Q Explain radar range equation.

The radar range equation relates the range of the radar to the characteristics of the transmitter, receiver, antenna, target and the environment. It is used as a tool to help in specifying radar subsystem specifications in the design phase of a program. Free space condition implies that the radar set and the target are isolated in an unbounded empty space. The condition is realized well enough for practical purposes if the following conditions are fulfilled:
(*a*) No large obstacles lie between antenna and the target along an optical line of sight.
(*b*) No alternative trasmission path via any reflecting surface can be followed by a substantial fraction of the total radiated energy.
(*c*) The intervening medium is transparent, *i.e.*, it does not absorb energy from the electromagnetic waves at the frequency used.
(*d*) The intervening medium is homogeneous with respect to the refractive index at the radar frequency.
If the transmitter delivers *PT* watts power into an isotropic antenna (one which radiates power uniformly in an directions is used), then the power density (W/m2) at a distance *R* from the radar is

$$= \frac{P_T}{4\pi R^2}$$

here the 4π*R*2 represents the surface area of the sphere at distance *R*. Radars employ directional antennas to channel the radiated power *PT* in a particular direction. The gain *GT* of an antenna is the measure of the increased power radiated in the direction of the target, compared to the power that would have been radiated from an isotropic antenna. So power density from a directional antenna

$$= \frac{P_T G_T}{4\pi R^2}$$

This energy is incident on the target and gets scattered in various directions. A part of the energy returns in the direction of the radar antennas. The target is usually described in terms of an equivalent cross-section σ such that if the total power contained in a section of the incident wavefront having the area σ were radiated by an isotropic radiator located at the target the strength of the radio wave reaching the radar receiving antenna would be the same as the strength of the actual echo produced by target.
Area σ is then referred to as the effective echo area of the target. Hence the power density of the echo signal at the radar

$$= \frac{P_T G_T}{4\pi R^2} \cdot \frac{\sigma}{4\pi R^2}$$

The receiving antenna effectively intercepts the power of the echo signal at the radar over a certain area called the effective area *Ae*. Since the power density (watts/m2) is intercepted across an area *Ae*, the power delivered to the receiver is

$$P_r = \frac{P_T G_T \sigma A_e}{\left(4\pi R^2\right)^2} \text{ watts}$$

Equation (12.4) is the free space radar equation.

Now the maximum range *R*max is the distance beyond which the target cannot be detected due to insufficient received power *Pr*. The minimum power which the receiver can detect is called the minimum detectable signal *S*min. Setting *Pr* = *S*min and rearranging the above equation gives

$$S_{\min} = \frac{P_T G_T \sigma A_e}{(4\pi)^2 R_{\max}^4} \qquad \text{...(12.5)}$$

or

$$R_{\max} = \left[\frac{P_T G_T \sigma A_e}{(4\pi)^2 S_{\min}}\right]^{1/4} \qquad \text{...(12.6)}$$

Now G_T depends on the type of antenna system used. For a circular paraboloid, as used in microwave radar

$$G_T = \frac{8}{3} \cdot \frac{\pi A_T}{\lambda^2} \qquad \text{...(12.7)}$$

For dipole radiator, the gain gets increased by 50%. Hence effective

$$G_T = \frac{3}{2} \cdot \frac{8}{3} \cdot \frac{\pi A_T}{\lambda^2} = \frac{4\pi A_T}{\lambda^2} \qquad \text{...(12.8)}$$

Hence the circular paraboloid antenna with dipole radiator, Eq. (12.6) giving the free space radar range equation becomes,

$$R_{\max} = \left[\frac{P_T A_e A_T \sigma}{4\pi \lambda^2 S_{\min}}\right]^{1/4} \qquad \text{...(12.9)}$$

Generally the same antenna is used for reception and transmission, so that

$$G_T = G_R = G$$

Where G is given by

$$G = \frac{4\pi A}{\lambda^2} \qquad \text{...(12.10)}$$

Where $A_T = A_e = A$

The equation (12.9) may be written as,

$$R_{\max} = \left[\frac{P_T A^2 \sigma}{4\pi \lambda^2 S_{\min}}\right]^{1/4} \qquad \text{...(12.11)}$$

or

$$R_{\max} = \left[\frac{P_T G^2 \lambda^2 \sigma}{(4\pi)^3 S_{\min}}\right]^{1/4} \qquad \text{...(12.12)}$$

Q. Explain Block Diagram of RADAR system.

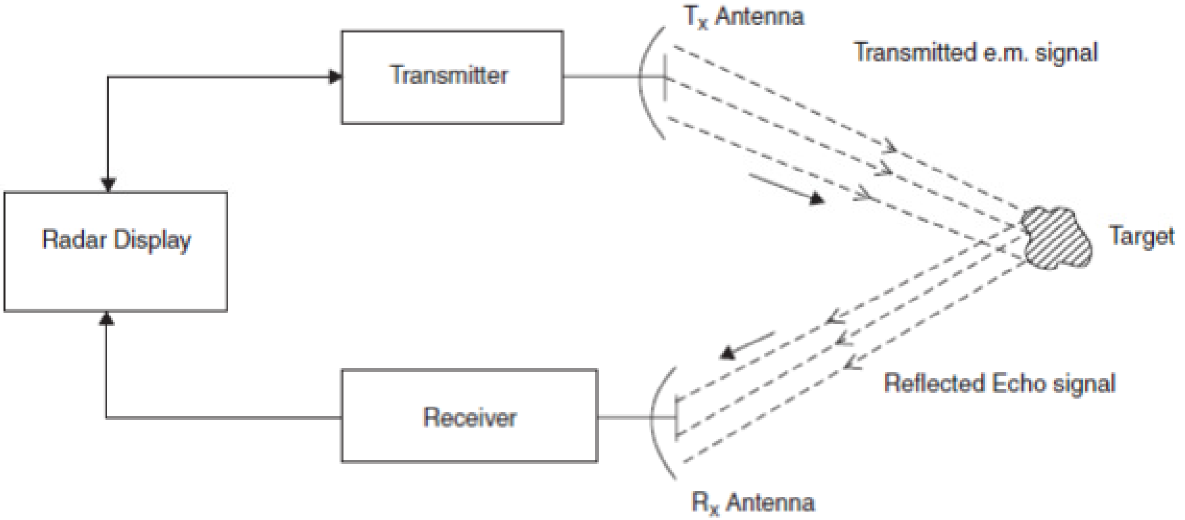
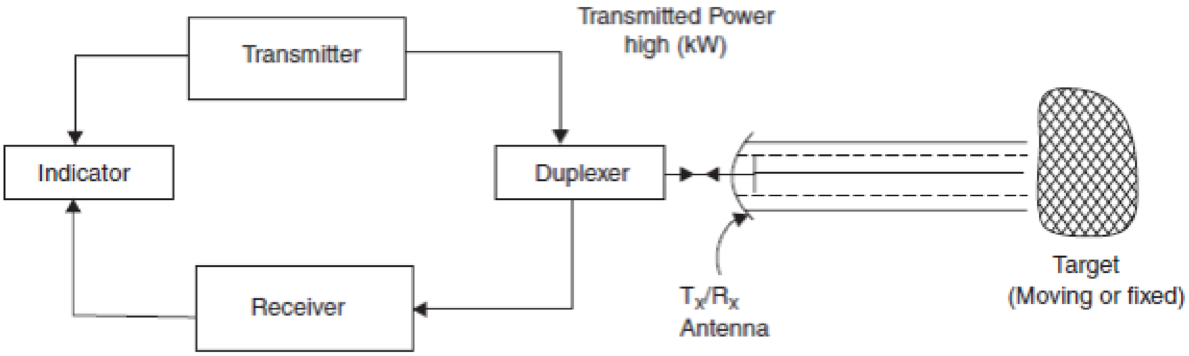


Fig. 12.1 Block diagram of basic radar

Such a radar where a single antenna is used for both transmitting and receiving is called a monostatic radar, which is most usual form of radar.



Example 12.1. Use the radar range to determine the required transmit power for the TRACS radar given,

$S_{min} = 10^{-13}$ watts, $G = 2000$, $\lambda = 0.23$ m, PRF = 524 and $\sigma = 2.0$ m^2

Solution: By using equation (12.22),

$$R_{max} = \frac{C}{2PRF} = \left(\frac{3 \times 10^8}{2 \times 524}\right)$$

$$= 286.2 \text{ km.}$$

Now by using Eq. (12.12),

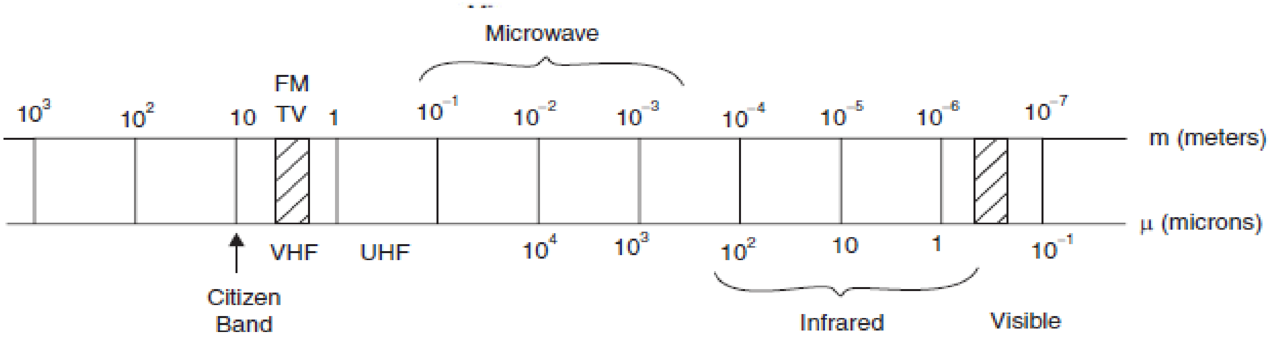
$$P_T = \frac{S_{min}(4\pi)^3 \cdot R_{max}^4}{G^2\lambda^2\sigma}$$

$$= \frac{(10^{-13})(4\pi)^3(286.2 \times 10^3)^4}{(2000)^2(0.23)^2(2.0)}$$

$$P_T = 3.1 \text{ MW}$$

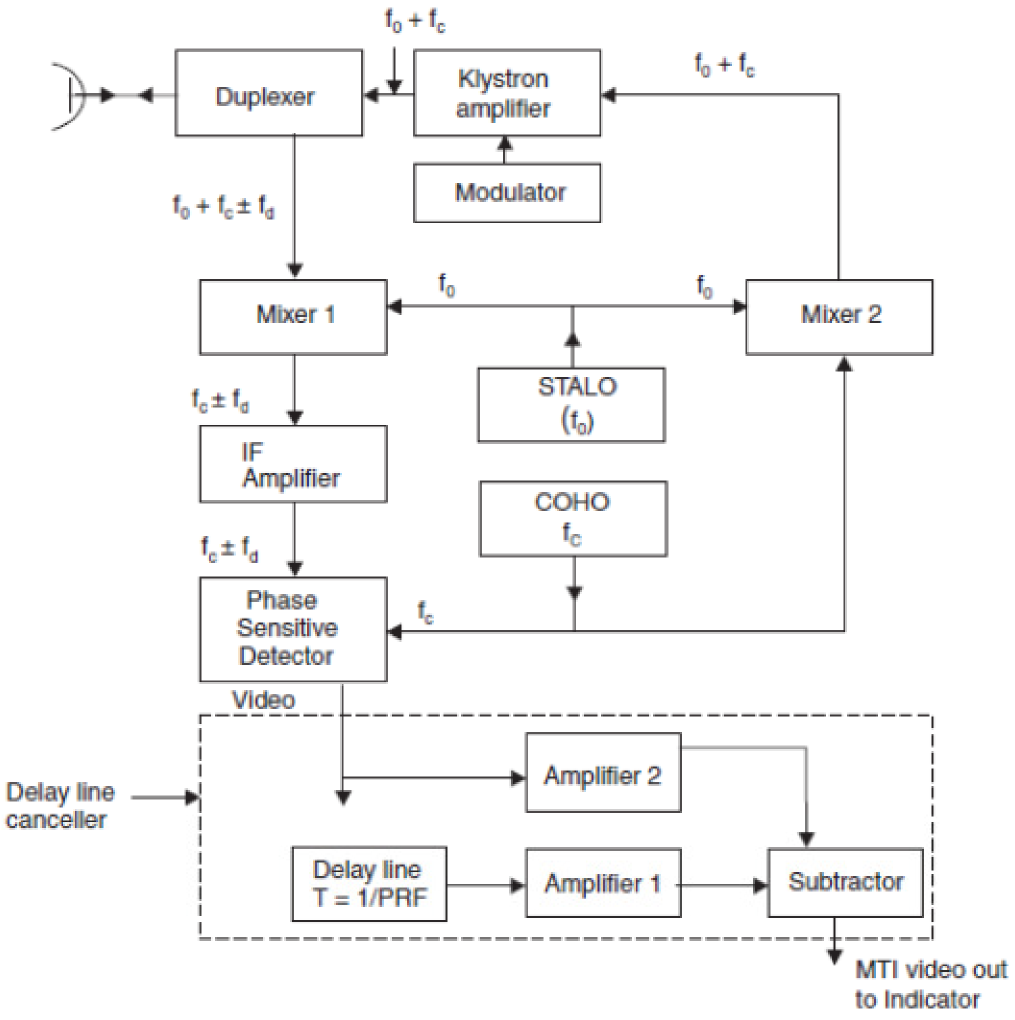
Q. Give the detail of frequency range use in RADAR.

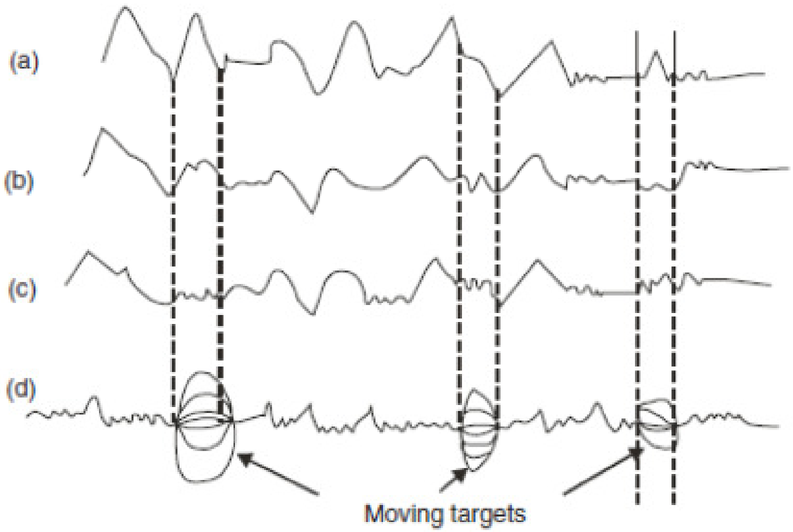
(*a*) Skywave HF-OTH (over the horizon) can operate as low as 4 MHz
(*b*) Groundwave HF Radars operate as low as 2 MHz.
(*c*) Millimeter radars operate up to 95 GHz, and
(*d*) Laser radars (lidars) operate in IR and visible spectrum.



Band designation	*Nominal frequency range*	*Specific radar bands based on ITU assignments for region 2*
HF	3–30 MHz	
VHF	30–300 MHz	138–144 MHz
		216–225 MHz
UHF	300–1000 MHz	420–450 MHz
		890–942 MHz
L	1000–2000 MHz	1215–1400 MHz
S	2000–4000 MHz	2300–2500 MHz
		2700–3700 MHz
k_u	12–18 GHz	13.4–14.0 GHz
		15.7–17.7 GHz
K	18–27 GHz	24.05–24.25 GHz
k_a	40–300 GHz	33.4–36.0 GHz

Q. Explain MTI RADAR.





A block diagram of an MTI radar is shown in Fig. The block diagram shows two mixers. Mixer 2 generates the transmitter frequency ($fo + fc$), which is obtained by the sum of frequencies produced by two oscillators. The first is STALO (stable oscillator) producing fo and second is the COHO (Coherent oscillator) producing fc. The transmitted frequency drives a multicavity klystron amplifier, which acts as an output tube. This amplifier provides the desired amplification for proving a high power pulse when modulator switches on the tube. The transmitter pulse is the output via the duplexer.

The echo pulse from the target (due to transmitted pulse) is received by the MTI radar antenna. If the echo is due to a moving target, the echo pulse undergoes a doppler frequency shift. The received echo pulses ($fo + fc \pm fd$) then pass through mixer 1 of the receiver which hytrodynes the received signal of frequency ($f0 + fc + fd$) with the output of STALO at $f0$ and produces a difference frequency ($fc \pm fd$) at its output. These two mixers 1 and 2 are identical in all respects except that mixer 1 produces a difference frequency whereas mixer 2 produces a sum frequency. This difference frequency signal is further amplified by an IF amplifier and is given to the phase sensitive detector or phase discriminator. This detector compares the IF signal with the reference signal from the COHO oscillator. This difference is the doppler frequency. The detector provides an output depending upon the phase difference between these two signals. Since all received signal pulses will have phase difference compared with the transmitted pulse, the phase detector gives output for both fixed and also for moving targets. Phase difference is constant for all fixed targets but varies for moving targets. Doppler frequency shift causes this variation in phase difference. A change of half cycle in the doppler frequency shift would cause an output of opposite polarity in the phase detector output. The output of the phase detector therefore successive pulses in case of a moving target. However, for fixed targets the magnitude and polarity of the output will remain the same for all transmitted pulses. In Fig. 2 that those returns of each pulse that correspond to stationary targets are identical with each pulse, but those portions corresponding to moving targets keep changing in phase. It is thus possible to subtract the output for each pulse from the preceding one, by delaying the earlier output by a time equal to the pulse interval, or 1/PRF. Since the delay line also attenuates heavily and since signals must be of the same amplitude if permanent echoes are to cancel an amplifier follows the delay line. To ensure that this does not introduce a spurious phase shift, an amplifier is placed in the undelayed line, which has exactly the same response characteristics than amplifier 1. The delayed and undelayed signals are compared in the subtractor,

Q. Explain the application of RADAR.

1 Air Traffic Control (ATC): Radar used to provide air traffic controllers with position and other information on aircraft flying within their area of responsibility (airways and in the vicinity of airports). The high resolution radar is used at large airports to monitor aircraft and ground vehicles on the runways, taxiways and ramps. The GCA (ground controlled approach) or PAR (precision approach radar) provides on operator with high accuracy aircraft position information in both the vertical and horizontal. The operator uses this information to guide the aircraft to a landing in bad weather. The MLS (microwave landing system) and ATC radar beacon systems are based on radar technology.

2. **Air Navigation:** The weather avoidance radar is used on aircraft to detect and display areas of heavy precipitation and turbulence. Low-flying military aircraft rely on terrain avoidance and terrain following radars to avoid colliding with obstructions or high terrain. Military aircraft employ ground-mapping radars to image a scene. The radio altimeter is also a radar used to indicate the height of an aircraft above the terrain and as a part of self contained guidance system over land.

3. **Ship Safety:** There are one of the least expensive, most reliable and largest applications of radar. Radar is found on ships and boats for collision avoidance and to observe navigation buoys, especially when the visibility is poor. The automatic detection and tracking equipments are available with these radars for collision avoidance. Similarly shore based radars of moderate resolution are used from harbour surveilliance.

4. **Space:** Radars are used for rendezvous and dockign and was used for landing on the moon. The large ground based radars are used for detection and tracking of satellites. The satellite-borne radars used for remote sensing (SAR, Synthetic Aperture Radar).

5. **Remote Sensing:** All radars are remote sensors, and used for sensing geophysical objects (the environment). The radar astronomy are used to probe the moon and planets. The earth resources monitoring radars measure and map sea conditions, water resources, ice cover, agricultural land use, forest conditions, geological formations, environmental pollution (Synthetic Aperture Radar, SAR and Side Looking Airborne Radar, SLAR).

6. **Law Enforcement:** The radar speed meter, familiar to many, is used by police for enforcing speed limits. Radar has been considered for making vehicles safer by warning of ponding collision, actuating the air bag, or warning of obstructions or people behind a vehicle or in the side blind zone. It is also employed for detection of intruders.

7. **Military:** Radar is an important part of air-defence systems as well as the operation of offensive missiles and other weapons. In air defence it performs the functions of surveillance and weapon control. Surveillance includes target detection, target recognition, target tracking,

and designation to a weapon system. Weapon-control radars track targets, direct the weapon to an intercept, and assess the effectiveness of the engagement (called battle damage assessment). A missile system might employ radar methods for guidance and fuzing of the weapon. High resolution imaging radars, such as synthetic aperture radar, have been used for reconnaissance purpose and for detecting fixed and moving targets on the battle field.