24 GHz URAD With Arduino

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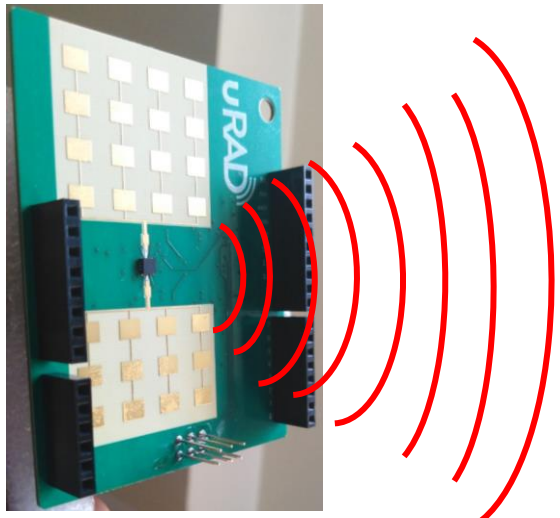
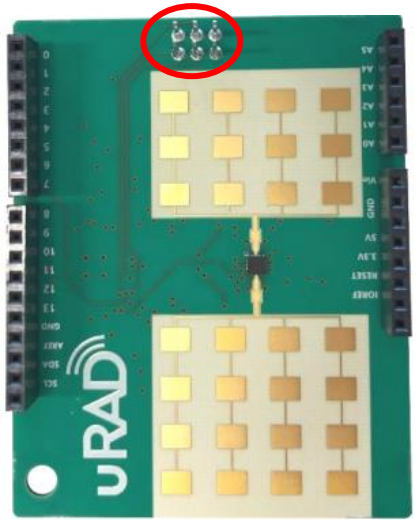
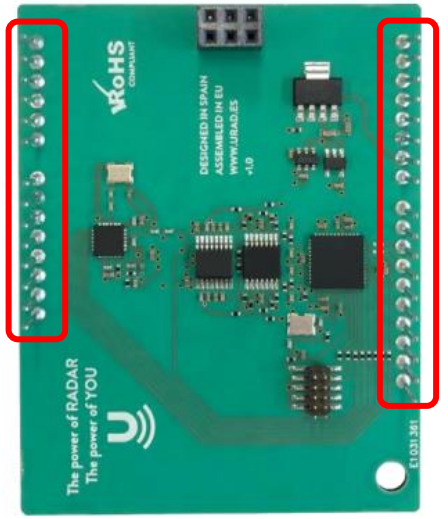
Hardware Description:

- Top layer: 24 GHz transmitter and receiver antenna.
  - ❖The microwave is emitted perpendicular to this layer



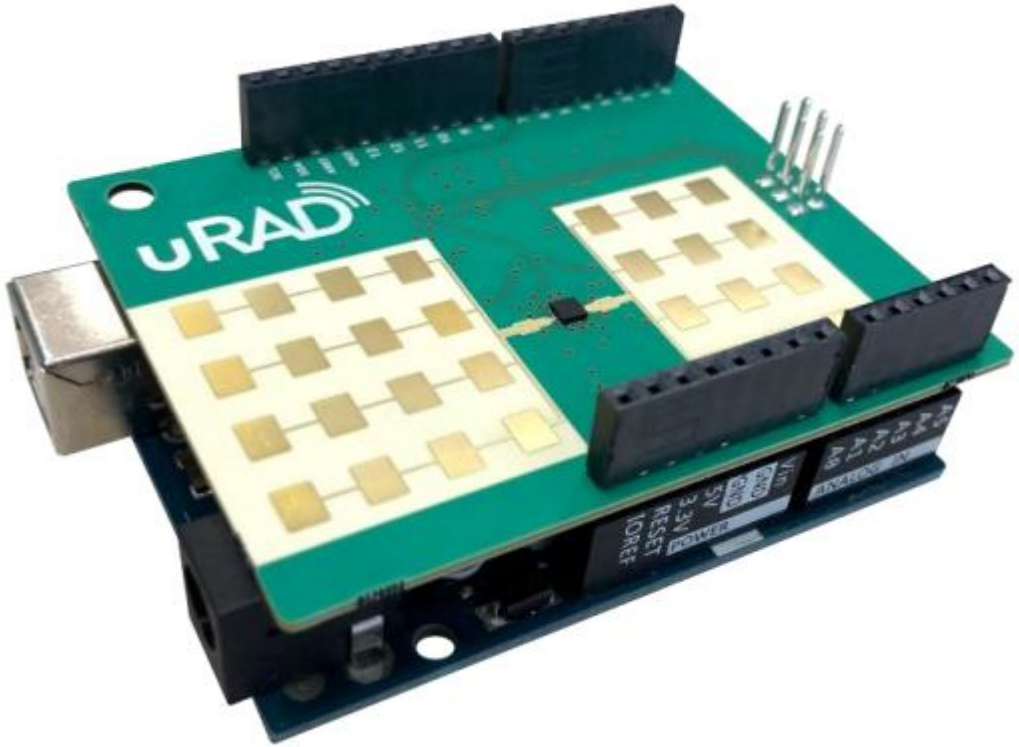


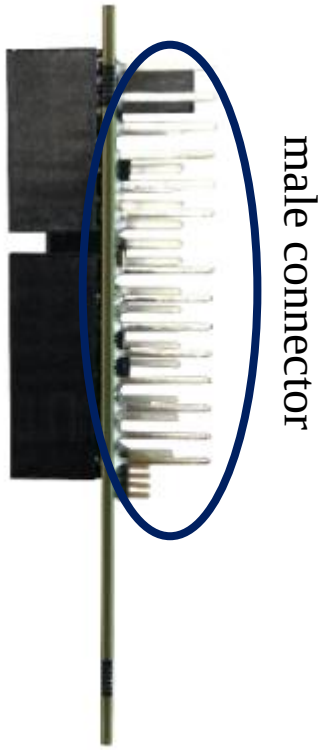
- Bottom layer: power supply and signal processing units, which are controlled by powerful microprocessor.
- Four different connectors to interface it with Arduino board.



Assemble with Arduino:

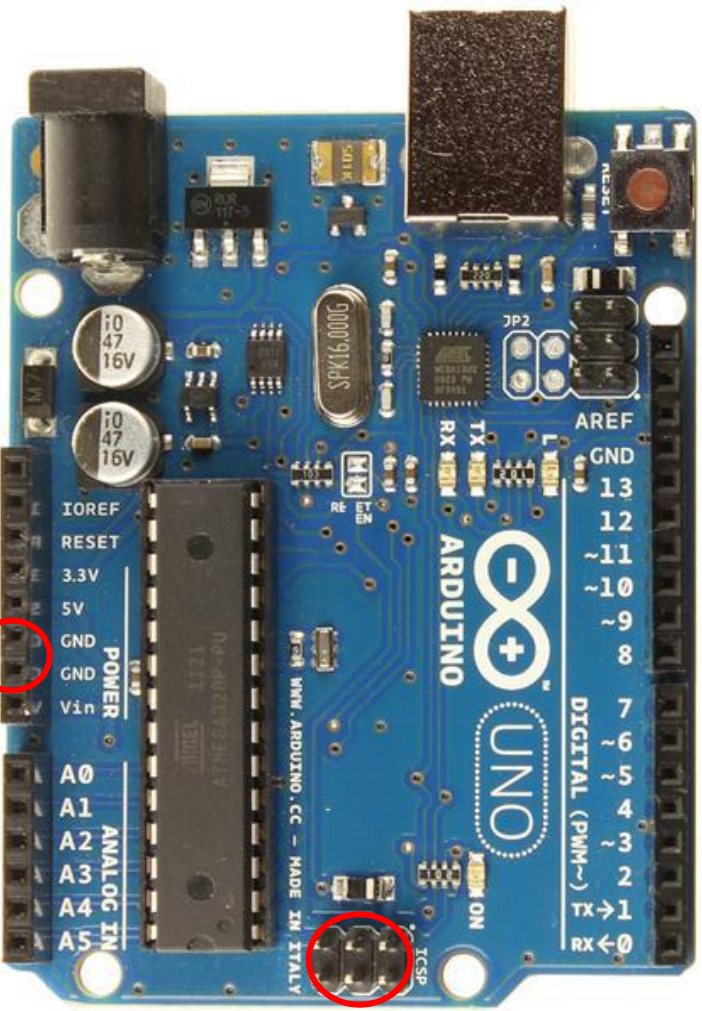
- Carefully connect the male connector of the uRAD to compatible female connector of the Arduino board





- Don’t insert the male connector completely!
- Enough contact is sufficient.
- Avoid bending the pins.

Power Connection:



- uRAD is powered by 5V power pin of Arduino (left pin) and they also share GRN power pin (2 pins/on the left).
- uRAD share one pins for SPI communication protocol (pin 7) and another pin (pin 6) for ON/OFF or logic HIGH/LOW .
- ICSP connector: transmit and receive data between uRAD and Adruino (bottom 6 pins).

- ❑ Don’t use these pins for any other purpose.
- ❑ Don’t cover the antenna with metal or electronic element.

Suggestion/Advice

- Before disconnecting the Arduino-uRAD board PLEASE close all Arduino IDE program and any process that might run on uRAD board.

- During uploading program to the uRAD board you might encounter connection error, “COM connection unavailable”, which restarting your computer will help rectify the problem.

- If the connection between Arduino and uRAD is not correct both GUI and Serial communication version of uRAD software fails to start. Therefore, check the pins are well connected and all indicator light are flashing correct.

Power LED: indicate the Arduino board is receiving power.

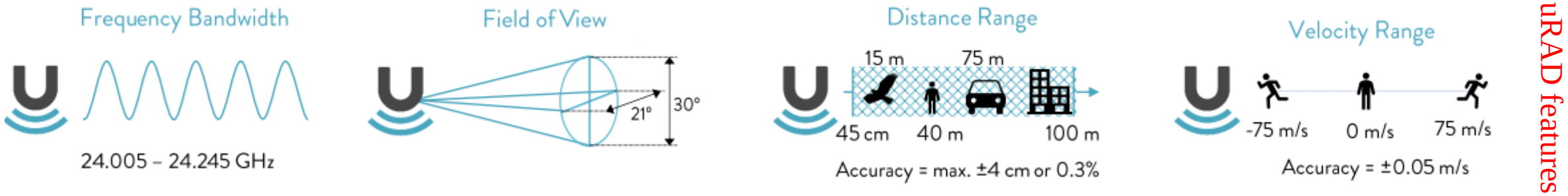
TX and RX LED: indicate the Arduino board is connected to the PC. You should expect them to blink faster.

Main Feature of uRAD:

- Radar detects elements that fall within its action radius.
- The transmitted EM wave which reflected by an object is registered by the radar in order to detect the object.
- uRAD can detect up to 5 objects in its field of view using information such as:

1. distance to the object and it's relative radial velocity
2. reflected power level used as reference to determine objects size and detection level

   ❑ i.e. very small and far object are not detected.



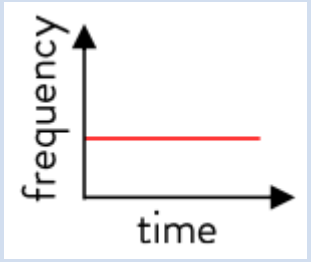
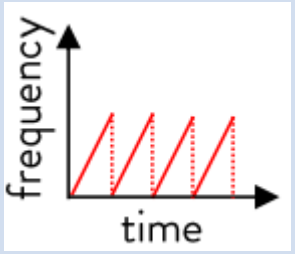
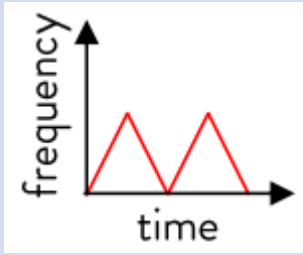
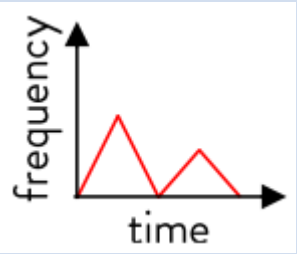
uRAD features

❑ Only object radial velocity can be measured. Therefore, the object must face the radar in direction of EM wave radiation.

uRAD Parameter Configuration:

❑ Radar Mode:

- uRAD have four operating mode depending on type of waveform transmitted

	Continuous wave (CW)	Sawtooth wave	Triangular wave	Dual-rate wave
				
Waveform	• Single frequency is transmitted, e.g. Doppler radar	• A frequency ramp or frequency modulated continuous wave (FMCW) is transmitted		
Measured parameter	❖ Measure Velocity	❖ Measure Distance	❖ Measure both velocity and distance	
Distance range (m)	0 to 60	0.45 to 100	0.45 to 100	0.45 to 75
Velocity range (m/s)	0 to ± 75		0 to ± 75	0 to ± 75
Update rate max(sample/sec)	38	21	13	7

❖ uRAD can differentiate between two target at same distance with different velocity, and vise versa.

uRAD Parameter Configuration:

- $f0$:
  - It is operating frequency of CW mode or starting frequency of ramp in other modes.
  - uRAD can be configured to work from $24.005\ GHz$ to $24.245\ GHz$

$f0$	CW mode	Mode 2,3, & 4 (ramp mode)
Range values	5-245	5-195

  - ❖ The minimum frequency sweep allowed in uRAD is $50\ MHz$.

- BW:
  - Referee to the operational bandwidth of the ramp modes (mode 2,3,4).
  - In other words, its frequency sweep which is varied in every ramp.
  - Depending on $f0$ used, the minimum BW value is $50MHz$ and the max bandwidth allowed by uRAD becomes

$$\boldsymbol{BW_{max} = 245 - f0}$$

uRAD Parameter Configuration:

❑ BW: Continued……

- The BW value determines the accuracy of the system, i.e. higher BW means better accuracy.
- Higher BW enable uRAD to effectively distinguish between targets very close to each other.

BW	Mode 1	Mode 2,3, & 4 (ramp mode)
Range values	-	$BW_{min} = 50\text{MHz}$ to $BW_{max} = 245 - f0$

❖ Since mode 1 is mono-frequency the BW has no sense. Any value defined don't affect the configuration.

❖ Although minimum BW is $50\ MHz$, its advised to use BW_{max} or $150\ MHz$ unless its required to use BW_{min}.

❖ In case of operating multiple uRAD module in same area, set different $f0$ and BW to reduce mutual interference.

❑ $Ntar$:

- It's the maximum number of target to detect.
- Maximum of 5 target can be targeted in all modes of operation.

❖ **If more than 5 target available in the field of view, then uRAD gives information on significant 5 target with significant reflected power**

uRAD Parameter Configuration:

❑ Ns:

- It is maximum number of samples uRAD takes of the reflected wave to compute distance, velocity, and etc.
- Ns is vital in mode 2,3, & 4 since it defines the ramp duration thus the update rate.

Ns	Mode 1	Mode 2	Mode3	Mode 4
Range value	50 to 200	50 to 200	50 to 200	50 to 200
Update rate (samples/ sec)	38 to 21	21 to 15	13 to 9	7 to 5

❖ **In mode 1, higher Ns makes uRAD better differentiate targets with the same velocity.**

- Selecting lowest $\boldsymbol{Ns}$ allow best update rate, however, the maximum distance uRAD can see is defined as:

$$Distance_{max} = 75 \times \frac{Ns}{BW}$$

➢ **E.g. For $Ns = 50$, and $BW = 240MHz$** $\quad Distance_{max} = 15.625\ m$

➢ **E.g. For $Ns = 200$, and $BW = 50MHz$** $\quad Distance_{max} = 300\ m$

❖ Although maximum distance is $Distance_{max} = 300\ m$, uRAD doesn't emit enough power to see target at 300 m.

❖ The maximum detectable distance is around $\boldsymbol{100\ meters}$.

uRAD Parameter Configuration:

❑ R_{max}/V_{max}:

- R_{max} is the maximum distance where the target will be searched (detection zone length).
- In case of uRAD mode 1 operation, where no distance is detected, R_{max} means V_{max}: maximum velocity range where the target will be searched.

R_{max}/V_{max}	Mode 1	Mode 2,3, & 4 (ramp mode)
Range values	0 to 75	1 to 100

❖ If you select $R_{max} = 100\ m$ in mode 2,3 or 4, uRAD will search target in the range defined by $\boldsymbol{Distance_{max}}$. One can detect target farther than 100 meters.

❑ MTI:

- MTI activates/disactivates the Moving Target Indication (MTI) mode.
- MTI mode allow to neglect static targets and only provide information about moving targets.

❖ **State 0: MTI mode is deactivated thus information about ALL target, static or not, is provided.**
❖ **State 1: MTI mode is active and all information related to static targets are neglected.**

MIT	Mode 1	Mode 2,3, & 4 (ramp mode)
Range values	-	0 (disabled) /1 (activated)

❖ In mode 1, MTI has no relevance since by default this mode is only for moving targets. This mode is preferred in indoor application where only measuring moving target is desired.

uRAD Parameter Configuration:

❑ Mth:

- Mth defines uRADs sensitivity as used to detect movement and uRAD send alert when it detect a moving target.

- One can define up to 4 detection thresholds
  - $\rightarrow Mth = 4$ makes uRAD very sensitive to any reflection.
  - $\rightarrow Mth = 1$ only very reflective targets activates the alert.

- The threshold defined as function of target reflectivity which proportional to size of target and inversely proportional to the distance.

Mth	Mode 1,2,3, & 4 (All modes)
Range values	1 (low) to 4 (high) sensitivity

❑ Detected information:

- $Distance$: returns distance to each detected target.
- $Velocity$: returns relative radial velocity between uRAD and each detected target.
- $Movement$: return true if target moves or false otherwise.

uRAD Parameter Configuration:

❑ Detected information:

- SNR: returns the Signal-to-Noise Ration of detected target. Based on reflected signal strength one can get an idea of size and reflectivity of the target.

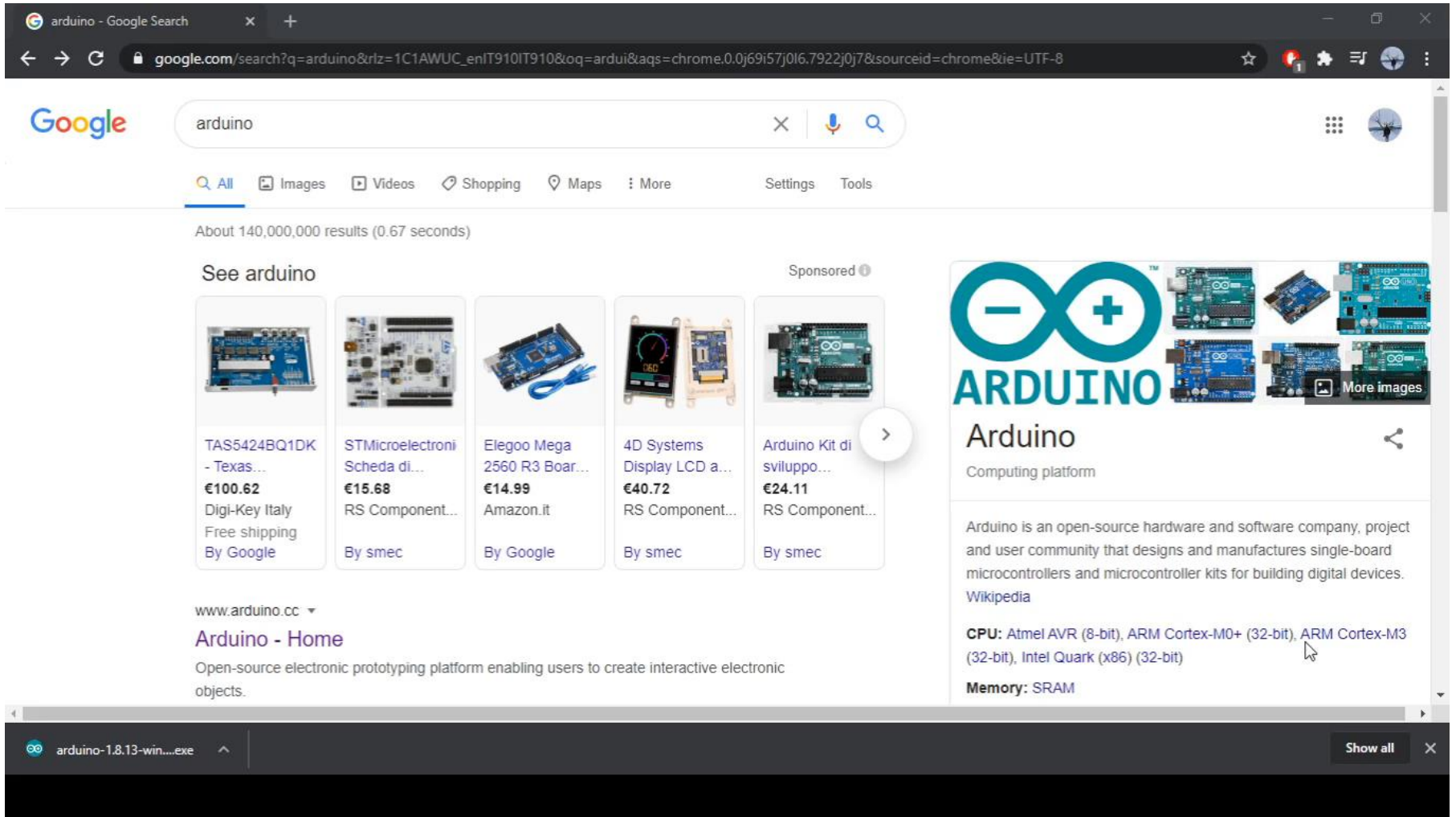
- I/Q: return total reflected signal decomposed into In-phase and Quadrature components for advance data signal processing.

	Mode	Unit
Distance	2, 3, 4	meters
Velocity	1, 3, 4	meters/seconds
SNR	All	dB
Movement	All	TRUE/FALSE
I, Q	All	Arbitrary units from 0 to 4095

Installing ARDUINO

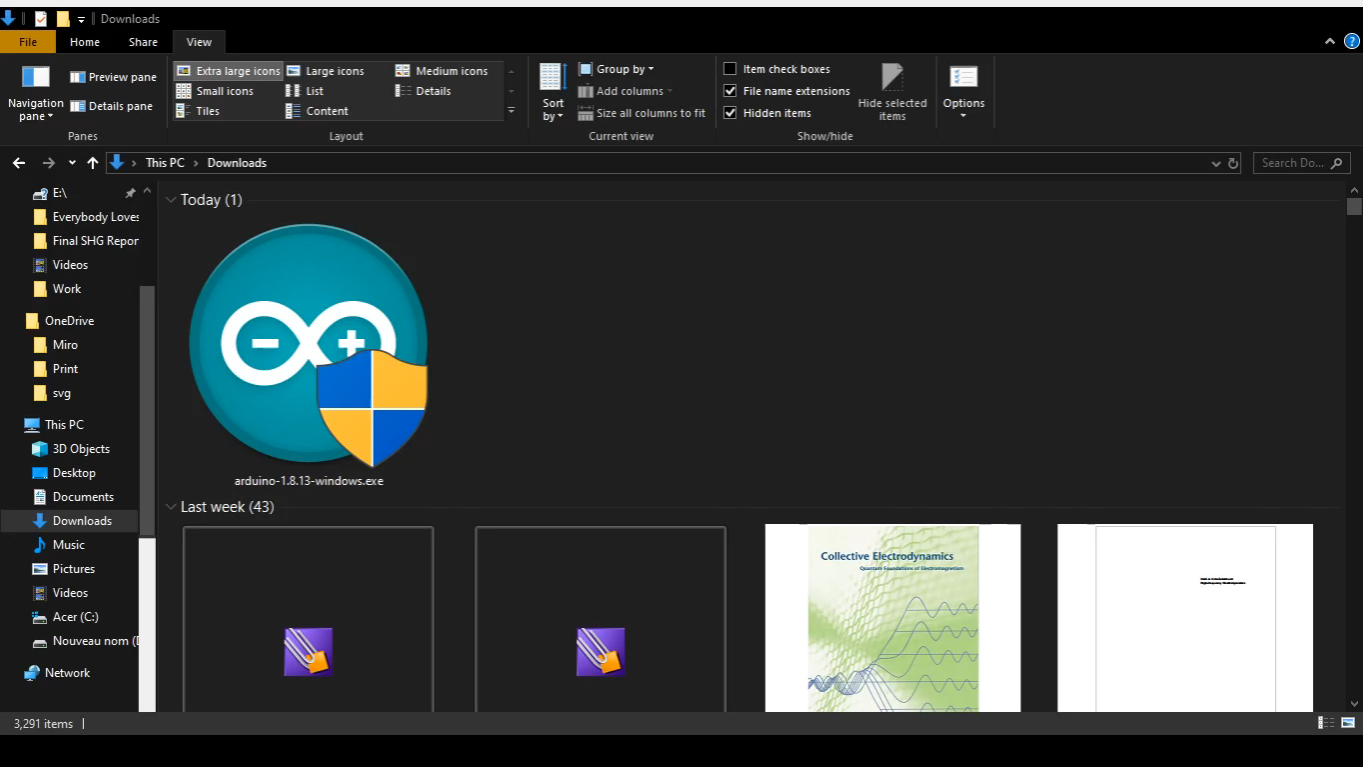
1. Download the latest version of the IDE from https://www.arduino.cc/ or https://www.arduino.cc/en/Main/Software

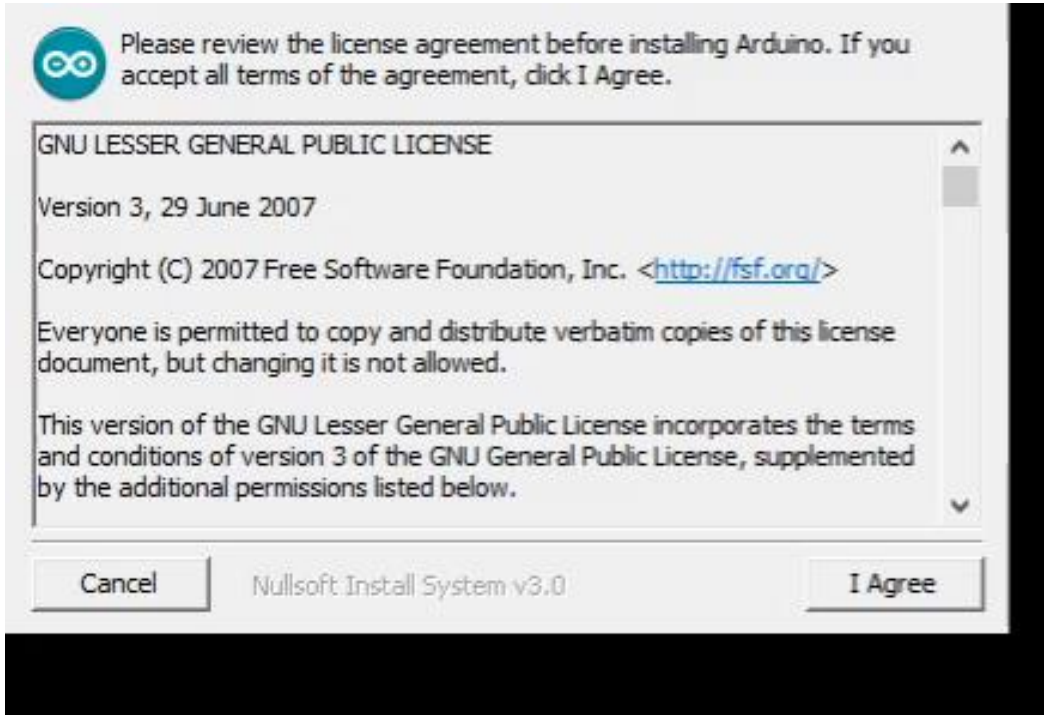
2. For Windows: use either Windows installer or Windows ZIP file



Installing ARDUINO

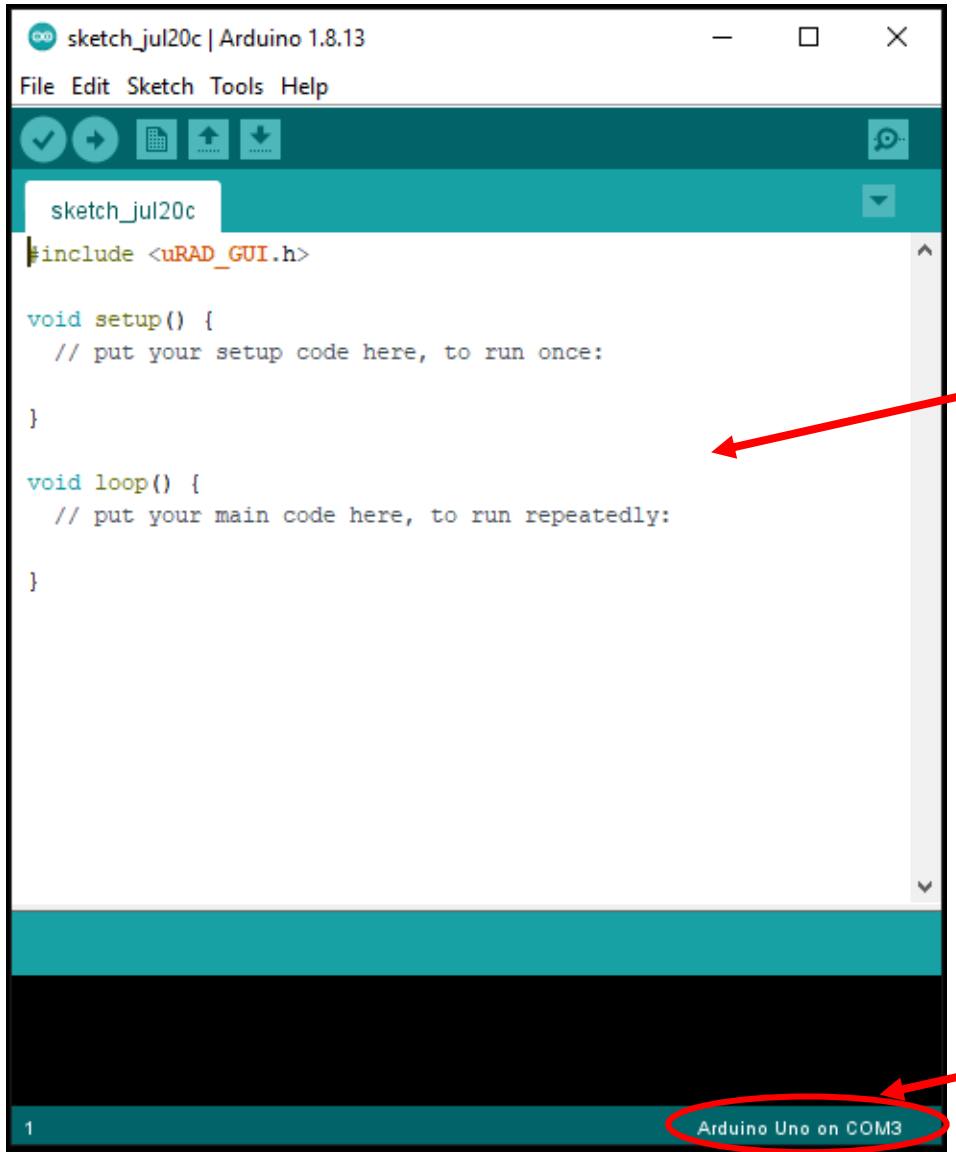
1. Once downloaded, navigate to your download path and double click arduino-1.8.13-windows.exe
2. If security warning shows up click “Run” or “Allow” and accept the license agreement. Click “Next” to choose the IDE installing folder and then click “Install”.





Start Arduino IDE

- Once downloaded and installed so the next step will be to open the Arduino program and access the Arduino development environment.

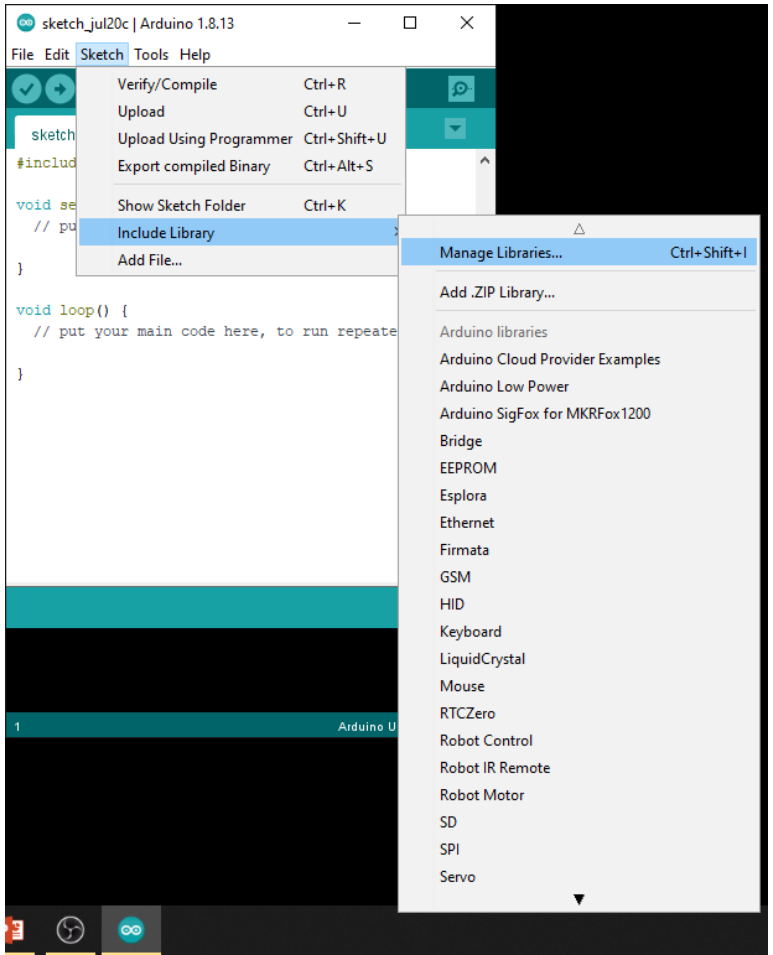


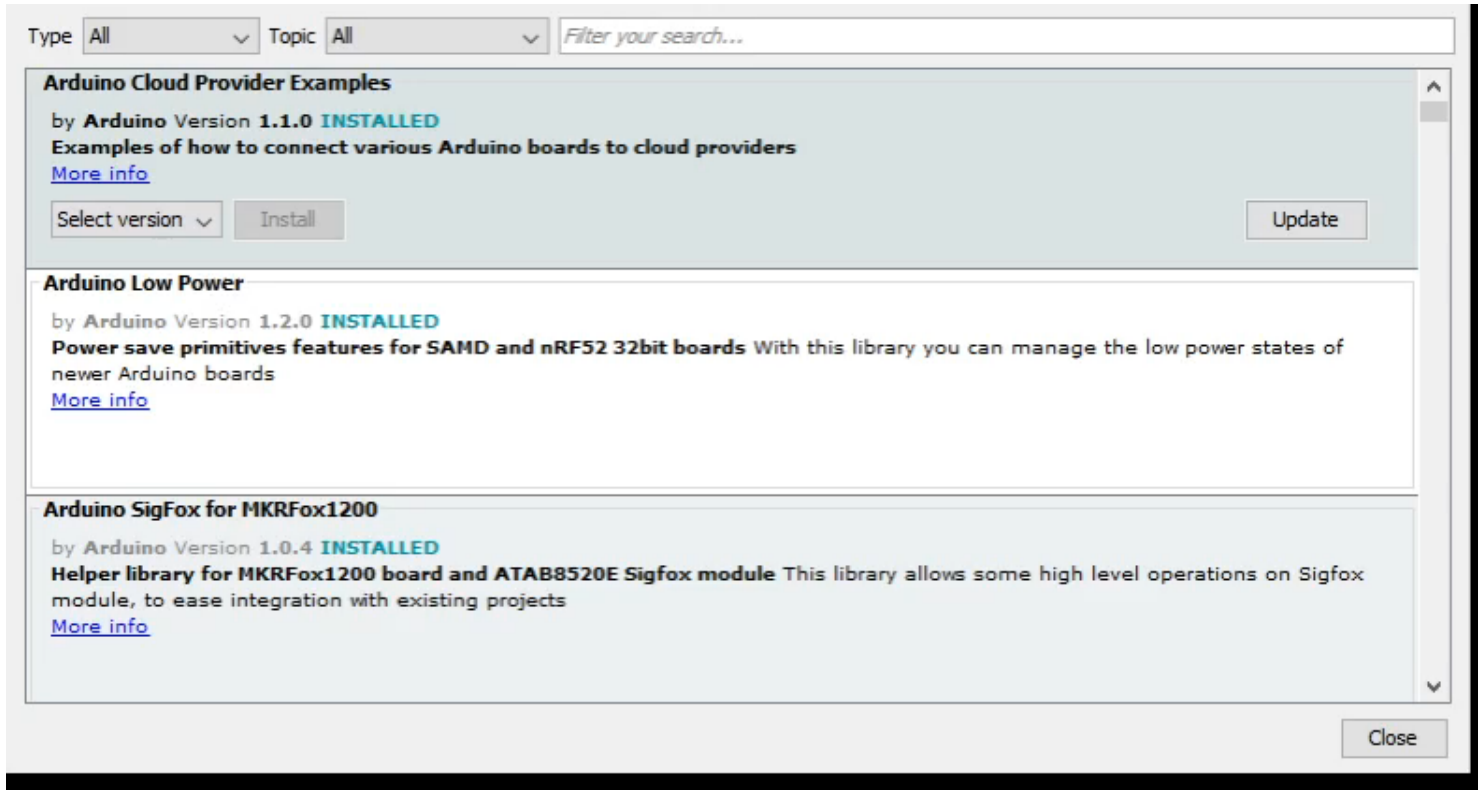
Arduino development environment

Communication via Serial Port: COM3

Installing Libraries

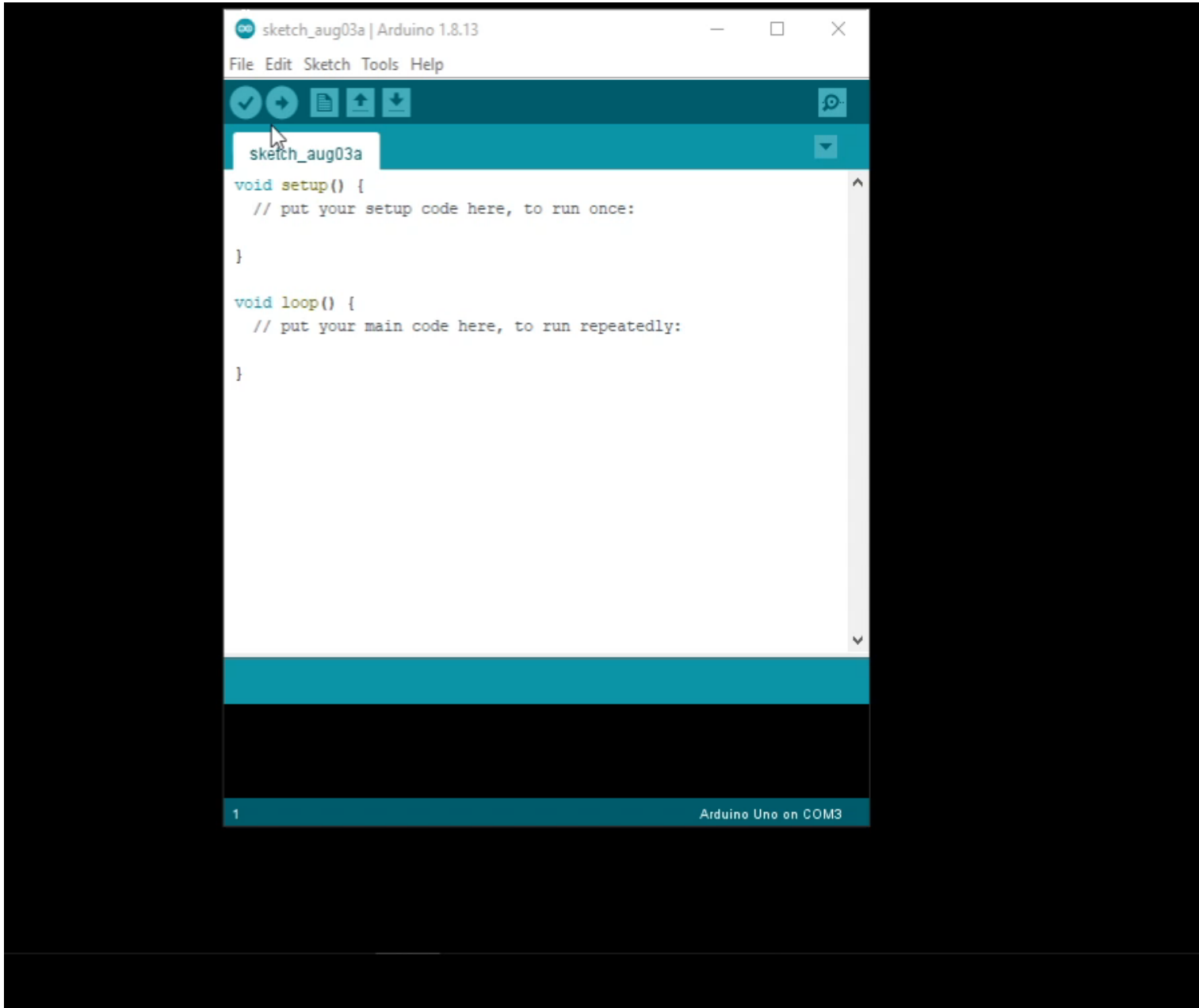
- The libraries make it easier to connect a sensor, screen, module, etc.
- In order to install the libraries: Open Arduino IDE Program, select the tab Sketch → Include Library→ Manage Library.
- One can install any new library one might need/update the library with the new version.





Installing uRAD/uRAD-GUI

1. Open Arduino IDE and navigate Sketch -> Include Library -> Add .ZIP Library
2. Inside Arduino_software\Library find uRAD.zip or uRAD_GUI.zip
3. In Sketch -> Include Library dropdown menu you will observe uRAD/uRAD_GUI library
4. Once the library is installed, one can create uRAD object or access the existing examples under File->Examples->uRAD/uRAD_GUI



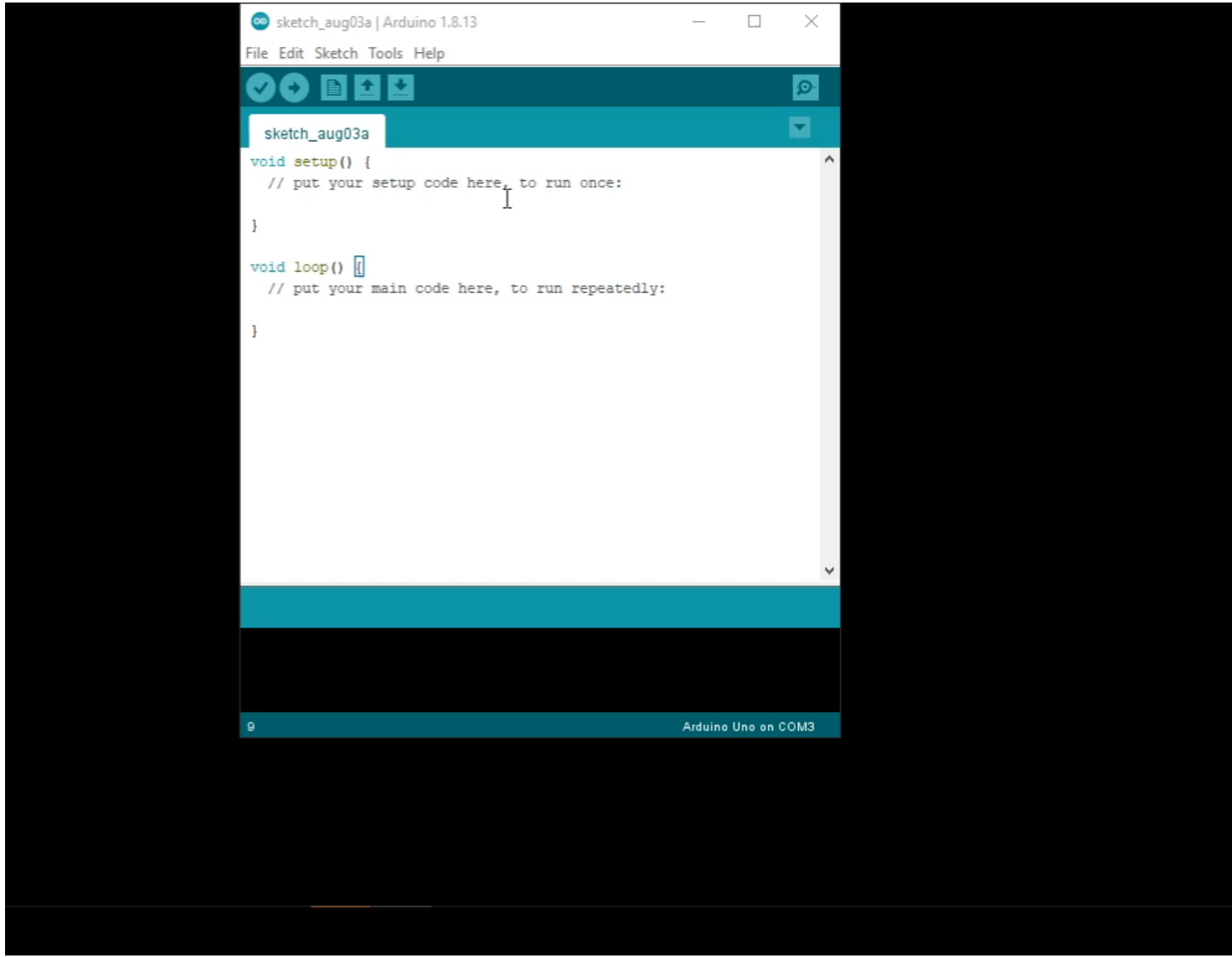
Arduino Connection

- The Arduino IDE has a serial terminal connection to visualize data sent in serial port.
- All Arduino has a serial port

- One can check where Arduino connected by

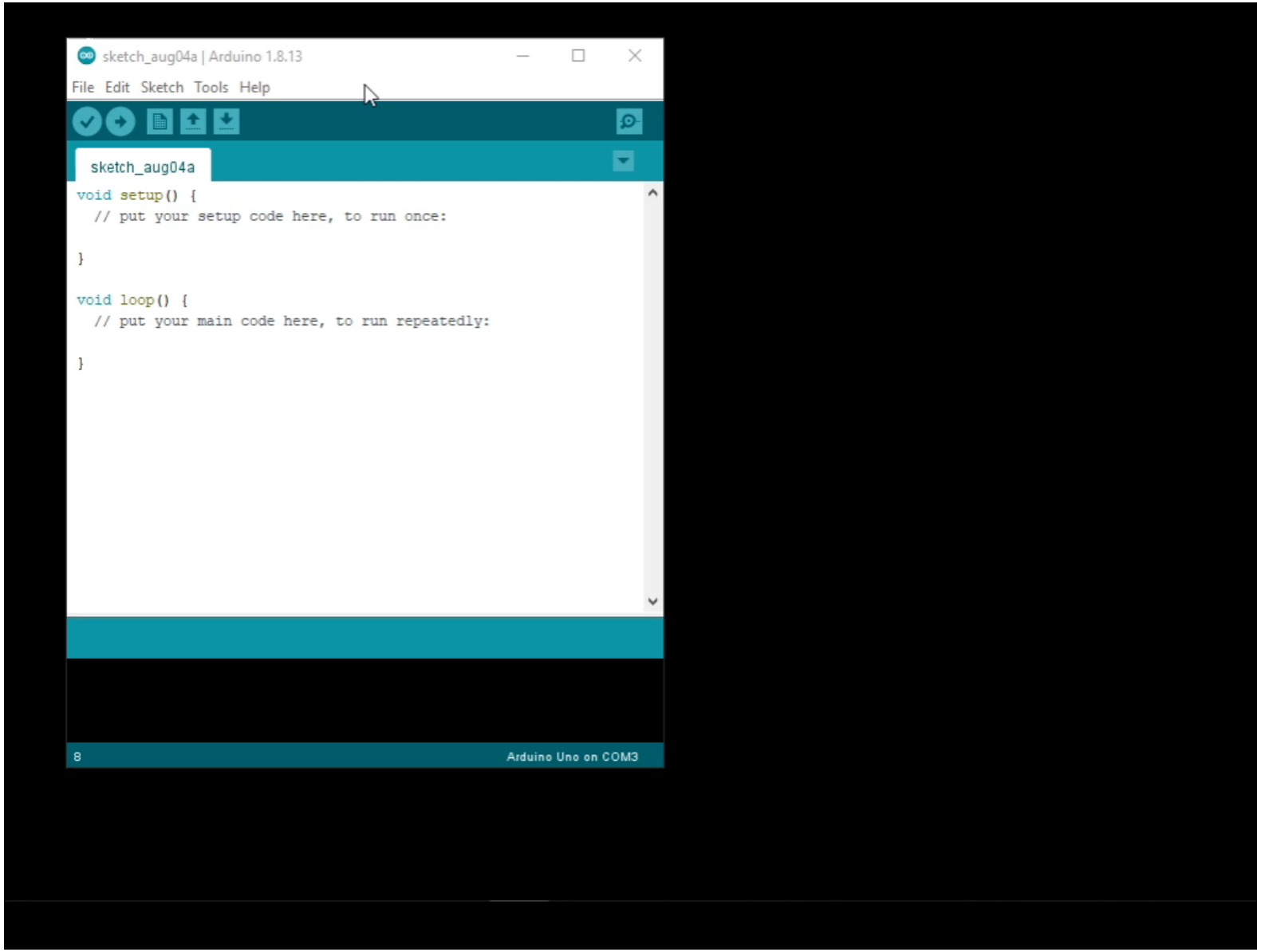
Tools→ Port “COM3(Arduino uno)” →Serial Port

- Its also possible to select where Aurduino connected in **Device Manager**
- The serial window has different configuration window such as: data transfer rate is given in **Baud,** **autoscroll** for data display, **Show timestamp**, etc.



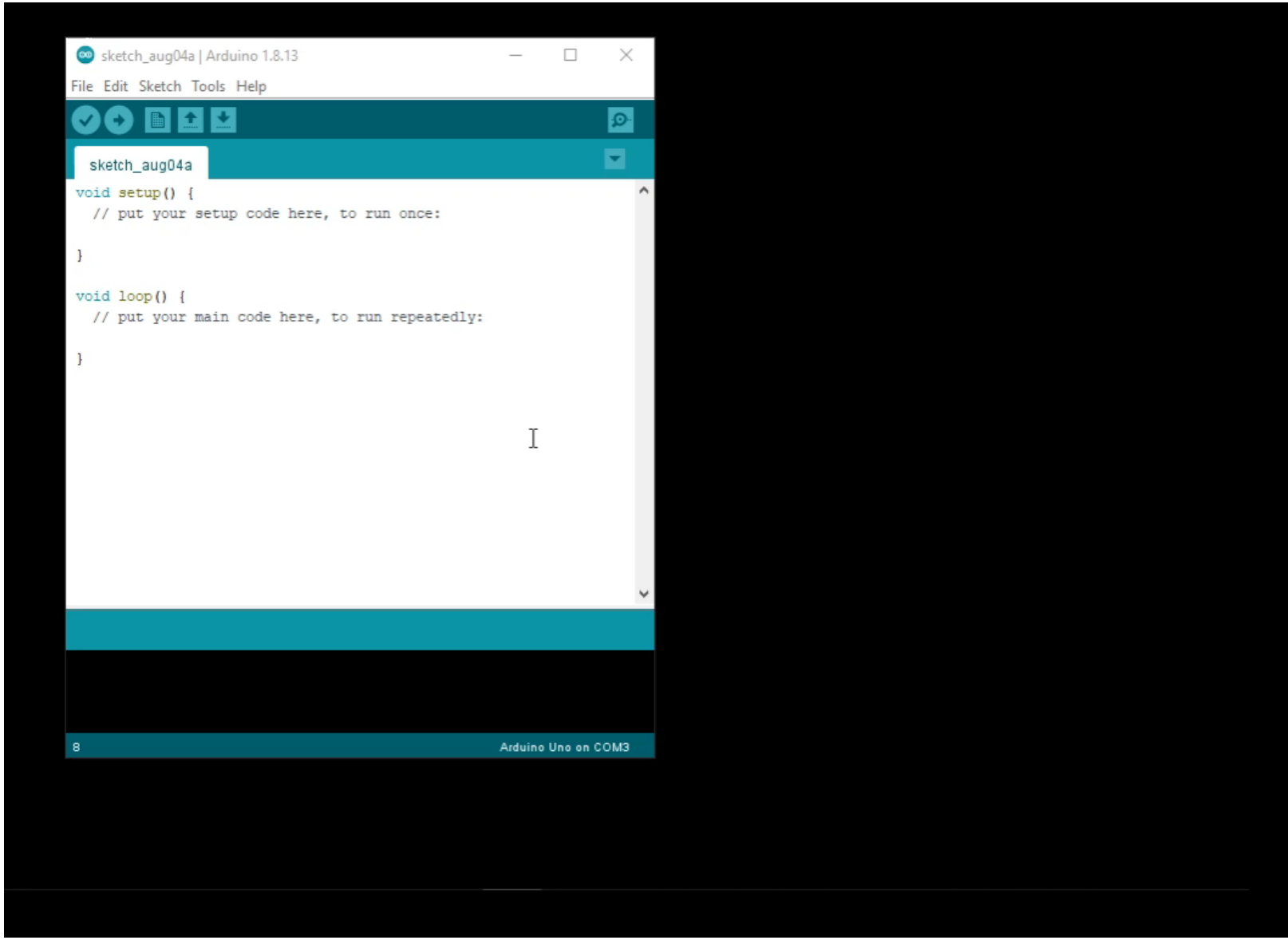
uRAD Application Examples

1. Open Arduino IDE and navigate File → Example →uRAD
2. Inside one can find different application examples such as: uRAD-distance-meter, uRAD_movement_detector, and uRAD_Doppler_speed_meter



uRAD-GUI Application Examples

1. Open Arduino IDE and navigate File → Example →uRAD_GUI
2. Inside one can find code to run uRAD_load_GUI
3. Once the code is uploaded to uRAD, inside uRAD\Arduino_software_win_v1.0\GUI one must execute InstallFont.bat with an administrator privilege by right-click on it
4. Running **uRAD_GUI** in the same folder bring the GUI interface



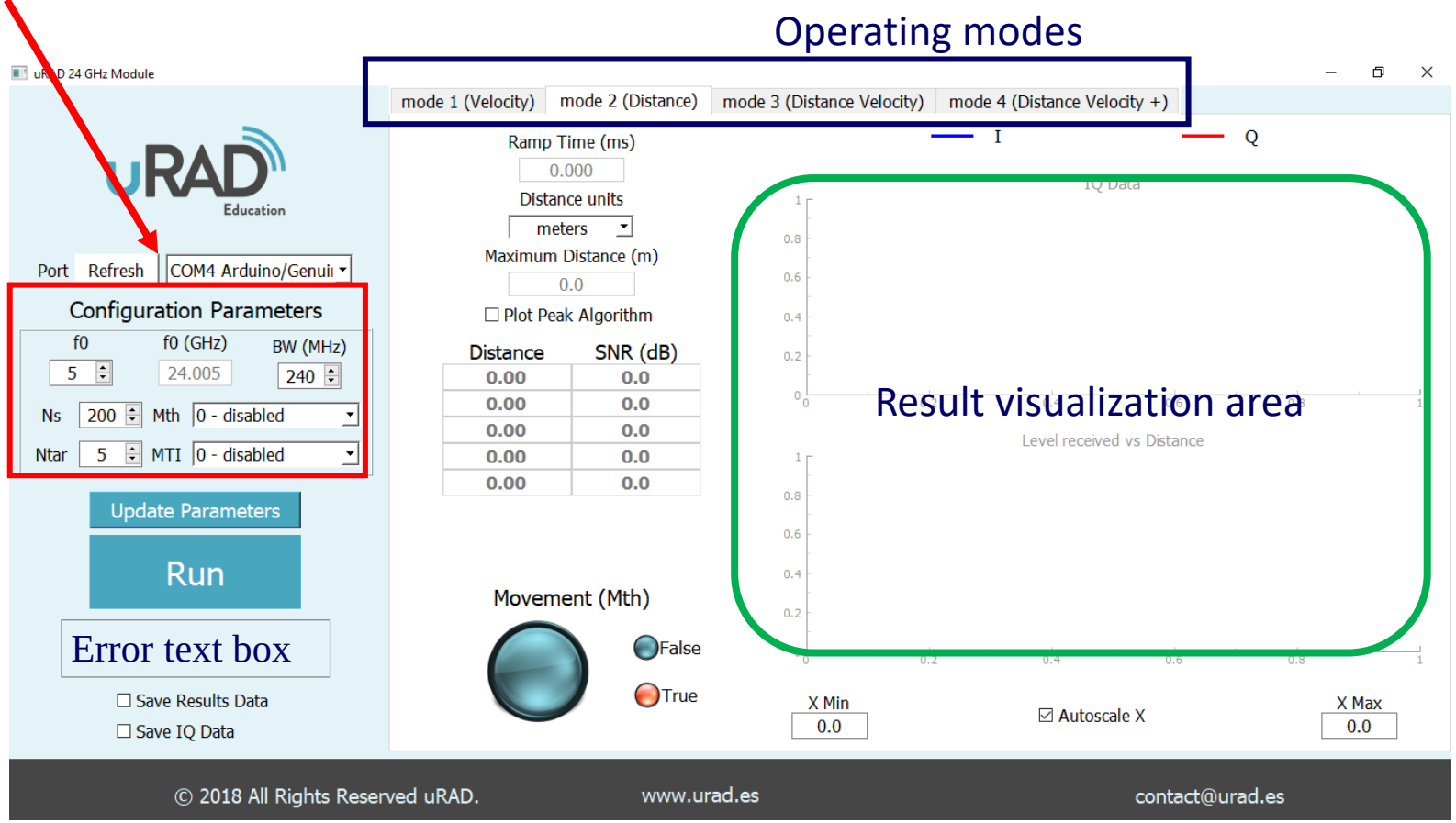
Configuration parameters for uRAD_GUI

❖ Left part of uRAD_GUI with light blue background correspond to configuration parameters (ref: slide 8-13), power buttons, and saving results. The right side of uRAD_GUI contains mainly result visualization area.

USB Port: selects USB port where Arduino is connected.
Refresh if you connected after running the GUI.

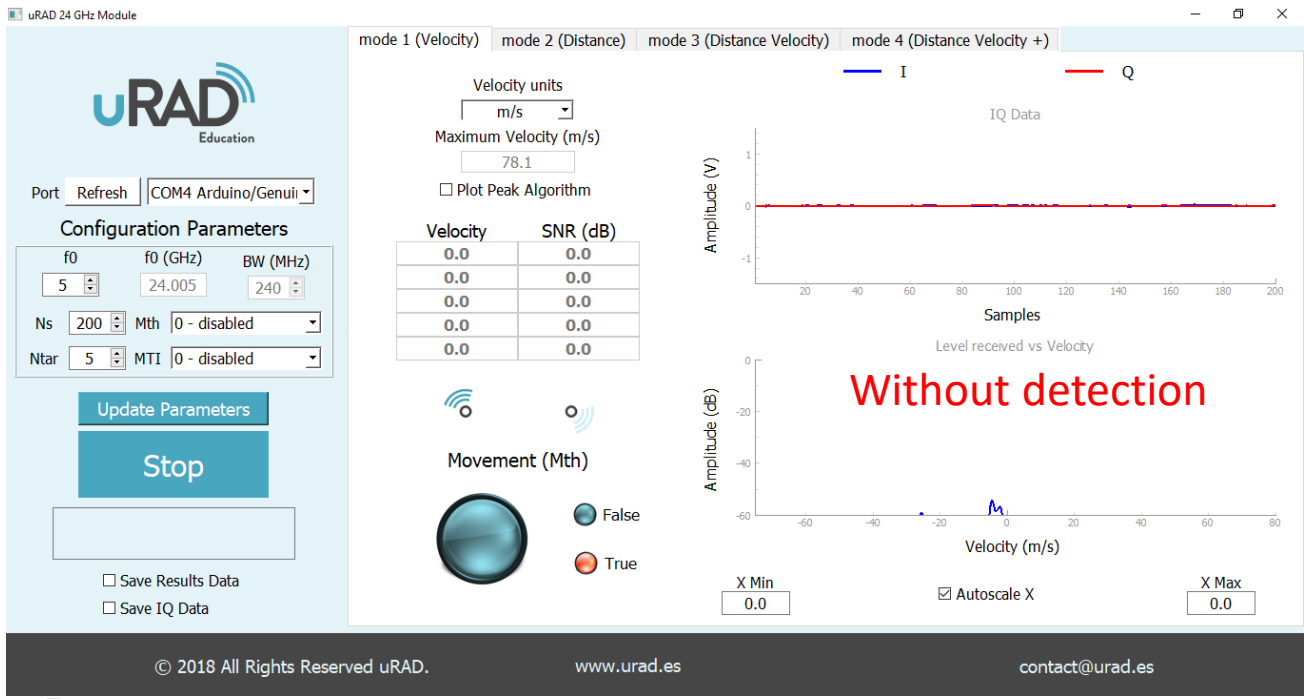
- $f0$: Tx frequency
- BW: bandwidth (MHz)
- Ns: number of samples
- N_{tar}: number of targets
- M_{th}: movement detection threshold
- MTI: moving target indicator

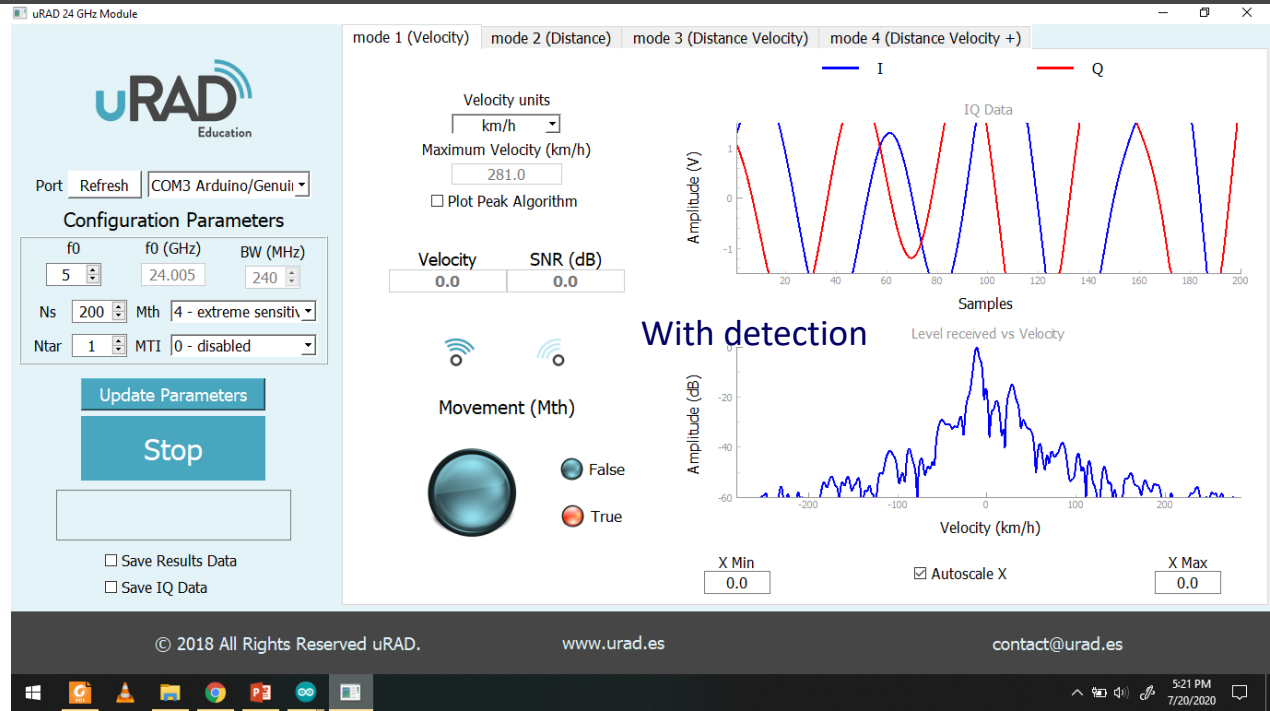
- N.B. If you place the mouth a few second value of parameters it will show range of value to choose from.



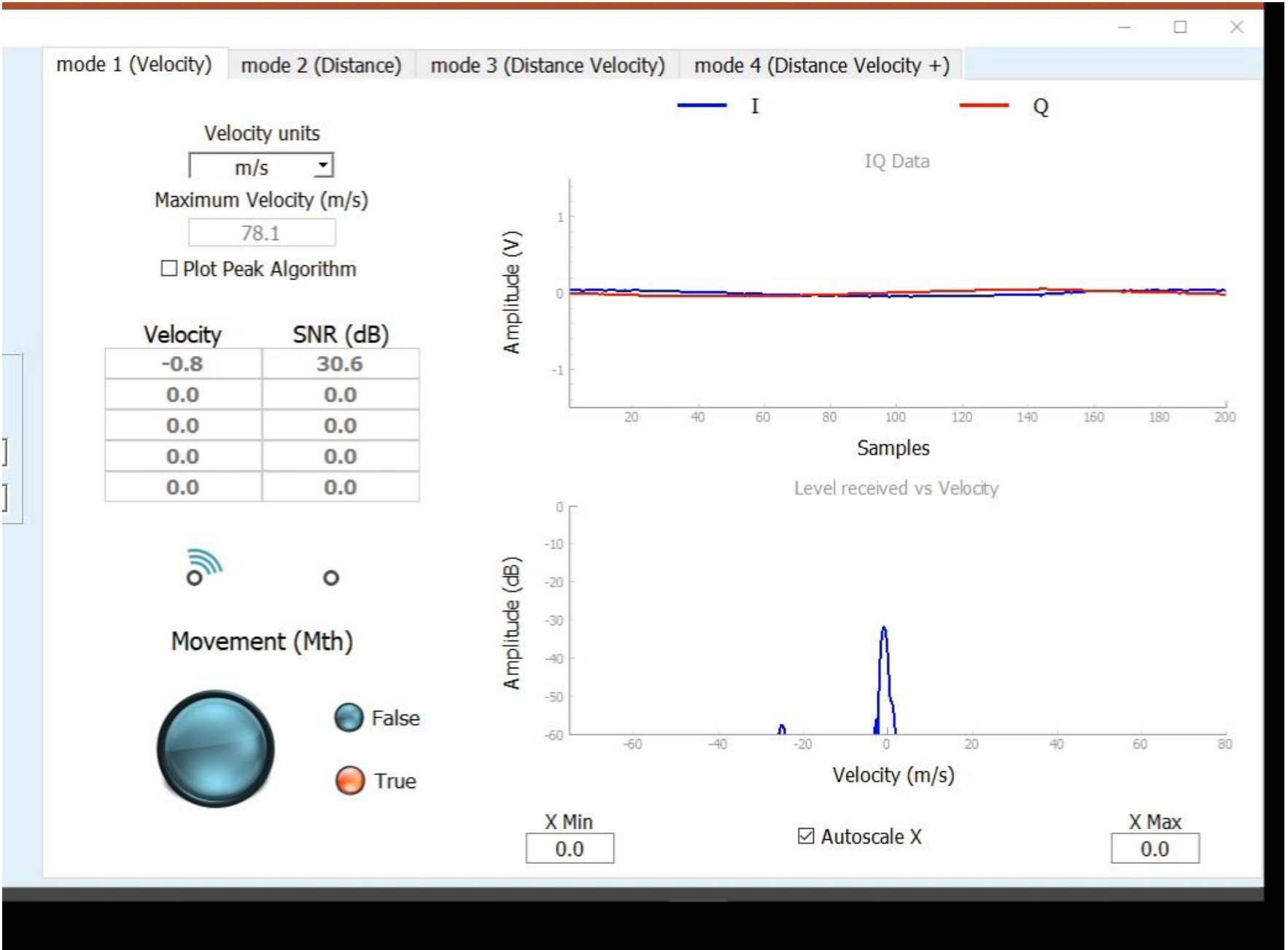
Visualization Mode 1

- Mode 1: the Doppler mode for velocity is displayed.
- Upper right graph/IQ Data: shows the I(blue) and Q(red) received signal. The total signal S becomes $S = I + iQ$
- X-axis represents the number of samples (N_s) which can be modified and updated.
- Bottom right graph/ Level received Vs Velocity: correspond to the FFT of complex signal $S = I + iQ$, that gives information about the target.
- The frequency spectrum peaks are used to calculate the velocity of the target.





Visualization Mode 1



When there is no detected target, no signal appears in IQ data or peak in the spectrum.

When there is target present and detected, the variation of I & Q signal is seen and a peak appear in the spectrum.

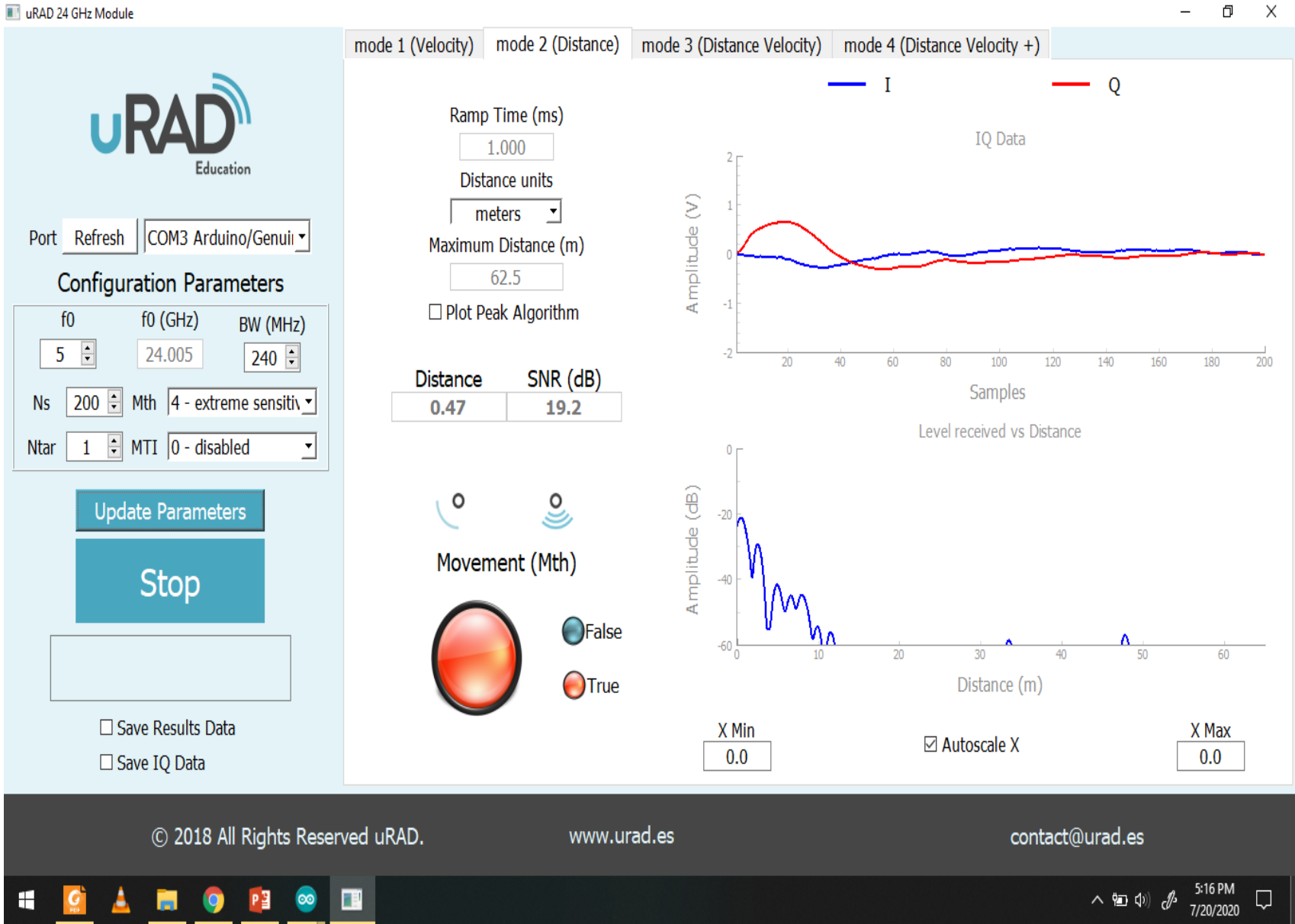
N.B On the spectrum, many peaks are present. Some of them are targets, other correspond to noise, interference, bounce, etc. The program is design to detect only target related peaks.

Visualization Mode 2

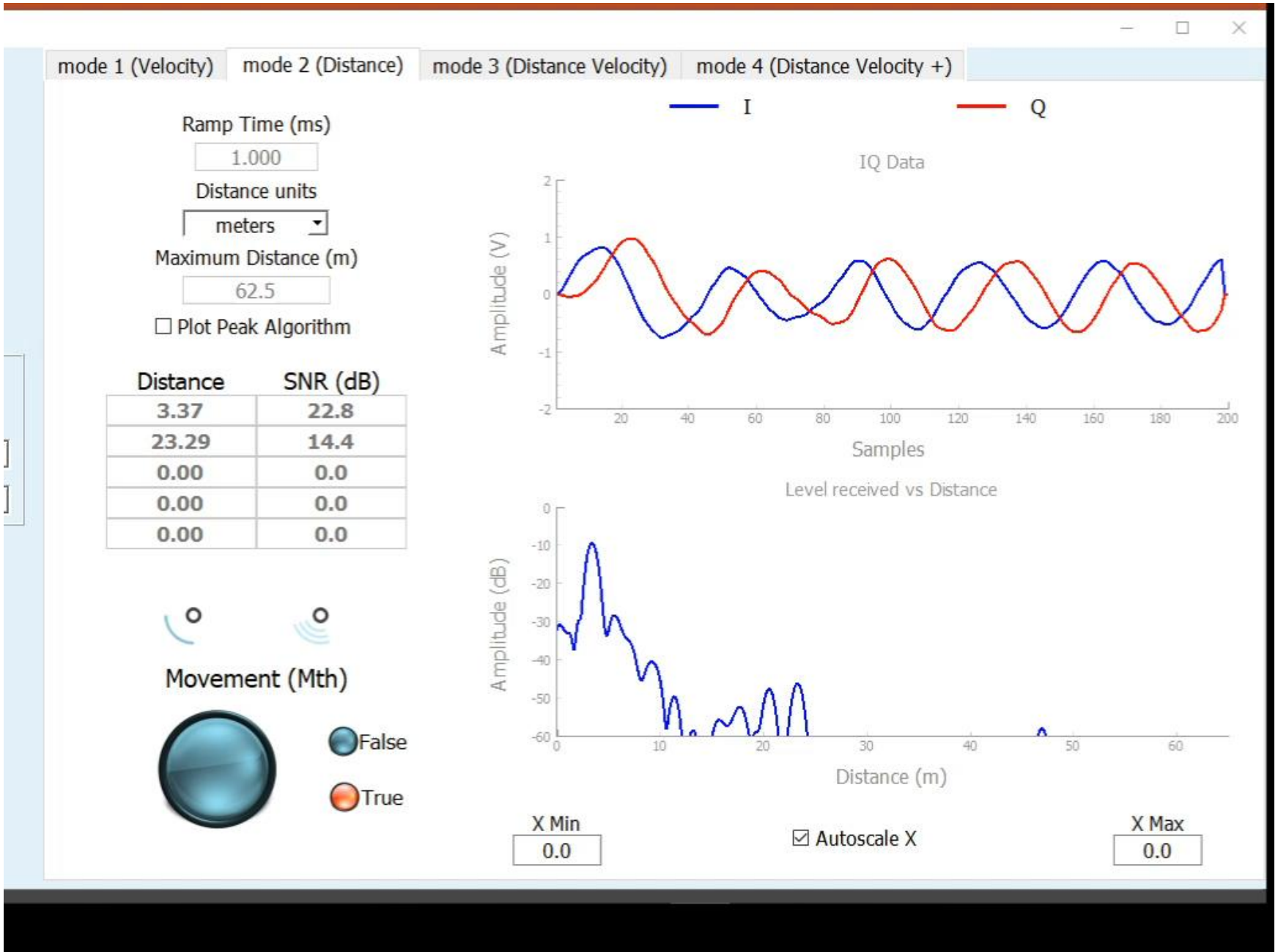
- **Mode 2 only measures the distance.**
- **The spectrum graph titled *Level received Vs Distance*.**
- **The distance measured by using ramp signal and its duration given in *Ramp Time* (ms).**
- **The Maximum Distance measured:**

$$D_{max} = 75 * \frac{Ns}{BW}$$

displayed in distance unit, i.e. m/ft.



Visualization Mode 2

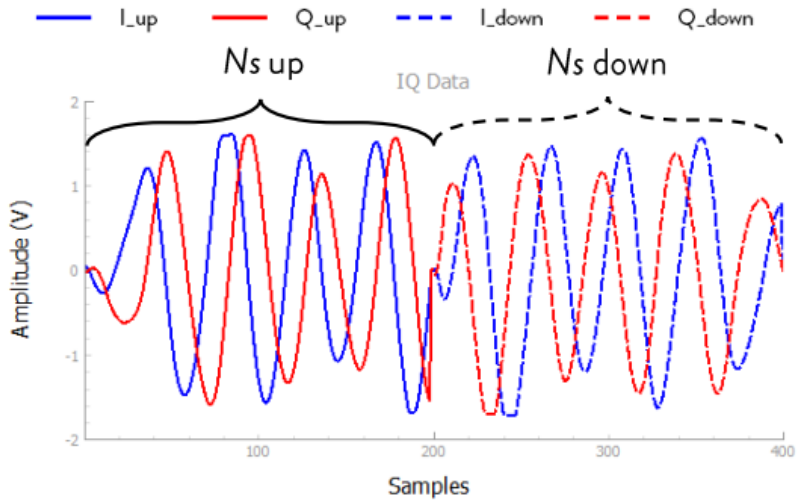


Visualization Mode 3

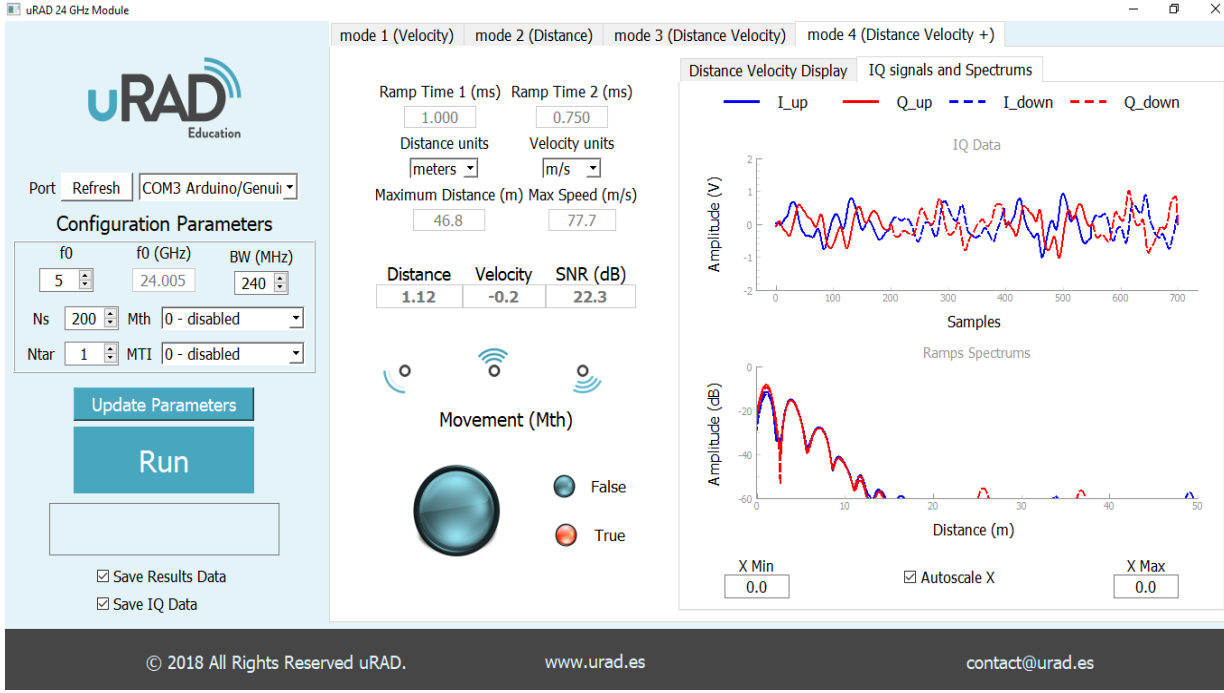
- **Mode 3 allow both velocity and distance calculation because the signal emitted varies in frequency according to the triangular shape, with ramp up and down.**

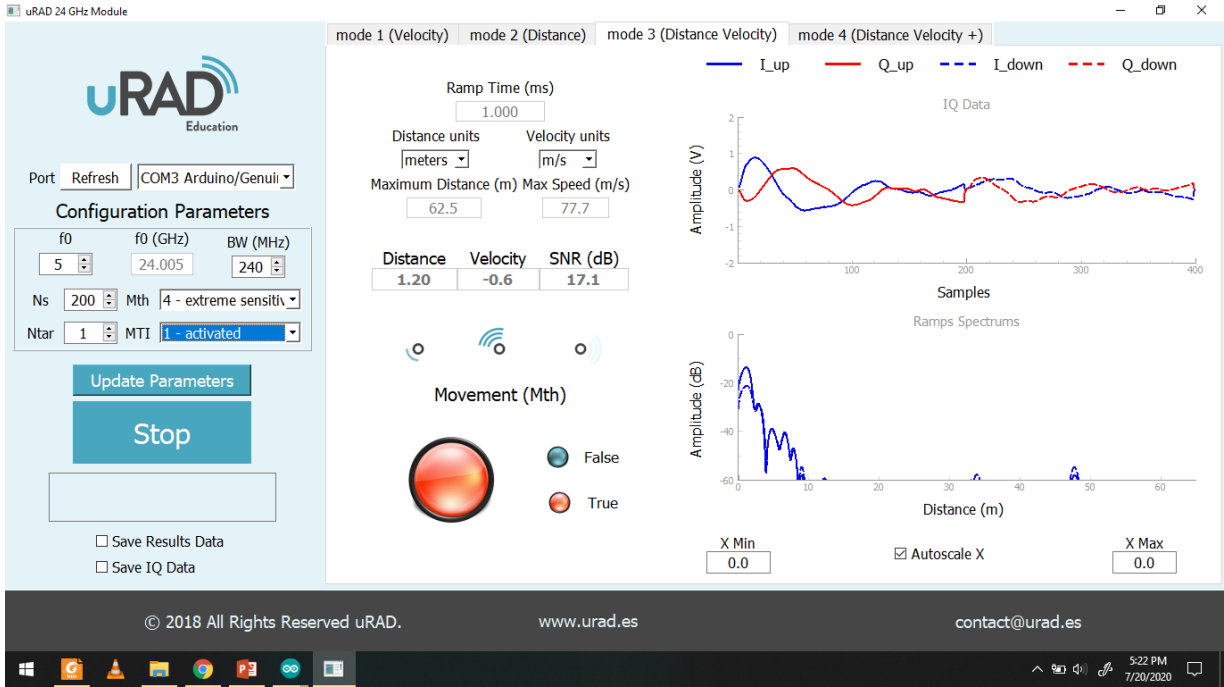
- **The IQ Data graph shows the I (blue) and Q (red) value of the up (——_up) and (– – – _down) down ramp.**

- **The horizontal axis has twice the sample number. E.g. for max sample size $N_s = 200$**

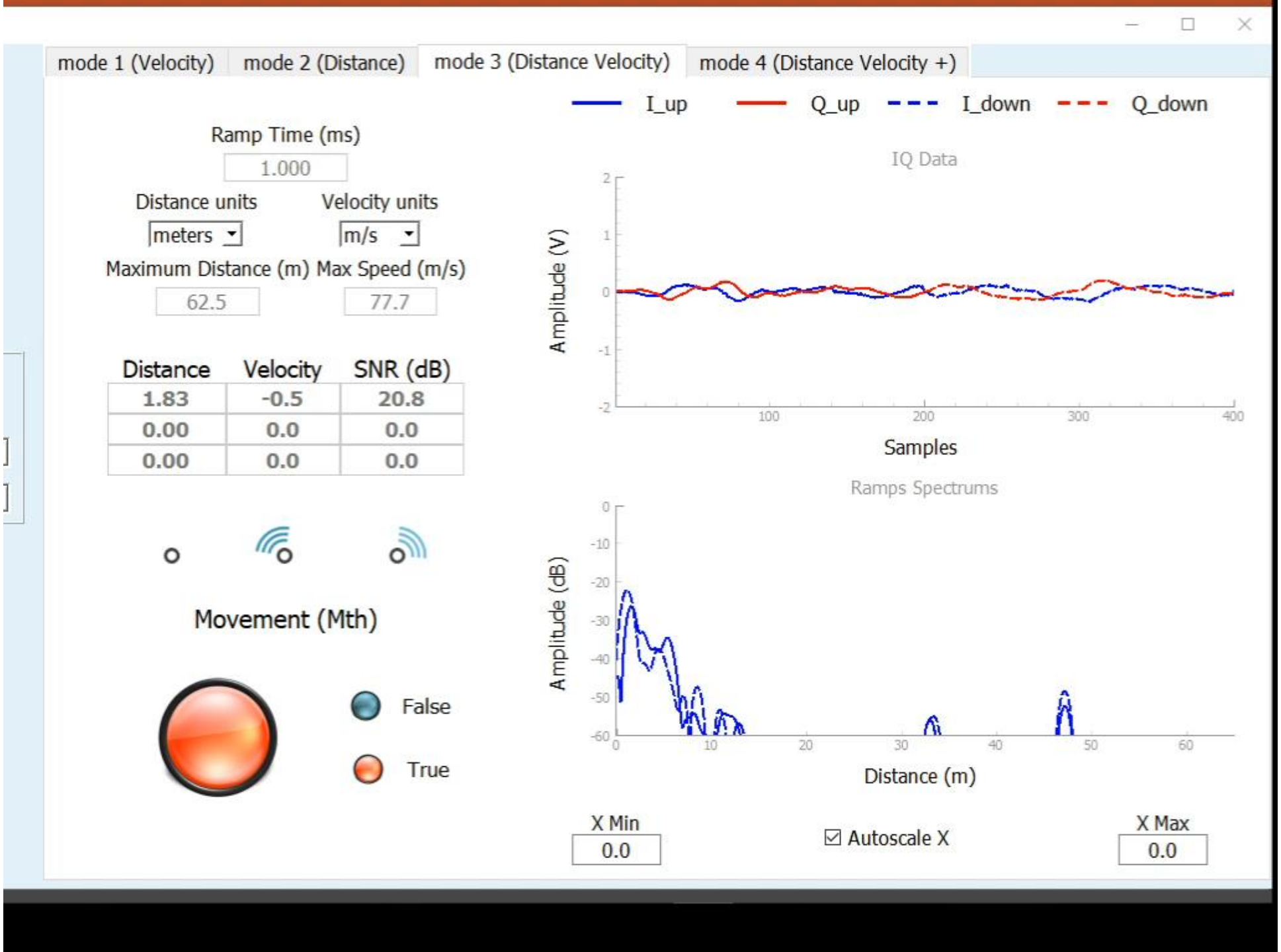


- **The spectrum plot has two signal plots with continuous line for FFT of up-ramp complex data and discontinuous one for down ramp.**



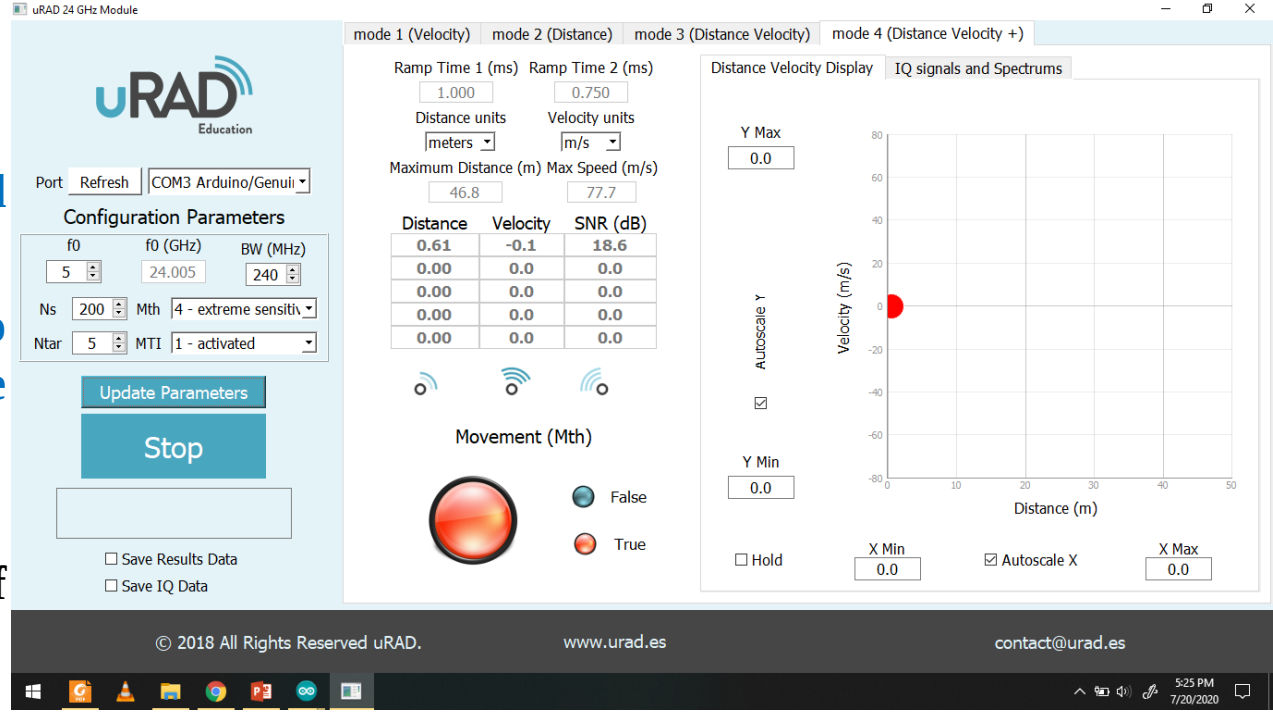


Visualization Mode 3

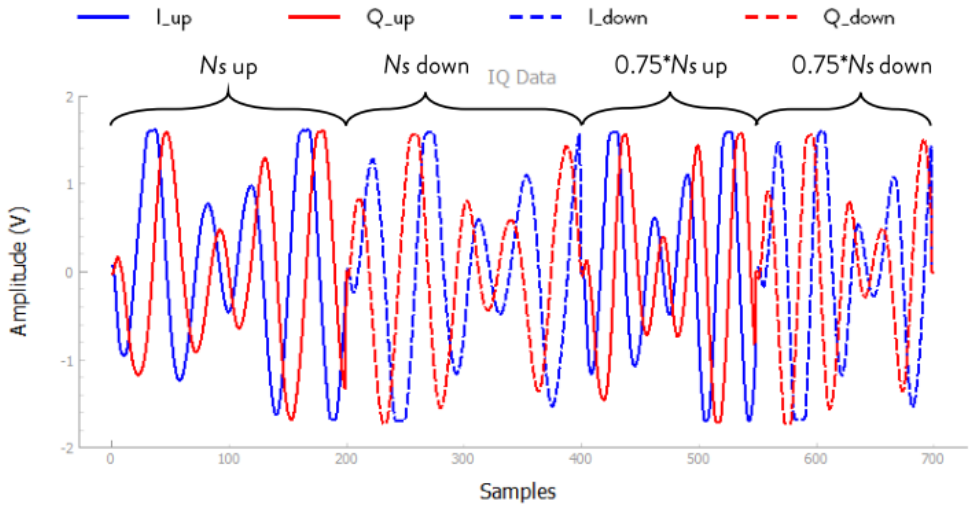


Visualization Mode 4

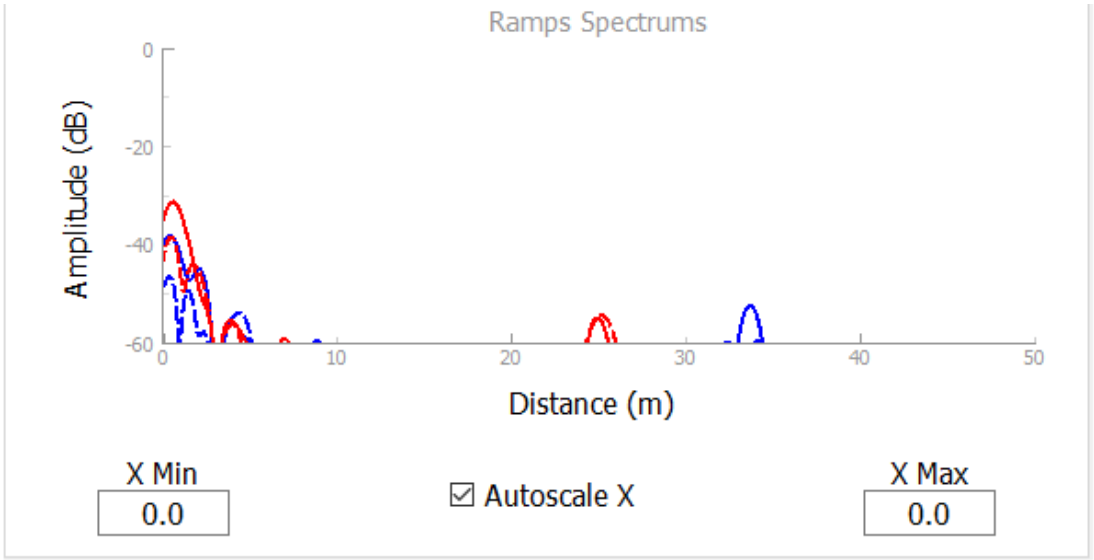
- Mode 4 is similar to mode 3, allow both velocity and distance measurement.
- Transmitted signal varies in frequency according to two consecutive triangle of different duration. The first triangle is formed by up ramp up and another by down ramp.

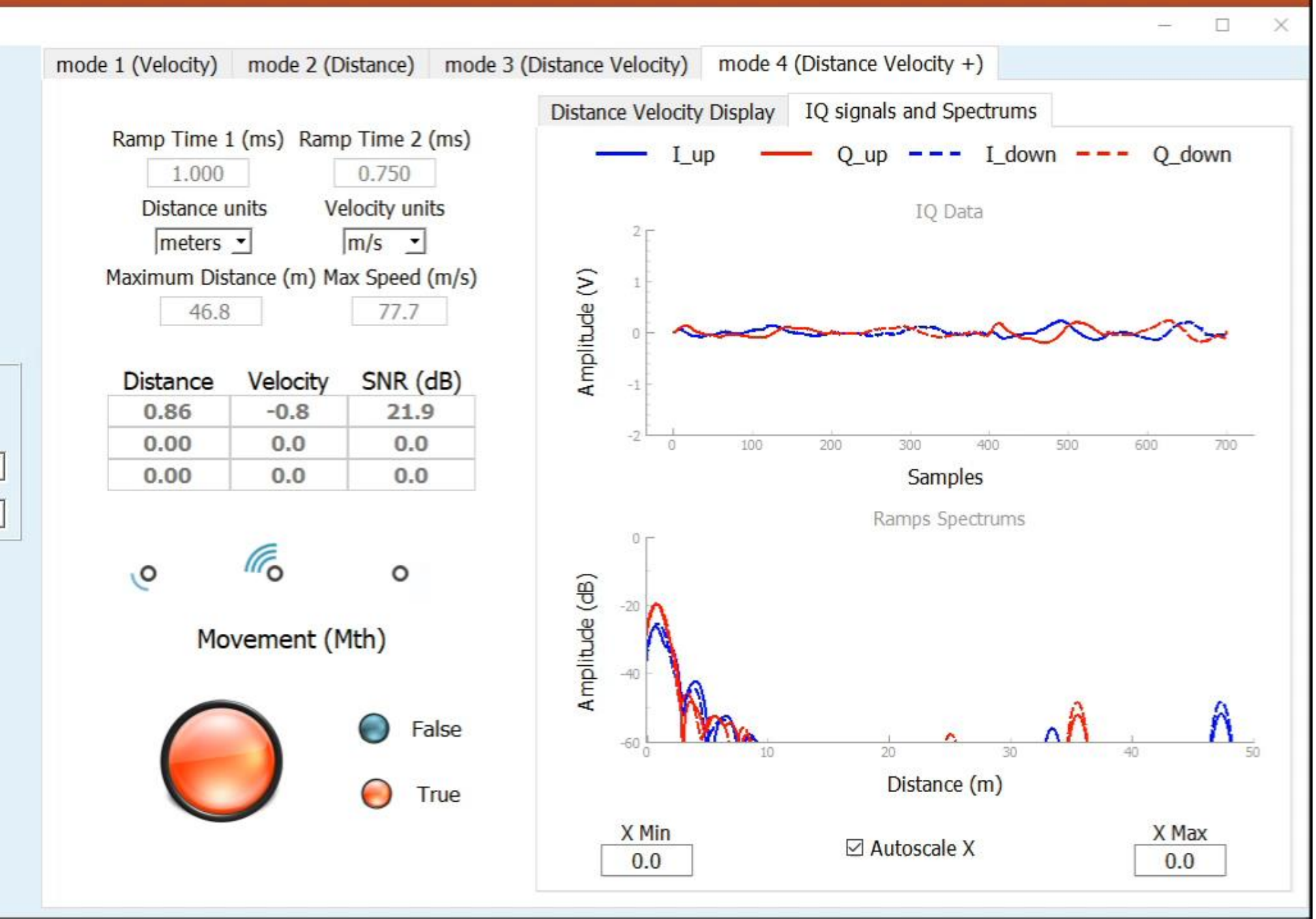


- The IQ Data graph shows the I (blue) and Q (red) value of the up (——_up) and (– – – _down) down ramp.
- For max sample size $N_s = 200$ the horizontal axis becomes:



- The spectrum plot has 4 signal plots with blue continuous line for FFT of up-ramp and discontinuous one for down ramp. Similar trend for red line for down ramp.





Visualization Mode 4

Programming Arduino for uRAD: Sample

```
#include <uRAD.h>              // include the installed uRAD library
uRAD my_first_uRAD;        // creates object with any user defined name---system names are in red while user defined names are in green

// Define input parameters which are integer value of type "byte"
uint8_t mode, f0, BW, Ns, Ntar, Rmax, MTI, Mth;

// Define output array from detection results
bool movement[1];           //Return movement status

void setup(){

serial.begin(250000);        //Serial port baud rate

mode = 2;                  // Sawtooth mode
f0   = 5;                 // Starting frequency of 24.005 GHz (min frequency of 50MHz)
BW   = 240;                // Use all available bandwidth BW=240 MHz (uRAD BW=24.005-24.245 GHz)
Ns   = 200;               // Number of samples registered from reflected wave to compute distance or velocity
Ntar = 1;                 // Number of desirable target to detect
Rmax = 25;                 // Radar searching/detection range
MTI  = 0;                 // MTI is disabled
```

Programming Arduino for uRAD: Sample

```
// load configuration parameters
my_first_uRAD.loadConfiguration(mode, f0, BW, Ns, Ntar, Rmax, MTI, Mth)

// once configuration parameters are loaded we switch ON/OFF the uRAD
digitalWrite(6, HIGH);        // Switch on uRAD by sending power on pin 6

delay(100);                   // Recommended delay after powering up uRAD
}

// Detectable parameters are defined here
//my_first_uRAD.detection(distance, velocity, SNR, I, Q, movement)

void loop(){
my_first_uRAD.detection(0, 0, 0, 0, 0, movement);     // target detection request

// print the results through the serial port
if(movement[0]==true){
serial.print("Alert. Intruded detected.");
}
}
```