**Lab 4：Microstrip Patch Antenna with Microstrip Feedline and Impedance Matching**

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| **Introduction**   1. What is dipole antenna?   A **dipole antenna** (also known as a **doublet** or **dipole aerial**) is defined as a type of RF (Radio Frequency) antenna, consisting of two conductive elements such as rods or wires. The dipole is any one of the varieties of antenna that produce a radiation pattern approximating that of an elementary electric dipole. Dipole antennas are the simplest and most widely used type of antenna.  A ‘dipole’ means ‘two poles’ hence the dipole antenna consists of two identical conductive elements such as rods or metal wires. The length of the metal wires is approximately half of the maximum wavelength (i.e.,=) in free space at the frequency of operation.  This wire or rod is split at the center, and the two sections are separated by an [insulator](https://www.electrical4u.com/electrical-insulator-insulating-material-porcelain-glass-polymer-insulator/), these sections are known as an antenna section.  These two antenna sections are connected to a feeder or [coaxial cable](https://www.electricalknowledge.com/electricians-tools/best-coaxial-cable/) at the end closest to the center of the antenna. **Note that wavelength is the distance between two consecutive maximum or minimum points.** The basic dipole antenna with the center feed point is shown in the figure below.    The radio-frequency (RF) [voltage source](https://www.electrical4u.com/voltage-source/) is applied to the center between the two sections of the dipole antenna. This [voltage](https://www.electrical4u.com/voltage-or-electric-potential-difference/) and a [current](https://www.electrical4u.com/alternating-current/) flowing through the two conductive elements produce a radio signal or an electromagnetic wave to be radiated outwards from the antenna.  The current is maximum and voltage is minimum at the center of the dipole antenna. Conversely, the current is minimum and voltage is maximum at the ends of the dipole antenna.  The radiation pattern of the basic dipole antenna is shown in the figure below. It is perpendicular to the axis of the antenna.    So the dipole antenna is one type of [transducer](https://www.electrical4u.com/transducer-types-of-transducer/) which converts electrical signals into RF electromagnetic waves and radiates them at the transmitting side and converts RF electromagnetic waves into electrical signals at the receiving side.   1. S11 Parameter Plot of dipole antenna   In the S11 Parameter Plot, the resonant frequency corresponds to the point with the smallest S11 parameter. This indicates that the antenna is best matched near the resonance frequency. A low S11 value indicates better impedance matching, while a high S11 value may mean that there are large reflections.   1. Radiation Pattern Plot of dipole antenna   For an ideal full-wavelength Dipole Antenna, the Radiation Pattern Plot exhibits relatively uniform radiation in the horizontal plane, showing the omnidirectionality of the antenna. This means that in the horizontal direction, the antenna radiates relatively uniformly in intensity with no apparent directivity. And there is usually a zero point or a region of weak radiation in the vertical plane. This is because the Dipole Antenna radiates relatively weakly in the vertical direction, showing a zero point, which is called the "electrical plane" or "zero point" of the antenna. Although the Dipole Antenna radiates weaker in the vertical plane than in the horizontal plane, there is still some radiation, which is usually reflected in some of the sub-flaps of the Radiation Pattern Plot.   1. Co-pol and Cross-pol Radiation pattern plot   Co-pol radiation plots are used to evaluate the performance of an antenna in the direction of its design polarization, as well as the gain and radiation characteristics in the co-polarization direction.Cross-pol radiation plots are used to evaluate the performance of an antenna in a direction perpendicular to its design polarization direction, as well as the radiation characteristics in the cross-polarization direction. In practice, the performance of copolarization and cross-polarization is usually measured by a specified Polarization Cross-Polarization Discrimination (XPD), which represents the power ratio between copolarization and cross-polarization.   1. Gain vs Frequency plot of dipole antenna   Gain vs Frequency plot of a dipole antenna illustrates how the antenna's gain changes across different frequencies. The gain of an antenna is a measure of its ability to direct or concentrate energy in a specific direction compared to an isotropic radiator (idealized point source that radiates uniformly in all directions).   1. Directivity vs Frequency plot of dipole antenna   A Directivity vs Frequency plot for a dipole antenna illustrates how the antenna's directivity (the ability to focus radiation in a specific direction) changes across different frequencies. Directivity is often represented in dB, indicating the gain of the antenna in the main lobe direction compared to an isotropic radiator. Directivity is a key parameter for directional antennas like dipoles, as it determines how effectively the antenna can transmit or receive signals in a specific direction. The Directivity vs Frequency plot helps engineers assess the antenna's performance characteristics over a range of frequencies, aiding in the design and optimization process.   1. Antenna Efficiency plot of dipole antenna   Antenna Efficiency plot is a graph that shows how an antenna's efficiency varies at different frequencies. This graph provides information about the performance of an antenna in converting input power into radiated power and how efficiently the antenna performs over a range of frequencies.  **Lab results & Analysis**：  Use the formula below, we can get that the length of total dipole L=33mm, and E=L/2 when design a dipole antenna for operating at ~ 2.1 GHz.      And the design is in below:   1. S11   Direct simulation, get:    So we need to optimize the parameters.    Comparing all of the values, we find that when l\_pat=27mm and wq=0.7mm, we have best reflection coefficient.  So the final S11 is:     1. Radiation pattern (Total Gain on E&H plane)     phi=0deg  phi=90deg   1. HPBW     We get HPBW = 15.54 deg   1. Antenna efficiency      1. How the width and length of the patch affect the pattern and resonant frequency? | |
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| **Score** | 100 |