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Reducing Radio Frequency Susceptibilities in Commercial-Off-the-Shelf Camera Equipment for use in Electromagnetic Compatibility Testing

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Reducing Radio Frequency Susceptibilities in Commercial-Off-the-Shelf Camera Equipment for use in Electromagnetic Compatibility Testing

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by

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ABSTRACT

Reducing Radio Frequency Susceptibilities in Commercial-Off-the-Shelf Camera Equipment for use in Electromagnetic Compatibility Testing

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The Technical Testing and Analysis Center (TTAC) Group at Oak Ridge National Laboratory performs electromagnetic compatibility testing on various radiation detection units. These tests require remote viewing of the equipment's display to monitor its compliance with national and international standards. The Commercial-Off-the-Shelf (COTS) camera equipment that is used to monitor the displays exhibits radio frequency susceptibilities causing issues when determining the actual susceptibilities of the device under test. In order to mitigate this issue, a COTS camera was placed in two common test positions and cycled through three angled orientations with various radio frequency shielding methods applied. The development of these shielding methods was investigated in this thesis. The goal was to reduce the number of susceptible frequencies. The reduction of susceptibilities would greatly increase the viewing capacity of the cameras during testing. The techniques discovered have allowed for other COTS camera equipment to be modified and used effectively during electromagnetic compatibility testing.

DEDICATION

This thesis is dedicated to my parents. Mom, words are not enough to express my love and gratitude for all that you do for me. Dad, your vast knowledge continues to be an inspiration for me. I love you both.

− Kevin

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LIST OF ACRONYMS

American National Standards Institute	(ANSI)
Closed-Circuit Television	(CCTV)
Commercial - Off - the - Shelf	(COTS)
Electromagnetic Compatibility Testing	(EMC)
Electromagnetic Interference	(EMI)
Equipment Under Test	(EUT)
Gigahertz Transverse Electromagnetic Cell	(GTEM)
Institute of Electrical and Electronics Engineers Standards Association	(IEEE-SA)
International Electrotechnical Commission	(IEC)
National Voluntary Laboratory Accreditation Program	(NVLAP)
Oak Ridge National Laboratory	(ORNL)
Radio Frequency	(RF)
Technical Testing and Analysis Center	(TTAC)

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CHAPTER 1

INTRODUCTION

The Technical Testing and Analysis Center (TTAC) Group at Oak Ridge National Laboratory (ORNL) is an independent testing laboratory involved mainly in the testing of radiation detection units. The tests performed on these units are based on national and international standards such as the American National Standards Institute (ANSI), Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA), International Electrotechnical Commissions (IEC), Military Standards, and various other standards. The applicable standards contain the tests and outcomes required for all types of equipment being tested. The TTAC Group has the capability to test a variety of radiation detection devices and other equipment such as: hand-held detection units, backpack detection units, spectrometric detectors, personal protective equipment, and mobile detectors as well as a number of prototype radiation portal monitors that are sent by sponsors for evaluation. The TTAC Group is currently accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) making it imperative that TTAC be able to properly perform tests in compliance with the above applicable standards-based test for every product.

The TTAC Group performs electromagnetic compatibility (EMC) testing such as radiated emissions, radio frequency susceptibilities, and conducted immunities. The instruments used by the TTAC Group to conduct these tests are a semi-anechoic chamber and a Gigahertz Transverse Electromagnetic wave cell (GTEM). The semi-anechoic chamber is capable of testing a frequency range of 26 MHz to 18 GHz. The GTEM can test a frequency range from DC to 18 GHz.

CHAPTER 2

BACKGROUND

During radio frequency susceptibility testing, the equipment under test (EUT) is placed in the center of the GTEM and exposed to a range of radio frequencies at a specific intensity based on the EUT and the associated standards. Since the test operators cannot be in the chamber with the EUT during the test (for health and safety reasons), a commercial-off-the-shelf (COTS) camera is placed in the GTEM along with the EUT to monitor the activity of the equipment. The COTS camera outputs video to a remote viewing monitor to either be watched live during the test, or to be recorded for viewing at a later date. Recording the test allows the test operators the ability to review the test if any discrepancies are found in later tests. While this is a very helpful method for the test operators, the camera itself contains radio frequency susceptibilities that can cause viewing issues. Depending on the position of the COTS camera in the chamber, certain frequency bands will cause various malfunctions on the output signal. This occurs any time those specific frequency bands are scanned making it difficult or even impossible to see what is going on inside the chamber. It is vital that the operator be able to identify weather the EUT is functioning properly at all scanned frequencies. With this issue hindering their view of the EUT the identification becomes significantly more challenging and sometimes unattainable. This is considered unacceptable to the TTAC Group and therefore requires that a solution be researched and implemented. Pictures of the GTEM (Figure 1) and the COTS camera (Figure 2) that will be used in this experiment are shown below.

Figure 1: Gigahertz Transverse Electromagnetic Wave Cell (Used With Permission From: ETS-Lindgren Inc., 2013, p. 1).

Figure 2: Commercial Off the Shelf Panasonic WV CP470 (Adapted from: Panasonic, 2014, p. 1).

Objective

The objective of this thesis is to determine an effective shielding method to increase the viewing capacity of COTS camera equipment that is used in EMC testing. In order to achieve this goal, a COTS camera will be tested in the GTEM cell independently and with various radio frequency shielding materials and techniques. The COTS camera will be placed in the two most typical positions in the GTEM during testing of EUTs (centered and offset). It will then be cycled through the three most extreme angled orientations (+60°, 0°, and -60°) for a total of six locations/positions per shielding material/method. The COTS camera will then be exposed to typical radio frequency susceptibility testing procedures based on all ANSI standards used by the TTAC group (80 MHz to 2.5 GHz).

The above tests will allow sufficient data to be collected in order to find a viable solution to the adverse effects. It is hypothesized that with the addition of radio frequency shielding materials, the susceptible frequencies will be significantly reduced or removed from the COTS camera. The combination of acquired data and analysis will allow for a general modification process to be used on this and other COTS cameras.

Literary Review

The Technical Testing and Analysis Center (TTAC) Group at Oak Ridge National Laboratory performs electromagnetic compatibility testing on various radiation detection units. These tests require remote viewing of the equipment's display to monitor its compliance with national and international standards. The Commercial-Off-the-Shelf (COTS) camera equipment that is used to monitor the displays exhibits radio frequency susceptibilities causing issues when determining the actual susceptibilities of the device under test.

In order to mitigate this issue, the COTS camera will be tested with various radio frequency (RF) shielding and suppression materials applied to it. Before going further, it is important to understand the following terms as defined by Xingcun Colin Tong,

> *Electromagnetic compatibility* (EMC) is the capability of electrical and electronic systems, equipment, and devices to operate in their intended electromagnetic environment within a defined margin of safety, and at design levels or performance, without suffering or causing unacceptable degradation as a result of electromagnetic interference (EMI). EMC can generally be achieved by suppressing EMI and immunizing susceptibility of the systems and devices. *Susceptibility* is a relative measure of a device's or a system's propensity to be disrupted or damaged by EMI exposure to an incident field or signal. It indicates the lack of immunity. *Immunity* is a relative measure of a device's or system's ability to withstand EMI exposure while maintaining a predefined performance level. Radiated immunity is a product's relative ability to withstand electromagnetic energy that arrives via free space propagation. Conducted immunity is a product's relative ability to withstand electromagnetic energy that penetrates it through external cables, power cords, and input/output (I/O) interconnects. (Tong, 2008)

Immunity (susceptibility) control has two parts: conducted (on hard wire) and radiated (radio-wave coupling) (Whitaker, 2002). In an attempt to find an effective way of removing or reducing the susceptibilities seen in the COTS camera, solutions for both radiated and conducted susceptibilities were researched.

Since the enclosure of the COTS camera cannot be tampered with, it was decided that shielding fabrics would be the best way to fully surround the camera. EMI shielding fabrics make use of two independent methods for preventing radiated susceptibilities: reflection and absorption. Just like light off a mirror, reflecting fabrics bounce electromagnetic waves off its surface. On the other hand, in fabrics that use the absorption method, the electromagnetic wave penetrates the material and is absorbed as it passes through, much like heat loss through an insulating wall (William Kimmel, 2003). According to an application note by Learn EMC entitled Shield Theory, shielding a device with various metallic materials can be a very effective way to protect the device from electromagnetic interference. Simply surrounding a device in a metal box with no seams or entry points would be the best form of protection; however, in the real world that is typically not an option due to the additional cost, additional weight, and general loss of functionality in some cases. In the application note, calculations are used to determine the shielding effectiveness of copper foil. These calculations were theoretical and based on perfect situation numbers. It was found that the copper foil had a calculated shield effectiveness of 154 dB. Since most EMC test equipment has a maximum dynamic range of somewhere between 80 - 120 dB, the copper foil can essentially be considered impenetrable. When comparing the calculated shield effectiveness of the copper foil to shielding materials that can be more readily procured, there are more realistic effectiveness ratings averaging from about 50 dB to around 85 dB. (Learn EMC, 2013)

In an application note written by Metal Textiles entitled, EMI/RFI Shielding, it is stated that shielding effectiveness can be explained two ways: the first way is that circulation currents are induced by the EMI field on the resisting shield. The circulating currents create their own fields on the shield which then opposes or reduces the intensity of the EMI field, thus creating a barrier. The second explanation is that the shielding effectiveness is caused by either reflection or absorption or both depending on the material. The EMI field can either bounce off the shielding material and away from the device or it will penetrate the shield and be absorbed before affecting the device. In either explanation, "EMI from external sources will be reduced to much lower levels inside the shield than the level outside the shield, and only the particular shielded equipment benefited" (Metal Textiles, 2012). EMI can be radiated into a device through any kind of opening or imperfect joint on an enclosure, making it imperative that the shielding be completely closed (if possible) and sealed to achieve the most shielding effectiveness possible. (Metal Textiles, 2012)

In an article written by Holland Shielding Systems BV, entitled EMI Shielding Applications, it is stated that due to the complexity of current printed circuit board designs, it is simpler and more cost-effective to develop shields for the device's enclosure. The way the shielding is selected for the device is based on the frequency that is/will be affecting the device. For lower frequencies, <10 kHz, a thicker material is necessary. As the frequency increases, the material thickness can be decreased; however, as the frequency increases, the wavelength of that frequency shortens making gaps in the material more of an issue. For higher frequencies, 10 kHz to 40 GHz, great attention should be focused on minimizing the amount of gaps or holes in the shielding. (Holland Shielding Systems BV, 2015)

In an article produced by EMI Software titled, "What is Conducted Susceptibility?", it is explained that conducted susceptibility is the ability of a device to function properly when radio frequencies are introduced onto its interconnecting conductors such as power cables or data transmission lines. During typical conducted susceptibility testing, low and mid frequency noise is injected on to the device's power cables and/or data transmission lines to characterize how the device reacts. This can be injected as either a current or a voltage depending on the device and the test being performed. The current or voltage is increased after every successful test until the device shows susceptibility. The amplitude at which the device shows unacceptable behaviors as a response to the injected noise is known as the susceptibility threshold. In most cases, these unacceptable behaviors cease as soon as the injected noise is removed. (EMI Software, 2015)

In an Engineering Note titled, ILB, ILBB Ferrite Beads, the general description of how ferrite beads work and how they can reduce conducted susceptibilities on device cables is explained. A ferrite bead is basically a resistor that has a fluctuating resistance value that is dependent on the frequency being induced. The higher the frequency, the more impedance produced. Other forms of EMI restricting components such as inductors or capacitors can cause resonant problems at high frequencies making the ferrite bead the only practical solution (at high frequencies). The ferrite material, when used at high frequencies, provides resistive characteristics that attenuate the frequencies. This is caused by eddy currents that in turn heat the ferrite material a minuscule amount. (Vishay Dale, 2015)

CHAPTER 3

SCOPE

The scope of this thesis is to develop a general purpose technique for the reduction of radio frequency susceptibilities in COTS camera equipment being used in Electromagnetic Compatibility testing. A Panasonic-WV-CP470 Closed - Circuit Television (CCTV) camera will be used throughout the duration of the testing. The camera will be tested in the TTAC Group's GTEM wave cell (5400 Series). The GTEM is controlled by a LabVIEW program developed in-house at ORNL specifically for this application. The LabVIEW program controls three amplifiers and a signal generator. There will also be a broadband radio frequency power meter placed within the GTEM to monitor the frequencies being generated. Table 1 contains the ANSI standards used as references when developing the test plan:

Table 1: ANSI Standards Used by the TTAC Group, IEEE, January 21, 2015

Standard ID	Standard Description
N42.32	American National Standard Performance Criteria for Alarming Personal Radiation Detectors for Homeland Security
N42.33	American National Standard for Portable Radiation Detection Instrumentation for Homeland Security
N42.34	American National Standard Performance Criteria for Hand-Held Instruments for the Detection and Identification of Radionuclides
N42.35	American National Standard for Evaluation and Performance of Radiation Detection Portal Monitors for Use in Homeland Security
N42.38	American National Standard Performance Criteria Spectroscopy-Based Portal Monitors Used for Homeland Security
N42.43	American National Standard Performance Criteria for Mobile and Transportable Radiation Monitors Used for Homeland Security
N42.48	American National Standard Performance Requirements for Spectroscopic Personal Radiation Detectors (SPRDs) for Homeland Security
N42.53	American National Standard Performance Criteria for Backpack-Based Radiation Detection Systems Used for Homeland Security

The standards in Table 1 are used by TTAC to evaluate equipment supplied by sponsors or vendors/manufacturers. Since each standard has slightly different requirements needed for equipment acceptance, the frequency requirements that repeatedly occurred and the most severe intensity were selected in order to cover the full range of the standards. By testing to these extremes, the full range of requirements detailed by the standards can be tested in a single trial. Once the requirements were selected, they were utilized to decide the materials that could provide the camera the most benefit. These materials were: Pure Copper Polyester Taffeta® fabric, ShieldIt Super® fabric, and a Ferrite bead clipped to the video cable.

Equipment

A brief description of the equipment that will be used during the testing is necessary in order to apply the findings to future tests.

Panasonic Camera Description

The camera that was used for testing was a Panasonic-WV-CP470 Closed - Circuit Television (CCTV) camera (shown in Figure 2). This camera is most typically used by the TTAC Group during EMC testing. It is a COTS camera that is typically used in a network of similar cameras for surveillance purposes. The Panasonic camera outputs video through a BNC cable. The camera's output can be viewed on a remote monitor. The use of the BNC cable also gives the camera the capability to output to a Digital Video Recorder (DVR). The DVR is used to record the video output of up to four cameras. For detailed specifications on the Panasonic-WV-CP470 Closed-Circuit Television (CCTV) camera, refer to Appendix B.

Gigahertz Transverse Electromagnetic Wave Cell

The Gigahertz Transverse Electromagnetic (GTEM) wave cell is a radio frequency test chamber (shown in Figure 1). The following quote is taken from the GTEM Operation manual. It has been used to maintain the accuracy necessary to describe this instrument.

> "It is mainly used for Electromagnetic Compatibility testing such as radiated immunities and radiated emissions. The GTEM is a pyramidal tapered, dual-terminated section of 50-ohm transmission line. The cell is flared to create a test volume within which the EUT is placed. At the input, a normal 50-ohm coaxial line is physically transformed to a rectangular cross section with an aspect ratio of 3:2 horizontal to vertical. The center conductor, known as the septum, is a flat, wide conductor which, when driven by a signal generator, produces a reasonably sized region of a nominally uniform electric field distribution beneath it. This region of nominally uniform field is the test volume for radiated immunity (susceptibility) testing." (Gigahertz Transverse Electromagnetic (GTEM) Cell Operation Manual, 2013, p. 9).

Signal Generator and Amplifiers

The signal generator and amplifiers used during the tests are listed in Table 2. Figure 3 shows the Agilent Technologies Signal Generator in Stand By mode.

Table 2: Spectrum Analyzer and Amplifiers Used During Testing

Signal Generator	**Brand**	**Frequency Range**	
	Agilent Technologies E8257C	250 kHz-20 GHz	
Amplifiers	**Brand**	**Frequency Range**	**Wattage**
	Ophir RF 5127 Power Amplifier	20 – 1000 MHz	200 W
	Instruments for Industry S21-50	1 – 2 GHz	50 W
	Instruments for Industry S42-50	2 – 4 GHz	50 W

Figure 3: Agilent Technologies Signal Generator

LabVIEW User Interface

A LabVIEW Virtual Interface (VI) is used to set the test parameters for the signal generator and amplifiers. The VI was designed specifically for the signal generator and amplifiers (Table 2) to give several options for setting modifications. Depending on the test being performed, the VI uses pre-written spreadsheets to select the frequency and wattage needed to maintain the field intensity selected by the test operator. The main settings being used in this testing are the modulation type and percentage, field intensity, dwell time, and frequency ranges. Figure 4 shows the LabVIEW user interface.

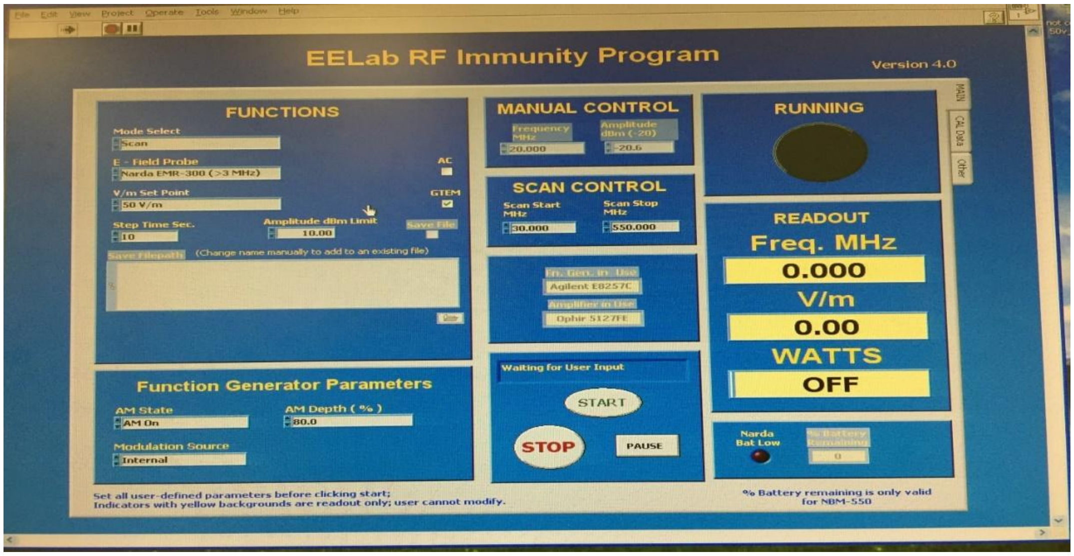

Figure 4: LabVIEW User Interface for RF Immunity Testing

High Frequency Broadband Meter

In order to monitor the field strength and frequencies during each test, a broadband field meter was placed in the chamber alongside the camera. The meter that was used was a Narda NBM-550. This high frequency broadband meter is calibrated to the same standards being tested in this thesis; refer to Appendix A. A fiber optic cable was used as the data transmission cable so as to not interfere with the quality of the tests being performed. There are several different probes that could be used with the Narda NBM-550 depending on the tests being performed. For this test, the > 3 MHz probe was used. This probe allows the Narda NBM-550 to test to frequencies above 3 MHz. Figure 5 shows the Narda NBM-550 with the >3 MHz probe attached.

Figure 5: Narda NBM-550 with >3 MHz Probe

GTEM Test Lamp

The TTAC Group conducts all tests in the GTEM with an RF lamp to view EUT display screens that do not have backlights. This lamp is necessary due to the lack of light in the GTEM during testing. The lamp was in the GTEM along with the Panasonic camera and the Narda Broadband RF probe during all testing conducted for this thesis. The GTEM was calibrated with this equipment inside so that it has no effect on the testing. The lamp will be used both to recreate the typical testing scenario of the TTAC Group and also to provide light for remote viewing of the camera image.

Shielding and Suppression Approach

In order to reduce the susceptibilities present in the camera, a few different methods were researched. Since radio frequencies can be both radiated into a device and/or conducted into the device through the power or transmission lines, it was decided that both failure opportunities were to be tested. The methods researched included: various shielding fabrics for radiated susceptibilities, ferrite beads for conducted susceptibilities, and the effectiveness of layering shielding fabrics for increased performance.

When discussing shielding fabrics, William Kimmel (2003) states, “Electromagnetic Interference (EMI) shielding involves two independent mechanisms: *reflection* and *absorption*. In reflection, an electromagnetic wave bounces off the surface, just like light off a mirror. In absorption, the electromagnetic wave penetrates the material and is absorbed as it passes through, much like heat loss through an insulating wall” (William Kimmel, 2003).

Only one shielding method (absorption) will be used during the testing involved in this thesis to maintain consistency throughout the materials. Absorption is also the preferred method in this application when looking at future testing using the camera. If the camera is shielded using a reflecting material, it may reflect some of the energy in the GTEM to the EUT during testing conducted by the TTAC Group. This can cause skewed results and for that reason is removed as an option.

As explained by Chris T. Burket (2010), “A ferrite bead is a passive device that removes noise energy from a circuit in the form of heat. The bead creates impedance over a broad frequency range that eliminates all or part of the undesired noise energy over that frequency range”. However, it is not an easy task to find the exact ferrite bead needed for an application. Ferrite bead suppliers have been known to use different materials for the same ferrite beads (Burket, 2010). That being said, it is not uncommon to use a trial and error type system when selecting the appropriate ferrite bead for an application. Figure 6 shows a wall dedicated to the various sizes, shapes, and impedances found in typical ferrite beads.

Figure 6: Wall of Various Ferrite Beads

The image in Figure 6 was taken at a certified Radio Frequency test facility that uses the trial and error system to find suitable ferrite beads during their testing. Another common issue seen with ferrite beads is where they should be placed for optimal performance. William Kimmel (2003) states, “Unshielded cables can also cause problems at high frequencies. In those cases, high-frequency filtering is needed directly at the interface to assure that the shield is not degraded at high frequencies. Common solutions are EMI filters on power and signal lines, or ferrite beads on the lines or cables. These must be installed as close to the shield penetration as possible” (p. 29.1 – 29.19). For this thesis, a ferrite bead with the correct diameter to encapsulate the cable will be attached (as close to the camera as possible) to the video cable of the camera.

When layering shielding fabrics, Less EMF Inc. (2014) states, “An RF absorber will absorb the bulk of the signal, and minimize reflection. The energy absorbed is released as a tiny, almost un-measurable amount of heat. Grounding is usually not needed…Some amount of RF does get through the shield, as no shield is 100% effective. You can use double or triple layers of shielding to improve performance” (Less EMF Inc., 2014). Since layering the shielding fabrics can improve performance, this can be added as a test option depending on the results found in early testing.

Using the information found and described above, the appropriate shielding and suppression materials were selected.

Selected Shielding and Suppression Materials

The materials chosen to shield the camera were: Pure Copper Polyester Taffeta® fabric, ShieldIt Super® fabric, and a Ferrite bead clipped to the video cable. The Pure Copper Polyester Taffeta® fabric states that it is capable of shielding from 10 MHz – 3 GHz at 80 dB.

ShieldIt Super® fabric is advertised to shield from 10 MHz – to 3 GHz at 60 dB. These materials will be using the absorption method of shielding as described in the above section. The copper fabric has a surface resistance of 0.05 ohms/sq. while the ShieldIt Super fabric has a surface resistance of 0.5 ohms/sq. A lower surface resistivity allows the fabric to dissipate the field energy more quickly making it more effective. For the ferrite bead, a general purpose ferrite bead will be placed as close to the camera as possible and sized to tightly encapsulate the video cable, per the description stated in the above section. The ferrite bead has a practical frequency of 0.1 -1.0 MHz. Figure 7 is a characteristic curve of the ferrite bead.

MATERIAL CHARACTERISTICS

MATERIAL	INITIAL PERMEABILITY	PRACTICAL FREQUENCY	RESIDUAL FLUX DENSITY(Br)	SATURATION FLUX DENSITY(Bs)	MAGNETIZIN GFORCE	CURIE TEMP	MATERIAL DENSITY
UNIT	ui	MHZ	Gauss	Gauss	Oested	℃	g/cm^3
F5B	700+/-25%	0.1-1.0	1200	2750	0.35	120	4.9

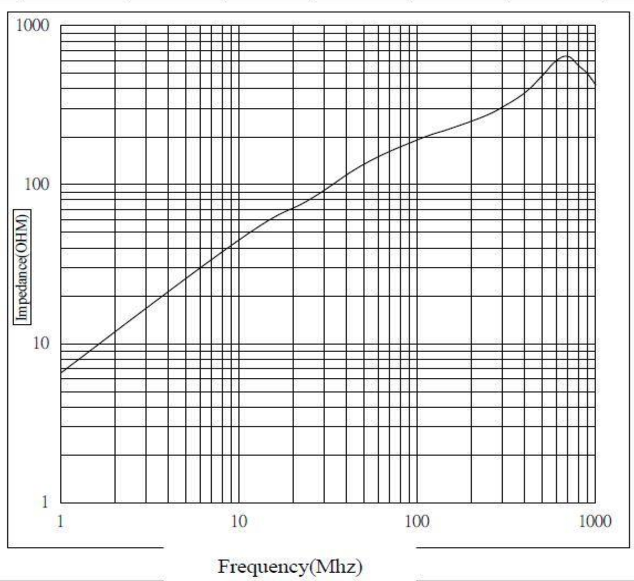

Figure 7:Material Characteristic Graph of Ferrite Bead Clip (Adapted from: www.EBAY.com, 2015)

Depending on the results found during the testing of the fabrics and ferrite bead, it may become necessary to layer the fabrics in order to increase performance.

CHAPTER 4

PROCEDURE

Initial Test Plan

Based on the previously mentioned ANSI standards used by the TTAC Group for EMC testing, the following specifications were used to test the camera:

- The camera will be exposed to an RF field intensity of 50 V/m
- The frequency range will be 30 MHz – 2.5 GHz
- The frequency range will be 80% amplitude modulated with a 1 kHz sine wave
- The frequency will sweep at a 1% change rate of the fundamental frequency
- There will be a 3 second dwell time on each individual frequency

Since the camera is used to monitor the EUT, its position is dependent on the EUT and the test operator to find the most effective viewing angle. These various positions needed to be recreated since there was no EUT present during the tests. The most typical and extreme locations as well as angled orientations were selected in order to test all possible scenarios. The camera was placed in two locations: centered in the GTEM, fully covered by the septum and offset in the GTEM where it was only partially covered by the septum. Figure 8 shows a top view of the GTEM with the camera in the two selected locations (centered and offset).

While in those two locations, the camera was cycled through three angle orientations: lens pointing straight ahead at a 0° angle, lens pointing up at a +60° angle, and lens pointing down at a -60° angle. Figure 9 shows the selected test angles.

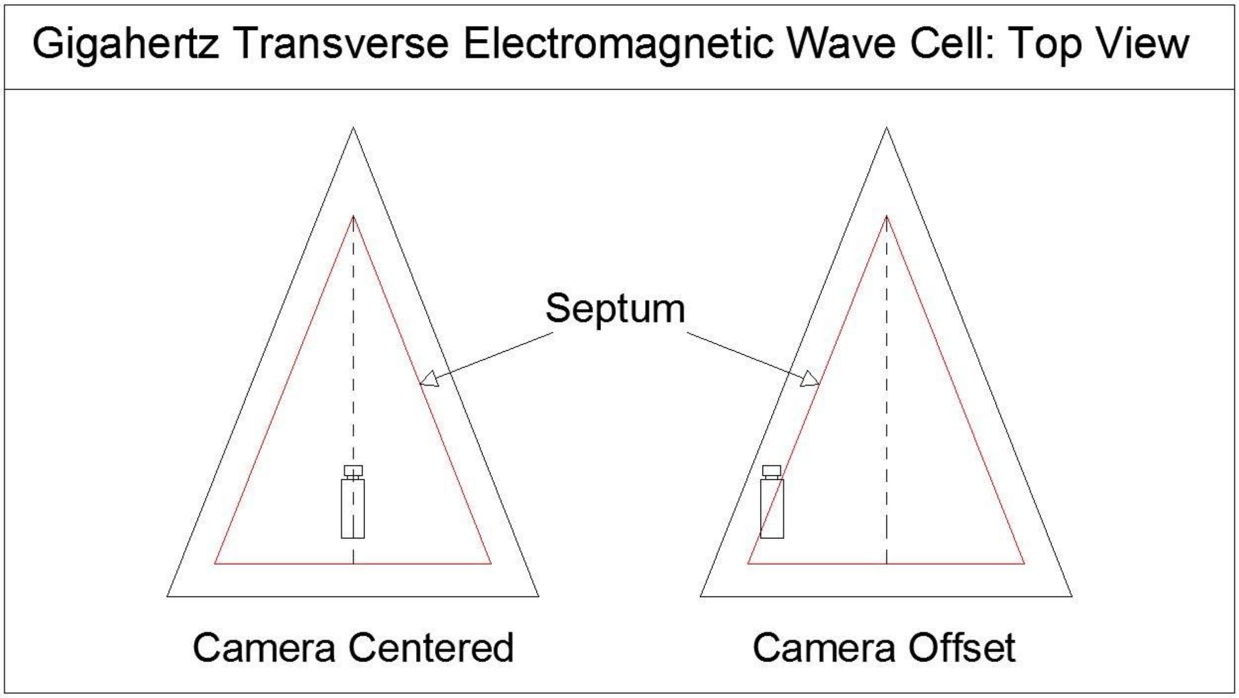

Figure 8: Camera Locations within the GTEM

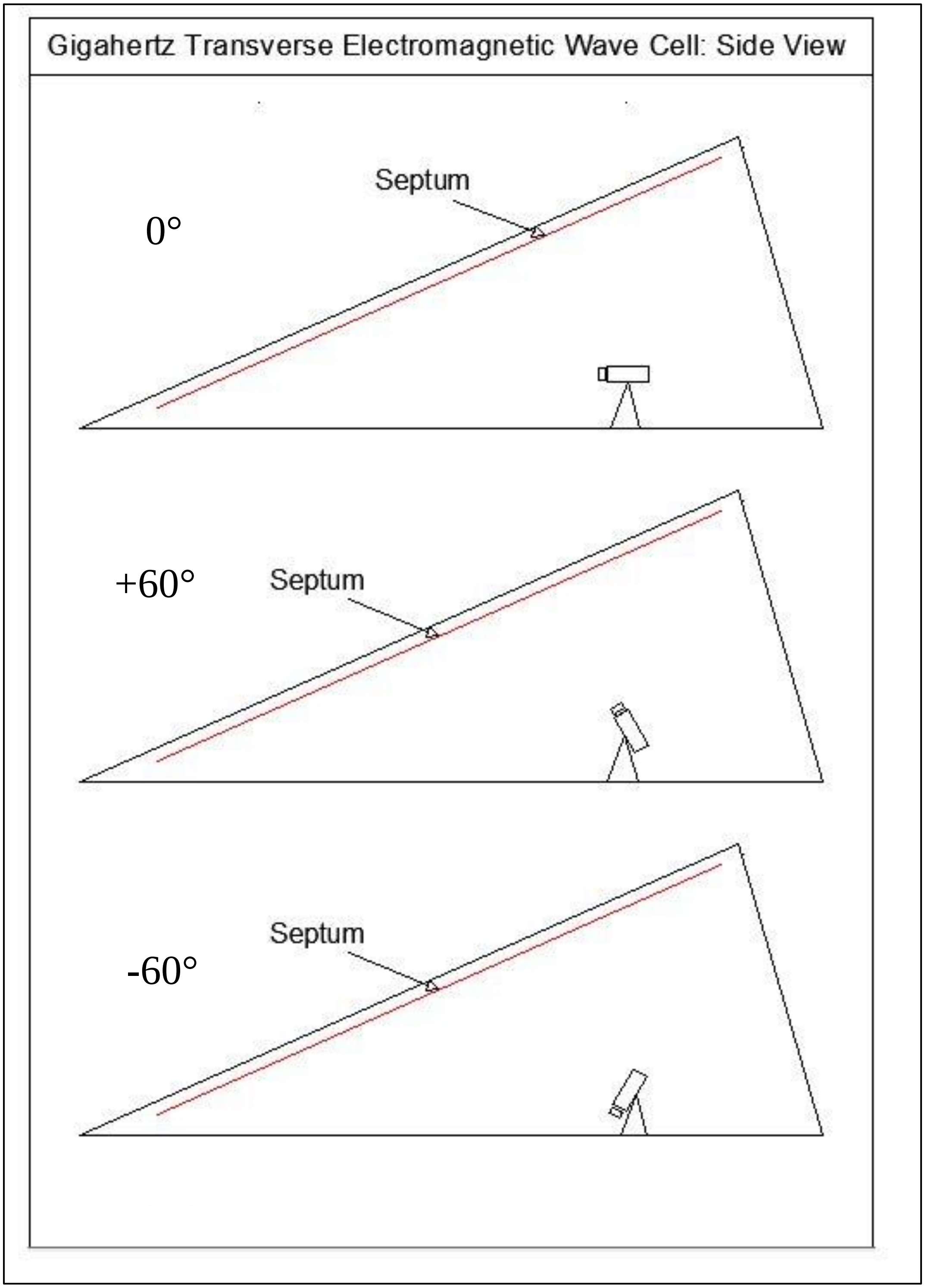

Figure 9: Camera Orientations within the GTEM

The testing started with the camera unshielded to retrieve a baseline set of data. For the first test, the camera was placed in the center of the GTEM and oriented straight ahead with a 0° angle. The center of the GTEM is defined, in this thesis, as the location where the camera is completely covered by the septum; refer to Figure 8. At this location, the septum is 35 inches above the floor of the GTEM, shown in Figure 10.

Figure 10: Measuring the Height of the GTEM Septum and Camera

The camera was supported above the floor of the GTEM by foam blocks so that the camera was 18 inches above the floor of the GTEM measured from the floor to the center of the camera. The camera was then set 22 inches from each side of the GTEM septum (width). The Narda probe was placed in the GTEM as close to the camera as possible so that it was reading the field applied to the camera. Once the setup was completed, the test could be initiated.

The test for each location and orientation was a scan from 30 MHz – 2.5 GHz with a dwell time of 3 seconds on each frequency. This first test took 29 minutes to complete. After the data for the first scan had been recorded, the camera angle was adjusted to +60°. All angle orientation adjustments made to the camera during the tests were measured with a protractor in order to ensure a consistent angle for each test setup. The camera's location remained in the center of the GTEM. Figure 11 shows the camera in the center of the GTEM with an orientation of +60°.

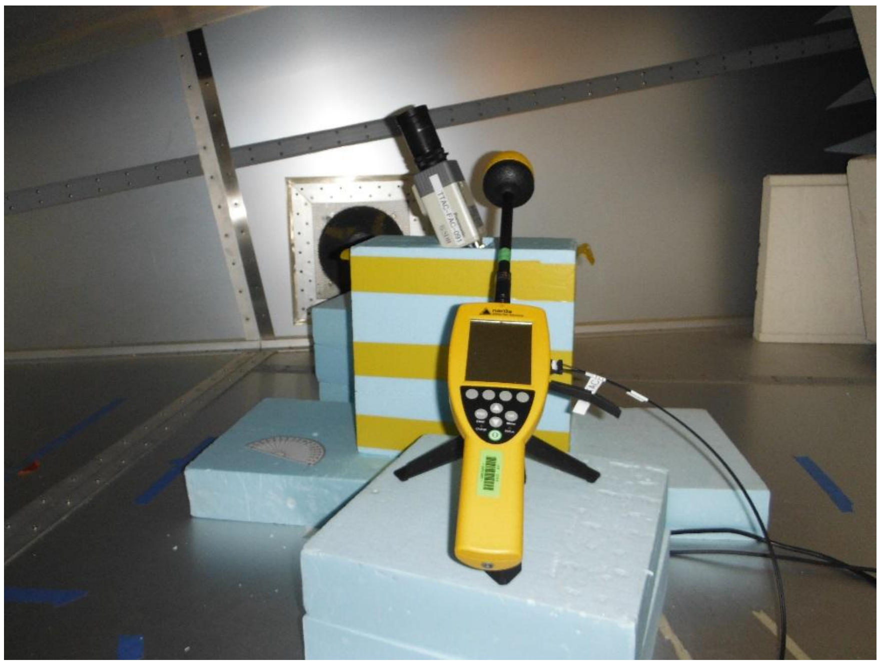

Figure 11: Camera Centered in the GTEM with a +60° Orientation

After changing the camera's orientation, the same scan (described above) was performed. When the scan was completed, the camera's orientation was adjusted once more to -60°, shown in Figure 12, not changing the cameras location.

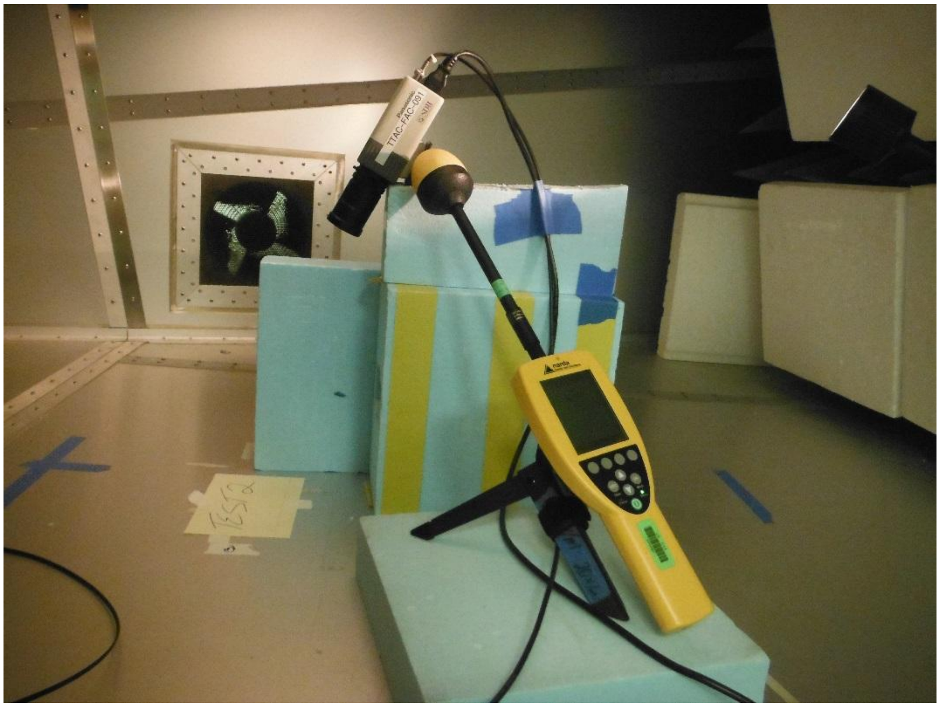

Figure 12: Camera Centered in the GTEM with a -60° Orientation

Again, the camera was subjected to the same scan as described above. The camera's orientation was then reset to 0° and the location was moved from centered in the GTEM to offset. The offset position is defined, in this thesis, as the location where the camera is only partially covered by the septum; refer to Figure 8. Similar measurements were used in the setup of the camera in the offset location: the camera was positioned where the septum is 35 inches above the GTEM floor and supported by foam blocks so that the center of the camera is actually 18 inches above the GTEM floor. The only difference was that instead of centering the camera 22 inches from each side of the GTEM septum, it was now 45.5 inches from the opposite edge of the GTEM septum (width). This placed only half of the camera under the septum. In Figure 13, the camera is in the offset location and at the 0° angle orientation.

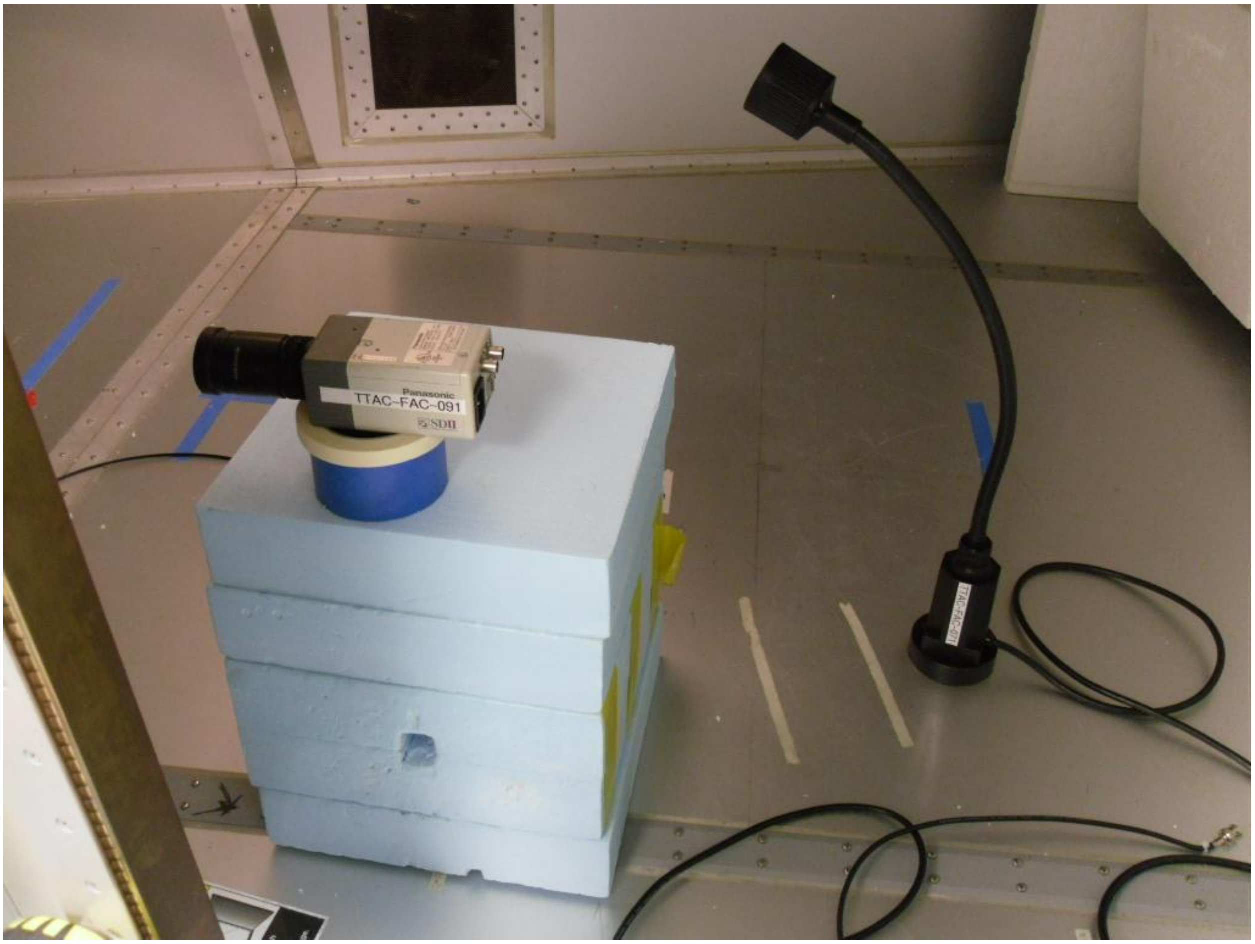

Figure 13: Camera Offset in the GTEM with a 0° Orientation

The camera was again subjected to the scan and cycled through the two other angled orientations in this location (+60° and -60°). Once completed, the camera had been through a total of 6 scans; two locations with six orientations (three orientations per location). Table 3 shows the six tests previously described.

Table 3: General Description of Tests to be Performed

Test	Material	Location	Orientation	Frequency Range	Dwell Time
1	None	Center	0°	30 MHz- 2.5 GHz	3 Sec.
2	None	Center	+60°	30 MHz- 2.5 GHz	3 Sec.
3	None	Center	-60°	30 MHz- 2.5 GHz	3 Sec.
4	None	Offset	0°	30 MHz- 2.5 GHz	3 Sec.
5	None	Offset	+60°	30 MHz- 2.5 GHz	3 Sec.
6	None	Offset	-60°	30 MHz- 2.5 GHz	3 Sec.

Following these first six tests (Baseline), the data were analyzed, for future use, in order to properly judge the performance of the shielding and suppression materials. The selected methods/materials were: Pure Copper Polyester Taffeta® fabric, ShieldIt Super® fabric, and a Ferrite bead clipped to the video cable. The camera went through the same six tests for each of the above listed materials (24 tests total). Table 4 shows a step by step diagram of the test sequence.

Table 4: Testing Sequence for the Camera and the Materials

Step	Description
1	The camera (no shielding material) is placed in the center of the GTEM (fully covered by the septum) pointing straight ahead (0°)
2	A frequency scan is initiated from 30 MHz – 2.5 GHz with a 3 second dwell time on each frequency
3	Any change in the video display is recorded as a susceptibility
4	The camera's orientation is changed to pointing +60° while still in the center of the GTEM
5	Steps 2 and 3 are repeated
6	The camera's orientation is changed to pointing -60° while still in the center of the GTEM
7	Steps 2 and 3 are repeated
8	The camera (no shielding material) is offset from the center of the GTEM (half covered by the septum) pointing straight ahead (0°)
9	Steps 2 – 7 are repeated
10	Steps 1 – 9 are repeated with Pure Copper Polyester Taffeta® shielding fabric added to the camera
11	Steps 1 – 9 are repeated with ShieldIt Super® shielding fabric added to the camera
12	Steps 1 – 9 are repeated with a Ferrite bead clipped to the video output cable

Recording Susceptibilities

During these tests, it was decided that susceptibilities were to be considered any disturbance on the camera's output monitor. Figure 14 shows the camera's video monitor when the camera is functioning properly. This image was used as a comparison when determining camera malfunctions due to susceptible frequencies.

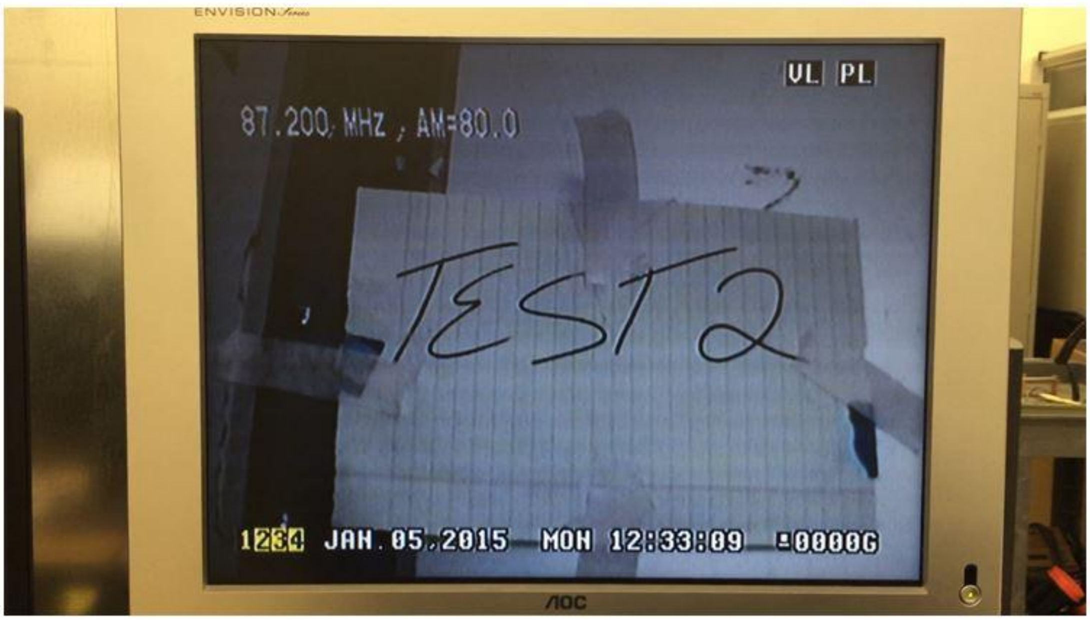

Figure 14: Panasonic Camera Functioning Properly (remote monitor)

Initial Findings

The following are graphs of the data collected during the initial testing of the COTS camera based on the specifications of the initial test plan described above. Each graph consists of the data from one location and the three subsequent orientations. Each data point represents a frequency that caused a disturbance on the remote monitor of the camera.

Susceptible Frequency Baseline (30 MHz – 2.5 GHz)

Figure 15 and Figure 16 are Baseline scans of the COTS camera (camera tested with no shielding or suppression materials). The susceptible frequencies seen in these two graphs were used as a reference when analyzing the performance of the shielding or suppression materials.

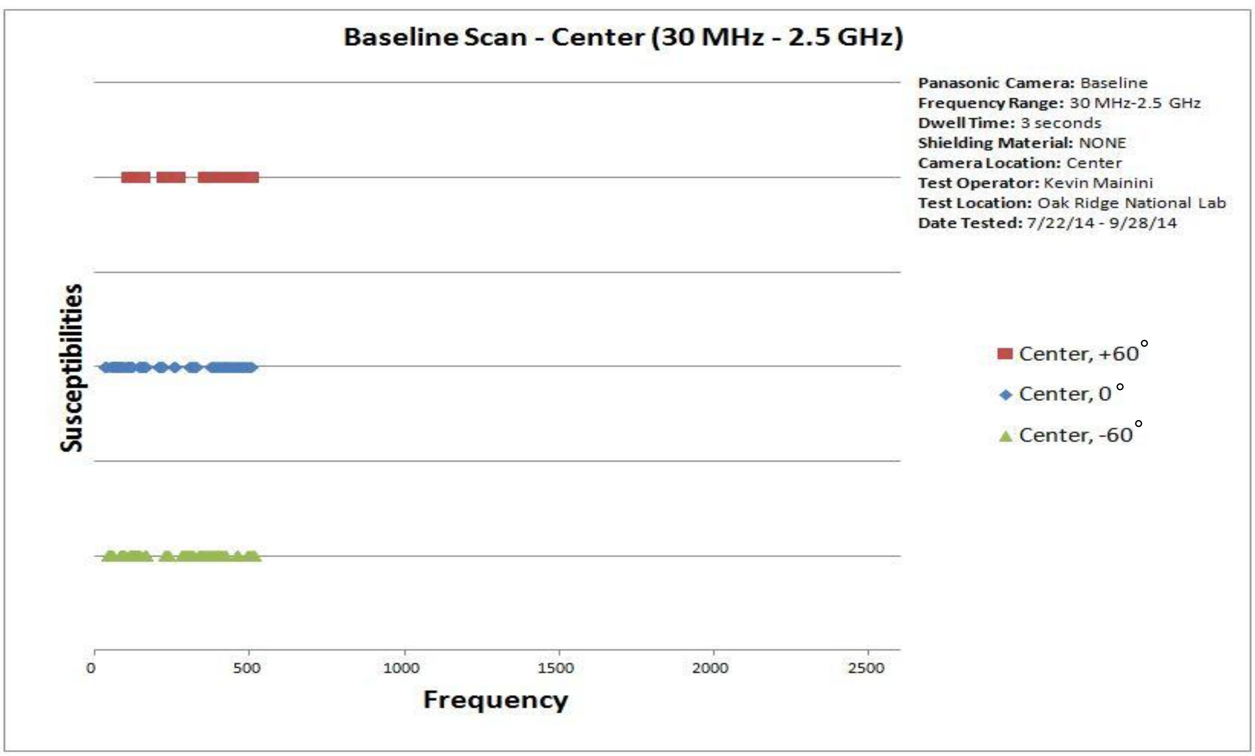

Figure 15: Baseline Scan – Center (30 MHz – 2.5 GHz)

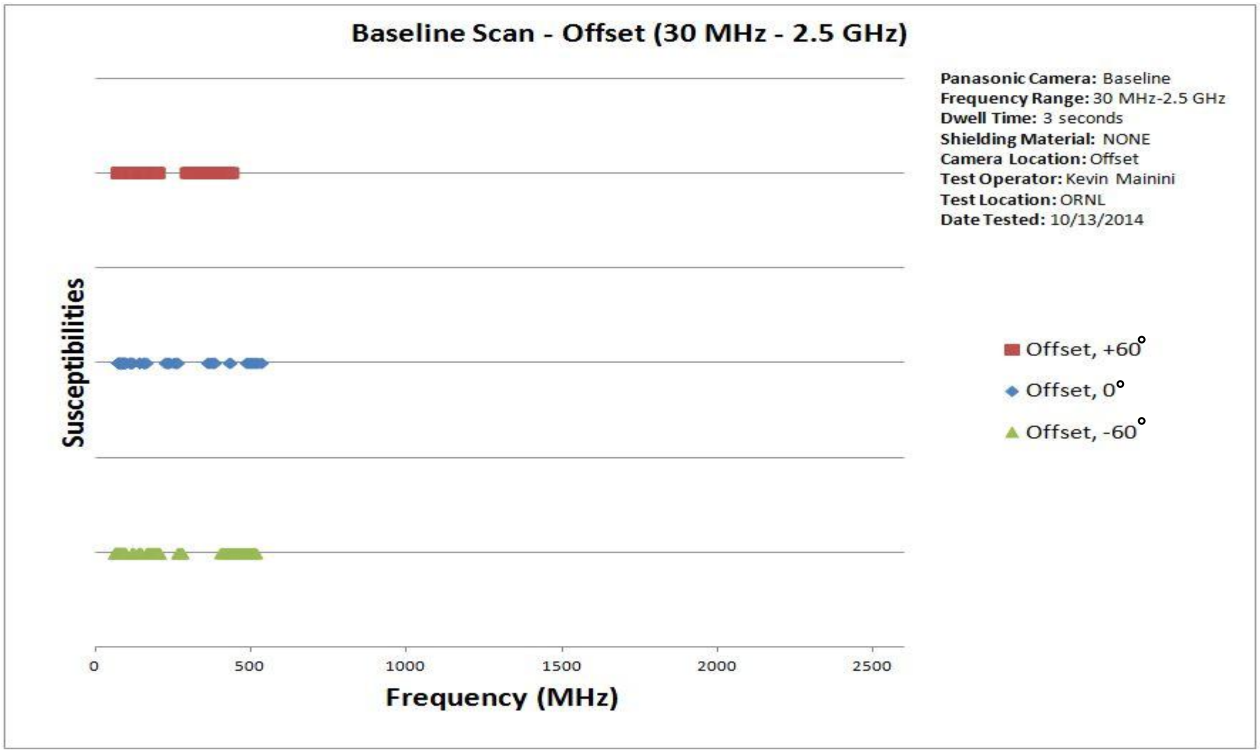

Figure 16: Baseline Scan – Offset (30MHz – 2.5 GHz)

Shielding and Suppression Material Performance (30 MHz – 2.5 GHz)

Figure 17 through Figure 22 show the susceptible frequencies recorded during the initial scan of the camera with shielding and suppression materials based on the initial test plan. Less susceptible frequencies (data points) represent better attenuation/performance of the shielding or suppression material in that location and orientation.

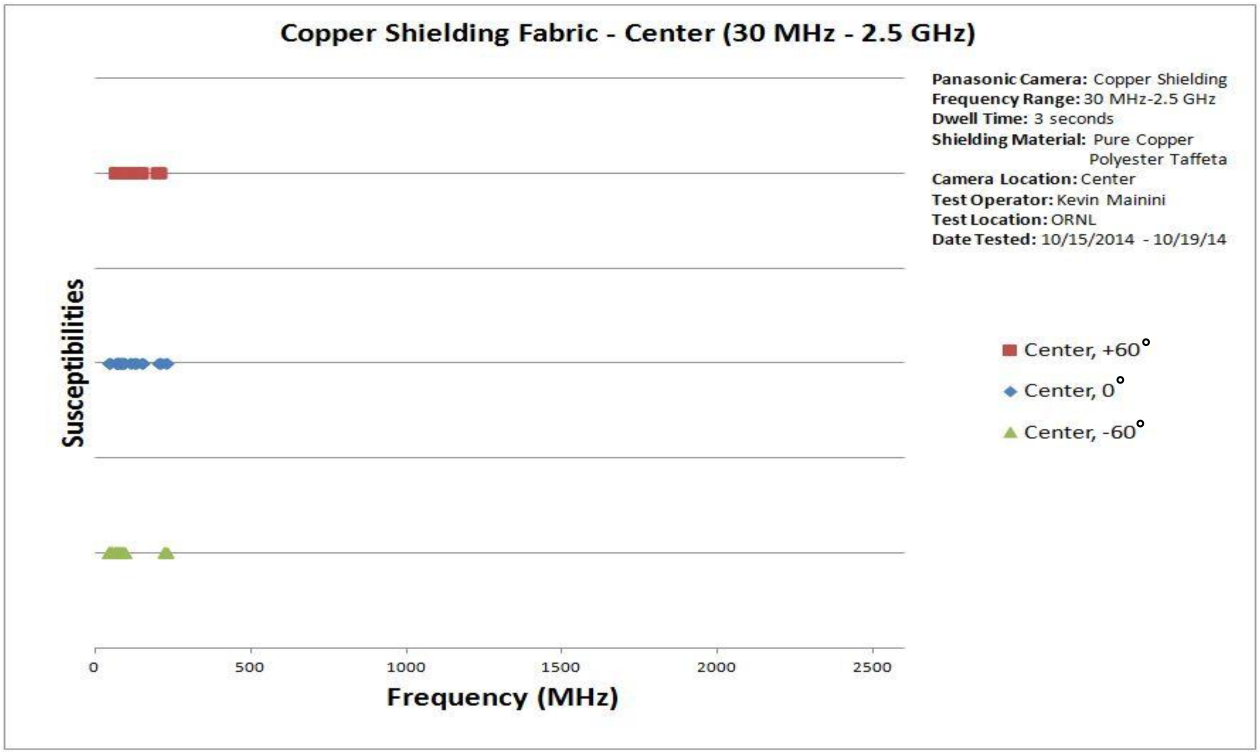

Figure 17: Copper Shielding Fabric – Center (30 MHz – 2.5 GHz)

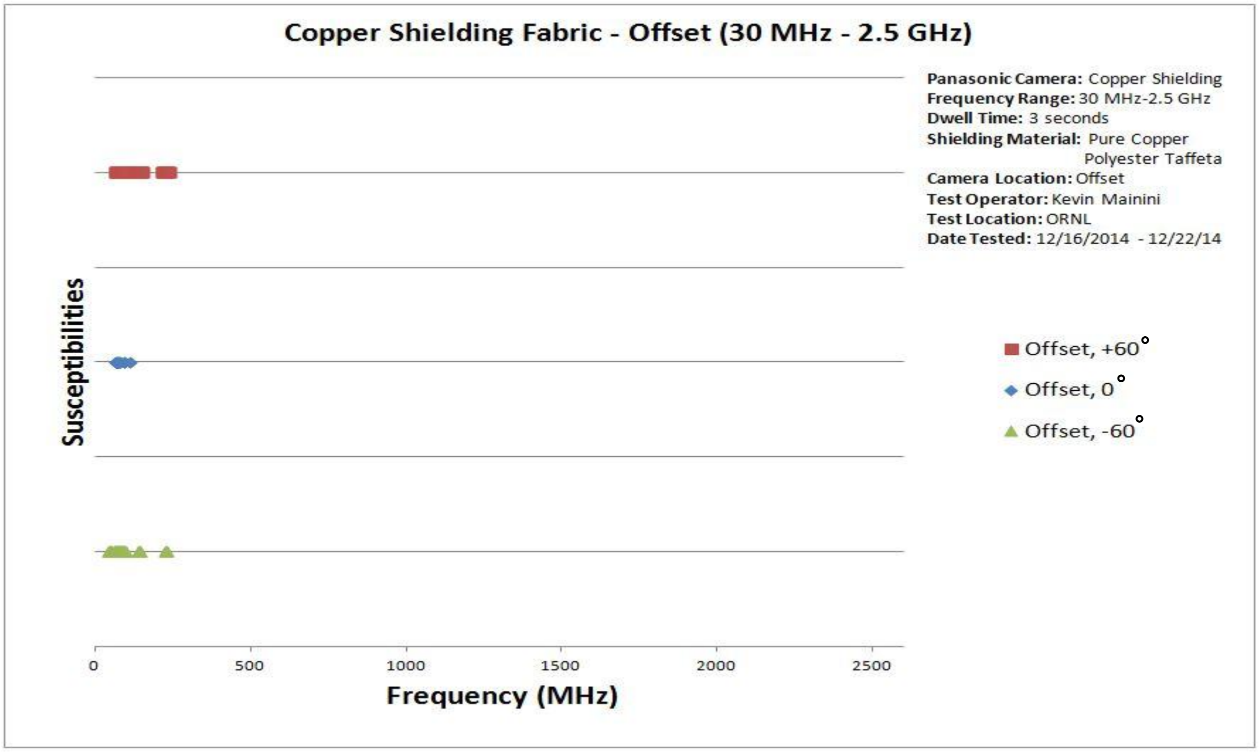

Figure 18: Copper Shielding Fabric – Offset (30 MHz - 2.5 GHz)

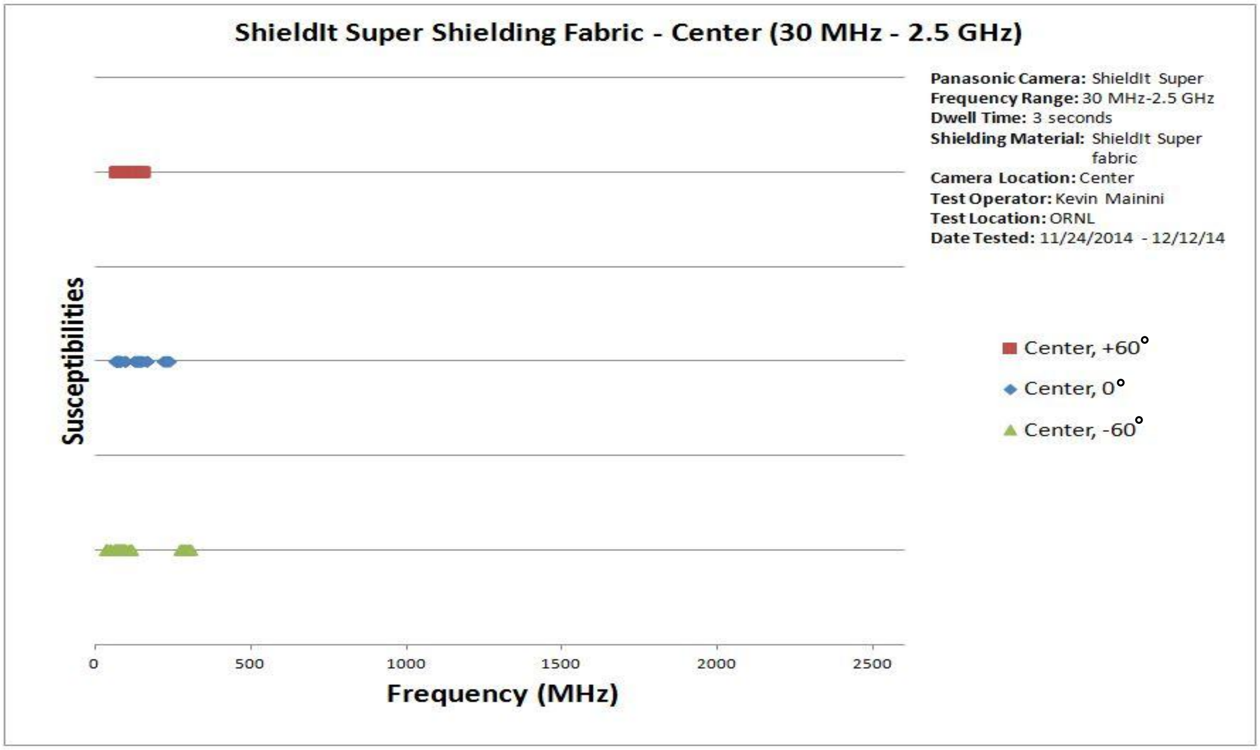

Figure 19: ShieldIt Super Shielding Fabric –Center (30 MHz – 2.5 GHz)

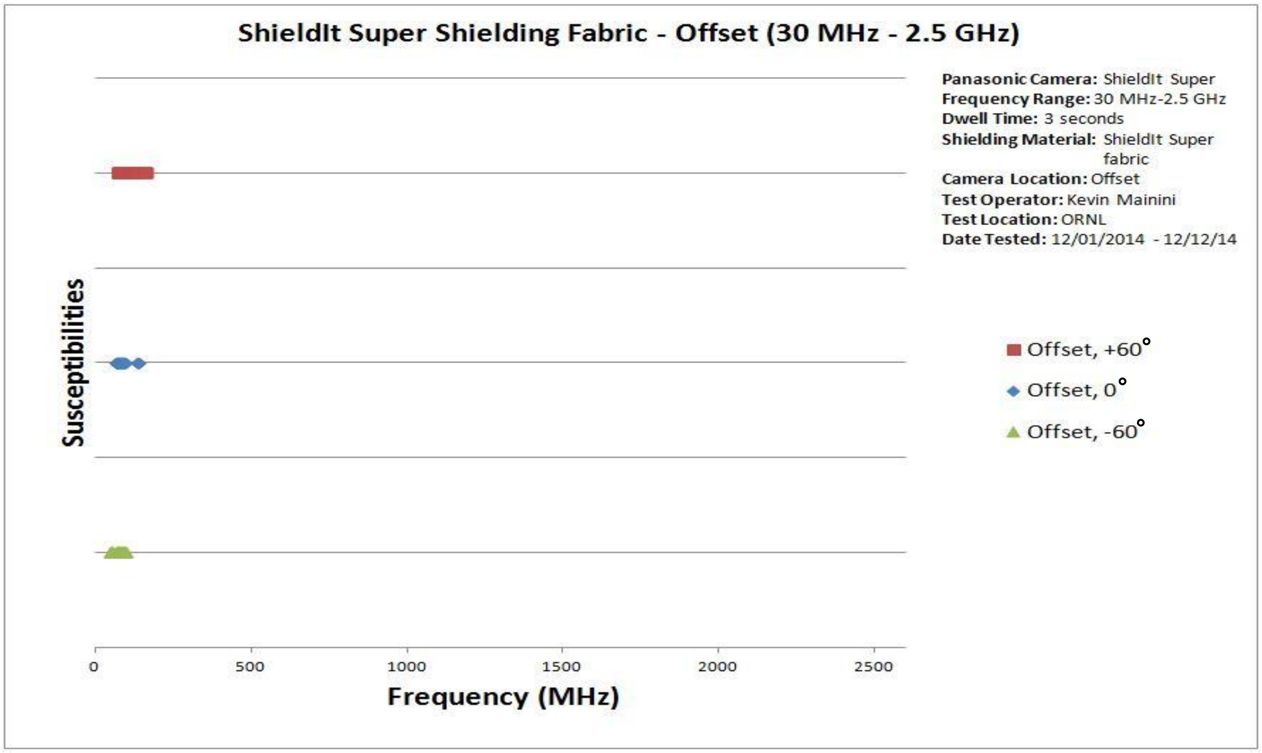

Figure 20: ShieldIt Super Shielding Fabric –Offset (30 MHz – 2.5 GHz)

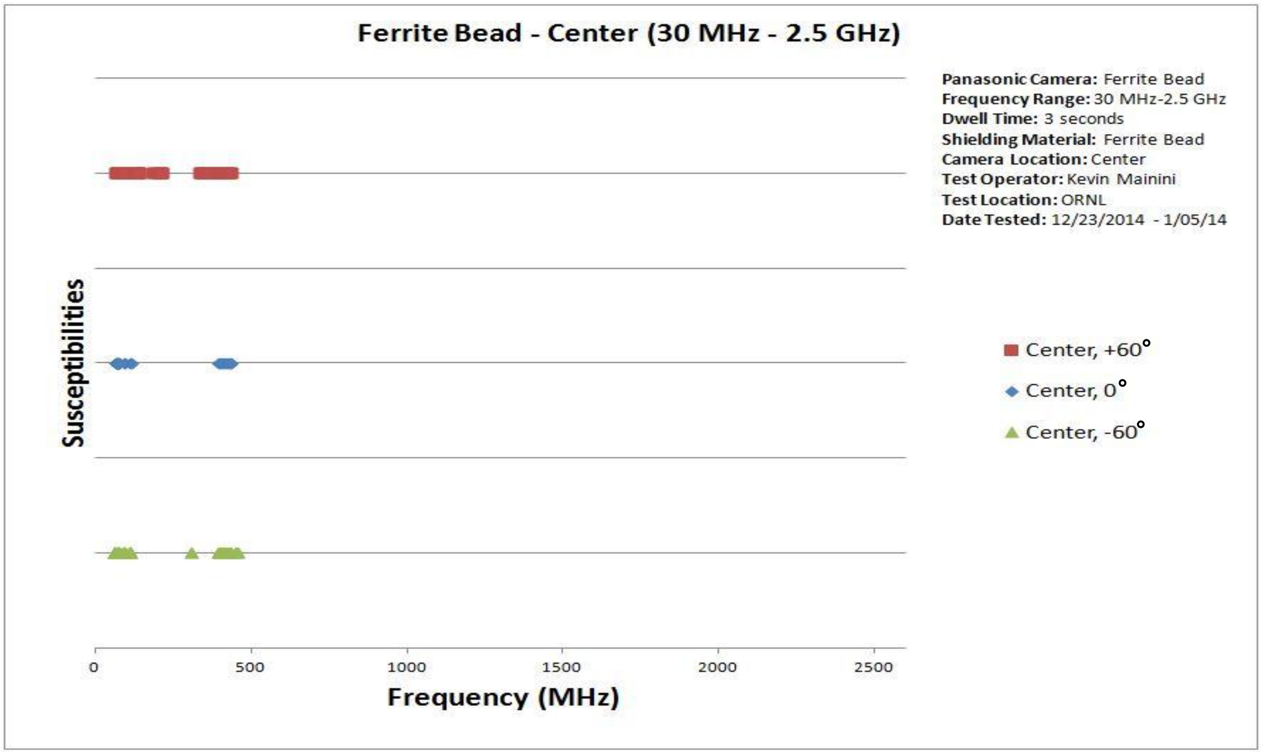

Figure 21: Ferrite Bead –Center (30 MHz – 2.5 GHz)

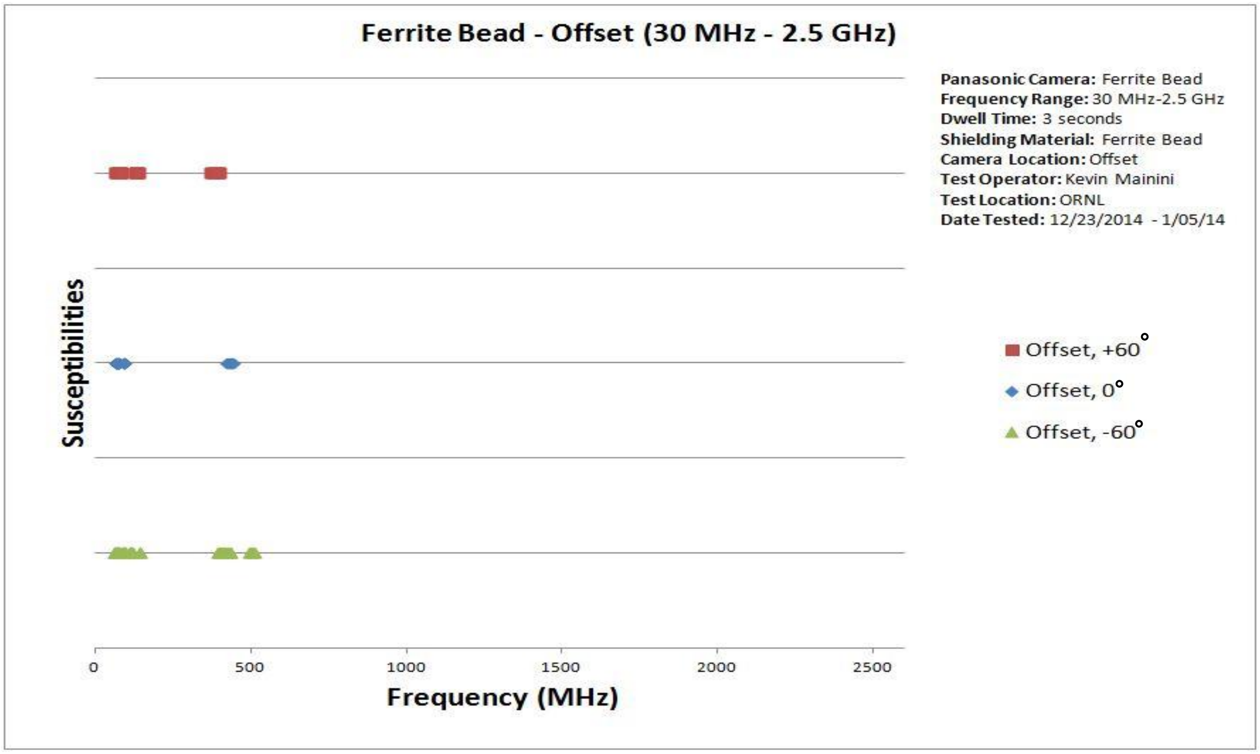

Figure 22: Ferrite Bead – Offset (30 MHz – 2.5 GHz)

As seen in Figure 15 through Figure 22, the camera was not susceptible to frequencies higher than 550 MHz. It was decided at this time, to modify the test plan in order to focus the test range more on the susceptible frequencies.

<u>Depiction of Video Disturbances Caused by Susceptibilities</u>

Figure 23 through Figure 29 show the various degrees of disturbances seen on the monitor due to the susceptibilities of the camera. They are listed in order from insignificant disturbance (Figures 23 and 24) to moderate disturbance (Figures 25 and 26) to extreme disturbance Figures 27, 28, and 29).

Insignificant disturbances include video ribboning which does not block the operator's view of the EUT's display screen but is still considered a susceptibility, in this thesis, because it causes a change on the output monitor. Both moderate and extreme disturbances significantly block the operator's view of the EUT's display screen.

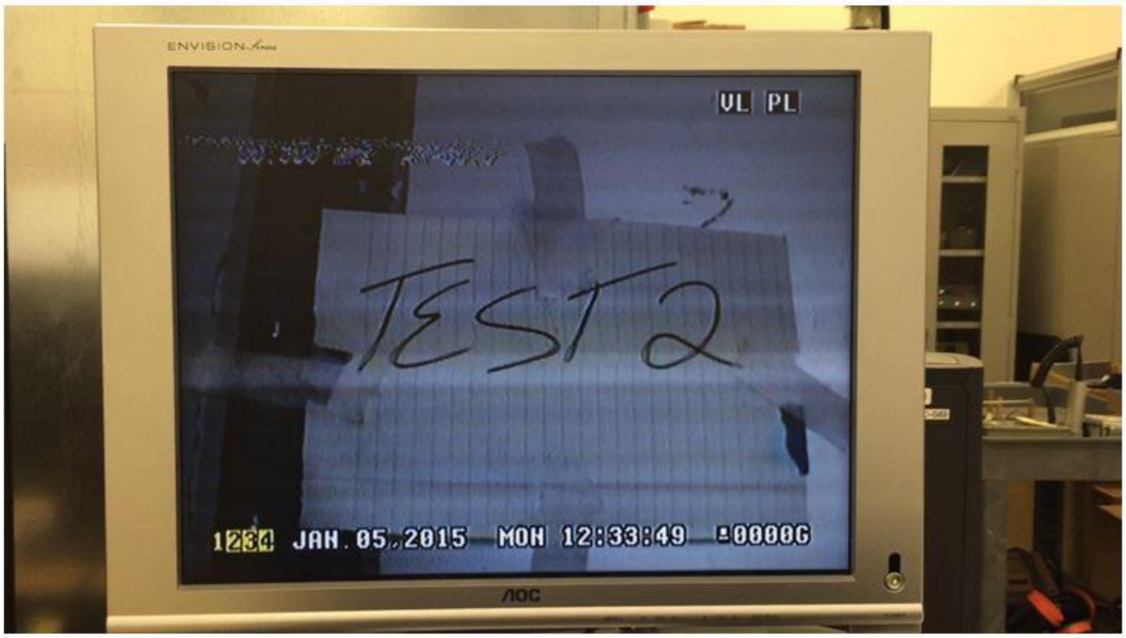

Figure 23: Video Ribboning

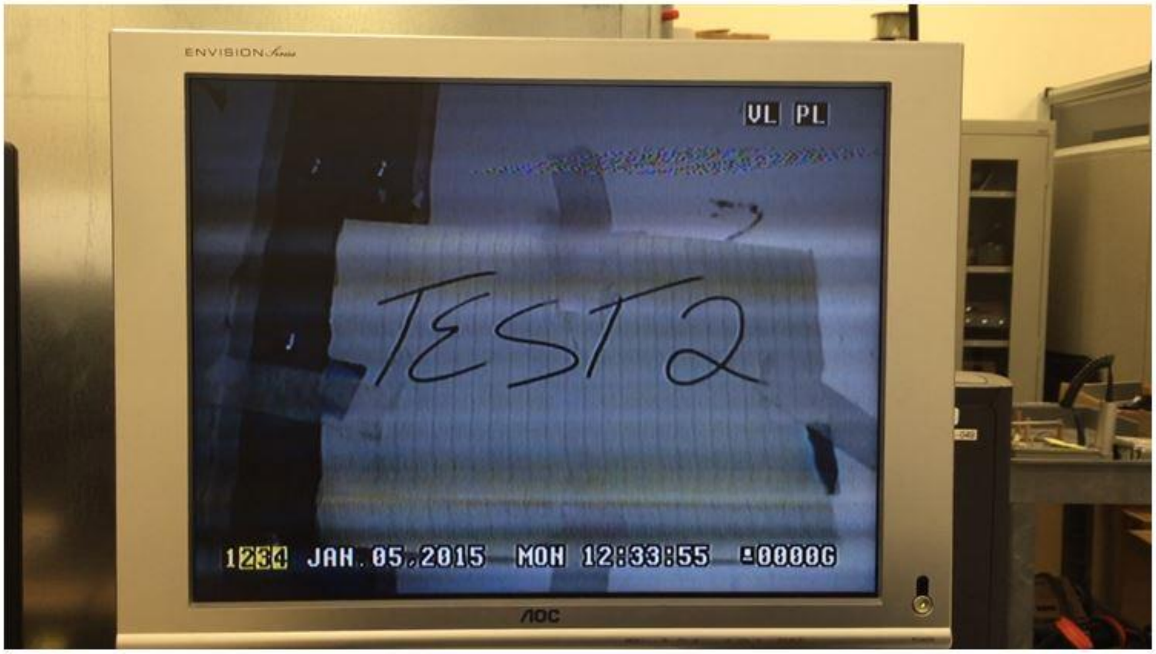

Figure 24: Increased Ribboning Speed

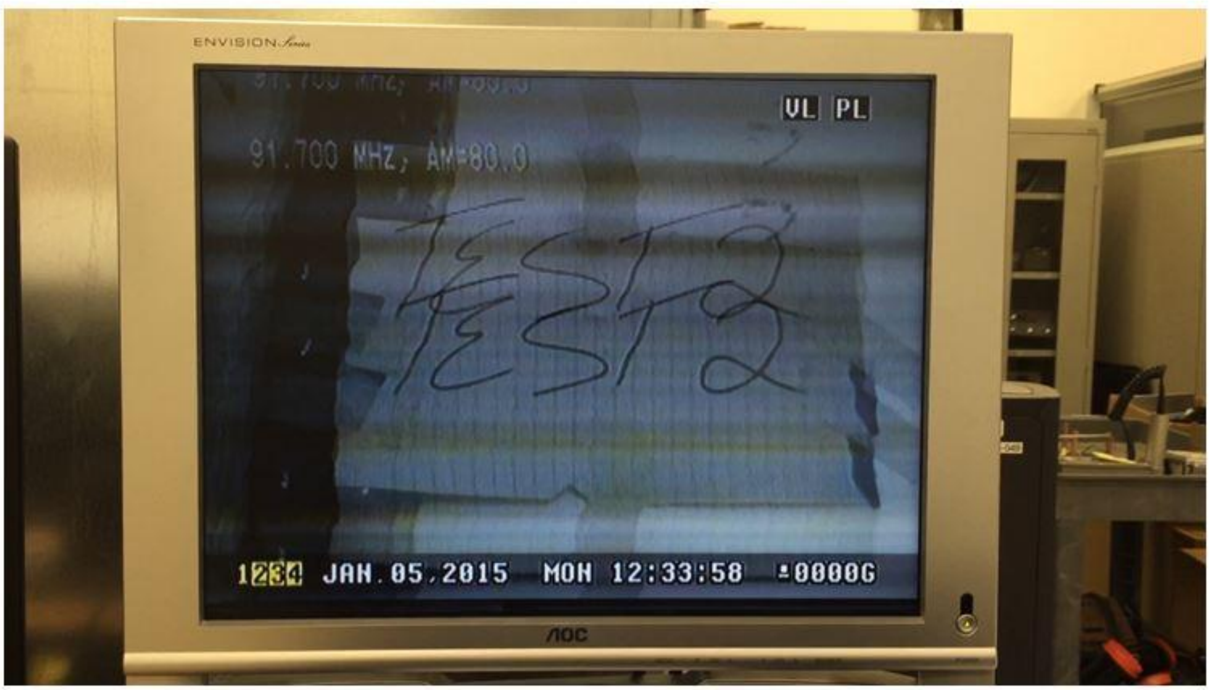

Figure 25: Vertical De-synchronization

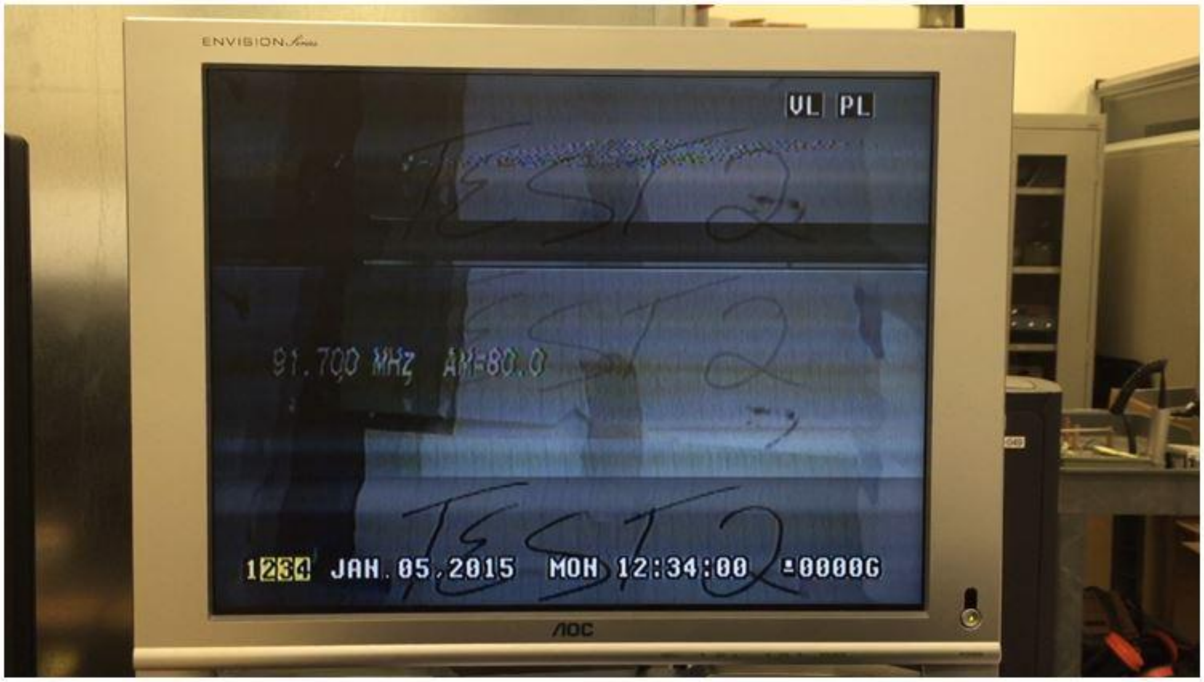

Figure 26: Increased Vertical De-synchronization

Figure 27: Increased Vertical De-synchronization and Ribboning

Figure 28: Horizontal and Vertical De-synchronization

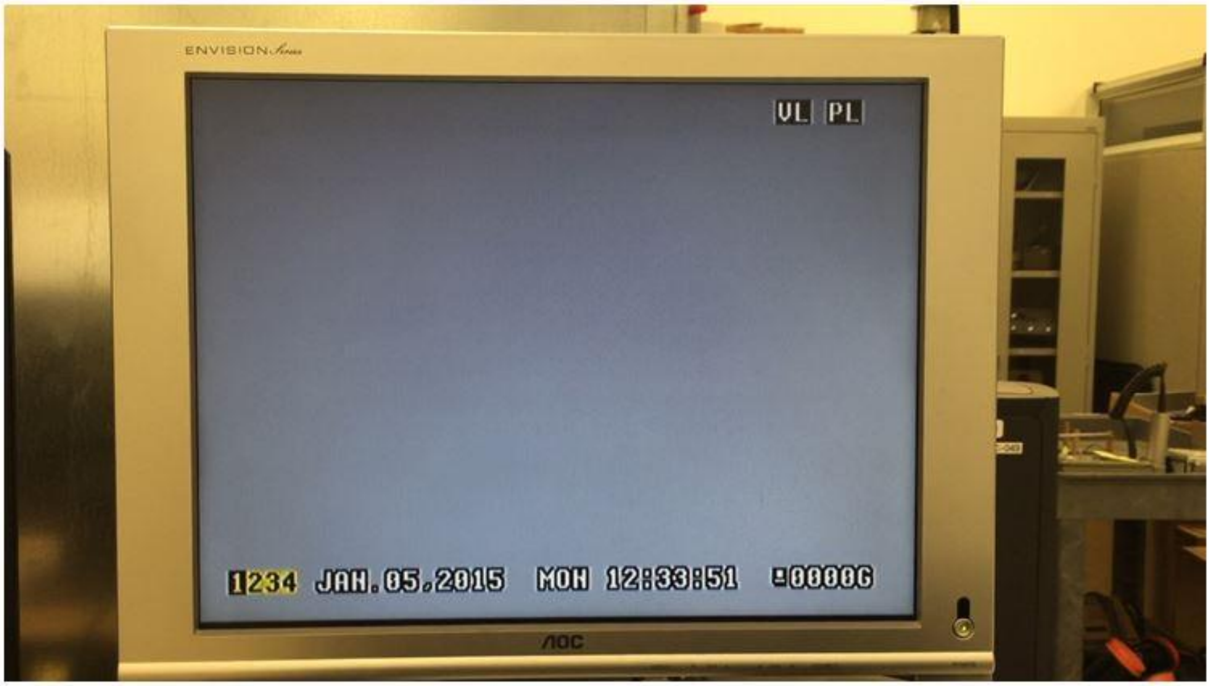

Figure 29: Complete Loss of Signal

Modified Test Plan

Following the initial tests and analysis, it was discovered that the COTS camera was not susceptible to any frequency past 550 MHz. This result led to the decision to modify the test plan and rescan the camera with a smaller frequency range at a longer dwell time. This allowed for a narrower test range with more detailed results. Therefore, based on the ANSI standards used by the TTAC Group for EMC testing (Table 1) and the data found in the initial testing, the following modified specifications were used to retest the camera:

- The camera will be exposed to an RF field intensity of 50 V/m
- The frequency range will be 30 MHz – 550 MHz
- The frequency range will be 80% amplitude modulated with a 1 kHz sine wave
- The frequency will sweep at a 1% change rate of the fundamental frequency
- There will be a 10 second dwell time on each individual frequency

This second test was a re-scan of all frequencies that showed susceptibilities in the initial testing. The second test scanned from 30 MHz – 550 MHZ with a 10 second dwell time on each frequency. This narrowed susceptibility re-scan took 50 minutes to complete. There were no modifications made to the physical setup of the COTS camera in the GTEM. Table 5 shows the general description of the susceptibility re-scan test to be performed.

Table 5: General Description of Susceptibility Re-Scan Test

Test	Material	Location	Orientation	Frequency Range	Dwell Time
1	None	Center	0°	30 MHz- 550 MHz	10 Sec.
2	None	Center	+60°	30 MHz- 550 MHz	10 Sec.
3	None	Center	-60°	30 MHz- 550 MHz	10 Sec.
4	None	Offset	0°	30 MHz- 550 MHz	10 Sec.
5	None	Offset	+60°	30 MHz- 550 MHz	10 Sec.
6	None	Offset	-60°	30 MHz- 550 MHz	10 Sec.

Following the six susceptibility re-scan tests, the camera was again tested with various radio frequency shielding and suppression materials. The materials were: Pure Copper Polyester Taffeta® fabric, ShieldIt Super® fabric, and a Ferrite bead clipped to the video cable. The camera went through the same six tests for each of the above listed materials (24 tests total). Table 6 shows a step by step diagram of the modified test sequence.

Table 6: Modified Testing Sequence for the Camera and the Materials

Step	Description
1	The camera (no shielding material) is placed in the center of the GTEM (fully covered by the septum) pointing straight ahead (0°)
2	A frequency scan is initiated from 30 MHz – 550 MHz with a 10 second dwell time on each frequency
3	Any change in the video display is recorded as a susceptibility
4	The camera's orientation is changed to pointing +60° while still in the center of the GTEM
5	Steps 2 and 3 are repeated
6	The camera's orientation is changed to pointing -60° while still in the center of the GTEM
7	Steps 2 and 3 are repeated
8	The camera (no shielding material) is offset from the center of the GTEM (half covered by the septum) pointing straight ahead (0°)
9	Steps 2 – 7 are repeated
10	Steps 1 – 9 are repeated with Pure Copper Polyester Taffeta shielding fabric added to the camera
11	Steps 1 – 9 are repeated with ShieldIt Super shielding fabric added to the camera
12	Steps 1 – 9 are repeated with a Ferrite bead clipped to the video output cable

Modified Test Plan Findings

Below, are graphs of the data collected during the secondary testing of the COTS camera based on the specifications of the modified test plan described above. Each graph consists of the data from one location and the three subsequent orientations. Each data point represents a frequency that caused a disturbance on the remote monitor of the camera.

Susceptible Frequency Baseline Re-Scan (30 MHz – 550 MHz)

Due to the modifications made to the test plan, a re-scan of the camera without any shielding or suppression materials was necessary. Again, these baseline scans (Figure 30 and Figure 31) were used as a reference when analyzing the performance of the shielding and suppression materials.

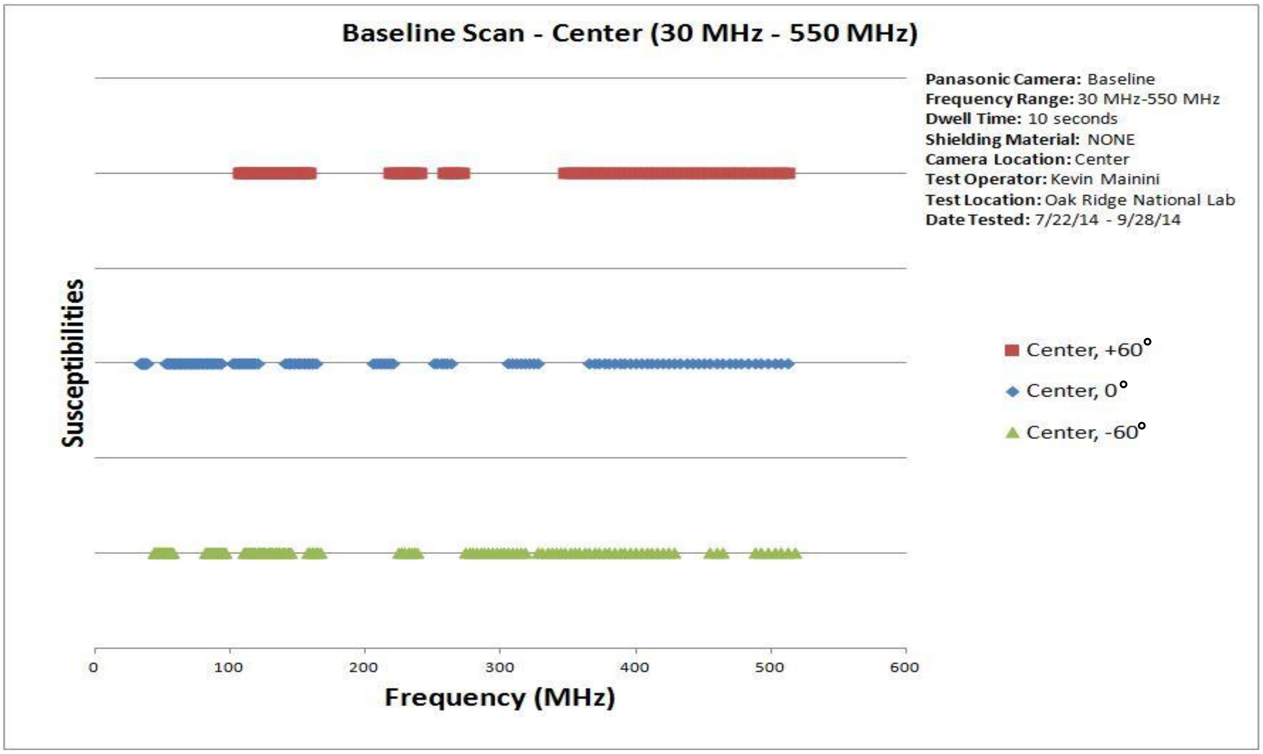

Figure 30: Baseline Scan – Center (30 MHz – 550 MHz)

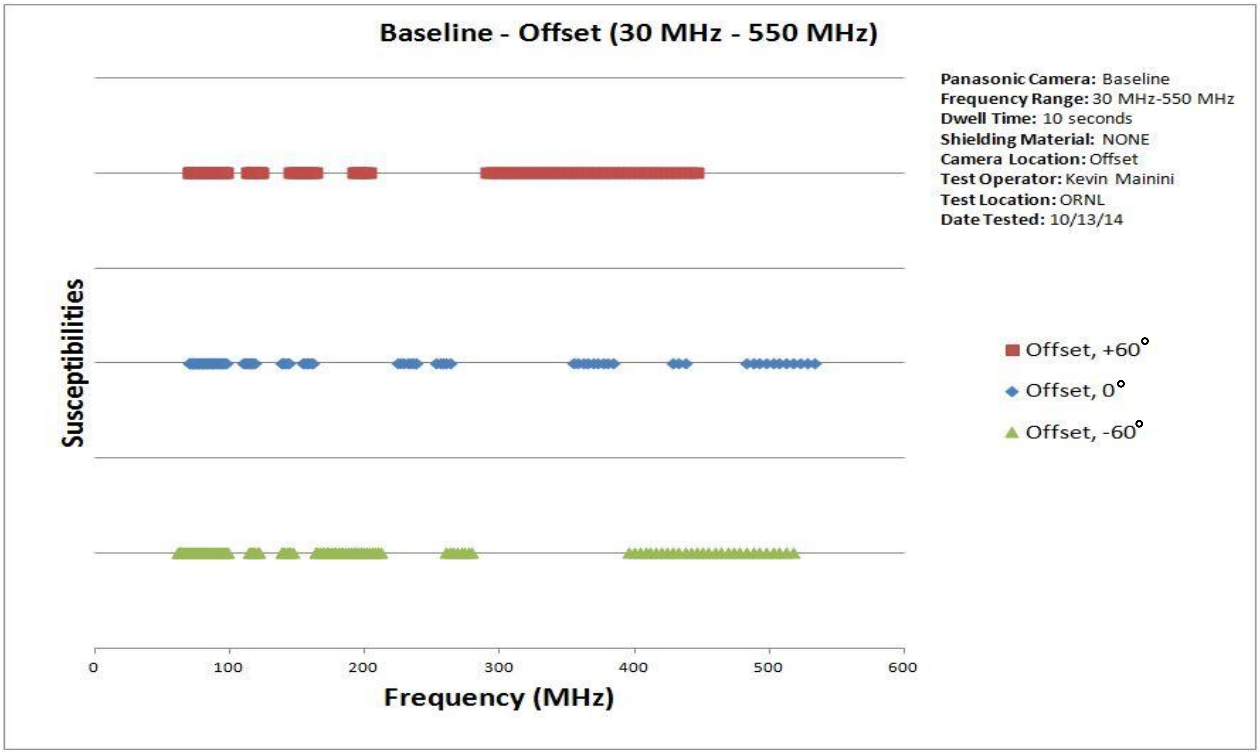

Figure 31: Baseline Scan – Offset (30 MHz – 550 MHz)

Shielding and Suppression Material Re-Scan Performance (30 MHz – 550 MHz)

Figure 32 through Figure 37 show the susceptible frequencies recorded during the re-scan of the camera with shielding and suppression materials based on the modified test plan. Less susceptible frequencies (data points) represent better attenuation/performance of the shielding or suppression material in that location and orientation.

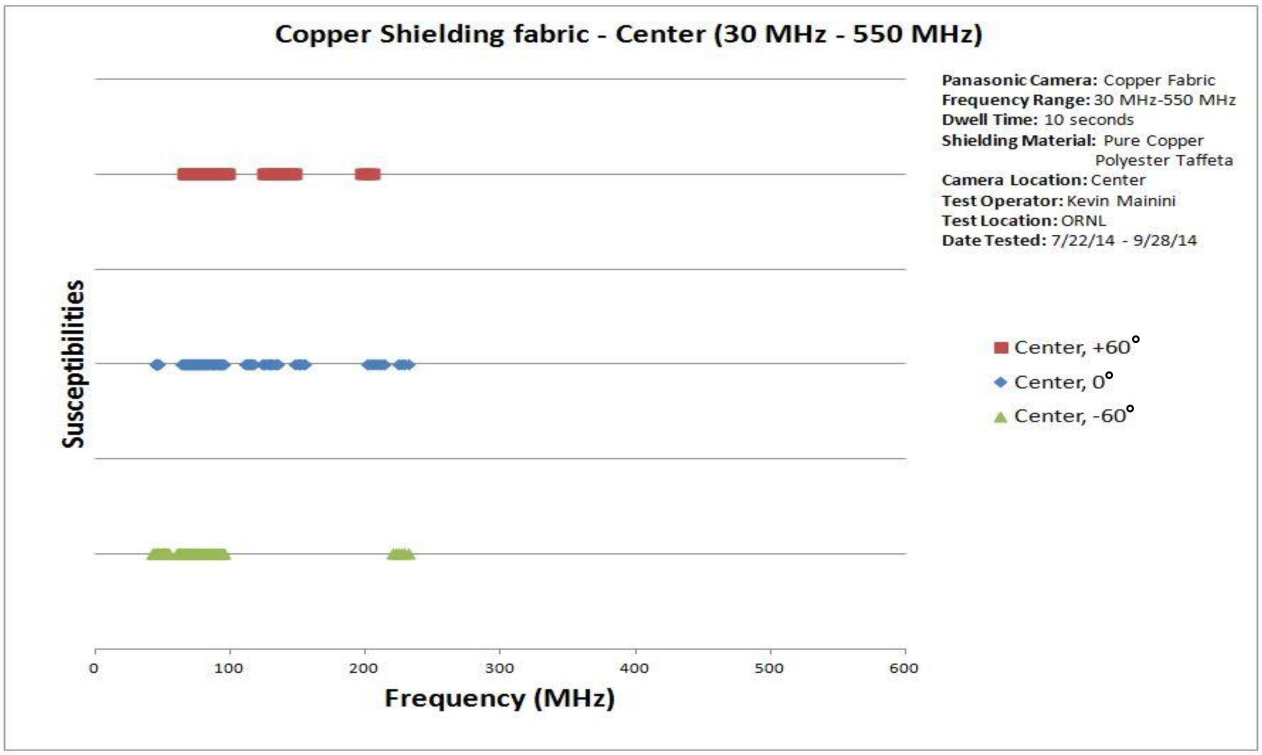

Figure 32: Copper Shielding Fabric – Center (30 MHz – 550 MHz)

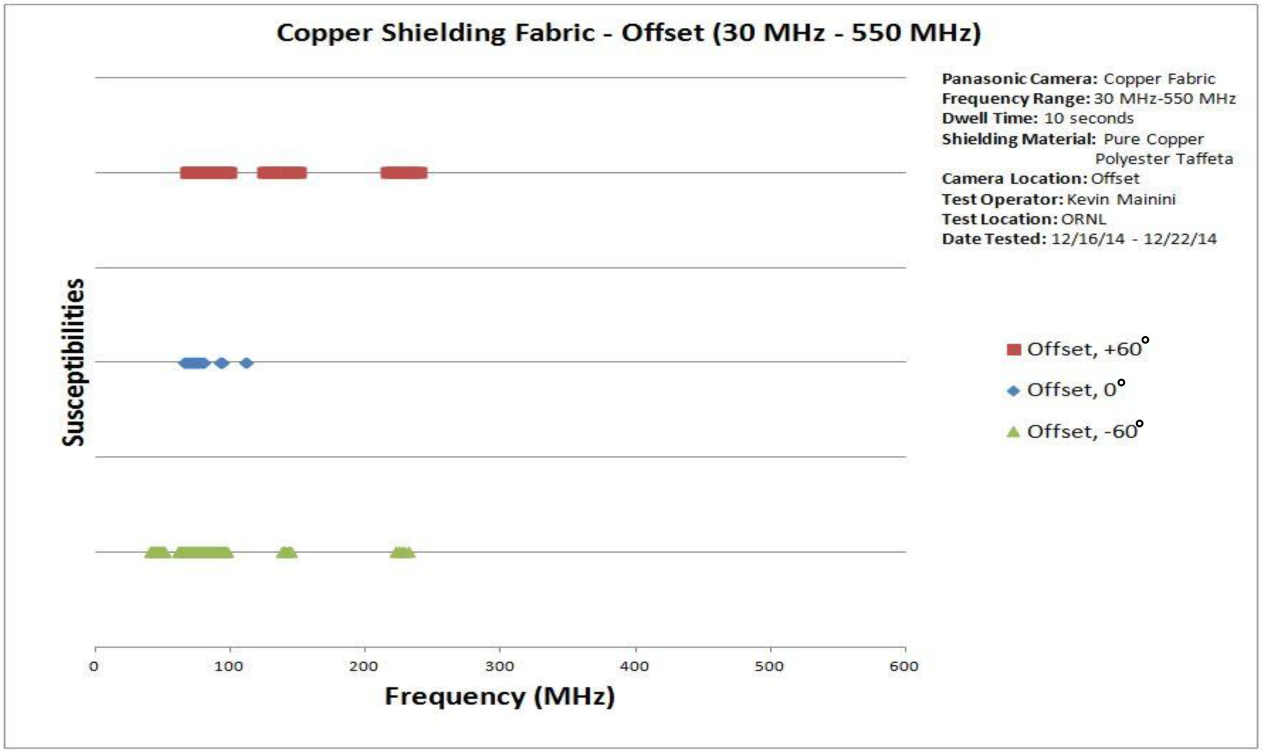

Figure 33: Copper Shielding Fabric – Offset (30 MHz – 550 MHz)

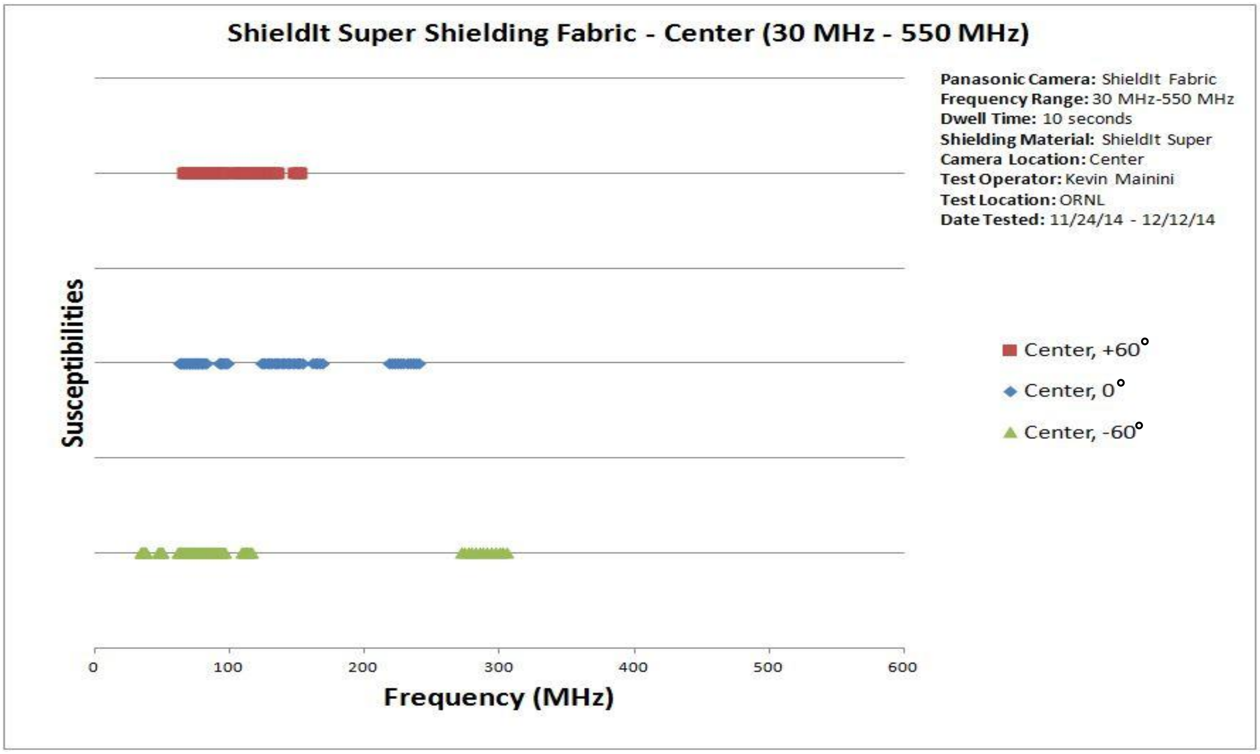

Figure 34: ShieldIt Super Shielding Fabric – Center (30 MHz – 550 MHz)

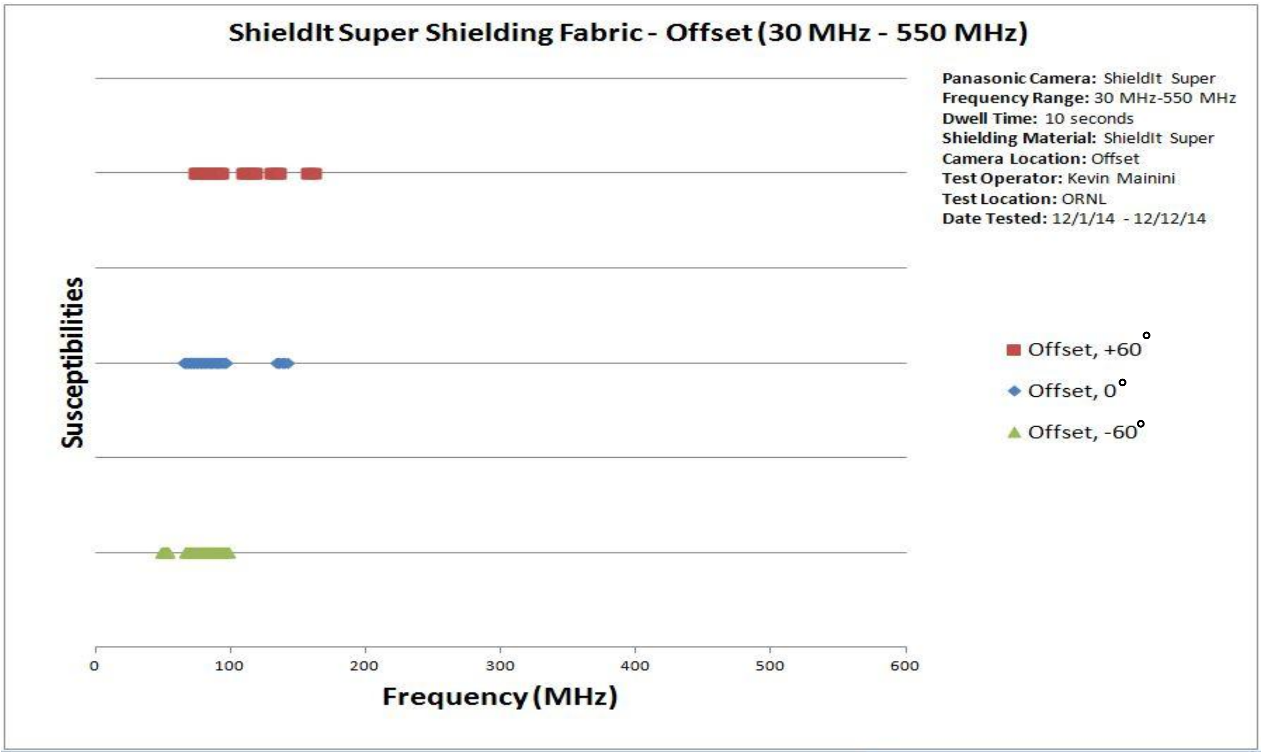

Figure 35: ShieldIt Super Shielding Fabric – Offset (30 MHz – 550 MHz)

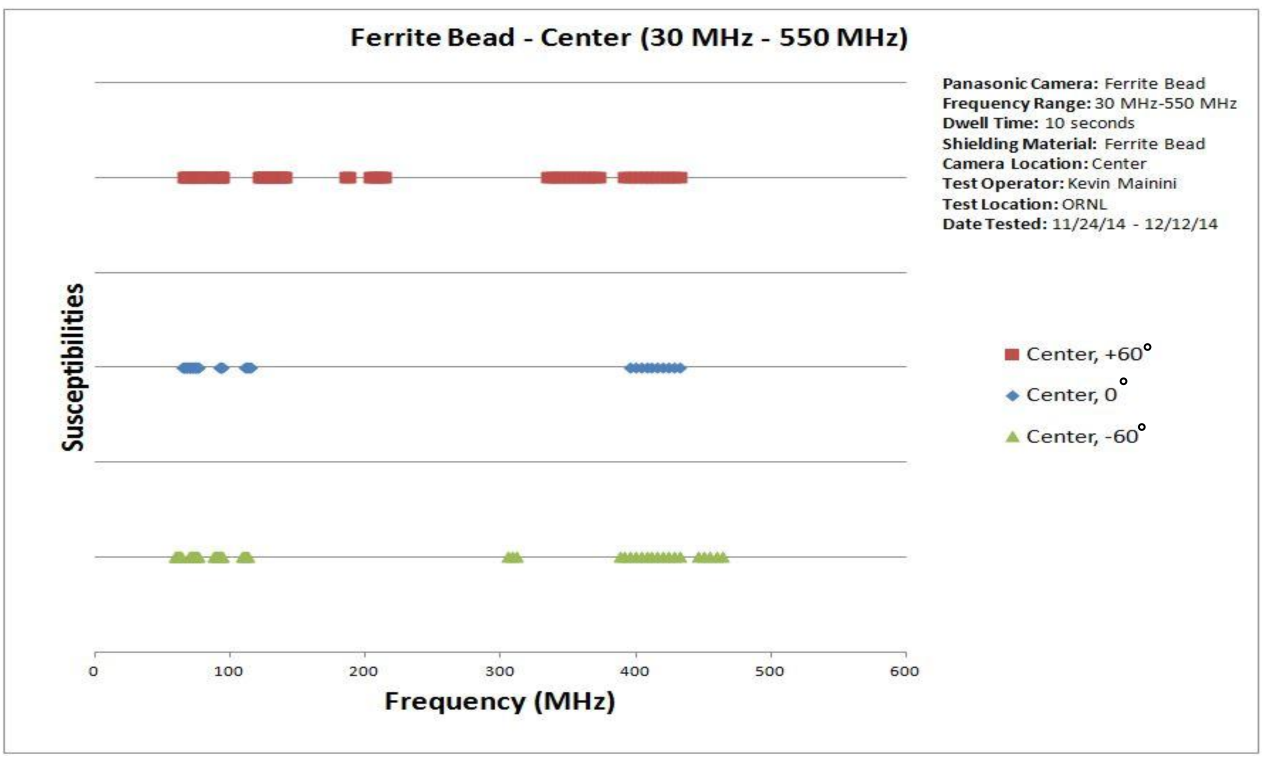

Figure 36: Ferrite Bead – Center (30 MHz – 550 MHz)

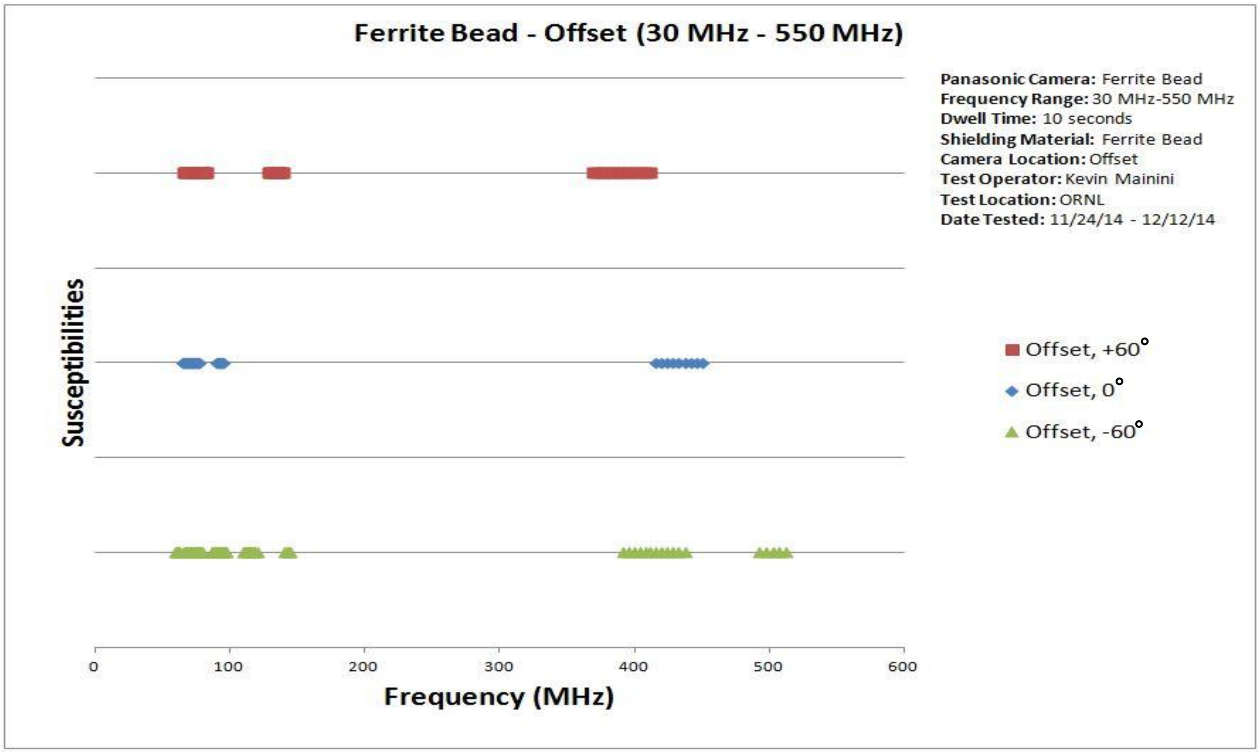

Figure 37: Ferrite Bead – Offset (30 MHz – 550 MHz)

<u>Data Analysis</u>

When comparing any of the shielding or suppression material data to the Baseline data, it can be seen that a significant amount of susceptible frequencies were able to be attenuated. A majority of the attenuated frequencies were toward the upper half of the modified test range (>300 MHz). However, it became apparent that none of the materials, on their own, would be able to shield all susceptible frequencies affecting the COTS camera. The full spectrum of video disturbances was still apparent as well (ribboning, de-synchronization, complete loss of signal, and combinations of all three). In an attempt to optimize the performance of the shielding and suppression material techniques, a final test plan was formulated. The final test plan would include a combination of the techniques, based on the collected data, designed to minimize the remaining susceptibilities.

Final Test Plan

After analyzing the results from the tests performed based on the modified test plan, enough data had been collected to create a final test plan. This final test plan was designed to measure the attenuation of the remaining susceptible frequencies. As a reference, the following specifications were used in the final test of the camera:

- The camera will be exposed to an RF field intensity of 50 V/m
- The frequency range will be 30 MHz – 550 MHz
- The frequency range will be 80% amplitude modulated with a 1 kHz sine wave
- The frequency will sweep at a 1% change rate of the fundamental frequency
- There will be a 10 second dwell time on each individual frequency

The physical test setup and radio frequency specifications were not modified in this test plan; however, since the centered test location showed the least amount of improvement, it was the only test location. With the offset test location removed, the camera was scanned a total of three times (one test location in three angled orientations). In this final test plan, the only modification made is that a combination of the selected shielding and suppression materials was used during the tests. Table 5 shows the general description of the final test to be performed.

Table 7: General Description of Final Susceptibility Test

Test	Material	Location	Orientation	Frequency Range	Dwell Time
1	Material Combination	Center	0°	30 MHz- 550 MHz	10 Sec.
2	Material Combination	Center	+60°	30 MHz- 550 MHz	10 Sec.
3	Material Combination	Center	-60°	30 MHz- 550 MHz	10 Sec.

The material combination was: two layers of Pure Copper Polyester Taffeta® fabric and a Ferrite bead clipped to the video cable. This combination was decided based on the results of the modified test plan. The copper fabric was able to attenuate frequencies greater than 250 MHz while the ferrite bead was effective at attenuating the middle frequencies. As stated in the Shielding and Suppression Approach section of this thesis, layering the shielding fabrics can increase their performance. It is for these reasons that this material combination was selected. Table 6 shows a step by step diagram of the final test sequence.

Table 8: Final Testing Sequence for the Camera and the Materials

Step	Description
1	The camera (with two layers of copper shielding and a ferrite bead clipped to the camera's video cable) is placed in the center of the GTEM (fully covered by the septum) pointing straight ahead (0°)
2	A frequency scan is initiated from 30 MHz – 550 MHz with a 10 second dwell time on each frequency
3	Any change in the video display is recorded as a susceptibility
4	The camera's orientation is changed to pointing +60° while in the center of the GTEM
5	Steps 2 and 3 are repeated
6	The camera's orientation is changed to pointing -60° while in the center of the GTEM
7	Steps 2 and 3 are repeated

CHAPTER 5

RESULTS

Figure 38 below shows the data collected from the final test plan. The camera was tested in the center of the chamber only with two layers of Pure Copper Polyester Taffeta fabric as well as a ferrite bead clipped to the camera's video cable. The graph consists of the data from one location and the three subsequent orientations. Each data point represents a frequency that caused a disturbance on the remote monitor of the camera.

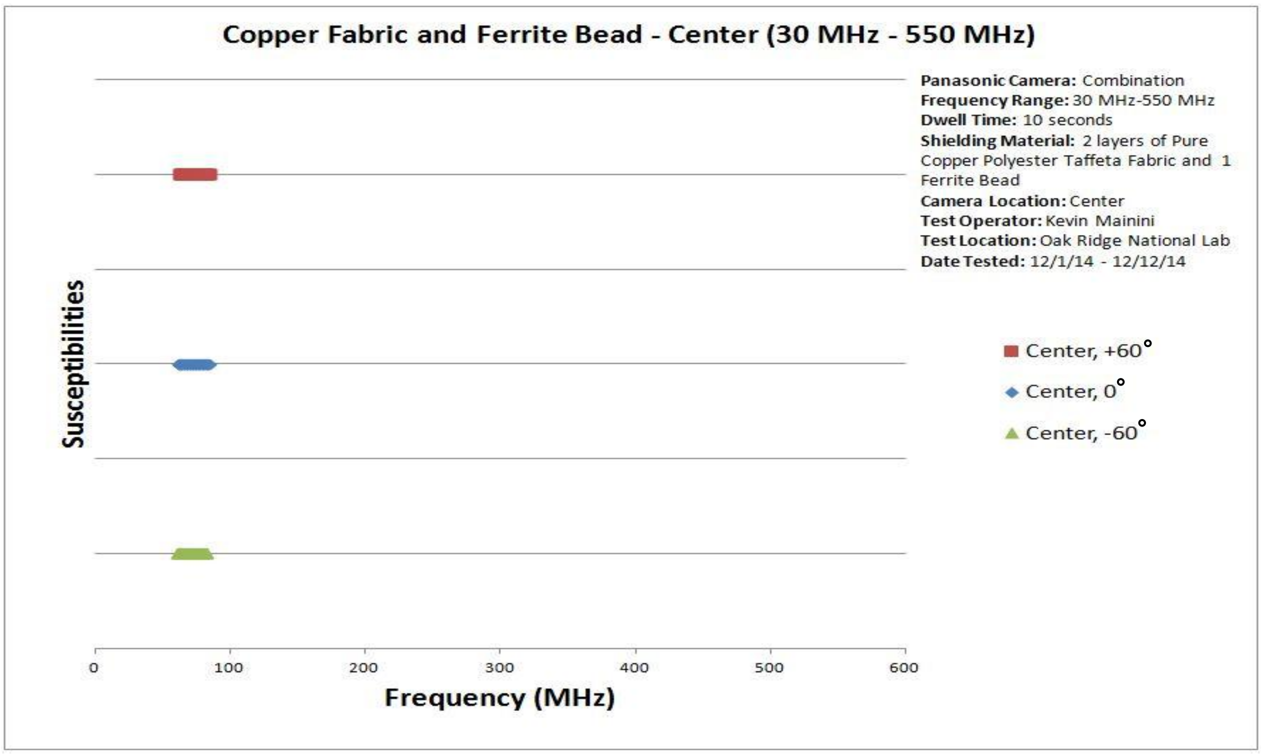

Figure 38: Combination of Shielding Materials – Center (30 MHz – 550 MHz)

Analysis of Final Results

As seen in Figure 38 above, almost all of the susceptibilities found in the camera were attenuated. There was only a small band of frequencies left that remained unfixed. However, the intensity of the remaining susceptibilities was drastically reduced. For purposes explained earlier in this thesis, any changes seen on the camera's remote monitor were recorded as susceptibilities. The susceptibilities seen in the final testing of the camera only contained a small amount of ribboning. They were recorded as susceptibilities because they created disturbances on the output monitor but the ribboning was so minute that a test operator would still be able to read an EUT display screen through the disturbance.

CHAPTER 6

CONCLUSIONS

The TTAC group uses COTS cameras to view the display screens of various radiation detectors that are undergoing EMC testing. These COTS cameras exhibit susceptibilities during this EMC testing which cause viewing issues for the test operators. In order to reduce or remove the susceptibilities exhibited by the cameras during testing, various radio frequency shielding and suppression methods were researched. The selected materials and methods were tested in the most extreme conditions, locations, and orientations typically tested by the TTAC Group. After testing the COTS camera in these conditions, locations, and orientations, the data collected was analyzed to further the testing and narrow the test focus in order to find the most viable solution.

The preferred method for reducing the amount of susceptible frequencies apparent in the COTS camera is layering the camera with two sheets of copper fabric and attaching a ferrite bead to the video cable. Not only were almost all of the susceptible frequencies attenuated completely by using this method, but the overall intensity of the field affecting the camera was greatly reduced. The reduction in field intensity allowed the camera to maintain full view of the EUT throughout the entirety of the final testing (with the exception of some video ribboning that had very little effect on the viewing capacity).

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APPENDICES

Appendix A: ANSI Electromagnetic Compatibility Standards

ANSI N42.32 – American National Standard Performance Criteria for Alarming Personal Radiation Detectors for Homeland Security

8.2 Radio Frequency

8.2.1 Requirement
The instrument shall not be affected by radio frequency (RF) fields over the frequency range of 80 MHz to 2.5 GHz at an intensity of 50 volts per meter (V/m). When exposed to these RF fields, the instrument shall function correctly. No alarms shall occur as a result of the RF radiation alone.

8.2.2 Test method
The test shall be performed using the following technique.
Prior to the RF test, expose the instrument to a 137Cs radiation field that produces a stable reading on the instrument (≤12% COV). For instruments with a digital and unit-less display record ten independent readings and determine the mean value, standard deviation, and coefficient of variation. For instruments with a non-numerical display (bar-graph, LEDs only, etc.) observe and record the response. Place the instrument and source in a RF controlled environment and expose it to a RF field of 50 V/m as measured without an instrument present in the test cell over a frequency range of 80 MHz to 2.5 GHz that is 80% amplitude modulated with a 1 kHz sine wave. The test should be performed using an automated sweep at a frequency change rate not greater than 1% of the fundamental. For instruments with a digital rate display, the instrument's response during the test shall be within ±15% of the pre-test reading. For instruments with a unit-less display, the instrument's response shall not change from the pre-test response by more than 10% of the full scale reading or ±1 unit, whichever is greater. For instruments with a non-numerical display (bar-graph, LEDs only, etc.), the instruments' display shall not change from the pre-test response. Remove the radiation source and repeat the test. No alarms shall occur as a result of the RF radiation alone. NOTE—The COV requirement is not applicable when testing without radiation sources.

ANSI N42.33 – American National Standard for Portable Radiation Detection Instrumentation for Homeland Security

8.2 Radio Frequency

8.2.1 Requirement

The instrument shall not be affected by radio frequency (RF) fields over the frequency range of 80 MHz to 2.5 GHz at an intensity of 10 volts per meter (V/m). No alarms shall occur as a result of the RF radiation alone.

8.2.2 Test method

The test shall be performed using the following technique. Expose the instrument to a 137Cs gamma source. Collect ten independent readings and calculate the mean reading, standard deviation, and coefficient of variation. Increase the exposure rate as needed to obtain a COV value that is ≤12%. NOTE—It may be necessary to increase the alarm threshold to prevent an alarm due to the exposure rate used for testing. Place the instrument and source in a RF controlled environment and expose it to a RF field of 20 V/m as measured without an instrument present in the test cell over a frequency range of 80 MHz to 2.5 GHz that is 80% amplitude modulated with a 1 kHz sine wave. The test should be performed using an automated sweep at a frequency change rate not greater than 1% of the fundamental frequency. Observe the instrument during exposure to the RF field. Repeat the test without the additional radiation field. NOTE—The COV requirement is not applicable when testing without radioactive sources. The results are acceptable if no alarms, spurious indications, or reproducible changes in response occur that exceed ±15% of the initial indicated value. If susceptibilities occur, retest the instrument over the frequency bands where susceptibility was observed at 10 V/m in three mutually orthogonal orientations. If the instrument now passes the test, the results are considered acceptable.

8.2 Radio Frequency (RF) Susceptibility

8.2.1 Requirement

The instrument should not be affected by RF fields over the frequency range of 80 MHz to 2500 MHz at an intensity of 10 volts per meter (V/m).

8.2.2 Test method

The test shall be performed using the following technique. Without radiation test sources, expose the instrument to an RF field of 20 V/m over a frequency range of 80 MHz to 2500 MHz that is 80% amplitude modulated with a 1 kHz sine wave. The test should be performed using an automated sweep at a frequency change rate not greater 1% of the fundamental (previous) frequency. Dwell time should be chosen based on the instrument's response time, but should not be less than 3 s. NOTE—20 V/m is selected so that the test can be performed in one orientation. Repeat the test with the instrument exposed to 137Cs and 252Cf positioned to provide a stable response on the instrument. If susceptibilities are indicated by substantial changes in the indicated readings (deviations exceeding ±15% of the initial mean gamma-ray or neutron readings) or other operational changes such as alarm activation, the RF exposure shall be repeated over the range of susceptibility at 10 V/m in three orientations relative to the emission source. The results are acceptable if no alarms, spurious indications, or reproducible changes in response occur that exceed ±15% of the initial indicated value.

ANSI N42.35 – American National Standard for Evaluation and Performance of Radiation Detection Portal Monitors for Use in Homeland Security

8.1 Radio Frequency (RF)

8.1.1 Requirement
The monitor should not be affected by RF fields over the frequency range of 80 MHz to 2500 MHz at an intensity of 10 volts per meter (V/m).

8.1.2 Test method
The system may be disassembled for test purposes, unless the monitor enclosure is designed to insulate internal components. All components including interconnections shall be tested. Due to the physical size of a portal monitor system, it may be necessary to reposition the system within the RF field to ensure that each area is exposed at the proper intensity. The test shall be performed using the following technique. Place the complete monitor or those components that have the greatest potential for susceptibility in a controlled RF environment and expose to a RF field of 20 V/m over a frequency range of 80 MHz to 2500 MHz that is 80% amplitude modulated with a 1 kHz sine wave. The test should be performed using an automated sweep at a frequency change rate not greater 1% of the fundamental (previous) frequency. Dwell time should be chosen based on the monitor’s response time, but should not be less than 3 s. NOTE—20 V/m is selected so that the test can be performed in one orientation. If susceptibilities are indicated by substantial changes in the indicated readings (deviations exceeding ±15% of the initial mean gamma-ray or neutron readings) or other operational changes such as alarm activation, the RF exposure shall be repeated over the range of susceptibility at 10 V/m in three orientations relative to the emission source. The test is acceptable if no alarms or other spurious indications occur and if there is no substantial change in response (reproducible deviations not exceeding ±15% of the initial mean gamma-ray or neutron readings) during the RF exposure.

8.2 Radio Frequency (RF) Susceptibility

8.2.1 Requirement

The monitor should not be affected by RF fields over the frequency range of 20 MHz to 2500 MHz at an intensity of 10 volts per meter (V/m).

8.2.2 Test method

NOTE—Due to the physical size of a portal monitor system, individual components can be gathered together for test purposes, although this is not recommended. Place the monitor (as a whole system or collection of components) in a controlled RF environment and expose it to an RF field of 20 V/m over a frequency range of 20 MHz to 2500 MHz that is 80% amplitude modulated with a 1 kHz sine wave. NOTE—Due to the physical size of a portal monitor system, it may be necessary to reposition the system within the RF field to ensure that each area is exposed at the proper intensity. The test should be performed using an automated sweep at a frequency change rate not greater 1% of the fundamental (previous) frequency. Dwell time should be chosen based on the monitor's response time, but should not be less than 3 s. NOTE—20 V/m is selected so that the test can be performed in one orientation. If susceptibilities are indicated by substantial changes in the indicated readings (deviations exceeding ±15% of the initial mean gamma-ray or neutron readings) or other operational changes such as alarm activation, the RF exposure shall be repeated over the range of susceptibility at 10 V/m in three orientations relative to the emission source. The test is acceptable if no alarms, spurious indications, or reproducible changes in response occur that exceed ±15% of the initial indicated value.

ANSI N42.43 – American National Standard Performance Criteria for Mobile and Transportable Radiation Monitors Used for Homeland Security

8.1 Radio Frequency (RF)

8.1.1 Requirement
The monitor should not be affected by RF fields over the frequency range of 80 MHz to 2500 MHz at an intensity of 10 V/m. Because backpacks are typically used where they may be exposed to the higher intensities found in close proximity to cell phones, the performance requirement for RF is 50 V/m.

8.1.2 Test method
Place the complete monitor or those components that have the greatest potential for susceptibility in a controlled RF environment and expose it to a RF field of 20 V/m (50 V/m for backpacks) over a frequency range of 80 MHz to 2500 MHz that is 80% amplitude modulated with a 1 kHz sine wave. The test should be performed using an automated sweep at a frequency change rate not greater 1% of the fundamental (previous) frequency. Dwell time should be chosen based on the monitor's response time, but should not be less than 3 s. NOTE—20 V/m is selected so that the test can be performed in one orientation. Backpacks will require to be tested in multiple orientations. If susceptibilities are indicated by substantial changes in the indicated readings (deviations exceeding ±15% of the initial mean gamma-ray or neutron readings) or other operational changes such as alarm activation, the RF exposure shall be repeated over the range of susceptibility at 10 V/m (50 V/m for backpacks) in three orientations relative to the emission source. The test is acceptable if no alarms, spurious indications, or changes in response occur that exceed ±15% of the initial indicated value.

8.3 Radio Frequency

8.3.1 Requirement

The instrument shall not be affected by radio frequency (RF) fields over the frequency range of 80 MHz to 2.5 GHz at an intensity of 50 volts per meter (V/m). When exposed to these RF fields, the instrument shall function correctly. No alarms shall occur as a result of the RF field alone.

8.3.2 Test method

Prior to the RF test, establish the nominal reading. Place the instrument and source in a RF controlled environment and expose it to a RF field of 50 V/m as measured without an instrument present in the test cell over a frequency range of 80 MHz to 2.5 GHz that is 80% amplitude modulated with a 1-kHz sine wave. The test should be performed using an automated sweep at a frequency change rate not greater than 1% of the fundamental. The instrument's readings during the test should be within ±15% of the nominal reading. No other functional changes shall occur, such as alarm activation, mode changes, loss of display, etc. Remove the radiation source and repeat the test.

ANSI N42.53 – American National Standard Performance Criteria for Backpack-Based Radiation Detection Systems Used for Homeland Security

8.1 Radio Frequency (RF)

8.1.1 Requirements

A BRD should not be affected by radio frequency (RF) fields over the frequency range of 80 MHz to 6000 MHz. The field intensity shall be 50 V/m over the frequency range from 80 MHz to 1000 MHz. For frequencies over 1000 MHz, the intensity is 3 V/m. NOTE—Wireless interface technologies, such as IEEE 802.11, IEEE 802.15.1, and 900-MHz radio, may not work in the presence of RF. 50 V/m is selected due to the likely presence of RF emitters in close proximity to the BRD when worn. The remaining requirements are from the reference standard IEC 61000-4-3.

8.1.2 Test method

The susceptibility test shall be performed with and without radiation sources (background only). Statistical requirements are not used for background-only measurements.

A) Place the BRD in the test chamber oriented with the detection side (0° as shown in Figure 3) facing the emission source. RF test set up information can be found in IEC 61000-4-3.
B) With the BRD and any components normally used by the operator (e.g., tethered display) in position for test, expose the BRD to a gamma-ray and neutron radiation field (when applicable) using 137Cs and 252Cf.
C) Record ten readings with the source(s) present.
D) Calculate and record the mean, standard deviation, and COV. The COV shall be less than or equal to 12%. If the COV is greater than 12%, the radiation level should be increased to reduce the variation between readings. Due to the expected low response of the neutron detector, a COV greater than 12% is acceptable for the neutron response.
E) Using the acceptable mean reading, establish the acceptance range of ±15%.
F) With the sources in position, expose the BRD to an RF field of 50 V/m over a frequency range from 80 MHz to 1000 MHz and 3 V/m for frequencies up to 6000 MHz that is 80% amplitude modulated with a 1-kHz sine wave. The test should be performed using an automated sweep at a frequency change rate not greater 1% of the fundamental (previous) frequency. Dwell time at each frequency should be chosen based on the BRD's response time, but should not be less than 3 s.
G) Observe the response of the BRD during the RF exposure. Record any functional changes that may occur (e.g., alarms, fault indications) and frequency ranges where the gamma or neutron response went outside of the acceptance range.
H) Without changing the positions of the source(s) or BRD, repeat the RF exposure over the frequency ranges where the response was outside of the acceptance range to verify susceptibility.
I) Repeat f) through h) without the sources. Due to the low response levels, the use of ±15% of the average background readings is not required.

<u>Appendix B: Panasonic-WV-CP470 Series</u>

Panasonic

Super Dynamic II
Color Surveillance Cameras
with Low-Light B/W Mode

WV-CP470 Series

Lens : optional

A NEW HIGH END COLOR CAMERA WITH 24-HOUR SURVEILLANCE AND MULTIFUNCTION FEATURES.

Panasonic introduces the WV-CP470 Series cameras. Always on the job, these cameras automatically switch from color, in daytime, to high sensitivity black and white at night. With full 24-hour surveillance capabilities, features include, motion detection and error free title displays.

With 480 lines of horizontal resolution, in color mode, and 570 lines in black and white, the WV-CP470 Series defines high definition. It can operate in color mode at 0.8 lx (0.08 fc), using a F1.4 lens. In black and white mode sensitivity is an amazing 0.1 lx (0.01 fc). Plus, its linear sensitivity can be electronically enhanced up to 32 times. With ***Super Dynamic II*** capabilities, the WV-CP470 Series make it possible to obtain clear images of subjects in extreme lighting conditions. A built-in alarm output terminal makes connection to an extreme sensor a snap.

Indoors, outdoors and under the toughest conditions, the WV-CP470 Series provides constant and reliable surveillance.

Key Features

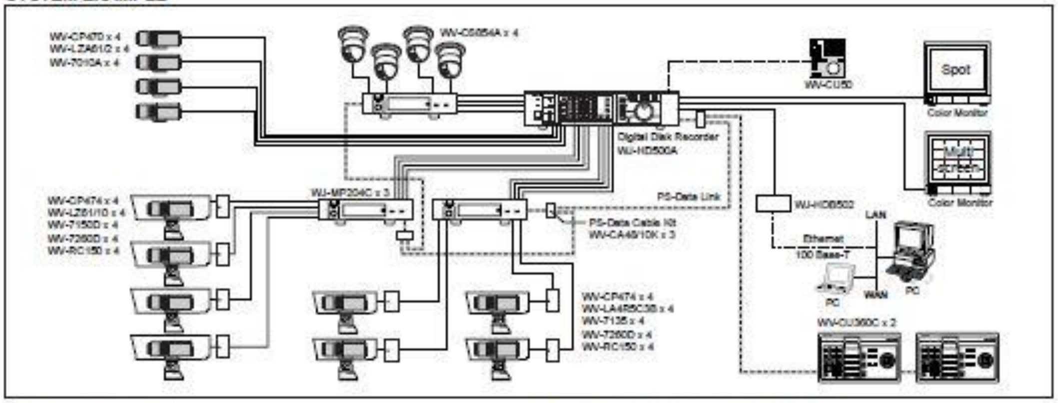
- 1/3-type double speed CCD color image sensor.
- Switches from selected color mode to B/W mode, automatically or manually.
- Built-in ***Super Dynamic II*** function has 64 times wider dynamic range when compared to a conventional camera.
- Super sensitivity of 0.8lx (0.08fc) at F1.4 in color mode, and 0.1lx (0.01fc) at F1.4 in B/W mode.
- 480-line resolution in color mode, and 570-line in B/W mode.
- Signal to noise ratio of 50dB.
- ELC function enables the use of fixed iris lens for indoor applications.
- Built-in Alarm output connector for external sensors.
- Built-in digital motion detector.
- Built-in 16 alphanumeric character display.
- Electronic shutter from 1/60 to 1/10,000 sec.
- Electronic sensitivity enhancement (Auto; up to 10x, Manual; up to 32x, and Off)
- Digital signal processing LSI's for high quality pictures:
  2H vertical enhancement, chroma averaging circuit, minimum of aliasing, knee circuit, and highlight aperture correction.
- Gen-lock connector for the large system applications.
- VD2 sync capability with Panasonic system products.
- Accepts both AC 24V & DC 12V for WV-CP474 camera model.

WIDE VARIETY OF OPTIONAL LENSES

Auto Iris Lenses	High-Speed Lenses	Zoom Lenses	Vari-focal Lenses
WV-LA2R8C3B	WV-LA210C3	WV-LZ61/10 (x10)	WV-LZA61/2
WV-LA4R5C3B	WV-LA408C3	WV-LZ61/15 (x15)	WV-LZF61/2
WV-LA8C3B	WV-LA908C3		WV-LZ62/2
			WV-LZ62/8



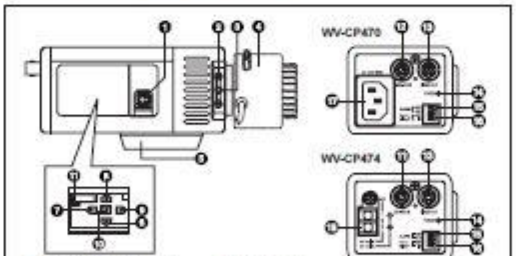

SYSTEM EXAMPLE



SPECIFICATIONS

Model No.	WV-CP470	WV-CP474
Pick-up Device	771(H) x 492(V) pixels, Interline Transfer CCD	
Scanning Area	4.8(H) x 3.6(V) mm (Equivalent to scanning area of 1/3" pick-up tube)	
Scanning	525 lines/60 fields/30 frames Horizontal: 15.734 kHz Vertical: 59.94 Hz	
Synchronization	Internal, Line-locked, External (VS/VBS) or Multiplexed Vertical Drive (VD2) selectable	
Video Output	1.0V[p-p] NTSC composite 75Ω/BNC connector	
Horizontal Resolution	480 lines (C/L), 570 lines (B/W)	
Signal-to-Noise Ratio	50dB (Equivalent to AGC Off, weight On)	
Dynamic Range	46dB	
Minimum Illumination	0.8 lx (0.08 fc) at F1.4 (C/L), 0.1 lx (0.01 fc) at F1.4 (B/W)	
Gain Control	ON (DNR-H), ON (DNR-L) or OFF (SET UP MENU) selectable	
White Balance	ATW1, ATW2 or AWC (SET UP MENU) selectable	
Aperture	Set Variable (SET UP MENU)	
Electronic Light Control	Equivalent to continuous variable shutter speeds between 1/60s and 1/10,000s	
Super Dynamic II	ON or OFF (SET UP MENU) selectable	
Electronic Shutter Speed	1/60(OFF), 1/100, 1/250, 1/500, 1/1,000, 1/2,000, 1/4,000, 1/10,000s selectable	
Lens Mount	CS-mount (supplied with C-mount adapter)	
ALC Lens	DC or Video selectable	
Ambient Operating Temperature	–10°C ~ +50°C (14°F ~ 122°F)	
Ambient Operating Humidity	Less than 90%	
Power Source and Power Consumption	120V AC 60Hz, 4.8W	24V AC 60Hz, 4.3W 12V DC, 440mA
Dimensions	70(W) x 65(H) x 128(D) mm [2-3/4"(W) x 2-9/16"(H) x 5-1/32"(D)]	
Weight (approx.)	460 g (1.01 lbs.) (without power cord)	450 g (0.99 lbs.)

MAJOR OPERATING CONTROLS



1. Auto Iris Lens Connector
2. Focus Adjusting Ring
3. Focus Fixing Screw
4. Lens(Option)
5. Camera Mounting Screw Hole
6. Down Button
7. Left Button
8. Up Button
9. Right Button
10. Set Button
11. Gen-lock Termination Switch
12. Gen-lock Input Connector
13. Video Output Connector
14. Power Indicator
15. Alarm Output Terminal
16. Day/Night In Terminal
17. AC Inlet Socket (WV-CP470)
18. AC/DC Compatible Input Terminal (WV-CP474)

OPTIONAL COMPONENTS

DIGITAL DISK RECORDERS

WJ-HD500A (with 16ch Multiplexer)
WJ-HD100

DIGITAL MULTIPLEXERS

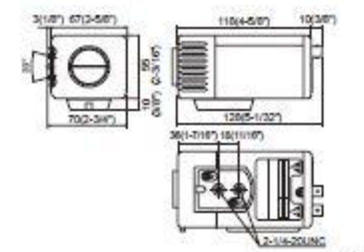
WJ-FS616C (16ch) WJ-FS416 (16ch)
WJ-FS216 (16ch) WJ-FS409 (9ch)

MATRIX SYSTEM 500

COLOR MONITORS

WV-CM2080 51cm (20")
WV-CM1780 41cm (16")
WV-CM1480 36cm (14")
WV-CM1420 34cm (13")
WV-CM1020 22cm (9")

APPEARANCE



Unit : mm (inches)

• Weights and dimensions are approximate. • Specifications are subject to change without notice. • These products may be subject to export control regulations.

Panasonic

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Appendix C: Narda NBM-550 High Frequency Broadband Meter

Electric and Magnetic Field Measurements from RF to Microwave

NBM-550 Broadband Field Meter

- **Available with Isotropic Probes to cover 100 kHz to 60 GHz**
- **Large Graphical Display**
- **Intelligent Probe Interface with Automatic Probe Parameter Detection**
- **Fully Automatic Zeroing**
- **Extensive Memory for Logging of up to 5000 Results**
- **GPS Interface and Mountable Receiver for Positioning Data Documentation (Optional)**
- **Voice Recorder for Adding Comments (Optional)**

Description

The NBM-500 Series is the most accurate non-ionizing radiation survey system available. It provides the broadest frequency coverage of electric and magnetic fields. Both flat response probes and probes shaped to international standards are available. All NBM probes have a non-volatile memory containing device parameters and calibration data. Probes are calibrated independently of the meter. Any NBM probe can be used with any NBM-500 Series meter and still maintain total calibration.

Applications

Precision measurement of electric or magnetic field strength for personal safety at work where high radiation levels are present, such as:

- General RF Safety program measurements
- Service work on transmitting and radar equipment
- Service work on mobile antennas, broadcasting and satellite communication systems
- Working with heating and packaging machines in the food industry
- Working with heating and hardening machines in the automotive industry
- Operating diathermy equipment and other medical instruments producing short-wave radiation
- Drying equipment in the tanning and timber industries

NBM-550 Broadband Field Meter

Features

DISPLAY
- Backlit Monochrome LCD; readable even in bright daylight
- Graphical User Interface (GUI) with selectable languages

OPERATION
- Simple-to-Use 9 button keypad
- Hold button soft key for "freezing" measurement display during readings
- User defined setups can be saved for repetitive survey needs
- Keypad can be locked to guard against inadvertent inputs
- User selectable "auto-off" feature to save battery life

READINGS DISPLAYED
- 5 Types of results can be displayed - actual, minimum, maximum, average and maximum average
- History Mode – history memory operates continuously in the background, allowing you to display past readings at any time, up to 8 hours
- Selectable Units – V/m, A/m, W/m^2, mW/cm^2 and "% of Standard" when using shaped frequency response probes
- Stored standards and guidances in the NBM's memory allow you to simultaneously display readings as a "% of Standard" if frequency is known
- Data memory for up to 5000 measurements

AVERAGING FUNCTIONS
- Time Averaging – 4 seconds to 30 minutes, in 2-second intervals
- Spatial Averaging – discrete or continuous

AUDIBLE ALARM
- Variable alarm threshold setting
- Audible indication of increasing or decreasing field strength

PROBE INTERFACE
- Automatic detection of probe type and calibration information
- Fully automatic and variable zero adjustment interval times
- Additional optical input for separating probe from meter

REMOTE CONTROL
- PC connection via USB or Optical interface
- Trigger input for externally initiating readings to be taken
- NBM-TS software enables remote controlled measurements
- Screenshots can be downloaded to PC

Rugged and lightweight housing, designed for easy one-hand operation

NBM-TS Software (supplied with NBM-550)

The supplied NBM-TS software provides for convenient data management, documentation of results and future evaluation. It also provides you the capability to remotely control the NBM and perform firmware upgrades. This innovative software package also allows you to link the optional GPS data with actual pictures from mapping programs like Google Earth™, making field survey data take on more relevance with the reader. And, to ensure it will be viable for years to come, this software was designed with Microsoft's Vista™ operating system in mind.

NBM Option Set

Consider the Option Set for the NBM-550 and how it can simplify your survey reports – a major advantage. This Option Set adds a GPS receiver and conditional logging. It also allows you to add voice storage to stored readings via our built-in microphone. By adding the power and versatility of audible comments to stored readings, you will not have to remember the particulars of when and where readings were taken – imagine that!

THE NBM-550 OPTION SET INCLUDES:

The Option Set is field (or factory) installable, so it can be added any time you choose, without having to return it to the factory.

NOTE: Narda strongly recommends that an optional check source be used to verify operation of the NBM Series. Any device capable of generating an upscale indication at microwave frequencies is acceptable, as well as Narda P/N 8699.

NBM-550 Broadband Field Meter

Specifications

NBM-550	
DISPLAY	
Display Type	Transflective LCD, monochrome
Display Size	10 cm (4 inch), resolution 240 x 320 dots
Backlight	White LEDs, selectable illumination time (OFF, 5s, 10s, 30s, 60s, PERMANENT)
Refresh Rate	200 ms for bar graph and graphics, 400 ms for numerical results
MEASUREMENT FUNCTIONS	
Result Units	mW/cm², W/m², V/m, A/m, % of Standard
Display Range, Fixed Triads	0.0001 to 9999 for all units (4 digits)
Display Range, Variable Triads	0.01 V/m to 100 kV/m 0.027 mA/m to 265.3 A/m 0.265 µW/m² to 26.53 MW/m² 0.027 nW/cm² to 2.653 kW/cm² 0.0001% to 9999%
Result Types (Isotropic, RSS)	Actual (ACT), Maximum (MAX), Minimum(MIN), Average (AVG), Maximum Average (MAX AVG)
Result Types (X-Y-Z mode)	Actual X, Actual Y, Actual Z (requires a probe with separate axes)
Averaging Time	Selectable, 4 seconds to 30 minutes (2 second steps)
Spatial Averaging	Discrete or continuously
Multi-position Spatial Averaging	Averaging of up to 24 spatially averaged results, each position and total will be stored
History View	Graphical display of actual results versus time (span of 2 minutes to 8 hours)
Frequency Correction	1 kHz to 100 GHz or OFF (direct frequency entry, interpolation between calibration points)
Hot Spot Search	Audible indicator for increasing and decreasing field strength (result type Act or Max)
Alarm Function	2 kHz audible signal (4 Hz repetition), adjustable threshold
Timer Logging	Start time pre-selection: up to 24 hours or immediately Logging duration: up to 100 hours Logging interval: 1 second to 6 minutes (in 11 steps)
RESULTS MEMORY	
Physical Memory	12 MB non-volatile flash memory for measurement results and voice comments
Storing Capacity	Up to 5000 results (including test parameters, time stamp and GPS data when available)
INTERFACES	
Remote Control	Via USB or optical RS-232 interface (selectable)
USB	Serial, full duplex, 460 kBaud (virtual COM port), multi-pin connector
Optical Interface	Serial, full duplex, 115 kBaud, no parity, 1 start and 1 stop bit
Earphone	3.5 mm TRS, > 16 ohms (mono), for voice recorder option only
External Trigger (to store results)	Uses the multi-pin connector. Interface cable with BNC connector available as an option, triggers when contacts shorted.
External GPS Receiver	Uses the multi-pin connector. GPS receiver with interface cable is available as an option
Probe Interface	Plug-and-play auto detection, compatible with all NBM series probes

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Environmental Specifications

NBM-550	
Recommended Calibration Interval	24 months
Battery	NiMH rechargeable batteries, 4 x AA size, 2500 mAh
Operation Time	20 hours (backlight off, no GPS) 12 hours (permanent backlight, no GPS) 10 hours (GPS receiver connected, no backlight)
Charging Time	2 hours
Battery Level Display	100%, 80%, 60%, 40%, 20%, 10%, low level (< 5%)
Humidity	5 to 95%, non condensing ≤29 g/m³ absolute humidity (IEC 60721-3-2 class 7K2)
Temperature Range Operating Non-Operating (Transport)	 -10°C to +50°C -30°C to +70°C
Size (h x w x d)	11.4 x 3.9 x 1.8 inches (290 x 98 x 45 mm) without probe and GPS receiver
Weight	20 oz. (550 g) without probe and GPS receiver
Supplied Accessories	Transit case for meter and up to 4 probes, NBM-TS PC Transfer Software, USB interface cable, rechargeable batteries, power supply, shoulder strap, bench-top tripod, manual, certificate of calibration

Option Set (Ordering Number 2401/40/USA)

CONDITIONAL LOGGING	
Logging Conditions	Selectable, - On upper threshold: Storing when measurements exceed the adjustable threshold - Out of gap: Storing when measurements are higher than the upper or lower than the lower threshold
Logging Range	Selectable, - Store all (as long as the condition is true), sampling rate 5 Hz - Store first and last event (when the condition was true)
VOICE RECORDER	
Microphone	Integral microphone at the top side of the instrument near the Narda logo
Recording Level	Fix level, VU-meter displayed when recording for level monitoring
Recording Length	30 seconds max. length per voice comment, 1 voice comment stored with relevant result
Recording Format	8-bit PCM mono, stored as WAV file (approx. 240 kB per 30 seconds)
Output	External earphone (adjustable output level) or via NBM-TS PC Software
GPS POSITION LOGGING	
Receiver Type	12-channel satellite tracking, DGPS capability, WAAS / EGNOS compatible
Displayed Position Data	Latitude (Lat) and Longitude (Long), selectable unit: DMS (degrees, minutes, seconds) / MinDec (decimal minutes) / DegDec (decimal degrees)
Geodetic System	WGS84 / NAD83
Position Accuracy	< 3 m (DGPS, WAAS), <15 m (SPS), high precision mode indicated by the NBM-550
Update Rate	1 second
Acquisition Time	2 seconds (reacquisition) up to 5 minutes (no data known)
Receiver Size/ Weight	2.4 inches (61 mm) in diameter, .8 inches (19.5 mm) in height 2.2 oz. (62 g) — approx. 3.5 oz. (100 g) with mounting plate
Receiver Mounting	Uses the tripod thread on the underside of NBM-550, mounting plate included

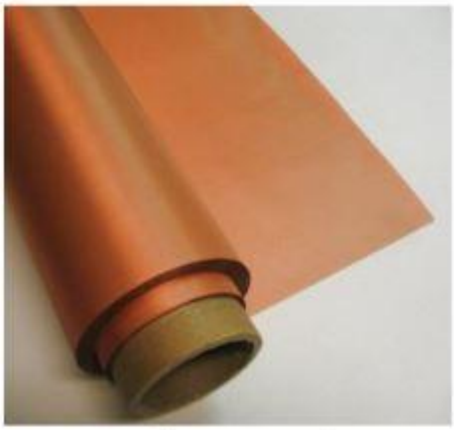
NBM-550 Broadband Field Meter

Ordering Information

NBM-550	Ordering Part No.
NBM-550 Narda Broadband Field Meter System Includes: NBM-550 Basic Unit (2401/01B) Transit Case, holds field meter and up to 5 probes (2400/90.06) Power Supply / Charger 100 VAC to 240 VAC Input, 9 VDC Output (2259/92.06) NBM-TS Software and PC Transfer (2400.93.01) USB Interface cable for NBM, 2 m (2400/90.05) Bench-top Tripod, 0.16 m, non-conductive 2244/90.32) Shoulder Strap, 1 m (2244/90.49) Operating Manual Certificate of Calibration ***Probes are NOT included***	2400/101B
Option Set for NBM-550 (GPS Interface and Receiver, Voice Recorder, Conditional Logging)	2401/40/USA
PROBES	
Probe EF 0391, E-Field, 100 kHz – 3 GHz, Isotropic	2402/01B
Probe EF 0392, E-Field, 100 kHz – 3 GHz, Isotropic	2402/12B
Probe EF 0691, E-Field, 100 kHz – 6 GHz, Isotropic	2402/14B
Probe EF 1891, E-Field, 3 MHz – 18 GHz, Isotropic	2402/02B
Probe EF 5091, E-Field, Thermocouple, 300 MHz – 50 GHz, Isotropic	2402/03B
Probe EF 5092, E-Field, Thermocouple, 300 MHz – 50 GHz, Isotropic	2402/11B
Probe EF 6091, E-Field, 100 MHz – 60 GHz, Isotropic	2402/04B
Probe HF 3061, H-Field, 300 kHz - 30 MHz, Isotropic	2402/05B
Probe HF 0191, H-Field, 27 MHz – 1 GHz, Isotropic	2402/06B
Probe EA 5091, Shaped E-Field, FCC, 300 kHz - 50 GHz, Isotropic	2402/07B
Probe EB 5091, Shaped E-Field, IEEE, 3 MHz - 50 GHz, Isotropic	2402/08B
Probe EC 5091, Shaped E-Field, SC6, 300 kHz - 50 GHz, Isotropic	2402/09B
Probe ED 5091, Shaped E-Field, ICNIRP, 300 kHz - 50 GHz, Isotropic	2402/10B
ACCESSORIES	
Test-Generator 27 MHz, Hand-Held	2244/90.38
Tripod, Non-Conductive, 1.65 m with Carrying Bag	2244/90.31
Tripod Extension, 0.50 m, Non-Conductive (for 2244/90.31)	2244/90.45
Handle, Non-Conductive Extension 0.42m	2250/92.02
Cable, Coaxial Multi-pin / BNC for NBM-550 External Trigger, 2 m	2400/90.04
Cable, Fiber Optic Duplex (1000 µm) RP-02, 2 m	2260/91.02
Cable, Fiber Optic Duplex (1000 µm) RP-02, 20 m	2260/91.03
Cable, Fiber Optic Duplex FSMA / RP-02, 0.3 m	2260/91.01
O/E Converter RS-232C (RP-02/DB-9)	2260/90.06
O/E Converter USB (RP-02/USB)	2260/90.07
Cable, Adapter, USB 2.0 - RS-232, 0.8 m	2260/90.53

PURE COPPER POLYESTER TAFFETA FABRIC

(Compare to Flectron®)



Shiny, smooth fabric with pure copper. Light weight and flexible. Easy to cut and sew like ordinary fabric. Better color stability due to tarnish resistant finish. High conductivity and shielding performance. Use it for drapes, wall covering, garments, pouches and more. Great price too!

Width: 1080 mm (42.5 inch)
Thickness: 0.08mm (3 mil)
Weight: 80 g/m² (about 35% Copper)
Surface Resistivity: 0.05 Ohm/sq.

SHIELDIT™ SUPER

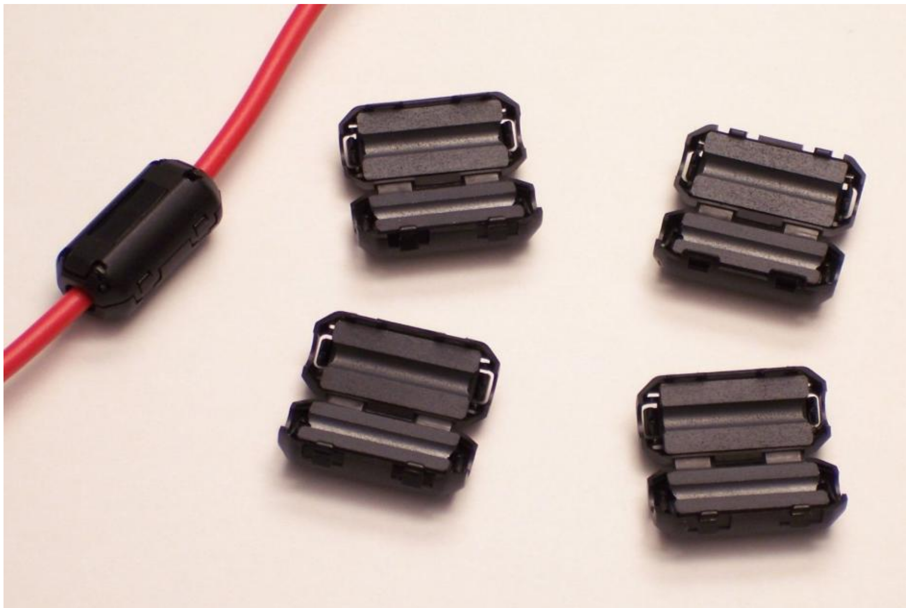
"With Hot Melt Adhesve Backing"

High quality flame retardant fabric for radiofrequency and microwave shielding. Rugged rip-stop polyester substrate (for superior strength and handling), conductive Nickel and Copper plated (for excellent shielding and low corrosion), then coated on one side with a non-conductive hot melt adhesive (activates at 130ºC = 266ºF) so you can iron it on to cotton, wood, glass or paper, or roll it into a tube and heat seal the seam! Maximum temperature is 200ºC (=392ºF). One side surface resistivity <0.5 Ohm/sq. Can also be cut and sewn like ordinary fabric.

This fabric offers an amazing shielding performance: **>60 dB from 10 MHz to 3+ GHz**. Will also block virtually all ELF & VLF electric fields when grounded. Great for shielding extension cords and computer cables. Connect strips of it to make a sheet shield under your bed, or hang it on the wall. Makes a great liner for drapes too! Line a vest or a hat to protect your vital organs from radiowaves and electric fields. It doesn't breathe well, and Nickel may cause skin irritation, so plan to line it with cotton if you will be using it against the skin. 230 g/m^2, 0.17 mm thick. UL 94V-0 level flame retardant. RoHS Compliant. Gray, **14 inch wide**.

Shieldit Super (Cat. #1220)

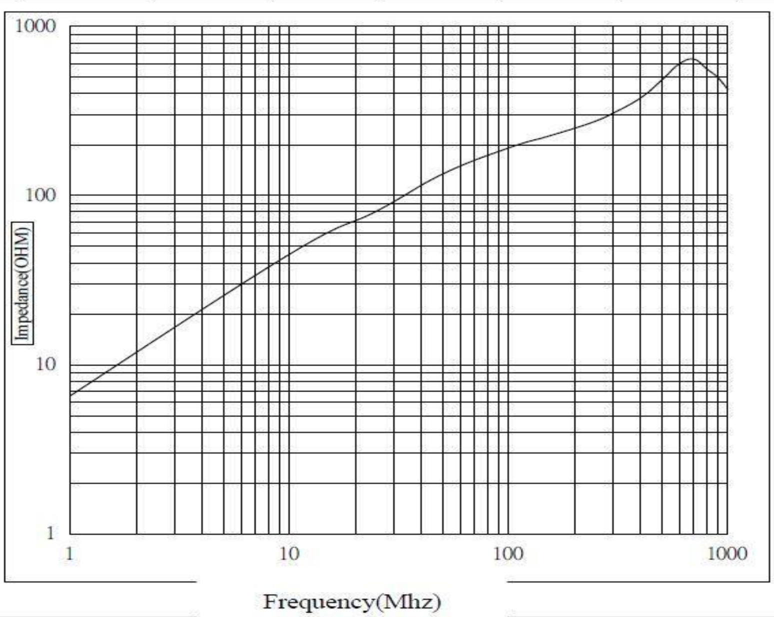
Ferrite Bead Clip



Source: EBAY, 2015

MATERIAL CHARACTERISTICS

MATERIAL	INITIAL PERMEABILITY	PRACTICAL FREQUENCY	RESIDUAL FLUX DENSITY(Br)	SATURATION FLUX DENSITY(Bs)	MAGNETIZIN GFORCE	CURIE TEMP	MATERIAL DENSITY
UNIT	ui	MHZ	Gauss	Gauss	Oested	℃	g/cm^3
F5B	700+/-25%	0.1-1.0	1200	2750	0.35	120	4.9



Source: EBAY, 2015

VITA

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	M.S. Engineering Technology with disciplines in Mechanical and Electrical Engineering, East Tennessee State University, Johnson City, Tennessee, 2015
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Publications:	Mainini, Kevin A. (2014). "Engineered Improvements to Increase Efficiency and Capabilities of Radiation Detection Test Equipment in the Technical Testing and Analysis Center." Oak Ridge National Lab. Oak Ridge, Tennessee