A historical approach

Classical Theory

Motorola made the fastest logic, ECL (Emitter Coupled Logic http://en.wikipedia.org/wiki/Emitter-coupled_logic). A logic gate switched in 1.35nsec.

A logic signal travels at 6 inches per nsec across a printed circuit board. Thus, the time a logic gates switched equalled the time it took for its output to travel 8 inches.

Motorola Phoenix were semiconductor experts, but lacked expertise in digital electronics. So in 1964 they hired me for my expertise in digital electronics to investigate whether by switching logic faster than it took for signals to propagate across the system, they might fall off a cliff into massive crosstalk.

> **Who in this audience says that the crosstalk between one signal line and another in a USB cable is a dv/dt or di/dt spike? Who says it is a flat topped pulse?**

I thought in terms of two voltage planes, one for ground and the other for 5v. I thought in terms of two parallel conductors above a ground plane. http://www.ivorcatt.org/digihwdesignp56.htm . If a 5v logic step travelled down one conductor, how large was the crosstalk into the parallel conductor? The formula in the main publication, by Jervis, said that the crosstalk could be greater than the original signal, which I knew must be wrong. Surely we did not have an amplifier?

After some puzzling results, I made the major discovery, that the signal broke up into two signals, Even Mode and Odd Mode, travelling at different velocities. I published this, with photographs and mathematical proof, in 1967 in the IEEE, but it is generally unknown today.
http://www.ivorcatt.org/digihwdesignp57.htm

> **Who in this audience knew that when a signal travels down a conductor above ground plane in the presence of another parallel conductor, two velocities are involved?**

Who in this audience knew that the crosstalk to the other conductor can rise to 50%, however far apart they are?

Let us return to the 5v supply by two voltage planes.

Would someone in the audience like to suggest what is the source impedance at a point when a logic gate lying between a 5v plane and a 0v plane wants to suddenly take current from the 5v supply and dump it in the 0v?

I asked Bill Herndon what was the source impedance at a point between two voltage planes, one at 0v and the other at 5v. He replied; "It's a transmission line." I said, "Is that your idea?" He said, no it wasn't; he wished it was. He said it came from Stopper in GEC, whom I never met. Bill previously worked at GEC across town.

To understand this, think in terms of the two square voltage planes, 5v and 0v, supplying 5v to a switching logic gate at one corner. Then we see that at their corner, they represent a two conductor transmission line whose width (and also Zo) increases with increasing distance from the corner. Thus, after 1nsec, the source impedance of the 5v supply is the Zo, characteristic impedance of a quarter circle of the pair of conductors at a distance from the corner where a signal could make the round trip in 1 nsec. Thus, the switching load sees a rapidly diminishing source impedance for the 5v supply.

Perhaps this is the realisation which led me to the fact that a capacitor, which is composed of two parallel plates, is a transmission line. I know that at that time, to turn a very narrow negative 150 picosecond pulse (generated by my EH125 pulse generator) to a positive pulse, I introduced two tantalum capacitors into a coaxial cable, one from inner to outer, and the other from outer to inner. The pulse happily inverted unchanged, presumably because it has not heard of the standard LCR model for a capacitor with its series inductance L and its self resonant frequency http://www.ivorcatt.com/2603.htm . Capacitors don't read.

The development of my ideas has been extraordinarily slow, extending over fifty years.

Until well after 1967 I avoided the formidable Maxwell Equations, even though they were written more simply then – such as dB/dt (e.g. in Professor Kip

http://www.ivorcatt.co.uk/x2671.pdf in 1962), rather than the more awe-inspiring divs and curls of today. In 1967, I merely used Faraday's Law v=dϕ/dt and the Law of Conservation of Charge.

After I had been 100% failed in Peer Review for decades, I changed from trying to publish my theories to asking questions about classical electromagnetism. I will now present these to you, preceded by the results of an experiment recently published in a non-peer reviewed journal. It is called "The Wakefield Experiment." http://www.ivorcatt.co.uk/x343.pdf . The results show that a charged capacitor does not store its energy in a static electric field [contradicting Wikipedia http://en.wikipedia.org/wiki/Capacitor "used to store energy electrostatically in an electric field."]

A very long piece of coaxial cable, representing a charged capacitor, was discharged into a piece of cable of the same characteristic impedance. Already in 1963 the Tektronix manual http://ivorcatt.co.uk/x212.pdf said;

"p2-2 "The output pulse duration is equal to twice the transit time of the charge line used, plus a small built-in charge time due to the lead length from the GR panel connectors to the mercury switch contact point.
The transit time of the cable is defined as the time required for a signal to pass from one end of the line to the other. For a 10-nsec charge line then, the duration of the output pulse would be 20 nanoseconds
p2-3 "The pulse amplitude obtained will be approximately one-half the power source voltage .... ""

For the next fifty years, nobody pondered this strange performance. In 1980 I published the suggestion http://www.ivorcatt.co.uk/97rdeat4.htm that " .... a steady charged capacitor is not steady at all ; it contains energy current, half of it travelling to the right at the speed of light, and the other half travelling to the left at the speed of light." After 47 years I realised that if we tapped into the charged capacitor along its length, we would get proof that a charged capacitor did not have an electrostatic field, and half of its energy was in a magnetic field. http://www.ivorcatt.co.uk/x3216.pdf .

Now let us return to the three unanswerable questions, which expose fatal internal flaws in classical electromagnetic theory.

First, "The Catt Question". http://www.ivorcatt.co.uk/cattq.htm

When a TEM step travels down a transmission line at the speed of light, where does the negative charge which appears on the surface of the bottom conductor come from?

Next, The Second Catt Question. http://www.ivorcatt.co.uk/x22j.pdf . When a TEM step travels along a transmission line, the electric field at the front edge goes from nothing to a 5v field between the two conductors. This field is D, so at the front edge there is a dD/dt , which is Displacement Current. This was invented by Maxwell in order for it to create magnetic field. However, the magnetic field created by this dD/dt is in the horizontal plane, some of it in the forward direction. But a TEM Wave only has magnetic field in the vertical direction. So we have to exclude either the TEM Wave or Displacement Current from classical electromagnetism.

Now The Third Catt Question. http://www.ivorcatt.co.uk/x3761.pdf . When a capacitor is charged, energy enters it at the speed of light. http://www.ivorcatt.org/icrwiworld78dec1.htm . There is no mechanism for the energy, once inside the capacitor, to slow down. When discharged, see The Wakefield Experiment, the energy exits at the speed of light. Why does classical theory say that the energy in a charged capacitor is stationary? http://en.wikipedia.org/wiki/Capacitor

New Theory

When a TEM step travels in a transmission line guided by two conductors, there are four features involved;

http://www.ivorcatt.co.uk/cattq.htm
- electric current in the conductors i
- magnetic field, or flux, surrounding the conductors B
- electric charge on the surface of the conductors +q , -q
- electric field, or flux, in the vacuum terminating on the charge (Figure 2), D

Theory N

Traditional theory, which I call “Theory N”, says that the electric current and charge cause the electric and magnetic field.

> **Who in this audience believes that when a battery is trying to light a lamp, it wants to send electric current or charge down the conductors, and that if successful, the current causes the Poynting Vector field ExH between the conductors?**

Theory H

In 1892, Heaviside reversed this. His Theory H says that the field causes the electric current.

http://www.ivorcatt.co.uk/x3117.htm
In Heaviside's magnificent, regal statement, "We reverse this." In his *Electrical Papers*, vol. 1, 1892, page 438, Heaviside wrote;

> Now, in Maxwell's theory there is the potential energy of the displacement produced in the dielectric parts by the electric force, and there is the kinetic or magnetic energy of the magnetic force in all parts of the field, including the conducting parts. They are supposed to be set up by the current in the wire [Theory N]. We reverse this; the current in the wire is set up by the energy transmitted through the medium around it [Theory H]…. 1 , 2

Heaviside's "Theory H" disappeared from the record, along with all his work on pulses down cables. He was not mentioned in any text book for more than fifty years. This was because not long after 1892, in 1897, Marconi achieved wireless signalling, which was much more glamorous, and led to the development of ever more sophisticated mathematics. Today, text books tell you that in order to understand electromagnetic theory, you must first master the mathematics of vectors and other mathematics. A Google search for "mathematics is the language of science", 200,000 hits, will reinforce this advice. In contrast, look for the mathematics in my talk. My talk is about physics, not mathematics.

When Catt was drawn into Heaviside's problem in 1964, he did not know that Heaviside had made any contribution, and he had to rediscover Heaviside's concept of "Energy Current" travelling in a transmission line guided by two conductors, which he found in Heaviside twelve years later.

Theory C

In 1976 Catt made the next advance, which is unknown to any professor or text book writer today.

Theory N. The battery yearns to send out electric current. If is succeeds, the current creates the Poynting Vector ExH. This energy is delivered to the lamp, which lights.

Theory H. The battery yearns to send out energy current – Poynting Vector – into the space between the conductors. If it succeeds, the energy enters the lamp sideways, as Professor Kip said. The Poynting Vecor, or field, also creates the electric current and electric charge.

Theory C. The critical path is for energy to be transferred from battery to lamp. This is via the intermediary of ExH field, Poynting Vector. Electric current and

charge are not in the path of energy, from battery to lamp. When a battery is connected to a lamp by two wires and the lamp lights, electric current is not involved.

http://www.ivorcatt.co.uk/2608.htm
"Although a cloud cannot exist without edges, the *edges* of a cloud do not exist They have no width, volume, or materiality. However, the edges of a cloud can be drawn. Their shapes can be manipulated graphically and mathematically. The same is true of the so-called 'electric current'.
....
Half of the primitives in electromagnetic theory disappear, and it ceases to be a dualistic theory. ρ and J disappear, becoming merely the physically non-existent results of the mathematical manipulation of E and H, with no more significance than "circularity" [see Letters in Wireless World, June 1979, p82)."

For the creation of "electricity" by mathematical manipulation, use Maxwell's Equations, for instance;

http://en.wikipedia.org/wiki/Maxwell's_equations
$\nabla \cdot \mathbf{D} = \rho_f$, which gives you the mathematical fantasy "charge", mathematically derived from a real electric field.

In science, there is no precedent for a mathematical derivation of something real being wrongly thought to be real.

A good example where mathematical manipulation takes us from the real to the fantasy is in the sequence; distance, velocity, acceleration, rate of change of acceleration, rate of change of rate of change of .... . Another example is length, area, volume, fourth dimension, fifth dimension. Mathematical rigour does not give us a dividing line between the real and fantasy. The mathematical manipulation of something real does not always give us something real.
Since today the ruling dogma is "mathematics is the language of science", such an issue cannot be discussed.

Ivor Catt 15 September 2013.