WIRELESS CHARGING MECHANISM FOR OUTDOOR APPLIANCE

Pchelnikov Yu.N.[1], Yelizarov A.A.[2], Pchelnikov A.G.[1]
[1]*SloWave Inc.*
104, Drexelbrook Ct., Cary, 27519, NC USA
Ph.: (+1 919) 3036212, e-mail: yupchel@gmail.com
[2]*Moscow Institute of Electronics and Mathematics, Higher School of Economics (MIEM HSE)*
3, Bolshoi Trekhsvyatitelskyi lane, Moscow, 109028, Russian Federation
Ph.: (+7 495) 9168856, e-mail: a.yelizarov@hse.ru

Abstract — A portable wireless device for recharging batteries of vehicles is described in this paper. Application of novel, based on coupled radial spirals antennas with dimensions significantly less than the operating wavelength in free space, makes it possible effective pumping of RF energy without radiation into surrounding medium.

МЕХАНИЗМ БЕСПРОВОДНОЙ ЗАРЯДКИ ДЛЯ ВНЕШНИХ УСТРОЙСТВ

Пчельников Ю. Н.[1], Елизаров А. А.[2], Пчельников А. Г.[1]
[1]*SloWave Inc.*
104, Drexelbrook Ct., Cary, 27519, NC USA
тел.: (+1 919) 3036212, e-mail: yupchel@gmail.com
[2]*Московский институт электроники и математики, Высшая школа экономики (МИЭМ ВШЭ)*
3, Большой Трехсвятительский пер., Москва, 109028, Россия
тел: (+7 495) 9168856, e-mail: a.yelizarov@hse.ru

Аннотация — Описан портативный прибор для бесконтактной зарядки аккумуляторов автомобилей. Применение новых антенн, построенных на связанных радиальных спиралях с размерами, существенно меньшими длины рабочей волны в свободном пространстве, делает возможной эффективную перекачку ВЧ энергии без излучения в окружающую среду.

I. Introduction

The most of the wireless transformers operate at RF and use antennas, which as a rule, are electric or magnetic dipoles. Operating at relatively low frequencies, much less their resonant frequency, these antennas have a small gain and can not be used as the energy transformers. A novel magnetic antenna, fabricated from a row of coupled arithmetic or logarithmic spirals operates at a resonant wavelength hundreds times less its diameter and length [1]. The significant decrease in the resonant wavelength is caused by the small gap between the radial spirals and the opposite directions of their windings (Fig. 1, 2).

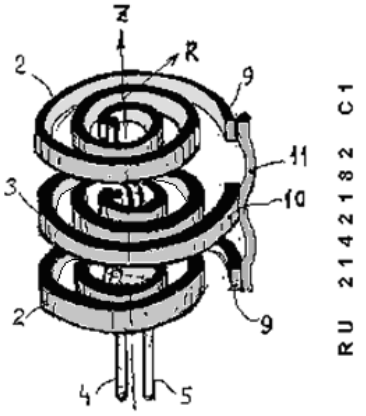

Fig. 1. Magnetic antenna according patent RU2142182.

Рис. 1. Магнитная антенна в соответствии с патентом RU2142182

On the figure 1, there are following elements: *2* are spiral conductors with one (the same) direction of winding, 3 is a spiral conductor with another direction, 4 and 5 poles are with opposite RF potentials connected to the internal ends of the spirals through one, 9 are external ends of spirals, all or just pairs being connected one to another.

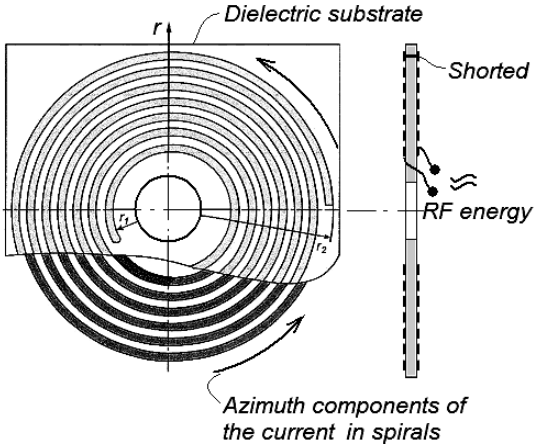

Fig. 2. Coupled arithmetic spirals on the dielectric substrate.

Рис. 2. Связанные арифметические спирали на диэлектрической подложке

In many cases of practical interest, wireless transformation of energy or an electromagnetic signal is required at relatively small distance between a generator and receiver. In these cases, can be successfully used antennas formed by coupled radial spirals [2].

Sensitive elements fabricated as one pair of coupled radial spirals were used previously for measuring thickness of metal or semi-conducting coatings [3]. Two pairs of coupled spirals placed in parallel at a distance compared to their external radius were successfully used for transmitting RF signal through the skin in the artificial ear [4]. In both cases, effective energy pumping from one pair of spirals to another takes place.

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II. Main Part

The main advantages of the coupled spirals is in the significant decrease in the resonant frequency as well as in the splitting electric and magnetic fields. Due to the opposite directions of winding, azimuth components of the currents excited in the coupled spirals (arrows in Fig. 2), have the same direction and their magnetic fields add one to another, spreading outside the spirals, while the electric field concentrates between spirals, in the dielectric substrate. Separating electric and magnetic fields leads to two positive effects: a multifold decrease in the resonant frequency and a small sensitivity to dielectric objects, e.g. a door, a cement wall, etc. The magnetic field spreading outside the antenna at the distance compared with its diameter (Fig. 3), passes through a dielectric barrier practically without reflection and loss and excites RF energy in the placed from the other side receiving antenna, the last may have the same or much less dimensions as the transmitting one.

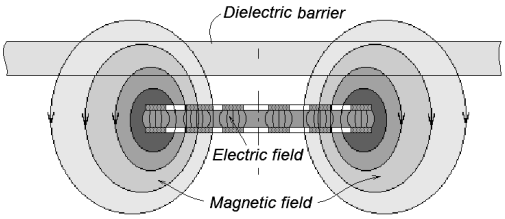

Fig. 3. Electric and magnetic fields distribution in coupled spirals.

Рис. 3. Распределение электрического и магнитного поля в связанных спиралях

It was shown in [5] that based on coupled logarithmic spirals antenna with external radius r_2 and internal radius r_1 installed on a dielectric plate with thickness b and relative permeability ε shorted at radius r_2 has a quarter-wave resonant frequency f_r approximately defined as

$$f_r \approx 2 \cdot 10^8 \frac{\sqrt{b/\varepsilon}}{(r_2 - r_1)^{3/2} tg\Phi}, \qquad (1)$$

where Φ is the angle between direction of winds and radius.

The offered in this paper technology of the wireless charging is based on the successful application of slow-wave structures for microminiaturization of RF elements, microwave and RF heating, physiotherapy and measurements [6].

III. Discussion

Fig. 2 demonstrates a possible schematic of wireless charging with help of the coupled spirals. Indoors antenna 1, installed on dielectric window 2 (door, wall, etc.) in the closed volume 3 (house or some box) is connected by RF cable 4 to RF generator 5 installed in volume 3. The generator turns on by a coded switch 6 similar to that being using for garage openers. Antenna 7, identical to antenna 1, is placed on or near window 2 from outside facing antenna 1. It is connected by flexible coaxial cable 8 to rectifier 9 connected in turn to battery 10.

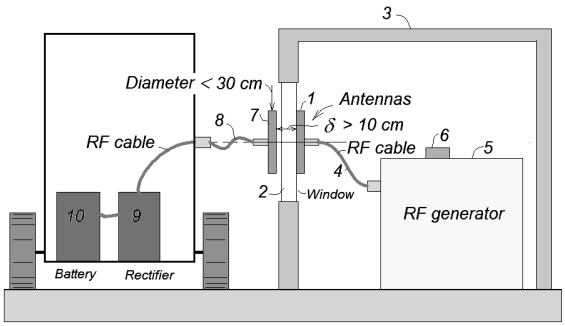

Fig. 4. Schematic of the wireless charging.

Рис. 4. Схема беспроводной зарядки

Generator 5 provides RF power at frequency f_r equal to the resonant frequency of antennas 1 and 7 when they are placed one opposite another. The power accumulated by antenna 1 does not radiate outside in the surrounding media but leaks only in antenna 7 the magnetic field of antenna 1 exciting currents in antenna 7. Due to a large energy accumulated by antenna 1, the leakage (pumping) in antenna 7 is intensive enough. This makes it possible operating at relatively large distance between antennas 1 and 7, distance comparable with the antennas' external radius.

Coupling between antennas 1 and 7 is provided mostly by the magnetic field, while electric energy is concentrated between spirals in each antenna. This is why a dielectric object placed between antennas, e.g. window 2, does not reflect or absorb transmitting energy.

IV. Conclusion

As it follows from described above physics, realization of the offered technology requires two antennas with external (*20...30) cm*, thickness (*0.5...1.5) cm*, and weight (*0.1...0.2) kg* each.

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