A Practical Low-Cost Ultra-Wideband Research Platform

Master Seminar Project 2017/2018

Bernd Baumann

Overview

- Requirements
- Existing platforms
- Our own platform design
- Conclusion

Our Requirements

IoT	Research	Positioning
IoT OS Support (Contiki)	Open-source	IMU (9 DoF), barometer, …
Low-energy	Individual power measurements	Interface for data logging
Low-cost	Multi-purpose Solution	Multi-purpose Solution
	SMA Antenna Connector	SMA Antenna Connector

Existing Platforms using the DW1000

pozyx® ACCURATE POSITIONING

OpenRTLS

decaWave

Insight SiP
It's all in the package

IN-CIRCUIT
ENGINEERING AS A PASSION

sewio

CIHOLAS inc

LAB1

Localization for you.
Heuel&Löher

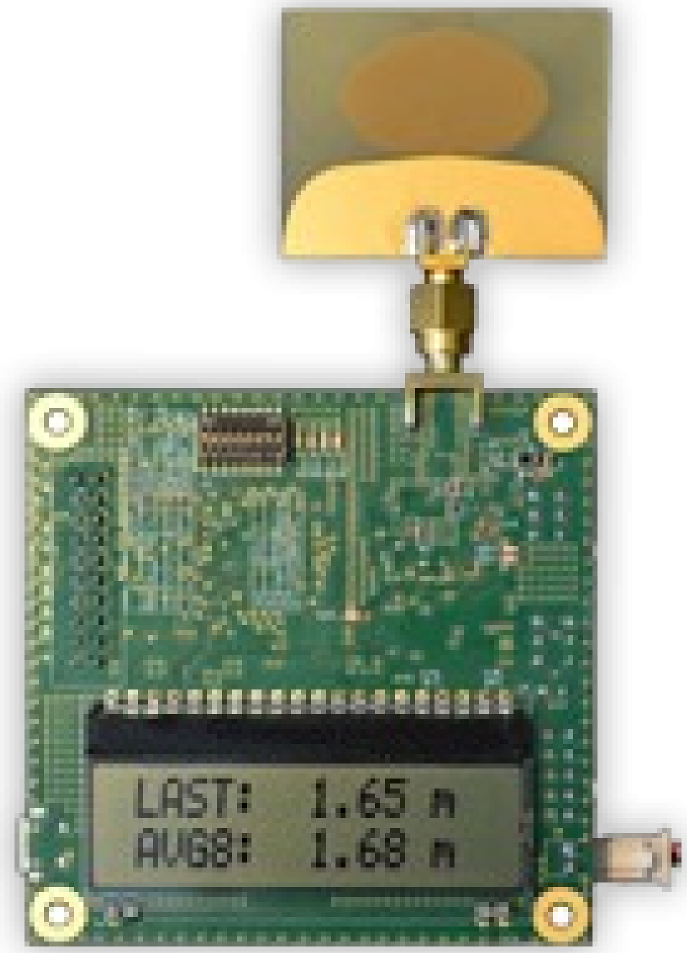
nanotron
TECHNOLOGIES

Be Spoon
We position

Sequitur
NEW WAYS
TO SAY HERE

decaWave

- ✓ SMA connector for UWB antenna
- ✓ Full firmware access
- ✓ BoM available
- ✓ Individual power measurement of DW1000
- ✗ no hardware design files
- ✗ No IMU and no extension headers
- ✗ 473 EUR for 2 tags
- ✗ High current draw of the STM32F105 MCU (47mA@72MHz, 1.2mA@125kHz)
- ✗ No interface for data logging



decaWave

IoT	Research	Positioning
IoT OS Support (Contiki)	Open-source	IMU (9 DoF), Barometer, ...
Low-energy	Individual power measurements	Interface for data logging
Low-cost	Multi-purpose Solution	Multi-purpose Solution
	SMA Antenna Connector	SMA Antenna Connector

CIHOLAS inc

- SMA connector for UWB antenna
- Hardware design files available
- IMU and pressure sensor included
- Multi-purpose solution
- no firmware source files
- 180 EUR per tag
- High current draw of the MCU (38mA active, 6.9mA idle)
- No interface for data logging

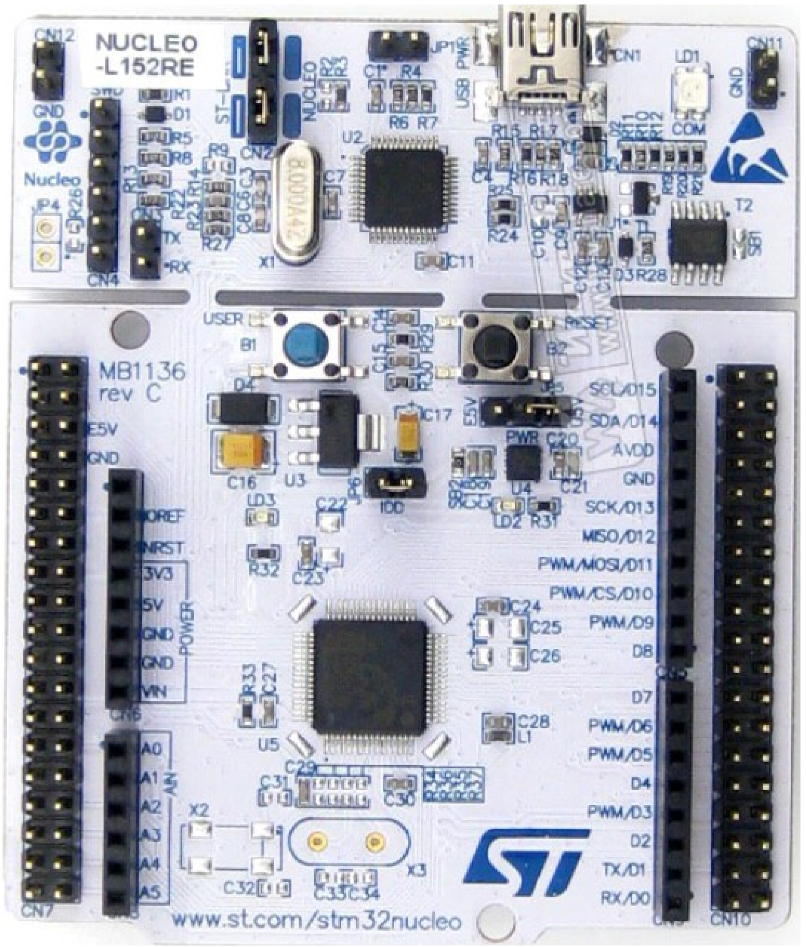
CIHOLAS inc

IoT	Research	Positioning
IoT OS Support (Contiki)	Open-source	IMU (9 DoF), barometer, ...
Low-energy	Individual power measurements	Interface for data logging
Low-cost	Multi-purpose solution	Multi-purpose solution
	SMA antenna connector	SMA antenna connector

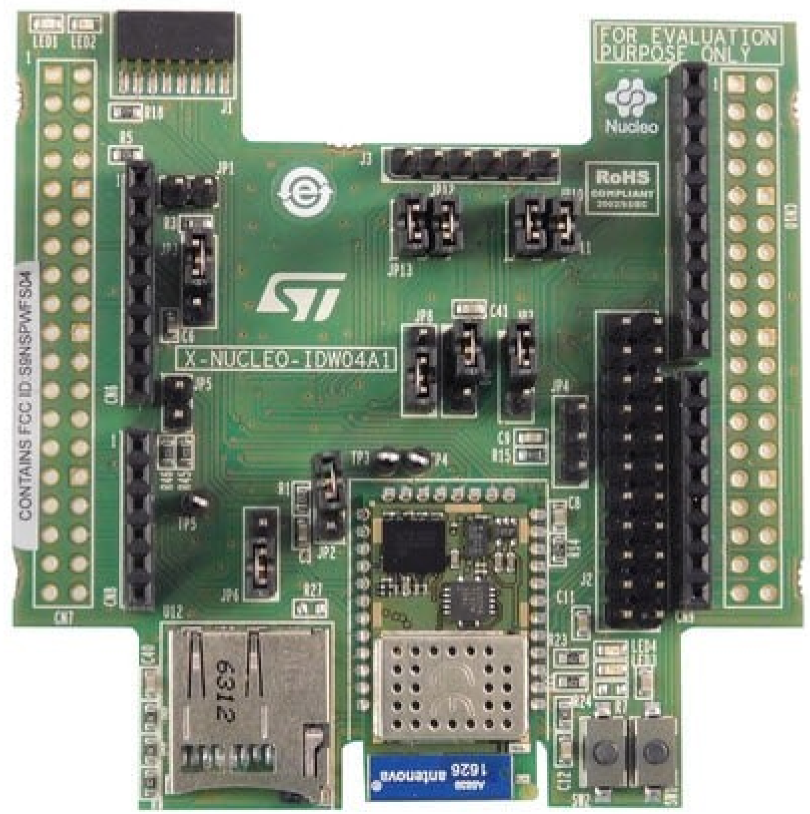
Existing Platforms - Conclusion

- No platform fulfilled all our requirements
- Focus on positioning
- No IoT platform design

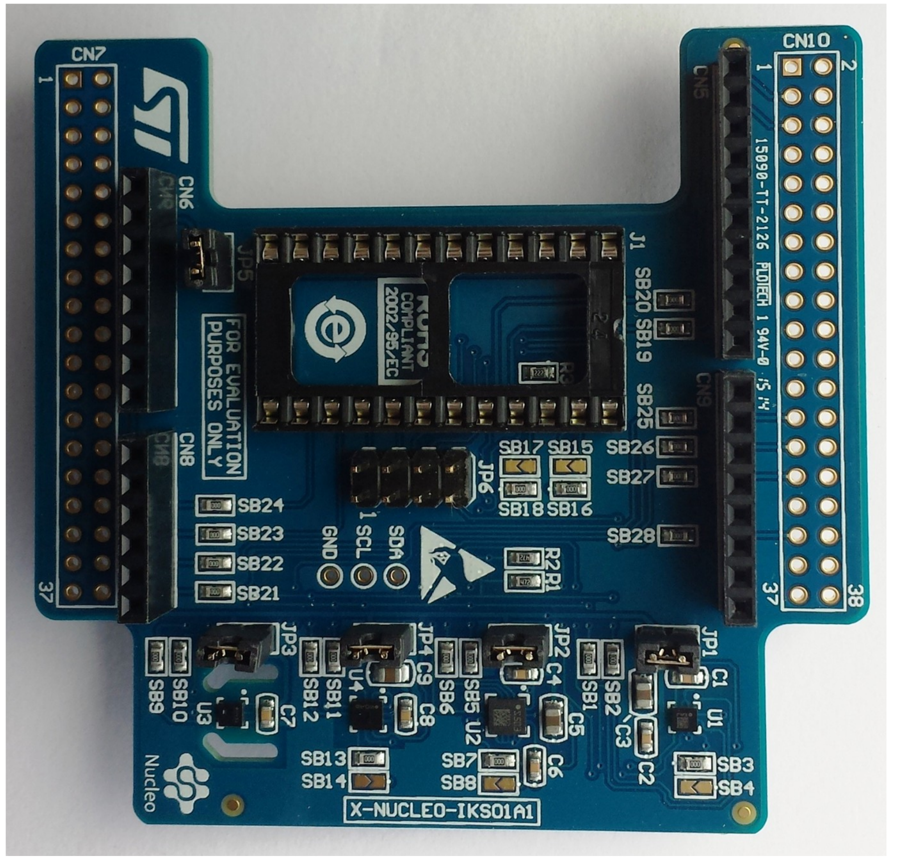
NUCLEO-L152RE

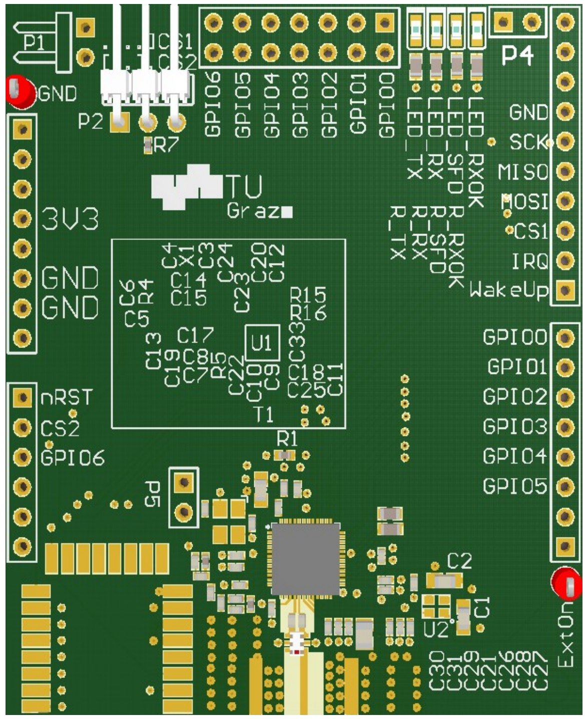


X-NUCLEO-IDW04A1



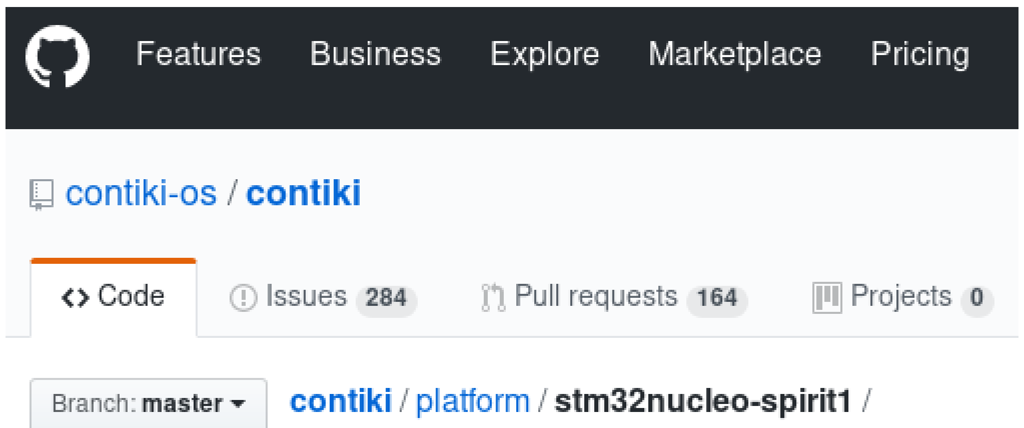
X-NUCLEO-IKS01A1





UWB extension shield

NUCLEO-L152RE



Master Project: UWB DW1000 Radio Driver for the Contiki OS

Michael Stocker

***Abstract*— This work describes the development of a DW1000 radio module driver for the Contiki OS. We first present the necessary background knowledge of the IEEE 802.15.4 ultra-wideband (UWB) standard and the Contiki OS. We then discuss the radio interface of the Contiki OS and our implementation of the required functions for UWB. After that, we show an experimental validation of the driver by using test cases as well as a server/client testing application. We also performed current consumption and received signal strength measurements to prove the developed system.**

I. INTRODUCTION

Ultra-wideband (UWB) communication systems refer to transceivers making use of a high bandwidth for data transmission. There are several ways of emitting an UWB signal, the most common one is to emit very short pulses, which is also called impulse-radio UWB (IR-UWB). According to FCC a more precise definition of what an UWB signal is: signals exceeding an absolute bandwidth $B >= 500MHz$ (resulting in a pulse width of $T_p \approx 1/B \leq 2ns$), or signals exceeding a relative bandwidth $B_r > 0.2$ or 20%.

Over the last few years UWB got more attention for several reasons. First, it can achieve high throughput over short distances, which can meet the requirements of interconnected home entertainment systems. Second, it also allows a high density of nodes, which will be essential for the ever increasing number of smart devices and sensor networks. Third, higher immunity to multi-path fading, and a very good time-domain resolution allowing for precise position estimation. The DecaWave DW1000 is the first low-cost IEEE 802.15.4-compliant UWB transceiver. At the

and transmission of test packets. Furthermore, we explain our server/client testing application for Contiki, which was used to validate the driver for the Contiki environment by transmitting test packets with different configurations.

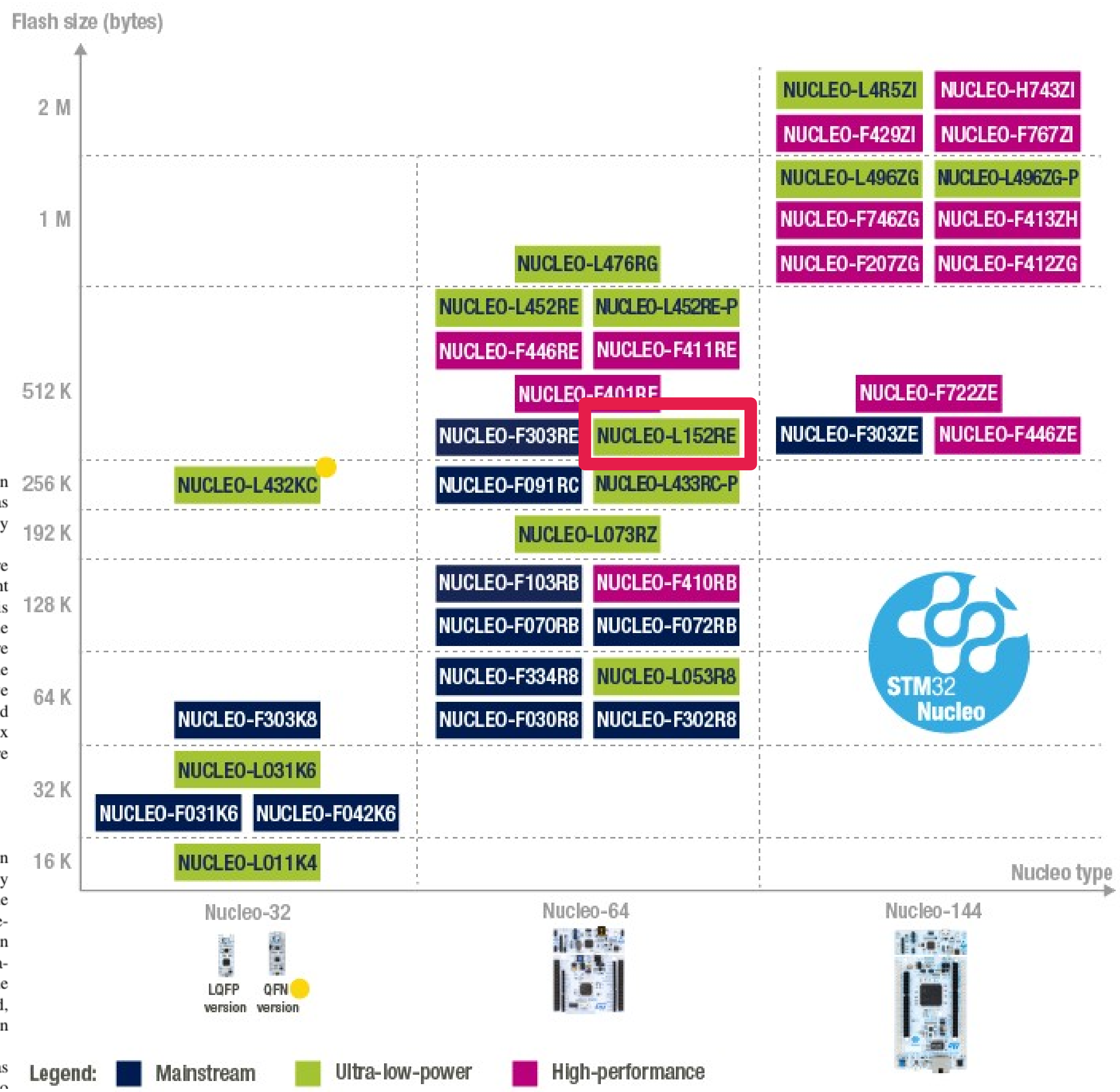
We discuss how we used the testing application to measure the power consumption of the radio device in different operational and power saving modes. We also used this application to measure the received signal strength while changing the transmission power. These measurements are performed to prove the mode switching capability of the driver. In the remaining chapters we discuss problems that we experienced, we conclude with a summary of our work and sketch an outlook of further work in the area. In the appendix we give give a more detailed view on the software/hardware setup and configuration parameters.

II. Background

A. IEEE 802.15.4

The IEEE 802.15.4 standard describes a transmission protocol for wireless personal area networks (WPAN). It only defines the last two layers of the OSI model, namely the MAC and the physical layer (PHY). The MAC layer is responsible for coordinating and sharing the medium between different network users. It further implements frame validation through CRC and automatic acknowledge messages. The PHY layer defines the actual wireless transmission method, link quality indicator, channel selection, CCA, transmission and reception of packets, as well as ranging [1].

In Figure 1 we can see the UWB physical layer frame as specified in IEEE 802.15.4. The MAC frame is passed to



UWB Extension Shield

P2
SPI-CS1/SPI-CS2

P4
LED supply

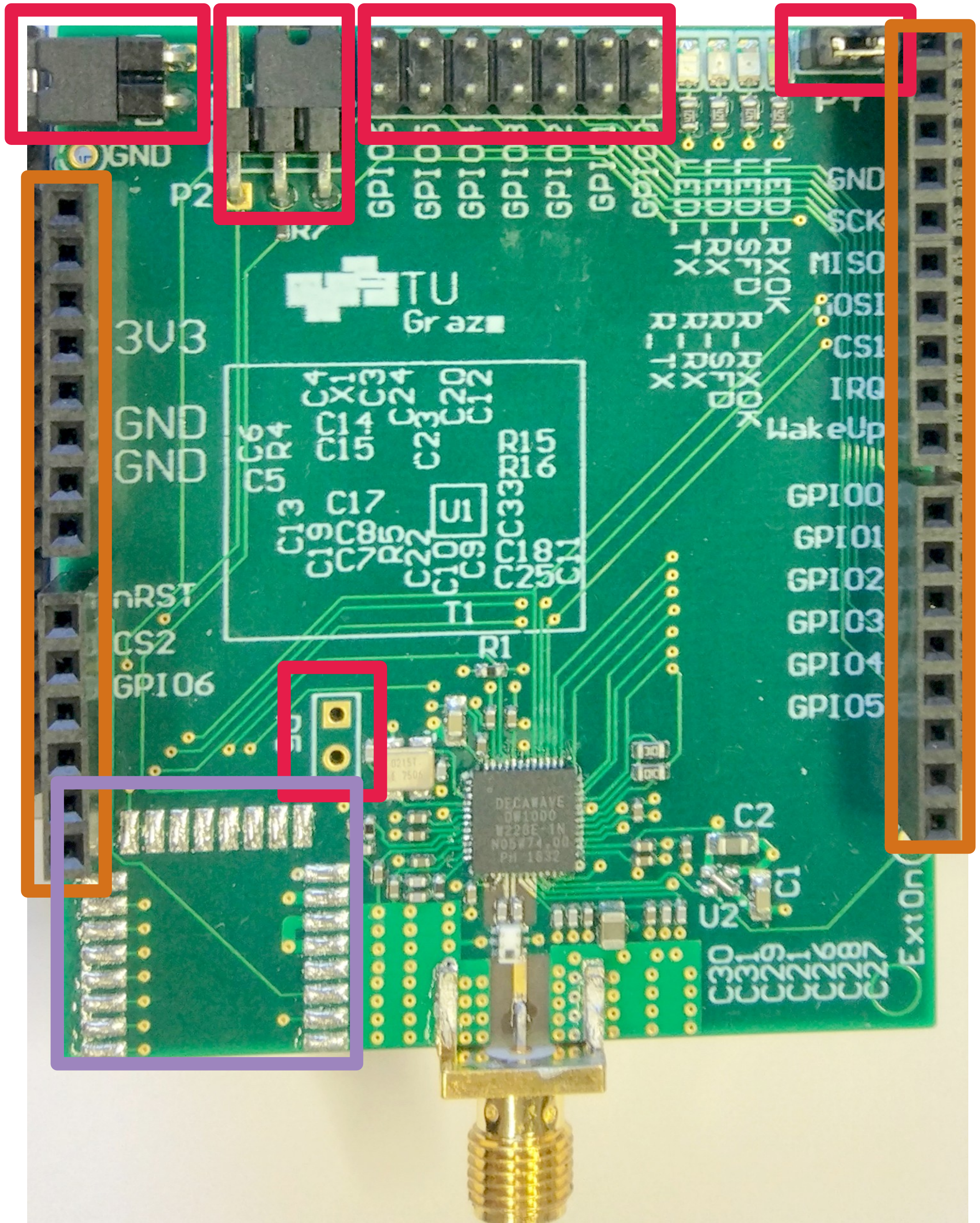
GPIO0 - GPIO6

P1
current measurements

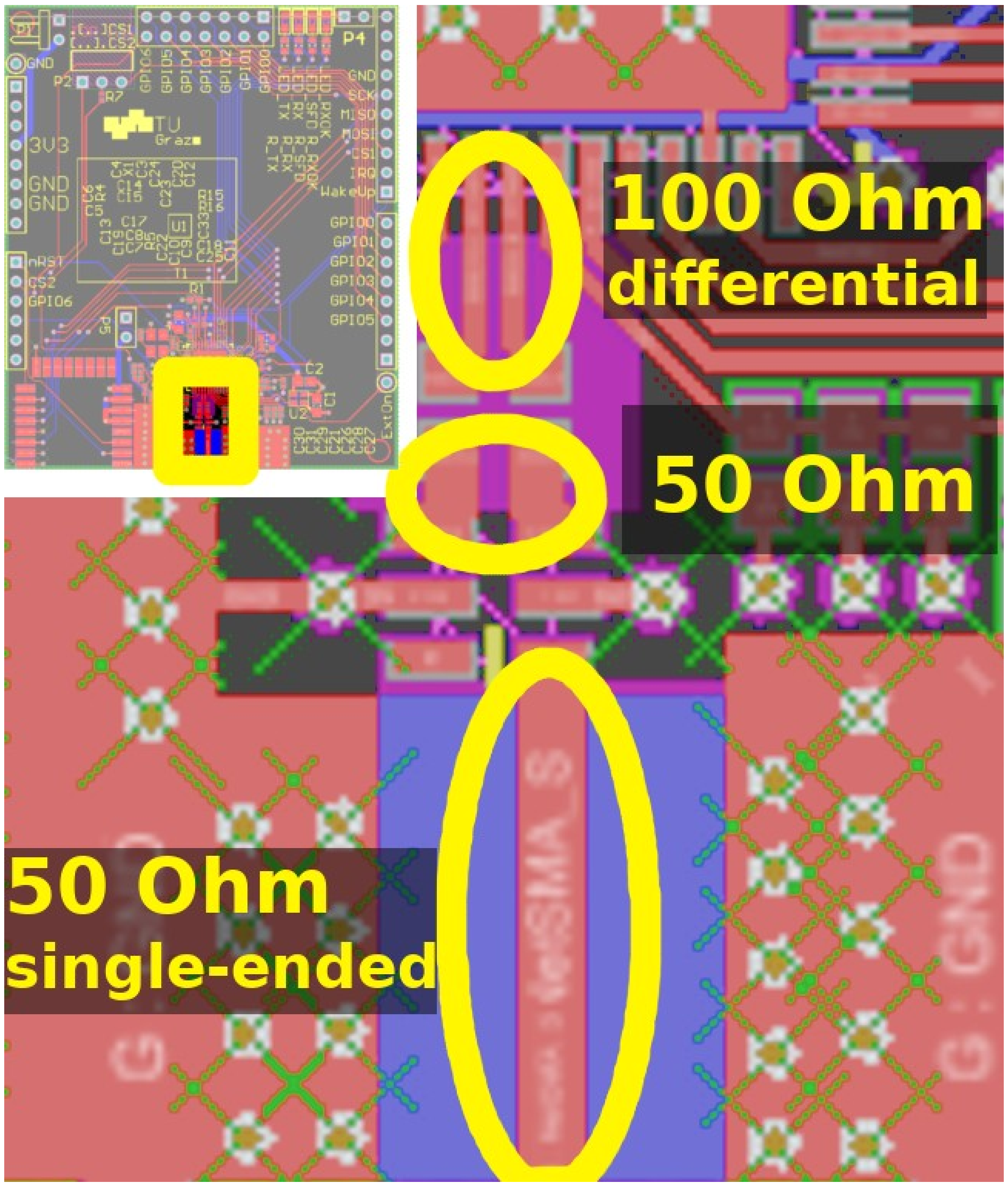
Arduino Header Connector

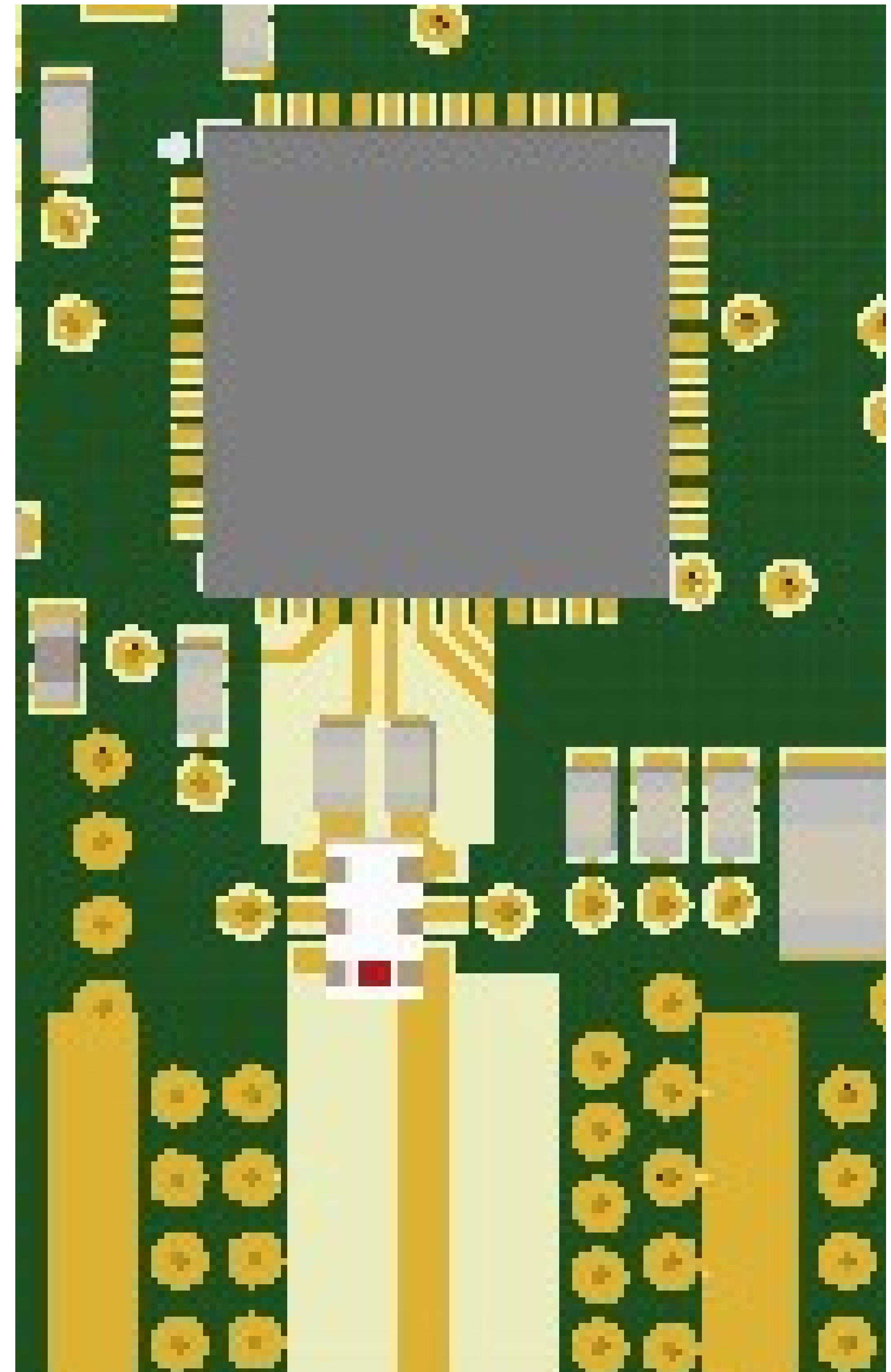
P5
DWM1000 supply

DWM1000 Footprint



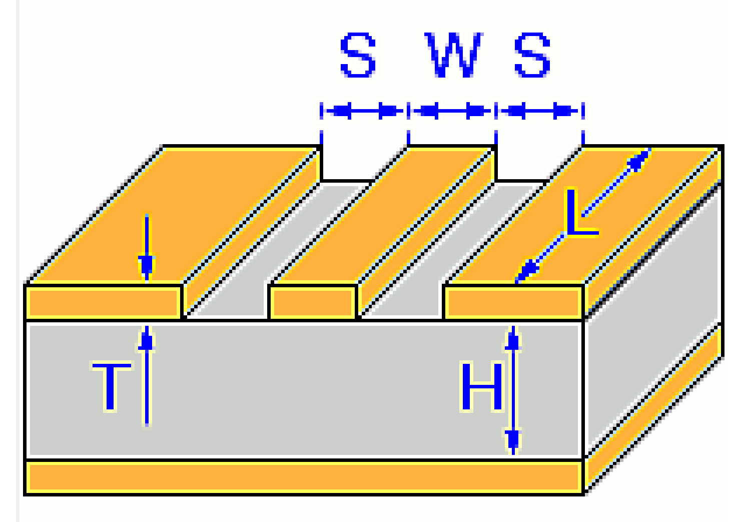
PCB Design – TX Line Design





PCB Design – TX Line Design

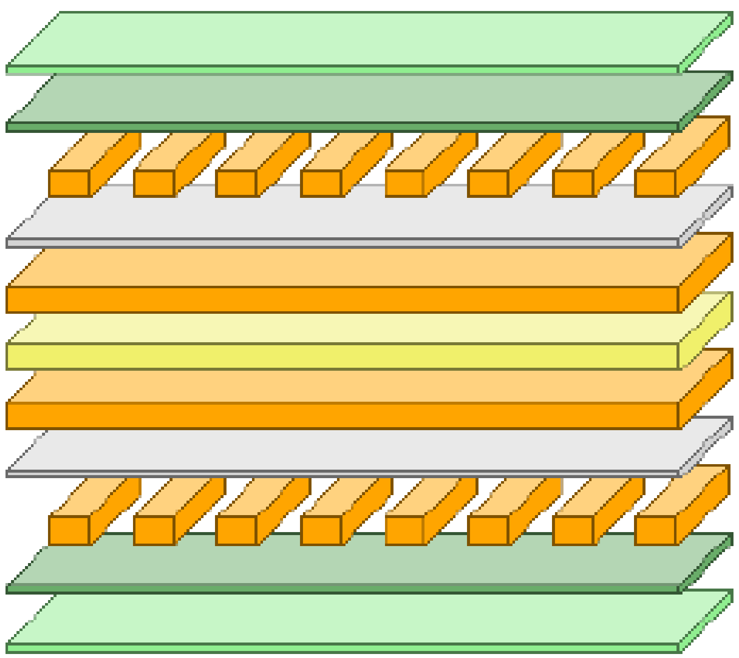
Net	Length in mm
100Ω differential	1.18
50Ω differential	0.35
50Ω single-ended	**5.4**



$$\frac{\lambda}{10} = \frac{1}{10} \cdot \frac{speed\ of\ light}{frequency} = \frac{1}{10} \cdot \frac{299\,792\,458\,\frac{m}{s}}{10 \cdot 10^9\,\frac{1}{s}} = 3mm$$

Tool	Result for W in μm
Altium 17 [24]	**700**
Multi-CB Online Tool [26]	636
PCB Calculator [28]	710
NI AWR TX Line [29]	672
Saturn PCB [30]	740

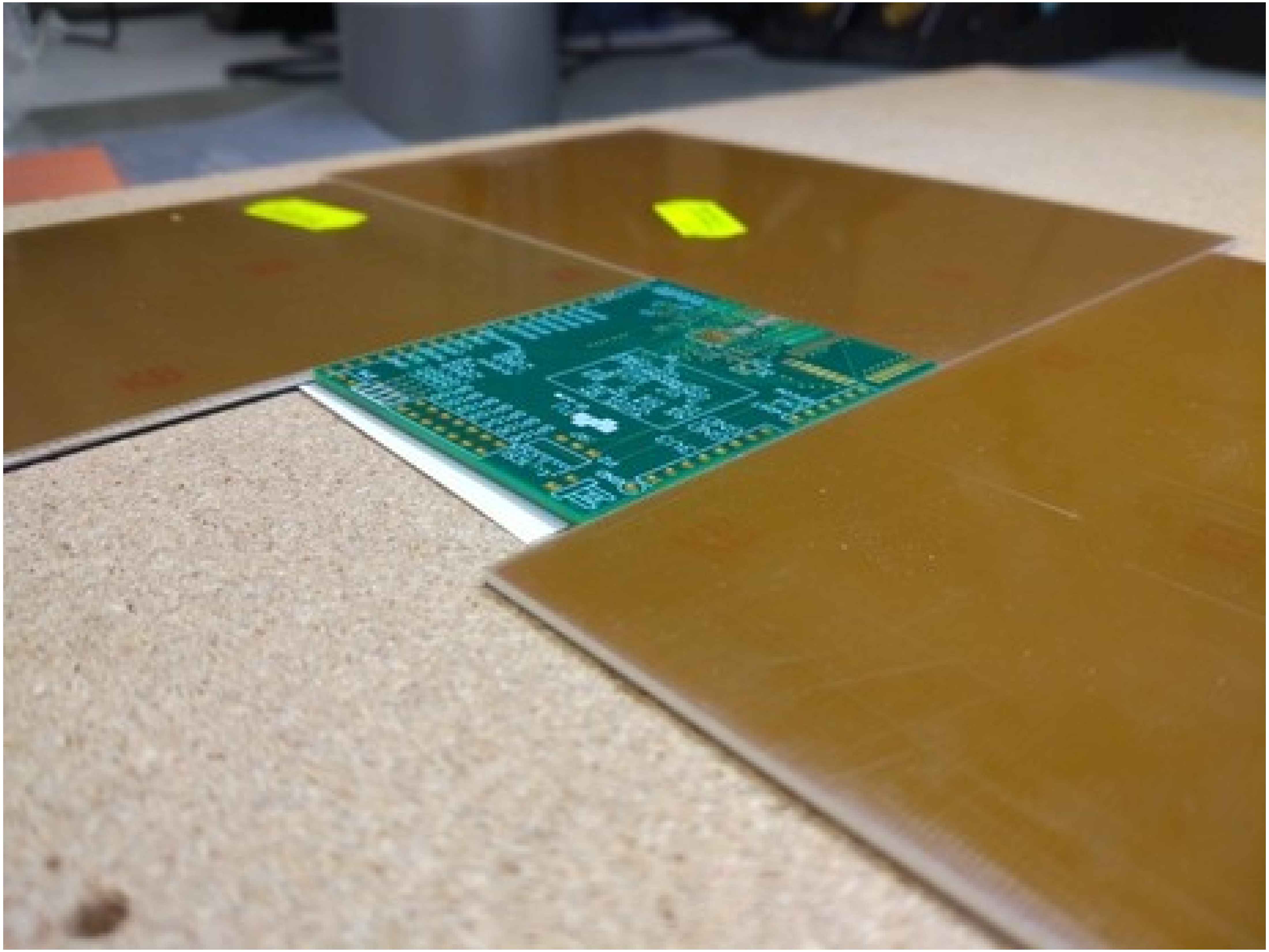
PCB Design – Layer Stackup



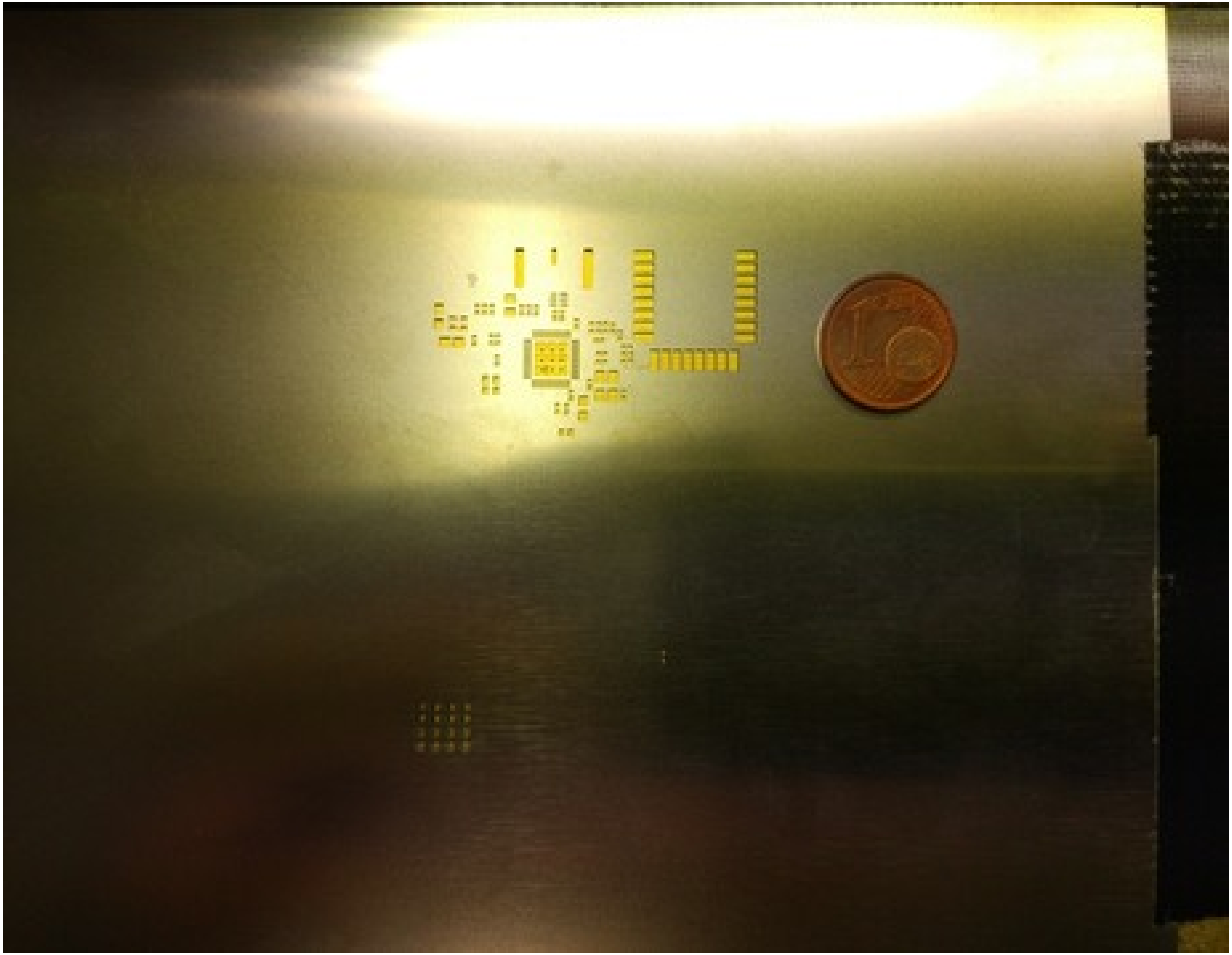
Name	Material	Thickness [μm]
Top Overlay	Ink	
Top Solder	Solder-Stop	10
Component Side	Copper	35
Dielectric	2 x Prepreg 7628	180+180
Ground Plane	Copper	18
Dielectric	FR-4 Core	700
Power Plane	Copper	18
Dielectric	2 x Prepreg 7628	180+180
Solder Side	Copper	35
Bottom Solder	Solder-Stop	10
Bottom Overlay	Ink	

Permittivity @ 5 GHz = 4.32

PCB Soldering

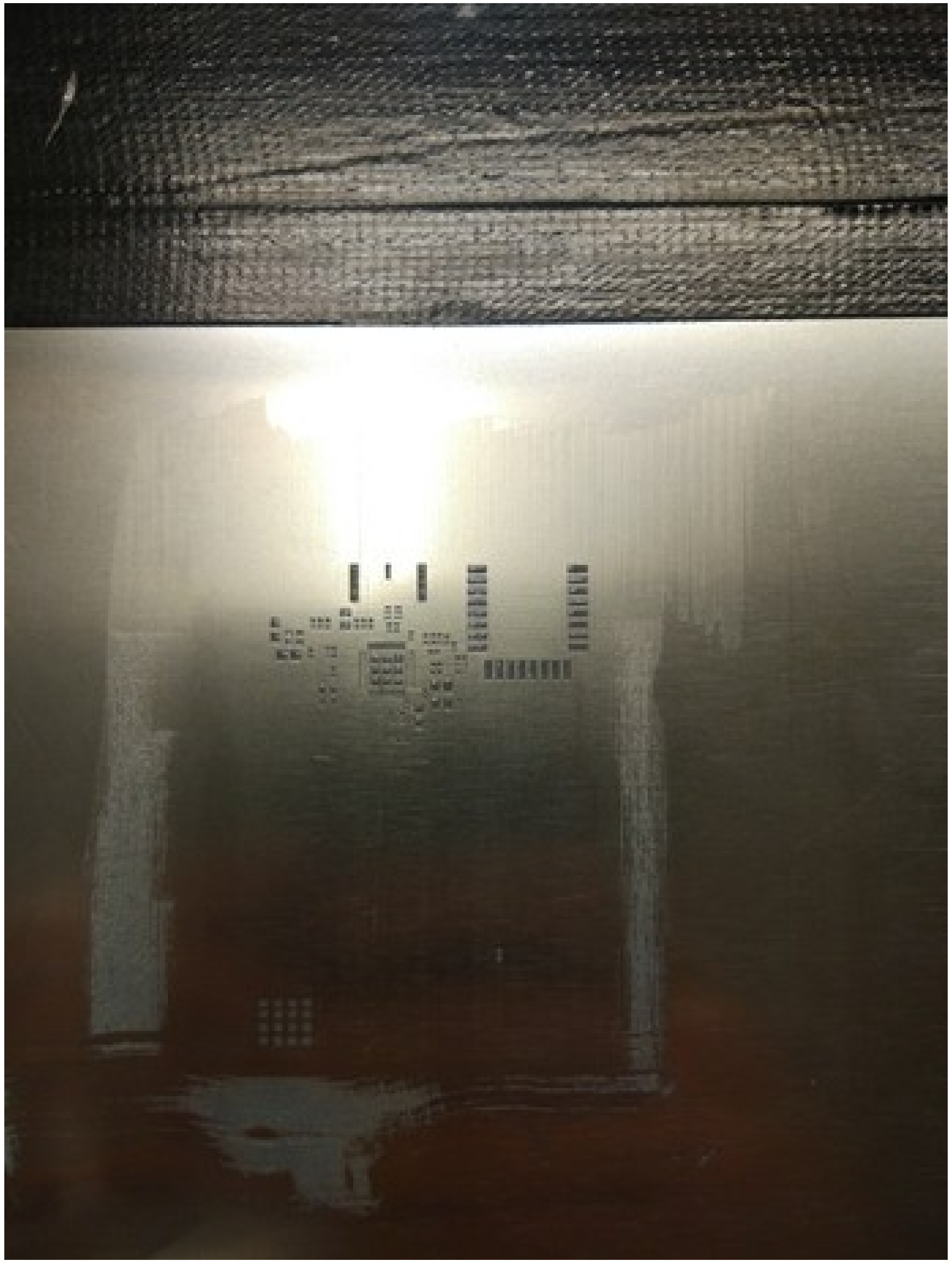


PCB Soldering



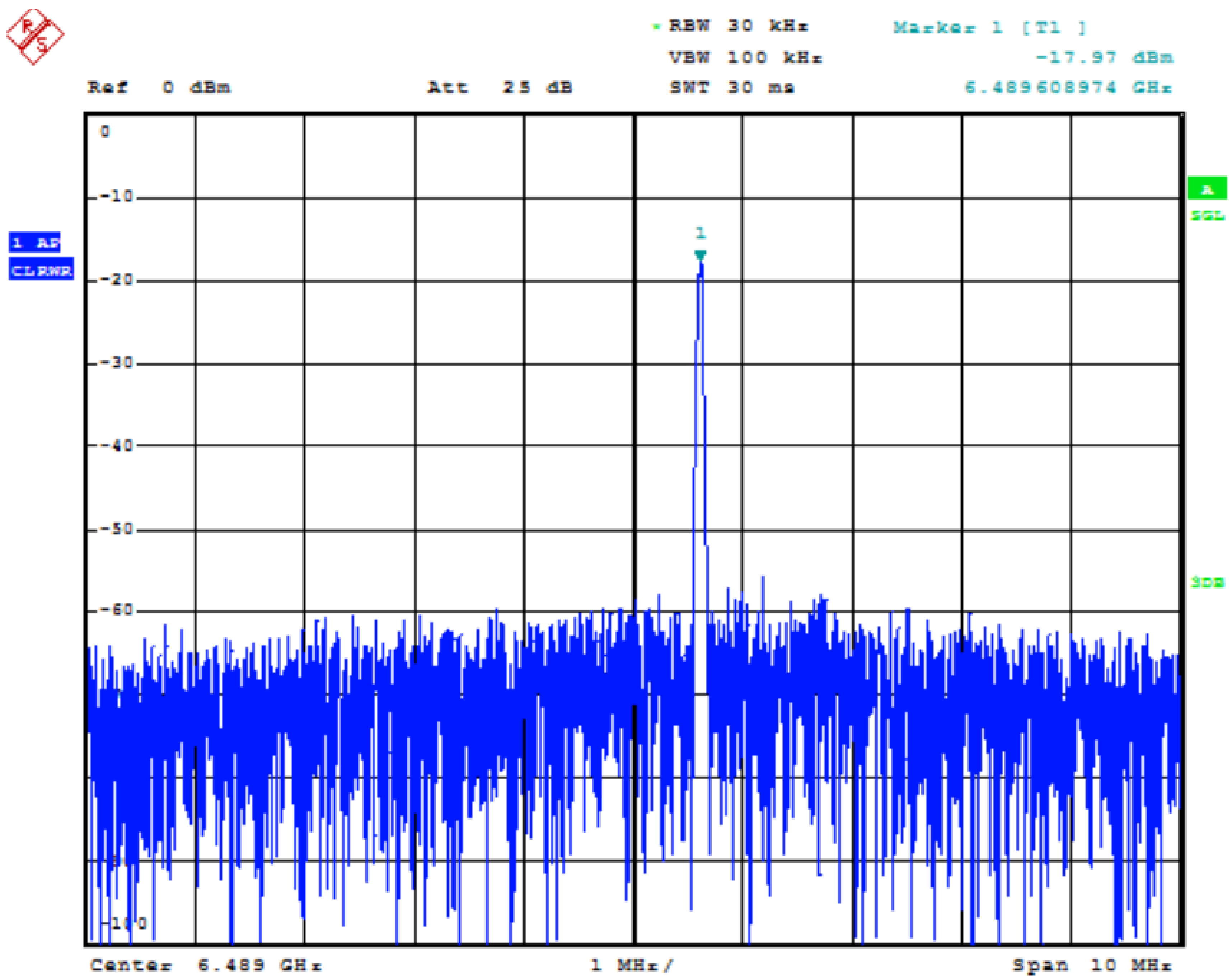
PCB Soldering

PCB Soldering

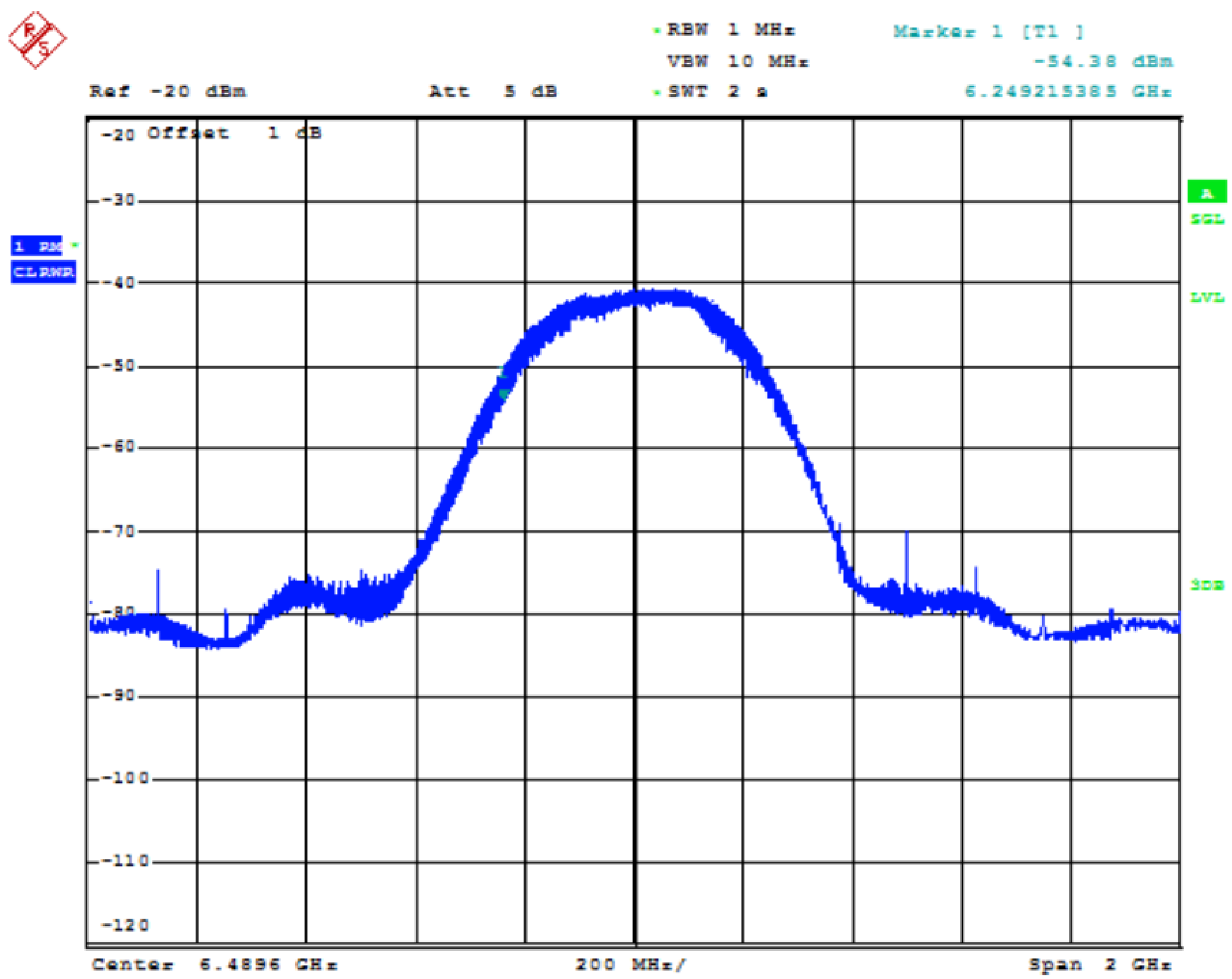


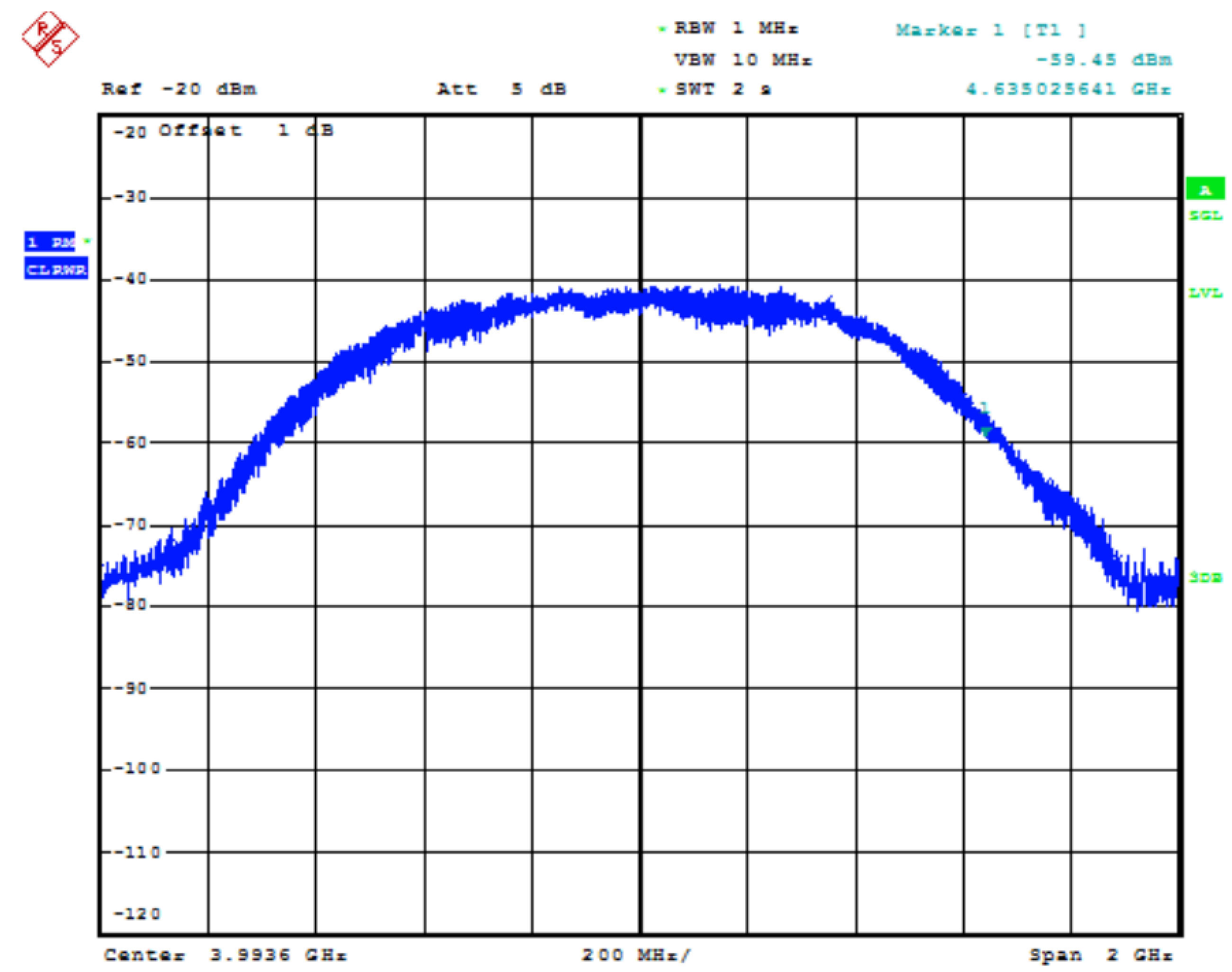
PCB Soldering

Evaluation - Crystal Trim

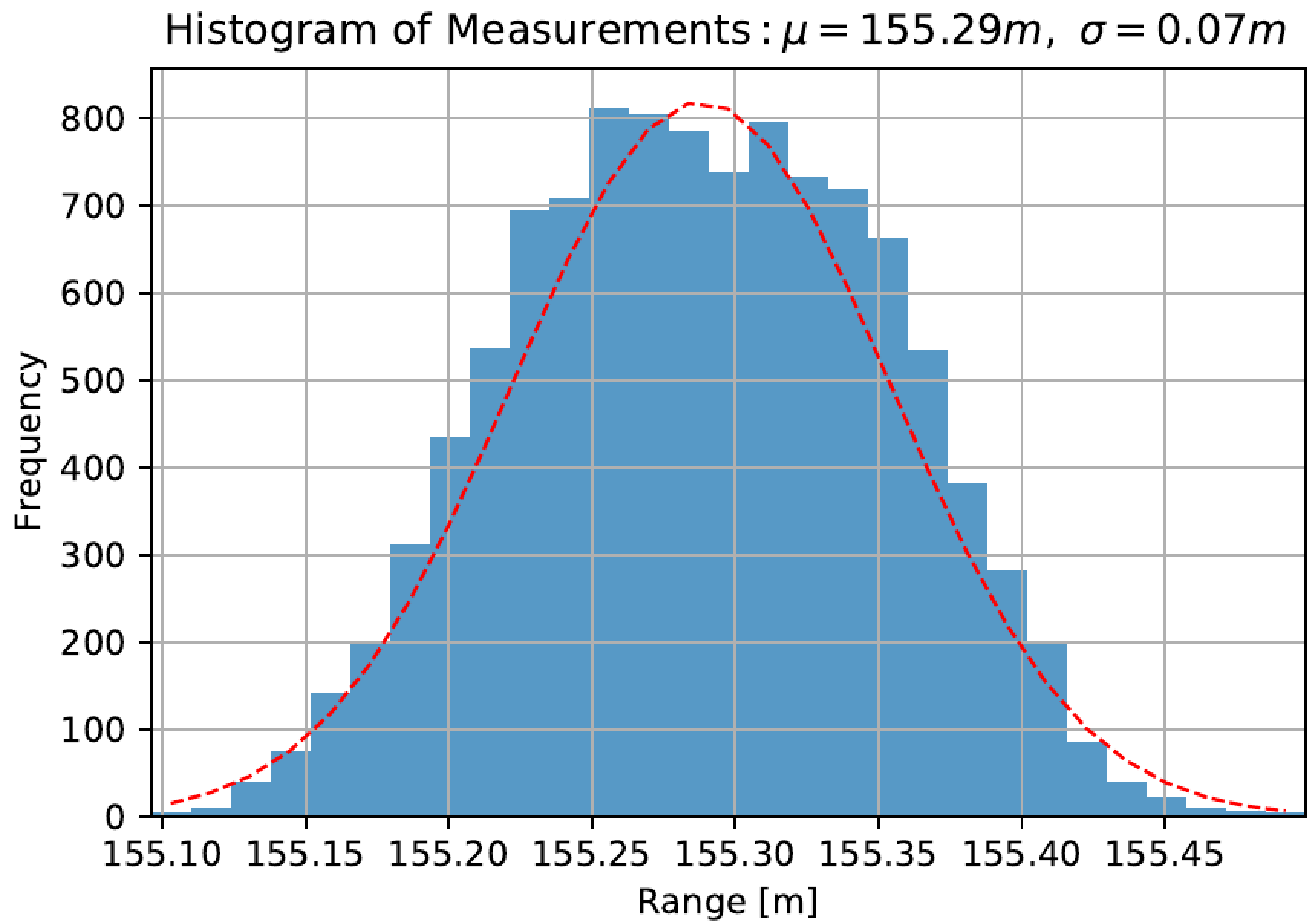


Evaluation – Transmit Power and Bandwidth





Evaluation – Antenna Delay Calibration



Our Requirements

IoT	Research	Positioning
IoT OS Support (Contiki)	Open-source	IMU (9 DoF), barometer, ...
Low-energy	Individual power measurements	Interface for data logging
Low-cost	Multi-purpose Solution	Multi-purpose Solution
	SMA Antenna Connector	SMA Antenna Connector

Our Requirements

IoT	Research	Positioning
STM32L152RE Contiki support + DW1000 Contiki driver by Michael Stocker	Open-source	IMU (9 DoF), barometer, ...
Low-energy	Individual power measurements	Interface for data logging
Low-cost	Multi-purpose Solution	Multi-purpose Solution
	SMA Antenna Connector	SMA Antenna Connector

Our Requirements

IoT	Research	Positioning
STM32L152RE Contiki support + DW1000 Contiki driver by Michael Stocker	Open-source	IMU (9 DoF), barometer, ...
STM32L152RE current draw: 7.55mA@32MHz (active) 21.5uA (sleep)	Individual power measurements	Interface for data logging
Low-cost	Multi-purpose Solution	Multi-purpose Solution
	SMA Antenna Connector	SMA Antenna Connector

Our Requirements

IoT	Research	Positioning
STM32L152RE Contiki support + DW1000 Contiki driver by Michael Stocker	Open-source	IMU (9 DoF), barometer, ...
STM32L152RE current draw: 7.55mA@32MHz (active) 21.5uA (sleep)	Individual power measurements	Interface for data logging
NUCLEO-L152RE + UWB = 47.42 EUR + WiFi + MEMS = 78.72 EUR	Multi-purpose Solution	Multi-purpose Solution
	SMA Antenna Connector	SMA Antenna Connector

Our Requirements

IoT	Research	Positioning
STM32L152RE Contiki support + DW1000 Contiki driver by Michael Stocker	Hardware design files, Calibration firmware, Contiki + DW1000 driver	IMU (9 DoF), barometer, ...
STM32L152RE current draw: 7.55mA@32MHz (active) 21.5uA (sleep)	Individual power measurements	Interface for data logging
NUCLEO-L152RE + UWB = 47.42 EUR + WiFi + MEMS = 78.72 EUR	Multi-purpose Solution	Multi-purpose Solution
	SMA Antenna Connector	SMA Antenna Connector

Our Requirements

IoT	Research	Positioning
STM32L152RE Contiki support + DW1000 Contiki driver by Michael Stocker	Hardware design files, Calibration firmware, Contiki + DW1000 driver	IMU (9 DoF), barometer, ...
STM32L152RE current draw: 7.55mA@32MHz (active) 21.5uA (sleep)	Connector to measure the current draw of the UWB shield	Interface for data logging
NUCLEO-L152RE + UWB = 47.42 EUR + WiFi + MEMS = 78.72 EUR	Multi-purpose Solution	Multi-purpose Solution
	SMA Antenna Connector	SMA Antenna Connector

Our Requirements

IoT	Research	Positioning
STM32L152RE Contiki support + DW1000 Contiki driver by Michael Stocker	Hardware design files, Calibration firmware, Contiki + DW1000 driver	IMU (9 DoF), barometer, ...
STM32L152RE current draw: 7.55mA@32MHz (active) 21.5uA (sleep)	Connector to measure the current draw of the UWB shield	Interface for data logging
NUCLEO-L152RE + UWB = 47.42 EUR + WiFi + MEMS = 78.72 EUR	Multi-purpose Solution	Multi-purpose Solution
	SMA Antenna Connector	SMA Antenna Connector

Our Requirements

IoT	Research	Positioning
STM32L152RE Contiki support + DW1000 Contiki driver by Michael Stocker	Hardware design files, Calibration firmware, Contiki + DW1000 driver	IMU (9 DoF), barometer, ...
STM32L152RE current draw: 7.55mA@32MHz (active) 21.5uA (sleep)	Connector to measure the current draw of the UWB shield	Interface for data logging
NUCLEO-L152RE + UWB = 47.42 EUR + WiFi + MEMS = 78.72 EUR	Multi-purpose Solution	Multi-purpose Solution
	SMA Antenna Connector	SMA Antenna Connector

Our Requirements

IoT	Research	Positioning
STM32L152RE Contiki support + DW1000 Contiki driver by Michael Stocker	Hardware design files, Calibration firmware, Contiki + DW1000 driver	X-NUCLEO-IKS01A1 includes IMU, pressure sensor, humidity sensor, temperature sensor
STM32L152RE current draw: 7.55mA@32MHz (active) 21.5uA (sleep)	Connector to measure the current draw of the UWB shield	Interface for data logging
NUCLEO-L152RE + UWB = 47.42 EUR + WiFi + MEMS = 78.72 EUR	Multi-purpose Solution	Multi-purpose Solution
	SMA Antenna Connector	SMA Antenna Connector

Our Requirements

IoT	Research	Positioning
STM32L152RE Contiki support + DW1000 Contiki driver by Michael Stocker	Hardware design files, Calibration firmware, Contiki + DW1000 driver	X-NUCLEO-IKS01A1 includes IMU, pressure sensor, humidity sensor, temperature sensor
STM32L152RE current draw: 7.55mA@32MHz (active) 21.5uA (sleep)	Connector to measure the current draw of the UWB shield	X-NUCLEO-IDW04A1 includes an SD card slot and an IEEE 802.11 b/g/n transceiver
NUCLEO-L152RE + UWB = 47.42 EUR + WiFi + MEMS = 78.72 EUR	Multi-purpose Solution	Multi-purpose Solution
	SMA Antenna Connector	SMA Antenna Connector