Course: CEC300

Department of Electrical, Computer, Software, and Systems Engineering

FLORIDA
ARIZONA
WORLDWIDE

EMBRY-RIDDLE
Aeronautical University

ATCRBS and Mode S Transponder

Where is the airplane?

Dr. Eduardo A. Rojas-Nastrucci

ATCRBS – Air Traffic Control Radar Beacon System

Developed in 1956, ATCRBS was the first air route surveillance radar system developed and purchased for the purposes of air traffic control. The technology was based closely on that of the military's IFF (Identification Friend or Foe) system.

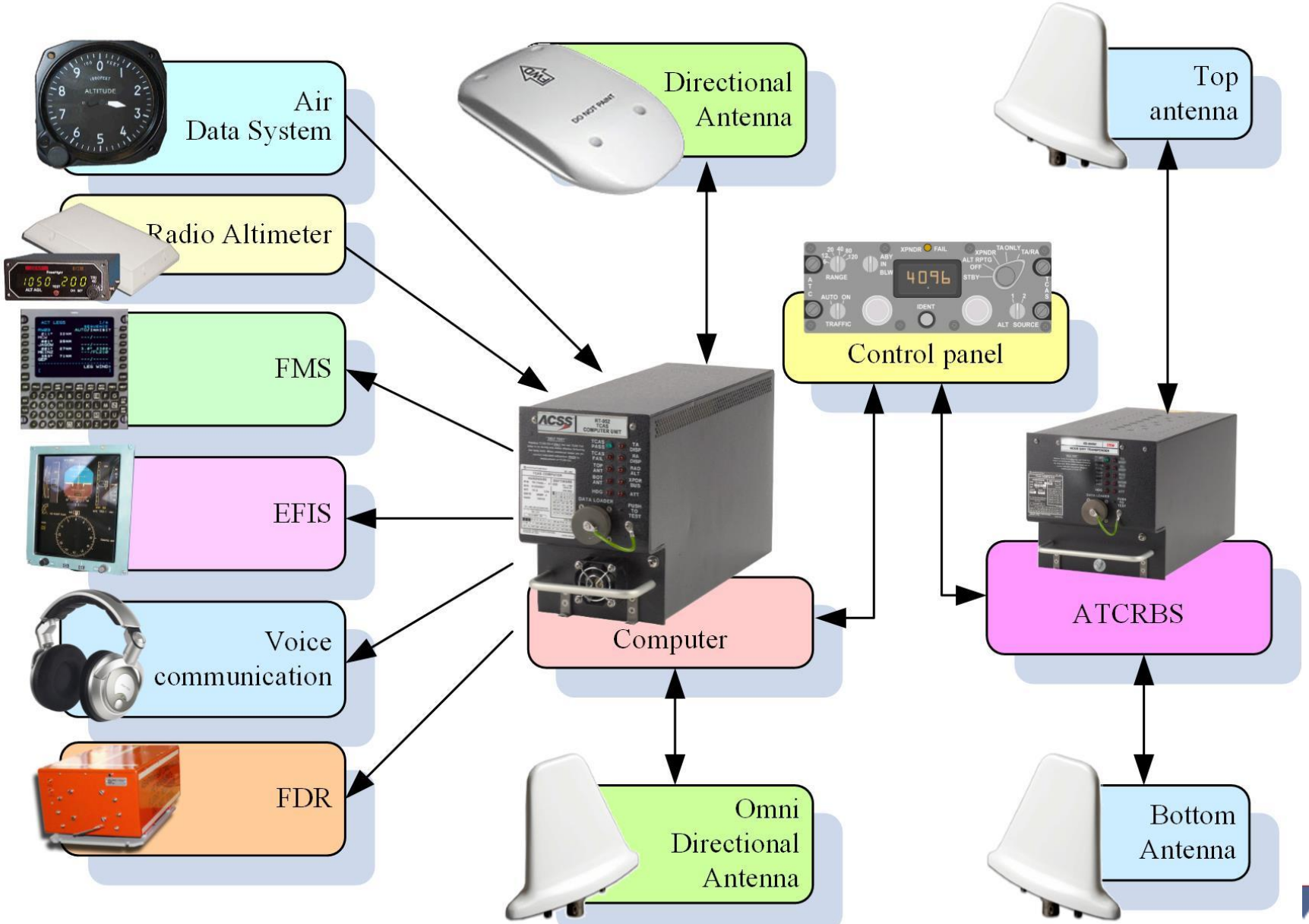
Interrogation from ground– 1030 MHz
Reply from airplane – 1060 MHz

ATCRBS – Air Traffic Control Radar Beacon System

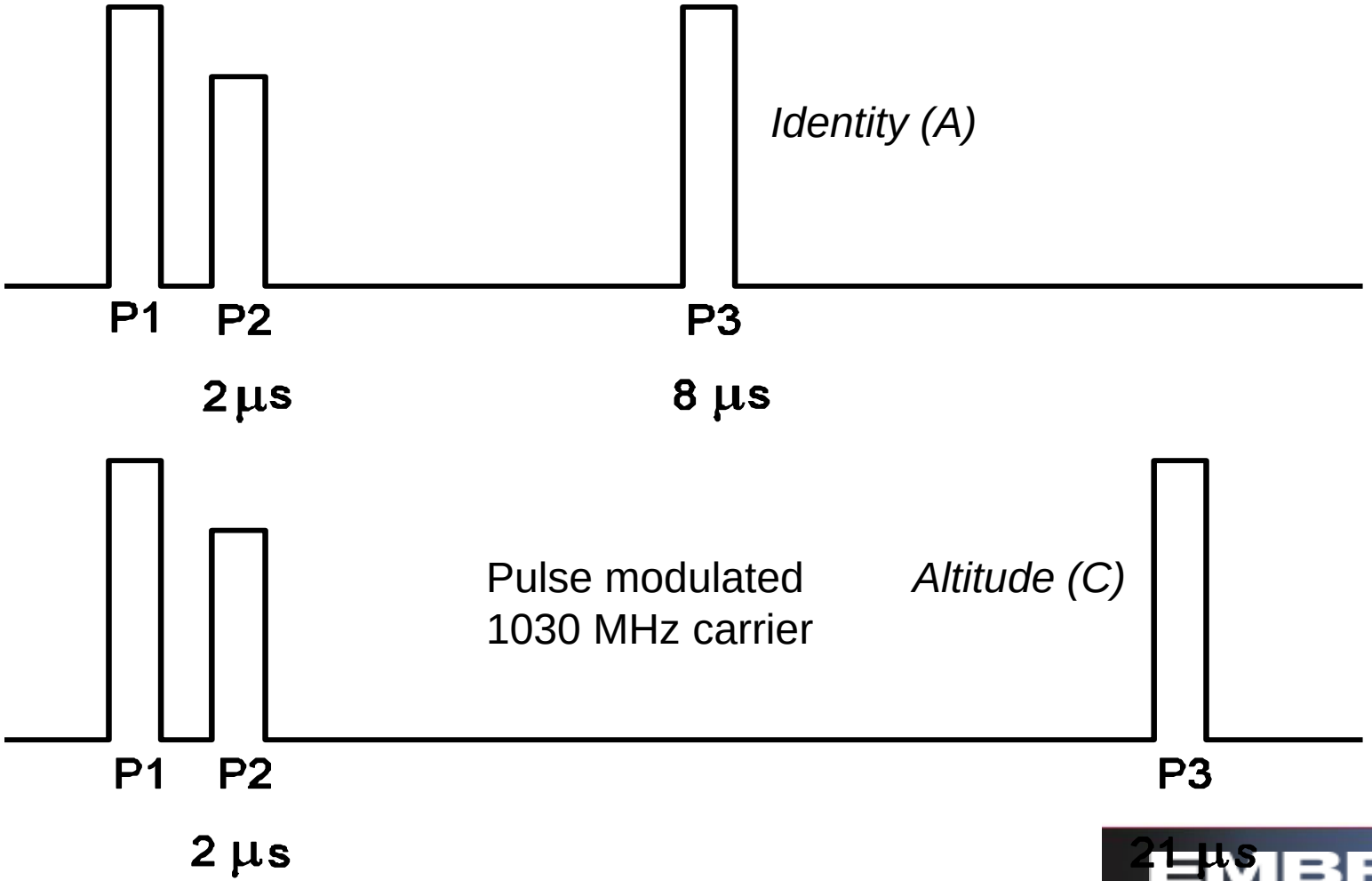
On the ground:

In the airplane:

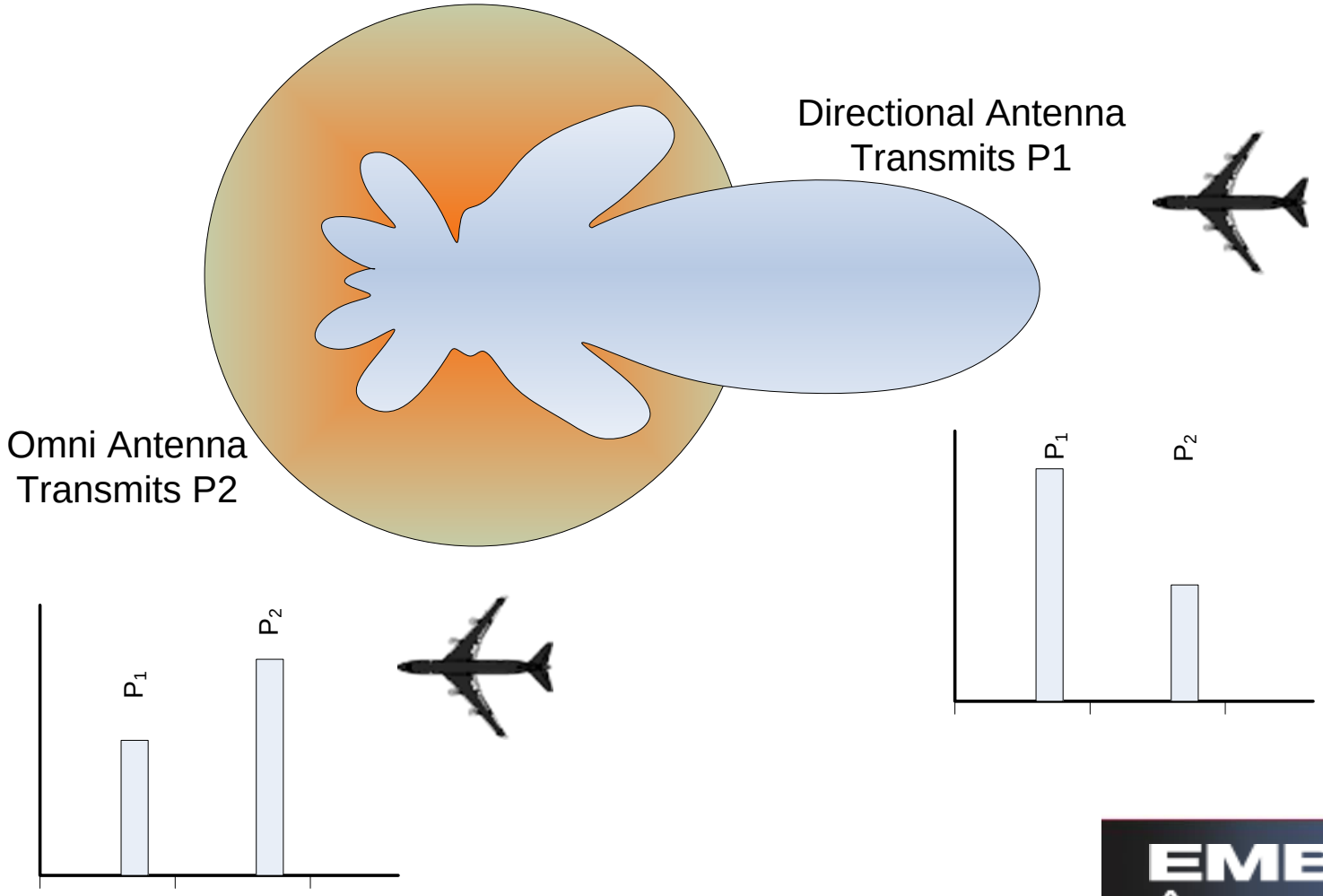
EMBRY-RIDDLE
Aeronautical University



ATCRBS Interrogations

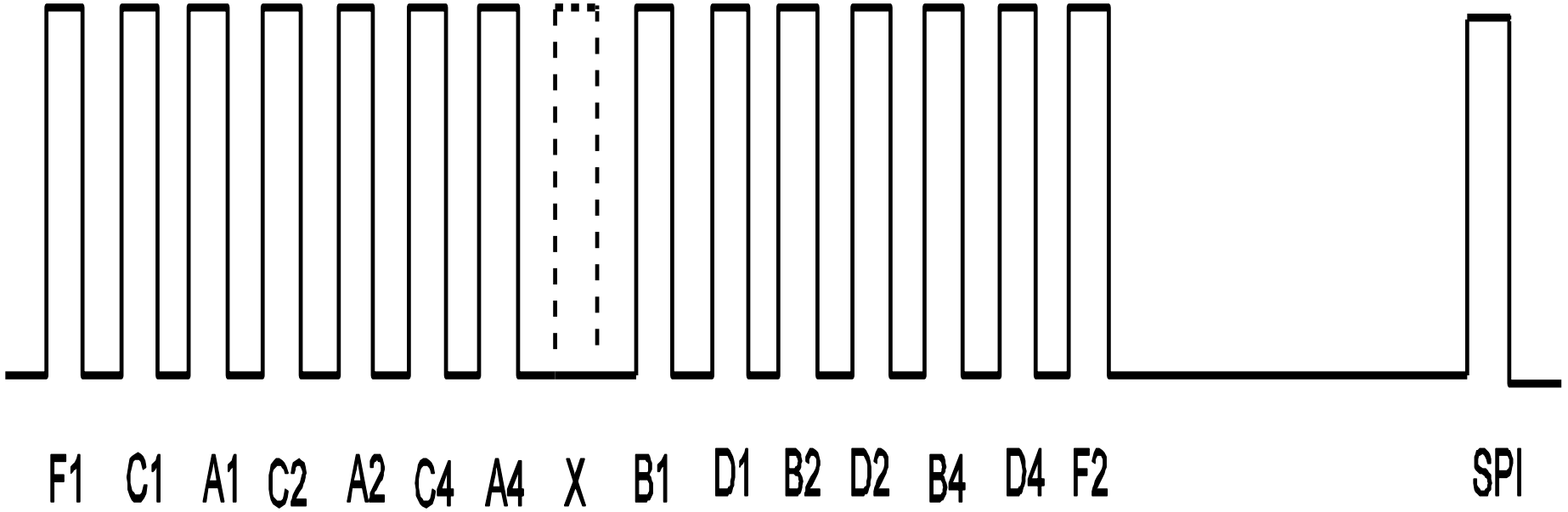


Sidelobe Suppression Pulse



EMBRY-RIDDLE
Aeronautical University

ATCRBS Replies



Pulse modulated 1090 MHz carrier

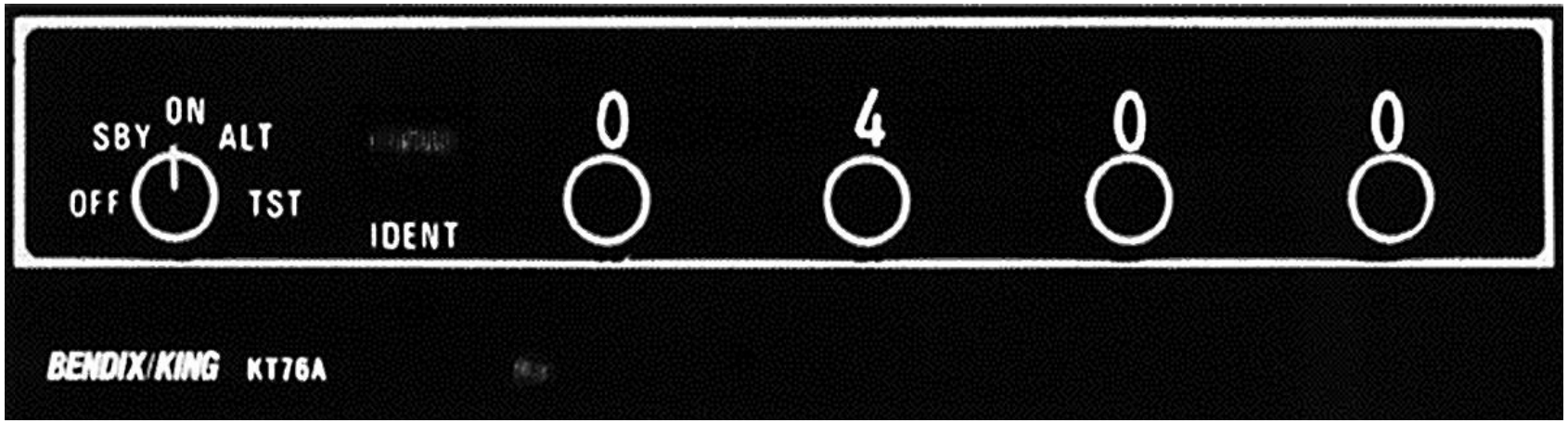
Replying to An Interrogation

An Interrogation Received With an SLS Less than P1 and Either 8μs or 21μs Separation Causes a Reply

The Delay from the Receipt of a Valid Interrogation to the Initiation of a Reply is Critical

The Time Delay From Rising Edge of P3 and the First Framing Pulse, F1 is 3μs

Typical ATCRBS Panel Mounted Transponder

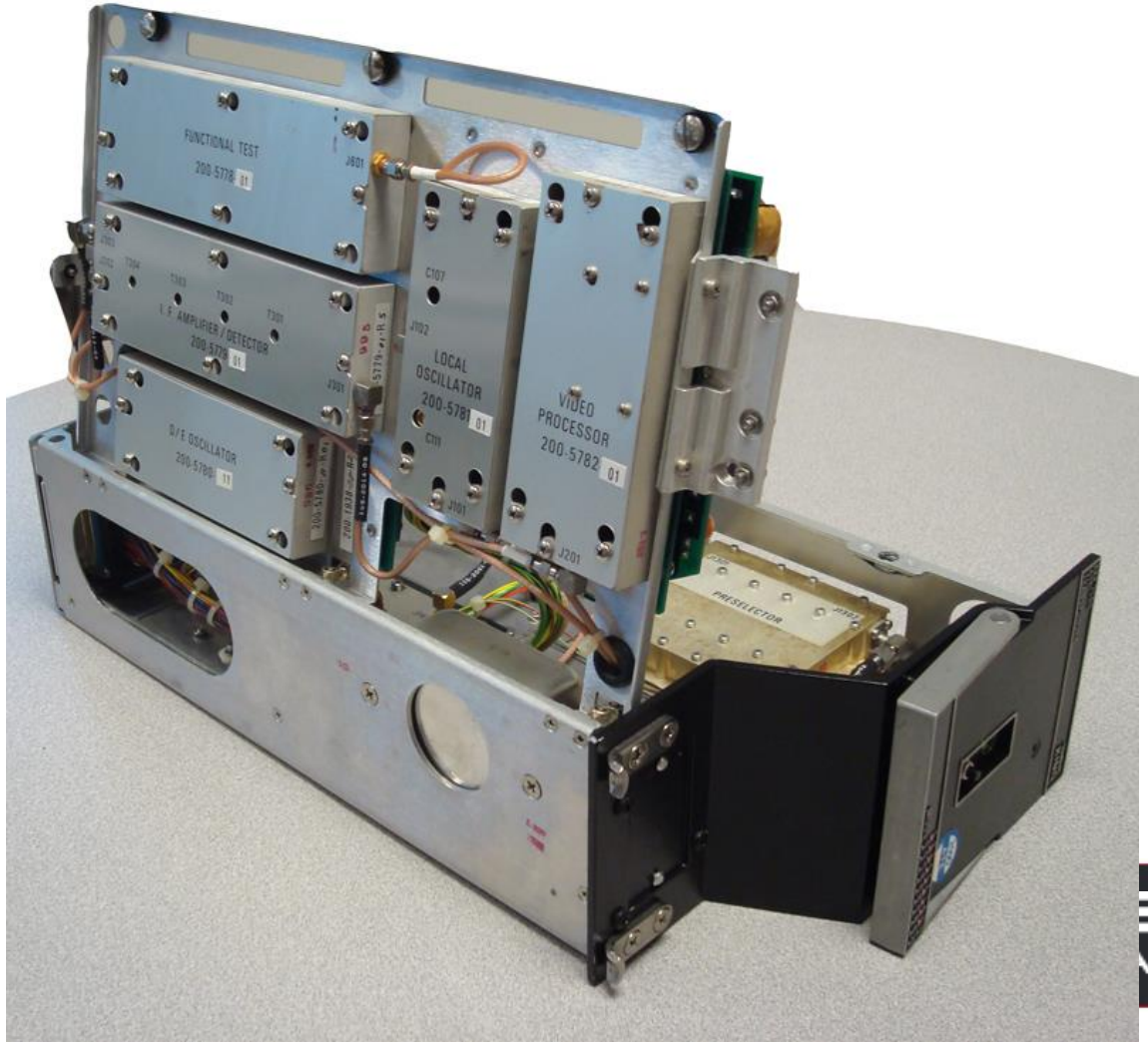


EMBRY-RIDDLE
Aeronautical University

An “ARINC” Style Transponder

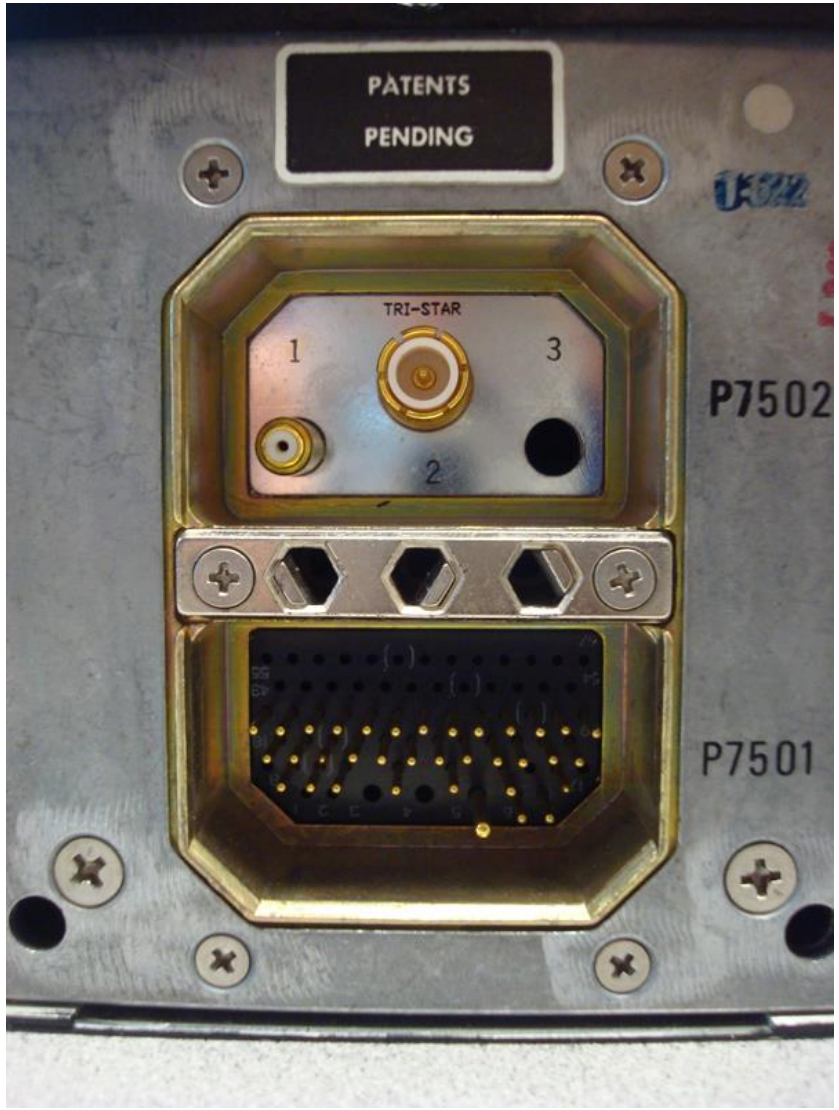
EMBRY-RIDDLE
Aeronautical University

An “ARINC” Style Transponder



EMBRY-RIDDLE
Aeronautical University

The ARINC Connector

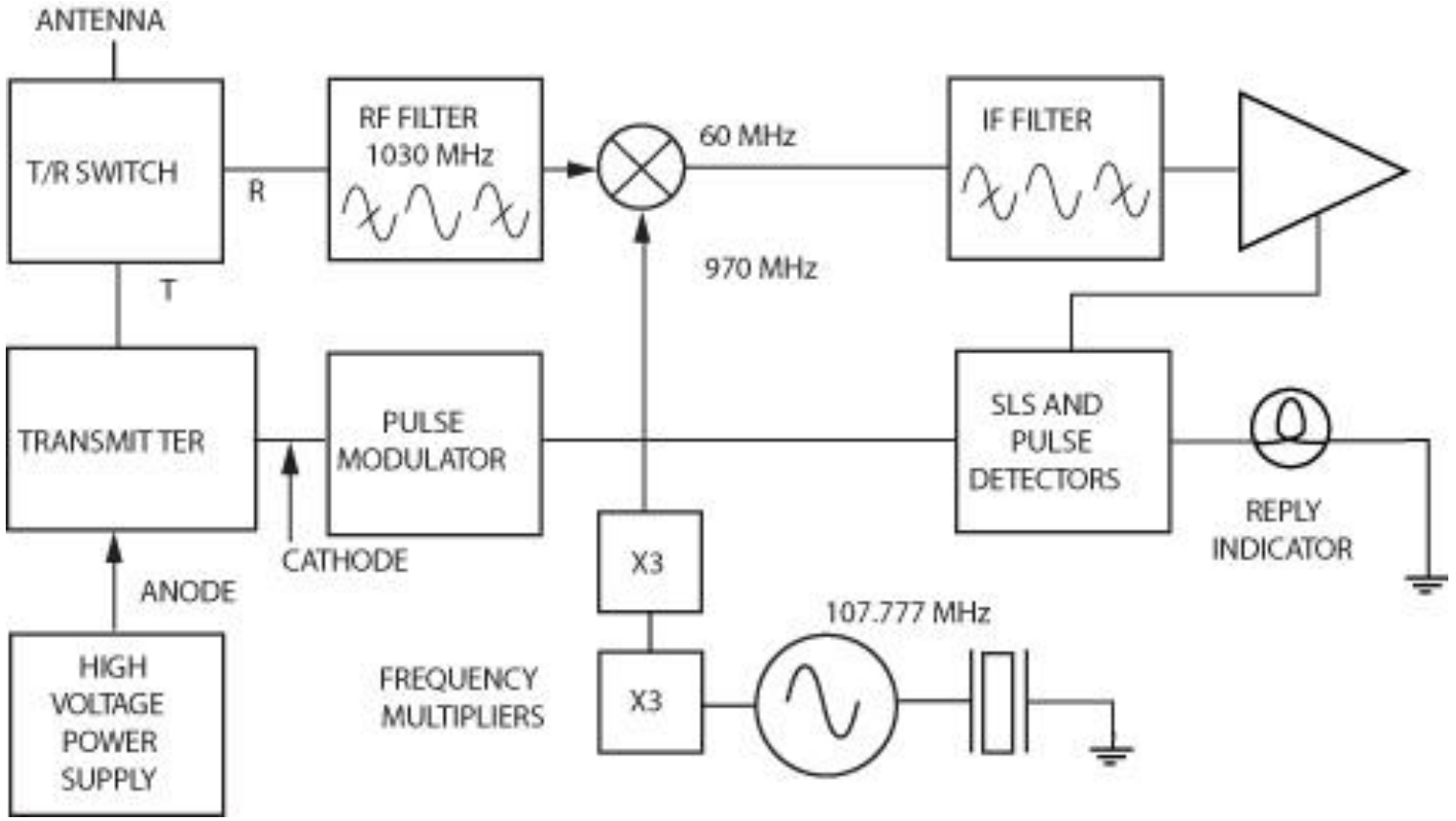


EMBRY-RIDDLE
Aeronautical University

The “Back End of a Rack

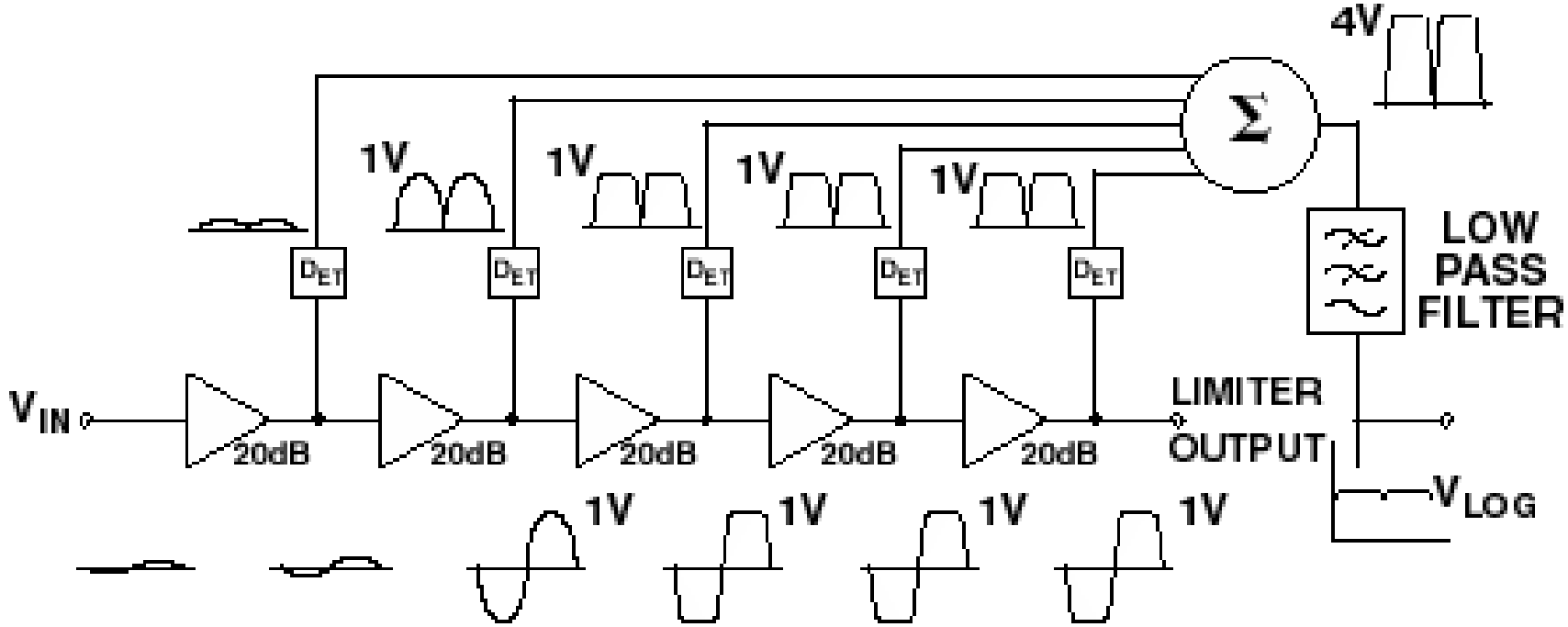
EMBRY-RIDDLE
Aeronautical University

ATCRBS Transponder Block Diagram



EMBRY-RIDDLE
Aeronautical University

Logarithmic Amplifier



***Purpose**: Obtain similar output for extreme changes in input power*

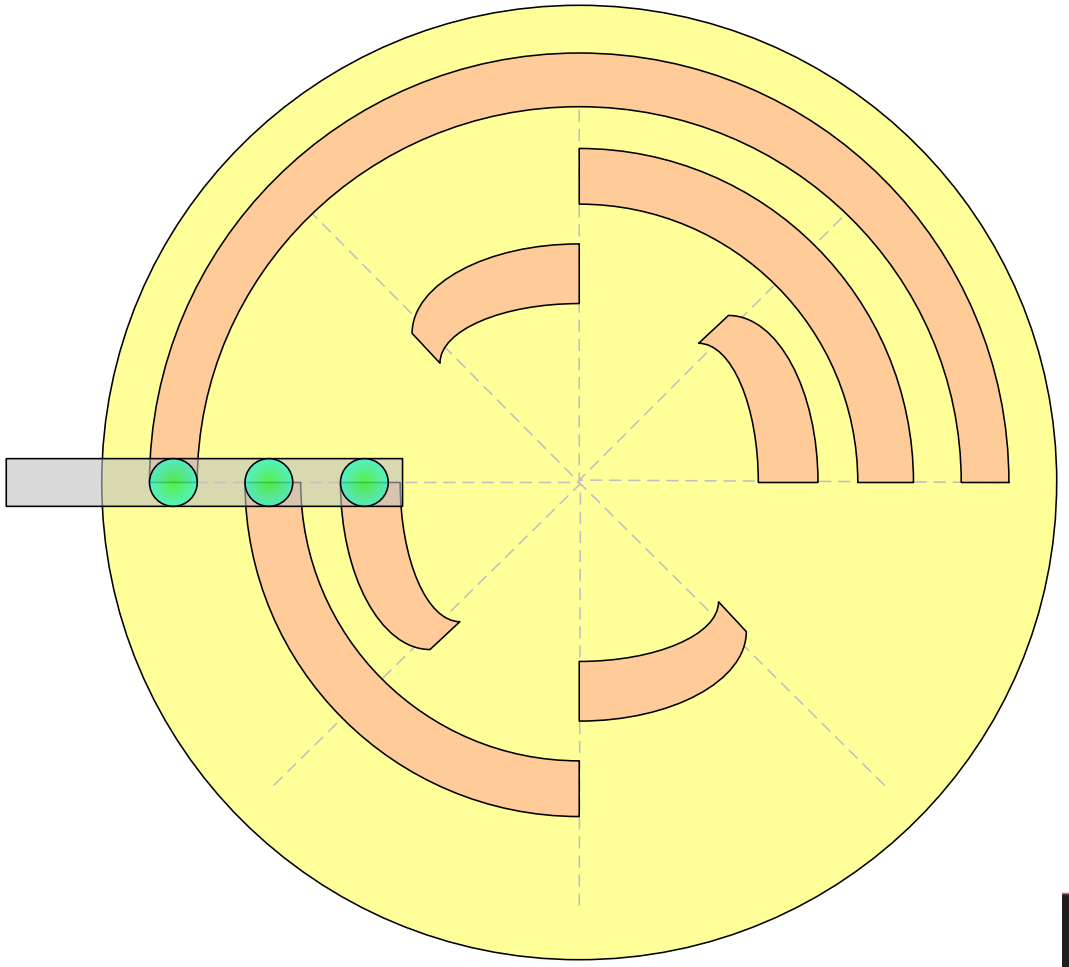
Transponder Sensitivity and Power Output

Transponder Minimum Triggering Level is Set to -73 dBm +/- 4 dB at the Transponder Input/Output Connector
Power Output for Class 1A or 2A ATCRBS Transponders is 125 Watts
Power Output for Class 1B and 2B ATCRBS Transponders is 70 Watts
No Class of Transponder may Exceed 500 Watts

Encoding Altimeter

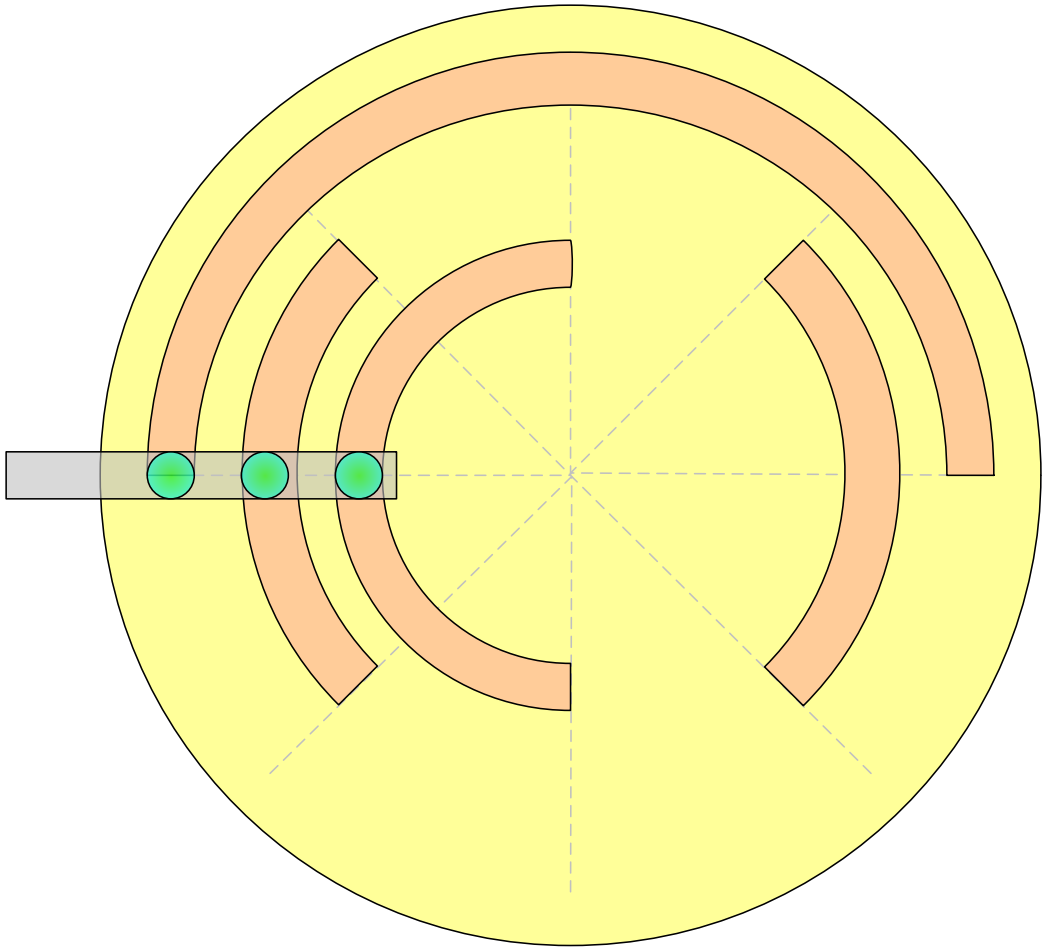
EMBRY-RIDDLE
Aeronautical University

3-Bit Binary Wheel



EMBRY-RIDDLE
Aeronautical University

3-Bit Gray Wheel



EMBRY-RIDDLE
Aeronautical University

The Gillham Code

It is used to transmit uncorrected barometric altitude between an encoding altimeter or analog air data computer and a digital transponder.

A form of Gray code
Range: -1200’ to 126,700’
100’ increments
Uses 11 of the available 12 bits
D1 is not used

Altimeter Encoder

EMBRY-RIDDLE Aeronautical University

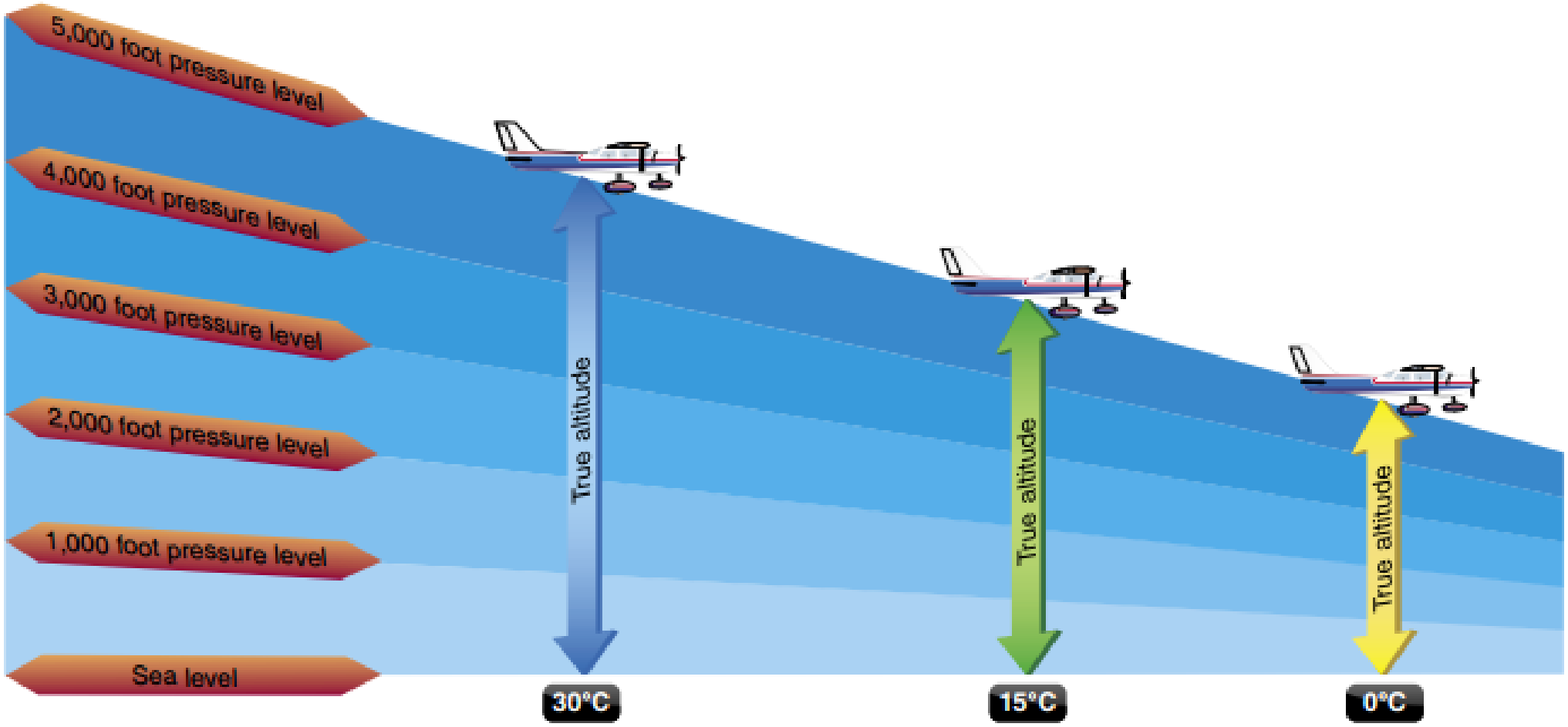
The Gillham Code

Gillham binary code [D124 A124 B124 C124]	Squawk octal code [ABCD]	Height [m]	Height [ft]
000 000 000 001	0040	−365.76	−1200
000 000 000 011	0060	−335.28	−1100
000 000 000 010	0020	−304.8	−1000
000 000 000 110	0030	−274.32	−900
000 000 000 100	0010	−243.84	−800
000 000 001 100	0410	−213.36	−700
000 000 001 110	0430	−182.88	−600
000 000 001 010	0420	−152.4	−500
000 000 001 011	0460	−121.92	−400
000 000 001 001	0440	−91.44	−300

...

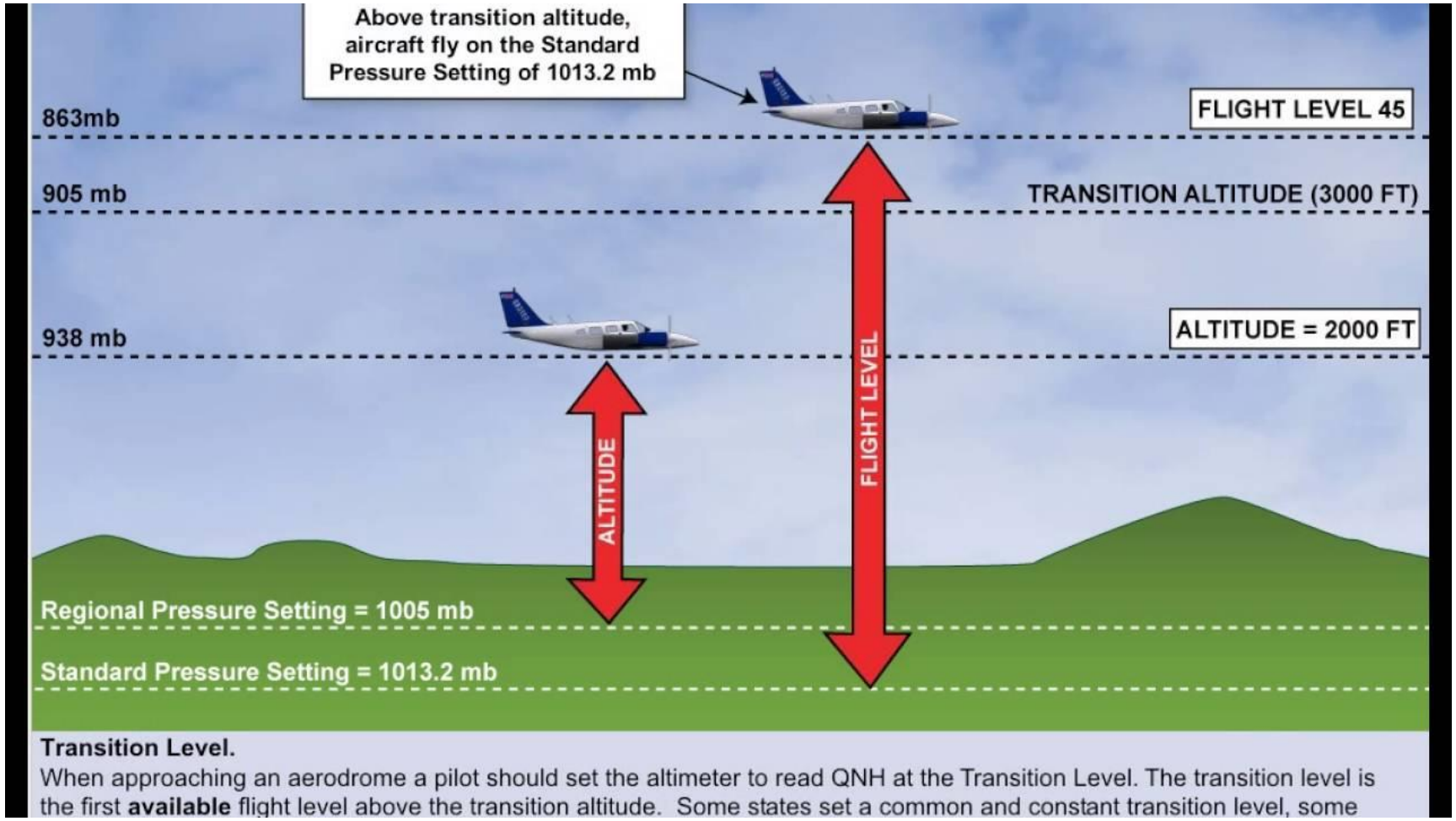
010 000 000 110	0032		126400
010 000 000 010	0022		126500
010 000 000 011	0062		126600
010 000 000 001	0042		126700

The Need to Use Pressure Altitude



EMBRY-RIDDLE
Aeronautical University

The Need to Use Pressure Altitude



EMBRY-RIDDLE Aeronautical University

Problems With ATCRBS

Garble
Wasteful of Spectrum
Required Repeated Interrogations
No Method of Insuring Interrogation or Reply was Received Error Free
Limited Capability; only altitude and an assigned identity

Reducing Garble

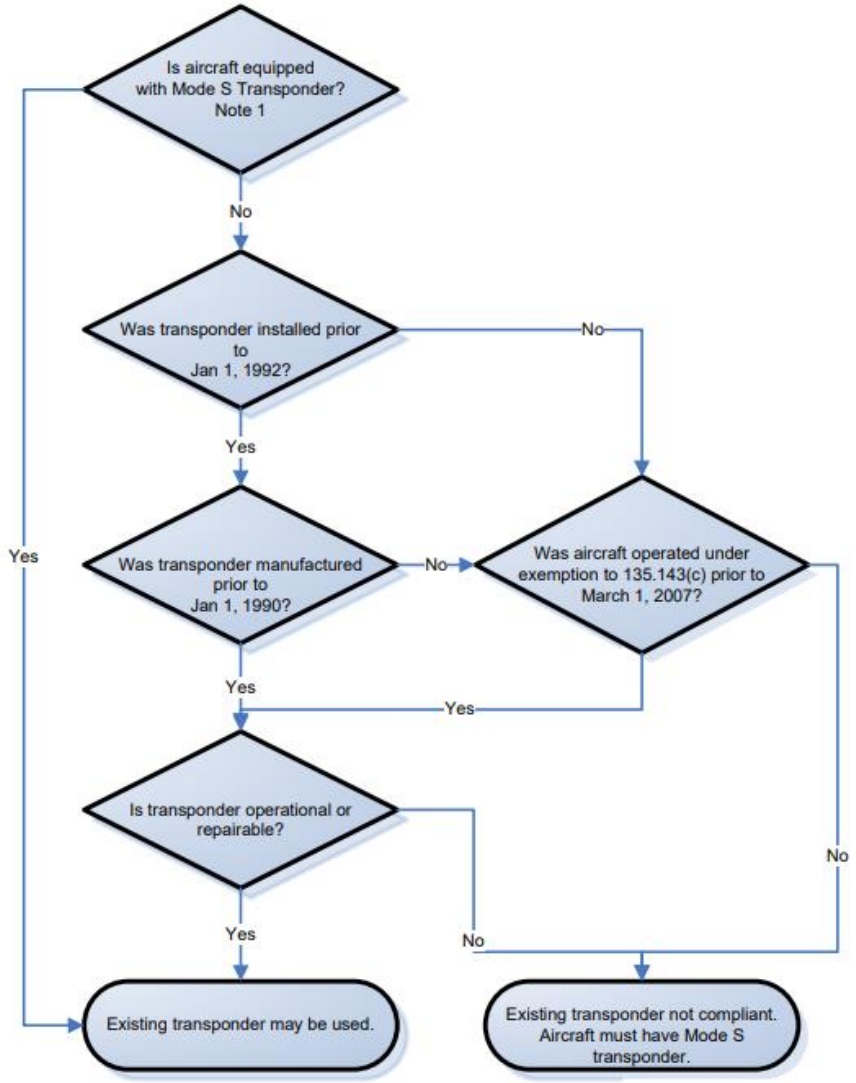
Selective Interrogations
Ability to Control Characteristics of Transponders
All Call
Reduce Probability of Reply to Separate Garbling Transponders, (Stochastic Acquisition)
Locking out Transponders
Roll Call

EMBRY-RIDDLE
Aeronautical University

Mode Select, Mode-S, Transponder

Replacing ATCRBS
Same frequencies as ATCRBS
Same signal levels and vertically polarized
Mode-S transponders will operate with legacy ATCRBS ground interrogators
Legacy interrogators will operate with Mode-S transponders
ATCRBS transponders will operate with Mode-S interrogators

Mode Select, Mode-S, Transponder



Note 1: A transponder is not required for operation under Part 135 however the operator must comply with the requirements of 14 CFR 91.215(b)

EMBRY-RIDDLE Aeronautical University

Mode S

Ground interrogators can selectively interrogate transponders
Every aircraft has a unique identity
More data than just identity and altitude may be sent
Stochastic acquisition helps resolve garbling
Mode S transponders can exchange data with other transponders and interrogators

ICAO 24-Bit Aircraft Address

Was Originally Called the Mode-S Address
Is Now Used for Emergency Locator Transmitters, and ADS-B
Every Aircraft, Worldwide has a Unique Identifier
Addresses are 24 Binary Bits

EMBRY-RIDDLE
Aeronautical University

ICAO 24-Bit Aircraft Address

2^{24} = 16,777,216

Each ICAO Member State is Assigned a Block of 24-Bit Addresses

Country Blocks, (number of addresses)

1024

4096

32,768

262,144

1,048,576

EMBRY-RIDDLE Aeronautical University

All-Call and Roll Call

All-Call Periods are for Acquiring the Identity of Aircraft
Roll-Call Periods Interrogates Only Aircraft that Have Been Identified

All-Call Period

Interrogator Sends All-Calls Which Includes the Interrogator's Identity
Airborne Transponder Replies to All-Calls and Echoes the Interrogator's Identity
All Mode-S Replies Include the Aircraft 24 Bit ICAO Identity
Ground Interrogator has "Acquired" the Aircraft
Further Interrogations will be Selective

EMBRY-RIDDLE
Aeronautical University

Mode S All-Call Period

Selective Type, P6 Type, All Calls are Transmitted
Mode A/C Interrogations Follow the P6 Type All-Calls
Mode-S Delay Time is 128 μs
Mode A/C Delay time is 3 μs
Common Receive Time for Mode A/C and Mode S

EMBRY-RIDDLE
Aeronautical University

All-Call Period

The Selective Calls of “Acquired” Aircraft are “Locked Out” by the Interrogator From Replying to All-Calls From That Interrogator

The transponder will continue to reply to other interrogator all-calls unless locked out by them.

The Transponder will Cancel the Lock-Out After 18 Seconds

Ground Stations Usually Reset Timer With Each Selective Interrogation

As Long as The Transponder is Being Selectively Interrogated by a Ground Station the Transponder will Ignore All-Calls from That Interrogator

Stochastic Acquisition

Used to separate garbling Mode S transponders on all call
Ground interrogator can uplink a reply probability
Reply probabilities are 100%, 50%, 25%, 12.5%, 6.25%, 0% (1/1, ½, ¼, 1/8, 1/16 and 0)
Eventually transponders miss a reply
More transponders garbling requires lower probabilities must be used and process takes longer
Each transponder identified is “locked out”

EMBRY-RIDDLE Aeronautical University

Mode-S Roll Call Period

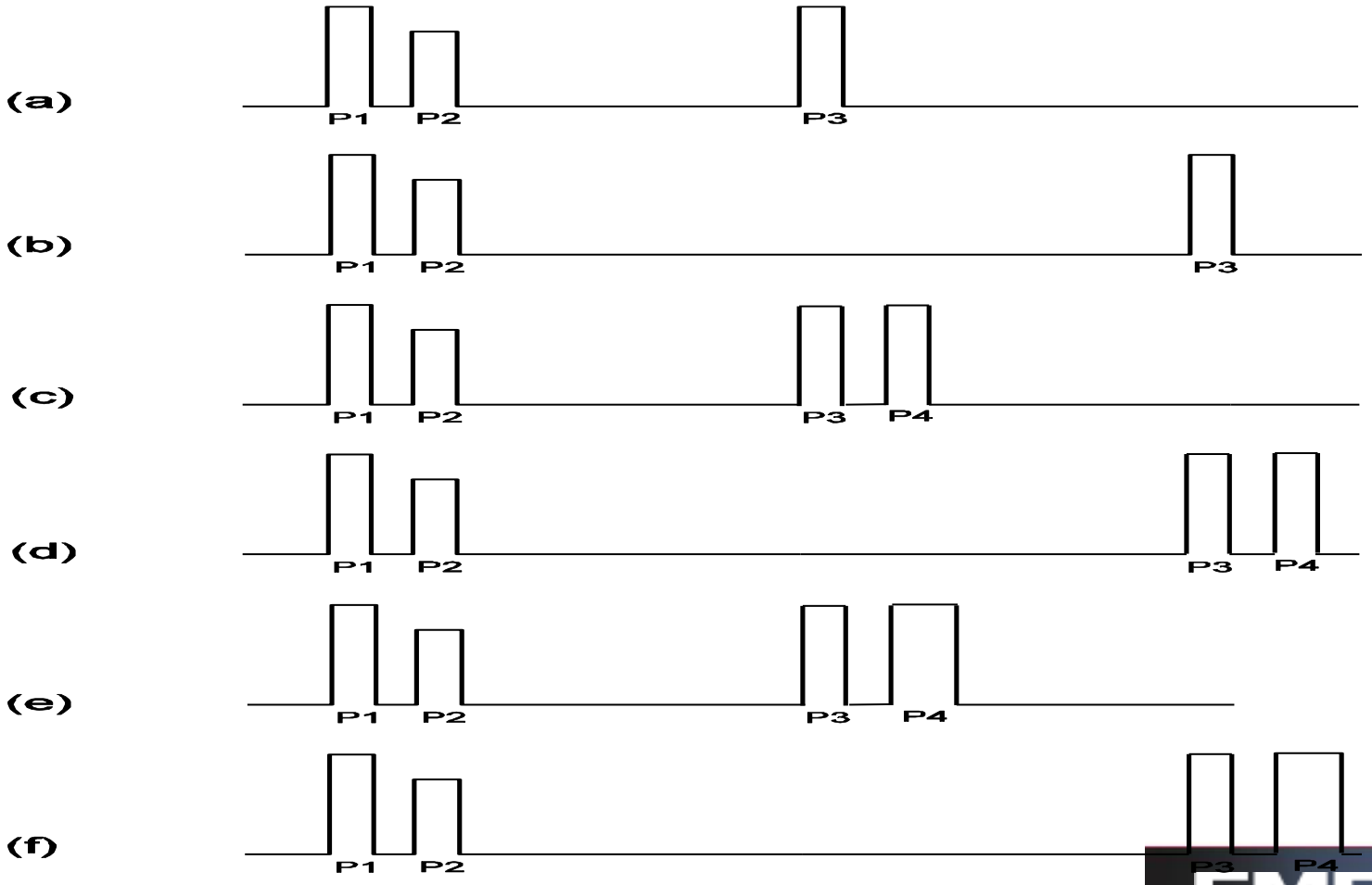
Only Mode-S Aircraft are Interrogated
Addressed Aircraft Were Positively Identified During the All-Call Period
Two Thirds of the Total Time is Devoted to the Roll-Call Period
One Third of the Total Time is Devoted to the All-Call Period

EMBRY-RIDDLE
Aeronautical University

Transponder Delay Time

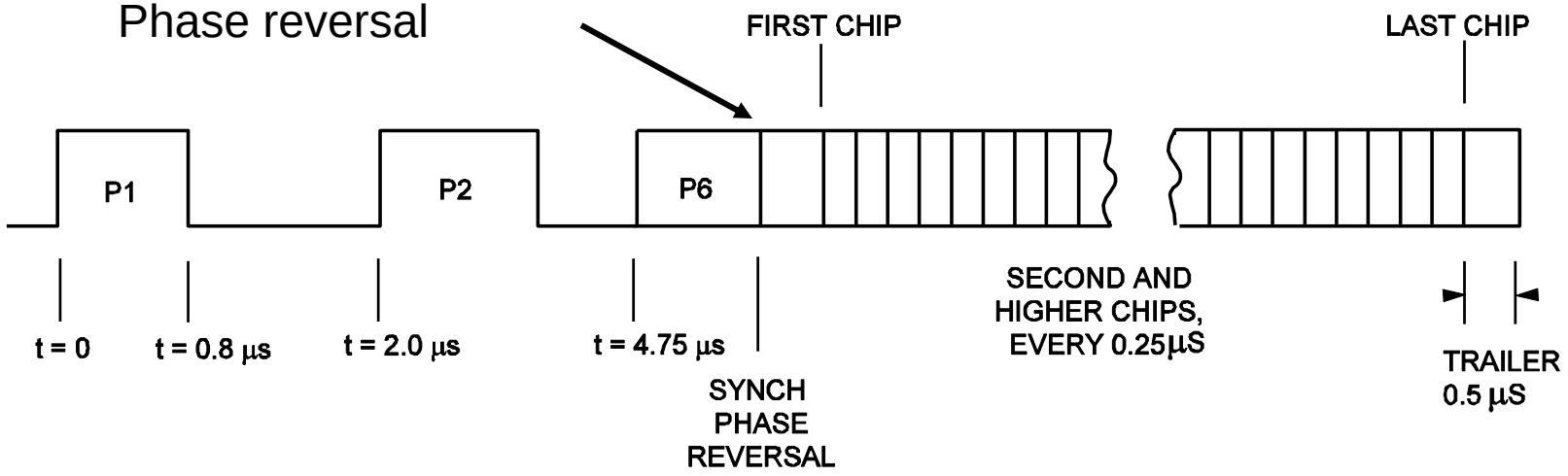
For ATCRBS interrogation: 3 us measured from the leading edge of P3
For Pulse Amplitude modulation, P4 type interrogation for Mode S reply: 128 us from the leading edge of P4
For P6 type interrogation: 128 us from the synch phase reversal

PAM Type Mode-S All Call Interrogations



Mode-S Selective Interrogation

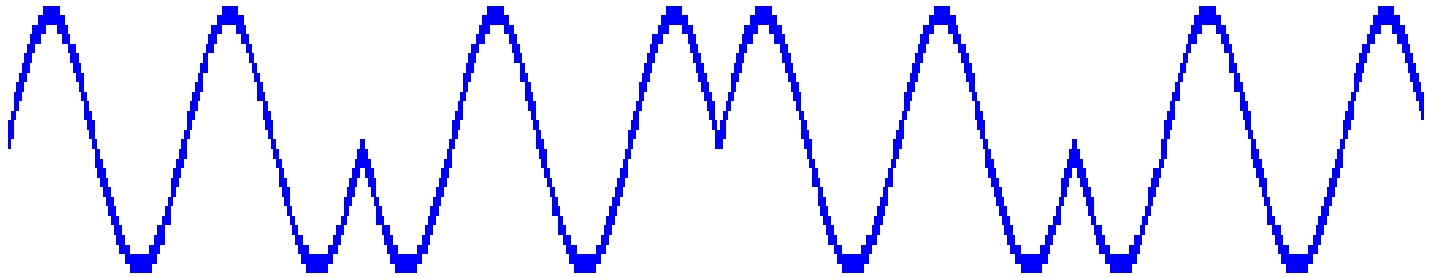
If there is a P5 used for SLS
It is overlaid on the synch
Phase reversal



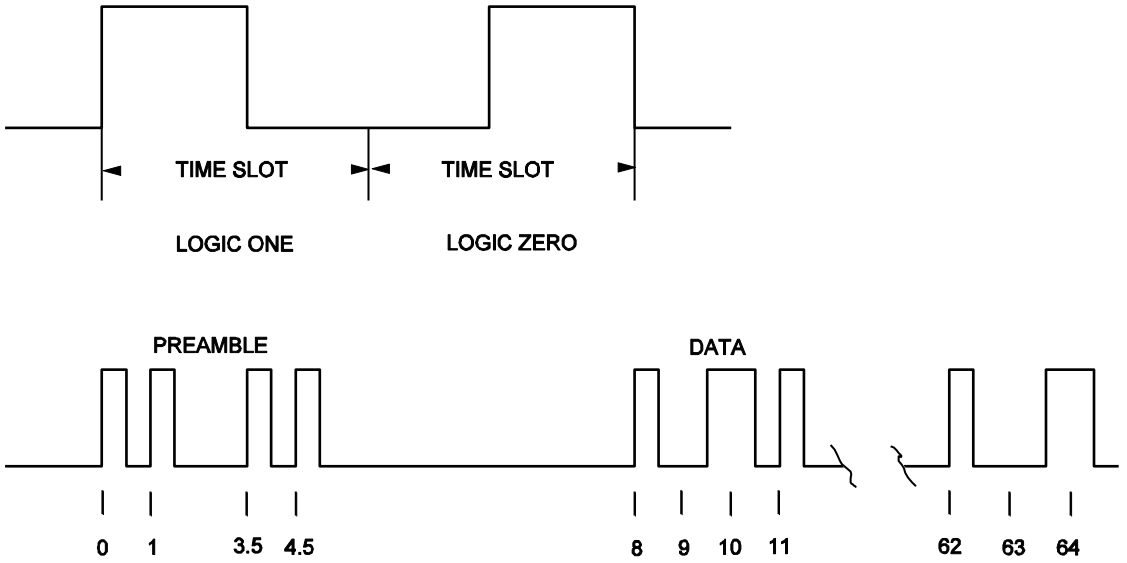
The “P6 type” interrogation is also used as an All call by using all 1’s as the aircraft address

DPSK

Differential BPSK
No absolute phase reference
Used in moving platforms



Mode-S Selective Reply

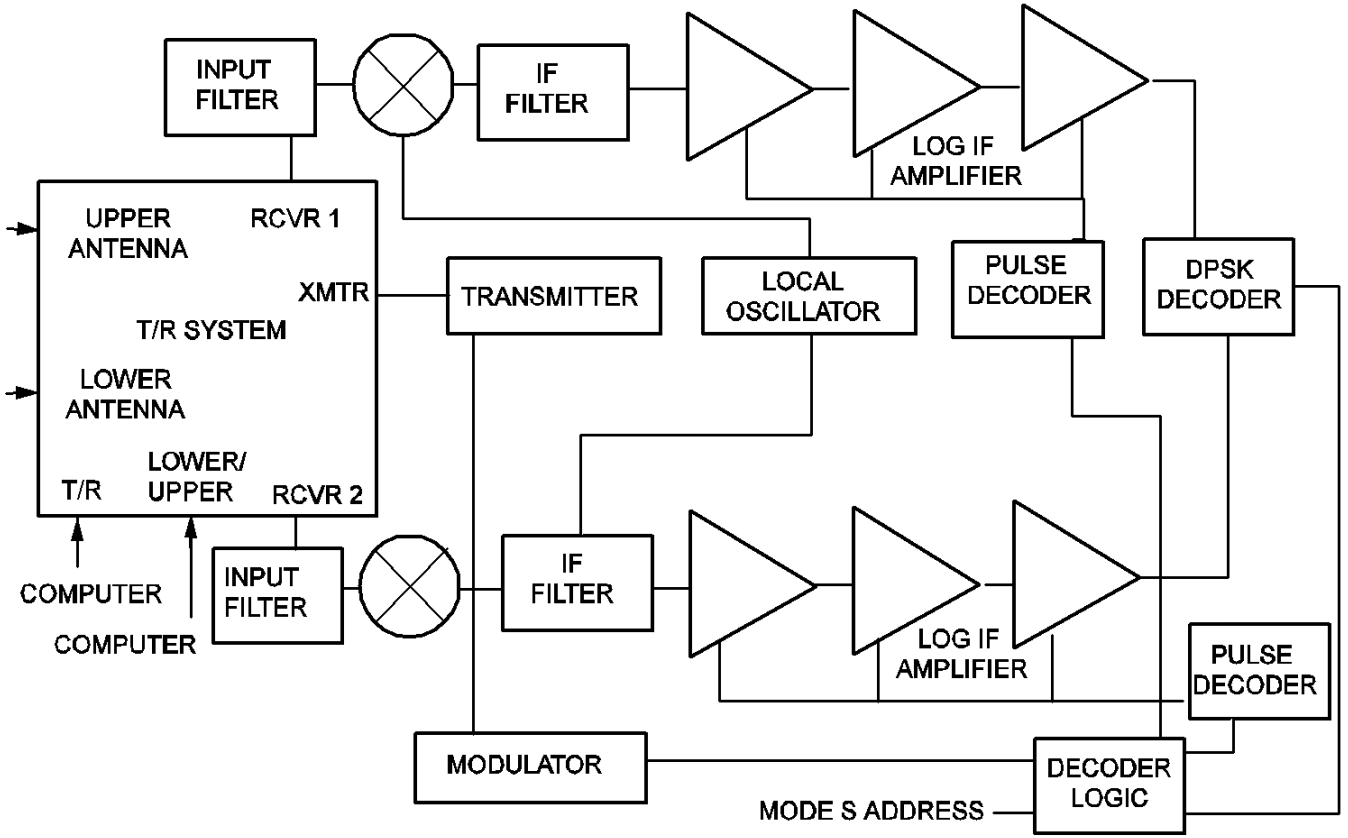


EMBRY-RIDDLE Aeronautical University

Error Detection

Make sure that data are accurately received
Incorporate error detection code
Simple error detection: Parity (ineffective)
Cyclic Redundancy Check (CRC)
Interleave in data
Ground/aircraft can make sure message is correct

Mode S Block Diagram



Space Diversity

Antennas on top and bottom of an aircraft
Independent receivers including decoding
“Best” signal determines which antenna is used for reply
If both received interrogations are error free the stronger signal determines the antenna
Squitters alternate from top to bottom