Nuclear Magnetic Resonance of Hydrogen Atom

TSUN-JEN CHEN(陳遵仁), YI-HSIEN LIU(劉宜憲)
Instructor : YUNG-FU CHEN, YA-PO YANG, PO-HAN CHEN, KUAN-HSUN CHIANG
Department of Physics, National Central University, Taiwan
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1. History

In 1944, Isidor Rabi was awarded the Nobel Prize in Physics for nuclear magnetic resonance (NMR) by extending the Stern–Gerlach experiment. In 1946, Felix Bloch and Edward Mills Purcell expanded the technique for use on liquids and solids, for which they shared the Nobel Prize in Physics in 1952.

2. Theory

According to the quantum theory, a hydrogen nucleus has two energy state determined by the magnetic dipole moment, $m = 1.4106067 \times 10^{-30} (J/G)$ which is either parallel or anti-parallel to the magnetic field. The energy of a hydrogen nucleus placed in static magnetic field can be described by

$$U = -\vec{m} \bullet \vec{B}$$

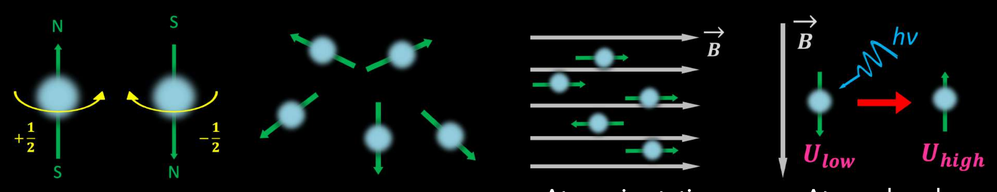
where is the magnetic dipole moment and the magnetic field. The occurrence of NMR is the process of energy transition, which the nucleus needs to absorb the energy difference between the two states, namely

$$\Delta U = 2mB$$

Therefore, a radio wave with energy

$$E = vh = 2mB$$

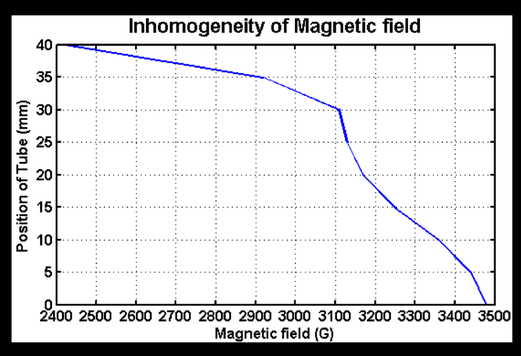
transmitted to the nucleus will be absorbed by the nucleus to induce the energy transition, and v is what we called resonance frequency.



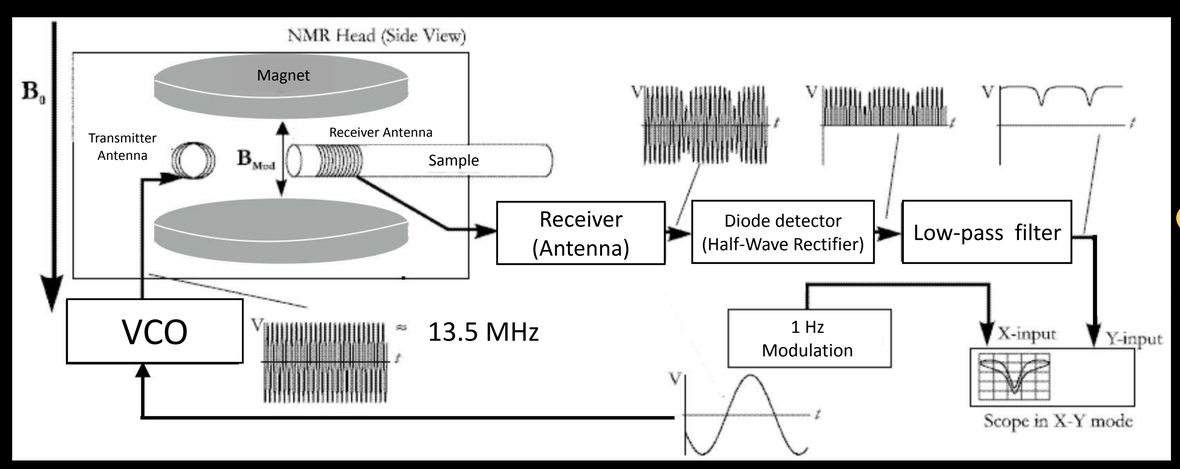
Spin of atom | Atoms in free space | Atoms in static magnetic field | Atom absorbs EM wave


Transmitter

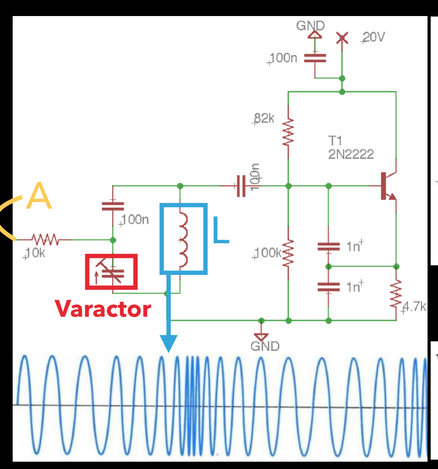
- Graph 1, The graph shows that the magnetic field is inhomogeneous. Therefore the water suffers different intensity of magnetic field. This situation makes our signal distributing in a range about 1MHz.



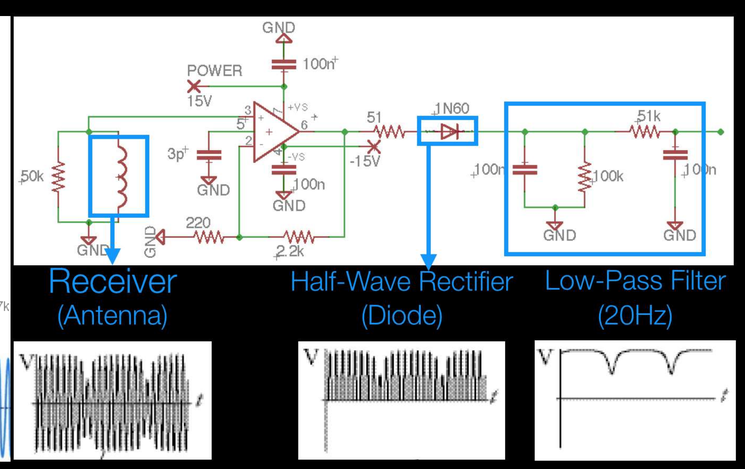
3. Experiment Procedure



- Figure 1,The main procedure of our experiment.



- Figure 2, Voltage controlled Oscillator



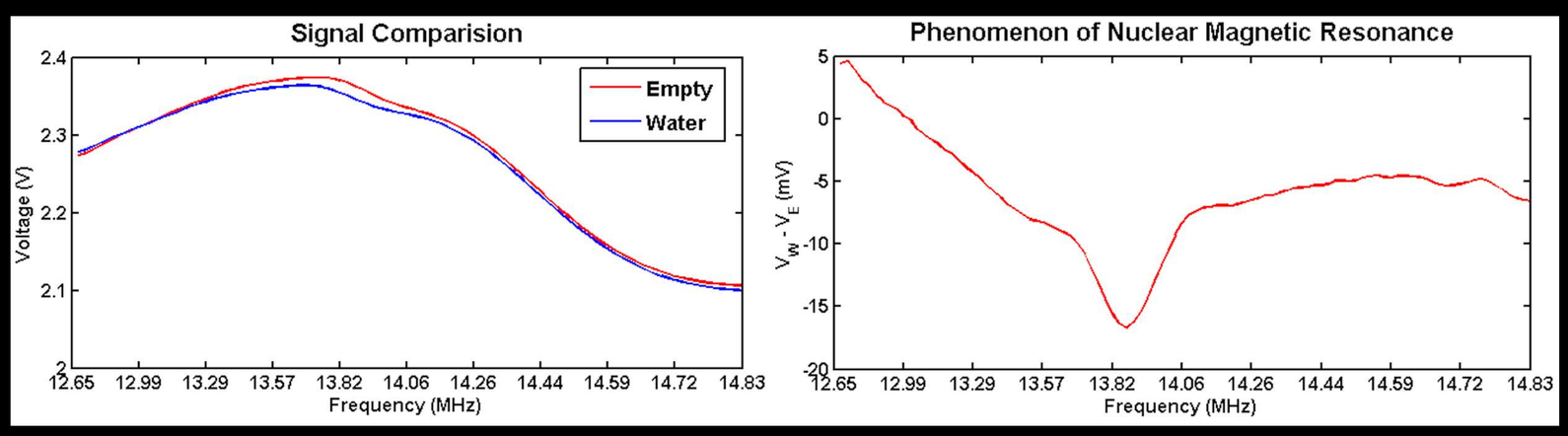
- Figure 3, Detector circuit


Base

- We set the test tube, transmitter, and receiver in the gap between the magnets.
- Then we input FM signal to the transmitter to emit EM wave in order to probe the absorption of hydrogen atom.
- Last is detections, including amplifying, half-wave rectifier, and low-pass filter.
- In graph 1, the magnetic field is inhomogeneous. Every part of water is soaking in different intensity of magnetic field.

- Figure 2 is a Colpitt's oscillator which is used to generate the resonance frequency.
- There is a varactor in the oscillator. The capacity of varactor will change with applied voltage. Therefore we can input a 1Hz signal to A to generate a FM signal and emit it through the transmitter (L).
- Figure 3 is our detector circuit. First, it amplify the signal from the receiver. Second, the diode(1N60) cut off the negative voltage. Last, there are two filter to erase the high frequency signal. Eventually, we get the amplitude of absorbed EM wave.

4. Experiment Result & Discussion



- Figure 4, The comparison of two signal.
- Figure 5,The phenomenon of NMR.

- In our prediction, the NMR signal will emerge in 13.5~14.3 MHz. The result shows that the NMR occurred in 13.7~14 MHz. Therefore, we can say this dip is the phenomenon of nuclear magnetic resonance.
- In figure 4, there is a dip in both signal at 13~14 MHz. The dip is caused by the glue in which there are hydrogen atoms on our transmitter and the test tube.(The glue is used to fix the transmitter and the receiver antenna on the test tube.)
- In the right and left sides of figure 5, theoretically, they should be symmetrical. We found that the water could affect the frequency of the oscillator. Therefore, the signal of water should be shifted a little bit before we subtract them with each other. However we did not have enough time to recalibrate the frequency. Hence, we have done some numerical process and guessed the difference of frequency in order to shift it. The result corresponded with our expectation.
- The structure of antenna can affect the frequency of maximal absorption.

5. Conclusion

- We demonstrate the phenomenon of NMR of hydrogen atom by scanning the radio frequency to the sample placed in a static magnetic field.
- The inhomogeneity of magnetic field causes that the resonance occurs in a range of frequency about 1MHz but an absolute value.
- Placing sample in the transmitter would affect the resonance frequency slightly.

6. References

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