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Reflection and transmission properties of common construction materials at 2.4 GHz frequency

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Abstract

Having an adequate shielding from radiofrequency (RF) electromagnetic fields (EMFs) may serve many causes: to protect sensitive electronic equipment from outside interference; to protect the environment from the high radiation generating equipment; to protect humans from excess radiation etc. Strong RF EMFs may be encountered in public domain but especially in occupational settings, where the process and technology of work requires the usage of RF EMFs. Technical measures to reduce the levels of EMFs include using construction materials with attenuation properties. Generally three types of microwave behavior can be observed: transmission, reflection and absorption. In this study the radiofrequency reflection and transmission characteristics of common building materials were investigated. The investigated materials can broadly be divided into three groups: 1) load bearing materials – concrete, aerated concrete, LECA concrete; 2) thermal insulation materials - foamed polystyrene, mineral wool; 3) cover materials – gypsum based plates and wood dust/chips boards. The samples were square shaped, with the size of 300 x 300 mm. The testing frequency was 2.4 GHz and the output power of the generator was 0 dBm. The study used three standard gain horn antennas for reflection and transmission measurements. The results show relatively good transmission properties for most of the materials. The least transmittance was measured in high performance concrete plate where only 34 % of the waves penetrated the material and 35 % were reflected off. Also with low transmission properties are gypsum board and oriented strand board. These materials were also measured to give low reflectance, 17 % by both. Besides concrete, waterproof plywood and particleboard with veneer gave off somewhat reflections. Other materials exhibited very small reflection properties.

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1. Introduction

The electromagnetic fields are an inherent component of the modern environment – also called as an electroclimate. The electromagnetic aspect of the environment has lately gained more attention as new wireless technologies and industrial processes have been developed. With the widespread use of these technologies the exposure levels of electromagnetic fields have raised abruptly and the need for environmental management of this risk factor is becoming more relevant. An option of environmental technology is controlling these fields by certain materials.

Having an adequate shielding from radiofrequency (RF) electromagnetic fields (EMFs) may serve many causes. In case of sensitive electronic equipment is used, interference from environmental RF EMFs may hinder the functioning of these devices. Microwaves can cause electronic interference [1, 2]. Electromagnetic compatibility (EMC) is most important e.g. in hospitals where critical systems are in work. A review study by Boyle looked at electromagnetic interference (EMI) effects of devices on medical electronic instrumentation and found the highest risk of interference to be with two-way radios used by emergency crews, followed by mobile phones [3].

Shielding measures against electromagnetic fields may also serve human safety. In recent time more attention has been paid on the safety from RF EMFs exposure [4]. Strong RF EMFs are encountered in an occupational setting, where processes such as radiofrequency welding, industrial microwave ovens, mobile communication with high power transceivers etc. are done. Strong RF EMF exposure may be titled also to workers at plastic sealers and glue dyers, also with operating or servicing radio/TV transmission equipment and radars [5].

In public domain, the majority of the RF EMFs exposure is contributed to the newly emerged wireless protocols. An overview study of many European countries found the RF exposure from wireless telecommunication technology continuously increasing and contributing more than 65 % of the total exposure [6].

Over 8.6 billion mobile electronic devices are operating at present day – more than the population of the Earth. Since 2010 the number of mobile devices per people worldwide has grown more than 5 times: from 0.29 to 1.62 in 2016 and forecasting up to 2.1 in 2020 [7, 8].

With the development of understanding of health effects from RF EMFs, a conception of risk groups has been introduced. Protecting children from the RF EMFs has been seen as most relevant [9, 10]. In an occupational environment, the new legislative acts define risk groups as female workers being pregnant or workers carrying medical implants [11]. The functionality of active medical implants, e.g. cardiac pacemakers, insulin pumps etc. may be at risk if the electromagnetic field is very strong [12].

Technical measures to reduce the level of EMFs include using construction materials with an attenuation properties that would reduce people's exposure that occupy these premises. Today a variety of building materials exist. Dependent on the composition and the structure of the building materials, these may greatly affect the microwave propagation.

Generally three types of microwave behavior can be observed: transmission, reflection and absorption. Transparent materials have low dielectric loss and microwaves pass through it with little attenuation. From opaque materials microwaves are reflected back and no transmission occurs. Within absorbing materials high dielectric loss causes absorption of microwaves the level of which is dependent on the dielectric loss factor. Absorption is related to transmission and reflection, where both are reduced and the microwave energy is absorbed within the material and converted into heat energy [13–16].

The reflection occurs with the conductive surfaces, where the microwave is reflected from the surface or from the inner layers of the material. The dielectric constant and the dielectric loss factor quantify the capacitive and conductive components of the dielectric response of the material [14].

Traditionally, conductive materials, such as Aluminum have been used for radiofrequency shielding applications. However, such conductive materials create a Faraday gage inside of which higher frequency electromagnetic fields will have countless of reflections which may hinder the connectivity of wireless devices and increase people's