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Planar Electromagnetic Vibrational Energy Harvester for IoT Applications

Nouman Ghafoor, Jeff Punch, Valeria Nico
CONNECT, Stokes Laboratories, Bernal Institute, University of Limerick, Limerick, Ireland

ABSTRACT: Nowadays, billions of wireless sensor nodes (WSNs) used in Internet of Things (IoT) applications are currently powered by batteries and require sustainable energy sources due to limitations in battery capacity, charging, and replacement, which not only affect operational efficiency but also contribute to environmental pollution. To address these challenges, electromagnetic vibrational energy harvesters (EM-VEHs) have emerged as a promising alternative to conventional batteries. A novel planar EM-VEH, comprising three cantilever beams and magnets serving as a proof mass is designed. A Halbach stack of magnets and rectangular coils are used as a transducer to convert vibrations into electrical energy. Initially, finite element analysis and experimental characterisation were carried out to determine the natural frequency and displacement of the device at 0.2 g acceleration. Then, to optimise the electromagnetic transducer, two different coil configurations were considered, resulting in a maximum power of 2.76 mW at 15.1 Hz and 0.2 g amplitude acceleration.

Proposed Design

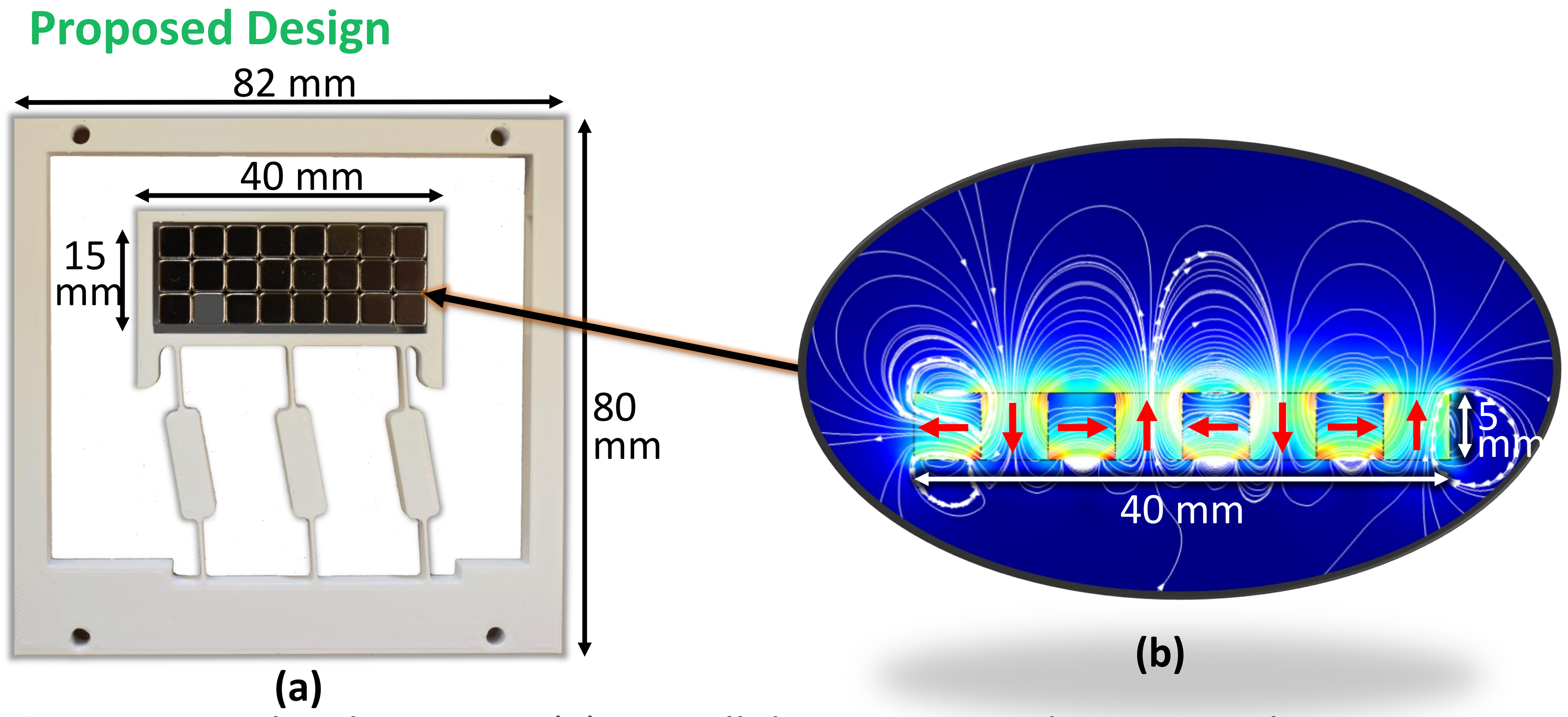

Figure. 1. Finalised EM-VEH. (a) Overall dimensions and magnets placement; (b) Halbach array arrangement, dimensions and magnetic field lines

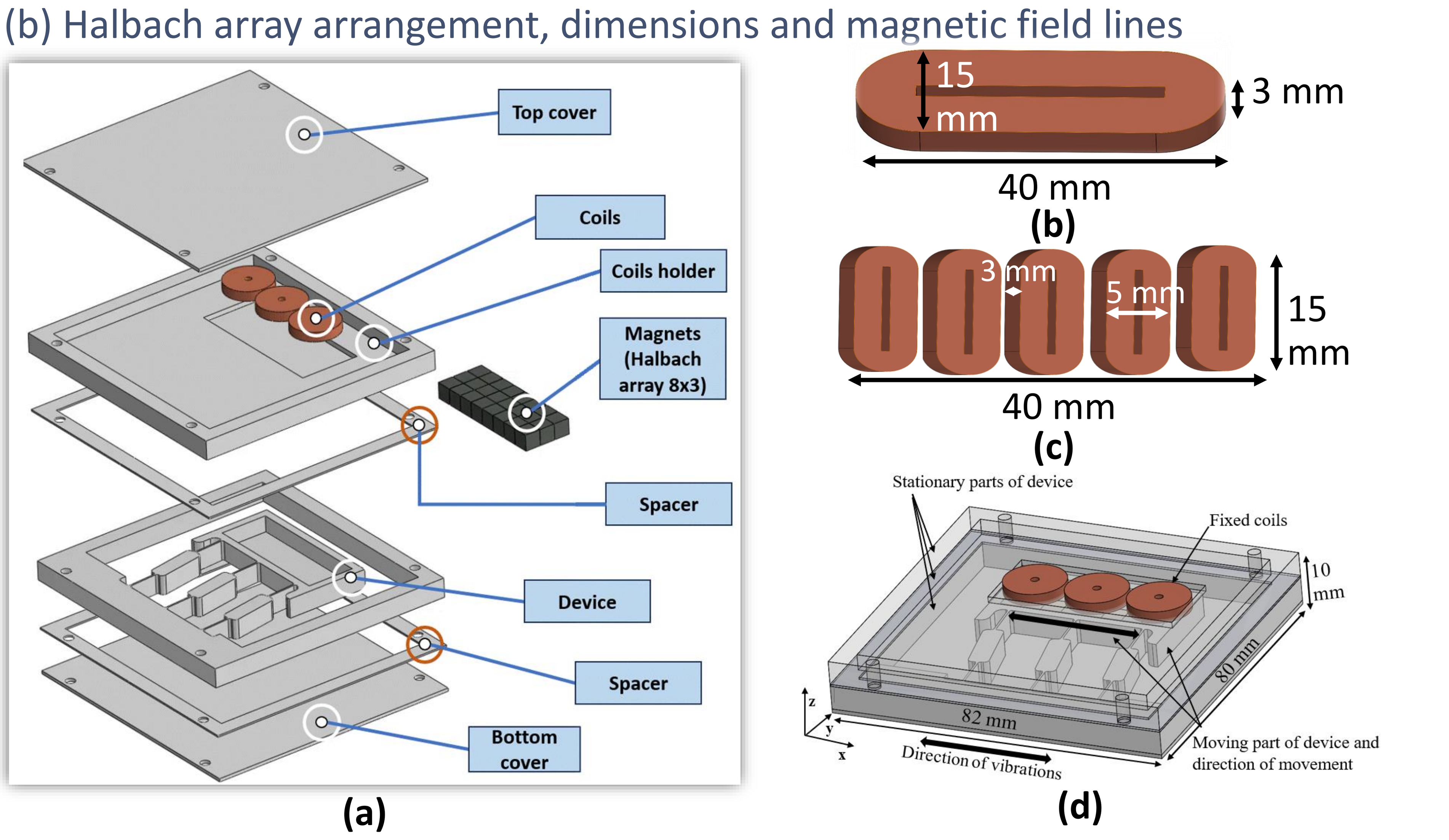

Figure. 2. EM-VEH assembly. (a) EM-VEH assembly exploded view and parts placement; (b) Single coil dimensions; (c) Five small coils dimensions; (d) Assembly of the device

Experimental results comparison of single and five coils for an acceleration amplitude of 0.2 g

Table 1- Comparison of single and five coils

Coil Configuration	Wire Diameter (mm)	Power (mW)	Difference %
Single	0.1	1.95	34.4%
Five		2.76	
Single	0.15	1.57	48.3%
Five		2.57	
Single	0.2	1.45	55.7%
Five		2.57	

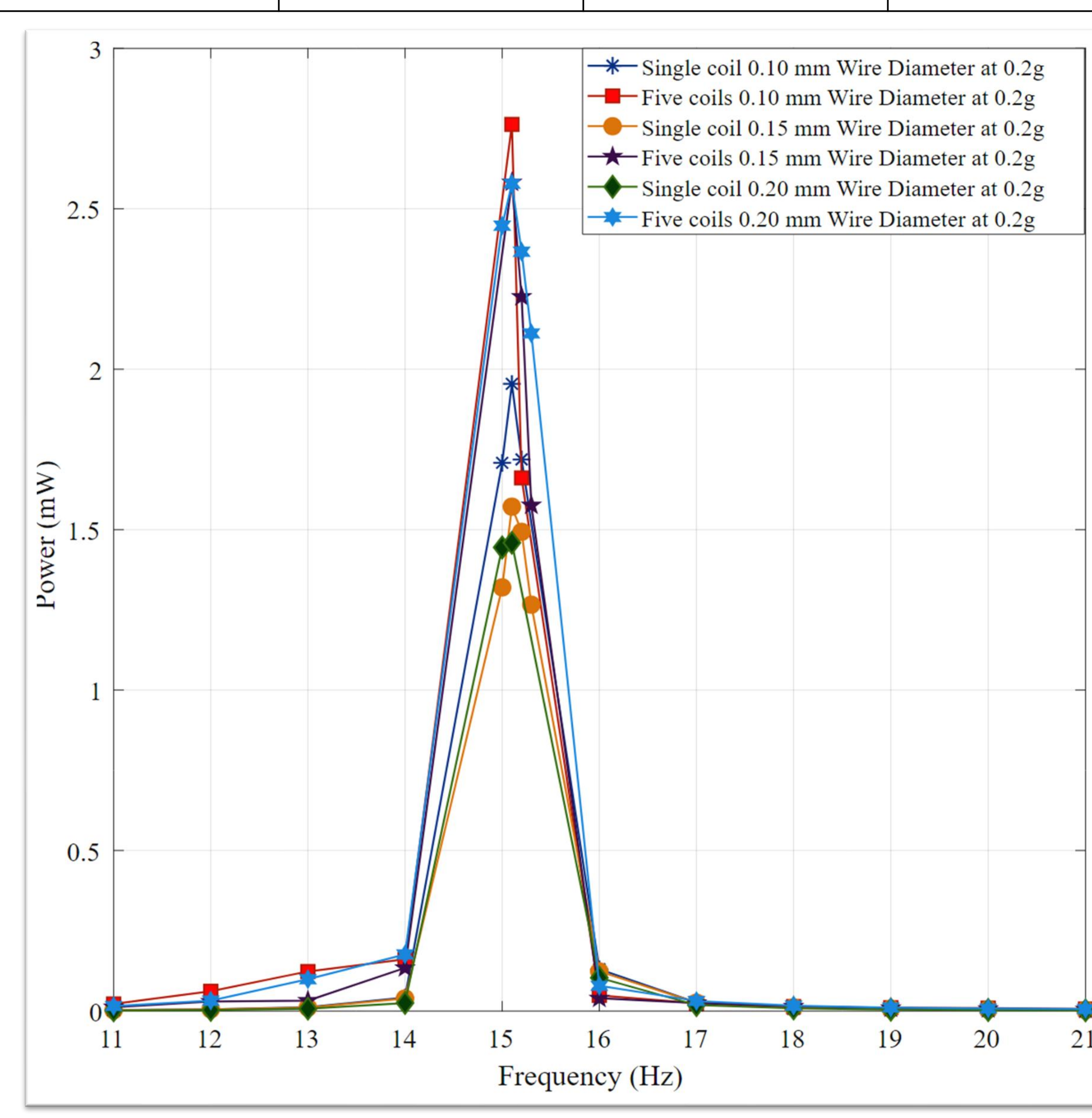

Figure. 3. Experimental comparison of the output power as a function of frequency of a single coil and five coils

Summary

A proof-of-concept planar EM-VEH with resonant frequencies in the 10 – 20 Hz range, which is ideal for numerous practical applications, was realised. The simulated natural frequency and displacement were 15.7 Hz and 3.92 mm, closely matching the experimental values of 15.1 Hz and 4.01 mm. Furthermore, the electromagnetic transducer was optimised experimentally. Two different coils with different wire diameters (0.1 mm, 0.15 mm and 0.2 mm) were tested under an acceleration amplitude of 0.2 g. Among these configurations, the optimal maximum output power of 2.76 mW was achieved using five small coils of 3 mm thickness and 0.1 mm wire diameter. The work is a significant step towards realising a viable planar harvester for better integration with power management circuitry and making it more suitable for Energy Source in Package (ESiP) form factors.