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Absorption And Shielding of Electromagnetic Waves by using Additional Air Grille "ZZ" Applied to HVAC Systems.

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Abstract—Recently, considerable attention has been paid to the design and development of highly efficient electromagnetic waves absorbing materials due to the increasing demand from civil, commercial and military applications. The paper is directed to develop an air grille with high absorption, shielding capacity and suitable size. The developed air grille ZZ structure consists of perforated stainless steel plate 50 cm × 50 cm with holes of diameter 4 mm symmetric shape and AL aluminum frame 60 cm × 60 cm with a NICR nickel chrome tubes filled with PB. ZZ grille has been developed in order to combine high absorption, shielding and control of electromagnetic waves radiation. The large electromagnetic absorption and shielding are attained by simultaneously choosing the reflection and transmission, which depends on effective material properties, requires an average dielectric constant and conductivity around 1 S/m, which is the SI unit of conductivity is Siemens per meter. The ZZ grille also has high stiffness versus density performance.

Index Terms—EM absorption; EM shielding; ZZ grille; HVAC absorption grille; Natural materials; Metamaterials ; Absorption and shielding index .

1. Introduction

Electromagnetic (EM) absorption and shielding is becoming a key issue in many areas. Recently, considerable attention has been paid to the design and development of highly efficient EM wave absorbing and shielding devices. Such devices performance become constant requirement to have healthy zone for the protection of life specially in the control rooms used for civil and military applications. Often, a metallic surface is used simply to reflect the EM radiation from the system of interest or to maintain safe EM field inside a closed zone. Sometimes, a true reduction of the radiated EM power, Up to full absorption, is needed, e.g. at control rooms when self-reflection of the waves in a package affects the operation of the devices.

The objective of this paper is to design an additional air grille suitable for absorption and shielding of electromagnetic waves radiated by HVAC systems. Also the paper describes the processing of such air grilled design which combine acceptable shape, light weight with adequate stiffness and high EM absorption.

2. Review

Bollen , P. et al. [1] developed a sandwich structure involving a honeycomb core filled with a carbon nanotube-reinforced polymer foam and glass fiber with reinforced composite face sheets in order to combine high electromagnetic absorption and high mechanical performance. The large electromagnetic absorption is attained by simultaneously minimizing the reflection and transmission, which, in terms of effective material properties, requires a low dielectric constant and conductivity around 1 S/m, Figure 1. The sandwich structure offers also high stiffness versus density performance.

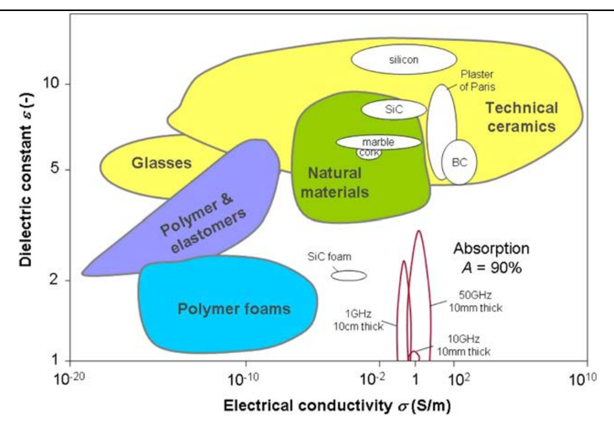

Fig. 1 Schematic chart of dielectric constant vs. electrical conductivity

Figure 1 presents a schematic chart of different families of materials showing the relation between the material dialectic constant and its electrical conductivity and with identifying the optimum region for high EM absorption. Also quantitate contours of iso-90% absorption are given for different material thicknesses.

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Qing, Z. et al. [2] designed a new hierarchical radar absorbing structure RAS with multifunction of ultra-light weight and anti-crushing made by glass fiber reinforced lattice composites filled with radar absorbing foams. Experiments were performed to reveal the electromagnetic absorption and anti-crushing behaviors. Mechanisms of the composite in electromagnetic absorption and anti-crushing were analyzed.

The newly designed composite lattice displays excellent performances in absorbing both microwave and mechanical energies at ultra-light weight. To balance the anti-crushing and radar absorption behaviors, key factors of the composite lattices, including the panel thickness, the relative density of the lattice, the cell dimension and the geometry, were revealed based on the analysis and experiments. They found that Panel thickness and cell dimension are the most significant parameters in radar absorbing performance of the RAS. Required performances become better with greater thickness and larger cell dimensions. Panel thickness and cell dimension also determine the strength and the mechanical energy absorptions. With hierarchical structures, the designed panels have excellent mechanical behaviors.

Yujin Chen. et al. .[3] reviewed the researches using the graphene based hetronano-structures to attenuate EM wave energy, whereas this materials exhibited very good EM absorption properties. They found that there are no publications concerning the EM absorption properties of G/Fe Nano composite. Therefore, they Fabricated Graphene /Fe Nano composites with enhanced EM absorption properties by a facile and green method. The obtained minimum reflection loss reached -31.5 dB at 14.2 GHz for the absorber thickness of 2.5 mm while the reflection loss was below -15 dB at frequency up to 0.9 GHz for the absorber thickness of 2 - 5 mm. They concluded that the deposition of magnetic nanostructures on the surface of Graphene was an efficient way to fabricate lightweight materials for applications in the EM absorption field.

Kebin F.,and Willie J. [4] provided an overview of the progress of electrical , mechanical , thermal and optical control of metamaterials with providing and outlook on their future prospects and applications. The electromagnetic materials (metamaterials) are artificial material which were fashioned to permit full access to a specific/any theoretically response, (i.e. tunable material) . The advent of metamaterials has created a new era for an electromagnetic materials designers with novel responses ranging from negative refractive index, super lensing , perfect absorption and cloaking. Metamaterials consist of unit cells in micro and microscopic scales designed to yield a specific response to EM waves. Therefore, their responses are derived from the geometry of unit cells, as opposed to their chemical composition. Finally the ability to modify the metamaterials exotic electromagnetic response in real time would enable metamaterials to transition into state of the art devices.

Rifai, A.B., andHakami, M.A. [5] investigated the effect of electromagnetic radiation from high voltage electric lines in inhabited area in an urban environment. Their measurement results in test locations gave benchmarked values against recommended safety levels. They are surveyed the electromagnetic radiation (EMR) resulted from huge electromagnetic fields (EMFs) called "e-smog". EMR is categorized by frequency and falls into two types: nonionizing in the low level radiation (up to 10^{16} Hz) e.g. power light, radio and TV frequencies, microwaves , visible light and ultraviolet. and ionizing (>10^{16} Hz) eg. X-rays, Gamma, rays….

The non-ionizing sources have low level radiation, "mistakenly" perceived as harmless to humans. However electrical and magnetic equipment cause e-smog and produce invisible EMFs and EMR that constantly attack the human body affecting its bio field which can be summarized as :

- Static electric field from synthetic materials makes human fell unwell.
- Residual magnetism from metals in the bed causes body discomfort.
- Power frequency fields from all wiring electrical outlets, extension cords and other appliances affect the ability of human cells to communicate with each other.
- Power frequency magnetic fields due to faults in wiring and electrical panel boxes
- Radio Communication frequency fields that include radio, TV, cordless phones, wireless devices cell phones and communication towers.
- Radioactivity and its by product radon gas , which enters homes from building materials such as granite (one-third of the granite is radioactive) and radon gas is emitted from the ground.

The effect of exposure to EMF's on the body and cells depends on the EMF frequency and strength. at low frequency the EMF' pass through the body while at radio frequencies the fields are partially absorbed and penetrate only a short depth into the tissue and may cause electric current to flow in the body. Low frequency magnetic fields induce circulating currents within the body, whereas their strength depends on the external magnetic field and the current flow loop size. When large enough can cause excitation of nerves and muscles. Also e-smog creates an artificial stress situation in the bio-system, which affects the metabolism as well as hormone production. Two more well know biological impacts of e-smog are the interruption of the main brain wave pattern leading to behavioral complications and the interferes with the body's communication system leading to unusual neurological function such as chronic fatigue syndrome and fibromyalgia.

Finally, they concluded the EMR causes harmful effects on human health in an accumulative manner increasing overtime and with the doze strength. Children, pregnant women, elders and those with poor health condition are especially at risk for a lifetime of exposure.

3. ZZ GRILLE DESIGN CONCEPT

The absorption and shielding capacity A, defined as the ratio

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of the absorbed and shielding power to the input power, depends, in addition to the size, on the effective dielectric constant e_{eff} and on the effective electrical conductivity $r$eff of the material or System. The analysis of the closed-form expression for the absorption A mentioned in [1] has shown that the best absorption is attained when e_{eff} is as small as possible (hence, ideally equal to 1) and when r_{eff} is between 0.1 and 10 S/m for frequencies between 1 and 100 GHz. The Optimum value of r_{eff} depends on the exact value of the frequency. For lower frequencies, the grille Size must be quite large to achieve, for instance, 90% EM absorption: Size of 10 cm x10 cm and 100 cm x 100 cm are required to Absorb 90% of the incoming power at frequencies of 1and 0.1 GHz, respectively, Figure.1

The ZZ grille conceptual design is based on selecting suitable geometrical shape computable with the HAVC grilles with holes of optimum diameter related EM absorption with minimum thickness to reach lightweight.

Then the stiffness of Stainless Steel perforated sheet is increased by using NICR hollow tubes at its periphery. Then the NICR tubes are to be filled with PB as material of good EM wave absorbing and shielding properties. All these parts are assembled on aluminum frame

3.1. PROCESSING OF THE ARCHITECTURE MATERIALS

Several steps is followed to processes the ZZ grille. The first step is the selection of 0.4 mm thickness, Stainless Steel 304 sheet 50cm× 50 cm. The second step is the manufacturing of 4 mm symmetrical holes with 4 mm pitch which is done by plasma machine. The third step is fixing the perforated Stainless Steel sheet in Aluminum frame 60 cm × 60 cm, Figure 2.

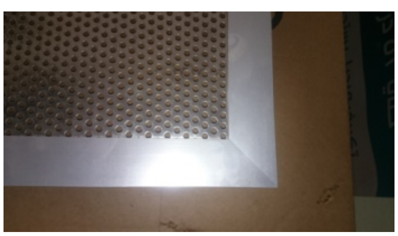

Fig. 2 Assembled SS sheet in Al frame

The forth step is selecting the diameter and length of NICR tubes which has 3/8'' (9.5 mm) diameter length 40 cm. The fifth step is filling the tubes with melted PB and closing its ends with polymer end caps, Figure 3.

Fig. 3 NICR tubes filled with PB

The last step is fixing the NICR Tubes to SS perforated sheet by NICR wire Figure 4.

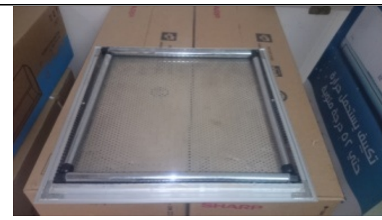

Fig. 4 Fixation of NICR tubes with grille

Figure 5. Shows the complete ZZ grille assembly

Fig. 5 ZZ grille assembly

The use of ZZ grille structures with various materials is a possible way to optimize the EM absorption and shielding for applications involving protection against a wide range of frequencies. However, as explained above, EM absorption for frequencies below 1 GHz requires panels thicker than 4 mm, as well as cell sizes larger than 30cm x 30 cm. Therefore, the metamaterials ideas are used in ZZ grille design concept to make thinner absorbing and shielding materials in the low-frequency range. In that case, the aim is to select a material that provides optimum absorption and shielding.

EM absorption requires shielding both the reflection and the transmission of the wave [6 - 12].

The need for an architecture/hybrid material solution naturally emerges at ZZ grille. The strategy followed is to build ZZ grille architecture relies on a natural material in order to start with a small dielectric constant, hence an average reflectivity. In order to reach the expected electrical conductivity, around 1 S/m, the NICR TUBES is filled with an amount of PB. However, in parallel to the increase in the electrical conductivity, the dielectric constant also increases due to the presence of the PB at NICR tubes.

This material naturally possesses the main advantages of PB tubes, i.e. average density and good thermal insulation. The face sheets must be selected so that they do not adversely affect the EM absorption and shielding. In order to improve the mechanical properties, the PB TUBES is introduced into a me-

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tallic NICR TUBES structure.

4. Electromagnetic Absorption Measuring and Evaluation

The developed ZZ grille EM performance is measured and evaluated using a Vector Network Analyzer (R&S. ZVA 40) which is calibrated and traceable to SI units with a type 3.5 mm calibration kit (Aglient 5052c) , Figure 6.

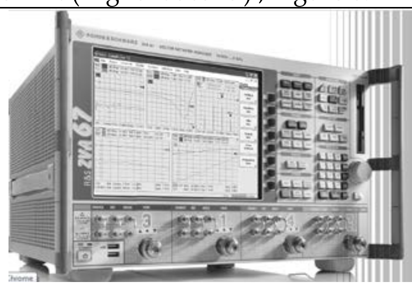

Fig. 6 Vector Network Analyzer

The scattering parameters (or S-parameters), phase and magnitude, are measured as a characteristic of the device connected between the two ports: $|S11|^2$ corresponds to the power reflected back at port 1, while $|S21|^2$ is related to the power transmitted from port 1 to port 2, through the device. After eliminating the influence of feeding probes on the S-parameters through calibration, the ratio of the power absorbed by the sample under test (Pabs) to the incident power (Pin) can be thus calculated as : $P_{abs}/P_{in} = A = 1 - |S11|^2 - |S12|^2$.

Measuring procedure is done under the following conditions:

- Three hours storage at ambient temperature followed by 90 minutes warm-up operation
- Specified environmental conditions met
- Recommended calibration interval adhered to stander

Figure 7 shows the variation of the absorption and shielding index A as a function of the frequency with coordinates(x,y,z) equal to (0,0,0), point 1, for ZZ grille. The measured A values in the range of frequencies from 8.5 to 12 GHz range have the values from 0.915 to 0.967 which is larger than than the prescribed value (90 %).

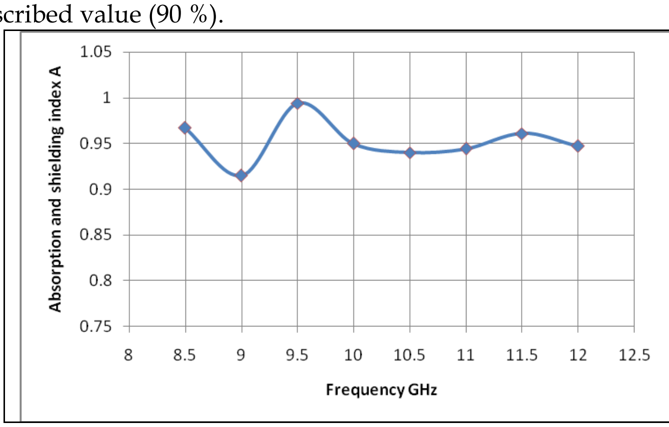

Fig. 7 Variation of absorption and shielding index A as a function of the frequency at point 1

Also the measured index A of the ZZ grille is done for the following points (2, 3, 4, and 5) having the coordinates (x,y,z) equal to (20,0,0) ,(0,20,20) , (0,0,20) (0,0, -20) respectively .
The results of measurements are shown in Figure 8 together with the first point (0,0,0) .
The measured index A for the first three points 1,2,3 of the measured five points achieves vales larger than a prescribed values Iso-90%. While the other 2 points at some frequencies greater than 10.5 GHz, the index A reach a lower value than 90 % with a minimum round 80 % .

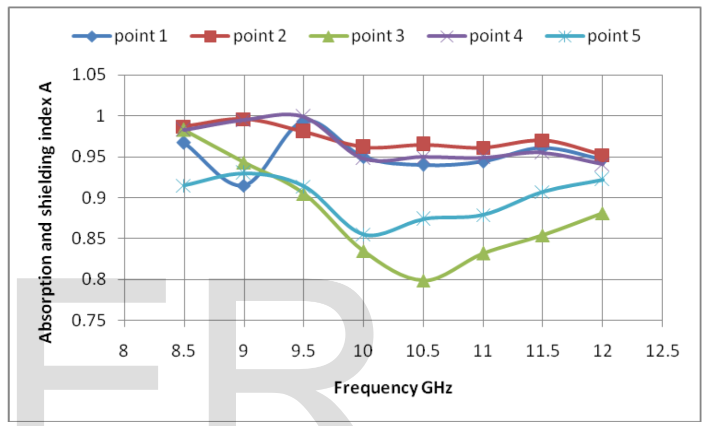

Fig. 8 Variation of absorption and shielding index A as a function of the frequency at points 1, 2,3,4,5.

Numerous parameters can be modified to achieve the optimum EM absorption and shielding level and that several sets of parameters: ZZ size, frame thickness and shape, percentage of PB at NICR tubes to attain the optimum absorption.
Therefore, a wide flexibility exists to optimize simultaneously the ZZ grille performance.

Here the first steps towards optimizing the mechanical and EM performance have been undertaken based on the production of a first generation of ZZ grille.

5. Conclusion

A versatile multifunctional EM-absorbing shielding ZZ grille has been designed; manufactured and tested the developed grille structure is based on hybrid materials structure solution, which gives excellent EM and mechanical performance.

Finally, the developed ZZ grille seems to be highly positive mean for EM waves absorption and shielding, along wide range of frequencies.

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The optimization of the developed ZZ grille EM absorption and shielding performance would be our next target to adapt its performance towards the required goal.

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