1st IET Colloquium on Antennas, Wireless and Electromagnetics
29 May 2013, Loughborough University, Loughborough, UK

Broadband wireless access in an energy efficient environment

Yaqiang Liu, Paul O'Leary

Affiliation

Waterford Institute of Technology

Cork Road, Waterford, Ireland

20018753@mail.wit.ie

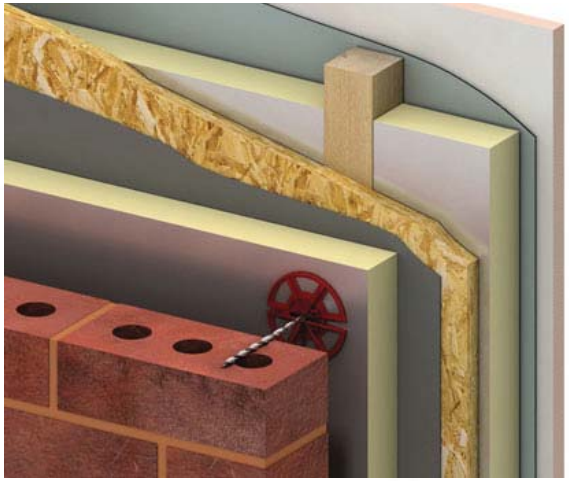
Introduction

Wireless access into and out of buildings is a fundamental requirement of current and future successful handheld device usage. A number of factors, guided by energy efficiency, can negatively influence the successful propagation of such wireless signals through the building envelope.

This work examines commonly used building materials in terms of their attenuation on wireless frequencies from 800-6000MHz and concludes that the external doors are the final remaining wireless openings.

Content

Building materials under test

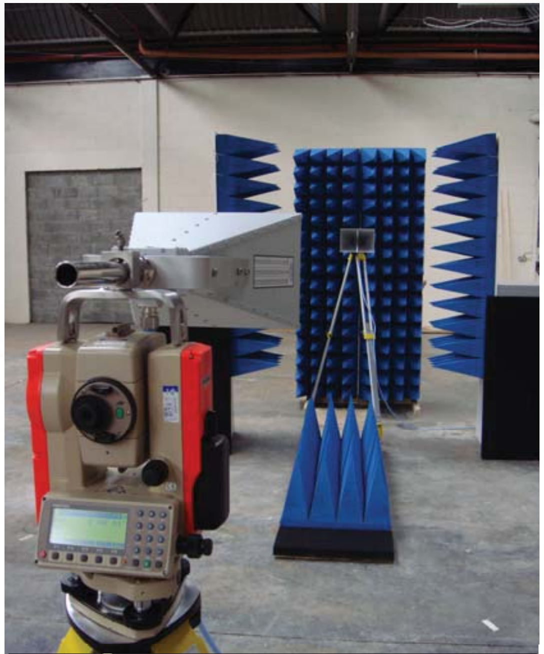


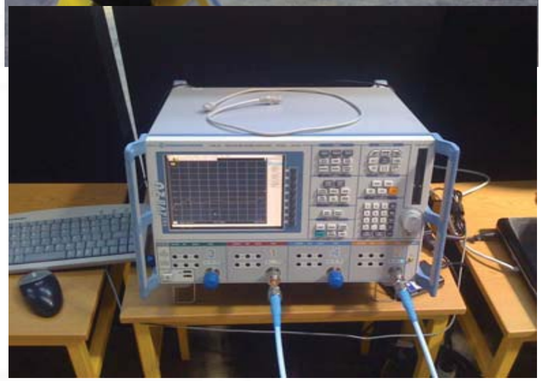
- Individual testing of typical building components
  - Wall and roof materials
  - Glass in window opes
  - Insulation
    - rock wool, polyisocyanurate, graphite-impregnated styrofoam



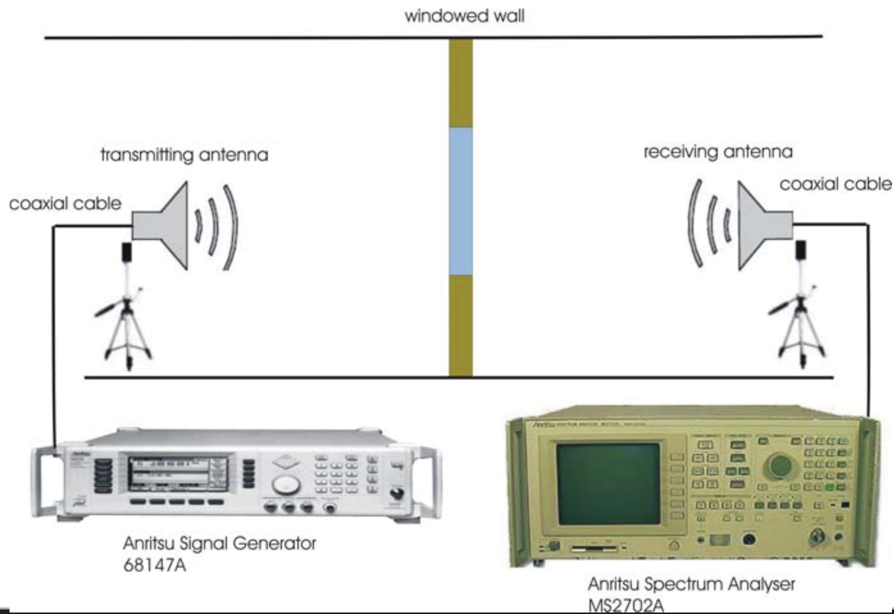


Test structures & equipment

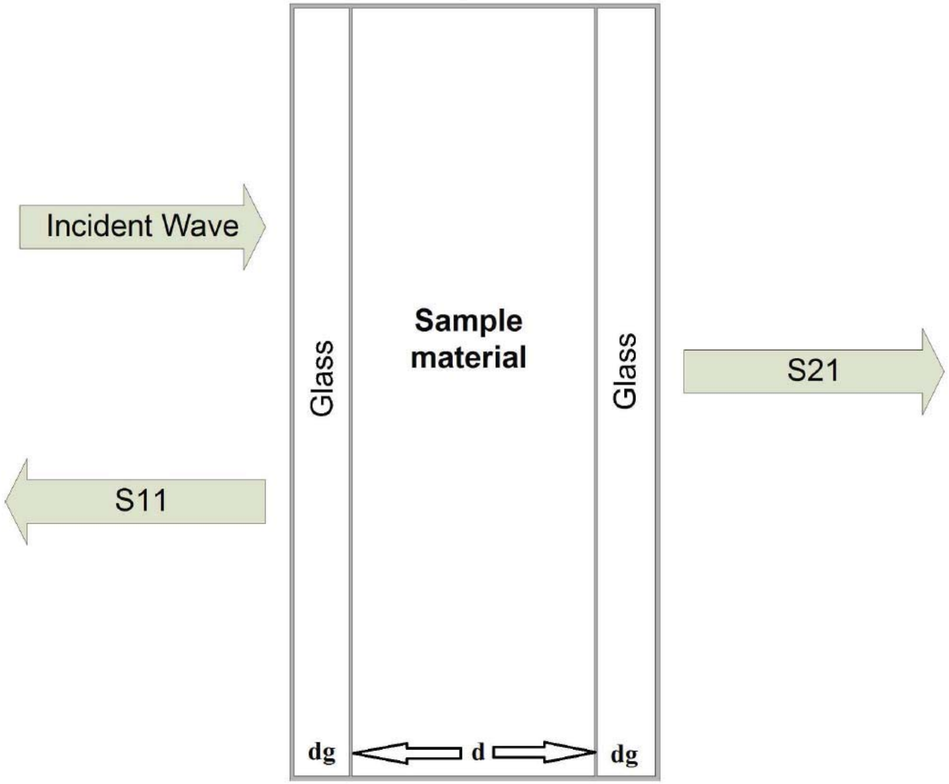




- Rohde & Schwarz ZVB-20 VNA
  - ZV-Z32 calibration kit
  - 7.62m Sucoflex 106 low-loss cables
- Anritsu 68147A signal generator
  - Anritsu MS2702A
    - Backup tests

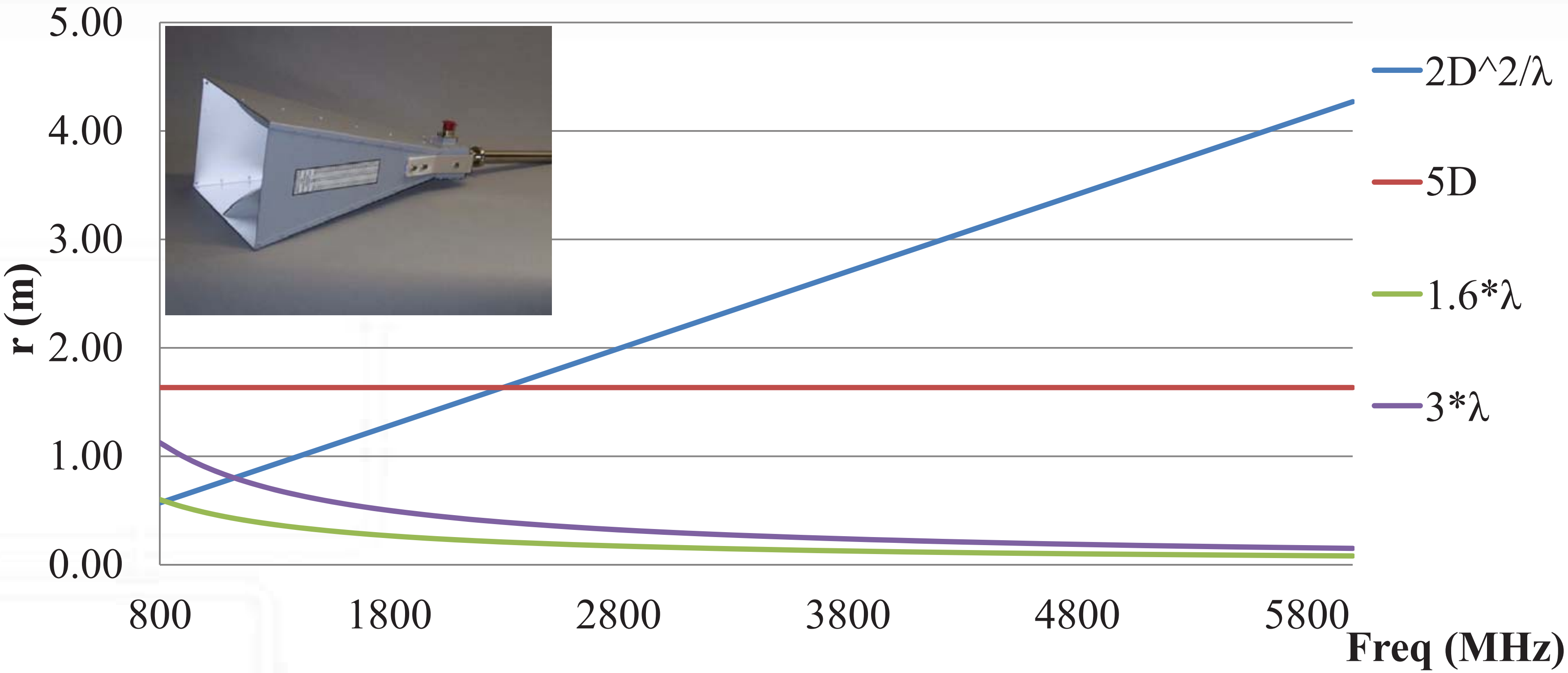


Test block diagram



- Propagated and reflected s-parameters of interest
  - Here MUT is double glazing

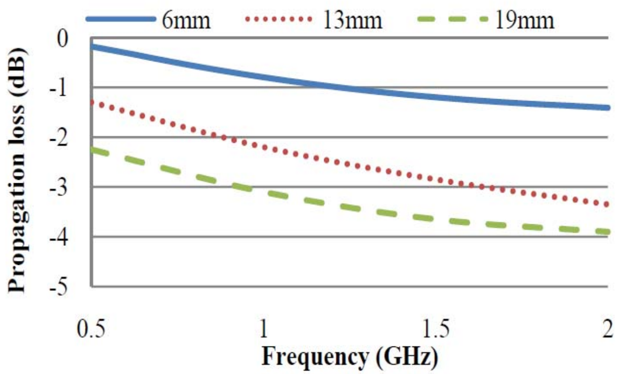
Far field selection criteria



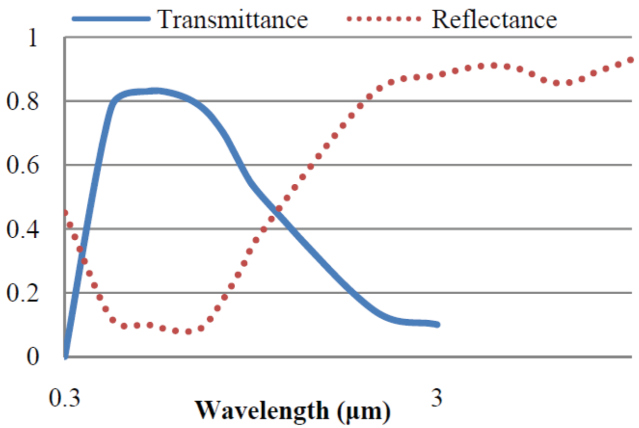
- Selection criteria: $2D^2/\lambda$, 5D, 1.6λ, 3λ (& more)
  - Schwarzbeck BBHA 9120 LFA Horn Antenna D=0.33m

Low energy & std. window propagation

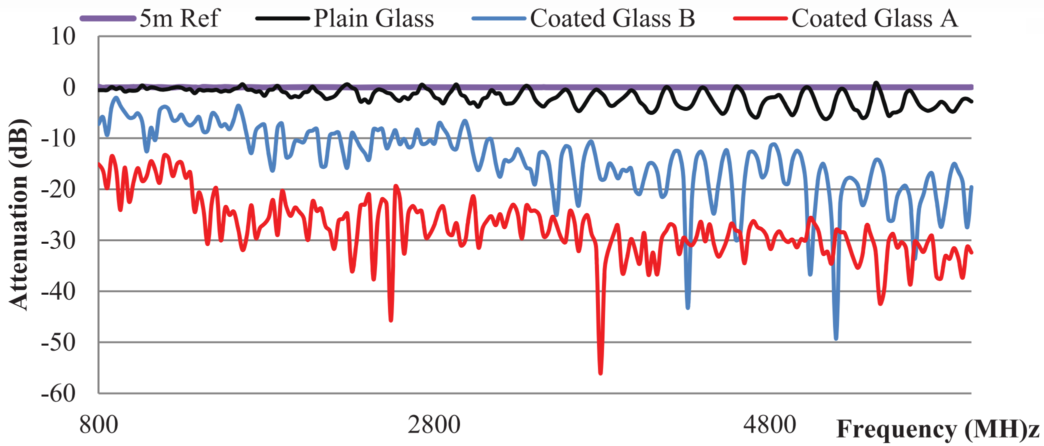
Standard glass



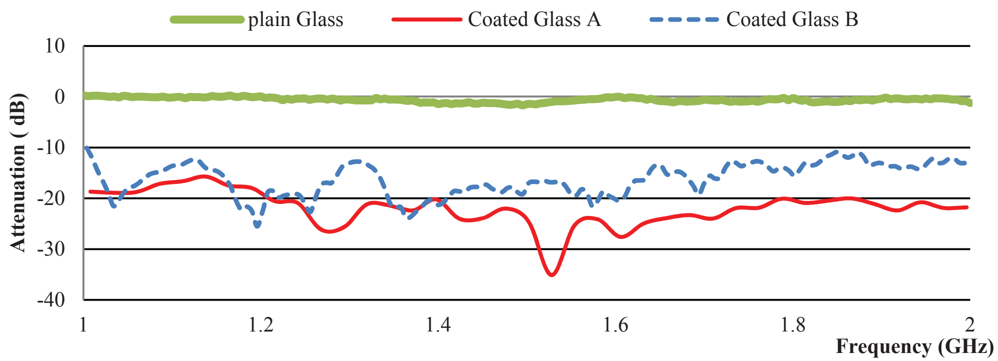
Coated glass: energy spectrum



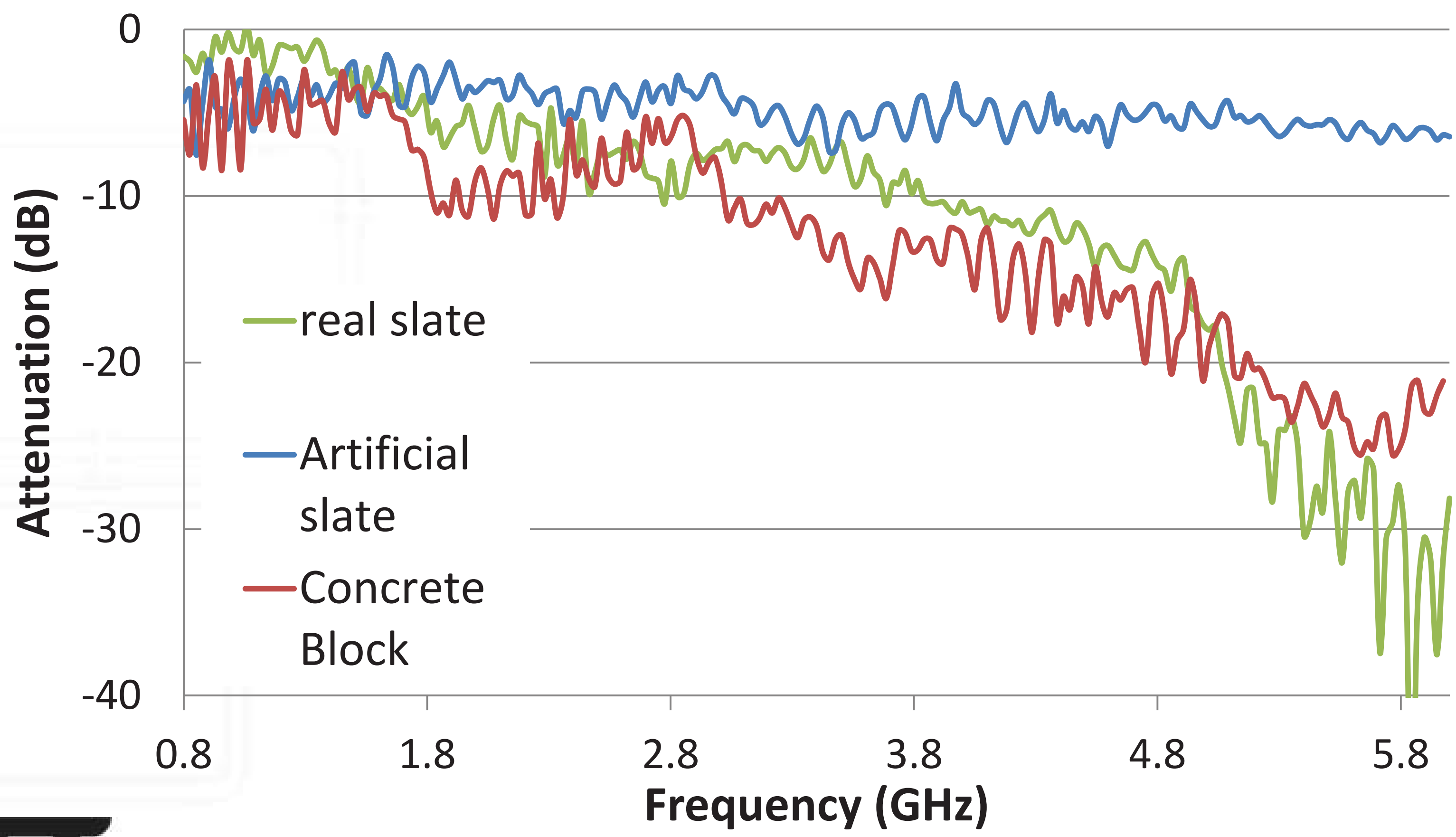
Open air results



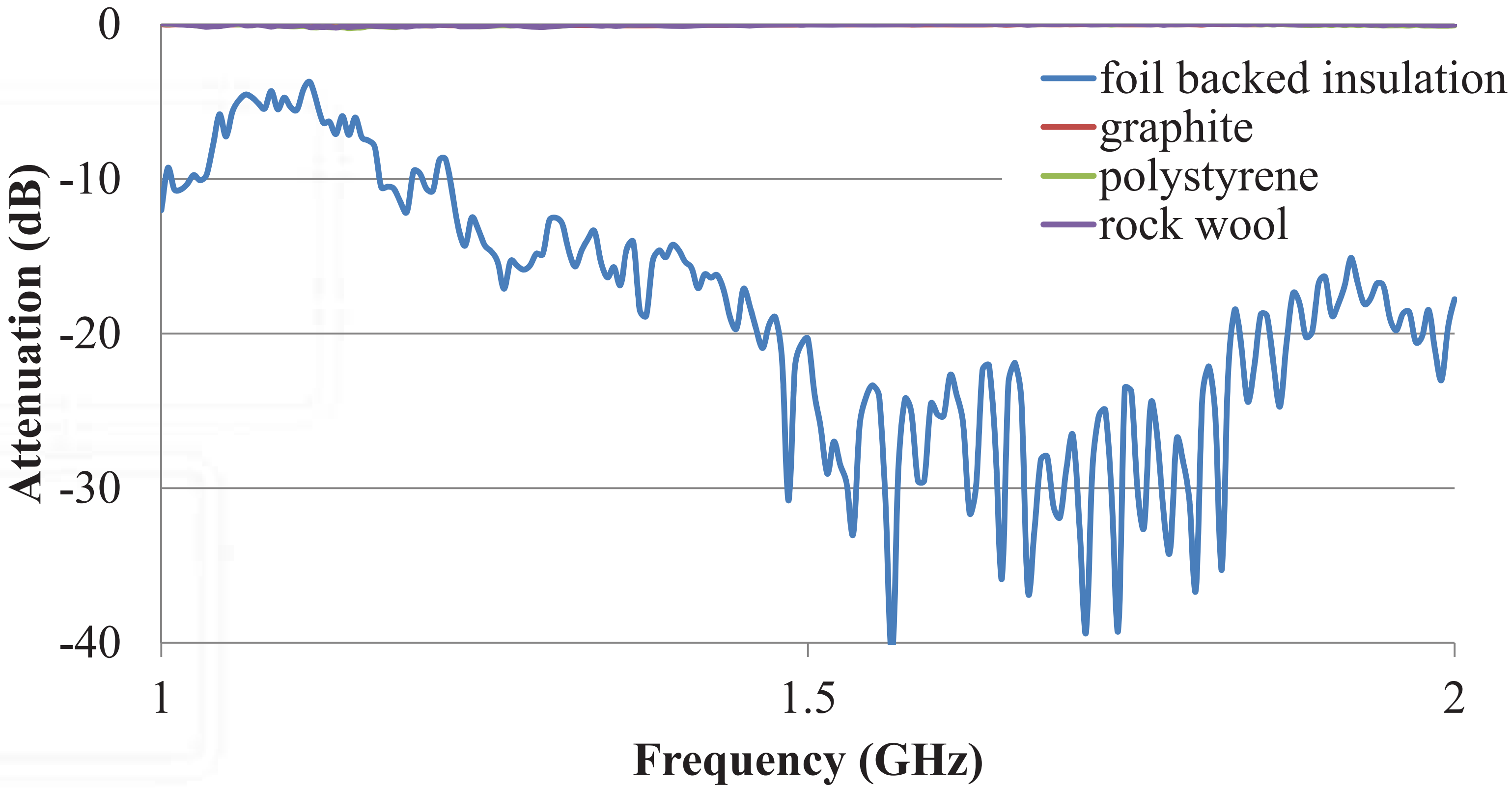
Anechoic chamber results



Dry building materials



Heat insulation materials



Results

- Low emissivity glass adds 10-30dB extra attenuation over standard glass
- Standard wall/roof insulation has a negligible effect on wireless attenuation
- More recent insulation is foil-backed
  - Adds 10-30dB attenuation depending on frequency
  - Combined with dry concrete block on edge leads to attenuations of 20-50dB

Conclusions

- Building heat energy efficiency efforts have lead to the introduction of transparent conductors in double/triple glazing
  - Also foil-back insulation in wall cavities and in roof
  - Prevents radioactive loss (gain in hot countries) of heat energy
  - However, also impacts significantly on wireless propagation
  - Front/back doors are the final opes for wireless!

Acknowledgements

The authors would like to acknowledge the support of Mr Bryan Hallissey of the WIT Department of Construction & Civil Engineering, for the use of the Total Station for the work described here and also for the directional gain tests on the antennas.

References

[1] D. Stolhofer, Yaqiang Liu and P.O'Leary, "RF Propagation Through Transparent Conductors In Energy Efficient Windows," *16th European Wireless Conference*, Lucca, Italy, April 2010.

[2] W. C. Stone, "Electromagnetic Signal Attenuation in Construction Materials." in *NIST Construction Automation Program Report No. 3*, October, 1997.

[3] Claes G. Granqvist, *Transparent conductors as solar energy materials: A panoramic review. Vol.91, pp. 1529-1598, 15 October 2007.*

[4] N. Knauer, "Investigation of the Physical Effects when Electromagnetic Waves pass through various Window Types", Diploma dissertation, Fachhochschule Hannover, Germany, 2006.

Technical Appendix

- The reflection and transmission coefficients are related to the scattering parameters by:

$$S_{11} = \frac{\Gamma(1 - T^2)}{1 - \Gamma^2 T^2} \qquad S_{21} = \frac{T(1 - \Gamma^2)}{1 - T^2 \Gamma^2}$$

- The reflection coefficient, Γ, can be obtained by inverting these equations:

$$\Gamma = X \pm \sqrt{(X^2 - 1)} \qquad X = \frac{{S_{11}}^2 - {S_{21}}^2 + 1}{2 * S_{11}}$$

Technical Appendix (2)

- Similarly, an expression for the transmission coefficient, T, can be obtained:

$$T = \frac{S_{11} + S_{21} - \Gamma}{1 - (S_{11} + S_{21})\Gamma}$$

- The free space wavelength, λ_0 , and the cut off wavelength, λ_c, are related to the transmission and reflection coefficients by the equation:

$$\frac{1}{\Lambda} = \left(\frac{\epsilon_r * \mu_r}{{\lambda_0}^2} - \frac{1}{{\lambda_c}^2}\right)$$

Technical Appendix (3)

- So, the permittivity and the permeability can be derived from the above equations :

$$\epsilon_r = \frac{\lambda_o^{\ 2}}{\mu_r}\left(\frac{1}{\lambda_c^{\ 2}} - \left[\frac{1}{2\pi L}\ln\left(\frac{1}{T}\right)\right]^2\right)$$

$$\mu_r = \frac{1 + \Gamma}{\Lambda(1 - \Gamma)\sqrt{\frac{1}{\lambda_o^{\ 2}} - \frac{1}{\lambda_c^{\ 2}}}}$$