High Power Microwave Effects on Coated Window Panes

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Abstract

Today window panes are usually coated with at least one metal or metal oxide layer to prevent heat energy of the light spectrum from propagating to the other side. This has given problems regarding radio propagation through windows, which might be utilized as a part of a buildings IEMI protection. This paper reports the results from measurements of the shielding effectiveness of a selection of modern window panes before and after irradiation with high power electromagnetic waves. The shielding effectiveness measurements are made in a nested reverberation chamber covering the range 1 – 18 GHz; both before and after high power irradiation at 1.3 GHz. The results show that the shielding effectiveness of window panes may be severely impaired due to thermal stress effects on the coatings during the irradiation, depending of the type of coating.

Keywords: HPM; window panes; glass; transmission; propagation.

1 Introduction

Today window panes usually are coated with at least one layer of metal or metal oxide to prevent heat energy from propagating through a window. In cold climate the purpose is to contain the long-wave infra-red light inside a building while in hot climates the needs are similar; only the direction is opposite, the infra-red waves should be kept on the outside. Furthermore, the high-energy, short wavelength ultra-violet rays should preferably be blocked by the window preventing them from reaching objects on the inside and thus converting to heat.

The coatings of the panes are optimized with infra-red or ultra-violet radiation in mind while no attention is paid to the radio and microwave parts of the electromagnetic spectrum. This has proven to give problems in modern communication systems since radio signals are efficiently blocked by modern energy saving windows [1] - [5].

With the purpose to determine the effects from high power microwave (HPM) irradiation this paper examines the shielding effectiveness (SE) of single window panes with different coatings. A comparison of SE results before and after the high power exposure is presented.

2 Method

The high power effects are determined using a comparative method where first the SE is measured before high power irradiation, as a reference, and then re-measured to reveal any effects of the irradiation.

The SE measurements conducted to determine the shielding properties of the panes where made in a nested reverberation chamber (RC), Figure 1. In the RC a mode stirrer is employed to create a mode stirred incident field impinging on the sample mounted over an aperture in the nested chamber. Inside the nested chamber a second mode stirrer revolves to change the mode of the field incident on the receiver antenna. For each frequency 252 different combinations of stirrer positions are used when measuring the isotropic transmission cross section, $\langle \sigma_a \rangle$, of the test object. From $\langle \sigma_a \rangle$ the SE is calculated [6]-[7].

In the present case the reference aperture is a square opening with an area, A, 300 x 300 mm^2. For a reference aperture with such a simple geometry one may express the result above in terms of shielding effectiveness, i.e. in terms of a dimensionless quantity, simply by comparing the power transmitted through the unshielded opening (i.e. the square opening) with the power transmitted through the opening when the shielded structure is mounted on it, i.e.

$$\langle SE_{apert,iso} \rangle = \frac{A/4}{\langle \sigma_a \rangle}. \quad (1)$$

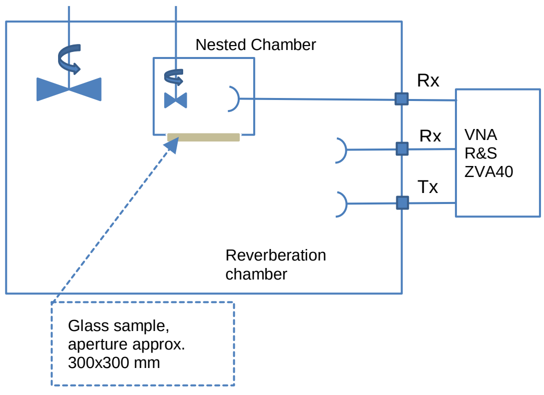

Figure 1. Simplified block diagram showing the reverberation chamber.

In (1) we approximate the transmission cross section of the unshielded opening by A/4 which is exactly true only at frequencies where the opening is electrically large. For frequencies above 1 GHz the error is less than 1 dB.

The HPM exposure was carried out in the Microwave Test Facility (MTF) at SAAB Aeronautics in Sweden. The MTF was set to work in the L-band giving the field strength 28 kV/m in 5 µs long pulses with a pulse repetition frequency of 390 Hz during a 10 s burst.

3 Measurement Samples

The measurement samples were four single window panes, as tabulated in Table 1. The specimen code found in the first column is an identifier for each sample; the second column explains of what specific glass type that specimen is.

Soft coated and hard coated low-emission glass are intended to reflect infrared light (i.e. heat) back while letting day-light pass through them. The difference between the two is the composition and method used for deposition of the coating layer.

Soft coating is deposited on pre-cut float glass in tens of nanometers thick layers using sputtering, a physical vapor deposition (PVD) where the layers consist of various metal oxides, typically tin-dioxide (SnO_2), interleaved with one or more layers of silver. Other metal oxides such as ZnO and TiO_3 may also be used. The more silver layers the lower emissivity and the better the reflection of ultra-violet rays.

Hard coating is applied on semi-molten glass in the production line using chemical vapor deposition (CVD) and typically consists of only one a few hundreds of nm thick layer of SnO_2.

Table 1. List of measurement samples – single window panes.

Single Panes, Standard Types	
Specimen Code	***Specimen type***
HC1-5	Solar Control, Soft Coated, Low-e glass; 1 Silver Layer
SC-5	Hard Coated, Low-e glass
Sp-5	Spandrel glass
2Ag-5	Solar Control, Soft Coated, Low-e glass; 2 Silver Layers

A spandrel pane is an opaque glass often placed as cladding element between clear-view windows to hide construction elements, insulation and building infrastructure installations. The opacity is achieved by adding coatings of metal, metal oxides or enamel on the rear (inner) side of the pane.

4 Results

4.1 Visual Effects

A visual inspection of the samples after the HPM exposure gave at hand that the two silver coated samples, HC1-5 and 2Ag-5, exhibited visually clear cracks looking like Lichtenberg figures indicating an electrical breakdown process due to thermal stress from the very strong electric field, see Figure 2 and Figure 3. However, the other two samples, the hard coated (SC-5) and the spandrel (Sp-5) glasses showed no visual deterioration.

4.2 Shielding Effectiveness Effects

Consequently, the SE measurements of the SC-5 and Sp-5 samples did not reveal any changes in SE at all. On the other hand, the two samples with cracked coatings the changes were evident.

The deterioration for the 2Ag-5 pane was approximately 5 dB between 1 and 1.8 GHz and from 6 GHz to 18 GHz while in the 2-5 GHz range there is no noticeable reduction in SE at all, cf. Figure 4. For the HC1-5 pane SE is on average

Figure 2. Cracks in the coating of the 2Ag pane resulting from HPM exposure.

Figure 3. Cracks in the coating of the HC1 pane resulting from HPM exposure.

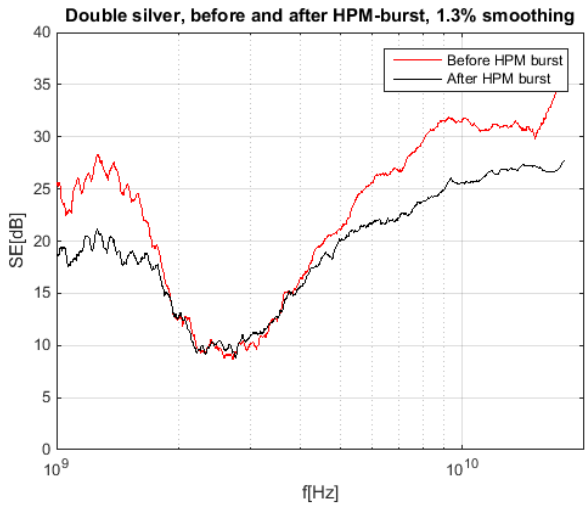

Figure 4. Comparing the shielding effectiveness measured on the double silver coated 2Ag sample before (upper) and after (lower) the HPM burst.

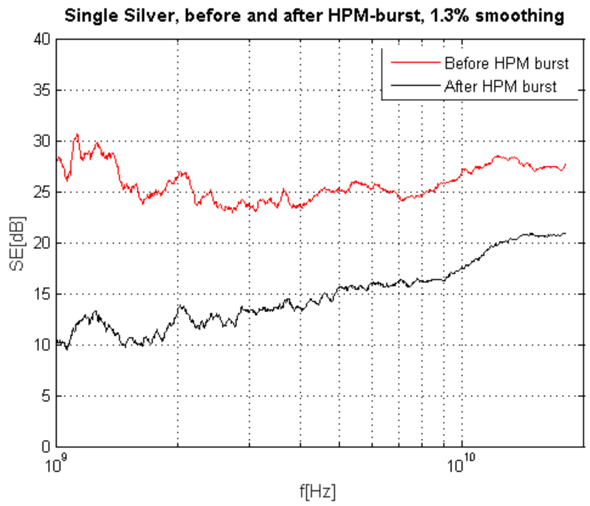

Figure 5. Comparing the shielding effectiveness measured on the single silver coated HC1 sample before (upper) and after (lower) the HPM burst.

approximately 15 dB lower at 1 GHz decreasing to approximately 7 dB at 18 GHz, cf. Figure 5.

5 Discussion

Measurement results have been presented for a group of window panes intended for different window applications.
The panes were subject to high power microwave irradiation after which the shielding effectiveness of the panes was measured and compared to the shielding effectiveness before the exposure.

An SE difference between panes with different coating was observed. Even though also the metal oxides are conductive, the main difference between unaffected and affected samples seems to be the metallic coating (silver) on the two affected panes while the unaffected samples were coated only with a metal oxide.

In this study we have shown that the potential of using window coatings as part of the protection against IEMI or unwanted electromagnetic emanations is not completely safe, depending on which type of coating the panes have – if it is possible to approach the facility with high power electromagnetic radiators.

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