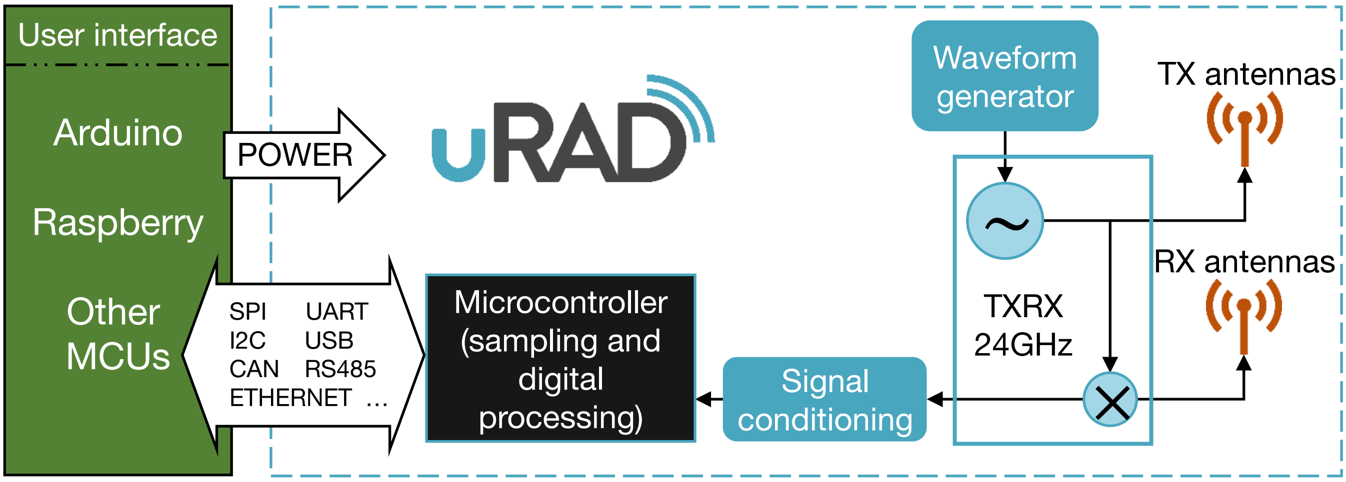
24 GHz Technology White Paper

uRAD 24 GHz Architecture

uRAD follows in each product of the 24 GHz family a similar hardware architecture that makes the most of radar technology, offering a high-performance solution where each part has been carefully designed. Everything is fabricated in planar technology to offer the most compact, lowest consumption and cost-effective product for each application.

In the radiofrequency part, Infineon's microwave radar transceivers are used together with specifically designed antenna arrays for transmission and reception. These solutions include only one transmitter antenna and one receiver antenna. Therefore, angular information is not provided. uRAD puts special care in the analog part that includes several filters, amplifiers and other integrated circuits for signal conditioning.

The core is a powerful microcontroller. Inside it, uRAD makes the different with an outstanding proprietary digital processing. This MC serves as interface with other platforms such as Arduino, Raspberry Pi or other MCUs where multiple communication protocols are available. uRAD gives control to these platforms and so, the user can program uRAD according to their desired applications. uRAD is powered externally by minimum voltage equal to 3.3V.

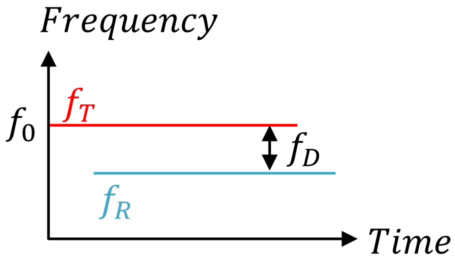


Modes of operation

The obtainable information is mainly determined by the transmitted waveform. uRAD implements several modes which correspond to different transmitted signals.

• Doppler - Continuous Wave (CW)

The radar transmits a constant frequency signal f_T. The reflected wave has the same frequency ($f_R = f_T$) if the reflecting object is static or a frequency difference f_D (Doppler frequency) proportional to the radial velocity of the object when moving. The radial velocity is the component of the target's velocity that points in the direction of the line connecting the object and the radar.



$$f_{Doppler} = f_T - f_R = \pm \frac{2f_0}{c} v_r$$

f_0 is the emitted frequency

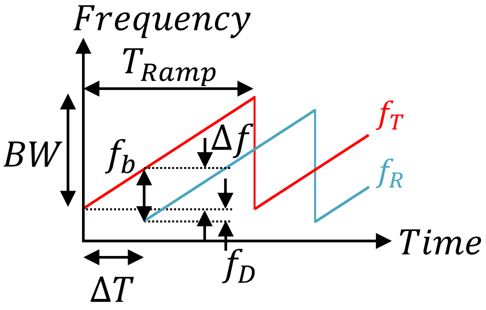
c is the velocity of light

The minus and plus sign indicates a target moving toward or away the radar, respectively.

In the received part, the reflected signal is mixed with the transmitted signal to obtain their difference. This new signal is sampled to obtain the digital information. Through the FFT of this digital signal, the Doppler frequency is obtained, and the radial velocity of the object calculated. By means of this waveform it is only possible to detect the target and determine its radial velocity, but not the distance between the radar and the object.

• Sawtooth - Frequency Modulated Continuous Wave (FMCW)

A FMCW radar transmits a signal f_T that changes its frequency with time. Therefore, the echo signal f_R is received with a frequency difference Δf due to the delay caused by the propagation time ΔT. Moreover, if the object is in motion, the radial velocity produces an additional frequency shift f_D due to the Doppler effect. Therefore $f_T - f_R = f_b = \Delta f + f_D$. Δf containes the information about the distance R from radar to target: $R = 2\Delta T/c$ in which c is the velocity of light. In the case of a sawtooth waveform:



$$\frac{BW}{T_{ramp}} = \frac{\Delta f}{\Delta T} \rightarrow R = \frac{c\ T_{ramp}}{2\ BW} \Delta f$$

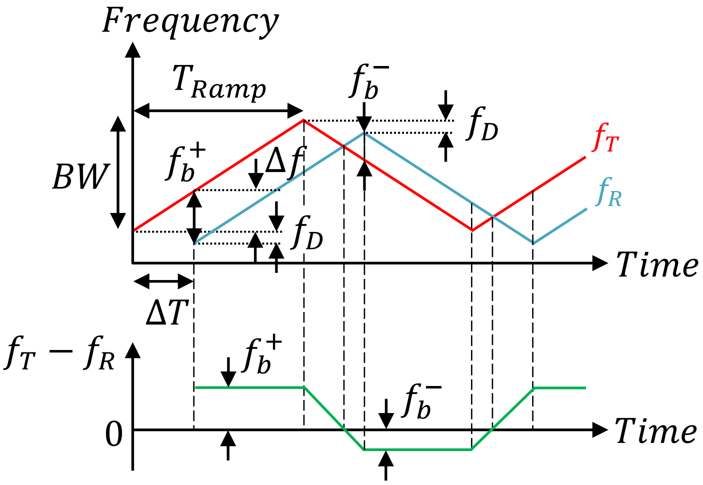
BW is the frequency bandwidth

T_{ramp} is the ramp duration

However, in reception we cannot measure Δf, we measure the total frequency shift f_b . Therefore, in a static scenario we can obtain the exact distance to a target because $f_D = 0 \rightarrow R = \frac{c\,T_{ramp}}{2\,BW} f_b$. If the target is moving, we cannot separate Δf form f_b. However, in most practical scenarios, $\Delta f \gg f_b$ and we can assume $R \approx \frac{c\,T_{ramp}}{2\,BW} f_b$. But, we know there will be a small error in the calculated distance due to the radial velocity. With the sawtooth waveform we can obtain the distance to a target but not the velocity. For calculating both parameter we need more complex modulation such as the triangular waveform.

- **Triangular - FMCW**

Making use of a triangular waveform it is possible to separate Δf from f_b because there are two different frequency shifts f_b^+ and f_b^- during the ascending and descending ramp, respectively.



$$f_b^+ = \Delta f + f_D$$

$$f_b^- = \Delta f - f_D$$

$$\Delta f = \frac{f_b^+ + f_b^-}{2}$$

$$f_D = \frac{f_b^+ - f_b^-}{2}$$

Now, measuring f_b^+ and f_b^- and from previous equations we obtain: $R = \frac{c\,T_{ramp}}{2\,BW} \Delta f$ and $v_r = \frac{c}{2 f_0} f_D$ from the Doppler effect equation with f_0 the central transmission frequency. Therefore, with a triangular waveform it is possible to obtain both the distance and velocity of the object. On the other hand, the disadvantage of this mode is the required double acquisition time and a more complex data process calculation which can reduce the update rate. Besides these modes, uRAD implements additional and more complex waveforms based on the triangular one to improve detection and reduce ghost targets.

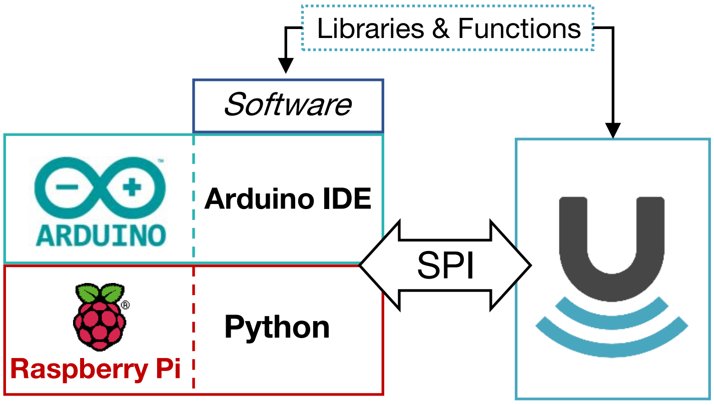
uRAD uses high-performance waveform generators to produce Doppler and FMCW waveforms in their radar solutions and let the user to select the most convenient mode for each particular solution. Next table summarizes some advantages and disadvantages of each performance mode.

Features	Doppler	Sawtooth	Triangular
Velocity measurement	Yes	No	Yes
Distance measurement	No	Yes	Yes
Accuracy	Best	High	Best
Complexity	Low	Medium	High
Update rate	Best	Very High	High

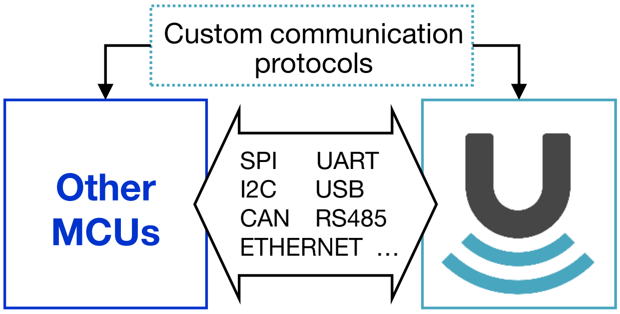
User Interface

uRAD facilitates to the final user the control over the configuration and measurement acquisition from the hardware. uRAD offers two kind of solutions.

uRAD shield products: Arduino and Raspberry Pi are the selected platforms for the user interface. The communication with both platforms is done by means of SPI communication interface. uRAD has created specific libraries and functions in Arduino IDE and Python for the ease of programming. For instance, in both platforms, just two simple functions included in your code are needed: one for configuring your shield and another one for acquiring the data.



uRAD custom solutions: uRAD hardware is able to communicate with a full variety of communication interfaces by means of physical connectors that can be chosen by the user. uRAD also implements communication protocols according to the user needs to facilitate the integration with bigger systems or to speed up the data interchange.



Warnings

uRAD's products may not be used for any applications or in any components used in life support devices or to operate nuclear facilities or for use in other mission-critical applications or components where human life or property may be at stake.

Additional information

For further information on technologies, our products, the application of our products, delivery terms and conditions and/or prices, please contact us in contact@urad.es or visit www.urad.es.

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