TRACKING RADARS

1 **SINGLE TGT TRACKER (STT)**

- **TRACKS A SINGLE TGT AT FAST DATA RATE.**
- **DATA RATE – 10 OBS/SEC.**
- **EMPLOYS A CLOSED LOOP SERVO SYSTEM TO KEEP THE ERROR SIGNAL SMALL.**
- **APPLICATION – TRACKING OF AIRCRAFT/ MISSILE TGTS**

TRACKING RADARS (contd)

2 AUTOMATIC DETECTION & TRACK (ADT)

- TRACKING IS PART OF AIR SURVEILLANCE TRACKING RADAR.
- LOWER DATA RATE THAN STT.
- CAN TRACK HUNDREDS/ A FEW THOUSAND TGTS SIMULTANEOUSLY.
- TRACKING IS OPEN LOOP.

PHASED ARRAY RADAR TRACKING

- ELECTRONICALLY STEERED PHASED ARRAY RADAR.
- LARGE NO OF TGTS CAN BE HELD ON TRACK.
- HIGH DATA RATE (LIKE IN STT)
- **BEAM IS ELECTRONICALLY SWITCHED FROM ONE ANGULAR POSITION TO ANOTHER IN A FEW MICROSECONDS.**

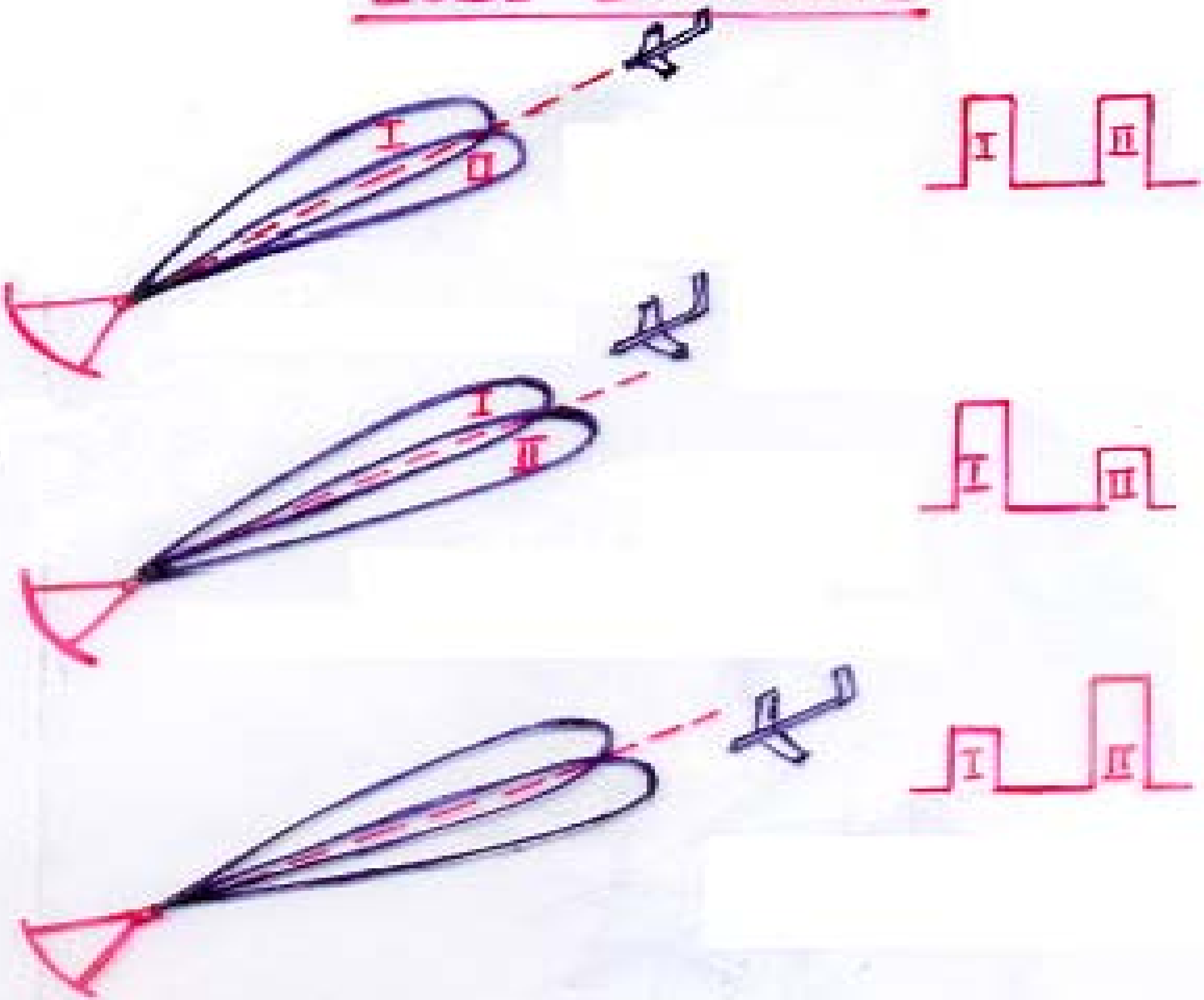
TRACK WHILE SCAN (TWS)

- SCANS A LIMITED ANGULAR SECTOR TO MAINTAIN TRACKS – **SIMULTANEOUS TRACK & SEARCH**
- DATA RATE : MODERATE
- CAN TRACK A NUMBER OF TARGETS.

EQUIVALENT OF TRACK WHILE SCAN IS **ADT :**

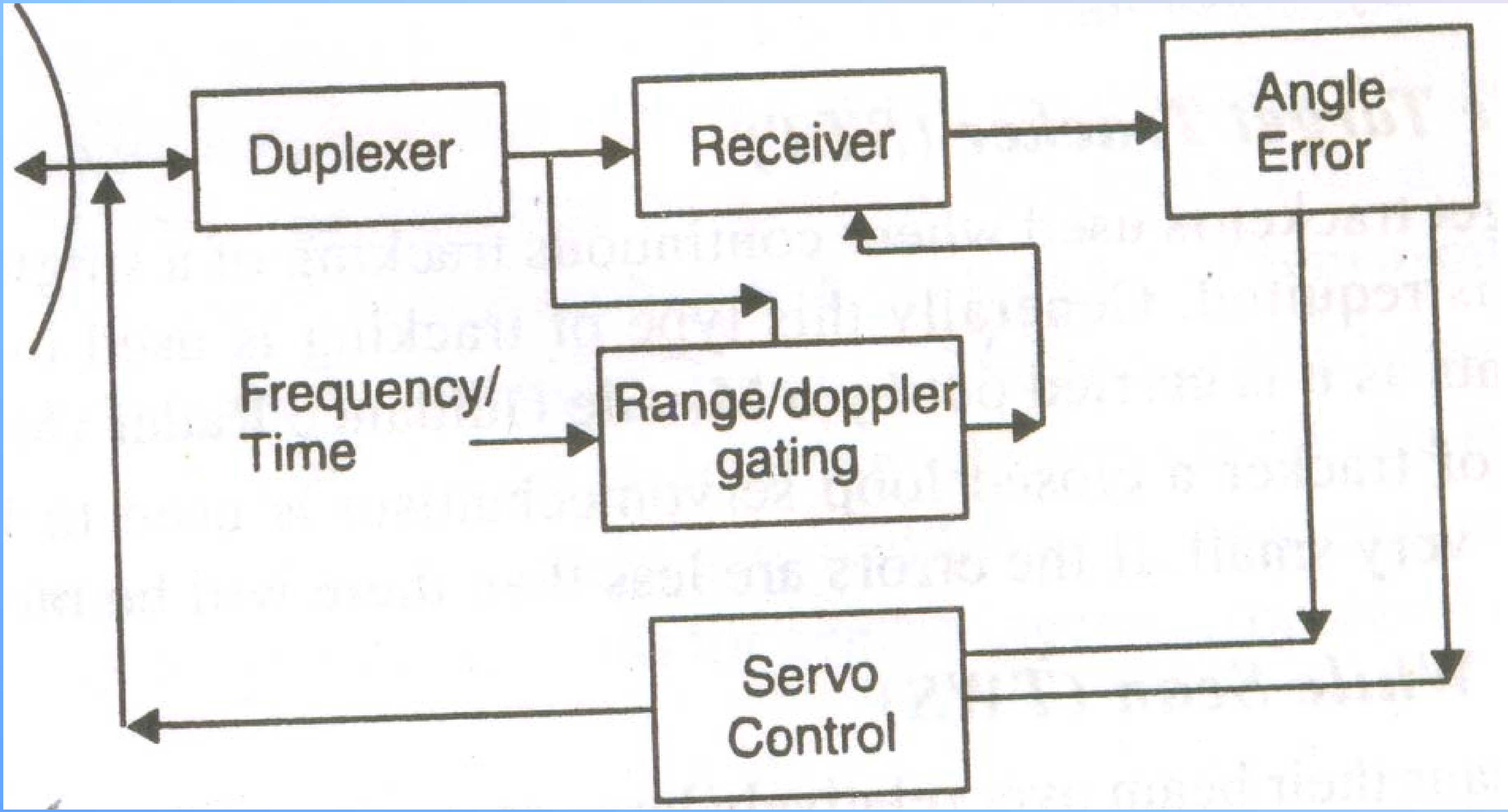
- TWS RADAR IS USED TO RAPIDLY SCAN A NARROW ANGULAR SECTOR, USUALLY IN BOTH AZIMITH & ELEVATION.
- SCANNING CAN BE PERFORMED WITH A SINGLE, NARROW BEAMWIDTH PENCIL BEAM; OR WITH TWO ORTHOGNAL FAN BEAMS (ONE FOR AZIMUTH AND THE OTHER FOR ELEVATION)

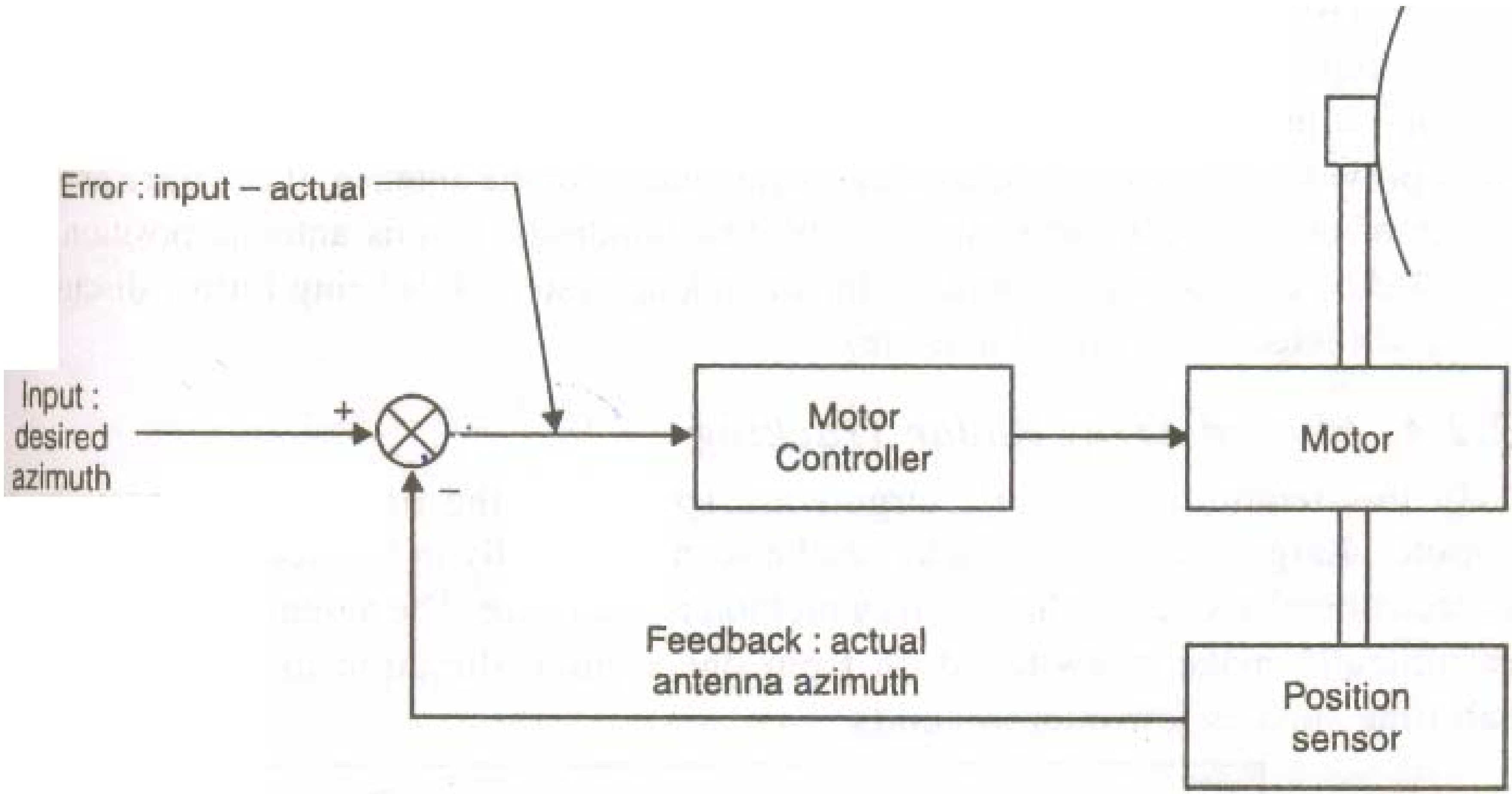
LOBE SWITCHING



- THE DIFFERENCE BETWEEN THE TWO AMPLITUDES GIVES THE LOCATION OF THE TGT WRT ANT. AXIS.
- THE AMPLITUDE AND THE SENSE OF ERROR SIGNAL CAN BE USED TO GENERATE THE CORRECTIVE SIGNAL WHICH WITH THE HELP OF SERVO CONTROL CAN BE USED TO MOVE THE ANTEENA SO AS TO BRING THE TARGET ON THE ANTENNA AXIS.
- DISADVANTAGE : LOSES EFFECTIVENESS WHEN TGT X-SECTION CHANGES BETWEEN DIFF. RETURNS.

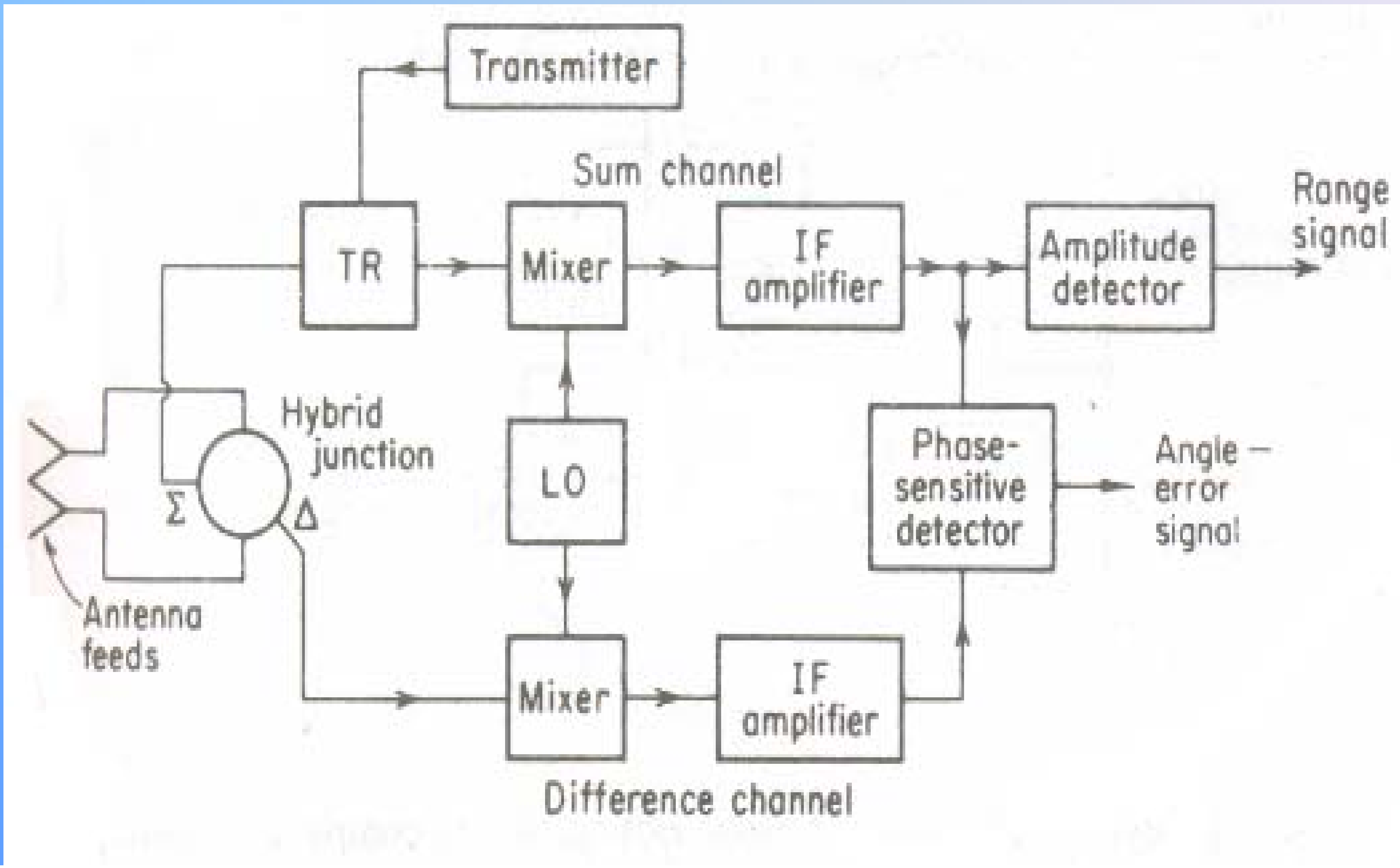
TRACKING & RADAR – BLOCK DIAGRAM





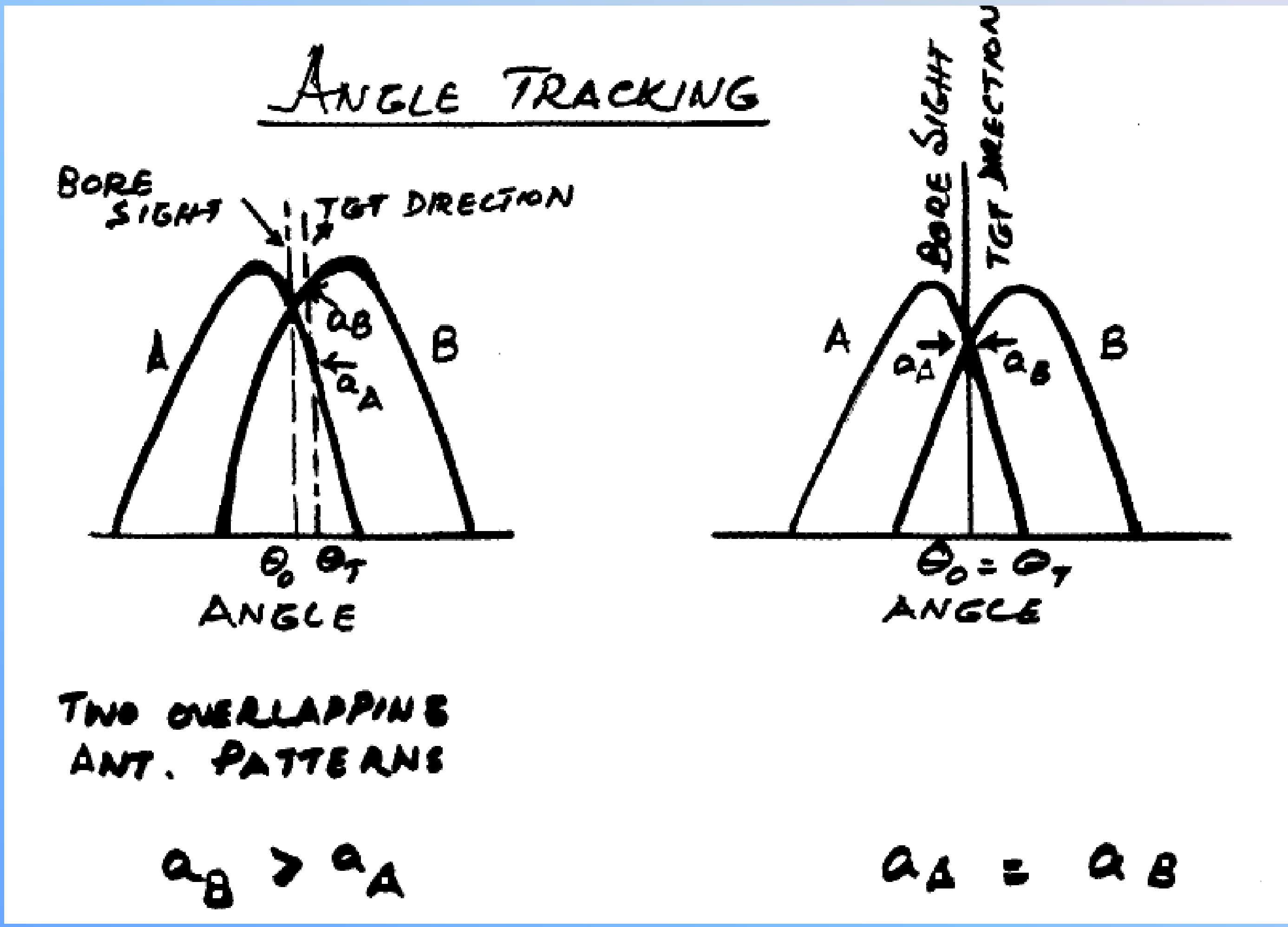
Servo mechanism.

BLOCK DIAGRAM – AMP COMPARISION MONOPULSE RADAR – SINGLE COORDINATE



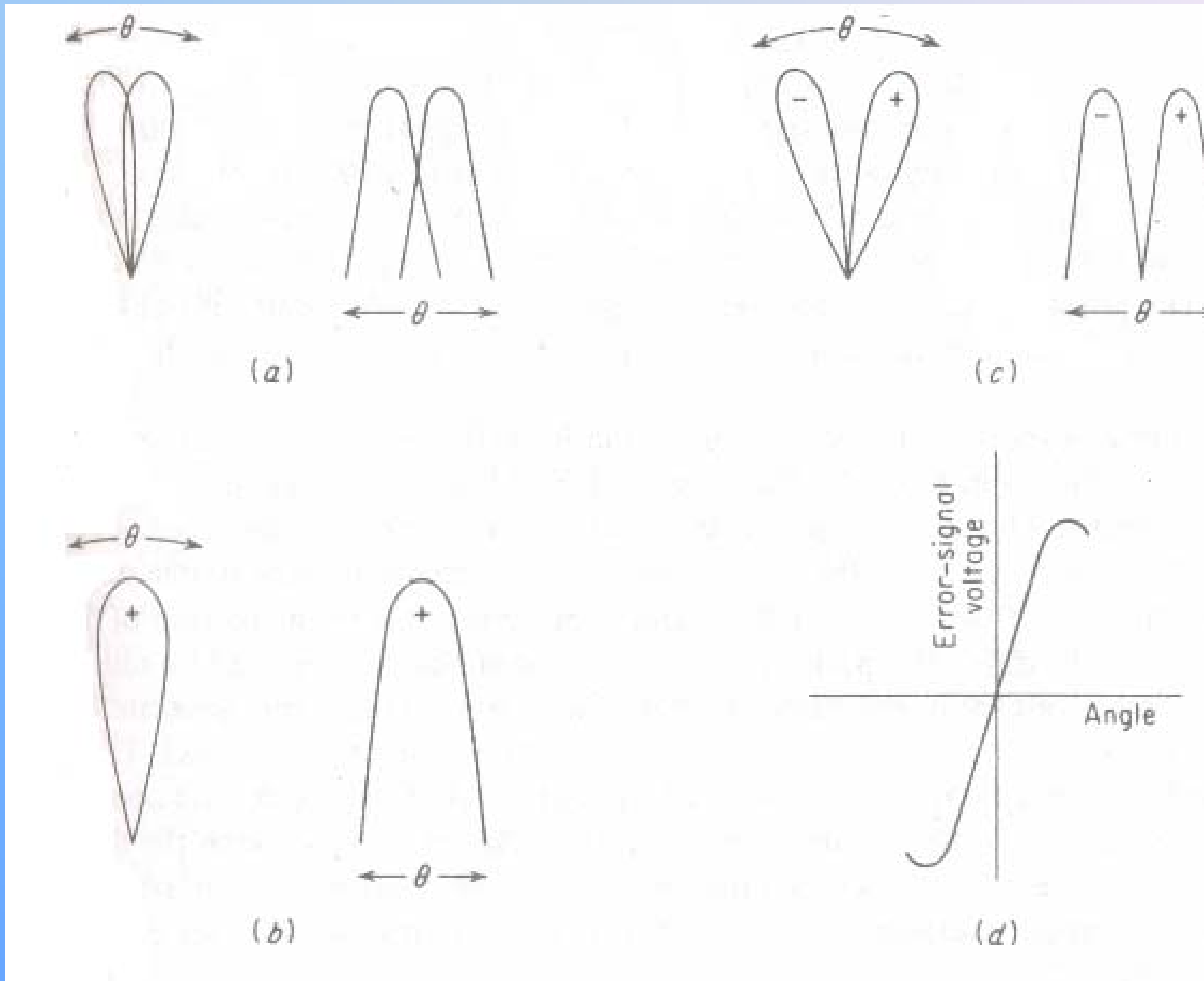
- SIGN OF O/P OF PHASE SENSITIVE DETECTOR INDICATES THE DIRECTION OF THE ANGLE ERROR RELATIVE TO THE BORESIGHT.
- **ANGLE ERROR ; MAGNITUDE IS PROVIDED BY THE DIFFERENCE PATTERN.**
- **DETECTION & RANGE : PROVIDED BY SUM SIGNAL.**
- SUM SIGNAL ALSO ACTS AS A REFERENCE FOR DETERMINING THE SIGN OF THE ANGLE MEASUREMENT.

ANGLE TRACKING



ANGLE TRACKING

- BEAM SHOULD BE MOVED TO THE RIGHT TO COINCIDE BORESIGHT & TGT POSITIONS.
- BORESIGHT POSITION Φ_0 IS LOCATED IN THE DIRECTION OF THE TARGET.
- THE ABOVE TWO BEAMS ARE SAID TO BE SQUINTED WITH A SQUINT ANGLE RELATIVE TO BORESIGHT DIRECTION.
- BORESIGHT DIRECTION : CROSSOVER OF 2 BEAMS.
- **AIM IS TO POSITION THE 2 BEAMS SO THAT $\Phi_0 = \Phi_T$ (TGT ON THE BORESIGHT)**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Error-signal voltage
Angle
(a)
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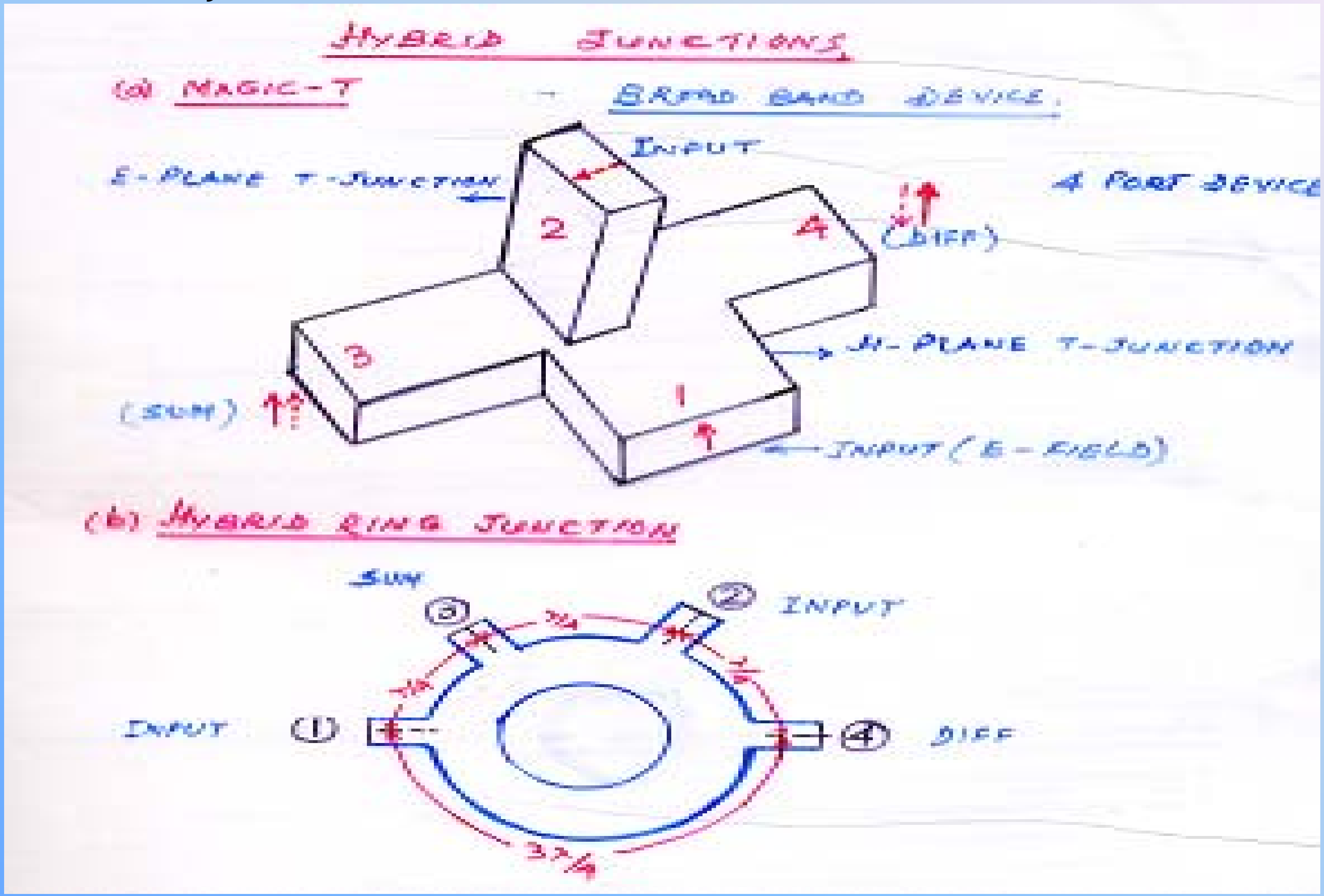
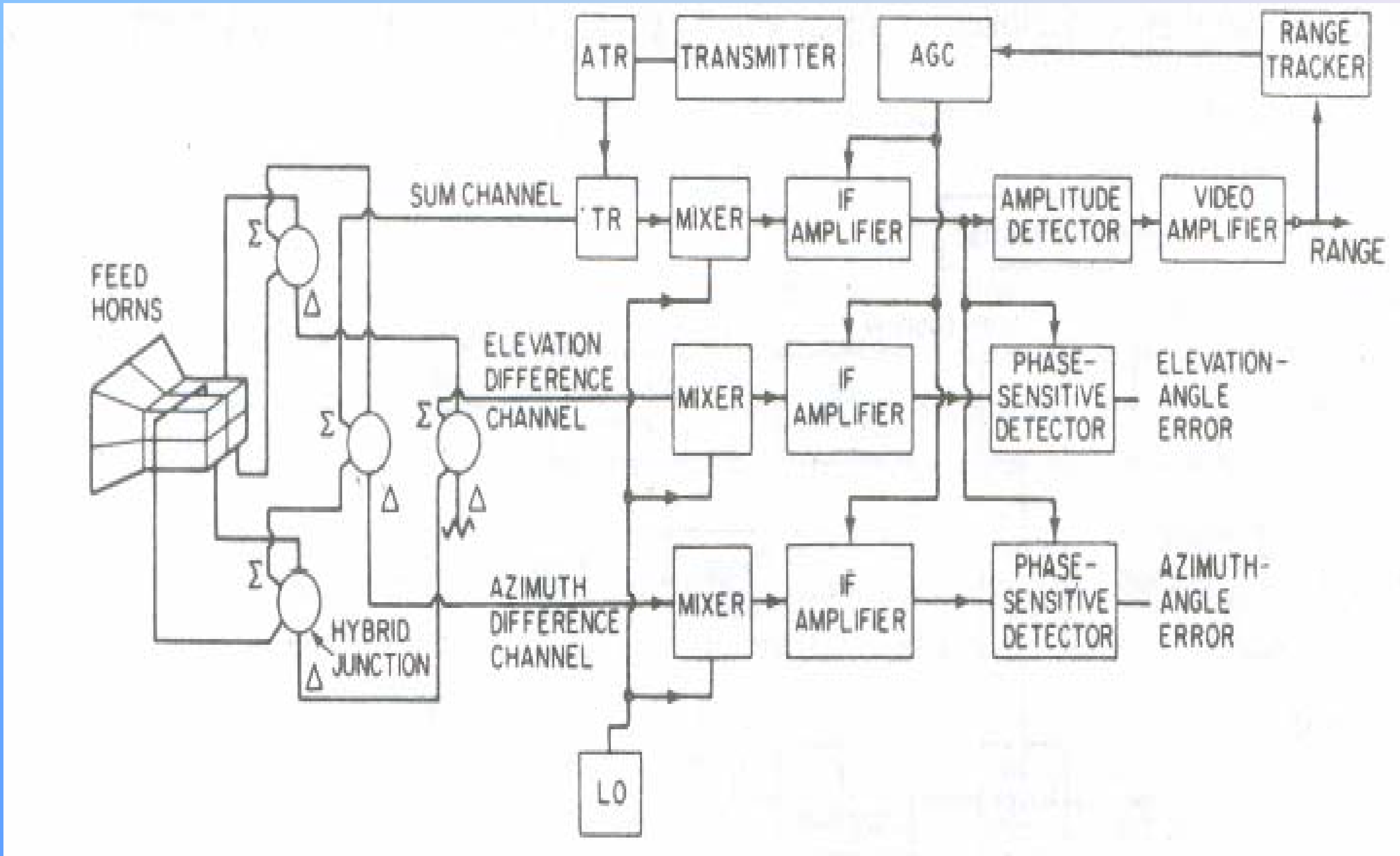
HYBRID JUNCTIONS



OPERATION DEPENDS ON LENGTHS BETWEEN PORTS AND HENCE THE DEVICE IS FREQ. SENSITIVE

TWO COORDINATE MTR (AMP COMPARISON)



SUM PATTERN : A+B +C +D

AZIMUTH DIFF. PATTERN : (A+B) – (C +D)

ELEVATION DIFF. PATTERN : (B+D) – (A+C)

AGC ENSURES THAT ANGLE – ERROR SIGNAL IS NOT EFFECTED BY CHANGES IN SIG. AMPLITUDE.

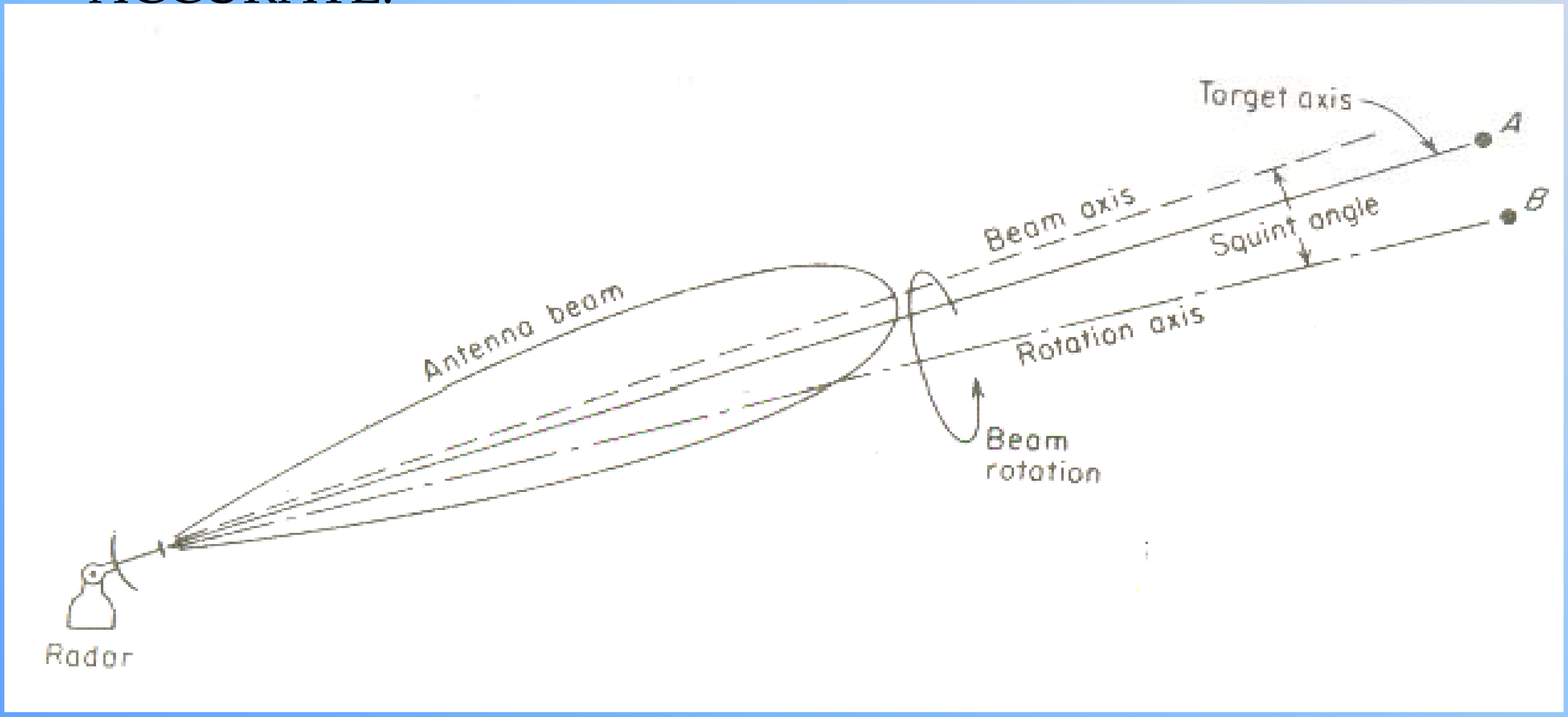
LIMITATIONS TO TRACKING ACCURACY

- GLINT/ANGLE NOISE/TGT NOISE
- RECEIVER NOISE
- AMPLITUDE FLUCTUATIONS OF TGT ECHO
- OTHERS (MECH PROPERTIES OF ANT, SERVO SYSTEM ETC)
- **GLINT OCCURS WITH COMPLEX TGTS WHICH HAVE MORE THAN ONE SCATTERING CENTRE (AIRCRAFT)**
- ECHOS FROM MULTIPLE SCATTERERS ARRIVE AT ANTENNA WITH SLIGHTLY DIFF. WAVE TILTS.

- GLINT FROM A COMPLEX TGT CAUSES DISTORTION OF THE ECHO WAVE FRONT; RESULTING IN AN ERROR IN THE MEASUREMENT OF ANGLE OF ARRIVAL
- GLINT SOMETIMES CAN CAUSE **BREAK TRACK**.
- **BREAK- TRACK OCCURS WHEN THE BORESIGHT OF THE TRACKING ANTENNA POINTS OUTSIDE THE ANGULAR EXTENT OF THE TARGET.**
- GLINT IS A MAJOR SOURCE OF ERROR, WHEN MAKING ANGLE MEASUREMENTS, ESPECIALLY AT SHORT RANGES.

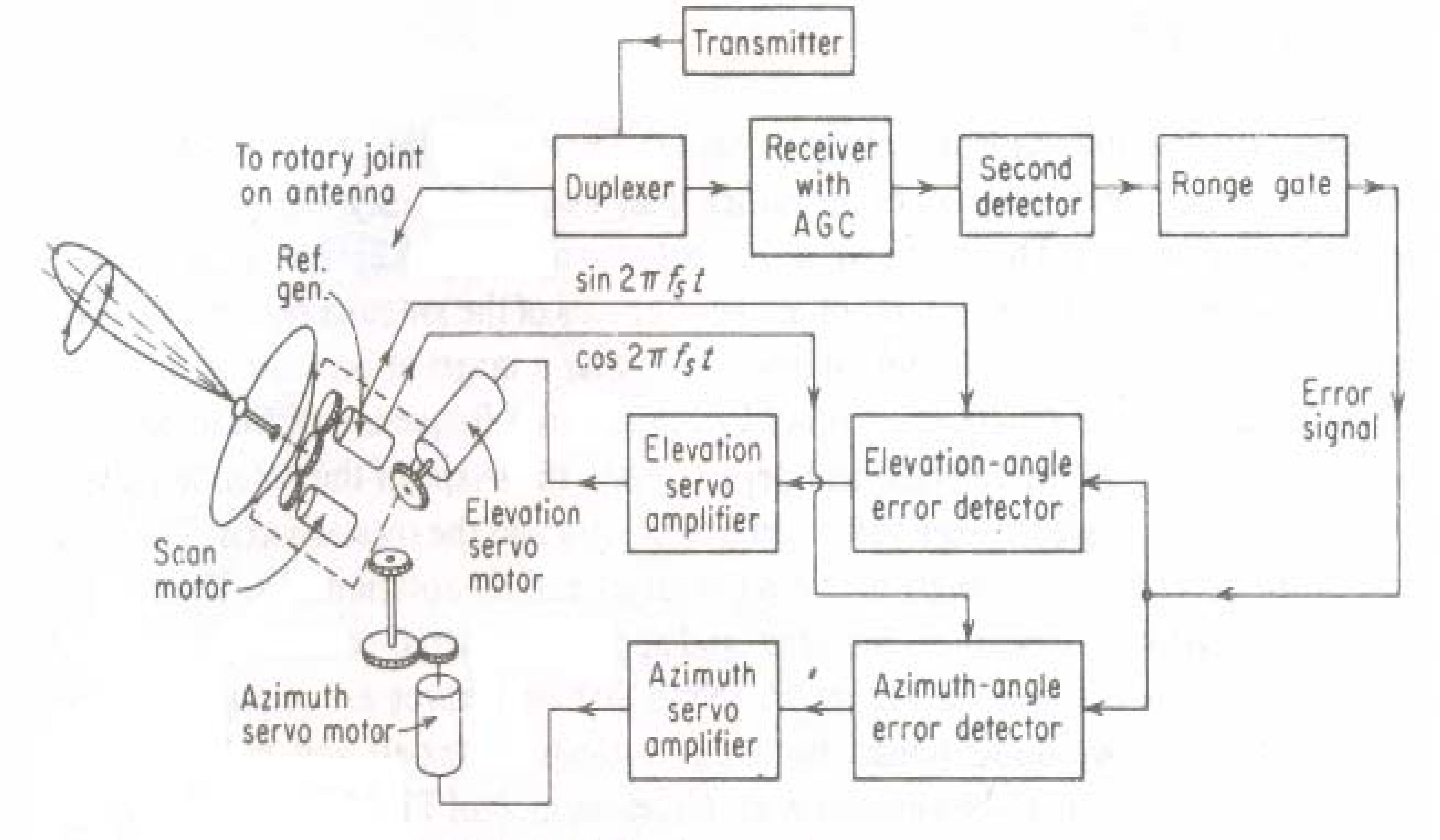
CONICA SCAN (CON - SCAN) & SEQUENTIAL LOBING

- A SINGLE ANTENNA BEAM IS TIME SHARED TO OBTAIN THE ANGLE MEASUREMENT IN A SEQUENTIAL MANNER
- TIME SHARING A SINGLE ANT. BEAM IS SIMPLER ,USES LESS EQPT THAN SIMULTANEOUS BEAMS BUT IT IS NOT AS ACCURATE.



- **SQUINT ANGLE – IT IS THE ANGLE BETWEEN THE AXIS OF ROTATION AND THE ANTENNA BEAM AXIS**
- A – TARGET LOCATION
- B – ON ROTATION AXIS
- SINCE THE TARGET IS OFFSET FROM THE ROTATION AXIS, ROTATION OF THE BEAM CAUSES MODULATION OF THE AMP. OF ECHO SIGNAL AT A FREQUENCY EQUAL TO BEAM ROTATION FREQ.(CONICAL SCAN FREQ)

CONICAL SCAN TRACKING RADAR



CONICAL SCAN TRACKING RADAR(contd)

- TYPICAL CONICAL – SCAN ROTATION SPEED MIGHT BE 30 REV/SEC
- **NUTATING FEED** – IT MAINTAINS THE PLANE OF POLARISATION
- **ROTATING FEED** – IT CAUSES THE PLANE OF POLARISATION TO ROTATE.
- **NUTATING FEED IS PREFERED** !!

COSRO – CONICAL SCAN ON RECEIVE ONLY

- MILITARY CONICAL – SCAN AND LOBE SWITCHING TRACKING RADARS ARE VULNERABLE TO ECM, SINCE CONICAL SCAN FREQ CAN BE DETERMINED EASILY.
- A HOSTILE ECM JAMMER CAN DISRUPT CONICAL – SCAN TRACKING OF RADAR BY RETRANSMITTING THE RECEIVED RADAR SIGNAL WITH AN AMP. MODULATION THAT IS THE INVERSE OF CONICAL SCAN FREQ.

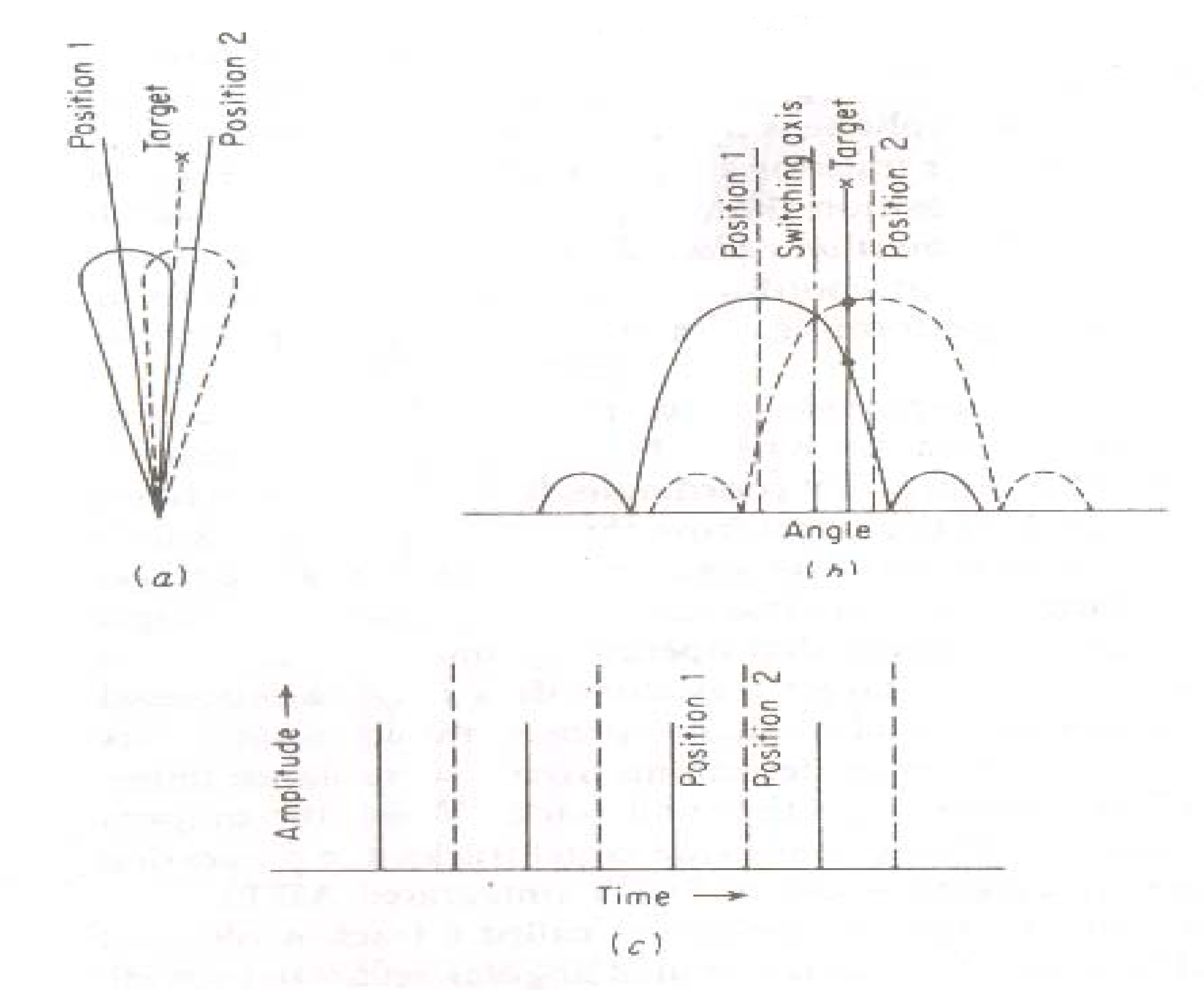
COSRO(contd)

- THIS TYPE OF COUNTERMEASURE IS CALLED **INVERSE GAIN** AND CAN DEGRADE CONICAL SCAN TRACKING OR LOBE SWITCHING TRACKING SYSTEMS

COSRO (contd)

- REMEDY (TO AVOID DETECTION OF CONICAL SCAN FREQ BY ECM JAMMER)
- **TRACKING RADAR ILLUMINATES THE TARGET WITH NON – SCANING BEAM AND APPLY CONICAL SCANNING ON RECEIVE ONLY**
- HENCE THE NAME **COSRO**
- ANALOGOUS OPERATION WITH SEQUENTIAL LOBING IS CALLED **LORO (LOBE ON RECEIVE ONLY)**

CONICAL SCAN SEQUENTIAL LOBING. LOBE SWITCHING ANTENNA PATTERNS



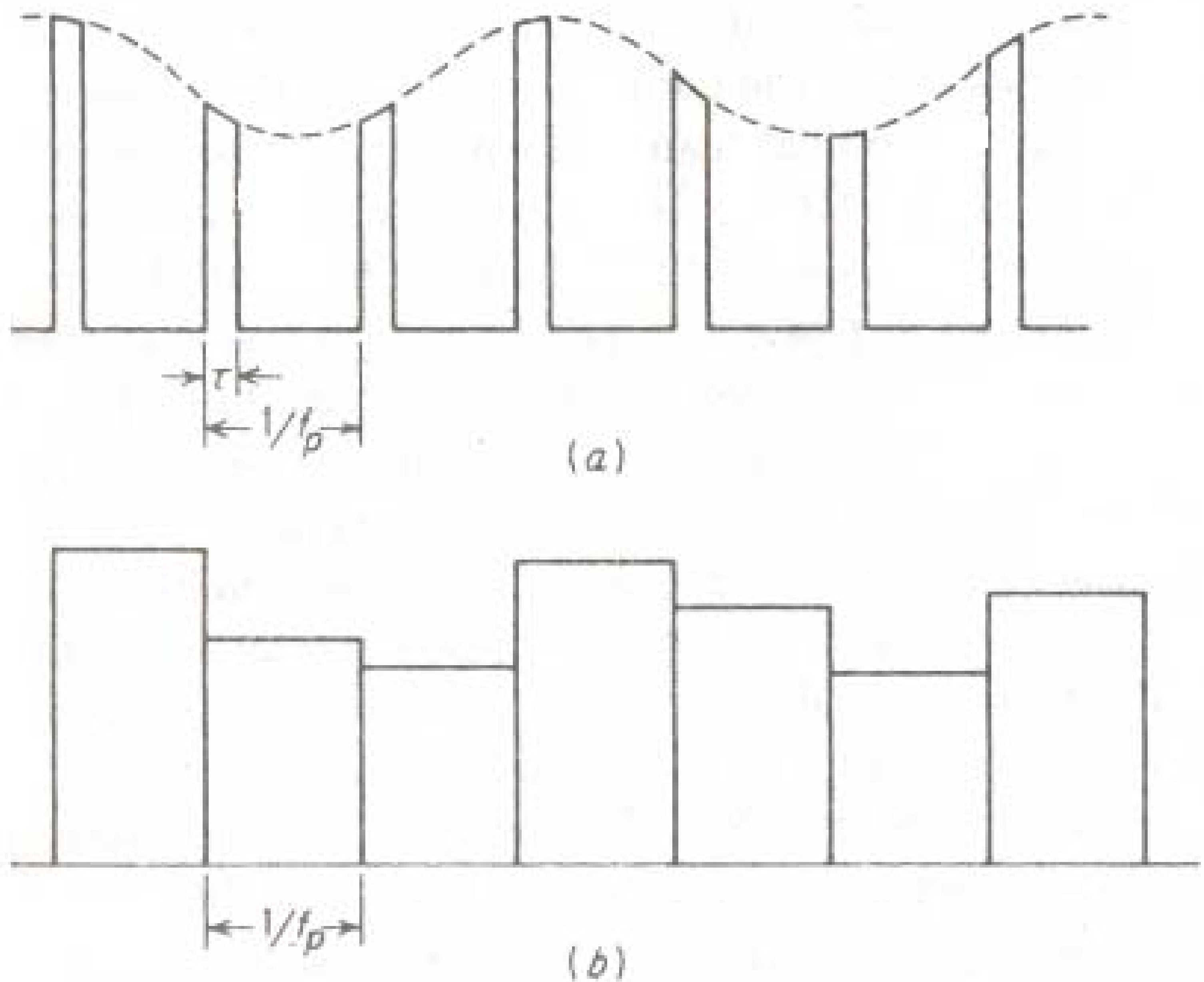
CONICAL SCAN (CONTD)

THE DIFFERENCE IN AMPLITUDE BETWEEN THE VOLTAGES OBTAINED IN THE TWO SWITCHED POSITIONS IS A MEASURE OF ANGULAR DISPLACEMENT OF THE TGT FROM THE SWITCHING AXIS.

- THE DIRECTION IN WHICH TO MOVE THE BEAM TO BRING THE TGT ON THE BORE SIGHT IS FOUND BY OBSERVING WHICH BEAM POSITION HAS THE LARGER SIGNAL.

SAMPLE AND HOLD CKT

- IT IS CONVENIENT TO STRETCH THE PULSES BEFORE LOW PASS FILTERING SO AS TO INCREASE THE ENERGY AT THE CONICAL SCAN FREQ AND TO PERFORM ANALOG TO DIGITAL CONVERSION.
- THIS PULSE STRETCHING IS DONE BY A SAMPLE AND HOLD CIRCUIT.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1/f_p
(a)
1/f_p
(b)

SAMPLE AND HOLD CKT

- PRF MUST BE SUFFICIENTLY LARGE COMPARED WITH CONICAL SCAN FREQ FOR PROPER FILTERING AND AVOIDING INACCURACY OF THE ANGLE MEASUREMENT
- THERE MUST BE ATLEAST 4 PULSES DURING EACH REVOLUTION OF THE CONICAL SCANNING BEAM SO AS TO OBTAIN UP –DOWN AND RIGHT-LEFT COMPARISONS

CONICAL SCAN

- PRF MUST BE ATLEAST 4 TIMES THAT OF CONICAL SCAN FREQUENCY; BUT IT IS PREFERABLE THAT IT BE MORE THAN 10 TIMES GREATER

COMPARISON –TRACKERS

- 1. **S/N RATIO-** IT IS GREATER IN MONOPULSE RADAR THAN IN CONICAL SCAN RADAR
- IT IS BECAUSE IN **MONOPULSE,** ANTENNA VIEWS TARGET **AT THE PEAK OF ITS SUM PATTERN**.
- **CONICAL SCAN** RADAR VIEWS THE TGT AT SOME ANGLE **OFF THE PEAK OF THE ANTENNA BEAM**
- .

COMPARISON –TRACKERS

- 2. **ACCURACY** : HIGHER IN MONOPULSE (DUE TO 1) IN RANGE AS WELL AS ANGLE
- 3. **COMPLEXIT Y** : MONOPULSE RADAR IS MORE COMPLEX, DUE TO RF COMBINING CIRCUITARY AT THE ANTENNA & 3 RECEIVING CHANNELS

COMPARISON –TRACKERS (contd)

- CONICAL SCAN RADAR HAS ONLY ONE RECEIVING CHANNEL & USES A SINGLE FEED.
- HOWEVER, DUE TO SOLID STATE AND DIGITAL TECNOLOGY, COMPLEXITY IS SELDOM A REASON FOR NOT CHOOSING MONOPLUSE.
- 4. MINIMUM NO OF PULSES **: MONOPULSE – SINGLE PULSE**
- CONICAL SCAN RADAR REQUIRES A MINIMUM OF 4 PULSES PER REVOLUTION OF THE BEAM, TO EXTRACT AN ANGLE MEASURMENT IN TWO COORDINATES.

COMPARISON –TRACKERS (contd)

5. MONOPLUSE FIRST MAKES ANGLE MEASUREMENT AND THEN INTEGRATES A NUMBER OF MEASUREMENTS TO OBTAIN THE REQUIRED S/N RATIO

CONICAL SCAN RADAR, INTEGRATES A NUMBER OF PULSES FIRST, AND THEN EXTRACTS THE ANGLE MEASUREMENT

COMPARISION TRACKERS (CONTD)

- .
- **6 . SUSCEPTIBILITY TO ECM**
- CONICAL SCAN RADAR IS MORE SUSCEPTIBLE TO ECM,
- A WELL – DESIGNED MONOPULSE TRACKER IS MUCH HARD TO DECEIVE.

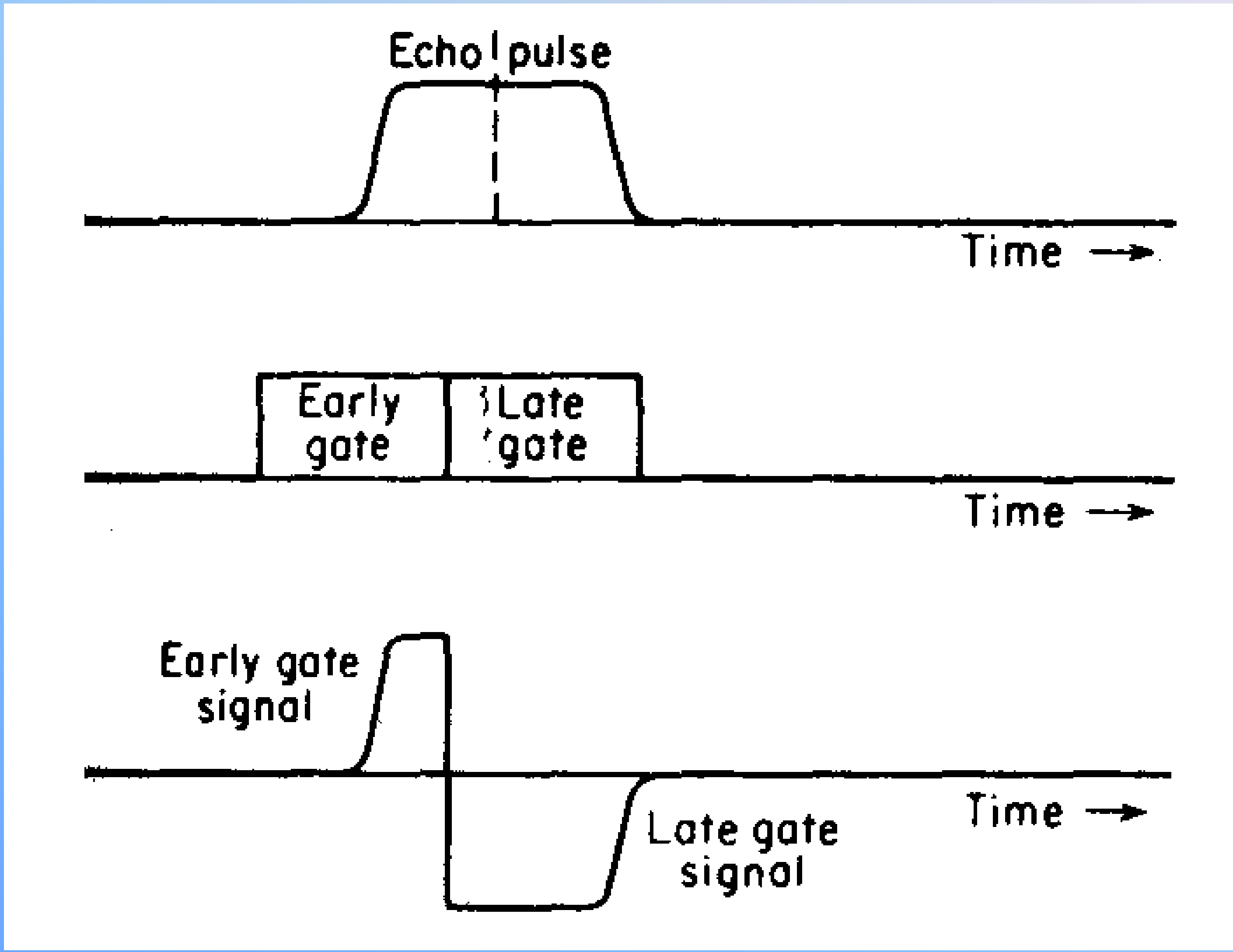
COMPARISION TRACKERS (CONTD)

- **APPLICATION- MONOPULSE**
- MONOPULSE TRACKERS ARE USED WHEN GOOD ANGLE ACCURACY IS REQUIRED AND
- WHEN SUSCEPTIBILITY TO ECM IS TO BE MINIMISED.
- **APPLICATION – CONICAL SCAN TRACKER**
- IT IS USED BECAUSE OF LOWER COST AND REDUCED COMPLEXITY.

TRACKING IN RANGE

- MANUAL TRACKING OF EARLIER DAYS HAS BEEN REPLACED BY CLOSED LOOP AUTOMATIC TRACKING, SUCH AS SPLIT GATE TRACKER.

TRACKING IN RANGE



TRACKING IN RANGE (CONTD)

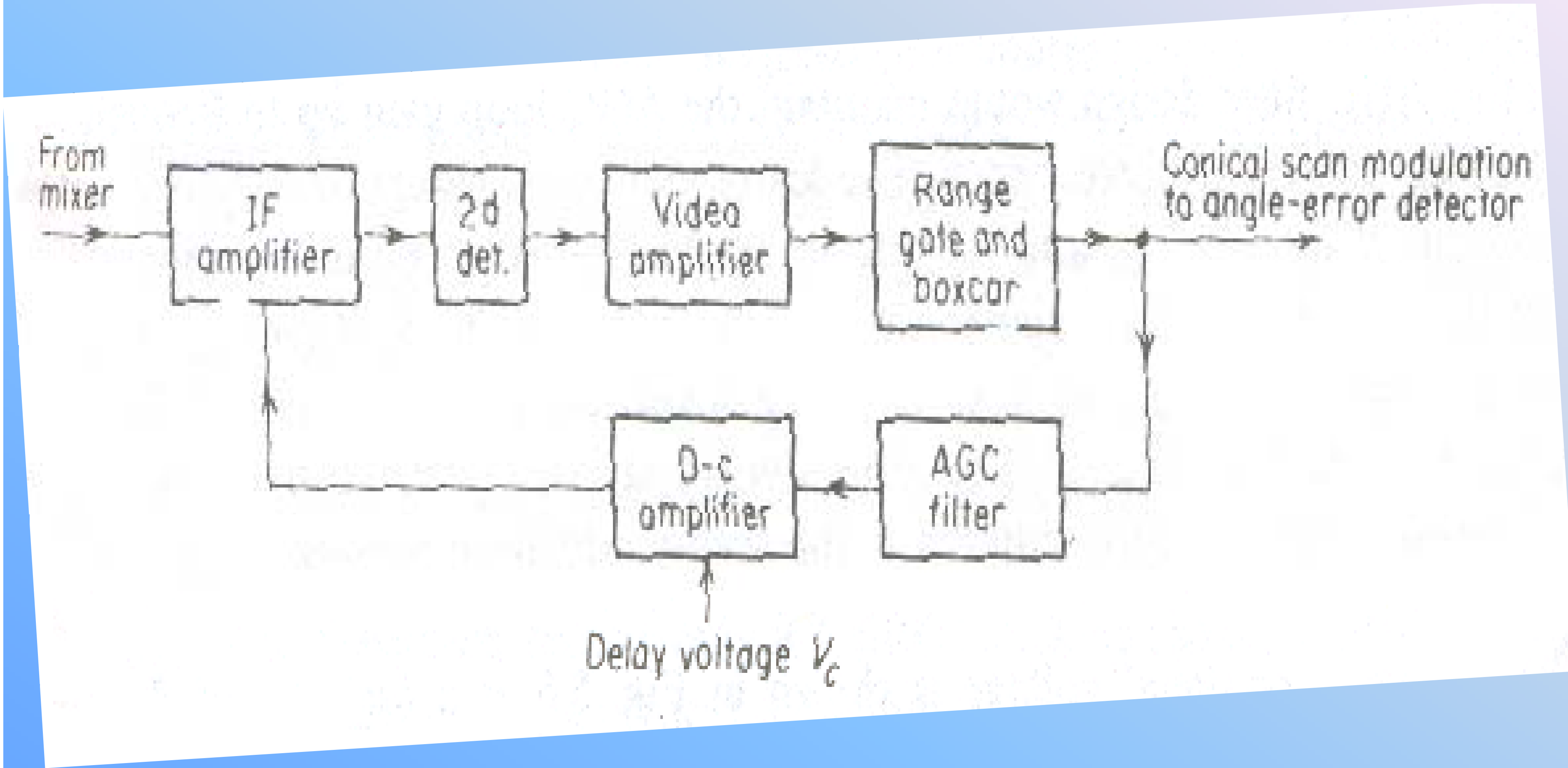
- PORTION OF THE SIGNAL IN EARLY GATE IS LESS THAN THAT OF THE LATE GATE.

- THE SIGNALS IN THE TWO GATES ARE SUBTRACTED TO PRODUCE THE DIFFERENCE ERROR SIGNAL

- **THE AMP OF THE DIFF. DETERMINES HOW FAR THE PAIR OF GATES ARE FROM THE CENTRE OF THE PULSE.**

AUTOMATC GAIN CONTROL

- PURPOSE : TO MAINTAIN CONSTANT ANGLE – ERROR SENSITIVITY IN SPITE OF AMPLITUDE FLUCTUATIONS OR CHANGES OF ECHO SIGNAL DUE TO CHANGE IN RANGE
- **AGC SIGNAL→ NEGATIVE DC VOLTAGE PROPORTIONAL TO PEAK SIGNAL VOLTAGE**
- CONSTANT ANGLE – ERROR SENSITIVITY PROVIDES STABLE TRACKING.
- AGC AVOIDS SATURATION BY LARGE SIGNALS
- AGC ALSO ATTEMPTS TO REMOVE THE NOISE – LIKE AMPLITUDE OF THE TGT ECHO SIGNAL.


From mixer
IF amplifier
2d det.
Video amplifier
Range gate and boxcar
Conical scan modulation to angle-error detector
D-c amplifier
AGC filter
Delay voltage V_c

AGC (contd)

- HOWEVER THE GAIN OF THE AGC LOOP SHOULD NOT BE SO MUCH SO AS TO SUPPPRESS THE ERROR SIGNAL.
- THE REQUIRED DYNAMIC RANGE FOR AGC WILL DEPEND ON THE VARIATION IN RANGE OVER WHICH TARGETS ARE TRACKED AND THE EXPECTED VARIATION IN TGT. CROSS SECTION.

AGC (contd)

- EX : RANGE VARIATION = 40 DB
- σ VARIATION = 40 DB
- VARIATION IN RADAR =N PARAMETERS = 10 DB
- DYNAMIC RANGE (FOR RX AGC) = 90 DB

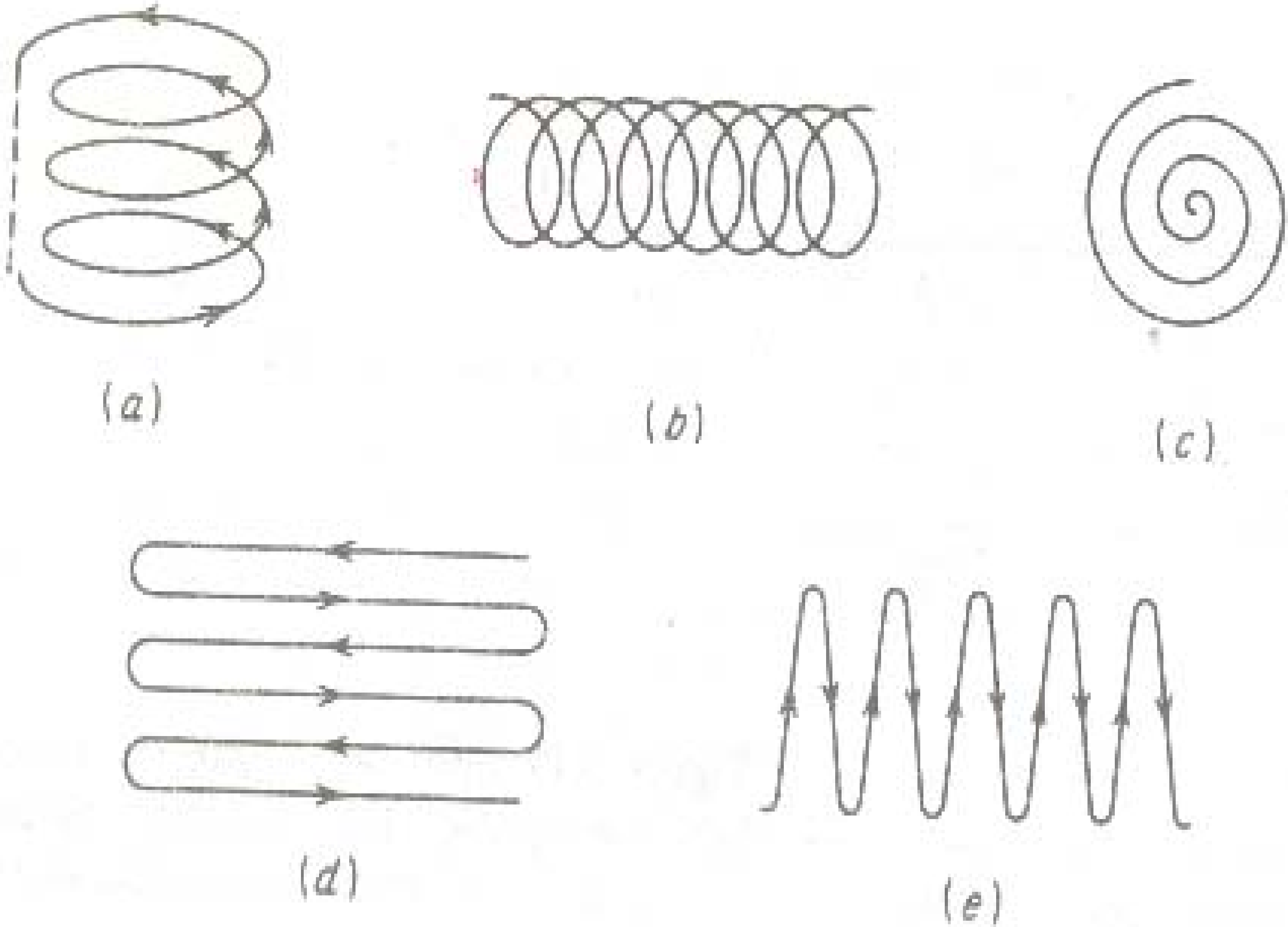
ACQUISITION

- A TRACKING RADAR MUST FIRST FIND AND ACQUIRE ITS TARGET BEFORE IT CAN OPERATE AS A TRACKER.
- SEARCH MUST BE DONE WITH CARE TO COVER THE ENTIRE VOLUME UNIFORMLY AND EFFICIENTLY.

TYPES OF SCANNING PATTERNS

HELICAL SCAN (Fig a)

- ANTEENA IS CONTINOUSLY ROTATED IN AZIMUTH AND LOWERED IN ELEVATION.


(a)
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(c)
(d)
(e)

PALMER SCAN (Fig b)

IT CONSISTS IN RAPID CIRCULAR SCAN (CONICAL SCAN) ABOUT AXIS OF THE ANTEENA, COMBINED WITH A LINEAR MOVEMENT OF THE AXIS OF ROTATION. IT IS SUITED TO SEARCH AREA WHICH IS LARGER IN ONE DIMENSION THAN ANOTHER.

- SPIRAL SCAN (Fig c) :

THIS SCAN COVERS AN ANGULAR SEARCH VOLUME WITH CIRCULAR SYMMETRY.

BOTH SPIRAL SCAN & PALMER SCAN SUFFER FROM THE DISADVANTAGE THAT ALL PARTS OF THE SCAN VOLUME DO NOT RECEIVE THE SAME ENERGY(UNLESS SCANNING SPEED IS VARIED DURING THE SCAN CYCLE).

RASTER/TV SCAN (Fig d)

- IT PAINTS THE SEARCH AREA IN A UNIFORM MANNER.
- IT IS A CONVENIENT MEANS FOR SEARCHING A LIMITED SECTOR, RECTANGULAR IN SHAPE.

NODDING SCAN (Fig e)

- IT IS PRODUCED BY OSCILLATING THE ANTEENA BEAM RAPIDLY IN ELEVATION AND SLOWLY IN AZIMUTH.
- IT IS USED TO COVER A LIMITED SECTOR (LIKE RASTER SCAN) AS WELL AS TO OBTAIN A HEMISPHERICAL COVERAGE (ELEVATION ANGLE UP TO 90^0 AND AZIMUTH SCAN ANGLE UPTO 360^0)
- USED IN HEIGHT FINDING RADARS.