PROPOSAL REPORT

Analysis of Radio Proximity Fuze Technology

CONTENTS

01

Introduction

What is a proximity fuse

1

Definition

A proximity fuze is a type of fuze that does not require direct contact and can automatically detonate the warhead at a predetermined distance near the target. It detects the target's presence and distance through specific sensing methods, enabling detonation at the optimal time and position to maximize damage through fragmentation or shock waves.

2

core role

The core function of a proximity fuze is to detonate ammunition at the optimal time and position, thereby achieving maximum damage to the target. It can effectively improve the success rate of strikes against high-speed mobile targets such as aerial and surface targets, and is widely used in various weapon systems including air defense missiles, artillery shells, air-to-air missiles, and torpedoes.

3

Key Advantages

The key advantage of proximity fuzes lies in significantly increasing the success rate of strikes against high-speed maneuvering targets such as aircraft and surface vessels. Compared to traditional contact fuzes, they do not require direct hits on targets and can detonate in the vicinity of targets, thereby effectively increasing the probability of damage to targets from fragments or shock waves.

02

Mainstream technology classification

Infrared proximity fuze

How It Works

The infrared proximity fuze works by passively detecting the thermal radiation of the target itself. For example, aircraft engine tail nozzles, skin friction, etc. generate heat, and the fuze senses the presence and distance of the target by detecting these thermal radiation signals, so as to achieve automatic detonation.

Advantages

The infrared proximity fuse has good concealment, does not emit signals, and is not easy to detect, reducing the risk of being detected by the enemy. At the same time, it is not subject to radio or radar interference and has strong anti-electromagnetic interference ability. In addition, it has a certain detection ability for stealth targets and can be used as a sharp weapon for anti-stealth.

disadvantage

Infrared proximity fuzes are susceptible to environmental interference, as weather conditions such as clouds and fog, as well as thermal sources like the sun and ground background, can all affect their detection performance. Additionally, they can be easily deceived by infrared decoys, as enemies can launch infrared decoys to interfere with the normal operation of the fuze, reducing its strike effectiveness.

Laser Proximity Fuze

1

How It Works

The laser proximity fuze accurately measures distance by emitting laser pulses and calculating the time it takes for the laser to return. When the laser pulse emitted by the fuze encounters a target, the target reflects the laser signal. The fuze then calculates the target's distance by detecting the return time of the laser signal, enabling automatic detonation.

2

Advantages

The laser proximity fuse has extremely high precision, enabling centimeter-level accurate detonation control, which can effectively improve the damage effect on targets. Meanwhile, the laser beam is narrow with concentrated energy, providing strong anti-interference capability that is extremely difficult to disrupt, ensuring the reliability of the fuse.

3

Disadvantages

Laser proximity fuses are significantly affected by weather conditions, such as rain, fog, and dust, which can severely reduce their detection effectiveness. Additionally, their core components are complex to manufacture and expensive, increasing the cost of the weapon system.

Sonic close explosion fuse

1

How it works:

Acoustic proximity fuzes are primarily used underwater, working through hydrophones to detect the propeller or engine noise of ships and submarines. They can sense the acoustic characteristics of a target, thereby determining the target's existence and distance, and achieve automatic detonation.

2

Advantages

Sound waves travel far underwater, making water an ideal medium for underwater detection. Acoustic proximity fuses can effectively detect underwater targets. Additionally, by analyzing acoustic characteristics, they can roughly determine the type of target, demonstrating a certain level of target recognition capability.

3

Disadvantages

Acoustic proximity fuzes are easily affected by noise interference; ocean background noise and acoustic decoys can impact their detection performance, reducing their reliability.

Radio proximity fuse

1

How It Works

Proximity radio fuzes detect and measure distance by emitting radio waves and utilizing the "Doppler effect" of target-reflected echoes. When the radio waves emitted by the fuze encounter a target, the target reflects back an echo, and the fuze determines the target's distance and speed by detecting the frequency changes in the echo, thereby achieving automatic detonation.

Advantages

The radio proximity fuze has an all-weather working capability, unaffected by conditions such as clouds, fog, rain, or snow, and can ensure normal operation under various complex meteorological conditions. Its effective range is relatively long, the technology is mature, the detection range is wide, and it is suitable for multiple weapon systems.

2

3

Disadvantages

Radio proximity fuzes are vulnerable to electronic interference and may be affected by enemy jamming equipment, which can cause the fuze to malfunction. Additionally, due to its active signal emission, it can be easily detected by the enemy, exposing its own location and presenting a certain risk of detection. Moreover, its anti-stealth capabilities are weak, and its detection effect on stealth targets is poor.

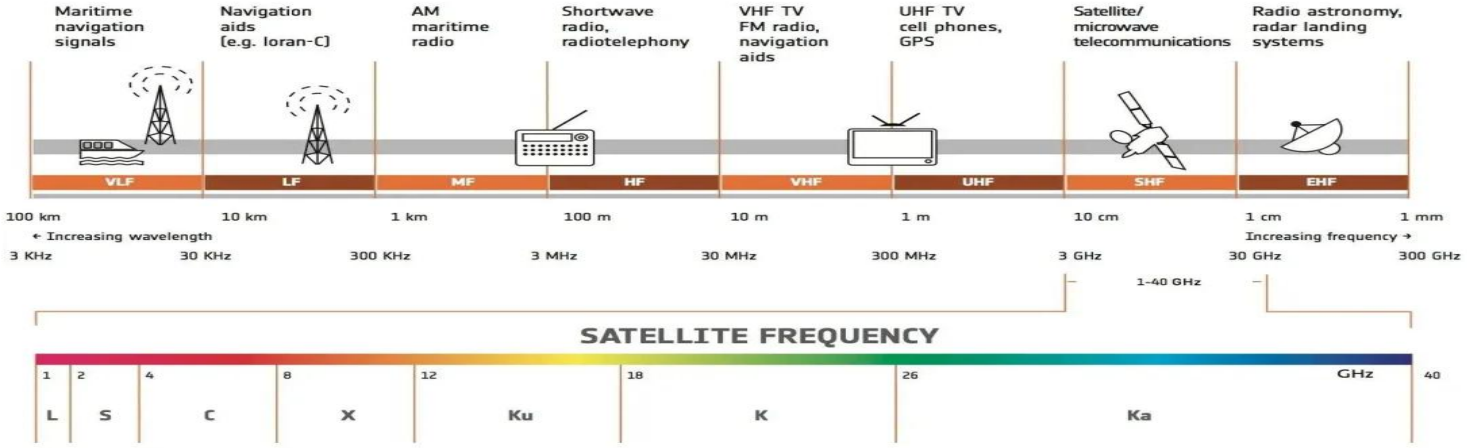
03

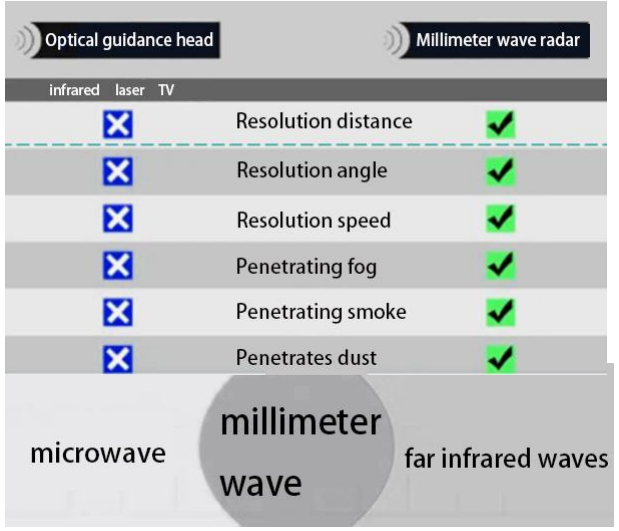
Radio Proximity Fuze Product Introduction

Millimeter-wave detectors: ushering in a new era of detection

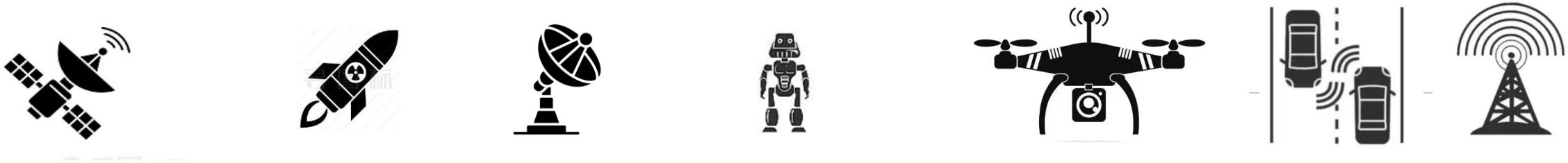
Millimeter wave detector: High bandwidth, low latency, anti-interference, enabling compact size, narrow beam, strong directivity, high gain, low cost, and all-weather operation.

- **Advantages of millimeter wave detectors: They have a wavelength range that overlaps microwave and far-infrared waves, combining the characteristics of both microwaves and infrared waves.**
- **Pain points of other detectors in the industry: LiDAR detection is highly affected by weather and costly; infrared**





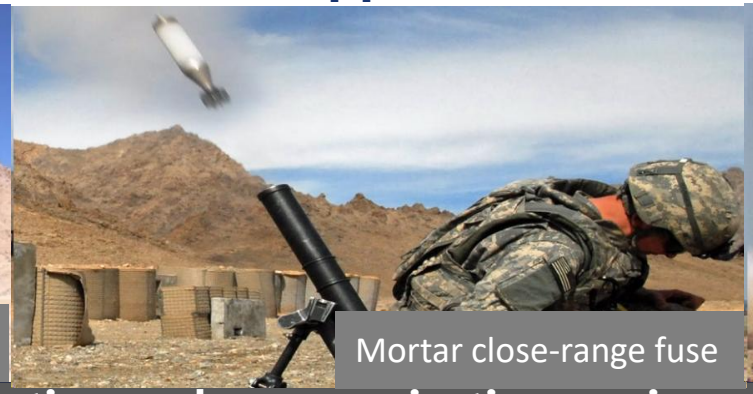
- **Millimeter wave detectors are mainly used in: smart ammunition, satellite remote sensing, seekers, radar, robotics, drones, automobiles, communications, electronic countermeasure systems, etc**



Application fields——radio detection equipment such as proximity fuses and altimeters

Millimeter-wave radar, as an all-weather detection technology, is the basic sensing means for smart munitions and can be applied to various detection equipment in

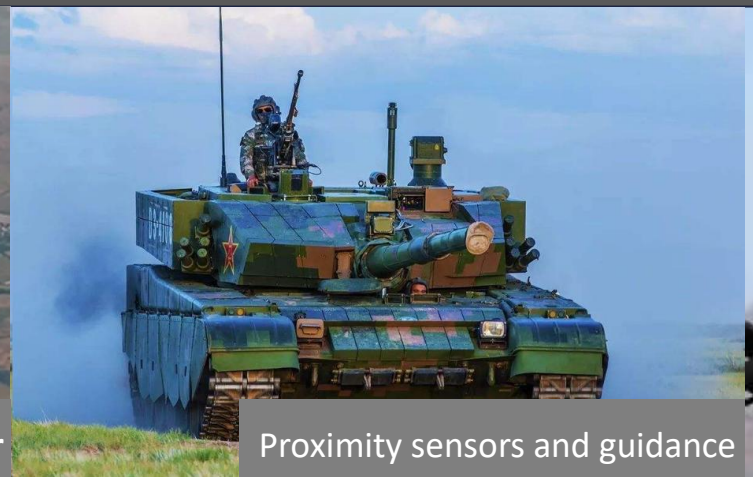

Howitzer proximity fuse


Mortar close-range fuse

Near-blow fuses to the air

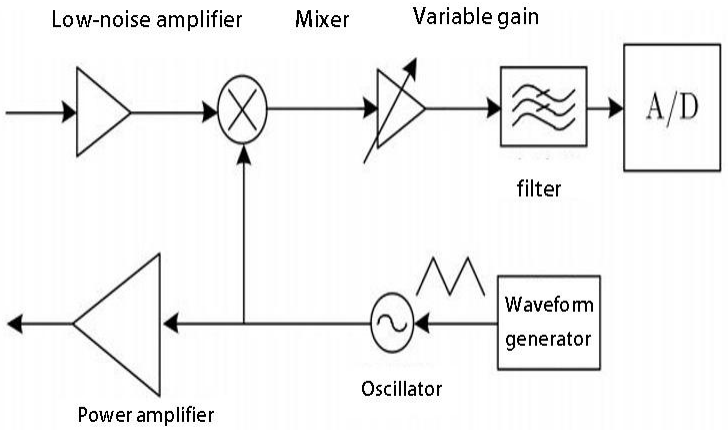
Low-cost millimeter-wave detection and communication equipment, as well as CMOS monolithic that can be mass-produced, are important development directions for advanced sensors

Unmanned aerial vehicle altimeter


Proximity sensors and guidance

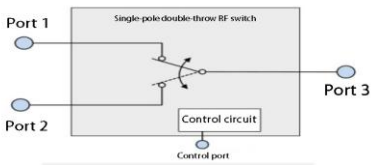

Friend or foe identification device

Core technology—Silicon-based millimeter-wave chips: Far ahead

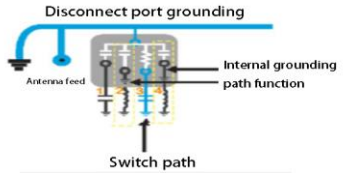


Core technologies for chip verification：
The military industry has high requirements for product reliability. Weiyuanxin uses high-frequency and high-performance equipment such as vector network analyzers, signal sources, spectrum analyzers, high-precision filters, and probe stations from the Microsystem Institute to conduct multiple index analyses on the stability and reliability of chips, meeting customer needs.

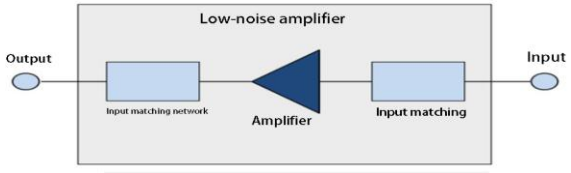
Structure name	Existing technical pain points	The company's technological competitive edge
Oscillator	The design should comprehensively consider mutually restrictive indicators such as power consumption, phase noise, frequency modulation range, and oscillation amplitude, and maintain good linearity; otherwise, it will result in low data accuracy.	A voltage-controlled oscillator with a maximum terahertz frequency of 150GHz was designed based on a 65nm process, featuring excellent linearity and precise distance measurement.
Low-noise amplifier	Because the noise of silicon-based transistors themselves is greater than that of the third-generation compound semiconductors, the design of low-noise amplifiers is more difficult.	Through process optimization, the influence of silicon-based transistor noise is reduced and the accuracy of signal recognition is improved.
DCR circuit mixer	The traditional (vehicle-mounted) mixer circuit processing mode is "RF - intermediate frequency - fundamental frequency", which is difficult to adapt to the response time in high-speed scenarios of weapons (30m/s vs.1000+m/s).	By self-developing a mixer with a DCR circuit, the conversion from "radio frequency to fundamental frequency" can be directly completed, which effectively addresses the signal leakage issue in high-frequency DC circuits
High-precision phase control technology for phased arrays	The industry generally adopts 6-shift phase commutators, with an average pointing accuracy of 5.6 degrees. There is a phenomenon of mutual coupling, which leads to gain reduction, beam pointing deflection, beam zero offset, etc	By adopting an 8-shift phase sensor, the pointing accuracy has been enhanced to 2.8 degrees, adapting to the development trend of high pointing accuracy and smaller caliber in weapons.



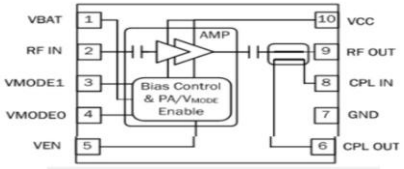
Switch switch



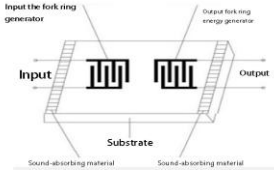
Tuner switch



Low-noise amplifier



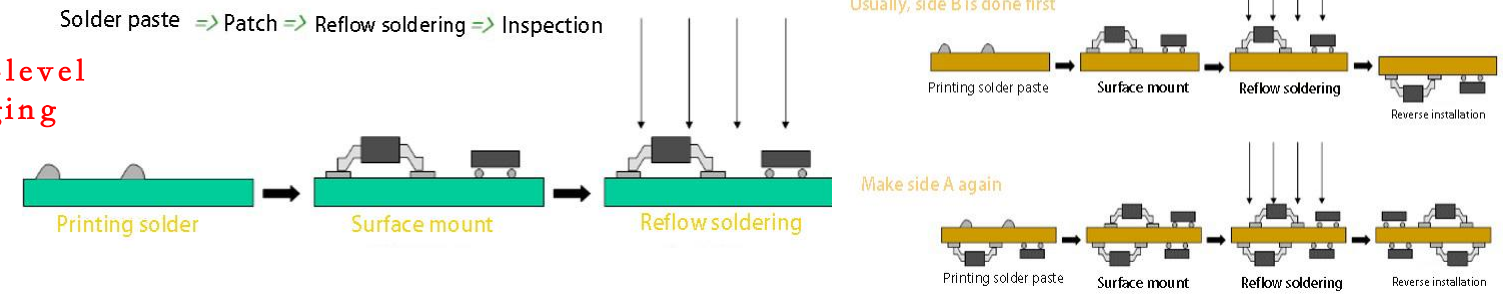
Power amplifier



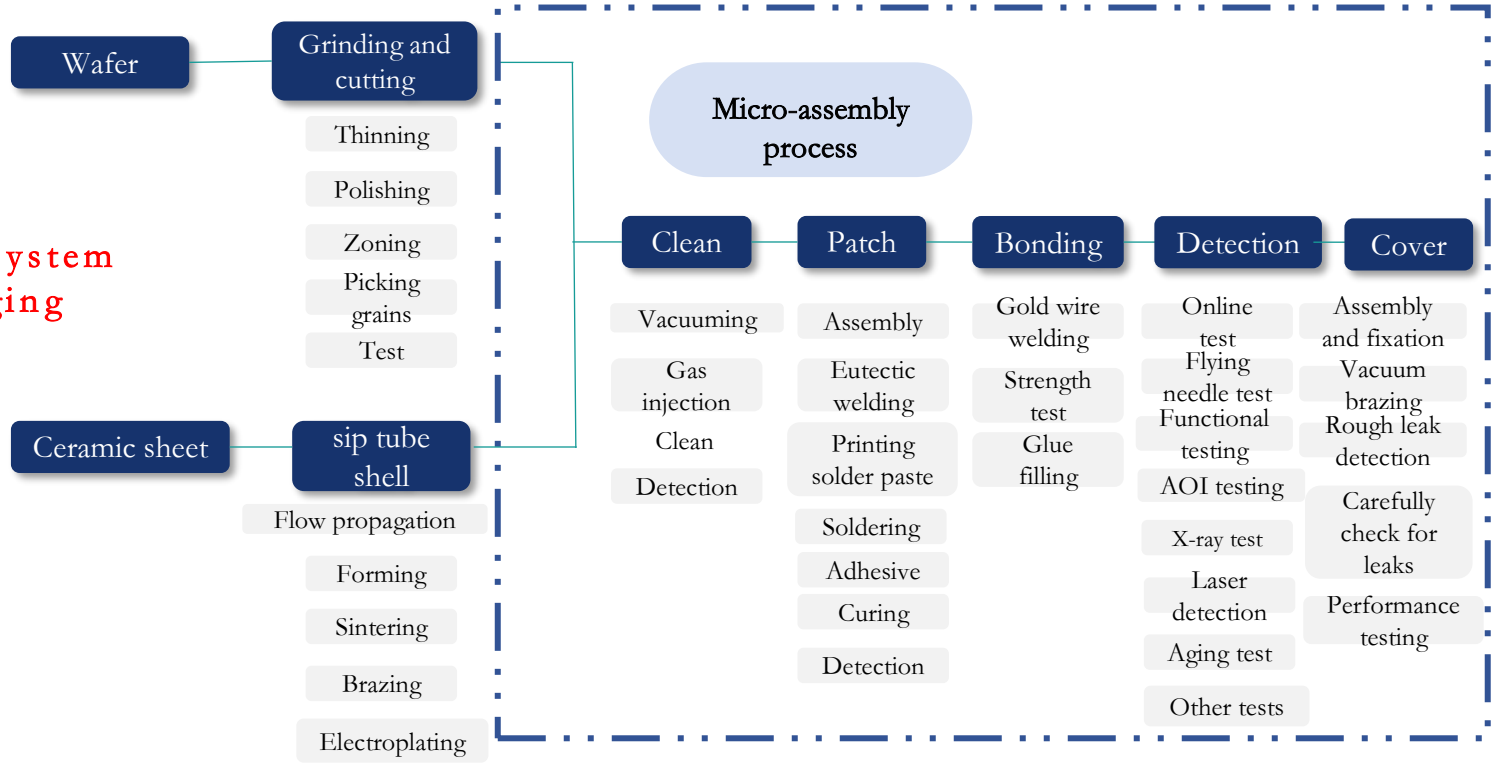
Filter

Core technology—Millimeter-wave Microsystems: Highly integrated

Board-level packaging

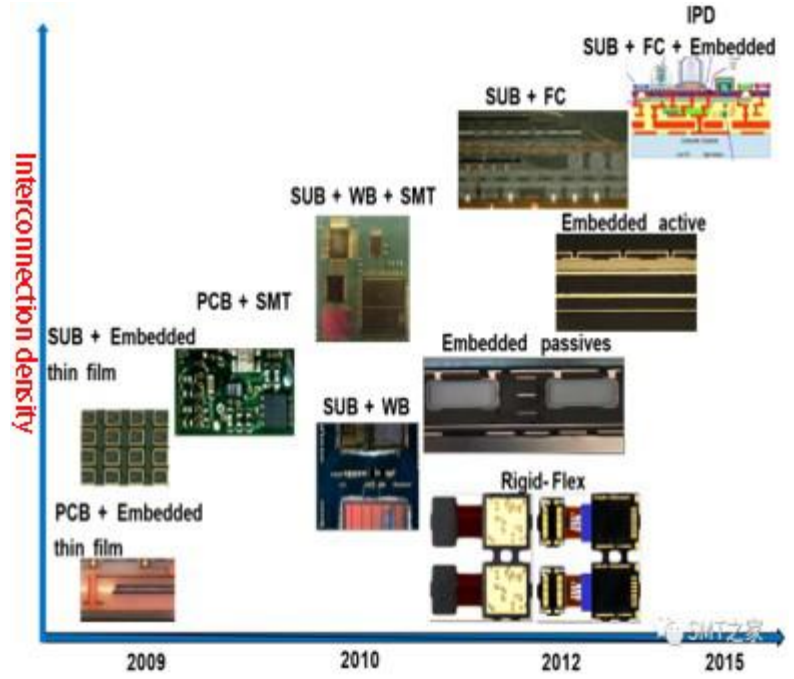


Microsystem packaging



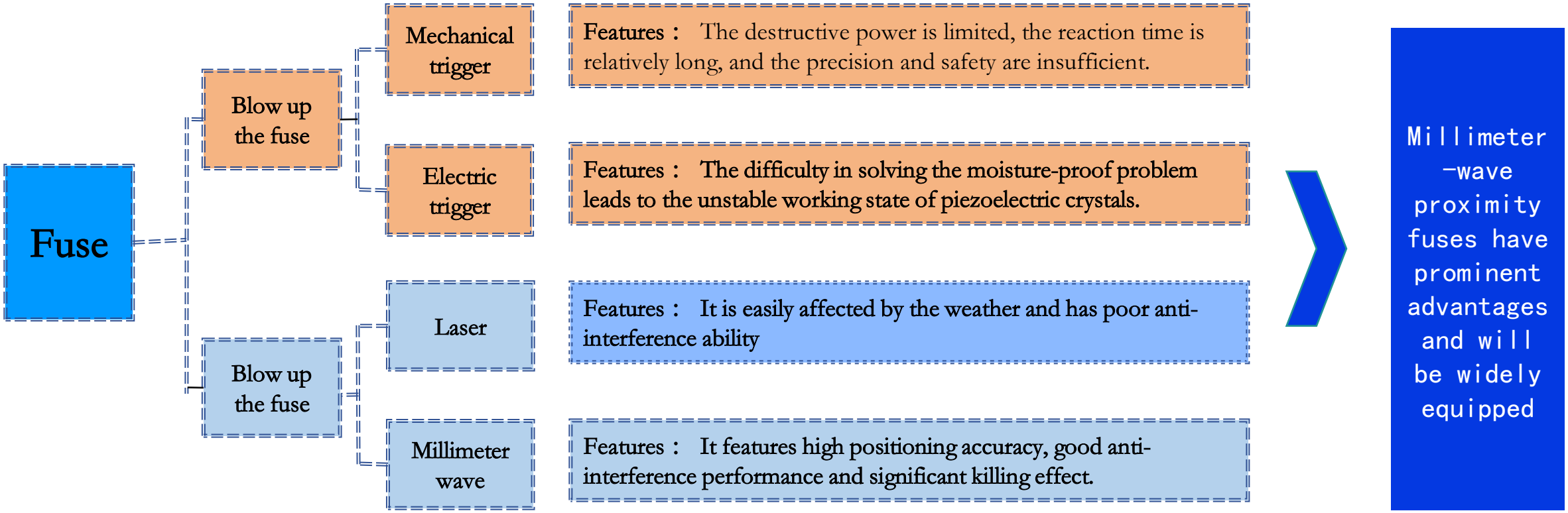
Microsystem packaging （sip packaging ）

Multiple passive circuits, active circuits, etc. with different functions are encapsulated in a single housing to become a single standard package that can provide multiple functions and has the functions of a system or subsystem. This is to meet the market demands for increasing system functions, reducing volume, lightening weight and lowering costs.



Market application : Blow up the fuse

- **The function of the proximity fuse : Solve the last mile problem of missiles.**
- **The working principle of the proximity fuse :** It is mainly applied to electronic fuses of various types of artillery shells for the army and navy, long-range rocket shells and ammunition for anti-aircraft weapons, capable of enabling weapons to explode at a **specific height** to achieve maximum lethality.



At present, electronic fuses account for 70% of the military weapons in the United States, while in China, it is only 10%. The proportion of electronic fuses urgently needs to be increased.

Market application : Blow up the fuse

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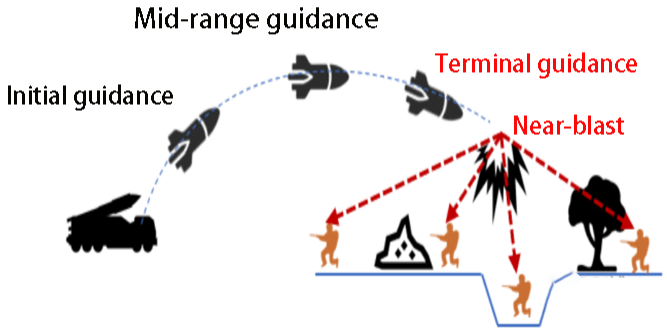
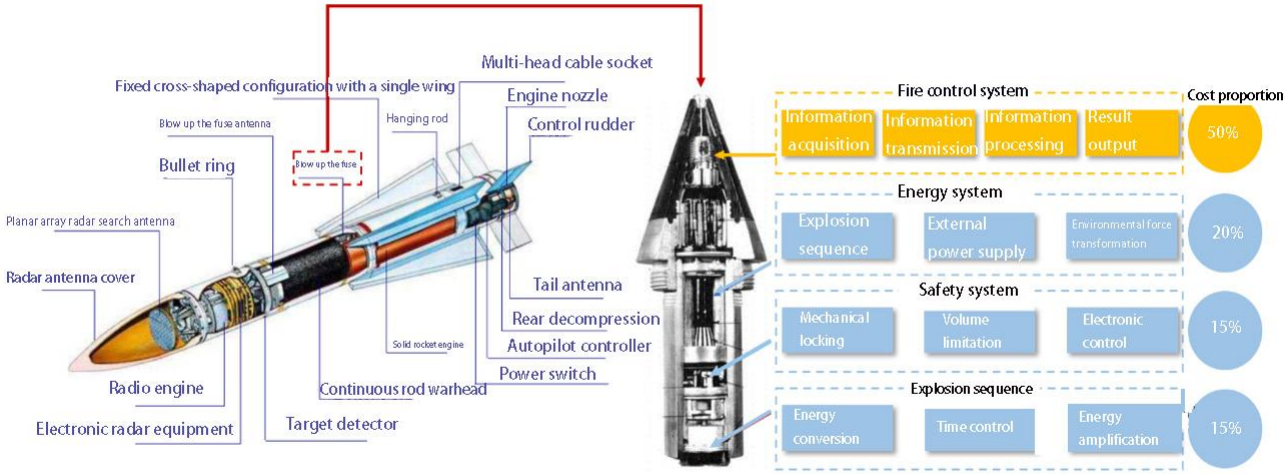
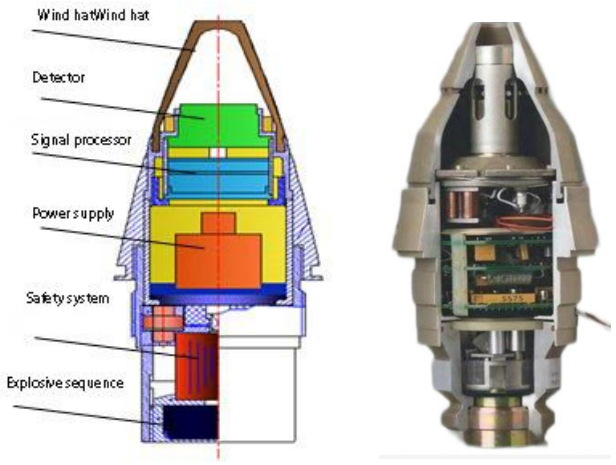




Low-cost millimeter-wave close-range fuses will be widely equipped



Military branch	Application field	Market demand (detectors)
Army	Ground-based missiles, grenades, mortars, shells	80 billion
Air Force	Air-to-air, air-to-ground missiles, aviation bombs	150 billion
Navy	Torpedoes, missiles	60 billion
Rocket Force & Space	Medium and long-range missiles	120 billion

The market size of military proximity fuses 410 billion yuan

Industry Analysis：Ammunition types to be used

Application scenarios of the company's products

Forced bomb
82/120 Ammunition

Medium and large caliber grenade
122/155 Guidance

Airborne missile
Small diameter guidance, 70/90 airborne
50/250/1000kg aircraft bombs

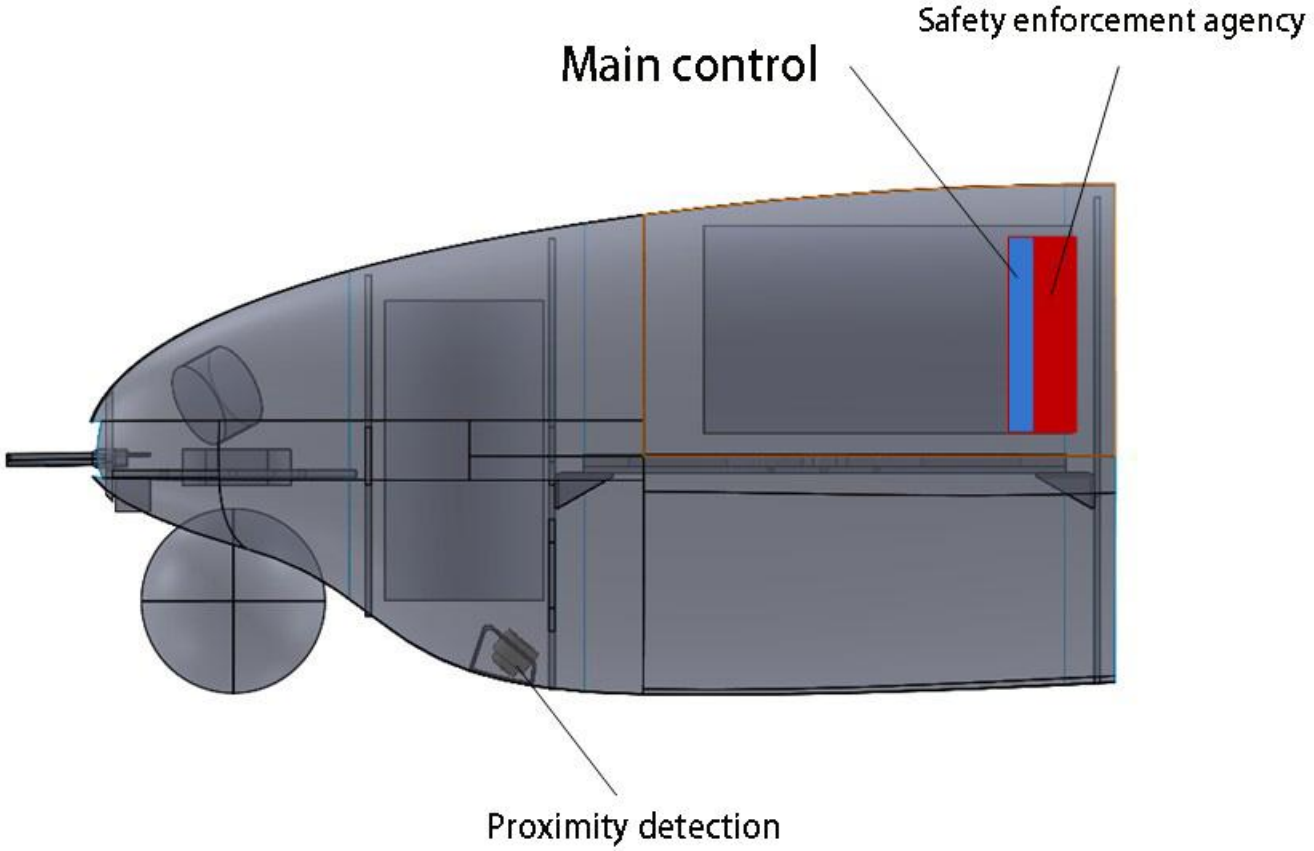
Ten-thousand-round ammunition
Naval shipborne guns

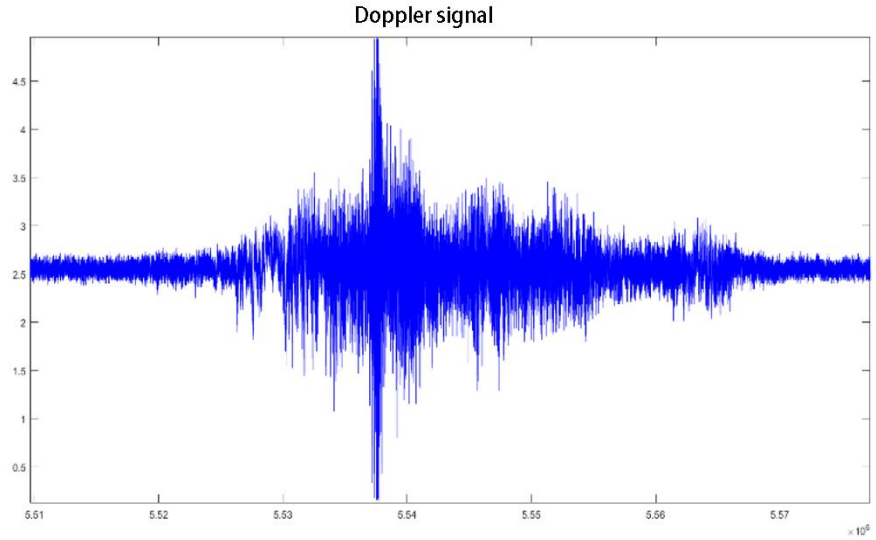
Rocket launcher
Medium and long-range 60km series Light series

Armillary arrow
Attack the small shoulder anti-missile of the unmanned aerial vehicle
The model products have been listed

Blow up the fuse—All types of artillery shells, long-range fire, aviation bombs, cruise missiles, etc. for the army, navy and air force

A self-killing unmanned aircraft approached to bombard the fuse





- **Proximity detection component**
- **Main control**
- **Safety system**

Technical specifications of air-to-air proximity detection components

Function： The airborne JZ detection component is mainly used for detecting airborne targets and outputs detection signals under certain off-target conditions.

Overall indicators

- Meeting speed: 100-1200m/s
- Targets: Missile targets, aircraft targets, etc
- Radio frequency bands: K, Ka
- Detection system: FMCW

Detector performance indicators

- Missed range :7m@ helicopter target
- 3m@ Missile target
- 6m@ Fighter jet target
- 3m@ Dji Phantom 4 drone

Structure and Weight

- External dimensions: According to user requirements, it can be installed on the head (Φ30X40mm) or on the side wall.
- Weight ⩽40g@ Head mounting

- Power supply 6V~8V
- Power :⩽1W(K-band, head mounting)
- Working temperature : -55℃~+75℃

Technical specifications of air-to-air proximity detection components

Reference platform	Anti-aircraft gun grenade	Tank gun grenade	Naval gun grenade

Product features

- All components are independently controllable in China, and the core millimeter wave and signal processing chips are self-developed chips
- Overload resistance > 30,000g (detection component for 35mm anti-aircraft guns >67000g)
- Low power consumption, low cost, high performance
- The live-fire test results were excellent

Technical specifications of air-to-air proximity detection components

Function : The ground-to-ground grenade proximity detection component mainly detects ground targets and outputs detection signals under certain detonation height conditions.

Overall indicators

- Intersection speed : 50-500m/s
- Objective: Typical ground
- Radio frequency band : K、Ka、V
- Detection system : FMCW

Detector performance indicators

- Blow high to the ground :
- 9m ± 3m
- 3m ± 1m

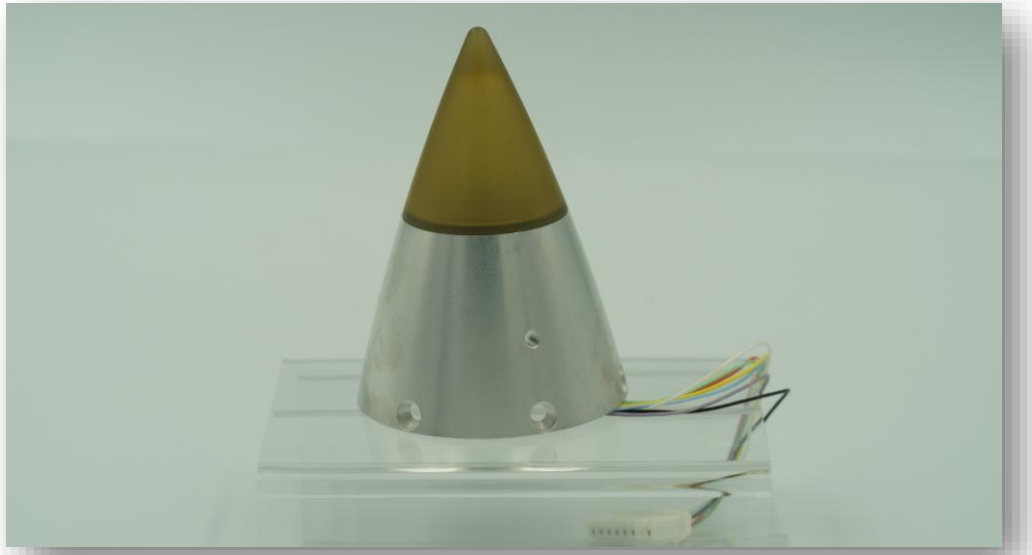
Structure and Weight

- External dimensions: It can be installed on the head according to the user's requirements(Φ30X40 mm)
- Weight ⩽40g@ Head mounting

Structure and Weight

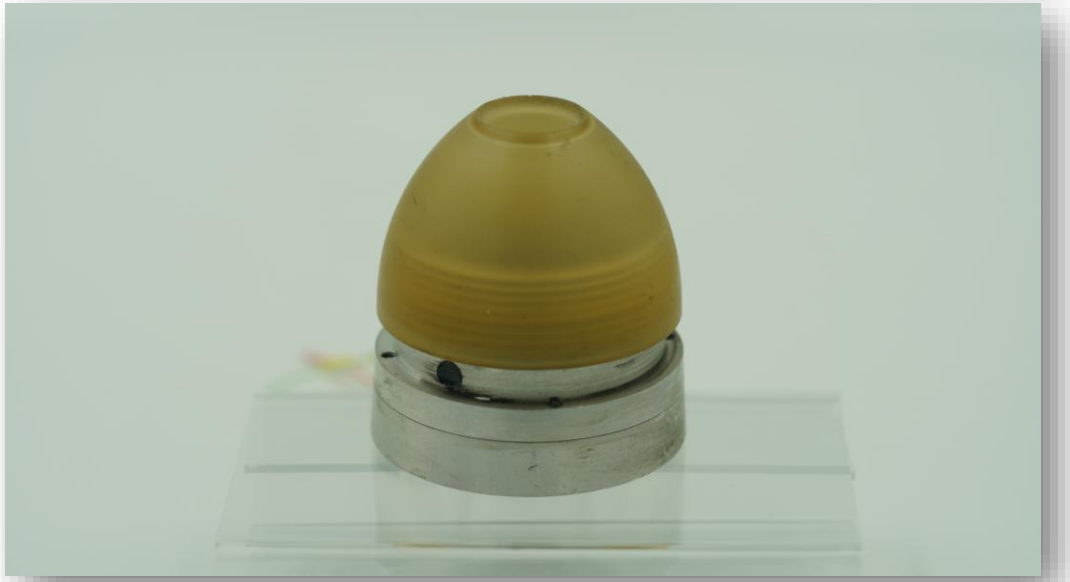
- Power supply: 6V~8V
- Power :⩽1W(K-band, head mounting)
- Working temperature : -55℃~+75℃

Product Introduction——Millimeter-wave near-blow fuse detector shelf products

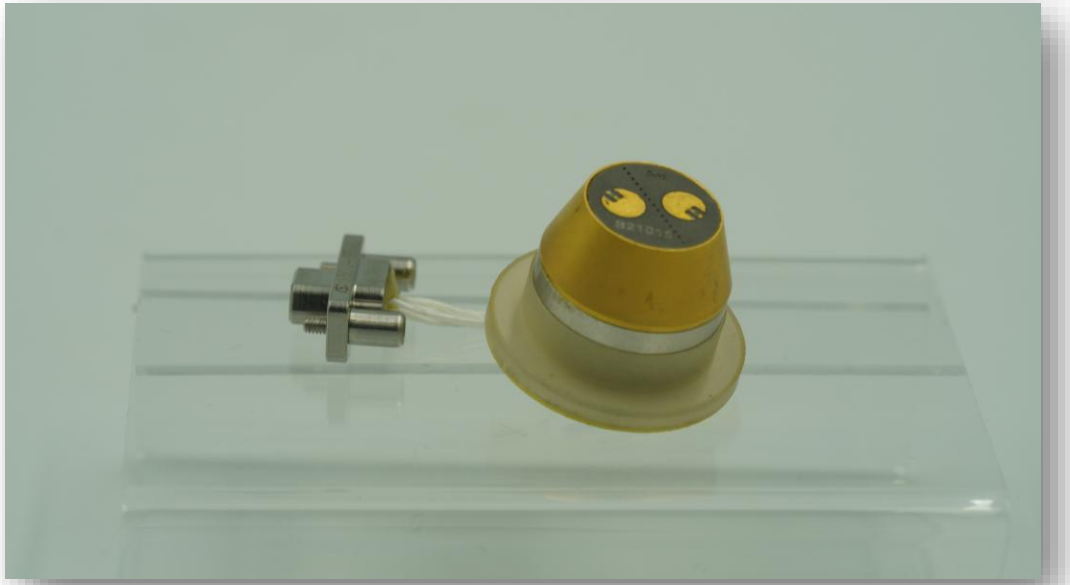


- **High cost-performance K/Ka band ground-to-air proximity detector**
  - Operating frequency band: K/Ka bands are selectable
  - Power consumption: ⩽1w (K band)
  - Size: φ25×50mm (customizable)
  - Adaptation targets: small unmanned aerial vehicles, cruise missiles, helicopters, fixed-wing aircraft, etc
  - Adaptive targets: small unmanned aerial vehicles, cruise missiles, helicopters, fixed-wing aircraft, etc.
  - Fixed range: 3m (small unmanned aerial vehicles, cruise missiles) 7m (helicopters, fixed-wing aircraft)
  - Intersection speed： 100~1200m/s
  - Overload resistance： ⩾50000g
  - Available platforms: Naval gun grenades, tank grenades
- **K/Ka band high cost-performance air-to-ground proximity detector**
  - Operating frequency band: K/Ka bands are selectable
  - Power consumption: ⩽1w (K band)
  - Size: φ35×45mm (customizable)
  - Adaptation targets: Various ground targets
  - Fixed distance: 10±1m (customizable)
  - Intersection speed： 50~500m/s
  - Overload resistance： ⩾30000g
  - Available platforms： Aviation rocket

Product Introduction——Millimeter-wave near-blow fuse detector shelf products

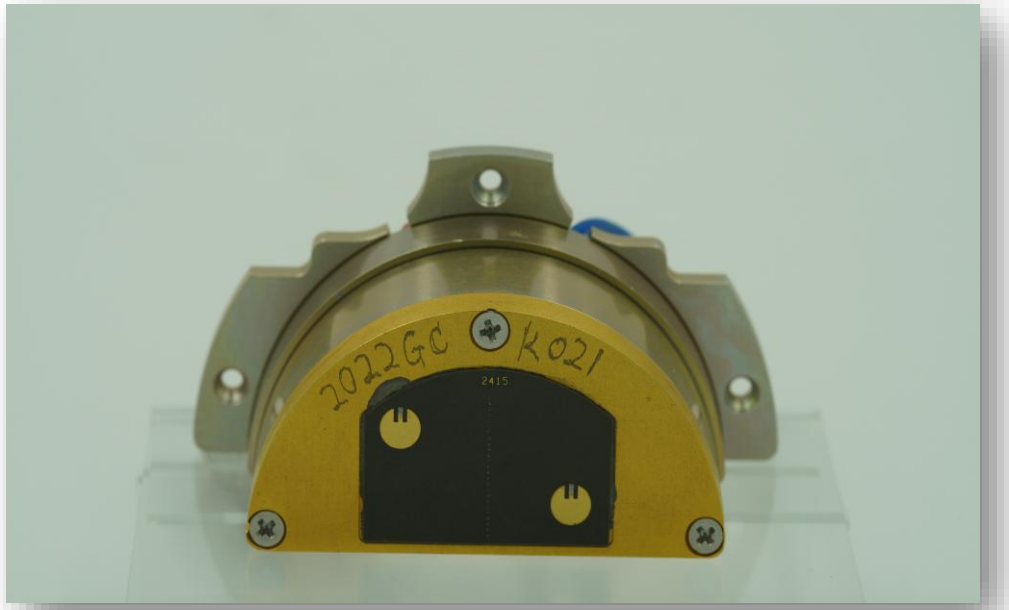


- K/Ka band high cost-performance ground proximity detector
  - Operating frequency band: K/Ka bands are selectable
  - Power consumption: ⩽1w (K band)
  - Size: φ30×40mm (customizable)
  - Adaptation targets: Various ground targets
  - Fixed distance: 10±1m (customizable)
  - Intersection speed： 50~500m/s
  - Overload resistance： ⩾30000g
  - Available platforms： Forced grenade, grenade, rocket



- K/Ka band small-caliber air-to-air proximity detector
  - Operating frequency band: K/Ka bands are selectable
  - Power consumption: ⩽1w (K band)
  - Size: φ20×25mm (customizable)
  - Adaptation targets: small unmanned aerial vehicles, cruise missiles, typical ground equipment, etc
  - Fixed distance: 3m (customizable)
  - Intersection speed： 100~1200m/s
  - Overload resistance： ⩾67000g
  - Available platforms： Small-caliber anti-aircraft ammunition

Product Introduction - Millimeter-wave Near-Blow Fuse Detector Shelf Product



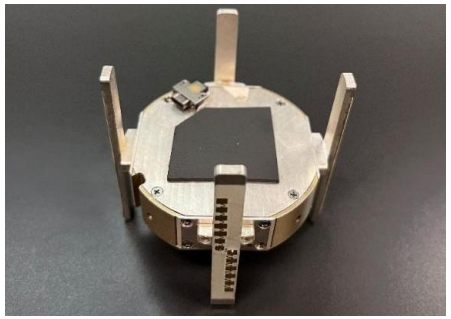
- **K/Ka dual-band composite ground proximity fuse**
  - Working frequency band： K/Ka dual-band composite
  - Power consumption： ≤2.5w
  - Size： φ36×40mm（Customizable）
  - Adapt to the goal： Various ground targets
  - Fixed distance： 10±1m（Customizable）
  - Intersection speed： 50~500m/s
  - Overload resistance： ≥30000g
  - Available platforms： Forced grenades, grenades, medium and large-caliber rockets, high-value guided ammunition

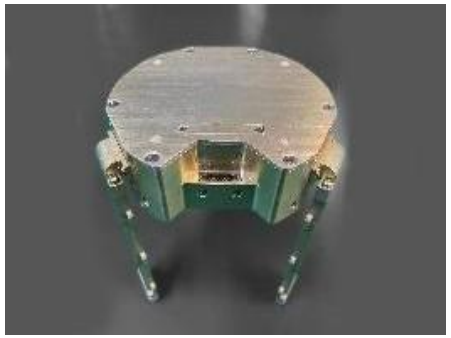
- **K/Ka dual-band composite air-to-air proximity fuse**
  - Working frequency band： K/Ka dual-band composite
  - Power consumption： ≤2.5w
  - Size： φ30×35mm（Customizable）
  - Adapt to the goal： Small unmanned aerial vehicles, cruise missiles, helicopters, fixed-wing aircraft, etc
  - Fixed distance： 3m（Small unmanned aerial vehicles, cruise missiles）
  - 7m（Helicopters, fixed-wing aircraft）
  - Intersection speed： 100~1200m/s
  - Overload resistance： ≥50000g
  - Available platforms： Aircraft gun grenades, tank grenades

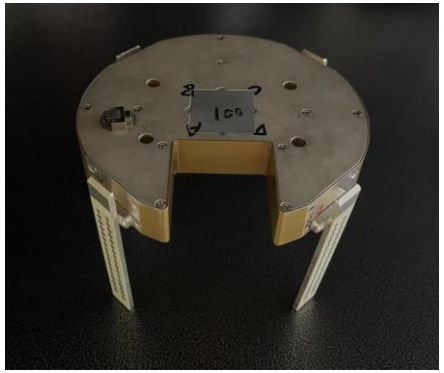
Product Introduction ——Millimeter-wave Near-Blow Fuse Detector Shelf Product

- **Install proximity detectors on the side walls of the K/Ka band**
  - Working frequency band： K/Ka bands are optional
  - Power consumption： ⩽1w（K band）
  - Size：φ20×65mm（Customizable）
  - Adapt to the goal： Various ground targets
  - Fixed distance： 10±1m（Customizable）
  - Intersection speed： 50~500m/s
  - Overload resistance： ⩾30000g
  - Available platforms: ammunition, aircraft bombs, missiles

Typical anti-aircraft product







Air-to-air fuse detector series

The R&D team, leveraging years of technological accumulation in the field of fuses, innovatively integrated frequency modulation, time-hopping, coherent processing, and digital matching filtering technologies. Through continuous experiments, iterations, optimizations, upgrades, and achievements, they have successfully developed a millimeter-wave near-burst fuse with strong anti-interference capabilities

Miniaturization and low cost

Blind spot-free detection

Fully domestic design

Strong adaptability to the target

The product is mainly applied to the close-range weapon systems of air-to-air platforms such as shoulder-resistant missiles and cruise missiles, and has been put into use in the market

Typical local products

K/Ka Reunite

K band

Ka band

V band

Low-cost digital fuse detector

Chip-ization of the entire machine

01

Product generalization

02

04

Continuous binding

03

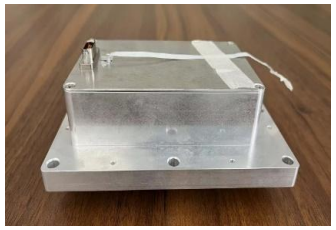
Production automation

- Low cost
- Digitalization, continuous distance measurement, speed measurement
- High precision
- Wide frequency range: K, Ka, V, W frequency bands
- Strong adaptability to the target
- Strong anti-interference ability
- Customizable (software binding)

The product is mainly applied to weapon platforms such as forced bombs, pomegranate bombs, aircraft bombs, rocket projectiles and missiles

Typical long-distance product

K/Ka Reunite



Ka band

Ka/W composite

Fully digital fuse detector

Digital high-speed processing technology

Strong anti-interference technology

01 02

04 03

Long-distance detection technology

High-precision detection technology

- Miniaturized design
- Wide coverage frequency：K/Ka/V/W frequency bands
- High-speed digital processing, capable of continuous distance and speed measurement
- The distance measurement and speed measurement accuracy are high
- It has a long working range, up to 150 meters
- Strong adaptability to the target
- Adjustable parameters and strong anti-interference ability
- Customizable

The product is mainly applied to weapon platforms such as aircraft bombs, firearm bombs and missiles

The advantages of radio proximity fuses——A comparison between traditional fuses and proximity fuses

Timed fuse

Working principle： The timing fuse is detonated by a combination of one or more mechanical, electronic or chemical timers

Disadvantage: It has poor accuracy and is unstable

Collision fuse

Working principle： It detonates upon impact, knocking or when the forward movement rapidly decelerates, usually when a physical impact occurs on an object such as a target

Disadvantage: Limited destructive power

Blow up the fuse

Working principle： The proximity fuse detonates the ammunition within a predetermined distance from the target through radio detection technology

Advantage： High detection accuracy, strong anti-interference ability and great destructive power

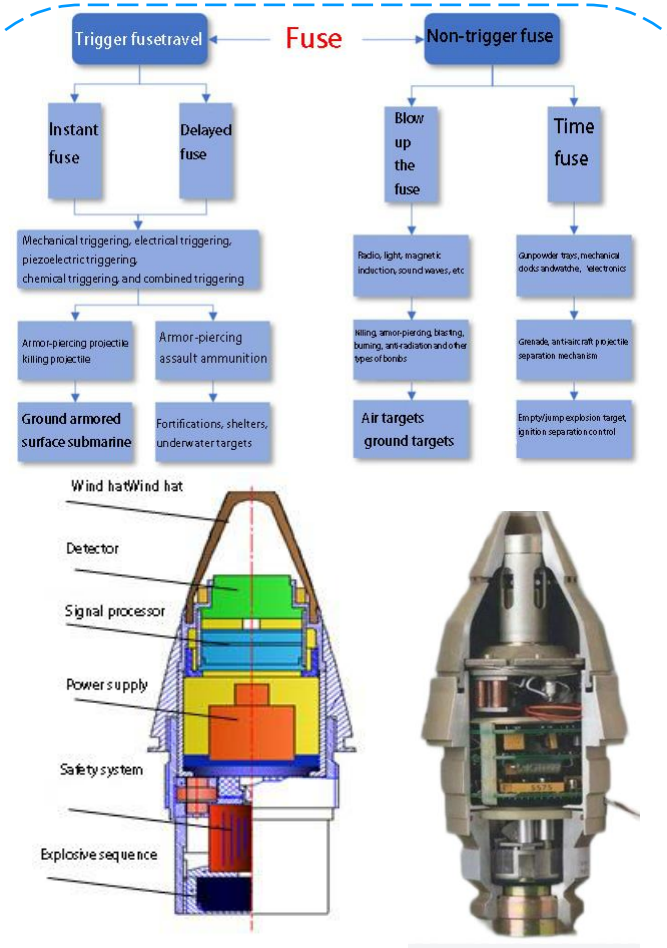
Proximity fuse products are the largest consumables in military industry and military trade

- **Detonate the fuse module close to the ground：** It is applicable to various caliber grenades, mortar shells and long-range rocket launchers, etc
- **The forced bomb close-range explosion fuse can be achieved:** The ground firing height is 9±3 meters, and it can be fixed at 3±1 meters. The landing Angle is 30-80°. Currently, the XX Institute of Ordnance has achieved 10,000 shell firing tests with a 100% qualification rate, suitable for 60, 82 and 120 mortar shells, etc
- **The distant fire explodes the fuse close to the ground**: It has completed the military verification for dual-band ground penetration to a height of 20±5 meters and is suitable for medium and long-range rocket launchers
- **Near-blow fuses to the air：** Fuses for medium and large-caliber anti-aircraft and anti-missile grenades. Achieved air-to-air target: 7m missed target @ Apache; 3m off-target range @ Flying Fish Missile (currently completed by the XX Institute of Ordnance for test verification)
- **Active defense fuse for armored vehicles：** The anti-interference anti-tank missile weapon can be triggered from a distance of 3 meters. The XX Institute has conducted a batch test of 4,000 rounds

The advantages of radio proximity fuses——A comparison between traditional fuses and proximity fuses

➢A comparison of several mainstream close-range fuses currently available in China

➢ **The principle of near-blow fuses :** It is mainly applied to electronic fuses of various types of artillery shells for the army and navy, long-range rocket shells and ammunition for anti-aircraft weapons, capable of enabling weapons to explode at a specific height to achieve maximum lethality.



	To the ground	To the air	Features
Point-frequency continuouswave system	√	√	There is no distance information, only simple speed information, and the spread of the explosion point is large. Low cost. It is mostly used on the older generation of grenades. Due to the single working mode of the transmitted signal, its anti-interference ability is relatively weak.
Pulse Doppler system	√	√	There is distance information, simple speed information, and blind spots at short distances. The cost is very high. It is mostly used on air-to-air missiles.
Frequency modulated continuous wave system	√	√	There is distance information and speed information. Low cost and no blind spots in distance. It is currently used on the new generation of grenades and low-cost anti-aircraft missiles. Due to the diversity of the transmitted signal parameters and the adoption of multi-parameter modulation methods, it has good anti-interference ability.
Ultra-wideband system	√	X	There is distance information, but the speed information is not obvious. There are blind spots at close range. The cost is relatively low At present, it is only used on the older generation of ground-strike grenades and bombs, and has not been involved in air applications. The transmitted signal is a baseband pulse signal, and its receiver is a wideband receiver, which is prone to interference from airborne, ground and other electromagnetic transmitting equipment. The ability to adapt to complex electromagnetic environments in the proximity mode is weak, and the proximity mode is often switched to the trigger mode, resulting in a decrease in the proximity operation rate.

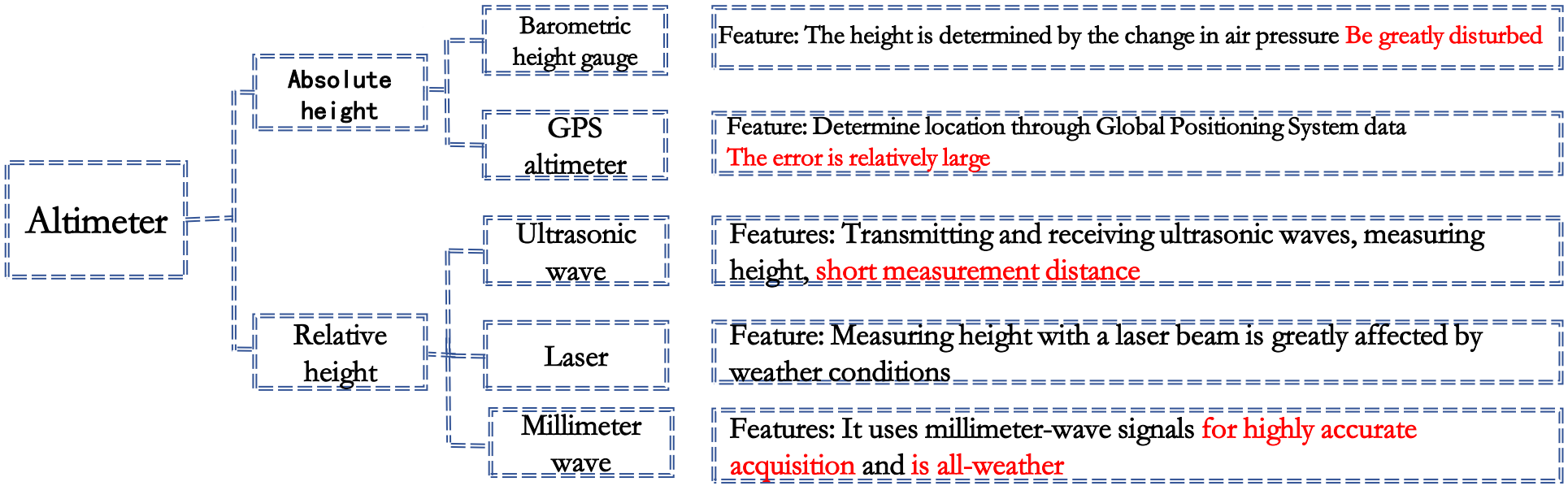
Note: In the table, "to ground" refers to the target being the ground, not the ground target. "To the air" refers to a target in the air.

Comparison of radio proximity fuses with other proximity fuses

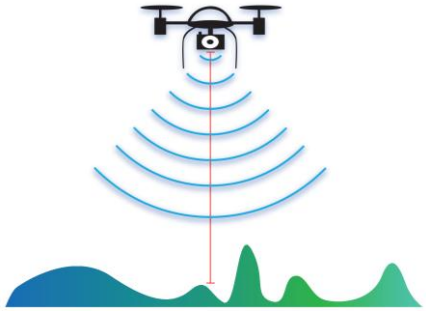
Fuse type	Detonation method	Cost	Hit efficiency	Environmental adaptability
Contact fuse	Direct collision explosion	low	low	poor
Time fuse	Detonation at preset time	low	General	General
Laser fuse	Optical induction detonation (laser detection)	high	high	Poor (affected by the weather)
Infrared fuse	Heat source induction detonation (infrared detection)	high	high	Generally (affected by temperature differences)
Radio fuse	**Distance sensing automatic detonation (radio wave)**	**Medium to low**	**high**	**Strong (all-weather applicable)**
Acoustic wave fuse	Acoustic wave/underwater pressure wave induction detonation	middle	middle	Weak (only effective underwater)

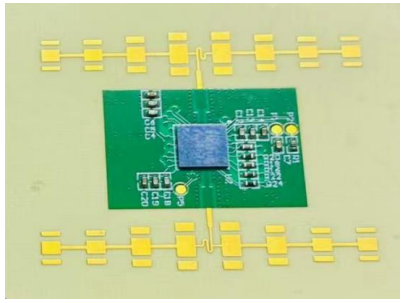
Market application: Unmanned aerial vehicle altimeter

- The millimeter-wave radar altimeter can provide height information for unmanned aerial vehicles (UAVs), with a measurement accuracy of ±0.1cm. It helps UAVs maintain a stable flight state during takeoff and landing, effectively preventing ground collisions during takeoff and landing.



Millimeter-wave altimeters will be widely used





Data from the Ministry of Industry and Information Technology shows that in 2023, the delivery volume of civilian drones in China alone reached 3.17 million. It is expected that by 2030, the delivery volume of unmanned aerial vehicles (UAVs) will exceed 5 million. The unit price of millimeter-wave UAV altimeters is approximately 3,000 yuan. With a penetration rate of 30%, the market size of civilian UAV altimeters is expected to exceed 4.5 billion yuan by 2030.

The market size is 4 to 5 billion yuan

Radio altimeter - Ka-band radio altimeter

It can be used for height measurement and terrain comparison of various types of unmanned aerial vehicles, helicopters, small aircraft, cruise bombs and large aviation bombs. Currently, hundreds of units have been sold

Independently design silicon-CMOS radar SOC chips

Linear Frequency Modulated Continuous Wave (LFMCW)

Antenna gain: 15dBi

The maximum height measurement can reach 1500 meters, and the measurement accuracy can reach ±0.1 meters

The anti-rolling Angle range is ±35°

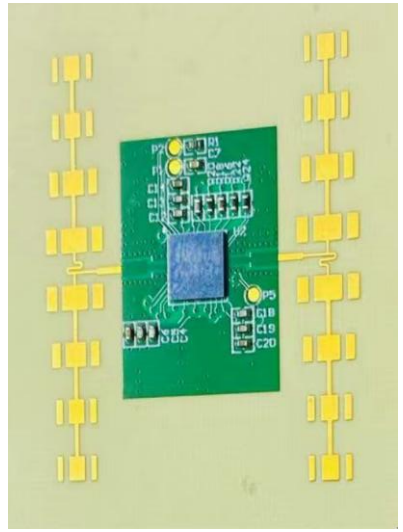
The anti-pitch Angle range is ±25°

Product dimensions (without casing) : 88x58x23mm

It weighs only 210 grams

Radio altimeter - Ka-band radio altimeter

- The WY-ALT600 millimeter-wave altimeter is a radar height measurement product independently designed and developed by the company. It adopts a silicon-CMOS process RF transceiver chip with completely independent intellectual property rights and operates in the 35GHz frequency band
- The altimeter emits a large-bandwidth linear frequency-modulated continuous sawtooth wave signal and receives the ground echo. Through refined signal processing, the relative height measurement value of the carrier is obtained and output to the display and control equipment via the serial port
- This type of altimeter features high measurement accuracy, small size, low power consumption and strong adaptability to various scenarios. It can meet the low-altitude height measurement requirements of aircraft such as unmanned aerial vehicles, helicopters or airships.



The new normal of the battlefield that fuses face

Diversification of threats

Low, slow and small targets, especially the saturation attacks of drone "swarms", pose a huge challenge to traditional fuses, requiring them to have stronger target recognition capabilities.

Cost-effectiveness ratio pressure

To deal with large-scale and low-cost threats, ammunition itself is required to have an extremely high cost-performance ratio, and fuses need to strike a balance between high performance and low cost.

Deterioration of the electromagnetic environment

From suppressed interference to information-based deceptive interference, the countermeasures have become increasingly complex. Main lobe interference has become an insurmountable obstacle for traditional fuses, and fuses must enhance their anti-interference capabilities.

The demand for miniaturization

The trend of miniaturization and multi-functionality of ammunition imposes strict requirements on the volume and power consumption of fuses. Fuses need to achieve more functions in a smaller space.

04

The future development trend of radio proximity fuses

Composite and multimodal

Multimodal detection fusion

Radio + infrared (IR)/Laser/ultraviolet (UV), different sensors complement each other's advantages to build a detection system that cannot be completely suppressed by a single means, enhancing detection reliability. Through the integration of multiple detection technologies, fuses can better perceive targets under different environmental conditions, enhancing the detection probability and strike effect of the targets

Signal system composition

Inside the radio channel, composite modulation signals such as OFDM-LFM are adopted, which combine the advantages of multiple signals and significantly enhance the complexity of the signal as well as its anti-interception and anti-analog capabilities.

Intelligence and cognition

Cognitive anti-interference

It can autonomously perceive the environment, understand the intention of interference, and intelligently select the optimal working mode (frequency, waveform, power) to ensure the stable operation of the fuse in complex environments.

Deep learning recognition

Based on models such as deep residual networks, precise identification of complex and aliasing interference signals is achieved, with a recognition rate of over 90% at a signal-to-noise ratio of -10dB, thereby enhancing the anti-interference capability of the fuses.

Online incremental learning

The fuse does not need to be returned to the factory. It can learn and adapt to unknown new types of interference on the battlefield, achieving "evolution in battle" and enhancing the adaptability of the fuse.

Softwareization and chipization

Software-defined radio

Software-defined radio fuses replace the expensive dedicated hardware customized for different needs in the past through a universal and programmable hardware platform, achieving software-defined fuse functions and enhancing the flexibility and scalability of the system.

Miniaturization and high integration

Based on radio frequency system-on-chip (SoC) and System-in-package (SiP) technologies, the entire fuse function is integrated onto a single chip, saving valuable space for ammunition and enhancing the universality of the fuses.

Rapid iteration ability

New algorithms and functions can be quickly deployed through software updates to respond to battlefield changes and keep the fuse leading in technology.

New system and new frequency bands

Frequency Controlled Array -MIMO

Frequency-controlled array (MIMO) technology employs a unique two-dimensional range-angle dependent beam to physically solve the main lobe interference problem. It has multiple advantages such as resistance to direction-finding deception and low interception (LPI), making it a revolutionary anti-interference technology.

Millimeter-wave frequency band

The millimeter-wave frequency band, with its large bandwidth and narrow beam characteristics, achieves higher-precision detection. Its inherent anti-interference advantage and low interception probability make it an ideal working frequency band for future fuses.

05

Low cost and technological evolution

The cost transformation of the fourth-generation technology

The era of vacuum tubes

The era of vacuum tubes was pioneering but they were large in size and high in power consumption. The cost has dropped from the initial $732 to $18. Relying on large-scale labor-intensive production, the production efficiency is low, making it difficult to meet the modern fuse's requirements for miniaturization and low cost.

The era of discrete transistors

The discrete transistor era was low-cost and easy to produce, but the performance improvement was limited. Maintaining a relatively low level for a long time makes it difficult to meet the high-performance requirements of modern fuses and cannot achieve the intelligent development of fuses.

The compound MMIC era

The compound MMIC era has superior performance and strong anti-interference ability, such as when GaAs material is adopted. However, the high cost, the expensive materials and processes, the chips not following Moore's Law, and the production relying on manual micro-assembly have low efficiency and poor consistency, which have restricted the low-cost development of fuses.

Technological inflection point

The dawn of RF CMOS technology

Rf CMOS adopts mature silicon-based CMOS technology, with low material and manufacturing costs. Moreover, it follows Moore's Law, and the cost will continue to decline, providing a hardware foundation for the low-cost of fuses.

The easy mass production feature of RF CMOS

Rf CMOS can adopt automated SMT assembly production, breaking away from manual reliance, significantly enhancing efficiency and quality, and meeting the demands of large-scale production, thus providing the possibility for the wide application of fuses.

The high integration feature of RF CMOS

Rf CMOS can integrate all functions such as RF and digital on a single chip, achieving a "system-on-chip", significantly reducing the volume and weight of the fuse, and enhancing the reliability and integration of the system.

The reconfigurability potential of RF CMOS

Rf CMOS is easy to control RF parameters through digital interfaces, laying a hardware foundation for "software-defined" and enabling fuses to be flexibly configured and adjusted according to different combat requirements.

Core solution

01

Chip-based software-defined radio fuses

Replace the past customized and expensive dedicated hardware for different needs with a universal and programmable hardware platform to achieve software-defined fuse functions, thereby enhancing the flexibility and scalability of the system.

02

The implementation method of software-defined fuses

Customize dedicated SOC chips (or integrated SIP chips) with RF and digital functions for mass production to minimize the unit price of the chips. By loading different software and algorithms, the specific functions, performance and working modes of the fuses are defined.

Exploration and Verification

Phase One: Proof of Concept

Develop RF circuits with custom CMOS RF SOC chips as the core, and through FPGA digital circuit control, realize RF reconstruction such as frequency and waveform as well as anti-interference coding. The range test successfully verified the detection and explosion point control capabilities, initially demonstrating the feasibility of software-defined fuses.

Phase Two: Chip integration

A SIP chip integrating digital radio frequency has been developed, which highly integrates radio frequency and digital functions, achieving ultimate miniaturization and low cost. This has laid a hardware foundation for the final product and promoted the development of fuse technology to a higher level.

Trend convergence

Chipization and softwareization

Chip-ization lays the hardware foundation, while softwareization endows the hardware with a soul, enabling flexible definition and rapid upgrade of fuse functions and providing support for intelligence.

Intelligence and integration

Intelligent algorithms efficiently integrate the multi-dimensional data provided by the compound, enhancing the fuse's perception and decision-making capabilities in complex environments.

New System and Intelligence

The new system provides high-quality data from the source, nourishes the intelligent brain, and enables the fuse to achieve a qualitative leap in performance.

06

Conclusions and Prospects

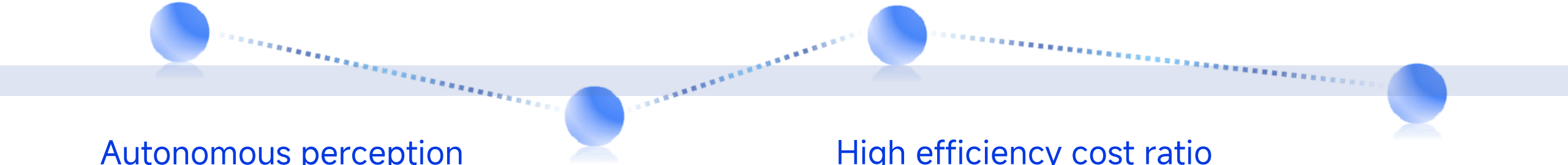
The role of future fuses

Online evolution

Be able to learn and grow in actual combat, continuously improve confrontation capabilities, and adapt to the constantly changing battlefield environment.

Dynamic decision-making

It can make the optimal anti-interference and detonation decisions within milliseconds, enhancing the combat effectiveness of the fuse.



Autonomous perception

Be able to "understand" the battlefield environment and target intentions, independently obtain battlefield information, and provide support for precise strikes.

High efficiency cost ratio

It can deal with larger-scale threats at a lower cost, enhancing the cost-effectiveness and combat effectiveness of the fuse.

The clear prospects of the low-cost path

The clarification of feasible paths

Adopting customized CMOS RF/digital chips to achieve software-defined radio fuses is the best way to resolve the contradiction between cost and performance, and points out the direction for the future development of fuses.

The highlighting of core advantages

In terms of cost, the generalization of hardware and large-scale procurement have led to a significant reduction in costs. In terms of performance, software-defined features bring flexible anti-interference capabilities and intelligent potential. In terms of efficiency, the development cycle of fuses for different types of bombs has been significantly shortened, enabling rapid deployment.

Prospects for future development

With the maturation of domestic CMOS technology and the further reduction of costs, software-defined fuses will enter a golden development period, laying a solid foundation for conventional ammunition to move from "dexterity" to "intelligence", and promoting the continuous progress of fuse technology.

THANK YOU FOR READING!