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The Development of Complex Coating Shape for Energy-Saving Glass using Harmony Search Algorithm

A A.S.Shibghatullah [1], Nor Fadilah Rahamad [2], Farah Ayuni Azmin [3]

[1,2,3] *Optimization, Modelling, Analysis, Simulation and Scheduling (OptiMASS) Research Group, Faculty of Information and Communication Technology,*
3Faculty of Electronics & Computer Engineering,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal, Melaka, Malaysia

Abstract

Frequency Selective Surface (FSS) is any surface that acts like spatial filter for electromagnetic wave and often used in indoors environment such as energy saving glass. Attenuation of GMS, GPS and personal communication signal leads to poor communication inside the building using regular shape of energy saving glass coating. Previous study has been applied to find out the optimum design of one unit cell coating structure of energy saving glass. The optimization method base on Harmony Search (HS) is used in this project to develop the complex shape of energy-saving glass by obtaining an improved return loss and transmission of signals. Computer Simulation Tools (CST) Microwave Studio Software will be used to design and simulate the unit cell of energy-saving glass. The complex shape of energy saving glass coating structure is obtained to reduce return loss and improved transmission coefficient.

Keywords: Frequency selective surface, energy saving glass, harmony search

Introduction

Nowadays, frequency selective surface has become popular application because its characteristic such as bandwidth, transfer function and the angle stability are determine by many critical parameters such as array periodicity, unit cell's pattern, element geometry size, property of dielectric substrate and others. FSS is said to be spatial filter which are some of the frequency band are transmitted and some of them are reflected when it exposed to electromagnetic wave and its often used in energy saving glass, body radar, dichroic glass, stealth aircraft, indoors environment and etc. Glass window such as energy-saving glass has become popular in modern building and vehicles. It was proven to be very useful to maintain the temperature level inside the building or vehicles. This technology falls under the Green Technology category for it helps on contribute saving the energy in building or vehicles.

This energy-saving glass use FSS application by applying a very thin coating of metallic-oxide on one side of ordinary float glass because the coating blocks the infrared radiation due to heat from outside of the building and transparent to the visible light (G, I, Kiani, et, al., 2010). The attenuated of useful signals of wireless communication systems

such as global positioning system (GPS), mobile communication system (GSM,UMTS,3G), wireless network (Wi-Fi) , wireless broadband (WiMax,LTE) and WLAN are the major problem using energy saving glass even though this glass play role of saving the energy. Thus, its limit the efficiency of energy saving glass function in wireless communication and microwave signals.

Problem Statement

The presence of metallic oxide coating cause energy saving glass panels attenuation of useful signal such as Wi-Fi, GSM, GPS and personal communication. This problem occur because the useful signals cannot penetrate into the glass due to the coating structure of the glass window that reflect the signal from letting pass through building. This may lead to the low bandwidth. To increase the signals strength, network devices also can be used but this will cause some budget to add on and it is no longer energy saving glass as it still need to cover the electricity cost.

Nevertheless, Most of the current studies show that regular shape of frequency selective surface has been use as an application for energy saving glass. According to current study, the transmission of signals improves when 10% of coating area is being removed and one of the regular shape cross dipole show that the transmission loss at 25 dB (G. I. Kianni et. al., 2011). The bigger size of coating etched part, the better efficiency of transmission signals. Hence to deal with this problem, complex shape of frequency selective surface is introduce so that the transmission coefficient will be improve and the loss can be reduce.
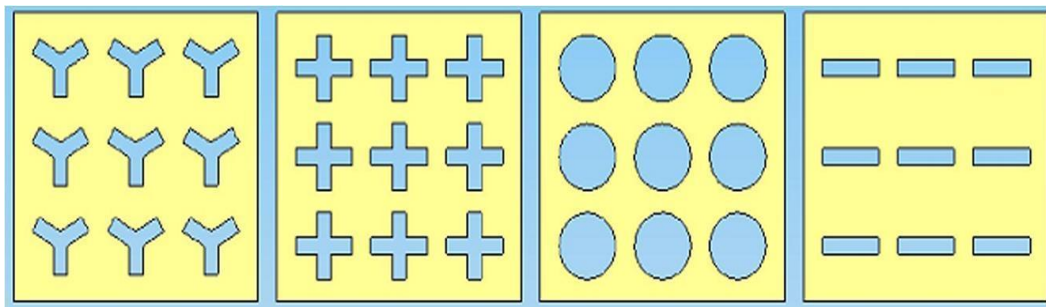

Figure 2: Regular shape of frequency selective surface

In addition, the past research, genetic algorithm (GA) and particle swarm optimization (PSO) has been widely used for optimization problem. Both this algorithm also has been use to solve this problem and also have its own strength to find optimal solution. New metaheuristic algorithm, Harmony Search is introduced as an optimization on this problem. Harmony Search (HS) is the improvisation process of musician. During which, each musician plays a note for finding the best harmony all together. In this algorithm, binary harmony search is being use due to the representation of this problem in binary string. Individual selection strategy and NOT gate was introduced as a strategy to improvise the harmony and as an operator for pitch adjustment.

Thus, this issue will be investigate and analyse to develop the coating structure of energy saving glass. The existing simulation software which is CST microwave studio software will be implementing to test and see the performance of complex shape of FSS.

Existing System

FSS is said to be spatial filter which are some of the frequency band are transmitted and some of it are reflected when it exposed to electromagnetic wave. The FSS has been applied on building like prison or hospitals where restricted of mobile phone usage is required for secure building applications (Roberts et al. 2012). Due to FSS characteristic such as typically narrow band, phase feature, angle stability, and fabricated in two-dimension periodic array of metallic elements with specific geometry shape. Some element geometries of FSS are dipole, square patch, circular patch, cross and Jerusalem cross (Mittra et al. 1988).

Nowadays, energy saving glass has become popular in modern building design as it can maintain the temperature level inside the building (Rafique et all. 2011). The thin coating of metallic-oxide that applies on energy saving glass has blocked the infrared radiation due to heat from the outside of the building. In addition, the regular shape are coated on energy saving glass which is the coating like filter where coating part are reflected part while etched part left, is where the transmission of signals are allowed to pass through (Johar et all. 2014). This regular shape of FSS has been coated on glass window like low-emissivity glass or energy saving glass. Current study shows that cross-dipole example, transmission of signals loss at 25 dB. (G. I. Kianni et. al., 2011)

In addition, the problem of energy saving glass criterion restrict certain amount of useful signals such as GPS, GMS, personal communication signals, wireless network (Wi-Fi), WLAN , and wireless broadband (LTE) (Ullah et all. 2011). Current study show Genetic algorithm (GA) is widely used as anoptimization method to solve this problem and Particle Swarm optimization (PSO) combine with FDTD technique also has been applied in designing frequency selective surface. Hence, Harmony Search (HS) optimization method will be used in this project as new approach of optimization method. Recently study shows that, Harmony Search algorithm was being use for an optimization method. Its solve some problem on scheduling problem, satellite heat pipe design, university course timetabling, Tetris agent optimization and other problem. Even though, Harmony Search is one of the new metaheuristic algorithms, it also has been widely array of real-life optimization method because it can employ some degree of randomness in searching for a solution (Romero et al. 2011).
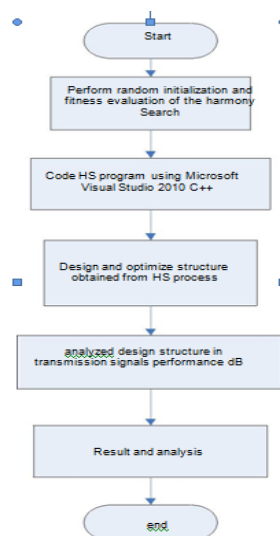
Design Methodology

Figure 1: General Process

Figure 1 shows the process of this project, which to develop the complex shape of FSS. According to this flowchart, an optimal base in Harmony search that inspire from musician is used in this project to help in designing the coating structure. Harmony search is used because it can consider all existing vector rather than only two parents. In addition, it also not sensitive to initial values and faster convergence. However, harmony search usage is similar to genetic algorithm which is to find best fitness values while harmony search was called to find the best harmony together. Nevertheless, HS proposed approach with the application of improved return loss and transmission coefficient. The CST microwave studio will be used to design and to test the result of the coating structure.

This paper will design method a complex shape of coating on an energy saving glass based on previous study and experiment. In this project harmony search (HS) optimization method is introduced to help in the design process. As this project will be using a set of binary which is '0' and '1', adaptive binary harmony search (ABHS) method will be implemented. The current study shows that, adaptive binary harmony search (ABHS) uses two strategies to make improvisation in knapsack problem that represent in binary bits. The two strategies that have been used are binary selection strategy and individual selection strategy (Wang et al. 2013). In the discrete binary harmony search (DBHS), NOT gate is being used as pitch adjustment because the binary optimization problem only has two value '0' or '1'(Geem 2005). HS will optimize the complex shape according to its step which are initialized the algorithm parameter and harmony memory, improvising new harmony, updating the harmony memory and checking the termination criterion.

HS is implemented to randomly generate a set of 100-bits binary and selecting the best harmony from harmony memory. To verify the effectiveness of selecting the harmony, the result will be tested by measuring the transmission coefficient and return loss. Encoded into pixel of 100 bits binary number it represents as coated in binary 1, and uncoated as binary 0. The HS operation applied with constraint state as 40% of coated side and 60% of uncoated side which is 40 bits coated and 60 bits uncoated. Thus, uncoated part must be continued side to produce good results. However, continued bit-0 is too long is not good either. To find a good result, the fitness function below will be used in this project.

Fitness Function

Equations of fitness function as shown in Equation (1) below.

a= number of occurrences of the "0"
b= number of occurrences of the
"00" c= number of occurrences of
the "000"
d= number of occurrences of the "0000"
e= number of occurrences of the "00000" or more

I= value for "0"	i = 1 point
j= value for "00"	j = 2 points
k= value for "000"	k = 3 points
l= value for "0000"	l = 2 points
m= value for "00000"	m = 1 point

$$\sum a.i + b.j + c.k + d.l + e.m$$

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Maximize f(x) =   (1)

Operator such as improvise harmony and update harmony memory will determine the best and optimum result. This research aims to develop the complex shape of coating structure of energy saving glass as well as to improve the transmission coefficient and reduce return loss inside the building.

System Design

Input	Process	Output	Simulation and result
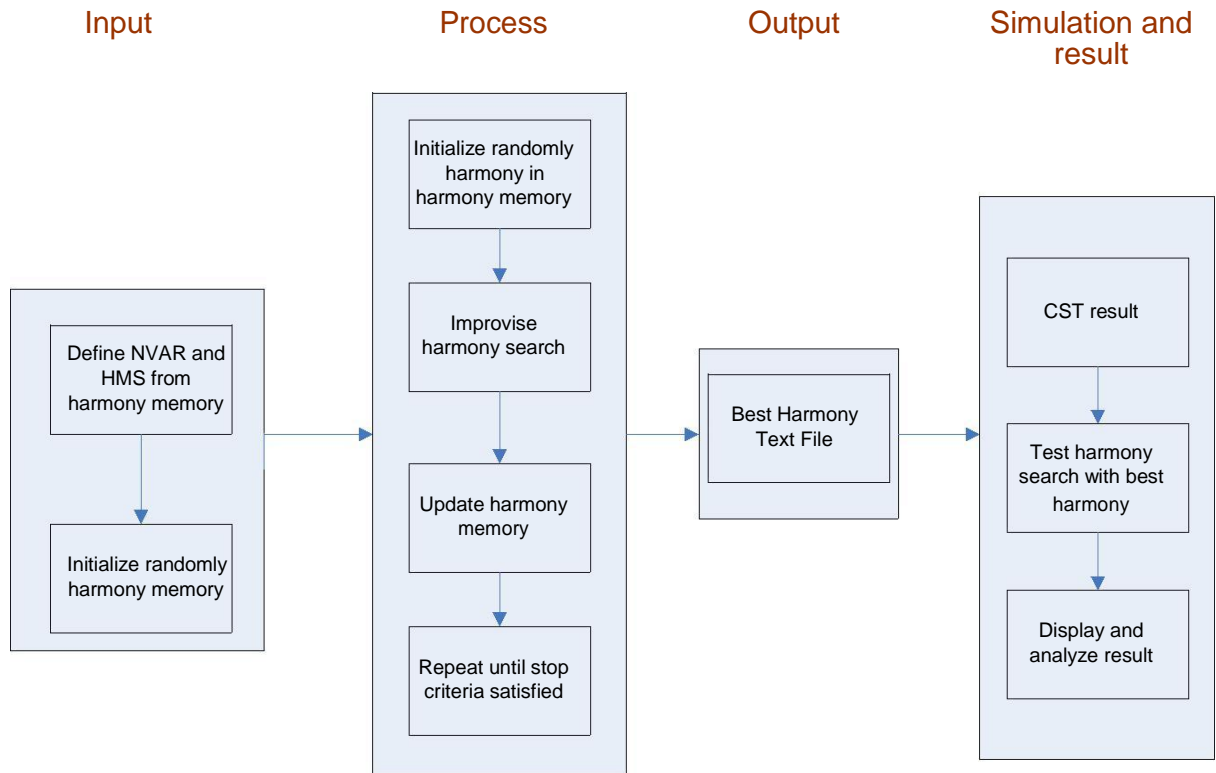
Figure 3: Detailed Design

Result

Table 1 below shows the results obtained from the simulation by using HS. The best fitness is 49, later the best harmony design will be simulated using Computer Simulation Technology to find its return loss and transmission coefficient

Table 1:
The results after 50 iterations

Iteration	50
No of variable/ NVAR	100
Harmony Memory Consideration rule/HMCR	0.8
Pitch Adjusting Rate/PAR	0.3
Best Fitness/Best Harmony	49
Best Harmony	01010000011000100001110000101000011110010011010000010000000100101010010100010111100111110001

| 01100011 |

Conclusion

The development of complex shape coating for energy saving glass with the method of harmony search optimization has been used in this project. Other methods such as PSO, GA, Ant colony or other metaheuristic method also can be used in order to develop new coating structure. A lot of variation using pre-existing numerical method can be applied and joined with HS to come out with a unique design for many purpose of application.

Acknowledgements

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