Action TU1208
Civil Engineering Applications of Ground Penetrating Radar

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Design and realisation of a cheap GPR for educational purposes

Vincenzo Ferrara (Italy), Margarita Chizh (Russia), Andrea Pietrelli (Italy)
(vincenzo.ferrara@uniroma1.it, mchizh@rslab.ru, andrea.Pietrelli@uniroma1.it)

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Talk Layout

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Motivation of the project

and participating teams

Motivation

One of the main objectives of the COST Action TU1208 is to foster a wider use of the GPR technique in Europe and beyond.

The dissemination of GPR technology concepts should be a starting point for introducing young people to the GPR technique.
Moreover, the availability of a detailled guide to build a cheap GPR prototype will allow several researchers and students to realize their own equipment, whenever they cannot afford to buy a commercial one.

The inspiration for this project was a radar prototype by Lincoln Laboratory at Massachusetts Institute of Technology (MIT) [6], but we worked at increasing the performance and interactivity of the MIT device, as well as on adapting it to the GPR case.

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Motivation

We hope that our project will facilitate the introduction of the GPR technique into the educational process in many Countries.

This presentation is an excerpt of a longer document that we prepared, which aims at explaining how to design and realize a frequency-modulated continuous-wave (FCMW) GPR, with detailled information for the step by step construction phases, schemes, software codes, and all the necessary documentation to independently build a GPR prototype.

The guide that we wrote aims at enhancing the overall technical literacy of students, enabling them to develop their own radar by using minimum prerequisite knowledge about radar systems.

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Teams participating in the project

project phase	Laboratory
• RF electronic hardware design. • DC power source design.	Electronics for the Environment Laboratory – Dep. of Information Eng., Electronics and Telecommunications (DIET) – Sapienza University of Rome
• Software development for implementing firmware into microcontrollers. • Software development for managing device by PC.	Remote Sensing Laboratory Bauman Moscow State Technical University & Electronics for the Environment Laboratory - DIET – Sapienza University of Rome
• Software development for interpreting the GPR signal detection.	Electronics for the Environment Laboratory - DIET – Sapienza University of Rome

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Basic principles

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Basic principles

This guide aims to describe the steps for building a GPR with the main following features:

- FMCW radar type
- Use of modular subsystems that allow you to replace components for implementing design alternatives, and get greater understanding in the case of educational activity
- Device managed by PC for interactive control of GPR
- Frequency sweep: f_{min}=1.3 GHz, f_{max}=2.6 GHz
- Choice of smaller interval for frequencies of use
- Choice of modulation wave shape
- Choice of modulating wave period
- COTS (components off-the-shelf)
- Low cost

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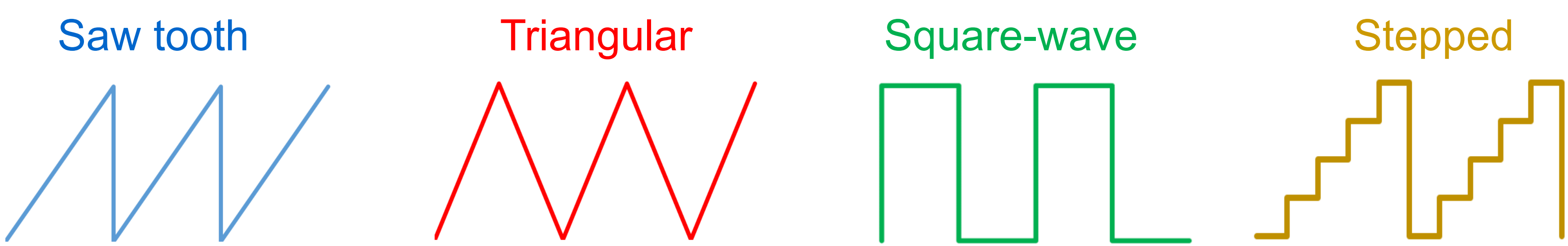
Basic principles

Essential characteristics

FMCW radar working is based on the continuous emission of sinusoidal waveform (CW), which frequency is suitably modulated (FM).
So, a basic design of a FMCW radar includes the following characteristics:

- The adoption of a local oscillator (LO).
- The received signal, properly amplified, is mixed with LO to create beat.
- The frequency of beat signal is proportional to the distance between the detected object and radar.

By including VCO device as LO, we can carry out different frequency modulations by changing voltage control waveform:



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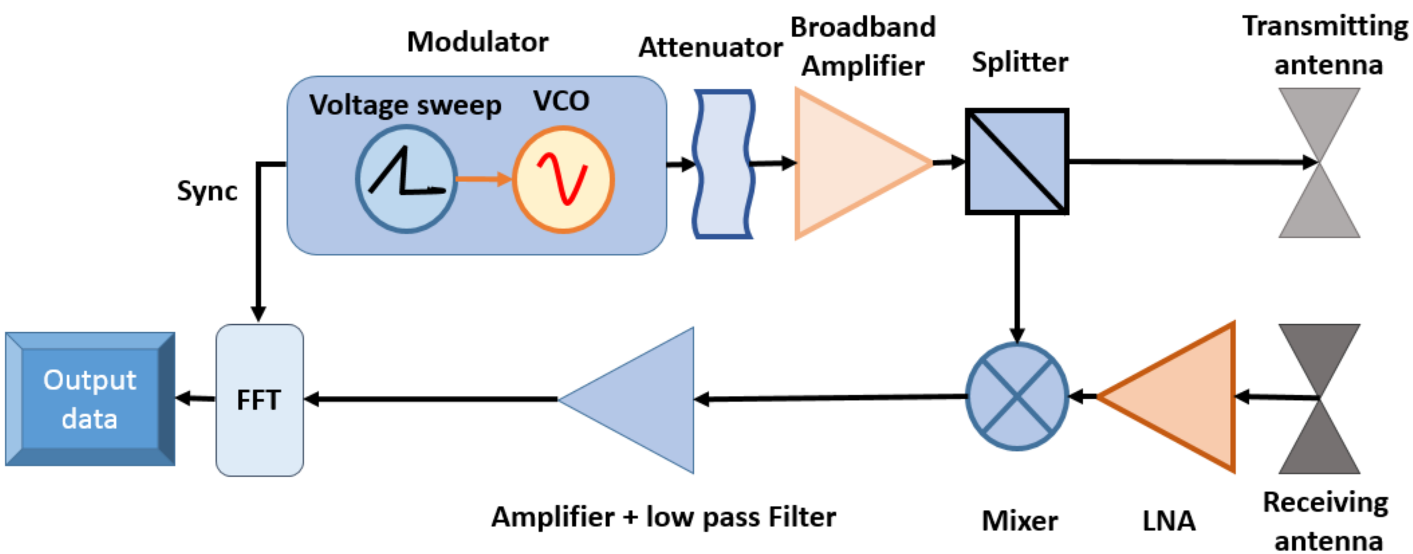
Basic principles

Signal processing

FFT

The application of the Fast Fourier Transform to the output signal allows to obtain frequency data, and consequently to calculate the distance of multiple detected objects.

The use of a low pass filter increases the signal to noise ratio, decreasing broadband high frequency noise.



FFT and Output data blocks are carried out inside the PC

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RF Hardware design

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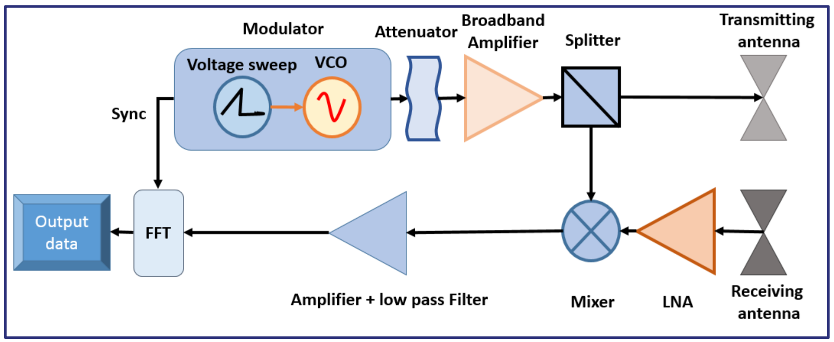
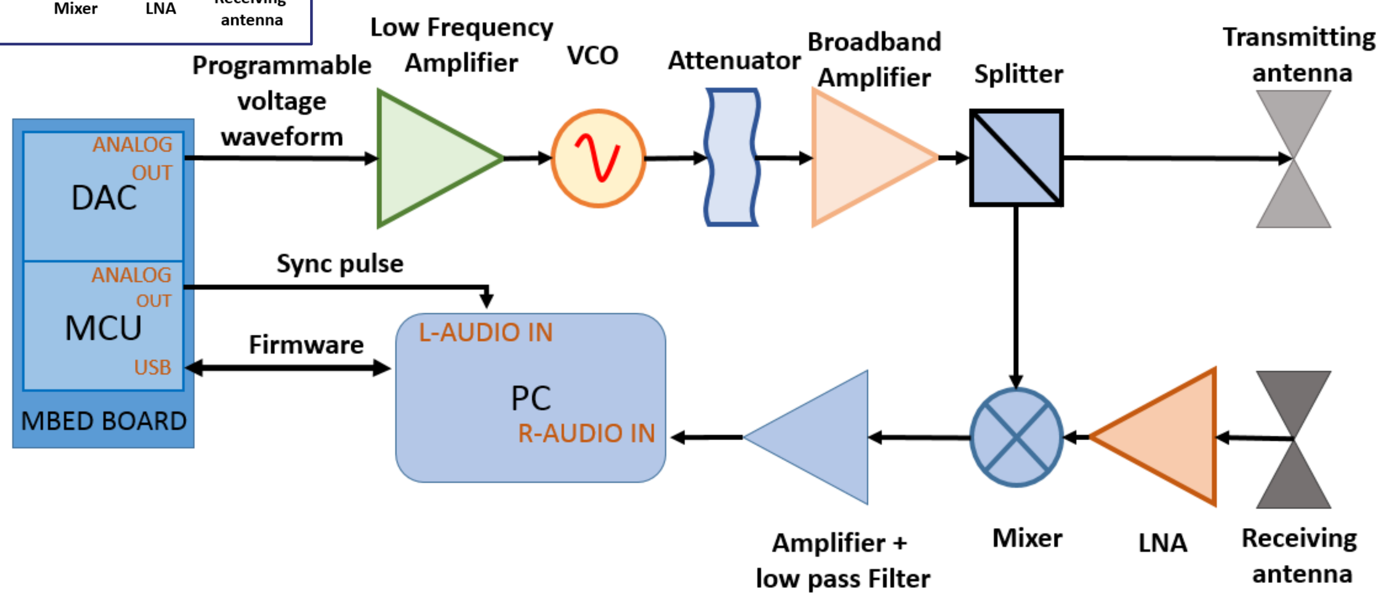
RF Hardware design

In order to increase interactive features and versatility of modulation shapes, we replaced the analog function generator with a versatile Mbed LPC1768 microcontroller (MCU) board, with high performance ARM Cortex-M3 core.



Block diagram of FMCW radar changed from basic to new version that adds control lines and connection to the PC.



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Guide

Guide structure

The guide includes:

- Bill of materials together with pdf datasheet of more important devices

Bill of material – RF subsystem.

Part number	Qty	Description	Manufacturer	datasheet	Approximate cost (€)
ZX95-2700A-S+	1	Voltage Controlled Oscil… Band 1300 to 2700 MHz…			
VAT-3+	1	SMA Fixed Attenuator 5…			

Bill of material – Amplifier+ Low pass filter (Amp2) subsystem.

Part number	Qty	Description	Manufacturer	datasheet	Approximate cost (€)
		…GP	Analog Device	OP467.pdf	16.04
			Vishay	-	0.085

Bill of material – Low frequency amplifier subsystem (Amp1).

Part number	Qty	Description	Manufacturer	datasheet	Approximate cost (€)
LT1077S8#PBF	1	Micropower, Single Supply, Precision Op Amp (U1)	Linear Technology	LT1077fa.pdf	2.61
Wo…					
ER…					
CR… KE…					
28…					

Bill of material – Power supply subsystem (DC-DC converters).

Part number	Qty	Description	Manufacturer	datasheet	Approx. cost (€)
TSRN 1-2465	2	DC/DC converter 6.5V 1° (U2,U3)	Traco Power	TSRN-1 DC_DC converter.pdf	12.08 x 2
R-78E5.0-0.5	1	CONV DC/DC 5V 500MA OUT THRU (U1)	Recom Power	R-78Exx-0.5 DC_DC converter.pdf	2.24
282834-4	2	4 Position Wire to Board Terminal Block Horizontal with Board 0.100" (2.54mm) Through Hole (P1, VinDC+VnSHDN+Gnd+Vout)	Buchanan - TE Connectivity	-	1.67 x 2
447687 (supplier: Jonathan ®)	1	FullPower - Battery Lipo 4S 2200mAh 35C Silver V2 – DEANS (BT1)	Full Power	-	25,90
C0603X103F5JACTU	2	Multilayer Ceramic Capacitor (MLCC) Standard 10000pF, ± 5%, 50 V DC, SMD (C1,C2)	KEMET	-	0.52 x 2
282834-2	1	2 Position Wire to Board Terminal Block Horizontal with Board 0.100" (2.54mm) Through Hole (BT1)	TE Connectivity AMP	-	0.8

Bill of material – mbed board

…rt number	Qty	Description	Manufacturer	datasheet	Approximate cost (€)
…-LPC1768	1	ARM mbed LPC1768 prototyping board (MBED)	mbed	LPC1768.pdf, mbed-005.1.pdf, lpc17xx_um.pdf, lpc17xx_ds.pdf, pc17xx_es.pdf,	58.23
…34-2	3	2 Position Wire to Board Terminal Block Horizontal with Board 0.100" (2.54mm) Through Hole (P1,P2,P3)	TE Connectivity AMP Connectors	-	0.8 x3
…3-020-10-…00	2	20P single row (female) lo profile SKT long ins	Mill-Max	-	1.86 x 2

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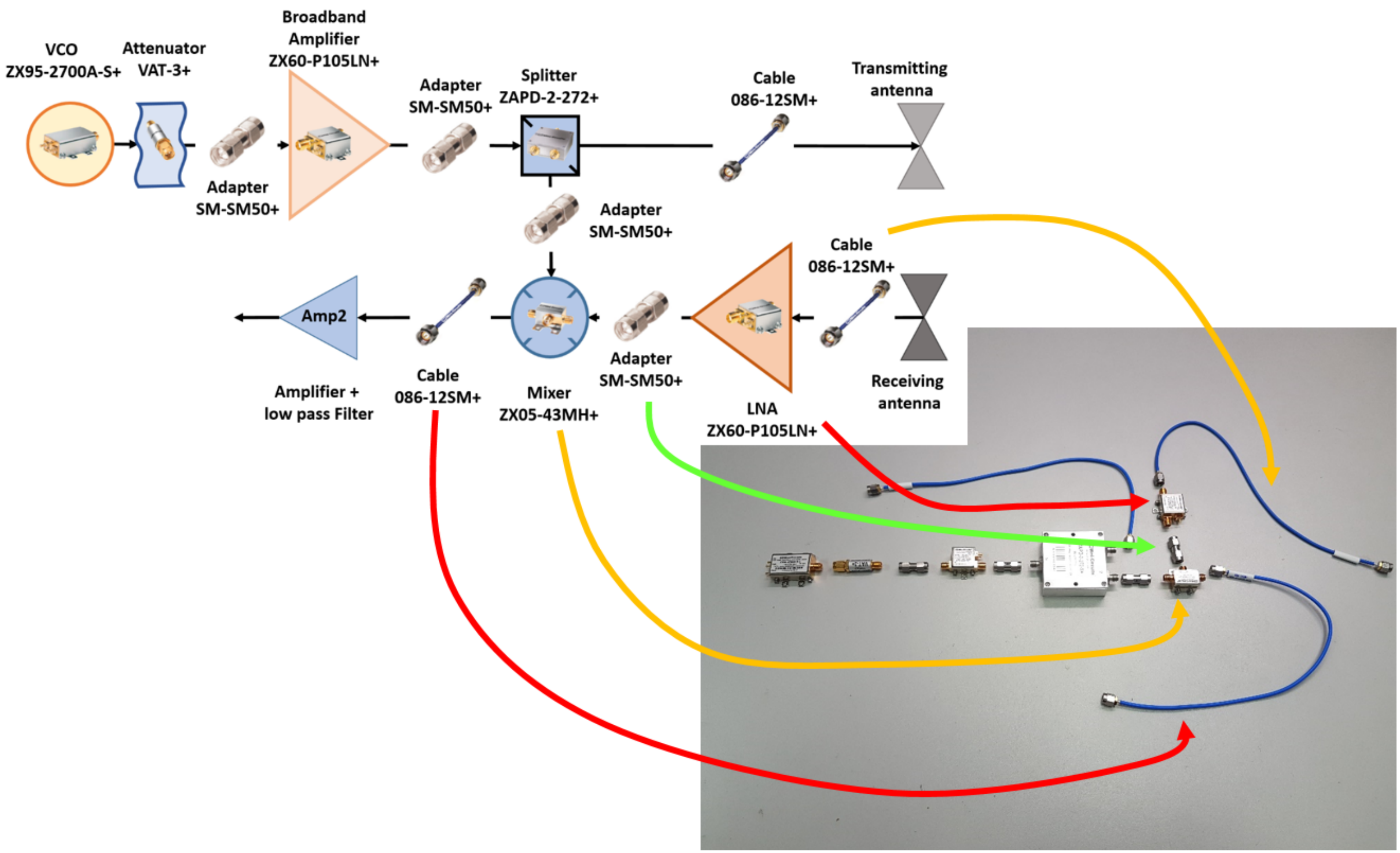
Guide

Guide structure

The guide includes:

- Identification and assembly of RF components



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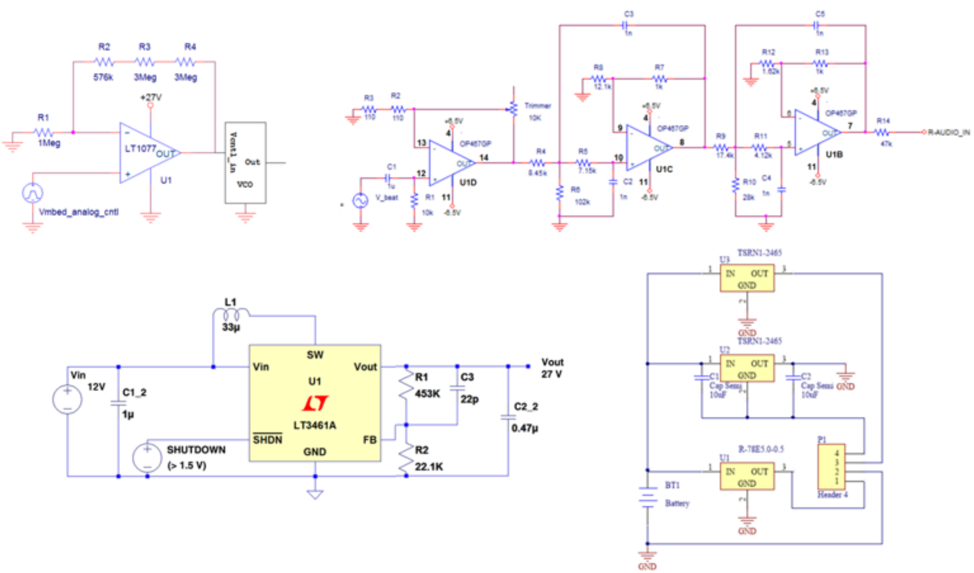
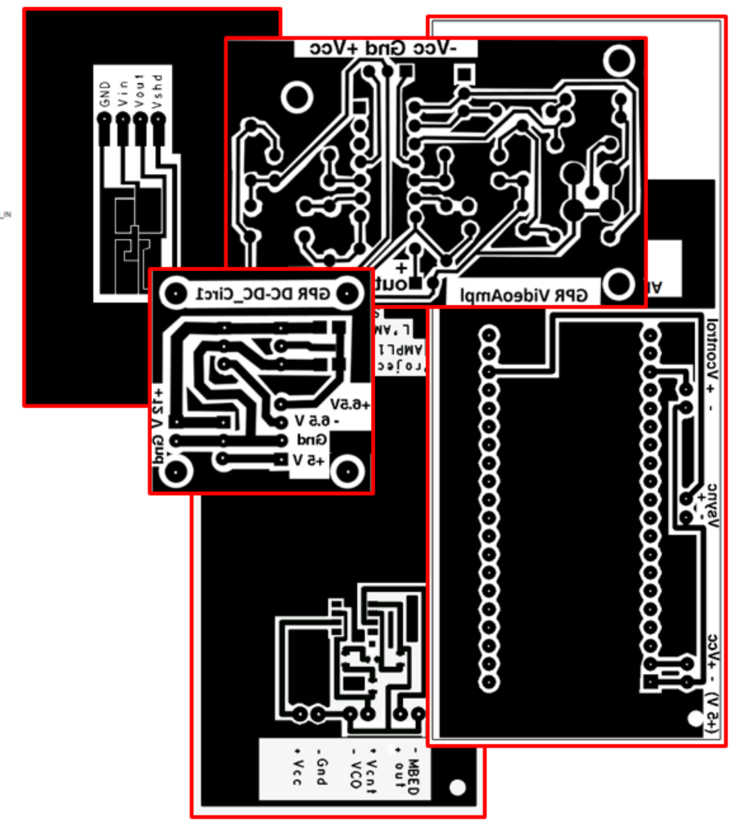
Guide

Guide structure

The guide includes:

- Schematics and PCBs (printed circuit board) together with picture files for reproducing them.





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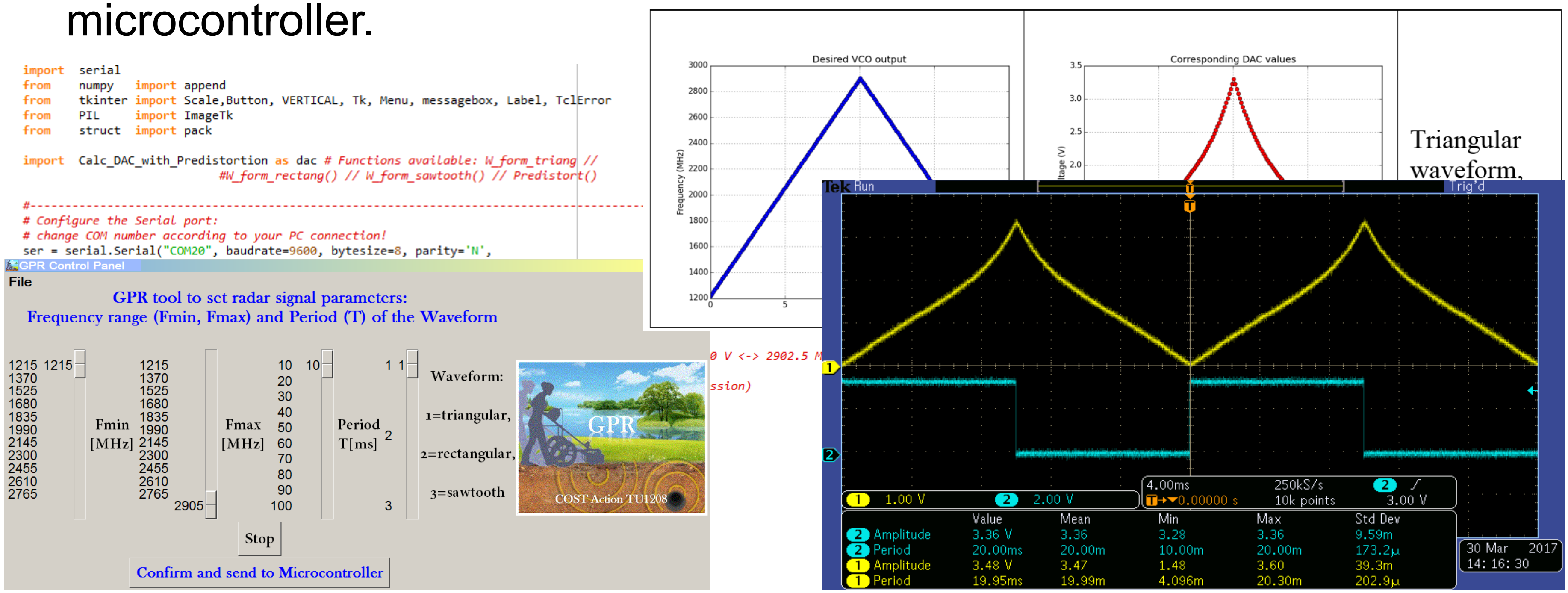
Guide

Guide structure

The guide includes:

- Detailed exposition of developed software codes. Specifically, it includes the firmware program providing control functionalities of the Mbed microcontroller, and the software program for building a graphical interface that provides an easy to use workspace, the user can switch many parameters to control the radar system and send it to the microcontroller.



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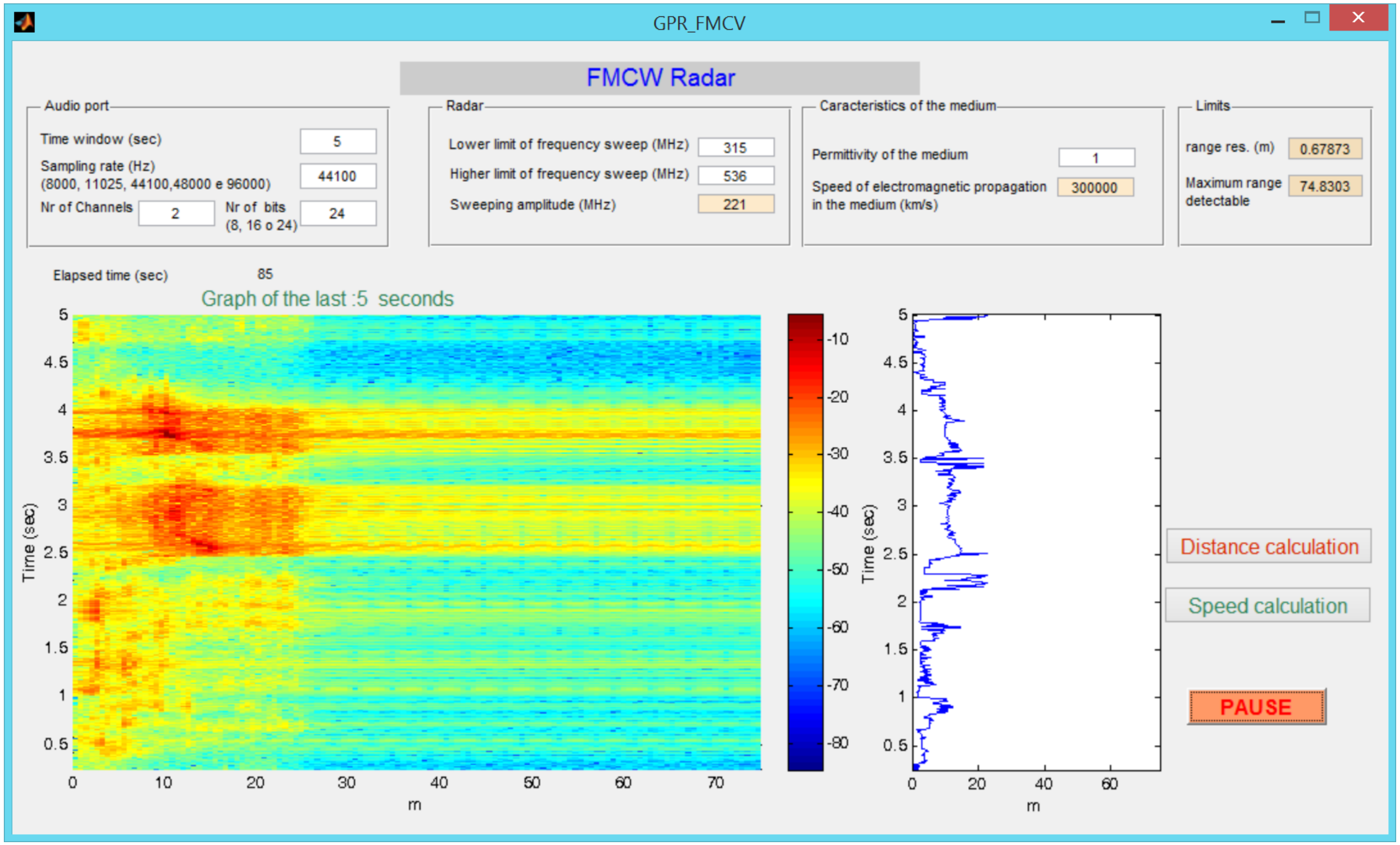
Guide

Guide structure

The guide includes:

- Suggestions and basic software for interpreting output signal.



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Conclusions

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Conclusions

- A full guide for designing and realizing an open-source low-cost GPR radar for educational purposes is available on-line.
- Hardware, firmware and software design and implementation are available with full explanation of the details, practical operational suggestions and comments on the entire code.
- The developed software and firmware programs allow interactive control of the GPR functioning, the implemented GUI program is user-friendly and will facilitate students' interaction with the radar system.

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Conclusions

- The total price of the radar does not exceed **600 euros**, however it can be further reduced with the use of cheaper smd RF component, but in this case it is necessary to use a more complex multilayer pcb. Anyway, the actual version of the radar is the most easy-to-learn and easy-to-built possible.

- Moreover, reducing the bandwidth of the frequency sweep, the price can be cut to 400 euros.

- Future work will include the design and realization of optimized antennas and proper radar kit form-factor.

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[7] Mbed DAC course-notes: https://developer.mbed.org/media/uploads/robt/mbed_course_notes_-_analog_input_and_output.pdf

Authors

Vincenzo Ferrara received the "Laurea" degree cum laude in Electronic Engineering in March 1980 from "La Sapienza" University of Rome. He joined the Department DIET of the same University, as Associate Professor of Electronic since 2001, and he is scientific responsible of Electronics for the Environment Lab of the DIET.

The scientific research conducted in the years after graduation concerns different topics: electronic systems for the environment, systems for the planning, design and management of broadcasting, geo-referenced detection and software models, application of new technologies for planning and sustainable development, satellite navigation, WSN low power low voltage, energy harvesting, design of RF circuits, LCD, porous silicon. Co-leader in the COST Action TU1208 Project 4.2 of first year of COST action: Advanced application of GPR to the localization and vital signs detection of buried and trapped people. Member of international scientific advisory committee of many conferences, as: Risk analysis, Sustainable Planning & Development, Brownfield, Disaster Management. TCP member of 2nd International workshop on collaborations in ERDM, 2014. (For more info, please visit https://sites.google.com/a/uniroma1.it/vincenzoferrara-eng/home).

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Authors

Margarita Chizh is a PhD student at Bauman Moscow State Technical University. Her primary area of research is microwave imaging, focusing on radar signal processing and radar systems development. She is also a junior researcher at the Remote sensing laboratory which develops and produces holographic subsurface radars for various applications (For more info, please visit http://www.rslab.ru/english/).

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Authors

Andrea Pietrelli received the B.S. degree in Automation Engineering from Sapienza, University of Rome, and the M.S. degree in Communications Engineering from Sapienza, University of Rome. Actually is a Ph.D. candidate on Electronics Engineering in joint supervision between D.I.E.T. department of Sapienza University of Rome and Laboratoire Ampere of École centrale de Lyon. His research areas include low power electronics, energy harvesting, microbial fuel cell, bioreactors, ground penetrating radar, wireless sensor network and radar system development.
(For more info, please visit
https://web.uniroma1.it/dip_diet/)

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