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Integration of Radar Technology in Smart homes: Applications, Technical Models, and Performance Evaluation

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Abstract:

Nowadays, with the development of science and technology, smart homes are used more and more widely in our daily lives. Radar technology plays a crucial role in the development of smart homes. The main research object is radar technology that is used in smart homes. This paper aims to study the current development trend of radar technology in smart homes, the future development trend of radar technology in smart homes and the role of products. This paper explores the current status, development direction and role of radar technology in smart homes. In this paper, data search, picture rendering and other methods are used. This paper mainly research in three types of radar technology: millimeter wave radars, infrared radars and laser radars. This paper mainly introduce the principle, preponderance and applications of these radars. According to the study, the potential of radar technology in smart homes is considerable.This paper is optimistic about the development of radar technology in smart homes.

Keywords: Radar Technology; Smart homes; Integration

1. Introduction

Smart homes are based on the residential platform, the use of integrated wiring technology, network communication technology, security technology, automatic control technology, audio and video technology to integrate homes life-related facilities, build efficient residential facilities and family schedule management systems, improve home security, convenience, comfort, artistry, and achieve environmental protection and energy saving living environment. Nowadays, as technology has developed faster and faster, people's lives are becoming increasingly convenient. Smart homes are also becoming more important in this process. Intelligence, integration, personalized customization, humanization and other characteristics also appear in smart homes. Smart homes have a greater involvement in people's lives. The size of the market for home furnishing is constantly expanding and is expected to maintain a growing trend in a few years. With the increasing importance, the functional requirements of smart homes are also increasing. At present, safety, convenience, energy saving and comfort are the most important core needs of smart homes.

In the process of smart home development, radar technology is a crucial factor in it. Many types of radars like continuous wave radar, pulse radar and so on can be used in smart homes. homes radar is mainly used to detect and sense the objects and motion state in the home environment. It can be applied to home security, smart home control, human body sensing and other fields. Compared with the traditional smart homes sensor, home radar has a higher detection range and accuracy. So it can adapt to different environments and application scenarios. For example, if someone passes by at night, it is necessary to have a device that can measure the distance between the lamp and the person to achieve the function of intelligent lighting. And traditional smart home sensors cannot do so well as radar systems do. The topic of this paper is to explore the application of radar technology in smart homes.

This paper is divided into five parts: the introduction of the paper, the literature review, the methods technology model basis, applications of radar technology in smart homes and the conclusion of the paper.

2. Literature review

At present, smart homes is in a stage of market expansion and technology integration and innovation. Nowadays, smart home systems have been widely used all over the world, the market scale continues to expand, compound annual growth rate is remarkable. According to statistics, by 2024, the global smart homes market size is expected to reach hundreds of billions of dollars. The demand for technology in today's smart homes is very large. At present, the main technical architecture of smart homes includes central control systems, intelligent devices, communication protocols and the key technologies adopted therein, including but not limited to wireless communication technology, Internet of Things technology and artificial intelligence technology. These technologies enable smart home devices to achieve remote control, automated management, information sharing and collaborative work. However, the existing smart home systems still have certain limitations, such as indoor monitoring, different brands of monitoring equipment may have compatibility problems, is difficult to achieve seamless integration and intelligent linkage. At the same time, smart home monitoring devices may leak users' private information, such as family habits, member activities, if hacked, consequences. In terms of environmental perception, the existing sensor technology may decrease the sensing accuracy under some extreme environments , such as high temperature and high humidity, and the sensing range is limited. In addition, a large amount of environmental data needs to be processed and analyzed efficiently. However, the current sensor technology may not be able to provide comprehensive environmental perception results in real-time and accurately. In terms of user interaction, smart home system operation is complex, users need a certain level of technology to effectively use, affecting the user experience. Therefore, the current smart homes still need continuous improvement and improvement in technology.

At present, radar technology is widely used in non-contact sensing. It is widely used in vital signs detection, motion detection and security monitoring. In terms of vital signs detection, the radar sensor can continuously, non-contact monitoring of heart rate and respiratory rate, has the advantages of low power consumption and small size, and is suitable for consumer electronic products, especially for infants, the elderly and patients who need long-term monitoring. In motion detection, the radar sensor can realize the accurate recognition of human presence and movement through non-contact mode. In the aspect of security monitoring, millimeter wave radar technology can output invasion target data in real-time, link cameras for tracking and shooting, improve the accuracy and reliability of video surveillance, and is suitable for airports, border defense and other perimeter protection. At the same time, radar technology can protect personal privacy, through the non-contact way to perceive the presence and activity of the human body, to optimize the office space experience and home life convenience. Radar technology to achieve high-precision non-contact detection mainly depends on its working principle and advanced technical characteristics. Radar can detect the target by transmitting electromagnetic wave and receiving its echo, and can obtain the distance from the target to the electromagnetic wave transmitting point, range change rate, bearing, height and other information. This feature makes radar technology widely used in intelligent security, smart offices, smart homes and other fields, and provide a more efficient and accurate non-contact detection solution for various scenarios. Therefore, the potential for radar technology to be used in smart homes is very huge.

At present, there are many kinds of sensors on the market, the most representative are radar, infrared sensors, ultrasonic sensors and vision sensors. The radar has the advantages of high precision, anti-interference ability, is not affected by light and color, and is suitable for complex environments. But the cost is relatively high. infrared sensor has high measurement accuracy and fast response speed, but is affected by ambient temperature and humidity, and the measuring distance is short. The ultrasonic sensor has good directionality and long propagation distance, but the measurement accuracy is relatively low and is susceptible to environmental factors. Vision sensors can provide rich environmental information, but with high requirements on

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light conditions, and the need to process a large number of image data, calculations are complex. Several sensors have advantages and disadvantages, and need to make a choice according to the actual situation. At the same time, in the application environment of multi-sensor fusion, radar technology, especially millimeter wave radar, can accurately measure the distance and speed of obstacles and provide accurate environmental perception information. At the same time, the radar sensor is suitable for fog, rain, snow and other special environment, can penetrate these interfering factors, and provides stable sensing data. To sum up, at present, compared with other traditional sensors, radar sensors still have certain advantages in smart homes.

In smart homes, many types of radar are applied in different places. The three most important types of radar are millimeter wave radar, infrared radar and laser radar. Below, this chapter will describe how these three types of radar work, their core components, and their applications in smart homes.

The first type is millimeter wave radar. Millimeter wave radar is a radar that works in millimeter-wave detection. Usually, millimeter wave refers to the 30 ~ 300GHz frequency domain (wavelength of 1 ~ 10mm). As shown in Figure 1 the principle of millimeter radar, the core components of millimeter wave radar mainly include an antenna and transceiver module. The basic principle of millimeter wave radar is to calculate the time difference between the emitted electromagnetic wave and the received reflected electromagnetic wave and estimate the distance of the target object by the electromagnetic wave propagation speed. As shown in the figure below, the main workflow of millimeter wave radar is as follows: First, linear FM pulses are generated by the synthesizer. Then the linear FM pulse is sent out through the transmitting antenna, and the reflected electromagnetic wave is received by the receiving antenna. The transmitted and received signals are combined by a mixer to generate an intermediate frequency (IF) signal and the time difference is calculated from the IF signal. Millimeter wave radar mainly uses the principle of frequency-modulated continuous wave, so it can also use the antenna array to achieve azimuth measurement, including horizontal Angle and vertical Angle detection, so it has strong micro-motion detection capability, can detect the relatively stationary human body, including slight finger movements, speech and other small actions[1]. Because the core components of millimeter wave radar are fewer, its compact size is easy to design products. Because millimeter wave has the ability to penetrate many objects including metal, they can work all day long, and are not affected by ambient temperature, rain and snow, haze and other weather, and can also work normally in strong light, dust and other environments. Because the antenna can transmit and receive in all directions, millimeter wave radar has a wide detection range, and cost savings. Now, millimeter wave radar is also widely used in many aspects of smart homes. On human presence sensing and status recognition, millimeter wave radar can accurately perceive the human presence, identify the human body status, such as stationary or moving, and trigger the interaction of smart home devices according to these states, such as the presence of the light on, the light off and other scenarios. In the bathroom, bedroom and other places prone to falls, millimeter wave radar can detect falls in real-time, and push alarm information in time, to ensure home safety[2]. Millimeter-wave radar is also being used to detect vital signs[3]. Millimeter wave radar can penetrate clothing, glass and other materials, non-contact monitoring breathing, heartbeat and other vital signs, suitable for the elderly health monitoring and emergency alarm[4].

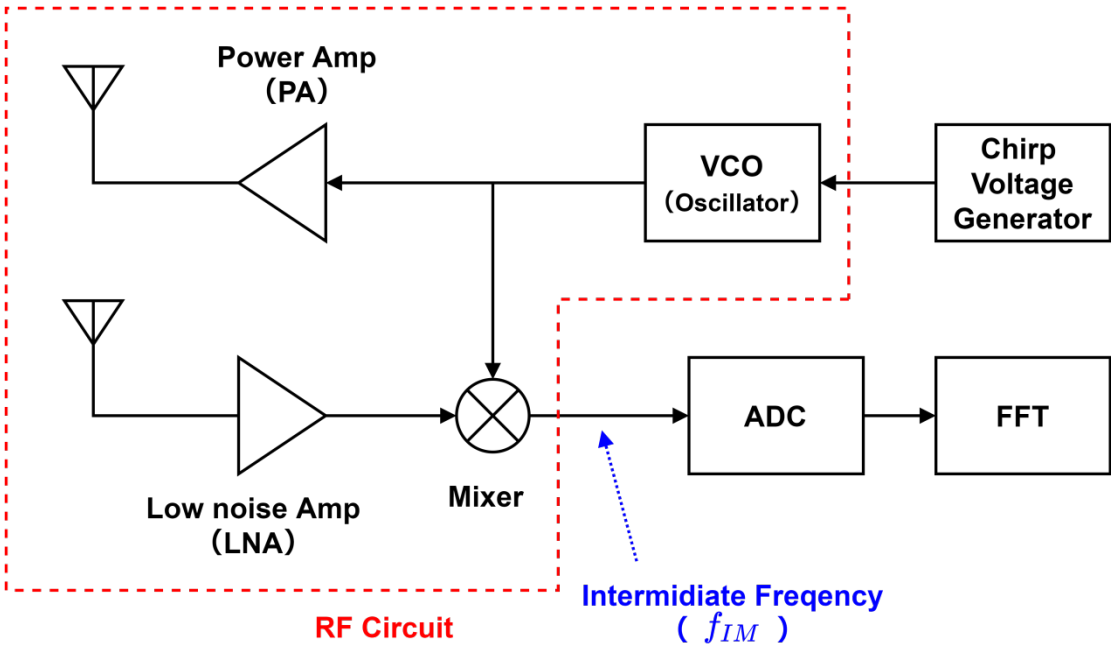

Figure 1 the principle of millimeter radar

The second type is called infrared radar. Infrared radar is an optical radar operating in the infrared band. As shown in Figure 2 the principle of infrared radar, the core components of infrared radar include an infrared radiation source, optical convergence system, infrared detection component, electronic component, control mechanism and display part. The working principle of infrared radar is to use infrared characteristics to detect objects. As shown in the figure, it determines the presence and location of objects by emitting infrared signals and receiving the reflected signals. Specifically, infrared radar uses the strong penetration of infrared rays and the characteristics of being unaffected by light to shine infrared rays onto the object to be detected, and then receives the reflected signal to determine the existence and location of the object. Since infrared radar can use infrared to acquire object data, it has high resolution and sensitivity, and can detect small temperature changes and thermal radiation. At the same time, it has strong adaptability, can still work normally at night or under low-light conditions, and has strong concealment[5]. However, in spite of its low cost, infrared radar is easily affected by the environment, such as the change in wind speed, temperature and other environmental factors may affect its detection effectiveness; Its penetration ability is weak, for some objects with high thermal radiation or specific reflection characteristics, its detection effect may not be good; Its detection range is limited compared with other radars, the detection range of infrared radar may be shorter, and there is no penetration of obstacles. At present, infrared radar plays an important role in smart homes. Infrared radar can detect the presence of the human body, thus triggering the automatic control function of the smart home system, such as automatically switching on and off the light, regulating the air conditioning temperature, and provides occupants with a convenient and comfortable living environment. In the intelligent security system, infrared radar detects intruders by monitoring infrared radiation, to achieve homes safety protection. Infrared radar technology is also used in the control of intelligent homes appliances, such as through the infrared remote control to control TV, air conditioning and other equipment, to realize the intelligent operation of home appliances .

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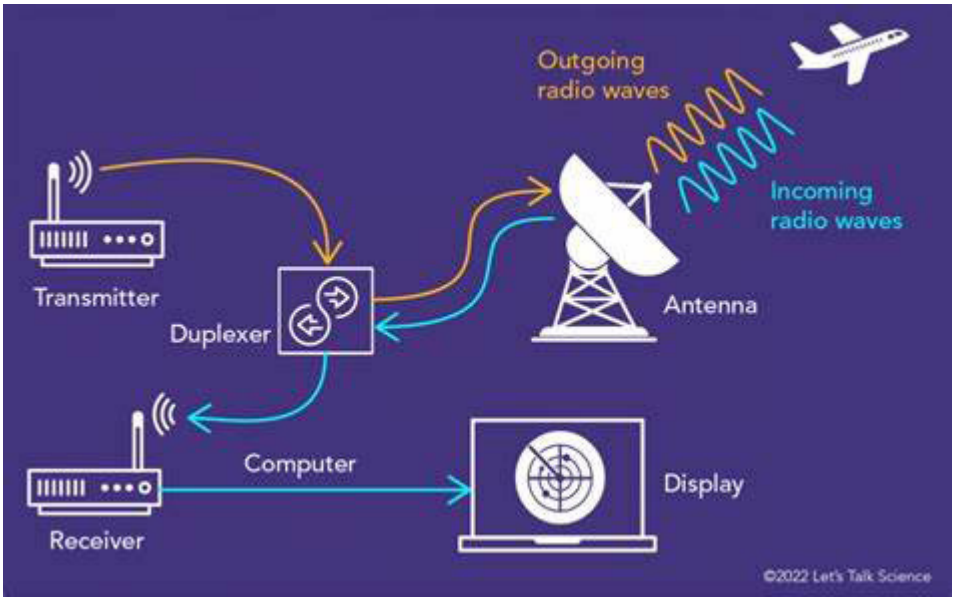

Figure 2 the principle of infrared radar

The third type of radar is laser radar. Laser radar is a radar system that transmits laser beams to detect the target's position, speed and other characteristic quantities. The core components of laser radar are the transmitter, laser, optical receiver, turntable and information processing system. As shown in Figure 3 the principle of laser radar, the laser changes the electric pulse into an optical pulse and emits it, and the optical receiver restores the optical pulse reflected back from the target into an electrical pulse and converts it into an electrical signal. These electrical signals are then processed and analyzed in order to extract useful information about the target object. The processed data can be used in various applications. The laser radar has a very high resolution in the detection process, whether it is Angle, distance, or velocity resolution can meet the needs of fine characterization. What's more, laser radar can accurately calculate the position of each point in three-dimensional space to create high-quality three-dimensional point cloud data. At the same time, the laser radar can still maintain stable work at night or under low light conditions, through the haze, smoke ability is relatively strong[6]. However, in extreme weather such as heavy rain, thick fog, or snow particles, the performance of laser radar may be significantly reduced, and the repair and replacement cost of laser radar may be higher due to high precision[7]. At present, laser radar is widely used in smart homes. In smart home security, laser radar can carry out precise scanning, detect the behavior of people in and out, and trigger the security mechanism in real-time. In intelligent control of lighting, it can sense the indoor light intensity and color, and automatically adjust the lighting system. In intelligent home appliance control , laser radar can scan and control household electrical equipment, such as smart refrigerators, washing machines, to make it more intelligent, energy saving. In smart homes navigation , using laser radar, smart home systems can establish a family map and realize automatic navigation and path planning.

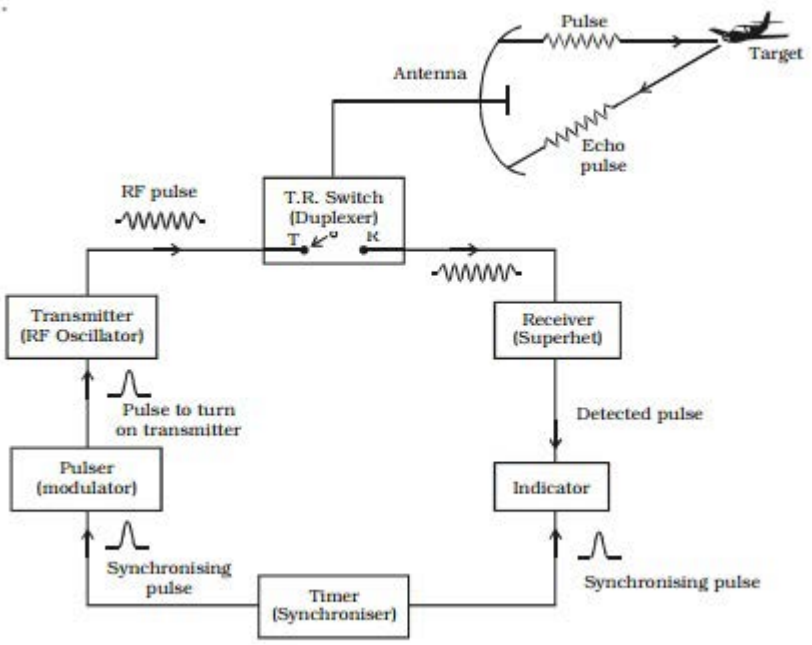

Fig . ' Block diagram of a radar system

Figures 3 the principle of laser radar

3. Applications

At present, radar is widely used in smart homes, especially in indoor environment monitoring and health detection, and the effect is extremely outstanding. The application of radar in indoor environment monitoring mainly includes personnel detection and tracking, environmental monitoring and energy management. Millimeter wave radar, due to its high resolution and penetration, can accurately perceive the presence of indoor personnel, location and movement trajectory. It is suitable for hotels, families, hospitals and other places, to improve service quality and safety[8]. At the same time, radar technology can also monitor indoor environmental parameters, such as air quality, temperature and humidity, and provides data support for intelligent buildings. In the aspect of energy management, radar can assist in intelligent lighting, air conditioning control and other functions, energy saving and emission reduction[9]. In a word, radar technology brings intelligent and accurate solutions for indoor environment monitoring. Radar is also very useful in health detection, especially in non-contact vital signs monitoring, showing great potential[10]. By transmitting and receiving electromagnetic waves, radar can accurately perceive the tiny movements of the human body, such as breathing and heartbeat, so that heart rate, respiratory rate and other physiological indicators can be monitored in real-time. In addition, radar technology can also be applied to fall detection, by analyzing the change of human posture,and timely alarm, to ensure the safety of users. These applications not only improve the convenience and accuracy of health detection, but also effectively solve the discomfort and limitations caused by traditional contact sensors .

4. Conclusion

This paper describes some of the current applications of radar technology in smart homes, including millimeter wave radar, infrared radar and laser radar in health detection, user interaction, intelligent control of home appliances, smart home security and other applications. Some differences and disadvantages in cost, performance and limitations are also presented. Radar technology plays a very important role in the development of smart home products, and makes a great contribution to the convenience and security of smart homes. Without radar technology, traditional sensors cannot provide users with a relatively private, safe, and convenient life.

In the future, it is believed that radar technology will have greater breakthroughs in the field of smart homes with the development of science and technology. Radar technology can be combined with future technologies (such as artificial intelligence and other technologies) to provide users with better services. Overall, I am optimistic about the fu-

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ture development of radar technology in the smart homes field.

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