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States Instantly Spreading through Space and Forward and Backward in Time

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Abstract: The article contains an application of a theory aiming to change the underlying mathematical structure of conventional quantum mechanics which is a no-work-around obstacle to create quantum computers. The theory modifications, along with geometrically feasible generalization of formal imaginary unit to unit value areas of explicitly defined planes in three dimensions, include implementation of idea that commonly used notions "state", "observable", "measurement" require a clear unambiguous redefinition. New definition helps to establish effective formalism which in combination with geometric algebra generalizations brings into reality a kind of physical fields, which are states in terms of the suggested theory, spreading through the whole three-dimensional space and full range of scalar values of the time parameter. The fields can be modified instantly in all points of space and past and future time values, thus eliminating the concepts of cause and effect, and one-directional time.

1. Introduction. States, observables, measurements

Unambiguous definition of states and observables, does not matter are we in "classical" or "quantum" frame, should follow the general paradigm [1], [2], [3]:

- Measurement of observable $O(\mu)$in state[1]$S(\lambda)$is a map:

  $$\big(S(\lambda), O(\mu)\big) \longrightarrow O(\nu),$$

  where $O(\mu)$ is an element of the set of observables and$S(\lambda)$ is element of another set, set of states, though both sets can be formally equivalent.

The result (value) of a measurement of observable $O(\mu)$ by the state $S(\lambda)$is a map sequence

$$\big(S(\lambda), O(\mu)\big) \longrightarrow O(\nu) \longrightarrow V(B),$$

where V is a set of (Boolean) algebra subsets identifying possible results of measurements.

Elementary example: A point moving along straight line (Fig.1.1):

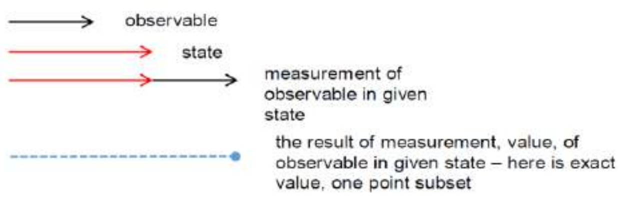

Fig.1.1. A state acts on observable in one-dimensional movement

A state is something external relative to observable. It evolves by itself, following its own laws, like, for example, gravitational or electromagnetic fields. It exposes itself only when interacting with an observable, making measurement of an observable.

Now, specifically for G_3^+, even subalgebra of geometric algebra G_3 over the three-dimensional Euclidean space[4], [5].

Contrary to the classical mechanics, as in the above example, where it does not matter are we considering a state or the result measurement of observable by the state, we need now to strictly distinguish between the cases.

Definition 1.1:*The set of states $S(\lambda)$ is set of elements of G_3^+:*

$$S(\alpha, \beta, I_S) \equiv \alpha + I_S\beta = \alpha + \beta(b_1B_1 + b_2B_2 + b_3B_3) = \alpha + \beta_1B_1 + \beta_2B_2 + \beta_3B_3,$$

$$\beta_i = \beta b_i, i = 1,2,3$$

If they are unit value elements:

$$\alpha^2 + \beta^2 = 1, \qquad b_1^2 + b_2^2 + b_3^2 = 1,$$

*I will call them **g-qubit** states. They can be conveniently written in exponential form$e^{I_S\varphi}$,where $\varphi = \cos^{-1}\alpha$.*

Remark 1.1: *Element of G_3^+can be not a unit value element, that's formally not g-qubit. It can be normalized, receiving in that way the form of a g-qubit with positive scalar factor:*

$$\alpha + \beta(b_1B_1 + b_2B_2 + b_3B_3) = \sqrt{\alpha^2+\beta^2}\left(\frac{\alpha}{\sqrt{\alpha^2+\beta^2}} + \frac{\beta}{\sqrt{\alpha^2+\beta^2}}(b_1B_1 + b_2B_2 + b_3B_3)\right)$$

[1] Correctly saying is "by a state". State is operator acting on observable.

When acting in measurements on observables (see below) they will additionally multiply the results by $\alpha^2 + \beta^2$. The requirement $\alpha^2 + \beta^2 = 1$ has nothing to do with the probability interpretation in conventional QM, it is just for convenient representation of g-qubits in exponential form.

End of Remark 1.1.

The set $\{B_1, B_2, B_3\}$ is an arbitrary triple of unit value mutually orthogonal bivectors in three dimensions satisfying, with not critical assumption of right-hand screw orientation $B_1 B_2 B_3 = 1$, the multiplication rules (see Fig.1.2):

$$B_1 B_2 = -B_3,\ B_1 B_3 = B_2,\ B_2 B_3 = -B_1{}^2$$

State parameters λ here is a quadruple of scalars $\{\alpha, \beta_1, \beta_3, \beta_3\}$, plus the triple of bivectors $\{B_1, B_2, B_3\}$.If the bivector basis is known, we can write :$S(\alpha, \beta, I_S) = S(\alpha, \beta_1, \beta_2, \beta_3)$

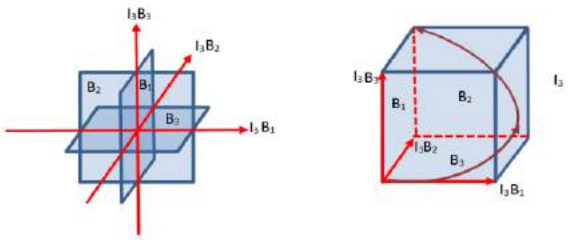

Fig.1.2. Basis of bivectors and unit value pseudoscalar

Definition 1.2: *The set of observables $O(\mu)$is generally comprised of elements of G_3:*

$$O(\gamma, v_1, v_2, v_3, \delta_1, \delta_2, \delta_3, p) = \gamma + I_3(v_1 B_1 + v_2 B_2 + v_3 B_3) + \delta_1 B_1 + \delta_2 B_2 + \delta_3 B_3 + I_3 p$$

All parameters $\gamma, v_1, v_2, v_3, \delta_1, \delta_2, \delta_3, p$ are (real[3]) scalars. I_3 is pseudoscalar, oriented unit value volume, that can be formally defined as geometric product of the three vectors dual to basis bivectors: $I_3 = e_1 e_2 e_3$, each e_i is orthogonal to B_i and is in default right-hand screw orientation with B_i.

Definition 1.3: *Measurement of observable $O(\gamma, v_1, v_2, v_3, \delta_1, \delta_2, \delta_3, p)$by a state $S(\alpha, \beta, I_S)$is a generalized Hopf fibration:*

$$O(\gamma, v_1, v_2, v_3, \delta_1, \delta_2, \delta_3, p) \xRightarrow{S(\alpha,\beta,I_S)} \overline{S(\alpha, \beta, I_S)}\, O(\gamma, v_1, v_2, v_3, \delta_1, \delta_2, \delta_3, p) S(\alpha, \beta, I_S)^4$$

The plane of the g-qubit state $S(\alpha, \beta, I_S)$does not generally coincide with the plane of bivector part of the observable it is applied to.

Remark 1.1: *Action of measurement separately on the scalar γ and pseudoscalar $I_3 p$ parts of observable does not change them. Action on the vector part $I_3(v_1 B_1 +$ v2B2+v3B3 is action on bivector observable $v_1 B_1 + v_2 B_2 + v_3 B_3$ multiplied by I_3.*

End of Remark 1.1.

Remark 1.2:*Any conventional quantum mechanics two-valued basis state qubit*

$$\begin{pmatrix} x_1 + iy_1 \\ x_2 + iy_2 \end{pmatrix}, \|x_1 + iy_1\|^2 + \|x_2 + iy_2\|^2 = 1,$$

can be lifted to G_3^+:

$\begin{pmatrix} x_1 + iy_1 \\ x_2 + iy_2 \end{pmatrix} \Rightarrow x_1 + y_1 B_1 + y_2 B_2 + x_2 B_3 = x_1 + y_1 B_1 + (x_2 + y_2 B_1) B_3,$ [5]

see [1], [2], [3].*Basis bivector triple $\{B_1, B_2, B_3\}$ is defined in the lift up to solid rotation in three dimensions. In that sense we can speak about principal fiber bundle $G_3^+ \to \mathbb{C}^2$ with the standard fiber as group of rotations which is also effectively identified by elements ofG_3^+*[6]

End of Remark 1.2.

A measurement can be conveniently written in exponential form.

$$e^{-I_S \varphi} O(\gamma, v_1, v_2, v_3, \delta_1, \delta_2, \delta_3, p) e^{I_S \varphi},\ \varphi = cos^{-1} \frac{\alpha}{\sqrt{\alpha^2 + \beta^2}}$$

Useful explicit formula of the result of measurement of aG_3^+ observable (no vector and pseudoscalar components), particularly demonstrating generalization of classical Hopf results[7] usually formulated with quaternions or Pauli matrices, is [1]:

$$\overline{S(\alpha, \beta, I_S)} O(\gamma, \delta_1, \delta_2, \delta_3) S(\alpha, \beta, I_S) =$$

$$\gamma + \big(\delta_1[(\alpha^2 + \beta_1^2) - (\beta_2^2 + \beta_3^2)] + 2\delta_2(\beta_1\beta_2 - \alpha\beta_3) + 2\delta_3(\alpha\beta_2 + \beta_1\beta_3)\big)B_1 + \big(2\delta_1(\alpha\beta_3 + \beta_1\beta_2) +$$

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[2] Opposite orientation $B_1 B_2 B_3 = -1$can be equivalently used

[3] In the suggested theory scalars are real, complex valued scalars make no sense

[4] Bar means order conjugate: $\overline{\alpha + I_S\beta} = \alpha - I_S\beta$

[5] Alternatively, though less convenient: $x_1 + x_2 B_3 + (y_1 - y_2 B_3) B_1$ or $x_1 + y_2 B_2 + (y_1 - x_2 B_2) B_1$

$\delta_2[(\alpha^2+\beta_2^2)-(\beta_1^2+\beta_3^2)]+2\delta_3(\beta_2\beta_3-\alpha\beta_1)\big)B_2+(2\delta_1(\beta_1\beta_3-\alpha\beta_2)+2\delta_2(\alpha\beta_1+\beta_2\beta_3)+\delta_3[(\alpha^2+\beta_3^2)-(\beta_1^2+\beta_2^2)]\big)B_3$ *(1.1)*

2. Clifford translations, Schrodinger equation, "small" measurements

Consider the notion of *Clifford translations* acting on g-qubit states. Clifford translation $e^{I_{B_C}\gamma}$by scalar value γin given plane$B_C$actson a state $e^{I_B\varphi}$ as:

$$e^{I_B\varphi}\to e^{I_{B_C}\gamma}e^{I_B\varphi}$$

Since generally the plane B_C of Clifford translation and plane I_B of the state the Clifford translation acts on are not parallel the result $e^{I_{B_C}\gamma}e^{I_B\varphi}$ is [8] :

$$e^{I_{B_C}\gamma}e^{I_B\varphi}=\cos\gamma\cos\varphi\ +\cos\gamma\sin\varphi\, I_B + \sin\gamma\cos\varphi\, I_{B_C}+\sin\gamma\sin\varphi\, I_{B_C}I_B$$ [6]

Let's check if Clifford translation transforms a g-qubit state intog-qubit state.

Suppose I_B andI_{B_C} are expanded in a bivector basis $\{B_1,B_2,B_3\}$:

$I_B=\alpha_1B_1+\alpha_2B_2+\alpha_3B_3$,$I_{B_C}=\beta_1B_1+\beta_2B_2+\beta_3B_3$

Then:

$$\begin{aligned}e^{I_{B_C}\gamma}e^{I_B\varphi}=&\cos\gamma\cos\varphi\\&+\cos\gamma\sin\varphi\,(\alpha_1B_1+\alpha_2B_2+\alpha_3B_3)\\&+\sin\gamma\cos\varphi\,(\beta_1B_1+\beta_2B_2+\beta_3B_3)\\&-\sin\gamma\sin\varphi\,(\alpha_1\beta_1+\alpha_2\beta_2+\alpha_3\beta_3)\\&-\sin\gamma\sin\varphi\,[(\beta_2\alpha_3-\beta_3\alpha_2)B_1\\&+(\beta_3\alpha_1-\beta_1\alpha_3)B_2\\&+(\beta_1\alpha_2-\beta_2\alpha_1)B_3]=\end{aligned}$$

$$\cos\gamma\cos\varphi-\sin\gamma\sin\varphi\,(\alpha_1\beta_1+\alpha_2\beta_2+\alpha_3\beta_3)+$$

$(\alpha_1\cos\gamma\sin\varphi+\beta_1\sin\gamma\cos\varphi-$
$\beta2\alpha3-\beta3\alpha2\sin\gamma\sin\varphi B1+\alpha2\cos\gamma\sin\varphi+\beta2\sin\gamma\cos\varphi-\beta3$
$\alpha1-\beta1\alpha3\sin\gamma\sin\varphi B2+\alpha3\cos\gamma\sin\varphi+\beta3\sin\gamma\cos\varphi-\beta1\alpha2$
$-\beta2\alpha1\sin\gamma\sin\varphi B3$*(2.1)*

The square of the scalar part is:

$$\cos^2\gamma\cos^2\varphi+\sin^2\gamma\sin^2\varphi(\alpha\cdot\beta)^2 - 2\sin\gamma\cos\gamma\sin\varphi\cos\varphi(\alpha\cdot\beta),$$

where α and β are vectors with components $(\alpha_1,\alpha_2,\alpha_3)$ and $(\beta_1,\beta_2,\beta_3)$,

The sum of squares of bivector components is:

$$\cos^2\gamma\sin^2\varphi+\sin^2\gamma\cos^2\varphi+\sin^2\gamma\sin^2\varphi(\alpha\times\beta)^2 + 2\sin\gamma\cos\gamma\sin\varphi\cos\varphi(\alpha\cdot\beta)$$

Then sum of square of the scalar part and the sum of squares of bivector components then reads

$$\begin{aligned}&\cos^2\gamma+\sin^2\gamma\cos^2\varphi+\sin^2\gamma\sin^2\varphi\sin^2(\alpha,\beta)\\&\quad+\sin^2\gamma\sin^2\varphi\cos^2(\alpha,\beta)\\&\quad=\cos^2\gamma+\sin^2\gamma\cos^2\varphi+\sin^2\gamma\sin^2\varphi\\&\quad=1\end{aligned}$$

Thus, the result of Clifford translation $e^{I_{B_C}\gamma}e^{I_B\varphi}$ is a g-qubit state, its plane is normalization of bivector

$$\begin{aligned}&(\alpha_1\cos\gamma\sin\varphi+\beta_1\sin\gamma\cos\varphi\\&\quad-(\beta_2\alpha_3-\beta_3\alpha_2)\sin\gamma\sin\varphi)B_1\\&\quad+(\alpha_2\cos\gamma\sin\varphi+\beta_2\sin\gamma\cos\varphi\\&\quad-(\beta_3\alpha_1-\beta_1\alpha_3)\sin\gamma\sin\varphi)B_2\\&\quad+(\alpha_3\cos\gamma\sin\varphi+\beta_3\sin\gamma\cos\varphi\\&\quad-(\beta_1\alpha_2-\beta_2\alpha_1)\sin\gamma\sin\varphi)B_3\quad(2.2)\end{aligned}$$

and the Clifford translation parameter is:

$\cos^{-1}\big(\cos\gamma\cos\varphi-\sin\gamma\sin\varphi\,(\alpha_1\beta_1+\alpha_2\beta_2+\alpha_3\beta_3)\big)$ *(2.3)*

Let a state depends on time: $e^{I_B\varphi}=e^{I_B(t)\varphi(t)}$, and assume the Clifford translation is associated with a Hamiltonian $H(t)=I_3(\chi_1(t)B_1+\chi_2(t)B_2+\chi_3(t)B_3)$,[7] and the translation is infinitesimal one: $e^{-I_3\frac{H(t_0)}{|H(t_0)|}|H(t_0)|\Delta t}e^{I_B(t_0)\varphi(t_0)}$.

Bivector$I_3\frac{H(t_0)}{|H(t_0)|}\equiv I_H(t_0)$ is,in the suggested theory (see [9]), generalization of imaginary unit. Thus, we get:

$$e^{I_B(t_0+\Delta t)\varphi(t_0+\Delta t)}=e^{-I_H(t_0)|H(t_0)|\Delta t}e^{I_B(t_0)\varphi(t_0)}$$

and

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[6] In the case $I_{B_C}=I_B$ we trivially have rotation of $e^{I_B\varphi}$ by angle γ in plane I_B

[7] The G_3 form of a Hamiltonianis in one-to-one map with its matrix form in the Pauli matrix basis, see [1]

$$\lim_{\Delta t\to 0}\frac{\Delta e^{I_B(t_0)\varphi(t_0)}}{\Delta t}=\lim_{\Delta t\to 0}\frac{e^{I_B(t_0+\Delta t)\varphi(t_0+\Delta t)}-e^{I_B(t_0)\varphi(t_0)}}{\Delta t}$$
$$=\lim_{\Delta t\to 0}\frac{(1-I_H(t_0)|H(t_0)|\Delta t)e^{I_B(t_0)\varphi(t_0)}-e^{I_B(t_0)\varphi(t_0)}}{\Delta t}$$
$$=-I_H(t_0)|H(t_0)|e^{I_B(t_0)\varphi(t_0)}$$

that gives Schrodinger equation in terms of geometric algebra for the state $e^{I_B(t)\varphi(t)}$:

$$-\frac{\partial}{\partial t}e^{I_B(t)\varphi(t)}=I_H(t)|H(t)|e^{I_B(t)\varphi(t)}$$

That means that the Schrodinger equation governs evolution, under the Hamiltonian Clifford translations, of states which, in turn, can act on observables.

Let's consider special sort of measurements of an observable which, for some minor simplicity, has only bivector part, $O(\gamma,\delta,I_O)=\delta_1B_1+\delta_2B_2+\delta_3B_3\equiv O(\delta_1,\delta_2,\delta_3)$.

The measurements will be called "small" ones[8] if the value of αin the state $S(\alpha,\beta,I_S)=\alpha+I_S\beta$is close to one and value of β is close to zero. With these assumptions, formula (1.1) reads:

$$\overline{S(\alpha,\beta,I_S)}O(\delta_1,\delta_2,\delta_3)S(\alpha,\beta,I_S)\approx$$

$(\delta_1\alpha^2-2\delta_2\alpha\beta_3+2\delta_3\alpha\beta_2)B_1+(2\delta_1\alpha\beta_3+\delta_2\alpha^2-$
2δ3αβ1B2+-2δ1αβ2+2δ2αβ1+δ3α2B3=α2Oδ1,δ2,δ 3+2αδ3β2−δ2β3B1+δ1β3−δ3β1B2+δ2β1−δ1β2B3 (2.4)

By denoting the state bivector parts:

$$\beta_1B_1+\beta_2B_2+\beta_3B_3\equiv S(\beta_1,\beta_2,\beta_3)$$

and taking dual vectors:

$o(\delta_1,\delta_2,\delta_3)=-I_3O(\delta_1,\delta_2,\delta_3)$ and $s(\beta_1,\beta_2,\beta_3)=-I_3S(\beta_1,\beta_2,\beta_3)$

we see that the expression in square brackets in (2.4) above is (see Sec.1):

$$\begin{aligned}&[(\delta_3\beta_2-\delta_2\beta_3)B_1+(\delta_1\beta_3-\delta_3\beta_1)B_2\\&\quad+(\delta_2\beta_1-\delta_1\beta_2)B_3]\\&=-I_3[(\delta_3\beta_2-\delta_2\beta_3)I_3B_1\\&\quad+(\delta_1\beta_3-\delta_3\beta_1)I_3B_2\\&\quad+(\delta_2\beta_1-\delta_1\beta_2)I_3B_3]\\&=I_3\big(o(\delta_1,\delta_2,\delta_3)\times s(\beta_1,\beta_2,\beta_3)\big)\\&=S(\beta_1,\beta_2,\beta_3)\wedge O(\delta_1,\delta_2,\delta_3)\end{aligned}$$

Finally, we get the result of "small" measurement:

$$\overline{S(\alpha,\beta_1,\beta_2,\beta_3)}O(\delta_1,\delta_2,\delta_3)S(\alpha,\beta_1,\beta_2,\beta_3)\approx$$

$$\alpha^2O(\delta_1,\delta_2,\delta_3)+2\alpha S(\beta_1,\beta_2,\beta_3)\wedge O(\delta_1,\delta_2,\delta_3)\ (2.5)$$

Take a state associated with Hamiltonian $e^{-I_H(t)|H(t)|\Delta t}$, where $I_H(t)=I_3\frac{H(t)}{|H(t)|}$ and Δt is small enough to make "small" measurements, that's $\cos(|H(t)|\Delta t)$ is close to one. Formula (2.5) then gives:

$$\begin{aligned}e^{I_H(t)|H(t)|\Delta t}O(\delta_1,\delta_2,\delta_3)e^{-I_H(t)|H(t)|\Delta t}&\\ \approx cos^2(|H(t)|\Delta t)O(\delta_1,\delta_2,\delta_3)&\\ +2\cos(|H(t)|\Delta t)I_H(t)\wedge O(\delta_1,\delta_2,\delta_3)&\end{aligned}$$

3. Maxwell equation in geometric algebra

I've mentioned in another place that what is called "quantum computer" implemented not through mysterious "entanglement" following from formal, physically not feasible tensor products but, in the suggested geometric algebra terms, should actually be a kind of analog computer. As shown below, states constructed from solutions of the Maxwell equations allow to get appropriate instrument for such implementation.

Let's show how the system of the electromagnetic Maxwell equations is formulated as one equation in geometric algebra terms[10].

Take geometric algebra element of the form: $F=e+I_3h$. The electromagnetic field F is created by some given distribution of charges and currents, also written as geometric algebra multivector: $J\equiv\rho-j$. Apply operator$\partial_t+\nabla$, where $\nabla=\frac{\partial}{\partial x}\hat{x}+\frac{\partial}{\partial y}\hat{y}+\frac{\partial}{\partial z}\hat{z}$[9]and multiplication is the geometrical algebra one, to the F. The result is:

$$(\partial_t+\nabla)F=\underbrace{\nabla\cdot e}_{scalar}+\underbrace{\partial_te+I_3(\nabla\wedge h)}_{vector}+\underbrace{\nabla\wedge e+I_3\partial_th}_{bivector}+\underbrace{I_3(\nabla\cdot h)}_{pseudoscalar}$$

Comparing component-wise $(\partial_t+\nabla)F$ and J we get:

$$\begin{cases}\nabla\cdot e\equiv dive=\rho\\ \partial_te+I_3(\nabla\wedge h)\equiv\partial_te-roth=-j\\ \nabla\wedge e+I_3\partial_th\equiv I_3rote+I_3\partial_th=0\\ I_3(\nabla\cdot h)\equiv I_3(divh)=0\end{cases}$$

Thus, we have usual system of Maxwell equations:

[8] I will call states also "small" if they make "small" measurements

[9] For any vector we write $\hat{a}=a/|a|$

$$\begin{cases} dive = \rho \\ \partial_t e - roth = -j \\ \partial_t h + rote = 0 \\ divh = 0 \end{cases}$$

equivalent to one equation $(\partial_t + \nabla)F = J$.

Without charges and currents the equation becomes:

$(\partial_t + \nabla)F = 0$*(3.1)*

The circular polarized electromagnetic waves are the only type of waves following from the solution of Maxwell equations in free space done in geometric algebra terms.

Indeed, let's take the electromagnetic field in the form:

$F = F_0 exp[I_S(\omega t - k \cdot r)]$ *(3.2)*

requiring that it satisfies (3.1)

Element F_0 in (3.2) is a constant element of geometric algebra G_3 and I_S is unit value bivector of a plane S in three dimensions, generalization of the imaginary unit [9], [1]. The exponent in (3.2) is unit value element of G_3^+[1]:

$e^{I_S\varphi} = \cos\varphi + I_S \sin\varphi,\ \varphi = \omega t - k \cdot r$

Solution of (3.1) should be sum of a vector (electric field$e$) and bivector (magnetic field $I_3 h$):

$$F = e + I_3 h$$

with some initial conditions:

$$e + I_3 h|_{t=0,\vec{r}=0} = F_0 = e|_{t=0,\vec{r}=0} + I_3 h|_{t=0,\vec{r}=0} = e_0 + I_3 h_0$$

Substitution of (3.2) into the Maxwell's (3.1) will show us what the solution looks like.

The derivative by time gives

$$\frac{\partial}{\partial t}F = F_0 e^{I_S\varphi} I_S \frac{\partial}{\partial t}(\omega t - k \cdot r) = F_0 e^{I_S\varphi} I_S \omega = F I_S \omega$$

The geometric algebra product ∇F is:

$$\nabla F = F_0 I_S e^{I_S\varphi} \nabla(\omega t - k \cdot r) = -F_0 e^{I_S\varphi} I_S k = -F I_S k$$

Or

$$\nabla F = F_0 e^{I_S\varphi} \nabla(\omega t - k \cdot r) I_S = -F_0 e^{I_S\varphi} k I_S = -F k I_S,$$

depending on do we write $I_S(\omega t - k \cdot r)$ or $(\omega t - k \cdot r)I_S$. The result should be the same because$\omega t - k \cdot r$is a scalar.

Commutativity $I_S k = k I_S$is valid only if $k \times I_3 I_S = 0$. The following agreement takes place between orientation of I_3, orientation of I_S and direction of vector k[1].

The vector $I_3 I_S = I_S I_3$ is orthogonal to the plane of I_S and its direction is defined by orientations of I_3 and I_S. Rotation of right/left hand screw defined by orientation of $I_S$gives movement of right/left hand screw. This is the direction of the vector $I_3 I_S = I_S I_3$. That means that the matching between$\hat{k}$ and I_S should be $\hat{k} = \pm I_3 I_S \Longrightarrow \hat{k} I_S = \mp I_3$.

Assume first that orientation is $I_3 = \hat{k} I_S$.Then Maxwell equation becomes:

$$F(I_S\omega - I_3|k|) = F\big(\omega I_S - |k|\hat{k} I_S\big) = 0$$

or $(e + I_3 h)\omega = (e + I_3 h)k$

Left hand side of equation is sum of vector and bivector, while right hand side is scalar $e \cdot k$ plus bivector $\wedge k$, plus pseudoscalar $I_3(h \cdot k)$, plus vector $I_3(h \wedge k)$. It follows that both$e$and h lie on the plane of I_S and then:

$$\omega e = I_3 hk,\ \omega I_3 h = ek \rightarrow \frac{\omega^2}{|k|^2} I_3 hk = \omega e$$

Thus, $\omega = |k|$ and we get equation $I_3 h\hat{k} = e$ from which particularly follows $|e|^2$=$|h|^2$ and $\hat{e}\hat{k}\hat{h} = I_3$.The result for this case is that the solution of (4.1) is

$$F = (e_0 + I_3 h_0) exp[I_S(\omega t - k \cdot r)]$$

where $e_0$and $h_0$are arbitrary mutually orthogonal vectors of equal length, lying on the plane S. Vector k should be normal to that plane, $\hat{k} = -I_3 I_S$ and $|k| = \omega$.

In the above result the sense of the I_S orientation and the direction of k were assumed to agree with $I_3 = \hat{k} I_S$.

Opposite orientation, $-I_3 = \hat{k} I_S$, that's k and I_S compose left hand screw and $\hat{k} = I_3 I_S$, will give solution of the same form $F = (e_0 + I_3 h_0) exp[I_S(\omega t - k \cdot r)]$but $I_3 = \hat{e}\hat{h}\hat{k}$.

Summary:

For a plane S in three dimensions Maxwell equation (3.1) has two solutions

- $F_+ = (e_0 + I_3 h_0)exp[I_S(\omega t - k_+ \cdot r)]$, with $\hat{k}_+ = I_3 I_S$,$\hat{e}\hat{h}\hat{k}_+ = I_3$, and the triple$\{\hat{e}, \hat{h}, \hat{k}_+\}$ is right hand screw oriented, that's rotation of $\hat{e}$to $\hat{h}$ by $\pi/2$ gives movement of *right hand screw* in the direction of $k_+ = |k| I_3 I_S$.
- $F_- = (e_0 + I_3 h_0)exp[I_S(\omega t - k_- \cdot r)]$, with $\hat{k}_- = -I_3 I_S$,$\hat{e}\hat{h}\hat{k}_- = -I_3$, and the triple $\{\hat{e}, \hat{h}, \hat{k}_-\}$ is left hand screw oriented, that's rotation of $\hat{e}$ to $\hat{h}$ by $\pi/2$ gives movement of *left hand screw* in the direction of $k_- = -|k| I_3 I_S$ or, equivalently, movement of *right hand screw* in the opposite direction, $-k_-$.
- $e_0$and h_0, initial values of $e$and$h$, are arbitrary mutually orthogonal vectors of equal length, lying on the plane$S$. Vectors $k_\pm = \pm|k_\pm| I_3 I_S$ are normal to that plane. The length of the "wave vectors"$|k_\pm|$ is equal to "angular frequency" ω.

Maxwell equation (3.1) is a linear one. Then any linear combination of F_+ and F_- saving the structure of (3.2) will also be a solution.

Let's write:

$$F_+ = (e_0 + I_3 h_0)exp[I_S\omega(t - (I_3 I_S) \cdot r)]$$

$$= (e_0 + I_3 h_0)exp[I_S\omega t]exp\big[-I_S[(I_3 I_S) \cdot r]\big]$$

$$F_- = (e_0 + I_3 h_0)exp[I_S\omega(t + (I_3 I_S) \cdot r)]$$

$$= (e_0 + I_3 h_0)exp[I_S\omega t]exp\big[I_S[(I_3 I_S) \cdot r]\big] \quad (3.3)$$

Then for arbitrary scalars λ and μ:

$\lambda F_+ + \mu F_- = (e_0 + I_3 h_0)e^{I_S\omega t}\left(\lambda e^{-I_S[(I_3 I_S)\cdot r]} +\right.$ *μeISI3IS⋅r(3.4)*

is solution of (3.1). The item in the second parenthesis is weighted linear combination of two states with the same phase in the same plane but opposite sense of orientation. The states are strictly coupled because bivector plane should be the same for both, does not matter what happens with that plane.

Formula (3.4) does not immediately looks like an element ofG_3^+ due to the factor $(e_0 + I_3 h_0)$. But necessary transformations (see [10]) of the initial bivector basis $\{B_1, B_2, B_3\}$ into triple of unit value orthonormal bivectors $\{I_S, I_{B_0}, I_{E_0}\}$where$I_S$is bivector,

dual to the propagation direction vector;I_{B_0} is dual to initial vector of magnetic field;I_{E_0} is dual to initial vector of electric field, change(3.4)with $\lambda = \mu = 1$into:

$$\lambda e^{I_{Plane}^{+}\varphi^+} + \mu e^{I_{Plane}^{-}\varphi^-}\Big|_{\lambda=\mu=1} \quad (3.5)$$

Where

$\varphi^\pm = \cos^{-1}(\cos\omega(t \mp [(I_3 I_S) \cdot r]))$,

$$I_{Plane}^{\pm} = I_S sin\omega(t \mp [(I_3 I_S) \cdot r]) + I_{B_0} cos\omega(t \mp [(I_3 I_S) \cdot r]) + I_{E_0} sin\omega(t \mp [(I_3 I_S) \cdot r])$$

4. Clifford translations of states (3.5)

Linear combination of the two equally weighted basic solutions of the Maxwell equation $\lambda F_+ + \mu F_-$ with $\lambda = \mu = 1$,can be written for exponential form purposes as [10]:

$2\sqrt{2}\cos\omega[(I_3 I_S) \cdot r]\left(\frac{1}{\sqrt{2}}\cos\omega t +\right.$

*121+sin2ωt*sin*ωt1+sin2ωtIS+*cos*ωt1+sin2ωtIB0+*sin*ωt1+sin2ωtIE0(4.1)*

I will call suchG_3^+states ***spreons*** because they are defined, spread, over the whole three-dimensional space for all values of time, and instantly change under Clifford translations over the whole three-dimensional space for all values of time, along with the results of measurement of any observable.

Arbitrary Clifford translation written in the $\{I_S, I_{B_0}, I_{E_0}\}$ basis:$e^{I_{B_C}\gamma} = \cos\gamma + \sin\gamma(\gamma_1 I_S + \gamma_2 I_{B_0} + \gamma_3 I_{E_0})$when acting on spreons (4.1) also written in exponential form

$2\sqrt{2}\cos\omega[(I_3 I_S) \cdot r]\, e^{I_{sp}\varphi}$, where $I_{sp} = I_S \frac{\sin\omega t}{\sqrt{1+sin^2\omega t}} + I_{B_0}\frac{\cos\omega t}{\sqrt{1+sin^2\omega t}} + I_{E_0}\frac{\sin\omega t}{\sqrt{1+sin^2\omega t}}$and

$\varphi = \cos^{-1}\left(\frac{1}{\sqrt{2}}\cos\omega t\right)$,reads:

$$e^{I_{B_C}\gamma} 2\sqrt{2}\cos\omega[(I_3 I_S) \cdot r]\, e^{I_{sp}\varphi} = 2\cos\omega[(I_3 I_S) \cdot r]\left(\cos\gamma\cos\omega t + \cos\gamma\sqrt{1 + sin^2\omega t}\, I_{sp} + \sin\gamma\cos\omega t\, I_{B_C} + \sin\gamma\sqrt{1 + sin^2\omega t} I_{B_C} I_{sp}\right) =$$

$$2\cos\omega[(I_3 I_S) \cdot r]\Big(\cos\gamma\cos\omega t + \cos\gamma\sin\omega t\, I_S + \cos\gamma\cos\omega t\, I_{B_0} + \cos\gamma\sin\omega t\, I_{E_0} + \sin\gamma\cos\omega t\, I_{B_C} + \sin\gamma\, I_{B_C}\big(\sin\omega t\, I_S + \cos\omega t\, I_{B_0} + \sin\omega t\, I_{E_0}\big)\Big) =$$

$$2\cos\omega[(I_3 I_S) \cdot r]\Big(\cos\gamma\, e^{I_S\omega t} + \cos\gamma\, I_{B_C} e^{I_S\omega t} +$$

$\sin\gamma\, I_{B_C}\left(e^{I_S\omega t}+I_{B_0}e^{I_S\omega t}\right)\big) = 2\cos\omega[(I_3 I_S)\cdot r]e^{I_{B_C}\gamma}\left(e^{I_S\omega t}+I_{B_0}e^{I_S\omega t}\right)$ (4.2)

This result is explicitly defined for all values of t and r,that's instantly spreads through the whole three-dimensions and for all values of time, future and past.

Measurement of any, for example G_3^+observable $C_0+C_1I_S+C_2I_{B_0}+C_3I_{E_0}$,by the state (4.2) gives a G_3^+ element $O\left(C_0,C_1,C_2,C_3,I_S,I_{B_0},I_{E_0},\gamma,\gamma_1,\gamma_2,\gamma_3,\omega,t,r\right)$also spread through the whole three-dimensional space for all values of the time parameter t.

Let's first rewrite $e^{I_S\omega t}+I_{B_0}e^{I_S\omega t}$ as single g-qubit:

$$e^{I_S\omega t}+I_{B_0}e^{I_S\omega t} = \cos\omega t + I_S\sin\omega t + I_{B_0}\cos\omega t + I_{E_0}\sin\omega t \equiv SP\left(I_S,I_{B_0},I_{E_0},\omega,t\right)$$

Take only bivector part of the observable $O(C_1,C_2,C_3)\equiv C_1I_S+C_2I_{B_0}+C_3I_{E_0}$ (scalar part does not change in measurements.)Without applying Clifford translation measurement by state $SP\left(I_S,I_{B_0},I_{E_0},\omega,t\right)$ gives (see (1.1)).

$$\overline{SP\left(I_S,I_{B_0},I_{E_0},\omega,t\right)}\, O(C_1,C_2,C_3)SP\left(I_S,I_{B_0},I_{E_0},\omega,t\right) = 2C_3I_S + 2(C_1\sin 2\omega t + C_2\cos 2\omega t)I_{B_0} + 2(-C_1\cos 2\omega t + C_2\sin 2\omega t)I_{E_0}$$

Including the position dependent factor into the measurement we have:

$$8\cos^2(\omega[(I_3I_S)\cdot\vec{r}])\left(C_3I_S + (C_1\sin 2\omega t + C_2\cos 2\omega t)I_{B_0} + (-C_1\cos 2\omega t + C_2\sin 2\omega t)I_{E_0}\right)$$

With the Clifford translation $e^{I_{B_C}\gamma}SP\left(I_S,I_{B_0},I_{E_0},\omega,t\right)$we get:

$e^{I_{B_C}\gamma}SP\left(I_S,I_{B_0},I_{E_0},\omega,t\right) =$
$\cos\gamma\cos\omega t - \gamma_1\sin\gamma\sin\omega t - \gamma_2\sin\gamma\cos\omega t -$
γ3sinγsinωt+cosγsinωt+γ1sinγcosωt−γ2sinγsinωt +γ3sinγcosωtIS+cosγcosωt+γ1sinγsinωt+γ2sinγcosωt−γ3sinγsinωtIB0+cosγsinωt−γ1sinγcosωt+γ2sinγsinωt+γ3sinγcosωtIE0.

To make the results more readable use the "small" state approximation. Then from (2.5) we get:

$$4\cos^2(\omega[(I_3I_S)\cdot\vec{r}])\overline{e^{I_{B_C}\gamma}SP\left(I_S,I_{B_0},I_{E_0},\omega,t\right)}O(C_1,C_2,C_3)e^{I_{B_C}\gamma}SP\left(I_S,I_{B_0},I_{E_0},\omega,t\right) =$$

$$4\cos^2(\omega[(I_3I_S)\cdot\vec{r}])\Big\{(\cos\gamma\cos\omega t - \gamma_1\sin\gamma\sin\omega t - \gamma_2\sin\gamma\cos\omega t - \gamma_3\sin\gamma\sin\omega t)^2\left(C_1I_S + C_2I_{B_0} + C_3I_{E_0}\right) + 2(\cos\gamma\cos\omega t - \gamma_1\sin\gamma\sin\omega t - \gamma_2\sin\gamma\cos\omega t - \gamma_3\sin\gamma\sin\omega t)\Big[\Big((\cos\gamma\sin\omega t + \gamma_1\sin\gamma\cos\omega t - \gamma_2\sin\gamma\sin\omega t + \gamma_3\sin\gamma\cos\omega t)I_S + (\cos\gamma\cos\omega t + \gamma_1\sin\gamma\sin\omega t + \gamma_2\sin\gamma\cos\omega t - \gamma_3\sin\gamma\sin\omega t)I_{B_0} + (\cos\gamma\sin\omega t - \gamma_1\sin\gamma\cos\omega t + \gamma_2\sin\gamma\sin\omega t + \gamma_3\sin\gamma\cos\omega t)I_{E_0}\Big)\wedge O(C_1,C_2,C_3)\Big]\Big\}.$$

We see that with or without Clifford translation the result of measurement is instantly defined through the whole three-dimensions and for all values of time, future and past.

5. Conclusions

The seminal ideas: variable and explicitly defined complex plane in three dimensions, the G_3^+ states as operators acting on observables, solution of the Maxwell equation(s) in the G_3 frame giving G_3^+ states, spreons, spreading over the whole three-dimensional space for all values of time, along with the results of measurement of any observable, allow to put forth comprehensive and much more detailed formalism replacing conventional quantum mechanics.

The spreon states, subjected to Clifford translations, change instantly forward and backward in time, modifying the results of measurements both in past and future. Very notion of the concept of cause and effect, as ordered by time, disappears.

In the case of computations, executed through Clifford translations, all measured observable values are retuned all together. Any number of test observables can be placed into continuum of the $(t,\vec{r})$ dependent values of the spreon state, thus fetching out any amount of values.

References

[1] Soiguine, Geometric Phase in Geometric Algebra Qubit Formalism, Saarbrucken: LAMBERT Academic Publishing, 2015.

[2] Soiguine, "Geometric Algebra, Qubits, Geometric Evolution, and All That," January 2015. [Online]. Available: http://arxiv.org/abs/1502.02169.

[3] Soiguine, "What quantum "state" really is?," June 2014. [Online]. Available: http://arxiv.org/abs/1406.3751.

[4] Doran and A. Lasenby, Geometric Algebra for Physicists, Cambridge: Cambridge University Press, 2010.

[5] Hestenes, New Foundations for Classical Mechanics, Dordrecht/Boston/London: Kluwer Academic Publishers, 1999.

[6] Soiguine, "Anyons in three dimensions with geometric algebra," July 2016. [Online]. Available: https://arxiv.org/abs/1607.03413.

[7] W. Lyons, "An Elementary Introduction to the Hopf Fibration," *Mathematics Magazine,* vol. 76, no. 2, pp. 87-98, 2003.

[8] Soiguine, "Polarizations as States and Their Evolution in Geometric Algebra Terms with Variable Complex Plane," *Journal of Applied Mathematics and Physics,* vol. 6, no. 4, pp. 704-714, 2018.

[9] M. Soiguine, "Complex Conjugation - Relative to What?," in *Clifford Algebras with Numeric and Symbolic Computations*, Boston, Birkhauser, 1996, pp. 284-294.

[10] Soiguine, "The geometric algebra lift of qubits via basic solutions of Maxwell equation," 21 May 2018. [Online]. Available:

https://arxiv.org/abs/1805.11953.