Quantum Impedances, Entanglement, and State Reduction

Peter Cameron*
Strongarm Studios
Mattituck, NY USA 11952

(Dated: April 20, 2013)

The measurement problem, the mechanism of quantum state reduction, has remained an open question for nearly a century. The 'quantum weirdness' of the problem was highlighted by the introduction of the Einstein-Podolsky-Rosen paradox in 1935. Motivated by Bell's Theorem, nonlocality was first experimentally observed in 1972 by Clauser and Freedman in the entangled states of an EPR experiment, and is now an accepted fact. Special relativity requires that no energy is transferred in the nonlocal collapse of these entangled two-body wavefunctions, that no work is done, no information communicated. In the family of quantum impedances those which are scale invariant, the Lorentz and centrifugal impedances, satisfy this requirement. This letter explores their role in the collapse of the wave function.

INTRODUCTION

As every circuit designer knows, impedances govern the flow of energy. This is not a theoretical musing.

A novel method for calculating mechanical impedances[1], both classical and quantum, was presented earlier[2, 3]. In that work a background independent version of Mach's principle emerged from a rigorous analysis of the two body problem, permitting simple and direct calculation of these impedances.

The two body problem is innately one-dimensional, populated by string-like topologies. The mechanical impedances derived from Mach's principle can be converted to the more familiar electrical impedances by adding electric charge to these string-like objects[4].

Physics without calculations is not physics, but rather philosophy. This novel tool, this method of calculating impedances, is of no use to physics without a model to which it may be applied. The model adopted earlier [3–8] remains useful. It comprises

- quantization of electric and magnetic flux, charge, and dipole moment
- interactions between these three topologies - flux quantum, monopole, and dipole
- the photon
- confinement to a fundamental length, taken to be the Compton wavelength of the electron

Coupling impedances of the interactions between these three topologies have been calculated[3]. With the exception of the Lorentz and centrifugal impedances, they are parametric impedances, in the sense that they are scale dependent, and consequently energy dependent.

The role of the resulting impedance network, the 'scattering matrix', in the phenomenology of the unstable particles was discussed earlier[4], with the concept of coherence length playing a central role. In that note coherence length was defined as the lifetime of the wave function multiplied by the speed of light, or the wave function light cone, the boundary between local and non-local.

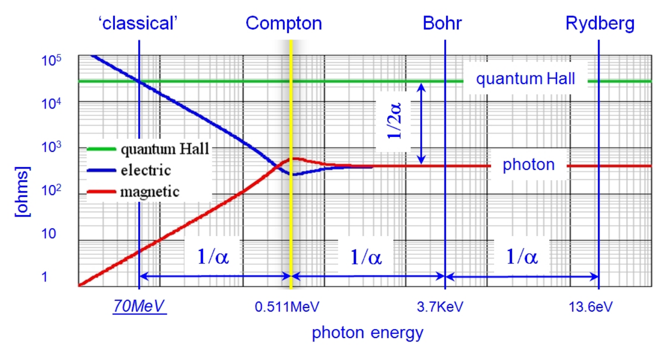

FIG. 1. Photon and electron impedances as a function of spatial scale as defined by photon energy. The role of the fine structure constant α is a prominent feature of the figure.

This revealed a strong correlation between the unstable particle coherence lengths and conjunctions of the mode impedances (where impedances are matched and energy can flow without reflection) and provides strong impetus for the present letter, which further explores the manner in which quantum impedances define coherence lengths, as well as the transition to incoherence that results from loss of phase information in state reduction.

QUANTUM IMPEDANCES

Quantum impedances can be divided into two categories. The first has one member, the only known massless particle - the stable photon. The second contains all the massive particles, stable and unstable.

In the **first category**, the photon impedance is further divided into the scale dependent near-field and the 377Ω scale invariant far-field impedances[9], as shown in figure 1 for a 0.511MeV photon.

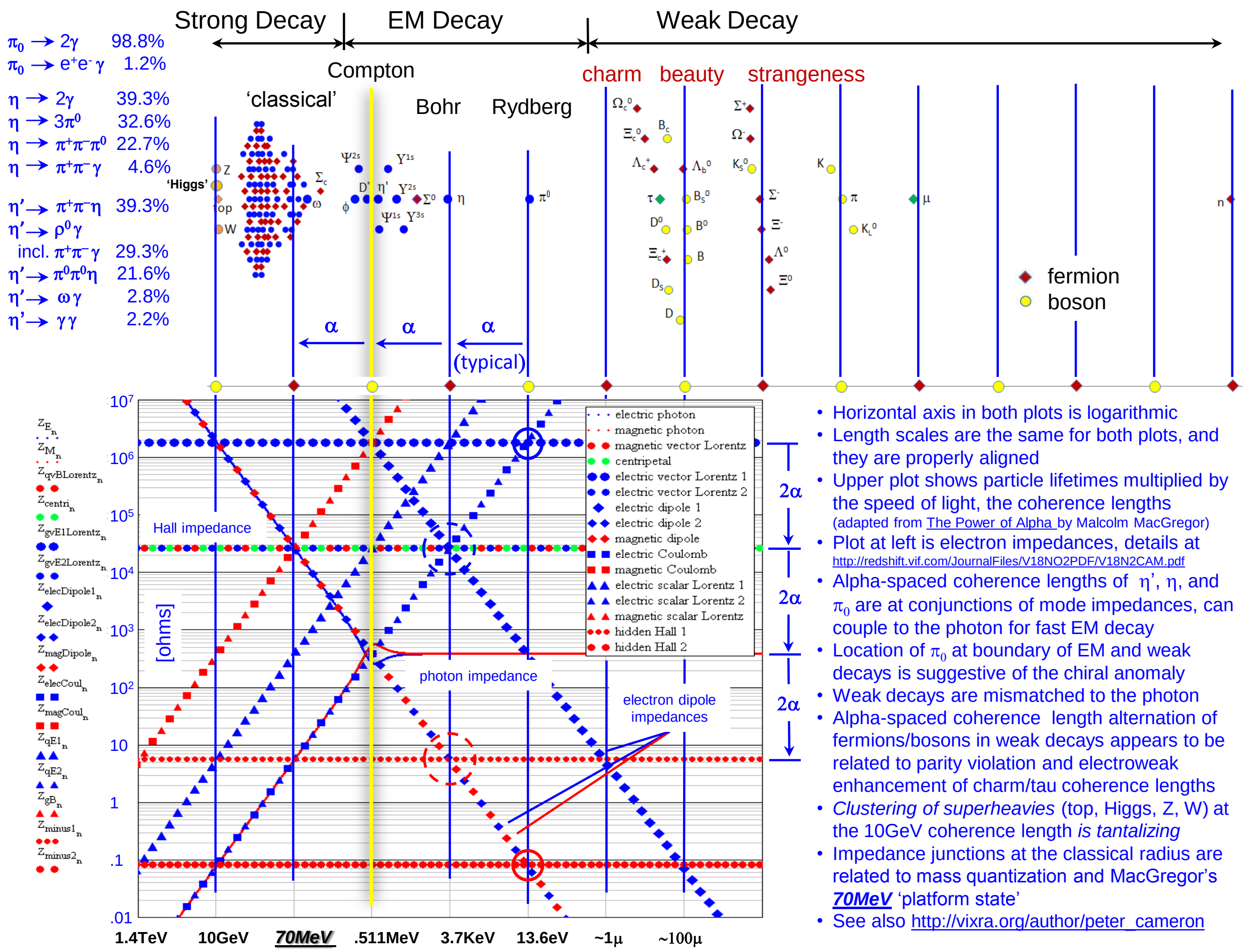

FIG. 2. A composite of 13.6eV photon impedances[9] and a variety of background independent[2]electron impedances[3, 10], measured branching ratios of the π_0, η, and η', the four fundamental quantum lengths shown in fig.1, and the coherence lengths of the unstable particles.[11–13]

The photon impedance is strictly electromagnetic. Unlike massive particles, it has no mechanical impedance.

In the **second category**, that of the massive particles, the impedance commonly encountered in the literature [14–23] is the scale invariant quantum Hall impedance. It is an electromechanical impedance. It provides one of the essential keys to understanding how to calculate background independent quantum impedances for all forces. The impedance plot of figure 2 is reproduced from earlier notes[3, 4, 10], and shows results from such calculations.

In addition to the purely electromagnetic photon impedances and the electromechanical impedances of the massive particles, it is possible to define a purely mechanical impedance, an inertial impedance, associated with the centrifugal force[2–4].

The centrifugal force is in some sense a mechanical equivalent of the vector Lorentz force present in the quantum Hall effect. Like the Lorentz force, it is perpendicular to the direction of motion, and hence can do no work. Like the Lorentz force, it is velocity dependent. Unlike velocity dependent forces other than the Lorentz and centrifugal forces, it is not dissipative. This impedance is numerically equal to the scale invariant quantum Hall impedance, and is plotted in figure 2 (green dots).

THE UNSTABLE PARTICLES

Unlike entangled states, where unitary evolution of the two (or more) body wave function requires nonlocal phase coherence, in the case of the unstable particles the essential phase coherence is self coherence. The nonlocality constraint introduced by entanglement will be addressed in the following section.

Here the focus is on the relationships between the impedance and coherence length plots of figure 2. They were explored in some detail in an earlier note[4]. In this section the discussion will be confined primarily to those aspects relevant to single body state reduction.

The bottom line here, and throughout this note, is that the coherence lengths are defined by a combination of both differential phase shifts and conjunctions of the mode impedances.

In the impedance network of figure 2, the conjunctions of the mode impedances (calculated[10] from the model) are precisely ordered in powers of the fine structure constant on both axes of the plot, in both the impedance and energy scales. With three exceptions, the unstable particle coherence lengths are also ordered in powers of the fine structure constant. These exceptions are:

- the Σ_c and the short lived resonances in the region between the electron classical radius and the 10GeV fine structure line
- the Σ_0 and the excited meson states in the vicinity of the electron Compton wavelength
- the τ and the charm family - displaced to longer coherence lengths, perhaps a result of electroweak interference

All three of these exceptions are intriguing, for what are apparently different reasons. They will hopefully be addressed in detail at some future time.

In the present view each of the unstable particles might be taken as comprised of some coupled subset of the modes shown in the impedance plot, a non-linear superposition with phase-sensitive dynamics. The logical source of the non-linearity, of the dispersion that ultimately results in decoherence and state reduction, is the mode coupling mechanism, which might also be taken to be the confinement mechanism. This will be discussed in more detail in the following sections.

The master oscillator for phase coherence is the electron Compton frequency, the frequency corresponding to the Compton wavelength. It is naturally built into the dynamics of the impedance network, into the response of the mode structure to excitation. The electron is stable, the Compton frequency is infinitely precise, the reference linewidth infinitely small.

In this view an unstable particle is a collection of coupled oscillators, the oscillators being the appropriate network modes, with the coupling at the nodes, at the mode impedance conjunctions. One might suppose that the coherence lengths are a simple function of the oscillator quality factors, the Q's of the resonances. The longest lived unstable particle, the neutron, would then have a Q of about 10^{24}. The neutron is particularly interesting, as its coherence length is extended to infinity when entangled with the proton.

However, as was noted earlier[3], the extended lifetimes of the weakly decaying particles can be understood in terms of their impedance mismatch to the photon and electron. This not only obviates the need for high Q in long lifetime, it also provides a mechanism for parity violation.

In the unstable particles, the interacting modes of the self-coupled wavefunction can be thought of as oscillating in and out of coherence, the wave function alternating from fermion to boson as they do so. Linear and angular momentum mix, velocities and phases shift. The effect of this can be seen in the coherence length plot of figure 2, in the alternating fermion and boson lines of the weak decays.

ENTANGLEMENT

Entanglement provides an additional constraint, the constraint introduced by nonlocality. It becomes necessary to couple two wave functions without the exchange of energy, without violating special relativity. The forces associated with the scale invariant impedances, the vector Lorentz and centrifugal forces, are obvious candidates for such a coupling.

In the case of massive particles, either or both of these forces could bear responsibility for state reduction of the entangled two body wave function. Either or both of these scale invariant impedances could carry the phase information (not an observable in quantum mechanics) that maintains the phase coherence of the entangled state.

Those impedances cannot transport energy. To be operative in state reduction, they might function as mode couplers, shifting the relative phases of the entangled two body wave function.

From here it is a small step to the single particle wave function and self coherence, via the Lorentz impedance and the Aharanov-Bohm effect.

"All well and good," you might say, "but what about the photon? How can either of these impedances couple to an entangled photon?"

Perhaps they can't. And perhaps they needn't. The photon far field impedance is scale invariant.

Consider an entangled photon pair. They remain entangled via the scale invariant 377Ω electromagnetic far field impedance. The interaction of either of the two with the external environment brings transition to the scale dependent near field impedances, nonlocality is lost, the photon decoheres, the magnetic and electric flux quanta decouple. And the phase of its now-unentangled partner is determined, defines the state into which it will eventually collapse.

It would seem that the photons don't need either of the massive particle impedances to accomplish this, that their own scale invariant impedance is equal to the task. Or at least, this is what Maxwell's equations seem to suggest. But then, there is the Planck particle.

THE PLANCK PARTICLE

The relative strengths of the gravitational and Coulomb forces between the electron and the Planck particle can be determined within an accuracy of a few parts per billion by simply calculating the impedance mismatch between these two particles[8].

This mismatch limits the amount of work the Planck particle can do, the amount of energy it can give, to that associated with the rest mass of the electron. However its scale invariant impedances, Lorentz and centrifugal, are available at their full strength to assist in the mode coupling concommitant with state reduction.

The massive particle wave function sees the scale invariant impedances of both electron and Planck particle as being of the same strength. One wonders whether this is an essential requisite for state reduction. And for confinement.

AT LOW ENERGY

At non-relativistic energies the relevant fundamental length scale becomes not the Compton wavelength, but rather deBroglie. The deBroglie frequency is the Doppler shift of the Compton frequency.

In technological applications, it would seem that there is some usefulness in the application of these ideas to circuit design. For instance, one would think that spintronics would benefit from matching both Coulomb and dipole impedances to the lattice.

The question is whether this usefulness is strictly in the domain of quantum computing, or whether it might find application in more widespread present day room temperature technologies[23–28].

DISCUSSION

The impedance plot of figure 2 is not complete. Missing are the longitudinal dipole-dipole impedances, the longitudinal and transverse charge-dipole impedances, and the Coriolis impedance. There may be others, and likely are.

It should be noted that the charge-dipole impedances are scale invariant, as is the Coriolis impedance, and therefore might also contribute to state reduction. In general, impedances associated with inverse square potentials are scale invariant.

Given the spin dependence of the weak interaction, one would expect that adding the longitudinal impedances to the figure would give additional insight into the weak decays.

And the role of the Coriolis impedance beckons particularly strongly.

CONCLUSION

Proton spin structure remains a mystery[29–31].

The idea of generalized quantum impedances continues to slowly expand the scope over which it seems to be applicable, and able to provide interesting new insights into the workings of the standard model.

In the **realm of the superheavies**, the clustering of the top, Higgs, Z, and W at the 10GeV (or more precisely, 9.59GeV) coherence line of figure 2 is an interesting example, showing the role of magnetic impedances in the creation and decay of these particles.

To attack the problem of proton spin structure with the tool of generalized quantum impedances is the most difficult physics problem imaginable to this writer.

ACKNOWLEDGEMENTS

The author thanks Michaele Suisse for discussions, literature searches, and helpful suggestions and comments on drafts of this note.

* petethepop@aol.com

[1] Flertcher, N. and Rossing, T., The Physics of Musical Instruments, 2nd ed., Springer, p.19 (1998).

[2] Cameron, P., "The Two Body Problem and Mach's Principle", submitted to Am. Jour. Phys (1975), in revision. The unrevised version of this note was published as an appendix to the Electron Impedances note [3].

[3] Cameron, P., "Electron Impedances", Apeiron, vol.18, no.2, p.222-253 (2011). `http://redshift.vif.com/JournalFiles/V18NO2PDF/V18N2CAM.pdf`

[4] Cameron, P., "Generalized Quantum Impedances: A Background Independent Model for the Unstable Particles" (July 2012), p.2. `http://vixra.org/abs/1207.0022`

[5] Cameron, P., "Photon Impedance Match to a Single Free Electron", Apeiron, vol.17, no.3, p.193-200 (2010). `http://redshift.vif.com/JournalFiles/V17NO3PDF/V17N3CA1.pdf`

[6] Cameron, P., "Possible Origin of the 70MeV Mass Quantum", Apeiron, vol.17, no.3, p.201-207 (2010). `http://redshift.vif.com/JournalFiles/V17NO3PDF/V17N3CA2.pdf`

[7] Cameron, P., "Magnetic and Electric Flux Quanta: the Pion Mass", Apeiron, vol.18, no.1, p.29-42 (2011). `http://redshift.vif.com/JournalFiles/V18NO1PDF/V18N1CAM.pdf`

[8] Cameron, P., "Quantum Impedances: Background Independent Relations between Gravity and Electromagnetism". This paper is available at `http://vixra.org/abs/1211.0052`

[9] Capps, C., "Near Field or Far Field?", Electronic Design News, p.95 (16 Aug 2001). `http://edn.com/design/communications-networking/4340588/Near-field-or-far-field-`

[10] The mathcad file that generates the impedance plots is available from the author.
[11] MacGregor, M. H., "The Fine-Structure Constant as a Universal Scaling Factor", Lett. Nuovo Cimento 1, p.759-764 (1971).
[12] MacGregor, M. H., "The Electromagnetic Scaling of Particle Lifetimes and Masses", Lett. Nuovo Cimento 31, p.341-346 (1981).
[13] MacGregor, M. H., The Power of Alpha, World Scientific (2007). see also http://70mev.org/alpha/
[14] Jackson, J. and Yovits, M., "Properties of the Quantum Statistical Impedance", Phys. Rev. 96, 15 (1954).
[15] Landauer, R., IBM J. Res. Dev. 1, 223 (1957).
[16] Imry, Y., and Landauer, R., "Conductance Viewed as Transmission", Rev. Mod. Phys., vol.72, no.2, p.306-312 (1999).
[17] von Klitzing, K. et al, "New method for high-accuracy determination of the fine-structure constant based on quantized Hall resistance", PRL, vol.45, no.6, p.494-497 (1980).
[18] von Klitzing, K., "25 Years of Quantum Hall Effect", Seminaire Poincare 2, 1-16 (2004). http://www.bourbaphy.fr/klitzing.pdf
[19] Kabir, S. et.al, "Application of Quantum Mechanical Wave Impedance in the Solution of the Schrodinger Equation in Quantum Wells", Solid-State Electronics vol.34 no.12, p.1466-1468 (1991).
[20] Datta, T. and Tsu, R., "Quantum Wave Resistance of Schrodinger Functions" (2003). http://arxiv.org/abs/cond-mat/0311479
[21] Gabelli, J. et al, "Violation of Kirchoffs Laws for a Coherent RC Circuit", Science 313 p.499-502, (2006).
[22] Seminario, J., "Quantum Current-Voltage Relation for a Single Electron", J. Phys. B: At. Mol. Opt. Phys. 40 F275F276 (2007).
[23] Tsu, R., Superlattice to Nanoelectronics, 2nd Ed., Elsevier, Chapter 11 (2011).
[24] Brillouin, L., Wave Propagation in Periodic Structures - Electric Filters and Crystal Lattices, 2nd Ed., McGraw Hill (1946).
[25] Khondker, A. et al, "Transmission Line Analogy of Resonance Tunneling: The Generalized Impedance Concept," J. Appl. Phys., vol.63, no.10, p.5191-5193 (1988).
[26] Tung, H., and Lee, C., "An Energy Bandpass Filter Using Superlattice Structures", IEEE Jour. Quant. Elect., vol.32, no.3, p. 507-512 (1996).
[27] Villegas, D. et al, "Longwave Phonon Tunneling Using an Impedance Concept", PIERS Online, vol.4, no.2, 227-230 (2008).
[28] Vasquez, H. et al, "Probing the conductance superposition law in single-molecule circuits with parallel paths", Nature Nanotechnology (2012). doi:10.1038/nnano.2012.147
[29] Krisch, A.D., "Collisions of Spinning Protons", Scientific American, 257, p.42 (1987).
[30] Bass, S., "The Spin Structure of the Proton", Rev.Mod.Phys. 77, p.1257-1302 (2005). http://arxiv.org/abs/hep-ph/0411005
[31] Leader, E., "On the controversy concerning the definition of quark and gluon angular momentum", Phys. Rev. D 83, 096012 (2011). http://arxiv.org/pdf/1101.5956v2.pdf