EMF shielding by building materials

Attenuation of microwave band electromagnetic fields by common building materials

The U.S. National Institute of Standards and Technology (NIST) and the University of the German Federal Armed Forces have separately done extensive testing of how well various common building materials can shield (dampen) electromagnetic fields. A wide range of materials and thicknesses were tested, such as bricks, concrete, lumber, drywall, plywood, glass and rebar.

Keywords: *microwave, radio frequency, RF, shielding, building materials, concrete, bricks, window, shielding fabric, shielding paint*

The need for shielding

The ambient levels of microwave radiation have risen exponentially since the mid-1990s and have reached levels where independent scientists are concerned about the public health. There are also people who are hypersensitive to this type of radiation and have acute symptoms at levels common in cities.

Building houses of shielding materials, or shielding existing houses, may be a solution to this public health issue. The problem is to get sufficient shielding, since a reduction (attenuation) of the radiation will often need to be 20 dB (hundredfold) or more.

Microwave frequencies

The tests were conducted for frequencies that cover emissions from cell phone towers, 3G, 4G, some 5G, Wi-Fi, DECT, cordless phones, digital television, GPS, wireless smart meters, baby monitors and many other devices.

The frequency bands used by broadcast radio (AM, FM, shortwave, etc.) and wireless power systems were not covered. Since they are lower frequencies, it is reasonable to expect less shielding of these types of signals than demonstrated in the tests.

The later 5G systems will use higher frequencies than used in these tests. The tested materials will probably shield the 5G signals better than 3G/4G signals, though the higher frequencies are better at penetrating small gaps (holes, slits) in the walls of a house, as well as the holes in shielding fabrics and meshes.

Measuring shielding effectiveness

The effectiveness of a shielding material is how much the radiation is reduced while passing through the material compared to when there is unrestricted passage. This is called attenuation. The result is given in decibels.

Decibels	**Reduction of power density**	**Reduction of field strength**
dB	uW/m^2	V/m
10	10x	3x
20	100x	10x
30	1,000x	32x
40	10,000x	100x
50	100,000x	316x

For protecting humans against EMF, these are the magnitudes that are relevant.

The NIST measurements

The National Institute of Standards and Technology in the United States published their results in a 1997 report titled *Electromagnetic Signal Attenuation in Construction Materials* (report NISTIR 6055). This report is freely available on the web.

The reason NIST did these extensive tests was to prepare for future generations of wireless control systems at construction sites, as well as for tools to measure the thickness of walls. It was not related to protecting the public health against EMF.

In general, these tests show that standard building materials provide poor shielding. Materials such as gypsum drywall, glass and lumber are almost fully transparent to microwave radiation. Even bricks are not a very effective shielding material.

The shielding values do vary with the frequency, with the materials mostly performing better at higher frequencies. However, that is not always the case.

All the numbers in the following tables show the shielding in decibels (dB) at various frequencies.

Concrete

NIST tested eight different concrete mixes, each at three different thicknesses. The concrete was solid and without any reinforcement. The key findings were:

- the attenuation increases with higher frequencies
- the attenuation varies little between the eight mixes
- the attenuation depends directly on the thickness of the concrete

If a concrete wall that shields (attenuates) by 15 dB is doubled in thickness, the wall will then attenuate by 2 x 15 dB = 30 dB.

The measurements also found that thick concrete could provide good shielding, with typically 25 dB attenuation for eight inches (203 mm) at 1 GHz. However, these measurements turned out to be misleading. The samples NIST used were cured for 28 days, but later measurements by Pauli & Moldan in Germany showed that concrete loses some of its ability to absorb microwaves over time. In their experiments they found that 16 cm (6½ inch) concrete attenuates 5 dB less between curing for one month and nine months.

Reinforced concrete

Concrete reinforced with a mesh of steel rebar is not really better than plain concrete. NIST tested two standard mesh sizes (70 mm and 140 mm between rebars) and compared with a concrete wall without rebar. 19 mm (3/4”) thick rebar was used on a 203 mm (8”) thick concrete wall.

Concrete 203 mm (8”)	500 MHz	1 GHz	2 GHz	5 GHz	8 GHz
without rebar	23	27	35	55	73
with rebar 140mm OC	23	27	31	53	68
with rebar 70 mm OC	26	30	37	56	71

The above table shows the attenuation in decibel (dB) for concrete that has cured for 28 days. The attenuation will be less when fully cured.

Concrete blocks

Concrete blocks with hollow cavities inside were tested for walls one, two and three blocks thick. The study did not test the shielding value of the blocks if filled with concrete. It would probably be slightly less than a solid concrete wall of the same thickness.

Masonry block (concrete block)	500 MHz	1 GHz	2 GHz	5 GHz	8 GHz
203 mm (8")	8	12	11	15	18
406 mm (16")	13	17	18	27	30
609 mm (24")	26	28	30	39	39

Lumber

Regular lumber in thickness up to six inches was tested. The wood was either spruce, pine or fir, which are the typical sorts used for construction in North America. Heavier types of wood, such as oak, may have a better shielding effect.

It was found that fresh (moist) lumber provides more shielding than lumber that has aged. This must be because of the water content. The table below is for dry lumber.

Dry lumber	500 MHz	1 GHz	2 GHz	5 GHz	8 GHz
38 mm (1.5")	2	3	3.3	4	4
76 mm (3")	1.5	3	4.7	8	9
152 mm (6")	4.5	6	8.5	20	25

Bricks

Brick walls consisting of one, two or three bricks were tested. Even three courses of bricks do not provide much useful shielding, except at the highest frequencies.

Brick	500 MHz	1 GHz	2 GHz	5 GHz	8 GHz

89 mm (1 brick)	0	3.5	5.5	15	16
178 mm (2 bricks)	3.5	5.5	7.5	32	14
267 mm (3 bricks)	4	7	10.5	32	27

Glass panels

Glass window panels with regular clear glass were tested and found to have very little shielding effect. NIST did not test windows with a metallic coating (low-E), which do provide very significant shielding (see later).

Glass panels	500 MHz	1 GHz	2 GHz	5 GHz	8 GHz
6 mm (1/4")	0	0.8	1.4	1	1.5
13 mm (1/2")	1.2	2.2	3.4	0	1.6

Drywall

Gypsum drywall consists of 85-95% gypsum. The rest is mainly paper and various additives. Drywall has no shielding effect.

Drywall	500 MHz	1 GHz	2 GHz	5 GHz	8 GHz
6 mm (1/4")	0.1	0.3	0.6	0	0.4
13 mm (1/2")	0.1	0.3	0.6	0	0.4

The German measurements

Much more extensive tests of building materials and special shielding materials were done at the University of the German Federal Armed Forces by Peter Pauli and Dietrich Moldan. Their first report was published in 2000 in both English and German.

The same authors have since continued their tests and published expanded versions of the original report. The most recent is from 2015. However, these later versions are available in German only. The data is displayed in large colorful charts that can be interpreted with the help of a German dictionary.

The English version displays data for about 80 different materials while the 2015 German edition lists 150 materials. The materials were tested at frequencies ranging from 100 MHz to 10 GHz using standard test methods (including NATO MILSTD 285 and IEEE 299). The results are largely consistent with the NIST results; however, since these reports are copyrighted we can't display the results.

As mentioned earlier, a major discovery is that concrete provides less shielding once it has cured for nine months, compared to after just one month. (The English version displays data for one-month-old concrete only.) This raises the question of how much humidity influences porous materials. Will they perform as well in dry Phoenix, Arizona as they do in humid Munich, Germany?

Other important results are how well regular sheet metal, aluminum foil and metal-coated (low-E) window glass can shield microwaves — as opposed to bricks, concrete, roof tiles and wood. Much can be done with inexpensive shielding materials.

The reports also cover several materials specifically developed for shielding, including special plasters, gypsum boards, copper-coated wallpaper, shielding fabrics and rigid meshes (netting). Most of these materials were developed by European firms and may not be available elsewhere. The 2015 edition also has a section about shielding paints. The shielding values of these materials vary greatly, with some providing less than 10 dB (tenfold) attenuation while others exceed 50 dB (hundred thousand fold).

In general, the materials using metals (reflective shielding) perform much better than the non-metallic materials (absorptive shielding). The exception is some materials using a type of clay ("lehm"). The clay tests are not in the English version.

Also not in the English version is documentation of how the width of a slit affects the effectiveness of a shield.

The many graphs can be understood well by someone without a good knowledge of German, though a dictionary will be helpful.

The 2015 edition also includes extensive information on how to shield houses. Even though this part has many illustrations, it requires a proficiency in the German language to read.

References

Electromagnetic signal attenuation in construction materials (report NISTR 6055), National Institute of Standards and Technology, 1997.

Reduction and shielding of RF and microwaves: construction materials, screens, wainscots and tissues, Peter Pauli and Dietrich Moldan, 2000.

Reduzierung hochfrequenter strahlung im bauwesen: Baustoffe und Abschirmmaterialien, Peter Pauli und Dietrich Moldan, Berufsverband Deutcher Baubiologen, 2015.

The two German reports can be purchased from Dr. Dietrich Moldan, Am Henkelsee 13, D-97346, Iphofen, Germany.

Other EMF shielding documents

See www.eiwellspring.org/shielding.html

2012 (updated 2017)