INTRODUCTION TO RADAR & SATELLITE ENGINEERING

ECE 514E – RADAR & SATELLITE ENGINEERING

Wednesday, 10 February 2021

ECE 514E – RADAR and SATELLITE ENGINEERING (3 Units)

Pre-requisites: ECE 328 - Principles of Communication Systems, ECE 416 - Digital Communication Systems

Course Purpose:
To enable students be familiarize with modern radar and navigation systems and principles of design radio-navigation and location systems, as well as radar systems

Expected Learning Outcomes:
Upon completion of this course, a student should be able to:

i. explain principles of operation of radar systems;
ii. apply theoretical and practical knowledge about principles, methods and applications of modern radar systems;
iii. measure and identify the parameters which determine the performance of radar systems;
iv. explain the function of satellite subsystems;
v. apply orbital mechanics formula and tools to spacecraft mission design;
vi. select appropriate launch systems and understand their effect on satellite and payload design and performance;
vii. design and analyse satellite links;
viii. evaluate satellite subsystem performance

Course Content:
Basic Principles of Radar, Antenna parameters, Radar equation. Performance parameters, target cross-section, MTI and Doppler radar: Doppler Effect, CW radar, FM CW, Delay line cancellers, Pulse Doppler Radar. Scanning, Duplexers and Radar receivers: Sequential lobbing, Conical Scanning, Monopulse Tracking RADAR, Tracking with surveillance RADAR, Acquisition, Radar receiver, Radar Displays; Duplexers.

ECE 514E SYLLABUS

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ECE 514E SYLLABUS (2)

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(d) explain the function of satellite subsystems;

(e) apply orbital mechanics formula and tools to spacecraft mission design;

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ECE 514E SYLLABUS (3)

Course Content (1)

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ECE 514E SYLLABUS (4)

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ECE 514E SYLLABUS (5)

Course Content (2)

Introduction to satellite communication: international regulation & frequency coordination, satellite frequency allocation & band spectrum, active & passive satellites.

Orbits and Launching Methods: Kepler's laws, orbital elements, apogee and perigee heights, orbital perturbations, effects of non-spherical earth, atmospheric drag, the geostationary orbit, antenna look angles, polar mount antenna, limits of visibility, earth eclipse of satellite, sun transit outage, launches and launch vehicles, power supply, altitude control, station keeping, thermal control, transponders, antenna subsystem.

ECE 514E SYLLABUS (6)

Course Content (3)

- **Earth station:** transmit/receive earth stations.
- **Space Segment:** Introduction, equivalent isotropic radiated power, transmission losses, link power budget equation, system noise, carrier-to noise ratio.
- **Interference:** interference between satellite circuits, combined (C/I) due to interference on uplink and downlink, antenna gain function, pass band interference.

ECE 514E SYLLABUS (7)

Recommended book:

(a) Skolnik M. I**, Introduction to Radar Systems**, McGraw-Hill

(b) Gerard Maral, Michel Bousquet, **Satellite Communications Systems: Systems, Techniques and Technology**, ISBN: 0-471-49654-5.

(c) M. Richharia,, **Satellite Communication Systems**, 2nd Edition, McGrawHill Telecommunication Series, ISBN: 0-07-134208-7.

(d) Kadish J.E. and East T.W.R., **Satellite Communication Fundamentals**, Artech House Books, ISBN: ISBN-10: 1580531369

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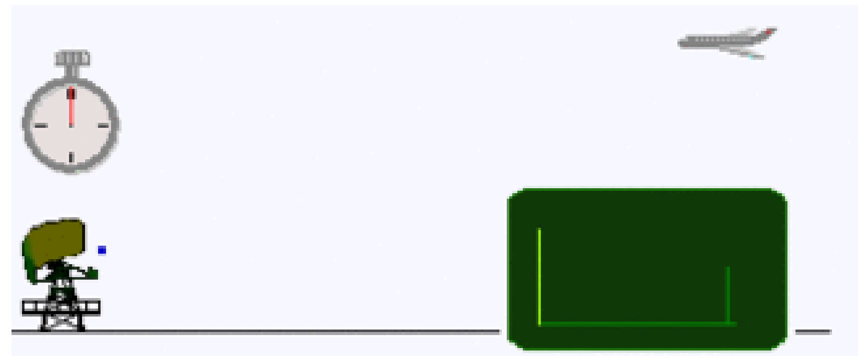
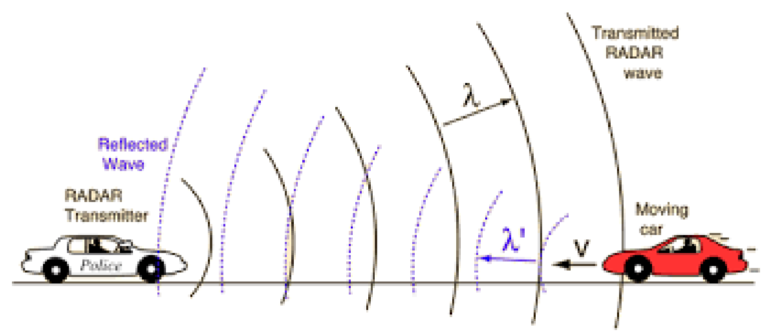
RADAR DEFINITION

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 location of objects.



ENGLISH DICTIONARY DEFINITION

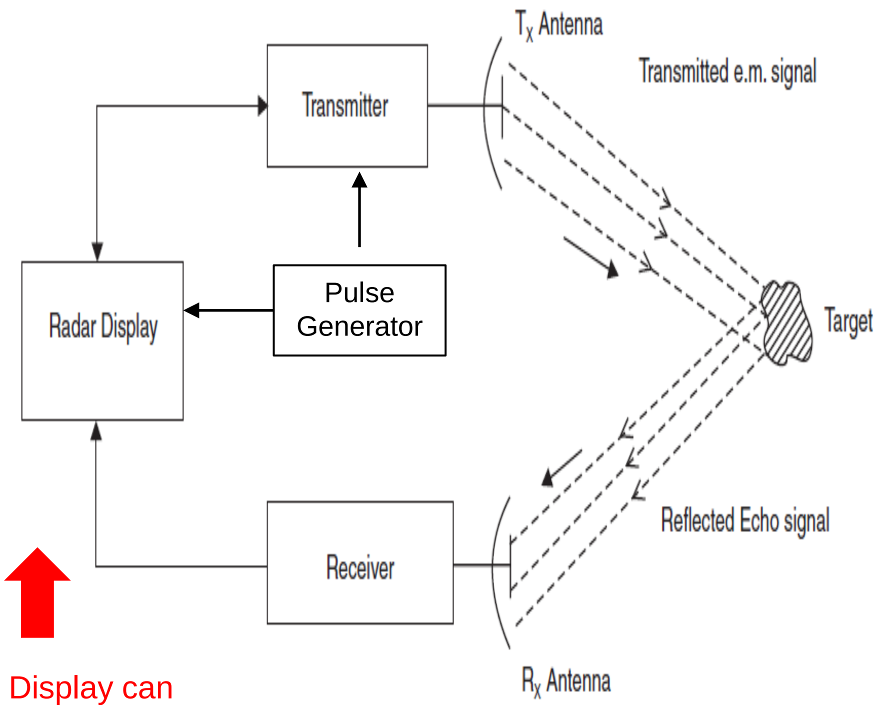
- Radar has over time become an English language noun.

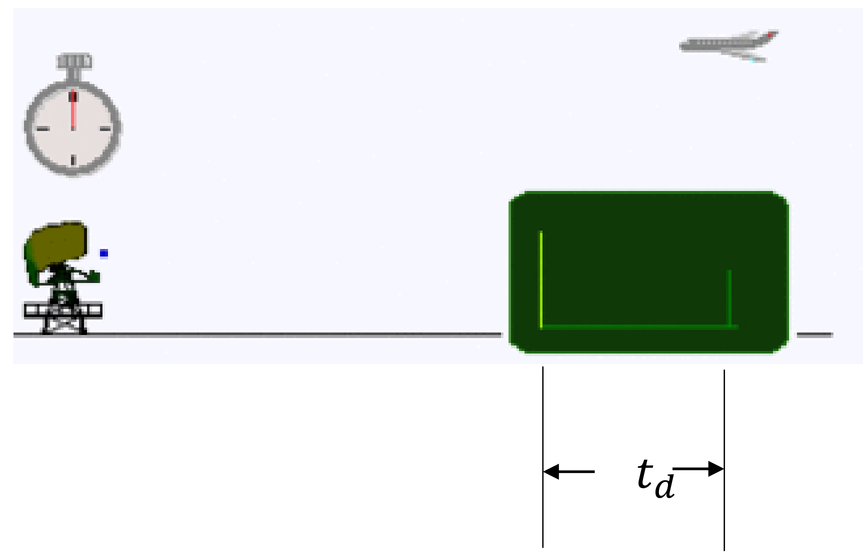
From Wikipedia, the free encyclopedia

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.

SIMPLE BLOCK DIAGRAM OF A RADAR SYSTEM





Display can be raw or synthetic

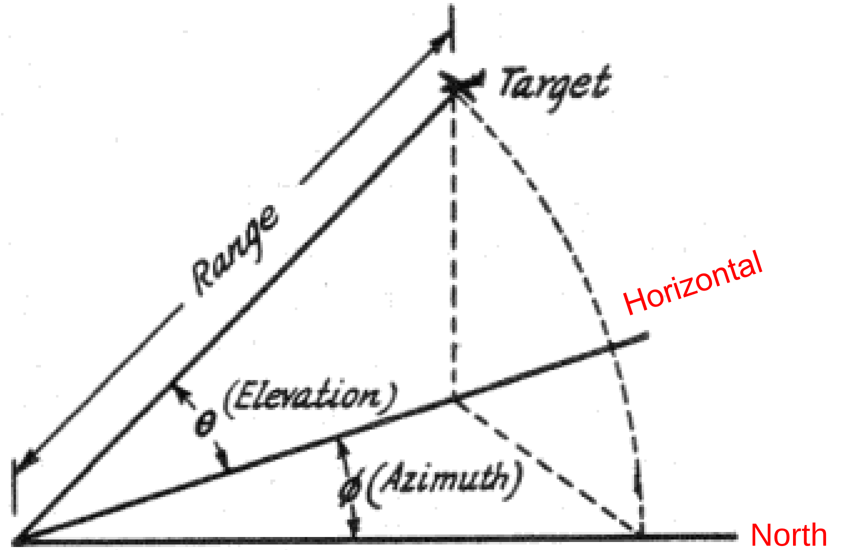
The antenna can single (Monstatic) or Double (Bi-static)

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

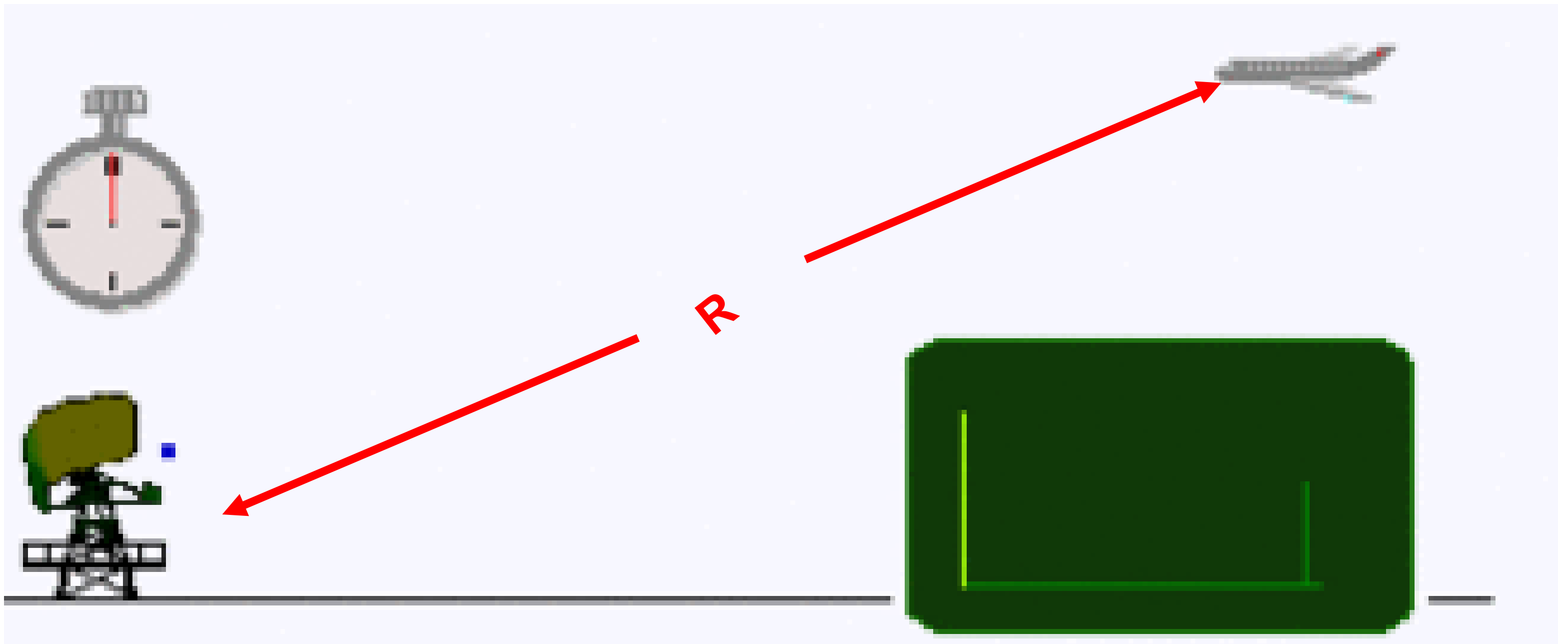
2. Target angles (azimuth & elevation)

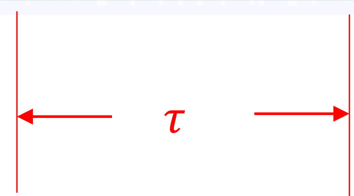


3. Target size (radar cross section)

4. Target speed (Doppler)

MEASUREMENT OF RANGE





$$2R = C\tau$$

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

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

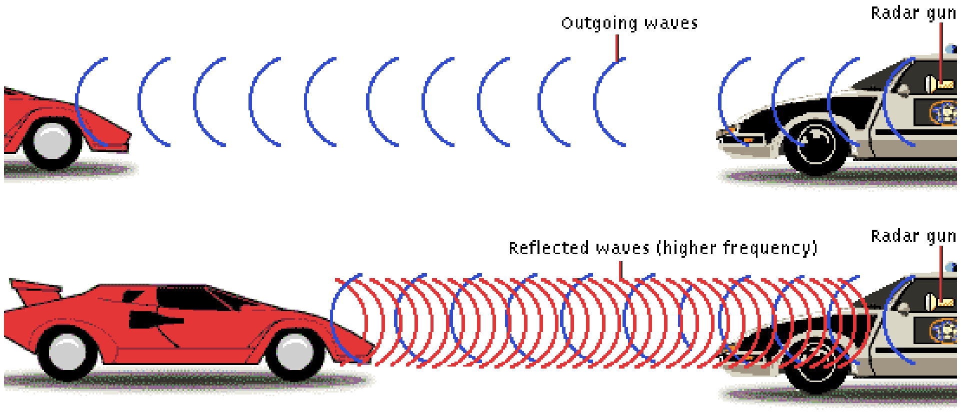
MEASUREMENT OF SPEED

Speed can be measured by

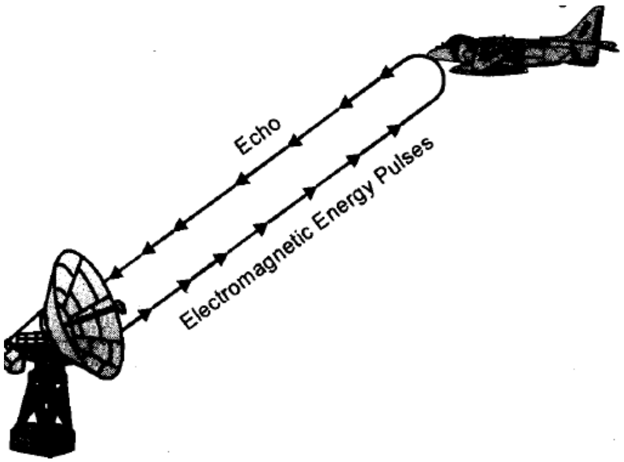
a) making many range measurements over time and evaluating:

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

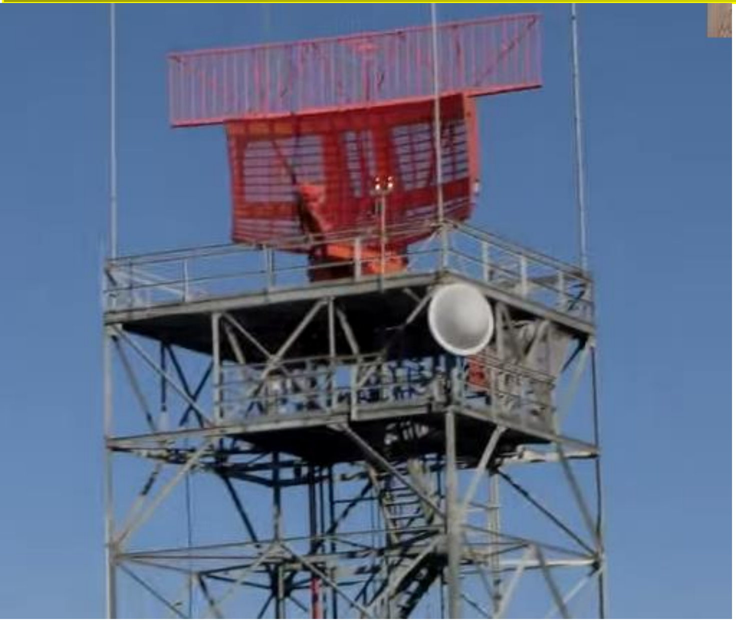
b) Using the change in frequency of the echo signal, i.e Doppler effect

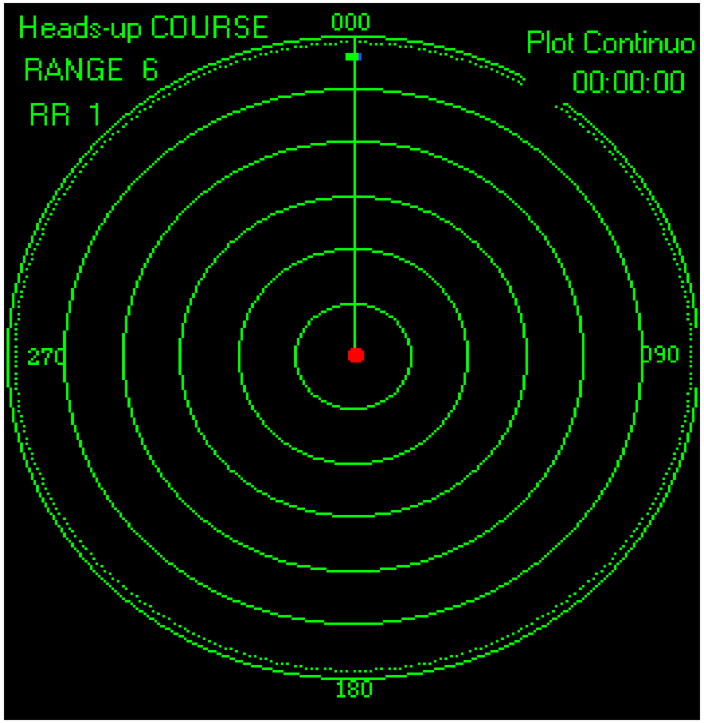


COMMON RADAR APPLICATIONS



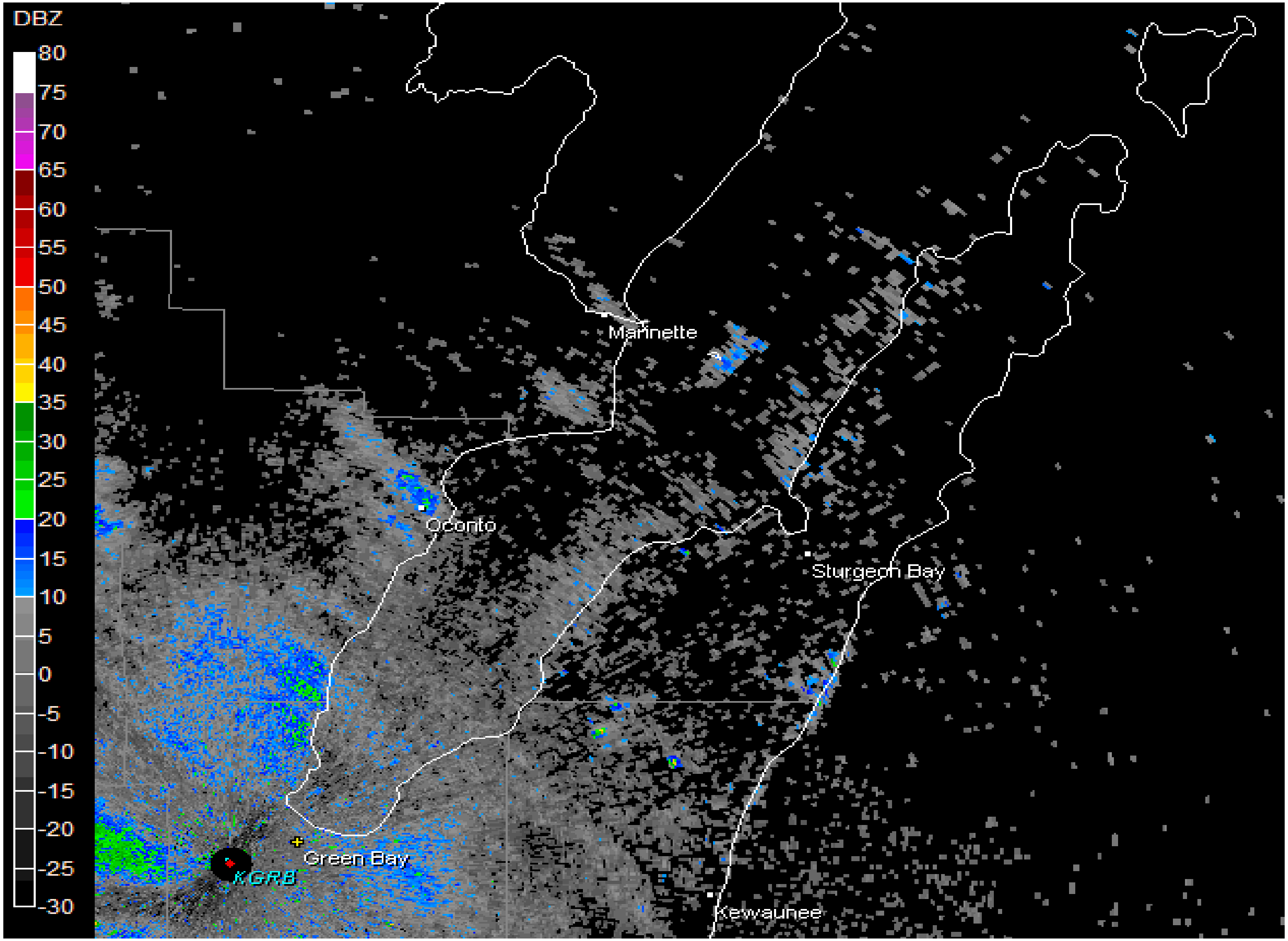
AIRPORT NAVIGATION – AIRCRAFT POSITION USING A RANGING RADAR





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

AIRPORT NAVIGATION – DOPPLER WEATHER RADAR



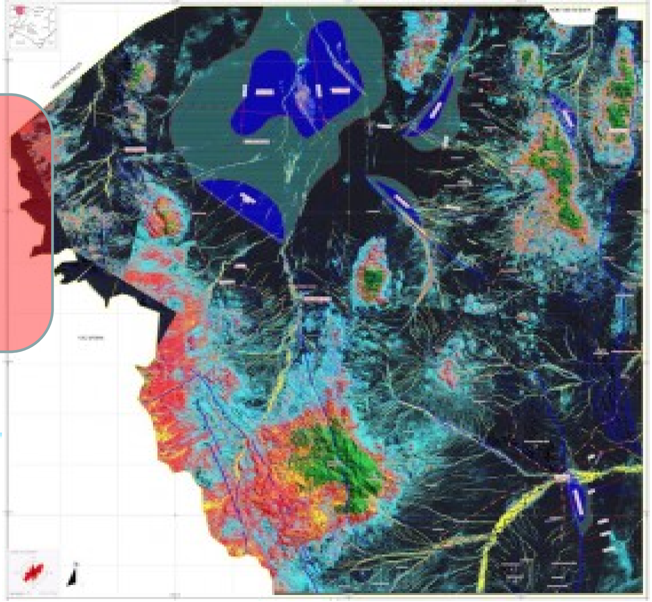
EXPLORATION RADAR

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

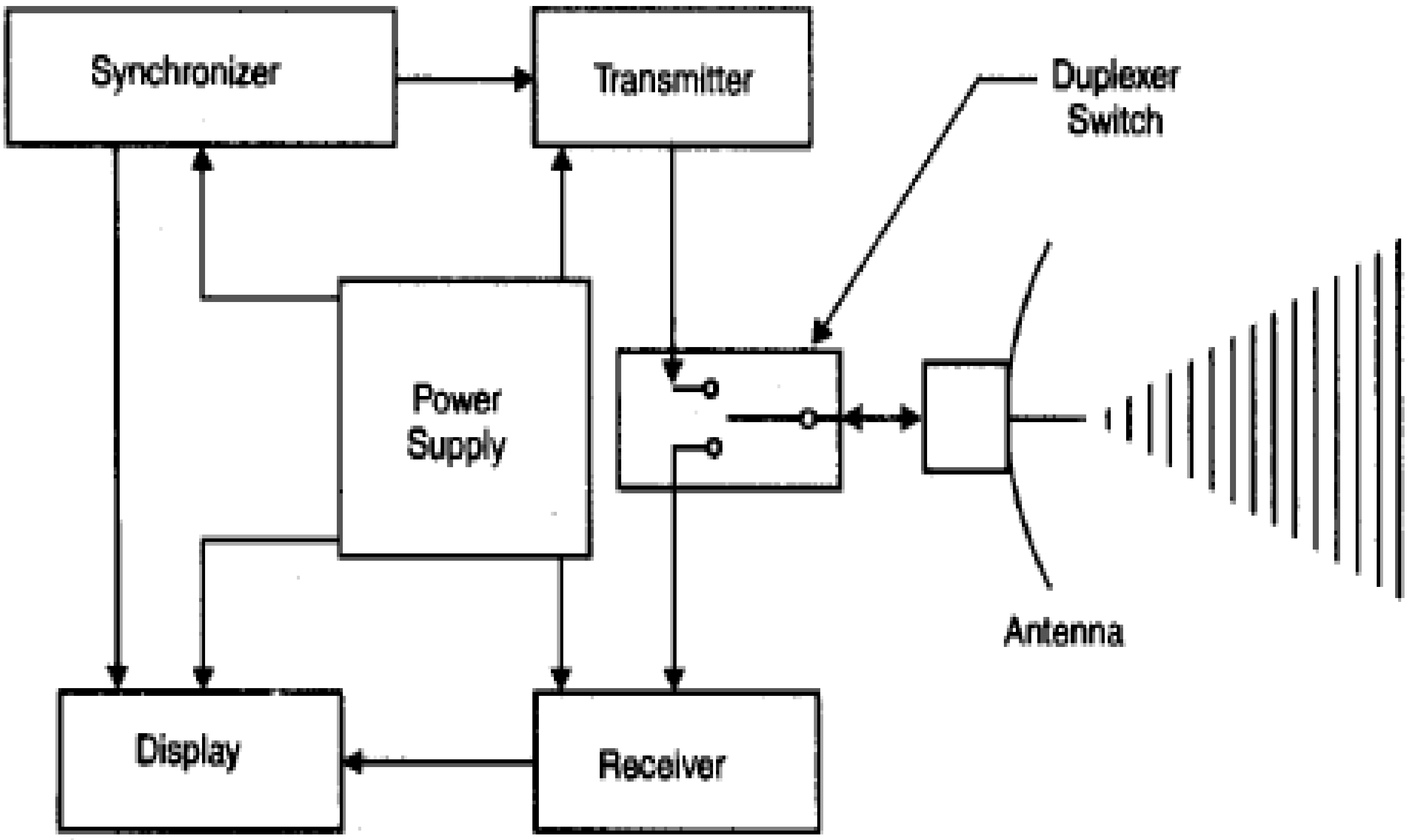
Two major aquifers have been recorded and proven by drilling. The large Lotikipi Basin Aquifer is estimated to store 207 billion cubic meters of water, the same volume of the nearby Lake Turkana. About the size of the US state of Rhode Island, the aquifer replenishes at a rate of 1.2 billion cubic meters 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.

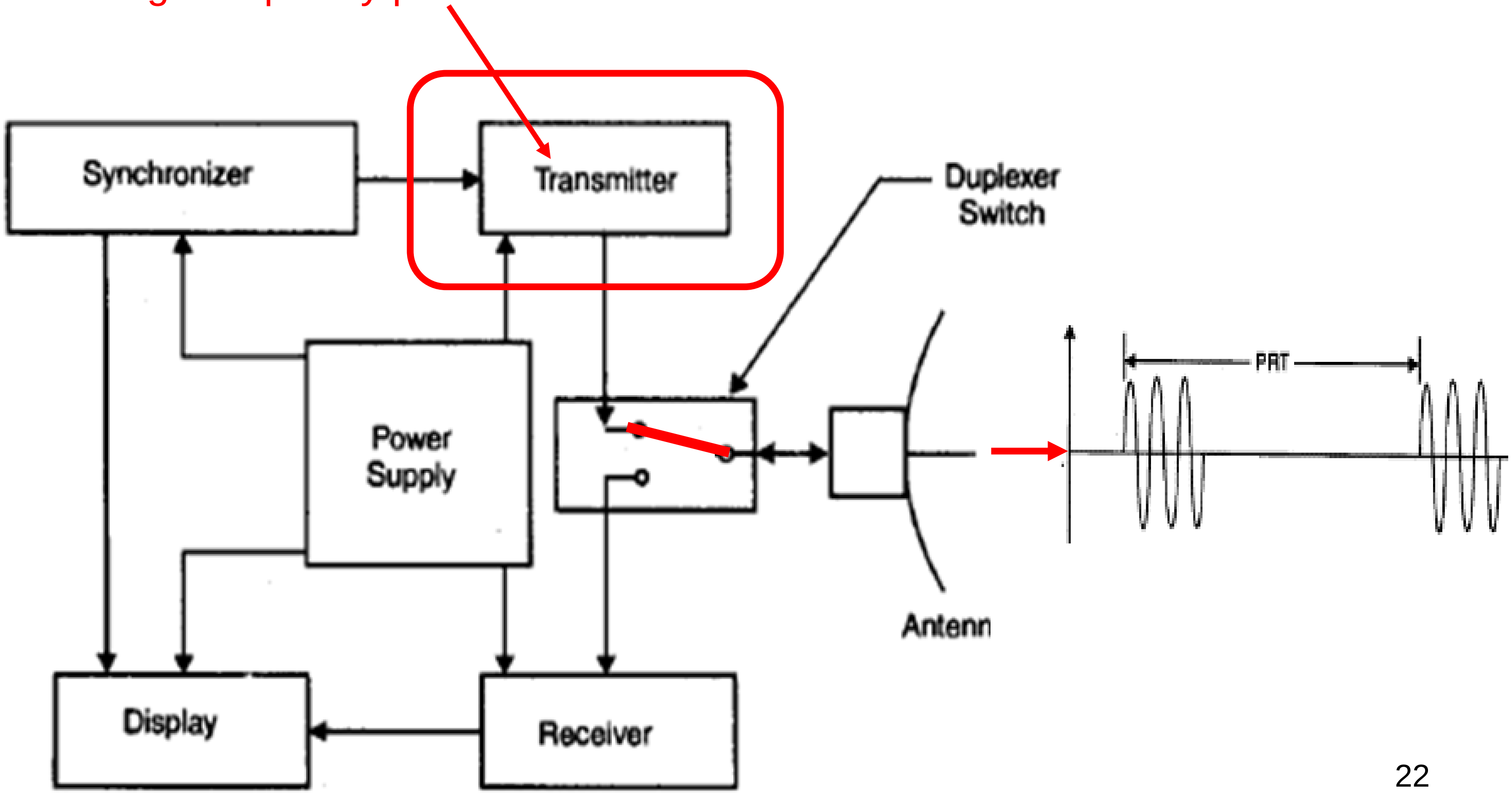
BLOCK DISAGRAM OF A BASIC MONOSTATIC PULSE RADAR SYSTEM



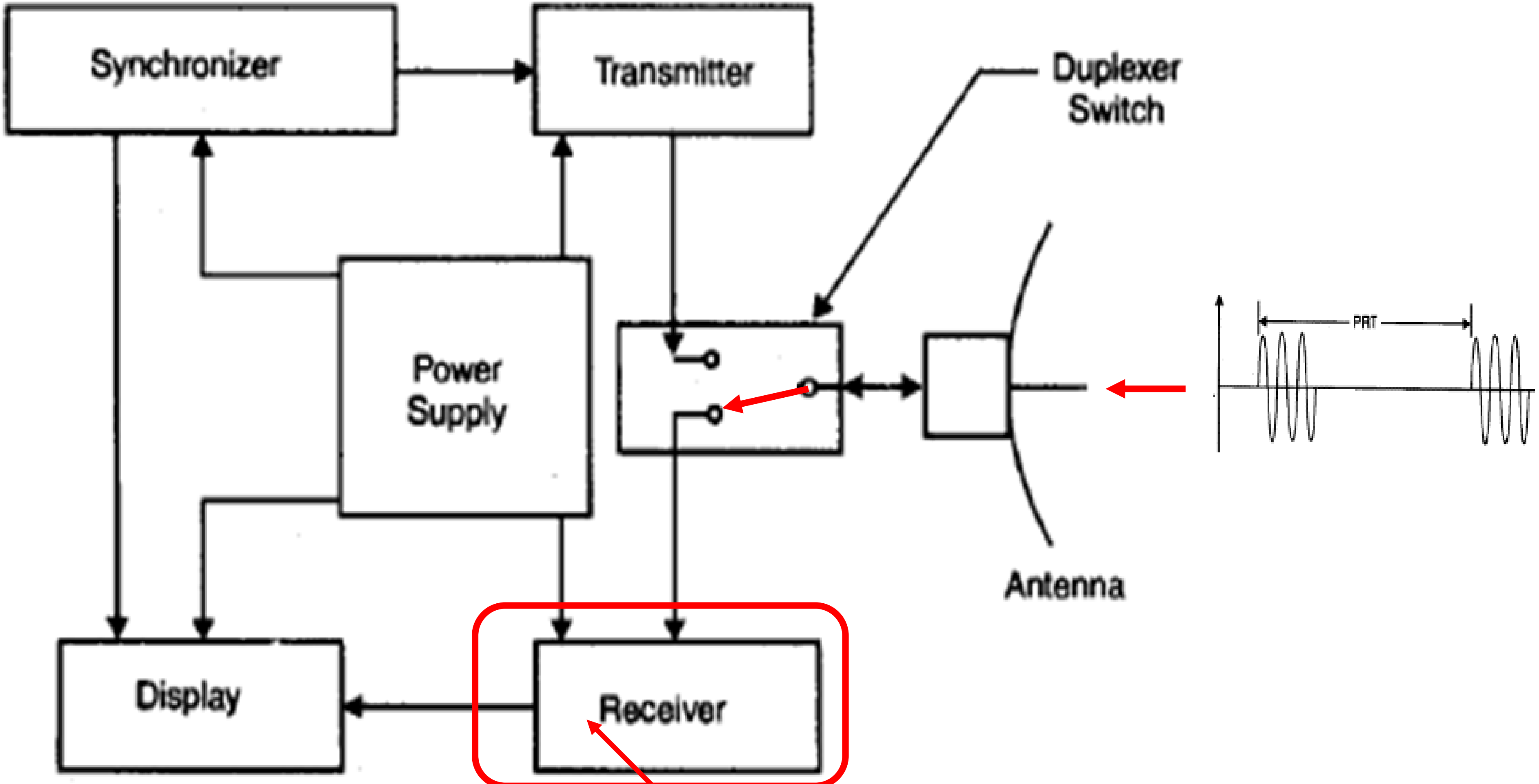
BASIC PULSE RADAR TRANSMITTER

Transmitter

Creates the pulse to be sent and modulates it using Frequency Shift Keying (FSK) to create a high frequency pulse train.



PULSE RADAR RECEIVER

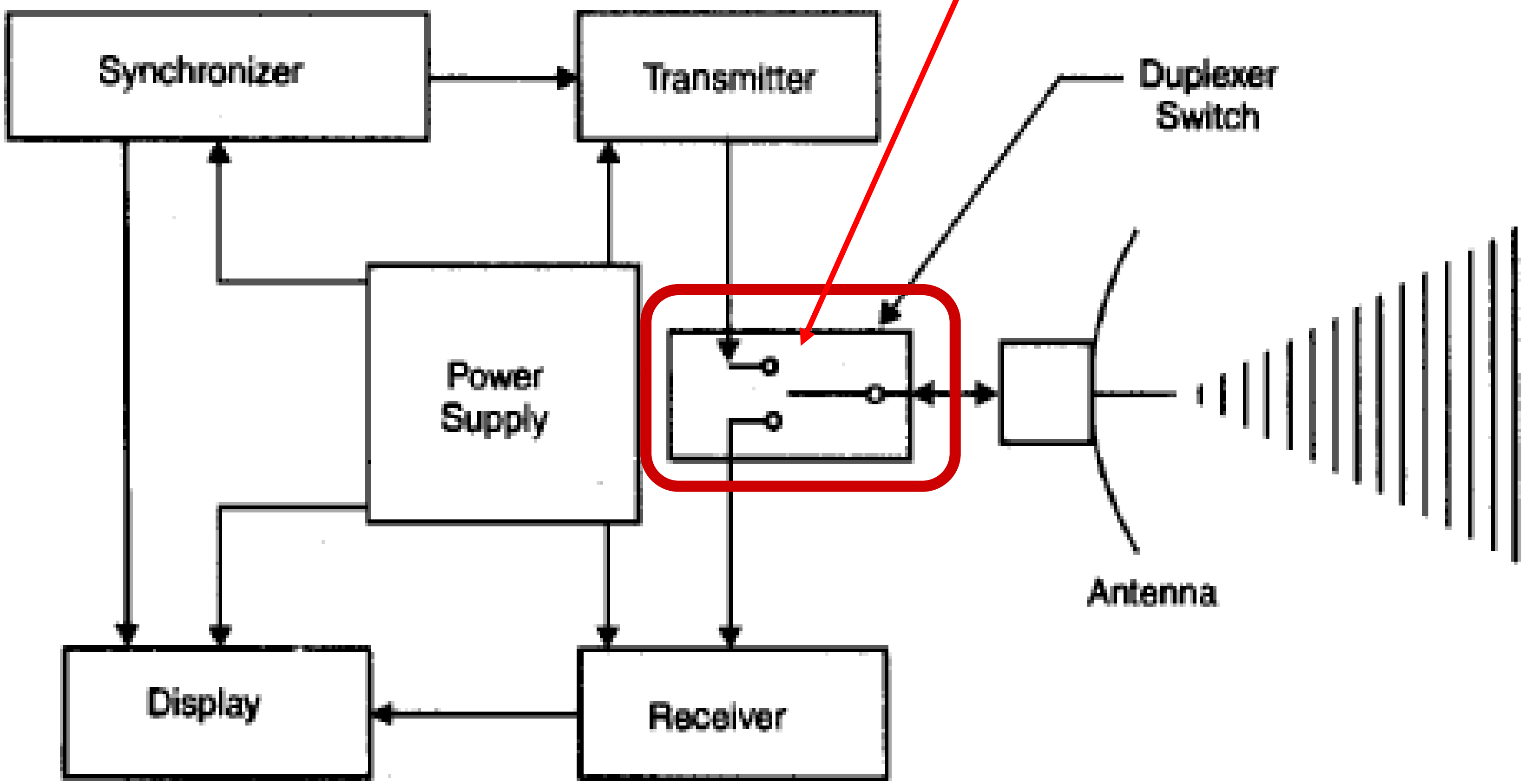


Receiver
detects the echo from the target (also called scatterer), amplifies it and feeds the signal to the display unit.

PULSE RADAR DUPLEXER

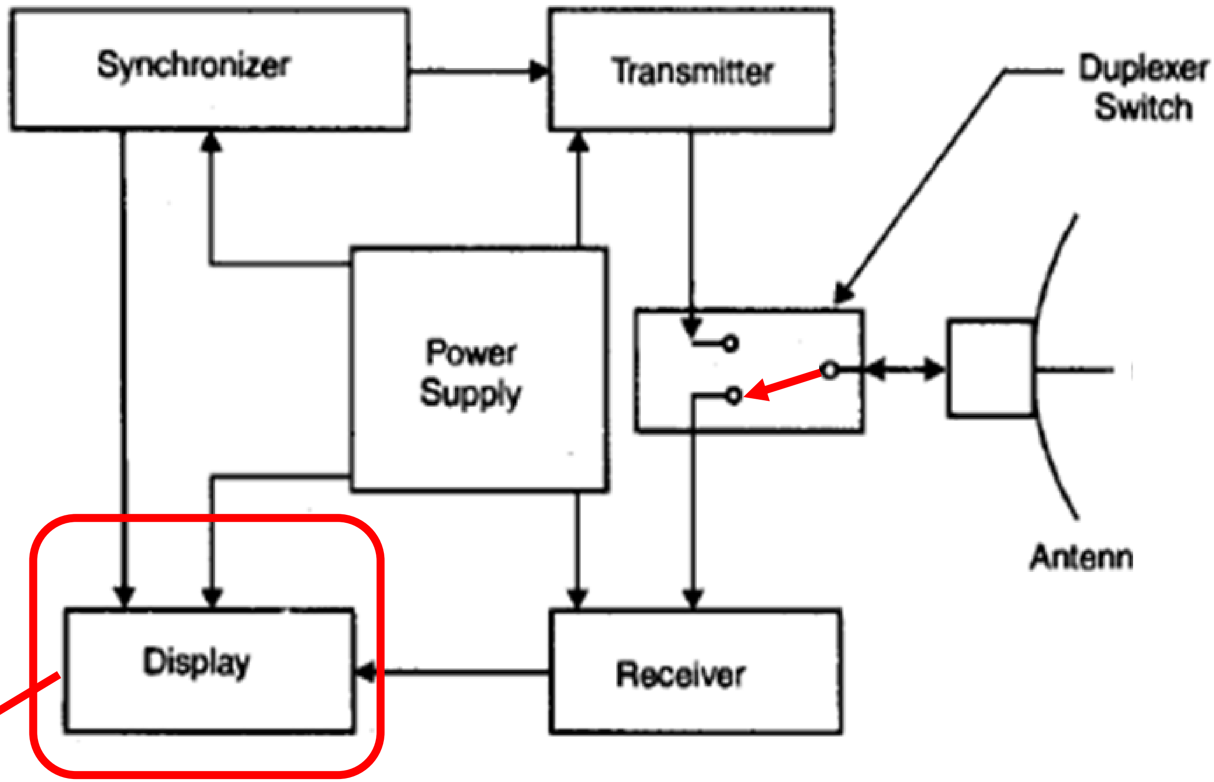
Duplexer

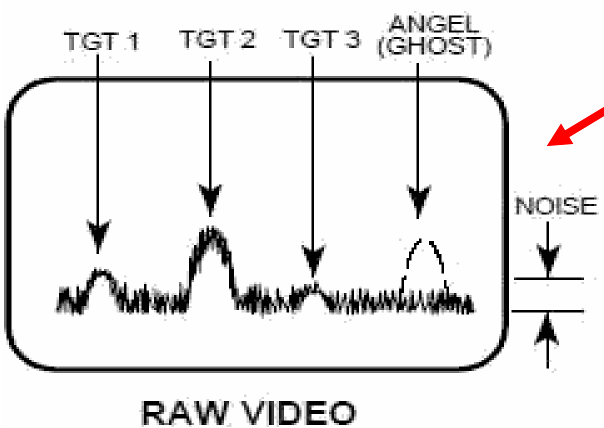
1. Isolates the transmitter and receiver during transmission and reception.
2. Protects the receiver from high power transmitter and
3. Helps use a single transmitter/receiver antenna.



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.



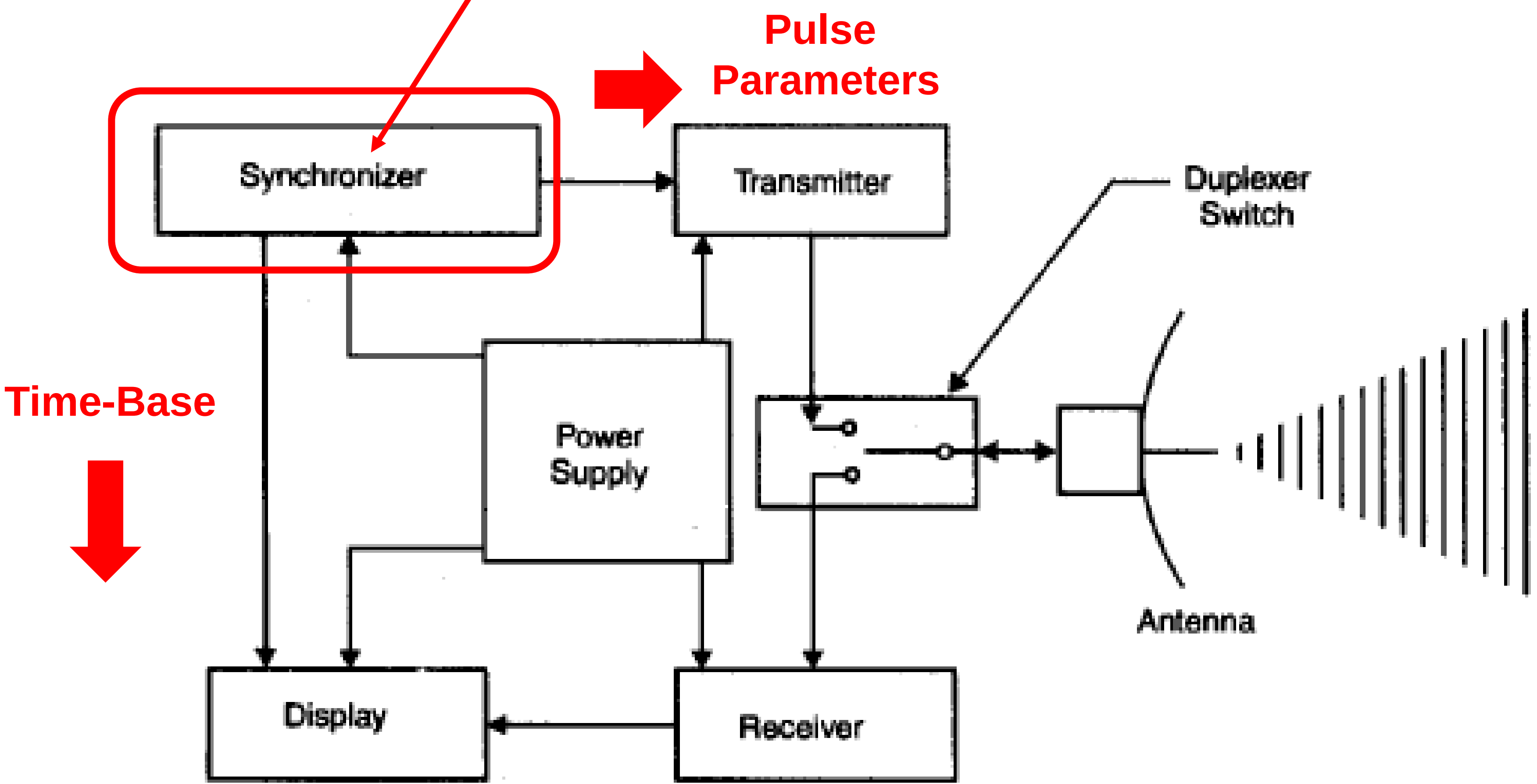


A ghost is a phony target that usually fades in and out and could be caused by birds, weather, or other unwanted temporary reflections.

BASIC PULSE RADAR SYNCHRONIZER

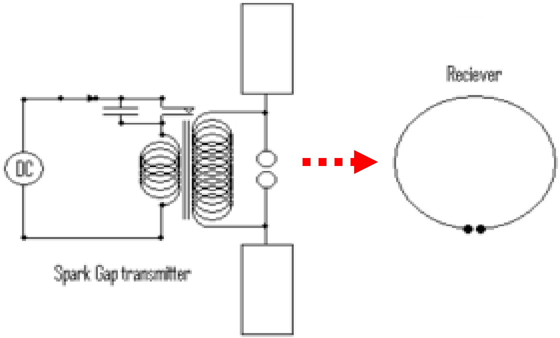
Synchronizer:

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



HISTORY OF THE RADAR – EARLY YEARS

Heinrich Hertz
German Physicist
1857-1894



- In **1887**, **Heirich 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

1881-1857

- 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.

CHAIN HOME SYSTEM (1)

1. The volume of sky to be kept under surveillance was literally 'floodlit' with r.f. pulsed energy at 6/20/50MHz.

2. The back-scattered pulses or echoes' from all aircraft within this volume are received back at the ground station by a set of crossed-dipoles connected to a low-noise, high-gain receiver and displayed as a Y-deflection along the time base of a CRT.

3. The aircraft range was simply a precise measurement of the elapsed time between the transmitted pulse and the 'echo'

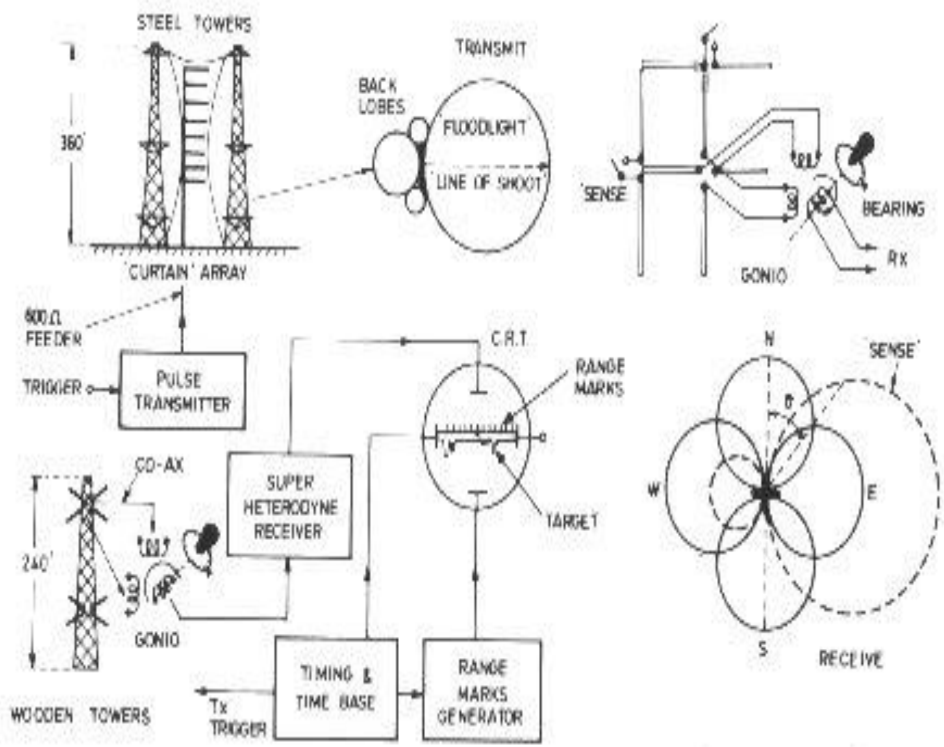


Fig. 1. Principles of CH (Chain Home) R.D.F. system

CHAIN HOME SYSTEM (2)

1. The bearing is a measurement of the ratio of 'echo' strengths of the X- and Y-components of the crossed-dipoles.

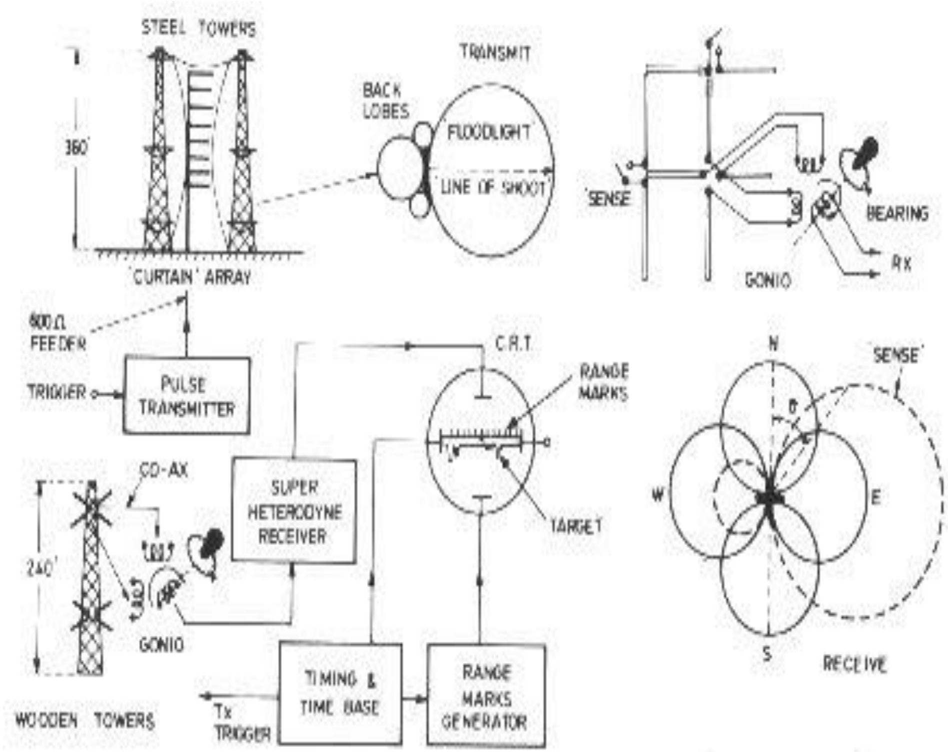
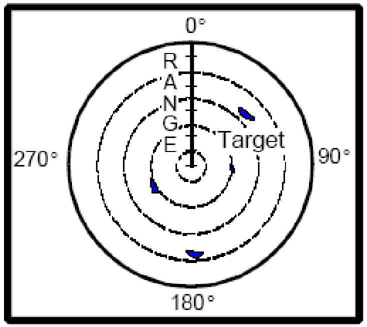


Fig. 1. Principles of CH (Chain Home) R.D.F. system

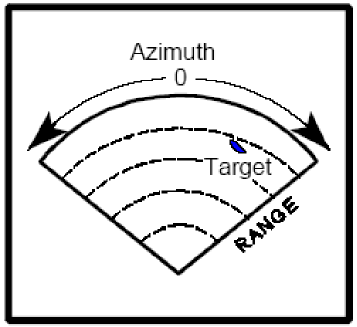
PLAN-POSITION INDICATOR

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