Magnetic Resonance

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Electrons revolve about the nucleus of an atom and spin around their axis. In addition, the nucleus has a spin of its own. All of these moving charges have associated magnetic fields (magnetic moments), and magnetic resonance is concerned with the interactions of some of the fields with each other, and with at least two external magnetic fields applied to the atom.

Consider an electron circulating about the nucleus. The electron has angular motion and is a charged particle held in orbit by the oppositely charged nucleus. Applying Kepler's law (the radius vector of the particle sweeps out equal areas in equal times) and that angular momentum, $P\phi$, is conserved and quantized, $P\phi = Lh = mr^2\phi$ (L = orbital quantum number, and h = Planks constant/2π). The area swept out in one period, t, is:

$$A = \int_o^t {}^1\!/_2\,(r^2\phi)dt = Lht/2m$$

Finding the equivalent magnetic dipole moment, μ, produced by a closed current loop, I, to be:

$$\mu = L(eh/2m) \qquad \text{Eq. (1)}$$

And eh/2m is defined as the Bohr magneton, μB.

Consider the electron spin about its own axis. The derivation of the spin moment similar to the above produces and electron spin moment of two Bohr magnetons. Dirac's relativistic quantum theory of the electron and many experiments give the correct value of one Bohr magneton, for which the spin quantum number of the electron is ${}^1\!/_2$.

The total angular momentum P_J, is found by adding vectorially the orbital and spin angular momentum of the electron,

$$P_J > \; P_L + \; P_S = h(L+S)$$

And the total magnetic moment becomes:

$$\mu = \; \mu_B(L+2S)$$

P_L and P_S, which can be thought of as precessing about P_J, contribute to the average magnetic moment, vectorally adding the moments gives:

$$\mu j \;=\; \mu_B[L\;\cos\;(LJ) + 2S\cos\,(SJ)] = \;\mu_B J(\frac{S^2 + J^2 - L^2}{2J^2}).$$

Using a more rigorous wavemechanics approach, S^2 is replaced by S(S + 1), etc, to give:

$$\mu_J = \;\mu_B g^J \qquad \text{Eq. (2)}$$

where

$$g \equiv 1 + \frac{S(S+1) + J(J+1) - L(L-1)}{2J(J+1)}$$

g = Lande`-g factor and for an atom on the ground state, L = 0, S = J, and g becomes equal to 2.

If we add the nuclear spin and its magnetic moment to this, the vector problem would become overwhelmingly complex. There is a simpler way which will be evident later, but for simplicity now, we will just add the external magnetic field H.

Just as a spinning top will precess in the intergalactic space field surrounding the earth, so will the magnetic moment vector of the electron precess in the magnetic field. The torque in the electron case being produced by the interactions of the dipole and the external field.

Equating the time rate of change of angular momentum to the torque on the dipole, one can derive the precessional frequency in complete analogy to the top's behaviour. The precessional frequency can be derived from an energy standpoint and will give more insight. The potential energy of a magnetic dipole in a magnetic field is

$$W = \;-\mu H = \;\mu_{B_o^q}\, JH$$

if we confine ourselves to an atom in the ground state then J = S and S = $\pm\,{}^{1}\!/_{2}$, the spin being either parallel or antiparallel with the external field.

The magnetic moment is defined as positive or negative according to the condition of parallelism or antiparallelism, respectively. Thus, the energy difference between the two possible electron spin states can be equated to $hW_L$where $W_L$is the frequency of precession and:

$$hW_L = W\big(S = \;{}^{1}\!/_{2}\big) - W\big(S = \;{}^{1}\!/_{2}\big) = \;g\mu_B\; H = rH \qquad \text{Eq. (3)}$$

Electromagnetic radiation at W_L freq, with the correct polarization will be absorbed by dipoles in the lower state, making transitions to the higher state.

Electron spin resonance is a technique used in the lab for measuring this splitting using radio freq, technology—Fib. 1 (b) Since the nucleus carries a charge, its angular spin does produce a nuclear magnetic moment. A nuclear magneton, μ_n, is defined the same as the Bohr magneton, except the mass of the electron is replaced by the mass of the proton. A nuclear g – factor ($g_n = gI$) is alsodefined where I is the spin of the nucleus. The proton's magnetic moment is 2.7935 nuclear magnetons while the neutron's moment is -1.9135 μm. The + or – sign refers to the condition of weather the angular momentum vector has the same or opposite directions as the magnetic moment.

A nucleus with spin I, will have QI + 1 possible orientations in a magnetic field and 2J + 1 energy levels. For simplicity, consider a hydrogen atom in a molecule. The nucleus is a proton with a spin of $1/_2$ and its magnetic moment is either parrallel or antiparrallel to the field this produces energy levels as shown in Fig. 1(c), Fig. 1(b) electron spin moment in a magnetic field.

Referring to the Jensen machine stated: natural magnetic resonance freq = 2.80GHz the nuclear magnetic resonance of a free electron when charges in magnetic states are induced by magnetic field the changes in states causes a condition called electron paramagnetic resonance, or EPR. The EPR of a free electron is 2.80 H MC. Where H is in gauss. This should be the initial state of the defining mathematical format.

Dealing with Resonance at High Power Levels.

Resonance frequencies may be maintained quite constant at high power levels so long as the load remains constant. We are all familiar with AM and FM propagation, where in the case as AM, the voltage amplitude varies, and with FM, the frequency is modulated.

However, the output power sees a constant load impedance, that of the matched antenna system. If this changes, the input to the antenna is mismatched, and standing waves are generated resulting in a loss of power. The frequency is a forced response and remains constant. Power is lost and efficiency becomes less and less, depending on the degree of mismatch. Let's assume the Jensen amplifying transformer is in a resonating condition. Its output is connected to a transmission line which is X number of miles long. Without any customer load at all, power will be required to change the line. This will present capacitive reactance, $X_C = 1/_2\ fc$. The power factor cos angle ϕ will be leading, though negligible on short systems. The effect must be reckoned with on multiple grid long systems operating above 60 KV. What we have is a capacitor and the effects are evident as line impedance. Another parameter is varying power factor due to changing inductive loads. Taken together this forms a complex impedance load continually varying and this is what the "Jensen" machine will "see" when connected to power distributing network grids. Such a resonant machine will never sustain resonance as shown in the sketch. The circuit consists of a capacitor in series with an inductor and this is a series resonant circuit of minimum impedance and maximum current. Theoretically, the current limiting is effected by series resistance in the circuit including the resistance of the inductor,

$$\text{Resonance freq, } f_0 = {}^1\!/_2\,\pi\sqrt{LC}$$

$$L = {}^1\!/_4\,\pi^2 f^2 C \quad Pf = 1.00$$

$$C = {}^1\!/_4\,\pi^2 f^2 L$$

$I = {}^E\!/_R$ as X_L and X_C cancel.

As load power factor and complex impedances continually vary, reflected impedance in the secondaries reflect back into the primary and then reflect back to the resonant network, L and C, which fall out of resonance and the machine's output falls virtually to zero.

For this machine to work, some means would have to be formulated to instantaneously vary the frequency to match varying load impedances. Surely a most challenging task. First, the capacitor should be removed and the inductor designed with sufficient distributed capacitance to prove integral LC. Then calculate what frequency will resonate the R.C.L. network. This will not cure the impedance problem, but will provide a more stable experimental set-up. The concept has merit but if pursued further R & D should be in the 60 Hz power frequency area.