Date: 10-9-14

Subject: Electromagnetic shielding and low-e glass

Recently we have been contacted about the effect if any of low-e glass on blocking radio and cell phone transmissions. There have been studies and investigations on the subject going all the way back to the mid 1950's even prior to the commercialization process of applying low-e coatings to flat glass.

You rarely hear about it but the simple fact is low-e coatings in windows can attenuate electromagnetic wavelengths. In the wavelengths that cellular and Wi-Fi operate; unless the whole building is designed with all materials to have electromagnetic attenuation, it is unlikely that low-e glass will have an adverse effect on the operation of these devices. In some instances buildings with a full curtain wall with a large quantity of low-e glass could have some effect and should be reviewed by the building designer. Laminated glass in conjunction with low-e coatings affects transmissions more than non-laminated.

There are design considerations that can overcome this issue such as antennae number and location on the building. There are consultants that can help architects ensure good reception and transmission is considered in the building design.

Following are two white papers done on the subject, one by Cardinal IG and one by PPG as it relates to this phenomenon.

Objective

This report concerns the electromagnetic shielding effectiveness of Cardinal CG's low emissivity window coatings. The portion of spectrum of interest is the ultra high frequency band (UHF) which carries signals from cell phones, cordless phones, some broadcast television, GPS, computer wireless, satellite radio, and public 2-way radio (police, fire, ambulance).

Test Methods and Description

Samples of E272 and E366 (both produced on Coater 1 at Spring Green) were sent to an outside lab (Garwood Labs, Inc) specializing in electromagnetic testing. The lab measured the shielding effectiveness (SE) of the coatings from 500 MHz to 5 GHz (roughly corresponding to the UHF band). SE is typically measured in decibels; for clarity all decibel measurements in this report have been converted to percent transmittance (%T). See the appendix for the equation relating SE and %T.

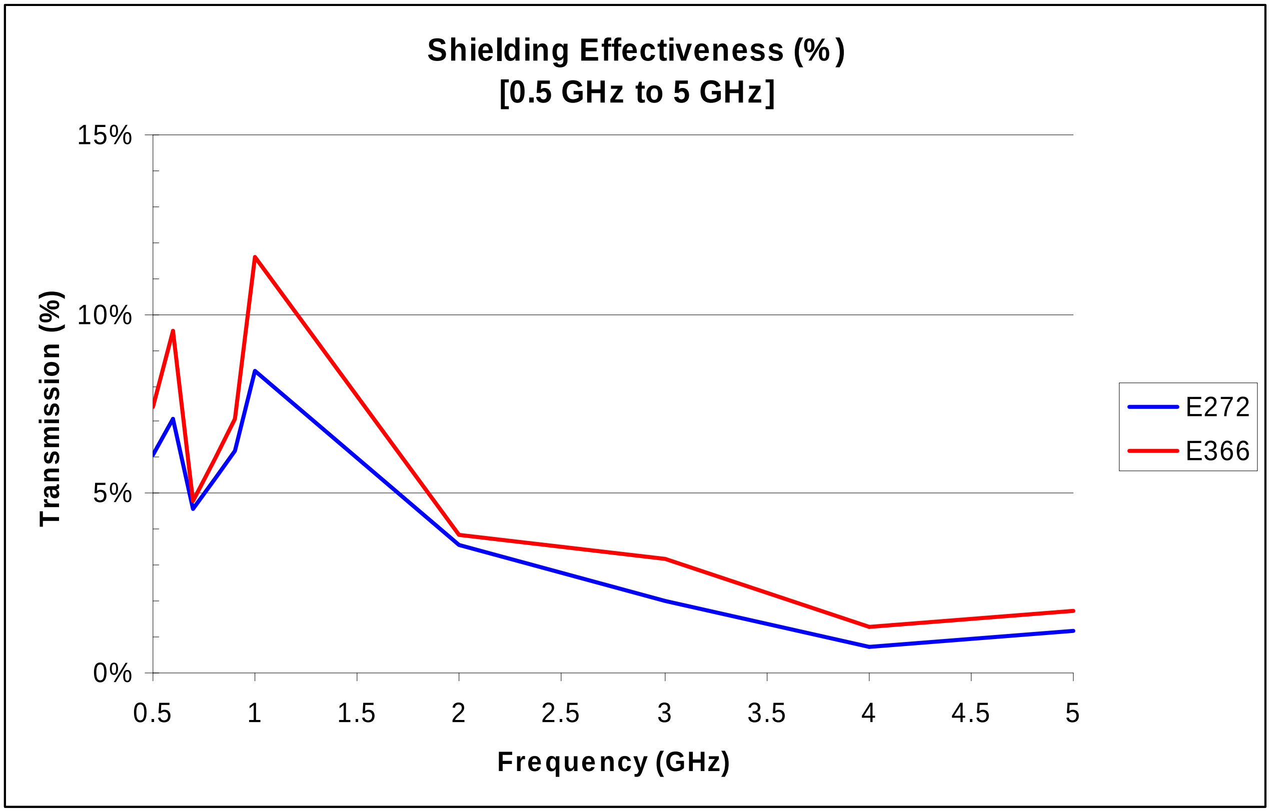
Results & Conclusions

Research yielded two journal articles pertaining to the shielding effectiveness (SE) of low emissivity coatings. The first article claimed an average %T of 5.85% (for the frequency range of 1 to 2 GHz) for a commercially available single silver coating[1]. The second article claimed an average %T of 1.07% (from 30 kHz to 1.2 GHz) for a double silver coating designed for high shielding effectiveness[2].

Measurements on the Cardinal CG coatings are found below.

% Transmission 500 MHz to 5 GHz

	Transmission (%)	
Frequency (GHz)	**E272**	**E366**
0.5	6.1%	7.4%
0.6	7.1%	9.6%
0.7	4.6%	4.8%
0.8	5.4%	6.0%
0.9	6.2%	7.1%
1.0	8.4%	11.6%
2.0	3.6%	3.9%
3.0	2.0%	3.2%
4.4	0.7%	1.3%
5.0	1.2%	1.7%
Average	**4.5%**	**5.7%**



The measurements on Cardinal CG samples agree with the literature numbers quite well, although the numbers are not directly comparable because the measurements cover different portions of the spectrum. The fact that the E272 sample shields slightly more effectively then the E366 sample is a little surprising and no reason can be offered at this time.

[1] M. Gustafsson, A. Karlsson, A.P.P. Rebelo, B Widenberg *"Design of Frequency Selective Windows for Improved Indoor Outdoor Communication"* IEEE Transactions on Antennas and Propagation, Vol. 54, No. 6, June 2006 pp. 1897-1900.

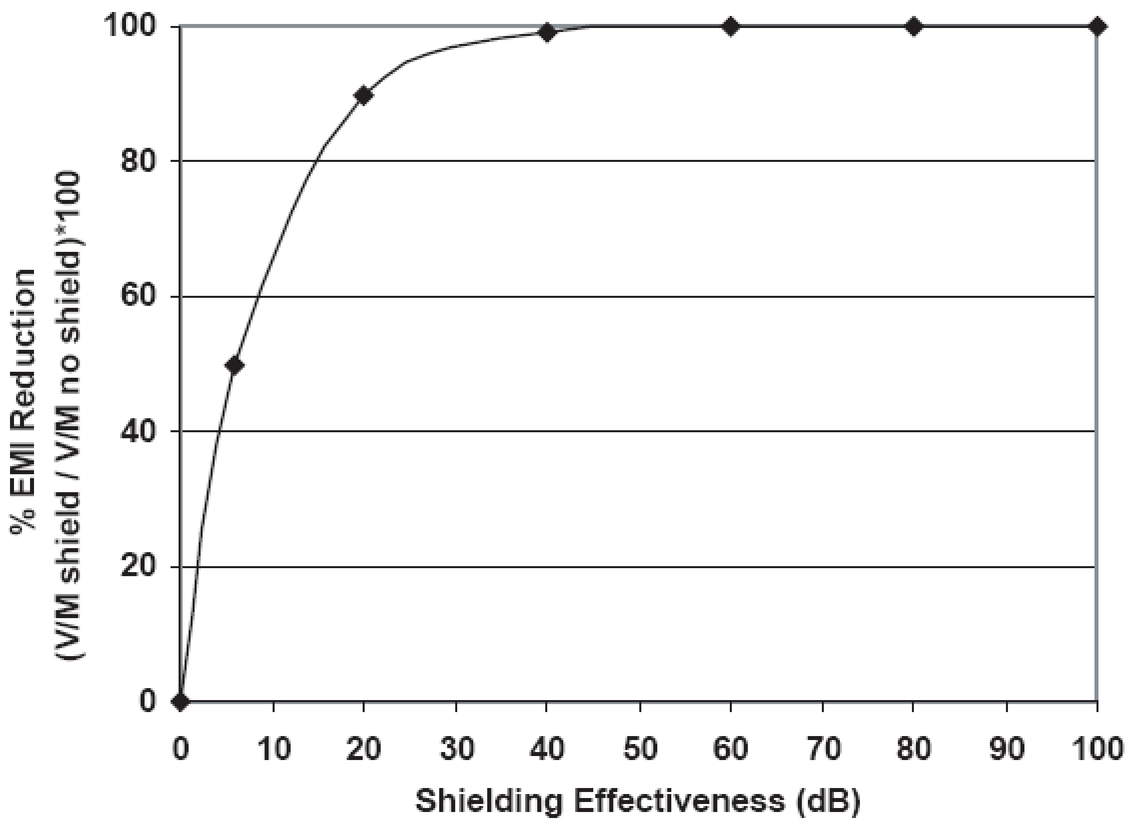
[2] F. Sarto, M.S. Sarto, M.C. Larciprete, and C. Sibilia *"Transparent Films for Electromagnetic Shielding of Plastics"* Rev.Adv.Mater.Sci. 5 (2003) 329-336.

Appendix

SE = log(E_O/E_I)

%T = E_I/E_O

SE = Shielding Effectiveness (dB)
E_O = Field strength without shielding material
E_I = Field strength with shielding material in place



Glass Technology
SINCE 1883

Radio and Microwave Frequency Attenuation in Glass

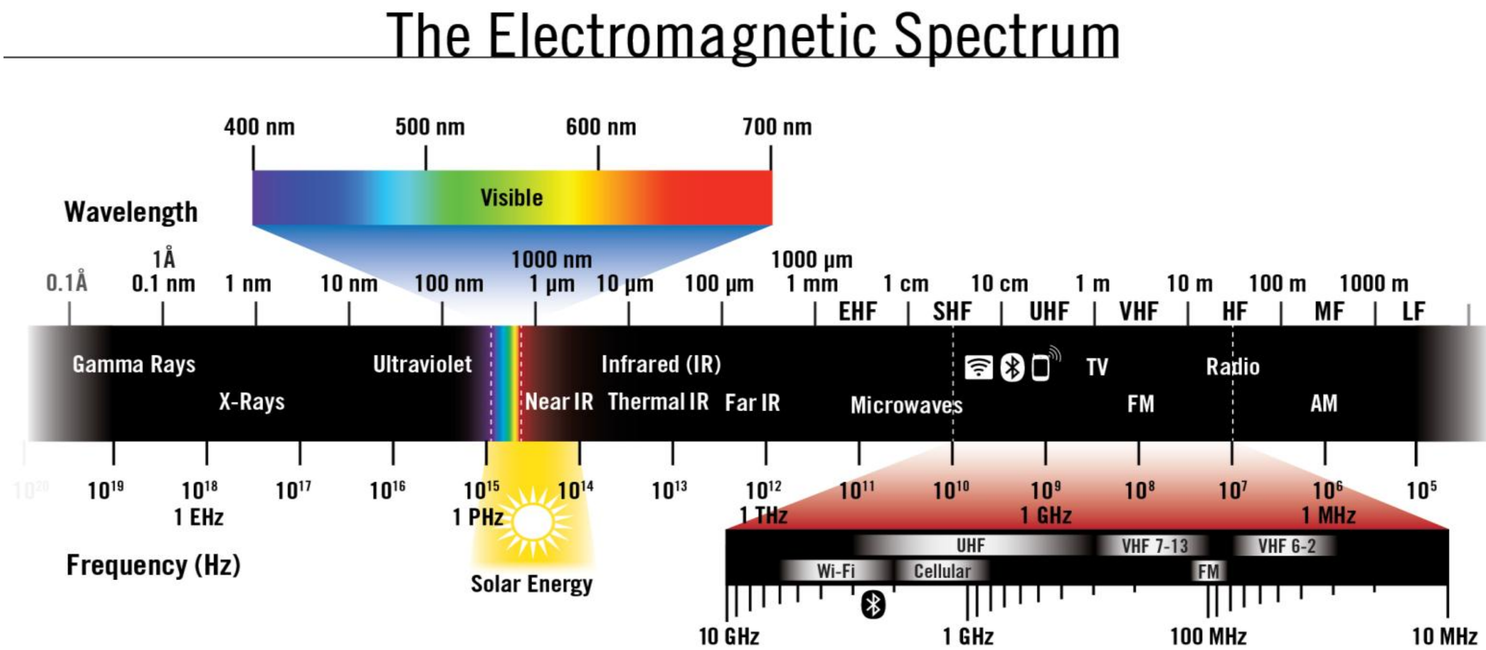


Figure 1

In today's post 9/11 world, safety and security take high priority in building design and construction. In addition to physical protection, information security is also a significant consideration in today's architectural designs. The materials used for construction of architectural buildings can influence information security via electromagnetic signal attenuation. This document discusses signal attenuation in glass, particularly in the radio and microwave frequency ranges.

In some situations designers want as little signal attenuation as possible while in other cases signal blocking is necessary such as in secure government installations. At the same time architects and their clients want to maintain the styling trends of modern day architecture while achieving the desired blocking the transmission of various types of airwave information communications. Since glass is a major material contributing to building performance and aesthetics, what can be done to help achieve the continued use of vast areas of glass in architectural design yet provide the desired security of information?

The answer is to use transparent, conductive, metal-based coatings on the glass. Most high efficiency, IR reflecting, low-E glass coatings have one or more thin, continuous layers of metallic silver. Silver, like other highly-conductive metals, is an effective blocker of electromagnetic waves. The reduction of radio frequency signal intensity after passing through a material is called attenuation, which is usually expressed in units called decibels (dBs). A decibel is a logarithmic unit, so as examples, a 10 dB attenuation is a reduction by a factor of 10, a 20 dB attenuation is a reduction by a factor of 100, and a 40 dB attenuation is a reduction by a factor of 10,000. Testing of glass samples has shown that more or thicker silver layers mean more attenuation of electromagnetic waves. Currently, the maximum number of silver layers commercially available in any given architectural, low-E product is three. Solarban® 70XL Solar Control Low-E Glass is PPG's triple silver coated glass with three distinct and separate silver layers in one coating. PPG's double silver product is named Solarban® 60. Vision glazing construction incorporating two or more Solarban® 70XL triple silver coated surfaces will permit a high level of RF attenuation while providing excellent energy performance while still maintaining appropriate visible light transmittance (VLT).

Figure 1 above shows the electromagnetic spectrum. It also identifies the regions of that spectrum that are utilized by RF devices such as Wi-Fi, Bluetooth, cellular phones, radio and TV. The chart in Figure 2 below represents PPG RF attenuation testing results of several samples including PPG coated glass products through the range of 800 to 3000 MHz which covers the communication frequencies of many of the common electronic devices just mentioned. These measurements indicate that a glass laminate with one embedded, triple silver, low-E coating blocks approximately 40 dBs, while two embedded, triple silver coatings provide attenuation of approximately 54 dBs. That is nearly as much as a 1/8" thick, solid aluminum plate can block! However, a building using curtain wall construction containing two lites of Solarban® 70XL coated glass would not necessarily be impervious to these radio frequencies. The data provided in Figure 2 for PPG glass products represents the glass performance only and does not take into account the framing or wall system. A portion of the entire curtain wall assembly or a representative portion of the building envelope must be considered in order to determine the overall level of signal attenuation. The glass constructions tested to develop the data shown in Figure 2 are laminates which can be used to provide physical security in addition to signal attenuation. For designs not requiring laminated glass, similar signal attenuation can be achieved with the same glass products used in a non-laminated glass construction.

Radio and Microwave Frequency Attenuation in Glass

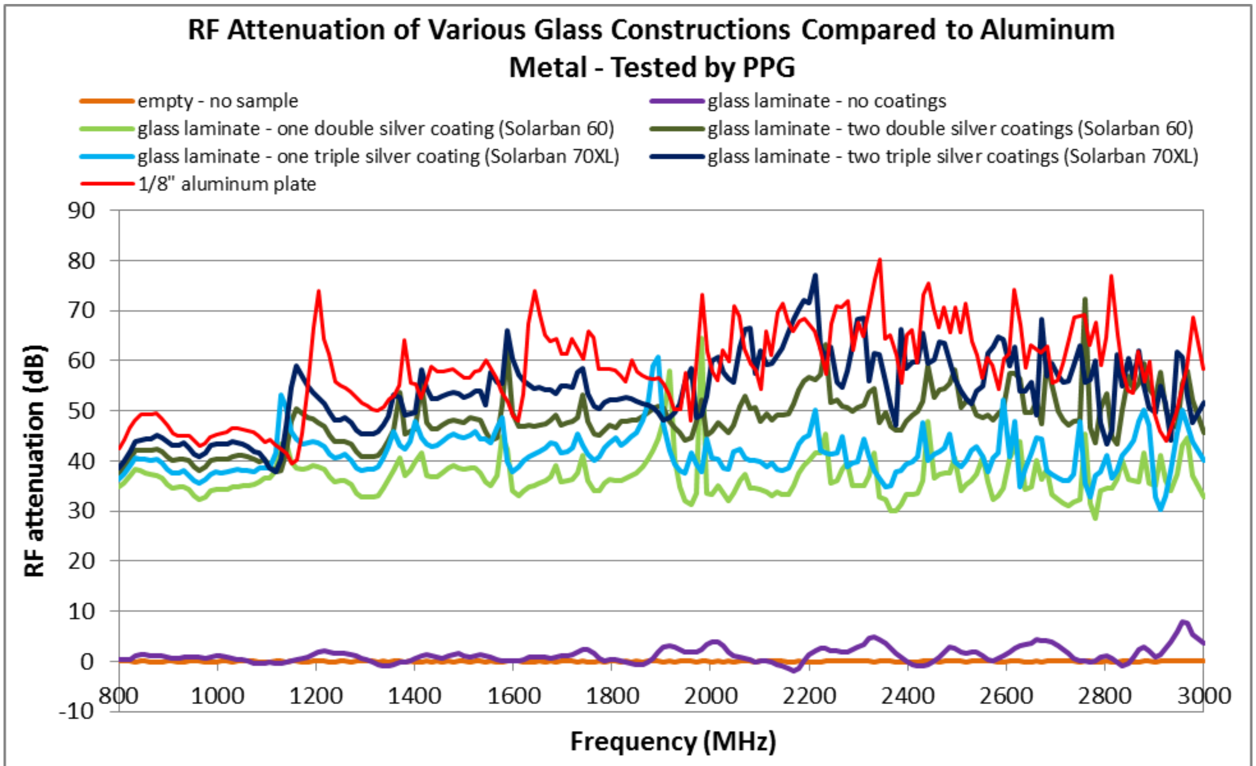


Figure 2

Depending on the designer's goal, there are many other aspects of building construction that can affect RF transmission both positively and negatively. Most building materials that do not incorporate metallic layers such as masonry materials (including concrete, blocks and bricks), petroleum-based roofing materials, wood, non-foil insulation, etc. will allow passage of radio waves with minimal attenuation. To insure good cell phone or other radio wave reception inside a building where RF security is not a concern, silver based low-E glass can still be successfully used. In curtain wall constructions where the entire building may be enveloped in signal blocking, low-E coated glass, a couple of common solutions are: 1) Incorporate uncoated glass in strategic, line-of-site signal areas or in spandrel zones where opacifying ceramic frits are used on the glass in conjunction with traditional non-foil insulation. 2) Installing external antennas combined with radio repeaters inside the building can provide excellent transmission of select radio waves no matter what the building construction.

For nearly complete shielding of RF, utilize a glass construction with two or more lites of triple silver Solarban® 70XL coated glass along with metallic foils, metal roofs, and other signal blocking construction materials. This can be very effective. If it is possible that these metallic components can be made contiguous and then grounded, a Faraday Cage will be formed effectively shielding all electrical fields from passing through.

In summary, windows which incorporate high performing silver based, low-E coatings such as PPG's Solarban® 70XL coated glass can provide RF transmission security if desired, but use of these coatings does not preclude the ability of RF devices to communicate with the outside world if airway transmission of information is necessary or desired. If RF transmission is needed, but security is still a concern, traditional methods of encrypting the signal or data can be used, but even the best coding can be interpreted by a seasoned hacker.

Table 3 below shows the optical and thermal performance of window constructions typical of those tested for RF attenuation. Those results are shown in Figure 2 displayed earlier in this document.

Performance Data of Misc. Monolithic Laminates and Insulating Glass Units with Laminated Inners Containing One or Two Silver Based, Low-E Coated Surfaces

		Transmittance			Reflectance			U-Value							
** All information represents Center of Glass Performance Data **	IGU Thick	UV	Visible	Solar	Visible Exterior	Visible Interior	Solar Exterior	Winter Night	Summer Day	SC	SHGC	RHG	LSG	Tdw-K	Tdw-ISO
6mmClear060PVB6mmClear	0.506	0%	86%	61%	8%	8%	6%	0.95	0.86	0.82	0.71	175.8	1.21	27.2%	58.3%
6mmSB60(2)Clear060PVB6mmClear	0.536	0%	72%	32%	9%	10%	28%	0.93	0.85	0.52	0.45	116.0	1.60	19.9%	45.8%
6mmSB60(2)Clear060PVB6mmSB60(3)Clear	0.506	0%	61%	25%	10%	10%	30%	0.95	0.86	0.45	0.39	102.4	1.56	16.4%	38.0%
6mmSB60(2)Cl050AS6mmSB60(4)Cl060PVB6mmCl	1.229	0%	57%	23%	11%	12%	29%	0.28	0.27	0.41	0.35	85.2	1.63	15.3%	35.8%
6mmSB70XL(2)Clear060PVB6mmClear	0.506	0%	60%	23%	14%	16%	50%	0.95	0.86	0.36	0.32	84.6	1.88	16.2%	38.2%
6mmSB70XL(2)Clear060PVB6mmSB70XL(3)Clear	0.506	0%	43%	15%	18%	18%	52%	0.95	0.86	0.30	0.26	71.1	1.65	10.4%	25.9%
6mmSB70XL(2)St050AS6mmSB70XL(4)St060PVB6mmClear	1.229	0%	31%	10%	17%	19%	54%	0.28	0.26	0.26	0.22	55.1	1.41	6.8%	17.8%

Interlayer material is 0.060" thick Solutia Saflex PVB.

Simulations were ran using LBNL Window6.3 and Optics6 software with version 31.0 of the International Glazing Database and represents center of glass performance data.

Due to the potential for a perceived variation in angular color, caution is advised when low-e coatings are embedded within a laminate where the coating is adjacent to the interlayer material. While all low-e coatings have the potential for this phenomenon regardless of the glass substrate involved, different low-e coatings may exhibit color variation to varying degrees and the variation is typically random in nature. The potential for color variation may be minimized when the tinted substrate is located in front of the coating and highlighted when the tinted substrate is behind it, with darker tints resulting in greater highlighting of the color shift.
This general color variation is described in the Glass Association of North America (GANA) Informational Bulletin called "Design Considerations for Laminated Glazing Applications" (GANA LD 01-0708). A quote from it states "There are also design considerations, which must be taken into account when a low e or reflective coating is used in the construction of a laminate. When the coating, applied to the glass substrate, is placed in contact with the interlayer, the refractive index of the coating is changed and will result in a perceived color shift."
If you are considering this type of unit construction, PPG recommends a full size mock-up review under job site conditions.

Performance data is based on representative samples of factory production. Actual values may vary slightly due to variations in the production process. This data is to be used for comparison purposes and should not be considered a contract. It is the recipient's responsibility to ensure the manufacturability of the above glazing configurations as well as evaluating appropriate design considerations such as wind and snow load analysis, thermal stress analysis, and local building code compliance. PPG recommends that a full size mock-up be reviewed under the specific job-site conditions and retain the mock-up as a basis of acceptable product.

Simulations provided are not NFRC approved.

Figure 3

For the optical and thermal performance of additional glass constructions of PPG Flat Glass Products, please see the Construct IGU Tool at: http://www.ppg.com/corporate/ideascapes/glass/tools/Pages/default.aspx

HISTORY TABLE		
ITEM	DATE	DESCRIPTION
TD-151	May 13, 2014	Original Issue Date