

# Antenna Design System Based on Augmented Reality

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**Abstract.** This paper presents a new antenna design system based on augmented reality (AR). This system can be used for learning courses about antenna design and it provides a new education method for antenna design for the future. Nowadays coursework and curricula in antenna design is challenged by the fact that it is difficult to have a sense of presence and interaction. However, augmented reality can enhance the user's interest and engagement, because it has higher degree of interaction and visualization compared with the traditional antenna design software. This system is based on AR and can display the antenna model which enhances the user's visualization. Besides, this system has two interactive ways which make the users have more interactions. First, the new antenna design system can recognize the two-dimensional logo through the mobile phone camera and display the antenna model on the phone screen. Second, this system can make the antenna model rotated, moved, zoomed in and out, and changed in color and so on through virtual buttons or smart gloves. Finally, this system can change the antenna's surface area, volume and other parameters to design an antenna. This system can also display the designed antenna in real-time and show the radiation intensity of the receiving antenna as well. The distance between the receiving antenna and the transmitting antenna can be calculated. Therefore, this system can be used for education in antenna design and can greatly improve the interest of students and beginners.

**Keywords:** antenna, augmented reality, education, smart gloves, virtual button

## 1 Introduction

Augmented Reality (AR) is a subset of Mixed Reality (MR) that enables seamless integration of real-world environment and computer-generated objects in real time [1]. Recent advances in hardware and software for mobile computing have boosted the ubiquity of AR and brought about many emerging applications, not limited only to vision but also encompassing all other senses such as touch and hearing. AR is becoming more and more popular and gradually changes people's lives. It is widely used in many areas such as education, entertainment and so on [2]. However, it has been not found that AR is applied in the context of antenna design.

Nowadays coursework and curricula in antenna design is challenged by the fact that it is difficult to have a sense of presence and interaction. Traditional software for antenna design, such as High Frequency Structure Simulator (HFSS), Computer Simulation Technology (CST), etc. is highly professional but weak in interaction and engagement which makes it difficult for beginners to master. On the contrary, AR can enhance the user's interest and engagement because it has higher degree of interaction and visualization. Therefore, this system combines the antenna design with AR can greatly improve the visibility of the antenna design and makes it easier for beginners to master, so it can be used for education in antenna design. This system provides a new education method for antenna design for the future.

The antenna design system was developed by using Unity3D and Android Studio platform. It uses Unity3D to make antenna model rotated, moved and complete other operations, and uses Android Studio to change unity project into android application so that it can connect with mobile phones, smart gloves,

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Virtual Reality (VR) glasses and other hardware devices. In addition, this system uses Vuforia Software Development Kit (SDK) which is the plug-in for Unity3D platform. Vuforia SDK is more popular than other SDK since it has more documentations, and, from Unity3D, the application can easily be ported to multiple end-user devices. This system is designed with two interactive modes, one is based on virtual buttons and the other based on smart gloves. The smart gloves are designed to interact, and the interactive gestures are optimized to more easily and intuitively control the motion of the antenna model.

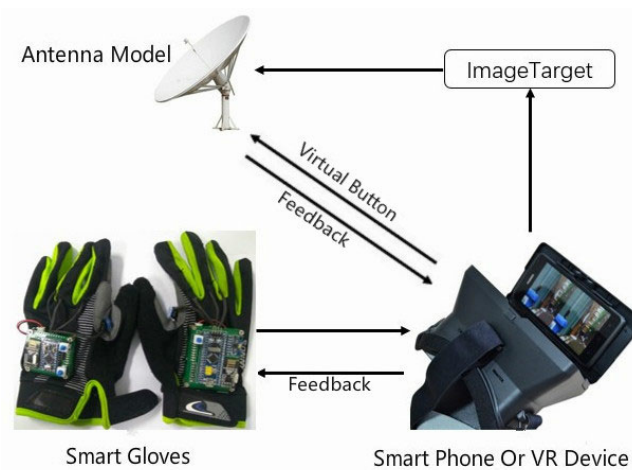
## 2 System Design

This system combines the antenna design with AR in three ways, antenna model display, antenna measurement and antenna design. Besides, it provides two interactive modes for the user to control the antenna model. Each section is described in detail below.

### 2.1 System Overview

This system has two interactive ways, namely virtual buttons and smart gloves. In addition, it has two modes, namely antenna design mode and antenna measurement mode. In the antenna design mode, the user can design the volume and surface area of the antenna model. In the measurement mode, the user can change the distance between the transmitting antenna and the receiving antenna, and observe the electric field strength, magnetic field strength, radiation intensity and other parameters' change.

When using the smart gloves, the user can recognize the two-dimensional logo through the mobile phone camera and display the antenna model on the phone screen. Through scanning different logos, different models can be displayed. Smart gloves can connect with the phone through the Bluetooth 4.0, and send codes to the phone, then can be controlled to design the antenna model by the phone. When using virtual buttons, the user can control the model directly by pressing the virtual buttons. The system structure is shown in Fig. 1. The smart gloves can recognize the two-dimensional logo through the mobile phone camera and control the antenna model. Besides the user can control the model directly by pressing the virtual buttons.



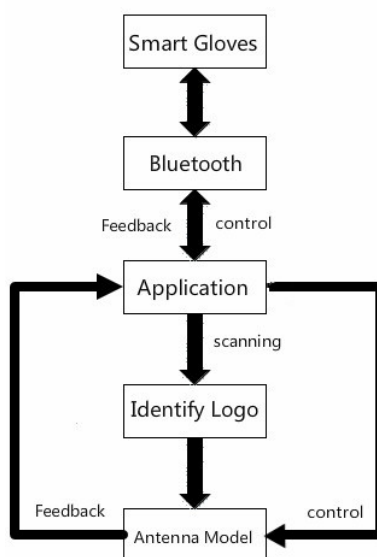
**Fig. 1.** System structure

### 2.2 Antenna Model Display

Because AR can achieve excellent visual effects, display the antenna model through AR to deepen the user's impression and increase the user's interest [3]. The new antenna design system can recognize the two-dimensional logo through the mobile phone camera and display the antenna model on the phone screen. Then it can use virtual buttons or smart gloves to control the antenna model, for example, changing the size, angle, and color of the model.

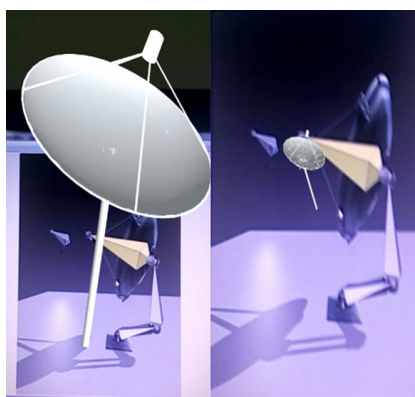
When using the smart gloves, the user can use simple gestures to control the model. For example, the antenna model will slowly shrink with the palm shrinking. When the palm slowly rotates, the antenna model will follow the rotation. These gestures are simple, intuitive and very easy for beginners to master.

The process of using smart gloves for model display is shown in Fig. 2. Smart gloves can connect with the phone through the Bluetooth 4.0, and recognize the two-dimensional logo through the mobile phone camera, then can be controlled to design the antenna model by the phone.

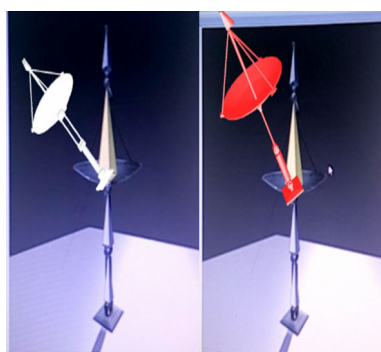


**Fig. 2.** Use smart gloves for model display

When using virtual buttons, the user presses the corresponding button to make the model rotated, moved, zoomed in and out, and changed in color and so on. The model is zoomed in and out by using the virtual button, which is shown in Fig. 3. The model is changed in color, which is shown in Fig.4.



**Fig. 3.** Antenna model scaling



**Fig. 4.** Antenna model color change

### 2.3 Antenna Measurement

In the measurement mode, the user can change the distance between the receiving antenna and the transmitting antenna through smart gloves or virtual buttons, and observe the electric field strength, magnetic field strength, radiation intensity and other parameters. This system incorporates the advantages of AR into the antenna design. It can real-time calculate and display the radiation intensity, so it can be used to judge whether the radiation has been affected by the surrounding environment or not. Therefore, it can help to decide where the antenna should be placed.

The user should pre-set the current values, wavelength, direction coefficient, length and other parameters for the transmitting antenna, then keeps the transmitting antenna model stationary and moves the receiving antenna model. This system will calculate the distance between two antennas and show the three most commonly used parameters of the receiving antenna: radiation intensity, electric field strength, and magnetic field strength. The parameters which should be preset by the system are listed as follows, the transmitting antenna wavelength  $\lambda=0.35\text{m}$ , current  $I = 95\text{mA}$ , length  $L = 0.26 \text{ m}$ , the transmitting antenna and receiving antenna directivity coefficient  $D = 1$ .

Antenna radiation intensity formula is discussed and shown as follows. The distance between the receiving antenna and the transmitting antenna is calculated by

$$R = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} . \quad (1)$$

where  $R$  is referred as the distance between the receiving antenna and the transmitting antenna,  $(x_1, y_1, z_1)$  is referred as the coordinates of the transmitting antenna,  $(x_2, y_2, z_2)$  is referred as the coordinates of the receiving antenna.  $(x_1, y_1, z_1)$  and  $(x_2, y_2, z_2)$  will be calculated by the system. Directional coefficient definition is

$$D = \frac{E^2(\theta, \varphi)}{E_0^2} . \quad (2)$$

where  $E^2(\theta, \varphi)$  is referred as the square of the electric field strength in the maximum radiation direction,  $E_0^2$  is referred as the square of the electric field strength of the point source antenna,  $D$  is referred as the directional coefficient. The electric field strength definition is

$$E_m = \frac{\sqrt{60P_r D}}{R} . \quad (3)$$

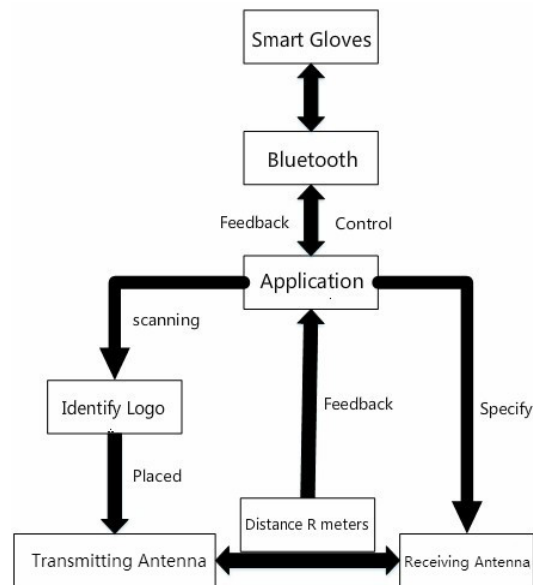
where  $E_m$  is referred as the electric field strength in the maximum radiation direction,  $P_r$  is referred as the radiation intensity. The magnetic field strength definition is

$$H_m = \frac{E_m}{120\pi} . \quad (4)$$

where  $H_m$  is referred as the magnetic field strength in the maximum radiation direction. Antenna radiated power definition is

$$P_r = 40\pi^2 I^2 \left(\frac{L}{\lambda}\right)^2 . \quad (5)$$

where  $I$  is referred as the transmitting antenna current,  $\lambda$  is referred as the transmitting antenna wavelength,  $L$  is referred as the transmitting antenna length. The process of using the smart gloves for antenna measurement is shown in Fig. 5. Smart gloves can connect with the phone through the Bluetooth 4.0, and recognize the two-dimensional logo through the mobile phone camera. The user can change the distance between the receiving antenna and the transmitting antenna through smart gloves, and the system will show electric field strength, magnetic field strength, radiation intensity and other parameters on the phone screen. The antenna measurement mode is shown in Fig. 6.



**Fig. 5.** Use smart gloves for antenna measurement



**Fig. 6.** Antenna Measurement mode

## 2.4 Antenna Design

In the antenna design mode, this system can change the surface area and the volume of the antenna model by changing the length of the X-, Y-, and Z-axis. This system gives two basic shape model of antenna in advance: the rectangular antenna and the cylindrical antenna. The two models are chosen because they are common and easier to observe than the surface antenna. The user can design the volume and surface area of the antenna model by means of using smart gloves or virtual buttons. The designed antenna can be placed in the realistic environment because AR has higher degree of visualization. The user can adjust the antenna size and other parameters according to the environment to observe effects. This system can observe the design more visually and is more easy to master. The process of using the smart gloves for antenna design is shown in Fig. 7. Smart gloves can connect with the phone through the Bluetooth 4.0, and recognize the two-dimensional logo through the mobile phone camera. The user can control the basic shape antenna model by means of using smart gloves, and the system will show the volume and surface area of the antenna model on the phone screen. Cylinder model design is shown in Fig. 8, and cube model design is shown in Fig. 9.

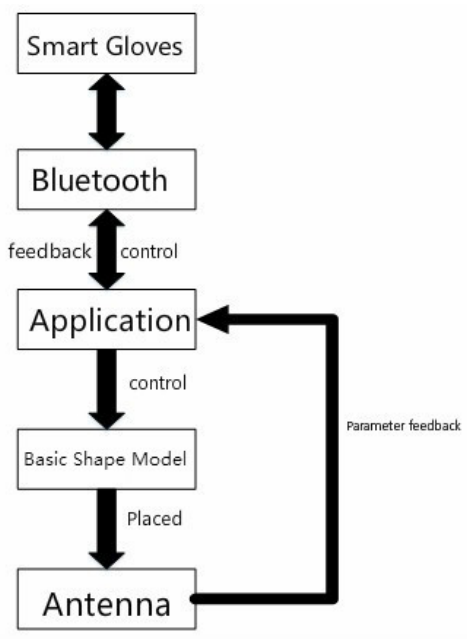


Fig. 7. Use smart gloves for antenna design

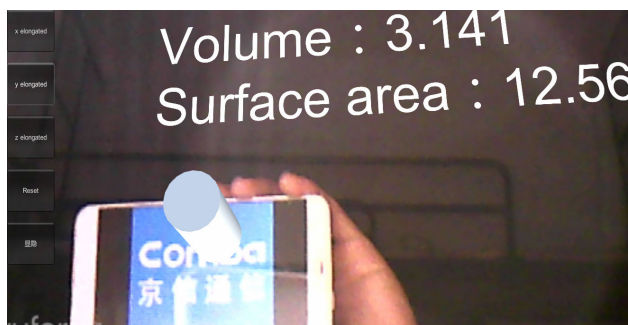


Fig. 8. Cylindrical parameter display

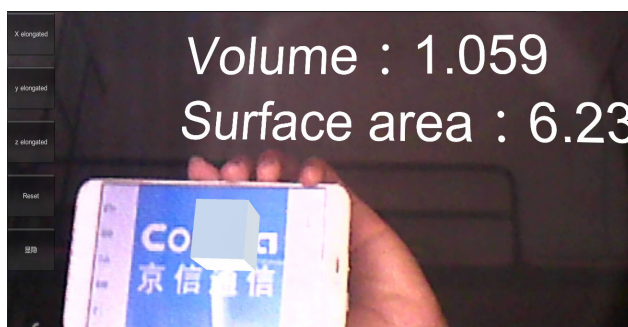


Fig. 9. Cube parameter display

## 2.5 Smart Gloves

In order to enable the user to interact with the antenna model, we designed the smart gloves. When the user wears VR glasses, they do not conveniently control the model, so they can use the smart gloves to control antenna model [4]. The smart gloves are divided into the left hand and right hand, as shown in Fig. 10. The left and right hands of the smart gloves have two buttons and two bending sensors, the resistance value in the bending sensor changes with the degree of bending. The smaller the degree of bending is, the smaller the resistance of the sensor will be. The degree of bending can be divided into



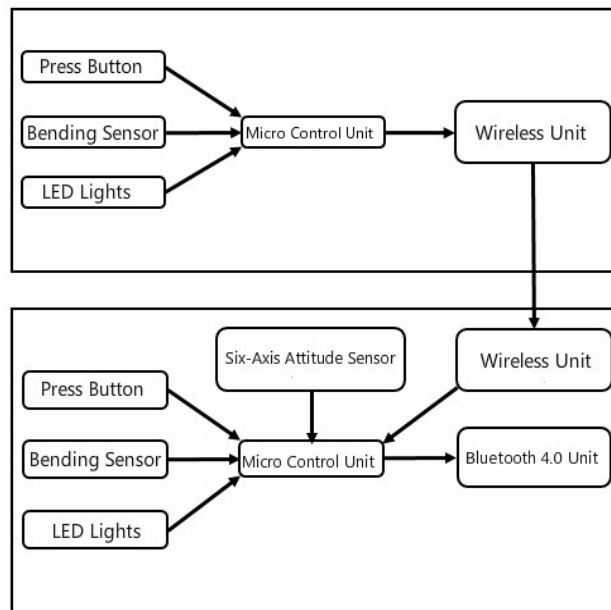
2046 levels. In addition, the right hand is also equipped with an accelerometer to read the angle information.



**Fig. 10.** Smart gloves

The main hardware of the smart glove can be divided into five modules: micro-control unit, wireless unit, Bluetooth 4.0 unit, bending sensor, and six-axis attitude sensor. Micro-control unit is used for smart gloves data processing. The left and right hands of the smart gloves are equipped with one micro-control unit. The right hand is equipped with Arduino Pro Mini and the left hand is equipped with STM32F103C8T6. The wireless unit is used for data transmission between the left hand glove and the right hand glove. This glove selects NRF24L01 wireless module, the operating frequency band is 2.4GHz-2.5GHz and the power consumption is very low. The Bluetooth 4.0 unit is used for communication between gloves and android smartphones. This glove is equipped with the CC2531 Bluetooth 4.0 module, operating at 2.4GHz and it can support up to 80 meters communications. The bending sensor can be fixed on the measured surface and it can detect the degree of bending by detecting the changes of the sensor resistance. These gloves use MPU6050 six-axis attitude sensor, which can accurately obtain the glove's angle information.

These smart gloves have simple and intuitive interactive gestures. For example, the antenna model will slowly shrink with the palm shrinking. When the palm slowly rotates, the antenna model will follow the rotation. The hardware structure of the smart glove is shown in Fig. 11.



**Fig. 11.** Hardware structure of the smart gloves

Smart gloves are the main interactive hardware, and it is necessary to design a variety of interactive gestures to meet various interactions. In this system, the gloves should be design to realize 19 kinds of interactive gestures, including zooming in and out of X-, Y-, and Z-axis, positive and negative movement of X-, Y-, and Z-axis, rotation of X-, Y-, and Z-axis, globally zooming in and out, model switching, and so on. Theses gloves need a lot of gestures because X-, Y-, and Z-axis need to be operated accurately. So many interactive gestures may cause the difficulty of learning and operating and other issues. Therefore, it is necessary to design a simple method for the operations in three dimensional axis. These gloves use the accelerometer to achieve the operations. As the accelerometer can recognize the current hand angle, when the palm of the hand is located in the XY surface, YZ surface, XZ surface of Cartesian coordinate system, it represents the X-, Y-, and Z-axis. For example, when the palm face coincides with the XY surface, it represents the X-axis operation. Right hand bending sensor resistance is divided into 16 levels to achieve zooming in and out. These gloves can compare the current bending data with the previous bending data. If the resistance becomes smaller, indicating that the fingers is open, so the antenna model zooms in, if the resistance becomes larger, indicating that the fingers tighten, so the antenna model zooms out. The smart gloves' gesture codes are shown in Table 1. The horizontal coordinate represents gesture to be executed, and the coordinate represents the states of the button on the smart gloves.

**Table 1.** Smart gloves' gesture codes

	Lefth thumb	Lefth index finger	Lefth middle finger	Lefth hand ring	Right thumb	Right index finger	Right middle finger	Right hand ring	XY surface	YZ surface	XZ surface
Global zoon in	√	-	-	×	×	√	√	×	-	-	-
Global zoon out	√	-	-	×	×	√	√	×	-	-	-
X-axis zoom in	×	-	-	√	×	√	√	×	√	×	×
X-axis zoom out	×	-	-	√	×	√	√	×	√	×	×
Y-axis zoom in	×	-	-	√	×	√	√	×	×	√	×
Y-axis zoom out	×	-	-	√	×	√	√	×	×	√	×
Z-axis zoom in	×	-	-	√	×	√	√	×	×	×	√
Z-axis zoom out	×	-	-	√	×	√	√	×	×	×	√
X-axis positive shift	×	√	√	×	√	×	×	×	√	×	×
Y-axis positive shift	×	√	√	×	√	×	×	×	×	√	×
Z-axis positive shift	×	√	√	×	√	×	×	×	×	×	√
X-axis neqative shift	×	√	√	×	√	√	√	√	√	×	×
y-axis neqative shift	×	√	√	×	√	√	√	√	×	√	×
Z-axis neqative shift	×	√	√	×	√	√	√	√	×	×	√
X-axis rotation	√	√	√	√	×	×	×	×	√	×	×
Y-axis rotation	√	√	√	√	×	×	×	×	×	√	×
Z-axis rotation	√	√	√	√	×	×	×	×	×	×	√
Model switch	×	×	×	√	√	√	√	√	×	×	×
Reset	√	√	√	√	√	√	√	√	√	√	√

Note. √ representative 1, × representative 0, - representative 0 or 1.

### 2.6 Virtual Buttons

In addition to smart gloves, this system also designed virtual buttons for controlling the antenna model. Virtual buttons detect the mark of the preset logo and calculate whether the mark is blocked, if blocked then the button is pressed. As the virtual buttons need to be operated directly by fingers, there will be a false touch, which limits the operating accuracy. To prevent false touch, this system use the long press virtual buttons, each button which is pressed over one second can be considered valid.

In order to clarify the location of the virtual buttons, this system needs designing the two-dimensional logo interface first. If the virtual button is placed on the edge of the two- dimensional logo, it will cause the decrease of the recognition rate and speed. So the location of the button should be slightly away from the edge of the two-dimensional logo so as to increase the recognition rate.

In order to expand the virtual buttons' recognition range and make the operation simpler, virtual buttons are mainly designed in the shape of rectangle. Virtual buttons are placed together so that the fingers can press buttons continuously during the sliding process. Each button has the same function so as to achieve the sliding effect. For example, to enlarge the model, the function of each button is set to be



0.05 times, then slide five buttons continuously, it will enlarge 0.25 times gradually. The virtual button is placed as shown in Fig. 12. The blue rectangle represents the position of the virtual buttons.

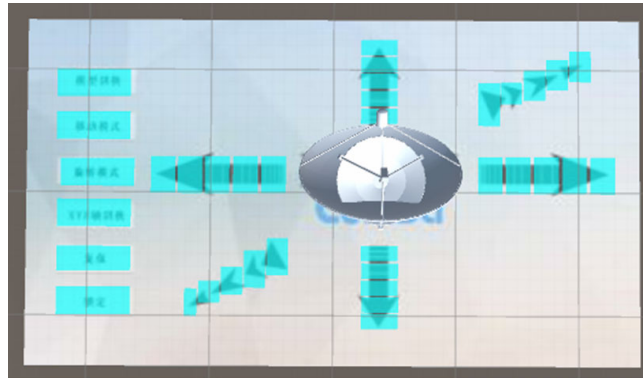


Fig. 12. Virtual button markup

### 3 Application Interface

Antenna display mode is integrated with antenna measurement and antenna design into one software in the end. The software interface includes the antenna design mode and antenna measurement mode. In the antenna design mode, the user can design the volume and surface area of the antenna model by means of using smart gloves or virtual buttons. In the measurement mode, the user can change the distance between the receiving antenna and the transmitting antenna through smart gloves or virtual buttons, and observes the electric field strength, magnetic field strength, radiation intensity and other parameters' change. Interactive methods include smart gloves and virtual buttons. Besides, the user can choose the single or double screen mode. In the single screen mode, the antenna model is displayed on smartphone screen and can be controlled by using smart gloves or virtual buttons. In the double screen mode, the model is displayed by VR glasses and can only be controlled by using smart gloves. The overall interface of the system is shown in Fig. 13.

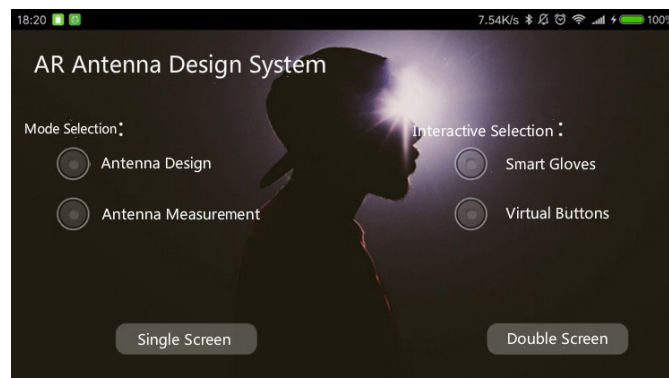


Fig. 13. Application interface

### 4 Conclusion

This paper presents an antenna design system based on AR, which was developed based on Unity3D and Android Studio platform, and uses the computer vision algorithm provided by the Vuforia SDK. It's run on the smart phone and can be used with smart gloves. This system provides a method to design and display a simple antenna model. Traditional software for antenna design is highly professional but weak in interaction and engagement which makes it difficult for beginners to master. On the contrary, AR combines virtual antenna model with real scenes which increases engagement and is more attractive. This system incorporates the advantages of AR into the antenna design, and has two interactive ways, so it has higher degree of interaction and visualization compared with the traditional antenna design software and

is easier for users to understand and master the antenna design. Therefore, this system can be used for education in antenna design and can greatly improve the interest of students and beginners. Comparisons of this system and other antenna design methods in education are shown in Table 2. Other antenna design methods in education are weak in interaction, but this system has higher degree of interaction and more attractive. Although this system can increase students' interest, it is not professional enough at present. This system needs to increase more function of antenna design in the future. This system provides a new education method for antenna design for the future.

**Table 2.** Comparison of this system and other antenna design methods in education

Name	Comparison
Antenna Design System Based on Augmented Reality	Combine antenna design, AR and smart gloves, has higher degree of interaction and visualization, easier for students to master and more attractive
Wireless Communications Engineering Education via Augmented Reality [5]	Combine antenna design and AR, has higher degree of visualization but no interactive method
Internet Support of Education in Antenna and Microwave Techniques [6]	Using the Internet for learning antenna design, lack of interactivity and telepresence
Electromagnetic simulation for education on antenna engineering [7]	Using WIPL-D for learning antenna design, highly professional but weak in interaction and engagement, difficult for students to master

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