RADAR SYSTEMS

RADAR IS AN ACRONYM;

RADIO DETECTION AND RANGING

PIONEERS;

* HEINRICH HERTZ : REFLECTION OF E-M WAVES
  c1888

* ROBERT WATSON-WATT: RADAR AS WE KNOW IT TODAY.
  1935-

THERE ARE MANY APPLICATIONS OF RADAR;

* AIR TRAFFIC CONTROL (ATC)
  AIR SURVEILLANCE RADAR (ASR)

* NAVIGATION : AIRCRAFT / SHIPS

* SPACE EXPLORATION

* REMOTE SENSING : WEATHER RADAR

* LAW ENFORCEMENT : X- K- BAND SPEED TRAPS

* MILITARY : TARGETTING SYSTEMS;
  HARRIER : BLUE VIXEN
  ALTIMETERS

THE RADAR BANDS

L- BAND	1 - 2 GHz	ASR
S- BAND	2 - 4 GHz	WEATHER RADAR / ASR
C- BAND	4 - 8 GHz	WEATHER RADAR
X - BAND	8 - 12 GHz	SPEED TRAPS
Ku - BAND	12 - 18 GHz	SAT. COMMS.
K - BAND	18 - 27 GHz	FIXED μ-WAVE LINKS
Ka - BAND	27 - 40 GHz	PCS CELLULAR

mm-WAVES;

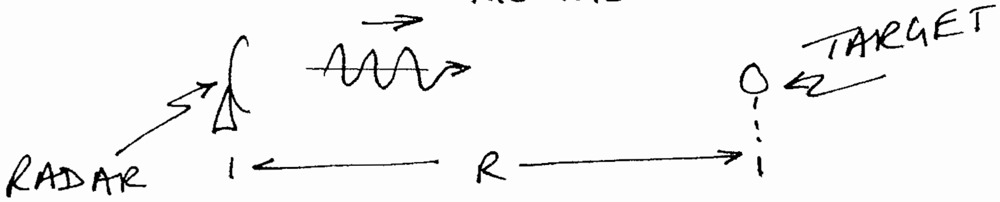
77 GHz	VEHICLE GUIDANCE
94 GHz	CLOUD RADARS
??? GHz	MILITARY PRECISION RADARS

THE PRINCIPLES OF RADAR

THE FUNDAMENTAL PRINCIPLE OF RADAR IS THIS;

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

$c = 3 \times 10^8 \, ms^{-1}$



IN TIME T_R A PULSE CAN TRAVEL TO THE TARGET AND BACK - A DISTANCE OF 2R.

EACH MICRO-SECOND OF ROUND-TRIP TIME, CORRESPONDS TO A RANGE OF 150m:

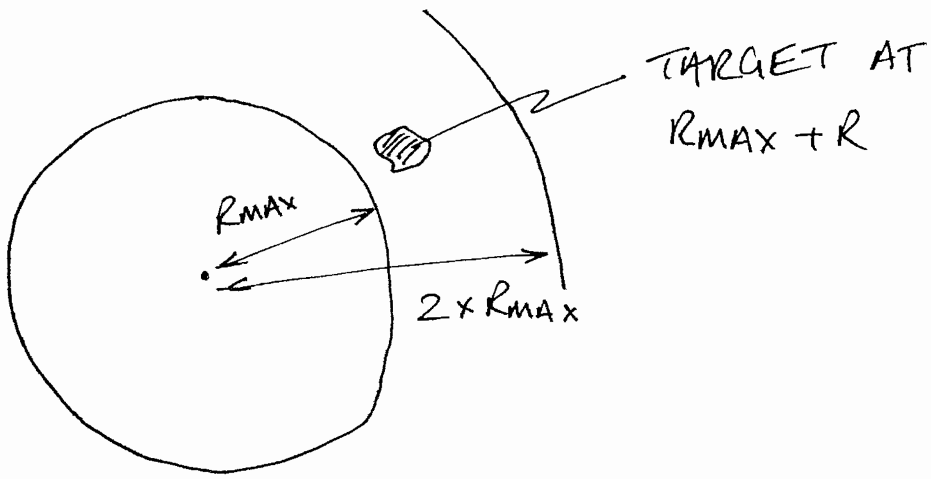
$$R = \frac{3\times10^{8} \times 1\times10^{-6}}{2} = 150\text{m.}$$

IF THE RADAR SENDS PULSES OF ENERGY EVERY T_S SECONDS, THE MAXIMUM RANGE (UNAMBIGUOUS RANGE)

$$R_{MAX} = \frac{c\,T_S}{2}$$

T_S - IS THE PULSE REPETION TIME (PRT)
$1/T_S$ = PRF - PULSE REPETION FREQUENCY

ECHOES THAT ARRIVE AFTER THE TRANSMISSION OF THE NEXT PULSE ARE CALLED <u>SECOND</u> OR <u>MULTIPLE TRIP</u> ECHOES



TARGETS AT $R_{MAX} + R$ APPEAR AT R.

MORE ON THIS LATER...

THE RADAR EQUATION

FROM A RADAR TRANSMITTER OF P_t WATTS, THE POWER DENSITY AT A DISTANCE R, RADIATED FROM AN ISOTROPIC ANTENNA IS;

$$\text{POWER DENSITY FROM ISOTROPIC ANT.} = \frac{P_t}{4\pi R^2} \quad (Wm^{-2})$$

MOST RADARS USE A DIRECTIVE ANTENNA SUCH AS A PARABOLIC REFLECTOR SYSTEM TO DIRECT THE ENERGY IN ONE PARTICULAR DIRECTION ....

$$\text{POWER DENSITY FROM DIRECTIVE ANT.} = \frac{P_t}{4\pi R^2} G_T. \quad (Wm^{-2})$$

THE TARGET INTERCEPTS SOME OF THIS POWER AND RE-RADIATES THE POWER BACK. (SOME IS ABSORBED, SEE WHAT WE SAID WHEN WE LOOKED AT RAIN ATTENUATION)

IF WE ASSUME THAT THE TARGET HAS AN EFFECTIVE BACK-SCATTERING (OR RADAR) CROSS-SECTION σ_b, THE POWER INTERCEPTED BY THE TARGET IS;

$$\frac{P_t}{4\pi R^2} \times G_T \times \sigma \quad (\text{WATTS})$$

σ_b HAS UNITS OF m^2.

THE RADAR-CROSS-SECTION OF A POINT TARGET CAN BE DEFINED AS;

$$\sigma_b = \frac{4\pi \times (\text{REFLECTED POWER PER UNIT SOLID ANGLE IN THE DIRECTION OF THE SOURCE})}{\text{POWER DENSITY OF THE INPUT WAVE}}$$

A <u>POINT TARGET</u> IS ONE THAT CAN BE CONSIDERED TO BE SMALL COMPARED TO THE ANTENNA BEAM VOLUME AT THE TARGET.

ASSUMING THAT THE TARGET RADIATES ISOTROPICALLY, THE POWER DENSITY AT THE RECEIVER, (ASSUMED TO BE LOCATED AT THE SAME SITE AS THE TRANSMITTER) CAN BE WRITTEN AS;

$$\text{RECEIVED POWER DENSITY} = \frac{P_t G_T}{4\pi R^2} \times \sigma \times \frac{1}{4\pi R^2}$$

THE RECEIVED POWER P_r IS GIVEN BY

$$P_r = \text{RECEIVED POWER DENSITY} \times A_e$$

A_e - EFFECTIVE ANTENNA APERTURE (COLLECTING AREA)

SINCE

$$G_R = \frac{4\pi \; A_e}{\lambda^2},$$

ASSUMING THE SAME ANTENNA IS USED FOR BOTH THE TRANSMITTER AND THE RECEIVER, WE CAN WRITE; $G_T = G_R = G$

$$P_r = \frac{P_t \, G^2 \lambda^2}{(4\pi)^3 \, R^4} \, \sigma_b$$

THIS EQUATION IS KNOWN AS THE <u>RADAR EQUATION</u>

NOTE THAT $P_r \propto \frac{1}{R^4}$ WHICH CAN BE A LIMITING FACTOR, WE CAN ALSO WRITE

$$R_{MAX} = \left[\frac{P_t \, G^2 \lambda^2 \sigma_b}{(4\pi)^3 \, S_{MIN}} \right]^{1/4}$$

S_{MIN} IS THE MINIMUM DETECTABLE SIGNAL (MDS)

THE RADAR-CROSS-SECTION USUALLY IS HIGHLY DEPENDENT ON ORIENTATION AND GEOMETRY

⇒ THE ANALYTICAL EXPRESSION IS OFTEN COMPLEX – FINITE ELEMENT METHODS

TARGET	σ_b m^2
SIDE-WINDER MISSILE	0.5
CESSNA	1.5
FIGHTER AIRCRAFT	5
BOEING 707	32
HERCULES C130	80
BOEING 747	100
BOEING B-52	125
STEALTH BOMBER	??
CAR	100
BICYCLE	2
HUMAN	1
SMALL CARGO SHIP	150
LARGE CARGO SHIP	16,000
SUBMARINE PERISCOPE	5
STEALTH SHIP	??

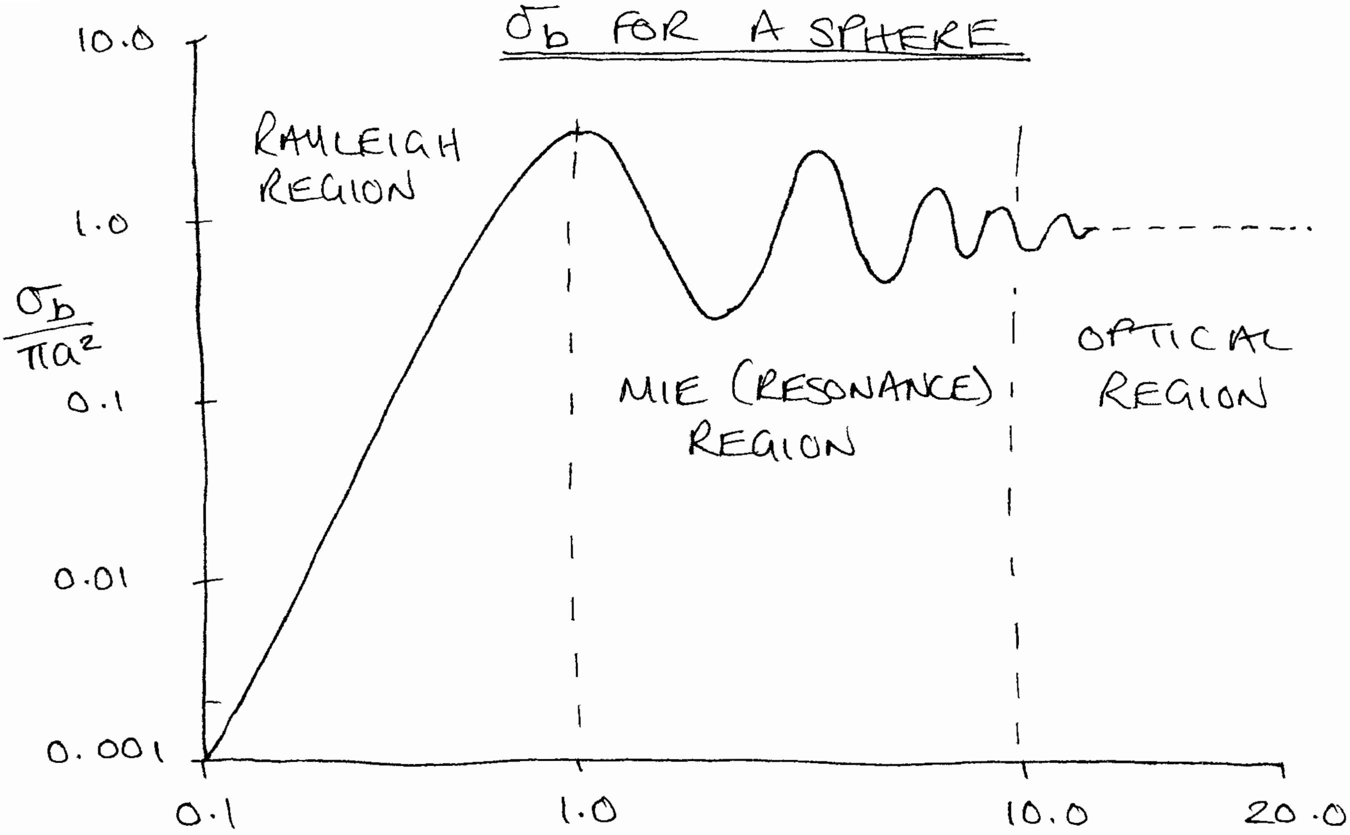
NOTE THESE CROSS-SECTIONS ARE AVERAGED OVER 360° IN AZIMUTH, AT M-WAVE FREQ.

THE RADAR CROSS-SECTION IS USUALLY LESS THAN THE GEOMETRIC CROSS-SECTION BECAUSE;

* SOME POWER IS ABSORBED (ABSORPTION CROSS-SECTION σ_A)

* REFLECTIONS FROM DIFFERENT REGIONS OF THE TARGET THAT INTERFERE DESTRUCTIVELY AT THE RECEIVER

σ_b FOR A SPHERE



$$\frac{2\pi a}{\lambda} = \text{CIRCUMFERENCE IN WAVELENGTHS}$$

* IN THE RAYLEIGH REGION $\sigma_b \propto \lambda^{-4}$
  $\sigma_b \ll \pi a^2$

* MIE-REGION OBJECT CROSS-SECTION x3 GEOMETRIC CROSS-SECTION

* OPTICAL REGION $\sigma_b = \pi a^2$

=> IF YOU WANT TO DETECT RAIN STORMS CHOOSE $\lambda \approx$ CIRCUMFERENCE OF A RAINDROP.

=> USE LARGE λ TO SEE AIRCRAFT IN A RAIN STORM.

RADAR SYSTEM TYPES

RADARS CAN BE CLASSIFIED INTO EITHER

* PRIMARY

OR

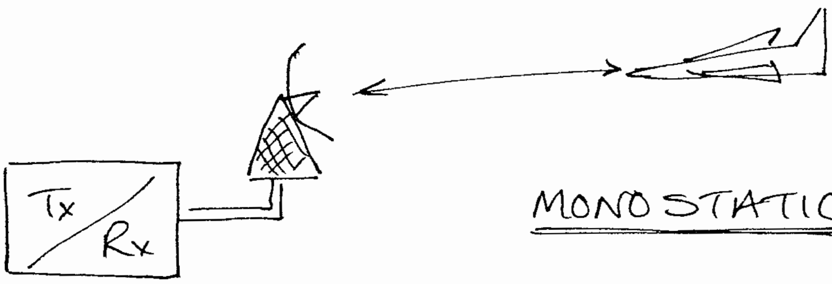
* SECONDARY.

WE HAVE BEEN DISCUSSING PRIMARY RADARS; THE RETURN SIGNAL IS SIMPLY REFLECTED FROM THE TARGET.

SECONDARY RADARS HAVE ACTIVE TARGETS. THE SIGNAL FROM THE TRANSMITTER IS RECEIVED AT THE TARGET, AMPLIFIED AND RE-TRANSMITTED BACK TO THE RECEIVER. THE RE-TRANSMISSION SYSTEM AT THE TARGET IS CALLED A TRANSPONDER. SECONDARY RADARS ARE USED FOR AIR-TRAFFIC-CONTROL SYSTEMS, AND FOR MILITARY IFF (IDENTIFICATION-FRIEND-OR-FOE) SYSTEMS

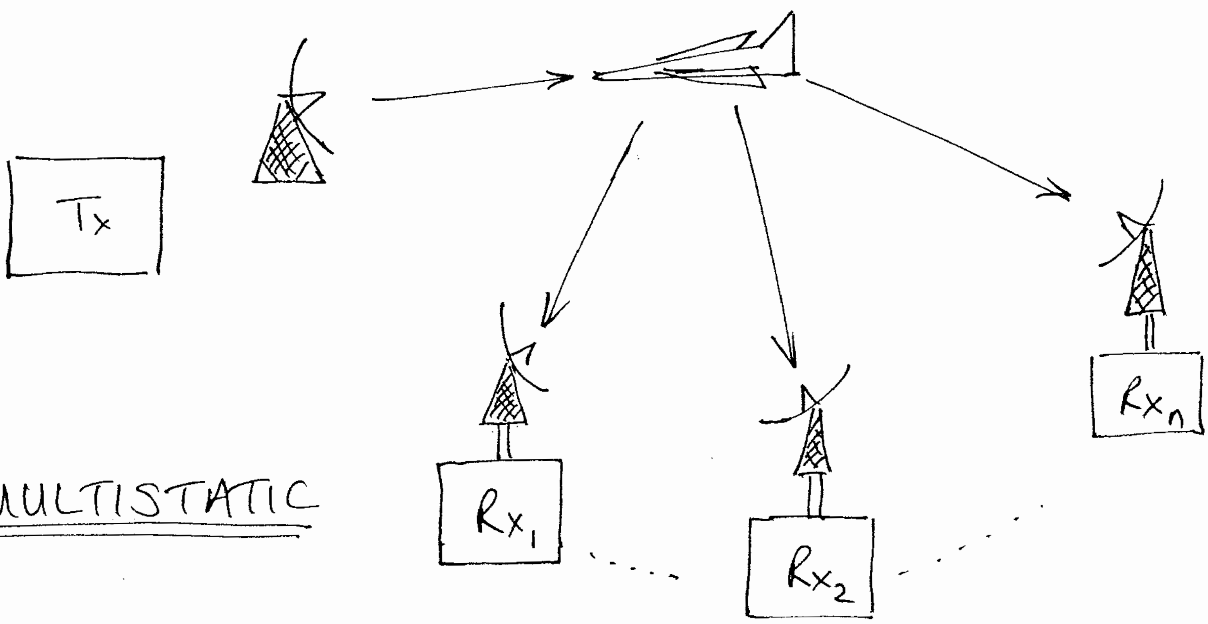
MONOSTATIC AND BI-(MULTI-) STATIC SYSTEMS

MONOSTATIC RADARS HAVE THE TRANSMITTER ANTENNA AND THE RECEIVER ANTENNA AT THE SAME LOCATION (USING THE SAME ANTENNA USUALLY)



MONOSTATIC

MULTISTATIC RADAR MAKE USE OF TWO OR MORE SITES; ONE FOR THE TRANSMITTER AND ONE OR MORE FOR THE RECEIVER SITES;



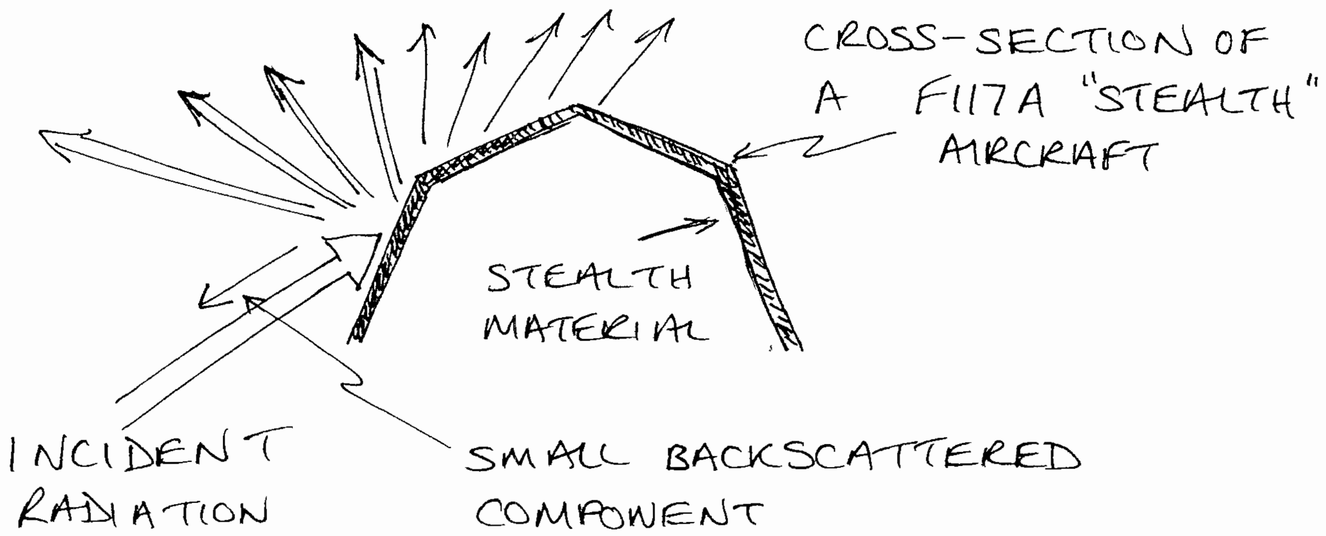
MULTISTATIC

BI-STATIC AND MULTI-STATIC RADARS HAVE BECOME AN EXTREMELY IMPORTANT TOPIC IN RECENT YEARS

"STEALTH" MATERIALS

SO-CALLED STEALTH MATERIALS ARE DESIGNED TO BE BOTH LOSSY (INCREASING THE ABSORPTION CROSS-SECTION) AND CONFIGURED SUCH THAT THE RADAR CROSS-SECTION IS MINIMIZED.

HOWEVER IN ORDER TO MINIMIZE THE RADAR CROSS-SECTION, THE INCIDENT ENERGY IS REFLECTED IN OTHER DIRECTIONS



IF WE ONLY HAVE A MONOSTATIC RADAR THE PROBABILITY OF DETECTION (POD) IS LOW

MULTI-STATIC RADAR PERFORMS MUCH BETTER WITH A HIGHER POD