Metasurface Waveguide for Wireless Information Transfer from Sensors inside High-power Motors

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Condition monitoring (CM) methods are used on electrical machines to predict failure and optimise maintenance. Smart sensors are of interest for enhanced CM that can improve the reliability and efficiency of electrical machines, and minimize their downtime (A. Livshitz, et al, Online condition monitoring and diagnostics of power distribution equipment, Power Systems Conference and Exposition, IEEE PES, 2004). Transmitting through wires is an easy way to send data from inside to outside a machine. However, the potential for retrofitting sensors, even when far from suitable wire entry points, is less limited if the sensors are wireless. For example, it is impractical to set a wired sensor on the dynamic parts, and metal wires are undesirable in some regions of a high-voltage motor.

With wireless transmission, a large number of sensors can be implemented in the machine, and they can be placed on dynamic structures, for example, on the rotor of a motor. The latter is important because the rotor part causes nearly 10% failures of induction motors by estimation (P. F. Albrecht, et al, Assessment of the reliability of motors in utility applications-Updated, IEEE Transactions on Energy Conversion 1, 39-46, 1986).

The structure of a high-power motor can be modelled as a combination of two cylinders: rotor and stator. The rotor is placed inside the stator with a small air gap of a minimum size of 0.2 mm in between (Y. Ohashi, et al, Superconducting rotating electrical machine, US Patent US8384255 B2, 2013). On one of the cavities, a terminal box is attached outside the surface. This terminal box typically receives the information of the sensor by cables; and it transfer all their monitoring information to outside of the motor. Here, we propose to use the thin air gap as a communication channel. Thus, all the information of the sensors will be transmitted wireless, without the inconvenience of the cables. In order to make this channel highly efficient, we propose the use of periodic structures to guide the electromagnetic waves from sensors to the terminal box.

Electromagnetic chiral edge states (CESs) have been observed in photonic crystals in periodic pin structures. These states allow the construction of highly confined and efficient waveguides (Z.Wang, et al, Observation of unidirectional backscattering-immune topological electromagnetic states, Nature 461.7265, 772-775, 2009). Recently, it has been proven that instead of using rods, the electromagnetic waves can propagate along a periodic holey structure waveguide (O. Quevedo-Teruel, et al, Ultrawideband metasurface lenses based on off-shifted opposite layers, IEEE antennas and wireless propagation letters, 15, 484-487, 2016). In the case of a high-power motor, holey structures reduce the manufacturing cost comparing to the case of metallic rods. Additionally, holes will disturb significatively less the functionality of the overall motor.