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THEME:

« Realization of an application for decoding and visualization of Mode_S radar data in ASTERIX format »

Presented by:

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Dedication

Dedication

With an enormous pleasure, an open heart and immense joy, that I dedicate my work

To my Mother,

"You gave me life, tenderness and courage to succeed.

All that I can offer you will not be able to express the love and gratitude that I have for you.

As a testimony, I offer you this modest work to thank you for your sacrifices and for the affection you have always shown me.

To my father,

"The strong shoulder, the understanding eye and the person most worthy of my esteem and respect.

No dedication can express my feelings, may God preserve you and give you health and long life. »

To my brothers: Adem & Amine

To my partner : Oussama

To all my best friends from the class of 2020.

To my family and all the people I love.

Ayyoub

DEDICATION

I dedicate this memoir

To my dear parents my mother and my father

For their patience, their love, their support and their encouragement.

Soul brothers.

My friends and my colleagues.

Without forgetting all the teachers whether primary, middle, secondary or higher education.

OUSSAMA

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Abstract

ملخص:

في هذه المذكرة، سننجز تطبيق يسمح بفك ترميز وعرض بيانات الرادار الثانوي نمط "س" تحت صيغة أستيريكس فئة 048.

لقد تحصلنا على مقطع الأستيريكس من شركة الطيران الإرلندية رايانير و أتممنا فك ترميز وعرض البيانات التالية: معرف الطائرة 24 بت، هوية الطائرة، سرعة الطائرة، الإتجاه المغناطيسي، إرتفاع الطائرة...

يعتبر هذا التطبيق خطوة كبيرة في تصميم نظام جزائري يفك ترميز ويعرض بيانات الرادار الثانوي نمط "س" تحت صيغة أستيريكس فئة 048.

Abstract:

In this thesis, we will realize an application of decoding and visualization of Mode S radar data in ASTERIX format of category 048.

We obtained the ASTERIX message from the Irish airline Ryanair, decoded the message and displayed the following information: ICAO address, identification, speed, magnetic heading, flight level…, in a radar screen with many options.

This application is considered as a big step for the design of an Algerian system which decodes and visualizes the ASTERIX message of category 048.

Résumé:

Dans cette thèse, nous réaliserons une application de décodage et de visualisation des données radar en mode S au format ASTERIX de la catégorie 048.

Nous avons obtenu le message ASTERIX de la compagnie aérienne irlandaise Ryanair, décodé le message et affiché les informations suivantes : adresse OACI, identification, vitesse, cap magnétique, niveau de vol..., dans un écran radar avec de nombreuses options.

Cette application est considérée comme un grand pas pour la conception d'un système algérien qui décode et visualise le message ASTERIX de la catégorie 048.

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Abbreviations

ENNA: National Establishment of Air Navigation

ASTERIX: All Purpose Structured Eurocontrol Surveillance Information Exchange

RADAR: Radio Detection and Ranging

ICAO: The International Civil Aviation Organization

AAC: Area Control Center

TRACON: Terminal Radar Approach Control Facility

ATC: Air Traffic Control

ACC: Area Control Centre

FIR: Flight Information Region

HAWK: Homing All the Way Killer

PSR: Primary Surveillance Radar

CW: Continuous wave

SSR: Secondary Surveillance Radar

FRUIT: False Replies Unsynchronized In Time

RF: Radio Frequency

IRF: Interrogation Repetition Frequency

PRF: Pulse Repetition Frequency

SPI: Special Position Identification

TMA: Terminal Control Area

MSSR: Monopulse Secondary Surveillance Radar

IC: Interrogator Code

ATM: Air Traffic Management

BDS: Binary Data Source

DAP: Downlink of Aircraft Parameters

ELS: Elementary Surveillance

II: Interrogator Identifier Code

SI: Surveillance Identifier Code

GICB: Ground Initiated Comm-B

EHS: Enhanced Surveillance

ADLP: Airborne Data Link Processor

GDLP: Ground Data Link Processor

ATN: Aeronautical Telecommunication Network

ACAS: Airborne Collision Avoidance System

ELM: Extended Length Message

DF: Downlink Format

Abbreviations

UF: Uplink Format

SLM: Standard Length Message

AICB: Air Initiated Comm-B

CRC: Cyclic Redundancy Code

AA: Aircraft Address

ISLS: Interrogator Side Lobe Suppression

IISLS: Improved Interrogation Side Lobe Suppression

SLS: Side Lobe Suppression

SPR: Sync Phase Reversal

DPSK: Differential Phase-Shift Keying

PPM: Pulse-position modulation

LVA: Large Vertical Aperture

RPM: Revolutions Per Minute

PC: Personal Computer

LAN: Local Area Network

WAN: Wide Area Network

ICAO: International Civil Aviation Organization

FAA: Federal Aviation Administration

IP: Internet Protocol

OSI: Open Systems Interconnection

BSC: Binary Synchronous Communications

HDLC: High-Level Data Link Control

PXSe: Protocol eXchange Server Ethernet

LAPB: Link Access Procedure, Balanced

TCAS: Traffic Alert and Collision-Avoidance System

UTC: Co-ordinated Universal Time

SARPs: Standards and Recommended Practices (ICAO)

UDP: User Datagram Protocol

TCP: Transmission Control Protocol

SDLC: Software Development Life Cycle

TCP/IP: Transmission Control Protocol/ Internet Protocol

UDP/IP: User Datagram Protocol/ Internet Protocol

FRN: Field Reference Number

FSPEC: Field Specification

UAP: User Application Profile

Abbreviations

RDP: Radar Data Processing

SPI: Special Position Identification

SP: Special Purpose Indicator

FX: Field Extension Indicator

MB: Message, Comm B

ME: Military Emergency

MI: Military Identification

W/E: Warning/Error Condition

LSB: Least Significant Bit MB Message

NM: Nautical Mile, unit of distance

FL: Flight Level, unit of altitude (expressed in 100's of feet)

RDS: Raw Doppler Speed

REP: Field Repetition Indicator

SDP: Surveillance Data Processing (system)

PAM: PSR amplitude

CNF: Confirmed

CDM: Climbing / Descending Mode

KT: Knot

MSSC: Mode-S Specific Service Capability

ARC: Altitude Reporting Capability

AIC: Aircraft Identification Capability

MTD: Moving Target Detection

MCB: Most Significant Bit

REF: Reserved Expansion Field

BDS: Binary Data Source

ACAS: Airborne Collision Avoidance System

RA: Resolution Advisory

SAC: System Area Code

SIC: System Identification Code

MCP: mode control panel

FCU: Flight Control Unit

GMap: Google Map

Abbreviations

N/A: Not Available

LAT: Latitude

LONG: Longitude

BAR_PRE: Barometric pressure setting

TTA: True Track Angle

TAR: Track Angle Rate

IAR: Inertial altitude rate

General Introduction

Today, the number of passengers choosing to travel by air is growing steadily, according to ICAO statistics, the number of passengers using air transport is 4.3 billion per year (2018). For a good air traffic management and in order to ensure the safety of passengers and to avoid loss of life it is always necessary to supervise the airspace with surveillance systems.

In Algeria, the National Establishment of Air Navigation (ENNA) is the administration attached to the Ministry of Public Works and Transport. It gathers all the state services in charge of supervising air safety, its management, air transport and civil aviation activities in general.

For the ENNA to face the increase of air traffic and to guarantee the safety of the Algerian airspace a new surveillance system is needed that can process several targets without errors in real time and rich in information, this system is called the MSSR mode S.

In this project we performed an in-depth study of ASTERIX, which is a standard under which the surveillance data provided by the radar system is formatted.

This study allowed us to create an application for decoding and visualization Mode S radar data in ASTERIX Category 048 format.

We obtained the ASTERIX message from the Irish airline Ryanair, decoded the message and displayed the following information: ICAO address, identification, speed, magnetic heading, flight level…, in a radar screen with many options.

The realization of this application has the following main purposes:

- To test the good functioning of the decoding of the real decoding system and the visualization of the real radar image in Algeria.
- To have a good understanding of the information (fields) offered by the MSSR mode S
- Exploiting the Asterix message with an automatic and fast and efficient way

For this purpose our work will be structured around four chapters:

The first one will focus on radar generalities.

In the second chapter we will detail the MSSR mode S.

In the third chapter we will explain the ASTERIX protocol with an in-depth study of the 048 category.

The last chapter will focus on the realization of the application: Structure, operation mode, tests and simulations.

Chapter I:

Radar Generalities

Abstract:

In this chapter we are going to make some generalities about radar systems as well as some other definitions related to air surveillance.

First we had made an introduction on the evolution of the radar systems as well as the need for air traffic control through surveillance, then we spoke about the radar systems: the primary radar and the secondary radar.

At the end of the chapter we showed and analyzed the current radar coverage in Algeria plus a conclusion of the results found in this chapter.

I. 1. Introduction:

Radar systems have evolved tremendously since their early days when their functions were limited to target detection and target range determination. In fact, the word radar was originally an acronym that stood for radio detection and ranging. Modern radars, however, are sophisticated transducer/computer systems that not only detect targets and determine target range but also track, identify, image, and classify targets while suppressing strong unwanted interference such as echoes from the environment (known as clutter) and countermeasures (jamming). Modern systems apply these major radar functions in an expanding range of applications, from the traditional military and civilian tracking of aircraft and vehicles to two- and three-dimensional mapping, collision avoidance, Earth resources monitoring, and many others. [12]

I.2. The need for air traffic control through surveillance:

I.2.1. Surveillance definition:

Surveillance is a technique of instantaneous detection of targets and determination of their position (if possible acquisition of additional information related to these targets) and delivery of this information to air traffic controllers for the purpose of safe air traffic. [1]

I.2.2. Air traffic control:

Air traffic control guarantees the safety of air transport. Air traffic controllers are familiar with the rules defined by ICAO, provide instructions to pilots to avoid collisions between aircraft and to facilitate the movement of aircraft in the sky. [1]

I.2.3. Air traffic control phases:

Contrary to popular belief, pilots do not receive full instructions from the control towers installed at airports. We highlight three phases of control:

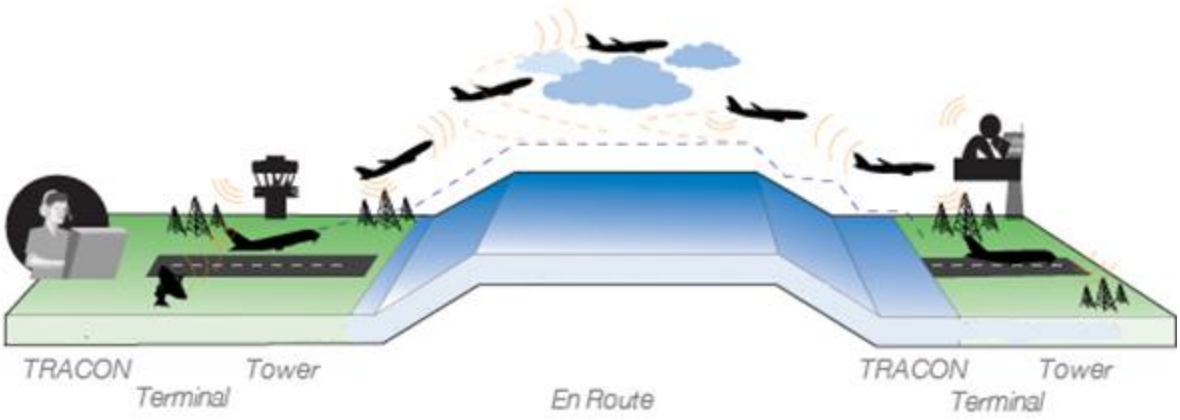


Figure I.1: Air Traffic Control (ATC) phases [1]

I.2.3.1. Tower control (TWR):

Controllers are on the top floor of the airfield control tower. Their job is to manage aircraft on the ground (taxiing, take-off and landing). In Algeria, there are 36 control towers. [1]

I.2.3.2. Approach control (APP):

Approach controllers can be at the control tower level or at the ACC (Area Control Centre) level depending on the traffic in the area. Their job is to guide aircraft between the take-off/route and route/landing phases. The approach is not a mandatory phase.

In Algeria there are five (5) APP controls. [1]

I.2.3.3. En route control:

It is at the level of the ACC that we find the air traffic controllers for the entire FIR Algeria (Flight Information Region). Their responsibility extends to the different sectors of the FIR. Their task is to give instructions to the pilots according to the information seen on their screens (this information is provided by the radars). Examples are: reduce speed to avoid close approaches between aircraft or slightly change course to avoid a turbulent area. Currently Algeria has a single ACC and is divided into seven sectors. [13]

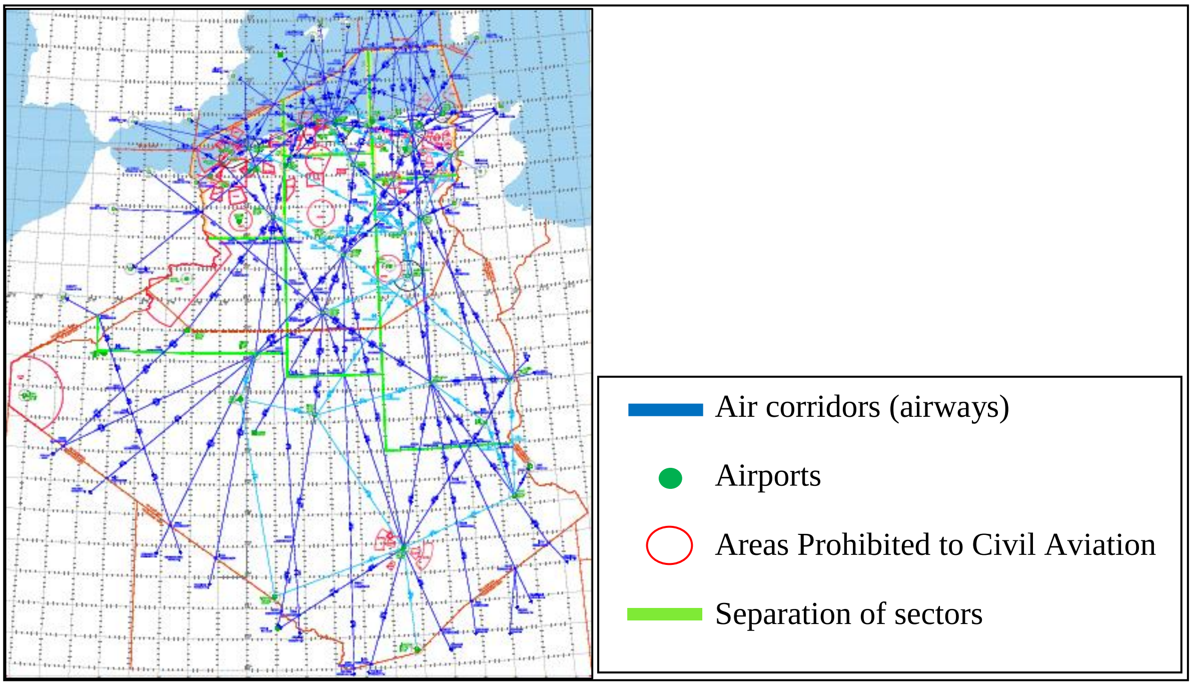


Figure I.2: The seven sectors of FIR Algeria [13]

I.3. Radar systems:

I.3.1. function principle:

The early radars worked by sending out a continuous wave and the reflected energy showed the presence of an object, such as a ship or an aircraft. Separate transmitting and receiving antennas were used. Today, police radars, designed for speed traps, use this principle as do intruder alarms, and simple radars used as proximity fuses mounted in the noses of shells. Frequency modulated continuous wave radars, in addition to those used in radar altimeters and in the HAWK antiaircraft missile system, are starting to be used in vehicles. Current pulse radars switch the same antenna between the transmitter and receiver to allow transmission and reception (monostatic) and are capable of measuring the range of the reflecting or scattering object, its azimuth angle, elevation angle, and radial velocity.

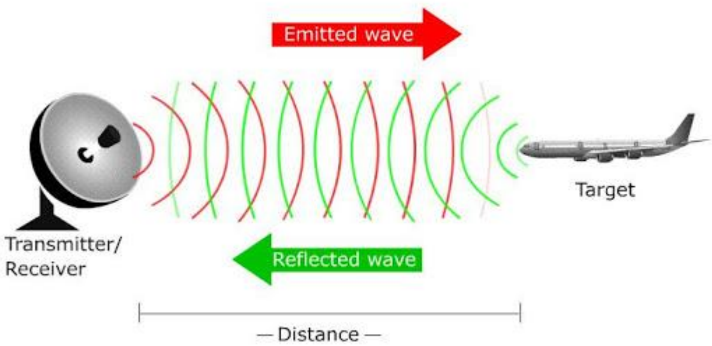


Figure I.3: Function principle of a radar system [12]

I.3.2. Primary Radar:

I.3.2.1. Desciption:

A Primary radar (PSR: Primary Surveillance Radar) is a conventional radar sensor that illuminates a large portion of space with an electromagnetic wave and receives back the reflected waves from targets within that space. The term thus refers to a radar system used to detect and localize potentially non-cooperative targets. It is specific to the field of air traffic control where it is opposed to the secondary radar which receives additional information from the target's transponder.

Figure I.4: Primary radar

This type of radar uses low vertical resolution antenna but good horizontal resolution. It quickly scans 360 degrees around the site on a single elevation angle. It can thus give the distance and radial speed of the target with good precision but requires often one or more radars to obtain the vertical position and the actual speed.

The advantages of the primary radar are no on-board equipment in the aircraft is necessary for detecting the target and can be used to monitor the movement of vehicles on the ground. The disadvantages are that the target and altitude can't be identified directly. In addition, it requires powerful emissions which limits its scope.

There are two types of primary radar: pulsed radar and continuous wave radar. [14]

I.3.2.2. Pulsed radar:

Conventional pulse radar emits rectangular pulses of duration T with a certain repetition frequency Fr. The energy emitted during the pulse duration is radiated into a transmitting antenna. The energy radiated by the target is received by the same antenna through a device called a duplexer which separates the transmission from the reception. [2]

I.3.2.3. Continuous wave radar:

Continuous wave radar (CW) radar transmits and receives at the same time. The transmitter generates a continuous sinusoidal oscillation at frequency F_t which is radiated by the antenna. On reflection by a moving target, the transmitted signal is shifted via the Doppler Effect by an amount F_d. [2]

I.3.3. Secondary Radar:

I.3.3.1. Description:

The secondary radar works according to a different principle: the target it illuminates generates (actively) the response signals. The secondary radar transmits microwave pulses (so-called interrogations). These are not intended to be reflected, as the target is equipped with a transponder that receives and processes them. Then, on a different frequency, the transponder formats and transmits a response message that can be received and decoded by our secondary radar. [1]

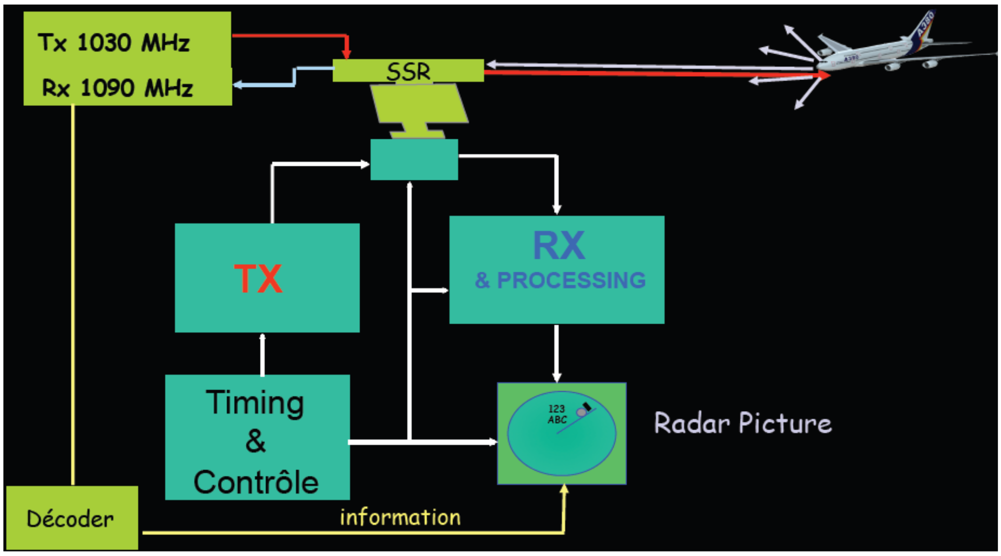


Figure I.5: Function principle of the SSR [2]

Secondary radar is a Cooperative Independent radar system:

- It is Independent because it emits a coded signal to be detected by airborne equipment of aircraft (Interrogation or Up-link).
- It is Cooperative because it needs to receive a specified signal from aircraft to detect it (Reply or Down-link).

I.3.3.2. Interrogation modes:

We have divided the SSR modes of interrogation into two main parts:

- Interrogation modes of conventional SSR
- The S Mode

I.3.3.2.1. Interrogation modes of conventional SSR:

Interrogation modes of conventional SSR are shown in the next figure:

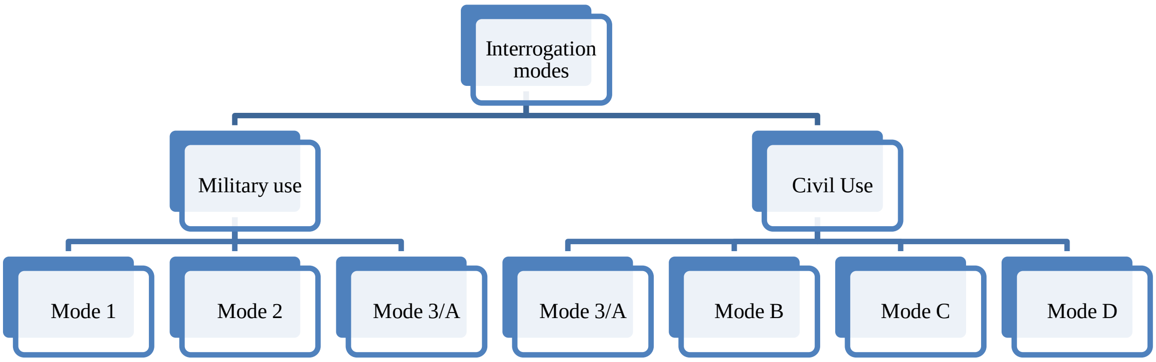


Figure I.6: Interrogation modes of conventional SSR [1]

a. Military Mode 1:

Is usually used to request role, mission or type of aircraft, therefore several military aircraft may give the same Mode 1 reply value. [1]

b. Military Mode 2:

Is usually used to request airframe number of an individual aircraft. [1]

c. Military Mode 3 and Civil Mode A:

They are the same interrogation mode, which is usually referred as Mode 3/A and used to request identity of an individual aircraft. [1]

d. Civil Mode C:

Is used to request the aircraft flight level with a resolution of 100ft and within the range of (-1000ft) to (+126,750ft); this is derived from the aircraft pressure altimeter. [1]

e. Civil Modes B and D:

They have never been used.

f. The use of conventional SSR interrogation modes:

Modes A and C are only used for civil air traffic control purposes.

Not all aircraft transponders are able to reply to all interrogation modes:

- Military aircraft transponders will reply to Modes 1,2,3/A and many also have Mode C capability.
- Civil aircraft transponders will not recognize Modes 1 and 2, but must recognize Modes 3/A and C.

I.3.3.2.2. The S Mode:

Mode-S was developed to improve SSR in relation with its main operational problems detected and with the transmission of more information than identity and height of aircrafts, in addition, the new surveillance system should be operationally compatible with the previous.

The Mode S solution to reduce fruit and garbling effects is the use of Selective interrogations, a Selective interrogation is a type of Mode S interrogation used to interrogate to a unique aircraft which was previously detected.

The Mode S solution to increase the aircraft identification codes is the use of a 24-bit code (ICAO address). An ICAO Aircraft Address is a unique hard-coded identification which is allocated by aircraft registering authorities to identify to each aircraft, this address is a code of 24-bit (6 hexadecimal digits), which allow defining up to 16,777,214 ID codes. [1]

I.3.3.3. Interrogation Format of Mode A & Mode C:

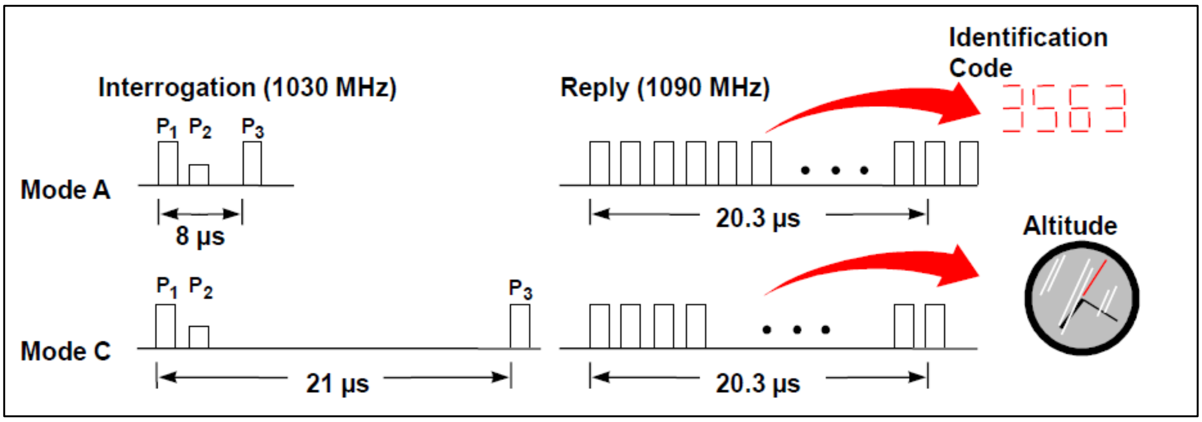


Figure I.7: Mode A and Mode C interrogation and reply pulses [1]

The interrogation consist of two pulses named P1 and P3, these pulses are transmitted in RF to the transmission frequency via the antenna directional pattern (Σ) of the interrogator.

The interval between P1 and P3 determines the mode of interrogation as follows:

- Mode 1: 3 ± 0.2 µsec.
- Mode 2: 5 ± 0.2 µsec.
- Mode 3/A: 8 ± 0.2 µsec.
- Mode B: 17 ± 0.2 µsec.
- Mode C: 21 ± 0.2 µsec.
- Mode D: 25 ± 0.2 µsec.

The features of this pulses as indicated below:

- The pulse duration is 0.8 ± 0.1 µsec.
- The rise time is between 0.05 and 0.1 µsec.
- The fall time is between 0.05 and 0.2 µsec.

I.3.3.4. Repetition Frequency & Stagger:

I.3.3.4.1. IRF (Interrogation Repetition Frequency):

Corresponds with the average of the number of interrogations per second transmitted by the radar. The term IRF is equivalent to the term PRF, which can have a value between 50 and 450 Hz according to EUROCONTROL specification. [1]

I.3.3.4.2. Stagger:

Is a function that slightly varies the Interrogation Repetition Period (around µsec) with a pseudo-random sequence of predetermined values(Used to avoid the correlation of undesired replies for both cases, out-range replies (second-time-around) or replies to other close Interrogators). [1]

I.3.3.5. Reply Detection of conventional SSR:

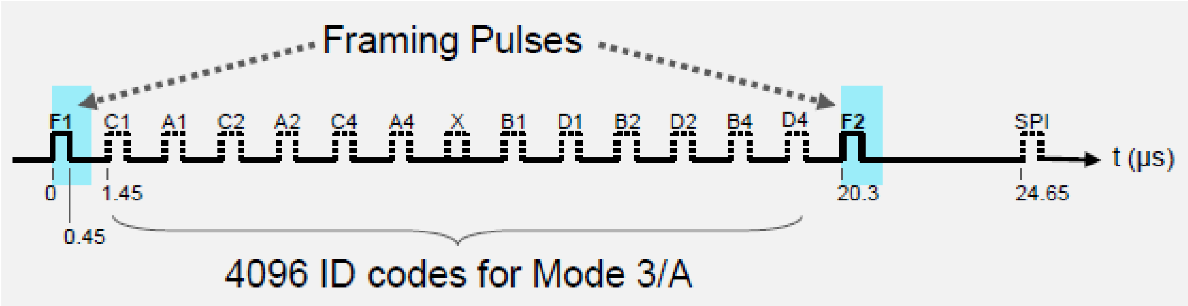


Figure I.8: SSR reply detection [1]

I.3.3.5.1. Reply report:

- Range and corrected azimuth of the reply.
- Code value of the reply.
- Information flags about the detection of:
    - Overlapped pulses, SPI pulse and Emergency code.
- Particular information of each possible pulse of the reply (from F1 to SPI):
    - Raw video level, monopulse video level and confidence percentage.
- An SSR reply is determined for two framing pulses or brackets (F1 and F2) spaced 20.3 µsec.
- Thirteen information pulses are located between the framing pulses. They have the following features:
    - They are spaced in increments of 1.45 µsec, from the first framing pulse (F1).
    - The designation of the pulses is as follows:

      C1, A1, C2, A2, C4, A4, X, B1, D1, B2, D2, B4 and D4.
    - The pulse X is not used.
    - The pulses A, B, C and D define an octal code of 4 digits (3 bits per digit) as follows: A (A4-A2-A1) B (B4-B2-B1) C (C4-C2-C1) D (D4-D2-D1), the possible values are between 7777 and 0000.
- In addition to the information pulses and in the particular case of Mode 3/A replies, a special position identification pulse (SPI) can be after the pulse F2, spaced at an interval of 4.35 µsec. This pulse is transmitted for a period of between 15 and 30 seconds, when the pilot activates it and only on the request of the ground air traffic controller. [1]

I.3.3.5.2. Features of Mode 3/A reply:

It provides 4096 ID codes. The identity code value is set by the pilot, as directed by air traffic control instructions (the value may sometimes be changed during flight).

Three particular codes are universally used to indicate emergency conditions: 7700 (emergency), 7600 (radio failure) and 7500 (hijack). [1]

I.3.3.5.3. Features of Mode C reply:

It provides 2048 codes (D1 pulse not used) to inform about aircraft flight level with a resolution of 100ft and within the range of -1000ft to +126,750ft. [1]

I.3.3.6. Secondary radar measurements:

I.3.3.6.1. Distance calculation:

The distance is calculated from the transit time (round trip) of a short radio pulse transmitted as follows: $R = \frac{C.\delta t}{2}$ … (I.1)

Where; **R:** distance, **C:** light speed, **δt:** the transit time

An SSR transponder replies to an interrogation, 3 ± 0.5 µsec after its detection. This delay is taken into account by the interrogator to determine the aircraft range from the radar antenna position (distance origin). [12]

I.3.3.6.2. Direction Measurement:

The azimuth of the transponder position is determined by the interrogator using the sliding window technique. This technique is currently replaced for monopulse technique in the new SSR systems called MSSR. [12]

I.3.3.7. Monopulse technique:

The idea of the monopulse consists in exploiting the response of a target on two different diagrams in order to deduce the exact position of the target by measuring the phase or amplitude differences of the received signals.

Monopulse measurement is therefore a measurement of the angular deviation between the direction of reception and the antenna axis. This measurement is made in the main lobe aperture of the directional pattern.

To the directional diagram noted Σ is called the sum diagram, is added an additional diagram noted Δ is called the difference diagram whose slope is very steep on both sides of the axis.

The Omni or Control radiation pattern (Ω) is designed to only cover the side lobes of the SUM pattern.

Advantages :

- Better accuracy in azimuth measurement.
- Degarbling possible thanks to the deviationometry information: the pulses of the same code can be grouped together if they have the same deviationometry, it is thus possible

to detect in most cases two close aircraft.

- Mastery of the single-pulse technique is essential for operation in "S" mode. [1]

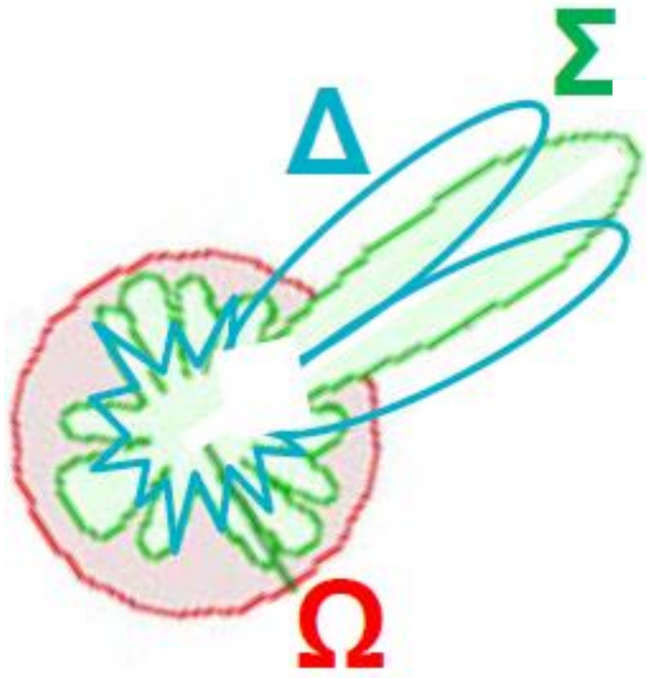


Figure I.9: Monopulse technique [1]

I.3.3.8. The disadvantages of conventional secondary radar:

- Insufficient in TMA for security reasons (transponder failure)
- Less accuracy: Conventional secondary radar is characterized by the use of the so-called "sliding window" technique for aircraft azimuth estimation. This technique has proven to be too imprecise to be used in the current separation (3 or 5 NM). [2]

Currently, SSR provides a limited surveillance service due to the rapid increase of air traffic density, and a number of known operational problems are generated. [2]
Those operational problems are mainly the following:

- Difficulty of SSR systems to decode the reply codes received.
    - Increment of Fruit provoked by the increase of number of SSR systems covering the airspace (Multiple coverage).
    - Increment of Garbling provoked by the need to reduce the minimum vertical separation of the airways to absorb the current air traffic.
- Insufficient number of codes to identify all aircrafts during their flight.
    - These problem is caused because Mode A only provides 4096 identification codes.

I.3.4. Radar coverage in Algeria:

Means of surveillance:

- One (01) radar station co-located in Oued Smar :
  - Primary radar (PSR) :148 KM range
  - Secondary radar (MSSR): 460 KM range
- Four (04) secondary radar stations in Oran, Annaba, El Oued and El Bayadh: (460 KM range)

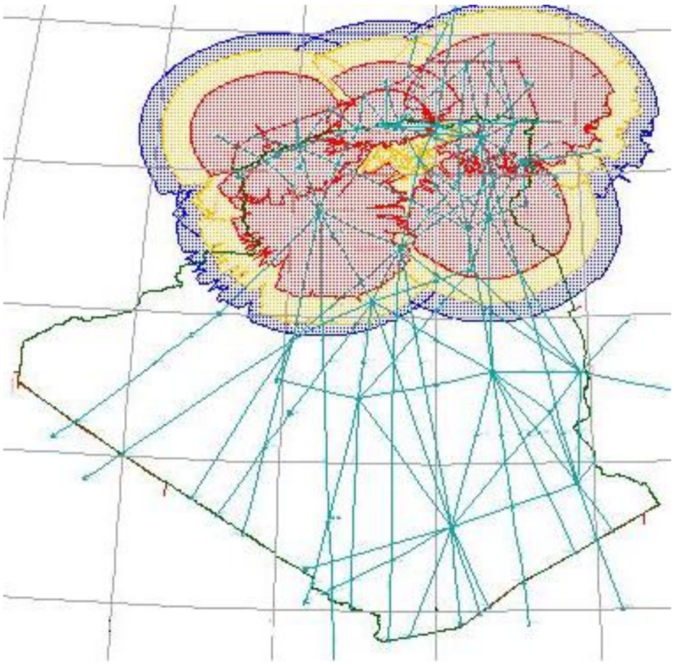


Figure I.10: Radar coverage in Algeria [13]

From figure (I.13) above we notice that just the Algerian north is covered with radars and there are also blind spots like Bousaada city. [13]

I.4. Chapter conclusion:

In order to solve the problems inherent in conventional secondary radar, a new generation of secondary radar has been developed: the S-mode (which will be detailed in the next chapter).

The radar coverage in Algeria has shown that it needs an extension to cover the uncovered areas (the blind spots in the north and the complete Algerian south), that's why ENNA is going to install new radar stations in Algeria which is the MSSR Mode S.

Chapter II:

Mode S Secondary Radar

Abstract:

In this chapter we will study and explain the MSSR Mode S on the software and hardware side, as well as some parameters related to the Mode S transponder.

First we had made an introduction on the Mode S and some parameters need to be correctly set/adjusted in the Mode S, then we well detailed this mode in several parts which are: Mode-S Improvements, Operational Levels, BDS Registers, and Communication Capabilities.

At the end of this chapter we made a description of an MSSR Mode S station and the different equipment that exist in the station plus a conclusion of the results found in this chapter.

II.1. Introduction:

Mode S has a better overall performance and in high density areas, improves the safety of air navigation.

However, Mode S is rather complicated (mainly for the technical personnel). So its use in not-so high density areas should be carefully considered.

Many parameters (e.g. those listed below) need to be properly set/adjusted and often in coordination with adjacent radars, these parameters are:

- Pulse repetition frequency (PRF)
- Mode interlace pattern (A/C, All-Call A/C/S, All-Call Mode S only, Roll-calls)
- Interrogator Code (IC)
- Use of lockout (coverage and protocol)
- Use of data Link capability
- Types of transponders in the airspace

II.2. Mode-S Improvements:

The main improvements of Mode-S are the following:

- A unique 24-bit address (ICAO Address)
- Improved Data integrity
- Altitude Report in 25 Feet Increments
- Provide Communication Services (datalink function)

II.3. Operational Levels:

The Concept of Operations levels of the Mode S specifies the employment criteria for the operational used, It provides information concerning the operational elements involved, the requirements of the users, airborne equipment functionality and the measures needed to ensure continued safe and efficient Air Traffic Management (ATM).

There are two types of operational levels: Depending on what Information can be extracted from Aircraft Transponders and Undeveloped. [1]

II.3.1. Depending on what Information can be extracted from Aircraft Transponders:

II.3.1.1. Elementary Surveillance (ELS):

Elementary surveillance is the minimum surveillance operability foreseen Mode-S for aircraft equipped with any type of Mode-S transponder.

This operational level reduces the problems about fruit and gargling through selective interrogations, and improves the Mode A identification codes shortage through the extraction of the aircraft ICAO address (aircraft address) and it allows the extraction of the following BDS Registers: BDS 1.0, BDS 1.7 and BDS 2.0.

Available information of ELS are:

- ICAO 24-bit address
- Mode A code
- Altitude report in 25-ft steps
- Flight status (including SPI & emergency situations)
- II/SI-code functionality
- Aircraft identification (BDS 2.0)
- Data link capability report (BDS 1.0)
- Common usage GICB capability report (BDS 1.7)

II.3.1.2. Enhanced Surveillance (EHS):

Enhanced surveillance enables additional surveillance capabilities between interrogators and transponders through datalink.

It allows the extraction of more BDS registers as BDS 4.0, BDS 5.0 and BDS 6.0, in addition to BDS registers used by ELS level.

Additional information compared to ELS:

- Selected vertical intention (BDS 4.0)
  - MCP/FCU selected altitude
  - FMS selected altitude
  - Barometric pressure setting
- Track & turn report (BDS 5.0)
  - Roll angle
  - True track angle
  - Ground speed
  - Track angle rate
  - True air speed
- Heading & speed report (BDS 6.0)
  - Magnetic heading
  - Indicated air speed
  - Mach number
  - Barometric altitude rate
  - Inertial vertical velocity

II.3.2. Undeveloped:

II.3.2.1. Mode S Subnetwork:

Mode S subnetwork manages the packet layer protocol to allow external interfaces with applications either locally attached (ground stations/transponders) or wide-area (located anywhere in the world) through specific services. This functionality requires an ADLP (Airborne Data Link Processor) in transponders and a GDLP (Ground Data Link Processor) in ground stations. [1]

II.3.2.2. ATN ISO 8208 Packet Layer Protocol:

It requires the use of an Airborne or Ground ATN Router to form the main interface to process and distribute packets through the wide-area network.

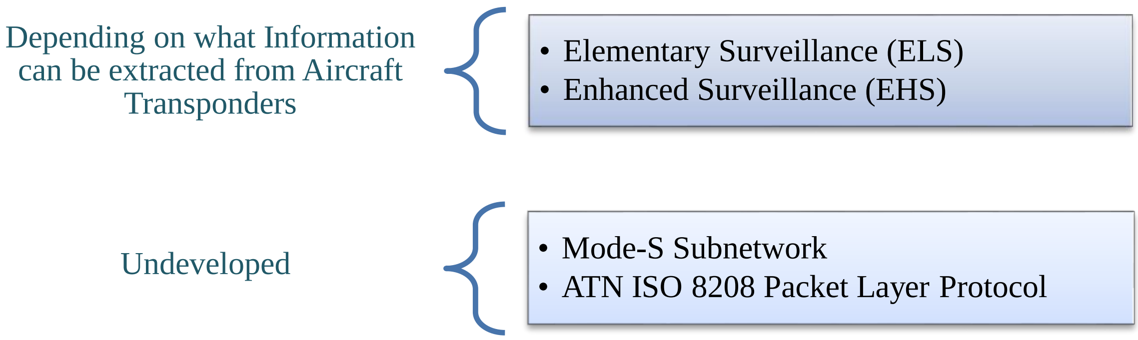


Figure II.1: Operational levels of the Mode S [1]

II.4. BDS Registers:

The BDS registers (Binary Data Source) also called Daps (Downlink of Aircraft Parameters) registers are registers located in the Mode S transponder and contain different information depending on the BDS code number (Up to 255 registers BDS can be implemented but only 50 registers are currently defined).

There are two categories of BDS registers: ELS registers and Additional BDS registers for enhanced operation.

II.4.1. ELS registers:

II.4.1.1. BDS 1.0 (data link capability report):

- It reports about the capability and protocols supported by transponder, e.g. ACAS, SI, UELM/DELM, basic specific services capability report, squitter capability, aircraft ID availability, etc.
- This register is broadcast by a transponder if its contain changes.
- All of the information in the register must be updated in real time at least every 4 seconds.

II.4.1.2. BDS 1.7 (common usage GICB capability report):

- It reports about availability of a determined group of BDS registers for their immediate extraction using the GICB protocol.
- It has a single bit flag for each of the BDS registers used for elementary and enhanced surveillance.
- The flags are updated at least every 5 seconds.
- This register is not broadcast on update but this is done by a single toggle bit set in BDS 1.0 (bit 36).

II.4.1.3. BDS 2.0 (Aircraft identification):

- It has the Aircraft Identification (Flight ID of the aircraft).
- The extraction of Aircraft ID is fundamental for ELS operation.
- If the aircraft ID changes during flight, the transponder must transmit this information as a broadcast for a period of 18 seconds.

II.4.2. Additional BDS registers for enhanced operation:

II.4.2.1. BDS 4.0 (Aircraft intention):

- It provides information about Selective Vertical Intention (selected Altitude, Barometric Pressure Setting, etc.).

II.4.2.2. BDS 5.0 (Track & turn report):

- It provides information about Roll Angle, True Track Angle, Track Angle Rate, True Air Speed and Ground Speed.
- The content of this register must be updated at least every 0.5 seconds.

II.4.2.3. BDS 6.0 (Heading & speed report):

- It provides information about Magnetic Heading, Indicated Air Speed, Mach number, Barometric Altitude Rate and Inertial Vertical Velocity.

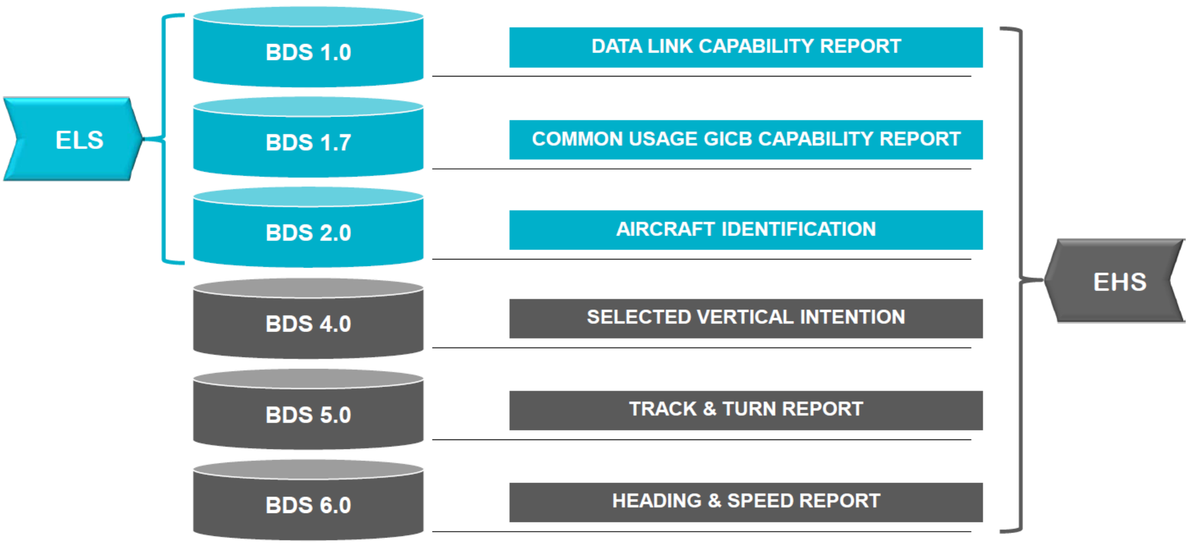


Figure II.2: BDS registers of Mode S transponders [1]

II.5. Communication Capabilities:

Communication capabilities gathers all the different information and data exchanges between the S-mode radar and the target transponder which are the following. [1]

II.5.1. Mode-S Protocols:

Mode-S uses different protocols to communicate with aircraft transponders, they are classified into three main categories, called: All-call Protocols, Surveillance Protocols and Data Link Protocols.

These protocols use uplink (UF) and downlink (DF) formats to establish a bi-directional ground station-aircraft communication. [1]

Category	Used for	Protocol
All-call	Detection & Surveillance of SSR Transponders	Mode A/C Mode A/C/S (Intermodes)
	Detection & Acquisition of Mode-S Transponders	Mode-S only All-Call (UF/DF 11)
Surveillance	Surveillance of Mode-S Transponders	Selective Surveillance (UF/DF : 4 & 5)
Data link	Surveillance of Mode-S Transponders	COMM-A & COMM-B (UF/DF: 20 & 21)
	Data Link with Mode-S Transponders	COMM-A & COMM-B (UF/DF : 20 & 21)
	Only Data Link with Mode-S Transponders	COMM-C & COMM-D (UF/DF 24)

Table II.1: Main Mode S protocols

II.5.1.1. All Call Protocols:

It corresponds with Mode-S only All-Call (UF/DF 11), Intermode All-Calls (Mode A/C/S) and Mode A/C All-Calls (SSR Modes), these category is used for the following purposes:

II.5.1.1.1. Detection & Surveillance of SSR Transponders:

For these purpose we need to Intermode and Mode A/C All-Calls protocols.

Intermode uplink formats are similar to the Mode A and C uplink formats, they add a pulse P4 after P3. Hence, there are two intermode formats, called Intermode A and Intermode C.

II.5.1.1.2. Detection & Acquisition of Mode-S Transponders:

For these purpose we need to Mode-S only All-Calls for obtaining of the Aircraft Address (ICAO address). Mode-S Only All-Call uplink (UF11) is not a selective interrogation. [1]

II.5.1.2. Surveillance Protocols:

Used for Surveillance of Mode-S Transponders, they are selective Mode-S surveillance protocols and called as UF/DF 4 and UF/DF 5. [1]

II.5.1.3. Data Link Protocols:

They are selective Mode-S protocols, there are two types of data link protocols, classified as: Surveillance and Data Link Protocols, and Only Data Link Protocols.

II.5.1.3.1. Surveillance & Data Link protocols:

Surveillance and data link protocols are UF/DF 20 and UF/DF 21. They use the COMM-A format in the uplink and the COMM-B format in the downlink for data transference. [1]

II.5.1.3.2. Only Data Link:

Only data link protocol is UF/DF 24. It uses the COMM-C format in the uplink and the COMM-D format in the downlink for data transference. [1]

II.5.2. Mode-S Link Formats:

II.5.2.1. Uplink (UF) & Downlink (DF):

ICAO defines 25 possible link formats (UF or DF), but only 6 formats are currently used for Mode-S, these formats are: UF/DF 4, UF/DF 5, UF/DF 11, UF/DF 20, UF/DF 21 & UF/DF 24. They correspond with some of the following types of protocols: All-Call, Surveillance & Data Link (only the Surveillance & Data Link protocols are selective interrogations). [1]

Type	Uplink	Information	Downlink	Information	Length
All-call	UF11	Aircraft address acquisition	DF 11	ICAO address	56-bit
Surveillance (Selective)	UF04	Altitude request	DF 04	Altitude (25 feet steps)	
	UF05	Mode A identity request	DF 05	Mode A identity	
Data link (Selective)	UF20	COMM-A (SLM) & Altitude request	DF 20	COMM-B (SLM) & Altitude (25 feet)	112-bit
	UF21	COMM-A (SLM) & Mode A identity request	DF21	COMM-B (SLM) & Mode A identity	
	UF24	COMM-C (ELM)	DF24	COMM-D (ELM)	

Table II.2: Uplink (UF) & Downlink (DF) [1]

II.5.2.1.1. All-call Protocols:

- It corresponds with the Mode-S only All-Call (UF/DF 11).
- UF/DF 11 protocols are used for obtaining the Aircraft Address (ICAO address).
- All-Call Mode-S only interrogation (UF11) is not a selective interrogation.
- All-Call Mode-S only protocols (UF/DF 11) have a data block length of 56-bit.

II.5.2.1.2. Surveillance Protocols:

- It corresponds with the selective surveillance protocols, called UF/DF 4 and UF/DF 5.
- UF/DF 4 protocols are used for obtaining the altitude or flight level of an aircraft.
- UF/DF 5 protocols are used for obtaining the Mode A identity of an aircraft.
- They have a data block length of 56-bit.

II.5.2.1.3. Data Link Protocols:

- It corresponds with the following selective protocols: UF/DF (20, 21 and 24).
- UF/DF 20 protocols are used for obtaining the altitude of an aircraft and for transferring data.
- UF/DF 21 protocols are used for obtaining the Mode A identity of an aircraft and for transferring data.
- UF/DF 24 protocol is used for only transferring data.
- All these protocols have a data block length of 112-bit.
- UF 20 & 21 provide a data transference service (56-bit data field) from ground stations to aircraft using SLM (Standard Length Message) protocol and COMM-A (uplink) format.
- DF 20 & 21 provide a data transference service (56-bit data field) from aircraft to ground stations using SLM (Standard Length Message) protocol and COMM-B (downlink) format.
- UF 24 provides an extended data transference service (80-bit data field) from ground stations to aircraft using ELM (Extended Length Message) protocol and COMM-C (uplink) format.
- DF 24 provides an extended data transference service (80-bit data field) from aircraft to ground stations using ELM (Extended Length Message) protocol and COMM-D (downlink) format.

II.5.2.2. GICB Protocol:

GICB (Ground Initiated Comm-B) protocol is used to extract the contents from any of the predefined BDS registers of a Mode-S transponder (Special Downlink SLM protocol).

The request is performed by the ground station via selective surveillance (UF4/5) or COMM-A (UF20/21) interrogations. In any case, the transponder always replies using a COMM-B protocol (DF20 or 21), which will correspond with the received uplink format (UF4/20 or UF5/21, respectively). [1]

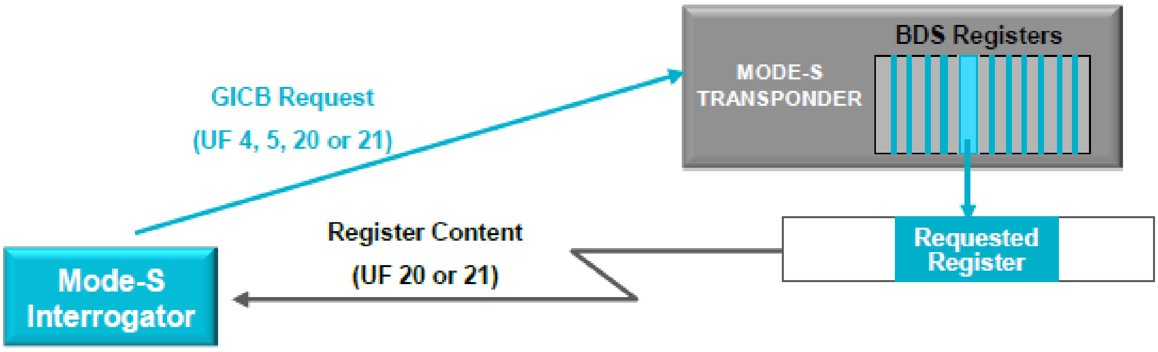


Figure II.3: GICB protocol [1]

II.5.2.3. AICB Protocol:

AICB (Air Initiated Comm-B) protocol allows that an aircraft requests the extraction of certain parameters of its BDS registers, when an interrogation of either selective surveillance (UF4/5) or COMM-A (UF20/21) is received (Downlink SLM protocol).

This request is performed via the corresponding reply (DF4, 5, 20 or 21) and enabling an internal AICB flag. Finally, the transponder sends the requested information, using the COMM-B protocol (DF20 or 21) corresponding with the uplink format received in a second interrogation (either UF4/20 or UF5/21, respectively). [1]

II.5.2.4. Data Block Structure "Uplink (UF) & Downlink (DF)":

The previous mode S link formats are transformed into a data block which is structured as follows:

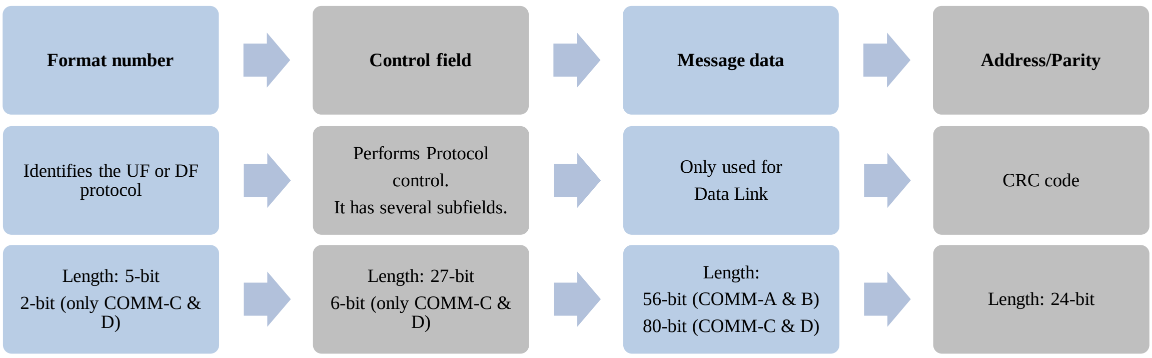


Figure II.4: Data block structure [1]

II.5.2.4.1. Format Number:

- It is normally a 5-bit field, except to identify a COMM-C or COMM-D protocol (it would be 2-bit with binary value equal to 1).
- It identifies the UF or DF protocol.
- ICAO defines 25 possible link formats, but only 6 formats are currently used for Mode-S (UF/DF: 4, 5, 11, 21, 22 and 24).

II.5.2.4.2. Control Field:

- It has normally 27-bit, except when the protocol corresponds with COMM-C or COMM-D (it would have 6-bit).
- Depending on the protocol used, it is divided in different subfields with different length.
- The different subfields are used to perform the protocol control.

II.5.2.4.3. Message Data:

- Only used by data link
- It can have two different length depending on the data link protocol used: 56-bit (COMM-A & B) or 80-bit (COMM-C & D).

II.5.2.4.4. CRC (Cyclic Redundancy Code):

- This code is determined by using a polynomial and the Aircraft Address (AA), except in the case of an All-Call interrogation (UF11) that uses 24 binary '1' as AA.
- The CRC code of a UF protocol is used by transponders to detect interrogation error. The interrogation is only accepted when no error is detected.
- The CRC code of a DF protocol is used by ground stations to detect and correct reply error.

II.5.3. Interrogator-Transponder Interoperability:

As in radar there are several modes (Mode A, Mode C, Intermode & Mode S; we have two modes in the transponder which are: Mode A/C (SSR) & Mode S.

Interoperability is the transponder's ability to respond to an interrogation mode.

II.5.3.1. Mode A & C Interrogations:

- Both types of transponder, SSR and Mode-S, reply using the corresponding SSR downlink format (Mode A or Mode C).

II.5.3.2. Intermode A & C Interrogations with short P4:

- Only SSR transponders reply using the corresponding SSR downlink format (Mode A or Mode C).

II.5.3.3. Intermode A & C Interrogations with long P4:

- SSR transponders reply using the corresponding SSR downlink format (Mode A or Mode C).
- Mode-S transponders reply using Mode-S only All-Call reply (DF11), putting a zero value in their Aircraft Address.
- ICAO doesn't recommend the use of Intermode A/C with long P4, to avoid the overlap of Mode A/C and Mode-S replies.

II.5.3.4. Mode-S Interrogations:

- Only Mode-S transponders reply using the corresponding downlink format.

INTERROGATION MODE	TYPE OF TRANSPONDER: Mode A/C (SSR)	TYPE OF TRANSPONDER: MODE-S
Mode A	Mode A reply	Mode A reply
Mode C	Mode C reply	Mode C reply
Intermode A Short P4	Mode A reply	No Reply
Intermode C Short P4	Mode C reply	No Reply
Intermode A Long P4	Mode A reply	Mode-S reply
Intermode C Long P4	Mode C reply	Mode-S reply
Mode-S Short P6	No Reply	Mode-S reply
Mode-S Long P6	No Reply	Mode-S reply

Table II.3: Interrogator/Transponder interoperability [1]

II.5.4. All-Call & Surveillance Processes:

II.5.4.1. Identifiers:

II.5.4.1.1. Interrogator Code (IC):

Each Mode-S interrogator operates using an Interrogator Code (IC), that code can be reallocated to other Mode-S interrogators if necessary, but two or more interrogators cannot operate with the same IC if they have overlapped coverages.

There are two types of IC: II-Code (Interrogator Identifier) and SI-Code (Surveillance Identifier):

- II-Code uses 4-bit to define the code, allowing up to 16 II-Codes (from 0 to 15).
- SI-Code uses 6-bit and allows up to 63 SI-Codes (from 1 to 63), but not all current Mode-S transponders detect this code.

The II/SI Code is included by interrogators in the Mode-S only All-Call interrogations (UF11) and by aircraft transponders in the corresponding reply (DF11).

The II-Code equal to ‘0’ is used to identify special interrogators which don’t use selective interrogations. [1]

II.5.4.1.2. Aircraft identifier (ICAO address):

Each aircraft Mode-S transponder uses a unique ICAO address (24-bit code), which is allocated by the responsible authority.

A Mode-S transponder replies to Mode-S only All-Call interrogations (UF11) indicating the II/SI Code of the interrogator that sent the interrogation and its ICAO address.

- A Mode-S transponder only replies to selective interrogations that have its ICAO address which is contained in the CRC code.
- The ICAO address is used in the selective uplink and downlink formats to generate the corresponding CRC code.

II.5.4.2. Interrogations"EUROCONTROL Limitations":

If radar system is working in SSR mode, PRF is limited between 50 and 450 interrogations per second but in Mode-S, the number of interrogation periods is limited up to 12 inside an antenna beam width, where all types of interrogations must be done (All-Call and Roll-Call). Mode-S All-call interrogations are limited to a maximum of 250 interrogations per second (All-call period repetition frequency for Mode-S is usually between 40 Hz and 150 Hz). [1]

II.5.4.3. Interrogations « Strategy »:

A Strategy is a sequence of interrogation periods programmed by an operator of a Mode-S Interrogator system. During the rotation of a Mode-S radar antenna, two different interrogation periods can be distinguished, one called All-Call and another one Roll-Call.

Eurocontrol specifies as a Basic Strategy, the alternating of both interrogation periods, All-Call and Roll-Call. [1]

Period	Interrogation modes
All-Call	Mode A/C Mode A/C/S (Intermodes) Mode S only All-Call (UF 11) Mix (UF 11 & Intermode with short P4)
Roll-Call	Selective Mode S (UF: 4, 5, 20, 21 or 24)

Table II.4: Alternating of All-Call and Roll-Call interrogation periods (Basic Strategy)

II.5.4.3.1. All-Call:

The All-Call period is used by Mode-S radars for detection and surveillance of SSR Transponders and acquisition of Mode-S Transponders: during All-Call periods, a Mode-S ground station can use the following interrogation protocols:

- Mode A/C.

- Mode A/C/S (Intermodes).
- Mode-S Only All-Call (UF 11).
- Mix (UF11 & Intermode with short P4).

II.5.4.3.2. Roll-Call:

The Roll-Call period is used for selective surveillance and/or data transference with Mode-S Transponders: during Roll-Call periods, a Mode-S ground station can use the following interrogation protocols:

- Selective Mode-S (UF: 4, 5, 20, 21 or 24).

II.5.4.4. Lockout protocol:

Lockout protocol is an effective strategy to decrease Fruit & Garbling issues during All-call Periods, and improve the acquisition probability.

Targets that have been acquired in the all-call period are subsequently selectively interrogated for surveillance information in the Roll-Call period. Therefore, a Mode-S interrogator can apply lockout on them to avoid they reply to its all-call interrogations.

Lockout protocol can only applied on acquired transponders by means of selective interrogations (UF4, UF5, UF20 & UF21).

A Mode-S Transponder only doesn't reply to Mode-S only All-Call interrogations that have been sent from an interrogator which locked it, an interrogator is identified by transponders through its IC code (II/SI code).

The transponder is locked out for a period of 18 seconds (internal timer).

An interrogator will normally reset the lockout timer by using all selective surveillance interrogations, to assure the acquired transponders don't reply during their flight inside its coverage. [1]

Lockout override:

Sometimes, a Mode-S interrogator can do that a Mode-S transponder ignores its lockout, if necessary. [1]

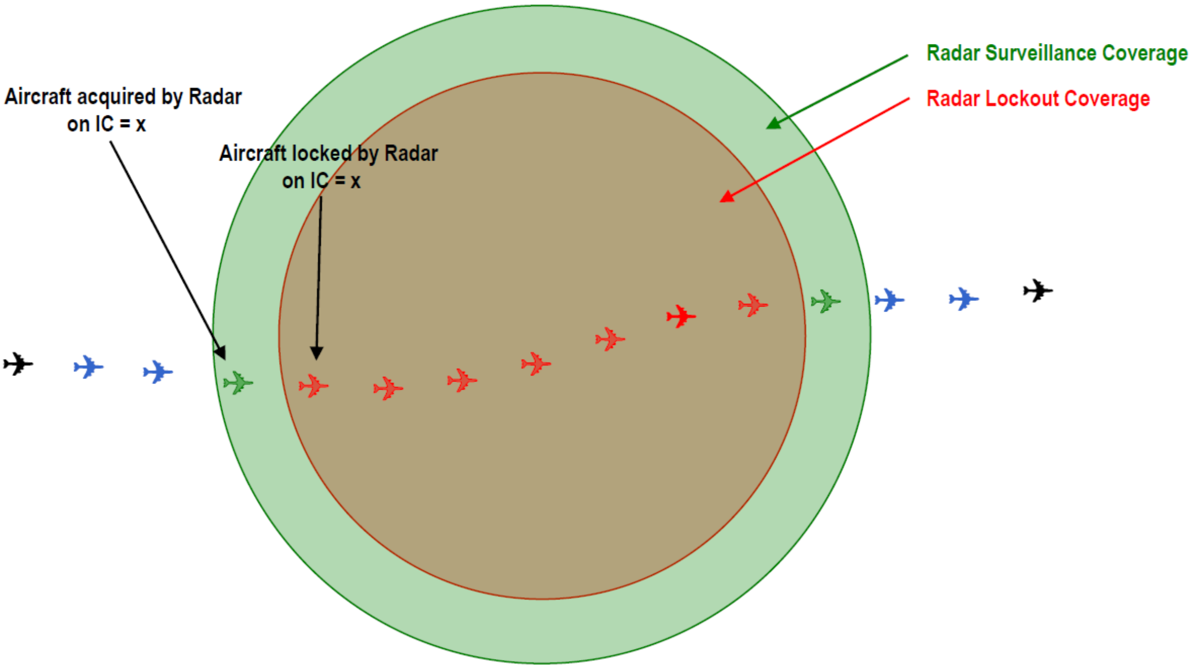


Figure II.5: Aircraft acquisition, selective interrogations and lock-out [1]

- Aircraft not in line of sight of radar or not in power budget (black color):
  - Does not receive All-Call interrogations (broadcast)
- Aircraft outside surveillance coverage (blue color):
  - Receives All-Call interrogations (broadcast) and replies, but replies not processed by radar
- Aircraft acquired by radar in surveillance coverage (green color):
  - Selective interrogations (Roll-Call)
  - Not locked: receive All-Call interrogations and replies
- Aircraft locked by radar in lockout coverage (red color):
  - Does not reply to All-Call interrogations

II.5.5. Uplink Formats:

II.5.5.1. SSR Modes:

This is equivalent to conventional SSR interrogations (already explained in the previous chapter).

Main features:

- Modes 1, 2, A & C
- Modes B & D are not used
- Modes A & C: used in Civil ATC
- P1 & P3: transmitted on SUM
- P2: transmitted on OMNI (ISLS)

- P1 & P2: transmitted on OMNI (IISLS)
- P1-P3 separation: 8.0 (A) or 21.0 (C) ± 0.2 µsec
- P1-P2 separation: 2.0 ± 0.15 µsec
- Pulse width: 0.8 ± 0.1 µsec

II.5.5.2. Intermodes (Mode A/C/S):

An Intermode interrogation consist of three pulses called P1, P3 and P4**,** which are transmitted on the SUM antenna pattern. The P1 & P2 pulses are sent together on the OMNI (Control) antenna pattern to perform IISLS function.

The interval between P1 and P3 determines the mode of interrogation:

- Intermode A: 8 ± 0.2 µsec.
- Intermode C: 21 ± 0.2 µsec.

The P4 pulse is always transmitted 2 ± 0.05 µsec after the P3 pulse and the P2 pulse is always transmitted 2 ± 0.15 µsec after the P1 pulse.

The features of the pulses P1, P2, P3 and short P4 are:

- The pulse duration is 0.8 ± 0.1 µsec.
- The rise time is between 0.05 and 0.1 µsec.
- The fall time is between 0.05 and 0.2 µsec.

The features of the long P4 pulse are:

- The pulse duration is 1.6 ± 0.1 µsec.
- The rise time is between 0.05 and 0.1 µsec.
- The fall time is between 0.05 and 0.2 µsec.

Mean features:

- Intemodes A & C
- P1 & P3: transmitted on SUM
- P2: transmitted on OMNI (ISLS)
- P1 & P2: transmitted on OMNI (IISLS)
- P1-P3 separation: 8.0 (A) or 21.0 (C) ± 0.2 µsec
- P1-P2 separation: 2.0 ± 0.15 µsec
- Pulse width (P1, P2 & P3): 0.8 ± 0.1 µsec
- Short P4 width: 0.8 ± 0.1 µsec
- Long P4 width: 1.6 ± 0.1 µsec

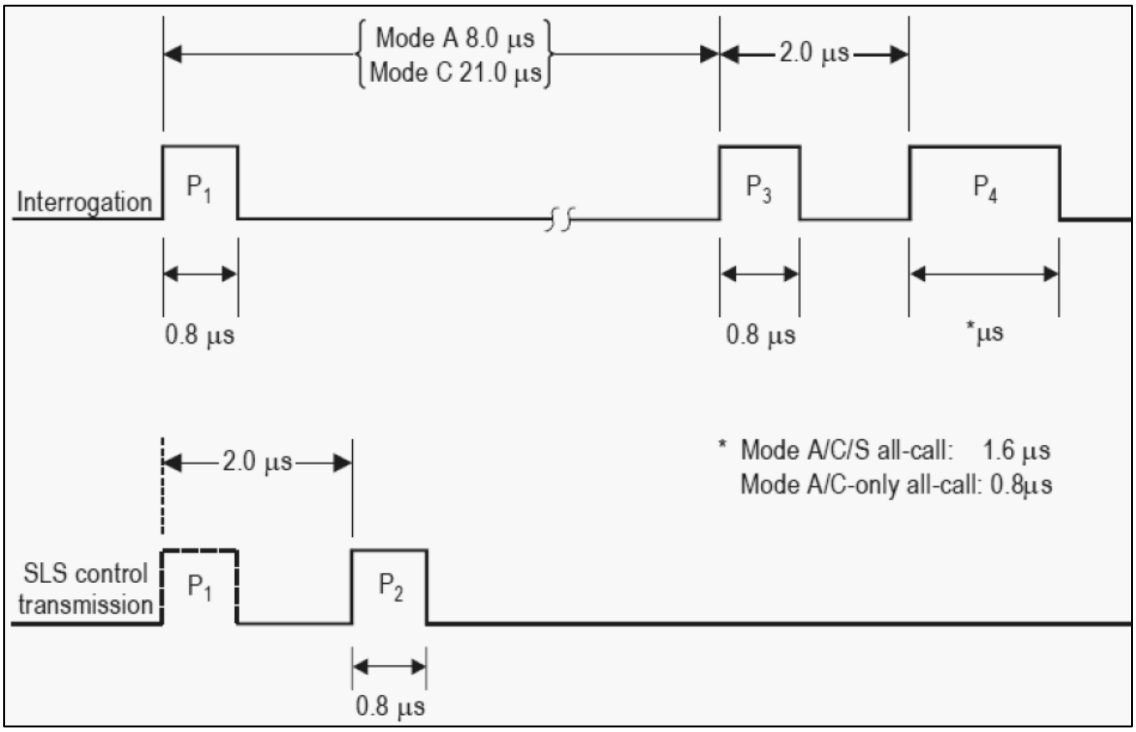


Figure II.6: Waveforms of mode A/C/S [1]

II.5.5.3. Mode-S:

Mode S is a Secondary Surveillance Radar process that allows selective interrogation of aircraft according to the unique 24-bit address assigned to each aircraft.

Mean features:

- P1, P2 & P6: transmitted on SUM
- P5: transmitted on OMNI (ISLS)
- P1 & P2: suppress Mode A/C Transponders
- P6: data block (DPSK Modulation)
- SPR: Sync Phase Reversal
- P1-P2 separation: 2.0 ± 0.15 µsec
- P2-SPR separation: 2.75 ± 0.05 µsec
- P6-SPR separation: 1.25 ± 0.05 µsec
- P5-SPR separation: 0.4 ± 0.05 µsec
- SPR-1st chip separation: 0.5 µsec
- Pulse width (P1, P2 & P5): 0.8 ± 0.1 µsec
- Short P6 width: 16.25 ± 0.25 µsec
- Long P6 width: 30.25 ± 0.25 µsec
- Chip width: 0.25 µsec
- Number of Chips (short P6): 56
- Number of Chips (long P6): 112

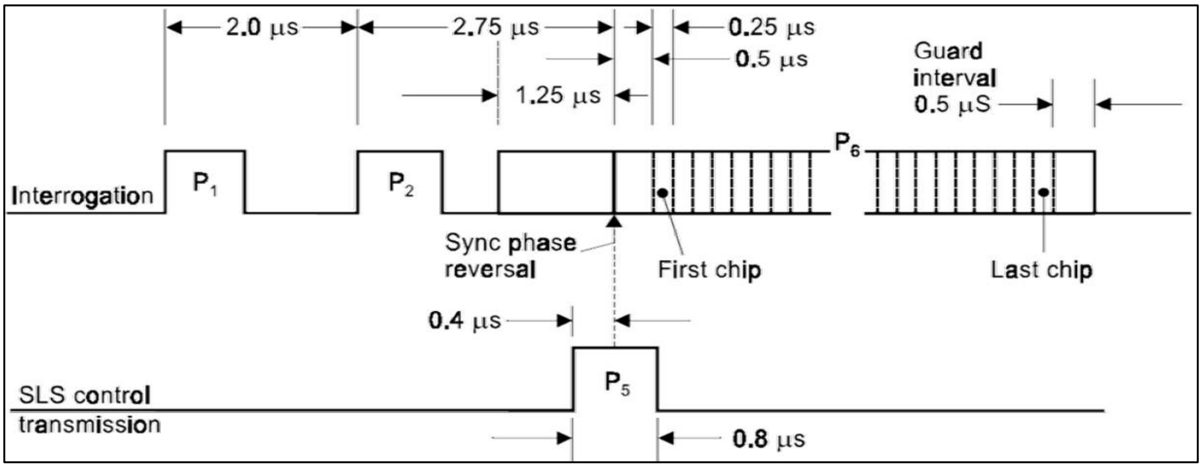


Figure II.7: Waveforms of Mode S [1]

Waveforms of Mode S:

- A Mode-S interrogation consist of three pulses called P1, P2 and P6, which are transmitted on the SUM antenna pattern.
- A pulse called P5 is sent on the OMNI (Control) antenna pattern to perform ISLS function.
- The P2 pulse is always transmitted 2 ± 0.15 µsec after the P1 pulse.
- The interval of time between P2 and SPR (Sync Phase reversal) is 2.75 ± 0.05 µsec.
- The interval of time between P6 and SPR (Sync Phase reversal) is 1.25 ± 0.05 µsec.
- The interval of time between P5 and SPR (Sync Phase reversal) is 0.4 ± 0.05 µsec.
- The features of pulses P1, P2 and P5 are:
  - The pulse duration is 0.8 ± 0.1 µsec.
  - The rise time is between 0.05 and 0.1 µsec.
  - The fall time is between 0.05 and 0.2 µsec.
- The features of short P6 pulse are:
  - The pulse duration is 16.25 ± 0.25 µsec.
  - The rise time is between 0.05 and 0.1 µsec.
  - The fall time is between 0.05 and 0.2 µsec.
- The features of long P6 pulse are:
  - The pulse duration is 30.25 ± 0.25 µsec.
  - The rise time is between 0.05 and 0.1 µsec.
  - The fall time is between 0.05 and 0.2 µsec.
- The features of Chips are:
  - The width is 0.25 µsec.
  - The number of chips for a short P6 is 56.
  - The number of chips for a long P6 is 112.

II.5.5.4. Mode-S (ISLS):

Interrogator Side Lobe Suppression is a technique used to avoid reply generation to interrogations by side lobes.

A pulse, called P5, is sent by Mode-S interrogators on the OMNI (Control) antenna pattern to perform ISLS function.

If this pulse interferes the detection of the SPR (Sync Phase Reversal) in the P6 pulse of the interrogation, the transponder cannot decode the interrogation data block and subsequently no reply is generated.

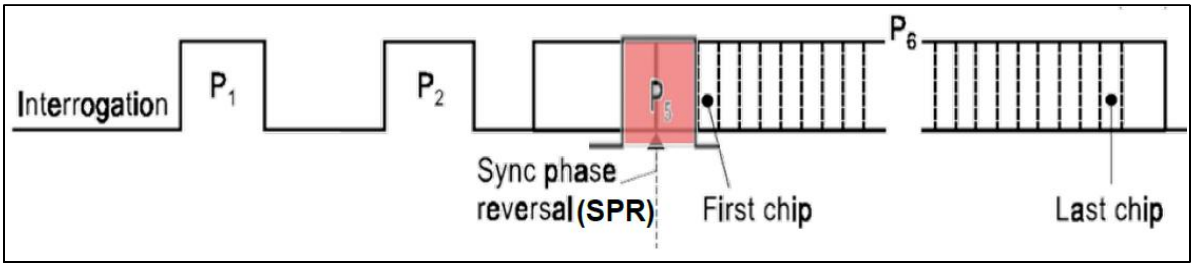


Figure II.8: ISLS waveforms [1]

II.5.6. Downlink Formats:

I1I.5.6.1. SSR reply:

This is equivalent to conventional SSR reply (already explained in the previous chapter).

Mean feautures:

- F1 & F2: framing pulses
- A, B, C & D: code pulses (octal code)
- X pulse: not used
- SPI pulse: only Mode A (optional)
- F1-F2 separation: 20.3 ± 0.1 µsec
- F2-SPI separation: 4.35 ± 0.1 µsec
- Separation between code pulses: 1.45 ± 0.15 µsec
- Pulse width: 0.45 ± 0.1 µsec

II.5.6.2. Mode-S Reply:

Mean features:

- Preamble: 4 pulses (PP1, PP2, PP3 & PP4)
- Data block: 56-bit (short reply) or 112-bit (long reply)
- Data block modulation: PPM Modulation
- PP1-PP2 separation: 1.0 ± 0.05 µsec
- PP1-PP3 separation: 3.5 ± 0.05 µsec
- PP1-PP4 separation: 4.5 ± 0.05 µsec
- PP1-Bit1 separation: 8.0 µsec

- Bit duration: 1.0 µsec
- Data block pulse width: 0.5 or 1.0 ± 0.05 µsec
- Data block lenght: 56 (short reply) or 112 (long reply) µsec

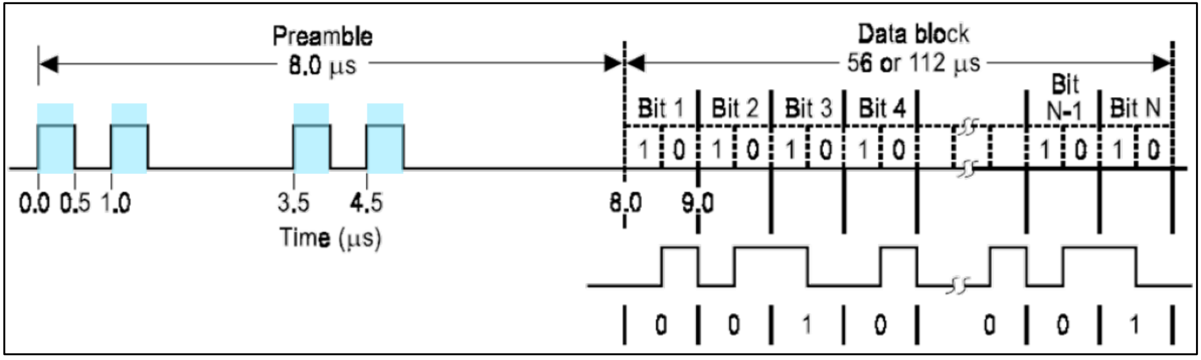


Figure II.9: Mode S reply waveforms [1]

Waveforms if Mode S reply:

- An Mode-S reply consists of a preamble and a data block.
- The preamble has 4 pulses. These pulses are spaced each other as follows:
  - PP1-PP2 : 1.0 ± 0.05 µsec
  - PP1-PP3 : 3.5 ± 0.05 µsec
  - PP1-PP4 : 4.5 ± 0.05 µsec
- The features of the preamble pulses are:
  - The pulse duration must be 0.5 ± 0.05 µsec.
  - The rise time must be between 0.05 and 0.1 µsec.
  - The fall time must be between 0.05 and 0.2 µsec.
- The data block has a number of bits of 56 (short reply) or 112 (long reply).
- The information inside the data block is modulated in PPM modulation (Pulse Position Modulation), which divides each Bit duration in two parts to define a value '0' or '1'.
- A value '0' has a low level in the first part, and a high level in the other one. The value '1' is the opposite case.
- The first Bit is spaced from the first preamble pulse in 8.0 µsec.
- The duration of each Bit is 1.0 µsec.
- The features of the data block pulses are:
  - The pulse duration must be 0.5 or 1.0 ± 0.05 µsec.
  - The rise time must be between 0.05 and 0.1 µsec.
  - The fall time must be between 0.05 and 0.2 µsec.

II.6. MSSR Mode S station:

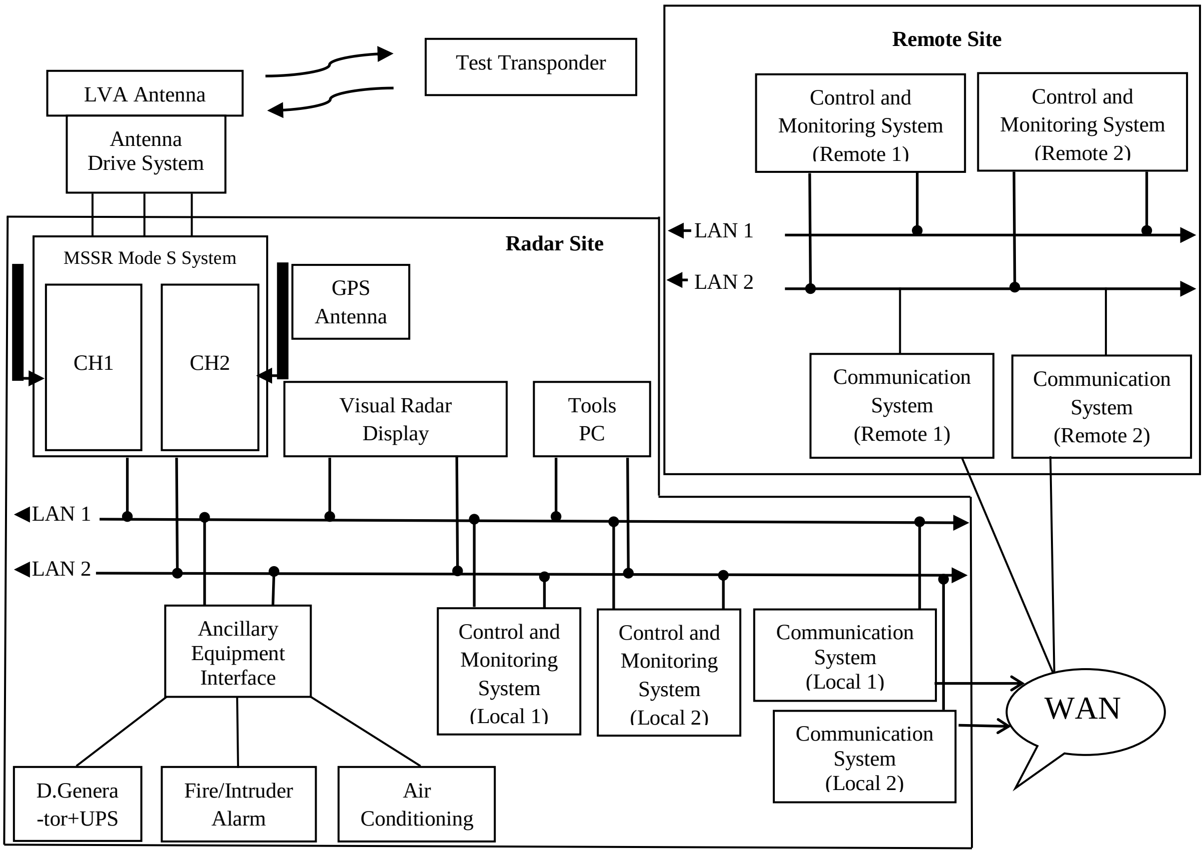


Figure II.10: MSSR Mode S station [1]

In an Area Control Center we will find in a radar station: a radar site and a remote site.

- **Radar site:** regroups the radar equipment of the region (such as the radar of Algiers in the Algiers ACC).
- **Remote site:** for the control and supervision of all stations in Algeria and also to extract data from all radars to see a complete radar image.

Notes:

- In the radar site we use the local word (i.e. the equipment that is linked to the station in the region).
- In the remote site we use the word remote (i.e. all the stations in Algeria)
- Each equipment must be dual either in the radar site or in the remote site for redundancy (in case of failure).

II.6.1. LVA Antenna:

An LVA (Large Vertical Aperture) antenna consists of a number of columns (each column is a vertical linear array of radiating elements) arranged in a horizontal linear array to produce a front two-dimensional beam.

II.6.2. Antenna drive system:

It's an antenna movement control system, it contains:

- Two electric rotating motors to turn the Antenna (6 rpm).
- Encoder to get true north
- Rotating joint

II.6.3. MSSR Mode S system:

These main functions are the transmission of interrogations (the modes) and the reception of aircraft responses and transform them into Asterix messages.

II.6.4. Visual radar display:

Produces a visual indication of echoes on a screen in order to derive certain information about targets.

II.6.5. Tools PC:

Use to save the data displayed in visual radar display

II.6.6. LAN:

Acronym for local area network, it is a local computer network linking the equipment in the two sites: radar site, remote site.

II.6.7. Ancillary equipment interface:

Diesel Generator: It is used in case we have a problem in the electricity sector (absence of electricity, disturbance and instability of electricity).

UPS (inverter): The inverter is used to stabilize the electricity to protect the radar station equipment, it also plays a very important role in the absence of electricity because it replaces the diesel generator during the response time of the diesel generator.

Fire/Intruder Alarm: For protection against fires and break-ins.

Air Conditioning: To put the metrological condition in the station under ambient conditions.

II.6.8. Control and Monitoring System:

Its role is to supervise and control the system's behavior in order to guarantee reliable and safe operations. It can monitor in real time the data received from the computer nodes, equipment and software functions that are installed either in the radar sites or in the ATC control room, there are two types of the control and monitoring system:

Local: supervises only the station equipment.

Remote: supervises the equipment of all stations in Algeria.

II.6.9. Communication System:

Use to transfer radar data to different users such as air traffic controllers, technical room...

It is also used to combine MSSR & PSR plots (when we have in a single station a couple of PSR & MSSSR)

II.6.10. GPS Antenna:

The role of the GPS Antenna (receiver) is the synchronization between the different components of the radar system.

II.6.11. WAN:

Acronym of Wide Area Network, is a computer network or a telecommunications network covering a large geographical area, typically on the scale of a country, it is used to link the two sites: radar site, remote site.

II.7. Chapter conclusion:

After this chapter we have a good understanding of the Mode S technology that we will install in Algeria (ENNA 2020 Project).

As Mode S is very rich in information it requires a Protocol to extract the information we need; it's the Asterix protocol which is our next chapter.

Chapter III:

ASTERIX Protocol

Abstract:

In this chapter we will study and explain the Asterix "All Purpose Structure Eurocontrol Surrveillance Information Exchange" protocol according to: importance, network side, the Asterix message.

First we had made an introduction on the Asterix protocol and its importance, then we gave an architecture of the Mode-S Radar Network communications and we explained it, after that we explained the Asterix protocol.

At the end we well detailed the category 048 of the Asterix message plus a conclusion of the results found in this chapter.

III.1. Introduction:

A few years ago, each radar manufacturer implemented closed technologies, so that the concept of system integration was very difficult to achieve; this changed with the emergence of new standards from the regulatory bodies of this type of service (ICAO, EUROCONTROL and FAA), so that “open” data transmission codes have been developed for radar systems. One of the most widely used open codes worldwide is Eurocontrol's Asterix.

The Eurocontrol Asterix Protocol is a standard protocol designed by EUROCONTROL for the exchange of information between radar sensors and control centers, its acronym corresponds to "All Purpose Structure Eurocontrol SurRveillance Information Exchange", which means Eurocontrol's All Purpose Structure for Surveillance Information Exchange.

This protocol encodes the information related to the aircraft detected by a radar, within a data transmission frame that can be perfectly transmitted in a LAN type network. [6]

III.2. Architecture of the Mode-S Radar Network communications:

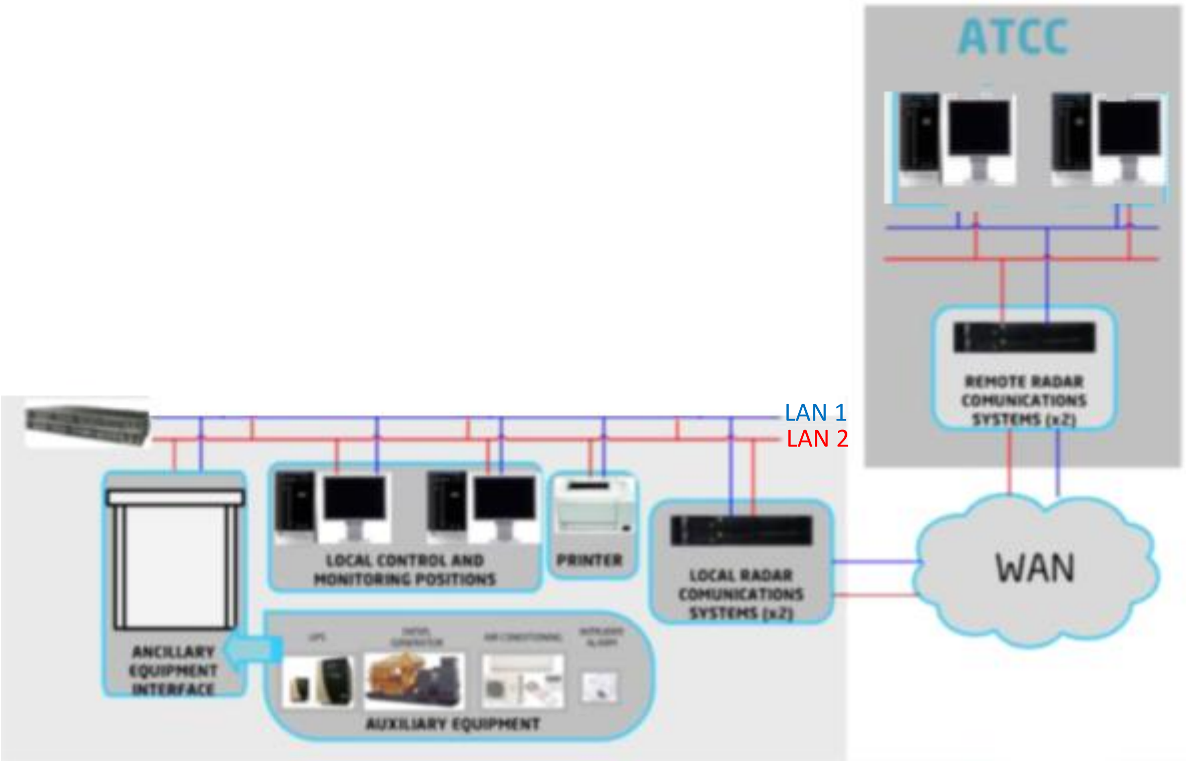


Figure III.1: Architecture of the Mode-S Radar Network communications [7]

III.2.1. Networks for Radar:

As with other industries, the aviation industry's existing non-IP networks for radar data and the associated infrastructure can be considered obsolete. The networks still work, but they are slow, and expensive to maintain. There is just too much communication equipment from different companies, many of them long gone, and a declining knowledge of how to maintain this equipment.

IP networks (intranets) are already in place. They are faster, cheaper and easier to maintain. Systems creating radar data often use synchronous interfaces and protocols compatible with the legacy networks. Replacing or upgrading these systems is expensive.

The aviation industry uses Eurocontrol's Asterix (All Purpose Structured Eurocontrol Surveillance Information Exchange) block data structures for Radar Data, an OSI presentation layer and independent of the underlying transport protocol. That largely simplifies the protocol exchange: the PXSe extracts the Asterix blocks from the synchronous protocol BSC, HDLC, LAPB, X.25 and forwards it via UDP or TCP/IP. (Because TCP is a character streaming protocol, the first 2 header bytes define the frame length. It is also possible using the length field of the Asterix protocol).[8]

III.2.2. LAN Radar computer:

If there is a local office associated with the radar, there may be a local area network (LAN) for linking workstations, computers and peripherals. The LAN will often provide access to other data bases, such as satellite or upper air, as well as radar. An Ethernet LAN has a bandwidth of (10 MBits/sec) which is usually adequate to service personnel at a local office. In addition, the LAN serves to connect the radar host computer to the wide area network (WAN). In the absence of a LAN, the radar host computer can perform the functions of the LAN. However, there is a performance impact when the radar host computer also handles the low-level communications tasks.

In summary, the communications bandwidth of the LAN provides a great deal of flexibility in deciding which networked processor actually performs the product generation.

To have this flexibility, the radar host computer, compute server and local user workstations should be compatible so that they can run the identical product generation software. [9]

III.2.3. WAN Radar computer:

Ideally, the wide area network is used for communicating many different kinds of data and forecast products including radar, satellite, surface, upper air, forecasts, model products, etc.

The costlbandwidth tradeoff determines the extent to which it is possible to integrate the communication of these various types of products. [9]

III.2.4. HDLC protocol:

The HDLC protocol is a link layer protocol of the OSI Model derived from SDLC (Synchronous Data Link Control). Its purpose is to define a mechanism to delimit frames of different types, adding an error control. It has been developed by the International Organization for Standardization "ISO". It is based on the ISO 3309 and ISO 4335 standards and supports half-duplex and full-duplex communication lines, point-to-point (peer-to-peer) and multipoint networks as well as switched and unswitched channels.

There are three categories of frames:

- Information frames transport data across the link and may encapsulate the higher layers of the OSI architecture.
- Supervisory frames perform the flow control and error recovery functions.
- Unnumbered frames provide the link initialization and termination.

1 byte	1-2 bytes	1 byte	variable	2 byte	1 byte
Flag	Address field	Control field	Information	FCS	Flag

Figure III.2: HDLC Protocol Structure

III.2.4.1. The Flag:

Field indicates the edges of the frame (beginning and end).

III.2.4.2. Address:

Is that of the recipient to whom the frame is sent.

III.2.4.3. The Command:

Field indicates the type of frame. There are three types of frames:

- Information frames ("I" Information).
- Supervisory frames ("S" Supervisory).
- Unnumbered frames ("U" Unnumbered).

III.2.4.4. The Data (information):

Is an optional field of variable length and contains the data to be sent.

III.2.4.5. The FCS:

Is a code added after the data to detect possible transmission errors, it is usually 16 bits long.

III.3. Asterix Protocol:

Asterix protocol defines a standard structure of the information that will be exchanged in a communication network, from encoding each bit of information to organizing the data within a data block. These transitions can make use of any available means of communication, such as LAN, Internet Protocols (IP), WANs, etc. For these transmissions, the data elements are grouped into ASTERIX categories. There are currently 256 different types of categories. [11]

III.3.1. Objectives of Eurocontrol's Asterix Protocol:

Asterix allows to implement the easy exchange of surveillance data within and between countries which has always been the main objective of air traffic control (ATC). Asterix is one of Eurocontrol's most widely used open codes worldwide, which facilitates system integration and the exchange of radar data between different regions, thereby strengthening air traffic control safety, its purpose is to enable a meaningful transfer of information between two application entities using a standard representation of the data being exchanged.

Asteirx message transmission can make use of any available communication means, e.g. synchronous/asynchronous serial lines, LAN (TCP/IP, UDP/IP), etc. The definition of the lower communication layers is outside the scope of the standard, which will be agreed between the data exchange entities. [11]

III.3.2. Asterix Data Organization:

The ASTERIX structure is based on the following basic concepts:

III.3.2.1. Data Categories:

The data to be exchanged on a medium between different users must be standardized and classified into categories. This is the information that can be transmitted and coded, whose data will be standard for all Asterix users.

The purpose of this classification is to facilitate the: identification of the data, the sending of the data and the establishment of a certain hierarchy based on its priority. [11]

Up to 256 data categories can be defined, according to the following classification and their use:

- Categories from 000 to 127 for standard civil and military applications.
- Categories from 128 to 240 reserved for special military applications.
- Categories from 241 to 255 for non-standard civil and military applications.

Data Categories Examples:

Category 001: Radar target information from a headend to a radar data processing system.

Category 002: Radar service messages.

Category 034: New version of Cat 002, SSR Mode S.

Category 048: New version of Cat 001 and Cat 016, SSR Mode S.

III.3.2.2. Data Item:

It is the smallest unit of information in each category. For each category, a set of Data Items is defined that constitutes the Data Item catalog. Applications that involve the exchange of information from a certain data category will make use only of the standardized Data Items in the catalogue. Each Data Item has a unique reference that uniquely identifies it. The symbolic reference consists of eight characters as follows: Innn / AAA, where [11] :

- **I:** indicates that it is a Data Item.
- **nnn:** is a three decimal digit number that indicates the data category to which it belongs.
- **AAA:** is a three decimal digit number that indicates the Data Item number.

Example:

I048/010: Data Source Identifier.

III.3.2.3. Data Field:

Data field is the physical implementation of a Data Item for communications purposes, that is, each Data Item is assigned to a slot called Data Field and have a length equal to an integer number of octets and have a unique Field Reference Number (FRN) assigned.

The correspondence between Data Items and Data Fields is standardized for each application through the User Application Profile. [11]

III.3.2.4. Data Block:

It is a unit of information that contains one or more records, all of which contain information of the same category. [11]

It is composed of :

- A data byte called Category (CAT), indicating to which category the transmitted data belong,
- A 2 octet field indicating the block size (LEN), including the CAT and LEN fields.
- One or more records that contain the data of the same category
- Each record is of variable length but with a defined octet limit. The length will always be a multiple of an octet.

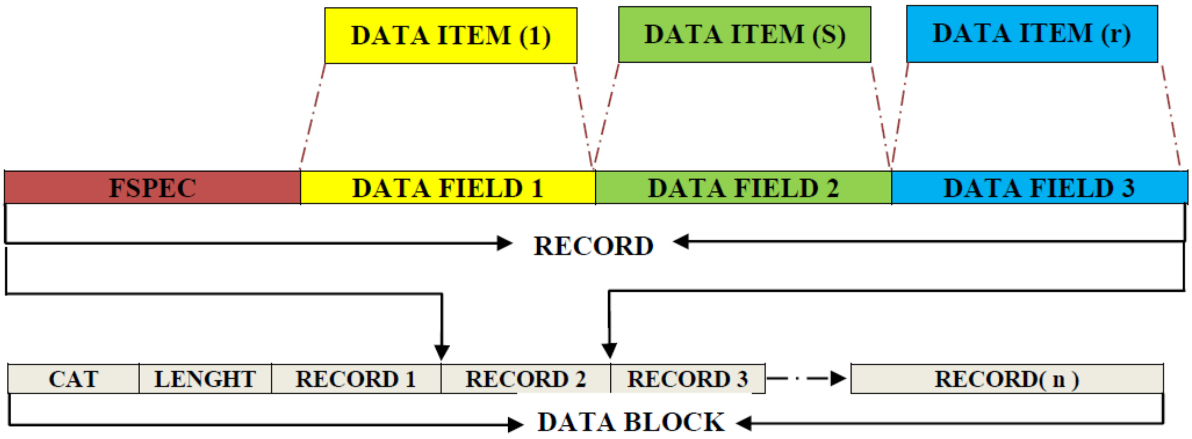


Figure III.3: Structure of an Asterix data block

III.3.2.5. Registers:

It is an ordered set of Data Fields of the same category transmitted within a data block, which is preceded by the Field Specification (FSPEC) field, where the Data Items present are indicated according to the UAP. [11]

A record is constituted by:

III.3.2.5.1. Field Specification (FSPEC):

OFS is the standard method and consists of using FSPEC as a sequential table of contents in the form of bits, where each bit indicates the presence or absence of an assigned Data Field.

FSPEC is a variable number of Data Fields in increasing order of FRN. The relationship between FSPEC bits, Data Fields, and Data Items is in UAP (see figure III.4,5).

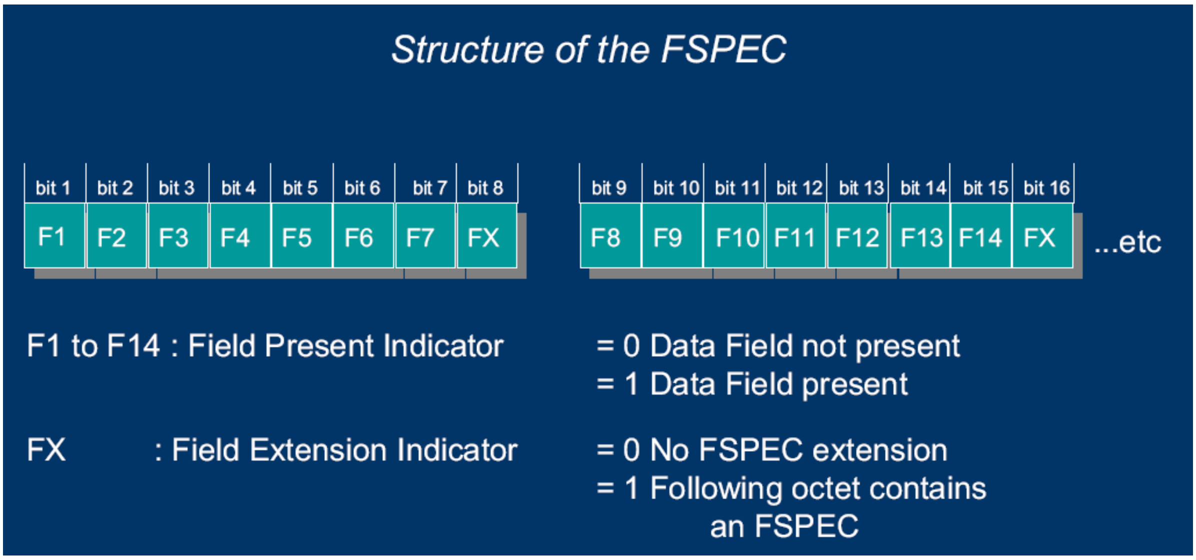


Figure III.4: Structure of the field specification (FSPEC) [6]

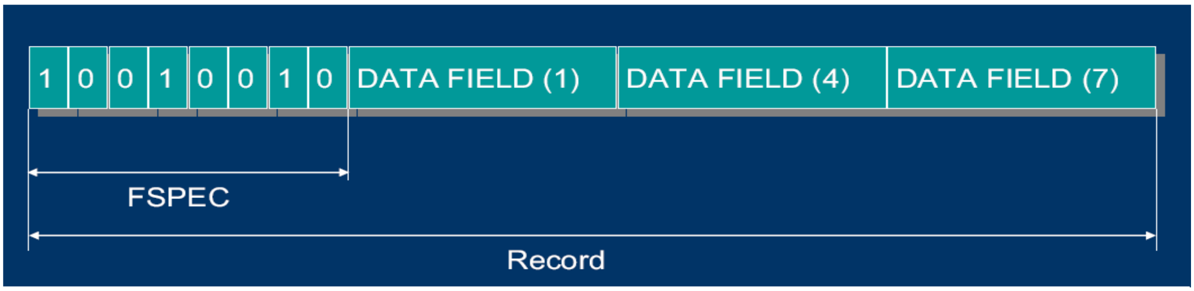


Figure III.5: Example of a one-octet FSPEC [6]

III.3.2.5.2. Field Type Definitions:

a. Fixed Data field:

A data field has a fixed byte size. [11]

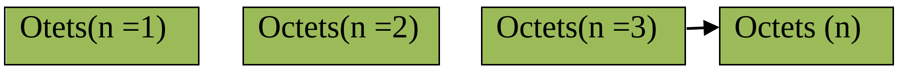


Figure III.6: Format of a fixed field

b. Extended Data field:

It is a data field, which can have a variable size. [11]

The last bit of the byte specifies whether the data field continues or stops:

- If last bit byte = 1 then the field continues.

➢ If last bit byte = 0 then the field stops. [11]

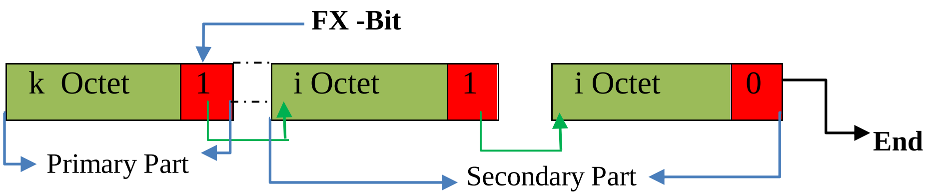


Figure III.7: Format of an extended field

c. Repetitive Data field:

In the data sent, a field may be present "n" times. [11]

- The first byte gives the number of repetitions.
- The following "n" bytes represent "n" fields with different values.

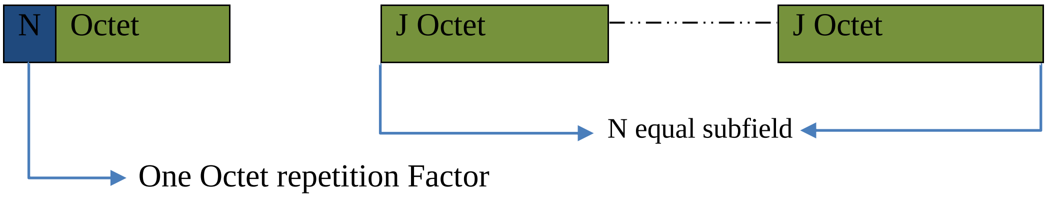


Figure III.8: Format of a repetitive data field

III.3.3. Description of radar data categories:

III.3.3.1. Category 000, Synchronization Messages:

Synchronization messages are used, for example, to provide time-stamped data when composite images of traffic are exchanged between processing systems. [11]

III.3.3.2. Category 001, the radar ratio of targets from a radar surveillance system to a radar data processing system (RDP):

Radar target reports are transactions containing parameters transmitted from a radar surveillance system to a Radar Data Processor (RDP) system.

Runway (track) or block messages or a combination of both can be transmitted.

The data stream is unidirectional from the radar station to the user system(s).

III.3.3.3. Category 002, Radar Service Messages:

Category 002 data transmission allows a radar station to inform its users about its current hardware configuration and processing status.

The data stream is unidirectional from the radar station to the user system(s) and represents the basic data necessary for the proper handling of surveillance radar data on the user side.

III.3.3.4. Category 034, transmission of the messages:

Used for the transmission of the messages of crossings by north or sector. This is a closed category that you should always use in the same format.

III.3.3.5. Category 048, transmission of the messages:

- Future version of cat 01.
- Version directly used by radar mode S.
- Used for the transmission of plots and tracks. This is a closed category that you should always use with the same format.

III.4. CAT 048 Transmission of Monoradar Target Reports:

III.4.1. Description:

The category that would be most useful and that would be present throughout the elaboration of the present project is CAT 048, since everything related to the monitoring and compensation system of the movements of the platform on the extra targets would have repercussions on this category. [11]

According to Eurocontrol specifications for this category, plot and track messages should have the following structure:

CAT = 48	LEN	FSPEC	Data First Recording	FSPEC	Data Ultimate Recording

Figure III.9: Structure for plots and tracks messages, Asterix CAT 048

- **CAT:** Header of an octet length indicating the type of category. In this case it is CAT = 048 since the data block contains target reports.
- **LEN**: Field of length two octets that indicates the total length of the frame, including CAT and LEN fields.
- **FSPEC**: Specification field. It indicates which data items make up the data block of the target.

III.4.2. CAT 048 Message composition :

III.4.2.1. Standard User Application Profile:

The following standard UAP shown in Table III.1 shall be used for the transmission of surveillance data from primary, SSR/ModeS or combined primary-SSR/Mode S radars [11] :

FRN	Data Item	Data Item Description	Length in Octets
1	I048/010	Data Source Identifier	2
2	I048/140	Time-of-Day	3
3	I048/020	Target Report Descriptor	1+
4	I048/040	Measured Position in Slant Polar Coordinates	4
5	I048/070	Mode-3/A Code in Octal Representation	2
6	I048/090	Flight Level in Binary Representation	2
7	I048/130	Radar Plot Characteristics	1+1+
FX	n.a. Field	Extension Indicator	n.a.
8	I048/220	Aircraft Address	3
9	I048/240	Aircraft Identification	6
10	I048/250	Mode S MB Data	1+8*n
11	I048/161	Track Number	2
12	I048/042	Calculated Position in Cartesian Coordinates	4
13	I048/200	Calculated Track Velocity in Polar Representation	4
14	I048/170	Track Status	1+
FX	n.a.	Field Extension Indicator	n.a.
15	I048/210	Track Quality	4
16	I048/030	Warning/Error Conditions	1+
17	I048/080	Mode-3/A Code Confidence Indicator	2
18	I048/100	Mode-C Code and Confidence Indicator	4
19	I048/110	Height Measured by 3D Radar	2
20	I048/120	Radial Doppler Speed	1+
21	I048/230	Communications / ACAS Capability and Flight Status	2
FX	n.a.	Field Extension Indicator	n.a.
22	I048/260	ACAS Resolution Advisory Report	7
23	I048/055	Mode-1 Code in Octal Representation	1
24	I048/050	Mode-2 Code in Octal Representation	2
25	I048/065	Mode-1 Code Confidence Indicator	1
26	I048/060	Mode-2 Code Confidence Indicator	2
27	SP-Data Item	Special Purpose Field	1+1+
28	RE-Data Item	Reserved Expansion Field	1+1+
FX	N.A.	FIELD EXTENSION INDICATOR	N.A.

Table III.1 : Standard UAP [10]

In the above table:

- The first column indicates the Field Reference Number (FRN) associated to each Data Item used in the UAP.
- The fourth column gives the format and the length of each item, a stand-alone figure indicates the octet-count of a fixed-length Data Item, 1+ indicates a variable-length Data Item comprising a first part of 1 octet. followed by n-octets extents as necessary.

III.4.2.2. Description of standard data elements:

III.4.2.2.1. Item I048 / 010, Data source identifier:

The Data Source Identifier is the identification of the radar station from which the information is received. It has a size of two octets (16 bits) and must be present in all ASTERIX packets.

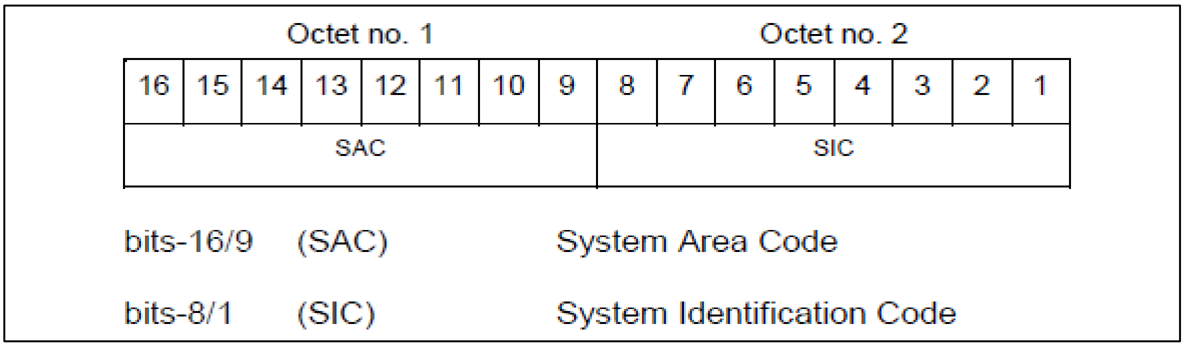


Figure III.10: Structure of the Data Source Identifier [10]

III.4.2.2.2. Item I048 / 020, target report descriptor:

The Target Report Descriptor specifies the type and properties of the target report. The size of the data item is variable, since it is composed of a first part of an octet and a second part (if necessary) of another octet.

Octet no. 1

8	7	6	5	4	3	2	1
TYP			SIM	RDP	SPI	RAB	FX

bits-8/6	(TYP)	= 000	No detection
		= 001	Single PSR detection
		= 010	Single SSR detection
		= 011	SSR + PSR detection
		= 100	Single ModeS All-Call
		= 101	Single ModeS Roll-Call
		= 110	ModeS All-Call + PSR
		= 111	ModeS Roll-Call +PSR
bit-5	(SIM)	= 0	Actual target report
		= 1	Simulated target report
bit-4	(RDP)	= 0	Report from RDP Chain 1
		= 1	Report from RDP Chain 2
bit-3	(SPI)	= 0	Absence of SPI
		= 1	Special Position Identification
bit-2	(RAB)	= 0	Report from aircraft transponder
		= 1	Report from field monitor (fixed transponder)
bit-1	(FX)	= 0	End of Data Item
		= 1	Extension into first extent

Figure III.11: **First part of the Target Report Descriptor.**

The structure of the optional second octet can be seen in Figure III.12:

Octet no. 1

8	7	6	5	4	3	2	1
TST	0	0	ME	MI	FOE/FRI		FX

bit-8	(TST)	= 0	Real target report
		= 1	Test target report
bits-7/6	(spare)	spare bits set to zero	
bit-5	(ME)	= 0	No military emergency
		= 1	Military emergency
bit-4	(MI)	= 0	No military identification
		= 1	Military identification
bits-3/2	(FOE/FRI)	= 00	No Mode 4 interrogation
		= 01	Friendly target
		= 10	Unknown target
		= 11	No reply
bit-1	(FX)	= 0	End of Data Item
		= 1	Extension into next extent

Figure III.12: Second part of the Target Report Descriptor [10]

III.4.2.2.3. Item I048 / 030, Warning / Error conditions:

This data item is used when an error/warning condition is detected by the radar station, for the reported target involved. It has a variable length that varies from 1 to N octets, depending on how many are needed.

Octet no. 1

8	7	6	5	4	3	2	1
W/E Value							FX

bits-8/2	(W/E Value)	Warning/error condition value	
bit-1	(FX)	= 0	End of Data Item
		= 1	Extension into first extent (next W/E condition value)

Figure III.13: Structure of the Warning / Error Conditions [10]

III.4.2.2.4. Item I048 / 040, Measured Position in Polar Coordinates:

This data item represents the measurement of an aircraft's position in polar coordinates relative to radar. It has a length of 4 octets and must be sent when an aircraft is detected in our airspace.

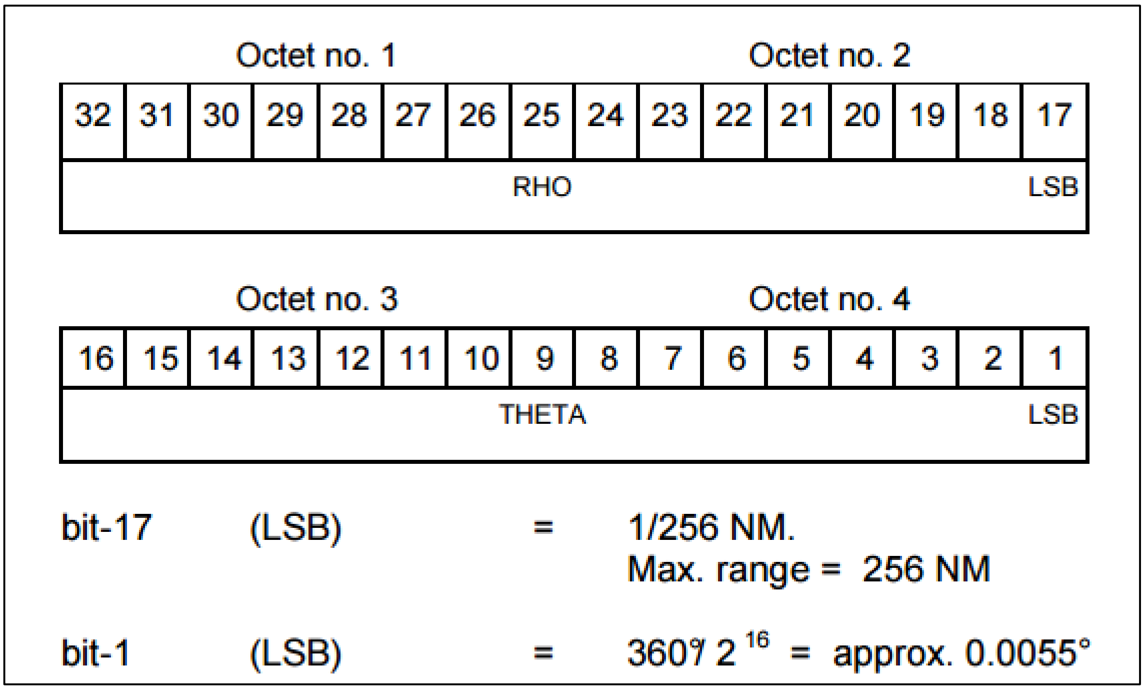


Figure III.14: Structure of the Data Item Measured Position in Polar Coordinates

III.4.2.2.5. Item I048 / 042, Calculated position in Cartesian coordinates:

With this data item we obtain the position in Cartesian coordinates of an aircraft. The length is 4 octets and the data item is optional.

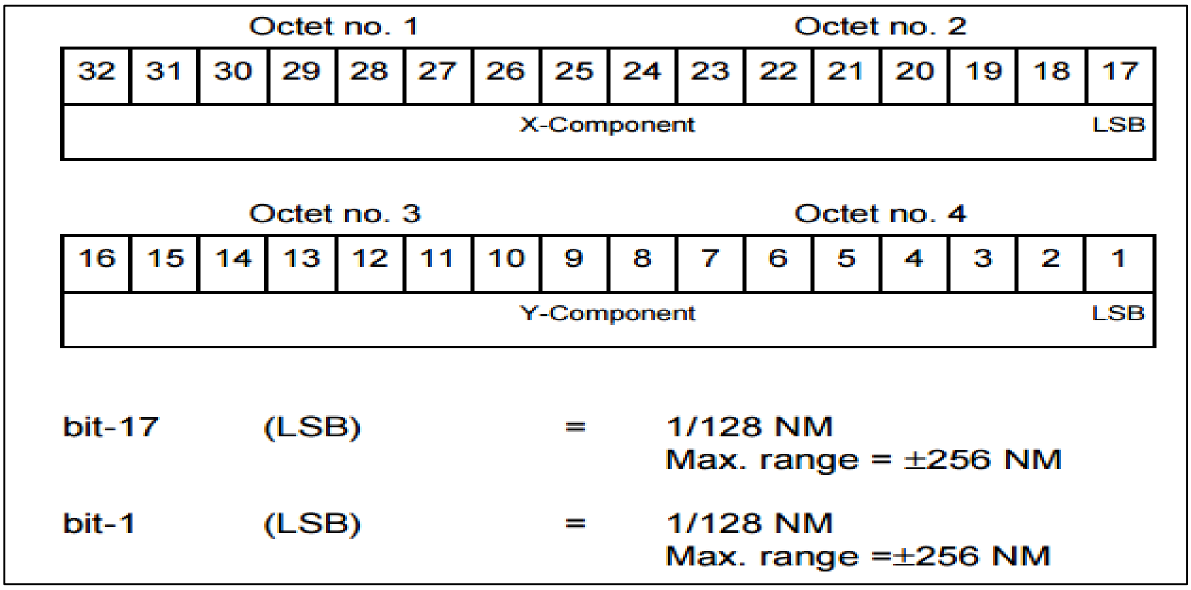


Figure III.15: Structure of the Data Item Calculated Position in Cartesian Coordinates

III.4.2.2.6. Item I048 / 050, Mode-2 code in octal representation:

With this data item we can respond when questioned in Mode-2. It has a length of 2 octets and is optional. This data item must be sent when Mode-2 is present (it represents the code for the plot) or when Mode-2 is absent and a local tracking is performed (in this case we must use the L in 1 bit).

Octet no. 1								Octet no. 2							
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
V	G	L	0	A4	A2	A1	B4	B2	B1	C4	C2	C1	D4	D2	D1

bit-16	(V)	=	0 Code validated
		=	1 Code not validated
bit-15	(G)	=	0 Default
		=	1 Garbled code
bit-14	(L)	=	0 Mode-2 code as derived from the reply of the transponder
		=	1 Smoothed Mode-2 code as provided by a local tracker
bit-13			Spare bit set to 0
bits-12/1			Mode-2 code in octal representation

Figure III.16: Structure of the Data Item Mode-2 Code in Octal Representation

III.4.2.2.7. Item I048 / 055, Mode-1 code in octal representation:

With this data item we can respond when we are interrogated in Mode-1. It has a length of 1 octet and is optional. This data item must be sent when Mode-1 is present (it represents the code for the plot) or when Mode-1 is absent and a local tracking is performed (in this case we must use the L in 1 bit).

Octet no. 1

8	7	6	5	4	3	2	1
V	G	L	A4	A2	A1	B2	B1

bit-8	(V)	= 0	Code validated
		= 1	Code not validated
bit-7	(G)	= 0	Default
		= 1	Garbled Code
bit-6	(L)	= 0	Mode-1 code as derived from the reply of the transponder.
		= 1	Smoothed Mode-1 code as provided by a local tracker.
bits-5/1			Mode-1 code

Figure III.17: Structure of the Data Item Mode-1 Code in Octal Representation

III.4.2.2.8. Item I048 / 060, Code Confidence Indicator Mode 2:

This data item represents the confidence level for each bit of a Mode-2 response given by a single-pulse SSR station.

Octet no. 1								Octet no. 2							
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
0	0	0	0	QA4	QA2	QA1	QB4	QB2	QB1	QC4	QC2	QC1	QD4	QD2	QD1

bits-16/13			Spare bits set to 0
bits-12/1	(QXi)	= 0	High quality pulse Xi
		= 1	Low quality pulse Xi

Figure III.18: Structure of the Data Item Mode-2 Code Confidence Indicator [10]

III.4.2.2.9. Item I048 / 065, Code Confidence Indicator Mode 1:

This data item represents the confidence level for each bit of a Mode-1 response given by a single-pulse SSR station. It is 1 octet long and is optional.

Octet no. 1

8	7	6	5	4	3	2	1
0	0	0	QA4	QA2	QA1	QB2	QB1

bits-8 /6			Spare bits set to zero
bits-5/1	(QXi)	=	0 High quality pulse Xi
		=	1 Low quality pulse Xi

Figure III.19: Structure of the Data Item Mode-1 Code Confidence Indicator [10]

III.4.2.2.10. Item I048 / 070, Code Mode-3 /A in octal representation:

This data item represents the code in Mode-3/A converted to an octal representation. It has a length of 2 octets and is mandatory when Mode 3/A is present. When Mode 3/A is absent, it must be sent with the L in 1 bit.

Octet no. 1								Octet no. 2							
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
V	G	L	0	A4	A2	A1	B4	B2	B1	C4	C2	C1	D4	D2	D1

bit-16	(V)	= 0	Code validated
		= 1	Code not validated
bit-15	(G)	= 0	Default
		= 1	Garbled code
bit-14	(L)	= 0	Mode-3/A code derived from the reply of the transponder
		= 1	Mode-3/A code not extracted during the last scan
bit-13		Spare bit set to 0	
bits-12/1		Mode-3/A reply in octal representation	

Figure III.20: Structure of Data Item Mode-3 / A Code in Octal Representation

III.4.2.2.11. Item I048 / 080, Code confidence indicator Mode- 3 /A :

This data item represents the confidence level for each bit of a Mode 3/A response given by a single-pulse SSR station. It is 2 octets long and is optional (see Figure III.20)

Octet no. 1								Octet no. 2							
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
0	0	0	0	QA4	QA2	QA1	QB4	QB2	QB1	QC4	QC2	QC1	QD4	QD2	QD1

bits-16/13		Spare bits set to 0	
bits-12/1	(QXi)	= 0	High quality pulse Xi
		= 1	Low quality pulse Xi

Figure III.21: Structure of the Data Item Mode-3 / A Code Confidence Indicator

III.4.2.2.12. Item I048 / 090, Flight level in binary representation:

With this data item we can obtain the flight level converted into binary. It has a length of 2 octets and must be sent when the C-mode or S-mode altitude code is present and decodable, to represent the flight level of the plot even if it is associated with a track.

Octet no. 1								Octet no. 2							
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
V	G	Flight Level													LSB

bit-16	(V)	= 0	Code validated
		= 1	Code not validated
bit-15	(G)	= 0	Default
		= 1	Garbled code
bits-14/1	(Flight Level)		LSB= 1/4 FL

Figure III.22: Structure of the Data Item Flight Level in Binary Representation

III.4.2.2.13. Item I048 / 100, mode C code and code Confidence indicator:

This item represents the C-Mode code (in Gray notation) as received from the transponder, along with the confidence level of each bit provided by an MSSR/Mode-S station. It is 4 octets long and is optional. It is used when an invalid or undecipherable C-Mode code is received.

Octet no. 1								Octet no. 2							
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17
V	G	0	0	C1	A1	C2	A2	C4	A4	B1	D1	B2	D2	B4	D4

Octet no. 3								Octet no. 4							
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
0	0	0	0	QC1	QA1	QC2	QA2	QC4	QA4	QB1	QD1	QB2	QD2	QB4	QD4

bit-32	(V)	= 0	Code validated
		= 1	Code not validated
bit-31	(G)	= 0	Default
		= 1	Garbled code
bits-30/29			Spare bits set to 0
bits-28/17			Mode-C reply in Gray notation
bits-16/13			Spare bits set to 0
bits-12/1	(QXi)	= 0	High quality pulse Xi
		= 1	Low quality pulse Xi

Figure III.23: Structure of the Data Item Mode-C Code in Code Confidence Indicator

III.4.2.2.14. Item I048 / 110, Height measured by 3D radar:

This data item represents the height of the target measured by a 3D radar. The height should use sea level as a 0 reference. The length is 2 octets and is optional. [10] [11]

Octet no.1								Octet no.2							
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
0	0	3D-Height													LSB

bits-16/15		Spare bits set to zero
bits-14/1	(3D-Height)	3D height, in binary notation. Negative values are expressed in two's complement LSB = 25 ft

Figure III.24: Structure of the Data Item Height Measured by a 3D Radar

III.4.2.2.15. Item I048 / 120, Radial Doppler speed:

This data item represents the target report information in Doppler speed. The structure of this field is a little more complex than the others, since it is composed of a main subfield and depending on its values, additional subfields.

Octet no.1							
8	7	6	5	4	3	2	1
CAL	RDS	0	0	0	0	0	0

bit-8	(CAL)		Subfield #1: Calculated Doppler Speed
		= 0	Absence of Subfield #1
		= 1	Presence of Subfield #1
bit-7	(RDS)		Subfield #2: Raw Doppler Speed
		= 0	Absence of Subfield #2
		= 1	Presence of Subfield #2
bits-6/1	(Spare)		Subfields #3/7: Spare
		= 0	Absence of Subfield
		= 1	Presence of Subfield

Figure III.25: Structure of the Radial Doppler Speed Data Item [10]

With these values, we see the presence or absence of the next subfields:

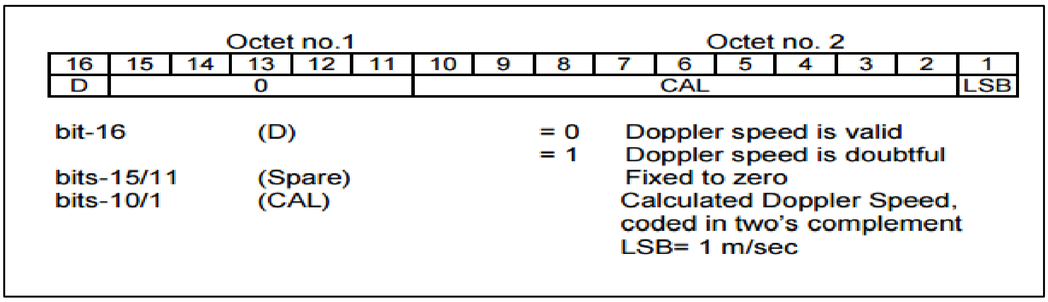


Figure III.26: Subfield Structure Calculated Doppler speed [10]

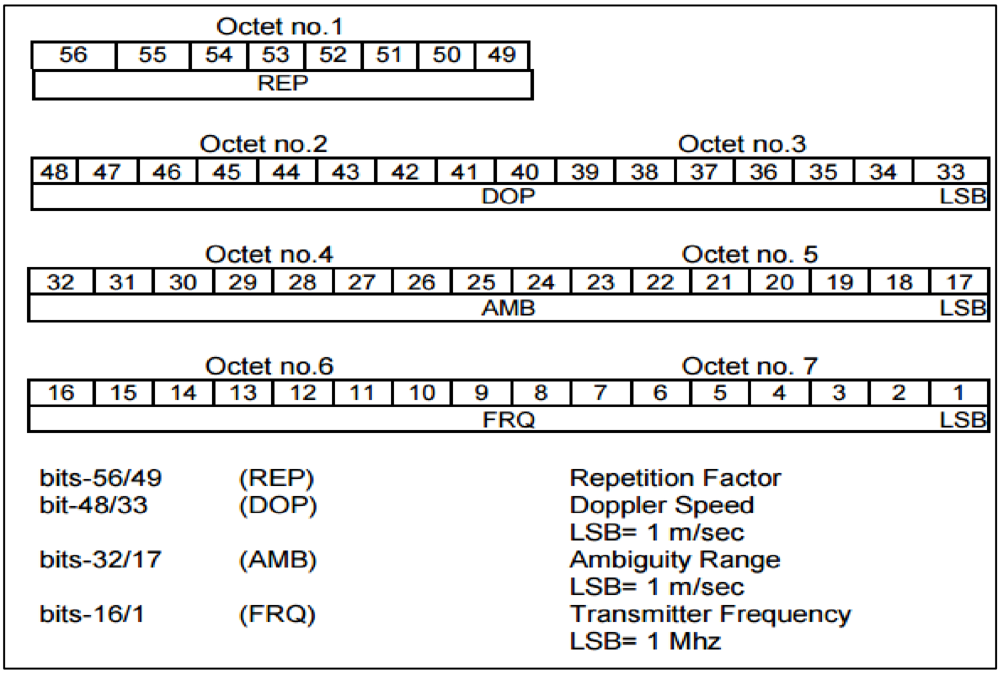


Figure III.27: Structure of the raw Doppler velocity subfield [10]

III.4.2.2.16. Item I048 / 130, Radar plot characteristics:

This data item provides additional information on the quality of the target report. It has a composite structure, that is, the first octet will serve us as an "index" to know what the following octets represent. This implies that it has a variable length.

Octet no.1

8	7	6	5	4	3	2	1
SRL	SRR	SAM	PRL	PAM	RPD	APD	FX

bit-8, octet1	(SRL)		Subfield #1: SSR plot runlength
		= 0	Absence of Subfield #1
		= 1	Presence of Subfield #1
bit-7, octet1	(SRR)		Subfield #2: Number of received replies for M(SSR)
		= 0	Absence of Subfield #2
		= 1	Presence of Subfield #2
bit-6, octet1	(SAM)		Subfield #3: Amplitude of received replies for M(SSR)
		= 0	Absence of Subfield #3
		= 1	Presence of Subfield #3
bit-5, octet1	(PRL)		Subfield #4: PSR plot runlength
		= 0	Absence of Subfield #4
		= 1	Presence of Subfield #4
bit-4, octet1	(PAM)		Subfield #5: PSR amplitude
		= 0	Absence of Subfield #5
		= 1	Presence of Subfield #5
bit-3, octet1	(RPD)		Subfield #6: Difference in Range between PSR and SSR plot
		= 0	Absence of Subfield #6
		= 1	Presence of Subfield #6
bit-2, octet1	(APD)		Subfield #7: Difference in Azimuth between PSR and SSR plot
		= 0	Absence of Subfield #7
		= 1	Presence of Subfield #7
bit-1, octet1	(FX)	= 0	End of Primary Subfield
		= 1	Extension of Primary Subfield into next octet

Figure III.28: Structure of the first Radar Plot Characteristics Octet [10]

With these values, we see the presence or absence of the next subfields:

Octet no.1

8	7	6	5	4	3	2	1
SRL							LSB

bits-8/1 (SRL) SSR plot runlength, expressed as a positive binary value.
LSB=360/2^{13} dg (0.044 dg)

Figure III.29: Structure of Subfield # 1: SSR Plot Runlength [10]

Octet no.1

8	7	6	5	4	3	2	1
SRR							LSB

bits-8/1 (SRR) Number of received replies for (M)SSR
LSB= 1

Figure III.30: Structure of Subfield # 2: Number of Received Replies for (M)SSR

Octet no.1

8	7	6	5	4	3	2	1
SAM							LSB

bits-8/1 (SAM) Amplitude of (M)SSR reply
LSB= 1 dBm

Figure III.31: Structure of Subfield # 3: Amplitude of (M)SSR Reply

Octet no.1

8	7	6	5	4	3	2	1
PRL							LSB

bits-8/1 (PRL) Primary Plot Runlength, expressed as positive binary value
LSB= $360/2^{13}$ dg (0.044 dg)

Figure III.32: Structure of Subfield # 4: Primary Plot Runlength

Octet no.1

8	7	6	5	4	3	2	1
PAM							LSB

bits-8/1 (PAM) Amplitude of Primary Plot
LSB= 1 dBm

Figure III.33: Structure of Subfield # 5: Amplitude of Primary Plot

Octet no.1

8	7	6	5	4	3	2	1
RPD							LSB

bits-8/1 (RPD) Range (PSR-SSR)
LSB= 1/256 NM

Figure III.34: Structure of Subfield # 6: Difference in Range between PSR and SSR plot

Octet no.1							
8	7	6	5	4	3	2	1
APD							LSB

bits-8/1 (APD) Azimuth (PSR-SSR)
LSB= $360/2^{14}$ dg

Figure III.35: Structure of Subfield # 7: Difference in Azimuth between PSR and SSR plot

III.4.2.2.17. Item I048 / 140, Time of Day:

This data item represents the absolute time stamp expressed as UTC (Co-ordinated Universal Time). It has a length of 3 octets and is mandatory in all ASTERIX packages. It must reflect the exact time of an event.

Octet no. 1								Octet no. 2							
24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9
Time-of-Day															

Octet no. 3							
8	7	6	5	4	3	2	1
							LSB

bits-24/1 (Time-of-Day) Acceptable Range of values:
0<= Time-of-Day<=24 hrs
bit-1 (LSB) = 2^{-7} seconds = 1/128 seconds

Figure III.36: Structure of the Data Item Time of Day [10]

III.4.2.2.18. Item I048 / 161, Track Number:

The track number is an integer value that misrepresents the reference to a track record on a particular track file. It has a length of 2 octets and must be sent when the radar station tracks.

Octet no. 1								Octet no. 2							
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
0	0	0	0	TRACK NUMBER (0..4095)											

Figure III.37: Structure of the Data Item Track Number

III.4.2.2.19. Data item I048 / 170, track status:

This data item represents the status of the monoradar track (PSR and/or SSR updated). It has a variable length of 1 to 2 octets (the second octet only when needed).

Octet no.1

8	7	6	5	4	3	2	1
CNF	RAD		DOU	MAH	CDM		FX

bit-8	(CNF)		Confirmed vs. Tentative Track
		= 0	Confirmed Track
		= 1	Tentative Track
bits-7/6	(RAD)		Type of Sensor(s) maintaining Track
		= 00	Combined Track
		= 01	PSR Track
		= 10	SSR/Mode S Track
		= 11	Invalid
bit-5	(DOU)		Signals level of confidence in plot to track association process
		= 0	Normal confidence
		= 1	Low confidence in plot to track association.
bit-4	(MAH)		Manoeuvre detection in Horizontal Sense
		= 0	No horizontal man.sensed
		= 1	Horizontal man. sensed
bits-3/2	(CDM)		Climbing / Descending Mode
		= 00	Maintaining
		= 01	Climbing
		= 10	Descending
		= 11	Invalid
bit-1	(FX)	= 0	End of Data Item
		= 1	Extension into first extent

Figure III.38: Structure of first part of Track Status [10]

Octet no.2

8	7	6	5	4	3	2	1
TRE	GHO	SUP	TCC	0	0	0	FX

bit-8	(TRE)		Signal for End_of_Track
		= 0	Track still alive
		= 1	End of track lifetime(last report for this track)
bit-7	(GHO)		Ghost vs. true target
		= 0	True target track.
		= 1	Ghost target track.
bit-6	(SUP)		Track maintained with track information from neighbouring Node B on the cluster, or network
		= 0	no
		= 1	yes
bit-5	(TCC)		Type of plot coordinate transformation mechanism:
		= 0	Tracking performed in so-called 'Radar Plane', i.e. neither slant range correction nor stereographical projection was applied.
		= 1	Slant range correction and a suitable projection technique are used to track in a 2D.reference plane, tangential to the earth model at the Radar Site co-ordinates.
bits-4/2	(spare)		Spare bits, set to 0
bit-1	(FX)	= 0	End of Data Item
		= 1	Extension into second extent

Figure III.39: Structure of First Extent of Track status [10]

III.4.2.2.20. Item I048 / 200, Calculated Track Speed in Polar Coordinates:

This item represents the track speed in polar coordinates. It has a length of 4 octets, the first 2 representing the speed on land and the other 2 the course.

Octet no. 1								Octet no. 2							
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17
CALCULATED GROUNDSPEED (max. 2 NM/s)															LSB

Octet no. 3								Octet no. 4							
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
CALCULATED HEADING															LSB

bit-17 (LSB) = (2^{-14}) NM/s = approx. 0.22 kt

bit-1 (LSB) = $360°/2^{16}$ = approx. 0.0055°

Figure III.40: Structure of the Data Item Calculated Track Velocity in Polar Coordinates [10]

III.4.2.2.21. Item I048 / 210, Track quality:

This data item represents the quality of the track in the form of a standard deviation vector. It has a length of 4 octets and is optional.

Octet no.1							
8	7	6	5	4	3	2	1
Sigma (X)							LSB

bits-8/1 (Sigma (X)) Standard Deviation on the horizontal axis of the local grid system

bit-1 (LSB) = 1/128 NM

Figure III.41: Structure of the first Track Quality octet [10]

Octet no.2

8	7	6	5	4	3	2	1
Sigma (Y)							LSB

bits-8/1	(Sigma (Y))	Standard Deviation on the vertical axis of the local grid system
bit-1	(LSB)	= 1/128 NM

Figure III.42: Structure of the second Track Quality octet

Octet no.3

8	7	6	5	4	3	2	1
Sigma (V)							LSB

bits-8/1	(Sigma (V))	Standard Deviation on the groundspeed within the local grid system
bit-1	(LSB)	= (2^{-14}) NM/s = 0.22 Kt

Figure III.43: Structure of the third Track Quality octet

Octet no.4

8	7	6	5	4	3	2	1
Sigma (H)							LSB

bits-8/1	(Sigma (H))	Standard Deviation on the heading within the local grid system
bit-1	(LSB)	= $360/(2^{12})$ degrees = 0.08789 degrees

Figure III.44: Structure of the fourth Track Quality octet

III.4.2.2.22. Item I048 / 220, Aircraft Address:

The Aircraft Address is a value assigned one wrongly to each aircraft. It has a length of 3 octets and must be present in all ASTERIX records.

Octet no. 1

24	23	22	21	20	19	18	17
AIRCRAFT							

Octet no. 2 / Octet no. 3

16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
ADDRESS															

Figure III.45: Structure of the Data Item Aircraft Address. [10]

III.4.2.2.23. Item I048 / 230, communication capability / ACAS and flight status:

This data item represents the communication capability of the transponder, the ACAS equipment on board the aircraft and the flight status. It has a length of 3 octets and must be present in all ASTERIX records related to S-Mode.

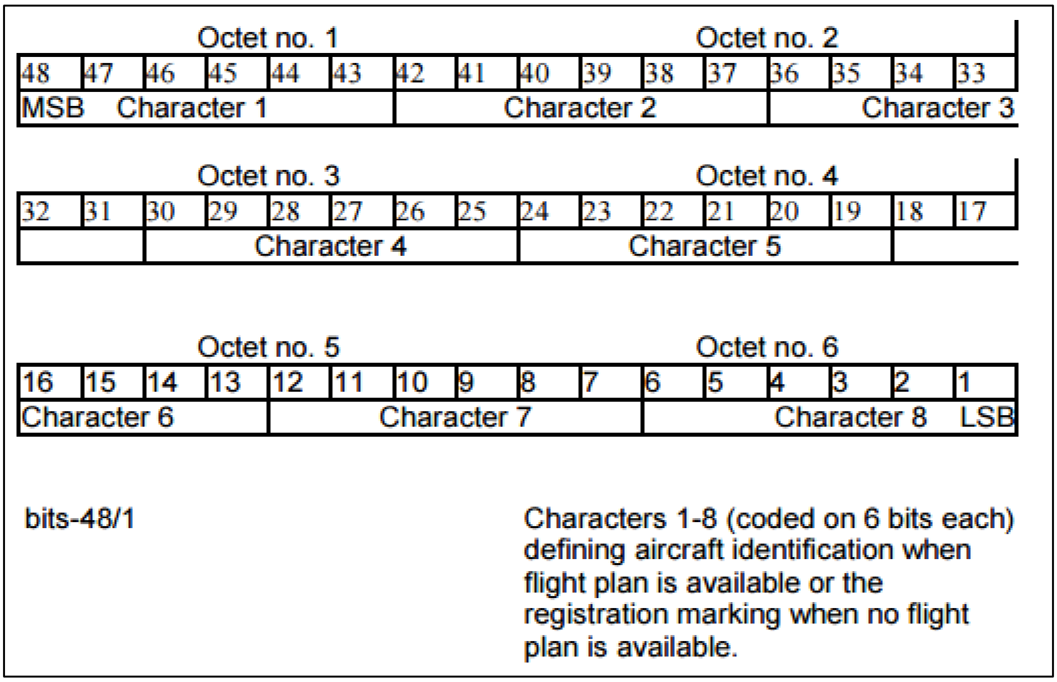
Octet no. 1								Octet no. 2							
6	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
COM			STAT			SI	0	MSSC	ARC	AIC	B1A	B1B			

bits-16/14	(COM)	Communications capability of the transponder = 0 No communications capability (surveillance only) = 1 Comm. A and Comm. B capability = 2 Comm. A, Comm. B and Uplink ELM = 3 Comm. A, Comm. B, Uplink ELM and Downlink ELM = 4 Level 5 Transponder capability 5 to 7 Not assigned
bits-13/11	(STAT)	Flight Status = 0 No alert, no SPI, aircraft airborne = 1 No alert, no SPI, aircraft on ground = 2 Alert, no SPI, aircraft airborne = 3 Alert, no SPI, aircraft on ground = 4 Alert, SPI, aircraft airborne or on ground = 5 No alert, SPI, aircraft airborne or on ground 6 - 7 Not assigned
bit-10	(SI)	SI/II Transponder Capability = 0 SI-Code Capable = 1 II-Code Capable
bit-9	(spare)	spare bit set to zero
bit-8	(MSSC)	Mode-S Specific Service Capability = 0 No = 1 Yes
bit-7	(ARC)	Altitude reporting capability = 0 100 ft resolution = 1 25 ft resolution
bit-6	(AIC)	Aircraft identification capability = 0 No = 1 Yes
bit-5	(B1A)	BDS 1,0 bit 16
bits 4/1	(B1B)	BDS 1,0 bits 37/40

Figure.III.46: Structure of the Data Item Communications / ACAS Capability and Flight [10]

III.4.2.2.24. Item I048 / 240, Aircraft identification:

The Aircraft Identification is 8 characters obtained from an aircraft equipped with a Mode S transponder. It is 6 octets long and contains the flight identification available in the transponder records.



FigureIII.47: Structure of the Data Item Aircraft Identification [10]

III.4.2.2.25. Item I048 / 250, Mode S MB data:

This data item contains Mode S -B information extracted from the aircraft's transponder. It has a variable length and is composed of a first octet (REP) representing the repetition factor, followed by at least one BDS report. It should be noted that this item must be present in every ASTERIX record that handles information related to a Mode S target.

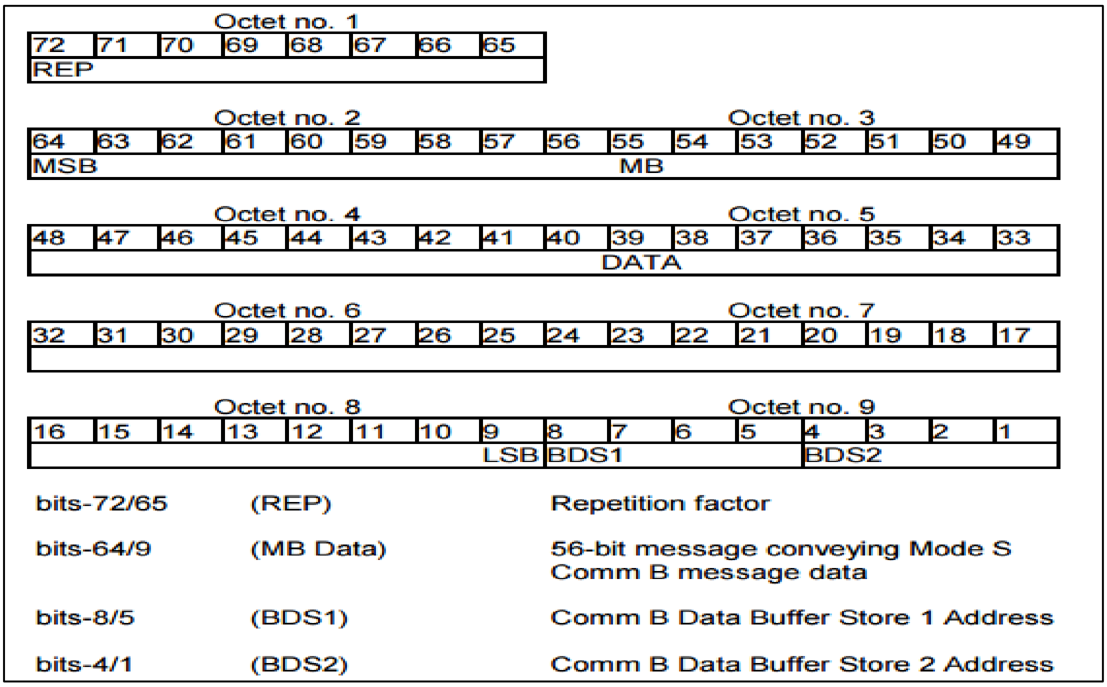


Figure III.48: Structure of the Data Item Mode S MB Data. [10]

III.4.2.2.26. Item I048 / 260, ACAS resolution advisory report:

This data item contains the current active RA (Resolution Advisory) generated by the ACAS associated with the transponder. It has a length of 7 octets and must be present as long as an RA was generated in the last scan.

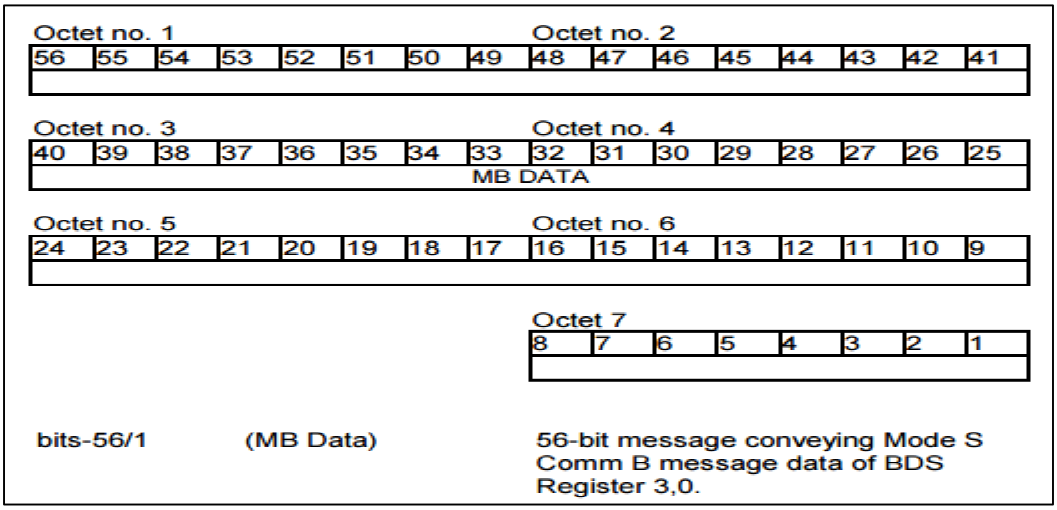


Figure III.49: Data Item Structure ACAS Resolution Advisory Report

III.4.2.2.27. The Special Purpose field:

The special purpose field is a non-standard data field, the contents of which are agreed upon between the two communications partners (MSSR Mode S and targets), what is encoded there is only known to those communication partners.

III.4.2.2.28. Reserved Expansion field:

The reserved Expansion field is defined by the Asterix Maintenance Group.

III.4.3. Data Source Identification (SAC/SIC):

For the identification of the data source, Eurocontrol establishes procedures and criteria for coding by means (SAC) and (SIC) which, once applied, are published by that body. The following tables represent the publication of the data source of the Asterix format for America. These data can be found on the Eurocontrol website [6]:

Organization of the SAC:

- 00 to 99: Europe.
- A0 to DF: USA and Canada.
- 02 to 96: Asia and the Pacific Region.
- D0 to FF: Mexico, Caribbean, Central and South America.
- 64 to EC : African.
- DA to EA: Middle East Region.

VI. Chapter Conclusion:

Asterix allowed the exchange of air traffic data in a simple and a standard way, which is that all the entities and organizations involved work hard to promote.

As we have seen category 048 is very rich in information, it is difficult to use this category manually (very long period of time to decode a record), that’s why we need an application to exploit the Asterix message category 048.

Chapter IV:

Realization of the Application

Abstract:

In this chapter we will show how we realized our application, this application allows to decode and visualize S mode radar data in Asterix format (category 048).

First we had made an introduction on the aims and importance of our application, then we explained the realization and the mode of operation of our application on five main parts which are: Choice of programming language, General Structure of the application, Data Decoding, Data visualization, use of the application.

IV.1. Introduction:

After the MSSR mode S receives responses from targets it will code these responses in Asterix format (as we saw in the previous chapter).

For users to be able to exploit the Asterix message it must be decoded (to extract the different fields that exist in the message) and also visualize it in a radar image to see the plots (targets) and the different information that we can have about them.

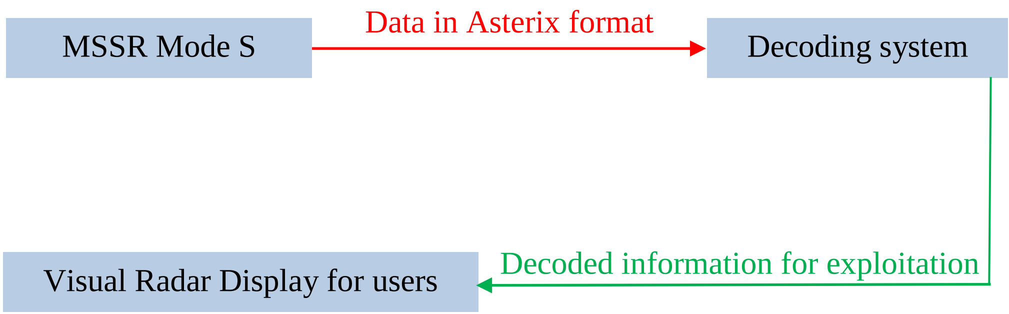


Figure IV.1: Simplified diagram of the route of the Asterix message

For this we have realized an application that can decode the data of the Asterix message category 048.

The realization of this application has the following main purposes:

- To test the good functioning of the decoding of the real decoding system and the visualization of the real radar image in Algeria.
- To have a good understanding of the information (fields) offered by the MSSR mode S (which is rich in information) either to researchers or students or engineers.
- Exploiting the Asterix message with an automatic and fast and efficient way and have all the information that exists in the message not just the information displayed on the radar screen.

IV.2. Choice of programming language:

In this application we have worked with two programming languages (one for decoding and the other for visualization) in order to facilitate our work and to give our application a better performance, these languages are:

- For decoding we have chosen the **Python** language for the following reasons:
  - **Portable:** the same code runs directly without change on most operating systems (Windows, Linux and Mac).
  - **Free:** free license for use as in our case we chose the integrated development environment “PyCharm Community Edition 2019.3.3 x64”.
  - **Popular:** Today most developers use Python language so we have found several documents that helped us in our application.
  - **Simple and easy:** the different loops (for, while ...) and conditions (if, else ...) are easy to use and there are several commands available in Python such as converting from one base to another.
  - **Fast:** Python can give the result in an exceptional amount of time compared to other languages.
- For the visualization we have chosen the **C#** language for the following reasons:
  - **Very powerful:** C# has a very good graphics (quality, a lot of tool box).
  - **Popular:** it is the first language chosen for the realization of desktop applications.
  - **Free:** free license for use as in our case we chose Microsoft Visual Studio C# 2015.

IV.3. General Structure of the application:

The application is a system that allows to decode the Asterix category 048 message and also to visualize the desired information in a radar screen.

This application works on three main steps which are as follows:

IV.3.1. Step 01 “Data injection”:

Injection of the Asterix message and also the name of the station that has generated (encoded) the chosen Asterix message.

For the station name we have generated a database of the five radar stations in Algeria (but we can add new stations if necessary), just write the name of the station in capital letters between two apostrophe: 'ALGIERS' 'ANNABA' 'ORAN' 'EL OUED' 'EL BAYADH'

IV.3.2. Step 02 "Data decoding":

The data that has been injected (Asterix message and station name) will go through a decoding system that will extract the different fields (information) that exists in your message with decoding and several calculations and it will also calculate the geographical coordinates of the targets in relation to the chosen station.

The fields and the geographical coordinates of the selected station will be displayed in the command window of Pycharm and some information (that we want to display) will be automatically saved on a text file that has been generated thanks to a special command on Python.

IV.3.3. Step 03 "Data visualization":

Opening the text file (which was generated by the decoding system) on the display system to display the plots (targets) and fields and also selecting the station name to display the station on the radar screen.

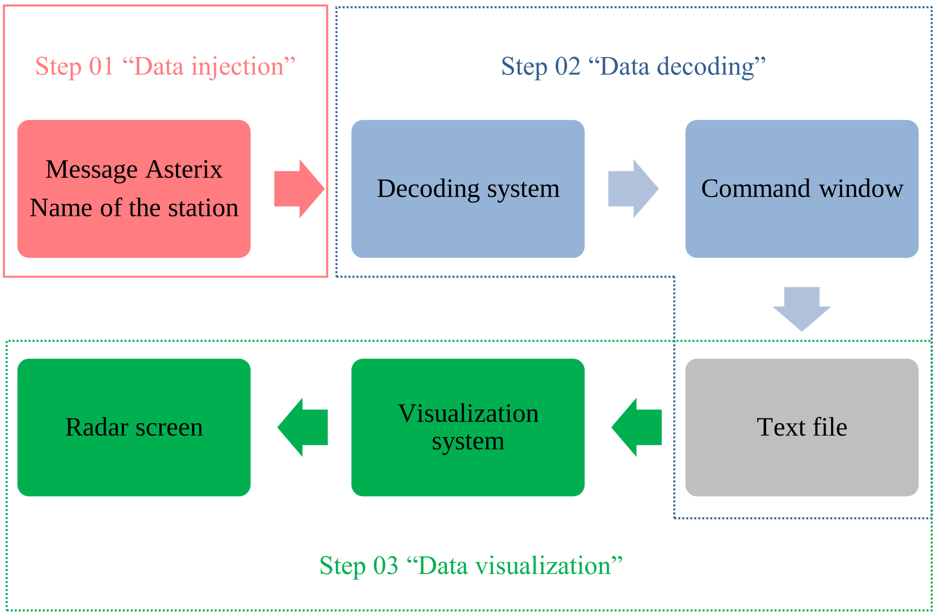
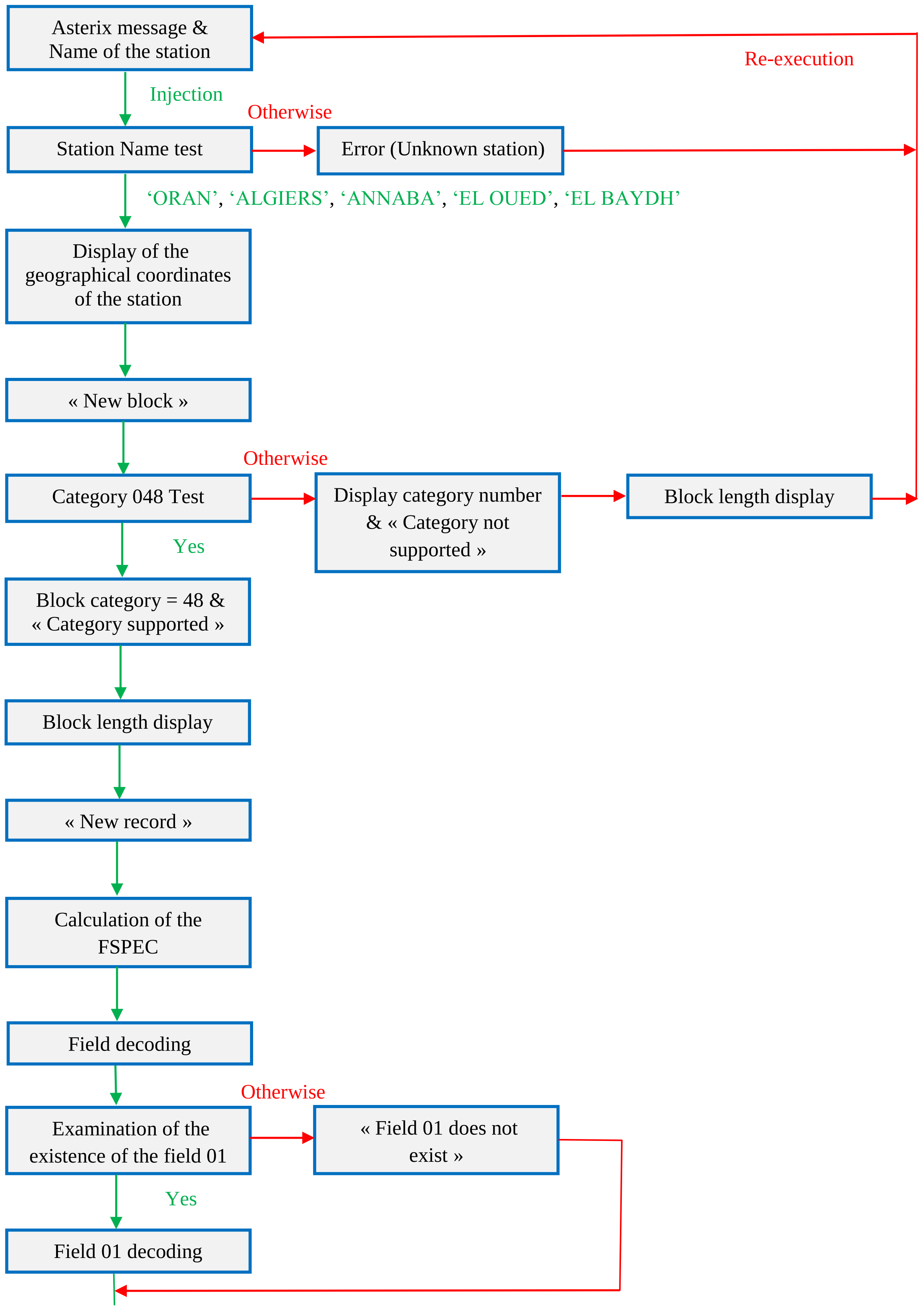


Figure IV.2: Simplified diagram shows the general structure of the application

IV.4. Data Decoding:

IV.4.1. Organization chart of the decoding system:

The organization chart we followed in data decoding is shown in the following diagram:



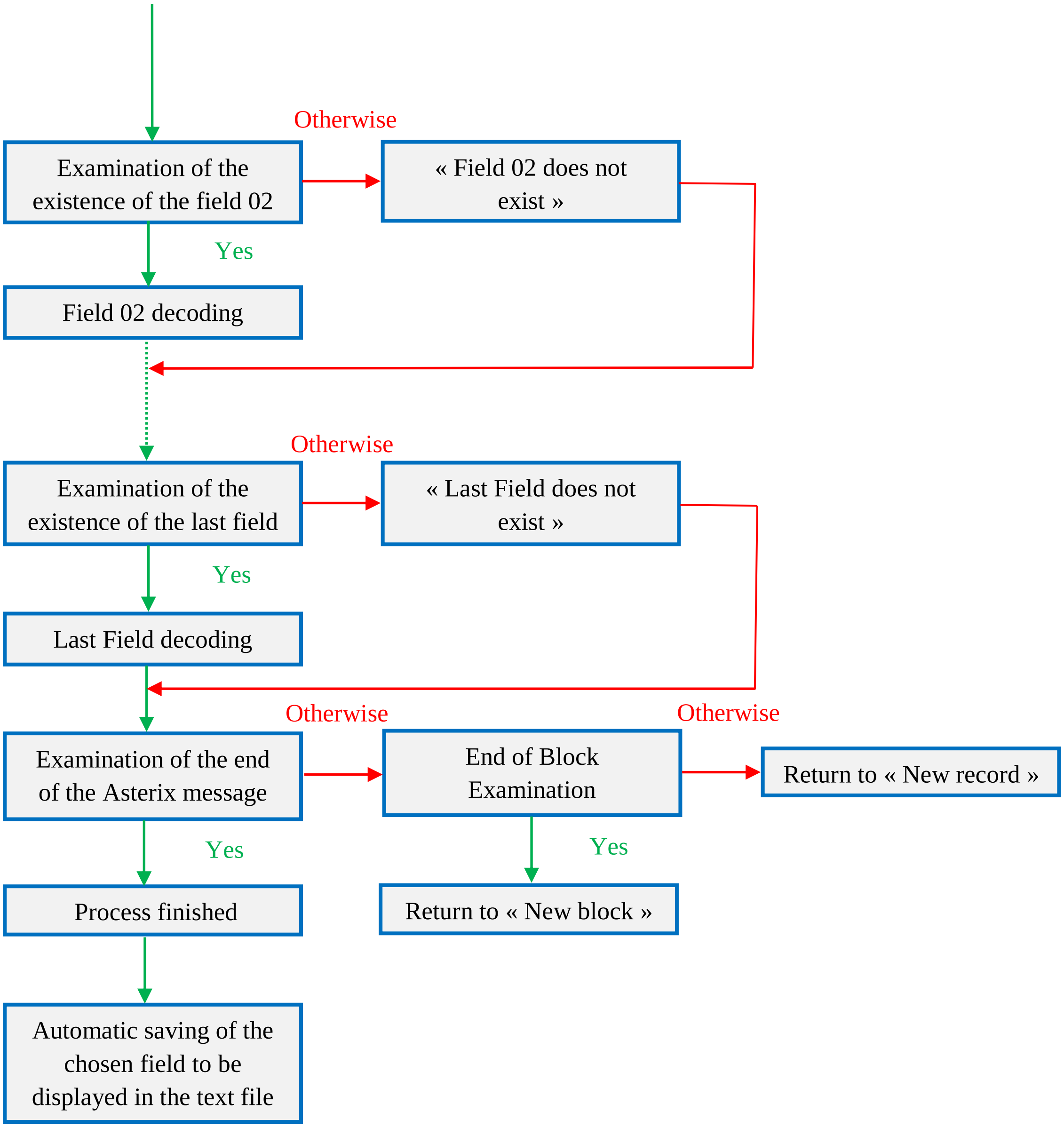


Figure IV.3: Organization chart of the decoding system

IV.4.2. Simulation & Testing:

In this part we will test and simulate the data decoding step following the flowchart above and also show how the integrated development environment Pycharm works.

IV.4.2.1. The opening steps of the decoding system:

Open: Pycharm→ select the open button → Home → Pycharm Projects → Decoding system → Asterix Message Decoder CAT048.py:

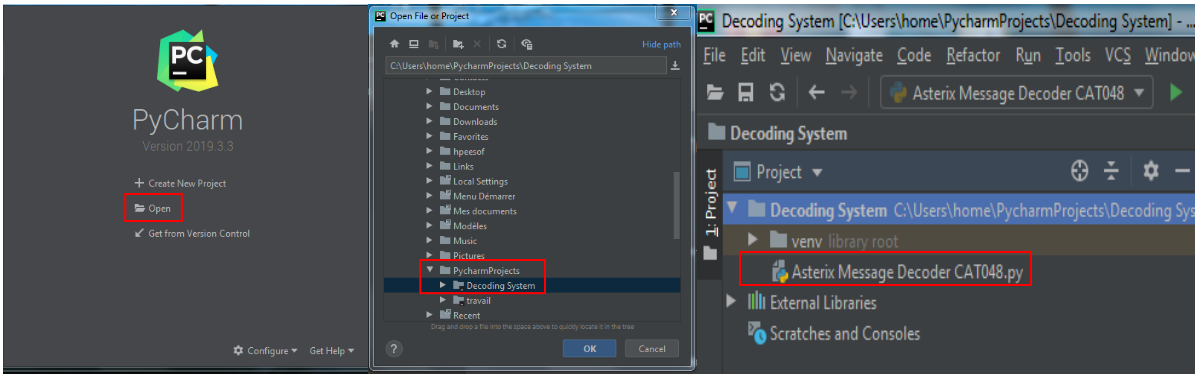


Figure IV.4: The opening steps of the decoding system

IV.4.2.2. Injection of Asterix message & Name of the station:

After running the program the command window will appear below the screen, the command window will ask for the Asterix message and the name of the station to decode the message.

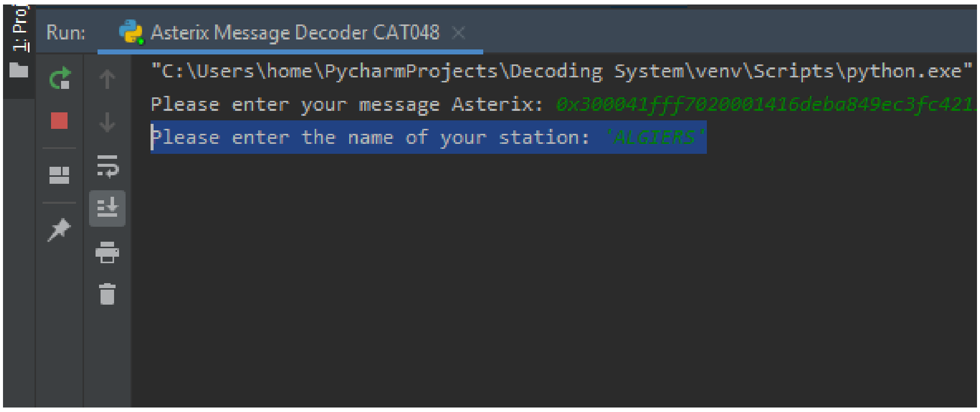


Figure IV.5: Injection of Asterix message & Name of the station

IV.4.2.3. Station Name test:

In this step the program will test the name of the station:

- If the name of the station is known ('ALGIERS' 'ANNABA' 'ORAN' 'EL OUED' 'EL BAYADH') it will display the geographical coordinates of the station.

As we have explained it is necessary to write the name of the station in capital letters between two apostrophes ('NAME OF THE STATION').

- If the station name is unknown it will display Error.

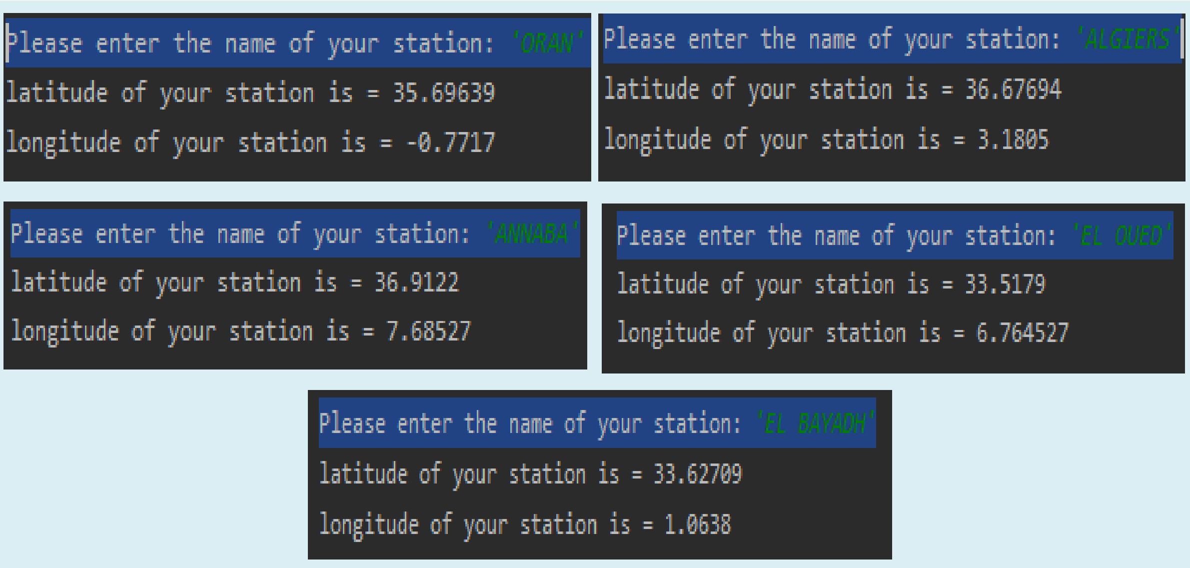


Figure IV.6: confirmation of station position

IV.4.2.4. Category 048 Test:

In this part the program will test the category of the Asterix message:

- If the category of the message is 048 it will display:
  - ➢ Block category = 48 → « Category supported » → Block length → New record
- If the category of the message is not 048 it will display
  - ➢ Category number & « Category not supported » → Block length

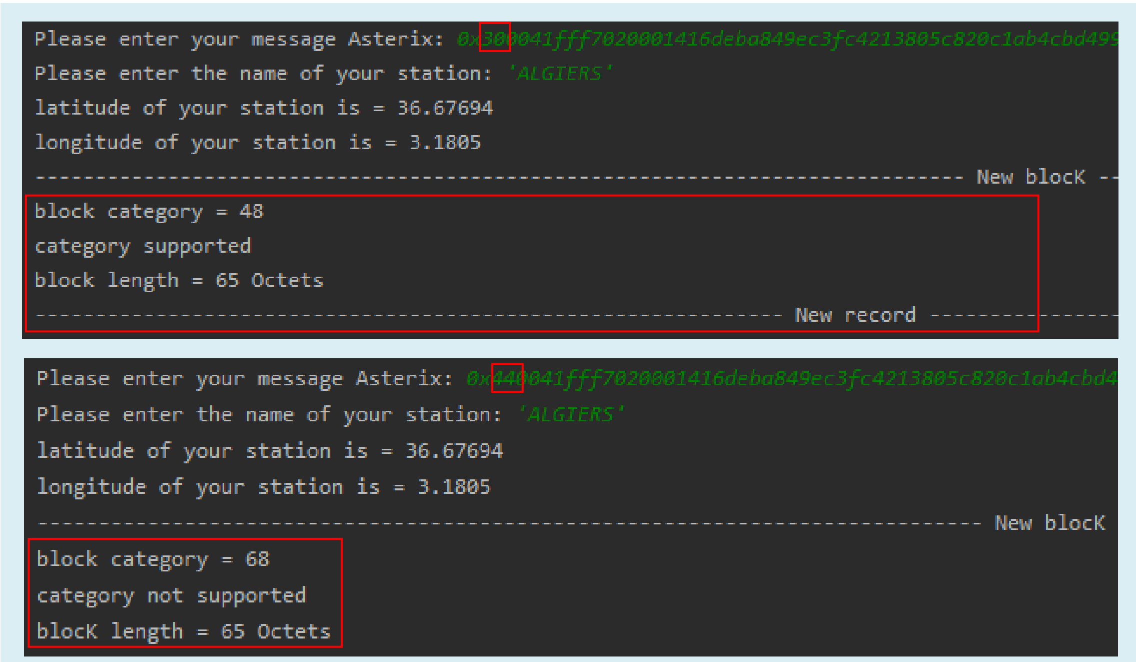


Figure IV.7: Category 048 test

IV.4.2.5. Decoding of an Asterix CAT 048 message:

For: calculation of FSPEC (Field Specification), field decoding, automatic saving of the chosen field to be displayed in the text file we have decoded an Asterix message, the message is as follows:

300041fff7020001416deba849ec3fc4213805c820c1ab4cbd4994b5617820038bd9eb2fbfe40 06080919f39a004dd50c8480030a80000400397083c17304020fd

The structure of this message Asterix is as follows:

30	0041	fff702	0001	416deb	a8	49ec3fc4	2138	05c8
Catego-ry	Block length	FSPEC	Data Source Identifier	Time-of-Day	Target Report Descriptor	Measured Position in Slant Polar Coordinates	Mode-3/A Code in Octal Representation	Flight Level in Binary Representation

20c1	Ab4cbd	4994b5617820	038bd9eb2fbfe4006080919f39a004dd50c8480030a8000040
Radar Plot Characteristics	Aircraft Address	Aircraft Identification	Mode S MB Data

0397	083c1730	40	20fd
Track Number	Calculated Track Velocity in Polar Representation	Track Status	Communications / ACAS Capability and Flight Status

Figure IV.8: Structure of the Asterix message

This Asterix message contains a single block category 048 which contains a single record.

In this record we have 14 fields that are shown above (Data Source Identifier, Time-of-Day... Communications / ACAS Capability and Flight Status).

The transponder of the aircraft and the Mode S radar governs the fields existing in the record, it depends on the configuration of the Mode S radar and the selected BDS registers in the transponder. The execution of this message in the command window is as follows:

```
---------------------------------------------- New blocK ----------------------------------------------

block category = 48

category supported

block length = 65 Octets

---------------------------------------- New record ----------------------------------------
```

```
**************** Calculation of FSPEC ****************

FSPEC = 11111111

FSPEC[8] = 1

Extension for FSPEC

FSPEC = 1111111111110111

FSPEC[16] = 1

Extension for FSPEC

FSPEC = 111111111111011100000010

FSPEC[24] = 0

No Extension for FSPEC

FSPEC = 111111111111011100000010

****************  Examination of the existence of the Data Source Identifier field****************

FSPEC[1] = 1

Data Source Identifier exists

SAC/SIC = 0/1

**************** Examination of the existence of the Time of day field ****************

FSPEC[2] = 1

Time of Day exists

Time of Day = 9:18:19

****************  Examination of the existence of the Target Report Descriptor field ****************

FSPEC[3] = 1

Target Report Descriptor exists

DESC = 10101000

DESC[8] = 0

No Extension for DESC

DESC = 10101000

TYP = 101

Single ModeS Roll-Call

SIM = 0

Actual target report

RDP = 1

Report from RDP Chain 2

SPI = 0

Absence of SPI

RAB = 0

Report from aircraft transponder
```

```
****************  Examination of the existence of the Measured position in polar coordinates field ****************

FSPEC[4] = 1

Measured Position in Polar Coordinates exists

RANGE = 73.921875 NM

AZIMUTH = 89.782 Deg

****************  Examination of the existence of the Mode-3/A code in octal representation field ****************

FSPEC[5] = 1

Mode-3/A Code in Octal Representation exists

V = 0

Code validated

G = 0

Default

L = 1

Mode-3/A code not extracted during the last scan

Bit 13 = 0

Spare bit set to 0

Mode-3/A reply in letters 0 0 0 B4 0 0 C4 C2 C1 0 0 0

****************  Examination of the existence of the Flight level in binary representation field ****************

FSPEC[6] = 1

Flight Level in Binary Representation exists

FL[16] = V = 0

Code validated

FL[15] = G = 0

Default

Flight Level = 370.0FL

****************  Examination of the existence of the Radar plot characteristics field ****************

FSPEC[7] = 1

Radar Plot Characteristics exists

bit 8 = SRL = 0

Absence of Subfield #1: SSR plot runlength

bit 7 = SRR = 0

Absence of Subfield #2: Number of received replies for M(SSR)

bit 6 = SAM = 1

Presence of Subfield #3: Amplitude of M(SSR) reply

Amplitude of (M)SSR Reply = 193 dbm

bit 5 = PRL = 0

Absence of Subfield #4: PSR plot runlength
```

```
bit 4 = PAM = 0

Absence of Subfield #5: PSR amplitude

bit 3 = RPD = 0

Absence of Subfield #6: Difference in Range between PSR and SSR plot

bit 2 = APD = 0

Absence of Subfield #7: Difference in Azimuth between PSR and SSR plot

bit 1 = FX = 0

End of Primary Subfield

****************  Examination of the existence of the Aircraft address field ****************

FSPEC[9] = 1

Aircraft Address exists

Aircraft Address = 171/19645

****************  Examination of the existence of the Aircraft identification field ****************

FSPEC[10] = 1

Aircraft Identification exists

Aircraft Identification = RYR5XW

****************  Examination of the existence of the Mode S MB data field ****************

FSPEC[11] = 1

Mode S MB Data exists

Repetition factor = 3

BLOC 01 = 8bd9eb2fbfe400

BDS = 6.0 code : Heading and speed

status = 1

Magnetic heading exists

Magnetic heading = 33.22265625 deg

status = 1

Indicated airspeed exists

Indicated airspeed = 245 knots

status = 1

Mach number exists

Mach number = 0.76 Mach

status = 1

Barometric altitude rate exists

Barometric altitude rate = -128ft/mn

status = 1

Inertial altitude rate exists

Inertial altitude rate = 0ft/mn
```

```
BLOC 02 = 80919f39a004dd
BDS = 5.0 code : Track and turn
status = 1
Roll angle exists
Roll angle = 0.703125deg
status = 1
True track angle exists
True track angle = 36.38671875deg
status = 1
Ground speed exists
Ground speed = 460knots
status = 1
Track angle rate exists
Track angle rate = 0.0deg/s
status = 1
True airspeed exists
True airspeed = 442knots
BLOC 03 = c8480030a80000
BDS = 4.0 code : Selected intention
status = 1
MCP/FCU selected altitude exists
MCP/FCU selected altitude = 37008 Feets
status = 0
FMS selected altitude does not exist
status = 1
Barometric pressure setting exists
Barometric pressure setting = 1013.2 mb
bits [40 - 47] = 00000000 reserved set to zeros
mode VNAV, mode Alt hold, mode Approach : does not exist
bits [52 - 53] = 00 reserved set to zeros
status = 0
Target alt source does not exist
****************  Examination of the existence of the Track number field ****************
FSPEC[12] = 1
Track Number exists
bits [16 - 13] = 0000 bits set to zeros
Track Number = 919
```

```
****************  Examination of the existence of the Calculated position in cartesian coordinates field ****************

FSPEC[13] = 0

Calculated Position in Cartesian Coordinates does not exist

****************  Examination of the existence of the Calculated track velocity in polar representation field ****************

FSPEC[14] = 1

Calculated Track Velocity in Polar Representation exists

CALCULATED GROUNDSPEED = 463.76knots

CALCULATED HEADING = 32.648deg

****************  Examination of the existence of the Track status field ****************

FSPEC[15] = 1

Track Status exists

Track status = 01000000

CNF = Confirmed vs. Tentative Track = 0 Confirmed Track

RAD = Type of Sensor(s) maintaining Track = 10 SSR/Mode S Track

DOU = Signals level of confidence in plot to track association process = 0 Normal confidence

MAH = Manoeuvre detection in Horizontal Sense = 0 No horizontal man.sensed

CDM = Climbing / Descending Mode = 00 Maintaining

FX = 0 End of Data Item

****************  Examination of the existence of the Track Quality field ****************

FSPEC[17] = 0

Track Quality does not exist

****************  Examination of the existence of the Warning/Error Conditions field ****************

FSPEC[18] = 0

Warning/Error Conditions does not exist

****************  Examination of the existence of the Mode-3/A code confidence indicator field ****************

FSPEC[19] = 0

Mode-3/A Code Confidence Indicator does not exist

****************  Examination of the existence of the Mode-C code and confidence indicator field ****************

FSPEC[20] = 0

Mode - C Code and Confidence Indicator does not exist

**************** Examination of the existence of the Height Measured by 3D radar field ****************

FSPEC[21] = 0

Height Measured by 3D Radar does not exist

****************  Examination of the existence of the Radial Doppler speed field ****************

FSPEC[22] = 0

Radial Doppler Speed does not exist
```

```
*************** Examination of the existence of the Communications /ACAS Capability and flight status field ***************

FSPEC[23] = 1

Communications / ACAS Capability and Flight Status exists

Communications capability of the transponder = 001 Comm. A and Comm. B capability

Flight Status = 000 No alert, no SPI, aircraft airborne

SI/II Transponder Capability = 0 SI-Code Capable

bit[9] = 0 spare bit set to zero

Mode-S Specific Service Capability = 1 Yes

Altitude reporting capability = 1 25 ft resolution

Aircraft identification capability = 1 Yes

B1A = BDS 1,0 bit 16 = 1

B1B = BDS 1,0 bits 37/40 = 1101


Process finished with exit code 0
```

Figure IV.9: The execution of the Asterix message

After this execution the program will automatically create a text file that contains some fields that we have chosen to display on the radar screen.

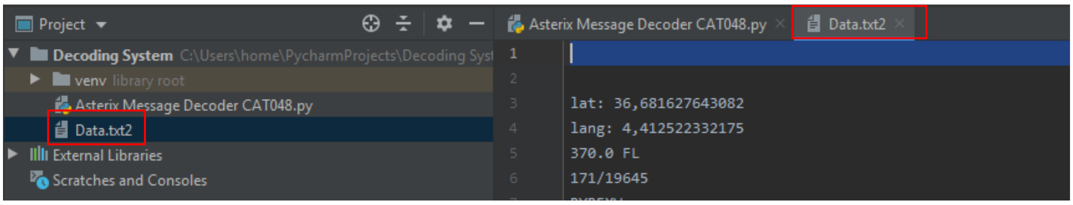


Figure IV.10: The text file generated by the decoding program

```
lat: 36,681627643082
lang: 4,412522332175
370.0 FL
171/19645
RYR5XW
460-- 33.22265625
SAC/SIC = 0/1
Time of Day = 9:18:19
RANGE = 73.921875 NM
Mode-3/A reply in letters = 000B400C4C2C1000
MCP/FCU selected altitude = 37008 feets
Barometric pressure setting = 1013.2 mb
Roll angle = 0.703125 deg
True track angle = 36.38671875 deg
Track angle rate = 0.0 deg/s
Mach number = 0.76 Mach
Inertial altitude rate = 0 ft/mn
Track Number = 919
Warning/Error Code = N/A
```

Figure IV.11: The contents of the text file

The contents of the text file are the following:

- Aircraft identification
- Flight level
- ICAO Aircraft Address
- Ground Speed-- Heading magnetic
- Data source identifier
- Time of Day
- Range
- Mode 3/A reply in letters
- MCP/FCU selected altitude
- Barometric pressure setting
- Roll Angle
- True Track Angle
- Track Angle Rate
- Mach number
- Inertial altitude rate
- Track number
- Warning/Error code

- Geographic coordinates of the target (latitude and longitude)

IV.4.2.6. Decoding of other fields:

Since our previous record does not contain all fields, it does not mean that we have not decoded all fields.

We will now make examples to decode the other fields to prove that we have decoded all the fields that exist in the Asterix CAT 048 message.

IV.4.2.6.1. Decoding the Calculated Position in Cartesian Coordinates field:

The length of this field is 4 bytes, for the decoding of this field see Annex A.

In order for the field to exist, bit 13 of the FSPEC = 1.

Let: Calculated Position in Cartesian Coordinates = 1e001900.

Calculated Position in Cartesian Coordinates relative to the radar station.

Run the program :

```
FSPEC[13] = 1
Calculated Position in Cartesian Coordinates exists
X-Component = 60.0NM
Y-Component = 50.0NM
```

Figure IV.12: Result of Calculated Position in Cartesian Coordinates field decoding

IV.4.2.6.2. Decoding the Track Quality field:

The length of this field is 4 bytes, for the decoding of this field see Annex A.

In order for the field to exist, bit 17 of the FSPEC = 1

Let: Track Quality = 5a400504

Run the program :

```
FSPEC[17] = 1
Track Quality exists
Sigma (X) = Standard Deviation on the horizontal axis of the local grid system = 0.703125 NM
Sigma (Y) = Standard Deviation on the vertical axis of the local grid system = 0.5 NM
Sigma (V) = Standard Deviation on the groundspeed within the local grid system = 1.1 knots
Sigma (H) = Standard Deviation on the heading within the local grid system = 0.35156 deg
```

Figure IV.13: Result of Track Quality field decoding

IV.4.2.6.3. Decoding the Warning/Error Conditions field:

The length of this field is 1 bytes followed by 1 bytes extents as necessary, for the decoding of this field see Annex A.

In order for the field to exist, bit 18 of the FSPEC = 1

Let: Warning/Error Conditions = 26

Run the program :

```
FSPEC[18] = 1
Warning/Error Conditions exists
Warning/Error Conditions = 00100110
Warning/Error Code = 19 Birds
FX = 0 End of Data Item
```

Figure IV.14: Result of Warning/Error Conditions field decoding (one Warning/Error code)

If we have two Warning/Error Conditions:

Let: Warning/Error Conditions = 271a

Run the program:

```
FSPEC[18] = 1
Warning/Error Conditions exists
Warning/Error Conditions = 00100111
Warning/Error Code = 19 Birds
FX = 1 Extension into first extent (next W/E condition value)
Warning/Error Conditions = 00011010
Warning/Error Code = 13 Target in Clutter Area
FX = 0 End of Data Item
```

Figure IV.15: Result of Warning/Error Conditions field decoding (two Warning/Error codes)

IV.4.2.6.4. Decoding the Mode-3/A Code Confidence Indicator field:

The length of this field is 2 bytes, for the decoding of this field see Annex A.

In order for the field to exist, bit 19 of the FSPEC = 1

Let: Mode-3/A Code Confidence Indicator = 0a01

Run the program:

```
FSPEC[19] = 1
Mode-3/A Code Confidence Indicator exists
bits [16 - 13] = 0000 Spare bits set to 0
QA4 = 1 Low quality pulse A4
QA2 = 0 High quality pulse A2
QA1 = 1 Low quality pulse A1
QB4 = 0 High quality pulse B4
QB2 = 0 High quality pulse B2
QB1 = 0 High quality pulse B1
QC4 = 0 High quality pulse C4
QC2 = 0 High quality pulse C2
QC1 = 0 High quality pulse C1
QD4 = 0 High quality pulse D4
QD2 = 0 High quality pulse D2
QD1 = 1 Low quality pulse D1
```

Figure IV.16: Result of Mode-3/A Code Confidence Indicator field decoding

IV.4.2.6.5. Decoding the Mode-C Code and Confidence Indicator field:

The length of this field is 4 bytes, for the decoding of this field see Annex A.

In order for the field to exist, bit 20 of the FSPEC = 1

Let: Mode-C Code and Confidence Indicator = 0a0700b0

Run the program:

```
FSPEC[19] = 0
Mode-3/A Code Confidence Indicator does not exist
FSPEC[20] = 1
Mode - C Code and Confidence Indicator exists
V = 0 Code validated
G = 0 Default
bits [30 - 29]= 00 Spare bits set to 0
Mode-C reply in Gray notation = C1 0 C2 0 0 0 0 0 0 D2 B4 D4
bits [16 - 13] = 0000 Spare bits set to 0
QC1 = 0 High quality pulse C1
QA1 = 0 High quality pulse A1
QC2 = 0 High quality pulse C2
QA2 = 0 High quality pulse A2
QC4 = 1 Low quality pulse C4
QA4 = 0 High quality pulse A4
QB1 = 1 Low quality pulse B1
QD1 = 1 Low quality pulse D1
QB2 = 0 High quality pulse B2
QD2 = 0 High quality pulse D2
QB4 = 0 High quality pulse B4
QD4 = 0 High quality pulse D4
```

Figure IV.17: Result of Mode-C Code and Confidence Indicator field decoding

IV.4.2.6.6. Decoding the Height Measured by 3D Radar field:

The length of this field is 2 bytes, for the decoding of this field see Annex A.

In order for the field to exist, bit 21 of the FSPEC = 1

Let: Height Measured by 3D Radar = 05c8

Run the program:

```
FSPEC[21] = 1
Height Measured by 3D Radar exists
bits [16 - 15] = 00 Spare bits set to zero
Height Measured by 3D Radar = 37000 feets
```

Figure IV.18: Result of Height Measured by 3D Radar field decoding

IV.4.2.6.7. Decoding the Radial Doppler Speed field:

The length of this field is 8 bytes, for the decoding of this field see Annex A.

In order for the field to exist, bit 22 of the FSPEC = 1

Let: Radial Doppler Speed = 400300e800020442

Run the program:

```
FSPEC[22] = 1
Radial Doppler Speed exists
CAL = Subfield #1: Calculated Doppler Speed = 0 Absence of Subfield #1
RDS = Subfield #2: Raw Doppler Speed = 1 Presence of Subfield #2
Repetition Factor = 3
 Doppler Speed = 232 m/sec
Ambiguity Range = 2 m/sec
Transmitter Frequency = 1090 MHz
bits [6 - 1] = 000000 bits set to zeros
```

Figure IV.19: Result of Radial Doppler Speed field decoding

IV.4.2.6.8. Decoding the ACAS Resolution Advisory Report field:

The length of this field is 7 bytes, for the decoding of this field see Annex A.

In order for the field to exist, bit 25 of the FSPEC = 1

Let: ACAS Resolution Advisory Report = 0701fc2c001fff

Run the program:

```
FSPEC[25] = 1
ACAS Resolution Advisory Report exists
56-bit message conveying Mode S Comm B message data of BDS Register 3,0 = 0701fc2c001fff
Message Type = 00000
Message Sub-type = 111
Active Resolution Advisories = 00000001111111
RAC (RA Complement) Record = 0000
RA Terminated = 1
Multiple Threat Encounter = 0
Threat Type Indicator = 11
Threat Identity Data = 00000000000001111111111111
```

Figure IV.20: Result of ACAS Resolution Advisory Report field decoding

IV.4.2.6.9. Decoding the Mode-1 Code in Octal Representation field:

The length of this field is 1 bytes, for the decoding of this field see Annex A.

In order for the field to exist, bit 26 of the FSPEC = 1

Let: Mode-1 Code in Octal Representation = 0a

Run the program:

```
FSPEC[26] = 1
Mode-1 Code in Octal Representation exists
V = 0 Code not validated
G = 0 Default
L = 0 Mode-1 code as derived from the reply of the transponder
Mode-1 code = 0 A2 0 B2 0
```

Figure IV.21: Result of Mode-1 Code in Octal Representation field decoding

IV.4.2.6.10. Decoding the Mode-2 Code in Octal Representation field:

The length of this field is 2 bytes, for the decoding of this field see Annex A.

In order for the field to exist, bit 27 of the FSPEC = 1

Let: Mode-2 Code in Octal Representation = 0a0e

Run the program:

```
FSPEC[27] = 1
Mode-2 Code in Octal Representation exists
V = 0 Code not validated
G = 0 Default
L = 0 Mode-2 code as derived from the reply of the transponder
bit[13] = 0 bit set to zero
Mode-2 code in octal representation = A4 0 A1 0 0 0 0 0 C1 D4 D2 0
```

Figure IV.22: Result of Mode-2 Code in Octal Representation field

IV.4.2.6.11. Decoding the Mode-1 Code Confidence Indicator field:

The length of this field is 1 bytes, for the decoding of this field see Annex A.

In order for the field to exist, bit 28 of the FSPEC = 1

Let: Mode-1 Code Confidence Indicator = 02

Run the program:

```
FSPEC[28] = 1
Mode-1 Code Confidence Indicator exists
bits[8 - 6] = 000 bits set to zeros
QA4 = 0 High quality pulse A4
QA2 = 0 High quality pulse A2
QA1 = 0 High quality pulse A1
QB2 = 1 Low quality pulse B2
QB1 = 0 High quality pulse B1
```

Figure IV.23: Result of Mode-1 Code Confidence Indicator field decoding

IV.4.2.6.12. Decoding the Mode-2 Code Confidence Indicator field:

The length of this field is 2 bytes, for the decoding of this field see Annex A.

In order for the field to exist, bit 29 of the FSPEC = 1

Let: Mode-2 Code Confidence Indicator = 0601

Run the program:

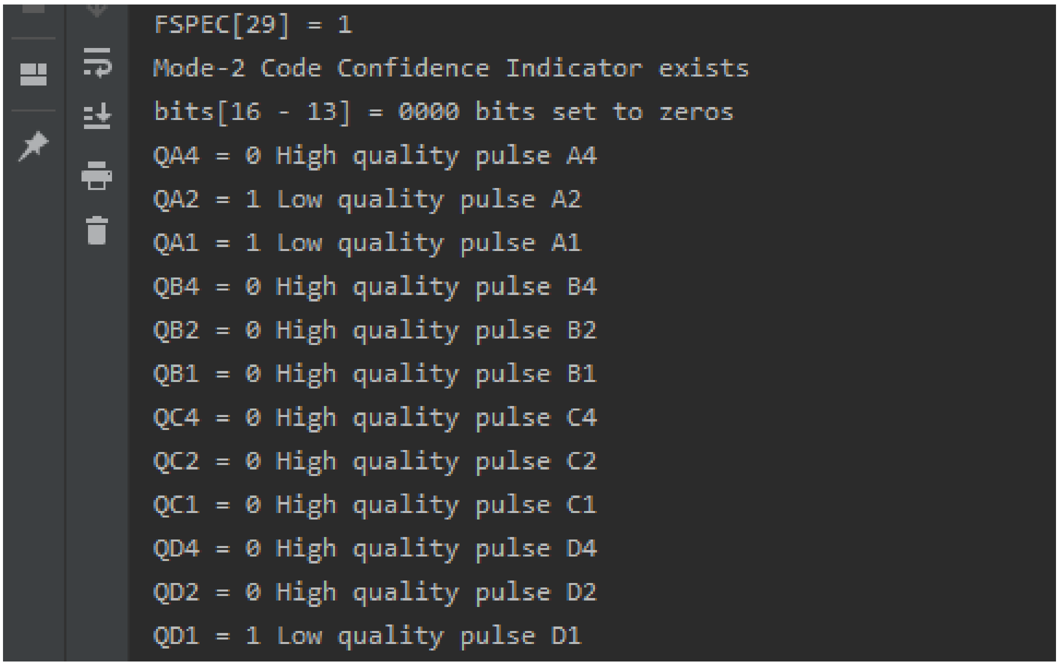


Figure IV.24: Result of Mode-2 Code Confidence Indicator field decoding

IV.4.2.6.13. The Special Purpose field:

The special purpose field is a non-standard data field, the contents of which are agreed upon between the two communications partners (MSSR Mode S and targets), what is encoded there is only known to those communication partners.

IV.4.2.6.14. Reserved Expansion field:

The reserved Expansion field is defined by the Asterix Maintenance Group.

IV.5. Data visualization:

IV.5.1. Description of the visualization system:

After decoding the Asterix message of category 048 we will now display the plots (targets) on a radar screen and also the information from the text file that was generated by the decoding system.

As is known, we used in this part the Visual Studio 2015 C# (Sharp) language, we displayed the data on a Gmap (Google Maps) version “GMap.NET.WindowsForms.1.7.5” for reasons:

- More realistic for targets captured by the radar.
- Great accuracy to target location.
- Ease of identifying the area in which the target is located.
- It allows us to display the map in various formats.

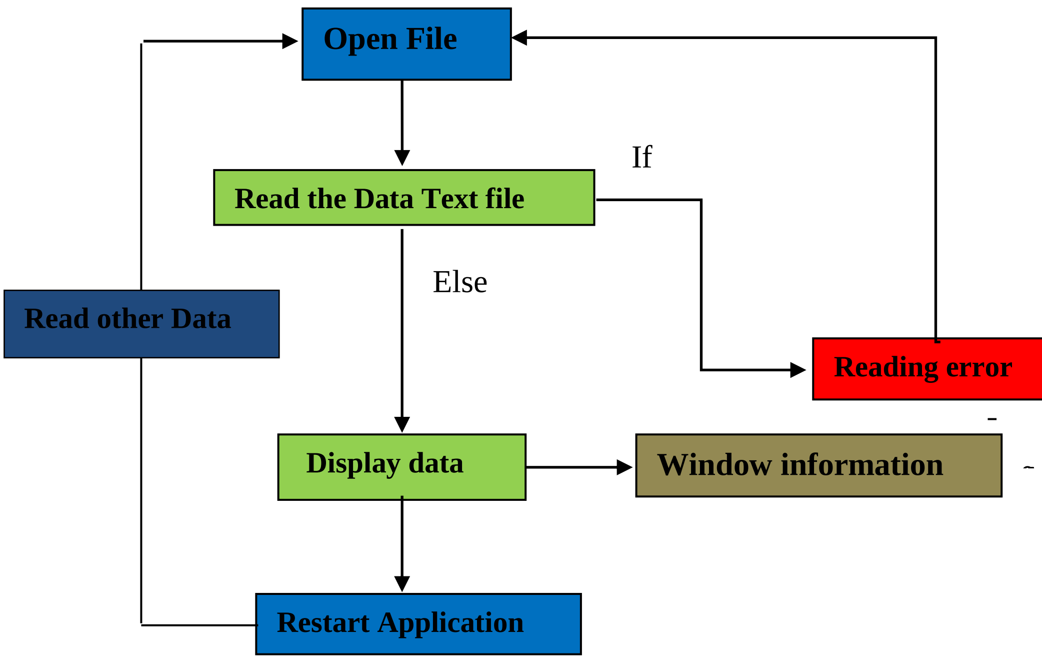


Figure IV.25: Organization chart of the visualization system

IV.5.2. Desktop application setup:

For ease of use we have created a desktop application on the name “Asterix-Cat048 Data Display”, you do not need to install Visual studio and GMAP just install the desktop application as follows**:**

- Open the folder” Asterix Data Display”
- Install the application “Asterix Data Display_Cat048.msi”.

- Open the folder" my file"→ Copy the content.
- Paste the content into this path:

  "C:\Program Files (x86) \Asterix Display_Cat 48\Asterix Data Display "

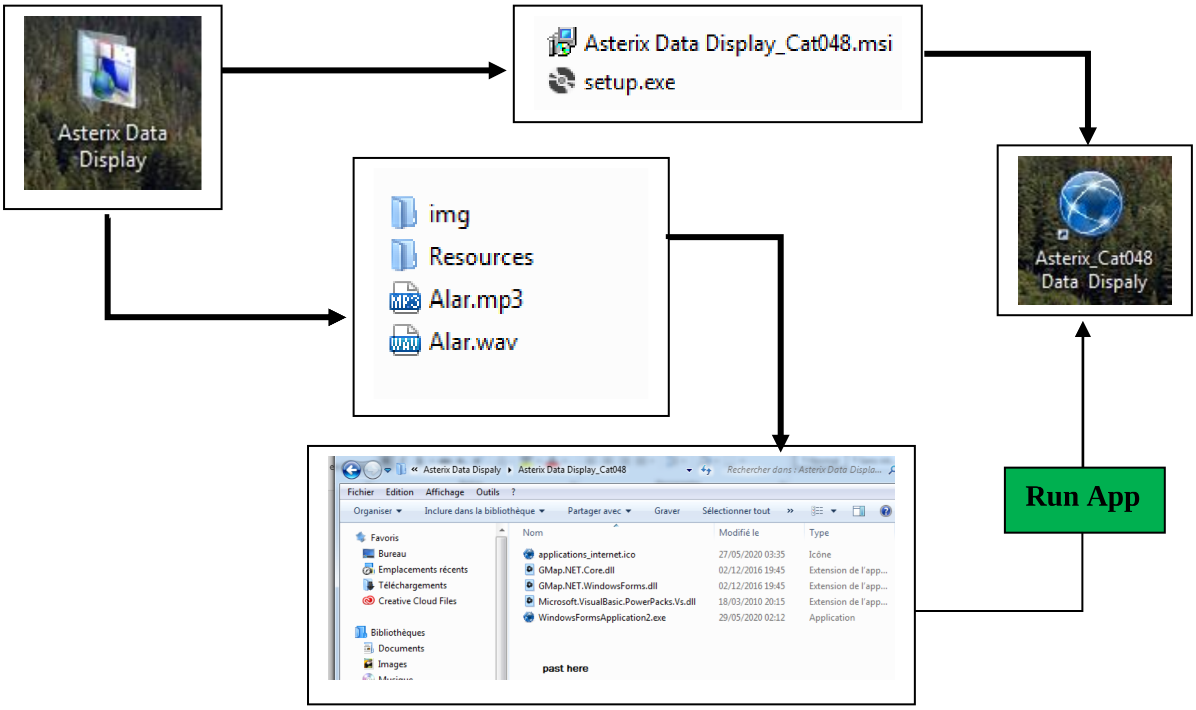


Figure IV.26: Installation method of the Asterix-Cat048 Data Display

IV.5.3. Visualization system interface:

The interface of the visualization system is shown in the following figure:

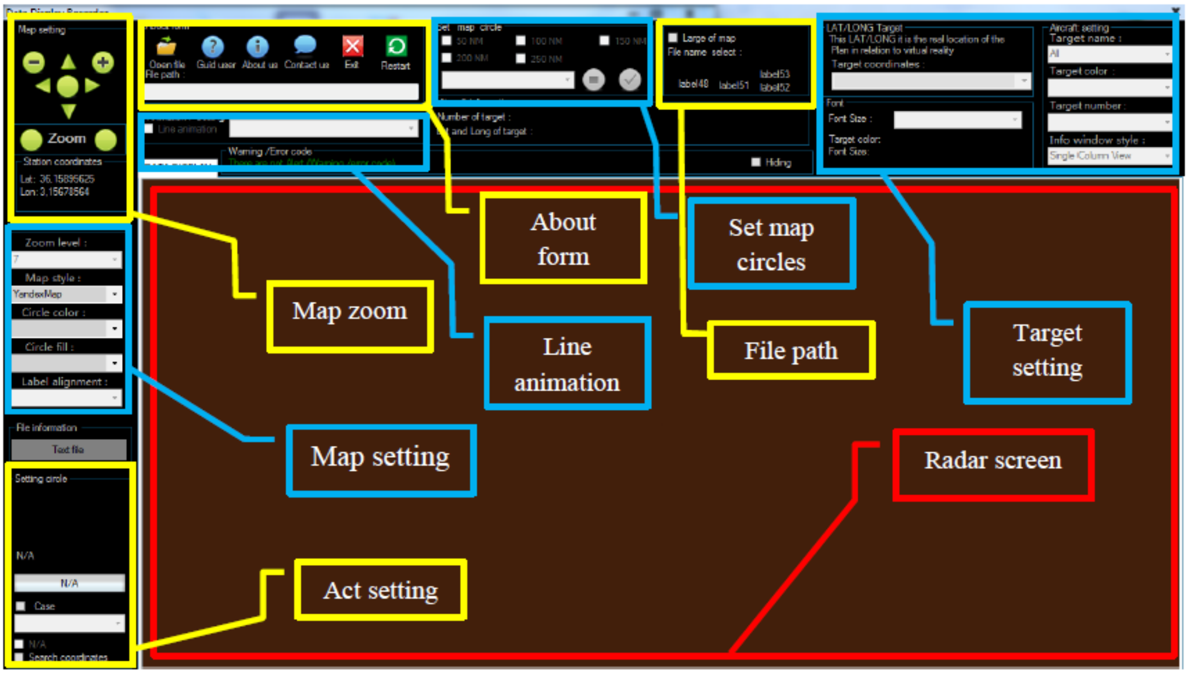


Figure IV.27: Visualization system interface

We are going to define the role of the four areas marked above which are: Act setting, Map style, Map zoom, Line animation, About form, Set map circles, File path, Target setting, Radar screen.

IV.5.3.1. Act setting:

This feature gives us:

- Select the station location (Name or Coordinates).
- Activate circles display.
- Activate N/A (Marker enable).

This feature allows us to choose how to work either station location or station coordinates. Selection of station location: It is a data base containing 5 station in Algeria.

Injection of station coordinates: We can enter a new station using the coordinates.

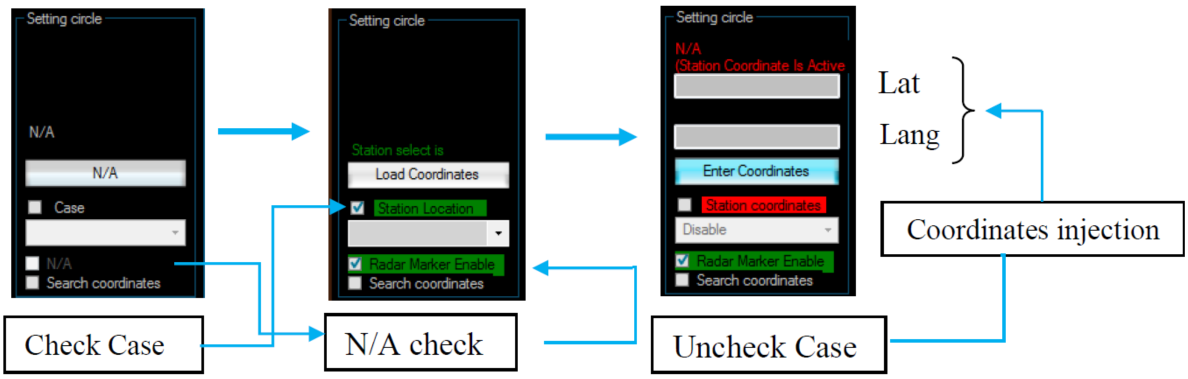


Figure IV.28: Marker enable and Choice of station

IV.5.3.1.1. Select of station location:

For the choice of the station there is a database containing the five stations in Algeria, it is necessary to choose the same station that we have chosen in the data decoding step, the choice is shown in the following figure:

Figure IV.29: Select of station location

IV.5.3.1.2. Injection of station coordinates:

This choice is to display a different station to the five current stations in Algeria, either a new station in Algeria or a station outside Algeria. In this example we will inject the coordinates of the radar station in Riyadh (Kingdom of Saudi Arabia).

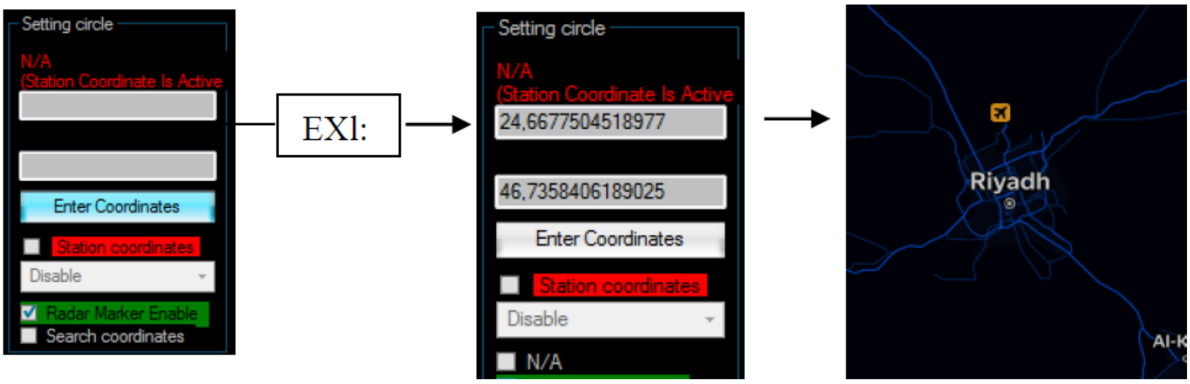


Figure IV.30: Example of injecting the coordinates of a radar station

IV.5.3.2. Map setting:

This area has the role of modifying the graphics of the radar image, it contains three options:

Map style, Circle color, Fill color.

IV.5.3.2.1. Map style:

There are several styles that are:

- ArcGIS_World_Topo_Map
- CzechTuristWinterMap
- WikiMapiaMap
- YahooHybridMap
- EmptyMap(SwedenMap)
- YandexMap

IV.5.3.2.2. Circle color:

For changing the color of the fifth circle (250 NM range).

IV.5.3.2.3. Circle fill:

Fill in the circle to change the background.

IV.5.3.3. Map zoom:

IV.5.3.3.1. Draging map:

Four buttons to move the map north, west, east and south.

IV.5.3.3.2. Map zoom size:

By buttons (+) To zoom in, and (-) To zoom out (Max Zoom = 24; Min Zoom = 1).

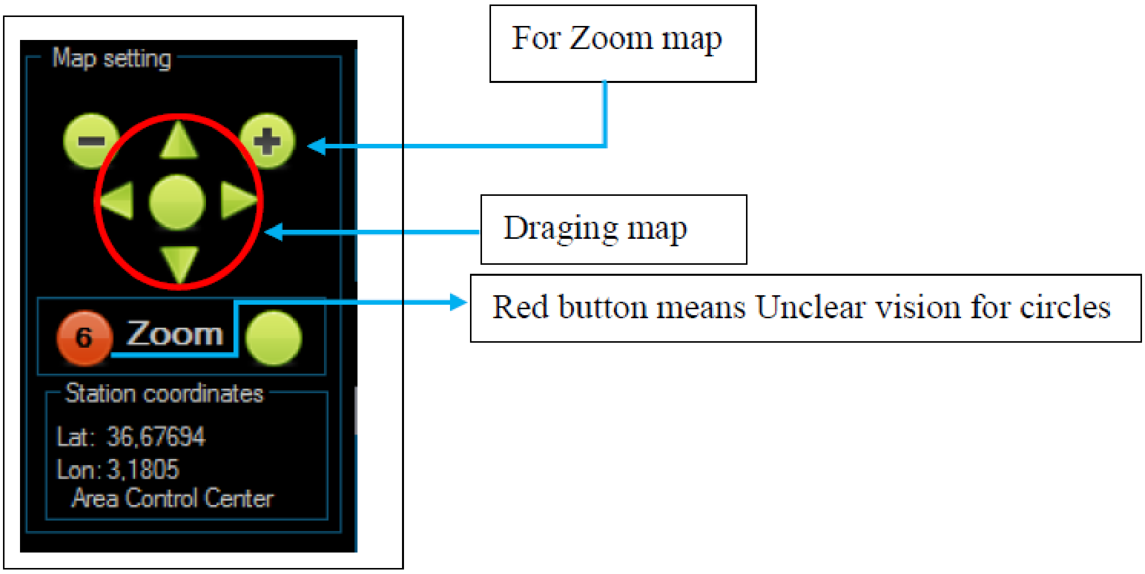


Figure IV.31: Map zoom tools

IV.5.3.4. Line animation:

It is a moving line whose center is the radar coordinates revolving in the same direction of radar rotation 12 rpm. The length of the radius of the rotating line is the same as the radar range (250 NM).

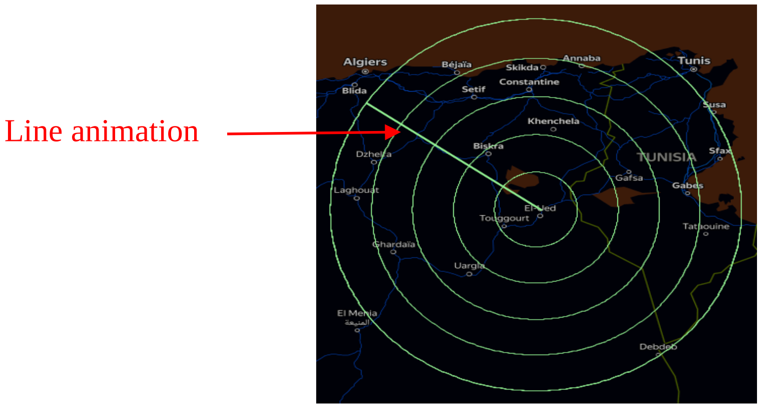


Figure IV.32: Line animation visualization

IV.5.3.5. About form:

The different tools that exists in “About form” are shown in the following figure:

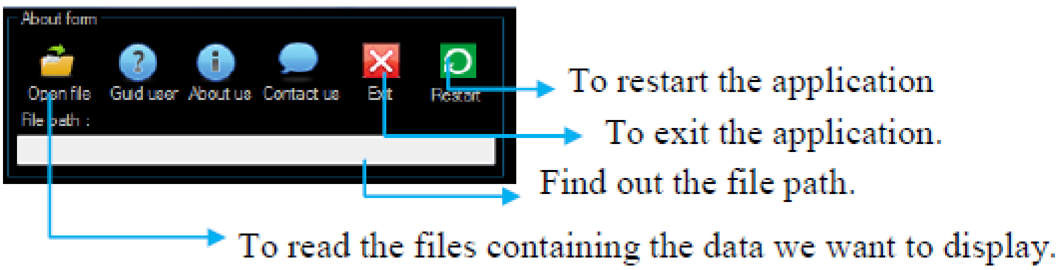


Figure IV.33: About form tools

IV.5.3.6. Set map circles:

These circles are present on the radar screen and their role is represented by two things:

- Know the areas covered by the radar.
- Assist the ATC in locating the target with great accuracy.

There are two methods to display the circles: View all, Select circle.

IV.5.3.6.1. View all method (with Appear, Hide button):

In this choice the five circles are displayed at the same time

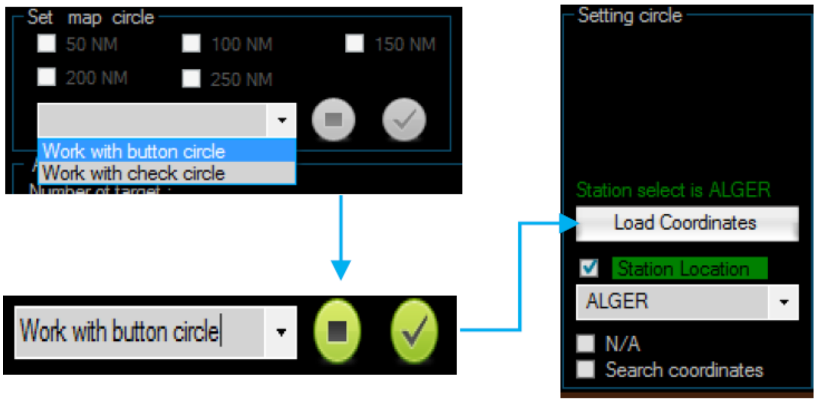


Figure IV.34: Steps for working with the View all method

After completion of the steps above the five circles appeared with a center which is the chosen radar station, and with a separation of 50 NM between two successive circles (5 * 50 = 250 NM).

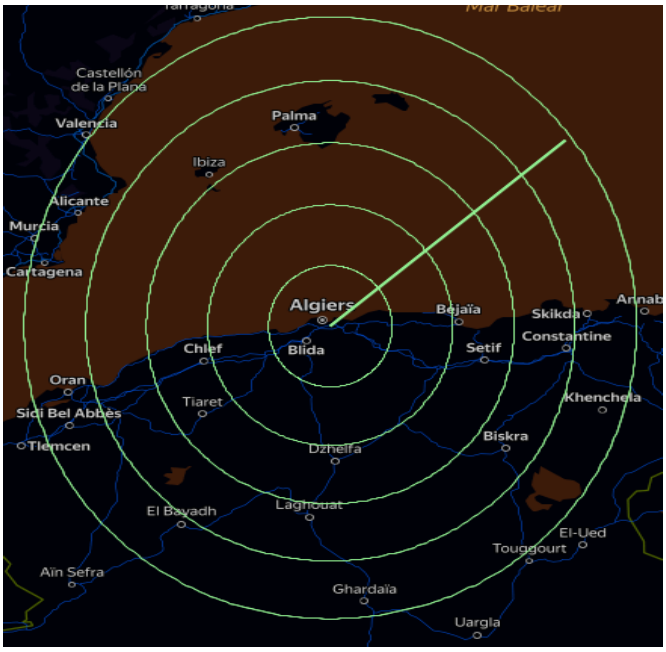


Figure IV.35: Visualization of circles with the View all method

IV.5.3.6.2. Select circle:

In this method the user who governs the appearing circles, just tick a box of the chosen circles.

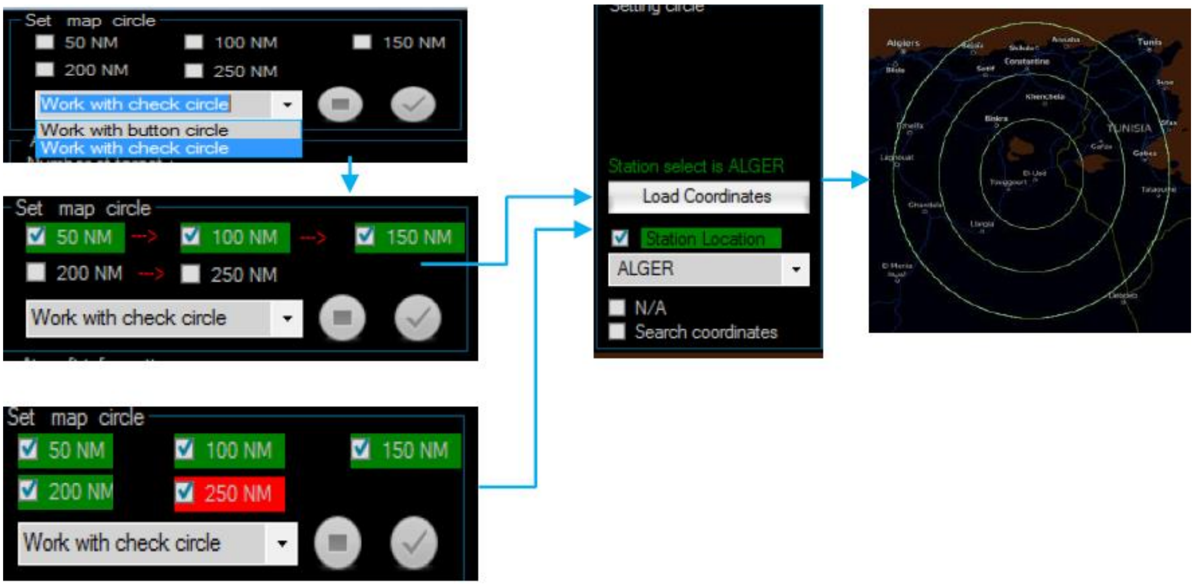


Figure IV.36: Visualization of circles with the Select circle method

IV.5.3.7. Target setting:

IV.5.3.7.1. Target color:

In some cases, the information does not appear to be unclear due to the names of regions and the background of the screen, so we can use this feature to change the colors.

IV.5.3.7.2. Target font size:

Sometimes the targets are many, so we must enlarge or reduce the size of the information font, it contains three sizes:

- Small font size (6)
- Medium font size (9)
- Big font size (12)

IV.5.3.7.3. The number of targets:

It's the number of targets within the radar range is calculated.

IV.5.3.7.4. Target name:

View all targets at once or choose a target from the list of target names within the radar range, when you click on the target, it takes you directly to its location.

IV.5.3.7.5. LAT and LONG target:

For viewing the coordinates of the aircraft.

IV.5.3.8. File path:

Once the data file is selected, the file name and size will be listed in this menu.

IV.5.3.9. Radar screen:

This is the most important area, it shows us the plots (targets), radar station, the circles, line animation, information window…

IV.5.4. Simulation & Testing:

Now we are going to make a simulation of the previously decoded Asterix message (the RYR5XW target), as well as tests and explanations concerning the areas of the interface of the visualization system.

Assuming this target was picked up by the "EL-OUED" station, doing the following steps:

- Case option
- N/A (Markers enable)
- Chose EL-OUED station
- Zoom Map = 7
- View circles
- View line animation

After we have followed the steps, we can see: the “EL-OUED” station, circles, line animation.

Now we need to inject a text file to visualize the plots, in this example we will choose the text file that contains the information of the target RYR5XW, noted although this text file is the same one that was generated by the decoding system.

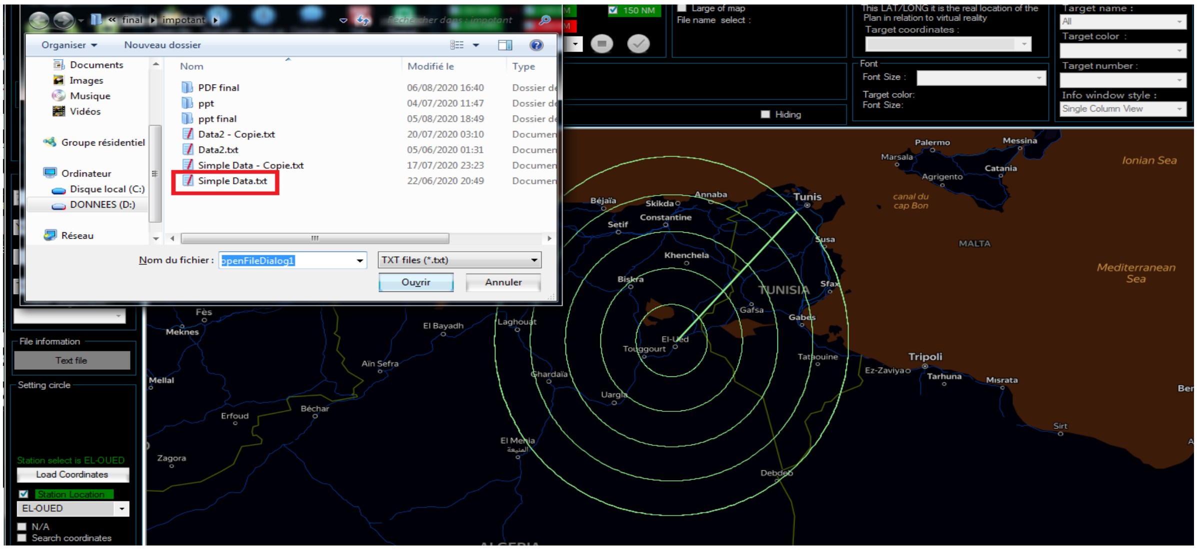


Figure IV.37: Injection of the text file into the visualization system

After injecting the text file of the target RYR5XW, this target will appear on the radar screen in the form of a plot; the subfields attached to the target on the radar screen are as follows:

- Aircraft identification
- Flight level
- ICAO Aircraft Address
- Ground Speed-- Heading magnetic

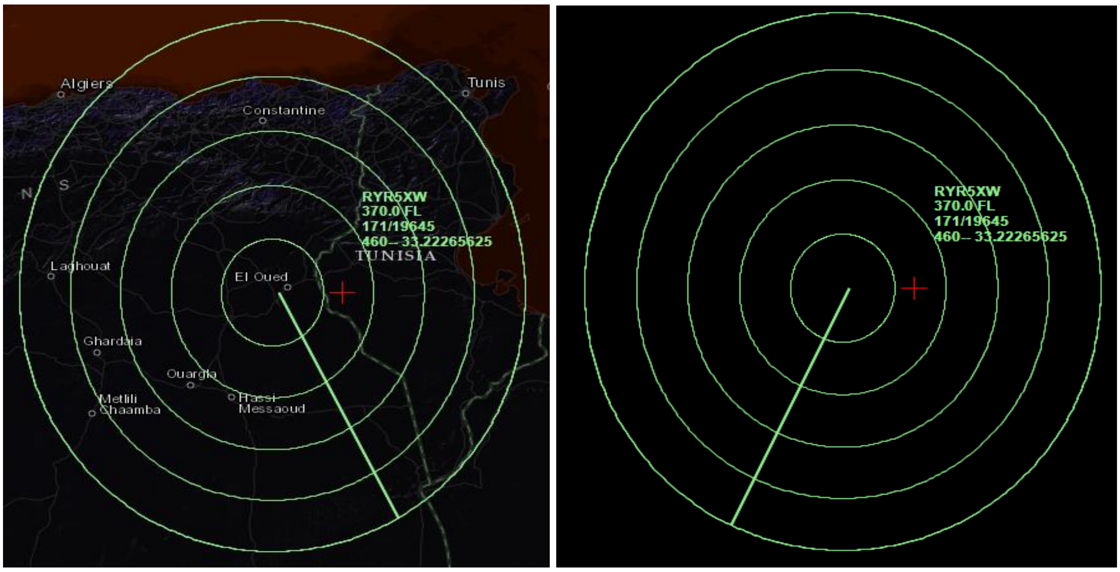


Figure IV.38: Target display with 2 methods

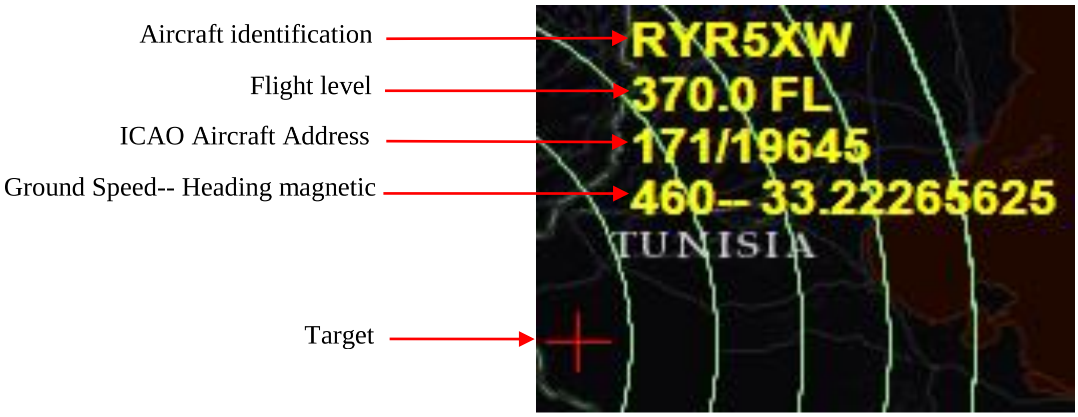


Figure IV.39: Subfields attached to the target

Now let's try to change the color and size of the writing:

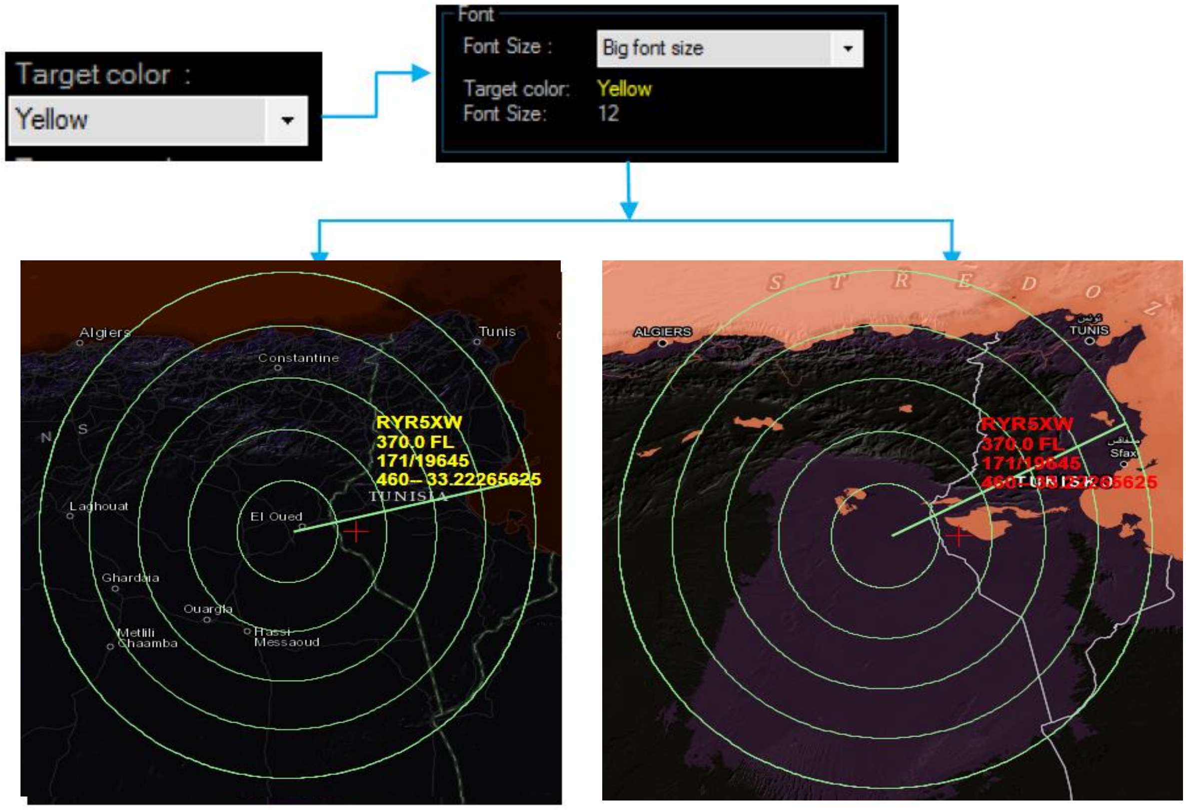


Figure IV.40: Color and font size test

File path:

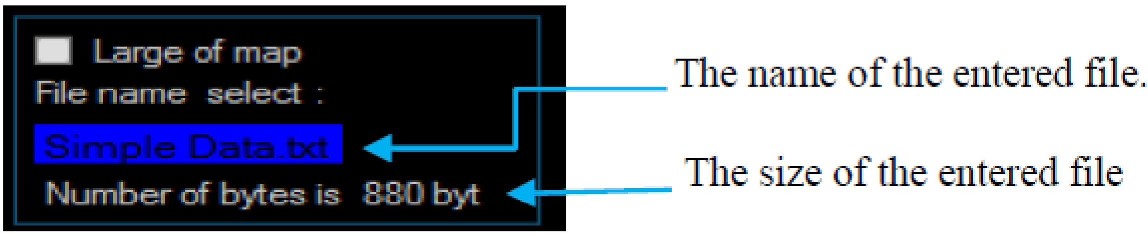


Figure IV.41: Display size and name of the selected text file

Target setting:

Figure IV.42: Number of target displayed

Figure IV.43: Target name display

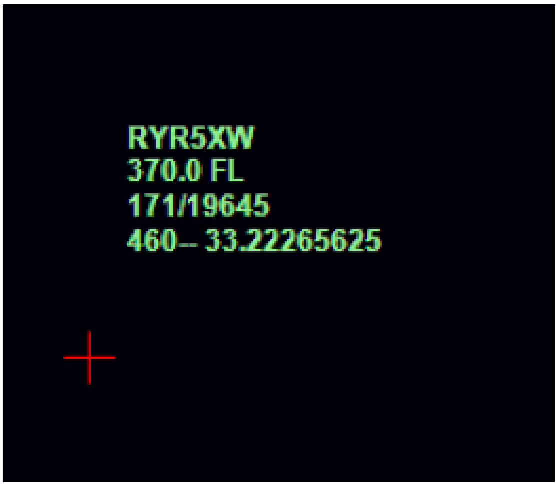


Figure IV.44: The selected Target display

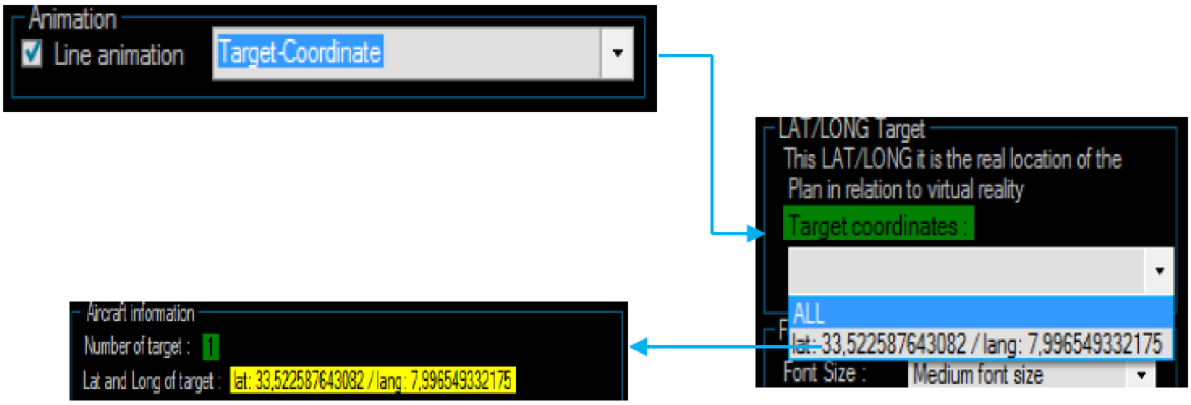


Figure IV.45: Target coordinates display

Information window: When the user wants more information about the target, we select the target from the list and clicks on it (on map). A window appears with more information which are as follows:

- SAC/SIC: Data source identifier
- Time of Day
- Range
- MODE-3/A: Mode 3/A reply in letters
- MCP/FCU_SA: MCP/FCU selected altitude
- BAR_PRE: Barometric pressure setting
- Roll Angle
- TTA: True Track Angle
- TAR: Track Angle Rate
- MACH: Mach number
- IAR: Inertial altitude rate
- Track number
- Warning/Error code

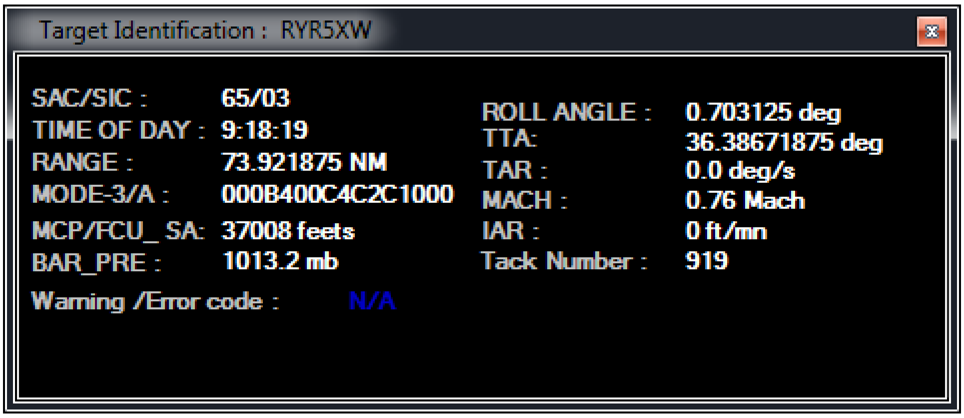


Figure IV.46: Information window

Warning/Error code: If there is no warning/error code, a window appears saying "there are not alert"

Figure IV.47: message warning /error code (no alert)

If there is at least one Warning/Error code in any target, a message appears indicating that there is an error + target name. After we click on the target that has a Warning/Error code, automatically an alarm sound is triggered + error name.

IV.6. Use of the application:

In this part of this chapter we will use our application (decoding system + visualization system), the use is to exploit the following Asterix message:

300129fff7024100416deba86400ea6000e5061820c14a2fc80494f2c73d2002a229732420140
26080f0fb2e6284be5003620692442f4020fdfff7024100416deba850005fe100d305c820c127
4eb6101238df8e2003b559eb2fbfe4006080919f39a004dd50c8480030a40000400384083c6a
894020fdfff7024100416deba84b007fd700c405f020c12a3df4101238e30c60039009ab25e01
40060ffdfc930ff04cd50ca380030a4000040038e06ed1ff64020fdfff7424100416deba86600bc
5400b2064020c1414632101238e32ca00285595522200400608730ab2beb04b450035206360
aa7402620fdfff702410041edeba83200154f00f1070820c1343f715014b3d30c2003d009ab26
fffffe6080702334a204cd50d7e80030a400004003b607759fcd4020fd

This is an Asterix message category 048 contains a single block, 5 records. As the execution of this message in the decoding system is very long and can't show it all, that's why we will just show the visualization part:

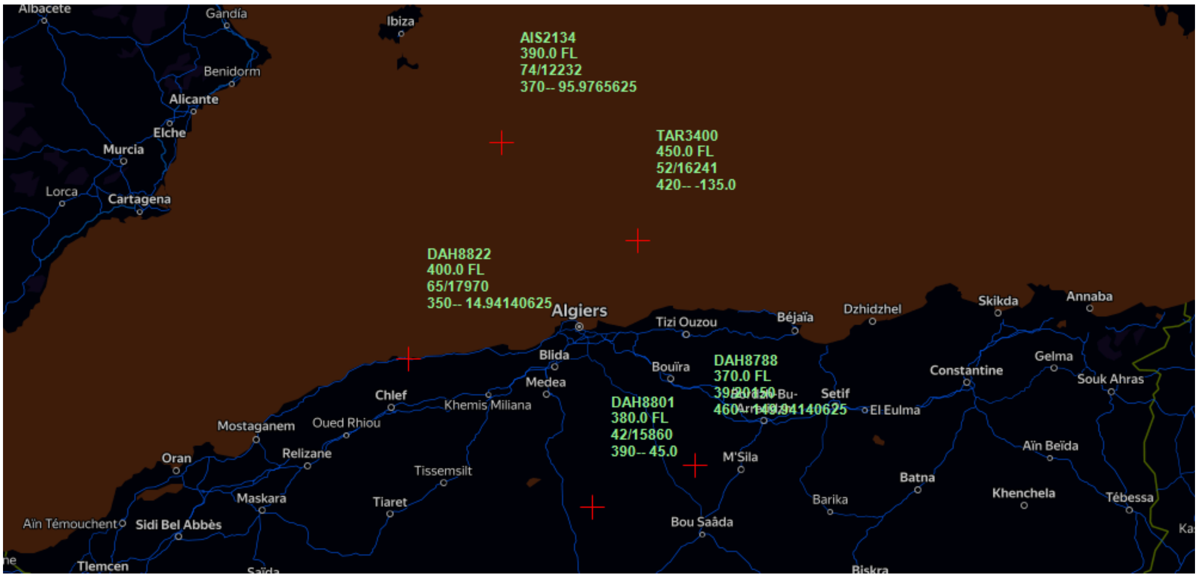


Figure IV.48: Target display on YandexMap

Figure IV.49: Target display on ArcGIS_World_Topo_Map

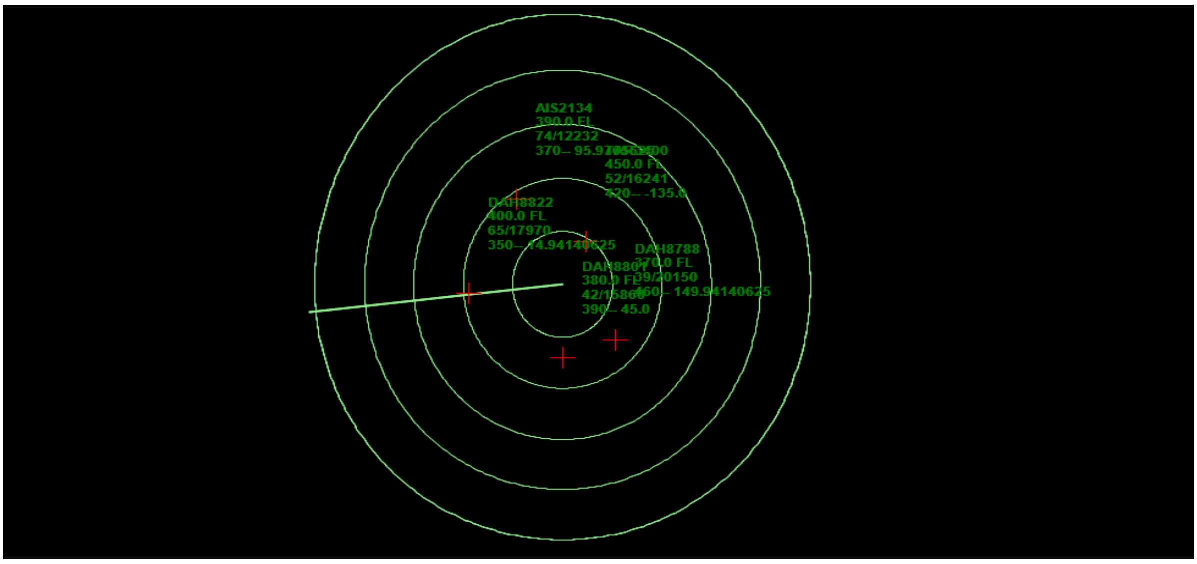


Figure IV.50: Target display on Empty SwedenMap_Map

We notice a message in red indicates that there's a Warning/Error code in the target DAH8822:

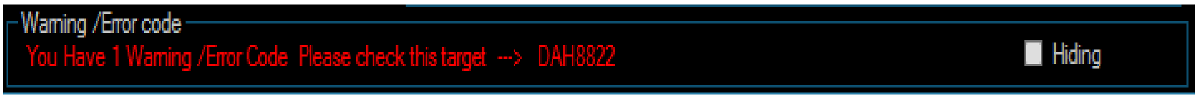


Figure IV.51: Warning/Error code message

To see the type of error, click on the desired target (DAH8822) to display an information window:

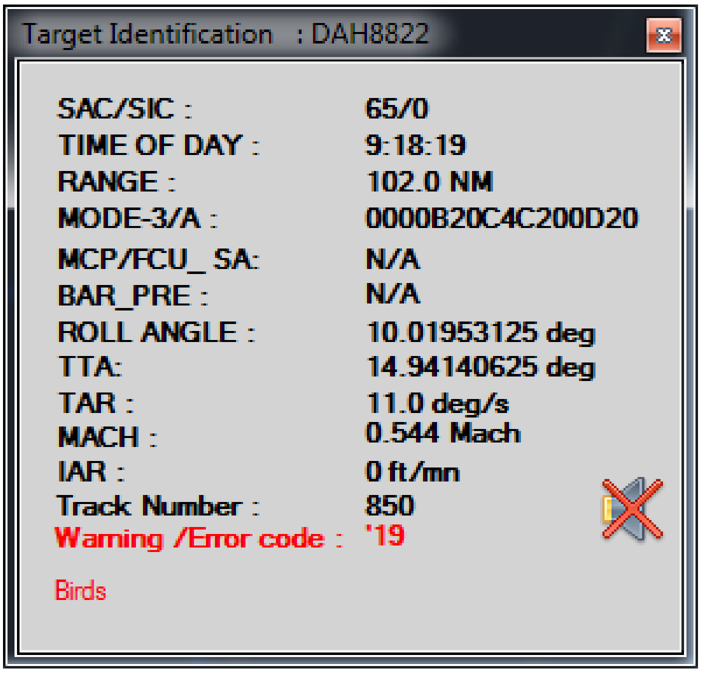


Figure IV.52: DAH8822 target information window

Displaying the information windows of the remaining targets:

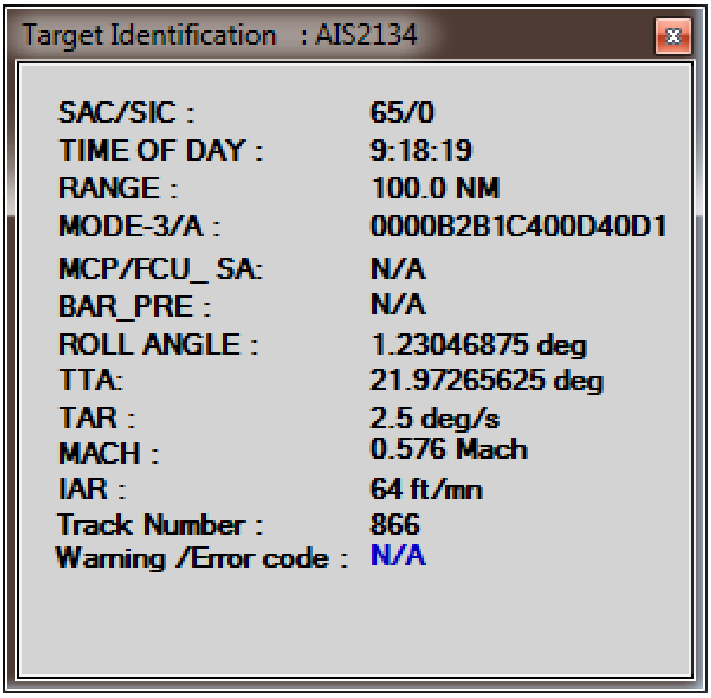


Figure IV.53: AIS2134 target information window

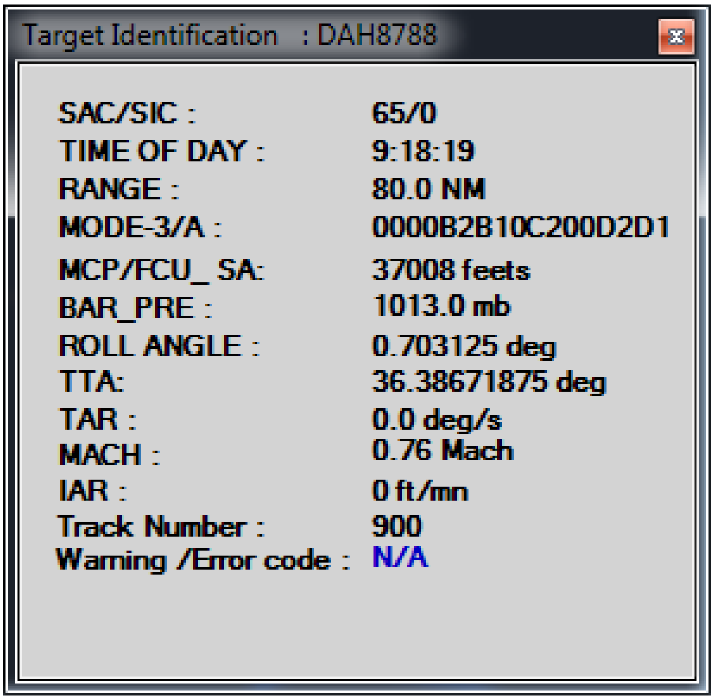


Figure IV.54: DAH8788 target information window

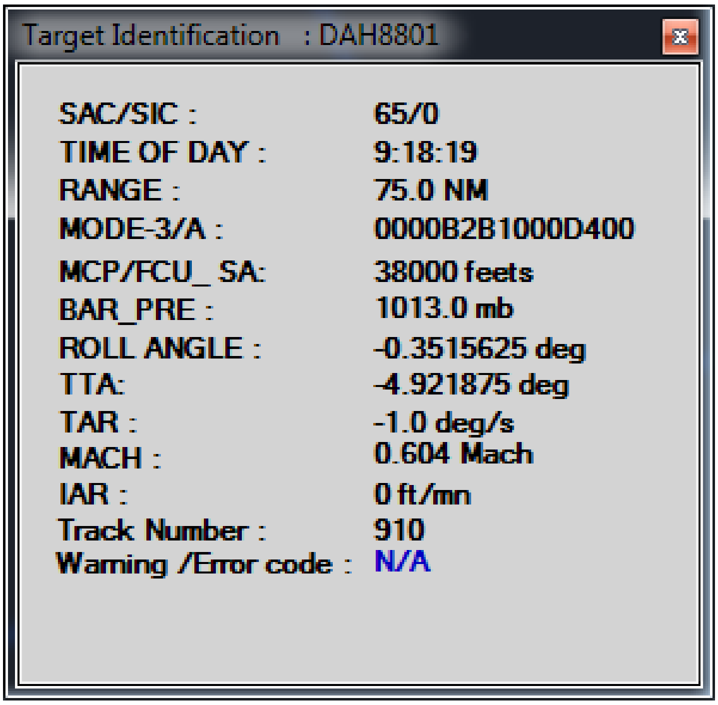


Figure IV.55: DAH8801 target information window

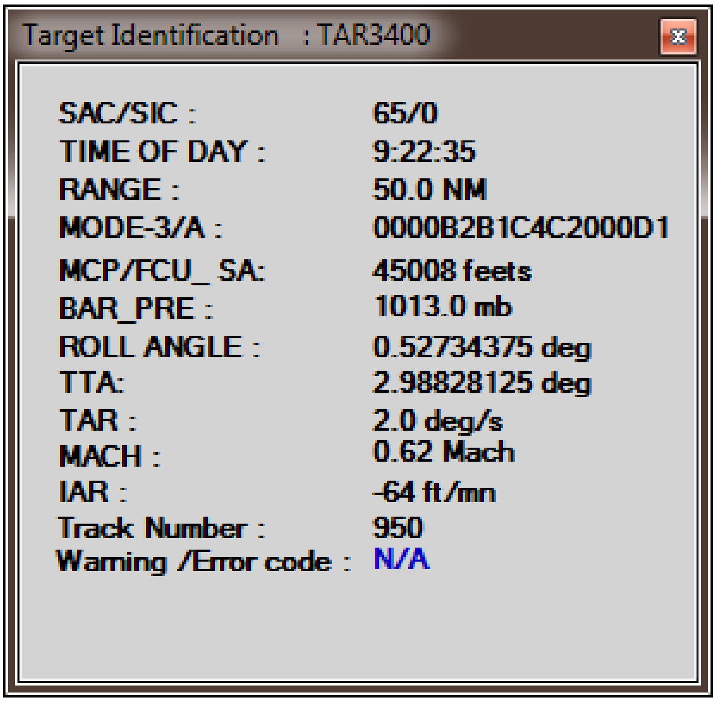


Figure IV.56: TAR3400 target information window

The display of the geographical coordinates of the targets:

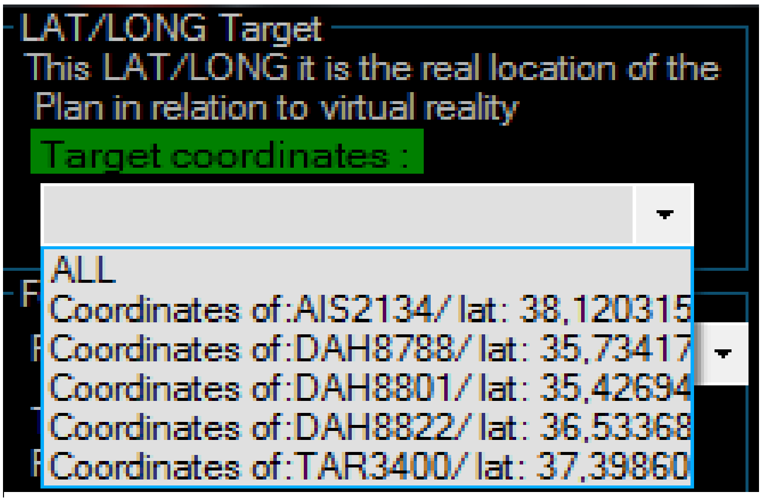


Figure IV.57: Choice of the target for the display of geographical coordinates

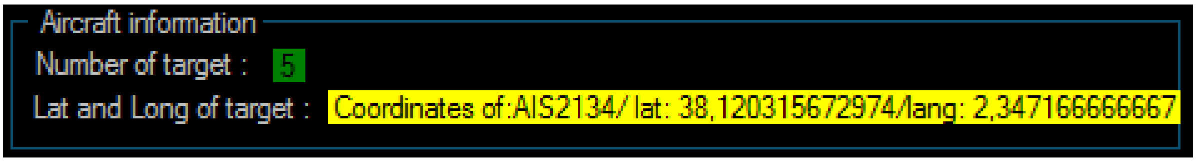


Figure IV.58: Display of the geographical coordinates of the AIS2134 target

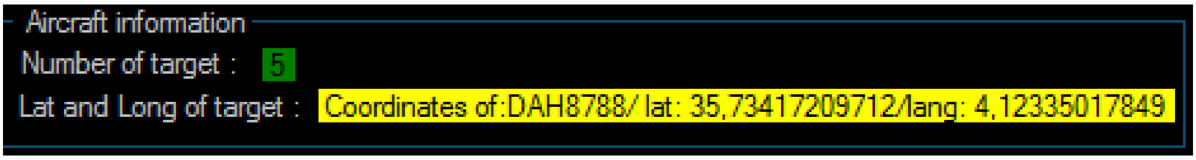


Figure IV.59: Display of the geographical coordinates of the DAH8788 target

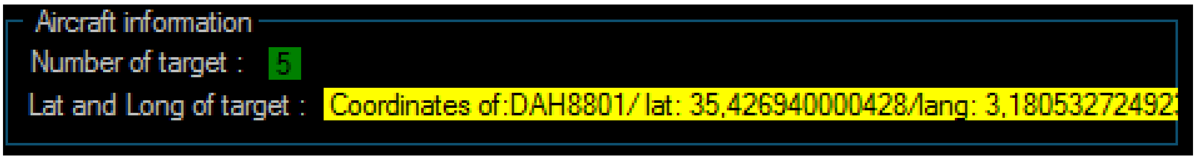


Figure IV.60: Display of the geographical coordinates of the DAH8801 target

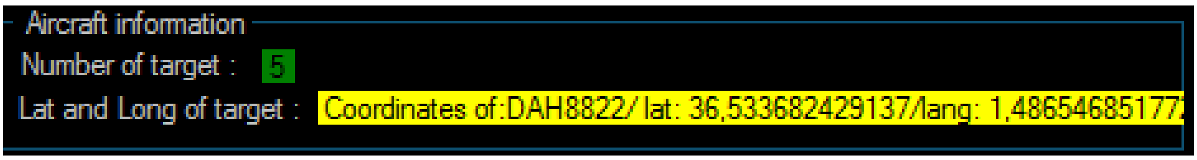


Figure IV.61: Display of the geographical coordinates of the DAH8822 target

Figure IV.62: Display of the geographical coordinates of the TAR3400 target

IV.7. Chapter conclusion:

After the realization of this application we can decode and visualize several Asterix messages of the category 048 in an exceptional time and with great precision.

The decoding system decodes all the fields that exist in our message (apart from the special field of application and father), this decoding allows us to fully exploit the Asterix message of category 048.

The visualization system allows us to see the targets, the station and the range all on the Gmap with a very good accuracy in the form of a real radar image.

General Conclusion

This study is very interesting insofar as it allowed us in parallel with the practical training period at the Area Control Center (ACC) of Algiers to approach certain fields of study in a way one can say profound and which are not included in our course cycle as much as CNS/ATM students.

We were also able to bridge the gap between theory and practice and to understand: the operating principle of many radar components, the ASTERIX protocol and the new surveillance system MSSR Mode S.

This work has allowed us to realize an application very close to the real decoding system and the real radar image, this application is considered as a big step for the design of a completely Algerian system, it is enough to find a link between the application and the LAN that transfers the ASTERIX message.

Future aspirations are:

- Study of the new radar coverage in Algeria and thus the new data routing to Algiers ACC and Tamanrasset ACC.
- Study of the undeveloped operational levels:
    - Mode-S Subnetwork
    - ATN ISO 8208 Packet Layer Protocol
- Study of the new surveillance system: ADS and the ASTERIX category 021 message.

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- CNS/ATM: Mr.Zabot.

[3]: https://www.icao.int/WACAF/Documents/Meetings/2011/asi_ws/pp1_ssr_modes_coordination.pdf

[4]: https://www.eurocontrol.int/sites/default/files/publication/files/surveillance-modes-principles-of-modes-operation-and-interrogator-codes-20030318.pdf

[5]: https://www.icao.int/MID/Documents/2019/MICA/MICA-MID%20 %20WP % 200 2%20-%20Mode%20S%20Surveillance%20Principle.pdf

[6]: http://ri.ues.edu.sv/id/eprint/531/1/10137143.pdf

[7]: https://www.icao.int/SAM/Documents/2017-ADSB/28%20INDRA.pdf

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[9]:http://80.82.78.13/get.php?md5=429ae8dd8a4be3ac44f603649fe64f09&key=RAT8IN5W9V32J6VB&mirr=1

[10]: EUROCONTROL STANDARD DOCUMENT FOR SURVEILLANCE DATA EXCHANGE Part 4: Category 048 (Transmission of Monoradar Target Reports)

[11]:https://rdu.iua.edu.ar/bitstream/123456789/1134/1/Trabajo%20Final%20de%20Grado.pdf

[12]: Radartutorial.com

[13]: https://www.enna.dz/

[14]: https://en.wikipedia.org/wiki/Primary_radar

A.1. Annex A «Structure of the fields of the ASTERIX message category 048 » :

EUROCONTROL STANDARD DOCUMENT FOR SURVEILLANCE DATA EXCHANGE

Part 4: Category 048

Transmission of Monoradar Target Reports

DOCUMENT IDENTIFIER: SUR.ET1.ST05.2000-STD-04-01

Edition: 1.21

Edition Date: July 2012

Status: Released Issue

Class: General Public

A.2. Annex B « Structure of the Aircraft identification field » :

Annexe 10: Volume IV

				b_6	0	0	1	1
				b_5	0	1	0	1
b_4	b_3	b_2	b_1					
0	0	0	0			P	SP	0
0	0	0	1		A	Q		1
0	0	1	0		B	R		2
0	0	1	1		C	S		3
0	1	0	0		D	T		4
0	1	0	1		E	U		5
0	1	1	0		F	V		6
0	1	1	1		G	W		7
1	0	0	0		H	X		8
1	0	0	1		I	Y		9
1	0	1	0		J	Z		
1	0	1	1		K			
1	1	0	0		L			
1	1	0	1		M			
1	1	1	0		N			
1	1	1	1		O			

Figure A.1: Character coding for transmission of aircraft identification

A.3. Annex C « Structure of the ACAS Resolution Advisory Report field » :

EUROCONTROL Specification for Surveillance Data Exchange ASTERIX

Part 12: Category 21

ADS-B Target Reports

DOCUMENT IDENTIFIER: EUROCONTROL-SPEC-0149-12

Edition Number: 2.2

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Data Item I021/260, ACAS Resolution Advisory Report:

Octet no. 1 / Octet no. 2

56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41
TYP					STYP			ARA							

Octet no. 3 / Octet no. 4

40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25
ARA (ctd.)						RAC				RAT	MTE	TTI		TID	

Octet no. 5 / Octet no. 6

24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9
TID (ctd.)															

Octet 7

8	7	6	5	4	3	2	1
TID (ctd.)							

Figue A.2: Structure of the ACAS resolution Advisory Report field

A.4. Annex D « Structure of the Mode S MB Data subfield » :

The 1090MHz Riddle: An open-access book about decoding Mode-S and ADS-B data BY Junzi Sun.

A.4.1. Selected intention (BDS 4,0):

```
+---------------------------------------+------+------+
| FIELD                                 | MB   |N-BITS|
+=======================================+======+======+
| Status                                |  1   |  1   |
+---------------------------------------+------+------+
| MCP/FCU selected altitude             |  2   |  12  |   **
|                                       |      |      |
| range = [0, 65520] ft                 |      |      |
|                                       |      |      |
| LSB: 16 ft                            |  13  |      |
+---------------------------------------+------+------+
| Status                                |  14  |  1   |
+---------------------------------------+------+------+
| FMS selected altitude                 |  15  |  12  |   **
|                                       |      |      |
| range = [0, 65520] ft                 |      |      |
|                                       |      |      |
| LSB: 16 ft                            |  26  |      |
+---------------------------------------+------+------+
| Status                                |  27  |  1   |
+---------------------------------------+------+------+
| Barometric pressure setting           |  28  |  12  |   **
|   -> Note: actual value minus 800     |      |      |
|                                       |      |      |
| range = [0, 410] mb                   |      |      |
|                                       |      |      |
| LSB: 0.1 mb                           |  39  |      |
+---------------------------------------+------+------+
| Reserved                              |  40  |  8   |
|   -> set to ZEROS                     |      |      |
|                                       |  47  |      |
+---------------------------------------+------+------+
| Status                                |  48  |  1   |
|   -> next 3 fields                    |      |      |
+---------------------------------------+------+------+
| Mode: VNAV                            |  49  |  1   |
+---------------------------------------+------+------+
| Mode: Alt hold                        |  50  |  1   |
+---------------------------------------+------+------+
| Mode: Approach                        |  51  |  1   |
+---------------------------------------+------+------+
| Reserved                              |  52  |  2   |
|   -> set to ZEROS                     |  53  |      |
+---------------------------------------+------+------+
| Status                                |  54  |  1   |
+---------------------------------------+------+------+
| Target alt source                     |  55  |  2   |
|   -> 00: Unknown                      |      |      |
|   -> 01: Aircraft altitude            |      |      |
|   -> 10: FCU/MCP selected altitude    |      |      |
```

-> 11: FMS selected altitude	56	

Figue A.3: Structure of the Selected intention (BDS 4,0) subfield

A.4.2. Track and turn (BDS 5,0):

FIELD	MB	N-BITS
Status	1	1
Sign, 1 -> Use two's complement	1	1
Roll angle range = [-90, 90] degrees LSB: 45/256 degree	3 11	9
Status	12	1
Sign, 1 -> Use two's complement	13	1
True track angle range = [-180, 180] degrees LSB: 90/512 degree	14 23	10
Status	24	1
Ground speed range = [0, 2046] knots LSB: 2 knots	25 34	10
Status	35	1
Sign, 1 -> Use two's complement	36	1
Track angle rate	37	9

```
|                                      |      |      |
| range = [-16, 16] degrees            |      |      |
|                                      |      |      |
| LSB: 8/256 degree / second           |  45  |      |
+--------------------------------------+------+------+
| Status                               |  46  |  1   |
+--------------------------------------+------+------+
| True airspeed                        |  47  |  10  |
|                                      |      |      |
| range = [0, 2046] knots              |      |      |
|                                      |      |      |
| LSB: 2 knots                         |  56  |      |
+--------------------------------------+------+------+
```

Figue A.4: Structure of the Track and turn (BDS 5,0) subfield

A.4.3. Heading and speed (BDS 6,0):

```
+--------------------------------------+------+------+
| FIELD                                | MB   |N-BITS|
+======================================+======+======+
| Status                               |  1   |  1   |
+--------------------------------------+------+------+
| Sign, 1 -> Use two's complement      |  1   |  1   |
+--------------------------------------+------+------+
| Magnetic heading                     |  3   |  10  |
|                                      |      |      |
| range = [-180, 180] degrees          |      |      |
|                                      |      |      |
| LSB: 90/512 degree                   |  12  |      |
+--------------------------------------+------+------+
| Status                               |  13  |  1   |
+--------------------------------------+------+------+
| Indicated airspeed                   |  14  |  10  |
|                                      |      |      |
| range = [0, 1023] knots              |      |      |
|                                      |      |      |
| LSB: 1 knots                         |  23  |      |
+--------------------------------------+------+------+
| Status                               |  24  |  1   |
+--------------------------------------+------+------+
| Mach number                          |  25  |  10  |
```

```
|                                       |      |      |
| range = [0, 4.092] Mach               |      |      |
|                                       |      |      |
| LSB: 2.048 / 512 Mach                 |  34  |      |
+---------------------------------------+------+------+
| Status                                |  35  |  1   |
+---------------------------------------+------+------+
| SIGN 1 -> Use two's complement        |  36  |  1   |
+---------------------------------------+------+------+
| Barometric altitude rate              |  37  |  9   |
|                                       |      |      |
| range = [-16384, 16352] ft/min        |      |      |
|                                       |      |      |
| LSB: 32 ft/min                        |  45  |      |
+---------------------------------------+------+------+
| Status                                |  46  |  1   |
+---------------------------------------+------+------+
| SIGN 1 -> Use two's complement        |  47  |  1   |
+---------------------------------------+------+------+
| Inertial altitude rate                |  48  |  9   |
|                                       |      |      |
| range = [-16384, 16352] ft/min        |      |      |
|                                       |      |      |
| LSB: 32 ft/min                        |  56  |      |
+---------------------------------------+------+------+
```

Figue A.5: Structure of the Heading and speed (BDS 6,0) subfield

When a parameter is signed (SIGN = 1), the two's complement should be used to calculate the value. The value can be calculated as follows:

(-2{Number of bits parameter} + value) * LSB**