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Technical Review of Shielding for RF Sensitive Devices

## 1. Topic Overview

Meterrific will design and implement a parking meter capable of providing the data and functionality desired by both drivers and city officials in an era of IoT devices. This parking meter must be able to withstand all nominal environmental conditions over a 10+ year lifetime and must have the hardware and software required to both monitor whether a car is in a given parking spot and provide internet connectivity. The internet connectivity will make it possible for many meters to share data to provide such services as navigation to open parking spots, payment for parking, and parking violations. This review will cover the existing methods used for housing radio frequency (RF) enabled electronics in variable environmental conditions. In order to holistically review the housings available, this review will focus on both existing smart-city infrastructure applications and unrelated applications that require environmental resistance. By examining the discrete properties of each category of material whose use is possible in this application, the review will attempt to provide a functional assessment of the overall effectiveness for each relevant material in the team's application.

## 2. Overview of Existing Environmental Shielding Methods

The chosen method for ascertaining the state of the art for a given topic is by reviewing the existing pre- and post-production-cycle products in the market. In the smart-city infrastructure field, there are a few major companies producing hardware-software solutions for parking usage and enforcement. This review will cover two of these companies along with a patent of a closely related product.

The first company is Parkeon, producer of the Strada Evolution. The Strada Evolution is a parking monitoring device that serves 10+ vehicles and is primarily used in parking lots [1]. The product is solar powered, has wireless internet capability, and has a marketed 12-year lifespan with no listed warranty [1]. The Strada Evolution is built entirely from anti-corrosive steel in a rectangular prism with dimensions: L290 x W311 x H1,544 mm [1]. The description of "anti-corrosive steel" is vague, but stainless steel would fit the description and may be the more precise material used. Pricing is not available for this device, as Parkeon works with each client on an individual basis to tailor the Strada Evolution to individual requirements.

The second company is IEM Group, maker of the PrestoEuropa. The PrestoEuropa is almost identical to Parkeon's Strada Evolution and functions as a central parking monitoring device for many cars, not individual spaces [2]. Similar to the Strada Evolution, the PrestoEuropa is solar powered and 3G wireless enabled [2]. The PrestoEuropa, however, only has a 2-year warranty with a 5-year extended option, including a failure rate of <1 per year [2]. The lower warranty period for the PrestoEuropa signals that the product may be less reliable than the Strada Evolution. The PrestoEuropa is built from extruded aluminum, in a rectangular prism with dimensions: L230 x W230 x H1645 mm [2]. Like the Strada Evolution, pricing is not available for the PrestoEuropa, as the company works with individual cities to implement a tailored product [2].

There are many existing patents related to smart city infrastructure, but one patent proposed a smart parking meter similar to the product proposed by Meterrific but lacking some critical software features included in the Meterrific proposal. This patent (U.S. Patent 10,424,125) outlines a parking meter capable of monitoring a single parking space using a camera while linking with the internet to provide parking attendants information regarding the status of a parking space [3]. The patent focuses entirely on improving revenue for the city and does not make provisions for an improved driver experience. In the area of housing design for the patented parking meter, the patent is somewhat broad in its description. The patent describes the housing as follows: "[The housing] is moisture and impact resistant since it is exposed to rain, snow and other elements. Also, light impacts to the housing may be delivered by people and objects, so the enclosure is generally formed of rugged materials such as metals or impact resistant plastics." [3]. The patent's description of housing design is in line with that of the Strada Evolution and PrestoEuropa, but with a smaller physical stature since the meter services individual parking spaces [3]. As the patented device is not yet in full production, there is no price associated with the device.

### 3. Environmental Shielding Effectiveness of Relevant Materials

From the review of existing parking meter solutions, the state of the art in electronics housings appears to be either a metal or plastic polymer solution [1][2][3]. In addition, the reviewed parking meter solutions have incorporated rectangular prism shaped enclosures for the electronics [1][2][3]. The shaping is likely a result of the rectangular design of most embedded processor boards. A quick review of other outdoor applications confirms that plastic polymer materials are a viable option for storing electronics in the long-term. For example, the DATEC-COMPACT is a handheld outdoor electronics housing made from ASA, a type of 3D-printable plastic [4]. This device is UV-stable and is rated IP65, meaning that it is protected from dust egress and low-pressure water jets from any direction [4][5]. An IP65 rating should be tolerable for most nominal weather conditions, but an Meterrific will aim for an IP66 rating, which handles all weather conditions, such as driving rain [5].

There are three main criteria for evaluating the effectiveness of environmental shielding of electronics housings: UV-stability, impact resistance, and weather resistance. Many plastics are not UV-stable and degrade over time, such as PLA and ABS. These materials are not suitable for prolonged outdoor use and would not be appropriate for Meterrific's projected use case. Plastics like ASA and PVC fare better in UV-stability and there exist outdoor electronics housing that are made from these materials [4]. Aluminum and stainless steel are UV-stable. Aluminum and stainless steel have high tensile strength ratings of 415MPa and 305MPa respectively [6][7]. ASA and PVC have much lower tensile strength ratings of 51MPa and 34MPa respectively, nearly an order of magnitude less than that of the metals [8][9]. Thus, the metal options provide better impact resistance than plastics for Meterrific's use case, with Aluminum providing the highest impact resistance. Finally, weather resistance is more dependent on the design of an electronics housing than the material used for the housing. Hermetically sealed joints and the minimizing of entries into the housing will result in better weather resistance. Plastics, being easier to manufacture and not requiring welding, may yield more reliable sealing of joints.

#### 4. RF Permissibility of Relevant Materials

Given the review of existing smart parking meters, the state of the art in electronics housings appears to be rectangular prism shaped and made of metal or plastics. Each of the parking meter designs in the review contain a radio frequency (RF) transmission device, transmitting at the 3G bandwidth of ~2GHz. Because these products use stainless steel and aluminum housings and are able to successfully communicate at ~2GHz frequencies, it is reasonable to assume that stainless steel and aluminum housings meet the required level of RF permissibility for Meterrific's application. For electronics housings using ASA or PVC, there is not sufficient evidence in existing products to assure the team that these materials have sufficient RF permissibility for 3G transmission. As a result, scholarly research was reviewed for materials similar to ASA and PVC. It is difficult to describe the results without the use of a table here, but overall, the researchers found that the dielectric constant of all plastics tested decreased with an increase in frequency but were so low at all frequencies that they would not influence radio transmission at the 2GHz band [10]. As a result of these findings, the RF permissibility of the electronics housing should not be a major factor in the determination of the material used for the housing.

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