Fractal Antenna for Wireless Power Transmission

#Junki Oasa, Daiki Iwahori, Yoshihiko Kuwahara
Graduate School of Engineering, Shizuoka University
3-5-1, Jyohoku, Naka-ku, Hamamatsu-shi, Shizuoka, 432-8561, JAPAN
tykuwab@ipc.shizuoka.ac.jp

Abstract

We proposed a fractal antenna for wireless power transmission in order to improve power transmission efficiency. We demonstrate two fractal antennas. One of type of wire has efficiency of not less than 80% in spite of large position deviation, another of type of plate keeps a constant efficiency in opposition to position deviation and also has wide frequency band, while maximum power transmission efficiency is 55%.

Keyword : wireless power transmission, fractal antenna, transmission efficiency, position deviation

1. Introduction

Electric vehicles (EVs) are increasing in popularity. However, they have several limitations such as low mileage, slow battery charging, and large battery volume and weight. Therefore, EVs are best suits for local transportation. If electric power could be supplied to the vehicle from the road, EVs are to replace vehicles with internal combustion engines. Recently, an experiment using electric bus was carried out in Korea in which an electric power by the electromagnetic-coupling method [1] [2].

In the recent wireless power transfer using the magnetic resonance [3], which can transmit electric power efficiently over 1 to 2 m, has attracted attention, and applications to cell phones and home electronics have been investigated. For vehicle applications, the power transmission must be efficient, safe, and applicable to vehicles of different heights. Therefore, the magnetic resonance method is appropriate for the use.

We have developed a prototype that transmits electric power and control information to the vehicle from the road, and we performed experiments [4]. Thorough the experiments, we found some demerits that the efficiency degraded when two coils do not face. In this article, we present that the fractal antenna has possibility to overcome the defect.

2. Fractal Antennas

The Fractal geometries are generated by an iterative process to a simple initial structure. It calls self-similarity. Several Fractal geometries have been examined to the antenna element to reduce the aperture and to have multi-band capabilities. Also, they applied to the array to form self-similarity radiation pattern and to have multi-band capabilities [5].

3. Analysis Model and Analysis Condition

Figure1 shows basic model of wireless power transmission using the magnetic resonance for reference, and figure 2, 3 show 2 types of fractal antenna. Transmitting antenna and receiving antennas are located face to face keeping an interval. Under the condition, the transmitting antenna moves along horizontal direction in the range of 0~900mm against a central point of receiving antenna. S_{11} and S_{12} are calculated by IE3D electromagnetic simulator. Considering for wireless power transmission for moving vehicle, it is better to keep a high efficiency in spite of position deviation.

3.1 Basic Model

We use a square coil with 1 turn for the reference. The dimension is shown in figure 1. The interval between the transmitting and the receiving antenna is kept to 300mm. We set 2 ports for each antenna. One is input (for transmitting, output for receiving) while the other is connected with capacitor (48pF) for resonance. The resonant frequency is 10MHz. The power supply voltage is 1V and internal resistance is 50Ω. For the receiving antenna, resistance of 50Ω is connected with port 1. The wires are made of copper, whose electrical conductivity is 5.76×10^{7}[S/m] and radius is 1[mm].

3.2 Fractal Model 1

The first fractal antenna structure is shown in figure 2, which is made of the copper wire. The radius and conductivity are the same as the basic model. The interval between the transmitting and receiving antenna is also kept to 300mm. In this structure, each element has 1 port for input (for transmitting, output for receiving). Capacitor (8pF) is series connected with the power supply (for transmitting, load for receiving).for resonance. The resonant frequency moves to 17.3MHz. We use the same power supply and load as the basic model.

3.3 Fractal Model 2

The second fractal antenna is made of the copper plate with thickness of 1 mm. The structure is shown in figure 3. A port is set on a vertex. In this case, we do not use a reactance part (capacitor or inductor) for resonance. By the complex fractal shape, resonant frequency becomes low without a reactance circuits. Therefore, we need not consider such specific limitation of capacitor or inductor as loss and electric strength. Interval between the transmitting and receiving antenna, power supply, and load are same as the basic model.

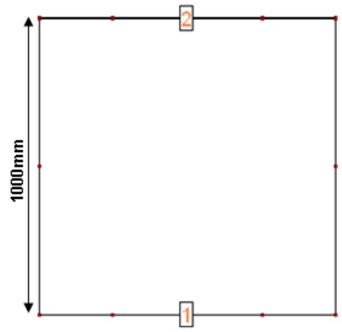
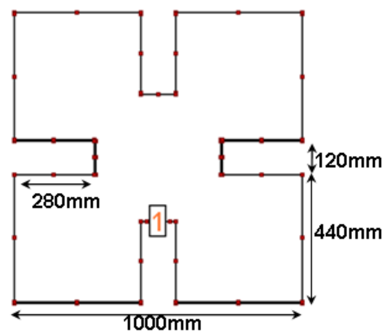


Figure1: Basic Model



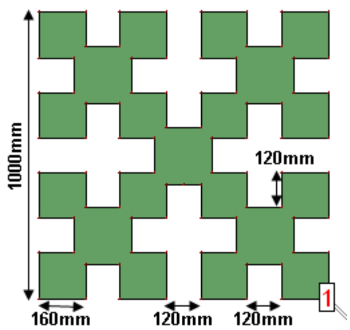


Figure2: Analysis Model 1 Figure3: Analysis Model 2

4. Analysis Results

Figure 4, 6, and 8 show the S_{11}, S_{21} characteristics of the transmitting and receiving antenna when horizontal position between two antennas vary. Figure 5, 7, and 9 show power transmission efficiency regarding the horizontal positional deviation.

4.1 Basic Model

As shown in figure 4, the larger of the positional deviation, the better of S_{11} and S_{12}. We cannot see 2 resonant peaks because the interval between 2 antennas is considerable large. From figure 5, the maximum power transmission efficiency is 87% when horizontal positional deviation is none and minimum power transmission efficiency is 3.6% when horizontal positional deviation is 900mm. Like this, transmission efficiency drops seriously as the deviation becomes large.

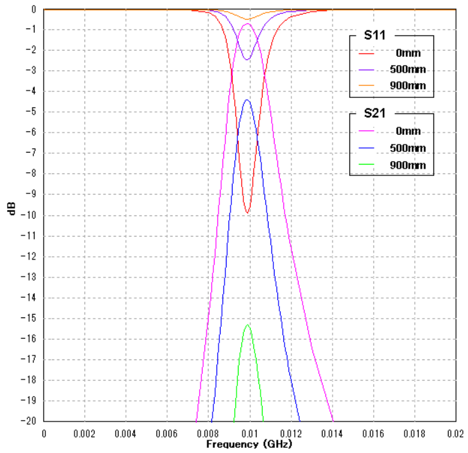


Figure 4: Frequency Response

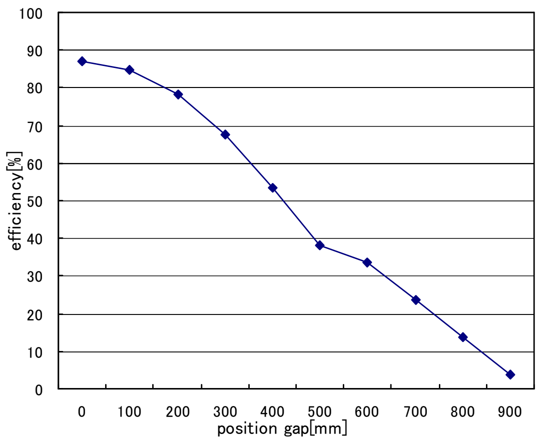


Figure 5: Parallel Translation Characteristic

4.2 Fractal Model 1

As shown in figure 6, the frequency band is narrower than that of basic model. This phenomenon is common in fractal antenna. However, it seems that S_{11} and S_{12} in the resonance are improves compared with the basic model. From figure7, maximum power transmission efficiency is 84.8% when horizontal positional deviation is none and minimum power transmission efficiency is 63.2% when the deviation is 900mm. Power transmission efficiency is maintaining not less than 80% up to the interval of 700mm.

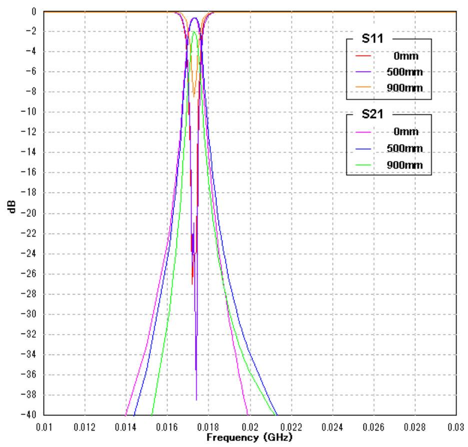


Figure 6: Frequency Response

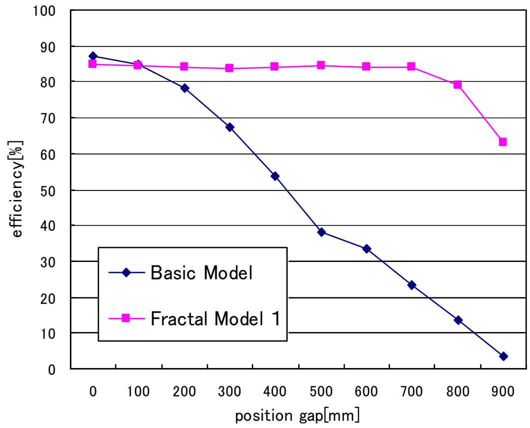


Figure 7: Parallel Translation Characteristic

4.3 Analysis Result of Fractal Model 2

As shown in figure 8, frequency band becomes wide considerably than that of the basic model. However, S_{11} and S_{12} in the resonance degrade. From figure 9, maximum power transmission efficiency is 55.5% when horizontal positional deviation is none and minimum power transmission efficiency is 34.8% when the deviation is 900mm. This model has performed comparatively stable to the positional deviation, though the efficiency is lower than that of basic model locating them face to face.

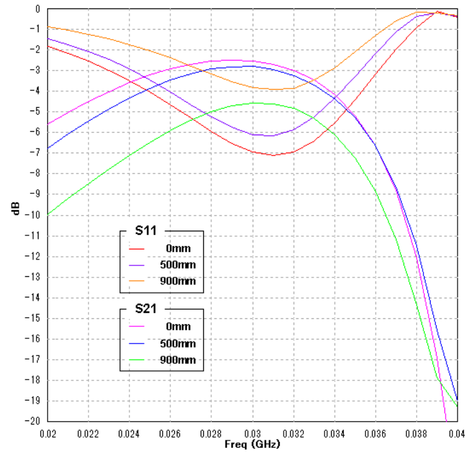


Figure 8: Frequency Response

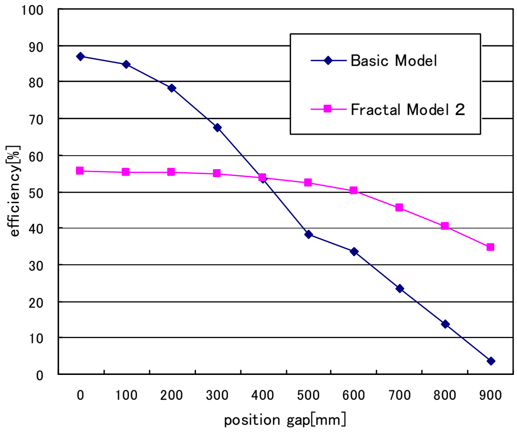


Figure 9: Parallel Translation Characteristic

5. Conclusion

By applying the fractal antenna to wireless power transmission, the efficiency against horizontal positional deviation is improved. Also, depending with the fractal structure, we can achieve a variety of resonant characteristic. In the future, we are to improve power transmitting efficiency by considering a variety of fractal shapes and to apply them to wireless power transmission for the moving vehicles.

References

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