Introduction of Phased Array Radar (PAR)

1. Radiation Principle of Phased Array Radar

1) Core Component of Phased Array Radar: Phased Array Antenna

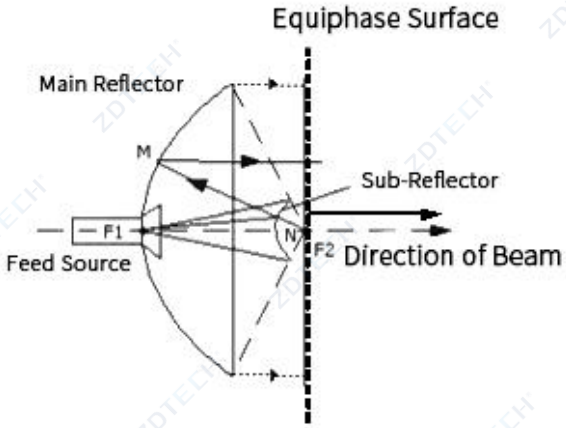
Conventional Radar: A parabolic antenna servo system mechanically rotates to achieve radar scanning

Phased Array Radar: Multiple phased array antenna units, each unit phase controlled to achieve radar scanning

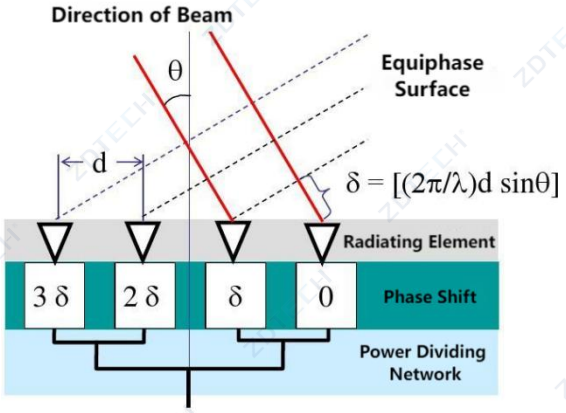
2) Radiation Principle

Parabolic Antenna: Energy synthesis is achieved by the special shape of the reflecting surface, but the direction can only be fixed;

Phased Array Antenna: Spatial energy synthesis is achieved by the phase shifters of each antenna unit and can be scanned electronically.



Conventional reflector antenna radiation



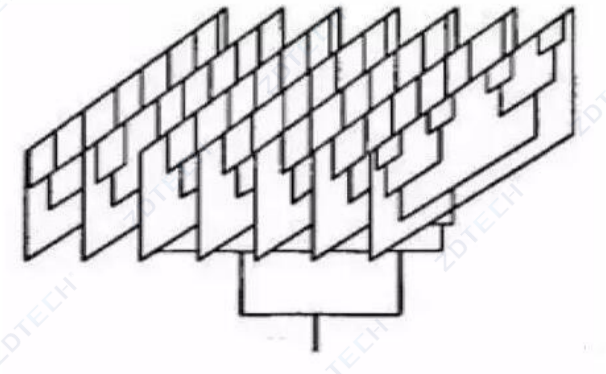
Phased array antenna radiation principle

2. Classification of Phased Array Radar

2.1 Classified by System: Passive Phased Array, Active Phased Array

1) Passive Phased Array: Multiple antenna units are synthesized through a radio frequency (microwave) network and connected to T/R components.

The most famous passive phased array radar is the airborne fire control radar widely used on second-generation/third-generation fighter jets. It has a centralized transmitter that distributes energy to each antenna unit through feeder network, and then realizes spatial synthetic radiation.



Complex feeder network for passive phased arrays

Passive phased array system airborne fire control

Disadvantages: The complex feeder network will lose a lot of energy, resulting in the second/third generation airborne fire control radar having low power and being unable to see far.

2) Active Phased Array: Each antenna unit is directly connected to 1-way T/R component. There are many active phased array radars, such as the famous F22/F35 airborne fire control radar, Aegis series phased array radar, etc. Each antenna unit is directly connected to the T/R transceiver component without loss:

Conventional reflector antenna radiation principle

Aegis series Phased array radar

Spaceborne highly integrated Phased array radar

Advantages:

The radar power is greatly improved and can see farther;

Highly integrated, covering all fields in aerospace;

Combined with the rapidly developing microelectronics technology, modularization and chipization, the cost will be greatly reduced.

2.2 Classified by Array Form: Planar Phased Array, Curved Phased Array

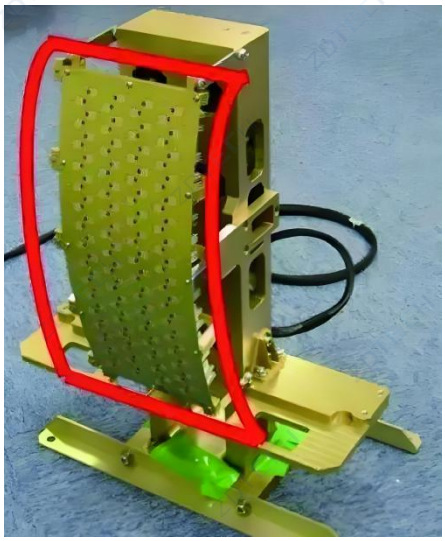
1) Planar Phased Array Radar: All antenna units are strictly installed on the same plane

Compared to curved phased arrays, planar phased array design is simple, easy to test and verify, and has high technical maturity;

2) Curved Phased Array Radar: Antenna units are mounted on a curved surface

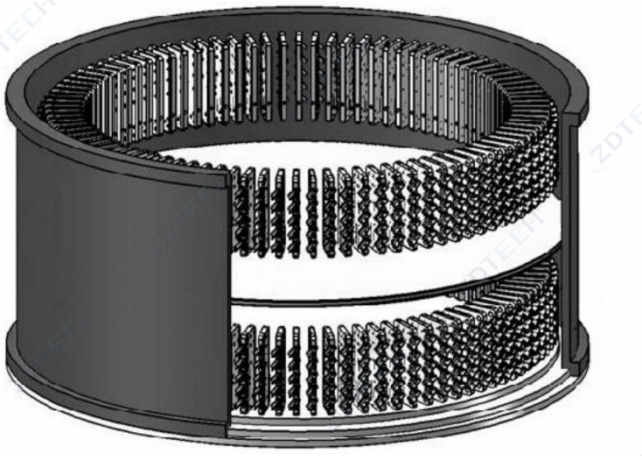
Curved phased arrays need to strictly follow the design of curved electromagnetic radiation theory, which is difficult and complex to test and verify. Special applications, generally designed to conform to the mounting platform.

① **Arc Surface Phased Array:** Generally installed in aircraft wings and other moving platforms, in order not to destroy the aerodynamic design, radar antennas all form an arc shape with the wings, fuselage belly or other platforms.



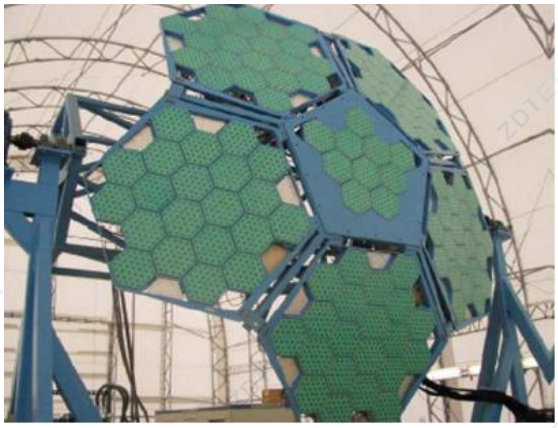
Phased array for wing arc curve

② **Cylindrical Phased Array:** It was first designed to reduce servo and realize single-soldier carry, and then widely used in special platforms such as warship masts, 5G base stations, unmanned airship fuselages, and so on;



Signal soldier cylindrical Phased array

③ **Spherical Cap Phased Array:** The earliest application in the field of satellite navigation, remote sensing telemetry, the realization of the antenna beam in the full airspace without deformation scanning, but the cost is high;



Navigation telemetry spherical cap phased array

④ **Arbitrary Surface Phased Arrays**: Widely used in large ground-based radar array co-form designs, where the antennas are mounted on rugged rocky and mountainous terrain, and amplitude/phase compensation corrections are made by rigorously mapping the curved shape of the array.

3. Phased Array Radar Components (Classified by function)

1) RF (microwave) Front-End: Emphasis on high-performance and integration, the future basis for the development of chip. Including highly integrated phased array antenna array, microwave transceiver components and other ancillary equipment.

2) Digital Backend: Emphasis on digital, software, is the basis of the future development of

intelligent radar. The digital part after A/D sampling and DDS, including digital information processing board, computer software.

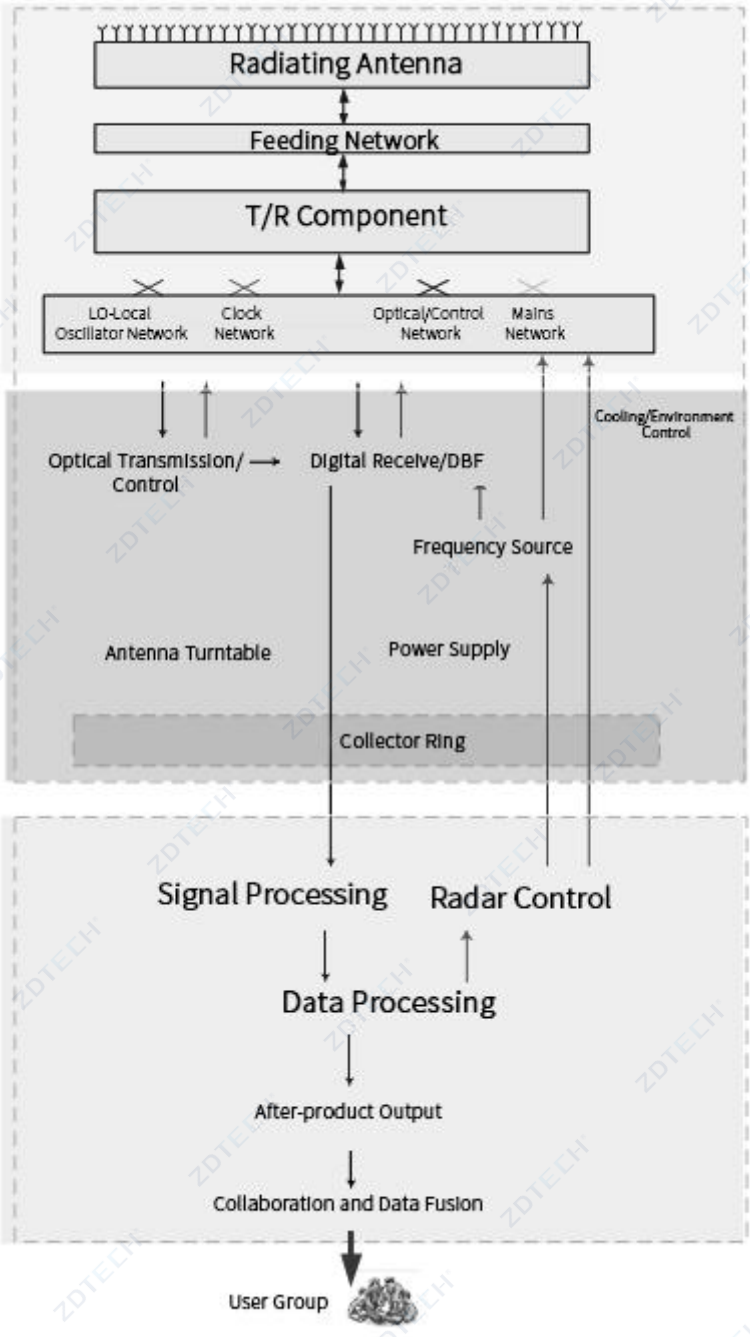


Diagram of phased array radar composition

4. Core Components

Phased array radar core components are also divided into RF component and digital component.

1) RF Component

The future competition for microwave hardware represented by highly integrated phased array antennas will be "performance and cost": performance is getting higher and higher, and cost is getting lower and lower!

Development trend: Commercial-scale chipization and large-scale production.

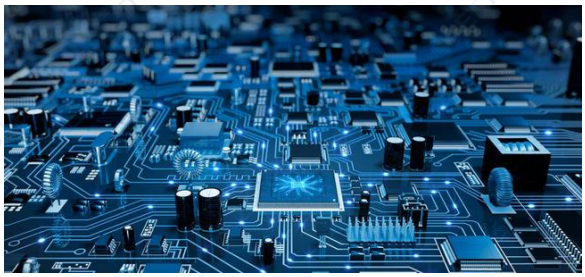
Traditional separated active phased array antenna

Highly integrated active phased array antenna

2) Digital Component

Computing chips with large-scale computing and processing capabilities (FPGA, DSP)

Radar processing algorithm and software system for intelligent development



Intelligent digital systems based on large-scale computing are an important link in the development of future radars

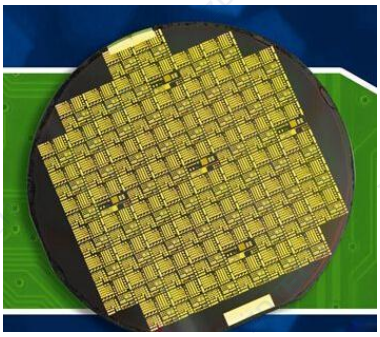
5. Development Trend

Hardware chipization, software intelligent

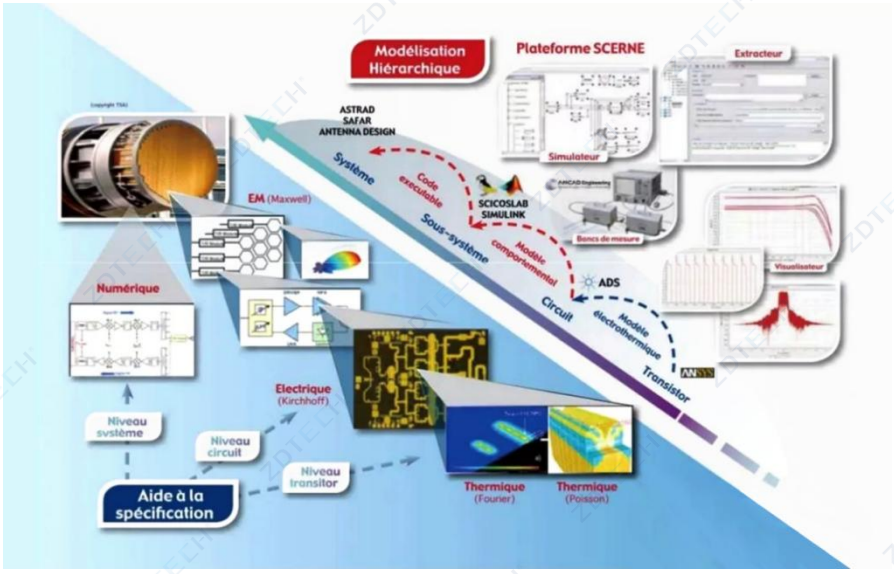
5.1 Hardware Chipization: It is not yet mature, but it must be the direction of development.

Bottleneck: Refined microwave chip simulation and design technology

Manufacturing process and micro-nanometer manufacturing technology



Microwave integrated circuit based on domestic GaN chip



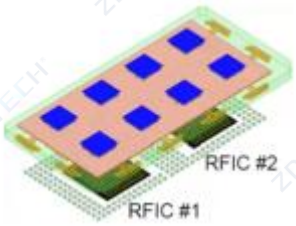
The U.S. military's integrated radar development roadmap

5.2 RF (analog) Chip

Multiple antenna units and transceiver modules are packaged (AIP: Antenna in Package), and vertical interconnection within the package is used to replace traditional radio frequency cables and other equipment. The size, weight and cost are greatly reduced. It is currently being used in 5G mobile communications and other fields.

Disadvantages: heat dissipation is difficult, and currently only low-power devices can be used

to meet mobile communication equipment; There is still no high-precision production line within 14nm, and the level of integration needs to be improved.



8-unit packaged millimeter wave RF chip

5.3 Microsystem technology

Based on the RF (analog) chip, the active phased array radar antenna surface is systematically packaged to achieve the goals of lightweight and low cost.

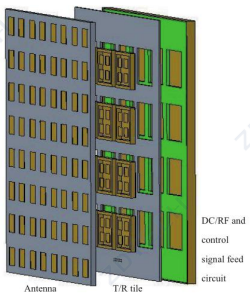
From AIP (Antenna in Package) to SIP (System in Package), single-chip integration has been upgraded to hybrid integration of multiple materials, chips and devices.

Integrated substrates include:

a. Traditional LTCC, HTCC (easy to design, large size)

b. New generation of Si and GeSi integration (difficult and with high process requirements)

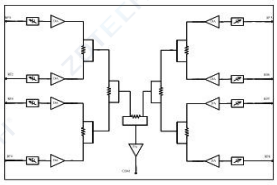
c. Hybrid integration: LTCC and heterogeneous integration such as Si or GeSi



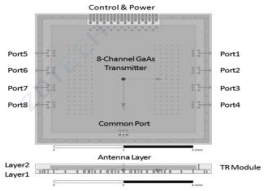
Exploded diagram of a typical microsystem phased array antenna

5.4 Typical products of microsystem technology

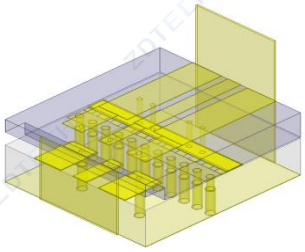
GeSi integrated 8-channel microwave transceiver components (T/R components), RF microwave chips, feeding circuits, and radiating antennas are all packaged in 6mm×6mm×2mm GeSi. The internal interconnection uses vertical silicon vias (TSV), and the external interconnection uses BGA or other methods.



8-channel T/R component schematic diagram



8-channel T/R component chip diagram



Schematic diagram of internal vertical