**Lab 9：Loop Antenna**

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| **Introduction**   1. What is loop antenna?   Loop antenna is a type of antenna which is formed by bending of a coil or uniform wire in the form of loop is known as a loop antenna. Basically, in loop antenna, the RF current-carrying coil is bent to various shapes like circle, square, rectangle, ellipse, etc. These antennas are known to be simple, inexpensive and versatile antenna and thus has a wide range of applications.    Figure 1. different shapes of loop antenna   1. The Classification of Loop Antenna 2. Small loopantenna   The small loop antenna is a loop. The antenna feed points would be in series with the loop, such that a small loop looks somewhat like a short circuit across the antenna feed. These antennas have low radiation resistance and high inductive reactance, so that their [impedance](http://www.antenna-theory.com/basics/impedance.php)is difficult to match to a radio impedance (often 50 Ohms). As a result, these antennas are most often used as receive antennas, where impedance mismatch loss can be a bit more easily tolerated in some systems.  picture of a loop antenna  Figure 2. small loop antenna  Figure 2. Small loop antenna: The radius is *a*, and is assumed to be much smaller than a wavelength (*a*<< ). The loop lies in the x-y plane.  Since the loop is electrically small, the current within the loop can be approximated as being constant along the loop, so that *I*= peak electric current along a loop antenna.  The fields from a small circular loop are given by (note *k=2pi/lambda*):  radiated fields from small circular loop antenna  The variation of the radiation pattern with direction is given by radiatin pattern for loop antenna, so that the radiation pattern of a small loop antenna has the same power pattern as that of a short dipole. However, the fields of a small loop have the E- and H- fields switched relative to that of a short dipole antenna; the E-field is horizontally polarized in the x-y plane for a small loop.  The small loop antenna is often referred to as the dual of the dipole antenna, because if a small dipole had magnetic current flowing (as opposed to electric current as in a regular dipole), the fields would resemble that of a small loop. Note that magnetic current is not a real thing, but if you imagine a flow of magnetic charge, the derived fields would be equivalent to a small loop antenna.  While the short dipole has a capacitive impedance (imaginary part of impedance is negative), the impedance of a small loop is inductive (positive imaginary part). The radiation resistance (and ohmic loss resistance) can be increased by adding more turns to the loop. If there are *N* turns of a small loop antenna, each with a surface area *S* (we don't require the loop to be circular at this point), the radiation resistance for small loops can be approximated (in Ohms) by:  radiation resistance for loop antennas  For a small loop, the reactive component of the impedance can be determined by finding the inductance of the loop, which depends on its shape (then X=2\*pi\*f\*L). For a circular loop with radius *a* and wire radius *p*, the reactive component of the impedance is given by:  reactive component (reactance) for small loop antennas   1. Large loop antenna   As loop antennas get larger, they become better antennas. A loop antenna will be resonant (with a purely real impedance) as the perimeter of the loop approaches one wavelength in size. This is so because, with the increase in the length, the circumference approximately reaches wavelength and in that case, the field pattern will vary and the maximum will shift from plane to the axis of the loop.  The one-wavelength perimeter loop antenna behaves like a [folded dipole antenna](http://www.antenna-theory.com/antennas/foldeddipole.php), with an impedance that is higher than that of a [half-wavelength dipole antenna](http://www.antenna-theory.com/antennas/halfwave.php).   1. Direction-finding   Here as we can see there are 4 arms of the loop. So, the horizontal arms (PQ and RS) act as a horizontal antenna while the vertical arms (PS and QR) act as a vertical antenna.    Figure 3. Rectangular loop antenna  In the first configuration, when the plane of the rectangular loop is placed normal to the direction of vertically polarized incoming waves, then the voltage of equal magnitude will get induced in each of the vertical antennas. This induced emf’s are given as **E1** and **E2** for arm PS and QR.  Now, induced emf’s in each of the vertical arms, allow the flow of current inside the loop. However, the direction of the flow of currents inside the loop will be opposite.  plane of loop antenna normal to incoming wave  This is so because, when the incoming wave is normal to the plane then the vertical sides of the loop antenna are equidistant from the transmitter. So, the two currents are of the same magnitude but different polarity thus cancels each other.  Further, in the second configuration, the **antenna is rotated by 90 degrees**along the zz’ axis. So, after rotation, the plane of the loop will be along the direction of the incoming waves.  Now, in this case, the two vertical arms PS and RQ are separated by a certain distance of the length of the horizontal arm. Thus the emf induced in both the arms despite having similar magnitude will have a difference in phase.  plane of loop antenna along the direction of incoming wave  This is so because the incoming radio waves will reach one vertical arm of the loop somewhat earlier than the other. Thereby leading to generate a certain phase difference between the induced voltage E1 and E2.  Thus the overall induced emf around the loop will be equal to the difference of the induced emf’s (suppose α) of the vertical arms.  Hence the overall induced emf will be:  **E1 – E2**  Another noteworthy point over here is that for the other positions of the plane wrt to the incoming wave other than normal, there will be a certain distance between the two vertical arms. And in that case, the phase of the two induced emf will be unequal.  Thus maximal loop emf is achieved when the plane of the loop is in parallel orientation wrt the direction of the incoming wave from the transmitter.  Suppose θ represents the angle between the loop plane and the direction of incoming wave, then the induced emf in vertical arm will be:  **E = Erms cos θ**  When the loop plane and incoming wave are in the same direction, i.e., θ will be either 0⁰ or 180⁰, then **maximal emf** will get induced. While when loop plane and incoming wave are perpendicular to each other i.e., θ will be either 90⁰ or 270⁰, then the induced emf will be **minimum**.  Thus we can say that the emf induced around the loop antenna shows dependency on the orientation of the plane and incoming wave. Along with this, it also depends upon the vertical height of the antenna, wavelength, width of the loop and electric field intensity.   1. Application 2. Radio Reception: Loop antennas are commonly used in AM radio receivers for receiving radio broadcasts. Their ability to efficiently capture electromagnetic waves in the AM frequency range makes them suitable for this purpose. 3. Magnetic Field Sensing: Loop antennas can be utilized as magnetic field sensors in applications such as metal detection, proximity sensing, and non-destructive testing. Changes in the magnetic field induce currents in the loop, allowing for detection of nearby metallic objects or changes in magnetic field intensity. 4. Direction Finding: In radio communication systems, loop antennas can be employed for direction finding purposes. By comparing signal strengths or phases received by multiple loop antennas, the direction of the signal source can be determined. 5. Wireless Communication: Loop antennas can be integrated into wireless communication systems, such as RFID (Radio Frequency Identification) systems and Near Field Communication (NFC) devices. They are particularly suitable for short-range communication due to their compact size and efficient coupling with nearby devices. 6. Medical Imaging: In medical applications, loop antennas are utilized in Magnetic Resonance Imaging (MRI) systems for transmitting RF pulses and receiving MR signals. These antennas are designed to produce homogeneous magnetic fields within the imaging region and efficiently receive the induced MR signals from the patient's body. 7. Inductive Power Transfer:\*\* Loop antennas are essential components in inductive power transfer systems, such as wireless charging pads for electronic devices. They enable efficient transfer of power from the transmitter to the receiver through magnetic coupling between the loops. 8. Environmental Monitoring: Loop antennas can be deployed in environmental monitoring systems for measuring electromagnetic radiation, such as in the study of natural electromagnetic phenomena or in monitoring electromagnetic interference (EMI) levels in industrial environments.   **Lab results & Analysis**：  We can get that the length of c=430mm when design a loop antenna with a 2:1 ratio of length to width for operating at ~ 0.7 GHz.  And the design is in below:       1. S11   Direct simulation, get:    So we need to optimize the parameters.  First, optimize the c:    We find when c=450mm or c=445mm, the center is 0.7GHz.  Then we optimize the lf:    At last we find when c=445mm, lf=80mm, we have best reflection coefficient.  So the final S11 is:     1. 3D Radiation pattern      1. Radiation pattern (Total Gain on E&H plane)   phi=180deg    phi=90deg     1. polarization radiation pattern.   phi=0deg    phi=90deg     1. Compare these antenna parameters with a square loop antenna. 2. For S11:   The 2:1 ratio antenna has a higher reflection coefficient at certain frequencies due to its narrower bandwidth and potentially more complex impedance characteristics. And the square loop antenna exhibits lower reflection coefficients over a wider bandwidth due to its more symmetrical and balanced geometry.   1. For radiation pattern:   The square loop antenna produces a more omnidirectional radiation pattern, with relatively equal radiation in all directions perpendicular to the plane of the loop. At the same time, the 2:1 ratio antenna exhibits a more directional radiation pattern compared to a square loop antenna. This directional pattern is due to the elongated shape, which tends to focus radiation along the longer dimension. | |
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| **Score** | 100 |