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INTERNET-OF-THINGS MULTISTATIC PASSIVE RADAR STATION

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Abstract

This paper aims at presenting an Internet-of-things multistatic passive radar station having autonomous and field deployed capabilities. The station is wirelessly connected to a data server and requires, under expected circumstances, no maintenance whatsoever for the projected period of operation. The wireless connection is through radio waves over the Wi-Fi radio protocol making the station an internet-of-things device.

A design of the autonomous station is disclosed. Different components are discussed together with their inter-relations. The requirements these components should satisfy, in accordance with the harsh field condition the station is subjected to, are established.

The design is supported by three inventions registered at the Bulgarian Patent Office.

Key words: Internet-of-things devices, multistatic passive radar, autonomous radar station, field deployed remote sensing instrument

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Introduction. Multistatic passive radars are engaged in tasks such as detection, identification and tracking of different kinds of objects, both in the air or on surface. A passive radar system does not require radio transmitters belonging to the system but instead employs transmitters owned by other parties. These transmitters are called transmitters of opportunity or non-cooperative transmitters [1]. Transmitters of opportunity may include the frequency modulation (FM) broadcasting transmitters [2, 3], digital video broadcasting (DVB) transmitters [4], etc.

When the radio waves emitted by the radio transmitters of opportunity reflect from targets they reach the passive radar receiver. Direct waves from the transmitters are also picked up by the passive radar station. By appropriate computation the passive radar identifies the target's position, speed, direction of motion, etc.

Passive radars can observe various objects such as drones, meteoroids and meteors, space junk debris, airplanes, spacecraft, Earth's ionosphere [5–7], etc.

Passive radars are either bistatic or multistatic [8]. The former employ a single receiver and a single transmitter. The latter utilize more than one non-cooperative transmitter and/or more than one receiver. The transmitters and receivers need to be located at considerable distances from each other in order to increase the accuracy of measurements. Multistatic passive radars enable the generation of 3D images of the observed scene. This property is of great use when applied to ionospheric remote sensing.

Internet-of-things and passive radar stations. To make a passive radar station autonomous, one needs communications. In-the-field communications cannot utilize wired networks because these are not available in most locations. Hence wireless means are the only option (Fig. 1). Variants of wireless networks for the given purpose include satellite phones, terrestrial cell phone networks, proprietary wireless networks, and wireless Internet access. The last option is becoming increasingly available in many locations, especially when the passive radar station is positioned near scientific and research facilities. With the use of range extenders Wi-Fi connection can be established at longer distances (Fig. 2). Having the passive radar station utilize Wi-Fi radio link, we arrive at an Internet-of-things (IoT) device obtaining all the benefits of this new trend in technology such as:

1. Lower cost or no cost of wireless network access.
2. Availability at locations in different countries without the need to register for local cell phone services.
3. Direct access to the Internet at high speeds that may not be available for all cell phone or satellite phone service providers.
4. No need for installation of proprietary wireless radio network infrastructure.

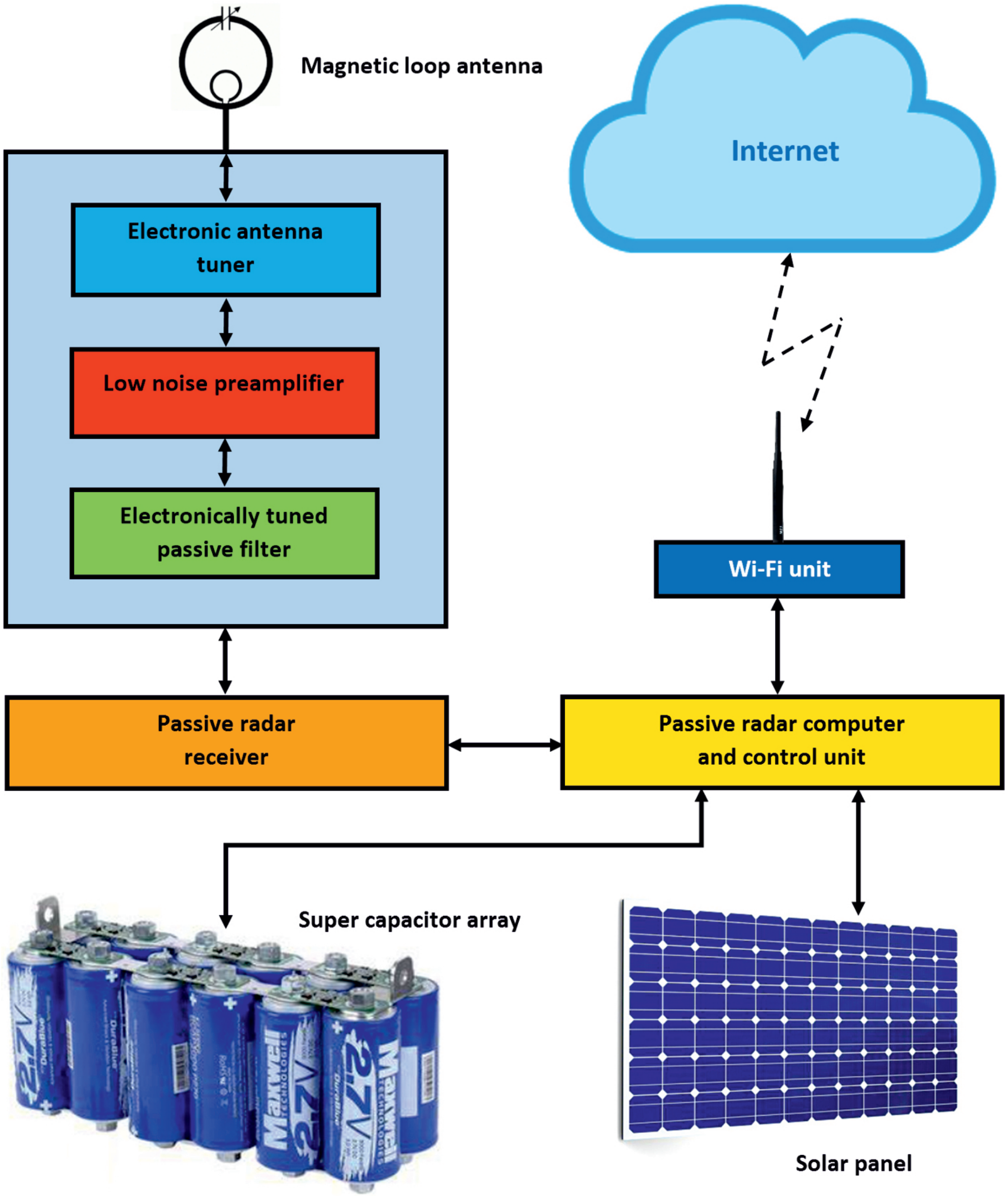

Fig. 1. Internet-of-things autonomous field-deployed multistatic passive radar station

5. Availability of off-the-shelf Wi-Fi hardware ready to be implemented in an IoT passive radar station (Fig. 2).

Available Wi-Fi modules come in different flavours such as single board modules or standalone devices. If a dedicated personal computer, for example a laptop,

Fig. 2. Wi-Fi hardware available off-the-shelf and ready to be implemented in Internet-of-things devices and instruments. On the left: a 2.4 GHz antenna; top-right: Wi-Fi module; bottom-right: Wi-Fi range extender

is implemented as the control unit of the multistatic passive radar station then it is to be expected that the computer shall have in-built Wi-Fi module already.

Power supply for the autonomous IoT multistatic passive radar station. The passive radar station requires autonomous power supply. Due to its stationary disposition on the ground or on building roofs or walls, the requirement for a lightweight power source is not present.

The electricity subunit powering the station has two major components: energy input device and energy storage device. For the energy input we choose a

Table 1

Types of supercapacitors suitable for the passive radar station

Manufacturer	Capacity [F]	Voltage [V]	Energy [Wh]	Weight [kg]	Energy density [Wh/kg]	Temp. range [°C]	Internal resist. [mΩ]
KEMET	200	2.70	0.203	0.062	3.274	−25/ + 60	30
AVX	3000	2.70	3.038	0.500	6.076	−40/ + 65	0.20
Eaton	3400	2.85	3.836	0.600	6.393	−40/ + 65	0.23
Cornell Dubilier	800	2.30	0.588	0.074	7.946	−25/ + 70	10
Maxwell Technologies	3400	3.00	4.250	0.490	8.673	−40/ + 65	0.13
Vishay	100	3.00	0.125	0.020	6.250	−40/ + 85	22
Würth Elektronik	350	2.70	0.354	0.065	5.446	−40/ + 65	3.5

solar cell (Fig. 1) because it is robust, has no moving parts and is easy to implement.

The storage unit on the other hand should withstand wide temperature changes and endure a large number of charge/discharge cycles. Because we are not aiming at high energy density, i.e. the unit being lightweight, our choice is the novel technology for energy storage – supercapacitors. Table 1 presents the leading products of a few manufacturers (see also Fig. 3).

As mentioned earlier, the energy density is not a major concern in choosing the supercapacitors for the passive radar autonomous station but temperature range is important. Most parts exhibit a wide temperature range of operation starting from −40 °C and ending at +65 °C. This temperature range is favourable for field deployed units working in the geographical latitudes of Bulgaria. The

Fig. 3. Supercapacitor array (left) and single cell (right). A single cell of 3000 F @ 2.7 V dimensions: 20 cm in length and 8 cm in diameter

charge and discharge cycles for all variants are practically unlimited without degradation of the capacity and internal resistance over time and usage.

Benefits of employing supercapacitors for energy storage over the available kinds of secondary (rechargeable) batteries are summarized in the following list:

Practically unlimited charge and discharge cycles;

Higher efficiency in charge and discharge modes;

Wider temperature range of operation having no noticeable degradation of efficiency.

Most supercapacitors are manufactured in discrete cells that can be combined in arrays (Fig. 3). Most frequently used large capacity cells are the 3000 F ones. Working with larger cells is easier hence we choose a 3000 F cells for our prototypes. Such a cell has maximum stored energy of 3 Wh (see Table 1). Our calculations demonstrate that for powering a laptop-based station with total power consumption of 100 W the storage unit is expected to provide energy for 16 h dark time (worst case) leading to 1600 Wh of energy stored. Five hundred and fifty cells are required for the station with a total weight of 267 kg. This figure might seem a lot but the station dimensions are nevertheless quite large. The latter are initially defined by the solar cell area requirements for 200 W power output in the worst case (overcast sky) leading to 2000 W installed nominal power under clear sky. Hence, the solar cell area required is around 20 m^2.

If a lower power unit is utilized instead of a laptop, having in general about 10 times lower power requirements, we arrive at 26 kg of supercapacitors storage unit and only 2 m^2 solar cells area. The choice between a laptop computer and a single board low power consumption computer depends on the implemented algorithms and their needs for computational performance for the passive radar station [9–11].

Final design of the multistatic passive radar station. The general design block diagram is shown in Fig. 1. The station consists of the following subunits:

1. Receiving antennas. In this variant the receiving antenna type is a magnetic loop antenna [12–14].
2. Receiver front-end unit with preselector properties having three components:
   (a) Electronic antenna tuner
   (b) Low noise preamplifier
   (c) Electronically tuned passive filter
3. Radio receiver. This is a digital output radio receiver with more than one channel.
4. Computation and control unit. A computer with control modules. May be as powerful as a laptop computer with graphics processing unit employed

in parallel computations. Or may be as small as a single board computer. The choice depends on the implemented algorithms and their computational requirements.

5. Wi-Fi radio module. May be in-built in the computer unit. If standalone device is to be employed, a small off-the-shelf module is implemented (see Fig. 2).
6. Supercapacitors array energy storage unit (see Fig. 3).
7. Solar cell energy input module. The module exhibits snow melting capabilities using heating elements.

In accord with the disclosed design, the station is autonomous. It endures large temperature changes and operates at very low solar exposures such as overcast sky and 8 hours of daylight only. The station is capable of working in harsh field conditions even during the winter in snowy and rainy weather.

Conclusion and future work. The avoidance of radio noisy environments for the deployment of multistatic passive radar stations requires the units to be field-deployed with endurance in harsh meteorological conditions. Another requirement is the radio communication to the main data server which is solved through Internet-of-things device.

The presented solution herein is only the initial step in a process of mastering and evolving the idea of autonomous passive radar stations. The authors have published a number of works, patents and innovations in this scientific field [15–18]. They have been motivated in their enterprise by scientific and research motives: their major scientific interest in multistatic passive radar implementation is the remote sensing of the Earth's ionosphere through the means of passive radars.

The authors' scientific research in passive radar innovations is ongoing.

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