

## Study of Energy Harvesting Using Two-Dimensional Small Vibrations

2次元の微小振動を利用した  
エネルギーハーベスティングの検討

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### 1. Introduction

Energy harvesting from our living environment and wireless electric power charging have become a remarkable trend in recent years. Main stream for the former is electric power generation from vibrations and temperature differences. However today's power levels are very low, that is those from  $100\mu\text{W}$  to several mW, which cannot be used in wide areas. One promising application of these technologies will be a power supply source for the future sensor network. As for the latter several new theories and experimental results have been reported. Unplugged battery charge for electric handy gadgets such as cellular phones is the most realistic requirement for these technologies.

In this paper, we have studied an energy harvesting device which might provide such high voltage that it can be used as power supply for electric handy gadgets. In our configuration, we exploit both horizontal and vertical vibrations using one pair of connected small Neodym magnets. The connected magnets can be vibrated not only by mechanical drive at low frequency but also by electrical drive at rather high frequency. Therefore this device can also be used as a wireless electric power charging device. Fundamental structure and mechanism of two dimensional vibrations will be explained. Possibility to be used as a wireless charger will also be illustrated. Simulation results of magnetic field between a Neodym magnet and a coil using COMSOL simulator is presented.

### 2. Proposed configuration and power generation mechanism

Schematic illustrations of our proposed energy harvesting device using vibrations are shown in Figs. 1(a) and (b). Assuming that the device is installed in a cellular phone for example and the phone is used on a palm or is stored in a pocket or a

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handbag, the harvesting device receives both vertical and horizontal vibrations. A pair of Neodym magnets is connected parallel with same magnetic polarity using a bridge bar. In the case of vertical vibrations, above bridge pitches like a seesaw as shown in Fig. 1(a). On the contrary, the bridge swing right and left against horizontal vibrations as shown in Fig. 1(b). In order to make the bridge pitch and swing freely, we will introduce fixture mechanism with stretched wire or string which penetrates the bridge.

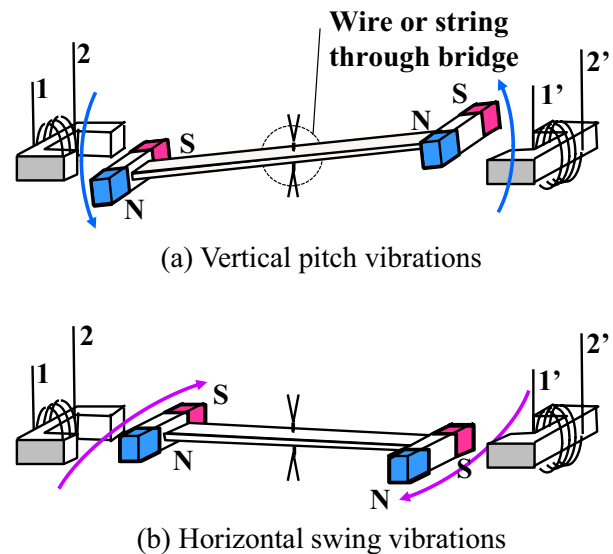


Fig. 1 Proposed energy harvesting device with two-dimensional vibrations.

The generated voltages from 1 to 2 and from 1' to 2' which are marked by  $V_{1-2}$  and  $V_{1'-2'}$ , respectively are proportional to the derivative of magnetic flux  $\Phi$  with respect to time as follows:

$$V_{1-2} \text{ and } V_{1'-2'} \sim -d\Phi/dt \quad (1)$$

The pitch and swing occur anti-symmetrically, but magnetic polarities are same for both magnets. Due to this feature, we can obtain same voltage for  $V_{1-2}$  and  $V_{1'-2'}$  for both pitch and swing vibrations as follows:

$$V_{1-2} = V_{1'-2'} \quad (2)$$

Thus the series connection of these outputs can provide twice voltage of Eq. (2).

### 3. Possibility of wireless electric charger

Conventional unplugged electric power chargers use an external coil to produce alternate magnetic field outside the coil. A miniature coupling coil is also assembled within handy gadgets to convert the magnetic field to electric power. Driving frequency is rather high compared with Figs. (1)'s pitch and swing vibrations, which requires a devised structure to achieve same function using mechanical vibrations. Our configuration can provide not only the pitch and swing vibrations but also roll vibrations. As shown in Fig. 2, an inertia moment for the roll vibrations is very small, which means the higher vibration frequency can be achieved. Same relation as Eq. (2) for generated voltages can be achieved, which provides twice voltage by the serial connection.

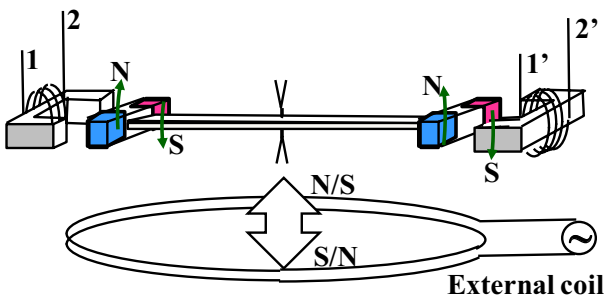


Fig. 2 Roll vibrations excited by external magnetic field.

### 4. Simulation results of magnetic field

The most crucial point in our configuration is design of the magnets, coils and interaction areas between magnets and coils as shown in Fig. 3. Generated voltage is proportional to the derivative of magnetic flux with respect to time as shown in Eq. (1). So the dynamic treatment which includes not only geometrical structure but also time factor is necessary to derive the generated voltage. In this paper, for simplicity we first simulate static magnetic-field distribution using COMSOL simulator. One example of simulated results is shown in Fig. 4.

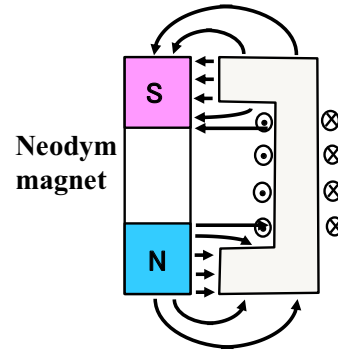


Fig. 3 Simulation model of magnetic field for interaction between magnet and coil.

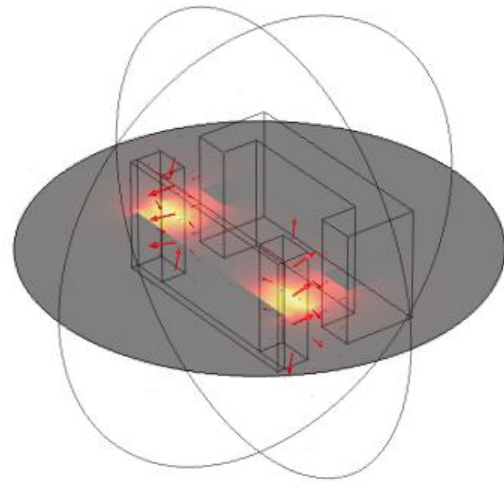


Fig. 4 Simulated magnetic-field distribution using COMSOL simulator.

### 5. Conclusion

We have proposed a new energy harvesting device which uses both vertical pitch and horizontal swing vibrations. A pair of parallel connected strong magnets such as Neodymium magnets can provide high voltage which might be used as power supply source for handy gadgets. The possibility of the device used as a wireless electric charger is pointed out. Simulated magnetic-field distribution between a magnet and a coil is also presented.

### Reference

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2. P. D. Micheson, et al, "Architectures for vibration-drive micropower generators," J. Microelectromechanical Systems, vol. 13, 2004, pp. 429-440.