**Project 2：Communication System**

|  |  |
| --- | --- |
| **Author** | Name： 蔡浩宇/曹子惠/李璐/李帅  Student ID:12112201/12112241/12110748/12112211 |
| **Introduction**  **Experimental objective:**  To be able to design, test and use microwave devices  **Principle of Wilkinson power divider:**  Wilkinson power divider: If the power divider k is equal to 1 and the power output from both ports is equal, this is a 3dB Wilkinson power divider.  **1).Transmission Line Theory:** The power divider uses precise length transmission lines internally to ensure phase delay matching at specific frequencies. This helps to achieve accurate allocation of input signals to different output ports.  **2).The principle of reflection phase invariance**: When the input signal is assigned to different output ports, the power divider ensures that the reflection coefficient at the output port is basically the same as at the input port. This means that the signal reflected back from any output port to the power divider will maintain phase consistency with the signal reflected back from other output ports.  **3).Symmetric network design:** In order to achieve balanced power division, the 3dB Wilkinson power divider usually adopts a symmetrical network design to ensure phase and amplitude matching between each output. This helps to ensure the balance and stability of the output signal.  The 3dB Wilkinson power divider achieves the function of accurately and evenly distributing input signals to different output ports through precise transmission line length and symmetrical network design.  1702023993152  1702024015651  1702024047688  **The theoretical basis of the design size of the Wilkinson power divider mainly includes the following aspects:**  the characteristic impedance of the transmission line: In order to achieve the matching of the power divider, the characteristic impedance of the transmission line needs to match the characteristic impedance of the input and output ports.  Length of transmission lines: In order to achieve equal work points, the three transmission lines need to be equal in length. The length of the transmission line is related to the operating frequency, and the length of the transmission line can be calculated according to the required frequency.  Transmission line width and dielectric constant: The width and dielectric constant of the transmission line affect the characteristic impedance of the transmission line and the calculation of the transmission line length. According to the selected dielectric material and characteristic impedance, LineCal in ADS can be used to calculate the transmission line width and dielectric constant. It is also necessary to consider the loss of the transmission line, the accuracy of the matching, and the frequency response  **Introduction to the principle of branch line coupler**：  A branch-line branch-node-line patch directional coupler is a type of coupler based on a patch line. It operates on the principle of mode coupling effects on patch linesBranch line stub line patch directional coupler typically consists of four transmission lines, a main line, a branch line, and two output lines. The main and branch lines are connected to each other by patch stub lines to form a coupling structure. The energy on the main line will be partially coupled to the spur line through the coupling structure, and then coupled to the output lines through the patch stub lines on the spur line. When the input signal passes through the main line, a portion of the energy is coupled through the branch line to the other output port, while the energy between the two output ports is isolated. In a branch line coupler, the input signal is transmitted through the input line to the interior of the coupler. Internally, the input signal is distributed to multiple output lines. This distribution is achieved by coupling the electromagnetic fields between the transmission lines. When an input signal is transmitted through an input line, it generates an electromagnetic field between the transmission lines inside the coupler. This electromagnetic field causes induced currents on the other transmission lines, which allows the input signal to be distributed with equal power on those transmission lines.  In short, the branch line coupler distributes the input signal to multiple output ports through the coupling effect of the electromagnetic field, enabling the branching and distribution of signals. It plays an important role in wireless communication systems for signal distribution and transmission.    **Theoretical basis of design size of branch line coupler:**  As can be seen from the figure above, the electric length of MLIN can be calculated by using linecal in ADS, and then the requirements for S parameter can be designed by using GOAL. OPTIM can be used to optimize the length, and the optimized circuit diagram can generate dxf files and import them into hfss for modeling, and then export them to Jialectron  **Introduction to Patch Antenna Design Principles：**  An antenna is a converter that transforms guided waves propagating on a transmission line into electromagnetic waves radiating in a predetermined direction of space electromagnetic waves radiated in a predetermined direction, or performs the opposite transformation.  A patch antenna is a common small antenna design typically used in wireless communication systems. It consists of a metallized dielectric substrate and a metal patch attached to it. The operation of a patch antenna is based on a resonance pattern created on the metal patch and radiated to send or receive signals at radio frequencies. The design principles include the following key elements: Substrate: A dielectric material such as ceramic, polytetrafluoroethylene (PTFE) or glass fiber reinforced polyimide (FR4) is usually used. The dielectric constant and thickness of the substrate affect the antenna's operating frequency. Metal patch: Located on one side of the substrate, it is usually a thin metal piece that can be shaped like a rectangle, circle, ellipse, etc. This metal patch plays the role of radiating the antenna signal. Feed point: the patch antenna is connected to the transmission line of the wireless system through the feed point, and the commonly used feed methods include patch line or coaxial cable. Ground plane: A large-sized metal plate, called a ground plane, is usually required on the other side of the patch antenna to improve antenna efficiency. Patch antennas are widely used because of their simplicity of construction, ease of fabrication, and flexibility in small devices. Its design principles allow engineers to adjust the antenna's frequency response, radiation characteristics, and impedance matching to specific application requirements.    **Theoretical basis of patch antenna design size**  The medium substrate is selected to estimate the size of the radiation patch. Set the dielectric constant of the dielectric substrate as 𝜀𝑟, the working frequency of the rectangular patch antenna as 𝑓, the speed of light as 𝑐, and the width W of the radiating patch according to the following formula:  The length of the radiation patch is generally , whereis the guided wave length in the medium. Considering the edge shortening effect, the actual radiation patch length 𝐿 is , where is the equivalent dielectric constant and ∆𝐿 is the equivalent radiation gap length, which can be calculated respectively by the following formula:  Where, is the characteristic admittance when the antenna is regarded as a transmission line, is the distance from the feeder line to the edge of the antenna.  **Parameter requirements:**  • (1) All devices use FR4 dielectric substrate, dielectric constant 4.4, thickness 1.6mm, surface copper thickness 1oz (0.035mm)  • (2) The port patch line impedance is 50Ω  • (3) Feed with SMA offset connector, SMA exposed core length 4mm, foot lateral spacing 4.7mm, overall width 6.5mm, please  Make sure it can pass the welding and does not cause short circuit  • (4) 100Ω patch resistance size 2.0mm x 1.2mm, please ensure that it can be welded and does not cause short circuit  • (5) The overall size of the PCB board is as small as possible, no more than 90mm×90mm  **Lab results & Analysis**：   1. **Wilkinson power divider, branch line coupler, patch antenna, HFSS and ADS simulation results (model diagram, S-parameter, optimization results)**   **Wilkinson Power Divider 950MHz**  ADS        HFSS      **Wilkinson Power Divider 2.4GHz**  ADS  IMG_256  IMG_256  HFSS      **Branch line coupler 1.45GHz**  ADS      HFSS    **Patch antenna 2.4GHz**  HFSS    **territory**       1. **LibreVNA test results: (1) Calibration results; (2) Device test results;**   **concrete figure**      **(1) Calibration results**    **(2) Device test results;**  Wilkinson Power Divider 950MHz        S11=-50dB<-15dB, S22=-19.75dB<-15dB, S21=-3.772dB>-4dB, S32=-28.51dB<-20dB  |S21-S31|=0.179dB<0.2dB, angle(S21-S31)=0.9<1  Branch line coupler 1.45GHz        S11=-20.58dB<-15dB, S21=-3.891dB>-4dB, S31=-3.951dB,>-4dB S41=-56dB<-20dB  |S21-S31|=0.06dB<1dB, 87<angle(S21-S31)=87.2<93  Patch antenna 2.4GHz    S11=-20dB<-10dB  Wilkinson Power Divider 2.4GHz        S11=-20.84dB<-15dB, S22=-17.74dB<-15dB, S21=-3.688dB<-15dB, S32=-22.64dB>-4dB,  |S21-S31|=0.11dB<0.2dB, angle(S21-S31)=0   1. **Analysis of test results and direction of improvement；**   After testing these devices, it is found that the requirements for S parameters can be met, and the center frequency offset is also within the range. The reason for the center frequency offset may be in the manufacturing process. Material characteristics, dimensional deviations, or assembly errors may cause the center frequency of the microwave device to shift, or electromagnetic interference or other interference sources in the surrounding environment may affect the performance of the microwave device, resulting in the center frequency shift. For the improvement of the problem, we can first ensure the correct S-parameter and make the center frequency offset as small as possible in the simulation modeling, accurate in the assembly of the device and carry out the experiment in the place with little interference from the external environment.   1. **Advance: Wireless communication system construction (voice, text or image transmission)**   Theoretical connection graph    Physical connection      By tuning the parameter, the best results were obtained when the frequency of the local oscillator was set to 1.3GHz and the frequency of the receiving end was set to 1.1GHz.  (Their sum is the transmitting frequency 2.4 GHz)  **Test result**      The final text valid message was successfully launched and received. | |
| **Experience**   1. Screenshot of class submission   bf67d3daaaadc1dc66dfdc0fd03e9e2  9f85037815ddad5e4c51bd7984f550c  84e7d97889d0e84a748a1a69249296b  df43ed1e9060b4d036533ace2587750  e64374a8a46a60e5f1b1258f59cfcb2  6749c836c0210d6565ac70f4af7b670  2.  The problems encountered in modeling and simulation are as follows: Model accuracy: In the modeling process, the simulation results are difficult to meet the requirements, and need to be continuously optimized. Nonlinear effects: There may be nonlinear effects in microstrip antennas and power splitters, which may affect the quality of signal transmission and reception. When designing a system, it is necessary to consider the effect of frequency selection and intermodulation interference on system performance, especially when there are multiple frequencies operating in the system at the same time.  In the USRP text transmission, garbled codes appear or only noise can be received, and the frequency of the receiver needs to be constantly adjusted to obtain the best frequency.  Since the manufacturer gave us a PCB with a dielectric constant of 4.4 and we used a dielectric constant of 4.3 for the design, this caused a shift in the centre frequency, making the results deviate from what we expected.  Exp:  In order to solve the problem of model accuracy, ADS and HFSS need to be used for more accurate modeling to ensure that the designed accuracy of the object meets the experimental requirements.  Spectrum analysis: Perform spectrum analysis to look at frequency selection and interference issues, through simulation or actual measurement, to find the best operating frequency and ways to suppress interference.  Learned to use microstrip line for USRP text transmission.  3. Presentation questions and answers for Project2  Question: Why does frequency deviation occur?  Answer: First of all, because the manufacturer makes boards with different dielectric constants than the ones used in the design, and at the same time, we have a certain frequency bias in the initial design, which finally leads to a certain frequency bias in the product, but they are all within 10 per cent.  Question: How do we calibrate our equipment?  Answer: We calibrated each of the ports we used using standard devices according to the VNA guide; at the same time, every time we measured a device, we recalibrated it according to its frequency to ensure that the results of each measurement were as accurate as possible.  4.Group contribution  12110748李璐 2.4GHz patch design and port soldering, participation in calibration testing, all device testing and communication system build and test, presentation  12112201蔡浩宇 2.4GHz wilkinson power divider design and port soldering, participation in calibration testing, all device testing and communication system build and test, presentation, report preparation  12112211李帅 1.45GHz branch line coupler design and port soldering, participation in calibration testing, all device testing and communication system build and test, presentation  12112441曹子惠 950MHz wilkinson power divider design and port soldering, participation in calibration testing, all device testing and communication system build and test, slide production , presentation, report preparation  **Proportions:** Everyone is 25%. | |
| **Score** | 100  It's all 100% full strength! 100%+100%+100%+100%=100 scores |