# INTRODUCTION TO RADAR ENGINEERING

ECE 521E – RADAR & SATELLITE ENGINEERING

Monday, 07 September 2026

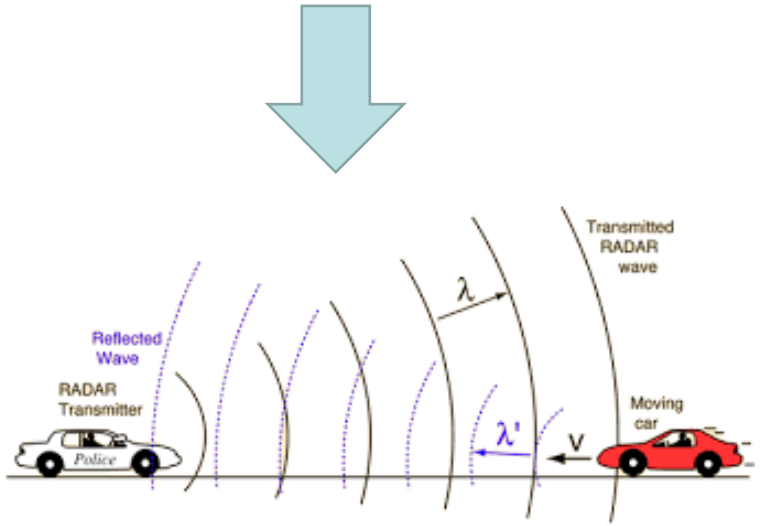
# RADAR DEFINITION

1. The word **Radar** evolved as an abbreviation for:

   Radio Detection And Ranging.



2. **Radar** is a system that uses electromagnetic system for the detection and for location of objects.



# ENGLISH DICTIONARY DEFINITION

- Radar has over time become an English language noun.

From Wikipedia, the free encyclopedia

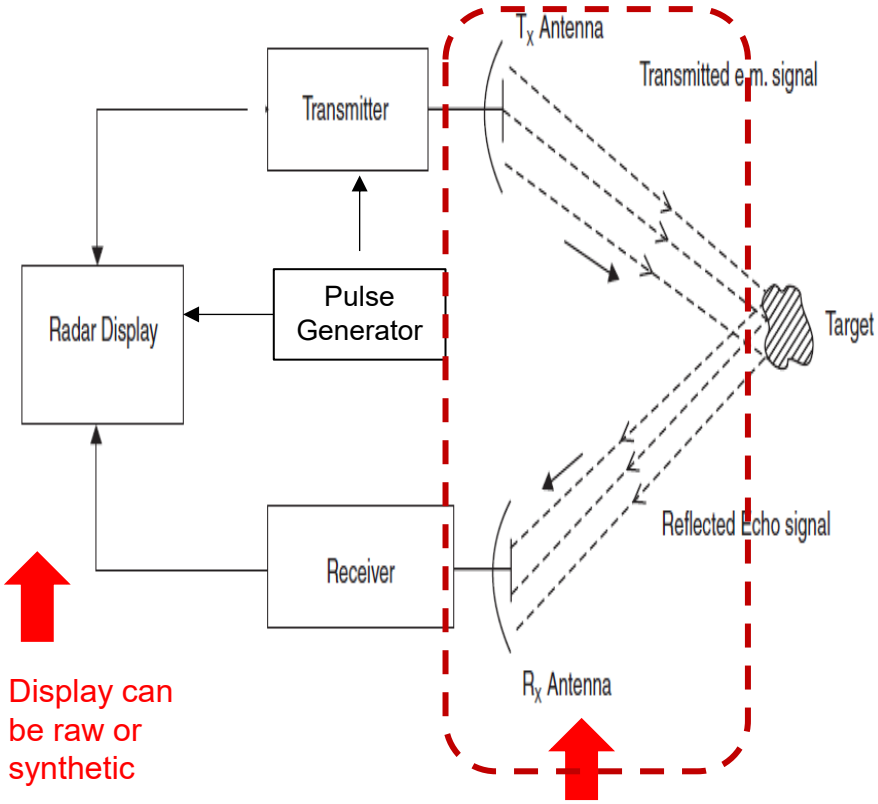
*For other uses, see Radar (disambiguation).*

**Radar** is an object-detection system that uses radio waves to determine the range, altitude, direction, or speed of objects. It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain. The radar dish or antenna transmits pulses of radio waves or microwaves that bounce off any object in their path. The object returns a tiny part of the wave's energy to a dish or antenna that is usually located at the same site as the transmitter.

# WHAT IS RADAR?
# BEST ANSWER

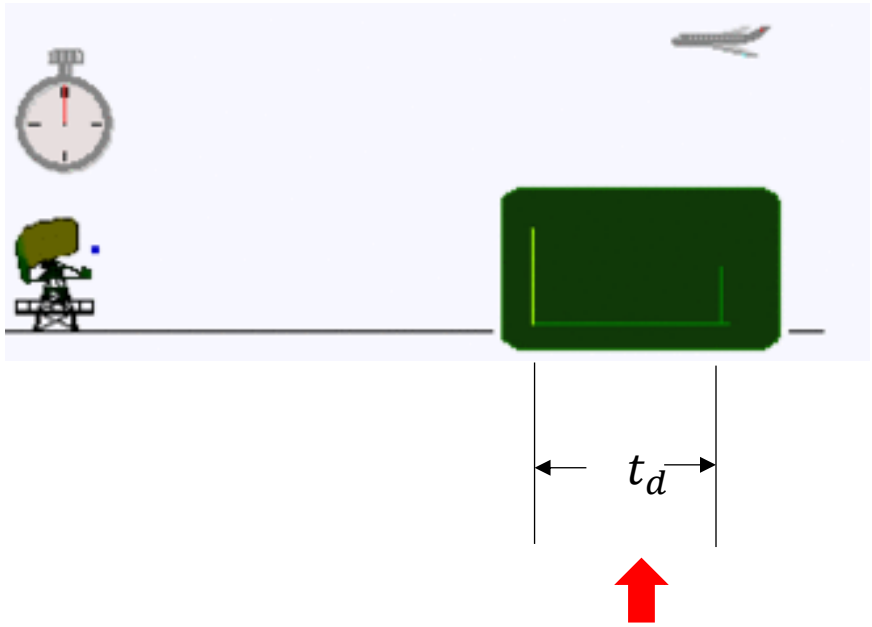
- Radar is an electromagnetic system for the detection and location of objects that reflect electromagnetic waves such as aircraft, ships, spacecraft, vehicles, people, and the natural environment.
- It operates by radiating energy into space and detecting the echo signal reflected from an object or target.

# SIMPLE BLOCK DIAGRAM OF A RADAR SYSTEM




Display can be raw or synthetic

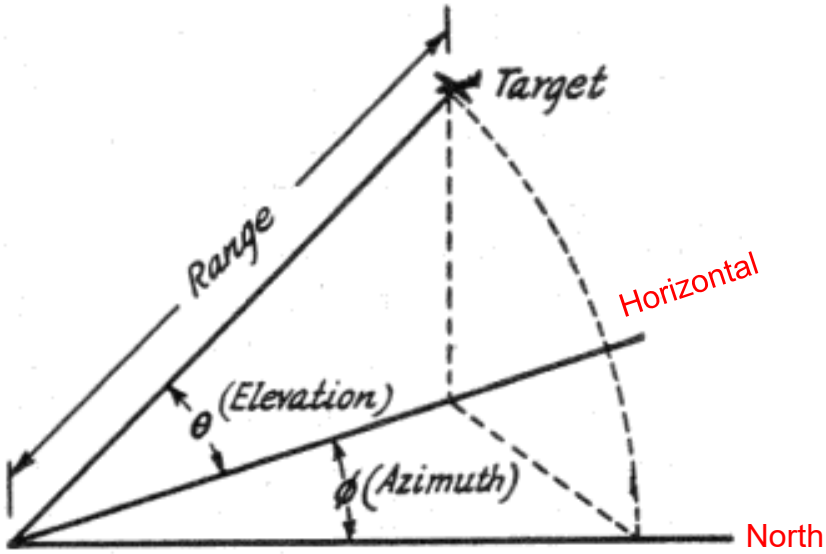
The antenna system can single (Monstatic) or Double (Bi-static)



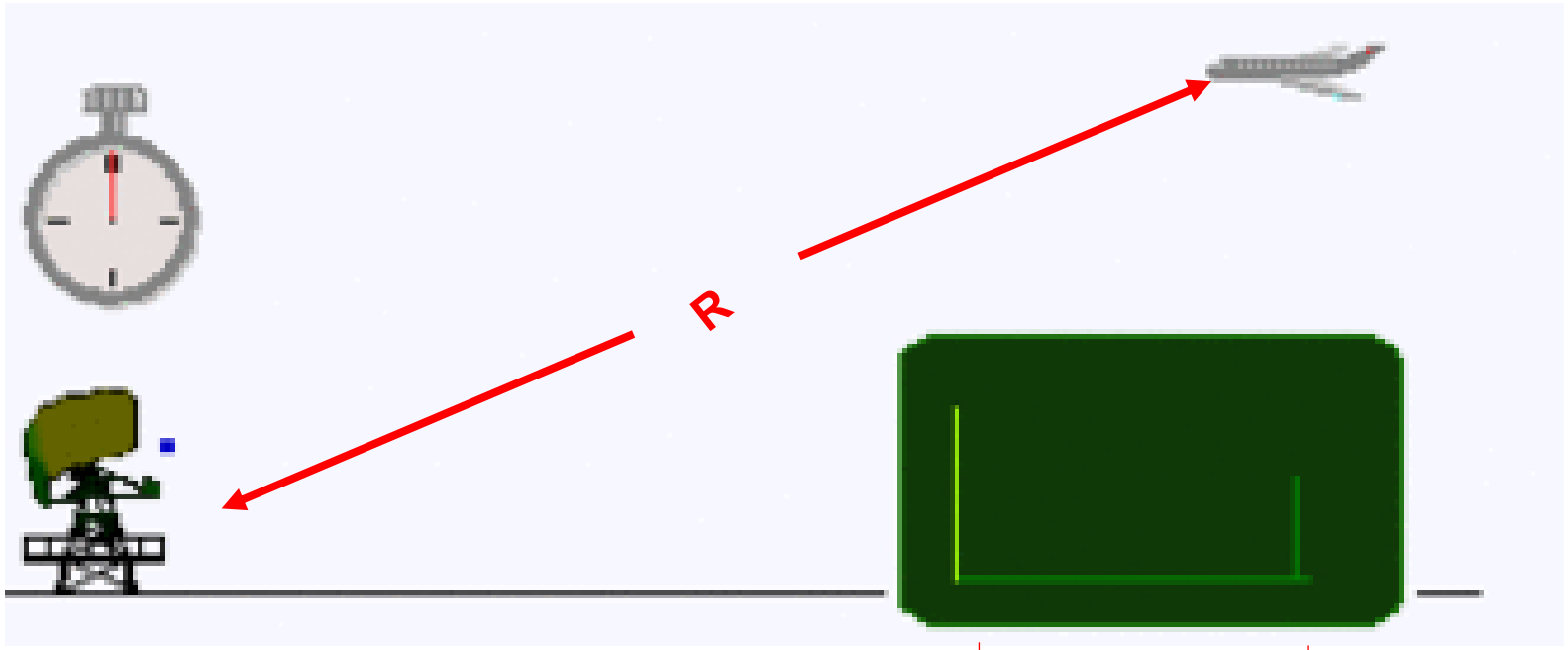

Time Delay $t_d$ can displayed on a CRO or processed by a computer and displayed as distance.

# TARGET PARAMETERS – OBSERVABLE BY RADAR

1. Target range
2. Target angles (azimuth & elevation)
3. Target size (radar cross section)
4. Target speed (Doppler radar)



# MEASUREMENT OF RANGE



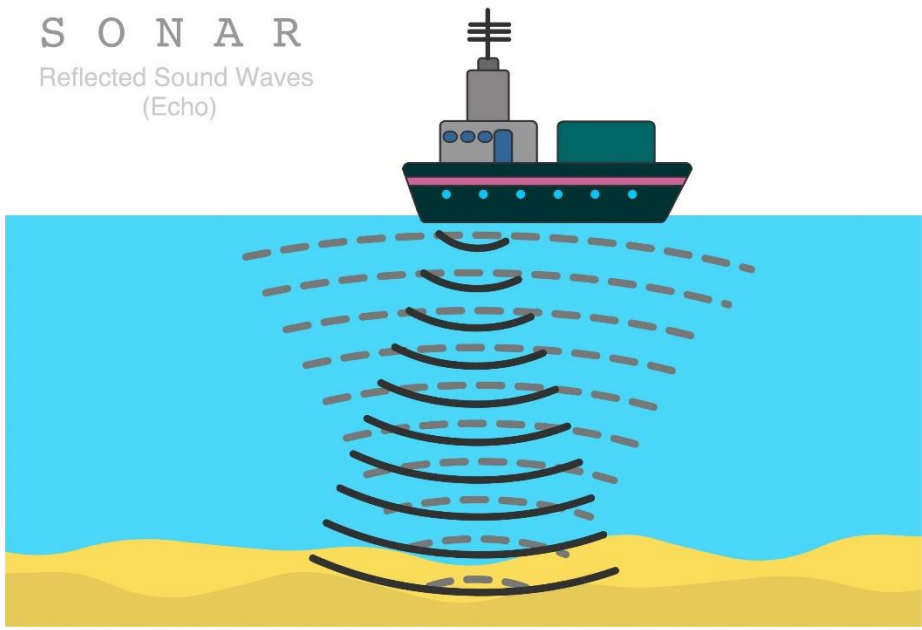

$$2R = c\tau$$

$$R = \frac{c\tau}{2}$$

$$where\ c = 3 \times 10^8\ \mathrm{m/s}$$

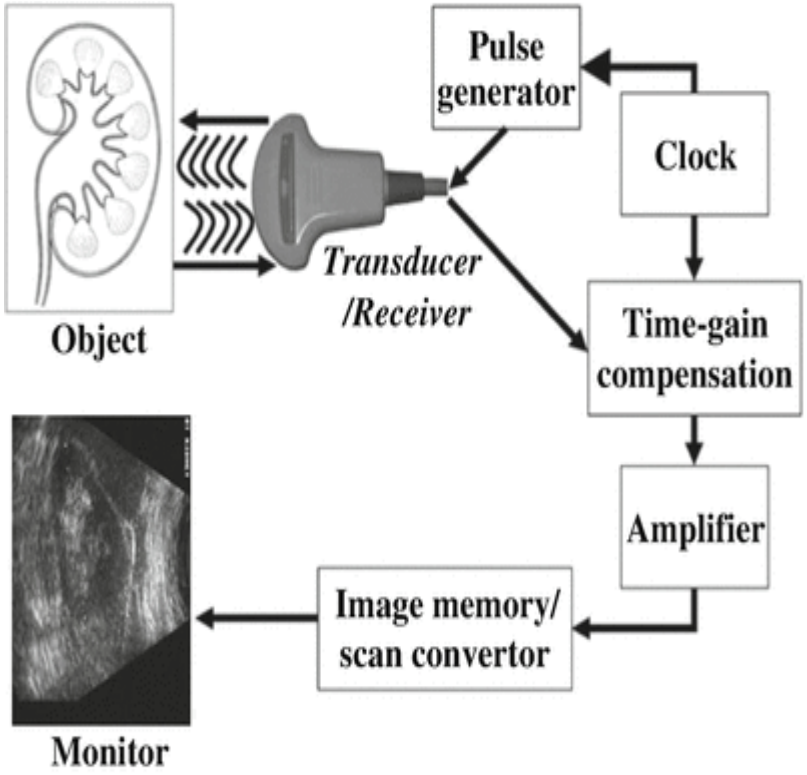
# UNDERWATER COMMUNICATION & RANGING - SONAR

1. **Sonar** (**So**und **N**avigation and **R**anging) is helpful for exploring and mapping the ocean because sound waves travel farther in the water than do electromagnetic waves.
2. Using sonar, we know the deepest part of the ocean is called the **Challenger Deep** is located beneath the western Pacific Ocean.
3. **Challenger Deep** is approximately 10,935 meters (11 km) deep.



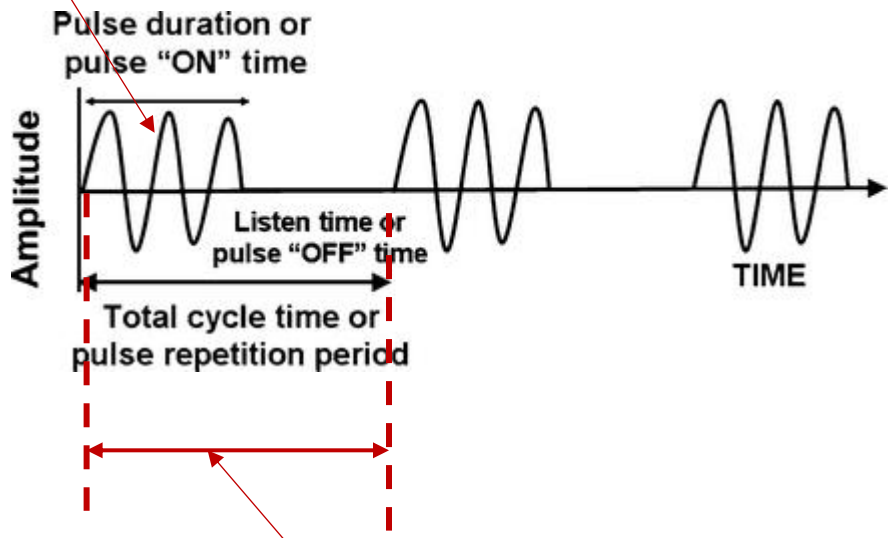
# ULTRASOUND IMAGING /01

1. **Ultrasound imaging** uses a dual-function piezoelectric transducer. Sound waves are transmitted into the body where they are at least partially reflected.
2. The echo causes the piezoelectric transducer to produce an electric current which is amplified and used to produce the soft-tissue image.

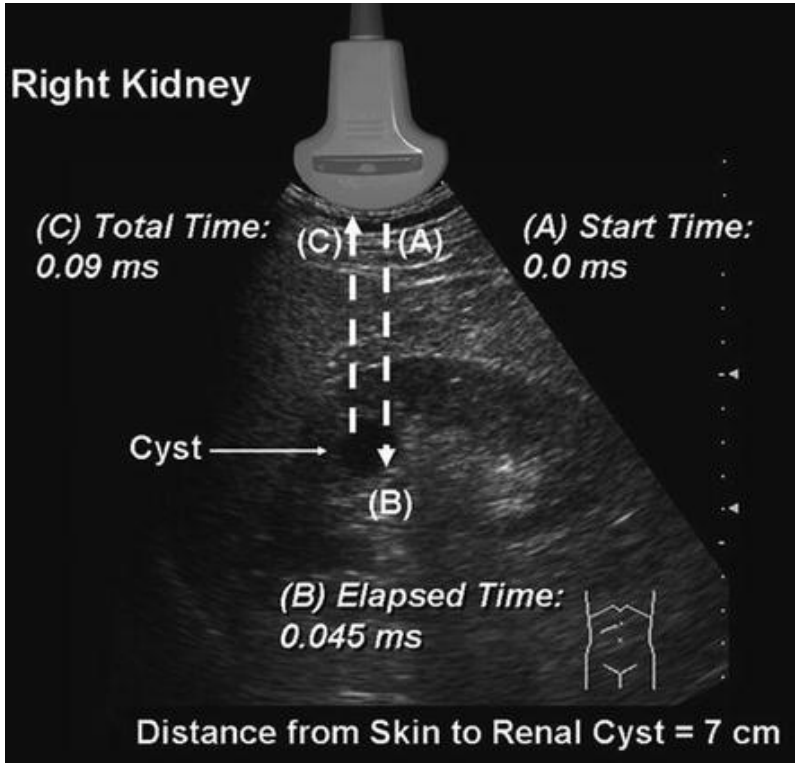


# ULTRASOUND IMAGING /02

Pulse frequency,
$p_f$ = 2.4 -14 MHz




Pulse Repetition frequency (PRF) = 1- 10KHz




*Further reading:*
https://radiologykey.com/physical-principles-of-ultrasound/

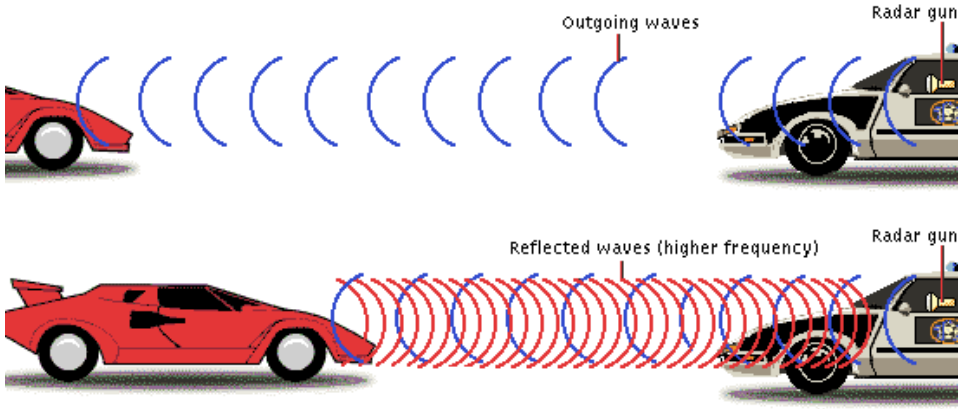
# MEASUREMENT OF SPEED

**Speed can be measured by**

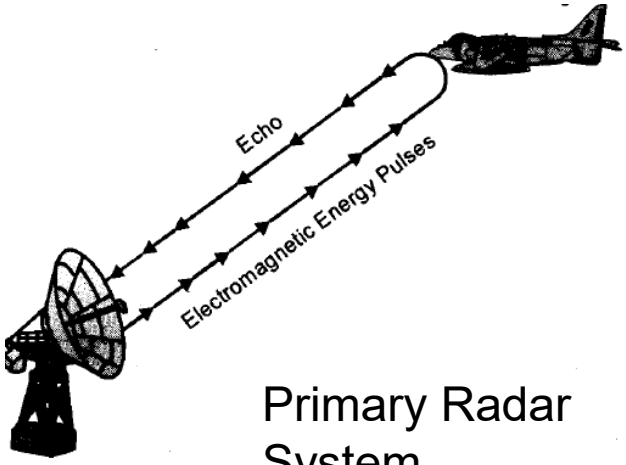
a) Making many range measurements over time and evaluating:

$$s = \frac{\Delta R}{\Delta t}$$

b) Using the change in frequency of the echo signal, i.e Doppler effect



# COMMON RADAR APPLICATIONS




Primary Radar System







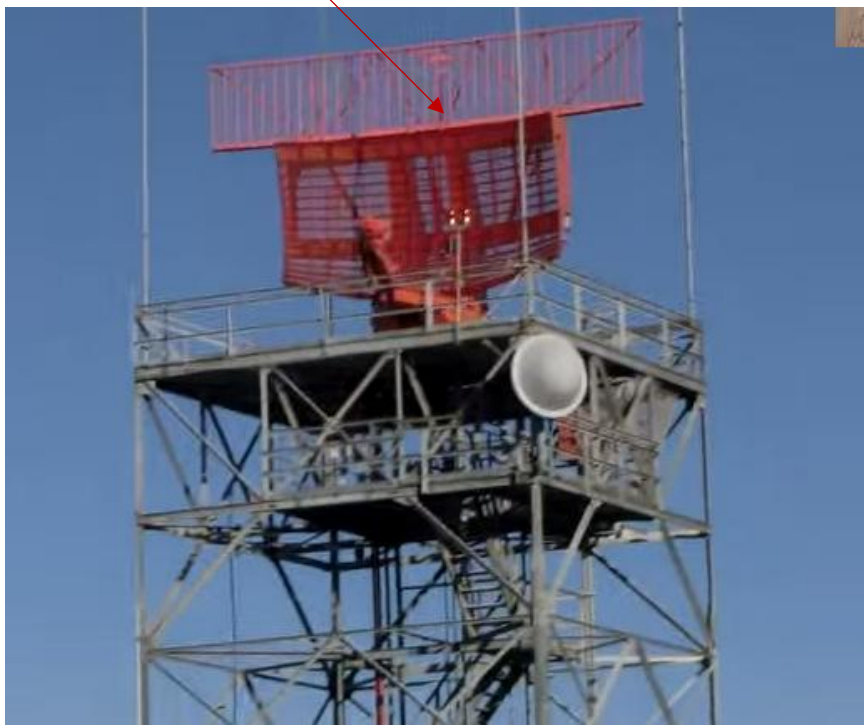
Remote measurement of speed of balls e.g. Tennis.

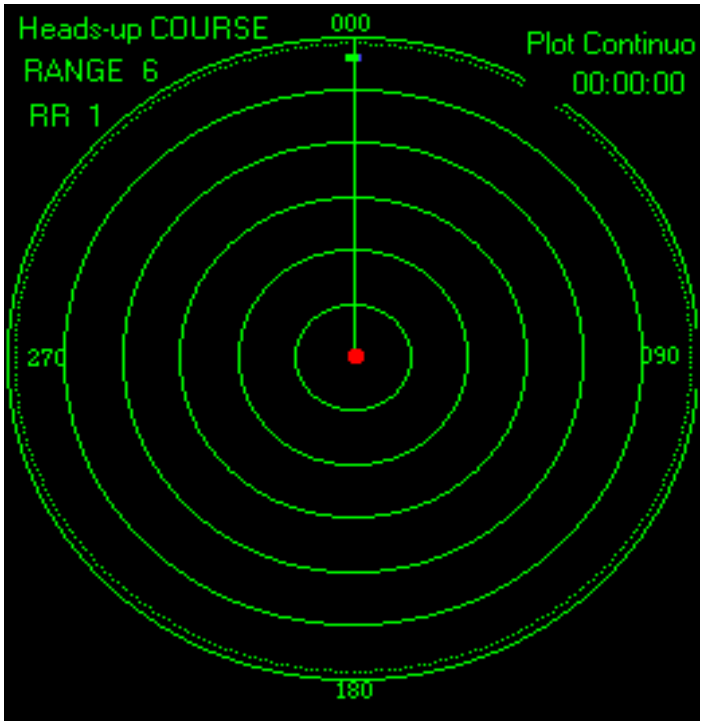



Self-regulation speed limit system

# AIRPORT NAVIGATION – AIRCRAFT POSITION USING A RANGING RADAR

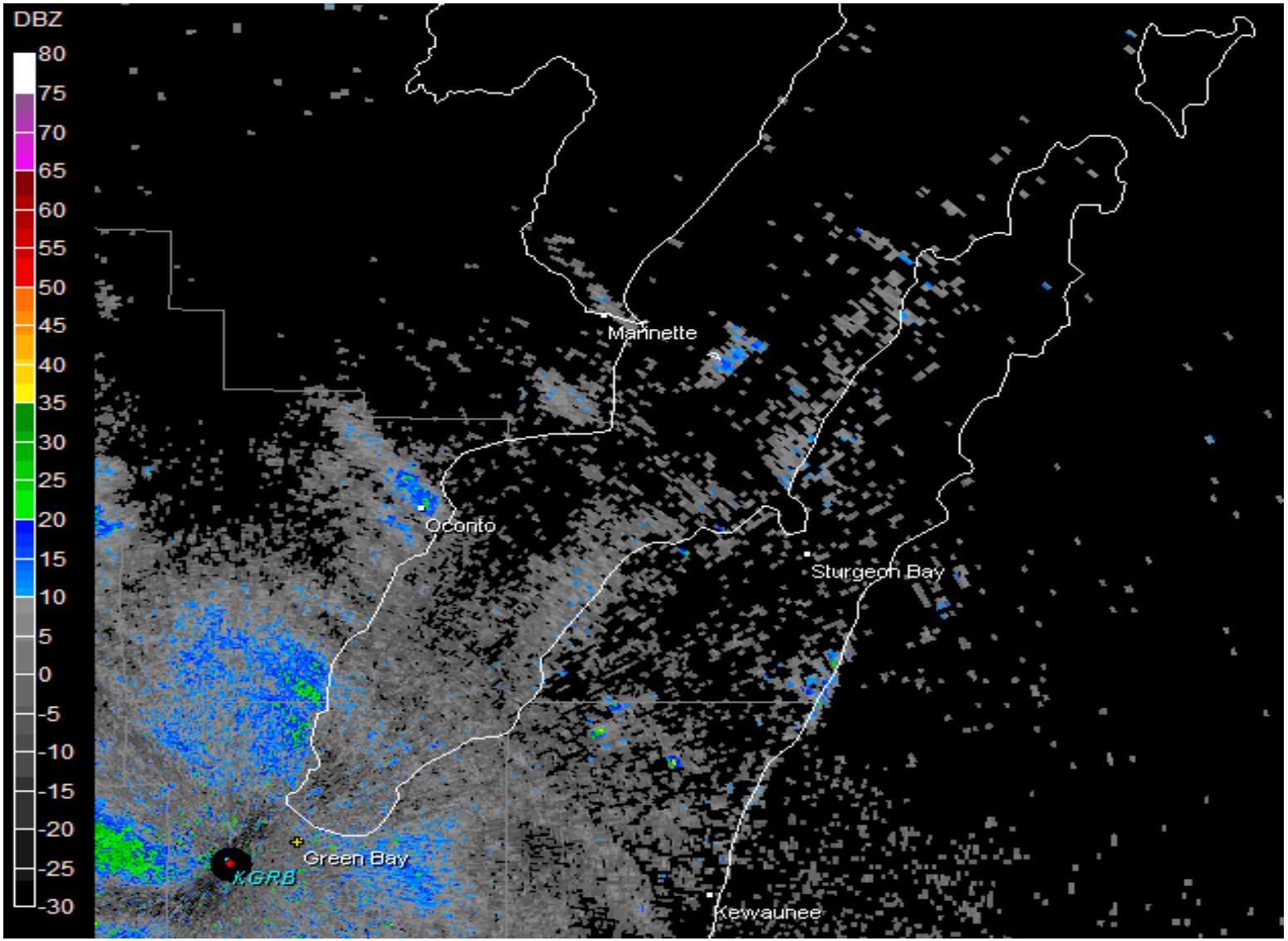
Rotating Antenna






a) Used by Air traffic controller to control aircrafts (landing and take-off)
b) Used by Aircraft accident investigators

# AIRPORT NAVIGATION – DOPPLER WEATHER RADAR



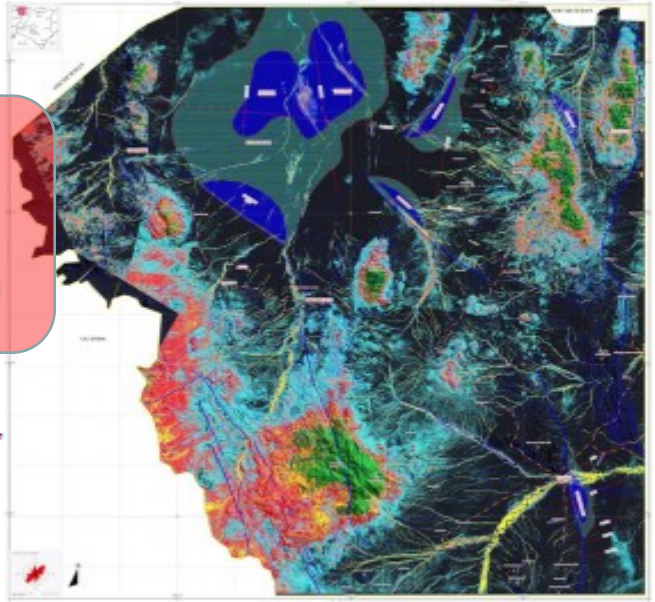
# EXPLORATION RADAR

## Vast Water Reserves Found in Drought-Prone Northern Kenya

**Sep 12, 2013** • Large underground water reserves have been found in Turkana, one of Kenya's driest and poorest regions. The discoveries were made by the natural resources exploration firm, Radar Technologies International, during the course of a survey of groundwater conducted for the Kenyan Government on behalf of the UN. The aquifers were detected with the WATEX System, RTI's state-of-the-art, space-based exploration technology.

Both shallow and deep aquifers were surveyed across northern and central Turkana County in an effort to identify supplies to combat drought and water scarcity for the 2 million people living in the region.

Overall, the RTI study found that Turkana hosts a minimum reserve of 250 billion cubic meters of water, which is recharged mainly by the rainfalls of the Kenyan and Ugandan highlands at a rate of 3.4 billion cubic meters per year. This new wealth of water could boost Kenya's share of available water by 17% and alone represents nearly double the amount of water that Kenyans consume today. This groundwater raises the prospect for improving the livelihoods of the Turkana people, most of whom live in poverty and have limited access to basic services and clean water.



A hydrogeologic map of Kenya's Turkana region created with the WATEX program. Credit: Radar Technologies International

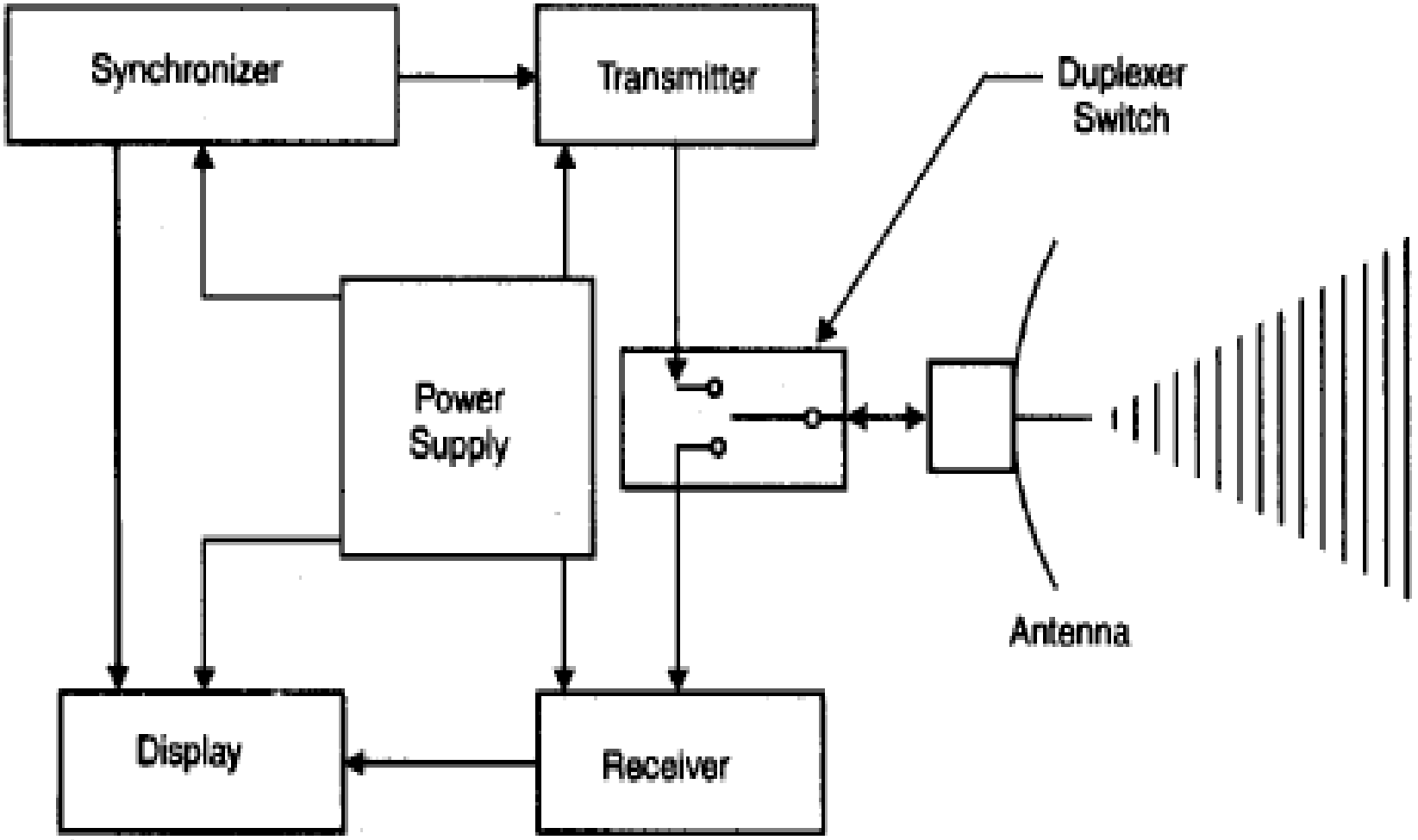
Two major aquifers have been recorded and proven by drilling. The large Lotikipi Basin Aquifer is estimated to store 207 billion cubic meters of water, the same volume of the nearby Lake Turkana. About the size of the US state of Rhode Island, the aquifer replenishes at a rate of 1.2 billion cubic meters a year. This paleo lake could be part of the "Land of Marvels", the ancient sources of the Nile that were explored by Queen Hatshepsut some 3,500 years ago.

The Lodwar Basin Aquifer, is situated within a short distance of Lodwar town and Turkana's oil reserves. It is fed by the perennial Turkwel River and has an estimated reserve of 10 billion cubic meters. RTI recorded three other large structures – Gatome, Kachoda and Nakalale – which could prove to store an combined 30 billion cubic meters once confirmed by drilling.

In addition to deep reserves, RTI also mapped 2 billion cubic meters of water passing only a few meters under the ground and easy to reach, significantly raising the prospect for local agriculture activities.

Looking ahead, RTI has recommended that all measures be taken to ensure the sustainability and viability of these newly discovered resources. RTI's work also establishes a new basis upon which future investigations and mapping in Kenya can be based.

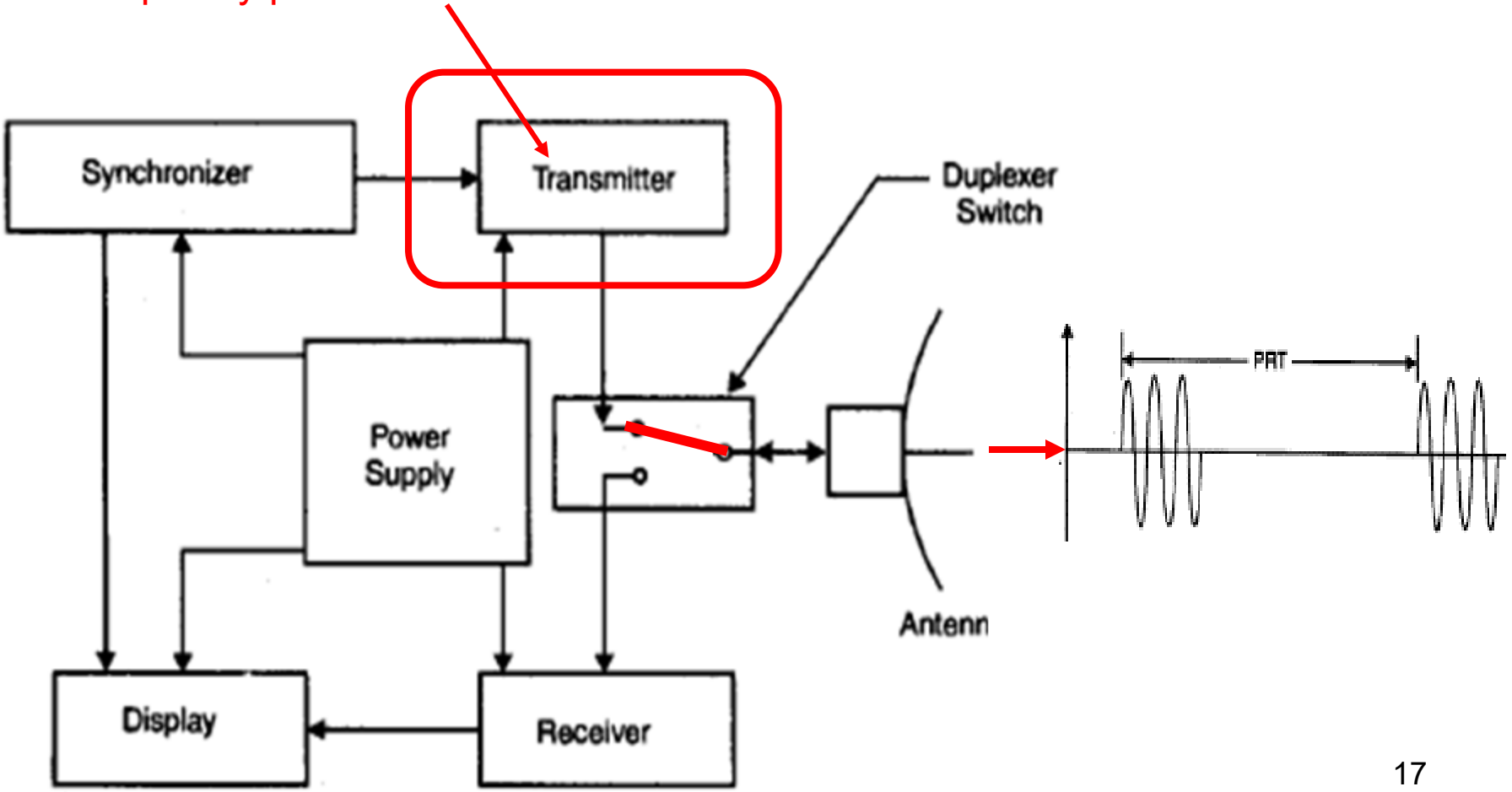
# BLOCK DISAGRAM OF A BASIC MONOSTATIC PULSE RADAR SYSTEM



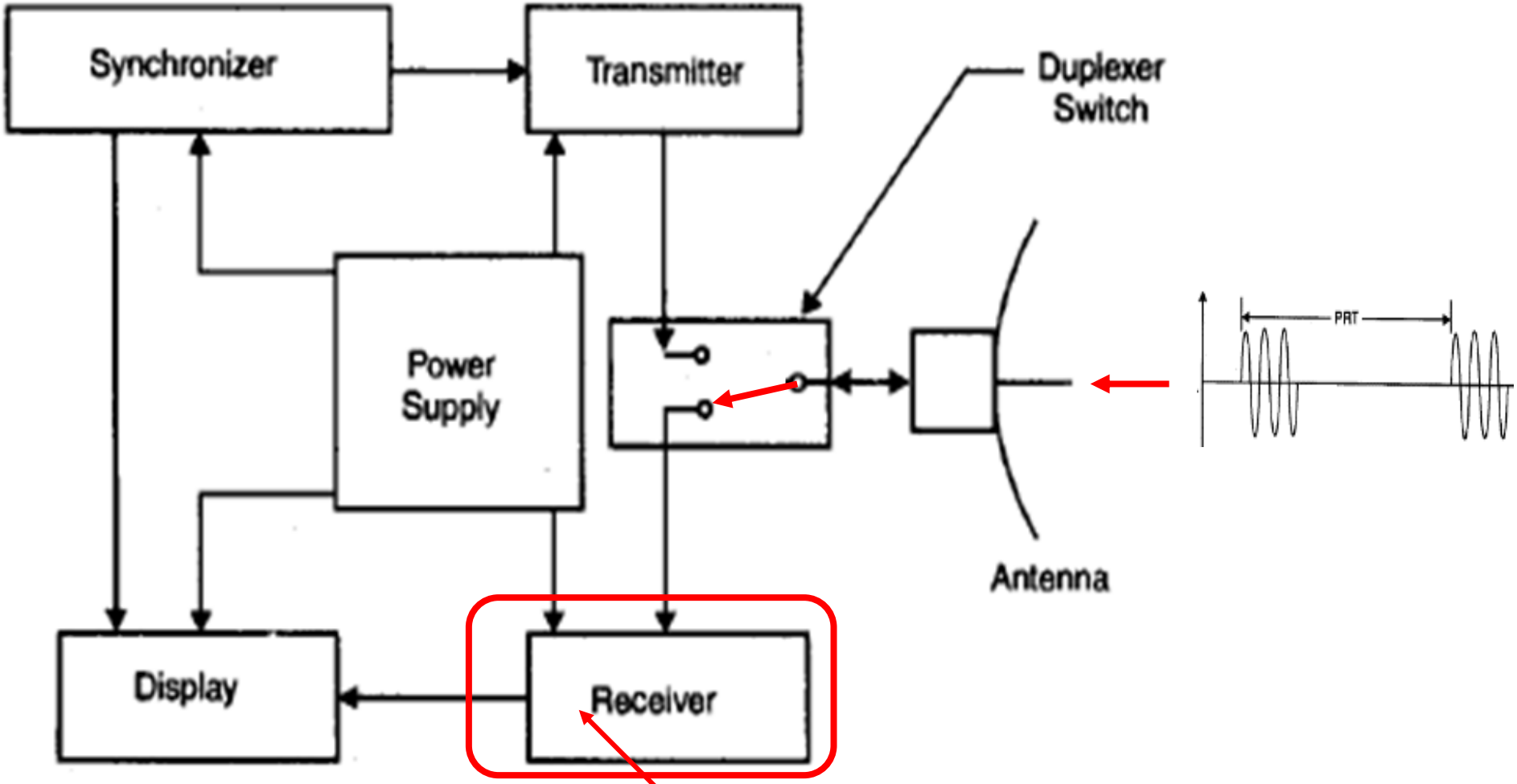
# BASIC PULSE RADAR TRANSMITTER

**Transmitter**

Creates pulses and modulates it using Amplitude Shift Keying (ASK) to create a high frequency pulse train.



# PULSE RADAR RECEIVER

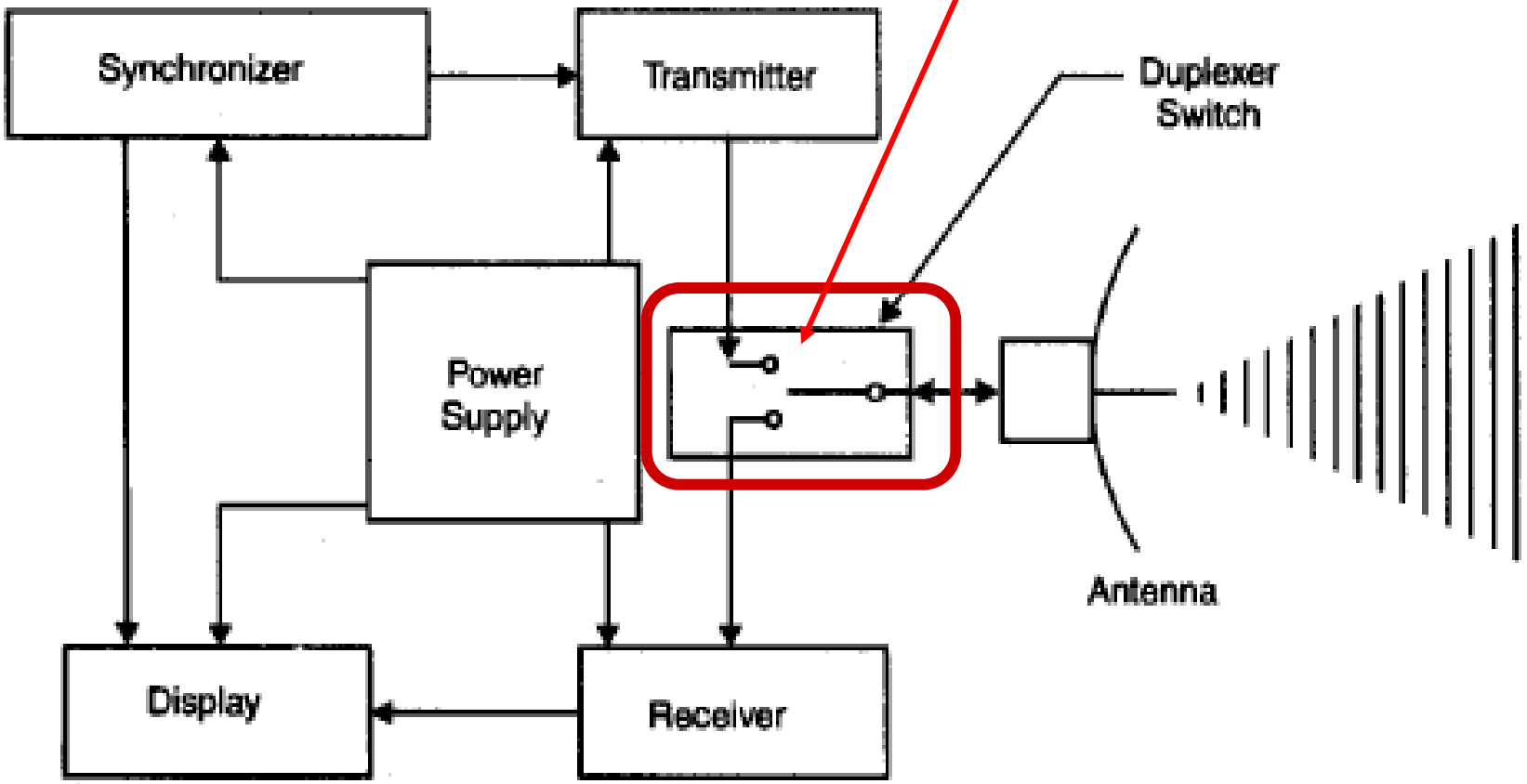



**Receiver**
detects the echo from the target (also called scatterer), amplifies it and feeds the signal to the display unit.

# PULSE RADAR DUPLEXER

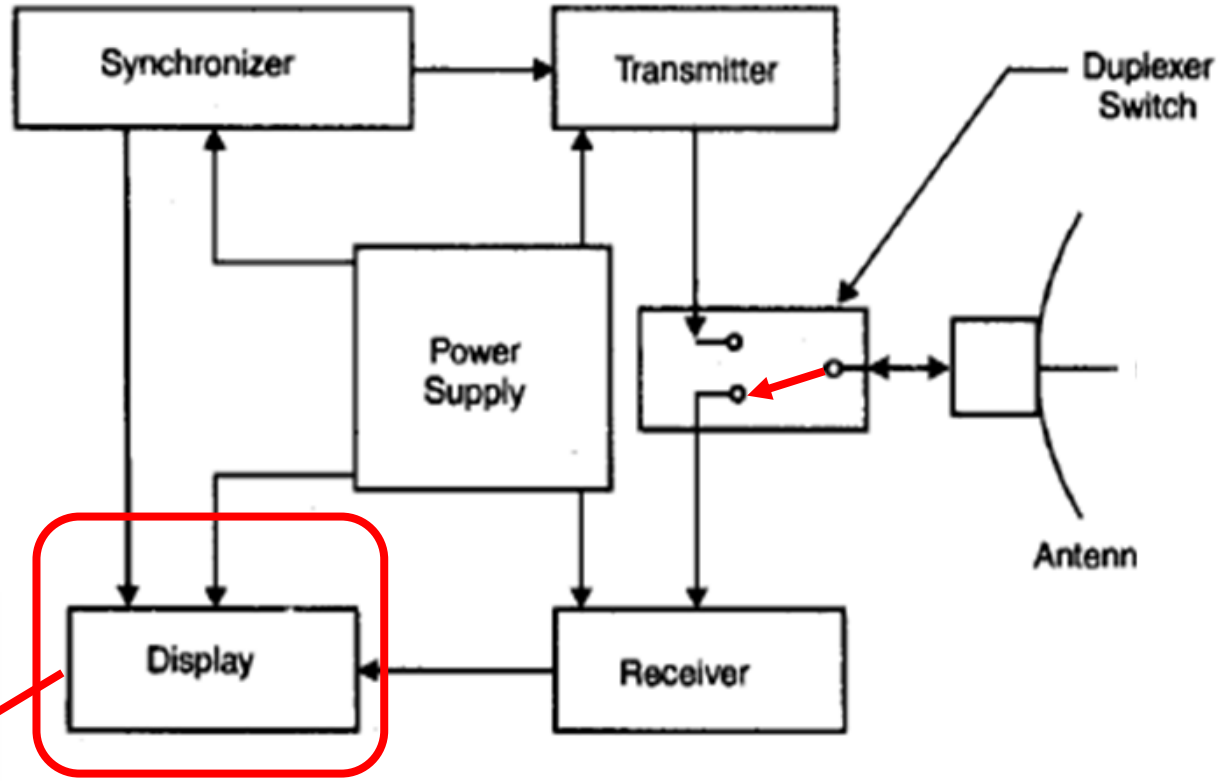
**Duplexer**

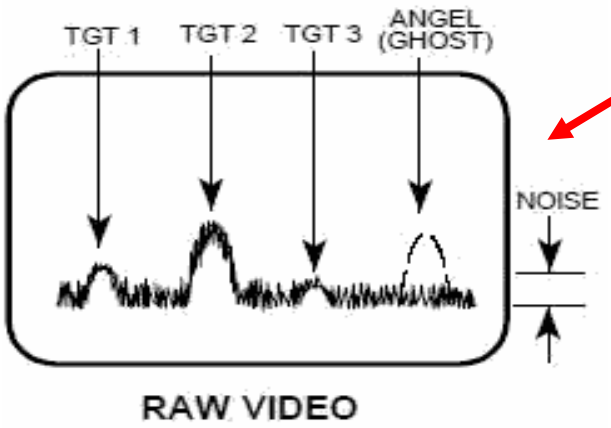
1. Isolates the transmitter and receiver during transmission and reception.
2. Protects the receiver from high power transmitter and
3. Allows use a single transmitter/receiver antenna.



# BASIC PULSE RADAR DISPLAY

1. Raw video displays are simply oscilloscopes that display the detected and amplified target return signal (and the receiver noise).
2. They require a human operator to interpret the various target noise and clutter signals.



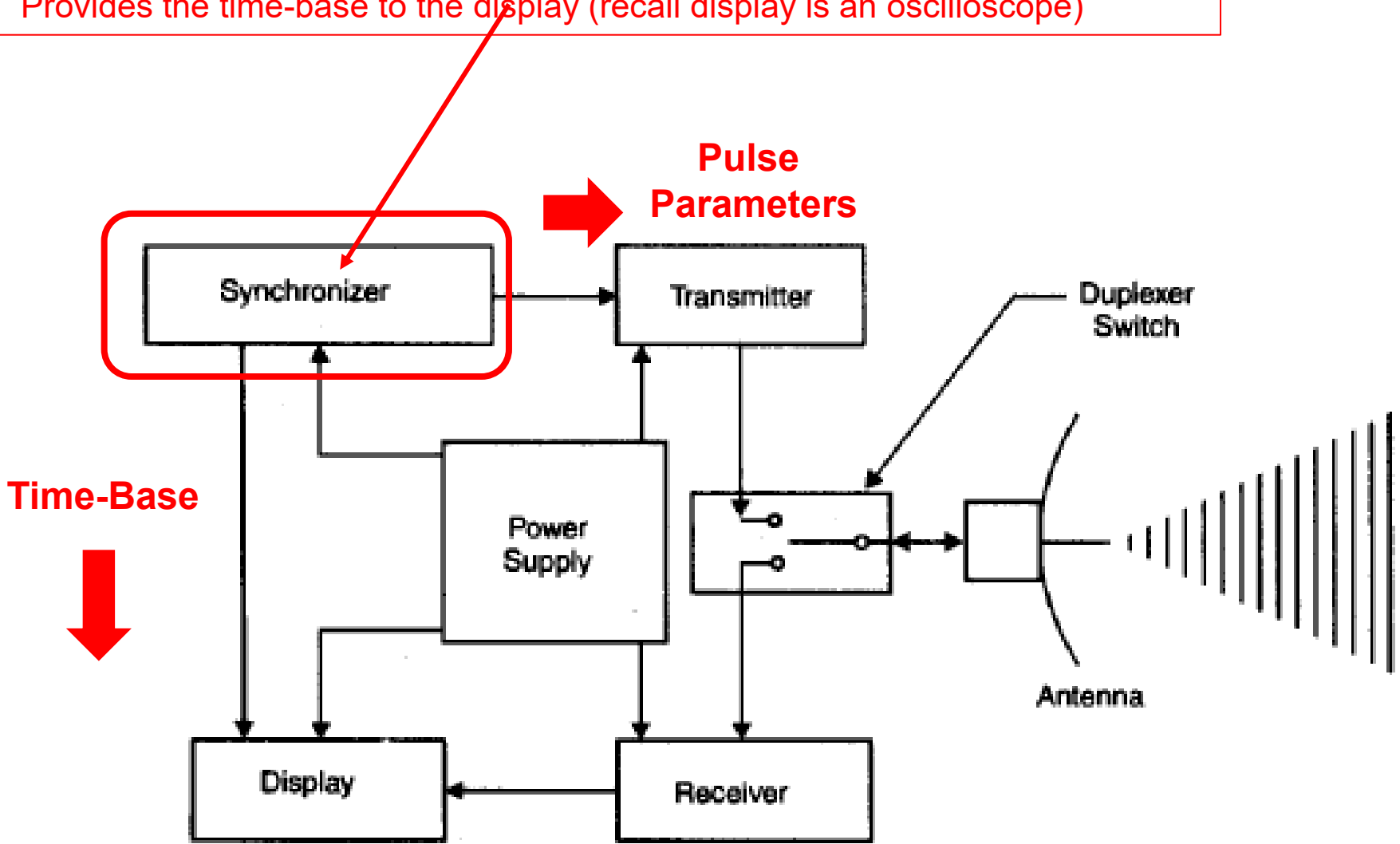




**A ghost** is a phony target that usually fades in and out and could be caused by birds, weather, or other unwanted temporary reflections.

# BASIC PULSE RADAR SYNCHRONIZER

**Synchronizer:**

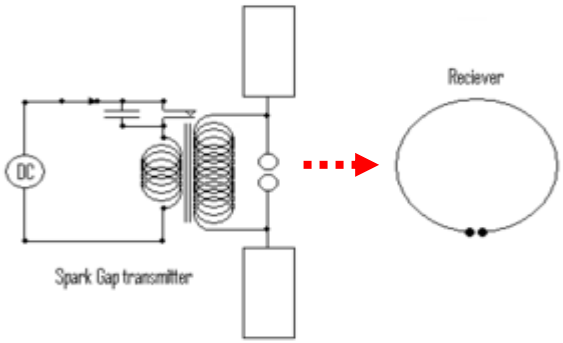
1. Sets transmitter parameters such as Pulse duration and Pulse Repetition Interval (PRT)
2. Provides the time-base to the display (recall display is an oscilloscope)



# HISTORY OF THE RADAR – EARLY YEARS



**Heinrich Hertz**
German Physicist
1857-1894




- In **1887**, **Heinrich Hertz** began experimenting with radio waves in his laboratory
- He discovered that some materials reflected radio waves while others absorbed them.
- Today his name is used as the SI unit for frequency, i.e the Hertz (Hz)

# HISTORY OF THE RADAR – EARLY YEARS




**Christian Huelsmeyer**

German Engineer

1881-1957

- In 1904, Christian Huelsmeyer, developed a system to avoid collisions of ships and boats using the telemobilescope – a rudimentary radar system that could detect ships up to 3 kms.



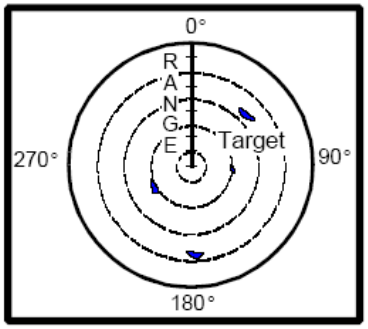
# INVENTION OF THE MODERN RADAR

1. Sir Robert Watson-Watt published a paper in 1935 entitled 'Detection of Aircraft by Radio Methods"
2. In the same year, a German Company called GEMA demonstrated the first commercial radar system.
3. Similar developments were taking place in USA and Britain.
4. Britain was the first country to exploit the system for air defence during the 2nd World War.

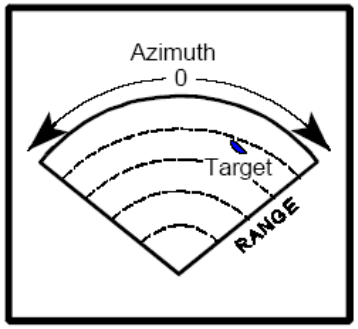
# PLAN-POSITION INDICATOR

1. In 1941 Ground Controlled Intercept Stations were developed where the antenna was rotated mechanically and signals displayed on a CRT screen in a pattern call the Plan Position Indictor.

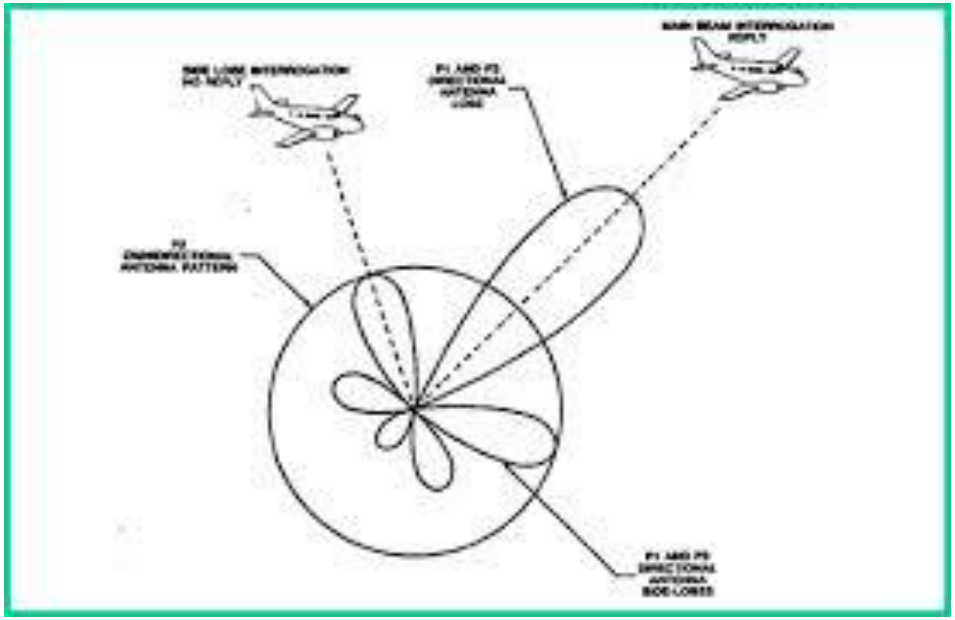
2. This simplified the amount of work performed by operators to track a target



PPI



SECTOR PPI



# LANDING JKIA - NAIROBI

- All aircrafts landing at JKIA approach from the Ngong Hills direction.
- Sectored PPI display is used.

