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Microwave Shielding Technology

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A simple system for measuring the attenuation of microwaves in the frequency range of 700 MHz–13 GHz has been used to compare attenuation by a large number of commercially available shielding materials. The standard system for such measurements would require IEEE STD 299. Implementation of this standard requires a number of different sources and receivers, making the measurements time consuming and expensive. The simple system described here uses two microwave horns and a network analyzer to compare the difference in attenuation due to a clear path from the transmitting horn to the receiving horn and a path with a shielding material inserted. This ratio, expressed in decibels, was obtained quickly and easily for a number of commercially available materials. The horns are A. H. Systems SAS-571 with a usable range of 700 MHz–18 GHz. The network analyzer is a hp 1397C with a high-frequency limit of 13 GHz. The materials tested include conducting paints on cloth such as denim, conducting woven fabrics, and metal meshes. The conducting paints and conducting fabrics mostly show large attenuation over the quoted frequency range, although almost never as high as stated by the manufacturer, which may be due to different methods used for the tests. Attenuation in decibels is given for 27 materials considered to be generally useful in protecting sensitive electronic equipment under difficult circumstances.

KEYWORDS: Conducting fabrics, Metal mesh, Microwave shielding, RF shielding

1. Introduction

Shielding of rooms containing data storage and processing equipment has been practiced for many years.[1] Permanent installations can be shielded using screen wire or solid metal in the walls and ceiling. Windows are slightly more difficult, but conducting glass window units can be purchased.[†]

The situation is more difficult when the data processing equipment must be set up and used in a temporary facility such as an unknown owner's building, a trailer, or a tent. In that case, a quick and easy-to-transport shielding solution is needed. A room with paintable walls may be painted on the inside with one of several conducting paints. An arrangement for grounding these walls is generally not too difficult, although a Faraday cage does not have to be grounded to be effective. Windows may be made of glass with a conducting coating or covered with plastic with a conductive coating. In each case, the manufacturer

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†Pilkington Architectural has developed and patented a range of security glasses called DATASTOP—both laminates and sealed units—specifically designed to reduce the transmission of EMI/RF. Supplier: Tempest Security Systems, Inc., P.O. Box 584, Troy, OH 45373.

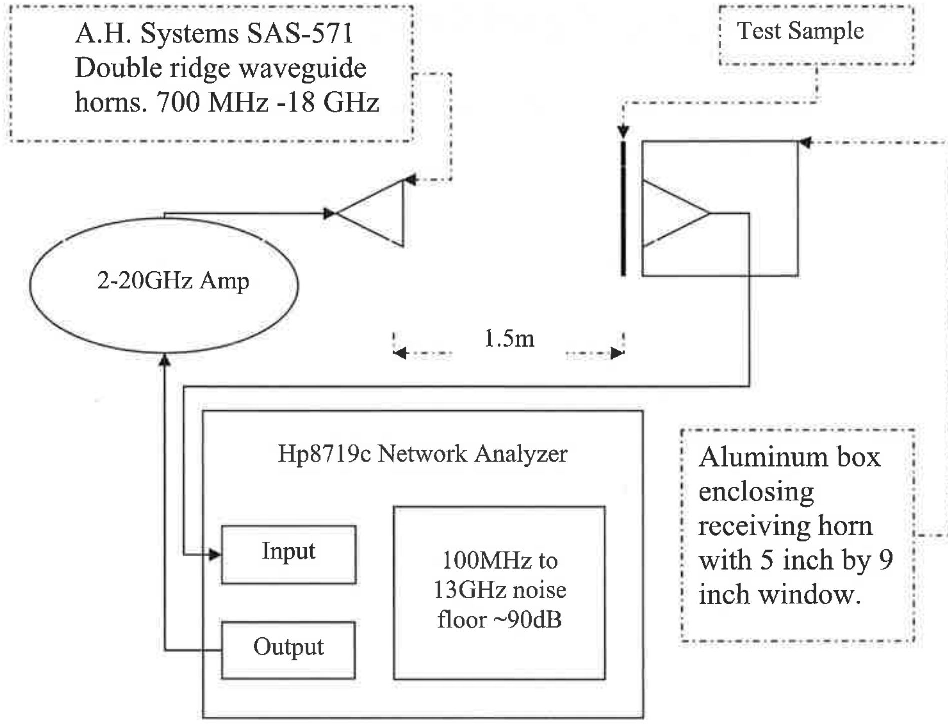

Fig. 1. The network analyzer used to measure S_{21} or S_{11}. The amplifier cannot be used when measuring reflection.

says that the transparent window material must be electrically connected to the conducting material in the walls of the enclosure.

Most manufacturers quote figures for the attenuation of electromagnetic radiation over some frequency range. Some give figures for electric fields and magnetic fields separately. Two main standards are used, the Mil-Std-285 (1956), which was canceled in 1997, and the IEEE Std-299-2006 that replaced it. The IEEE 2006 standard is extensive and relatively difficult to set up and manage. To make attenuation measurements in the microwave region from 300 MHz to 18 GHz a number of different setups are required. Such an elaborate procedure is no doubt required to have the most reliable absolute measurements. However, it is possible to make comparisons between different materials if, for each measurement, the same setup, same equipment, and same procedure are used.

As shown in Fig. 1, a microwave horn is mounted in a window in a closed aluminum box. This receiving horn is connected by coax to the HP network analyzer input port. The analyzer output port is connected to a microwave horn with or without a microwave amplifier.

Measurements were made by recording the power received by the horn in the aluminum box through a rectangular opening in the box wall. The network analyzer was operated in the transmission mode (S_{21}). Then the opening was covered with a sample of attenuating material, and the power transmitted by that material was recorded. Figure 2 shows the result using copper screen as the cover on the window. The attenuation caused by the screen is the

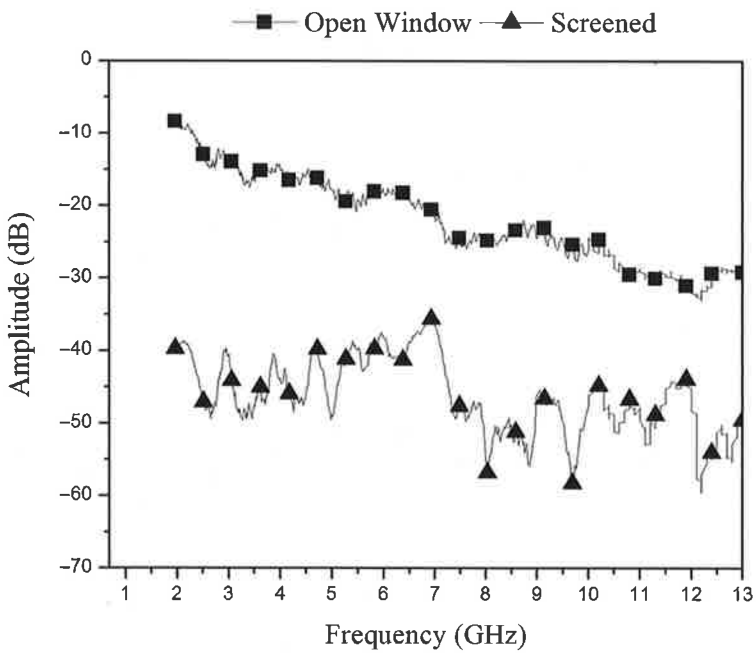

Fig. 2. "Open" refers to the power received when the window is uncovered. "Screened" refers to the power received when the 16 × 16 wire per inch copper screen was covering the window.

difference between the "Open" and the "Screen" responses. Depending on the frequency chosen, the attenuation is from 30 dB down to 20 dB. This agrees with the data published by one of the screen manufacturers.‡

2. Measurements

Many materials are presented for use as microwave shielding. An obvious candidate is any metal mesh, although the higher the high-frequency conductivity, the better the shielding. A number of conducting paints are available loaded with silver, copper, and graphite. Several manufacturers offer woven fabrics treated with compounds that render the fabric conducting. Glass with a conducting coating and transparent plastic with a conducting coating are manufactured for use as windows. Many of these materials can be purchased from a vendor, Less EMF, Inc., that does not advertise the name of the manufacturer.§ For the materials presented here, the Less EMF catalog number will be used to identify each one. It is useful to compare a woven metal mesh with some of the fabrics that have been treated with conducting coatings. It happens that our laboratory has a sample of a woven nickel mesh made in Russia from very fine nickel wire. The total surface resistance is

‡TWP, Inc., 2831 Tenth Street, Berkeley, CA 94710.

§Less EMF, Inc., 809 Madison Avenue, Albany, NY 12208.

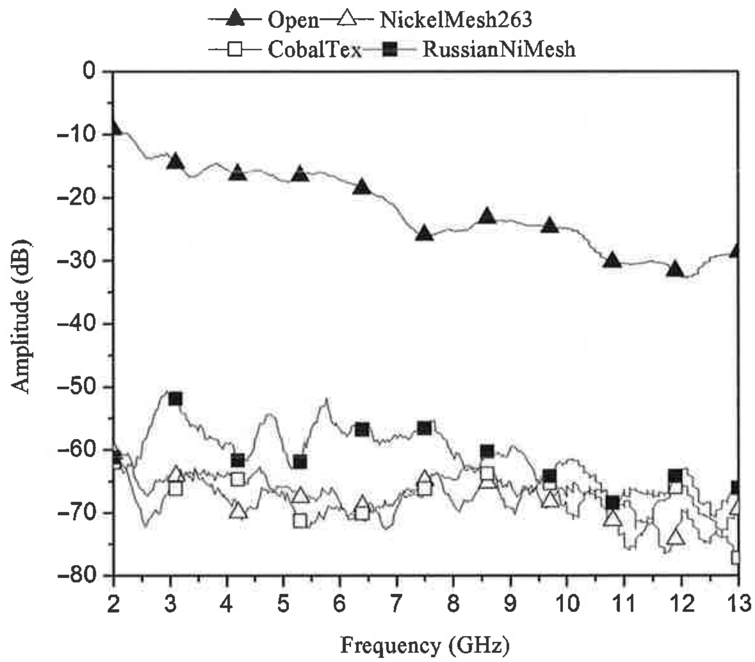

Fig. 3. The attenuation of each material is the difference between the curve labeled "Open" and the curve for that material. The materials attenuate from 50 to 40 dB, depending on the frequency.

0.5 ohm per square. This was compared with a polyester fabric, Nickel Mesh #263, described by the vendor as having a copper coat and then a nickel coating with a surface resistance of 0.1 ohm per square. A second comparison was made with a fabric, CobalTex #1271, described as a polyester taffeta weave with a surface resistance of 0.1 ohm per square. The polyester core is coated with nickel, then copper, then nickel, and finally a nickel–cobalt alloy. Figure 3 shows that the polyester fabrics coated with metals are slightly more effective at shielding than the Russian mesh made from fine nickel wire. Because these fabrics are such effective shields, and because they are light and flexible, a test was made to see how effective they might be in actual use. The Nickel Mesh #263 weighs 57 g/m^2. Another fabric, Zelt Fabric #1225, has a surface resistance of 0.03 ohm per square and a weight of 72 g/m^2. The vendor describes it as a tin and copper–coated plain-weave nylon fabric. It is so flexible that one could toss it over our aluminum box and cover the window in front of the receiving horn. Figure 4 shows the resulting attenuation for several arrangements of the fabric. "Zelt Tossed" means that the fabric was literally tossed onto the aluminum box so that it covered the open window. The curves show that the microwave attenuation did improve when the material was more carefully employed; however, it did not make a large difference, maybe 10 dB.

Several conducting paints were tested under various conditions. The idea was to pay attention to possible "real" situations. One real situation might be to coat a tent in which sensitive electronic equipment was to be used. One paint, CuPro-Cote #292, is a water-based paint loaded with fine copper granules. The vendor states that it can be brushed,

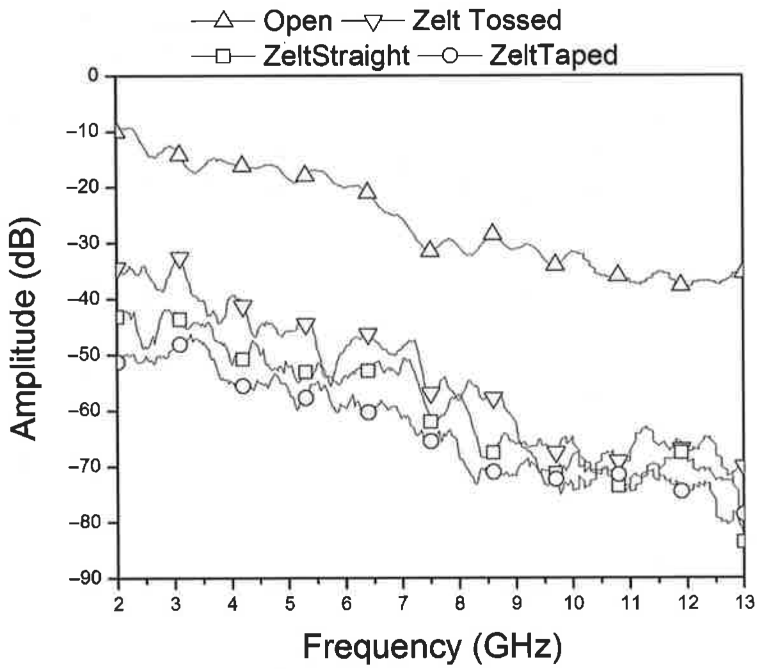

Fig. 4. The Zelt fabric was tossed onto the aluminum box for one measurement and then straightened so that it covered the box more closely. The curve labeled "Zelt Taped" is the measurement obtained when the fabric was taped to the box so that it fit closely.

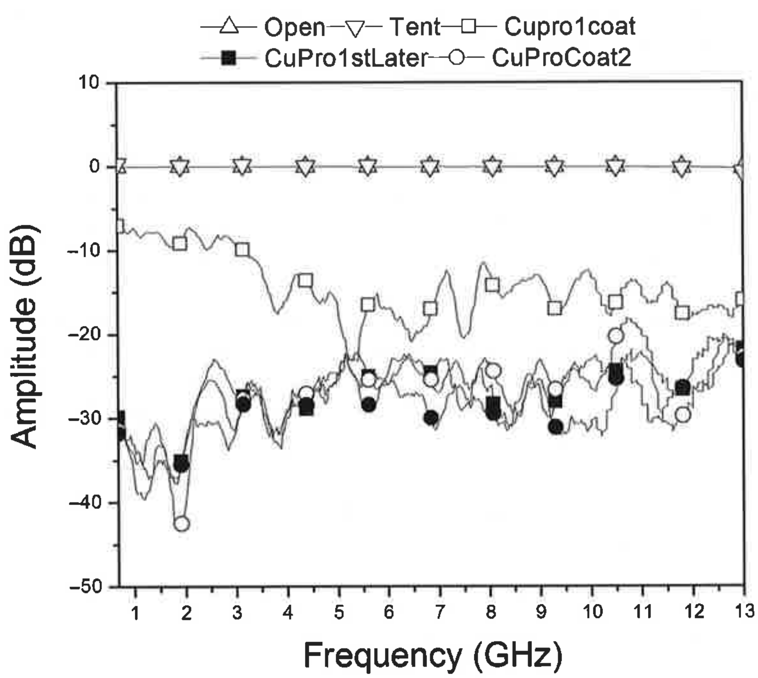

Fig. 5. CuPro-Cote conducting paint used for one coat and a second coat and the effects of drying of the paint.

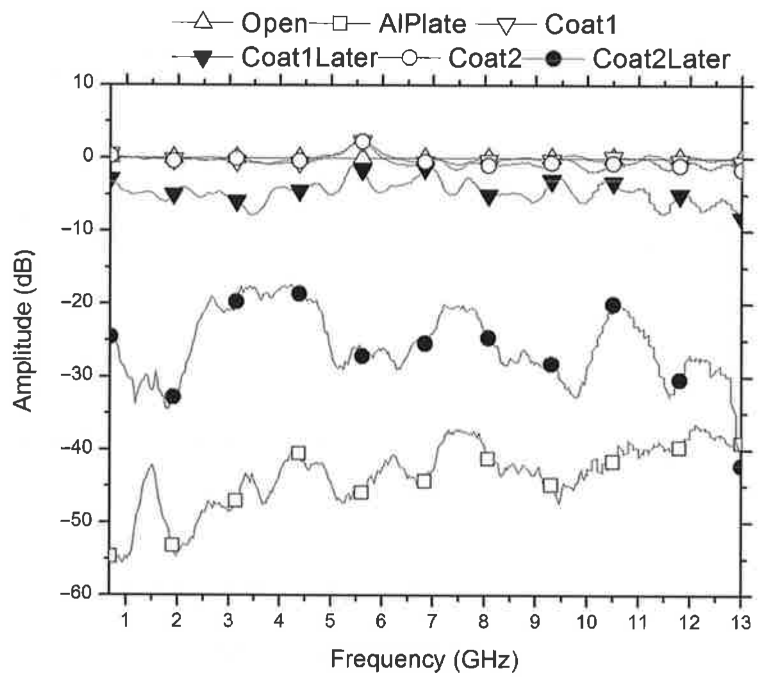

Fig. 6. Super Shield paint applied with an aerosol spray can onto tent material. Two coats produced between 20 and 30 dB after the solvent in the paint had dried. "Later" means the paint was allowed to dry for 10 min, which was long enough to produce maximum microwave attenuation. A measurement with the window covered with the aluminum plate produced between 40 and 50 dB.

roller applied, or sprayed but must be mixed constantly; even when sprayed the paint must be agitated to retain the copper grains in suspension. A sample of material was prepared by brushing the paint onto a piece of Army tent material cut to be larger than the window in the aluminum box holding the receiving horn. Figure 5 shows the result for several different situations. A new set of operating conditions was adopted for this test. The network analyzer was operated in the "Cal Thru" mode with the window in the aluminum box open. This removed the attenuation caused by the cables and the horns. In this case the "Open" curve becomes the zero of the attenuation. The window was first covered with the unpainted tent material to produce the "tent" curve, which shows zero attenuation. "CuPro1coat" means the tent material was painted and a curve taken as soon as possible. Ten minutes later, the curve "CuPro1stLater" was taken, and one can see that the drying enhanced the attenuation. A second coat, "CuProCoat2," did not make much difference, and allowing it to dry made no difference. Allowing a 24-h drying time also did not make any difference.

Another conducting paint was tested in the same way. Super Shield #285 is an acrylic base loaded with nickel flake in an aerosol can or as a liquid for painting. Figure 6 shows the results when two coats were sprayed onto army tent material. The system was run with the window uncovered in the "Cal Thru" mode to set the open window to 0 dB. Then one coat was sprayed and a measurement taken as soon as possible. There was no attenuation

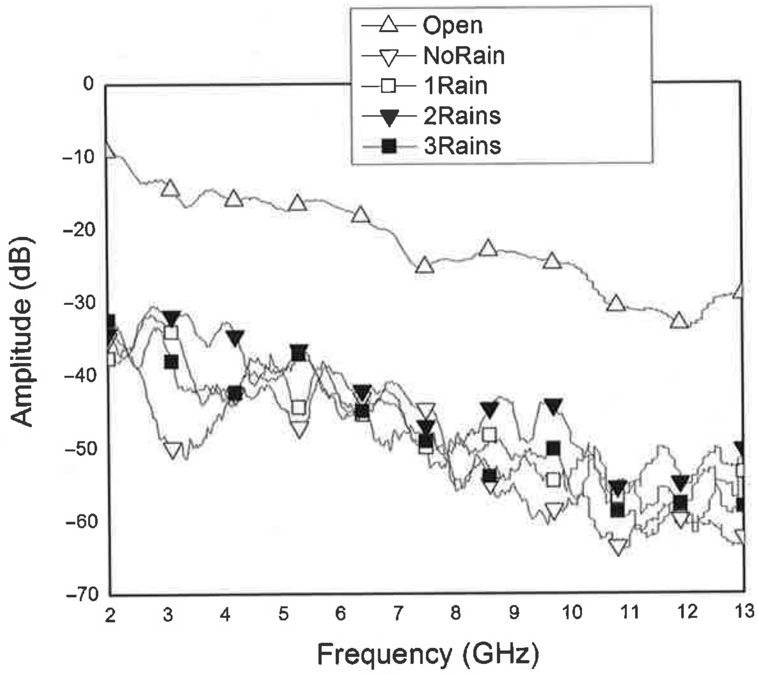

Fig. 7. Attenuation due to CuPro-Cote painted on tent material. The "Open" curve is the no attenuating material over the window test. Five days elapsed between the "1Rain" and "2Rain" tests and 3 days between the "2Rains" and "3Rains" test. Such delays seem not to matter because the data are repeatable. Little real difference is seen between the four curves with the painted tent material, implying that the paint did not wash away.

until 10 min later, when the material had dried and produced an attenuation of about 5 dB. A second coat was sprayed, and the attenuation deceased to zero until the solvents had dried. Then the attenuation increased to between 20 and 30 dB.

Anticipating that a tent might be treated with CuPro-Cote paint and then left in the rain, a test was made with a piece of tent material left out in the rain and then allowed to dry before it was taken to the laboratory. It was subjected to three times in the rain, although the second and third had to be with water from the garden hose because rain in our area is rare. Figure 7 shows that the rain had a small effect if any. Depending on the frequency, one can see up to a 12-dB difference, with the original coating having the higher attenuation. Our interpretation of the data is that they show no real difference due to the rain wetting and subsequent drying.

The performance of the CuPro-Cote paint was so good that a comparison was made with a lightweight conducting fabric. VeilShield #1270 is a mesh made of woven $^{1}/_{132}$-in. diameter polyester fibers coated with blackened copper with a surface resistance of 0.1 ohm per square. Figure 8 shows the comparison. The VeilShield attenuates slightly more than the paint, and this shows that it is not reasonable to use the paint instead of the lighter weight and easier-to-apply conducting fabric.

Two materials that could be used as windows in a building or tent were tested. Clear Shield #1210–24 is a polyester film sputter coated with silver and indium. About

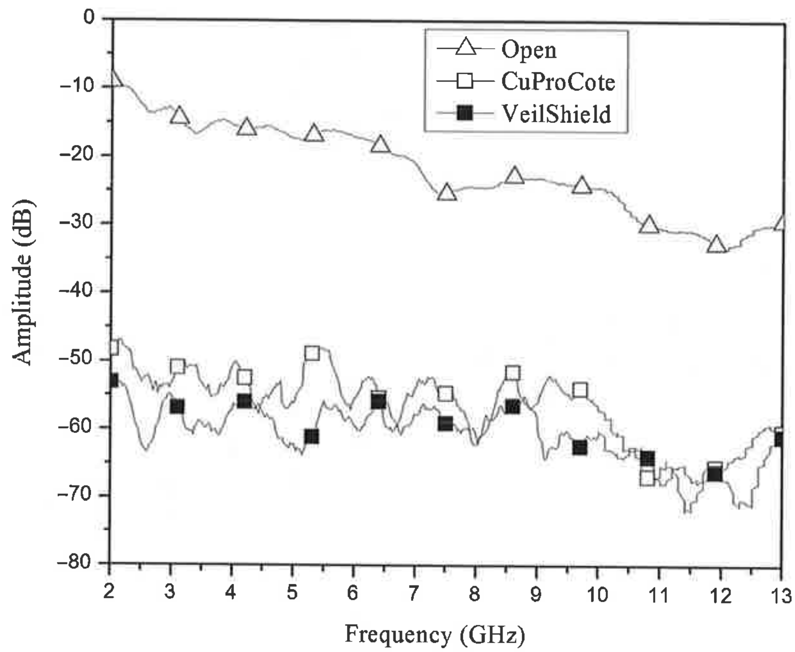

Fig. 8. Both the paint and the VeilShield fabric produce attenuation between 30 and 40 dB, and the difference is maybe 5 dB.

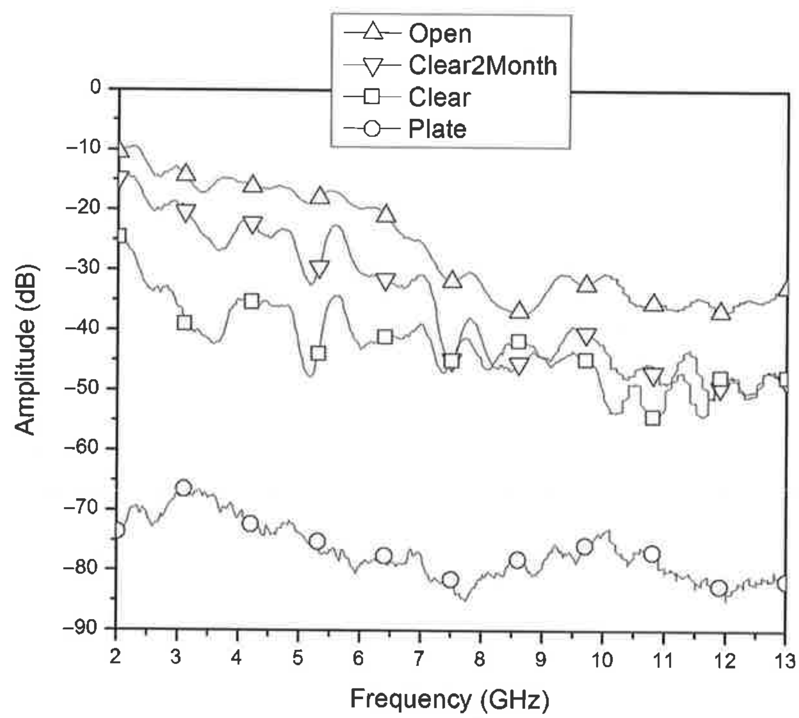

Fig. 9. Exposure to sun and rain for 2 months caused a decrease in performance of the ClearShield plastic of 10 dB at frequencies below 7 GHz but not much effect above 8 GHz.

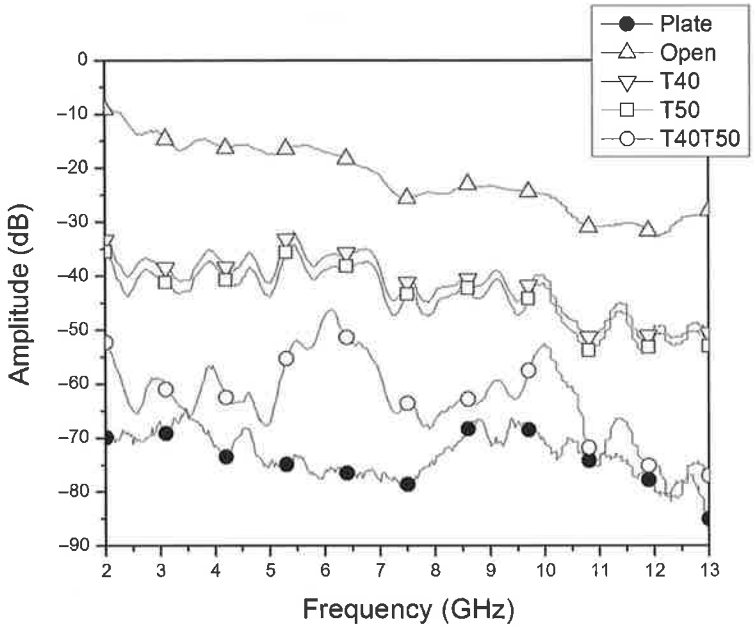

Fig. 10. Both the T40 and T50 glass produce about 20-dB attenuation at 7 GHz. When two panes are mounted on the frame (T40T50), the attenuations add. At some frequencies, the attenuation due to the two panes decreases. Notice the attenuation at 6 and 10 GHz.

80% transparent, it is 5 mils thick with a less than 27 ohm per square conductive coating on one side. The attenuation due to the as-received material was measured several times, always giving the same answer. Two samples were prepared on frames and placed on the second-floor roof of the laboratory. One sample was tested after exposure to rain and sun for 2 months and the second one after 4 months. The first sample was subjected to rain during the 2-month exposure, but the second sample experienced only sun during the last 2 months of exposure. See Fig. 9.

The second material suitable for a window is a conducting glass made by Pilkington. Figure 10 shows curves for single panes of T40 glass and T50 glass and then the two panes mounted on an aluminum frame as per the manufacturer's instructions. The frame holds the two panes apart by $^1/_2$ in. and allows both to have the conducting sides connected to the ground. The large decrease in attenuation at 6 and 10 GHz could be due to an interference effect dependent on the spacing between the two panes. Otherwise, it is clear that the glass produces a larger attenuation than the ClearShield plastic. The plastic has one advantage over the glass in that it is much lighter in weight. For a window in a temporary enclosure such as a tent, the plastic would be more practical.

Two other materials different from those reported above are one from Less Emf called Laminated Microwave Absorber #259 and ERS Fabric from a company named Stillpoints, Inc.[¶] Both are said to be absorbers due to graphite fibers incorporated into the flat

[¶]Stillpoints LLC, 2660 County Road D, Woodville, WI 54028.

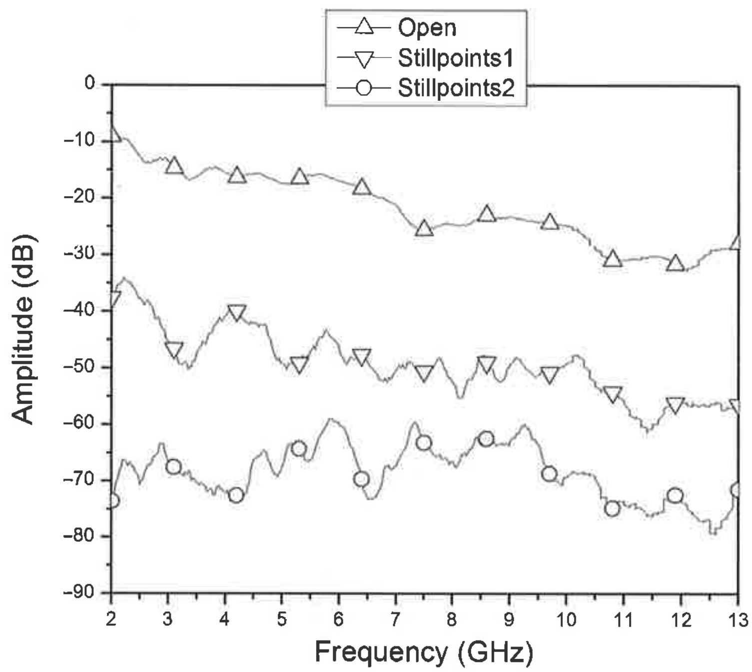

Fig. 11. A single layer of Stillpoints ERS Fabric produces about 30-dB attenuation, and a double layer produces about 20 dB more when covering the window in front of the receiving horn.

paper-like material. The Laminated Microwave absorber is encased in very thin clear plastic, so we cannot measure the resistance, and the ERS Fabric shows no conductivity on the surface. Figure 11 shows the results of using a single layer of the ERS Fabric and then a double layer on a frame placed over the window on our aluminum box. The ERS Fabric can be purchased in standard size 8.5 × 11 in. sheets or in a roll 35.5 in. wide by custom length. The Laminated Microwave Absorber can also be purchased in large rolls.

Because both the ERS Fabric and the Laminated Microwave Absorber are supposed to absorb microwave energy, a test was made of the absorption compared with a known good absorber, Echosorb, a commercially available graphite-loaded epoxy foam product in the form of pyramids of various sizes, depending on the frequency to be absorbed.[‖] The equipment setup was changed so that the transmitting horn was pointed at an 8 × 8 ft wall of Echosorb about 6 ft in front of the horn. A 5 × 5 ft aluminum plate was arranged to be placed in front of the Echosorb wall. The transmitting horn was placed on top of the aluminum box holding the receiving horn so that microwave power was directed at the wall and could be reflected back to the receiving horn. Figure 12 shows that for a measurement with just the Echosorb wall in front of the horns, little power is reflected. When the bare aluminum plate is placed in front of the Echosorb, more power is reflected,

‖ZAX Millimeter Wave Corporation, 555 West Allen Avenue, Unit 3, San Dimas, CA 91773.

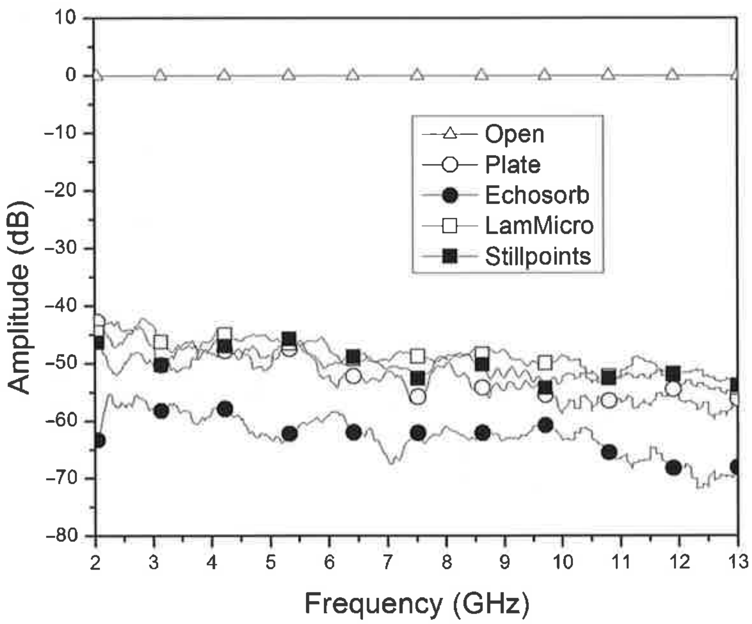

Fig. 12. The "Open" curve indicates that the network analyzer was run in the Cal Thru mode, which makes the power received at the uncovered open window 0 dB. "Echosorb" means that there was nothing in front of the Echosorb wall. "Plate" means the large aluminum plate was in front of the Echosorb wall. "LamMicro" and "Stillpoints" are the curves showing the power reflected when those materials covered the aluminum plate.

as expected. When the aluminum plate was covered with a sheet of Stillpoints ERS fabric, and when it was covered with a sheet of Laminated Microwave Absorber, as much power was reflected as if those materials were not there. In other words, they reflect as well as the aluminum plate. As shown in Fig. 11, the Stillpoints ERS fabric is a good shield for microwaves and our test on Laminated Microwave Absorber shows that it is also a good shield. However, the data in Fig. 12 show that neither of them is a good absorber of microwaves.

The conducting fabrics, which are lightweight and produce as much microwave attenuation as metal meshes, seem to be the easiest to employ on a temporary basis. Measurements were made, using the same procedure and setup as above, on all the fabrics currently available to us. These include the CobalTex and the NiMesh #263 already presented in Fig. 3. Additional fabrics tested include the NaturaShield #1225, a woven cotton material with a conducting core; ShieldIt Super #1220, a woven nylon plated with nickel and then copper; and Stretchy #251, a nylon–Dorlastan woven fabric coated with silver. We also tested a very thin woven stainless-steel mesh found in our laboratory that we labeled "flimsey." Figure 13 shows the curves for each of these materials compared with the aluminum plate covering the window, which should represent zero power intercepted by the receiving horn. These data were taken with the network analyzer operated in the Cal Thru mode, which makes the open window produce a power plot at 0 dB.

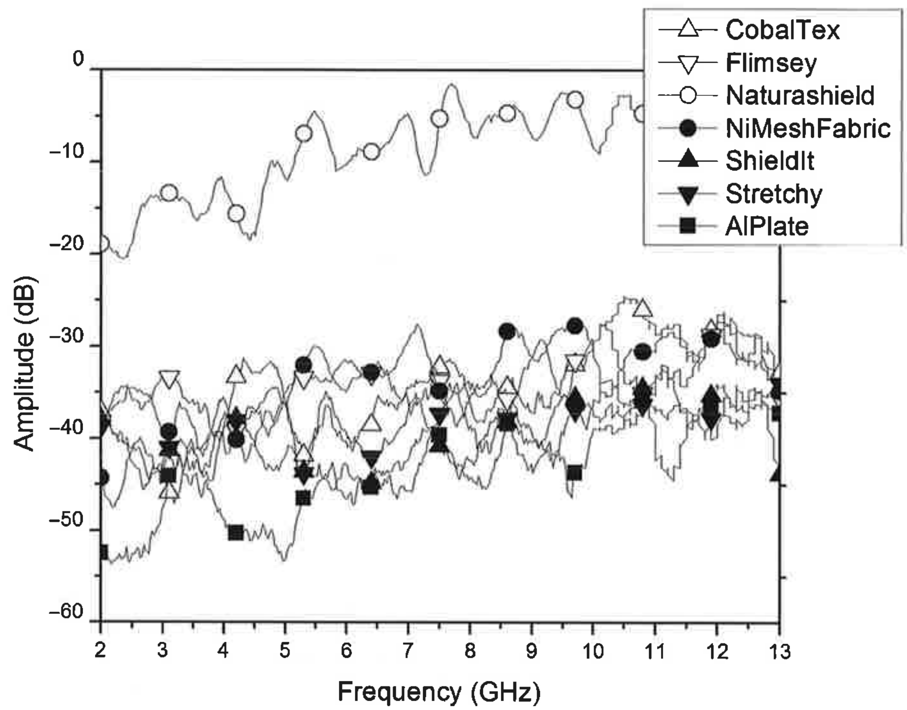

Fig. 13. Six materials plotted on the same figure for comparison. The NaturaShield is a very poor microwave shield. The other materials are all reasonably good, ranging from 35 to 45 dB at 2 GHz to 30 to 40 dB at 13 GHz. This figure is not meant to be used to evaluate an individual material but rather to show that there is not much difference between these materials.

3. Conclusions

Considering the materials reported on here, a recommendation can be made for shielding of sensitive electronic equipment deployed on a temporary basis. The conducting paints can be applied to tent material and make effective shields. However, the paint is heavy to transport and adds weight to the tent material. In addition, the paints make the tent material stiff and may crack if the tent is taken down and rolled up.

Metal meshes and screens are effective shields but are heavy and difficult to deploy on a temporary basis. Screen is particularly difficult to set up and take down. Some of the lighter weight meshes are easier to handle but still require some structure that will support a material fastened somehow to the structure with, for example, tape.

A temporary structure, such as a tent, may require a window. The glass with conductive coating is too heavy to transport and requires a strong support structure. It is suitable for a permanent structure.

The conducting fabrics are lightweight, excellent microwave shields, and easy to deploy. It is also easy to remove them for transportation to another site. As an example, two men could cover a tent, even a large one, with large pieces of the "Zelt" material. They can be fastened with clothespins or other types of clamps. If the overlap between pieces is large, an electrical connection is not needed. The clear plastic with conductive coating is good enough for a window in a tent and is lightweight and can be fixed in place with conducting tape.

Appendix A: Average Attenuation in Decibels Caused by Each Material

Material	Average	Stand Dev	Comment
Aluminum plate	45	2.1	
ClearShield	21	0.6	
ClearShield double	35	0.7	
ClearShield—roof 2 months	19	9.6	
ClearShield—roof 4 months	8	0.0	One trial
CobalTex	41	5.3	
Cu Screen 16 × 16	22	2.1	
Cu Screen 16 × 16 (2 layers)	43	0.0	On frame
CuPro-Cote	32	5.9	
Flectron	39	1.8	
Flectron not N #A1212	46	2.1	
Gold Cu mesh	48	15.4	
HP Silver mesh #1222	31	3.8	
Laminated Microwave Absorber #W259N	37	2.1	
NaturaShield #1255	8	0.1	
Ni mesh 263	40	6.2	
Red Cu mesh	34	4.1	
Russian gold mesh	37	8.4	
Russian nickel mesh	36	2.5	
Shield It Super #1220	39	1.0	Wet = 38
Silver flimsey	38	2.8	
Silver lining	33	5.4	
Solar curtain	25	2.8	
Solar curtain	31	4.2	Two layers
Stainless mesh #272	8	1.5	
Still Points	28	1.5	
Stretchy 251	37	4.4	
Super Shield 1 coat	8	0.0	
Super Shield 2 coats	24	4.0	
Super Shield 3 coats	26	1.7	
Tempest 40 glass	20	0.0	
Tempest 50 glass	22	1.4	
T40+T50	40	0.0	One trial
Laminate glass	40	0.0	One trial
VeilShield #1270	35	4.2	
Venetian blinds	0	0.0	Open or closed
Voskhod	41	2.8	
Y-Shield 1 coat	10	0.0	One trial
Y-Shield 1 coat, 10 min later	10	0.0	One trial
Y-Shield 2nd coat	20	0.0	One trial
Y-Shield 2nd coat, 10 min later	25	0.0	One trial
Y-Shield 2nd coat, 24 h later	28	0.0	One trial
Zelt Fabric #1225	43	7.3	

Appendix B: Materials Studied**

Conducting Paints

CuPro-Cote #Y292 Water-based paint loaded with fine copper granules. Can be brushed, rollered, or sprayed, but must be mixed constantly. When sprayed the paint must be agitated to retain the copper grains in suspension. Will cover 670 ft^2/gal/1 mil thickness. Dealer quotes 75 dB from 1 MHz to 1 GHz. A single coat on army tent material produces an attenuation of 30 dB at 2 GHz down to 20 dB at 13 GHz. Measured 0.8 ohm/square.

Super Shield #Y285 Acrylic base loaded with nickel flake in an aerosol can or as a liquid for painting. Dealer quotes 40–50 dB from 5 MHz to 1.8 GHz and 0.7 ohm/square. When sprayed on denim or tent material, it showed 10–20 dB from 2 GHz to 13 GHz for one coat but 20–30 dB over the same frequency range for two coats. Measured 2.4 ohm/square.

Y-Shield #Y290 Water-based paint loaded with holohedral (meaning complete symmetry, or no preferred direction) carbon. Dealer quotes "typical 40 dB attenuation" and a surface conductivity of 10 ohm/square. When painted on denim or tent material, it showed 20–30 dB over 2–13 GHz. Measured 4.2 ohm/square.

Silver Lining #V288 from Block EMF, 2335 Camino Vida Roble Building B, Carlsbad, CA 92009. Acrylic base loaded with silver particles. Covers 120 ft^2/q/2 mil thickness with less than 0.4 ohm/square. Dealer quotes 80 dB over 1 MHz–10 GHz. When painted on denim or tent material, it showed 35-dB attenuation from 2 to 13 GHz. Measured 0.4 ohm/square.

RF Shielding Fabrics

FlecTron #Y1212 Nylon ripstop fabric plated with copper. Surface resistance of 0.1 ohm/square and 2.1 oz/yd^2 weight with a thickness of 0.006 in. Cannot be laundered and will tarnish after exposure to liquids or skin oil. Dealer quotes about 70-dB attenuation between 10 MHz and 20 GHz. Measured attenuation was about 40 dB from 2 to 13 GHz.

High-Performance Silver Mesh Fabric #Y1222 Nylon mesh fabric—supposedly coated with silver—with <0.5 ohm/square and weight 40 g/m^2. Dealer quotes 60-dB attenuation from 30 MHz to 3 GHz. Measured about 36 dB over the range of 2–13 GHz.

Zelt Fabric #Y1225 Tin and copper–coated plain-weave nylon fabric with 0.03 ohm/square and a weight of 72 g/m^2. Dealer quotes 80-dB attenuation from 30 MHz to 1 GHz. Measured about 43 dB over 2–13 GHz.

NaturaShield #Y1255 Woven fiber with some conducting material inside of a cotton outer coating. 1×10^9 ohms/square with a weight of 125 g/m^2. Dealer quotes 20- to 35-dB attenuation from 100 MHz to 2.2 GHz. Measured 15–5 dB from 2 to 13 GHz. Very soft and looks like cotton but not a good microwave shielding material.

**Catalog numbers, when given, are from Less EMF, Inc.

ShieldIt Super #Y1220 A plain-weave nylon fabric plated with nickel and copper and then coated on one side with conductive acrylic having 0.1 ohm/square surface resistance. That side is coated with a polyethylene barrier and a hot melt adhesive so it may be ironed onto cotton, wood, glass, or paper. Dealer quotes attenuation of 80 dB at 100 MHz and 100 dB at 1 GHz. Measured 60–30 dB over 2–13 GHz.

VeilShield #Y1270 Mesh made of woven $^{1}/_{132}$-in. polyester fibers coated with blackened copper. Has 70% light transmission and 0.1 ohm/square surface resistance. Dealer quotes <40-dB attenuation from 10 MHz to 1 GHz. Measured about 35 dB from 2 to 13 GHz.

CobalTex #Y1271 Flexible, polyester taffeta weave with metal coating. The polyester core is coated with nickel, then copper, then nickel, and finally a nickel–cobalt alloy. The surface resistance is less than 0.1 ohm/square, and the weight is 100 g/m^2. The dealer quotes 65- to 80-dB attenuation over 30 MHz to 1 GHz. Measured about 40 dB over the range 2–13 GHz.

Nickel Mesh Fabric #263 Polyester fabric mesh coated with copper, then nickel. Surface resistance 0.1 ohm/square and a weight of 2 oz/yd^2. Dealer quotes "60 dB to 1 GHz with good performance to 18+ GHz." Measured about 40 dB over the range 2–13 GHz.

Voskhod (No manufacturer information) Woven polymer fabric treated with a metal compound by a process patented by a Russian company that has been out of business for some years. Measured from about 40-dB attenuation over the range from 2 to 13 GHz.

Stretchy #251 Medical grade silver–plated 92% nylon, 8% Dorlastan fabric stretches in both directions. Surface resistance less than 1 ohm/square unstretched. Measured 36 dB over 2–13 GHz.

Metal Meshes

Stainless-Steel Mesh #Y272 100% surgical stainless steel knitted into a flexible fabric. Dealer quotes 26 dB at 800 MHz and 15 dB at 1.9 GHz. Measured 2 dB at 2 GHz and 15 dB at 13 GHz. Weighs 190 g/ m^2. Not suitable for microwave shielding. Measured 8.2 ohms/square.

Russian Gold Mesh (No supplier information, obtained from unknown source) A woven metal mesh with high conductivity but unknown material. Light tan in color. Measures 50- to 30-dB attenuation from 2 to 13 GHz. Measured 0.3 ohm/square.

Russian Nickel Mesh (No supplier information) Woven nickel wire with a black color. Good conductor. Measured 50–35 dB over the range from 2 to 13 GHz. Measured 0.5 ohm/square.

Copper Screen 16 × 16 mesh (Standard copper screen) Measured 30–20-dB attenuation over the range of 2–13 GHz. A double layer shows about 40 dB over the same range. Measured 0.2 ohm/square.

Red Copper Screen (No supplier information; measured 40 × 40 mesh) Measured about 40-dB attenuation over the range 2–13 GHz. Measured 0.3 ohm/square.

Gold Copper Screen (No supplier information; measured 140 × 140 mesh) Measured 60–50 dB over the range of 2–13 GHz. Measured 0.3 ohm/square.

Silver Flimsy (No supplier information; measured using a microscope and found to be 140 × 140 mesh) Conductivity measurement shows that this is stainless steel. It still produces 45–35-dB attenuation over 2–13 GHz. Measured 20 ohms/square.

RF Absorbers

Laminated Microwave Absorber #Y259 Carbon sheet coated on both sides with some plastic. Dealer quotes ~3 ohms/square, which we cannot measure because of the plastic coating. Dealer does not quote an attenuation. Measured 40-dB attenuation from 2 to 13 GHz. Did measure the absorption.

Stillpoints ERS Fabric from Stillpoints, 2660 County Road D, Woodville, WI 54028 Carbon fibers in paper. No specs from company. Measured 35–20-dB attenuation over the range of 2–13 GHz. Did measure in absorption. Measured open (∞ ohm/square).

Aluminum Coating on Plastic

Solar Curtain #Y226 Nearly opaque due to an aluminum coating on a thin plastic. Dealer quotes "well over 20 dB reduction in common radiofrequency and microwave radiation." Measured 20–30-dB attenuation over the range of 2–13 GHz.

ClearShield #Y1210-24 Polyester film sputter coated with silver and indium. About 80% transparent, five mils thick with less than 27 ohms/square conductive coating on one side. Measured 20-dB attenuation over the 2–13-GHz range. Measured 33 ohms/square. Did not do well exposed to sunlight for 4 months.

Glass

Pilkington Architectural has developed and patented a range of security glasses called DATASTOP—both laminates and sealed units—specifically designed to reduce the transmission of EMI/RF. We tested T40, T50, and a laminated two-pane assembly. Measured 45–50-dB attenuation over the 2–13-GHz range. Supplied by Tempest Security Systems, Inc., P.O. Box 584, Troy, OH 45373.

Miscellaneous

Venetian blind with aluminum slats painted white. This was a standard blind purchased at the local hardware store. We tested the blind open, closed up, and closed down. No attenuation was measured in any configuration.

Ni/Cu/Co fabric tape, which has high conductivity #A225. High-flexibility fabric tape with conductive adhesive. Nickel, copper, and cobalt–coated nylon ripstop fabric (with antifray) offers excellent RF shielding properties (70 dB at 1 MHz, 100 dB at 1 GHz) and electrical conductivity (surface resistance of less than 0.1 ohm/square). It was used to seal gaps, seams, and edges of shielding fabrics, paints, or plastics. It can be used to create conductive pathways on surfaces or add shielding to cables and flexible conduits. Cuts easily with scissors. Extremely corrosion and tear resistant, –10 to 80°C. Only 0.005 in. thick, 1 in. wide, 25 ft per roll with paper release liner. Once applied to a surface, it cannot be reused because part of the conductive adhesive comes off on the surface when it is removed.

Reference

[1]Hemming, L. H., *Architectural Electromagnetic Shielding Handbook: A Design and Specification Guide*, IEEE Hoboken, NJ (2000).

The Authors

Dr. Lynn L. Hatfield received the B.S. degree in physics from Arkansas Polytechnic College in 1960 and the M.S. and Ph.D. degrees in physics from the University of Arkansas in 1964 and 1966, respectively. He was an Instructor of Physics at Little Rock University from 1960 to 1962. After receiving the Ph.D. degree, he spent 2 years as a Research Associate at Rice University and then joined the Physics Department at Texas Tech University, Lubbock, where he was Professor of Physics and Chairman of the department. He retired from the University in July 2007. He is now a Senior Research Associate in the Center for Pulsed Power and Power Electronics. His research has included measurements of atomic spectra and structure, optical pumping, polarized particle beams, insulator flashover, bulk breakdown, HV insulator aging, and attenuation of microwave radiation.

Mr. Bryan Schilder's father received an M.S. in mechanical engineering from SMU and was the reason Bryan chose engineering as his degree choice. He is an Eagle Scout. He graduated with a degree in mechanical engineering from Texas Tech University in 2009 and is working as a Field Engineer for Baker Hughes in Odessa, Texas.