DIFFERENT KINDS OF WALLS AND THEIR EFFECT ON THE ATTENUATION OF RADIOWAVES INDOORS

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ABSTRACT

This paper describes a study of how different walls and wall materials affect the attenuation of electromagnetic waves with frequencies 433MHz, 868MHz, 2.4GHz, and 5.0GHz. The attenuation of the transmitted signals has been studied by creating propagation models using an advanced computer tool. Concrete, wood, and plaster board are the studied wall materials. Furthermore, different wall thicknesses (0.15m, 0.20m, 0.25m, 0.30m, 0.40m) have been used. The long term goal of the research is to compile an easy-to-understand manual containing information on what kind of an effect do walls that differ by material and thickness have on the attenuation of electromagnetic waves. Thus, the simulation construction has been left fairly simple on purpose. Finally, an example of how the information can be used in practice is shown.

1 INTRODUCTION

There can be many kinds of things in a building that affect the way transmitted electromagnetic signals propagate and how fast they attenuate: large furniture, disturbing signals from microwave ovens and other devices, etc. The most obvious effect, however, is caused by the walls. Naturally, they often are in the way of the signal and cause signal reflection, deflection, and attenuation.

Nowadays, it is fairly easy to create so called propagation models fast using advanced computer tools. Propagation models, their reliability and weaknesses were considered in more detail in [1] and [2]. Unfortunately, these propagation models cannot be created without doing some background research, which often turns out to be a considerable amount of work. You have to know the height of the room, material of the walls, the floor and the ceiling, the thickness of the walls, etc. This can be frustrating because in many cases the problem is basically very simple. A fitter, for example, may wonder how many devices that use a known frequency to transmit signals he should install in a building so that they would work faultlessly.

In this paper the question of how different kinds of walls tend to affect the attenuation of electromagnetic signals is considered. The studied wall materials are concrete, wood, and plaster board. Signal attenuation has been studied using wall thicknesses

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0.15m, 0.20m, 0.25m, 0.30m, and 0.40m for all of the wall materials. Since propagation models were found useful and reliable in [1] and [2] they have been used in this study again. In order to be able to compile the results into a sufficiently easy-to-understand manual, the simulation construction has been left fairly simple on purpose.

In section two we go through what has been done in more detail. Section three contains the results of the study and also shows an example of how, for example, these results can be used in practice. The contents of this paper are reviewed once again in section four, this time more briefly and concentrating on the essential.

2 THE STUDY IN MORE DETAIL

As stated before, the purpose of this study was to find out how walls that differ by both material and thickness affect the attenuation of electromagnetic waves with frequencies 433MHz, 868MHz, 2.4GHz, and 5.0GHz. The target is to compile the results of this study into an easy-to-understand manual one day. Mainly for this reason the created simulation construction shown in Fig. 1 is not complex but on the contrary, clear and simple. The width of each of the seven rooms was between 2 and 4 metres. This is because the width of the rooms is rarely constant in real buildings. The height of the rooms in the simulation construction was 2.5 metres, the length of the whole construction was 20 metres, and the width of the construction was 15 metres.

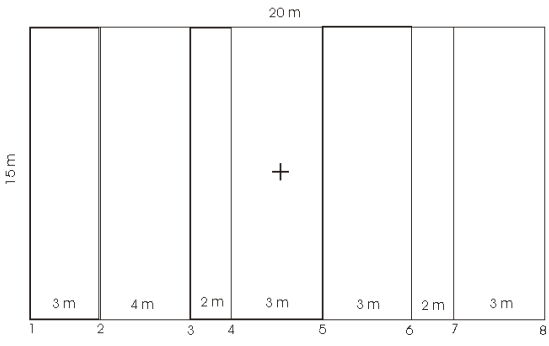

Fig. 1 Simulation Construction

The propagation models of this study were created using a computer tool based on an algorithm called Multi-Channel-Coupling. Many of the features of both the tool and the algorithm were discussed in [1] and [2]. Attenuation caused by both signal reflection and the signal going through the wall material has been considered in the simulations. The low power transmitter that was used in the simulations – depicted by a little cross in the centre of the propagation models – was an omni-directional antenna with a gain of about 2dB. The height of the transmitter was 1 metre.

The studied wall materials were concrete, plaster board, and wood. For all of these materials, attenuation of the transmitted signal was studied with wall thicknesses 0.15m, 0.2m, 0.25m, 0.3m, and 0.4m. The outer walls, the floor, and the ceiling were always made out of conducting material to avoid signal reflections.

Dielectric constant ε_r and conductivity σ are the electromagnetic properties that have the largest effect on signal attenuation [3]. Therefore they were, of course, used in this study as well. For concrete these parameters were $\varepsilon_r = 4$ and $\sigma = 0.05$ S/m, and for plaster board $\varepsilon_r = 2.3$ and $\sigma = 0.03$ S/m. Due to the fact that moisture content affects the electromagnetic properties of wood significantly, the selected parameters for wood

were ε_r = 4.2 and σ = 1.0 · 10^{-5} S/m. According to [4] these parameter values are the best for an average wooden material.

3 THE RESULTS OF THE STUDY

The propagation models showed that the attenuation of transmitted signals depended only on the used frequency when the walls were made of wood. This is a logical result because one of the electromagnetic properties of wood is that it has low conductivity and can even be seen as an insulator. The attenuation results caused by wooden walls are listed in Table 1. Fig. 2 shows one of the created propagation models (wooden walls, wall thickness = 0.15m, frequency = 2.4GHz) as an example.

Wall number	Frequency = 433 MHz	868 MHz	2.4 GHz	5.0 GHz
1	- 35 dB	- 45 dB	- 60 dB	- 65 dB
2	- 35 dB	- 45 dB	- 55 dB	- 60 dB
3	- 35 dB	- 40 dB	- 50 dB	- 55 dB
4	- 35 dB	- 40 dB	- 50 dB	- 55 dB
5	- 35 dB	- 40 dB	- 50 dB	- 55 dB
6	- 35 dB	- 40 dB	- 50 dB	- 55 dB
7	- 35 dB	- 40 dB	- 55 dB	- 60 dB
8	- 35 dB	- 45 dB	- 60 dB	- 65 dB

Table 1 The attenuation results of wooden walls (In this case wall thickness has no effect on the attenuation in practice.)

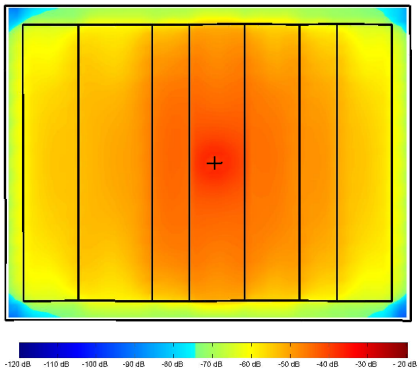

Fig. 2 The attenuation of 2.4GHz waves with 0.15m thick wooden walls.

When concrete walls were used the propagation models showed that both the used frequency and the thickness of the walls affect signal attenuation. This is clearly shown in Table 2. Again, this could be expected since concrete is both insulating and conducting material. Plaster board walls had the same kind of an effect on signal attenuation although the signal did not weaken as much as with concrete walls.

Wall Thickness	Wall number 1	2	3	4	5	6	7	8
0.15 m	-80dB	-70dB	-55dB	-45dB	-45dB	-55dB	-65dB	-80dB
0.20 m	-90dB	-75dB	-60dB	-45dB	- 45dB	-65dB	-70dB	-90dB
0.25 m	-100dB	-90dB	-60dB	-50dB	-50dB	-65dB	-80dB	-100dB
0.3 m	-100dB	-90dB	-60dB	-50dB	-55dB	-65dB	-80dB	-100dB
0.4 m	-120dB	-100dB	-65dB	-55dB	-55dB	-70dB	-80dB	-120dB

Table 2 The attenuation results of concrete walls (frequency = 2.4GHz)

As an example of how the information of the propagation models can be used in practice, let's take a look at table 2. It shows, for instance, that with 0.15m and 0.20m thick concrete walls the average signal attenuation per a room and a wall is about 10 – 15 dB. This kind of suggestive information can be used for fast on the spot evaluation when a thorough research is out of the question – the fitter that was mentioned in the introduction, for example, could appreciate this piece of information a lot.

4 CONCLUSION

A study of how walls that differ by material and thickness affect the attenuation of electromagnetic waves (433MHz, 868MHz, 2.4GHz, 5.0GHz) was presented in this paper. The studied wall materials were concrete, wood, and plaster board. Signal attenuation was studied by examining propagation models that were created using an advanced computer tool. A simulation construction was created and it was left simple so that the results could be compiled into an easy-to-understand manual in the future.

The results showed that the attenuation of transmitted signals depends only on the used frequency and not the thickness of the walls when the walls were made of wood. This is caused by the electromagnetic property of wood: it has low conductivity.

When the walls were made of concrete, the propagation models showed that not only the frequency of the transmission but the thickness of the walls as well had a significant effect on the signal attenuation. The same thing happened when the walls were made of plaster board although the attenuation was, of course, stronger when the walls were made of concrete.

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