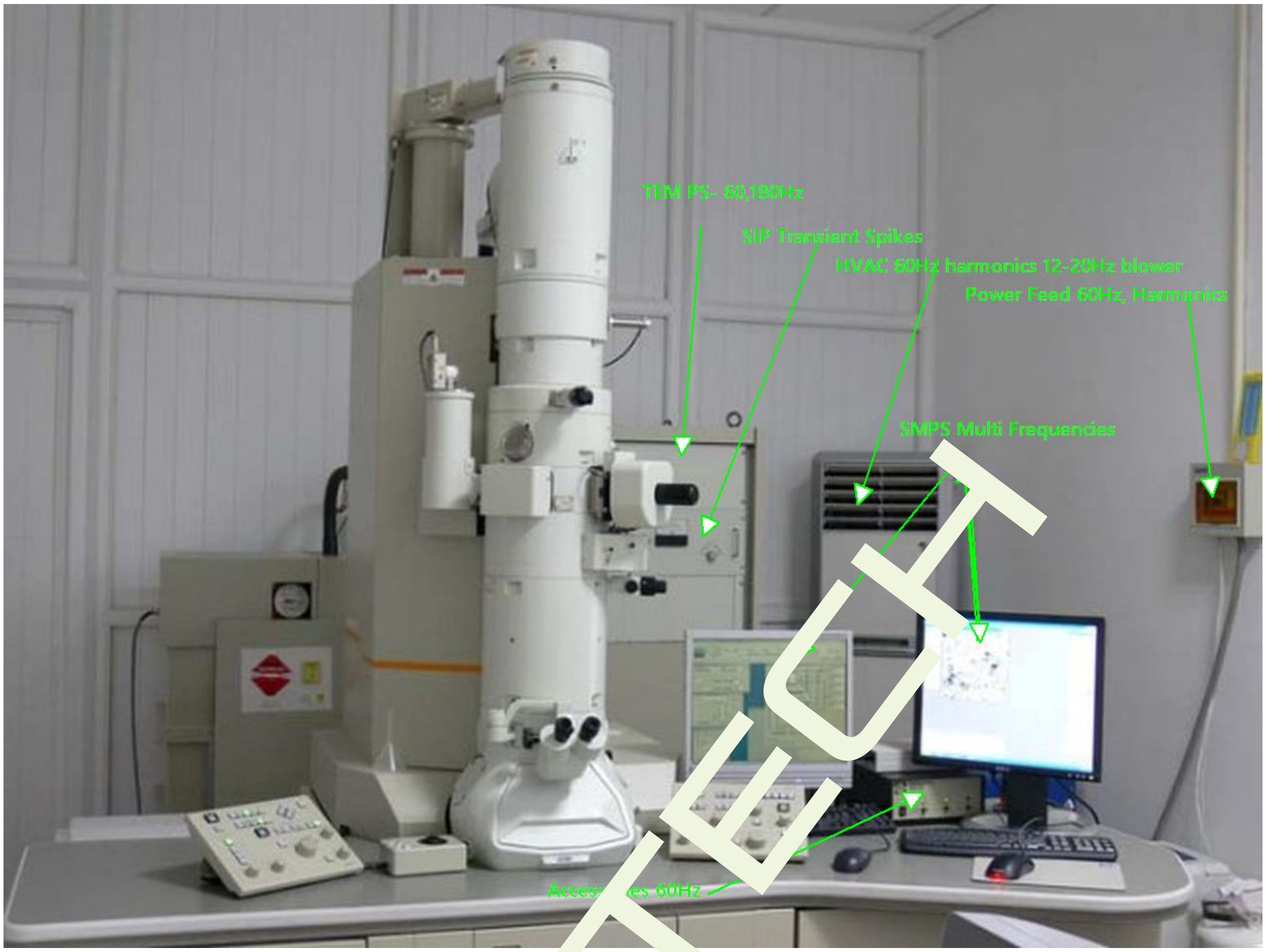


Figure #3

Finally, the electron microscope environs are filled with EMI sources. The microscope power supplies, vacuum system, sensors, even lenses generate secondary undesirable EMI. There are also many accessories normally used with a EM that if placed too close to the microscope can degrade instrument performance. Attached is a picture shown below with tool support EMI sources highlighted.



There are many unseen sources as well. Some high end TEMs have turbo pumps that have high powered motors. There are huge ion pump magnets on many TEMs and SEM, as well as electric solenoid valves. The scan coils in STEM and SEM create saw tooth fields rich in harmonics. These EMI sources have steep decay rates so effects are very local. Placing an ACS sensor near one of these localized sources can effectively amplify the noise instead of canceling them. Even the panels can get into the mix. Steel panels vibrating can modulate the earth magnetic field. If a sensor is placed right next to the panel is can act as a giant microphone, converting the acoustic vibration to magnetic fields, broadcasting them within the microscope space.

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Drew McCrady comes to Vitatech with 32 Years of experience from JEOL Instruments, USA, in the scientific instrument field including SEMs, TEMs, STEMs, FIBs, Mass Spectrometers, and other research tools. The last 15 years he was *in-charge* of environmental surveys, instrument siting, facilities documentation and installation project management at a prominent, world-class, international research imaging vendor. He has developed unique EMI magnetic field management, vibration and temperature control solutions with various partners across the industry. Mr. McCrady has performed and managed environmental surveys throughout the United States and Canada. He is an expert in EMI, vibration, acoustic, temperature and airflow measurements and remediation assessing the results and making recommendations. Beside decades of environmental remediation work, he has extensive experience working with US and international Active Compensation System (ACS) vendors to achieve optimal attenuation, imaging performance and stability. Mr. McCrady has a thorough knowledge of the building trades and working with contractors on complex research instrumentation construction projects. He has a clear understanding the expectations, concerns, fears and technical challenges encountered in the ever-changing and demanding world of high resolution imaging technology and *state-of-the-art* environmental control.