Development of a Shielding Box for Through-Facade Coupler (TFC) Evaluation

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Abstract

In this paper we present a tailored aluminium shielding box for the evaluation of "through-facade couplers (TFCs)", which are developed by us within another activity. The box shall mimic the damping of electromagnetic waves, coming from outside base stations, caused by facades. First, the original aluminium box is characterized in a broadband manner based on its shielding effectiveness. In order to improve its performance, foam absorbers and the shielding strips have been mounted to the inside and along the door of the aluminium box, respectively. The absorbers reduce the standing waves inside the small box and mimic therefore the wanted indoor environment in a better manner. The indoor signal is measured via different field probes and antenna, to achieve a robust characterisation. An isolation of better than 40 dB has been measured over a broad range of frequencies (1 GHz – 5 GHz). Thus, the developed shielding box can replace a typical building for the desired mobile and compact TFC evaluation.

1 Introduction

The word façade is defined as the outside or all of the external faces of a building. The façade includes of the modern windows with low emissivity glasses, the walls and other composite materials [1]. The façade used in modern homes and apartments could become an impediment to delivering high quality connection to indoor users and it leads to great attenuation of signal transmission [2]. As the façade has a huge impact on electromagnetic waves, its very important to analyze transmission properties of electromagnetic wave through these facades [3].
In order to achieve this goal, the performance of shielding box has been evaluated to analyze transmission properties of electromagnetic wave through the shielding box, because the electromagnetic behavior and the impact of the aluminum shielding box on communication link is similar with real scenario in the buildings [4,5]. Figure 1, illustrates the schematic of the proposed evaluation setup.

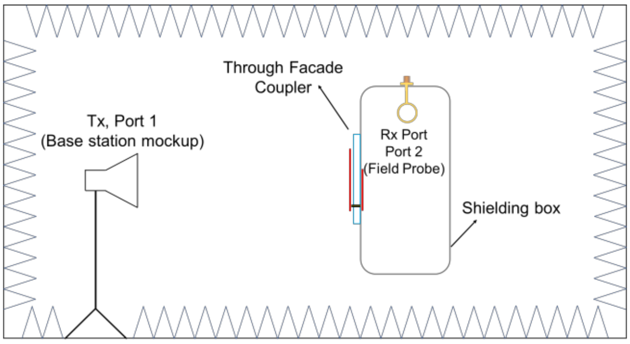

Figure 1 The main idea of the through façade coupler method

2 Introducing the Shielding Box

In our work, we consider aluminium enclosure as original shielding box. Figure 2 illustrates the original aluminium box.

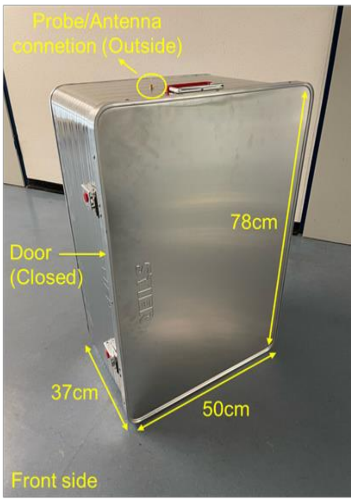

Figure 2 Original aluminum box with its size

In order to calculate the isolation rate, free space measurement by four different probes has been done. Figure 3 shows the different probes. A commercial magnetic prob, a commercial electric probe, a handmade magnetic probe and a WiFi probe are used to pick up the coupled signal inside the aluminum box.

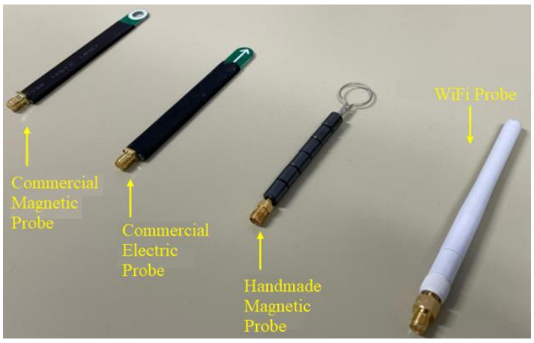

Figure 3 Probes for measurement of signal inside the box

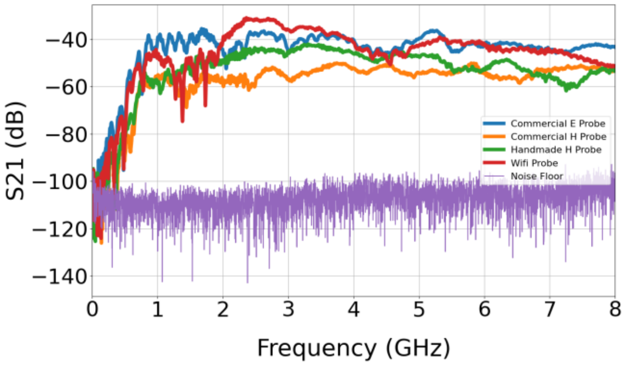

Figure 5 Free space measurement results

3 Free Space Measurement

Figure 4 shows the free space measurement setup. The distance between the horn antenna and the probes is 1.5 m and the horn antenna and the probes are carefully aligned at the same height.

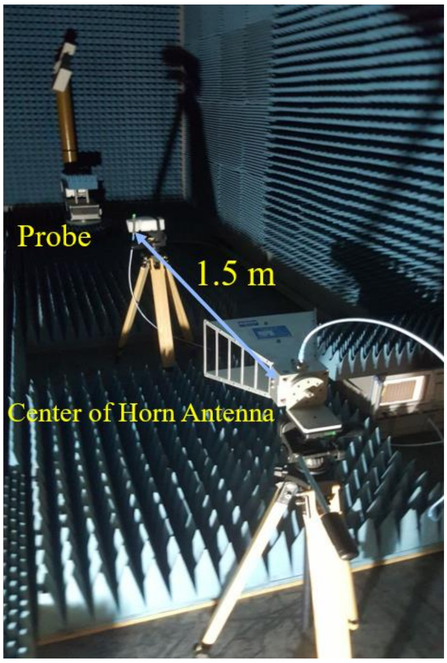

Figure 4 Free space measurement setup

Figure 5 shows the results of free space measurement. Due to working frequency of horn antenna and the measurement probes, the interested frequency range is between 1 GHz to 5 GHz.

To increase measurement accuracy and pick up all the electromagnetic fields inside the aluminum box, the measurements have done by four different probes. The received signals by different probes are in the range of -60 dB to -45 dB.

4 Analysing the Shielding Box

Figure 6 shows the measurement setup of aluminium box with probes. The distance between the horn antenna and aluminium box is 1.5 m. The transmitted signal inside the aluminium box is measured using different probes. Figure 7 shows the measurement results of aluminium box without absorbers. The isolation of aluminium box without absorbers is 15 dB in average.

By comparing both measurements, the isolation rate of original shielding box can be calculated. The isolation of aluminum box without absorbers is 15 dB in average.

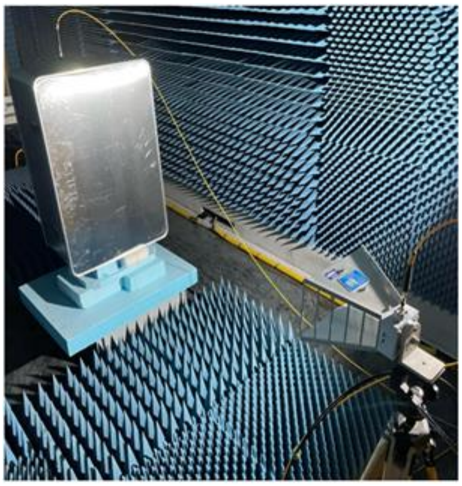

Figure 6 Measurement setup of aluminum box

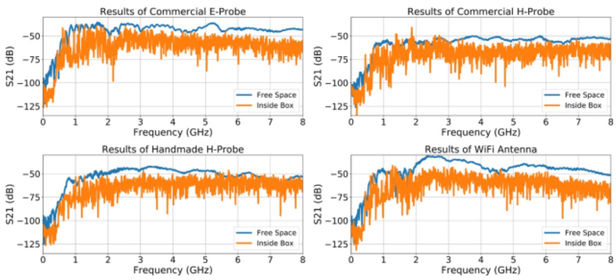

Figure 7 Measurement results of aluminum box without absorbers

5 Analysing the Shielding Box with Absorbers

To minimize the electromagnetic waves come into the aluminum box, the shielding strips are installed around the door, to replace the old rubber. The lossy foam absorbers are mounted inside the box, to reduce the standing waves. Figure 8 shows the aluminum box with absorbers.

Figure 8 The aluminum box with absorbers

The measurement inside the aluminum box with absorbers has done again. The received signal levels from different probes are below -80 dB, which indicates a good shielding performance of aluminum box with absorbers.
By comparing the free space measurement and measured signal inside the box, the isolation of aluminum box with absorbers can be calculated. Figure 9 illustrates the measurement results of aluminum box with absorber. There are standing waves inside the aluminum box, which can be seen from the perturbation of the measured signal. The perturbation from the measured signal is much better than the case without shielding strips and absorbers.

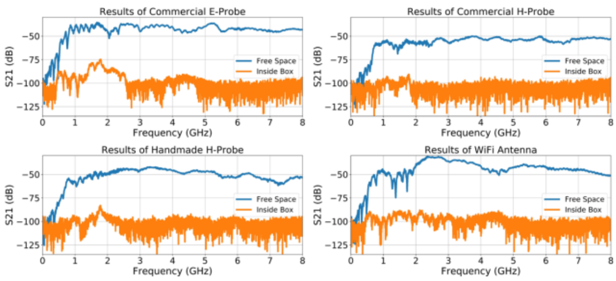

Figure 9 Measurement result of aluminum box with absorbers

Figure 10 illustrates the isolation of shielding box with absorbers. Inside the frequency range (1 GHz - 5 GHz) the aluminum box shows at least 40 dB isolation to the incoming signal.

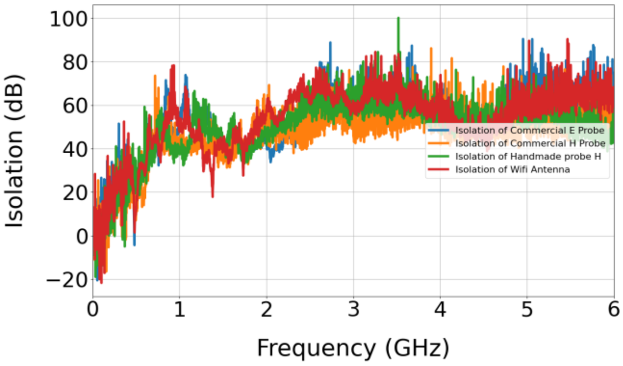

Figure 10 Isolation of aluminum box with absorbers

6 Conclusion

In this paper, a shielding box as a simple, practical and mobile mock-up of the EM blocking box is developed and presented. The original aluminium box can provide 15 dB isolation. The shielding effectiveness of aluminium box has improved by mounting absorbers and shielding strips. The measurement results show that 40 dB isolation to the incoming signal has been achieved.
The shielding box is portable and can be considered in outdoor scenarios to measure the 5G signal reception. The shielding box can be also used for through façade coupler evaluation, which is a crucial topic in outdoor to indoor communication.

7 Literature

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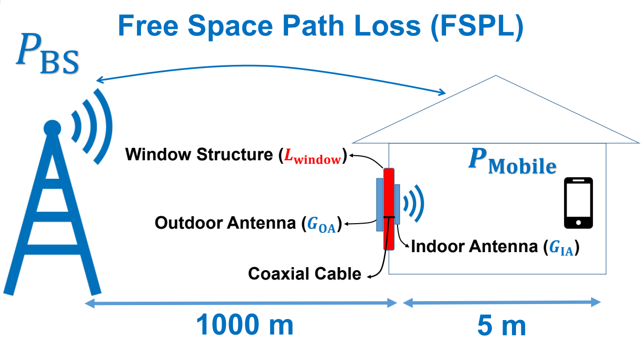
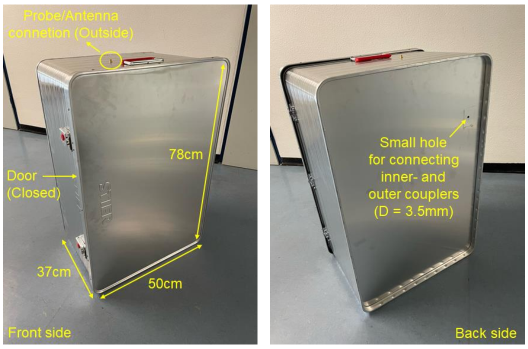
Communication Scenario with Window



Introducing the Shielding Box



- The shielding box is presented as simple, practical and mobile mock-up of the EM-blocking building shell.
- The shielding box is used to evaluate the performance of the couplers and can be considered as outdoor scenarion to measure the reception of 5G signal.

Friis Equation

Friis Equation in dB :

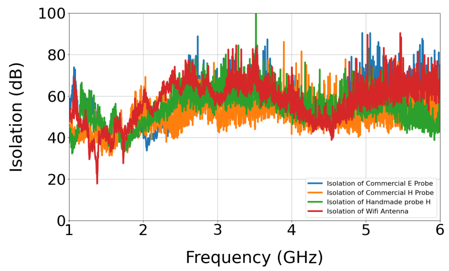
$$P_{Rx} = P_{Tx} + G_{Tx} + G_{Rx} + 20\log_{10}\left(\frac{\lambda_0}{4\pi D}\right)$$

$$-L_{window} - FSPL_{1005m} < -FSPL_{1000m} + G_{OA} - L_{coupler} + G_{IA} - FSPL_{5m}$$

- High gain antennas are required to fulfill the project goal
- Low profile antennas are necessary to provide a flat solution
- Coupler loss (Cable) should be minimized

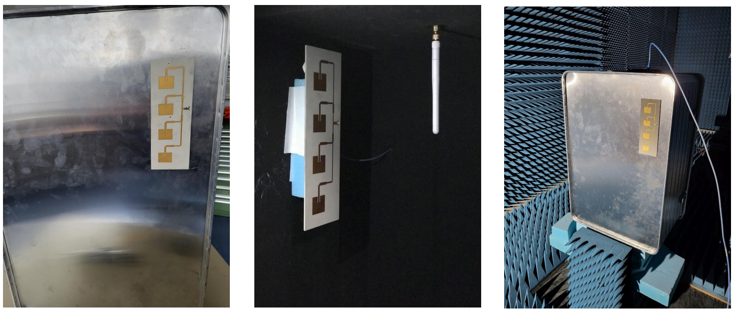
Mounting Absorbers to the Shielding Box

- The lossy foam absorbers and shielding strips have been attached on the aluminium box to increase the isolation level.
- The improved shielding box shows at least 40 dB isolation to the incoming signal similar to the building shell.

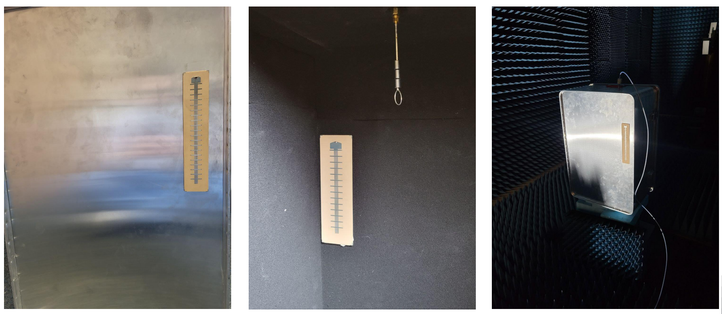


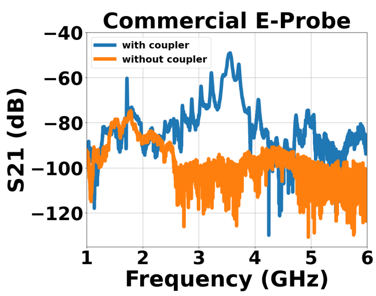
Developing Through Facade Coupler

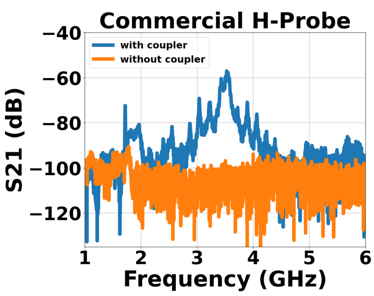
- Microstrip patch array antenna as coupler at 3.55 GHz.
- There is at least 35 dB improvment in measured signal with coupling system at 3.55GHz.

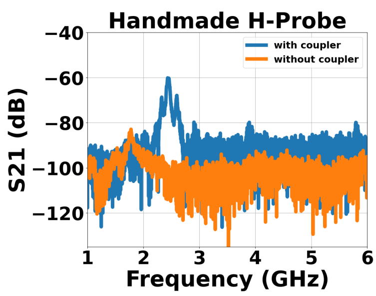


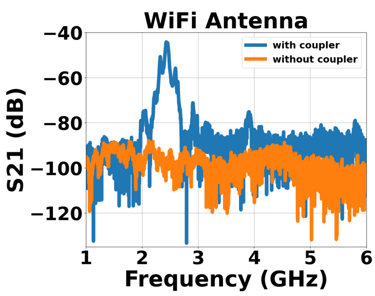
- Metamaterial Periodic Antenna as coupler at 2.44 GHz.
- There is at least 40 dB improvment in measured signal with coupling system at 2.44 GHz.











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