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5G-Based "Morphing" RF Ambient Energy Harvesters

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Our era is witnessing an explosive growth in the field of millimeter-wave (mm-wave) and Internet of Things (IoT) technologies with a projected 40 billion IoT devices to be installed by 2025, effectively necessitating a huge number of batteries needed to be continuously charged and replaced. The design and realization of energy autonomous self-powered "perpetual IoT" is therefore highly desirable and ambient RF energy harvesting has garnered a dramatically growing amount of interest. The available or existing ambient energy density of ambient RF and wireless sources keeps increasing due to the ever expanding wireless communication and broadcasting infrastructure, such as analog/digital TV, AM/FM radio, WiFi networks, and cellular/5G networks. The RF energy-harvesting technologies could be especially useful in charging batteries and powering up electronics wirelessly in scenarios in which it is hard to replace the batteries of the deployed wireless networks (e.g., bridges, buildings). It is also useful when the wireless networks are deployed in difficult to access areas (e.g., chemical plants and aircraft), and they can operate at any time of the day and at any topology as far as there exists a minimal ambient power. Ambient RF energy-harvesting systems can be easily integrated with different types of antennas as well as with other harvesting technologies, such as the solar cells. Through the use of the printed Rotman lens, this paper demonstrates a paradigm shift aiming to break the constraints imposed by the –often considered fundamental- trade-off between the angular coverage and the turn-on sensitivity of a wireless harvesting system can be broken using ambient 5G mmW signals that effectively constitute a "wireless charging grid". Using the proposed architecture, one can design and fabricate flexible mm-wave harvesters that can cover wide areas of space while being electrically large and benefit from the associated improvements in link budget (from source to harvester) and, more importantly, turn-on sensitivity. In the 5G Frequency Range 2 (FR2), prototypes translate to harvesters of 4.5 cm to 9.6 cm in size, which are perfectly suited for wearable and ubiquitous IoT implementations. With the advent of 5G networks and their associated high allowed EIRPs and the availability of diodes with high turn-on sensitivities at 5G frequencies, several µW of DC power (around 6 µW with 75 dBm EIRP) can be harvested at 180 m. In addition, this paper will introduce the first "morphing" RF energy harvesters taking advantage of origami-enabled shape reconfigurability and discuss details concerning the emergence of 5G-powered IoT nodes and, combined with the long-range capabilities of mm-wave ultra-low-power backscatterers, of long-range passive mm-wave RFIDs and metasurfaces.