Motion aware thin Bluetooth® LE beacon solution for smart labels

13-Jul-2021

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Revision: 1.1

1. Introduction

A beacon is a tiny Bluetooth radio battery powered transmitter. Its functionally resembles a lighthouse that can be seen by everyone within a certain range. Instead of a light, these small hardware devices constantly transmit Bluetooth Low Energy (Bluetooth LE) packets. These can be scanned and visually represented by any modern smartphones with a built-in Bluetooth transceiver using an appropriate and interactive application.

Beacons provide an inexpensive broadcasting solution capable of autonomous operation over very long periods of time. Furthermore, when used inside a building, for example, no additional technology is needed as everything can be integrated into the same eco-system of the wireless network. And with some extra functionality, the simple idea of broadcasting messages can be extended to enable beacons to be used in other application areas.

In this paper we will show how beacons can support extended functionality by employing a range of peripherals to allow them to process and display data while maintaining autonomous operation.

Figure 1: BLE eco-system example

A typical Bluetooth LE eco-system is presented in Figure 1. This example shows a proximity marketing use case where the deployed beacons broadcast an ID number through Bluetooth LE channels approximately 10 times/second. A Bluetooth-enabled device (e.g. a smart phone) placed close to the beacon receives this ID number. When an app recognizes this ID number, it links it to an action which can be as simple as displaying a marketing offer on the smart phone, or performing a more complicated task such as downloading an app.

Additional Bluetooth LE beacon use cases include, but are not limited to:

➢ **Indoor navigation**: GPS signals are very weak, if present at all, indoors. A network of BLE beacons can be used for accurate positioning in areas like large shopping malls museums, airports, etc.

➢ **Smart labelling**: Especially popular in large retail stores where traditional labels can be replaced with beacons to enable smart labelling schemes that help minimize the time and personnel needed to update product prices, introduce new offers, etc.

➢ **Healthcare**: BLE beacons can offer great improvements by reducing patient waiting times, notifying doctors about a patient's medical history including medicines, medical equipment tracking (asset tracking), injection devices, patches and more

An example of indoor navigating and smart labelling application can be seen in Figure 2 where visitors are both guided and informed using Bluetooth LE beacon technology.

Figure 2: Bluetooth LE beacon application example for indoor navigation/smart labelling applications

An example of healthcare application based on Bluetooth LE beacon is shown in Figure 3. In this case, the patient's vital readings can be seen and accessed remotely.
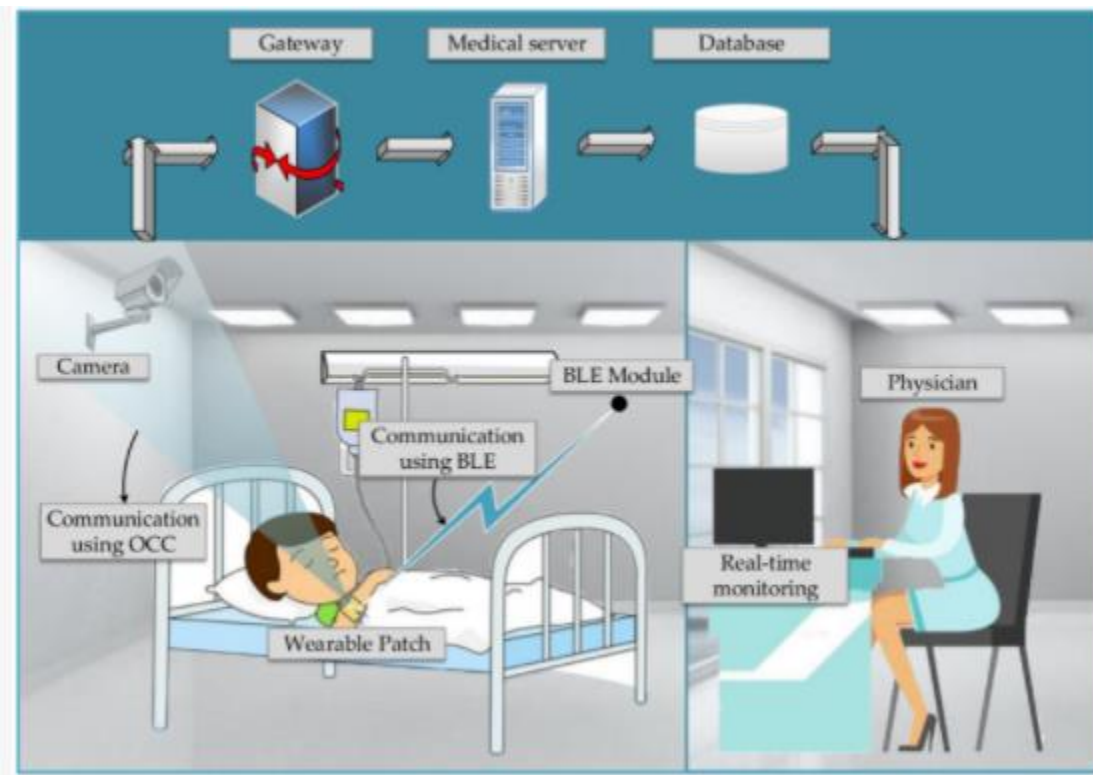

Figure 3: Bluetooth LE beacon application example of a healthcare applications

Without additional hardware, namely a motion sensor or visual aids, these use cases cannot be supported with a traditional Bluetooth LE beacon. An extended functionality version is required. In this paper, we present an extended functionality Bluetooth LE beacon solution including its most important peripherals: a low-profile thin battery, motion sensors and a user interface component (LCD, buttons). These peripherals will be further detailed in the next sections.

Another aspect, also outlined in this paper, is the use of flexible PCB technology for the Bluetooth LE beacon manufacturing. This is a key requirement for several niche applications such as smart labelling pharma product applications and wearable, medical applications.

1.1. Flexible PCB technology

Flexible circuitry adaption delivers the following advantages:

Dynamic Flexing: Flexible circuits have excellent bending or movement capabilities. This feature helps maintain connection through devices that extend, contract or telescope during application. This is a very useful advantage of the flex PCB technology in wearable and medical applications where the available space is very limited.

Reliability: Flexible circuitry has an excellent record of performance and reliability in the highly demanding area of medical applications. Its fundamental advantage is the elimination of the connection points, simplifying assembly and reducing the risk of interconnect faults such as poor solder joints, to provide increased reliability and durability.

Space and weight: Recent and growing demand for smaller and lighter devices makes flexible circuits an ideal choice in applications when space and weight are critical. Flexible circuits are ultra-thin and can be easily bent to adapt to almost any surface. These flexible circuits are also lighter compared to standard rigid PCB boards.

Cost: As flexible circuits can minimize the amount of connections required, they can be manufactured efficiently in high volumes. This helps to reduce the assembly cost. Avoiding the use of soldered wires, rigid printed circuits, and connectors offers further possibilities to reduce the total cost.

2. Bluetooth LE Beacon system overview

An extended functionality beacon BLE system typically consists of the following main components:

- **Bluetooth LE SoC unit:** A Bluetooth connectivity System on Chip (SoC) with a built-in Microcontroller unit (usually an ARM processor) for the necessary computing tasks. The main processor selection is driven by the type and the complexity of the device. Modern MCUs integrate most of the functions in a single chip. The Bluetooth LE SoC has an attached antenna, which broadcasts at a specific wavelength and frequency.

- **Battery:** A Bluetooth LE SoC should be able to operate for long periods of time, this is achieved by using an appropriate battery source. Coin cell battery have proven to be the most cost, size and duration effective solution. Rechargeable batteries are generally not recommended, due to the increased cost of supporting the charging operation using dedicated circuitry.

- **Motion Sensors:** A motion sensor with, for example, an accelerometer could be used, to increase battery life and hence the autonomy of the system by introducing system sleep mode capability when no movement is detected. This optional feature is, of course, dependent on the beacon use case.

- **User interface**: Depending on the use case, various Man Machine Interface options can be considered for usage in beacons:

  - A low power display such as e-paper technology that has the advantage of continuously showing a single image after being completely powered off, very useful for retail store labelling applications,

  - Mechanical buttons that could be used as a part of the ON/OFF mechanism, extending the battery life even further.

2.1. Extended functionality, low power, flexible Bluetooth LE beacon
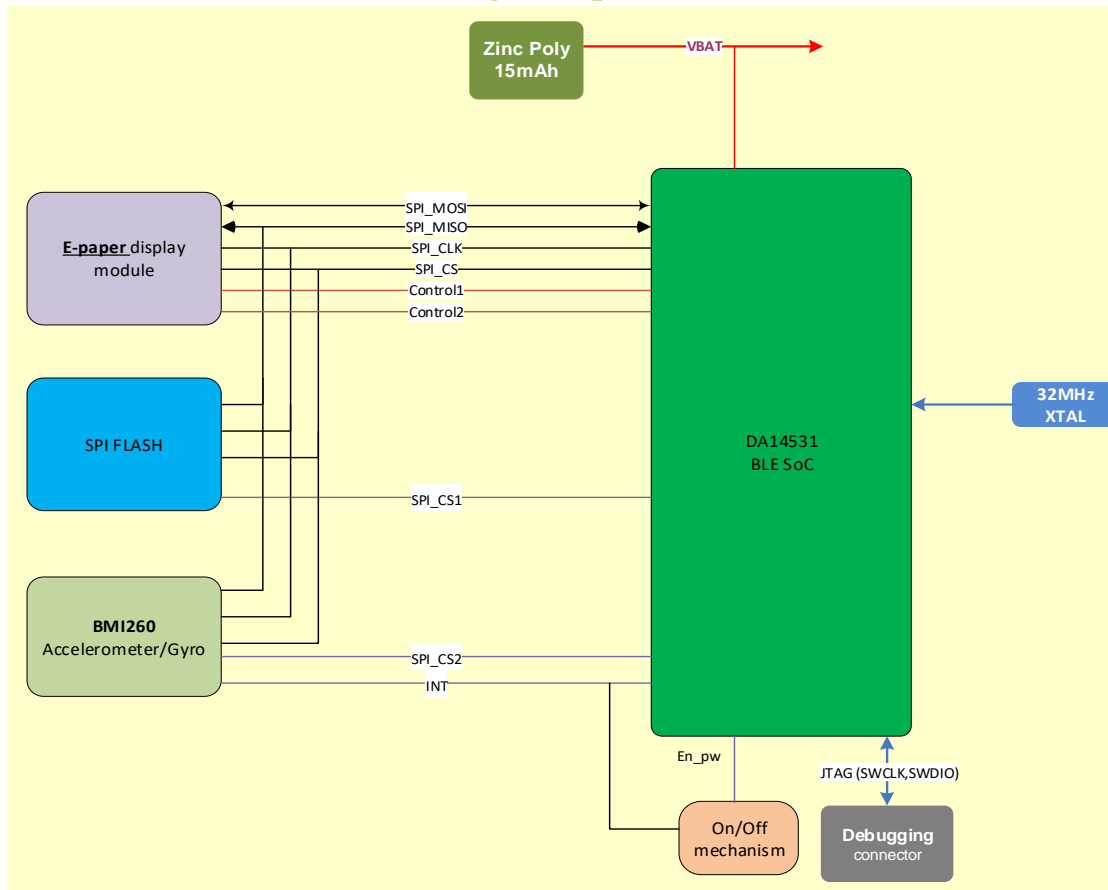

Figure 4: Block diagram of a beacon device with extended functionality

Figure 4 depicts a top-level block diagram for an extended functionality Bluetooth LE beacon device that consists of:

- o   Bluetooth Low Energy (Bluetooth LE) SoC powered by a microprocessor unit ARM Cortex class M0 for data transmission
- o   High-capacity SPI flash memory
- o   Accelerometer/Gyro sensor
- o   32MHz crystal
- o   On/Off power switch
- o   A low-resolution e-paper color display that can be also connected to the beacon system taking into consideration the limited display drive capabilities of the Bluetooth LE SoC

3. Hardware components & Implementation

In addition to providing extended functionality, Dialog's Bluetooth LE beacon proposal also supports the flexible approach in the key components. The PCB, battery and the LCD are all made from bendable materials allowing them to be placed in most non-flat surfaces, especially important for smart labelling applications.

Another key aspect of the Bluetooth LE beacon is that it should exhibit a very low power consumption from all its active components to support a long battery duration.

3.1.   DA14531 BLE SoC from Dialog Semiconductor

In the example shown in this paper, we needed a very low power, small-size Bluetooth LE MCU solution. Thus, we selected the DA14531 BLE SoC which is one of the world's smallest, low-power Bluetooth 5.1 System-on-Chip™ solutions. It's record-breaking low hibernation and active power consumption ensure long operating and shelf life with even with the tiniest, disposable batteries Available in a tiny 2.0 x 1.7 mm package, DA14531 is based on a powerful 32-bit arm Cortex M0+ with integrated memories and a complete set of analog and digital peripherals.
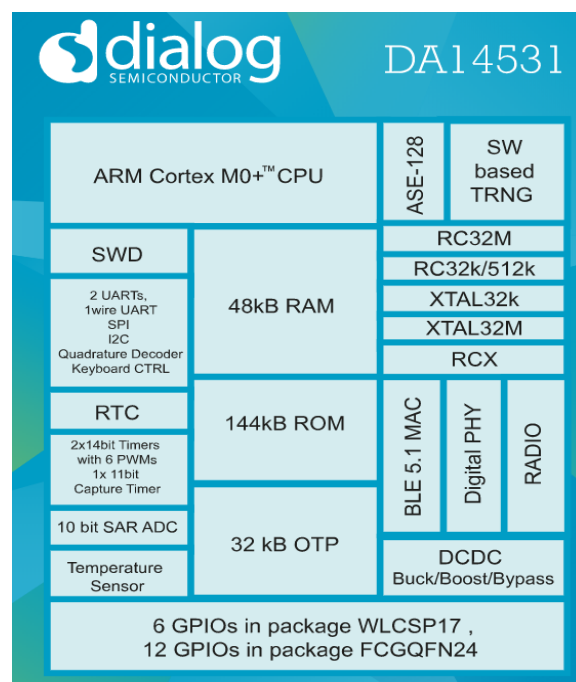
Figure 5: DA14531 block diagram

The main hardware components of an extended Bluetooth LE beacon system are analyzed below:

3.2.   Flex E-paper display

For smart labelling applications there is a need for a thin, low power display. E-paper displays appear to be the best fit for extended functionality beacon use cases as these displays only consume power when refreshing. Once an image becomes visible, an e-paper display requires no power to keep it displayed. This gives extraordinary battery life for the product.

For the example described in this paper, an all-in-one display was selected. This type of display does not need a negative power supply that would require additional complex and costly circuitry for the implementation, reducing the overall bill of materials cost. The display resolution is 212*104 pixels, and it connects to the main MCU via SPI interface using a 24 pin FPC connector.

3.3. Bosch Sensortec sensors

To add movement intelligence and to further reduce the power consumption of the system, required the addition of a motion sensor. In this paper, a Bosch BMI270 is being used. This is an ultra-low power motion sensor that combines an accelerometer and a gyroscope with several operating modes and self-calibrating algorithms. The BMI270 is a very good choice for this purpose, as it integrates many of the functions needed for extended beacon functionality. Moreover, its ultra-small size and low number of external components makes it ideal for use in a flexible system.

3.4. Flexible battery

In a flexible beacon system, a flexible battery is also required. In the system example of this paper a newly introduced, state of the art, solid state battery from Imprint Energy is being used. This battery material (Zinc poly) allows for high energy, safe and stable ultra-thin operation making it ideal for Bluetooth LE beacon applications since it is printable to any shape, with no need for additional sealing. This battery has a very low internal resistance that can withstand high current pulses over a long duration and delivers a nominal capacity of 15mAh. These features make this battery an excellent choice for the extended beacon application.

Figure 6: The actual 15mAh ZincPoly flex, ultra-thin battery

3.5. Actual DA14531 extended functionality flex Bluetooth LE beacon

Figure 7 and Figure 8 show the top and bottom views of an assembled Flexible PCB that implements the DA14531 beacon system introduced in Section 3. The figures also indicate the location of all the major components that were presented in the previous sections. The total thickness of the flex PCB is 0.23 mm. The base material is polyimide with properties as outlined in Table 1. The entire construction (PCB & peripherals) has a maximum height of approx. 2 mm, taking into account the highest components on each side namely the inductor (top) and the display connector (bottom). Most of the surface thickness is well below this number, while the flexible material of the board makes it quite adaptive and bendable allowing it to fit into any kind of enclosure. The flexibility of the entire Bluetooth LE beacon (PCB and e-paper, battery components) is presented in Figure 9.

Table 1: *Polyimide material properties*

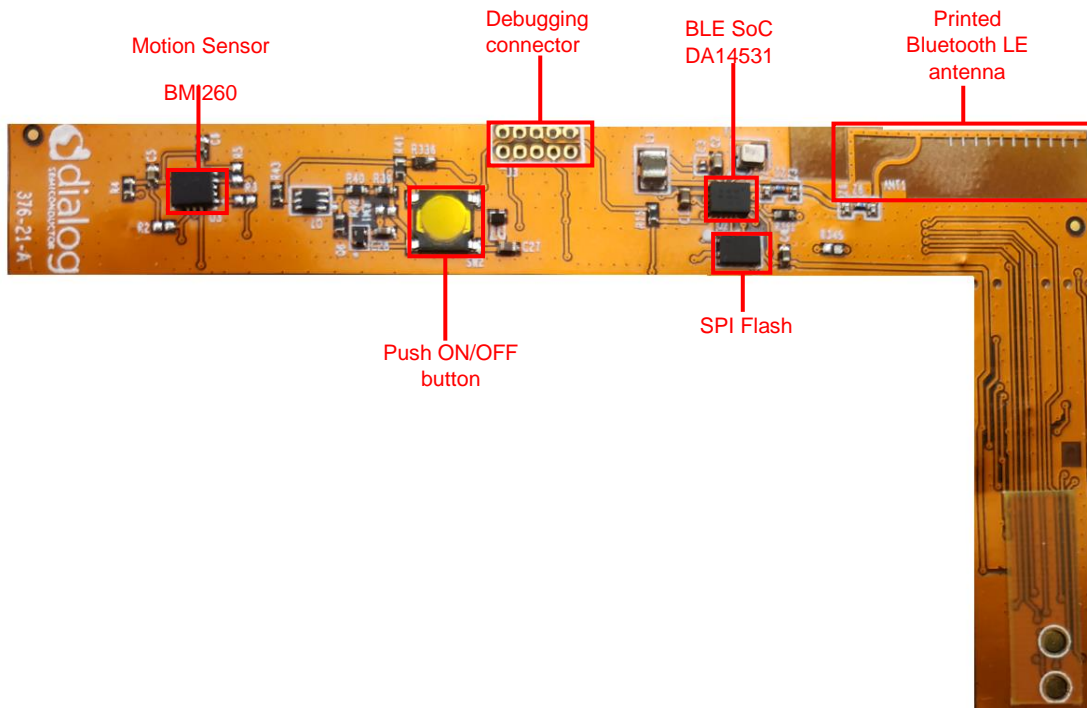| Polyimide Flex PCB base material properties		
Property	**Value**	**unit**
Copper adhesion	≥ 0.70	N/mm2
Dielectric constant	≤ 3.7 @ 1.1 GHz	
Solder path resistance	288	°C
Expansion	± 0.20	%

Figure 7: DA14531 Bluetooth LE beacon - Top
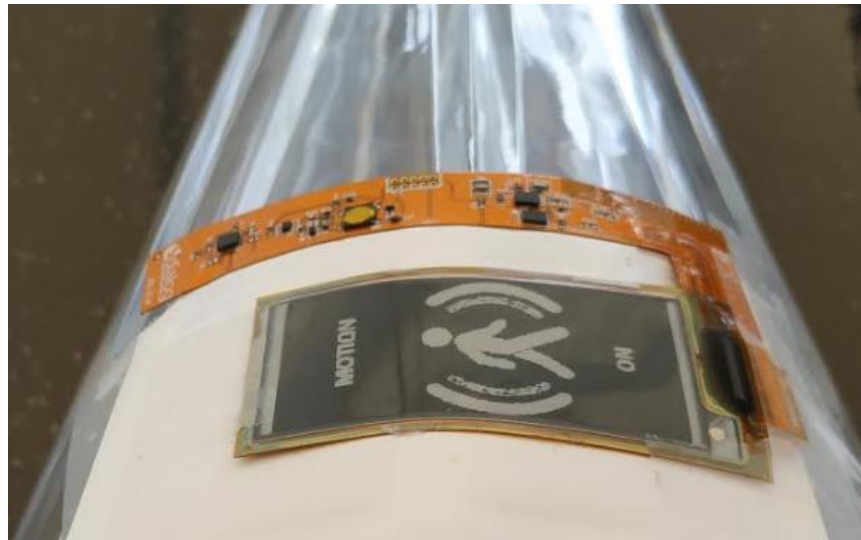
Figure 8:DA14531 BLE beacon - Bottom

Figure 9: Placement of the flexible Bluetooth LE beacon on an actual round (not flat) surface

4. Power & RF measurements section

As a design targeted for battery operation, the DA14531 Flex Beacon should exhibit an ultra-low power consumption that will allow it to deliver a long operating life. Figure 10 shows the total power consumption figure measured at about 500 uA (Average) this measurement was taken for the following conditions:

- o   E-paper display in screen refresh mode
- o   BLE advertice interval of 2s
- o   Scan mode event for nearby tag devices
- o   Accelerometer operation with an output data rate of 1.5Hz
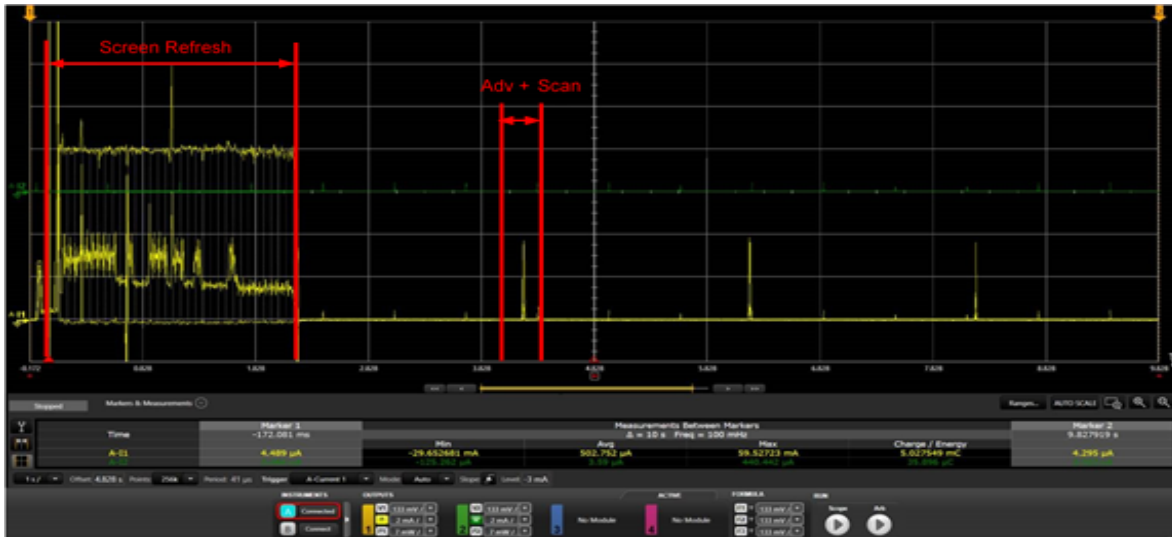
Figure 10: Overall power consumption of the DA14531 Flex Beacon

Error! Reference source not found. shows a total power consumption figure of 160 uA (Average), for the same conditions as above, excluding the screen refresh event.
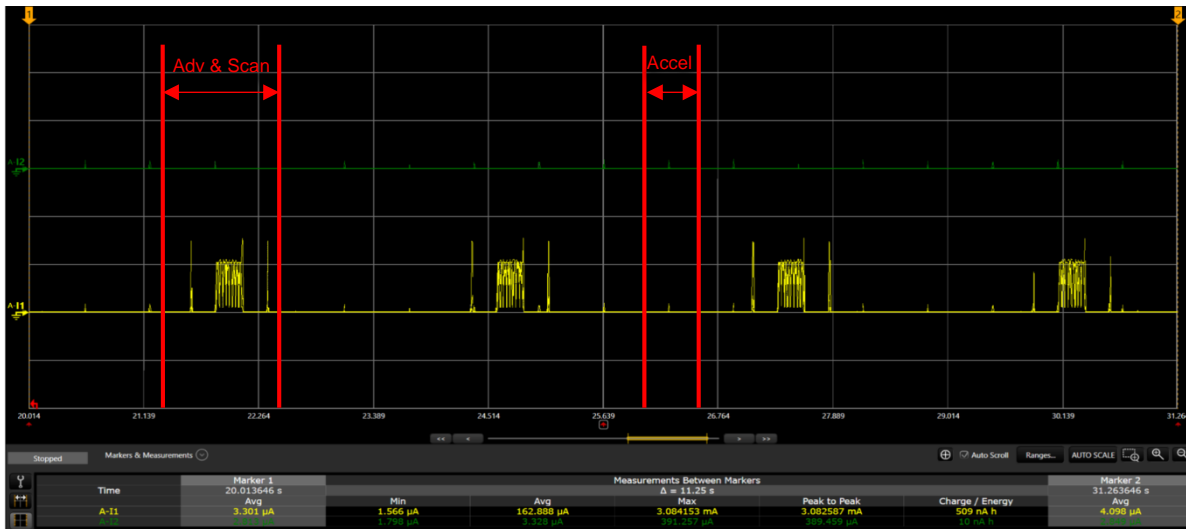
Figure 11: Power of the consumption of the DA14531 Flex Beacon without screen refresh

A very low power consumption is critically important during sleep mode, as this the default operational state for this kind of beacon. For this solution, a sleep current of 3.9 uA was measured with a static (fixed) picture on the e-paper display.

In Figure 12 there is the reflection coefficient for the flex polyimide PCB material as specified in Table 1 . The reflection coefficient for a matched antenna -28dB is almost identical to the FR4 material of standard non-flex PCBs thus giving good RF performance credits to the polyimide material used.
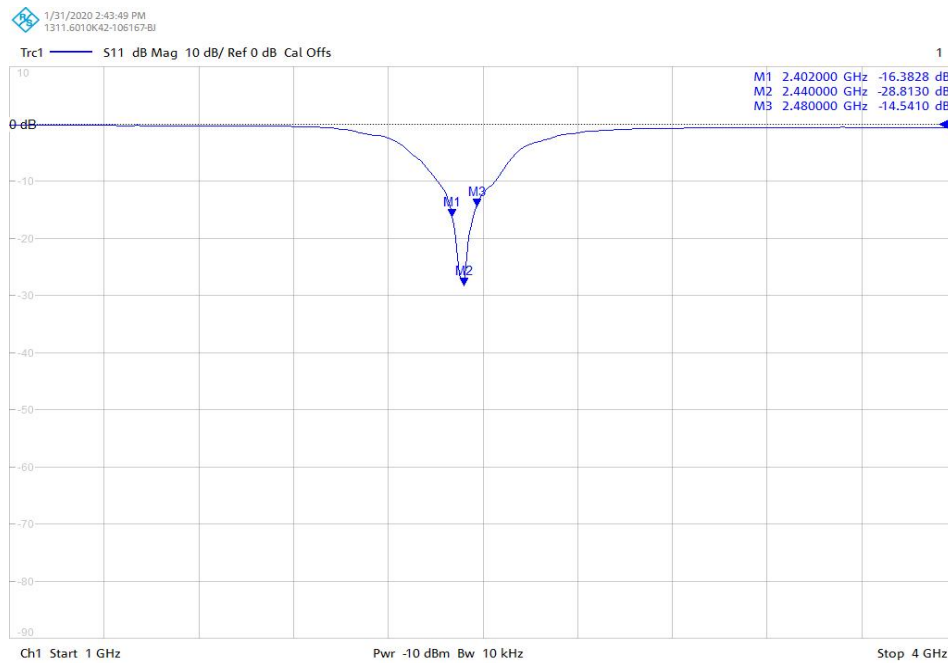
Figure 12: S11 magnitude in dB

5. Conclusions

This paper presents a low power, extended BLE beacon system based on Dialog Semiconductor's DA14531 Bluetooth LE SoC. Emphasis was given to the flex material PCB that exhibits increased reliability, cost savings and most importantly the ability to adapt to any surface thanks to its flexible properties. In addition, the flex material of the battery and the e-paper display components make this extended Bluetooth LE beacon an ideal candidate for healthcare and smart labeling applications.

6. References

[1]   Bluetooth LE beacon technology made simple

[2]   Bluetooth LE proximity marketing

[3]   DA14531 product info

[4]   Flex Circuits Advantages

[5]   The Complete Guide to Bluetooth Beacons

[6]   Real-Time Healthcare Data Transmission for Remote Patient Monitoring in Patch-Based Hybrid OCC/BLE Networks

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