

Impact of Plastering Mesh on Radio Propagation: Practical RF Measurements and Basic Principles

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Abstract

As apartment buildings age, the exterior walls usually have to be repaired after about 40-60 years. In the case of exterior wall renovations of apartment block, the old facade is usually completely renovated and the new surface is based on plastering. Plastering is used as a outermost facade surface especially in major overhaul cases, where energy efficiency is improved by increasing the thickness of the insulation layer. However, plastering can add surprising increment the radio signal attenuation caused by the exterior wall. The reason for this is the iron mesh used to support plastering. That mesh attenuates the signals of wireless systems, especially at low frequencies. In this study, it has been shown that the plastering mesh acts as a high pass filter and can double the wall overall attenuation at frequencies below 1 GHz used by cellular networks.

1 Introduction

At present, an exceptionally fast change in the climate is a well-known fact, and slowing it down requires rapid actions. Concrete actions to remedy the problems are limited in the near future mainly to the improvement of energy efficiency in different areas of life. [1] Housing accounts for a significant proportion of total energy consumption, 40-60%, and reducing this portion is one of the greatest opportunities to influence the overall energy consumption of industrialized countries. [2]

In general, the amount of energy that is needed for heating an individual house or an apartment complex depends largely on the insulation level of the exterior covers of the buildings. [3] Renovation of exterior walls of old houses generally aims to improve both energy efficiency and appearance of façade. In this process, the plastering is often chosen to be new outermost surface layer because it is lightweight and does not increase the overall thickness of the wall. In addition, the cheap price of plastering increases its popularity as a coating for new buildings. The purpose of this study is to examine the effects of the plastering meshes that are commonly used in thicker plastering, on the RF signal propagation at different frequency ranges and thereon on the coverage of the wireless communication networks.

This article omits the theoretical electromagnetic treatment of dense-eye mesh. That is because in this document it is intended only to provide a brief and comprehensible description of the effect of plaster mesh for both builders of apartment buildings and designers of mobile networks and wireless communication systems.

1.1 Age Distribution and Renovation Needs of Building Population

Increasingly tightened energy efficiency requirements throughout the EU area affect the choice of building materials for all new construction, but the same conditions are valid to materials used in the renovation of older buildings. The number of continuously ongoing renovations is considerable because the major part of apartment buildings in the European Union is old. [4] The countries with the highest growth rates of new buildings (1961-1990) are Hungary, Estonia, Latvia, and Finland. [4]

Although the life cycle of residential apartment buildings is expected to be almost always over 50 years, problems have been detected in the exterior concrete walls after about 30 years. [5,6] Exterior wall damage can be detected easily in the frontside of buildings, and the facade repairs are one of the most expensive renovations of old residential buildings, together with significant pipe and electricity overhauls. Usually, in old residential buildings, the facade has been damaged over large areas, and a substantial part of the wall area needs to be repaired at once. In this context, the total thickness of the insulation layer is almost invariably increased.

Adding insulation is done either directly on the old damaged surface or by removing the old coating and replacing the entire insulation layer. In either case, the outermost surface layer is chosen usually to be plaster, which is supported either fiberglass or metal mesh. [7,8,11]

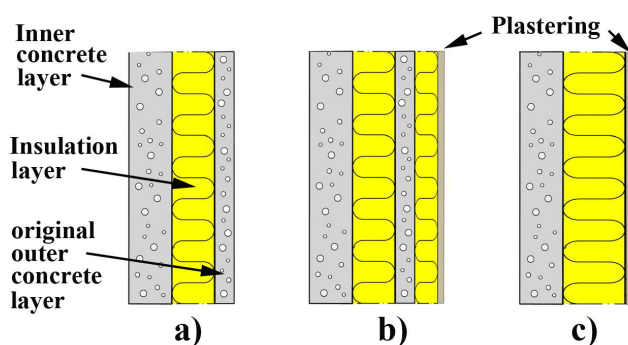


Figure 1. An exterior wall structure into which the insulation layers has been added during a renovation.

Figure 1 (a) illustrates the original situation before the overhaul. In Figure 1 (b), the old outer surface of the wall is left in place and an additional insulating layer covered with plastering is installed. Finally, Figure 1 (c) shows a case where the entire old outer surface and whole old insulation layer have been removed and replaced with a new insulation layer together with the plastering. [7]

1.2 Plastering types in renovation

Since the metal mesh embedded into the plaster can be expected to attenuate radio signals, it is necessary to brief the structures and methods related to the plaster. [9,10]

In the Nordic countries, and especially in Finland, plastering has already been used to trowel brick surfaces before the element construction became the typical wall structure. Even during the era of concrete element building, plastering has remained one of the most common coatings. The popularity of the plastering is based in particular on its lightweight construction, which makes it easy to attach onto a thick layer of wool-based insulation. [7,8] The plastering types are divided into two groups according to the material thickness and those are the thin plastering and the three-layer thick plastering. From the radio signal attenuation point of view, the most significant difference is not the thickness of the plaster layer, but the fact that the metal mesh of 19 mm eye-size is used to support the thick plastering layer.

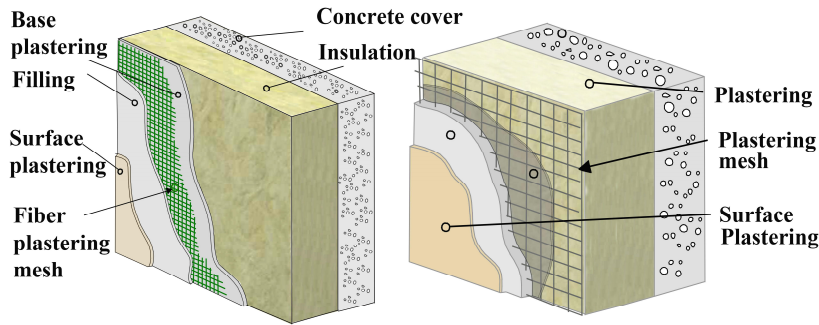


Figure 2. Layers in Thin and thick plastering.

The thick plastering is done in three steps, the first one being the bottom plastering needed for the fastening, the next the filling plaster containing the plastering mesh and the last one being the surface plastering. The plastering mesh is made of galvanized iron wire 1 mm thick. The principle of thin and thick plastering is shown in Fig 2.

2 Measurement Method

Measurements of the plaster mesh attenuation have been performed in the basement of Tampere University, where the external interference is quelled by over 300 mm thick concrete wall and ceiling structures. The far-field was ensured by placing two identical horn antennas (A-INFO JTXLB-880-NF) at a distance of 3.2 meters from each other. The plastering mesh to be studied was placed between the antennas. Horn antennas were connected by 5m coaxial cables (RG213) to a spectrum analyzer (R&S FSG series) and a signal generator (R&S SMJ series). The transmit antenna was driven by a signal generator, and the power of the received signal was measured by a spectrum analyzer. The frequency range of the equipment was limited from 650 MHz to 6 GHz, which was divided into 262 frequency points in which the received power was measured. An overview of the measurement settings is shown in Figure 3.

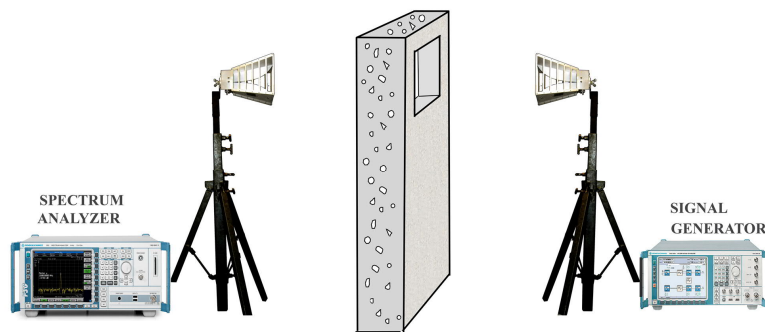


Figure 3. Measurement setup.

The overall size of the plaster mesh used in the measurements was 600 mm x 600 mm, with mesh sizes of 19 mm. The RF attenuation for the network is calculated by comparing the results of the plastering mesh measurements to the circumstances where there was no net between the antennas. In the measurement situation, the wall around to the mesh was covered with aluminum plates, so the structures surrounding the mesh attenuated multipath components by more than 40 dB at all measured frequencies.

3 Measurement results and analysis

In this measurement, RF -attenuation of generally used plastering mesh was studied and the main result is shown in the following figure, which shows the attenuation of the plaster mesh at different frequencies

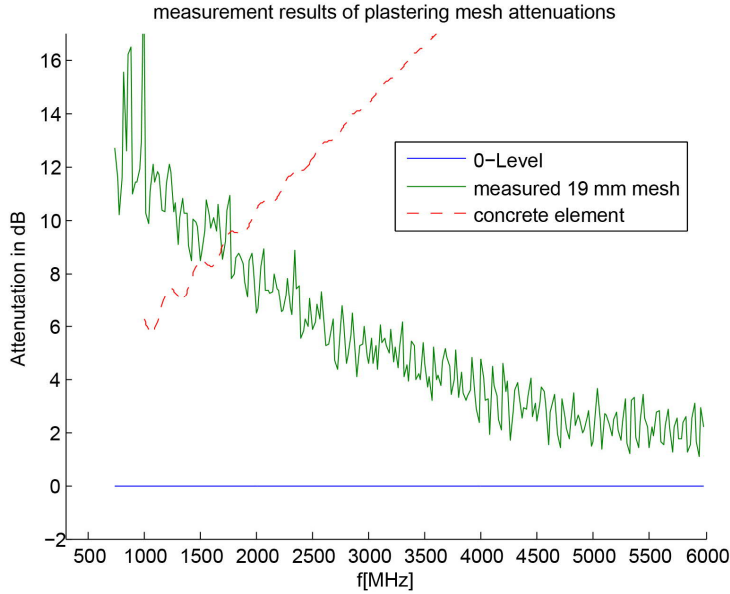


Figure 4. measured RF attenuations of a plastering mesh.

Figure 4 shows the obtained results of the RF measurements regarding the RF signal attenuation for the plastering mesh over the considered frequency range.

The underlying reason behind the observed RF attenuation of the iron mesh can be deduced through the theory of the waveguides. This theory explains also why the attenuation is inversely proportional to the frequency. The geometry of a rectangular waveguide is shown in Fig 5.

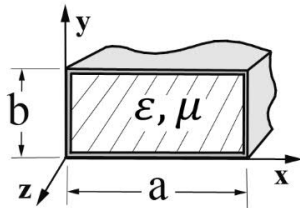


Fig 5. The geometry of rectangular waveguide

According to theory, the cut-off frequency of the dominant mode for a rectangular waveguide is, in general, of the form

$$f_c = \frac{c}{2a} = \frac{1}{2a\sqrt{\mu\epsilon}} \quad (1)$$

where the f_c is the cut-off frequency of the waveguide and a is the width of the rectangular system [12,13]. The speed of light, c , is assumed to be $3 \cdot 10^8$ m/s. All the frequencies $f > f_c$ will propagate through the structure under study without remarkable attenuation while the frequencies below f_c decay exponentially. Based on equation (1), the calculated cut-off frequency of normal plastering mesh is about 7.9 GHz.

With a plastering mesh made of thin iron wire, the attenuation behavior does not fully match the waveguide theory because the mesh structure is very short. However, the results of the check calculation support the measured curves very well.

In general, based on the obtained measurement results, the iron plastering mesh causes significant RF attenuation, especially at low frequencies, which until now has been commonly considered useful for wireless systems due to lower material RF attenuation. This is a new finding, which has not been observed earlier in the literature and may have substantial impact for wireless systems indoor coverage operating at 700-900 MHz range, where for example the IoT networks act.

Typically, plastering layer and iron mesh inside it is installed as a surface of a concrete sandwich element whose own additional attenuation is also shown in Figure 4 by the red color. A typical inner layer of the concrete element consists of reinforced concrete supported by 150 mm size steel mesh. That reinforcement does not affect RF attenuation because of its large mesh size.

The attenuation curve of the reinforced concrete layer, in Fig 4, is based on the measurements of the real wall. [14]. This attenuation of the concrete structure increases with increasing frequency and thus as a whole, the overall RF attenuation of the plastering mesh and the inner layer of the concrete element can eventually be fairly flat over a large frequency range used in wireless systems.

4 Conclusion

In the near future, the additional attenuation caused by the plaster mesh affects a large number of apartment blocks, because a large proportion of the apartment blocks in cities and suburbs are over 40 years old. In Finland, for example, approximately 50% of the entire housing stock is built between 1961 and 1990. [4] Their facades are being renovated annually by some EUR 670 million. [15] Plastering is by far the most common covering method for renovations and currently has no significant competitor measured by market share.

In this paper has shown based on RF measurements results performed between 0.7 and 6 GHz, that the widely used iron mesh in plastering can even double the entire RF -signal attenuation of the wall structure. The attenuation appears in particular at the lower frequencies, while at higher frequencies the impact is much slighter. This is because a metallic mesh acts like a high-pass filter whose cut-off frequency is determined by the relation of the mesh size and the wavelength of RF -signal. The remarkable attenuation of plastering mesh together with attenuation of 150 mm inner layer of the concrete element rises overall wall attenuation to be over 20 dB at all frequencies. This phenomenon should be taken into account in the assessment of wireless systems coverage in plastered modern buildings and older buildings after facade renovation as well.

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