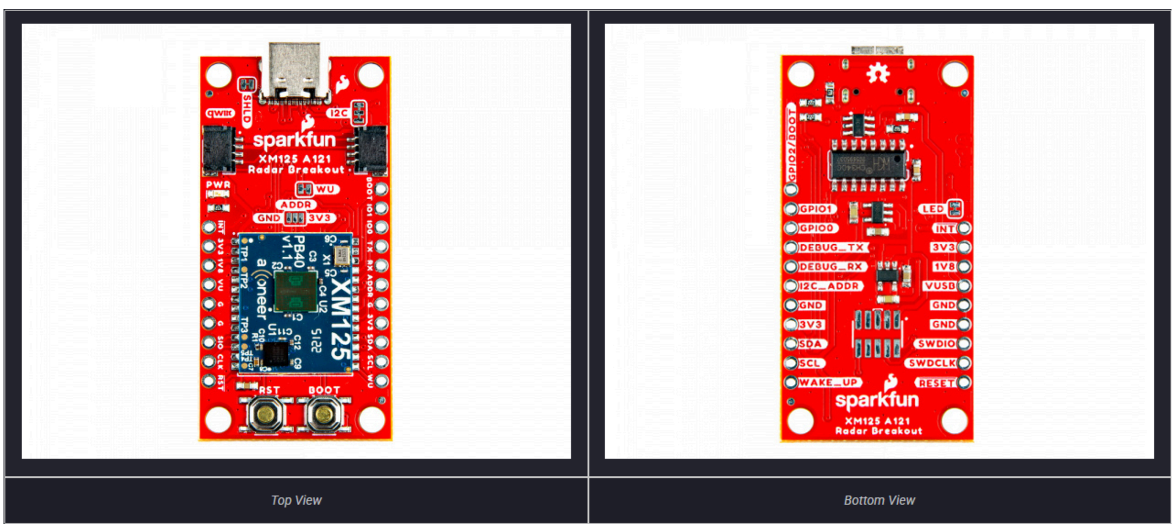
Sparkfun XM125:

- The sensor has remarkably low power consumption (Look into on datasheet)
- AP2112K 3.3V/600mA and RT9080 1.8V/600mA voltage regulators
- USB I^2C
- Motion detection (although probably not particularly useful for us)
- Acconeer Exploration Tool (https://github.com/acconeer/acconeer-python-exploration) "The ML interface *(no longer supported)*. Support for the Machine Learning interface in Exploration Tool has been dropped. If you still need to use it, it is possible to use an old version of Exploration Tool."
- **Note:** Due to the higher frequencies, pulsed coherent radar sensors may be regulated in certain countries. Be sure to check local regulations before use. (Assuming fine bc chosen by Josh)

XM125 Module Breakdown:



Top View Bottom View

Hardware Overview - Acconeer XM125 Hookup Guide

5V power from the USB C Connector or PTH is regulated down to *3.3V* with the AP2112K 3.3V/600mA voltage regulator. The voltage is further regulated down to *1.8V* with the RT9080 1.8V/600mA voltage regulator. The logic level for the XM125 is **3.3V** for the I/O pins.

There are two PTHs labeled **SDA** and **SCL** on one side of the board. These are the I^2C data and clock lines and are connected to two 2.2kΩ pull-up resistors. We also conveniently added a GND and 3.3V pin on one side should you decide to daisy chain additional I^2C devices to the PTH. (**SDA** – I^2C data, **SCL** – I^2C clock)

XM125 Programming:

[Arduino Library - Acconeer XM125 Hookup Guide]
[Arduino Examples- Acconeer XM125 Hookup Guide]

In addition to the Arduino IDE, you may need to install the STM32CubeProgrammer as well.
[STM32CubeProgrammer - Acconeer XM125 Hookup Guide]

Flashing Firmware
[Flashing Firmware to the XM125]

Python Exploration Tool
[Installing the Acconeer Python Exploration Tool]
[Getting Started with the Acconeer Python Exploration Tool]

XM125 Schematic:

[XM125 Breakout Schematic]

Data Sheets:

[A121 – Pulsed Coherent Radar (PCR)]
[ZED-F9F-02B - GNSS Module]

Timing Requirements:

Parameter	Min.	Typ.	Max.	Unit
Clock frequency			50	MHz
SS setup time	1.0			ns
SS hold time	2.0			ns
MOSI setup time	1.0			ns
MOSI hold time	2.5			ns
MISO Propagation delay VIO=3.3V and 10 pF Load	2.0		5.5	ns
MISO Propagation delay (VIO=1.8, Radar System Software Setting, 10pF)	3.0		7.5	ns

Table 12. SPI timing characteristics.

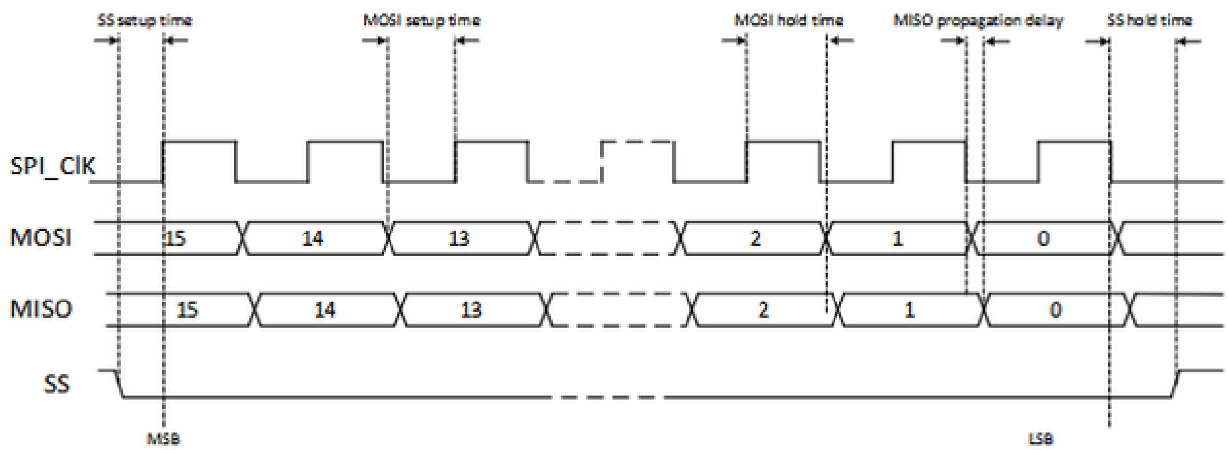
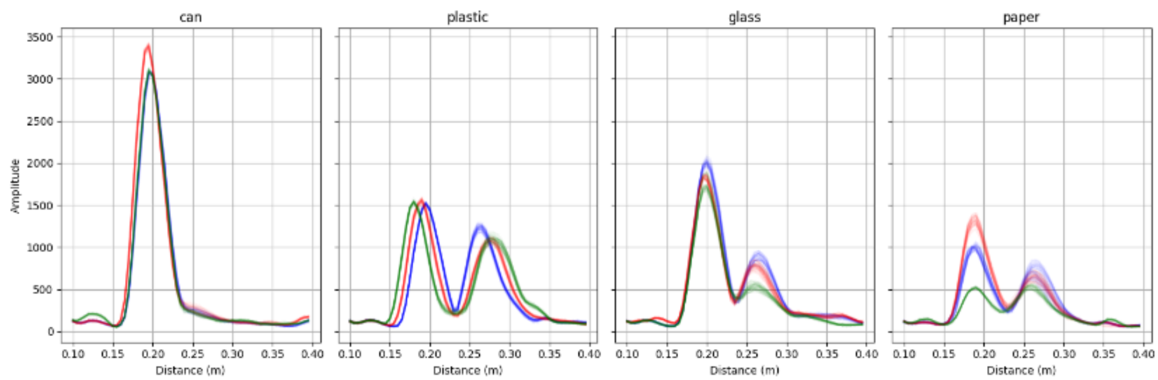


Figure 5.2. Timing diagram of SPI, CPOL=0 and CPHA=0.

Previous Research Papers:

Material Classification of Recyclable Containers Using 60 GHz Radar:

- [Material Classification of Recyclable Containers Using 60 GHz Radar]()
- The frame rate was set to 15 frames per second and the disc rotated at 0.5Hz, resulting in 30 frames per revolution. One revolution of data is hereafter referred to as the *classification window*.
- The graphs where two distinct peaks are present correspond to the case when the material has some degree of transparency, allowing the transmitted pulse to partially pass through the front of the container, reflecting off the back, resulting in a second peak.



- Based on these observations, the following features were selected as inputs to the classification model.
  • Main peak mean amplitude — Measured amplitude, reflected from the front of the container.
  • Secondary peak mean amplitude — Measured amplitude, reflected off the back of the container.
  • Peak amplitude ratio — The ratio between the main and secondary peak mean amplitudes.
  • Main peak amplitude variance — The variance of the amplitudes, acquired while rotating the container, at the main peak.
  • Secondary peak amplitude variance - The variance of the amplitudes, acquired while rotating the container, at the secondary peak.
  • Peak variance ratio — The ratio between the variance of the main and secondary peak amplitudes.
  These six features, along with the class label, were extracted from each classification window and used for training the classification model.

- One possible alternative to further improve the result and lower the miss-classifications is to extend the classification window to include a longer time series. However, this would increase the required measurement time.

A 60 GHz pulsed coherent radar for online monitoring of the withering condition of leaves:

- A 60 GHz pulsed coherent radar for online monitoring of the withering condition of leaves
- The advantage of using a pulse radar over continuous–wave (CW) radar is that pulse radar operates in the time domain and therefore it does not require the fast Fourier transform (FFT) analysis that characterizes CW radar. Without excessive computational needs, a highly integrated radar system can be implemented using low-power microcontrollers.
- In particular, the resonances for frequencies below 100 GHz occur at nearly 22 GHz for water vapor (H_2O) and 63 GHz for oxygen (O_2). Attenuation due to water vapor is a strong function of temperature, pressure, and humidity. Since this work focuses on measuring changes in the water content in the leaf and not the properties of surrounding vapor or gas in its environment, the choice for 60 GHz over 24 can be decisive.
- The lens performances are conditional to the distance from the integrated antenna. In this work, the construction that allows the maximum gain 9.1 [dB] and 10.0 [dB] for the Fresnel Zone Plate lens (FZP lens) and Hyperbolic Lens (HBL lens), respectively, was chosen. The outlined maximum gains are relative to the free-space scenario.
- Depending on the use case and based on different algorithms, four modes of operation are available for Acconeer pulse coherent radar: sparse, power bins, IQ, and envelope. The sparse service is ideal for motion-sensing applications requiring high robustness and low power consumption. The Power Bins Service is mainly intended for use in low-power applications where large objects are measured at short distances from the radar sensor. The IQ service provides the capability of detecting fine movement occurring in a target scene. This service is similar to the envelope service. Though, the envelope service is optimized for providing an accurate envelope estimate, while the IQ service is optimized for producing a phase-stable estimate. Since there is no use of phase information in the data process for monitoring the withering condition of leaves, the envelope service was selected. A detailed description of all settings for the envelope and other services can be found at

https://developer.acconeer.com/download/hardware-and-physical-integration-guideline-pdf

- The assembled EVK was connected to a computer. A standard corner reflector with RCS of 1 m^2 at 60 GHz was used to fix the path length of the radar signal from the transmit antenna of the PCR along the direction of propagation and to make the power of the reflected signal independent of the environmental background and the other objects.
- The working principle of the prototype:

The working principle of the suggested PCR prototype is to detect changes in the received signal and based on the following concepts:

1) PCR sensor is a time-of-flight system, which means that an electromagnetic (EM) wave emitted by a transmit antenna and travels toward a target through the medium with the complex refractive index n [-]. Also, a fraction of the signal is scattered back to the sensor and recorded by a receiver antenna [23].

2) In general, the transmitted signal $s_t(t)$ of PCR consisting of one wavelet pulse can be expressed as follows (1):

$$s_t(t)= a_t u(t)\bullet e^{j2\pi f_0 t} \quad (1)$$

where a_t describes the amplitude factor, f_0 [Hz] is the radar carrier frequency, and u(t) is the complex transmitted modulation [23].

3) Determined by factors such as the type of the target and distance to it r [m], the received signal $r_t(t)$differs from the transmitted signal (1) having a different amplitute a_r, and beeing delayed by $\tau_r[s]$: (2), [23]:

$$r_t(t)= a_r u(t-\tau_r)\bullet e^{j2\pi f_{0\bullet}(t-\tau_r)} \quad (2)$$

4) In addition, the distance r [m] to the target is can be determined by time delay $\tau_r[s]$, between the transmitted and received signal (3) [23]:

$$r = c \bullet \tau_r/(2 \bullet n) \quad (3)$$

where c [m/s] velocity of light in vacuum.

The factor of-two in (3) accounts for the round trip propagation path of the pulse.

5) EM waves propagate through free space or a medium with an amplitude and phase corresponding to a propagation constant (γ) [m^{-1}] (4–5), [23]:

$$a_r = a_t \bullet e^{-\gamma l} \tag{4}$$

and

$$\gamma = \alpha + j\beta \tag{5}$$

where α, attenuation of propagation constant γ [Np/m]; β phase of the propagation constant γ [rad/m]; l is the distance from source [m] (in the case demonstrated in this paper and shown in Fig. 1 $l = r$, denotes the one-way path of energy from the radar to the corner reflector, but in general terms is either the direct or reflected signal).

6) digital values of the received signal amplitude produced as an output of the analog-to-digital converter (ADC) were recorded and analysed.

- Review “2.4. Determination of RWC in a plant leaf applying the Beer-Lambert’s law” for attenuation constant derivation
- Although, the absence of a radome did not show any extreme deviations in measurements and their analysis (the R-Squared value was between 0.93%-95% in all investigated cases), it is not recommended such a setup for monitoring the withering condition of leaves because of reasons described in Section 2.1. (RADOME?)