SOC and SOH estimation in BMS based on Wireless Communication Network
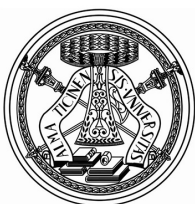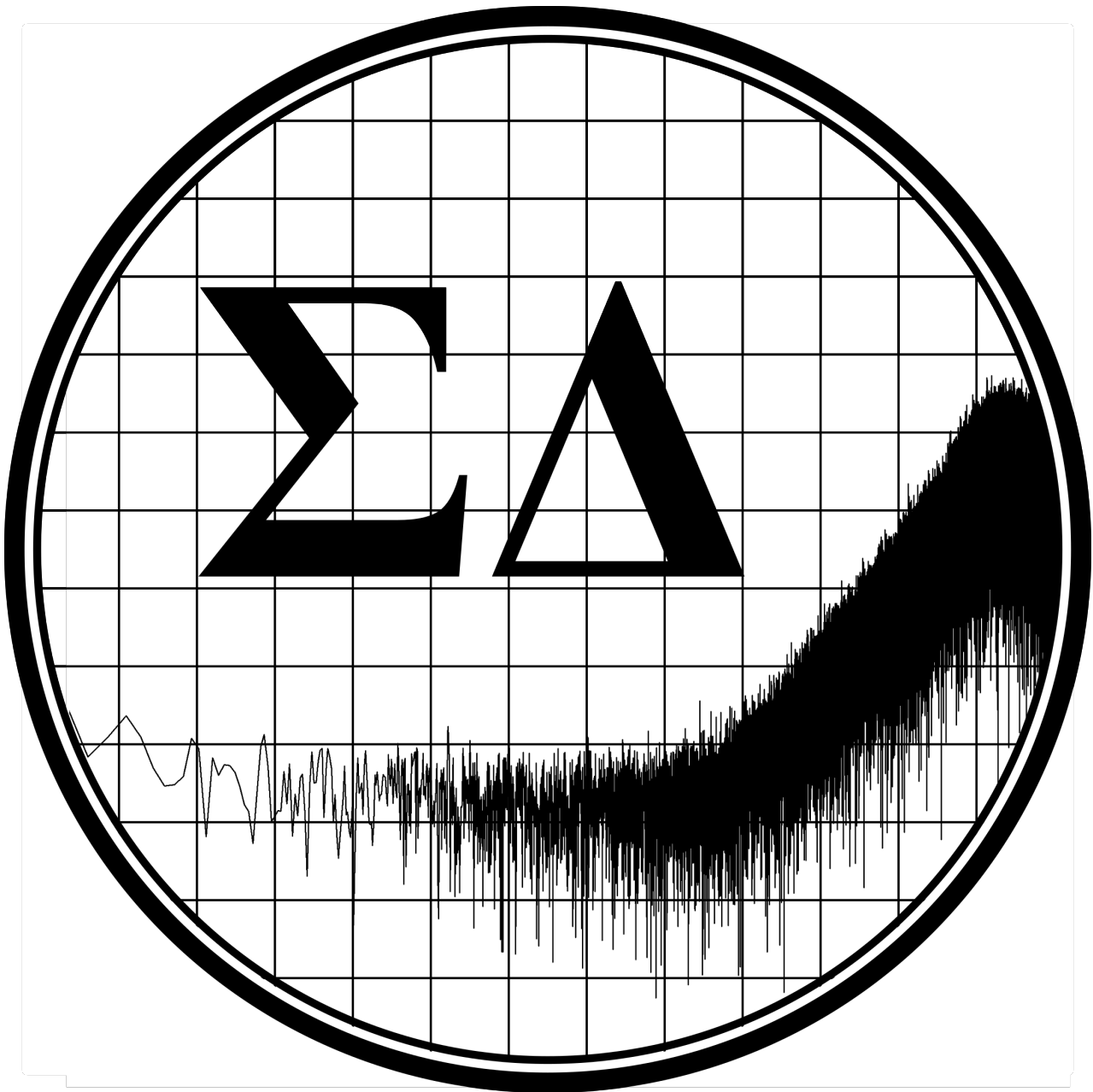
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Department of Electrical, Computer and Biomedical Engineering
University of Pavia

SOC and SOH estimation in BMS based on Wireless Communication Network

Dissertation submitted in partial fulfillment

of the requirements for the degree of

Master of Science

in

Microelectronics

by

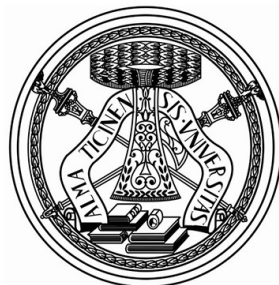**Harish Kumar Shivaramappa**

based on research carried out

under the supervision of

Prof. Piero Malcovati

and

Prof. Domenico Granozio

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December, 2022

Department of Electrical, Computer and Biomedical Engineering
University of Pavia

To

My Beloved Mother Miss.Kalavathi Shivaramappa ...

Acknowledgment

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Harish Kumar Shivaramappa
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Abstract

 Determining the SOC ad SOH of the Li-Ion batteries by employing the Conventional Coloumb count method and sophisticated Kalman filter algorithms in a wireless communication network(BLE). With the help of a Battery Emulator, The proposed Architecture measures synchronized current and voltage for SOC and SOH calculation by ensuring safety and adaptivity. By employing the Most Robust and Elegant Wireless Communication Network(BLE) in BMS, the architecture mitigates the problem of bulky and wired setups.

Keywords: BMS; SOC; SOH; BLE; Coloumb-Count; Kalman Filter; Battery Emulator.

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2.1 Introduction

An Antenna design and analysis are crucial in a wireless network that transmits and receives information through electromagnetic wave radiation in open space. Modern Antenna and RF design techniques more often testified against size, power, flexibility, radiation patterns, efficiency, etc... It is very unusual to use a wide variety of RF fundamental design techniques even though the usage of silicon and power is different because the fundamentals of RF design are most rigorous and robust from decades, hence RF fundamentals and design techniques remain intact. Nevertheless, modern RF applications demand to emphasize efficiency and power requirements, so this requirement needs some special RF Design treatments. Chapter .3 gives the extravagance of PCB antenna design practices, general guidelines for grounding, PCB stacking, spacings and via holes, etc. Matching networks in RF design are extremely important to increase the efficiency of the Antenna and RF line, so it is also explored in the same chapter how to pick the passive components for RF Antenna matching such as capacitors and inductors.

2.2 Antenna Basics :

An Antenna is a piece of metal exposed to free space. A piece of conductor behaves like an antenna when its length is a certain ratio or multiple of the wavelength of the signal.

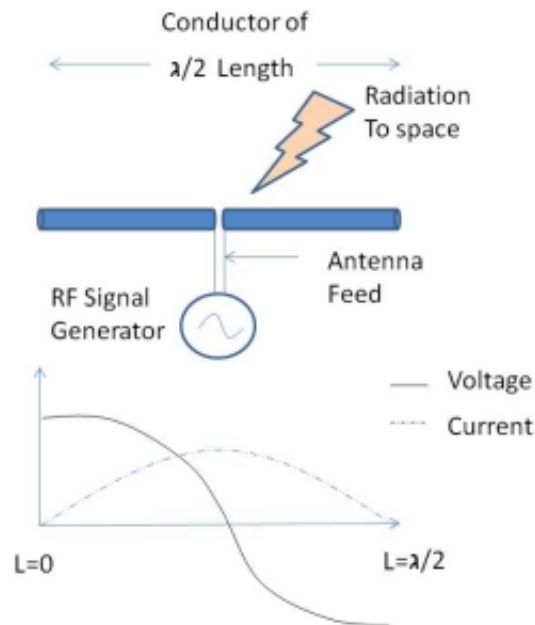This scenario is expressed as "resonance", where the antenna radiates the electrical energy to the open space.

Figure 2.1: Basic Diploe Antenna

Fig.1 shows the diploe antenna whose length is $\lambda/2$ and the fed has an input impedance of 50ω. Dipole antennas are the most basic antennas that have been used for broadcasting. In the Millennial age of technology, dipole antennas have been bulky and heavy, thanks to the PCB technology, which made diploe antennas extremely simple in construction and this became the center of attraction for the Bluetooth application in the modern era. Although diploe antennas are extremely comfortable for PCB we still face hurdles to manage proper grounding for the antenna..which can be addressed through quarter-wave antennas. The quarter-wave antennas have half of the length of the dipole antennas $\lambda/4$ their popularity became exponential because of the fed which can be single-ended. A single-ended feed to the antenna made life much easier to make a wide range of ground planes and better matching.

2.2.1   Antenna Types:

As discussed in the previous section quarter wavelength antennas can be more effective on the PCB because of their fed and ground plane management on PCB. Depending on the antenna dimensions and the shape antennas fall into different technologies namely FM, AM, Bluetooth, and wifi son on. Since the eccentric part of this chapter discusses the Bluetooth antenna design and guidelines, we can broadly classify three types of antennas. as Follows :

2.2.1.a   Wire Antenna :

These types of antennas are just a piece of wire extended over the PCB in open space, whose length is matched to $\dfrac{\lambda}{4}$ on the ground plane. In general, these antennas are fed by a 50ω matching transmission line, a Wire antenna gives a top-notch performance and supports a wide range of frequencies because of its three-dimensional exposure in open space. The shape of the wire antennas can be loop, wire, or helix.. depending on the application the shape is changed.
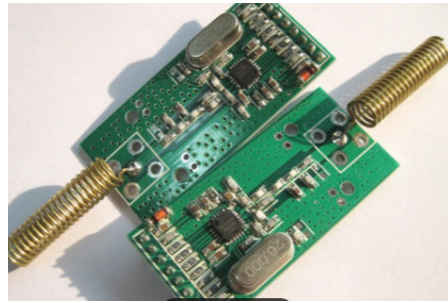

Figure 2.2: Wire Antenna

2.2.1.b   PCB Antenna :

Constructively this type of antenna is copper traces that are etched on the PCB. The Traces can be Zig-Zag, straight, MIFA, Meandered type, F-type, or Zip track so on., the shape of the antenna is chosen based on the antenna type and the space constraints on the PCB. PCB Antennas have only two-dimensional freedom, therefore certain guidelines are needed for the PCB antenna design due to the space constraints and poor quality of PCB stack-up. The space constraints of the PCB antennas lead to less efficiency compared with wire antennas nonetheless PCB antennas are cost-effective. In short manufacturing comfortability and its wireless range is ravishing for Bluetooth applications.
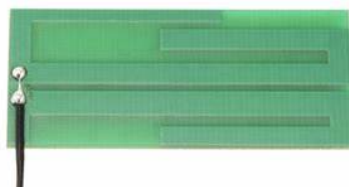

Figure 2.3: PCB Antenna

2.2.1.c   Chip Antenna :

This is a Small form factor IC that is in-house with a ceramic package or some metal case. These antennas are handier in terms of space management on the board and internally

their impendence is very well managed. A chip antenna can also take an advantage of three-dimensional freedom for radiation similar to wire antennas. Refer to figure 10 for the Nordic Bluetooth module having a chip antenna. It's true that chip antennas can gain upper hand in size and radion pattern on the contrary power handling capacity of the chip antenna is very minimal.

Figure 2.4: Chip Antenna

2.2.2   Antenna Parameters

The following section gives some key antenna performance parameters.

2.2.2.a   Return loss :

The return loss of an antenna signifies how well the antenna is matched to the 50-Ω transmission line (TL), shown as a signal feed in Figure 2.5. The TL characteristic impedance is typically 50 Ω, although it could be a different value. The industry standard for commercial antennas and testing equipment is 50-Ω impedance, so it is most convenient to use this value [1].

Return loss indicates how much of the incident power is reflected by the antenna due to mismatch (Equation 2.1). An ideal antenna when perfectly matched will radiate the entire energy without any reflection. If the return loss is infinite, the antenna is said to be perfectly matched to the TL, as shown in Figure 2.5. S11 is the negative return loss expressed in decibels. In most cases, a return loss $\geq$ 10 dB (equivalently, S11 ≤ -10 dB) is considered sufficient. Table **??** relates the return loss (dB) to the power reflected from the antenna (percent). A return loss of 10 dB signifies that 90% of the incident power goes into the antenna for radiation [1].

$$Returnloss(db) = 10 \times \log(\frac{Pincident}{Preflected}) \qquad (2.1)$$

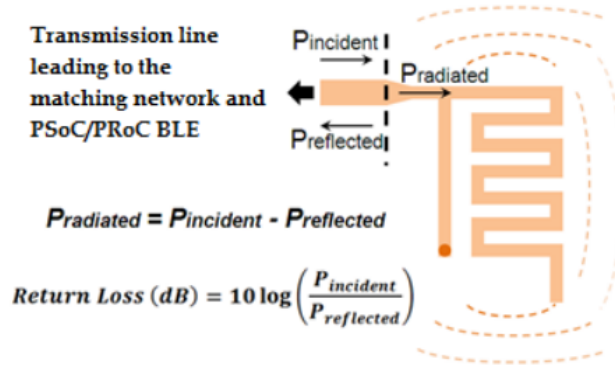
Figure 2.5: Antenna Return loss

S11 (dB)	Return Loss (dB)	Preflected/Pincident (%)	Pradiated/Pincident (%)
−20	20	1	99
−3	3	50	50
−10	10	10	90
−1	1	79	21

Table 2.1: Return Loss and Power reflected from antenna

2.2.2.b   Bandwidth :

Bandwidth indicates the frequency response of an antenna. It signifies how well the antenna is matched to the 50-Ω transmission line over the entire band of interest, that is, between 2.40 GHz and 2.48 GHz for BLE applications [1].

As Figure 2.6 shows, the return loss is greater than 10 dB from 2.33 GHz to 2.55 GHz. Therefore, the bandwidth of interest is around 200 MHz. Wider bandwidth is preferred in most cases, because it minimizes the effect of detuning resulting from the changes in the environments around the antenna in actual uses of the product (e.g. mouse placed on wood/metal/plastic table, hand kept around the mouse, etc.) [1]

2.2.2.c   Radiation efficiency:

A portion of the non-reflected power (see Figure 2.1) gets dissipated as heat or as thermal loss in the antenna. Thermal loss is due to the dielectric loss in the FR4 substrate and the conductor loss in the copper trace. This information is characterized as radiation
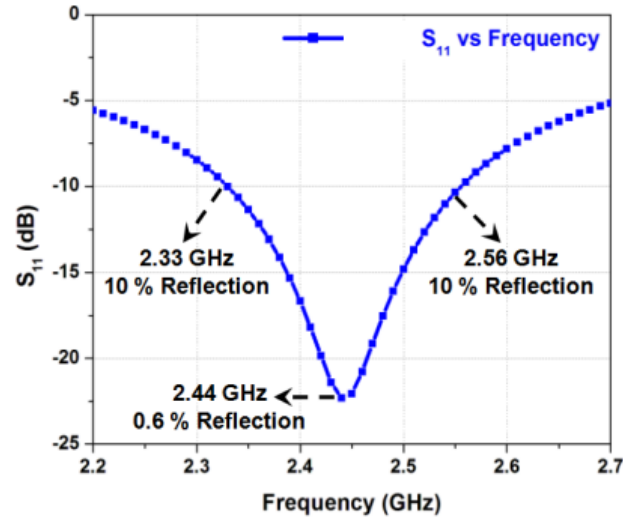
Figure 2.6: Antenna Bandwidth

efficiency. The radiation efficiency of 100 percent indicates that all non-reflected power is radiated to free space. For a small-form-factor PCB, the heat loss is minimal [1].

2.2.2.d   Radiation pattern:

Radiation pattern indicates the directional property of radiation, that is, which directions have more radiation and which have less. This information helps to orient the antenna properly in an application [1].

An isotropic dipole antenna radiates equally in all directions in the plane perpendicular to the antenna axis. However, most antennas deviate from this ideal behavior. See the radiation pattern of a PCB antenna shown in Figure 2.7 as an illustration. Each data point represents RF field strength, measured by the received signal strength indicator (RSSI) in the receiver. As expected, the contours are not exactly circular, as the antenna is not isotropic [1].

2.2.2.e   Gain :

Gain indicates the radiation in the direction of interest compared to the isotropic antenna, which radiates uniformly in all directions. This is expressed in terms of dBi—how strong the radiation field is compared to an ideal isotropic antenna [1].

2.2.3   PCB Meandered Inverted-F Antenna (PIFA)

PIFA antennas are much more popular in Bluetooth Low Energy stack because of the small size low profile and cost-effective compared to the conventional dipole and ceramic chip antennas. The proposed structure of the PIFA antenna is routed to gain all these
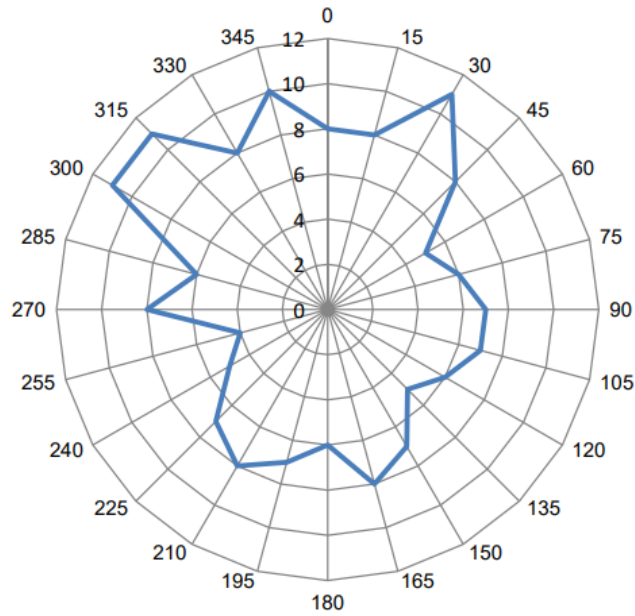
Figure 2.7: Antenna Radiation Pattren

advantages. Replacing the conventional PCB line in PIFA with the meandering line and meandering shorting strip improves the efficiency of the PIFA as well as the bandwidth. As a case study, the design and measurement results of the proposed PIFA are presented [2] in Figure2.8.
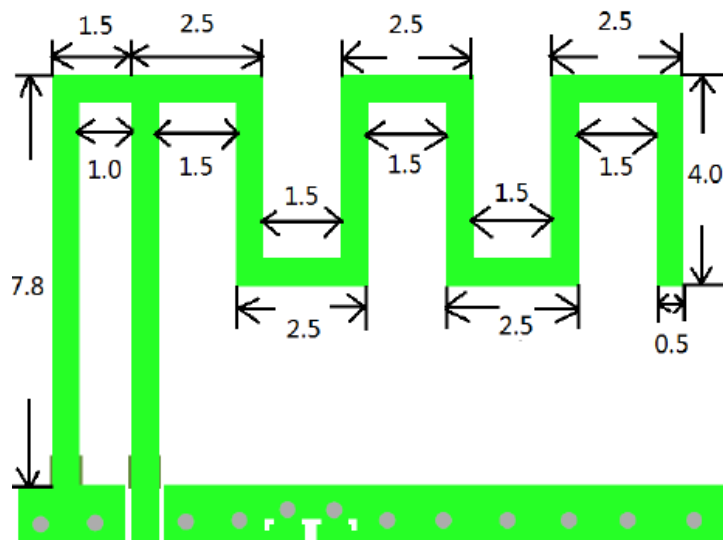

Figure 2.8: PCB Inverted Meandered F type Antenna

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