DESIGN OF AUTOMATIC DEPENDENT SURVEILLANCE-BROADCAST *(ADS-B)* RADAR USING SOFTWARE DEFINED RADIO

Submitted by

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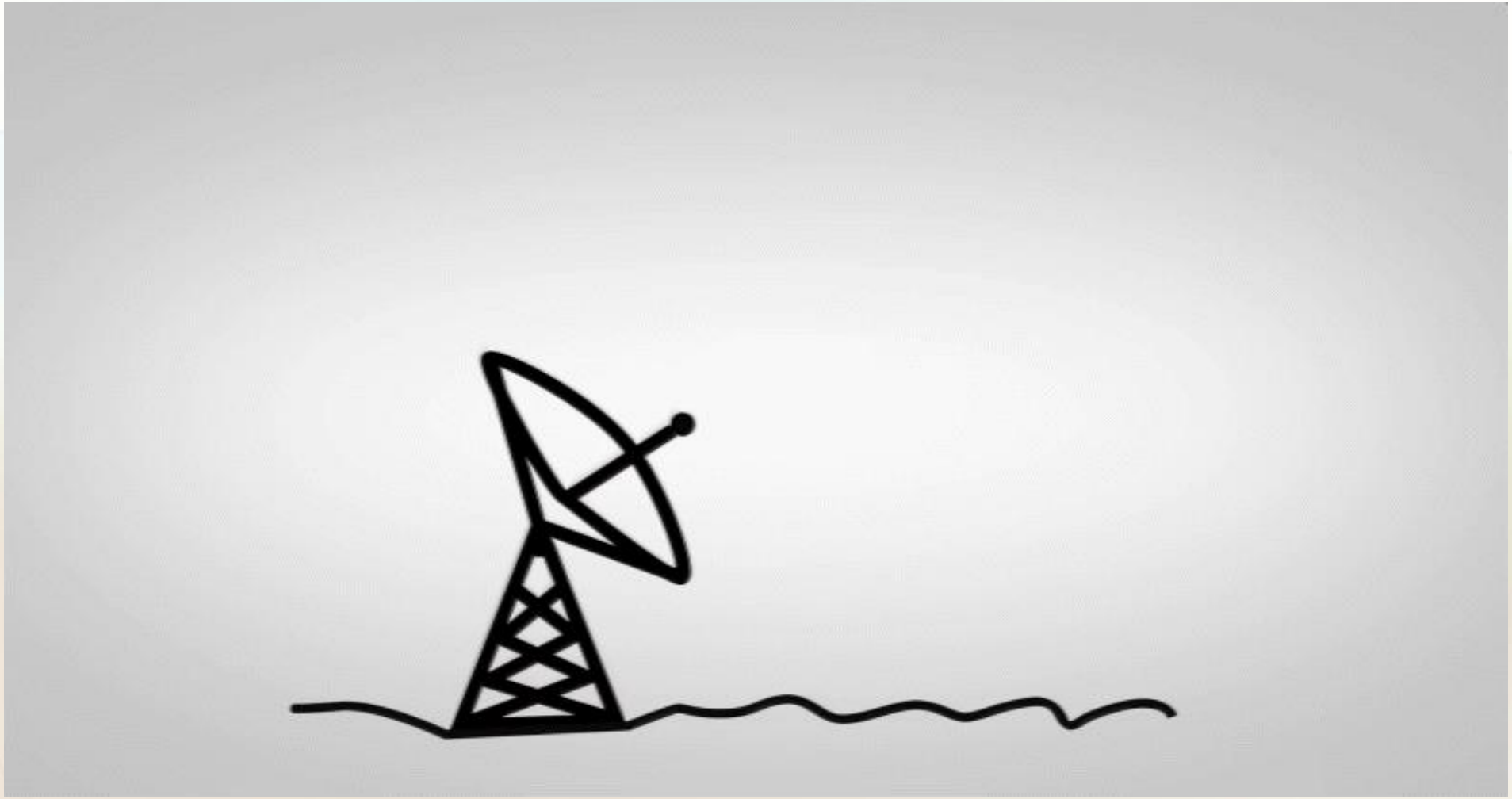
How basic RADAR Works?



How ADS-B Works?

Complete System Flow graph

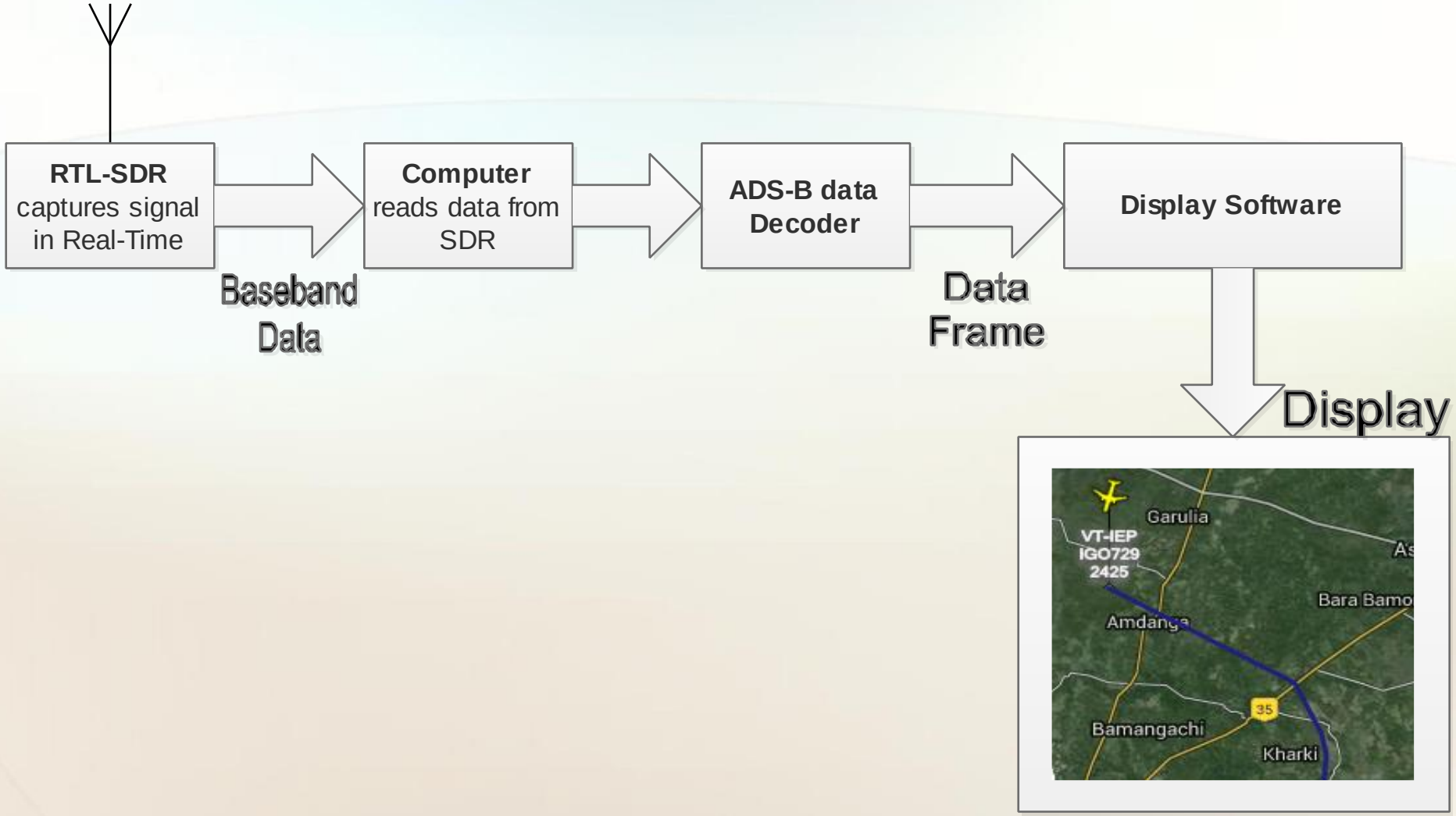


FIGURE-1: Complete flowgraph of ADS-B Radar

OBJECTIVES

- Design a Physical Layer decoder for ADS-B frame
  - ✓Selection of an antenna for proper reception
  - ✓Build-up a custom Asynchronous data reader interface for SDR
  - ✓Design of a fast ADS-B frame decoder
  - ✓Study various existing display software
  - ✓Develop a software network interface to convert the received stream into a format for standard display software
- Implement a ADS-B Surveillance Radar system in software

DESIGN

J-Pole Antenna

- Antenna is designed and fabricated to work at 1090 MHz.
- J-Pole antenna is selected because it is small in size, low cost, sturdy and wide bandwidth with 2.5 dBi gain in its pass band.
- Principal beam lobe of J-Pole is wider on one side than on the other.

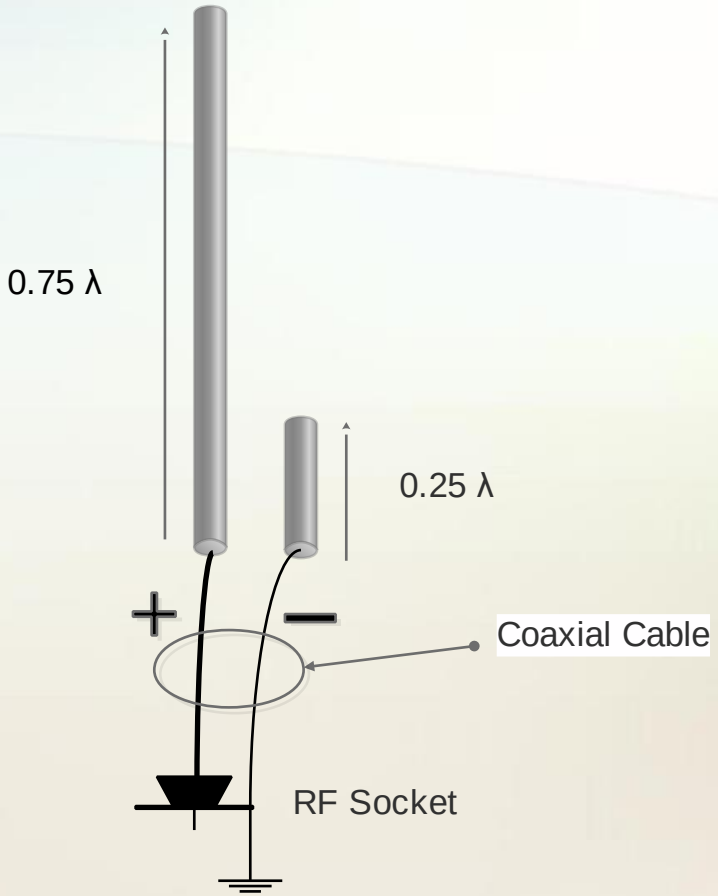


FIGURE 3 - J-Pole Antenna

Design Parameters

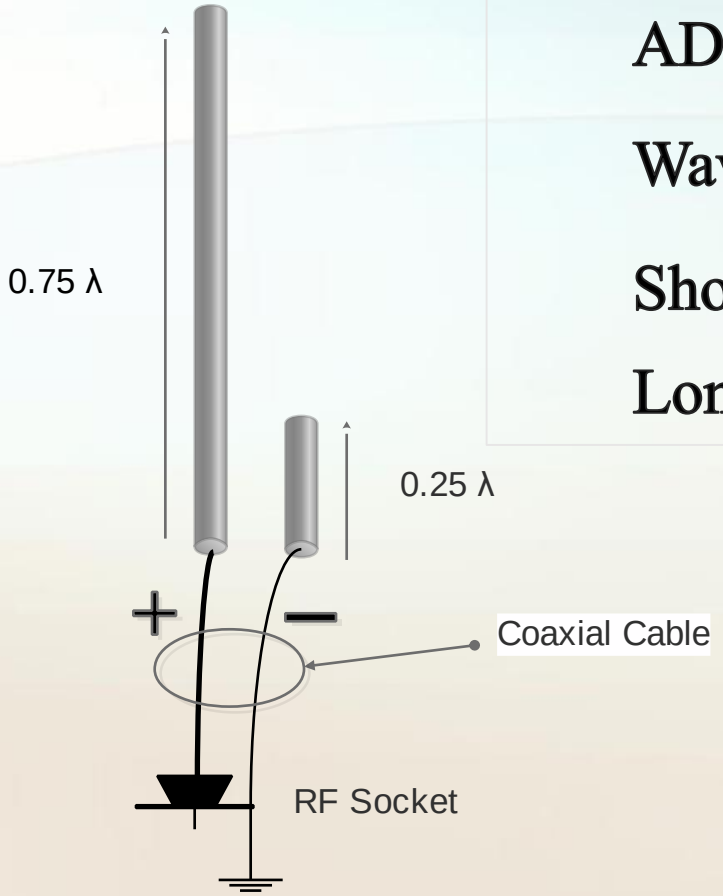


FIGURE 3 - J-Pole Antenna

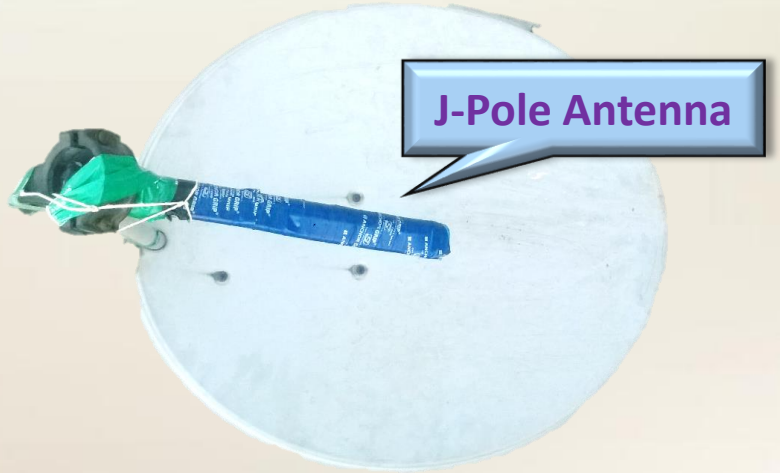
ADS-B frequency: $f = 1090\ MHz$

Wavelength: $\lambda = \frac{c}{f} = 27.5\ cm$

Short Section: $l\_ = 0.25\ \lambda = 6.9\ cm$

Long Section: $l_+ = 0.75\ \lambda = 20.6\ cm$

Fabricated Antenna



Realtek Software Defined Radio *(RTLSDR)* Specifications

- 22 MHz to 2200 MHz Tunable Range (*depends on tuner model*)
- Maximum 3.2 MHz sampling bandwidth (stable upto 2.8 MHz)
- 8-bit ADC (50 dB dynamic range)
- Less than 4.5dB noise figure LNA
- 75 Ohm input impedance
- R820T tuner IC consumes approximately 300 mA of current

RTL-SDR Block Diagram

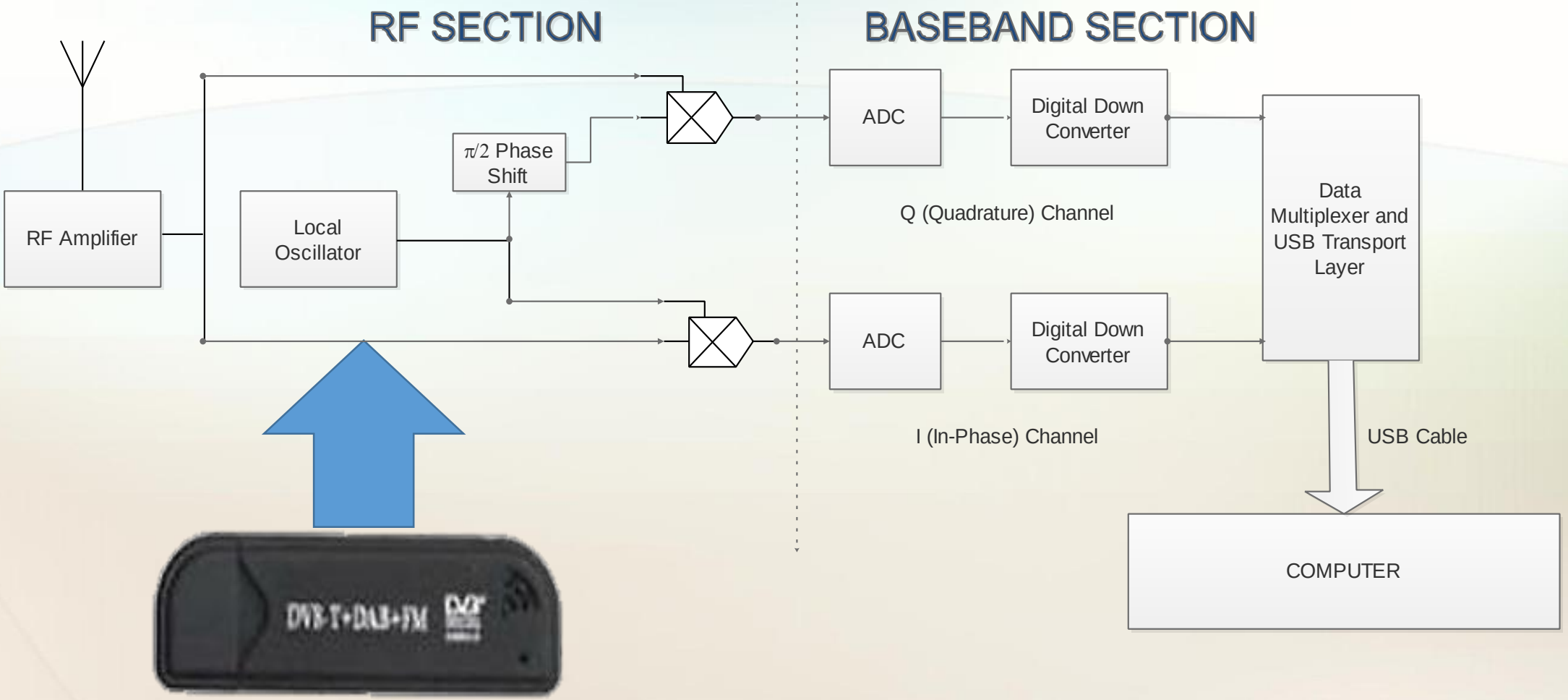


FIGURE 2 - RTL-SDR Block diagram

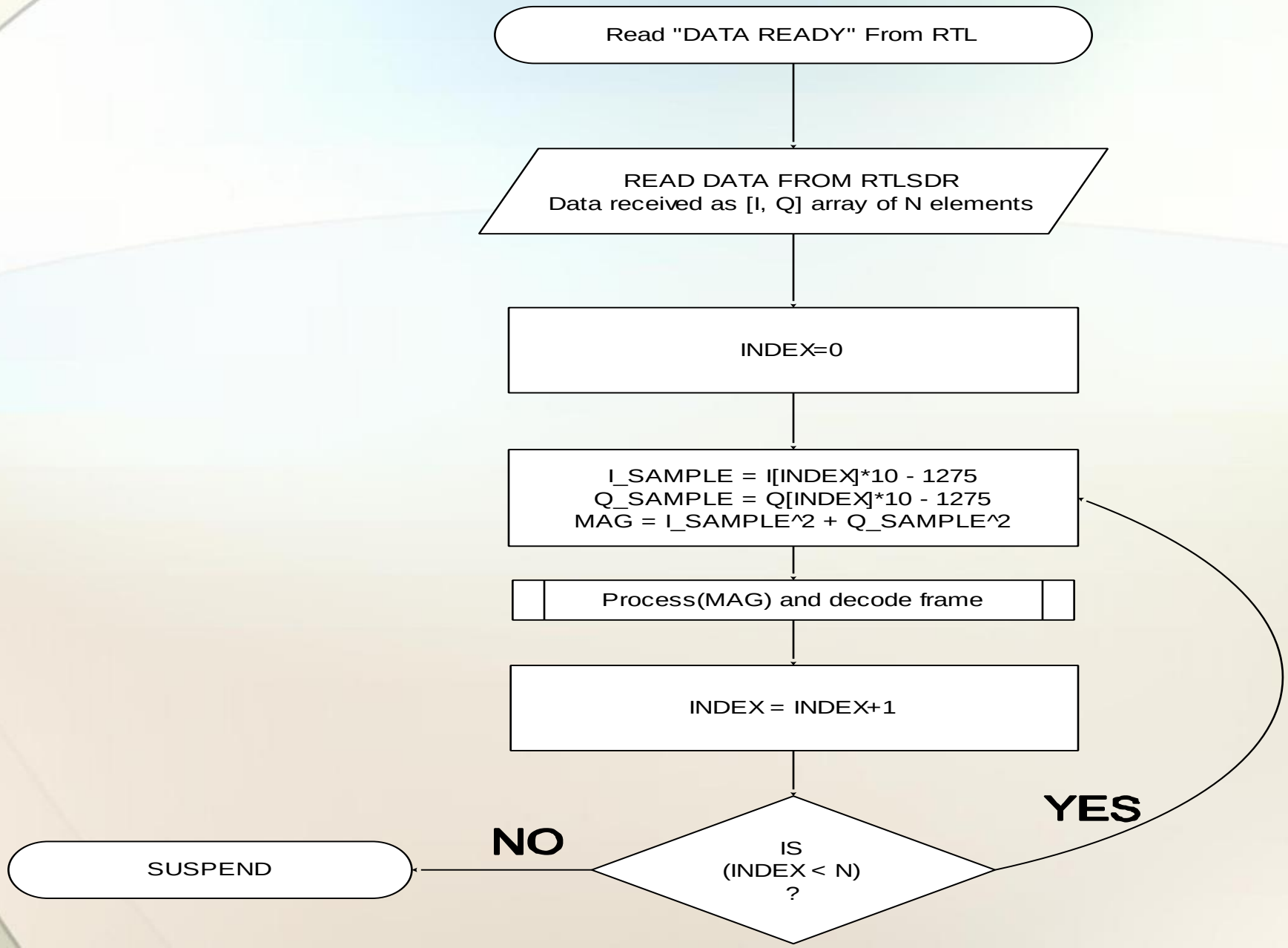
RTL-SDR Data Transfer Modes

- **Asynchronous transfer mode is used to achieve high speed, low data loss and real-time operation**

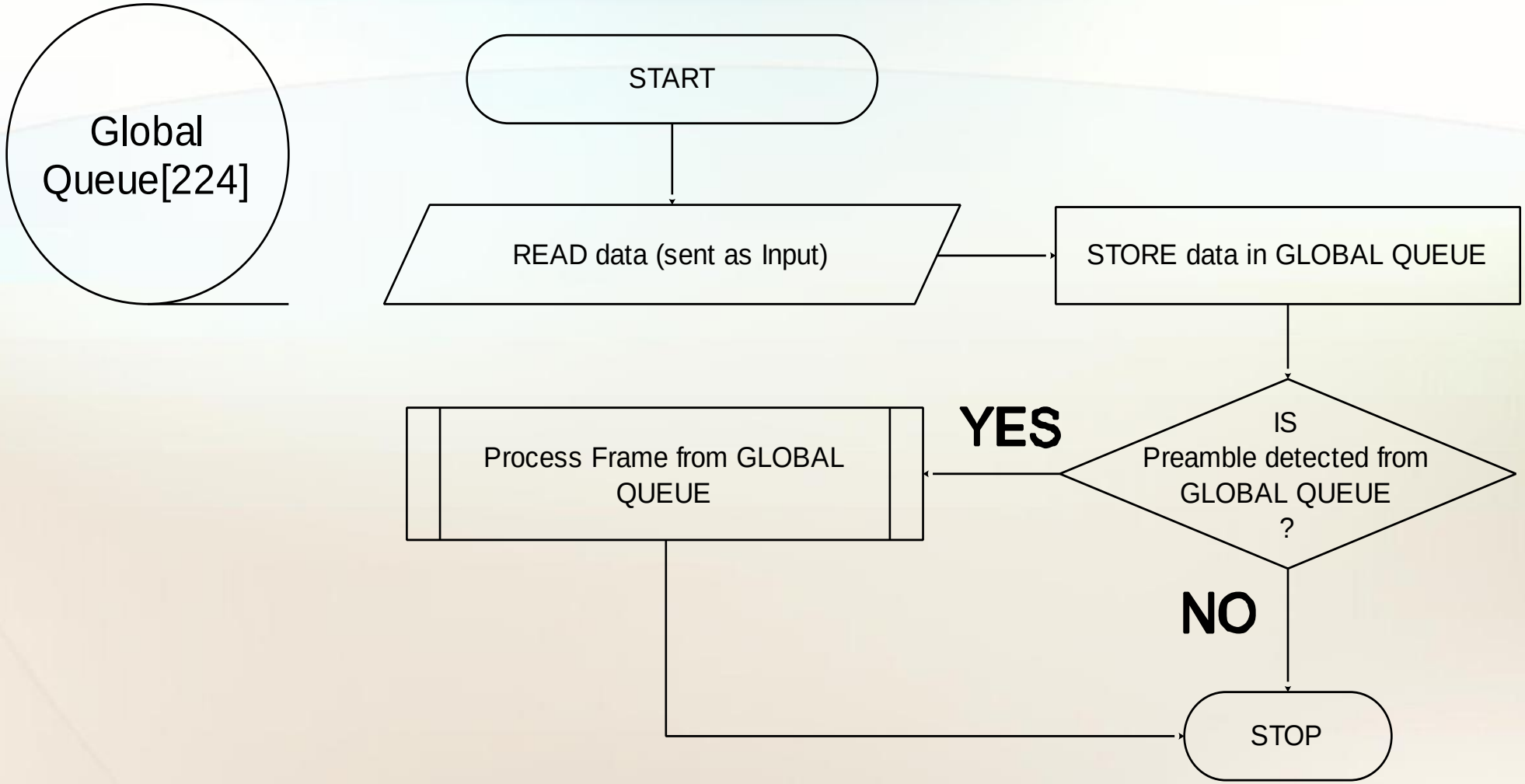
ADS-B Specifications

- Transmitter Frequency = 1090 MHz
- Transmission Mode = Asynchronous, Periodic
- Channel = Time Shared Channel
- Modulation = Amplitude Shift (On-Off) Keying
- Bit Rate = 1.04 Mbps
- Data Start signal = Preamble Bits (RZ line coded)
- Data frame format = Unpacked bits, Manchester Coded

ADS-B Data Reader



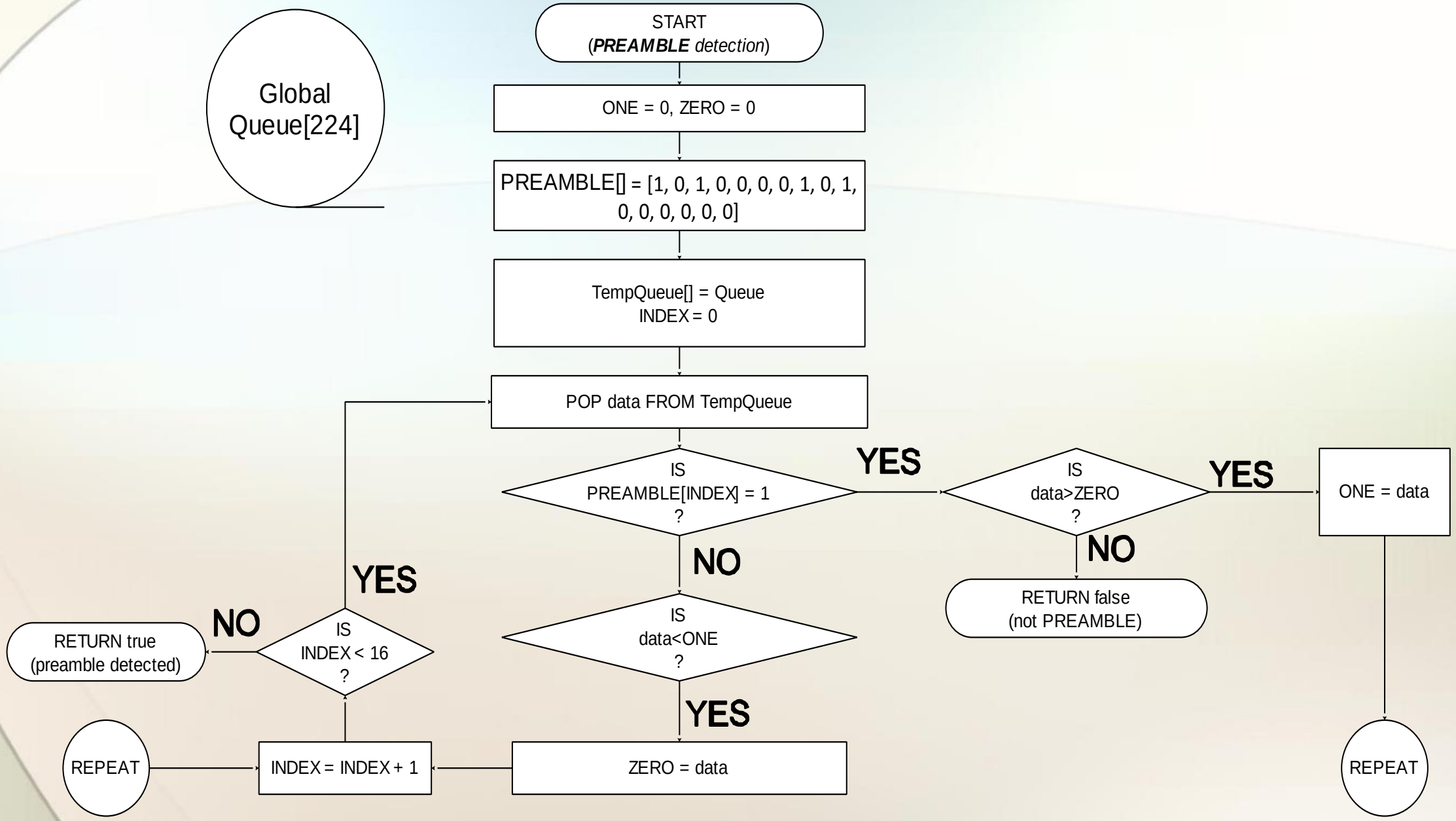
ADS-B Data Processing flow graph…



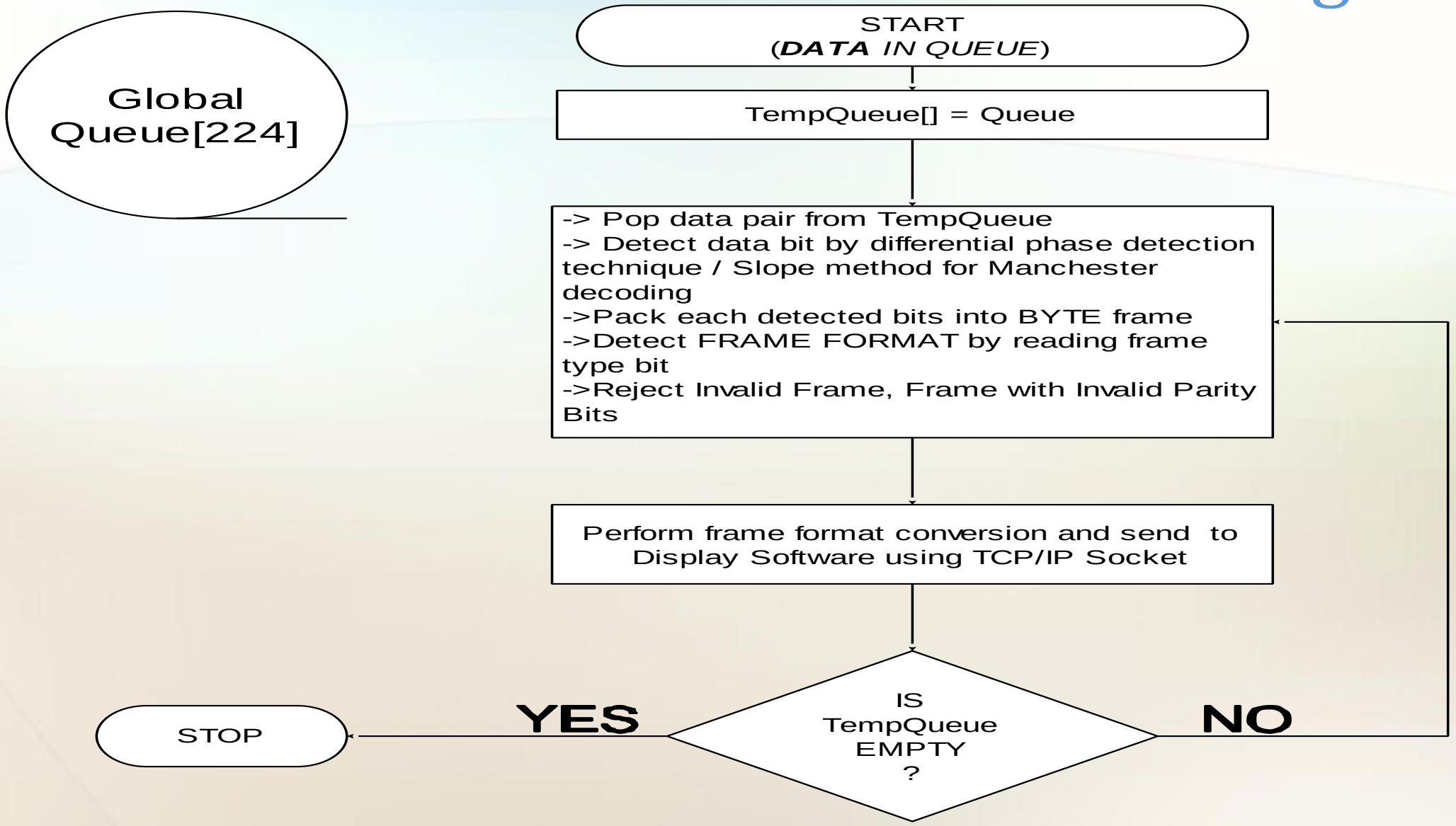
PREAMBLE DETECTION

- Preamble bits = [1, 0, 1, 0, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 0]
- Represents the beginning of a data frame
- Overall DC value = 0
- 1 bit is represented by 2 received bit pairs i.e., 0 = (0,0), 1=(1,0). *(RZ line coded)*

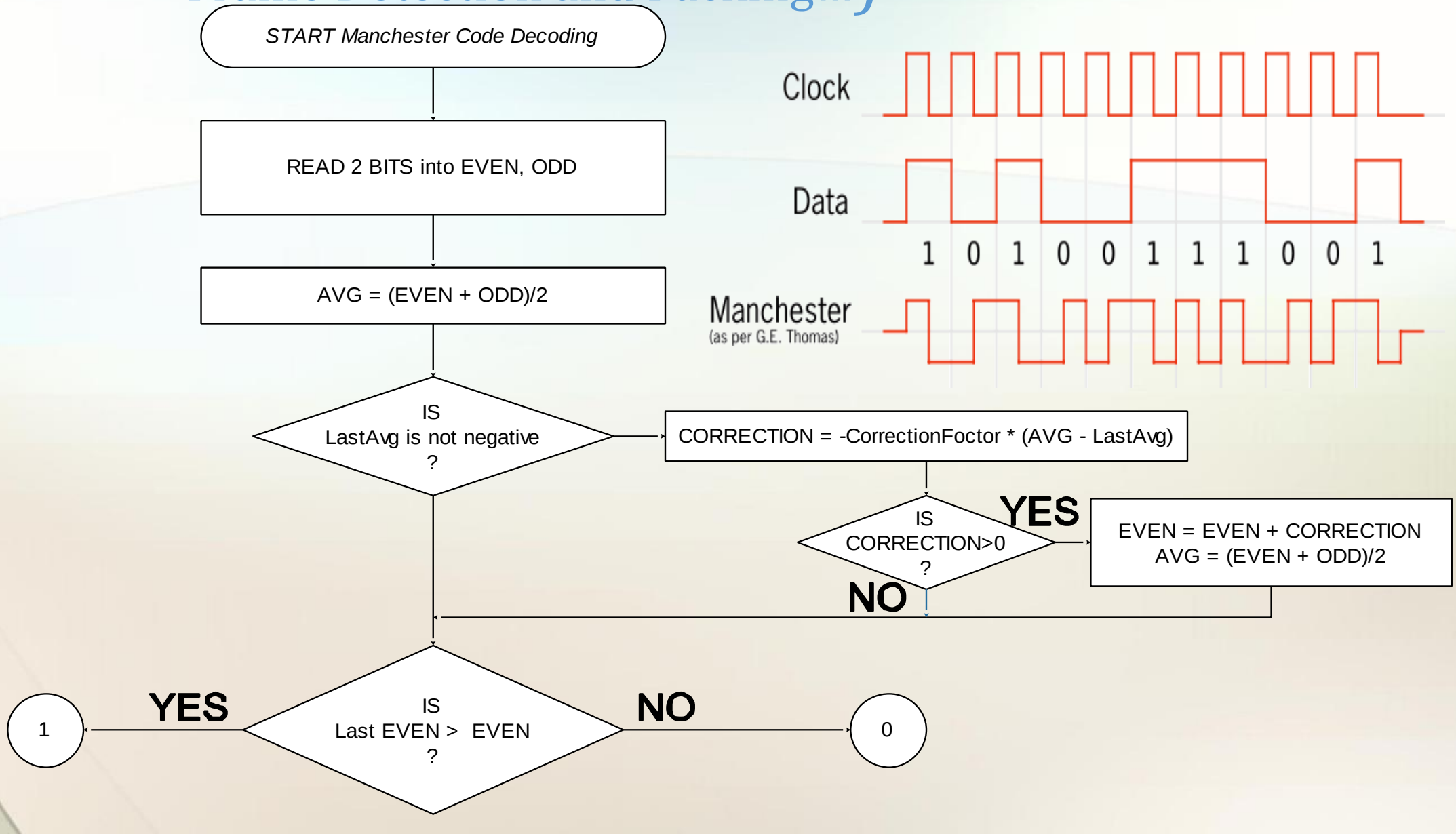
ADS-B Preamble Detection Flowchart



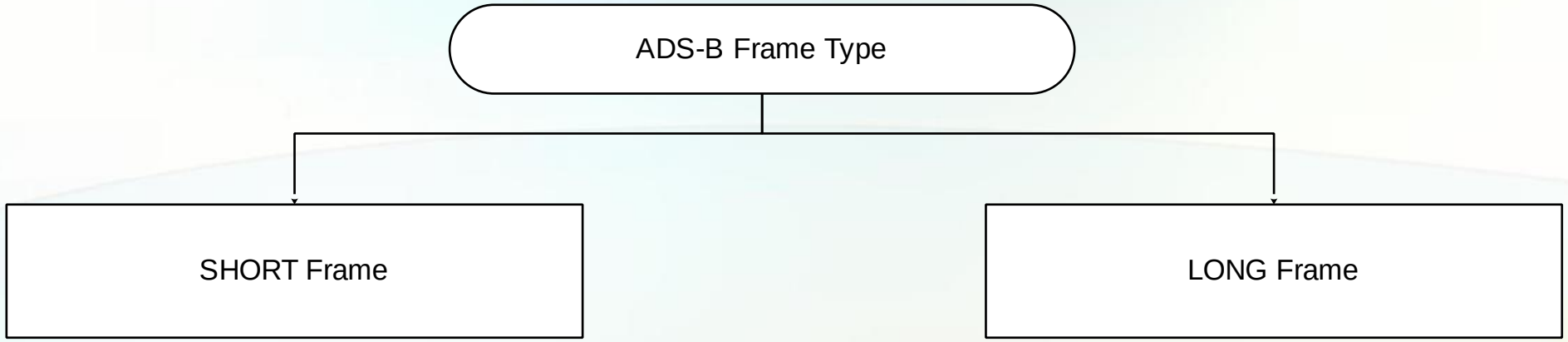
ADS-B Frame Detection and Packing



Manchester Code Data Decoding(ADS-B Frame Detection and Packing…)



ADS-B Data Frame Formats (ADS-B Frame Detection and Packing…)



- Frame is 52 bits long, which contains velocity, registration number, heading, etc.
- Used as reply to Ground Interrogation and Aircraft-to-Aircraft communications
- Our software can download the payload and communicate the packets to display software

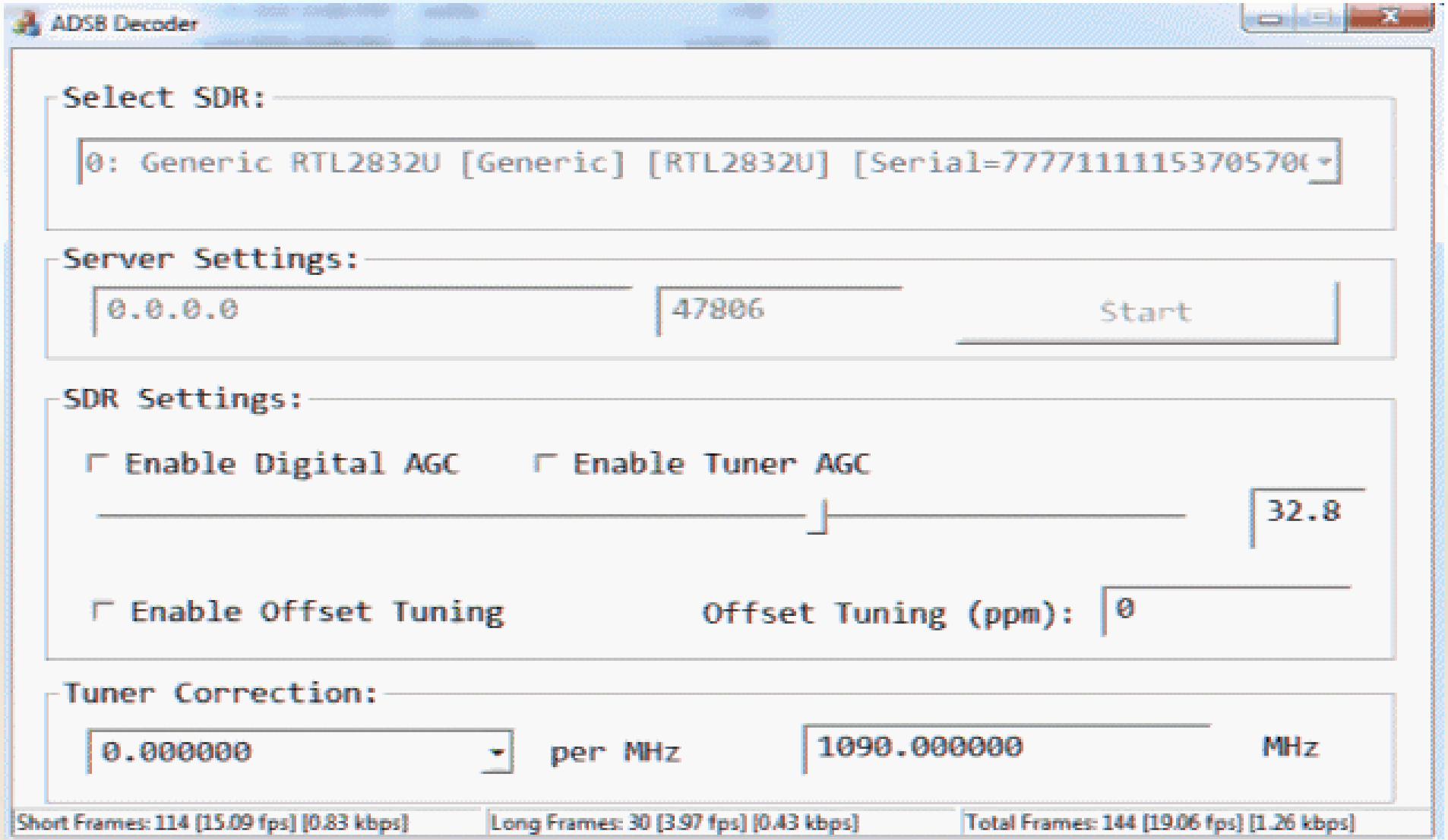
- Frame is 112 bits long, called ***Extended Squitter,*** *which contains* Positional Information about the aircraft
- May also carry undocumented, encrypted payloads and even Military specific data
- Our software can download the payload and communicate the packets to display software

ADS-B CRC Parity Checking(ADS-B Frame Detection and Packing…)

- Error detection codes are present in the decoded payload to verify if the received frame is valid or not
- Cyclic Redundancy check or CRC is a method of verifying the received code
- There are 2 methods for CRC check –
  - ✓ Table Method
    - More memory needed
    - Slow
    - Not used in this project
  - ✓ Polynomial method
    - Uses SHIFT and XOR operation
    - Utilizes a **Polynomial**
    - ADS-B Polynomial = ***0xfffa0480***
    - Very fast
    - Used in this paper
- If frames are valid by CRC check, save it
- If CRC check fails, then drop all the decoded frames and Restart the process

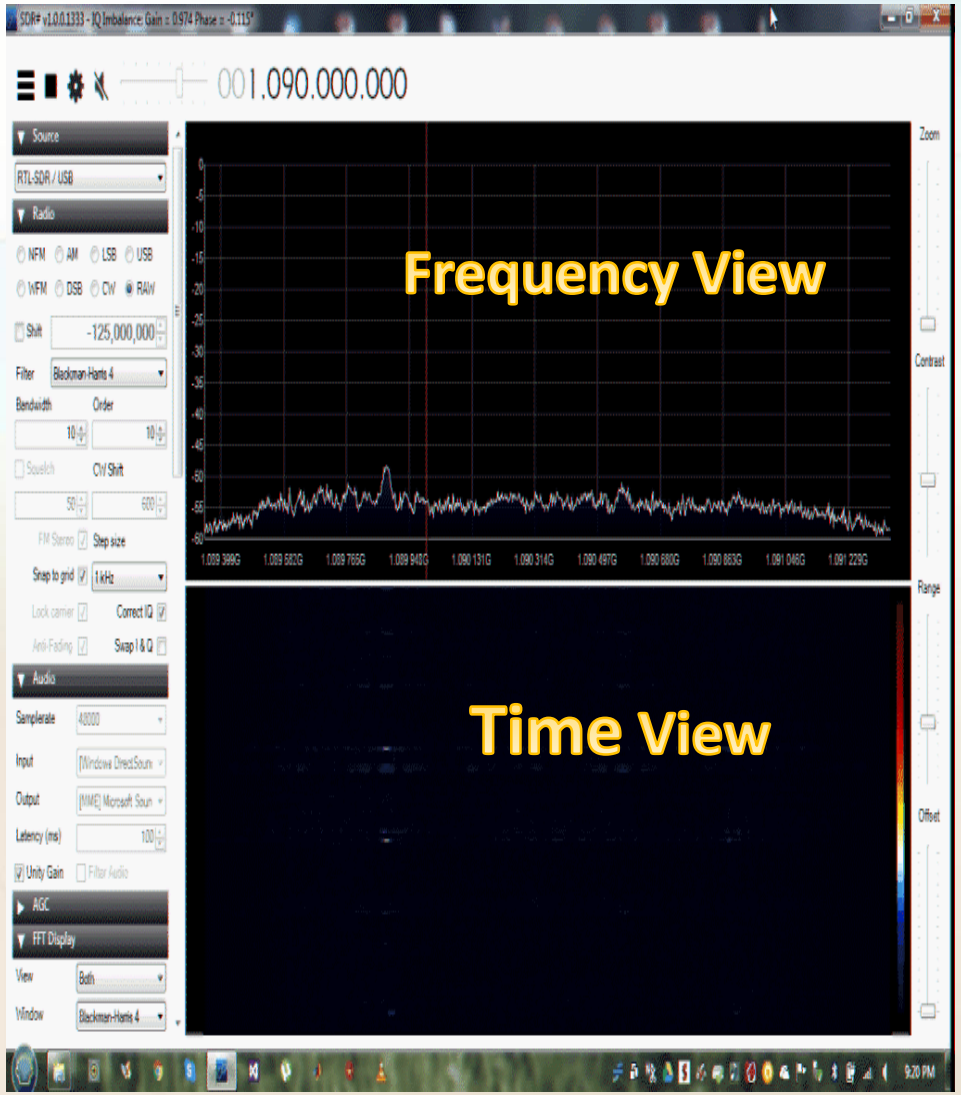
RESULTS

Developed ADS-B Graphical User Interface in MS Visual Studio 2012



ADS-B Software Input and Output

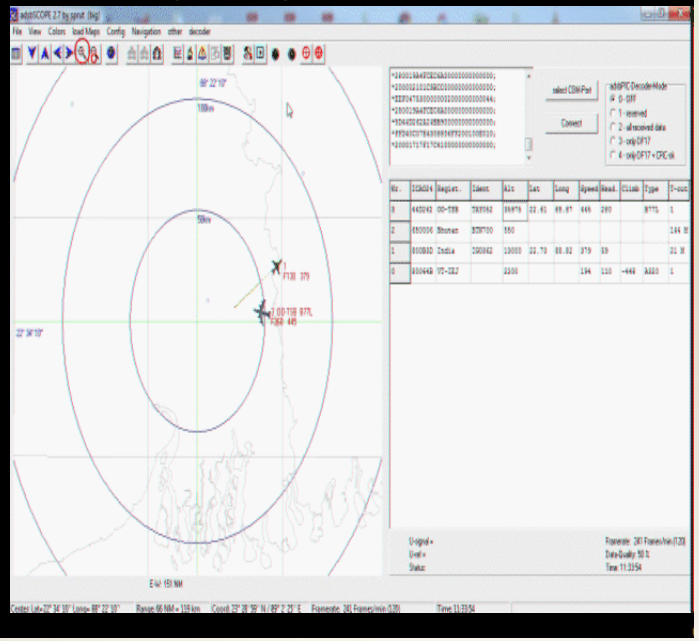
INPUT



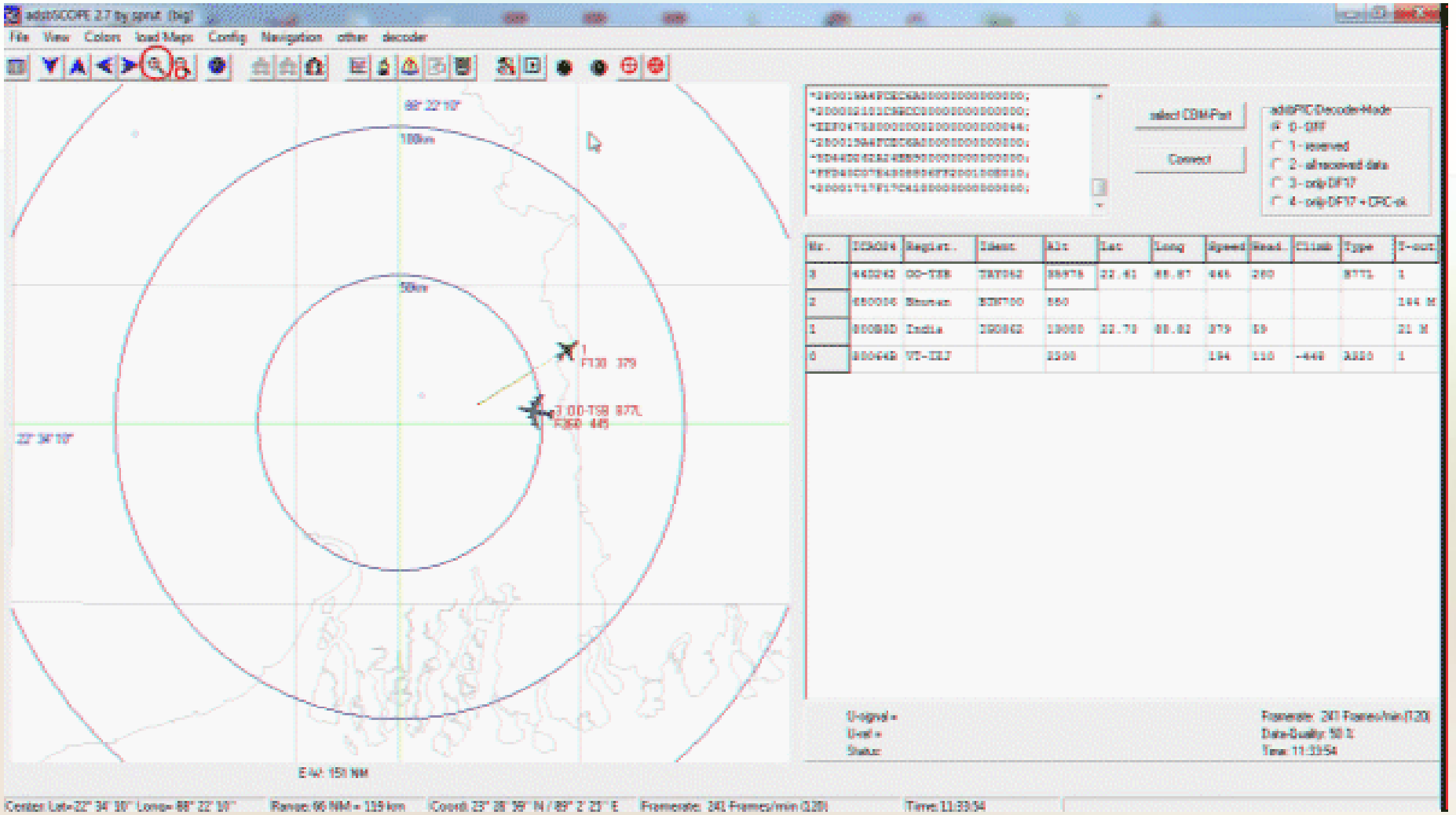
OUTPUT

```
*8000000000000000000000004000;
*1B4FDA8D4548C4;
*04000000008008;
*0B014298080000;
*8D780DAF9945A30980044708F28B;
*D184C0022384794581000010000;
*4708F28B020000;
*69022442051D40;
*8000000080802000100000000040;
*A8001A35200D33B3E33820B770F0;
*18F13F06600000;
*8D780DAF9945A30980044708F28B;
*6D7CCA2D184C00;
*200017183203C4;
*010000000C0000;
*6A315114C686E8;
*E380000000000048000000040000;
*C9980277D0000F10000040100000;
*64B9CCDB5F4F81;
*820200080000080000000000100;
*4018083E008000;
*200000000C0880;
*4200001080000l;
*04000004004080;
```

Standard Display Software



ADSB-SCOPE (*on Desktop*)



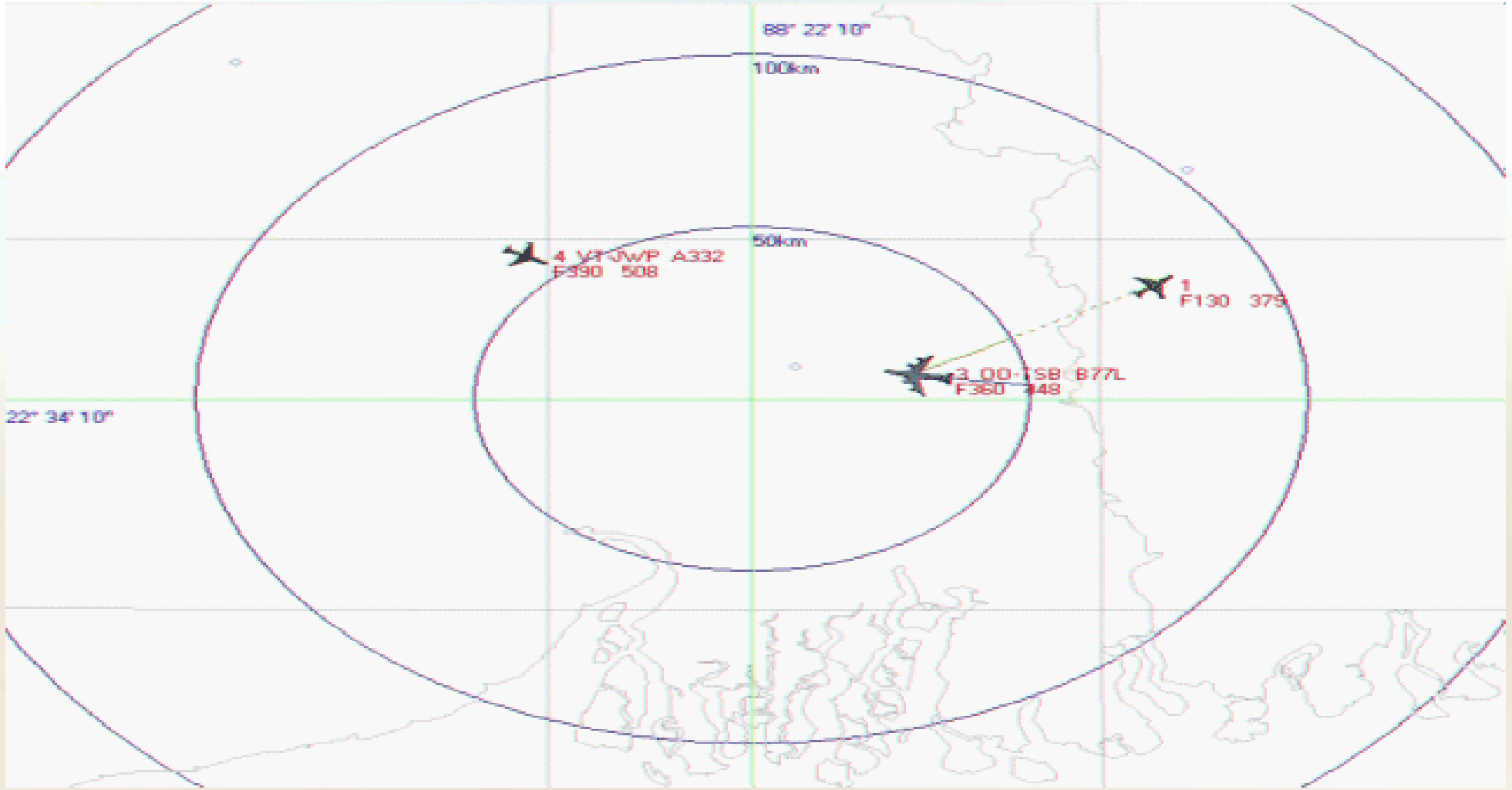
ADSB-SCOPE – List View

Nr.	ICAO24	Regist.	Ident	Alt	Lat	Long	Speed	Head.	Climb	Type	T-out
4	80043D	VT-JWP		39000	22.96	87.96	508	122		A332	2
3	44D262	OO-TSB	TAY052	36000	22.63	88.71	448	280		B77L	0
2	680006	Bhutan	BTN700	550							228 M
1	800B3D	India	IGO362	13000	22.73	88.82	379	59			105 M
0	80064B	VT-IEJ	IGO321	2150			188	164		A320	8

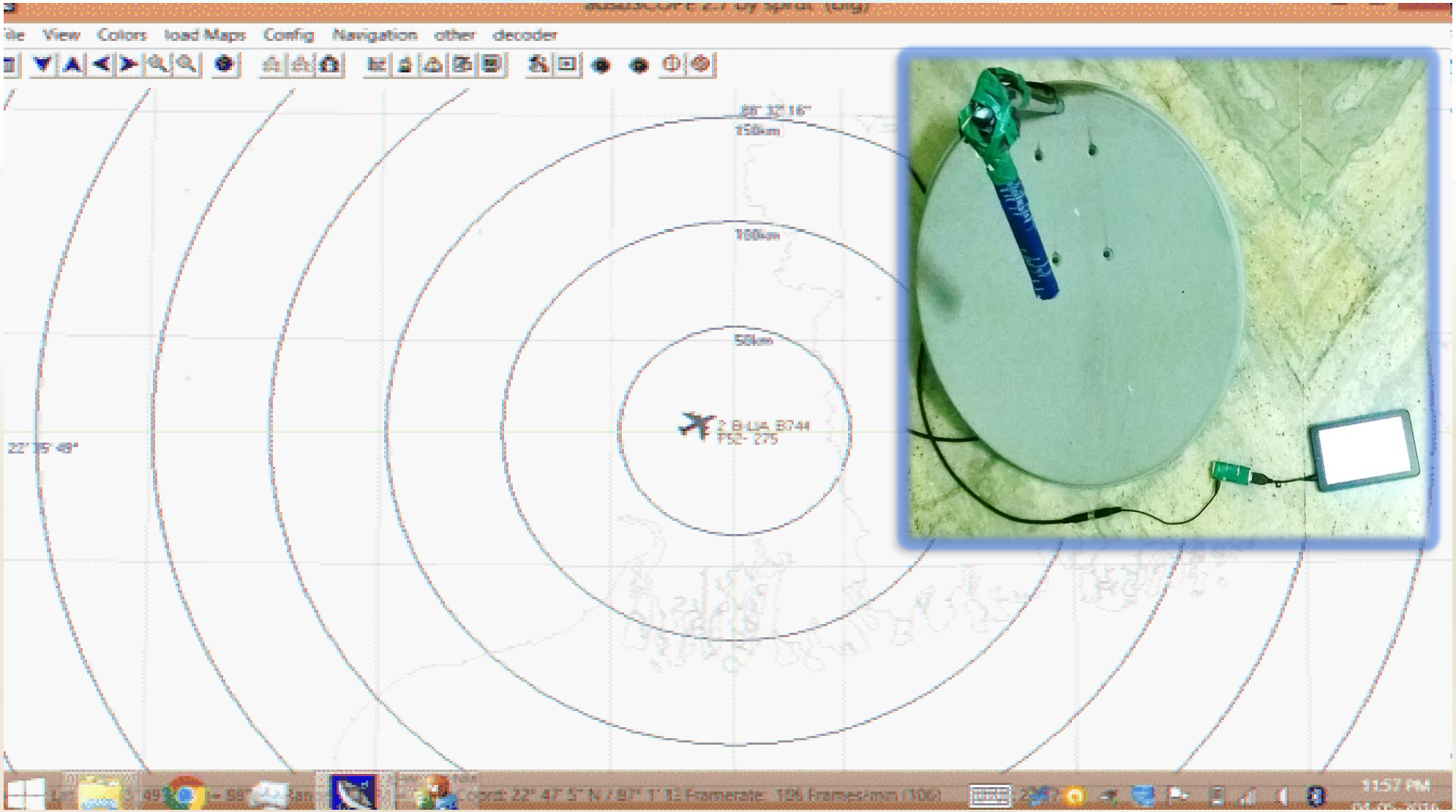
U-signal =
U-ref =

Framerate: 280 Frames/min (93)
Data-Quality: 70 %

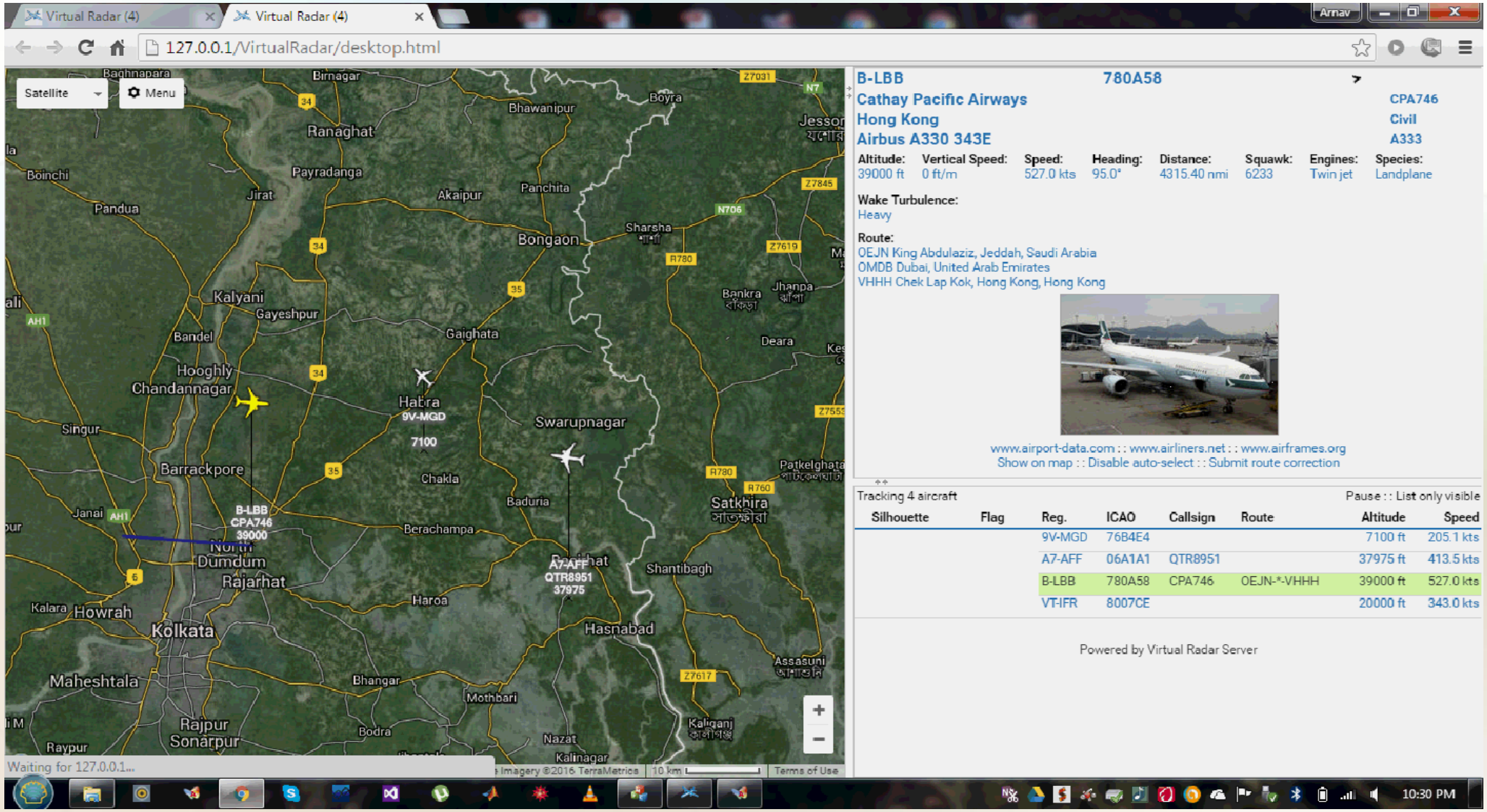
ADSB-SCOPE – Radar View



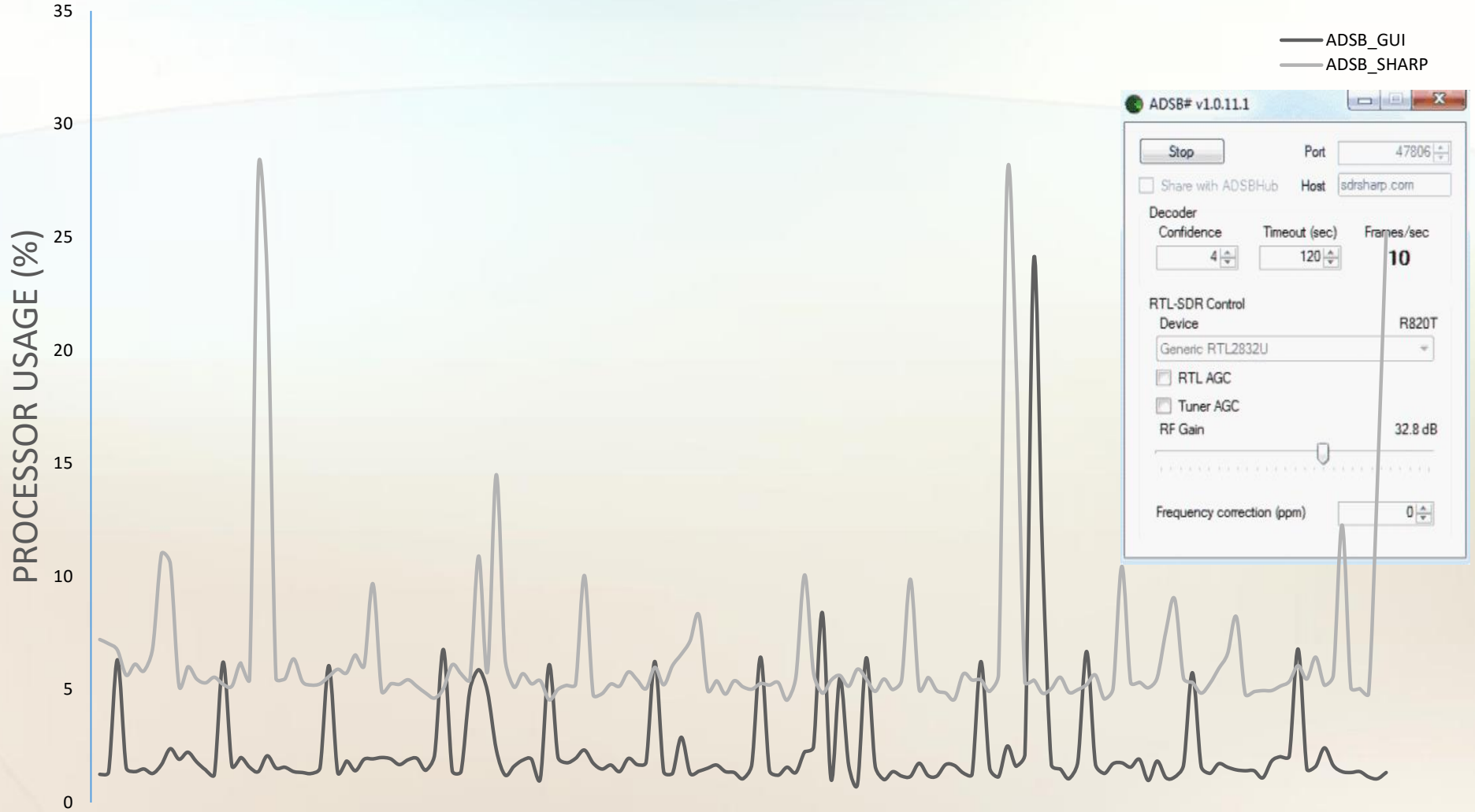
ADSB-SCOPE (*On Intel Atom UMPC*)



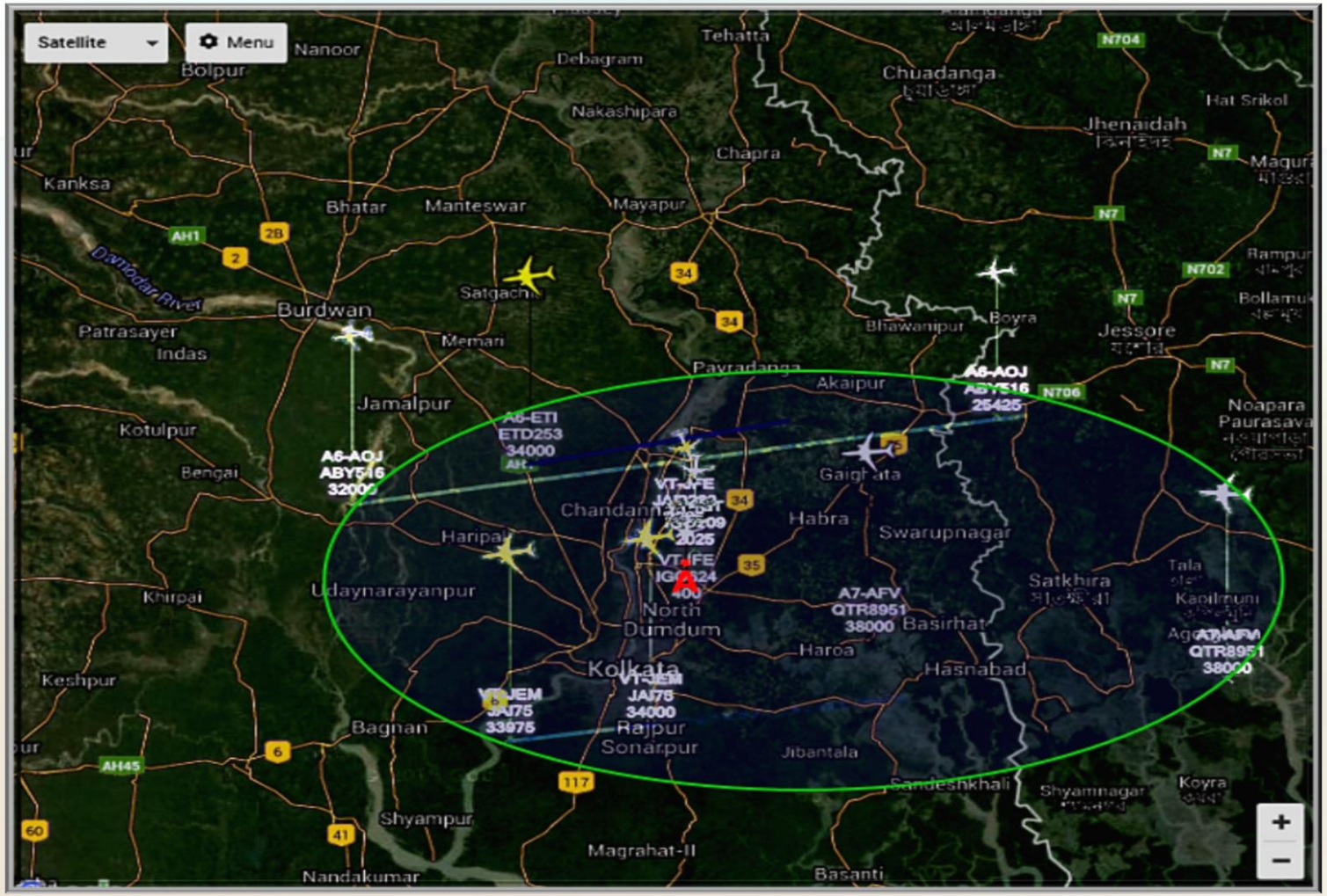
Virtual Radar – Alternative Display Software



ADSB-SCOPE vs. ADSB#



ANTENNA – *J-Pole Antenna Coverage*



OBSERVATIONS & CONCLUSIONS

- We have designed an ADS-B software which can be interfaced with commercial display software
- Our design algorithm consume less processor power
- Our software can detect ADS-B signals in indoor and in bad weather condition
- The software can be uploaded in IOT and can be displayed globally

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THANK YOU