DEVELOPMENT OF AN AERONAUTICAL TELEMETRY RECEIVER BASED ON SOFTWARE DEFINED RADIO

AUTHORS:

NIVIO GUILLAN, LAUTARO

WILLIG, MAURICIO

DIRECTORS:

URIZ, ALEJANDRO

ETCHEVERRY, JUAN ALBERTO

NW

UNIVERSIDAD NACIONAL DE MAR DEL PLATA

FACULTAD DE INGENIERÍA

LAC 2022

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INTRODUCTION

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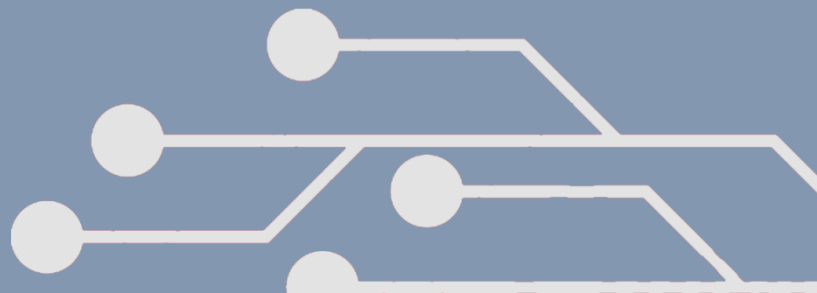
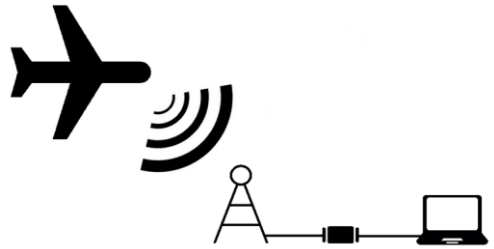


What is an aeronautical telemetry receiver?

- Device that allows the reception of physical magnitudes emitted by an aircraft::
  - Altitude
  - Speed
  - Position
- Information received in different communication protocols.
  - Protocols: Set of rules and regulations to transmit and receive information.



What is SDR?

- Radio communication equipment that allows components typically implemented in hardware to be made by software.

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Project proposal

- Purpose: Design and develop an aeronautical telemetry receiver
- Technique: Implementation through Software Defined Radio
- Protocols: ADS-B and ACARS
- Work items: Integrated circuits and laboratory instruments

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PRELIMINARY DRAFT

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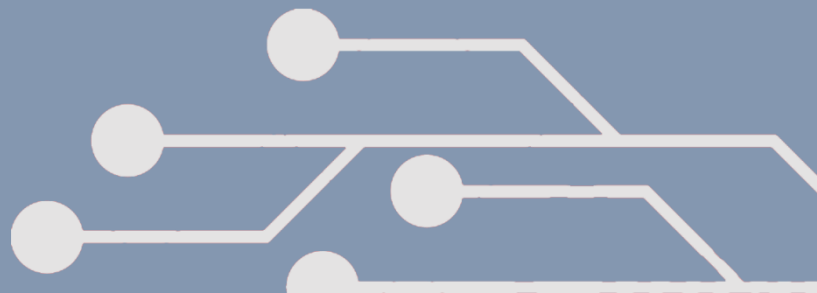
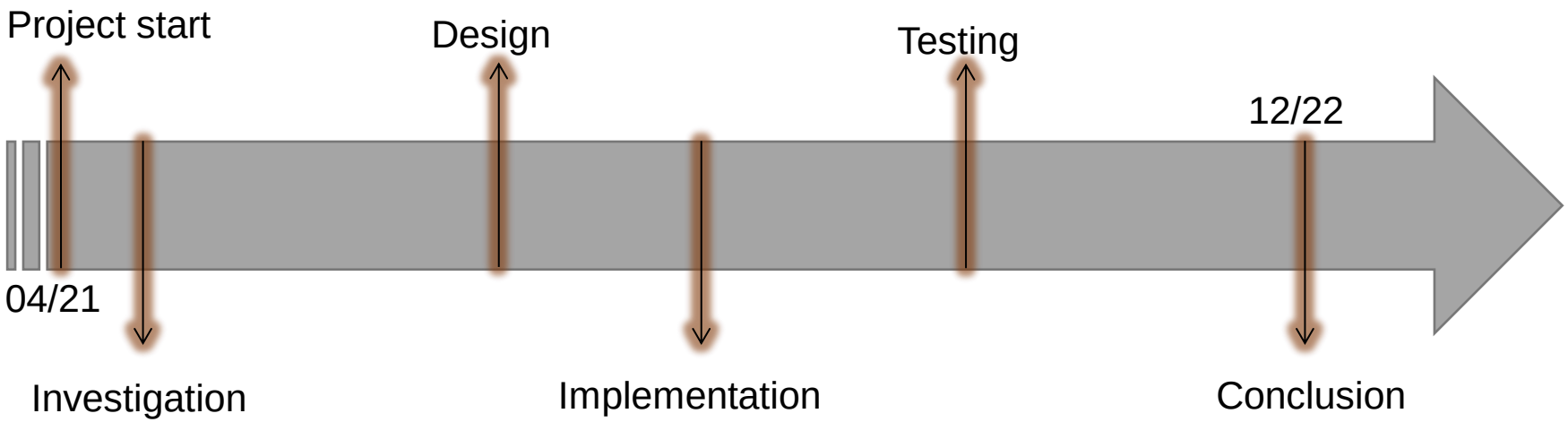


Timeline

- Gantt
- Binnacle
- Final project seminar



Specification of requirements

- **RF01:** Receive RF signal sent by different aircraft.
- **RF02:** Identify, decode and analyze messages in ADS-B
- **RF03:** Identify, decode and analyze messages in ACARS

- **RR01:** Signal to Noise Ratio greater than 15 dB
- **RR02:** Reception range greater than 100km

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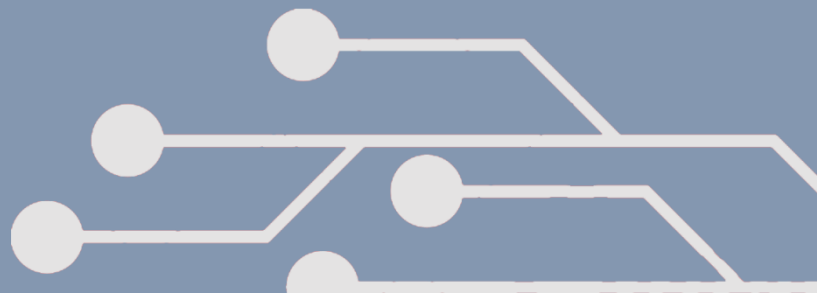
PROTOCOLS



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ADS-B

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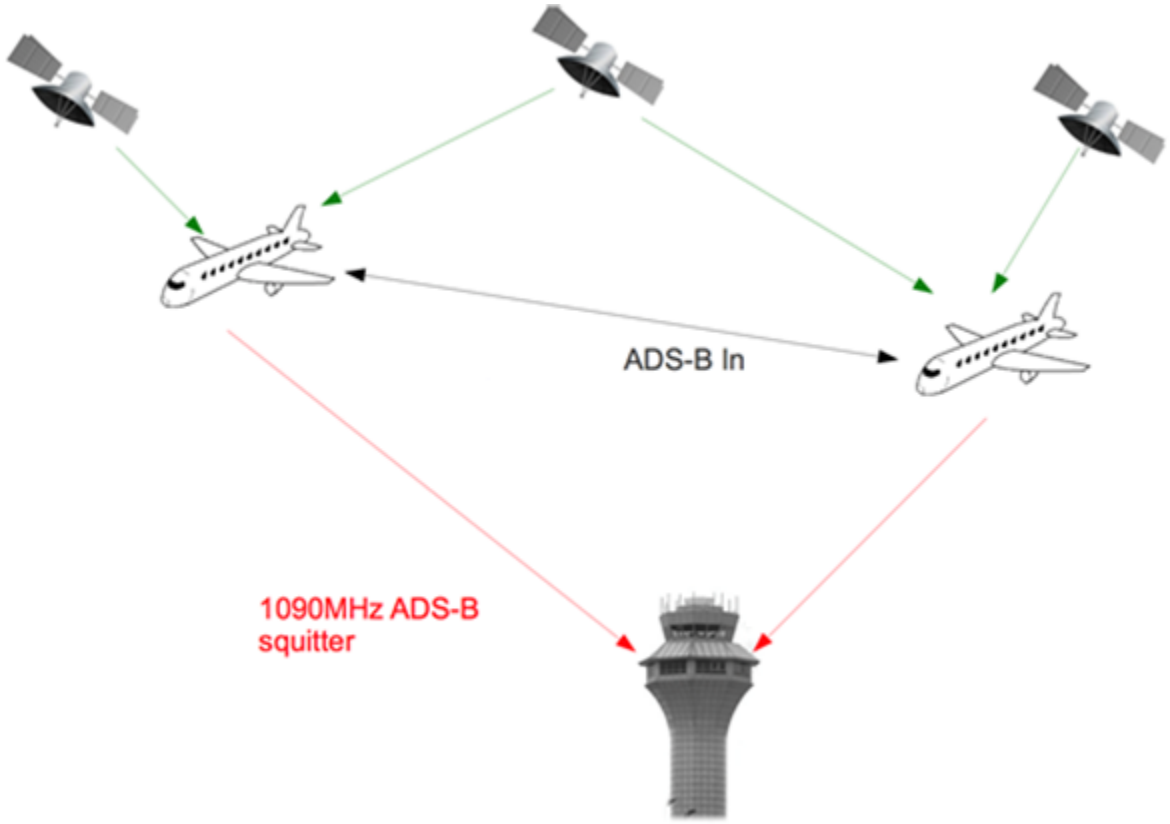
Automatic Dependent Surveillance Broadcast

- By its acronyms:
  - Automatic: transmits information without pilot or c intervention
  - Dependent: extracts data from the GPS system (and height)
  - Surveillance: allows monitoring aircraft position
  - Broadcast: it is freely issued to all users with ade equipment
- Air-to-ground or air-to-air type message



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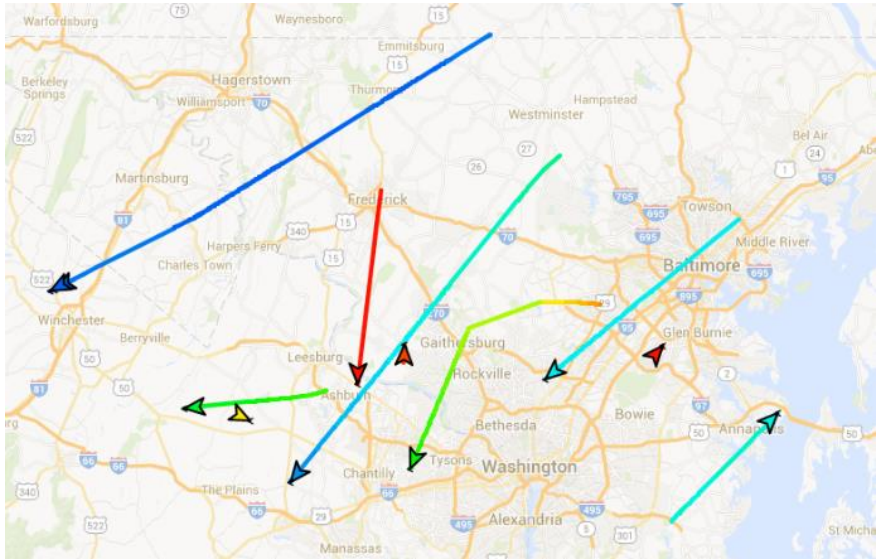
Technical characteristics

- Depending on the type of message:
  - address
  - position
  - speed
  - altitude
  - flight number
  - aircraft identification (ICAO)

Parameter	Value
Reception frequency	1090 MHz
Bandwidth	≈2 MHz
Modulation	PPM
Data transmission rate	1 Mbit/s



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ACARS

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ACARS

- Air data communication infrastructure between an aircraft and a ground station
- Used as a radio surveillance and communication system used by commercial airlines
  - Enables:
    - automatic control of the state of the aircraft
    - sent telemetry to the maintenance center
    - routing of operational and logistic communications

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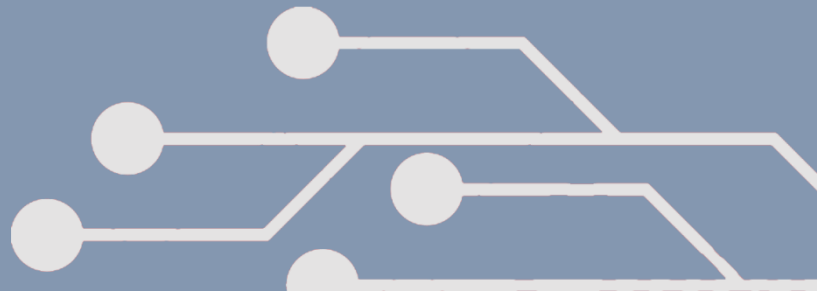
PROJECT – **ACARS**

Technical characteristics

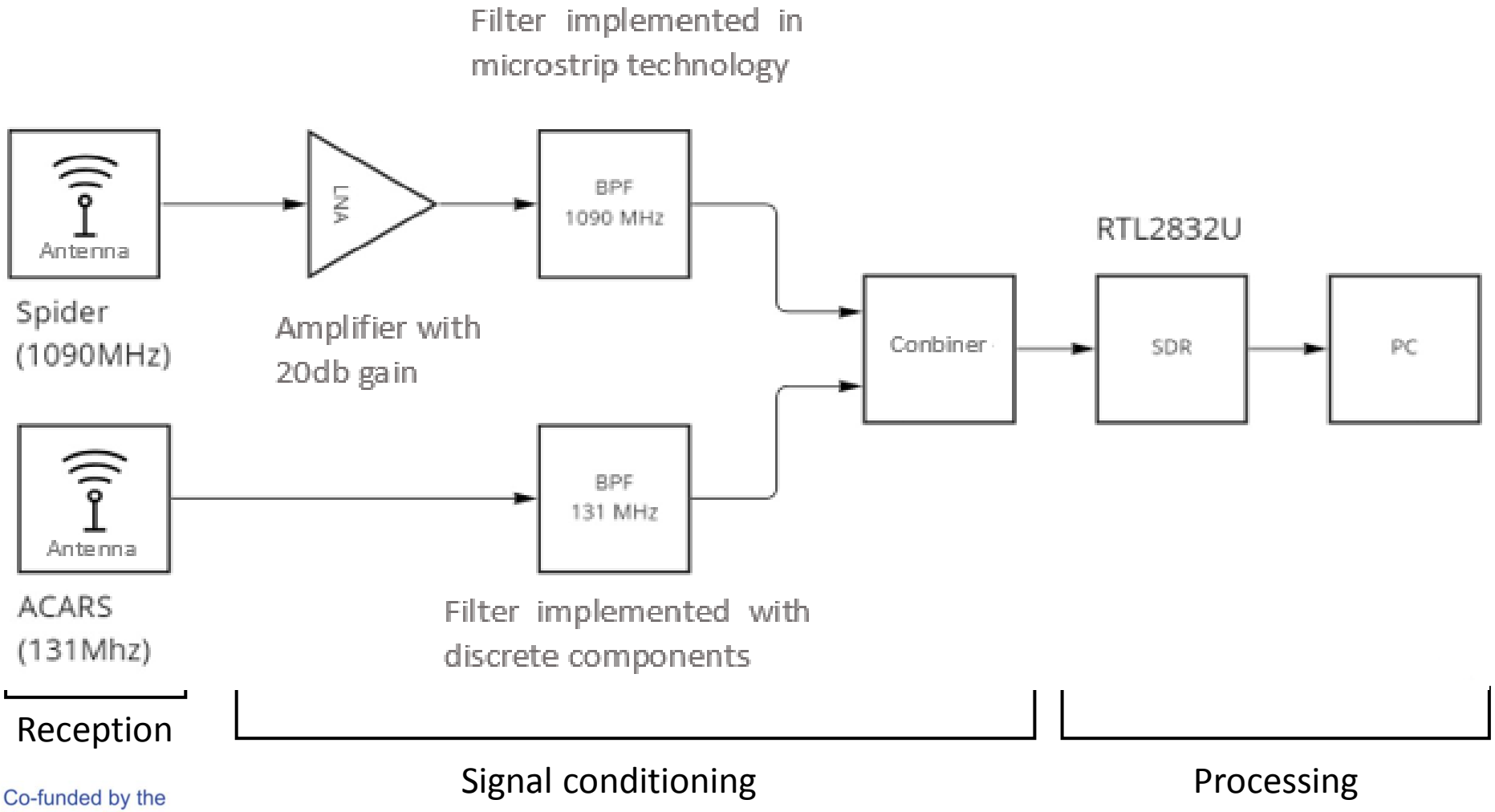
- Two types of message:
  - “Uplink”: from the base station on the ground to the aircraft
  - “Donwlink”: from the aircraft to the base station on the ground
- Two types of uses:
  - “ATC”: communicate the aircraft and the control tower (eg: takeoff request)
  - "AOC": communicate aircraft and control center (eg: maintenance bases)

Parameter	Value
Reception frequency	131,725 MHz (in Argentina)
Bandwidth	≈ 5 kHz
Modulation	MSK-AM
Data transmition rate	2400 bit/s

PROJECT



Solution design



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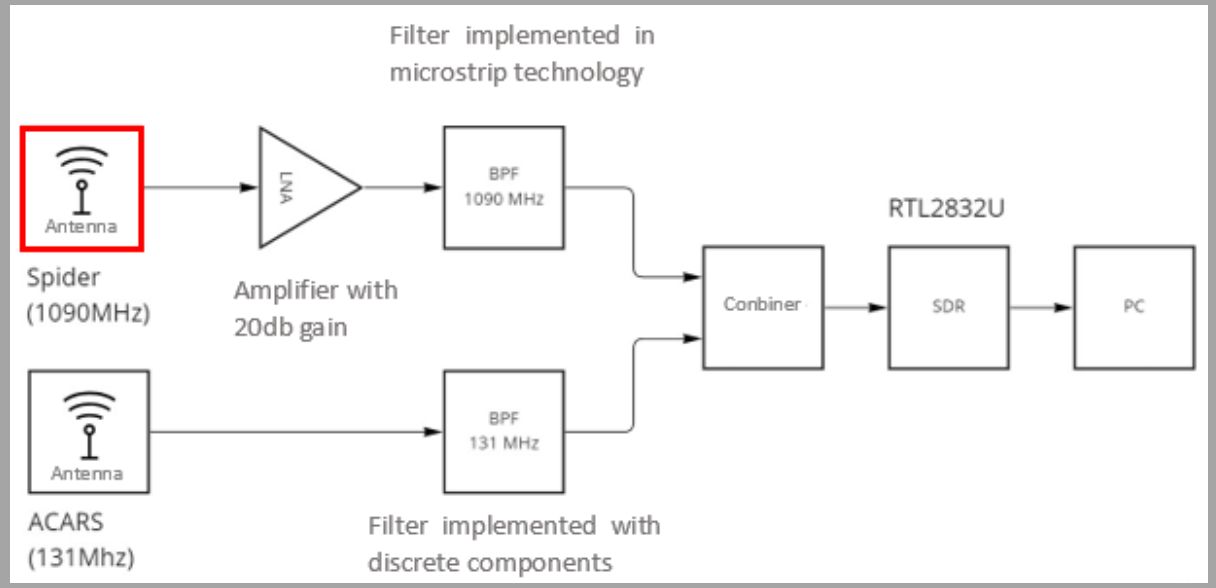
ADS-B antenna



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Design of an antenna tuned to 1090 MHz

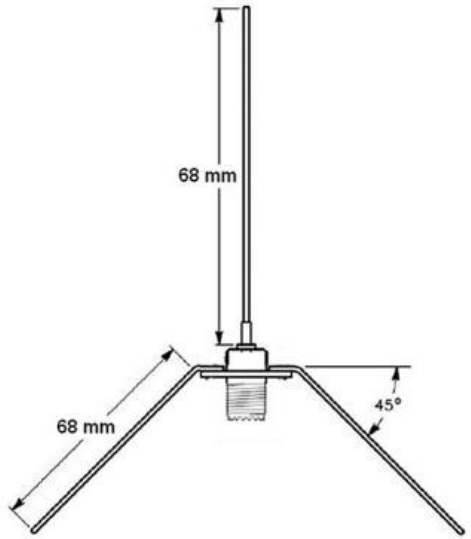
- **Proposal:** second design of an omnidirectional "λ/4" antenna with 8 elements and 1 center conductor
- SO-239 connector and central conductor of 50 Ohm RG8 coaxial cable.

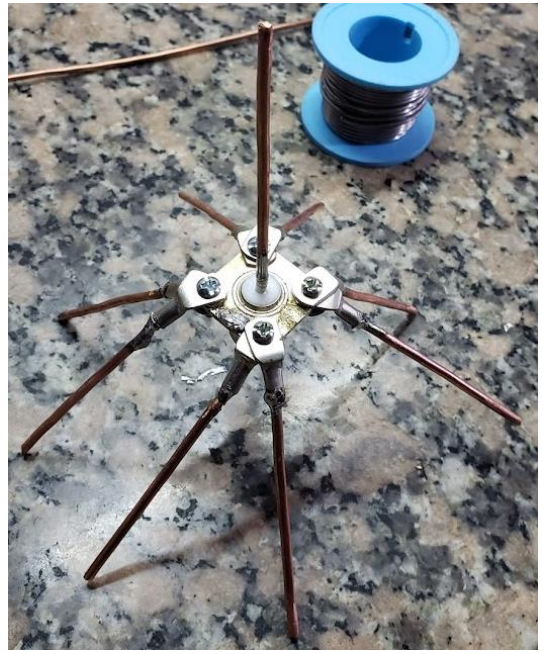
$$\text{Wavelength} = \frac{Speed\ of\ light}{Frequency}$$

$$\text{Wavelength} = \frac{299792000 m/s}{1090000000 Hz}$$

$$\text{Wavelength} = 0{,}275\text{m} = 275\ \text{mm}$$

$$\text{Quarter wavelength} = \frac{275mm}{4} = 68{,}75\text{mm}$$





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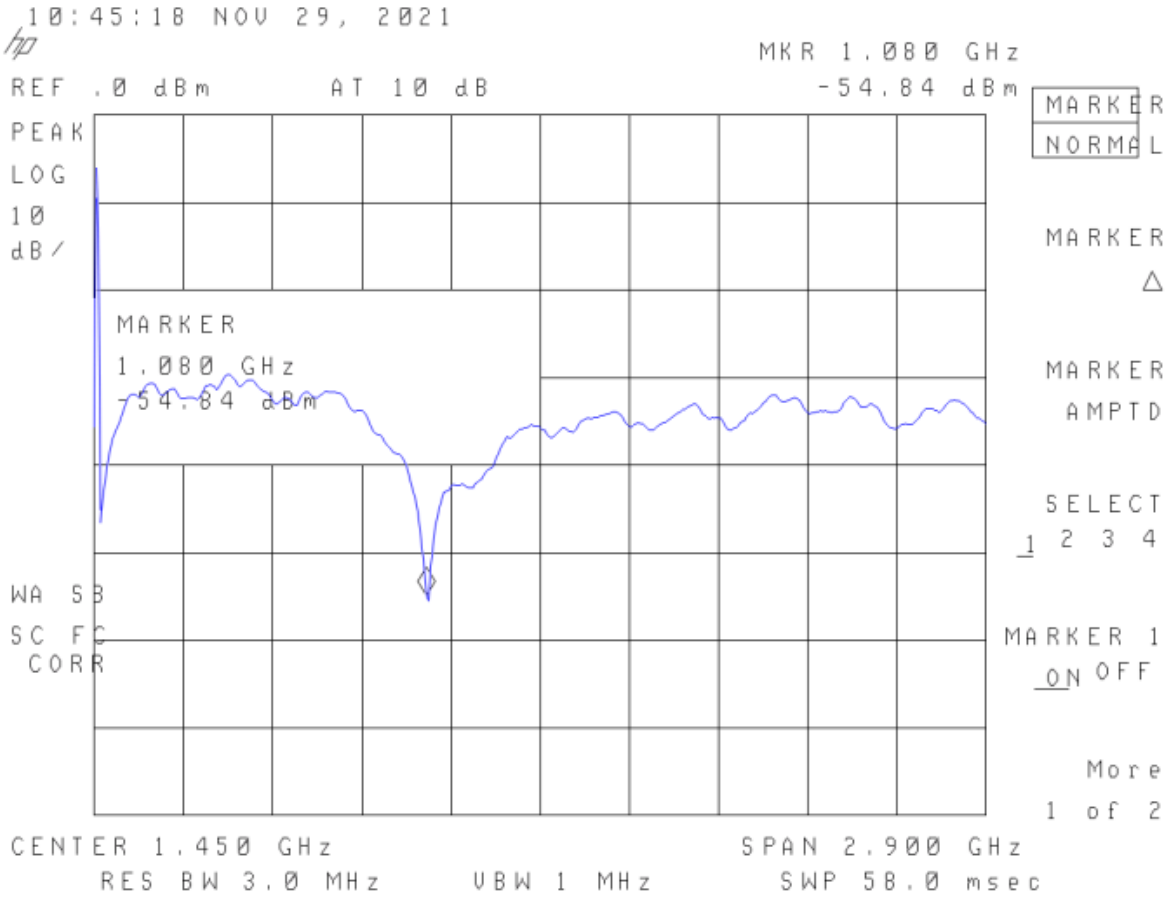
omnidireccional λ/4 antenna calibration

- **Objetive**: center the tuning frequency at 1090 MHz.
- The angle and length of the conductive elements have been modified.



HP 8594E Spectrum Analyzer Capture with HP 778D

Bidirectional Coupler

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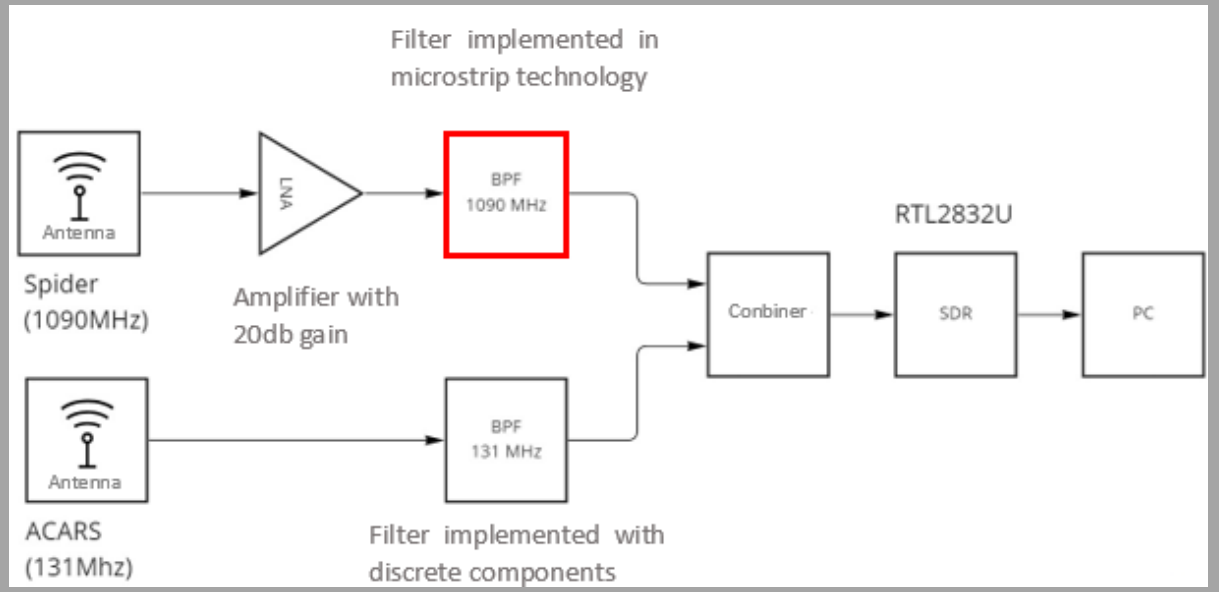
ADSB filter



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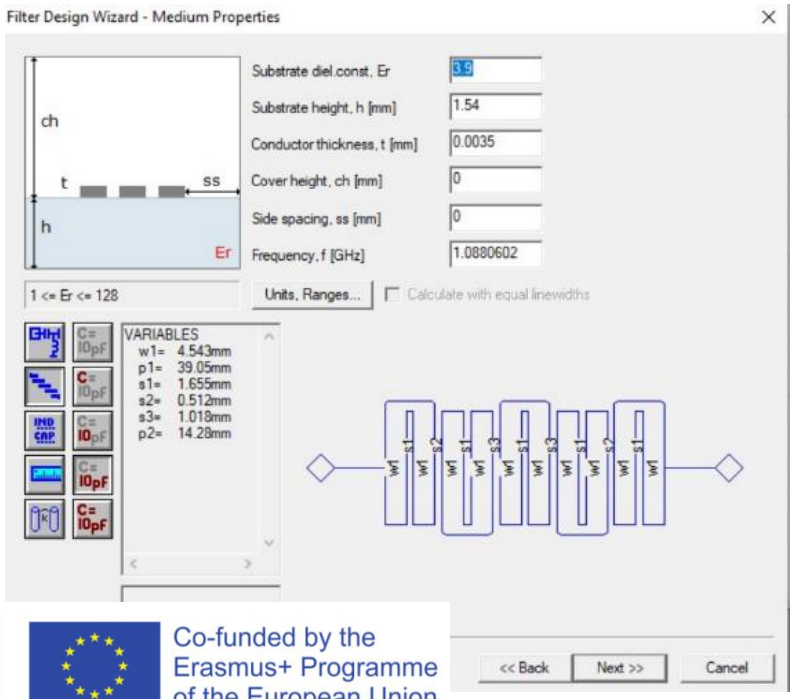
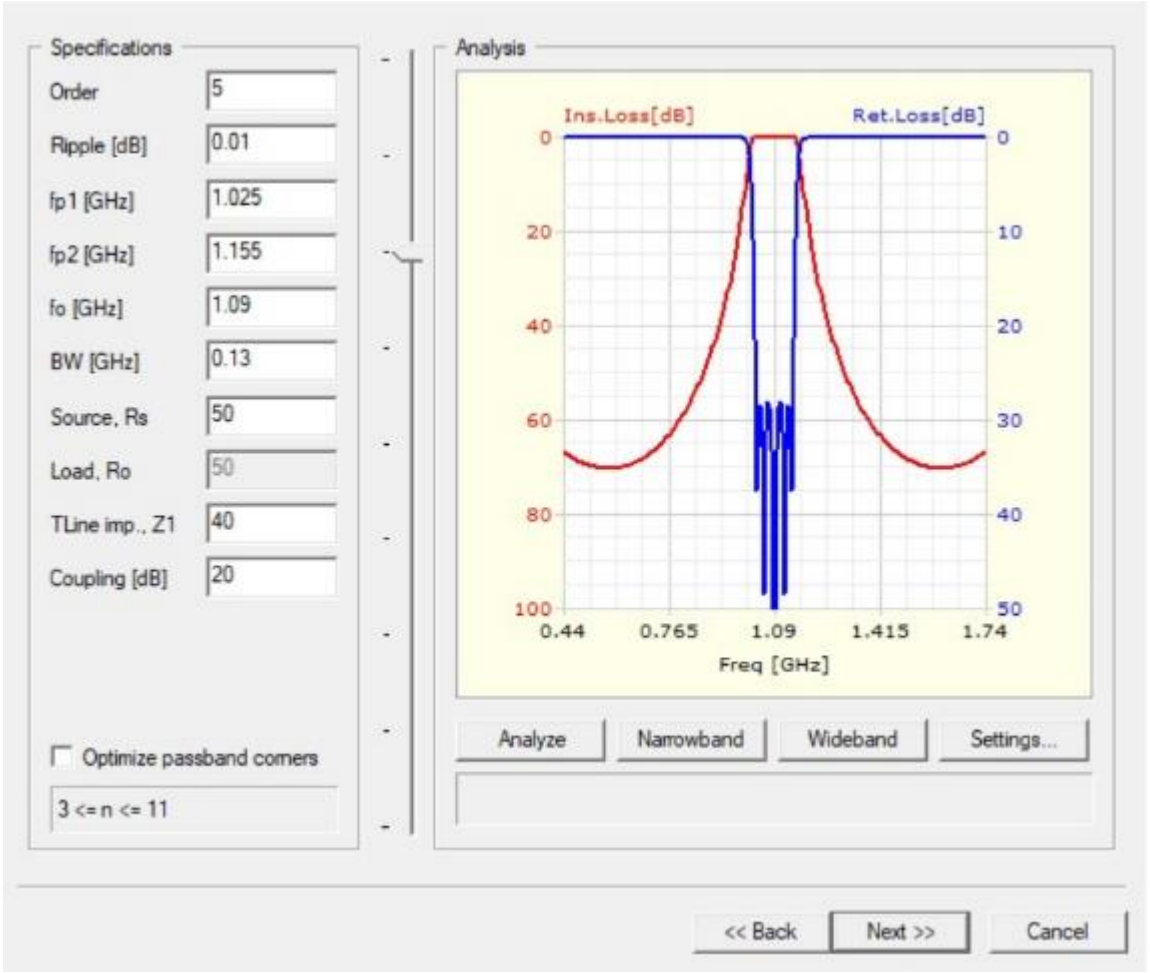
1090 MHz filter

- **Objetive**: to limit the ADS-B signal in band through the design and construction of a filter.
- **Solution:** Hairpin microstrip filter design of order 5.





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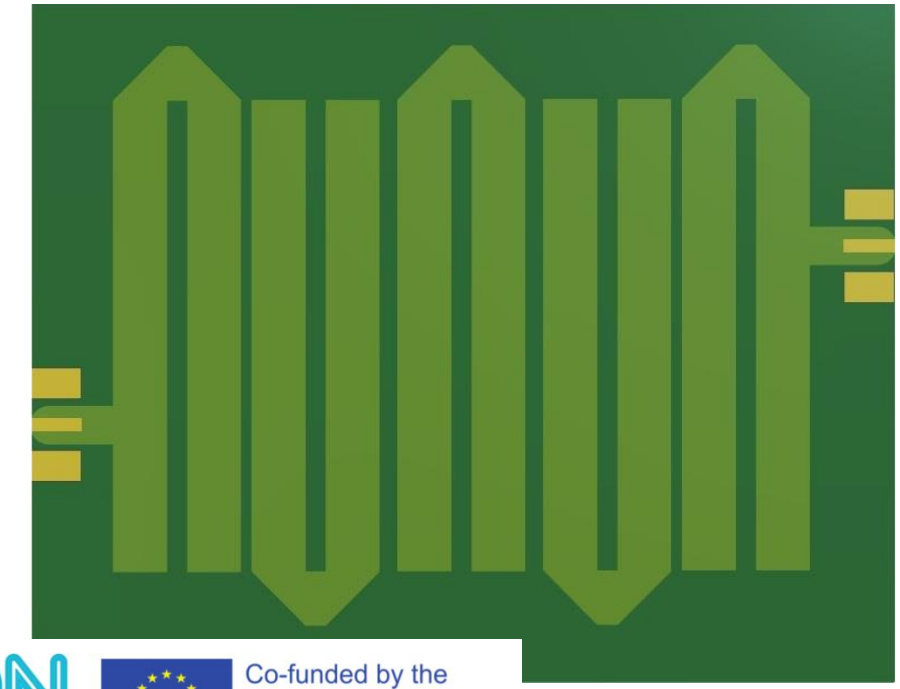
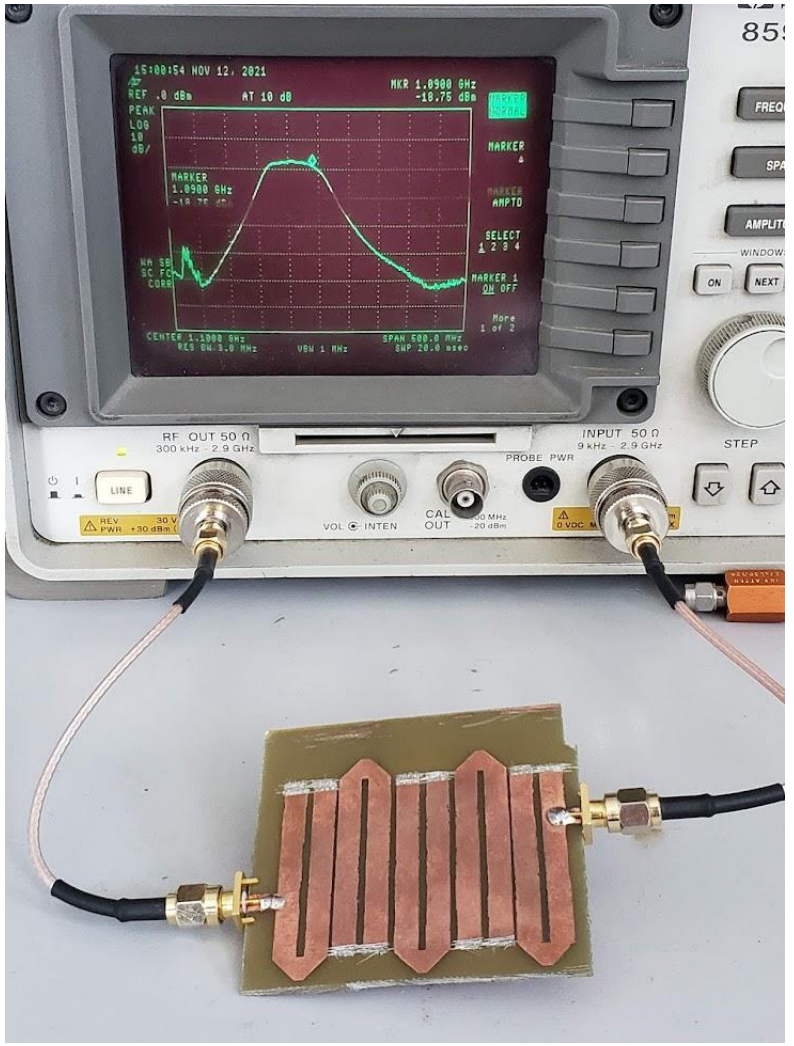
Microstrip filter

- Layout obtained after defining the parameters
- Filter construction and adjustment





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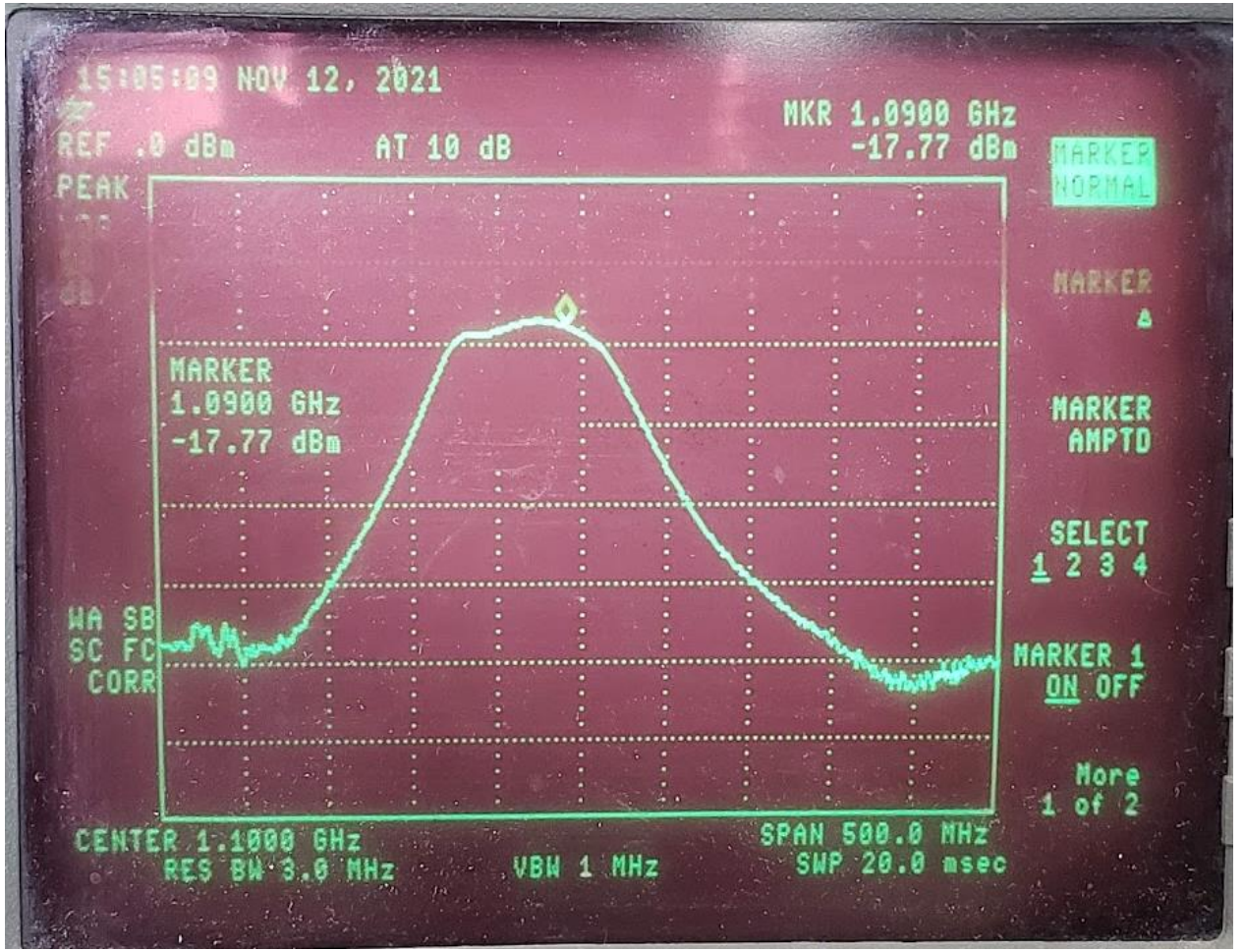
Microstrip filter

- Filter response after calibration.

- Passband attenuation, need to amplify the signal previously.



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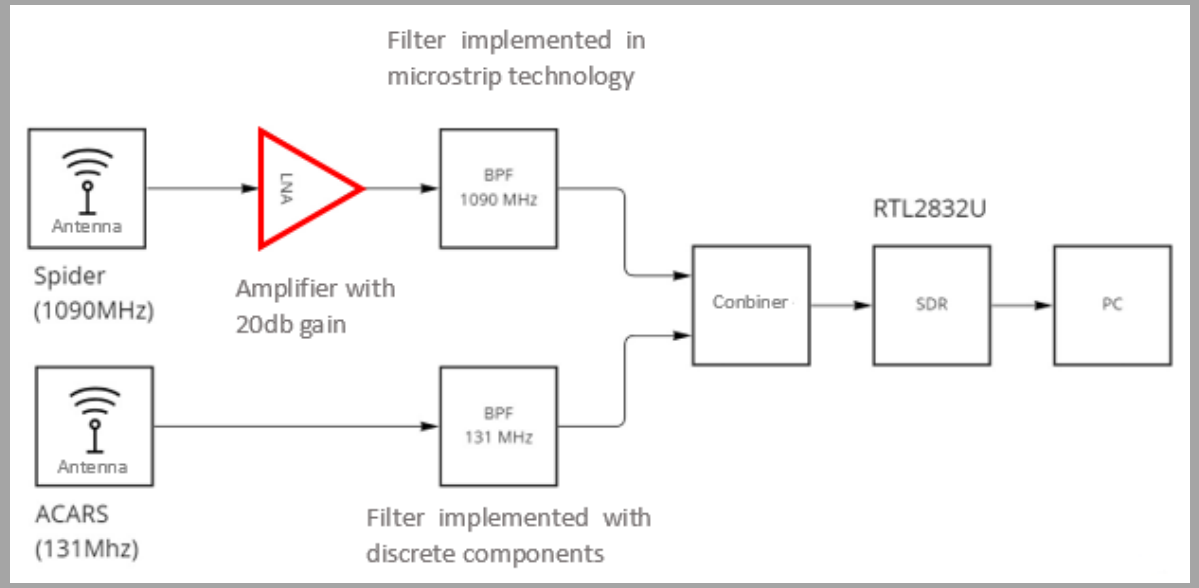
LNA



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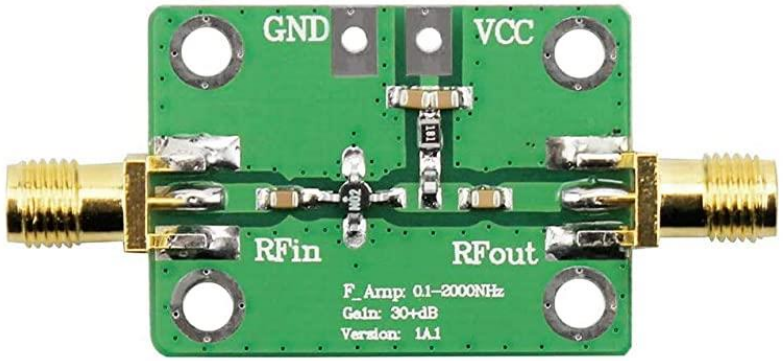
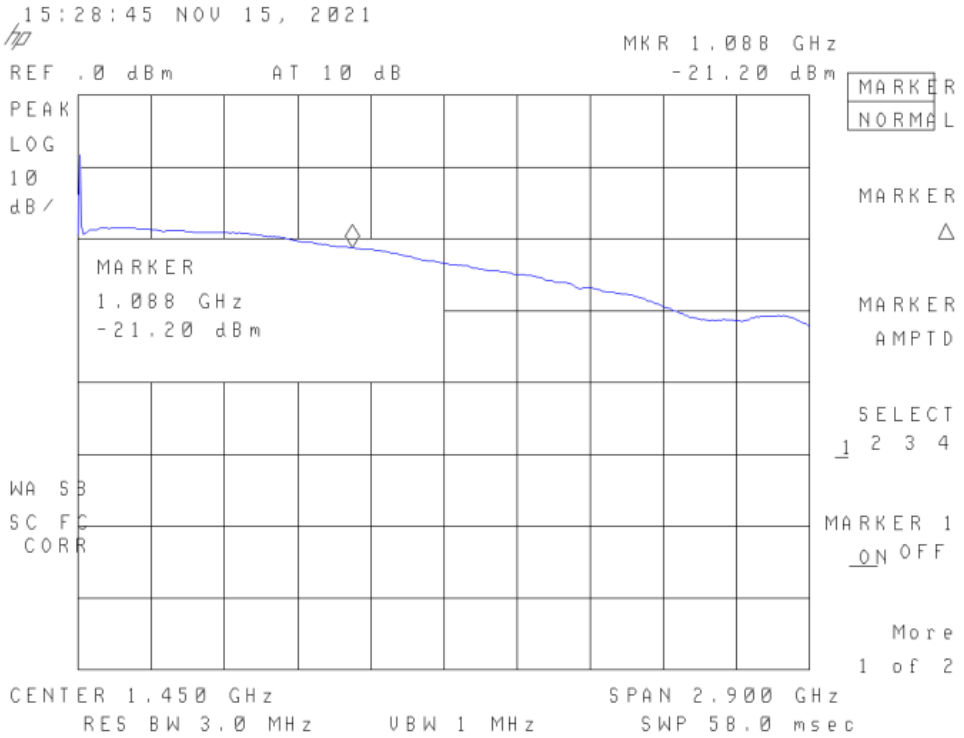
LNA: Low Noise Amplifier

- 18,8 dB of gain at 1090 MHz
- Low noise figure
- 9 V supply





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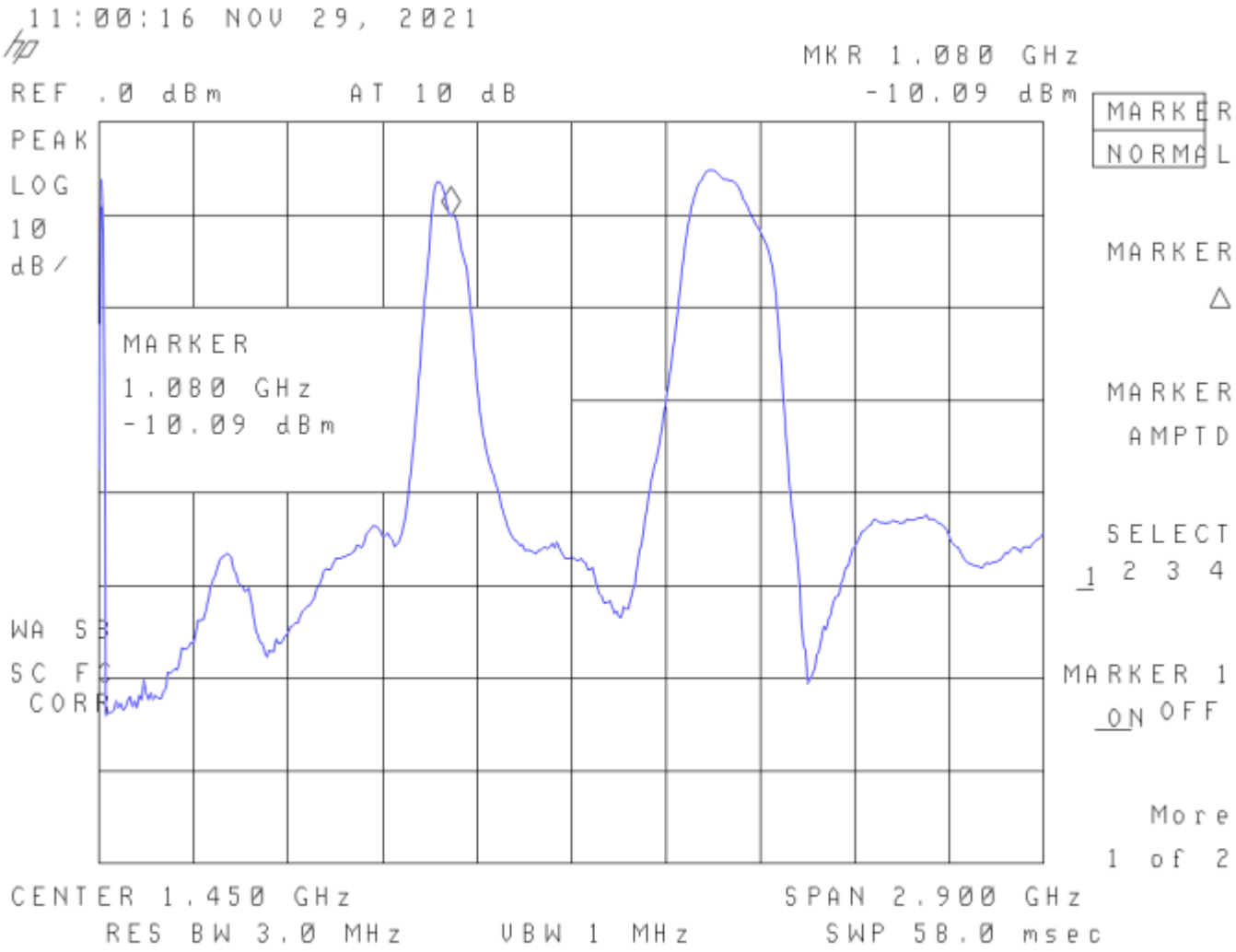
LNA + Microstrip filter

- Response after the inclusion of the pre-amplifier to the filtering stage
- Appearance of multiples of the fundamental frequency



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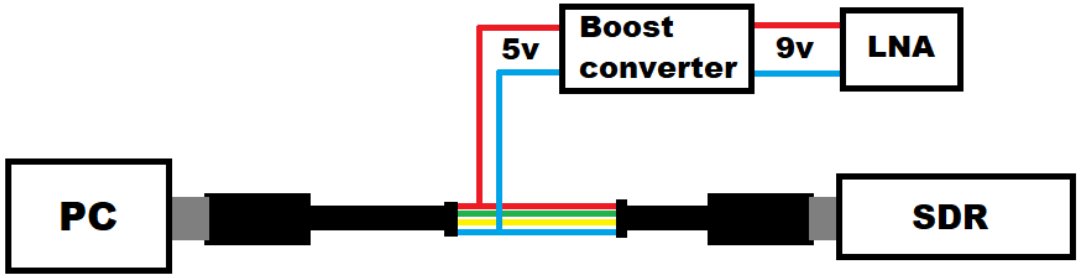
LNA: Low Noise Amplifier



- Copper shielding to prevent electromagnetic radiation from the amplifier from spreading through the rest of the system
- Power supply through a boost converter by derivation of the USB cable

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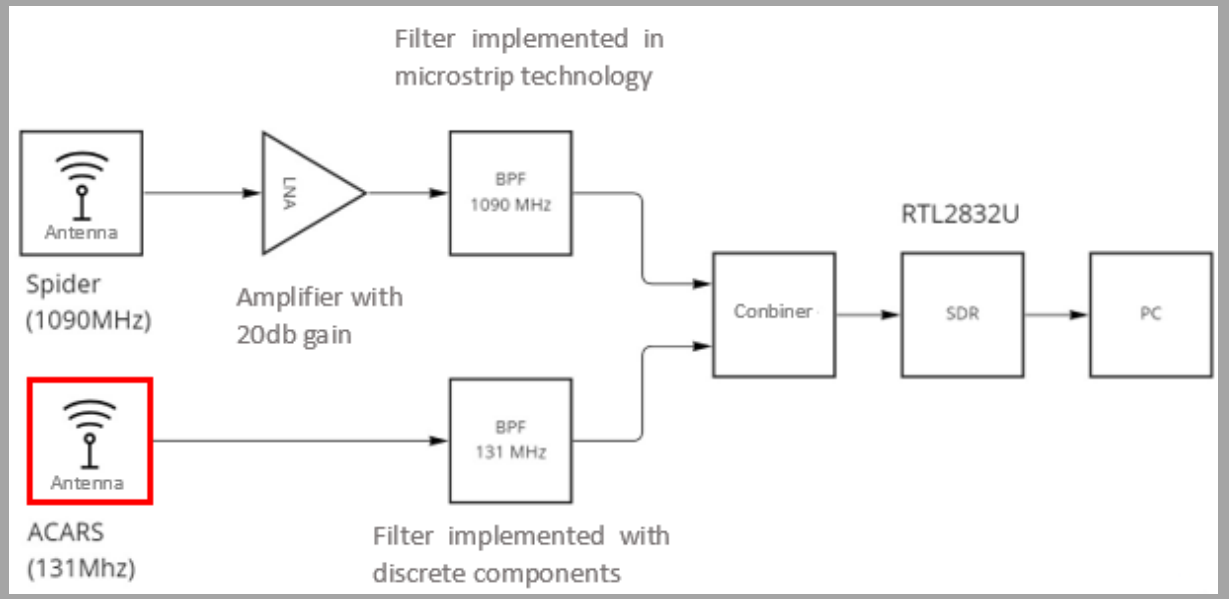
ACARS antenna



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Nagoya NA-771 commercial antenna

Parameter	Value
Frequency range	136-174 MHz / 400 – 520 MHz
Gain	2,15 dBi @ 144MHz
Impedance	50 Ohms
Length	38,15mm

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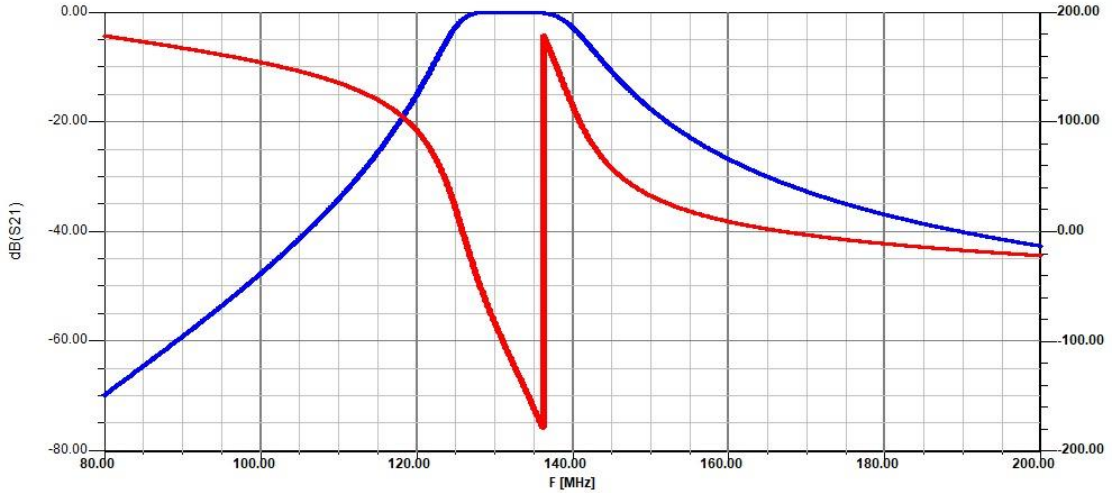
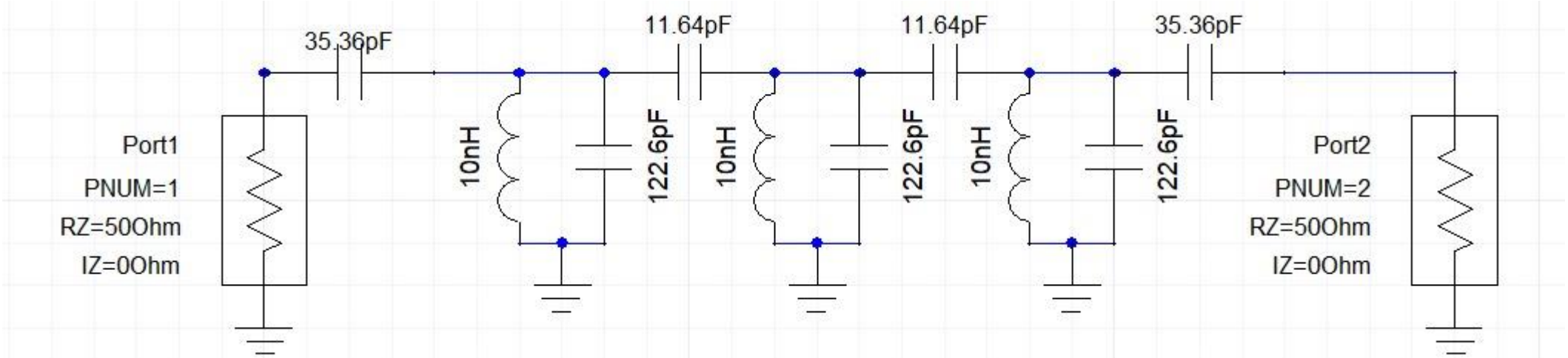
131 MHz LC filter

- LC filter with SMD components
- Focused on attenuating FM station frequencies (88 to 108 MHz)





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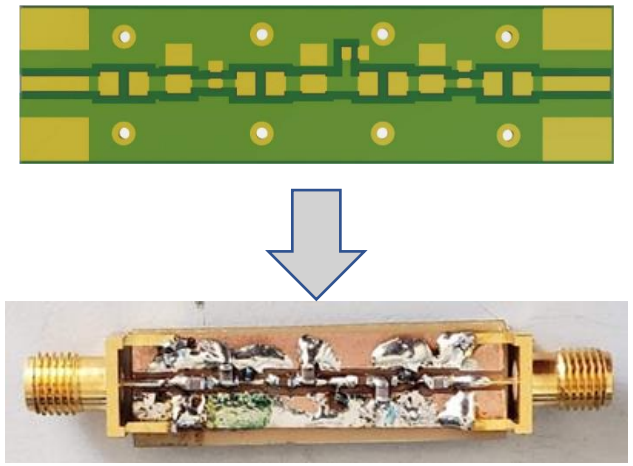
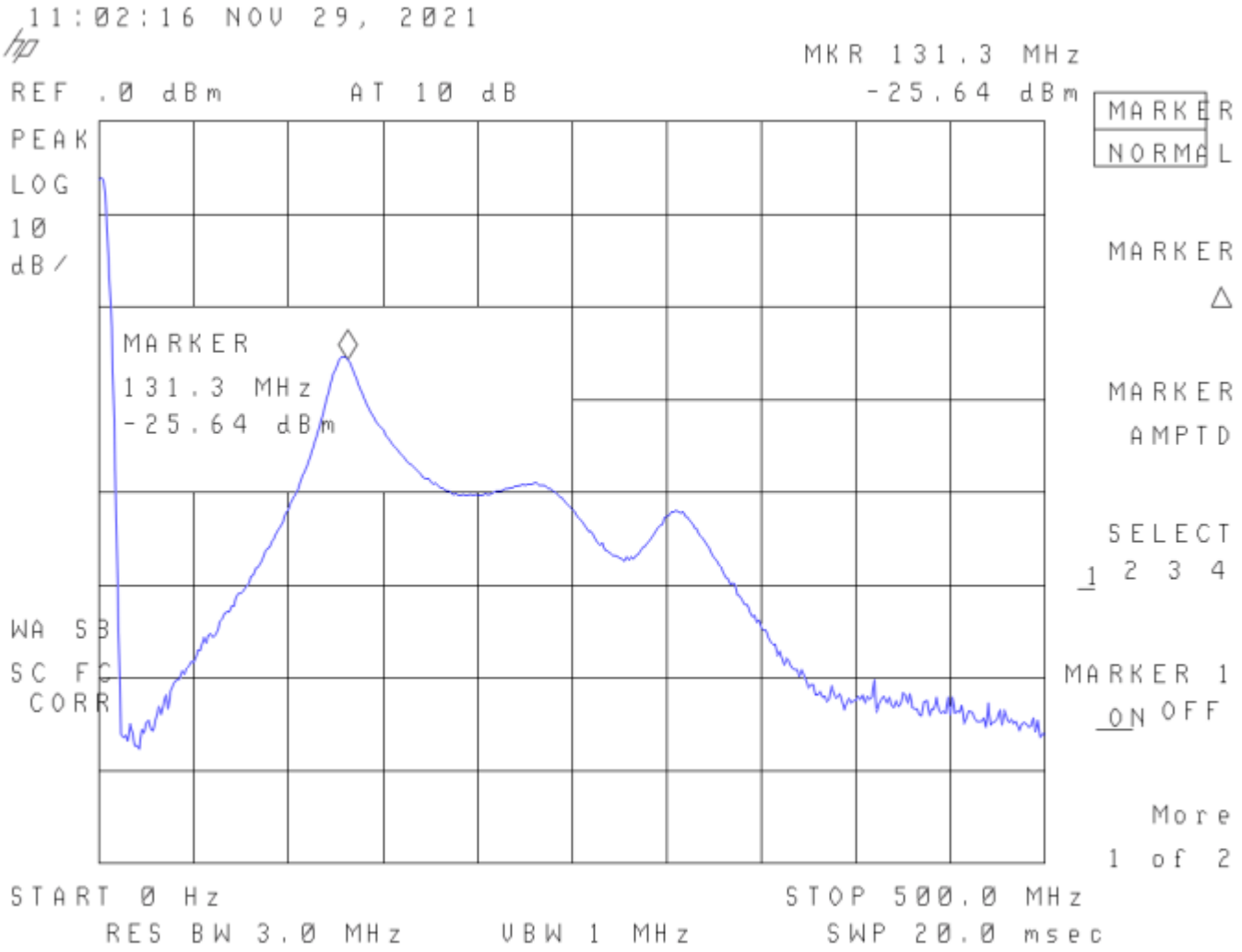
131 MHz LC filter

- Passband attenuation close to 5 dB (attenuator set to 20 dB)
- At 108 MHz (FM upper freq.) 20 dB rejection ar more than 60 dB at 88 MHz (AM lower freq.)





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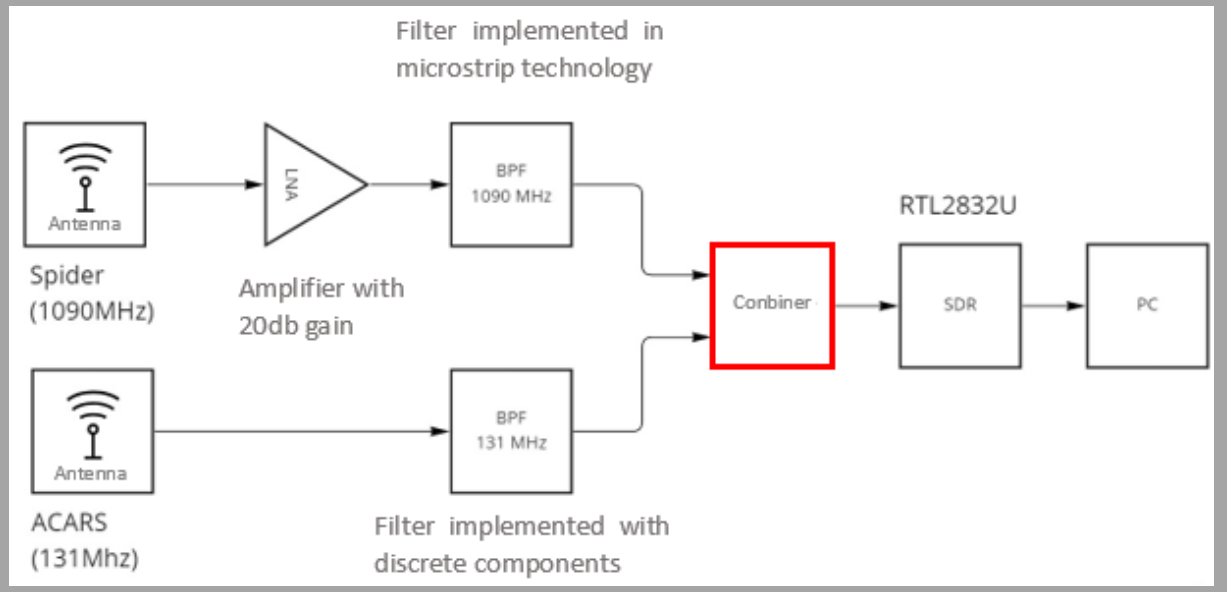
Combiner



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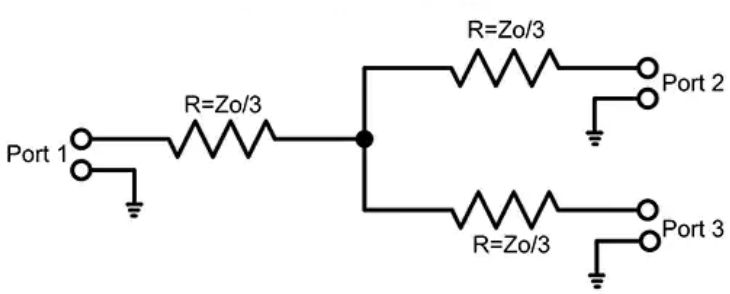
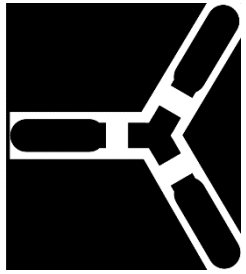
50 Ohms resistive combiner





- R = Zo/3= 16,66 Ohms
- 120° between channels

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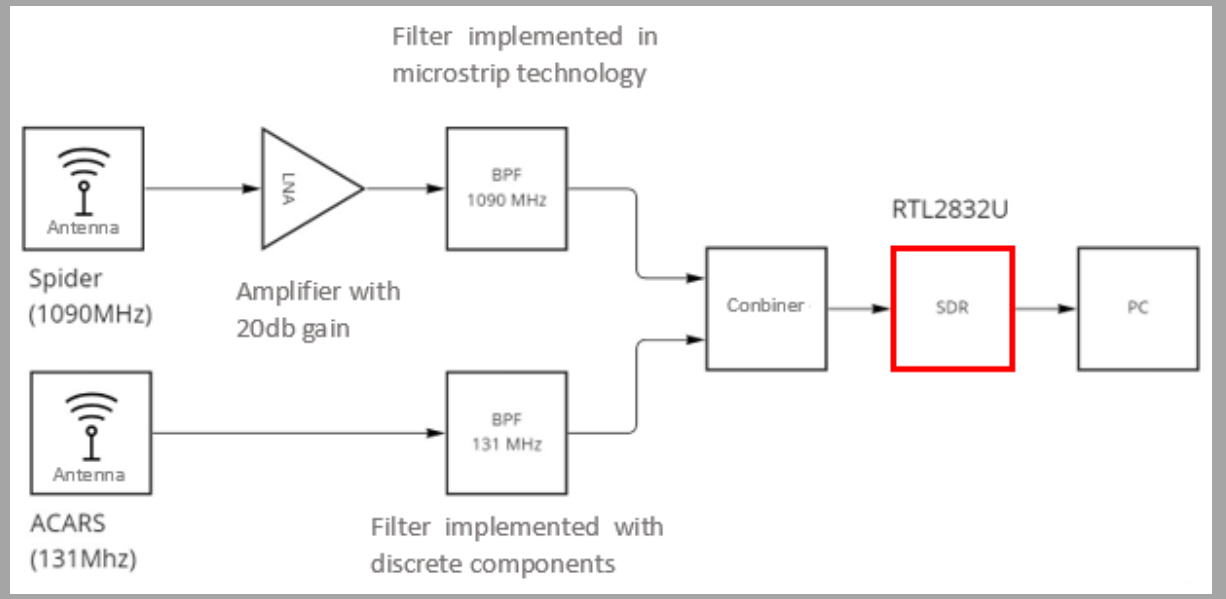
SDR



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RTL 2832U

- Wide software compatibility
- Optimal choice for the application
- Economic

Parameter	Value
Maximum simple rate	<2,56 MS/s
ADC	8 bits
Frequency range	24 MHz – 1766 MHz
Input impedance	50 Ohms
Typical current consumption	270 – 280 mA

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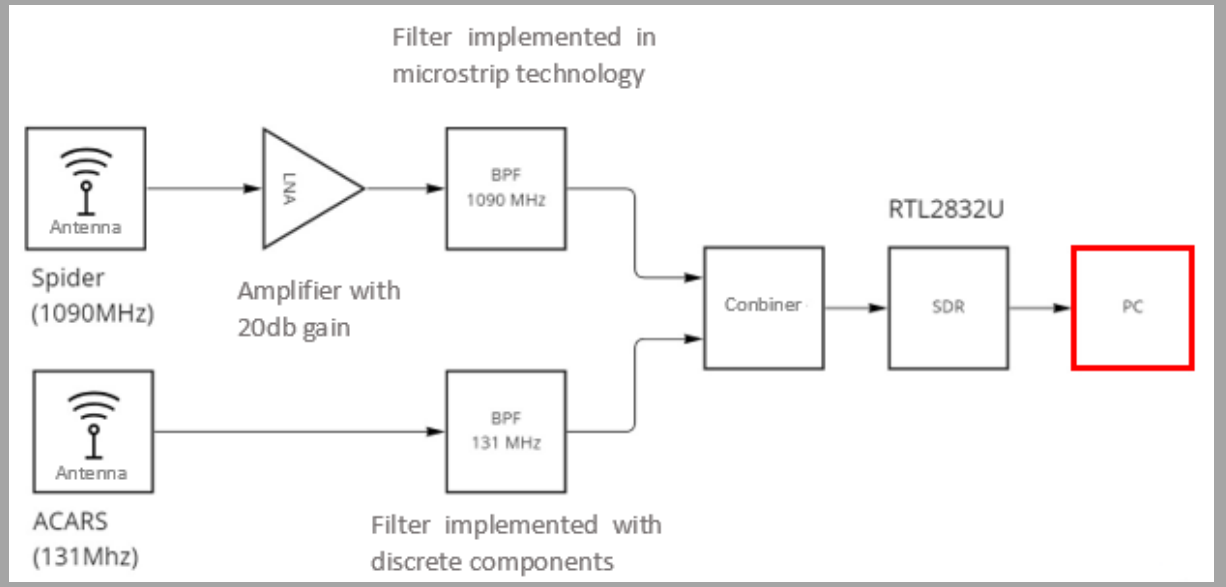
PC



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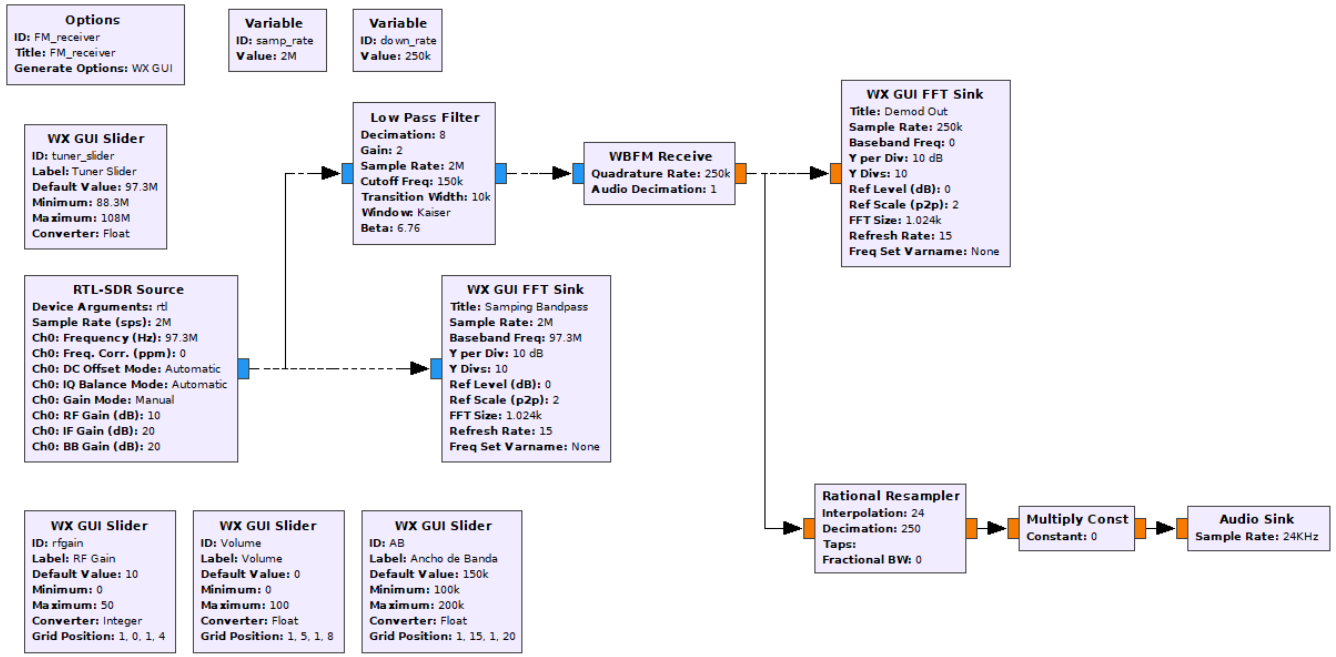
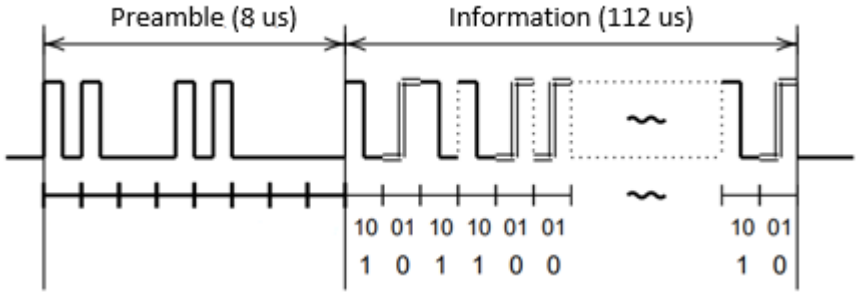
GNU Radio

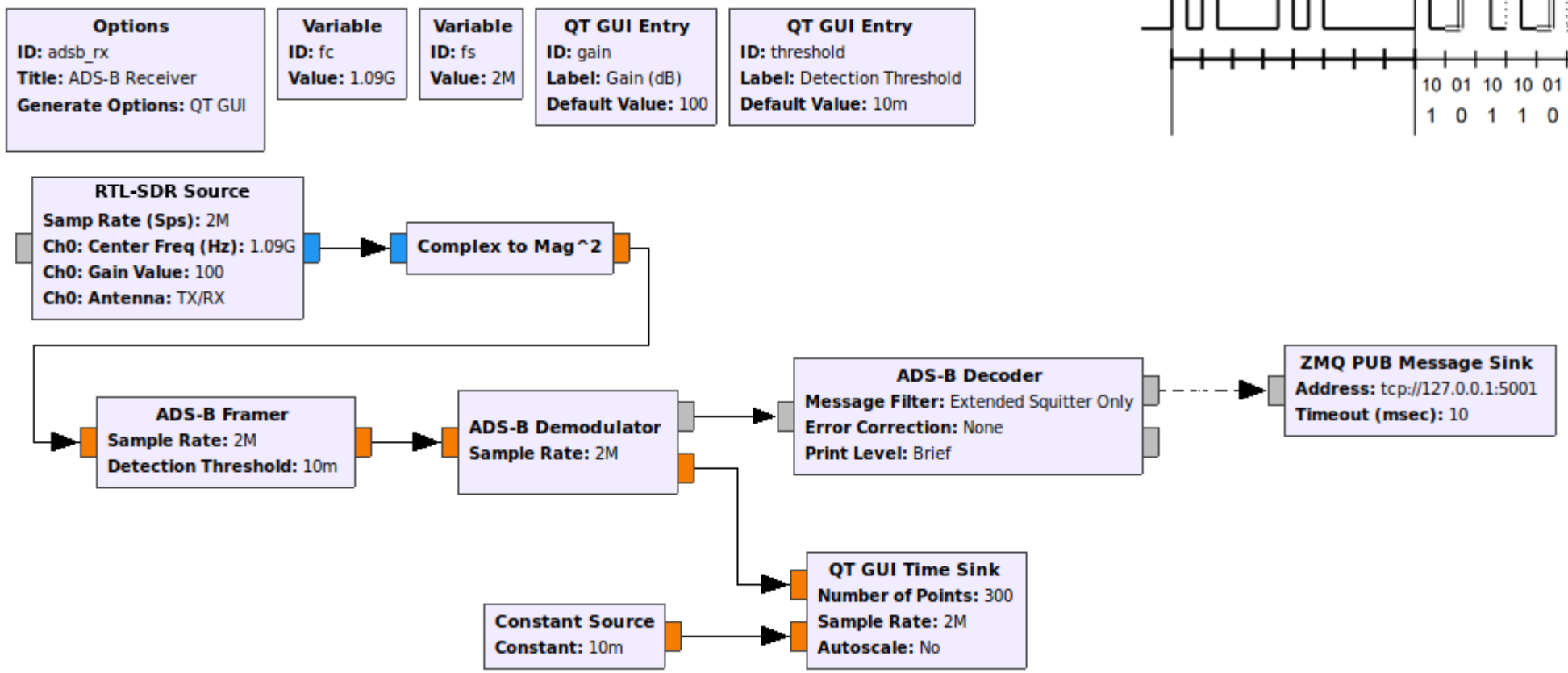
- Visual programming environment using blocks
- Provides processing for software-defined radio implementation
- Low cost SDR devices or simulation



GNU Radio
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

Processing in GNU Radio ADS-B





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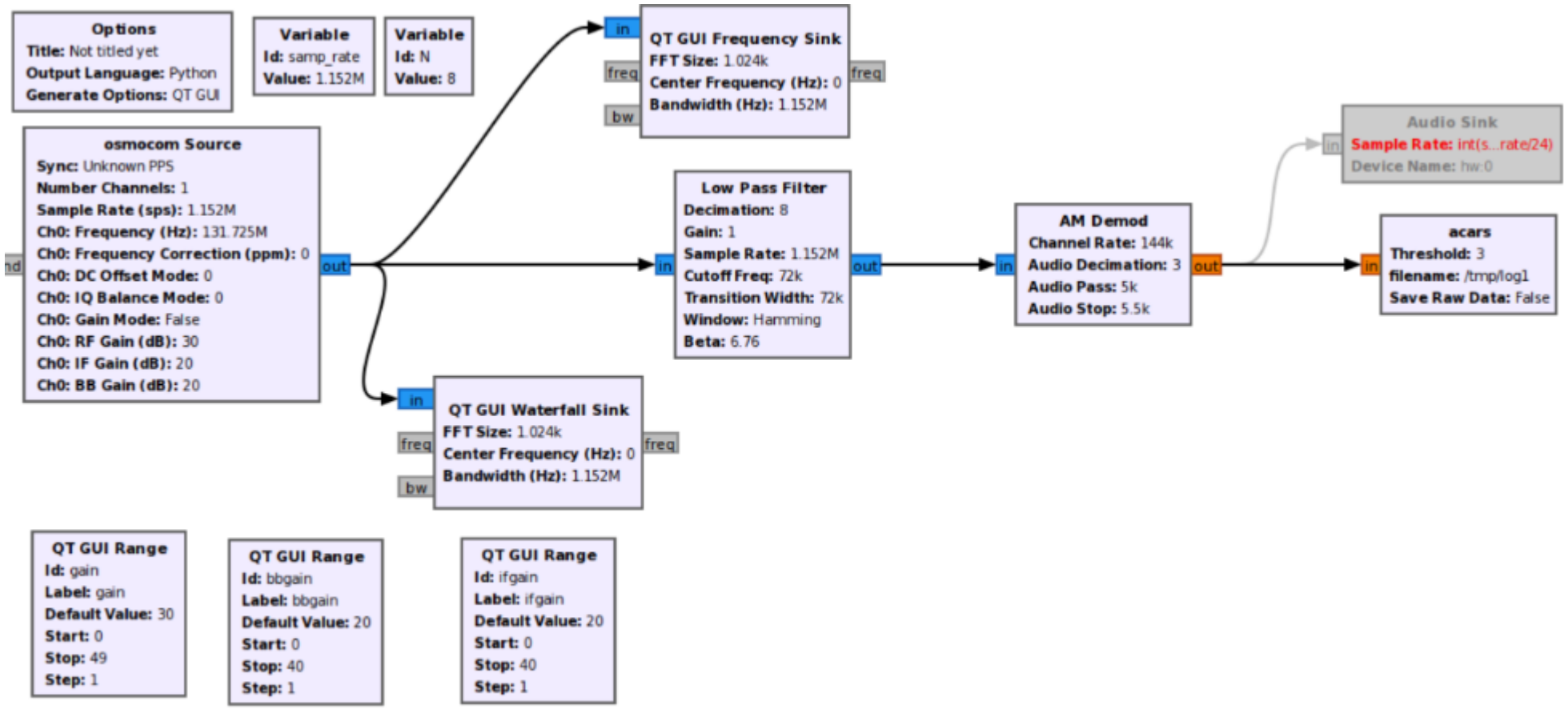
Processing in GNU Radio ACARS



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RESULTS

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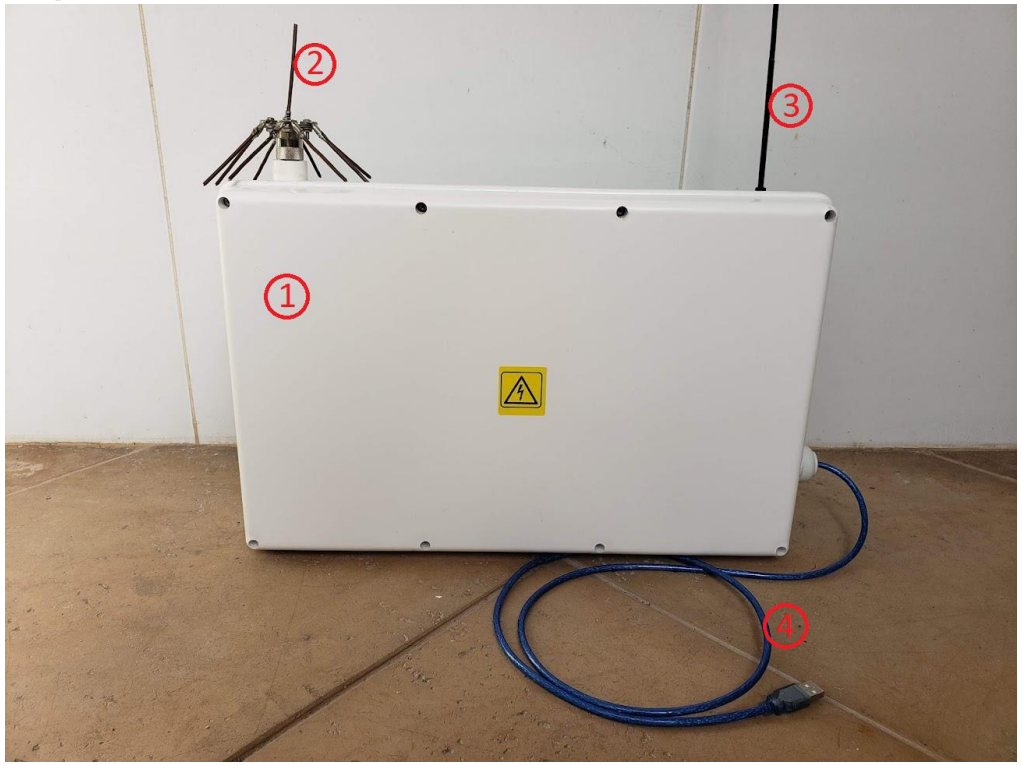
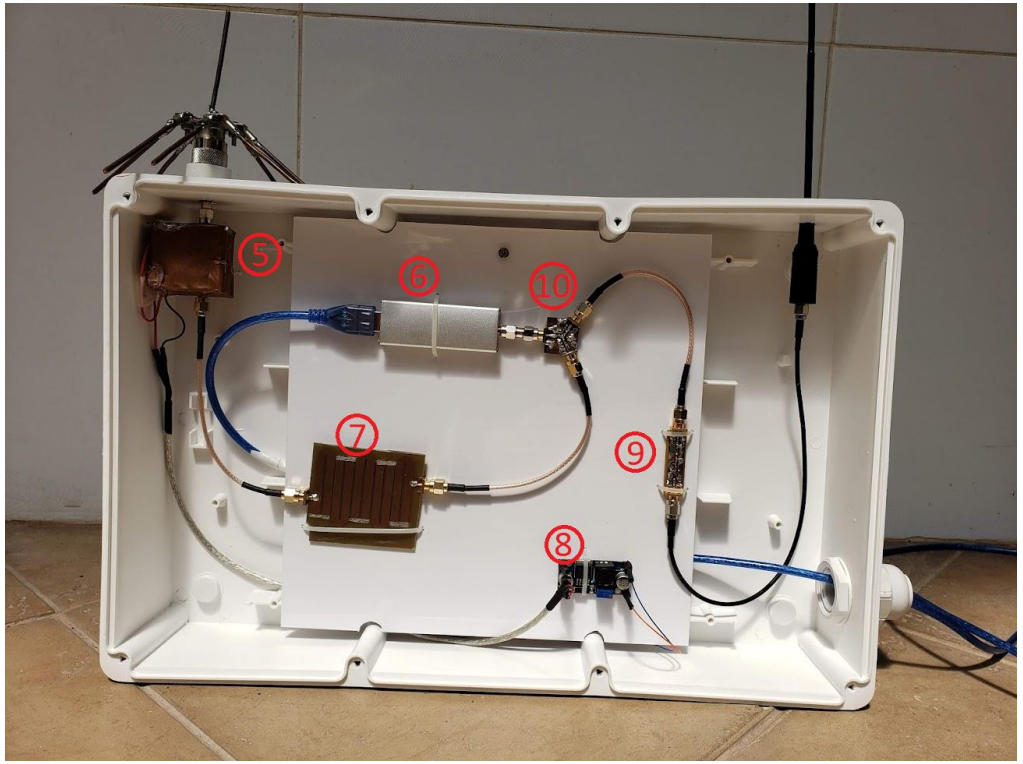
Final prototype



1. Waterproof box
2. ADS-B Antenna
3. ACARS Antenna
4. USB 2.0 cable



5. LNA
6. SDR RTL
7. ADS-B filter
8. Boost Converter
9. ACARS filter
10. Combiner

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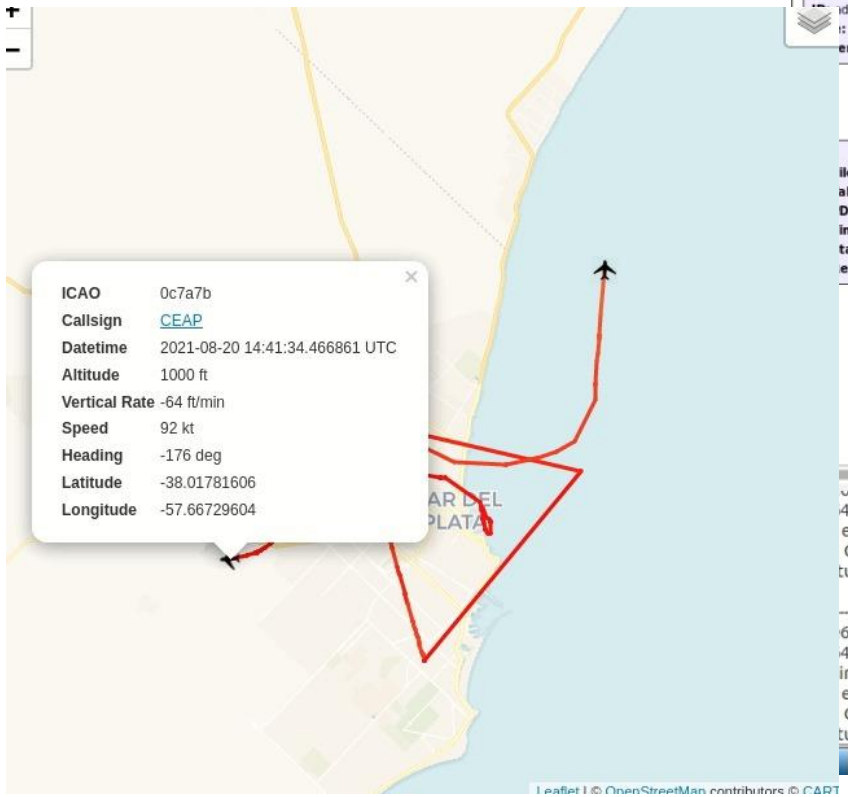
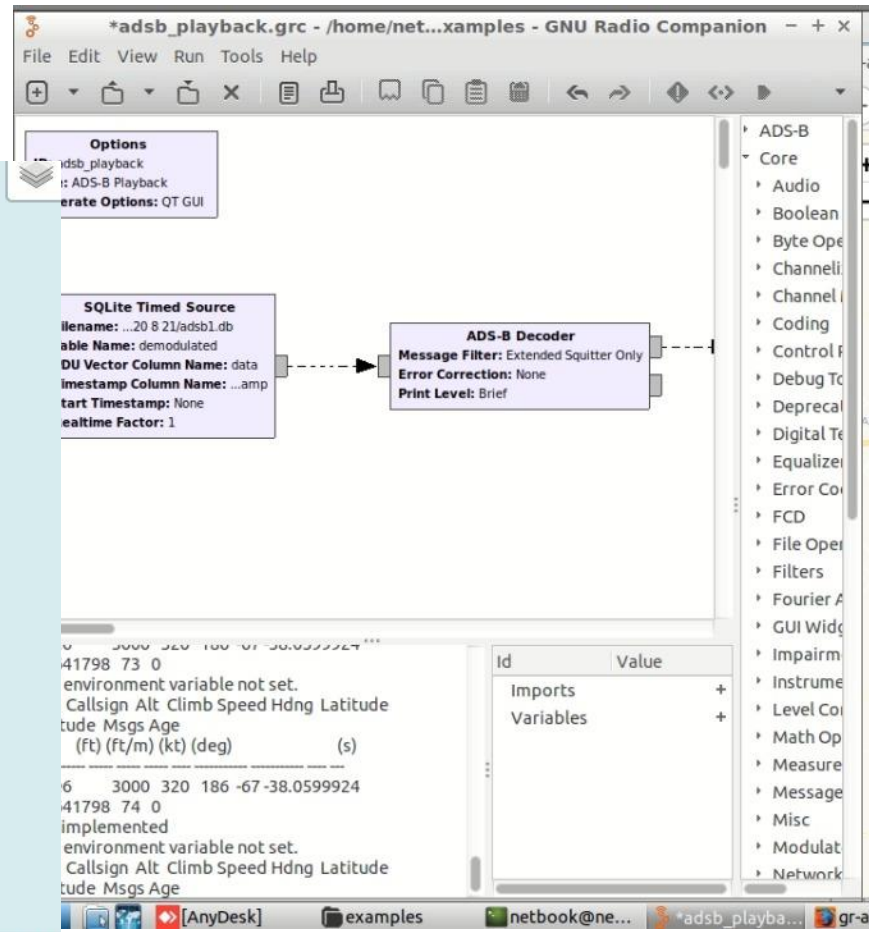
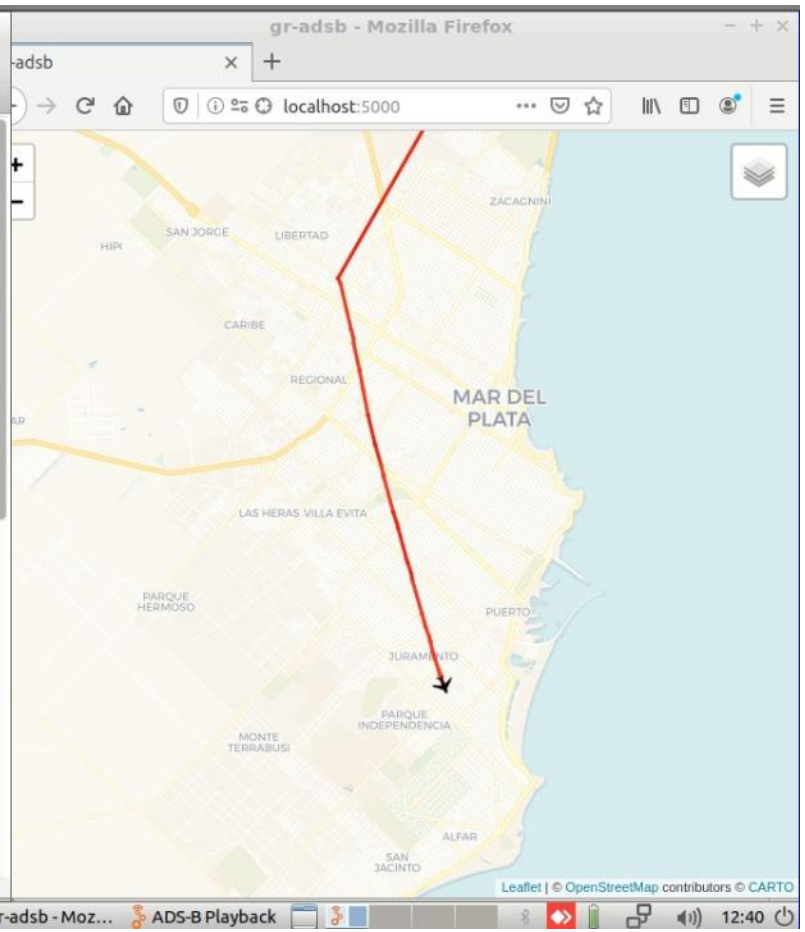
ADS-B

- GNU Radio + Web Server







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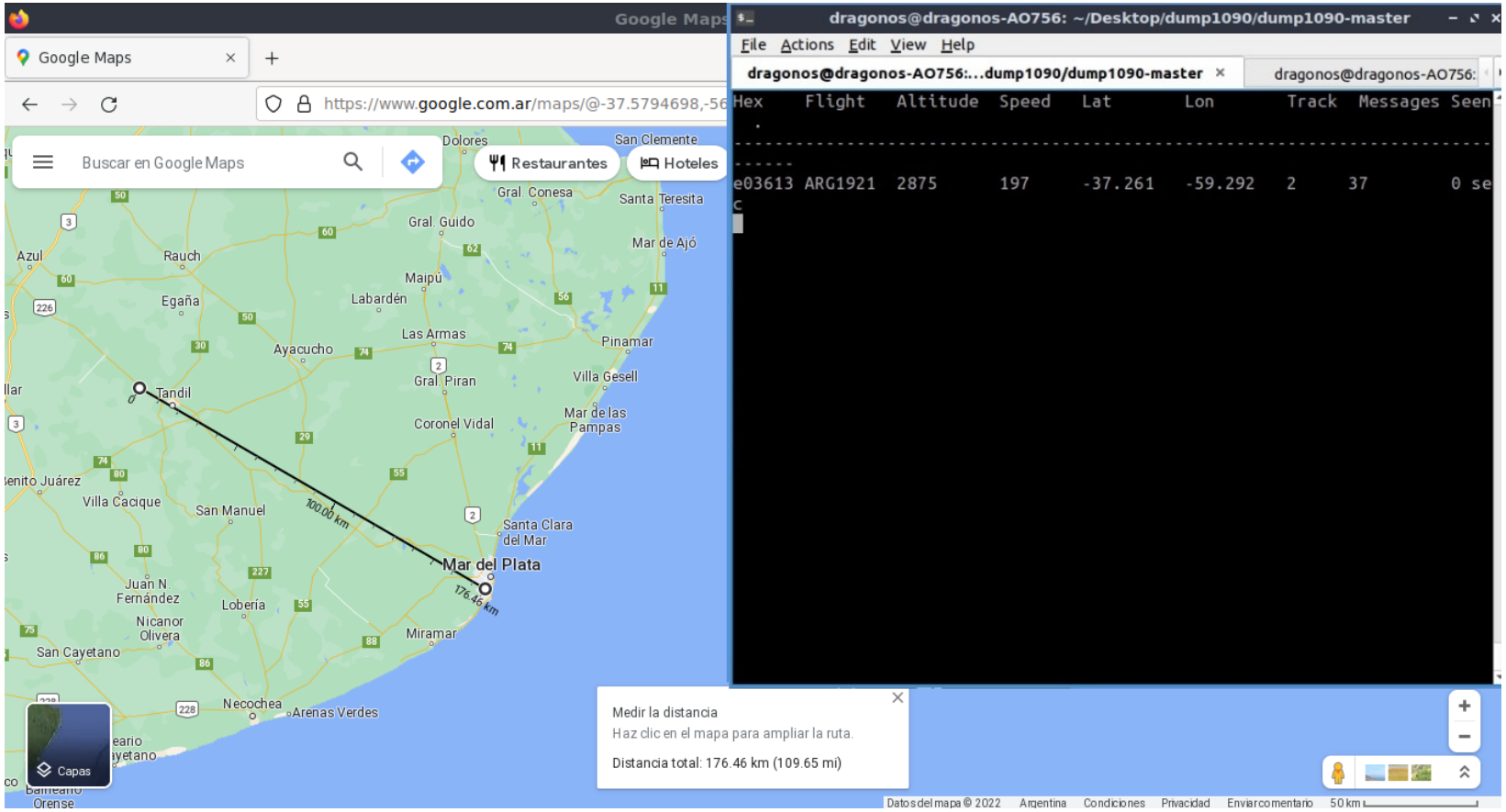
ADS-B

- AR1921 (FTE-AEP)
- Coordinates: S 37,261 W 59,292
- Reception range: 176 Km



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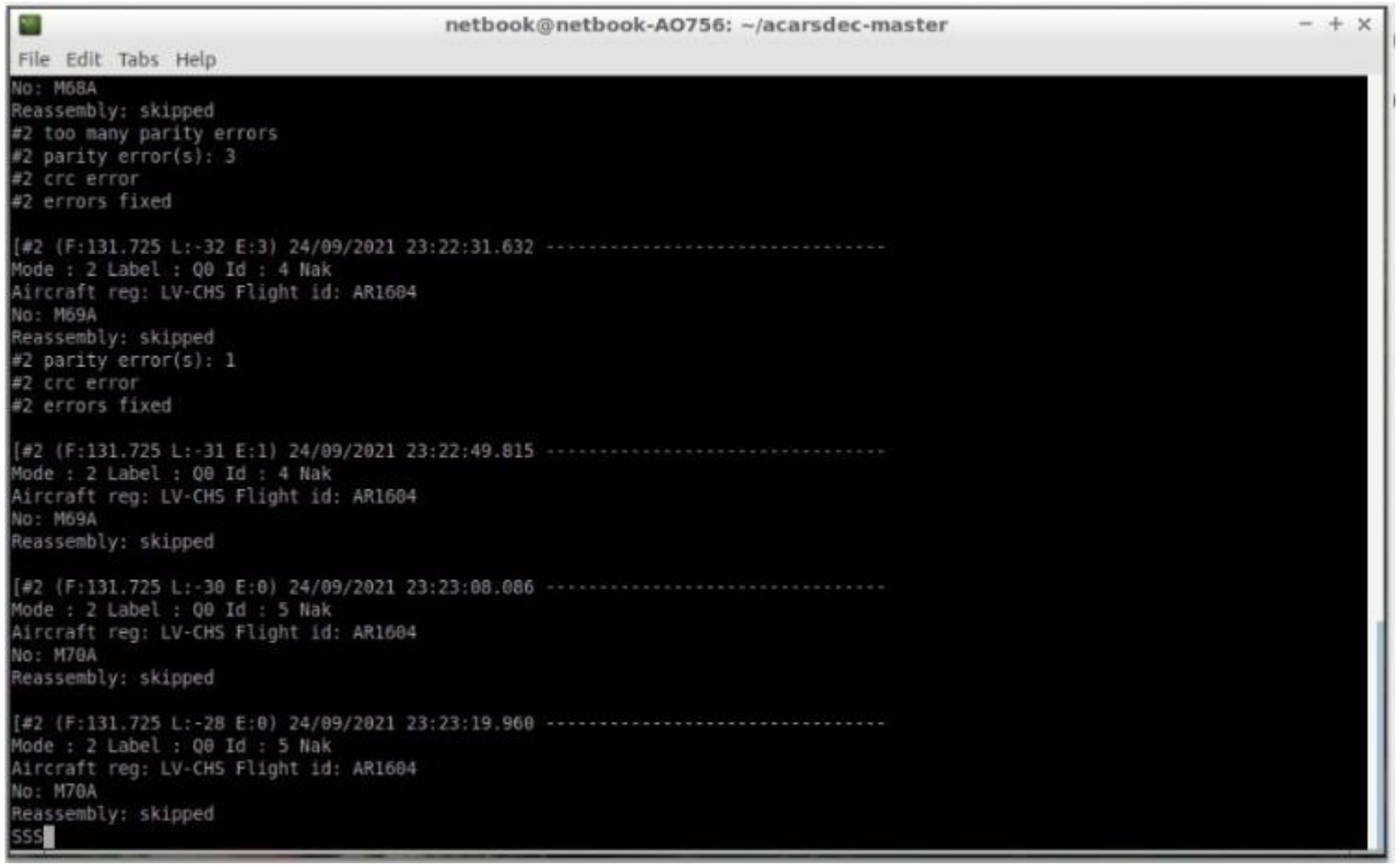
ACARS

- ICAO: LV-CHS
- AR1604 (AEP-MDQ)
- Identification against control tower



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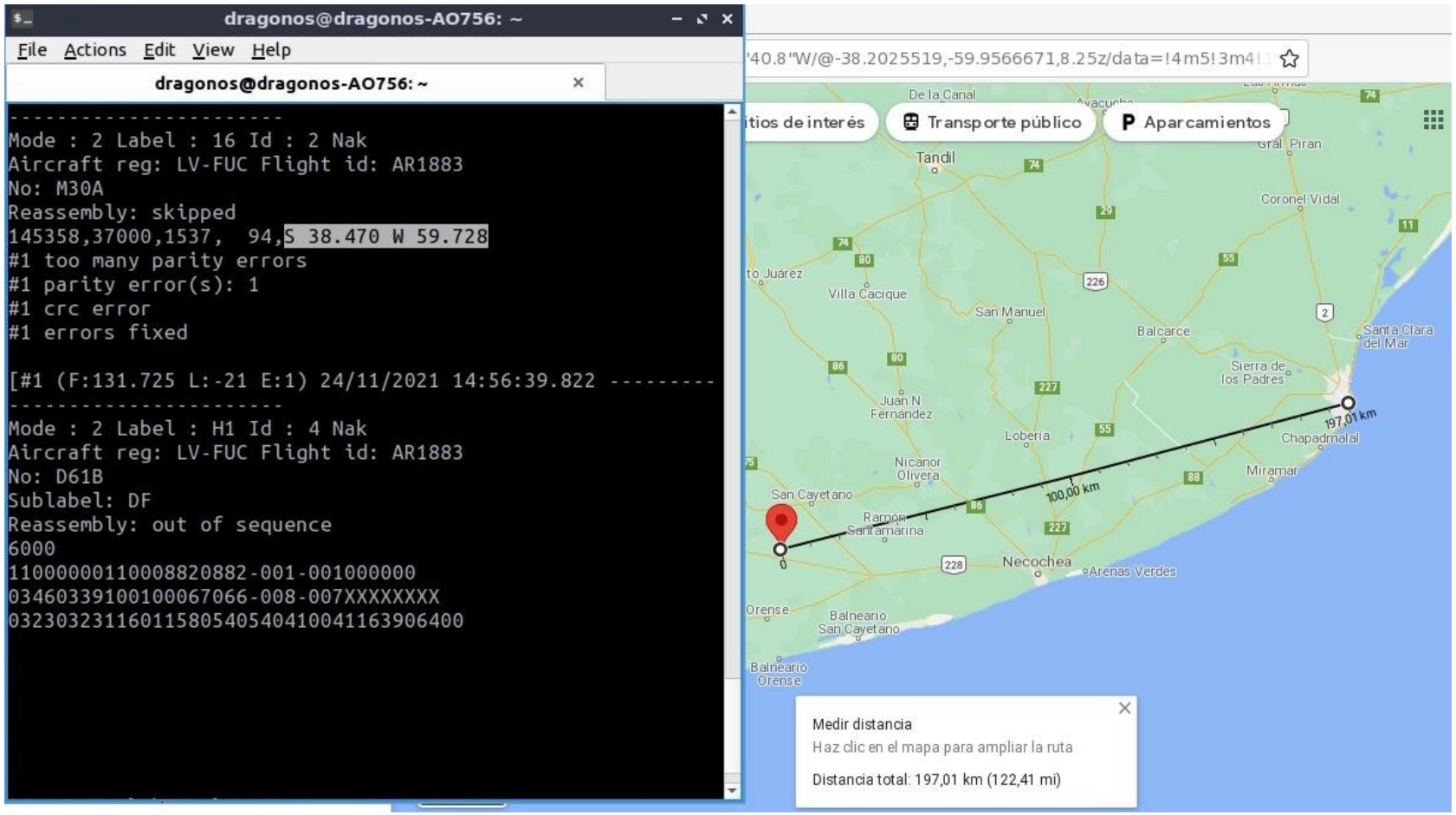
ACARS

- ICAO: LV-FUC – AR1883 (AEP-USH)
- Height: 37.000 feet
- Coordinates: S 38,740 W 59,728
- Reception range: 197 Km



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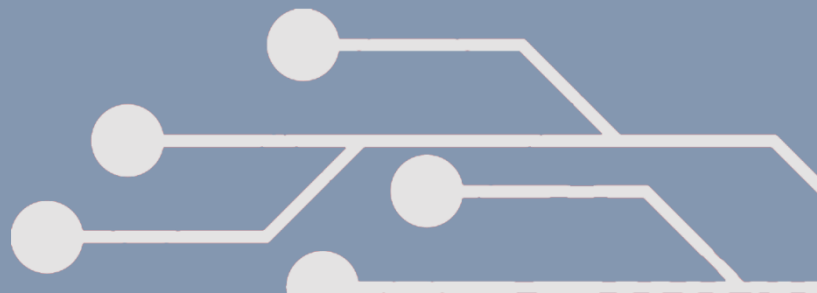
CONCLUSIONS



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CONCLUSIONS

Device

- Requeriments met
- ADSB antenna manufacturing
- Filter design
- SDR

Project

- Project management
- Professional development
- Challenges

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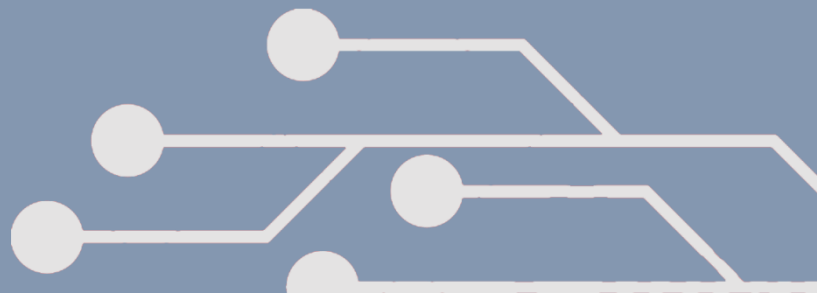
QUESTIONS?



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END

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