An open source and flexible ACARS receiver based on software defined radio

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4 mai 2017

Introduction

The goal of this demonstration is to show some of the benefits offered by a **software-defined radio (SDR)** receiver :

- **simplicity** of implementation due to the "on-the-shelf" building blocks.
- **low material cost** and integrated hardware.
- **versatility and extensibility** of the receiver.

$\rightarrow$ **excellent educational tool** to understand the receiver architecture.

For purposes of illustration, the discussion is based on a **concrete example of an ACARS receiver** developed during our final year project at ISAE-SUPAERO.

Introduction

Project purpose :

- Theoretical model of a VHF ACARS transmission system (PHY & MAC layers)
- Implementation of a SDR receiver enabling real time decoding operations and providing human-readable informations.

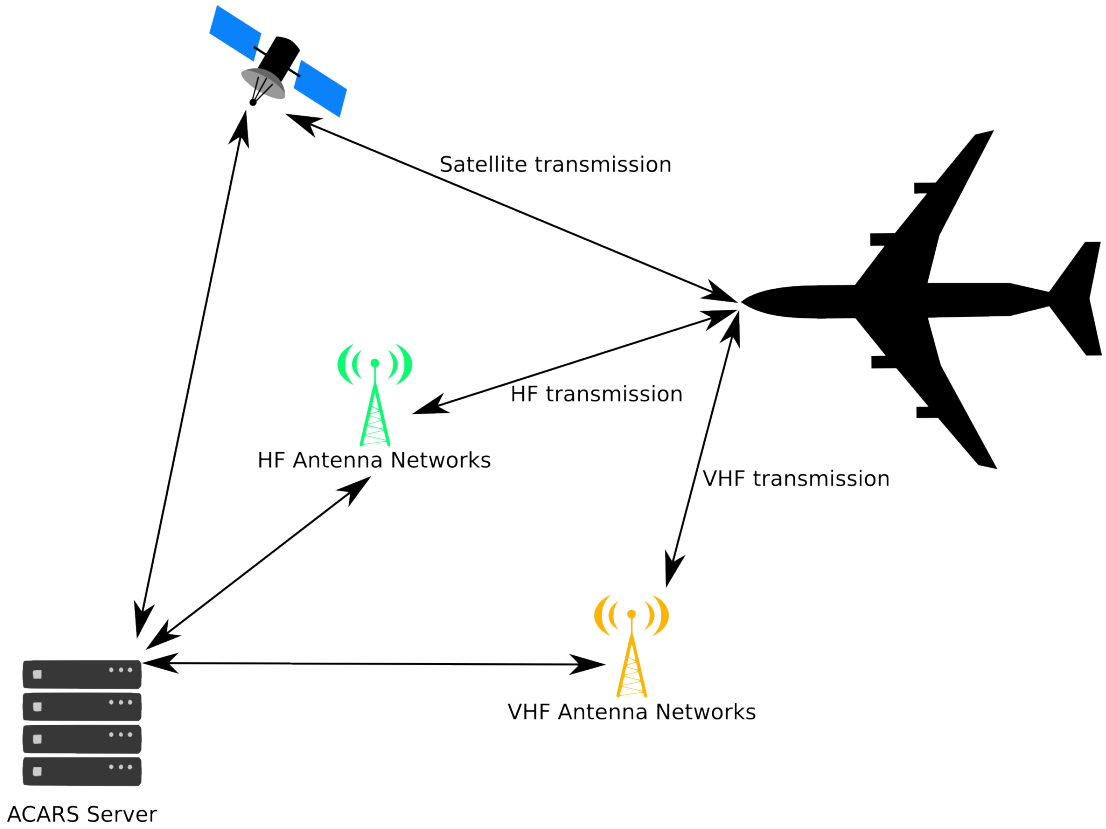
Summary

Summary

A brief history

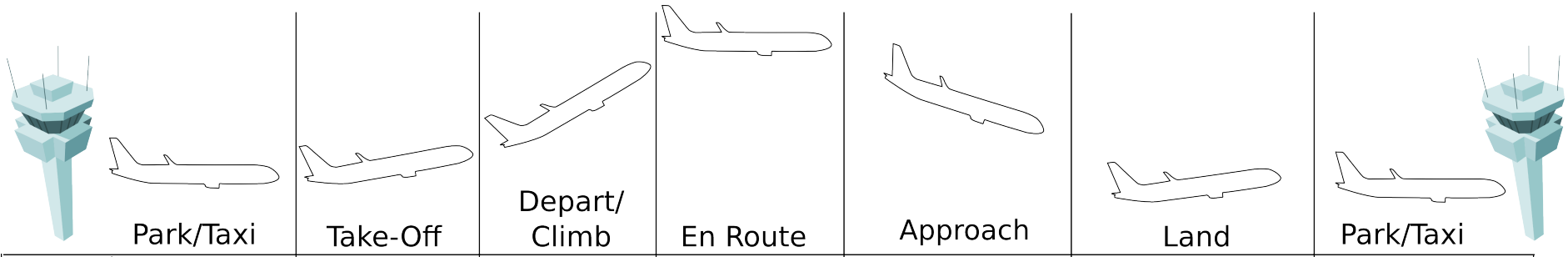
ACARS stands for **A**ircraft **C**ommunication **A**ddressing and **R**eporting **S**ystem.

- 1976 : Use of VHF in North America at the unique frequency of 131.550 MHz.
- 1984 : AIRCOM network which is an ACARS compatible network has been created by SITA.
- 1990 : Use of Satellite link.
- 1998 : Use of HF link.



ACARS network overview

Use of ACARS network



	Park/Taxi	Take-Off	Depart/ Climb	En Route	Approach	Land	Park/Taxi
From Aircraft	LINK TEST	ENGINE DATA	ENGINE DATA	DELAY INFO ETA	GATE REQUEST	ETA	FAULT DATA
To Aircraft	FLIGHT PLAN		FLIGHT PLAN	WEATHER REPORT	GATE ASSIGNEMENT	CONNECTING GATE	

ACARS communication according to the different flight phases

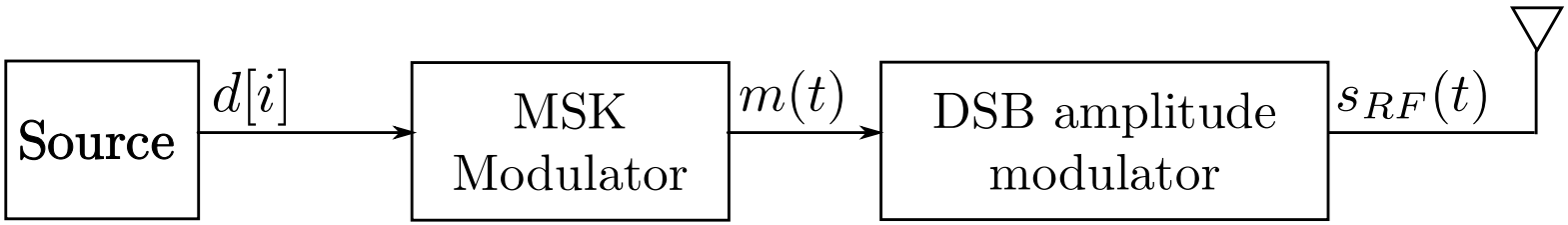
Frame format

Parameters	Nb of Bytes	Description
Pre-key	16	Identification and synchronisation parameters
Bit sync	2	
Char sync	2	
SOH	7	TEXT
Mode	1	
Address	7	
Ack/Nak	1	
Lable	2	
Block ID	1	
STX	1	
TEXT	220	
ETX	1	
BCS	2	End frame identification
BCS Suffix	1	

ACARS frame format

Summary

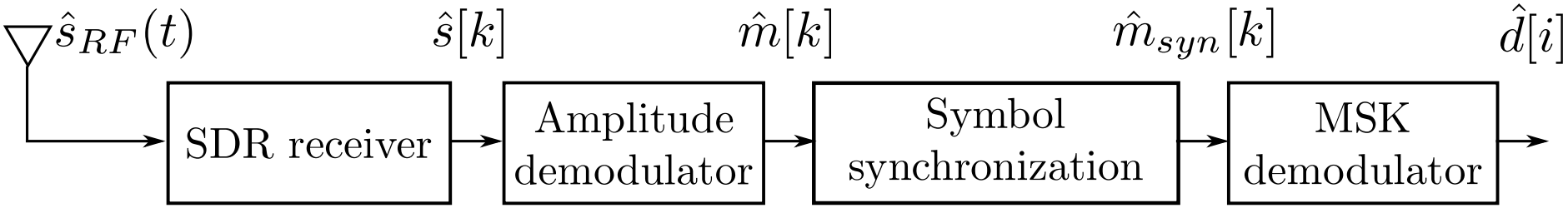
ACARS transmitter



Overall architecture of the ACARS transmitter

1. A binary source $d[n]$.
2. A MSK (Continuous-Phase Modulation) modulator to convert the digital sequence $d[n]$ into an analogical signal $m(t)$ with $T_{symbol} = 1/1200$ s.
3. A DSB (Double Sideband) amplitude modulator to center the output signal on the carrier frequency $f_0 = 131,725$ MHz.

ACARS receiver



Overall architecture of the ACARS receiver

1. Oversampling & computing of the analogical input signal by the SDR receiver to derive its numerical complex envelope.
2. Non coherent amplitude demodulation (no need to recover the carrier and the phase).
3. Frame & symbol synchronization thanks to the frame preamble (pre-key).
4. MSK demodulation to detect the transmitted bits.

Summary

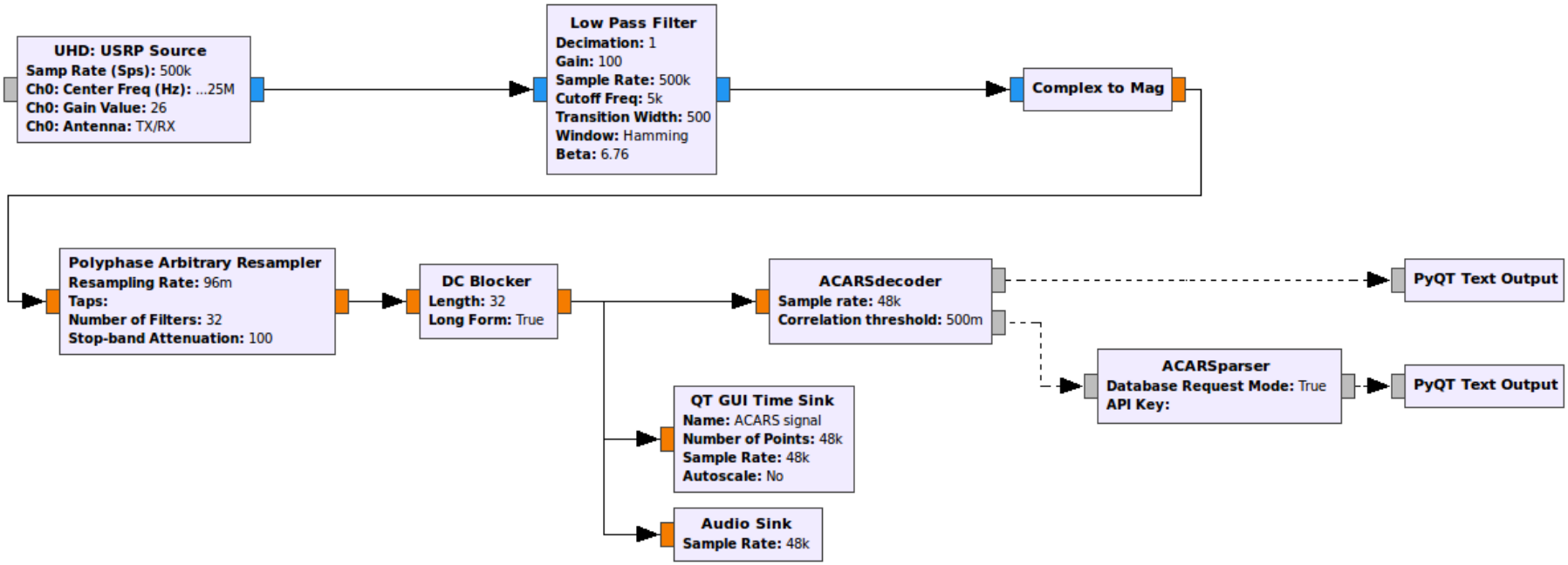
What is GNU Radio ?

- **Free** and **open-source** software.
- **SDR applications** development tool.
- Pre-compiled signal processing blocks in **C** or **python**.

Why GNU Radio ?

to offer to the community a flexible open-source ACARS receiver deployable with only **a VHF antenna** and a **SDR receiver**.

GNU radio receiver architecture



GNU radio receiver architecture

ACARSDecoder Block

Role : Demodulate the received symbols in order to retrieve the transmitted bits when an incoming frame is detected.

Parameters : *samp_rate*, *corr_thres*

Some programming features :

- Involved in the frame detection and symbol synchronization steps.
- Block-processing of the data flow.
- Frame structure check-up and parity bits control $\rightarrow$ incremental improvement of the receiver robustness.

ACARSParser Block

Role : Make the decoded data understandable.
Frame information is transmitted in binary format from **ACARSDecoder** block via **asynchronous** messages.

Parameters : *db_request_mode*, *API_Key*

Processed content :

- Transmission mode.
- Label.
- Aircraft Address (HTTP request).
- Aircraft flight number (IATA request).
- Text.

Example of interpreted frame [1]

```
--------------------------------------------------------
New Frame !
Time : yyyy-mm-dd hh:mm:ss
Transmission Mode : E ==> Category B - Air to Ground transmission
Airplane Address : . A - A A A A - Aircraft Model : Airbus A320-232(SL) (A-AAAA) Airline name
Departure Airport : Heathrow (LHR) - Arrival Airport : Blagnac (TLS)
ACK/NAK : NAK
Label : 1 0
Block ID : 2
STX
Message Sequence Number : M 1 8 A
Flight Number : B A 0 3 7 9
Text : D R C 0 1 1 6 0 4 - - - - 1 5 4 6
End of Frame
--------------------------------------------------------

--------------------------------------------------------
New Frame !
Time : yyyy-mm-dd hh:mm:ss
Transmission Mode : e ==> Category B - Ground to Air transmission
Airplane Address : . A - A A A A - Aircraft Model : Airbus A320-232(SL) (A-AAAA) Airline name
Departure Airport : Heathrow (LHR) - Arrival Airport : Blagnac (TLS)
ACK/NAK : 2
Label : _ DEL ==> General response, demand mode, no information to transmit
Block ID : V
End of Frame
--------------------------------------------------------
```

1. Date, Airplane Address and Airline company name have been changed to respect communication privacy

Example of interpreted frame [2]

```
--------------------------------------------------------
New Frame !
Time : yyyy-mm-dd hh:mm:ss
Transmission Mode : 2 ==> Category A - Broadcasting to all the stations
Airplane Address : . A - A A A A - Aircraft Model : Airbus A320-214 (A-AAAA) Airline name
Departure Airport : Orly (ORY) - Arrival Airport : Houari Boumediene (ALG)
ACK/NAK : NAK
Label : H 1 ==> Message to/from terminal
Block ID : 5
STX
Message Sequence Number : C 0 2 A
Flight Number : Z I 0 2 5 9
Sublabel : # C F ==> Central Fault Display
Text : B W R N / W N 1 7 0 3 1 5 1 1 0 6 0 0 4 6 2 0 0 0 0 6
   D A T A L I N K   A T C   F A U L T
End of Frame
--------------------------------------------------------
--------------------------------------------------------
New Frame !
Time : yyyy-mm-dd hh:mm:ss
Transmission Mode : 2 ==> Category A - Broadcasting to all the stations
Airplane Address : . A - A A A A - Aircraft Model : Airbus A320-214 (A-AAAA) Airline name
Departure Airport : Orly (ORY) - Arrival Airport : Houari Boumediene (ALG)
ACK/NAK : 5
Label : _ DEL ==> General response, demand mode, no information to transmit
Block ID : I
End of Frame
--------------------------------------------------------
```

2. Date, Airplane Address and Airline company name have been changed to respect communication privacy

Example of interpreted frame

```
--------------------------------------------------------
New Frame !
Time : yyyy-mm-dd hh:mm:ss
Transmission Mode : e ==> Category B - Transmitting from a specific station - Ground to Air link
Airplane Address : NUL - Aircraft Model : No Information Available (from https://planefinder.net)
Departure & Arrival Airports : No Information Available (from https://planefinder.net)
ACK/NAK : NAK
Label : S Q ==> Squitter Message
Block ID : NUL
STX
Version Number : 0 2
Service Provider : X S
IATA Station ID : T L S
ICAO Station ID : L F B O
Station Number ID : 0
Latitude : 4 3 3 7 N
Longitude : 0 0 1 2 3 E
Text : V 1 3 6 9 7 5 /
ETX
--------------------------------------------------------
```

Summary

Demo

Conclusion

Results :

- GNU Radio working receiver.
- Open-source project available at `https://sourceforge.isae.fr/git/supacars`

Enhancement and perspectives :

- Code optimization to reduce the receiver complexity.
- Study in depth ARINC 618 [1] and 620 [2] to enhance the receiver parsing features.
- Submit an article to the IEEE AESS Systems magazine.

Questions

Thank you for your attention.
Do you have some questions ?

References I

- ARINC, “Arinc 618 - air/ground character-oriented protocol specification,” Jun 2013.
- ARINC, “Arinc 620 - datalink ground system standard and interface specification,” Jan 2014.