Reflection and Absorption Characteristics of Electromagnetic Waves by PV Modules

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Abstract

The purpose of this study is developing PV modules absorbing electromagnetic waves.

In Japan, a lot of urban high-rise buildings stand in towns, for this reason, "Picture ghosting" occurs remarkably, which is generated by electromagnetic waves reflected at walls of buildings. In order to prevent this issue, the authors suggest that PV modules, which are used as outer walls of the buildings, have characteristics of absorbing electromagnetic waves. The method of absorbing is PV modules have characteristics of reciving antennas. In this papar, the authors explain the antenna characteristics of the PV module, which have a structure of Loop-antenna in itself (CL Module)

By changing the arrangement and wiring cells, the loop length is formed in CL module. The antenna potential of CL Module was simulated by FDTD method. As a result, the gain was bigger than normal antennas, and the radiation pattern of the antenna was improved in such a way that the terminal was set at the center of feeding edge. This radiation pattern is available to solve electromagnetic wavess issues couse at walls of the buildings.

For the future, the authords will design and analyze the most appropriate wiring cells as regard to antenna characteristics and electricity generated by the PV module.

Keywords: Picture ghosting, FDTD method, Loop-antenna, CL module

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1. Introduction

"Picture ghosting" is one of various TV waves obstacles, which is generated by time gap of direct waves from a TV waves tower and waves reflected at walls of buildings. In Japan, a lot of urban high-rise bhildings stand in towns, therefore, various reflective waves are generated and the TV interference occurs remarkably. The cost of countermeasure for this phenomenon is very high, for example, wave absorbers are set at walls of the buildings. For this reason, the solution of this issue is delayed. On the other hand, concerning natural energy, photovoltaic (PV) modules have been spread because of rising international consciousness to “Warming phenomenon”. Especially, in Japan, PV modules are increasing to use as outer walls for reason of aesthetic value, durability, easy maintenance, needless to say, and reducing cost. The authors have attention to these circumstances and suggest the method of preventing “Picture ghosting” by PV modules. The purpose of this study is designing and developing the PV modules absorbing TV waves. The Solution of the electromagnetic waves issue by using PV modules is to give another added values and contributes to spread the PV systems.

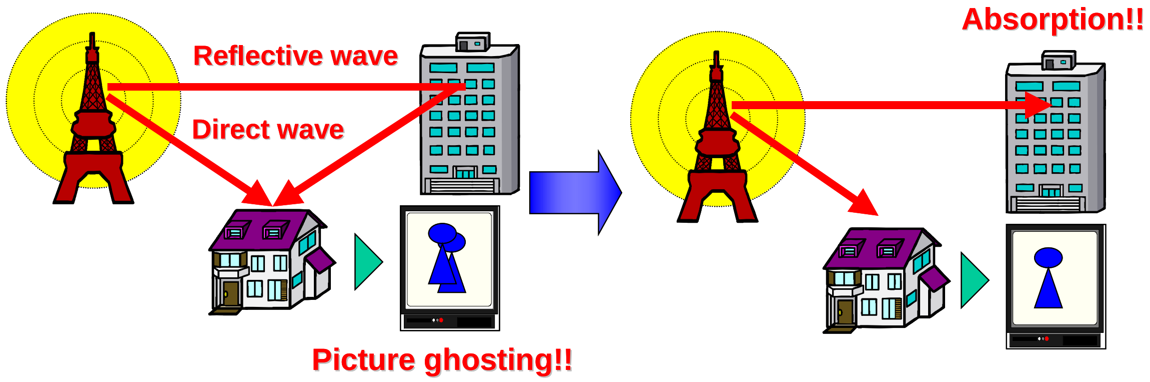


Fig.1 Fundamental principal of “Picture ghosting”.

2. The absorption method by the CL Module

PV modules should have characteristics of receiving antennas due to prevent “Picture ghosting” itself. As adding the structure of antennas to PV modules, Loop-antenna was adopted considering gain, radiation pattern and the relation of the target frequency to the size of cells. Loop-antenna shows a good receiving performance on the condition that the loop length is equal to the wavelength of the target electromagnetic waves. Therefore, by changing the arrangement and wiring cells, the loop lengh is formed in the PV modules, and they had characteristics of Loop-antenna (CL Module ; Cell Loop Module).

In Japan, VHF band is used as TV waves. The frequency band is 100 to 200MHz, changing to wavelength, 1.5 to 3m. In order to match to the target frequency, additionally considering the dielectric constant of EVA, CL Module has 1.2m loop length which consists of eight cells (The size of edge is 15cm ; 15cm *8 = 1.2m).

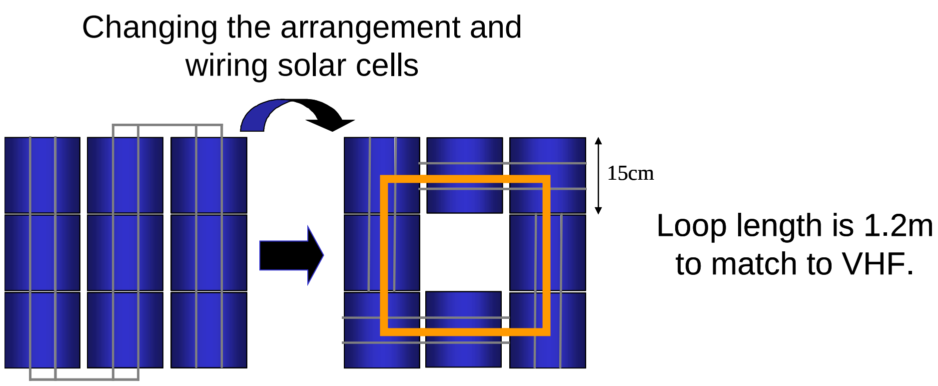


Fig.2 CL Module

3. Analysis by FDTD method

3.1 FDTD method

On this present study, FDTD method was used due to analyze CL module.

As a method of computing electromagnetic, Moment method and Finite element method have been used. Recently, FDTD (Finite Difference Time Domain method) method is used generally, which is analyzing electromagnetic in time domain by differing Maxwell’s equations.

Maxwell’s equations are shown below.

$$\nabla \times E(r,t) = -\frac{\partial B(r,t)}{\partial t} \tag{1}$$

$$\nabla \times H(r,t) = -\frac{\partial D(r,t)}{\partial t} + J(r,t) \tag{2}$$

The analysis environment of FDTD method and the flow chart are shown at Fig.3 and Fig.4. First step, analysis field is prepared surrounding wave sources and scatterers, and divided into a lot of minute rectangular solids (cell). Second step, some kinds of medium constants are given to each of cell, and Maxwell’s equations are formulated. Finally, electromagnetic is analyzed by computing the formulated equation in time domain. Additionally, the analysis environment of FDTD method is closed. Therefore, a virtual boundary (Absorbing boundary condition) must be set in order not to cause reflected waves at outer walls of the analysis environment.

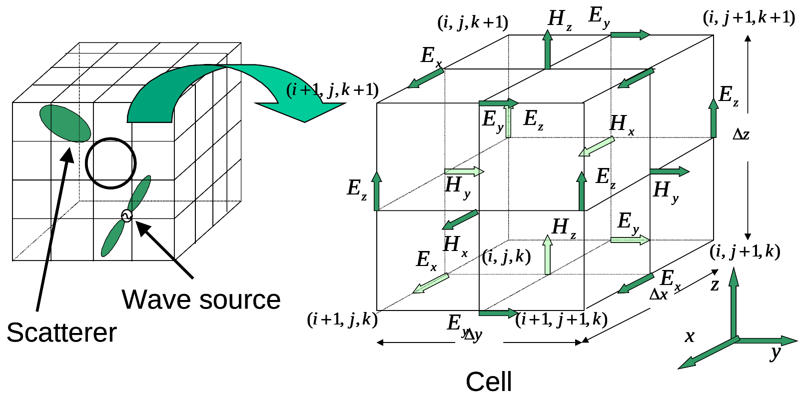


Fig.3 Analysis environment of FDTD method

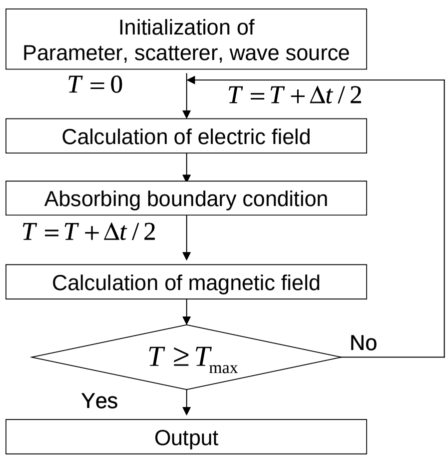


Fig.4 Flow chart

3.2 Characteristic of Antenna

<u>Antenna Impedance</u>

Feeding voltage $V(t)$, feeding current $I(t)$, are Fourier transformed, $V(\omega)$, $I(\omega)$. Antenna impedance is shown below.

$$Z_{in}(\omega) = \frac{V(\omega)}{I(\omega)} \tag{3}$$

The impedance seen looking into the terminals of an antenna is an important parameter that needs to be known in order to design a network that will provide a conjugate impedance match to the transmission line. The condition that reactance is zero is called resonance, in which case the antenna can be connected directly to a transmission line with a characteristic impedance equal to radiation resistance.

Additionally, resistance of impedance is called radiation resistance. It is that equivalent resistance which would dissipate the same amount of power as the antenna radiates when the current in that resistance equals the input current at the antenna terminals.

<u>Gain and Radiation pattern</u>

Gain is indicative of efficiency of an antenna. Gain is defined as a ratio of the electric power density of the maximum emission direction of an antenna and isotopic wave source.

$$Gain = \frac{ElectricPowerDensityOfAntenna}{ElectricPowerDensityOfIsotopicWaveSource} \tag{4}$$

Therefore, this antenna radiates electromagnetic waves which is G times electric power than input at the terminal.

Additionally, Radiation pattern is a map, which enable to confirm directions of radiated electromagnetic waves. Gain in the radiation pattern is ratios of electric field strength of various direction and the maximum emission direction. The E-plane pattern of a normal Loop-Antenna is shown in Fig 6. The antenna receives electromagnetic waves from various directions paralleling groud. Therefore, PV Modules should have the recieving performance of the normal Loop-antenna, for the solution of electromagnetic waves issue by setting PV Molules on walls of buildings.

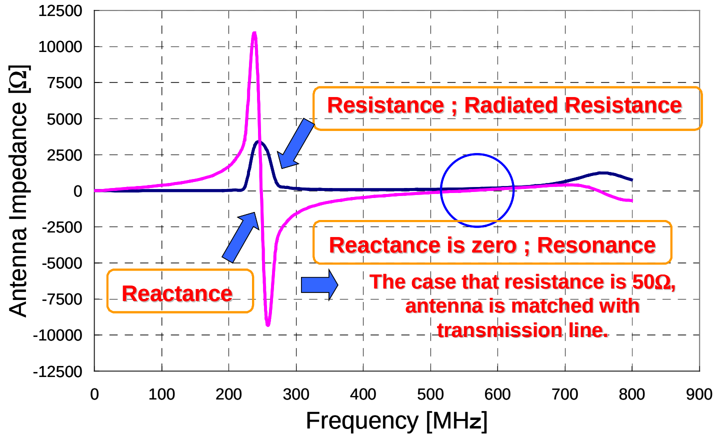


Fig.5 Antenna impedance of Loop-Antenna.

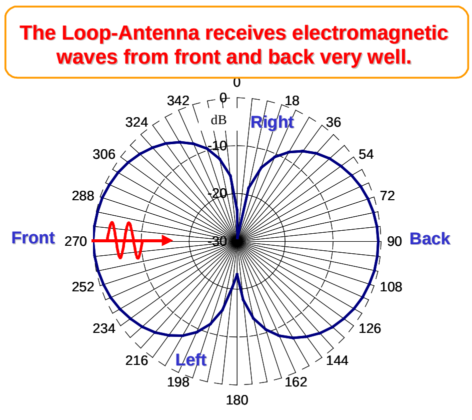


Fig.6 Radiation pattern of Loop-Antenna.

3.3 Analysis of the CL Module

The modeling and analysis environment of CL Module is shown in Fig 7(a). The analysis model was assumed that solar cells are conductance, and the other components which include the glass, EVA, the flame, and back sheet, are neglected in order to evaluate the characteristic of the antenna, which consists of only cells and electrical conducting ribbons. In addition, the model was smaller than really size of CL Module for reason of a relation of the analysis environment to performance of computer. In this case, CL Module was designed that the loop length is 50cm; therefore, the prospective resonance frequency is 600MHz. As s result, the tendency as below was performed.

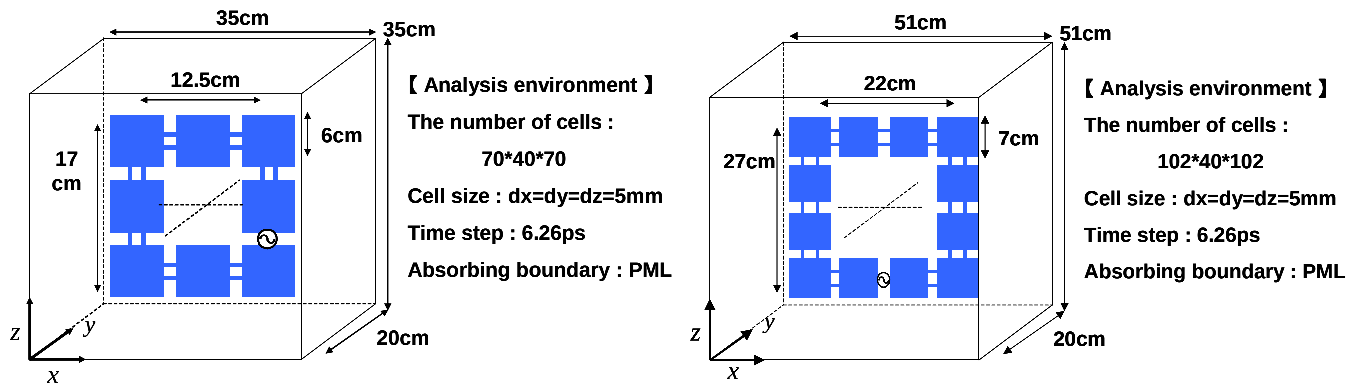
- The resonance frequency is 636MHz. The resultant wavelength of resonance frequency is equal to the minimum loop length which consists of cells and the electric conducting ribbons.
- Gain is 7.0dB, which is bigger than the normal Loop-Antenna (2.75dB).

The result of the radiation pattern (E-plane pattern) is shown in Fig 10(a). The electromagnetic waves from front is not received very well, and the gain of the horizontal direction is lower than the normal Loop-Antenna. For the solution of this issue, the characteristics is not available in this case. The reason is that the terminal of the CL module is not set at the center of the feeding edge. Characteristics of radiation pattern is influenced from standing waves on antennas, therefore, the case of CL Module causes interference from incident waves and reflected waves.

In summary of simulation results, the wavelength of the resonance frequency should be matched to the minimum loop length which consists of cells and electrical conducting ribbons, and the terminal should be set at the center of the feeding edge due to improve the characteristics of radiation pattern.

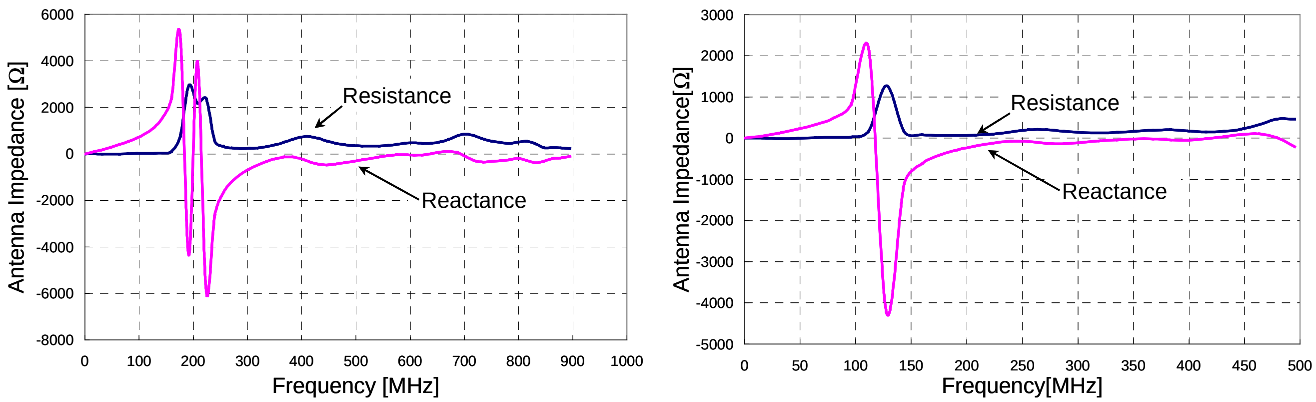
3.4 Analysis of appropriate wiring cells

Above results are taken into consideration, the authors desinged and analyzed the CL Module with appropriate wiring cells. The modeling and analysis environment is shown in Fig7(b). In this analysis, the loop length is 88cm, which consists of 12 cells. It corresponds with 340MHz. Additionally, the terminal is set at the center of the feeding edge. The results are shown below.



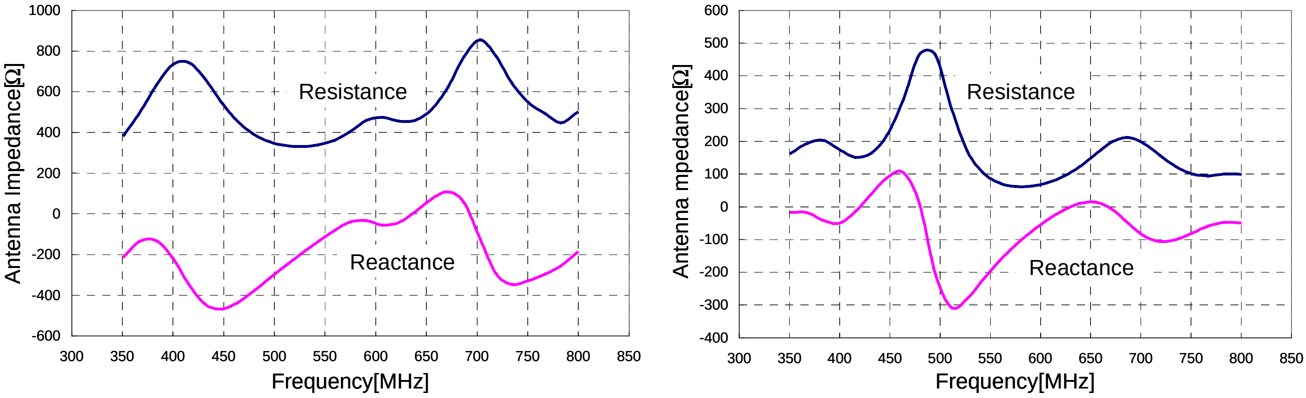
(a) CL Module (b) CL Module with appropriate wiring cells.

Fig.7 Modeling and analysis environment of CL Module.



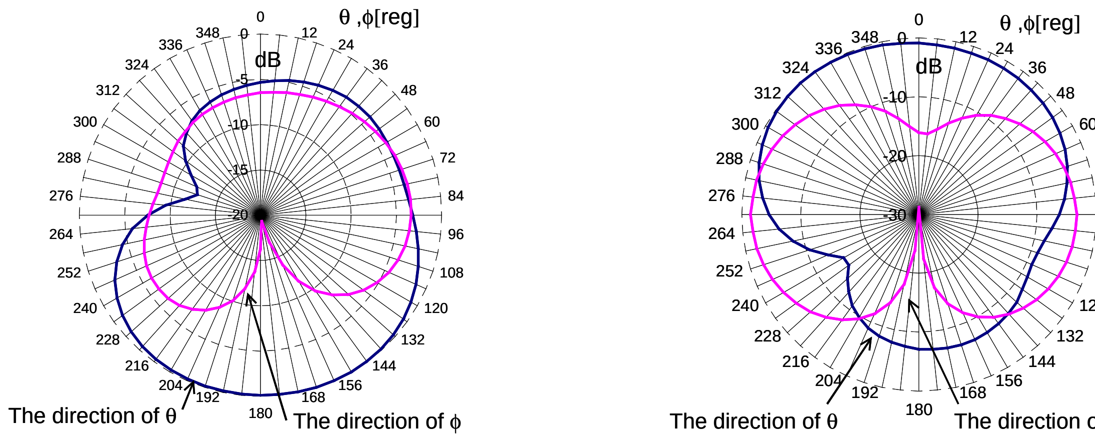
(a) CL Module (b) CL Module with appropriate wiring cells.

Fig.8 Simulated antenna impedance of CL Module.



(a) CL Module (b) CL Module with appropriate wiring cells.

Fig.9 Simulated antenna impedance of CL Module.



(a) CL Module (b) CL Module with appropriate wiring cells.

Fig.10 The radiation pattern of CL Module.

- The resonance frequency is 420MHz as predictably.
- Gain is 4.41dB, which is bigger than the normal Loop-Antenna.
- The result of the radiation pattern is shown in Fig 10(b). The CL Module can absorb electromagnetic waves from various directions; especially, the gain from front is bigger. In other words, the characteristic of the radiation pattern is similar with the normal Loop-antenna.

Thus, the CL module is in the resonance condition at the prospective frequency, the wavelength of which corresponds with the minimum loop length consists of 12 cells and electric conducting ribbons. In addition, by setting the terminal at the center of the feeding edge, the big standing waves are generated on the antenna. Therefore, the characteristic of radiation pattern was improved.

3. Conclusions

Regarding the absorption method, the CL Module achieved antenna characteristics by considering of the size of loop length and the position of the terminal. However, there are unavailable spaces, size of which is four cells. For the future, the authors will design and analyze the most appropriate wiring cells which has antenna characteristics and generates electricity sufficiently by filling the unavalable space.

References

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