Fundamental Concepts of Radar

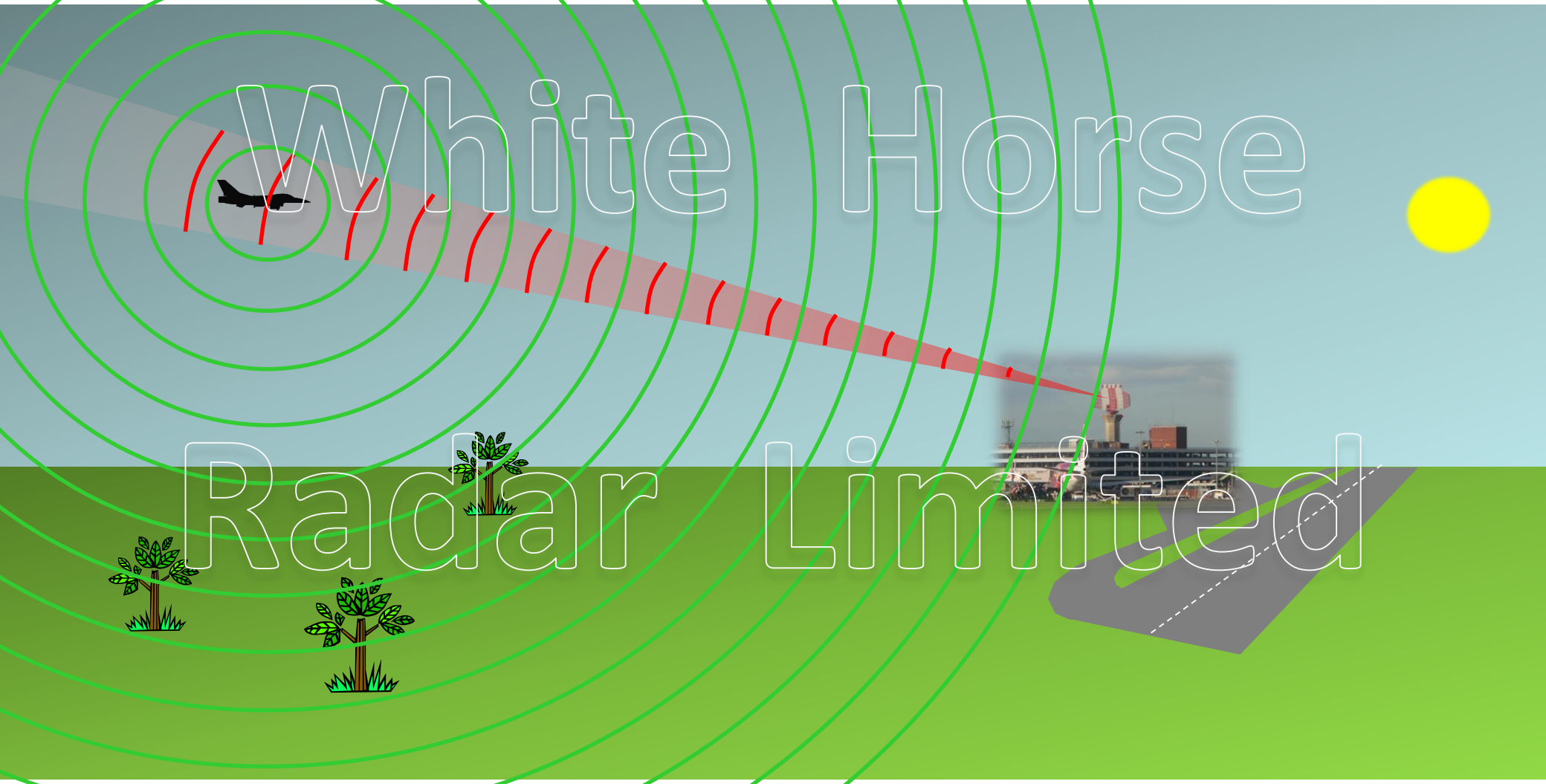
Dr Clive Alabaster & Dr Evan Hughes

White Horse Radar Limited

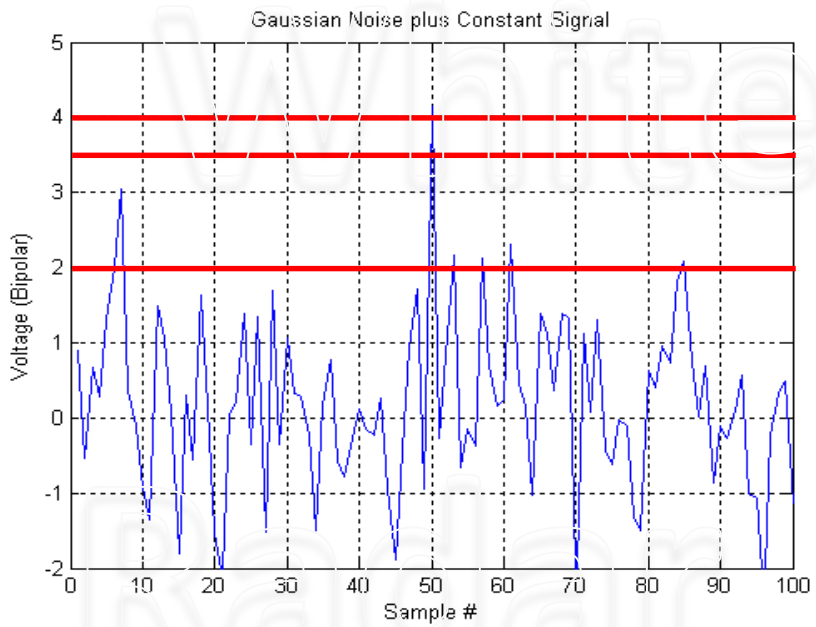
Contents

- Basic concepts of radar
- Detection Performance
- Target parameters measurable by a radar
- Primary/secondary radar
- Monostatic, bistatic, multi-static configurations
- Classification of Radars
- Block diagram
- Radar frequency bands
- Atmospheric attenuation
- Comparison of radar with other sensors
- Relationship between size, power, range and application

Basic Concept of Radar



Detection Performance



Bipolar Voltage (pre-detection)

Targets always detected in the presence of *noise*.

- Probability of detection < 1
- Probability of false alarm > 0
- Pd, Pfa low for high detection threshold
- Pd, Pfa high for low detection threshold
- Good Pd and Pfa is signal to noise ration (SNR) is high

False alarm rate = number of false alarms per second.

Target Information Available from Radar

- Range
- Range Rate (relative velocity)
- Direction (angle) in azimuth and elevation
- Classification (recognition / identification)

Target Track

Remember: *A radar exists to supply information to something / someone else. Radars are often integrated within a larger system. The information requirements of the recipient dictates the nature of the information required and, even, whether a radar is the best sensor for the job.*

Qualities of Radar Data

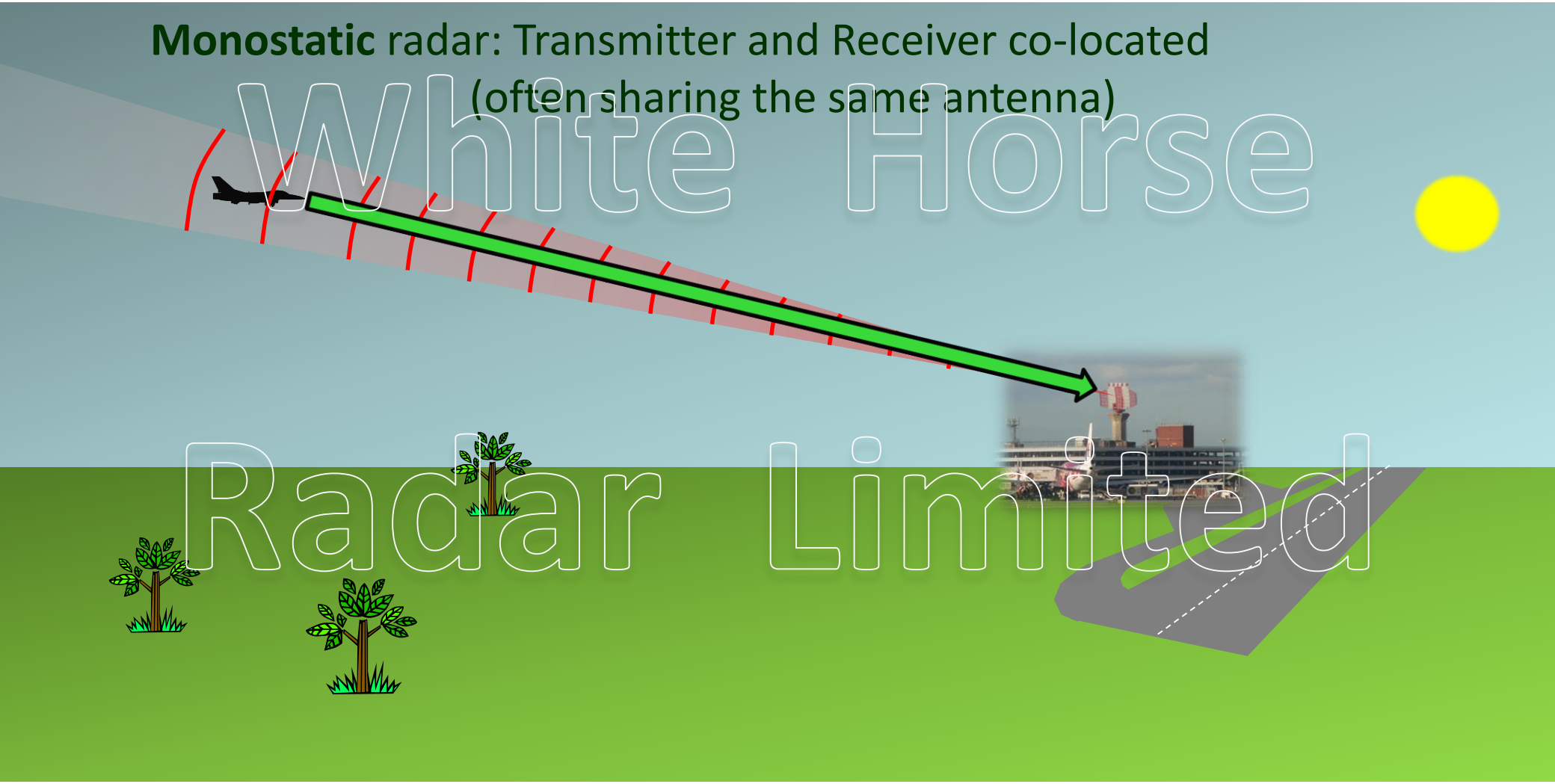
- **Detection Capability**
  Range, Probability of Detection (P_D), Probability of false alarms (P_{FA})
  False Alarm rate (FAR). SIGNAL TO NOISE RATIO (SNR)
- **Accuracy**
  i.e. the uncertainty/error in the measurement of range, velocity, angle…
  SIGNAL TO NOISE RATIO (SNR)
- **Resolution**
  i.e. the smallest difference between two similar targets
  (in range, velocity, angle…) which can be measured. FREQUENCY, BANDWIDTH
- **Ambiguity**
  Might the target data be ambiguous,
  what are the complications of overcoming any ambiguities? PRF
- **Interference**
  The ability of the radar to operate in adverse conditions of:
  Jamming, Clutter, Mutual interference…

Primary / Secondary Radar

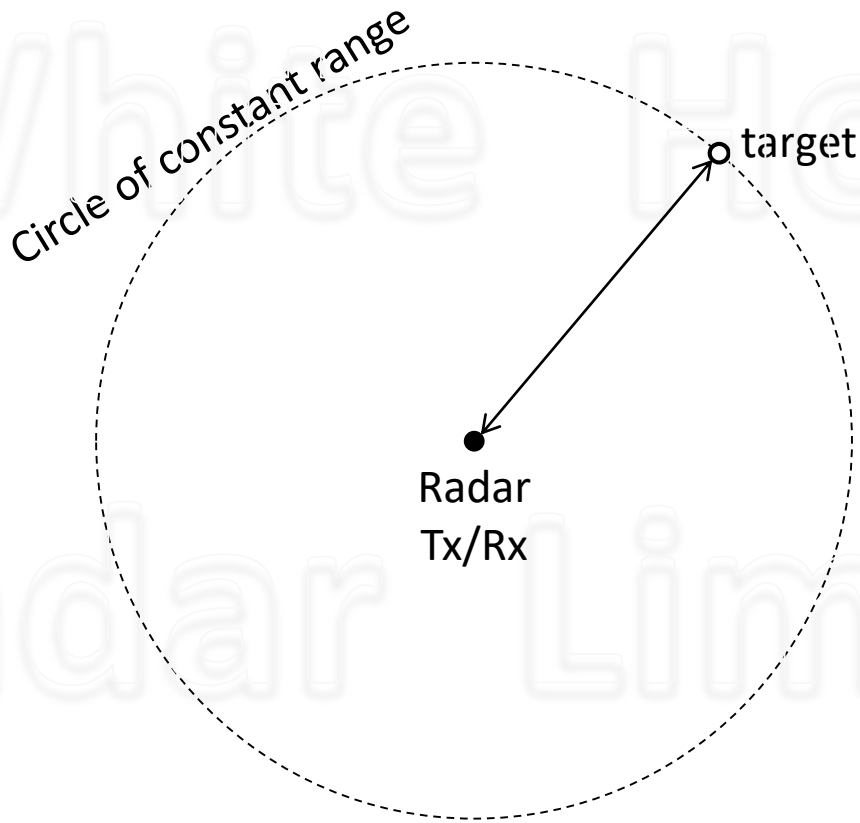
- Primary radar: echo of transmission
- Secondary radar: target transponder

Radar Configurations

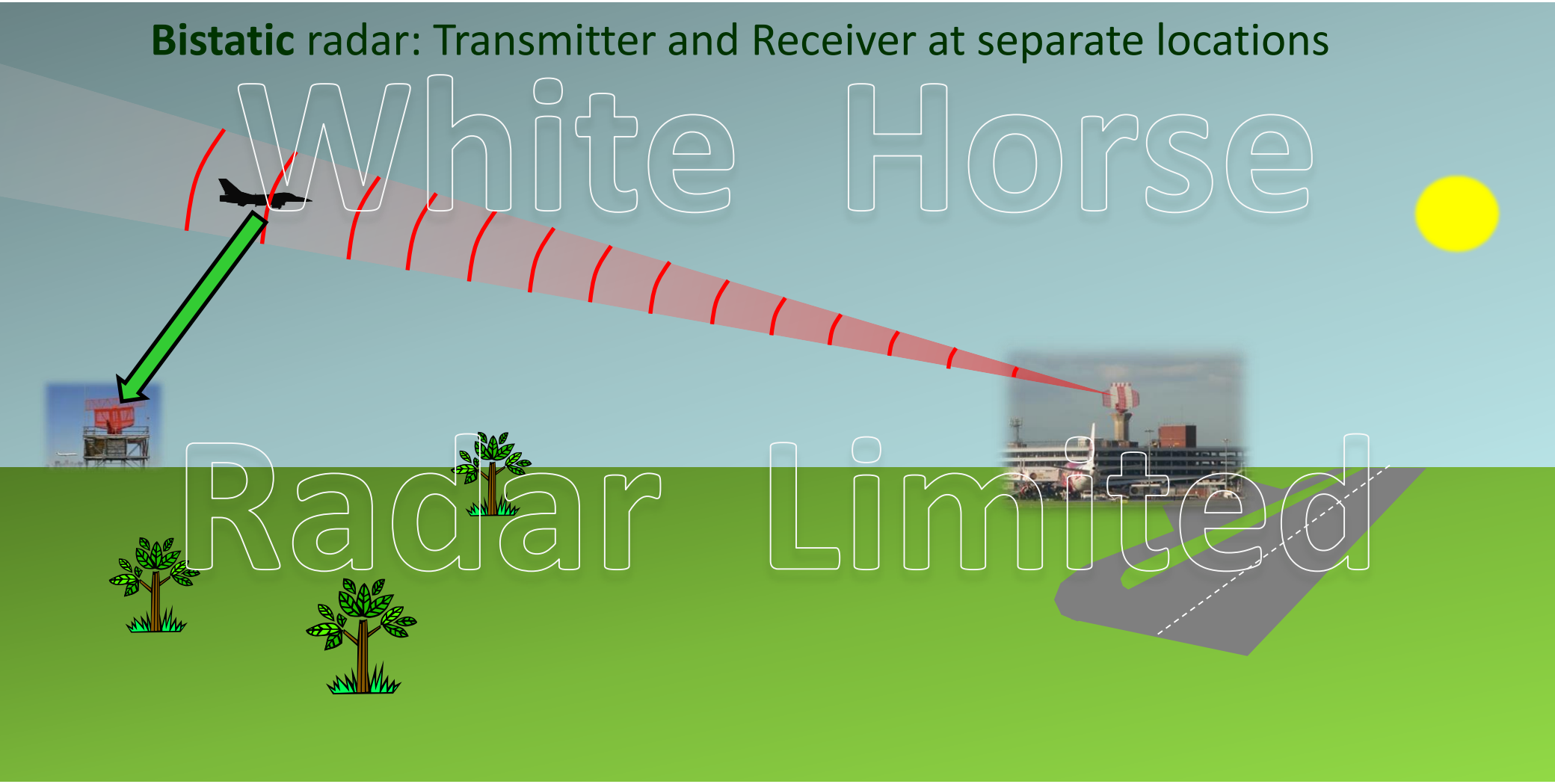
Monostatic radar: Transmitter and Receiver co-located
(often sharing the same antenna)



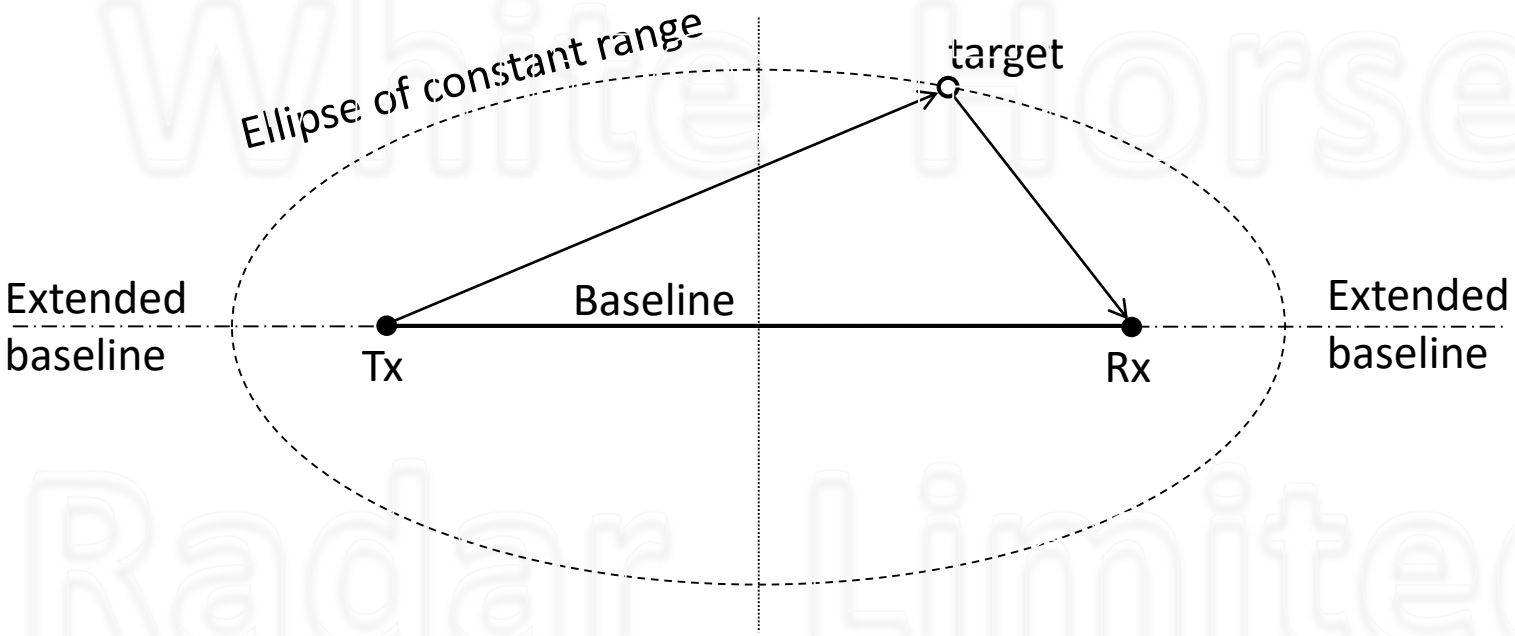
Monostatic Radar Range



Radar Configurations

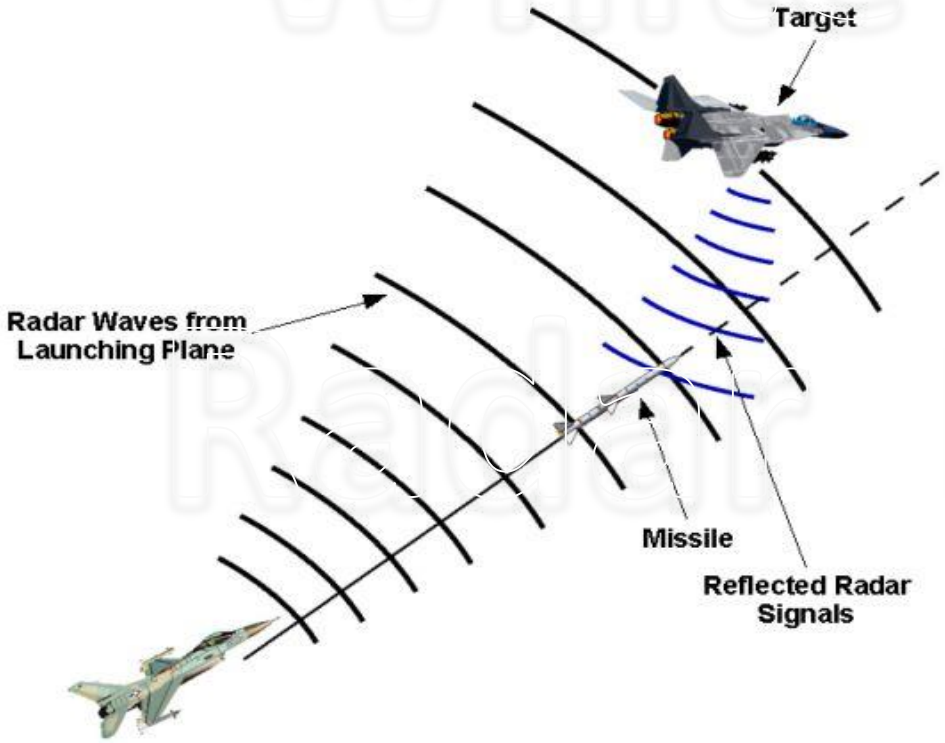


Bistatic Radar Range



Bistatic Radar Examples

Semi-active homing, air-to-air missiles

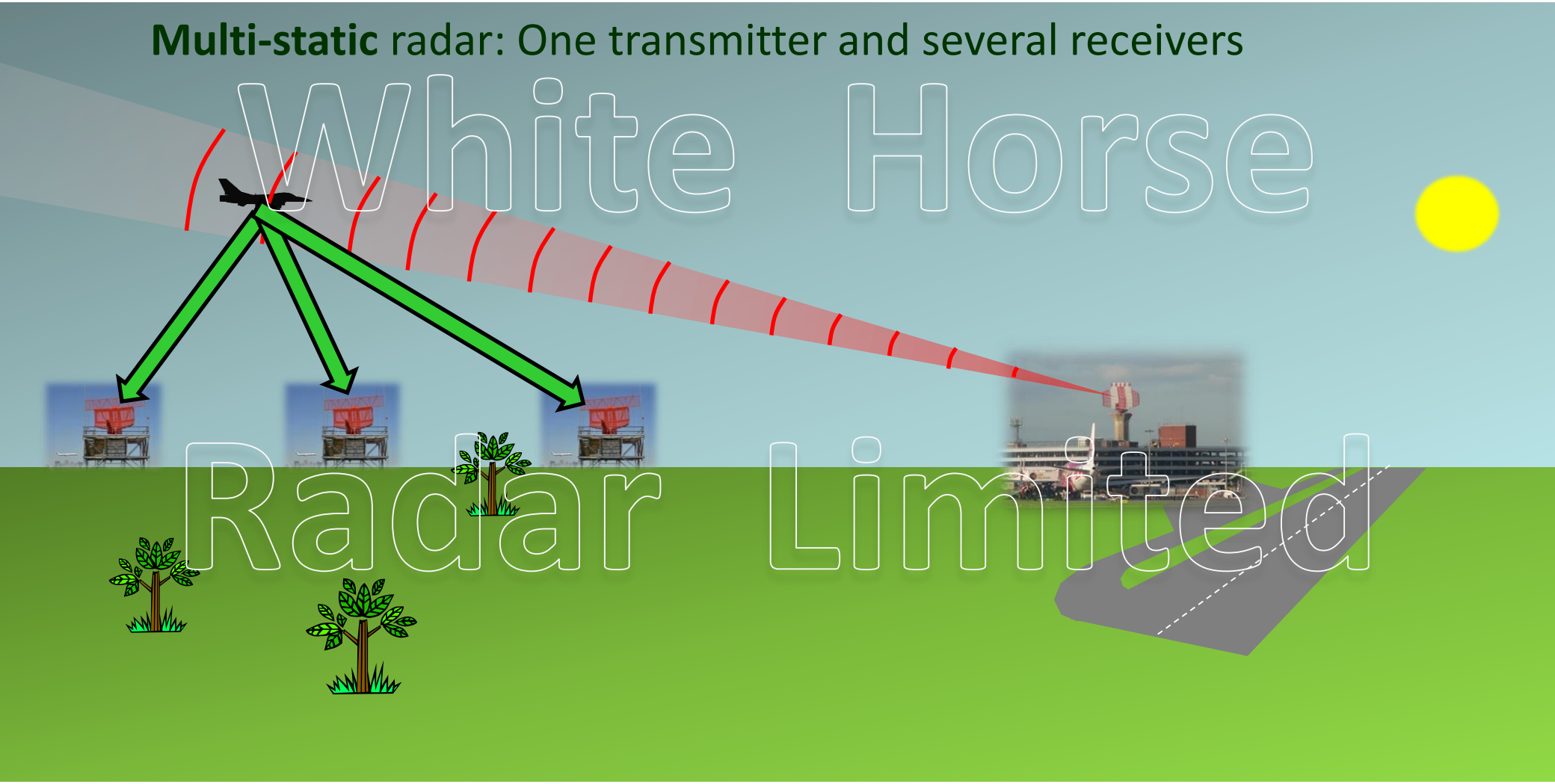


HF sky-wave OTH radar, Australia

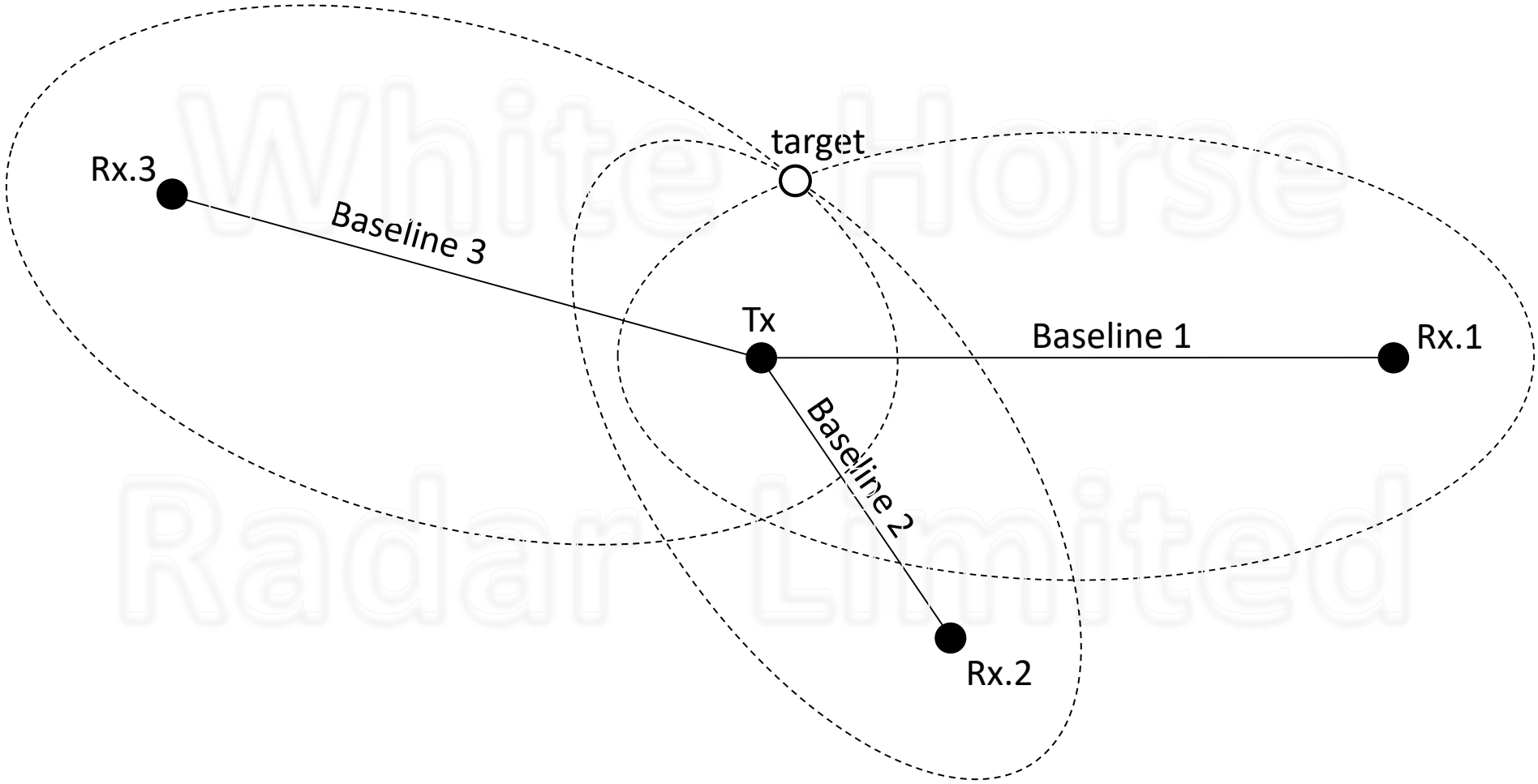
100 km separation

CAND98/0153-03
JORN PROJECT RECEIVER SITE, LAVERTON W.A.
PIC BY CPL DAVE BROOS, DEFENCE PUBLIC AFFAIRS.

Radar Configurations

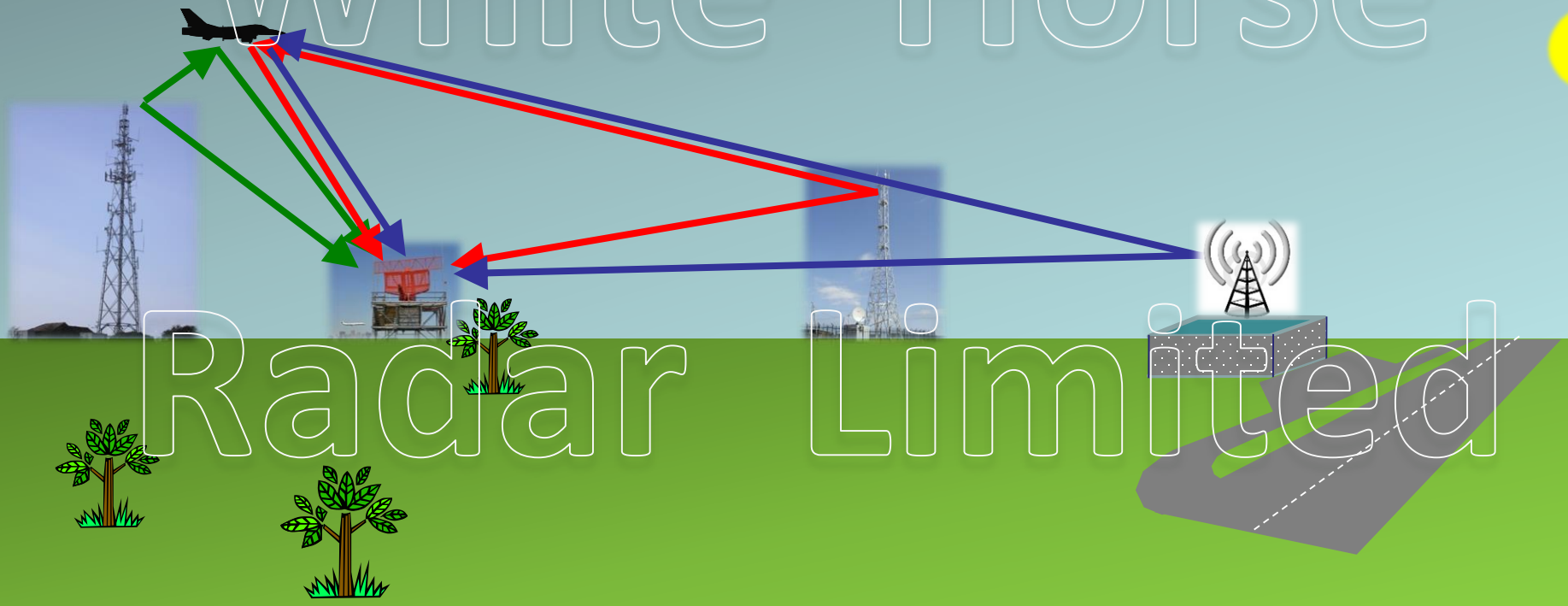


Multi-Static Radar



“Passive” Radar

***Passive radar**: Several transmitters which are “emitters of opportunity” e.g. DAB, mobile phone, broadcast comms/TV. One or more receivers.*



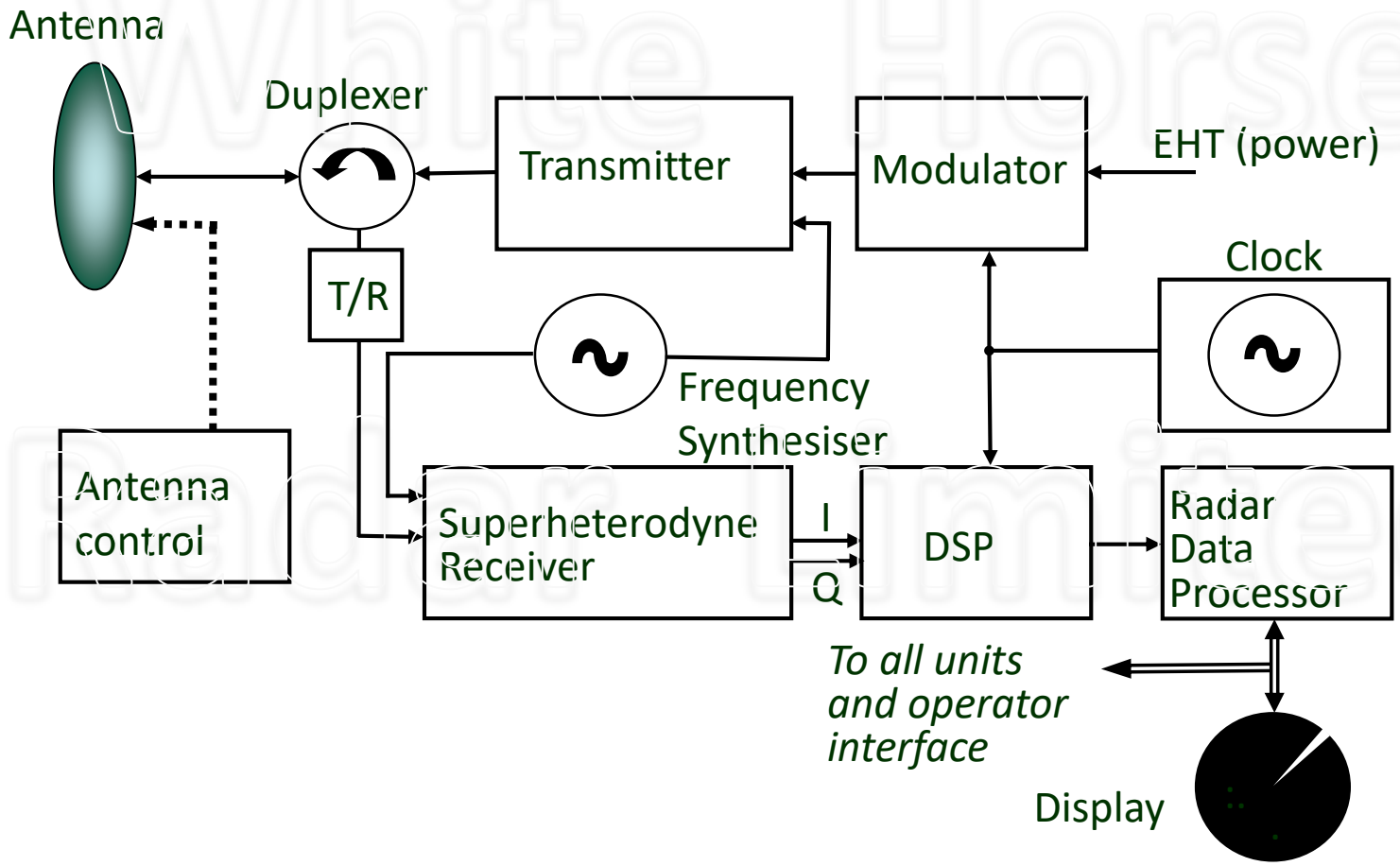
Direct paths and reflected signals compared to obtain angle, range and velocity.

Further Radar Classifications

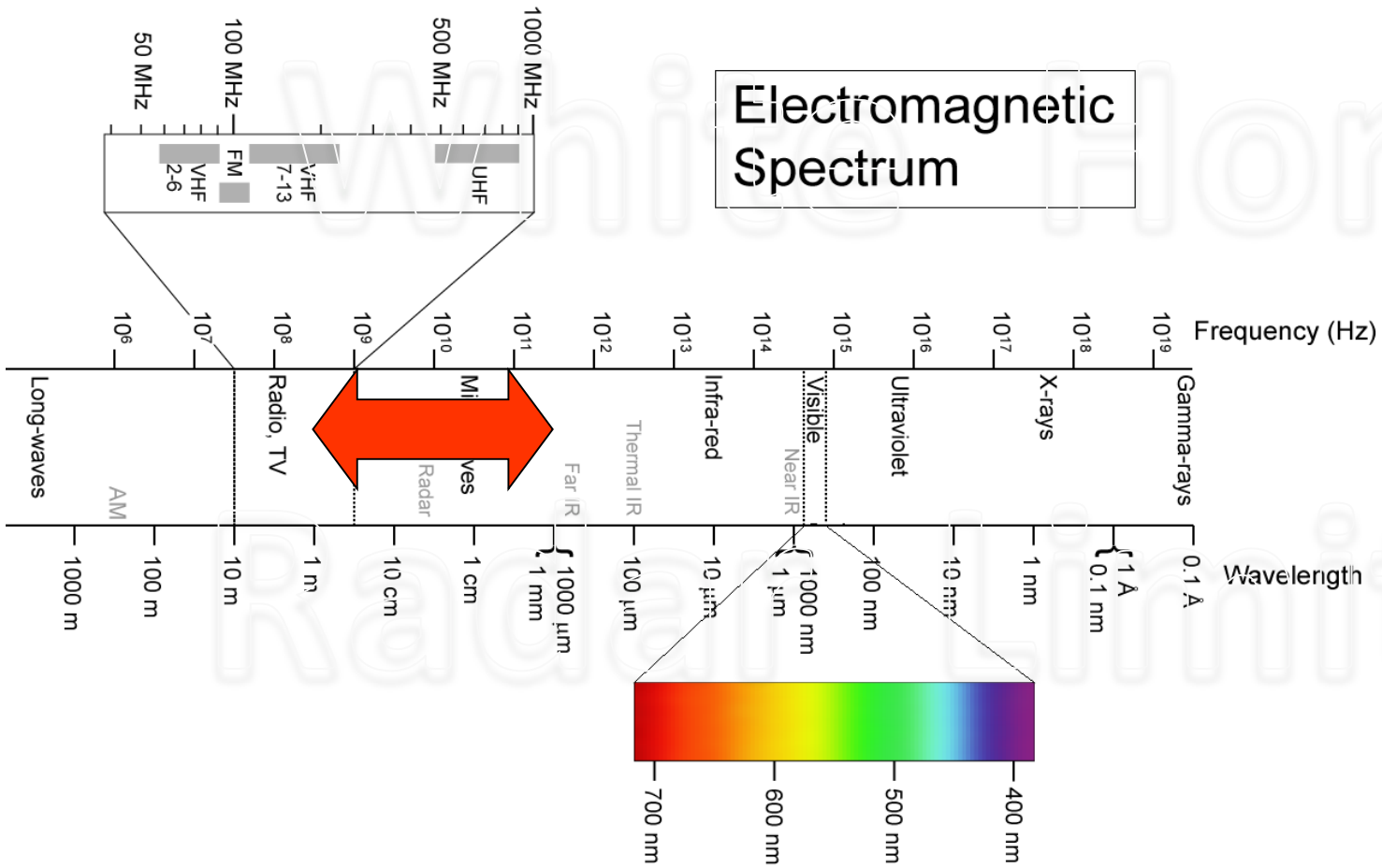
- **Frequency Band**
  Microwave, RF (metric), Wide band, Relationship with application, size, power…
- **Search / Track**
  Range, resolution & accuracy considerations of Search and Track, single target tracking (pros & cons), Track-While-Scan, role of the "tracker", Multi-Function radar.
- **Technique (Waveform & Processing)**
  Antenna m-scan vs e-scan (AESA), CW, FMCW, Pulsed & Pulsed Doppler (low, medium, high PRF), pulse compression, LPI, monopulse angle tracking, (G)MTI, STAP.
- **Application**
  Airborne Early Warning, Fire Control Radar (often airborne), Air Defence Radar (short, medium, long range), Missile seekers, Automotive, Battlefield Surveillance, Weapons Locating Radar, Ground Penetrating Radar, Security, Air Traffic Control, Airport Ground Movement, Weather Radar, Medical.

Radar Block Diagram

Primary, Monostatic Radar



Electro Magnetic Spectrum



$$f = \frac{c}{\lambda}$$

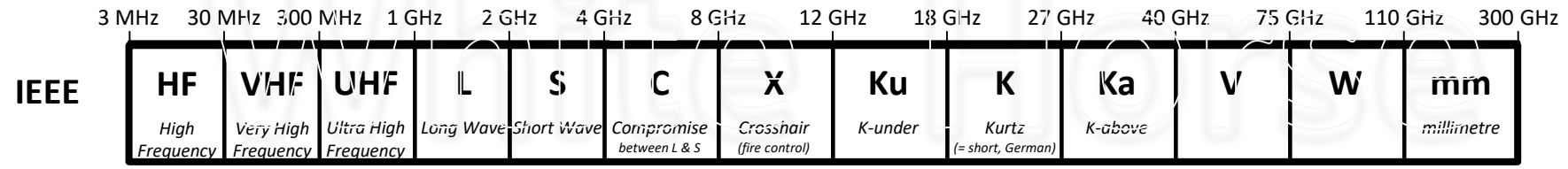
f = frequency

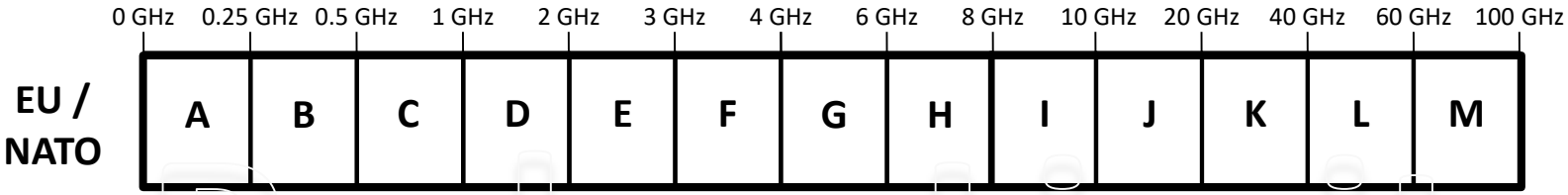
λ = wavelength

c = speed of light
= 300 000 000 m/s

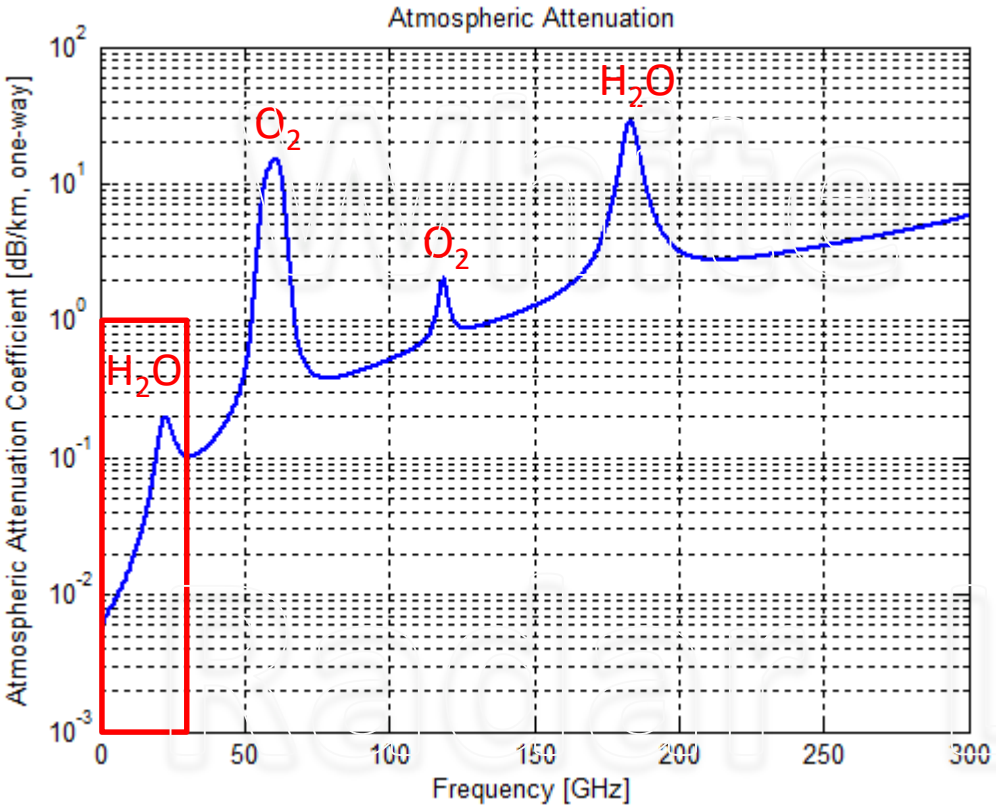
Higher frequency
↓
Shorter wavelength

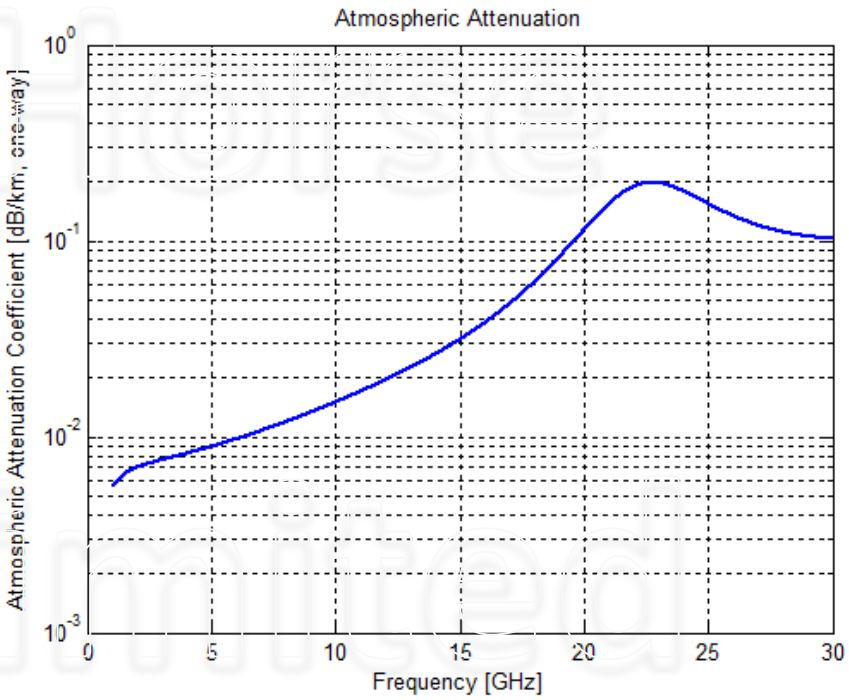
Radar Frequency Bands





Atmospheric Attenuation



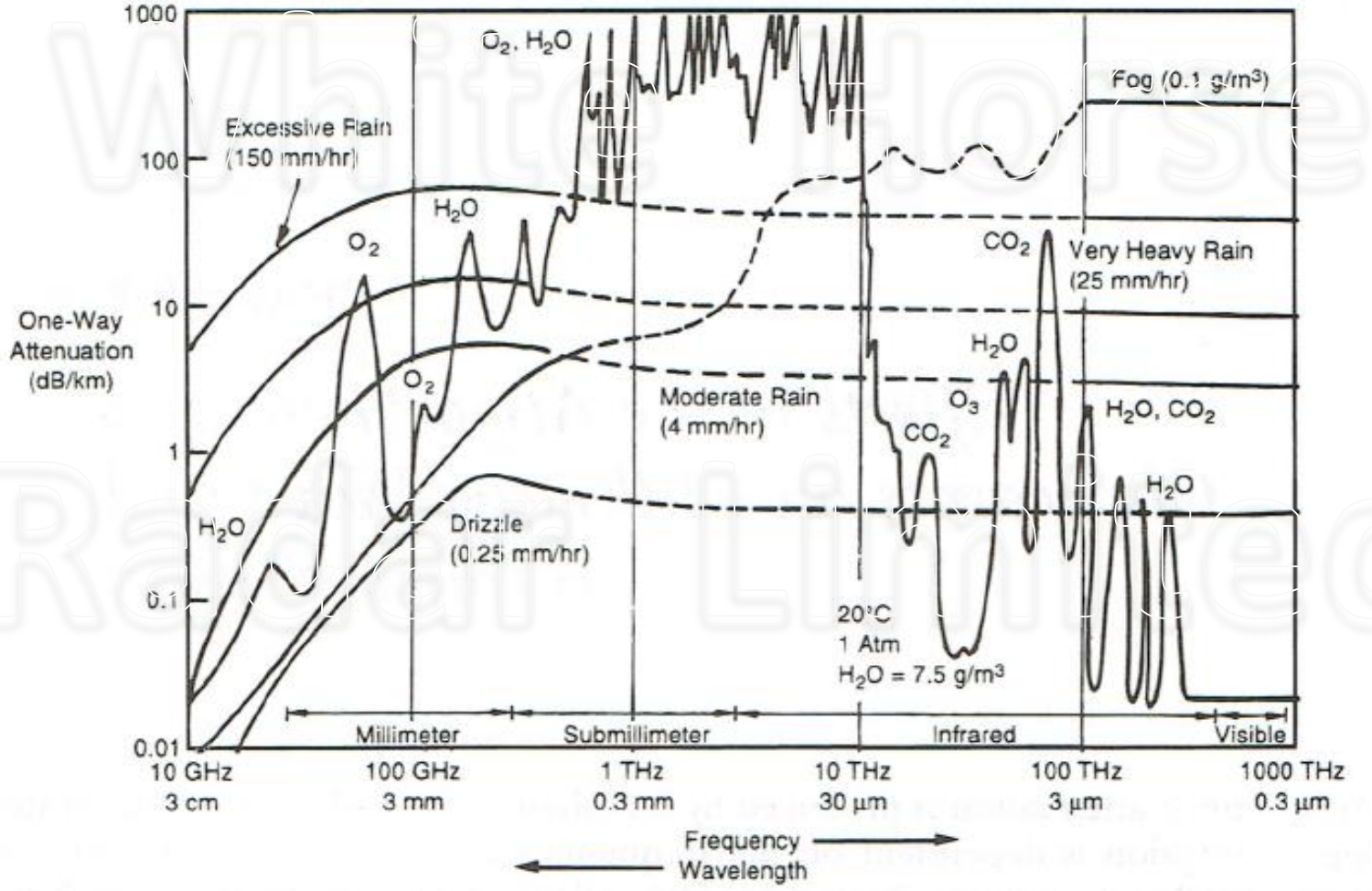


Sea-level, Air Pressure = 101325 Pa, Temperature = +15° C,
Water Vapour Density = 7.5 g/m^3.

As altitude increases, pressure reduces, water vapour content reduces, temperature tends to reduce all of which causes a reduction in atmospheric attenuation.

Atmospheric Attenuation

Effects of poor weather, sea-level, + 20° C



Comparison of Radar with other Sensors

Advantages of Radar:

- Its active nature, which allow it measure range and velocity,
- The choice of wavelength, which allows good penetration of the atmosphere and the weather,
- Its relatively poor resolution.

These characteristics allow it to be:

- All-weather, day/night,
- Long-range,
- Capable of detecting small moving targets, and
- Ideal for auto-alarm systems.

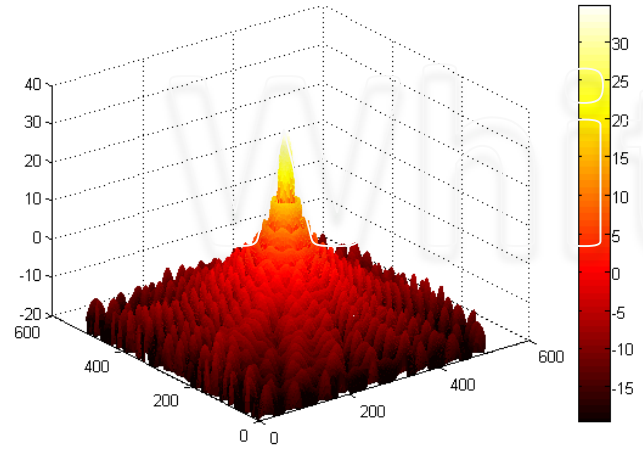
Comparison of Radar with other Sensors

Disadvantages of Radar:

- Being active the transmitted signal is liable to interception (location of source, intelligence, counter-measures)
- Unsuitable for imaging purposes, although synthetic aperture radar (SAR) and MMW radars are exceptions to this general principle.

Notwithstanding the these last two, radar is unrivalled in the long- to medium-range detection, and is frequently use in this capacity.

Basic Antenna Properties



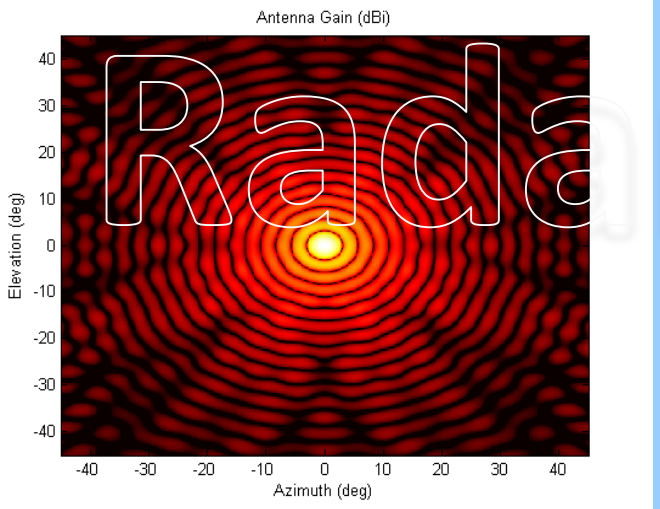
Antenna Gain – *definition*

$$\text{Gain} = \frac{\text{Power density from directive antenna}}{\text{Power density from isotropic radiator}}$$

when both fed with same power.

Usually expressed on a decibel scale with respect to an isotropic radiator (dBi)

Peak gain, often referred to simply as *gain*, occurs along the main beam boresight.



Main Beam

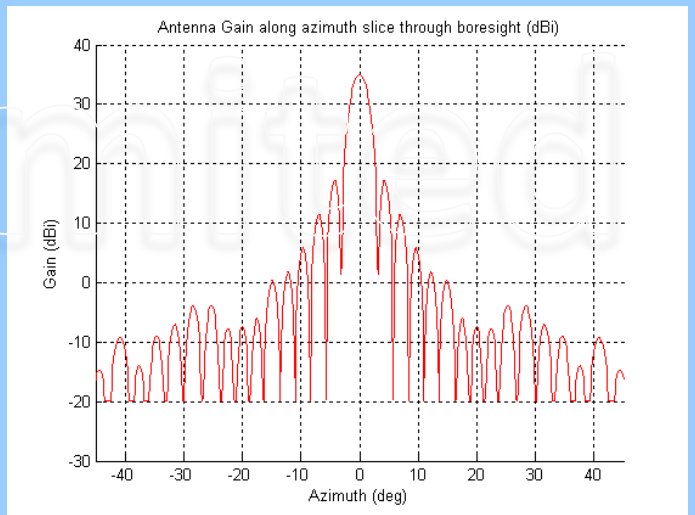
Beam width $\propto \lambda / D$

λ = wavelength,

D = dimension of antenna

Side Lobes

- An unavoidable feature of any antenna.
- Extend over full spherical angular range.



Resolution of Radar Imagery

Low resolution, I-band yacht radar

Synthetic Aperture Radar (SAR)

Radar Application vs. Frequency

Role	Range	Frequency	Peak Tx Power	Size (antenna)
ICBM Detection	2000-3000 km	400-500 MHz	5-10 MW	30m building fixed site
Long Range Air Defence	500 km	1.3, 3 GHz	100 kW – 2MW	11m x 7m transportable
Airborne Fire Control	100-200 km	9 – 10 GHz	1 – 10 kW	0.5 – 1m diameter
Battlefield Surveillance	10-20 km	10 – 15 GHz	10 – 100 W	50 cm man portable
Missile Seeker (anti-tank)	1-5 km	35, 94 GHz	100mW – 10W	140 mm diameter

Size Matters

ICBM Detection Radar
400 - 500 MHz, 30 m high, 3000 km range

Long range air defence
1.3 GHz, 11 x 7 m,
500 km range

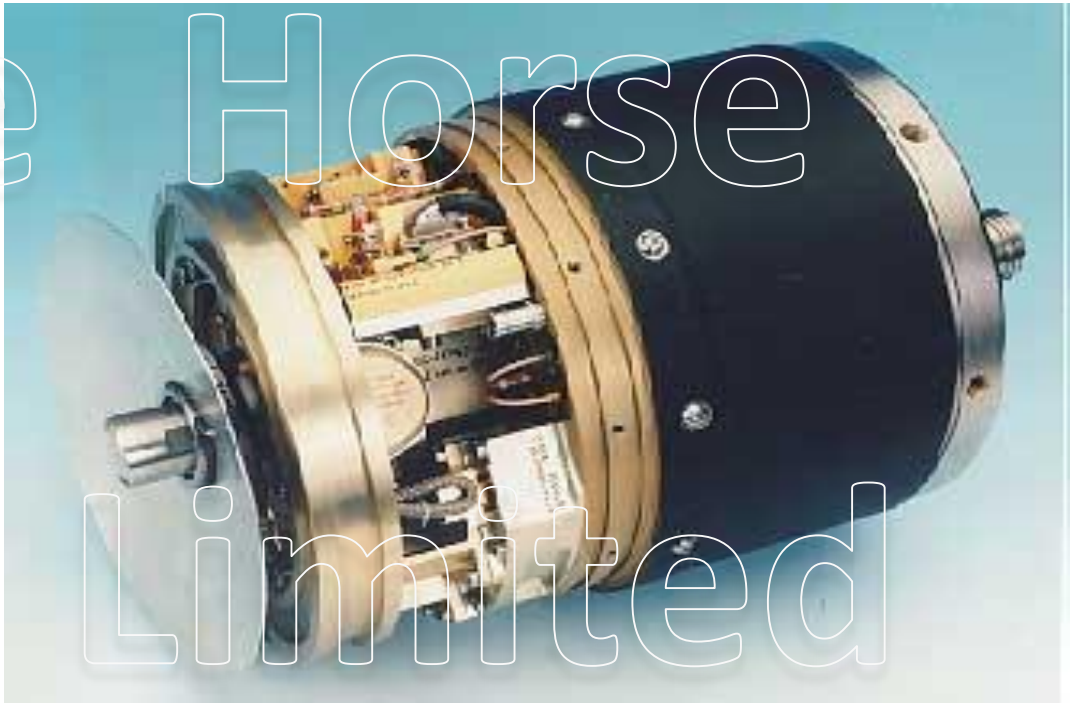
Frequency – Size – Range

Airborne Early Warning
3 GHz, 6 m,
400 km range

Airborne Fire Control
10 GHz, 0.8 m,
180 km range

Frequency – Size – Range

Short range air defence
35 GHz, 1 m,
10 km range



Active missile seeker
94 GHz, 0.14 m,
2 km range

Summary

- ✓ We have discussed the basic radar technique.
- ✓ The concepts of detection performance and the limiting effects of noise have been considered and the importance of the SNR has been stressed.
- ✓ Radar is a very powerful sensor which can generate useful target data which is usually required by a recipient within a greater system that, in turn, drives the radar specification.
- ✓ Radar has been compared with other sensors which often yield different data to that of radar.
- ✓ Many different radar deployments are possible.
- ✓ Radars may be classified in many ways. These classifications reveal their vast array of techniques and applications.
- ✓ The main sub-systems of a radar have been identified and their function described.
- ✓ Radar frequency bands have been discussed and the relationship between **frequency** and atmospheric/weather attenuation, size, power, range and application noted.

ANY QUESTIONS ?