Tishk International University
Engineering Faculty
Mechatronics Engineering Department

Avionics

TOPIC: Air Traffic Control System

Week4_Lecture1

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WHAT IS AIR TRAFFIC CONTROL?

- The Air Traffic Control (ATC) deals with that phase of air transportation which ensure safe, convenient and economic movement of aircraft from one airport to another airport.
- The aircraft flight from one airport to another involves the following basic actions :
  - The aircraft takes off from an airport
  - It maintains a proper altitude in air
  - It navigates from point to point safety
  - It lands at the desired airport

NEED OF AIR TRAFFIC CONTROL

- The basic purpose of air traffic control is protection of life and property by avoidance of collisions, through protective rules and regulation for air traffic.
- Aircrafts must be properly construct, provided with necessary equipments and maintained in good condition.
- The pilot must be well trained and licensed or certified to undertake flight.

FUNCTIONS OF AIR TRAFFIC CONTROL DEVICES

- Air Traffic Control :
  - This deals with,
    - To guide the aircraft, desiring to land or take off.
    - To control the taxiing of arriving and departing aircrafts between the runway and apron.
- Airway Traffic Control :
  - It deals with the movement of aircraft along the air routes with adequate lateral and vertical separation to avoid collision. This is particularly needed when visibility is poor.

Airway communication :

-
  - It deals with conveying of airway and weather information to the pilot during the flight.
- Non – Airway communication :
  - This presents a serious problem when personal flying is done by a large number of people. Such type of flying must be regulated to prevent interference to the main air traffic.

PURPOSE OF AIRTRAFFIC CONTROL

- The main purposes of ATC are :
  - Safety
  - Efficiency
  - Economy

- Safety :
  - Providing guidance to the pilot whose vision may be obstructed, during landing and take off.
  - Providing separation and right of way guidance to arriving and departing aircrafts when visibility is poor.
  - ICAO has classified visibility into three categories :

    Category I : Forward visibility of at least 800 m.

    Category II : Forward visibility of 400 m.

    Category III : Zero visibility consition.

- Efficiency :
  - Proper ATC helps in :
    - Speed movement of traffic.
    - Time tables and schedules of flights are maintained with reasonable limits, avoiding delays.
    - Avoiding waste of time so that airports are not waiting for business and space airway is not idle, facilities are thus effectively used.
- Economy :
  - Delay cause loss.
  - ATC is designed to avoid delays as far as possible. Idle planes, airports not used to capacity and airways not carrying the traffic of they are capable represent wasted investment.

FLIGHT RULES

- Two types of flight rules :
  - Visual Flight Rules (VFR)
  - Instrumental Flight Rules (IFR)

Visual Flight Rules (VFR) :

VFR may be described as clear weather flying, when the weather condition are such that aircraft can maintain safe separation by visual means by the pilots themselves.

Under VFR conditions there is very little of ATC. ATC monitor intervenes only when apparent conflicts develop between aircrafts.

Instrumental Flight Rules (IFR) :

IFR may be described as bad weather or blind weather, when visibility is poor or the height of the clouds falls below the visual meteorological conditions. In IFR conditions, ATC personnel guide the safe separation between aircrafts.

To avoid possibility of mid air collision at high speeds and density of traffic, IFR are described regardless of the weather conditions. This is called “positive control airspace” which is used where high speed jet operate at Airport Radar Service Area (ARSA) as well as the airspace at above 6000 m above MSL, in which jet fly from one airport to another airport.

AIR TRAFFIC CONTROL AIDS

- During VFR weather conditions, the flight is usually conducted by visual recognition of the object on the ground. IFR are used when the visibility is poor during night time or due to cloudy or foggy weather.
- During all visibility conditions, the following ATC aids are always available to the pilot during the flight :
  - Enroute aids or Airway aids
  - Landing aids

- Enroute Aids :
  - The following aids are available to the pilot during his flight from one airport to another :
    - Airway beacon
    - Low/Medium Frequency Radio Range (LFR/MFR)
    - Very High Frequency Omniconditional Range (VOR)
    - Tactical Air Navigation (TACAN)
    - Distance Measuring Equipment (DME)
    - Air Route Surveillance Radar (ARSR)
    - Market Beacon
    - Direction Finder
      - Radio Direction Finder (RDF)
      - Automatic Direction Finder (ADF)

- Landing Aids :
  - The following aids are available to any aircraft at the time of landing :
    - Instrumental Landing System (ILS)
      - Localiser
      - Glide Slope Antena
      - Outer Marker
      - Middle Marker
    - Precision Approach Radar (PAR)
    - Airport Surveillance Radar (ASR)
    - Airport Surface Detection Equipment (ASDE)
    - Approach Lighting System (ALS)

VISUAL AIDS

- The pilot is guided by visual aids during landing and take off operation, in day and night in all weather conditioned.
- Runway threshold, runway edges and runway centerline are the most essential items which should be clearly visible to pilot.
- The different types of visual aids :
  - Indicators
  - Markings
  - Lightings
  - Signs
  - Markers

- Indicators :
  - Wind Direction Indicator (Wind Cone)
  - Landing Direction Indicator
- Markings :
  - Runway Markings
  - Taxiway Markings
  - Apron Markings
  - Shoulder Markings
  - Other Markings

Lightings :

- Airport Beacon
- Identification Beacon
- Approach Lighting
- Circle Guidance Lighting
- Threshold Lighting
- Runway Lighting
- Taxiway Lighting
- Apron and Hanger Lighting
- Stopway Lighting
- Wind Direction Indicator Lighting
- Landing Direction Indicator Lighting

Air traffic control (ATC) is a service provided by ground-based air traffic controllers (also called control tower operators (CTO)) who direct aircraft on the ground and through a given section of controlled airspace, and can provide advisory services to aircraft in non-controlled airspace. The primary purpose of ATC worldwide is to prevent collisions, organize and expedite the flow of air traffic, and provide information and other support for pilots.[1]

Air traffic controllers monitor the location of aircraft in their assigned airspace by radar and communicate with the pilots by radio.[2] To prevent collisions, ATC enforces traffic separation rules, which ensure each aircraft maintains a minimum amount of empty space around it at all times. In many[*how?*] countries, ATC provides services to all private, military, and commercial aircraft operating within its airspace.[*citation needed*] Depending on the type of flight and the class of airspace, ATC may issue *instructions* that pilots are required to obey, or *advisories* (known as *flight information* in some countries) that pilots may, at their discretion, disregard. The pilot in command is the final authority for the safe operation of the aircraft and may, in an emergency, deviate from ATC instructions to the extent required to maintain safe operation of their aircraft.[3]

Airport traffic control tower

The primary method of controlling the immediate airport environment is visual observation from the airport control tower. The tower is a tall, windowed structure located on the airport grounds. Air traffic controllers are responsible for the separation and efficient movement of aircraft and vehicles operating on the taxiways and runways of the airport itself, and aircraft in the air near the airport, generally 5 to 10 nautical miles (9 to 18 km) depending on the airport procedures. A controller must carry out the job using the precise and effective application of rules and procedures that, however, need flexible adjustments according to differing circumstances, often under time pressure.[10] In a study that compared stress in the general population and this kind of system markedly showed more stress level for controllers. This variation can be explained, at least in part, by the characteristics of the job.[11]

Surveillance displays are also available to controllers at larger airports to assist with controlling air traffic. Controllers may use a radar system called secondary surveillance radar for airborne traffic approaching and departing. These displays include a map of the area, the position of various aircraft, and data tags that include aircraft identification, speed, altitude, and other information described in local procedures. In adverse weather conditions, the tower controllers may also use surface movement radar (SMR), surface movement guidance and control system (SMGCS), or advanced surface movement guidance and control system (ASMGCS) to control traffic on the maneuvering area (taxiways and runway).

Secondary surveillance radar (SSR)[1] is a radar system used in air traffic control (ATC), that unlike primary radar systems that measure the bearing and distance of targets using the detected reflections of radio signals, relies on targets equipped with a radar transponder, that reply to each interrogation signal by transmitting encoded data such as an identity code, the aircraft's altitude and further information depending on its chosen mode. SSR is based on the military identification friend or foe (IFF) technology originally developed during World War II, therefore the two systems are still compatible. Monopulse secondary surveillance radar (MSSR), Mode S, TCAS and ADS-B are similar modern methods of secondary surveillance.

SSR antenna of Deutsche Flugsicherung at Neubrandenburg, in Mecklenburg/Western Pomerania

Operation of SSR Radar

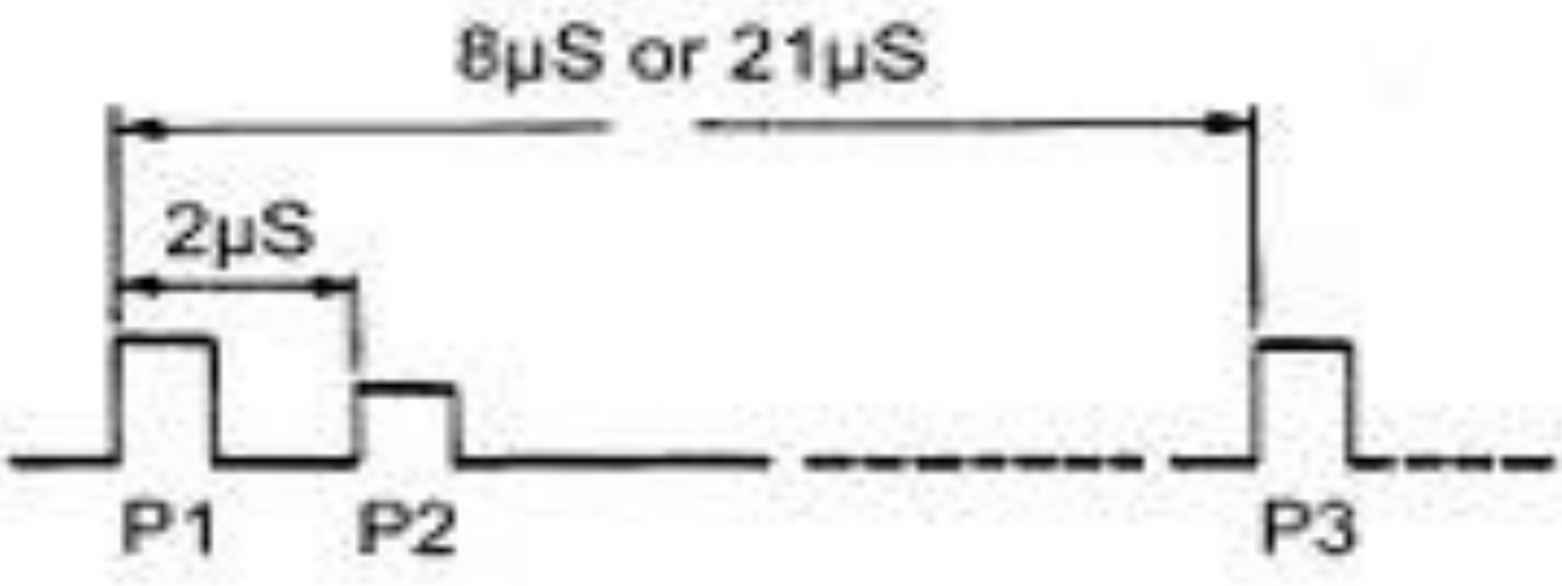
The purpose of SSR is to improve the ability to detect and identify aircraft while automatically providing the Flight Level (pressure altitude) of an aircraft. An SSR ground station transmits interrogation pulses on 1030 MHz (continuously in Modes A, C and selectively, in Mode S) as its antenna rotates, or is electronically scanned, in space. An aircraft transponder within line-of-sight range 'listens' for the SSR interrogation signal and transmits a reply on 1090 MHz that provides aircraft information. The reply sent depends on the interrogation mode. The aircraft is displayed as a tagged icon on the controller's radar screen at the measured bearing and range. An aircraft without an operating transponder still may be observed by primary radar, but would be displayed to the controller without the benefit of SSR derived data. It is typically a requirement to have a working transponder in order to fly in controlled air space and many aircraft have a back-up transponder to ensure that condition is met.[8]

Identification Friend or Foe (IFF) system

The need to be able to identify aircraft more easily and reliably led to another wartime radar development, the Identification Friend or Foe (IFF) system, which had been created as a means of positively identifying friendly aircraft from unknowns. This system, which became known in civil use as secondary surveillance radar (SSR), or in the US as the air traffic control radar beacon system (ATCRBS), relies on a piece of equipment aboard the aircraft known as a "transponder." The transponder is a radio receiver and transmitter pair which receives on 1030 MHz and transmits on 1090 MHz. The target aircraft transponder replies to signals from an interrogator (usually, but not necessarily, a ground station co-located with a primary radar) by transmitting a coded reply signal containing the requested information.[5]

Interrogation modes

There are several modes of interrogation, each indicated by the difference in spacing between two transmitter pulses, known as P1 and P3.[7] Each mode produces a different response from the aircraft. A third pulse, P2, is for side lobe suppression and is described later. Not included are additional military (or IFF) modes, which are described in Identification Friend or Foe



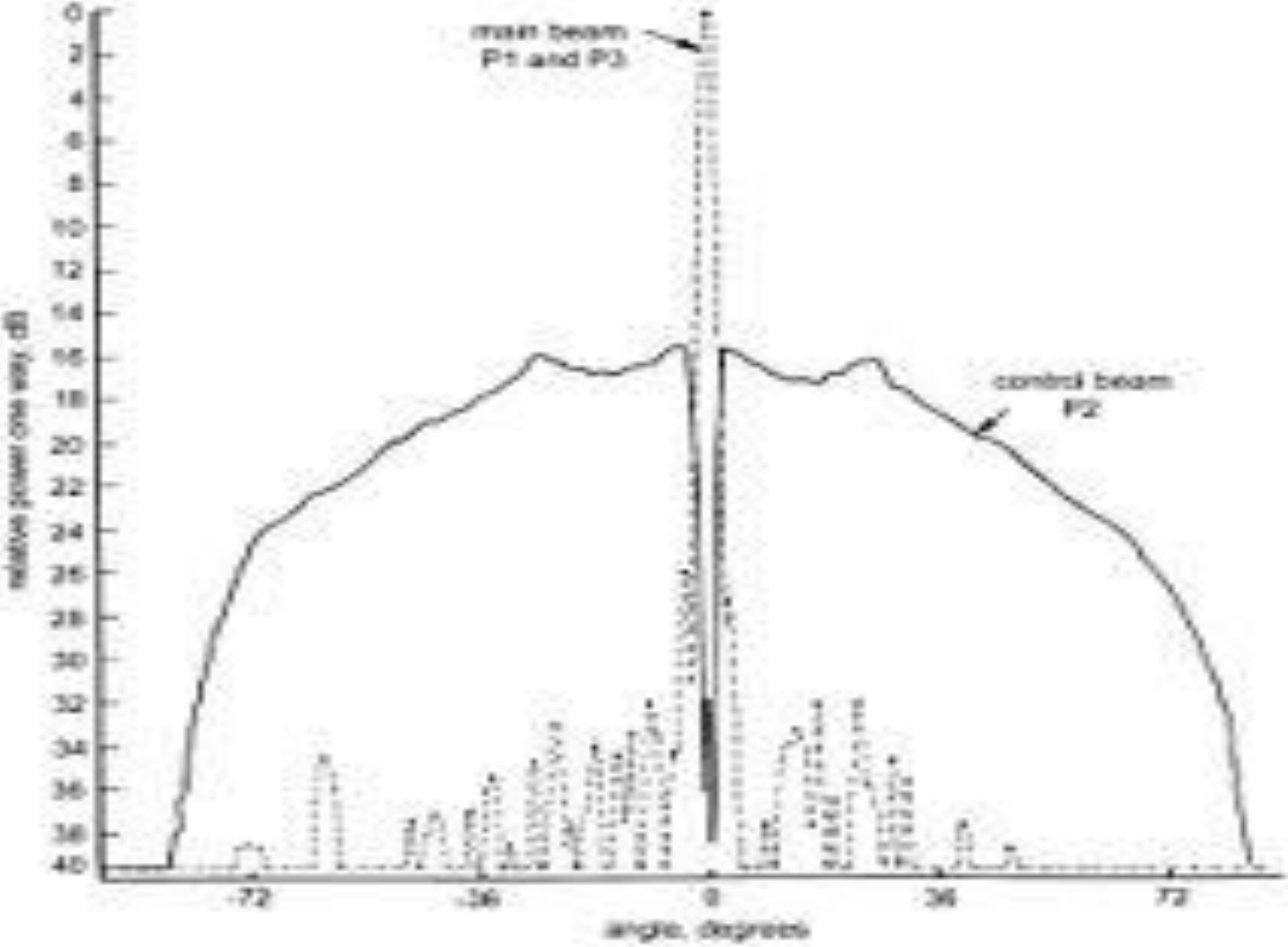
Mode A and C interrogation format

Mode	P1–P3 pulse spacing	Purpose
A	8 µs	Identity
B	17 µs	Identity
C	21 µs	Altitude
D	25 µs	Undefined
S	3.5 µs	Multipurpose

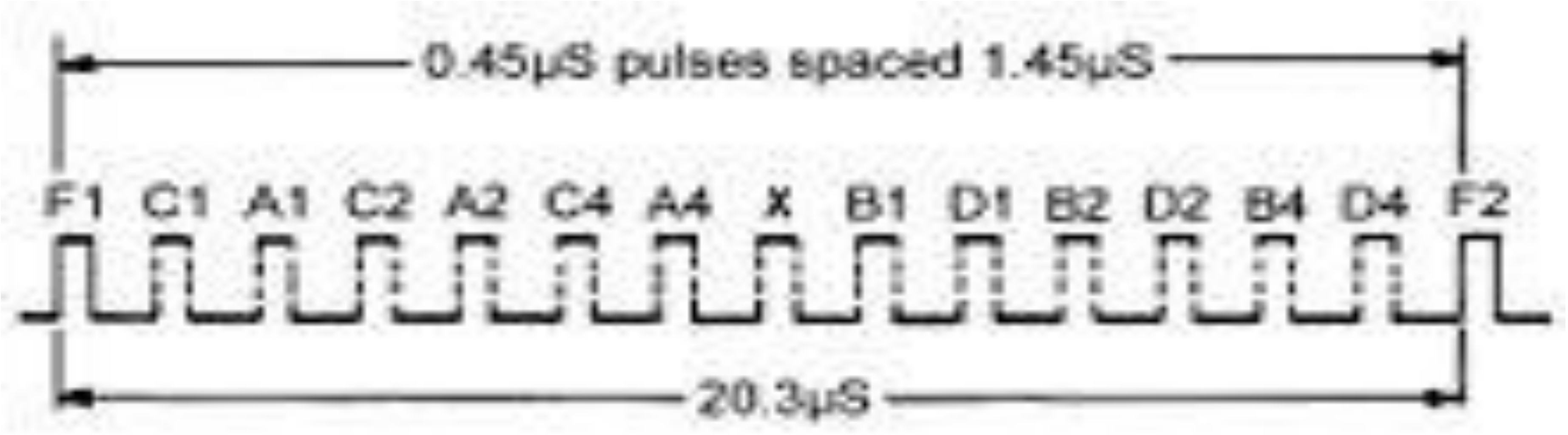
A mode-A interrogation elicits a 12-pulse reply, indicating an identity number associated with that aircraft. The 12 data pulses are bracketed by two framing pulses, F1 and F2. The X pulse is not used. A mode-C interrogation produces an 11-pulse response (pulse D1 is not used), indicating aircraft altitude as indicated by its altimeter in 100-foot increments. Mode B gave a similar response to mode A and was at one time used in Australia. Mode D has never been used operationally.

The new mode, Mode S, has different interrogation characteristics. It comprises pulses P1 and P2 from the antenna main beam to ensure that Mode-A and Mode-C transponders do not reply, followed by a long phase-modulated pulse.[7]

The ground antenna is highly directional but cannot be designed without sidelobes. Aircraft could also detect interrogations coming from these sidelobes and reply appropriately. However these replies can not be differentiated from the intended replies from the main beam and can give rise to a false aircraft indication at an erroneous bearing. To overcome this problem the ground antenna is provided with a second, mainly omni-directional, beam with a gain which exceeds that of the sidelobes but not that of the main beam. A third pulse, P2, is transmitted from this second beam 2 μs after P1. An aircraft detecting P2 stronger than P1 (therefore in the sidelobe and at the incorrect main lobe bearing), does not reply.[7]


main beam
P1 and P3
control beam
P2
relative power one way, dB
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
-72
-36
0
36
72
angle, degrees

Mode A



Mode A and C reply format

Although 4,096 different identity codes available in a mode A reply may seem enough, once particular codes have been reserved for emergency and other purposes, the number is significantly reduced. Ideally an aircraft would keep the same code from take-off until landing even when crossing international boundaries, as it is used at the air traffic control centre to display the aircraft's callsign using a process known as code/callsign conversion. Clearly the same mode A code should not be given to two aircraft at the same time as the controller on the ground could be given the wrong callsign with which to communicate with the aircraft.[7]

Mode C

The mode C reply provides height increments of 100 feet, which was initially adequate for monitoring aircraft separated by at least 1000 feet. However, as airspace became increasingly congested, it became important to monitor whether aircraft were not moving out of their assigned flight level. A slight change of a few feet could cross a threshold and be indicated as the next increment up and a change of 100 feet. Smaller increments were desirable.

FRUIT

Since all aircraft reply on the same frequency of 1090 MHz, a ground station will also receive aircraft replies originating from responses to other ground stations. These unwanted replies are known as FRUIT (False Replies Unsynchronized with Interrogator Transmissions or alternatively False Replies Unsynchronized In Time). Several successive FRUIT replies could combine and appear to indicate an aircraft which does not exist. As air transport expands and more aircraft occupy the airspace, the amount of FRUIT generated will also increase.[9]

Garble

FRUIT replies can overlap with wanted replies at a ground receiver, thus causing errors in extracting the included data. A solution is to increase the interrogation rate so as to receive more replies, in the hope that some would be clear of interference. The process is self-defeating as increasing the reply rate only increases the interference to other users and vice versa.[9]

Synchronous garble

If two aircraft paths cross within about two miles slant range from the ground interrogator, their replies will overlap and the interference caused will make their detection difficult. Typically the controller will lose the longer range aircraft, just when the controller may be most interested in monitoring them closely.[9]

Capture

While an aircraft is replying to one ground interrogation it is unable to respond to another interrogation, reducing detection efficiency. For a Mode A or C interrogation the transponder reply may take up to 120 μs before it can reply to a further interrogation.[9]

Air Traffic Control Radar Design

This example shows how to model a conceptual air traffic control (ATC) radar simulation based on the radar range equation.

Model Description

To make parameters for *Radar System Design* easier to change and easier to determine their values, the model has a GUI. Radar and weather parameters may be changed from this GUI. While simulating, the effects of these parameters can be seen on the scope display which shows the actual aircraft range in yellow and the estimated aircraft range from the radar in magenta. Another output that can be viewed is the calculated signal to noise ratio (SNR) is compared to the ideal SNR. Ideal SNR is also specified from the GUI. The result is shown in the display block and will be either 1 (SNR >= ideal SNR) or 0 (SNR < ideal SNR).

Simulink® and Stateflow® are used in the model, which is divided into three main subsystems, radar, aircraft, and weather.

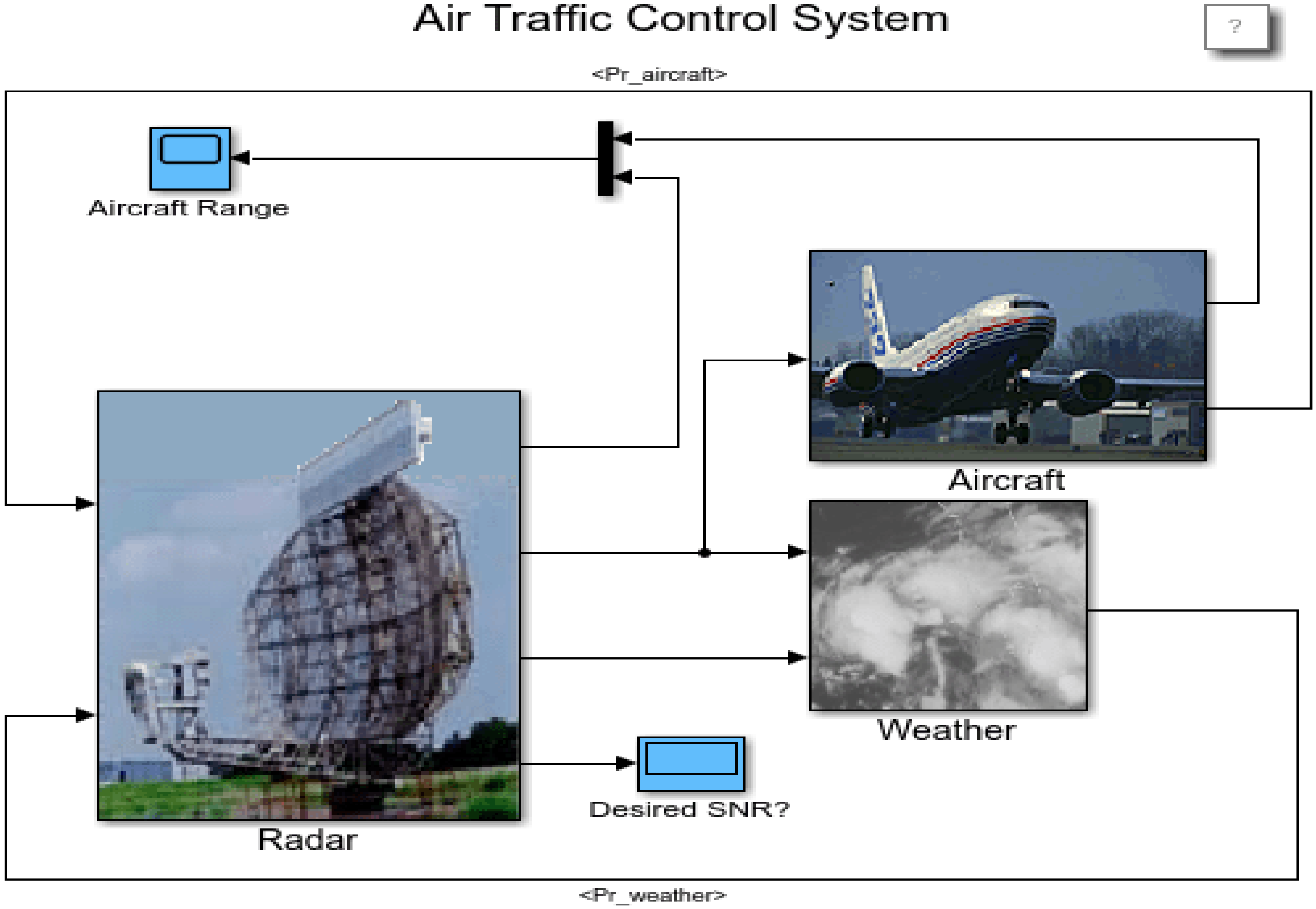
Using subsystems is helpful in two ways: the model is organized and easier to understand and the work can be split between multiple engineers by subsystems. The Stateflow machine labeled "check SNR" performs the logic comparing calculated SNR to the ideal SNR and output data based on this comparison.

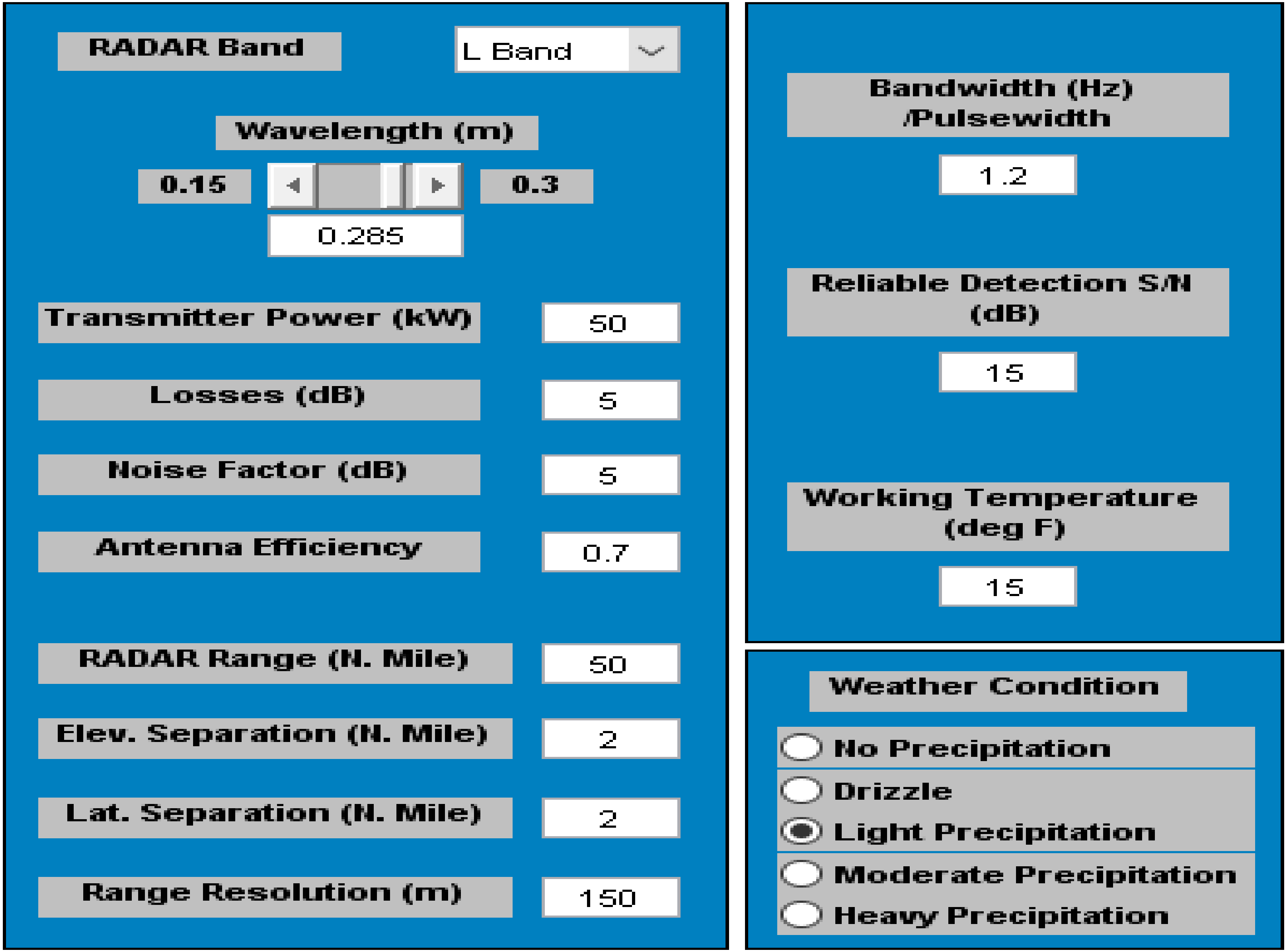
You can run the simulation to determine if the radar can pick up the aircraft by the output on the scope. Using the GUI, the radar and the weather parameters can be altered and will change the range where the aircraft can be "seen".

Open and simulate the aero_atc model.

```
open_system('aero_atc');
```

Air Traffic Control System





RADAR Band	L Band
Wavelength (m)	0.285
0.15	**0.3**
Transmitter Power (kW)	50
Losses (dB)	5
Noise Factor (dB)	5
Antenna Efficiency	0.7
RADAR Range (N. Mile)	50
Elev. Separation (N. Mile)	2
Lat. Separation (N. Mile)	2
Range Resolution (m)	150
Bandwidth (Hz) /Pulsewidth	1.2
Reliable Detection S/N (dB)	15
Working Temperature (deg F)	15

Weather Condition

- ○ **No Precipitation**
- ○ **Drizzle**
- ● **Light Precipitation**
- ○ **Moderate Precipitation**
- ○ **Heavy Precipitation**

Design Issues

Radar systems are designed for a specific purpose and can very seldom be used for other applications effectively. Each new radar specification requires the computation of new parameter values. When designing a radar for an application, there are a number of parameters which shape the design. Some of these parameters are contained or derived logically from the customer specification. Others are selected arbitrarily using the design engineer's best judgment. This is the first approximate solution for the system design. From here, continual refinement of the design parameters takes place until an optimum design is reached. If any changes occur in the customer specification, it could cause a need to rework the design process over from the beginning.

The parametric nature of this design strategy lends itself to automation.

```
sim('aero_atc');
```

Design Specification

We're interested in performing conceptual design for a ground-based air traffic control (ATC) radar. Let's take a look at a potential customer specification.

- **Customer Requirements**
  - Maximum Range = 50 Nautical Miles
  - Lateral Resolution = 2 Nautical Miles
  - Range Resolution = 150 meters
- **Logically Derived Parameters**
  - Scan Time, Hits per Scan, Receiver Bandwidth, SNR, Antenna Gain, $\text{Power}_{\text{ave}}$ * Antenna Aperture
- **Best-Judgement Parameters**
  - Target Cross-Section, Detection Performance, Coverage, Pulse Repetition Frequency, Integration Efficiency, Transmitted Waveform, Receiver Noise Figure, Attenuation, System Losses
- **Additional Concerns**
  - Weather

https://www.mathworks.com/help/simulink/slref/air-traffic-control-radar-design.html

https://www.matlabexpo.com/online/2021.html#section1


Thank You!