Qubit state represented by pendulum oscillations

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Oct 30, 2018

Abstract: As qubit can be a polarization division multiplexed (PDM) quadrature amplitude modulated (QAM) symbol of light, its state has direct correspondence with polarization state of classical light. Even more intuitively, the state may be represented by pendulum oscillations.

1. Introduction

Quantum physicists have been considering quantum superposition, which was believed to make quantum computers more powerful than classical ones, were beyond any classical intuition. For example, in [1], it is stated: "A left circularly polarized photon can encode a 0, for example, while a right-circularly polarized photon can encode a 1. Quantum systems can also register information in ways that classical digital systems cannot: a transversely polarized photon is in a quantum superposition of left and right polarization, and in some sense encodes both 0 and 1 at the same time.". For another example, in [2], it is stated: "Unlike the classical bit, the qubit can exist in coherent superpositions of its two states, denoted as $|0\rangle$ and $|1\rangle$."

For us communication engineers/scientists, however, it is intuitively obvious that transversely polarized classical/quantum light is obtained by multiplexing left-circularly and right-circularly (or horizontally and vertically) polarized classical/quantum light with proper relative phase, which means state so called "quantum" superposition is just a polarization state and can even be classical. While bits are digital, the bits are carried by analog symbols, including binary ones, which may be superpositioned.

Fundamental misunderstanding of most, if not all, quantum physicists on quantum state is, seemingly, that they thought phase unique to quantum state, even though classical radio waves, as solutions of Maxwell's equations, do have phase, which may be modulated to carry information. For example, in [1], it is stated "the channel that randomizes the phases of input states" "transmits classical information perfectly, but transmits no quantum information at all". For another example, in [2], it is stated "Unlike classical information, qubits are susceptible to both traditional bit errors

$|0\rangle \leftrightarrow |1\rangle$, and also phase errors $|0\rangle \leftrightarrow |0\rangle$, $|1\rangle \leftrightarrow -|1\rangle$.", though classical symbols do suffer from amplitude errors and phase errors.

As a qubit, in this case, is superposition of a left-circularly and right-circularly (or vertically and horizontally) polarized photon with various relative amplitude and relative phase, which are analog, and we can use QAM (Quadrature Amplitude Modulation) to modulate amplitude and phase of a photon, such qubit is a PDM (Polarization Division Multiplexed) QAM symbol of light. While quantum physicists often state "the unit of quantum information is the quantum bit or qubit" [1], it is as metaphysical as stating "the unit of quantum energy is quantum Joule or quJ". Just as quantum energy is energy, quantum information is information, unit for which is "bit", and a qubit actually is an analog symbol.

A superpositioned state of a qubit is a unit vector in two dimensional Hilbert space over **C** as $ae^{i\theta_0}|0\rangle + be^{i\theta_1}|1\rangle$ $(a, b, \theta_0, \theta_1 \in \mathbf{R},\ a^2 + b^2 = 1, 0 \leq\ \theta_0, \theta_1 < 2\pi)$. Though quantum physicists often ignore absolute phase and only consider relative phase of $\theta_0 - \theta_1$ important, absolute phase is retained in this letter, because correspondence to classical state is more obvious.

Classical polarization state, on the other hand, is represented as $ae^{i\theta_H}E_H + be^{i\theta_V}E_V$ $(a, b, \theta_H, \theta_V \in \mathbf{R},\ 0 \leq\ \theta_H, \theta_V < 2\pi)$, where E_H and E_V are vectors of horizontally and vertically polarized electric field, respectively. Space of classical polarization state becomes a Hilbert space by introducing inner product as $E_H \cdot E_H = E_V \cdot E_V$.=1 and $E_H \cdot E_V = 0$.

Thus, it is obvious that there is one to one correspondence between superpositioned state of a qubit: $ae^{i\theta_0}|0\rangle + be^{i\theta_1}|1\rangle$ and classical polarization state: $ae^{i\theta_H}E_H + be^{i\theta_V}E_V$. That is, superposition is not something specific to quantum state and can be classical.

If "superposition" means multiplications of some coefficients followed by additions, elements of modules over coefficient groups, in general, can be superpositioned. For example, velocity toward northeast is superposition of velocity toward north and east and, in a sense, simultaneously represents velocity toward north and east.

2. Intuitive representation of superpositioned state of a qubit or classical polarization state

Binary quantum state of oscillations, such as superposition of polarization modes of photons, has classical representation as polarization state of classical radio waves. Because the state is binary, it is in a two dimensional vector space. However, polarization state is very poorly intuitive, which should be the reason why quantum physicists misunderstood it something classically impossible.

If, instead of radio waves, visible light is used, we can see polarization state by our eyes. However, what we see is very remote that we can merely see changes in brightness of light through various polarizers. We can't see something oscillating or, in case of circular polarization, circulating.

On the other hand, vectors representing position or velocity are mechanical and, thus, much more intuitive than polarization state of radio waves or light. However, as vector space of position or velocity is over **R**, it is not appropriate to represent binary quantum states of oscillations, which needs a vector space over **C**. To have such a vector space, we need something with phase, that is, something oscillating.

The simplest mechanically oscillating apparatus should be a pendulum. Fortunately, in the three dimensional real world, a pendulum has two orthogonal directions of oscillations, north/south and east/west, which means vector space of its oscillating state is two dimensional over **C**, which is just enough to represent binary quantum state of oscillations.

Actually, linear oscillations of a pendulum represent linearly polarized qubiit states. Oscillations of a pendulum in northeast/southwest direction is superposition of oscillations of the pendulum in north/south and east/west directions. So are left and right circular oscillations, though north/south and east/west oscillations are superpositioned at different relative phase from northeast/southwest linear oscillations.

With a pendulum, we can actually see the pendulum oscillating and, in case of circular oscillations, which represents circular polarization, circulating. Elliptic oscillations of the pendulum, which represents elliptic polarization, can also be seen.

If a pendulum oscillating in northeast/southwest direction or left or right circularly is viewed from north and east, we can see as if the pendulum is oscillating in east/west and north/south directions, respectively, with smaller amplitude, which corresponds to projection of quantum state. If north/south component of the oscillations of the pendulum is dumped, the pendulum will oscillate linearly in east/west direction with smaller amplitude, which corresponds to passing diagonally or left or right circularly polarized photons through a horizontal linear polarizer.

3. Conclusions

It is shown that, as superpositioned state of a qubit corresponds to classical polarization state and that the state may, even more intuitively, be represented by two dimensional oscillations of a pendulum.

As "quantum" superposition is not really quantum, we should just say "superposition", not "quantum superposition". Moreover, as "qubit" is an analog symbol, not very different from other binary analog symbols, for example, those used by BPSK (Binary Phase Shift Keying), it is actually "qusymbol".

References

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