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Recent trends and advancements in Radar Communication systems: A Review

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ABSTRACT
Radar (Radar detection and Ranging) plays an important and inevitable role for Modern Tele Communications in the areas of Electronic Warfare(EW),Air Traffic Management, Ground Surveillance, other Military applications, Speed Detection etc. All this systems requires to have high power gain, Adaptive beamforming, Faster scanning Rate, Low probability of detection, High reliability, Less Maintenance cost, Capability of performing multiple tasks. Many of the modernized Radar systems/techniques are replacing the old systems. This review will give the comprehensive outlook of Radar system, its advancements and recent trends. This paper represents the modern Radar systems like Passive Radars, 3D Radars, Advanced scanning Methods; GNSS based landing Systems, Automotive Radar and Satellite Tracking Radar in brief.

Keywords: AESA, PESA, EW, GBAS, LIDAR, M-LAT, GNSS, GPS, PSR, SSR, ILS, WAM, TDOA, ATC, ADS-B, ADAS, FMCW

1. INTRODUCTION
Radar is used to track the speed, Range and Direction of the aircraft, Ship etc. There are several functions of Radar. To know the modern advancements in Radar Systems one must know its evolution. In fact, it came across several steps .Doppler, Maxwell and Hertz are the scientists who sowed the seeds for improvements for early days Radar. By following maxwell's theoretical concepts about EM waves hertz illustrated the existence of electromagnetic waves, he identified that EM Waves are reflected by metallic items. Within the framework of his experiments he used unique reflectors. In 1904, the German technician Hülsmeyer performed the first detection experiments using radar waves. While experimenting with Hertz's reflector, he noticed that electric powered waves that have been emitted from a transmitter and contemplated by using a metallic floor may be used to hit upon remote metal objects.

In the year of 1921 Magnetron was invented by the US-American physicist Albert Wallace Hull. In the year of 1930, Lawrence A. Hyland, located an aircraft for the first time by using Radars[23]. In the year of 1936, Klystron(Microwave oscillator/amplifier) developed by the technicians George F. Metcalf and William C. Hahn.In the year of 1939,Multicavity–Magnetron was invented by John Turton Randall and Henry Albert Howard Boot both are from the university of Birmingham. After world war-2, plenty of research deployed towards different types of Radar systems both for civilian

and military applications. Early Monopulse, MTI, Doppler, SAR Radars are developed during 1960s.

Phased Array Radars ,Ballistic missile defense and satellite surveillance Radars were developed during 1975s.After the evolution of digital techniques more advancements came in to Radar manufacturing markets after 1990's. As, microwave technology moving towards millimeter wave technology the Global Air Navigation Plan(GANP) keep on searching and predicting the possibilities for the implementations for the new low cost efficient alternative surveillance techniques like ADS-B MLAT systems and MIMO systems.
The existing systems like MSSR and Mode S Radars are going to be the backup systems for the emerging surveillance techniques .Most of the Aircrafts are enabled with ADS-B/Output Transponders in order to avail the ADS-B Surveillance systems.

2. MODERN RADARS

2.1 Passive Radars-M-LAT

Mutilatertaion system will replace the conventional Secondary Surveillance Radar(SSR)soon. Based on the principle of time difference of arrival (TDOA) it works[21]. With a Wide area Multilateration system it is highly possible to replace SSR and ATC(Air Traffic center) greatly. Multilateration normally consists of a number of ground stations, which are kept in effective locations around an airport, its local terminal area or a wider area to cover the larger surrounding airspace. Passive Radars are utilizing the several receivers and track the position, range and speed of an objects which is to be tracked. Unlike the Normal Radars(Active Radars),Passive Radars are continuously receiving the signal from other electromagnetic sources and can use the sources like commercial FM Radio(nearly 100 MHz) and Digital TV Transmitters(Nearly 600MHz), cell telephone base stations, GPS signals, and Wifi have also been used for passive radar.

Active Radars Can be Monostatic or Multistatic. But Passive radars definitely not be a Monostatic. Conventional Radar detectors and Radar Waning receivers(RWR) are the examples of Passive Radar. MLAT do not want to use specialized equipment's to implement the same. It uses Airport transponder signal to estimate aircrafts range.It needs of minimum four Receiver stations. MLAT have been implementing by the different countries across the world. To facilitate the A-SMGCS(Advanced –Surface movement Guidance and control systems) MLAT/SMR(surface Movement Radar)must be implemented in all the airports.

2.2 AESA VS PESA

Active electronically scanned array (AESA)technique is providing many technological advantages over to PESA(Passive Electronically Scanned Array).AESA is eradicating the need of a Radar Warning Radar[8]. This technique enables the high resistance to jamming as it creates the number of frequency concurrently within the seconds even[3]. The differences between this two methods are given below[17[24]

PESA Radar	AESA Radar
All the Antenna Modules (Transmitter/Receiver)are operating at a single frequency.	Each Antenna Modules can generate different frequency. Attaining wide bandwidth is easier here.
Though Multiple threats tracking	Multiple threats can

is possible efficiency is not same like AESA.	be tracked continuously.
Susceptible for Jamming	Susceptible for less Jamming as it creates 100 different frequency at a second. Can be much useful for offensive Electronic Warfare(EW)

Table 1: AESA Radar vs PESA Radar.

Modern Jet Fighters are enabled with AESA Radars[20].

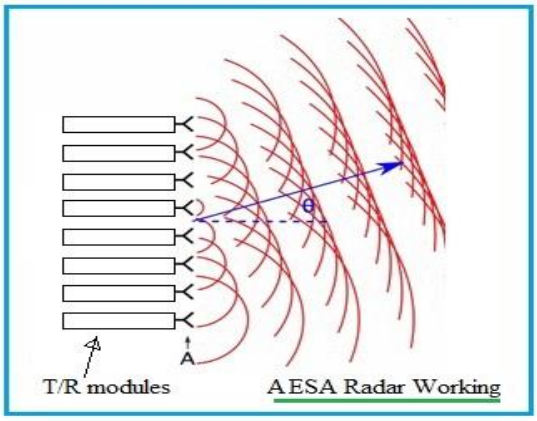

Fig 1:AESA Radar working principle.

2.3 3D Radars

3D Radars are being an adaptive Radar in terms of beam width, clutter reduction, PRF usage. 3D Radars provides three dimensional tracking and enables the higher accuracy and resolution as it uses in the field of defense. This Radars can be as a Primary and Secondary. 3D Radar uses very narrow pencil beams. Here Antenna elevation is keep on changing in order to scan the assigned area. This Radars are suitable for Military purposes and weather monitoring purposes. Currently in the market three dimensional LRR(Long Range Radar),MRR(Medium Range Radar) and LTR (Long Range Tactical Systems)and ARSR(Air Route Surveillance Radar) are available[6].

LTR Radar Range coverage is in the range of 210 NM to 240 NM. Furthermore, ARSR can be useful for Air traffic and primary surveillance purpose with range of 100NM to 200 NM. It provides an integrated early warning air defense system. As the technology moves toward millimeter waves there is a need of designing Antennas for Massive MIMO Radars also highly significant.

MIMO radars consists of 256 Antennas and can provides the continuous beam forming .There is huge need of Full dimension MIMO that means it has to radiate the beams vertically and horizontally.3D FD-MIMO will be very much helpful to the next generation millimeter technology

even for 5G Mobile networks effectively. The special type of beam forms also playing an important role here[13].

2.4 LIDAR based Speed Detection

For speed detection, Doppler based continuous Wave (CW)Radar being used[12]. It uses the frequency band of X, KU, K ,& KA: Those radar works on these frequency band: 10.525 GHz, 13.45 GHz, 24.150 GHz or 24.125 GHz, 33.4 - 36.0 GHz. The Radar gun uses LIDAR technique. Apart from speed detection ,there are several attributes are expected to possess by the Radars like Tailgating monitoring, Multiple lane observation, High quality video capturing, Low speed detection and to verify whether passengers are wearing seatbelts etc.

The policeman Radar gun uses LIDAR technique which making use of Laser technology but it be affected by environmental effects. LIDAR based radar operating ranges varies from 10 m – 75 m. It is illuminating White/red light flash in the range of (650 nm) and Infra-red flash in the range of (> 800 nm).

2.5 GABS –An alternative of Instrument Landing Systems.

A ground based augmentation framework (GBAS) conveys differential GNSS amendment information progressively to improve the precision approach and landing for airplane[19]. The GBAS ground station utilizes information from two to four Global navigation satellite system(GNSS) reference collectors situated around the air terminal to make an amendment message. The revision information is transmitted by means of a VHF Data Broadcast(VDB,108.025 MHz to 117.95 MHz) to the beneficiary of the moving toward plane to address its got GNSS signal.

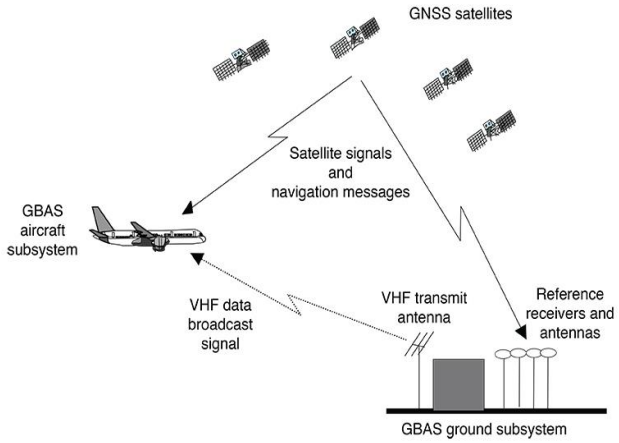

Fig 2: Working principle of GABS

Satellite based landing is the replacement of Instrument landing or Microwave landing system.

2.6 Automotive Radars-ADAS

This Radar is based on Radar and Lidar Sensors. It makes use of Artificial intelligent technology. It include the features of Adaptive Cruise Control, Cross Traffic Alert, Lane Change Alert, Intelligent Parking assistance, Blind Spot Detection and Autonomous Emergency Braking etc[22].

Radar Based ADAS (Advanced Driver Assistance System) guides the driver if there is any ambiguities presence in the particular situation[15]. Vision based ADAS system making use of Automotive Cameras this could be insufficient due to various weather conditions. So Radar based ADAS System playing an important role here. For this purpose Frequency Modulated continuous

wave Radar is being used. Automotive Radar moving towards 77GHz frequency band instead of conventional 24 GHz range as it provides accurate Range speed and reduced Antenna Size [15].

2.7 ADS-B

Automatic Dependent Surveillance-Broadcast (ADS-B) is a modern surveillance technique and it is used to identify, range of an Aircraft. It is carried out by using GNSS. At frequency of 1090 MHz utilized by plane that allows you to continuously broadcast the altitude, air velocity, identification, category of plane over a radio message. This functionality is the basic stage of ADS-B and referred to as "ADS-B output". ADS-B Input provides the situational awareness between flights and enables the self-separations to avoid the collisions [16]. The current ADS-B device based on the inputs from the Global Positioning System (GPS), or other means e.g. GLONASS, GALILEO etc.

Modern Aircrafts are equipped with ADS –B transponders and it became mandatory requirement by ICAO[9]. Although ADS-B affected by an Ionosphere delay it enables the curved based landing and automatic landing. Once GNSS effectively integrated this could be the most effective one. The block diagram is Clearly explains the basic principle of this technology. The unites states of America FAA(Federal Aviation Administration)has commended the requirement to use the ADS-B systems to all the airports and the subsequent installations of Air Traffic management to accommodate the same. Obviously, the conventional Primary and Secondary Radars will be replaced by because of this.

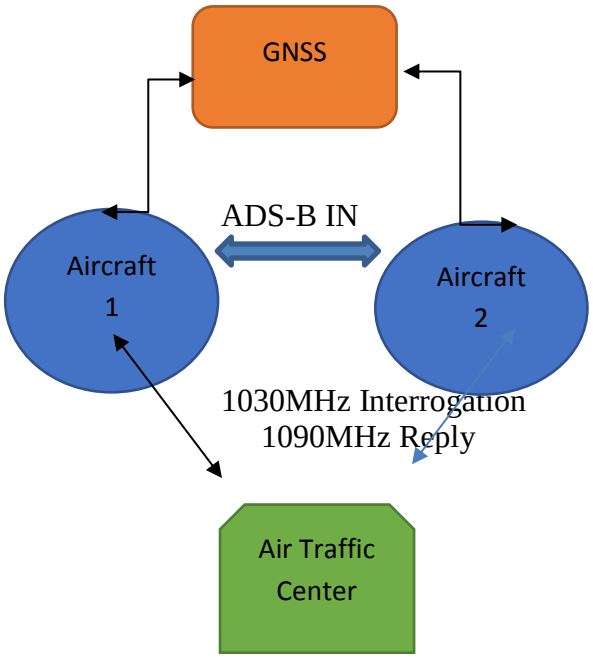

Fig 3: Principle of ADS-B

EGNOS(The European Geostationary Navigation Overlay Service) currently allows the localizer to guide the aircraft in Vertical direction. Recent performance-based navigation (PBN) alternative to ILS Cat I, accommodating advanced arrival tactics. EGNOS positioning additionally will increase the supply of ADS-B. Meanwhile, Galileo receivers are included in Search and Rescue beacons and new Galileo offerings for the aviation community are being explored. Due to the technology of Airport Multilateration, Surface Movement Radars and ADS-B, will enable A-SMGCS systems and integrated airport operations. This could provide the additional backup and warning mechanism

with having the availability of suitable display of surveillance information on a consolidated display. Most of the new Airports are adopting such a modernized technology.

ADS-B is decrease cost than conventional radar and lets in better satisfactory surveillance of airborne and surface movements. ADS-B functionality additionally enhances surveillance on the airport floor, so it can additionally be used to screen visitors on the taxiways and runways of an airport. ADS-B is now extensively used in air visitors, however now not all aircraft are equipped with it. This is in particular real for small private and navy aircraft. However, different techniques along with MLAT (Multilateration) are used to capture these plane inside the airspace as nicely[21].

2.8 Current trends in Military Radars

Gallium nitride (GaN) transmitters, radio Frequency (RF) tiles, and solid state modular 3-D radar are among the most recent developments in cutting edge military radar systems[5]. Digital Arrow Row Transceiver (DART) to be structure and fit-perfect with the current transmit-and-get line replaceable units (LRUs) in its heritage radar system [2].

Effective utilization of Transmitter power, productivity, and money saving advantages GaN (gallium nitride) transmitter innovation offers, DART consolidates the essential usefulness of the reception apparatus transmitter LRU and Receiver LRU into one. SPAR Tiles[2], which are RF gatherings containing Antenna components, gallium arsenide (GaAs) and gallium nitride (GaN) semiconductors[14], transmit and Receiver modules, and RF and power distribution networks. It additionally gives "electronic countermeasures (ECM) by means of versatile beamforming strategies in serious ECM conditions [7][16].

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CONCLUSION

Radar's received power reduces with the fourth power of the Range, which is why radar systems need of high powers, often in the megawatt range, to be effective at long range .To enhance the Range resolution and maximum coverage new millimeter wave technology related Radar systems being developed. Millimeter wave technology[4] uses the frequency range of 3GHz to 300GHz, 5G mobile networks also uses this frequency ranges[3]. As the millimeter waves are prone to environmental factors such as Rain, Fog etc. In the year of 2025, conventional Radar systems can be the backup for modern systems like ADS-Band MLAT systems as it doesn’t have the complicated mechanical parts and involving less maintenance cost. From MLAT[21], multiple dual telecommunication media can be established though high maintenance cost required.

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