A RESOLUTION OF THE CATT ANOMALY

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ABSTRACT. The Catt anomaly - more correctly the 'Catt Question' - was posed by Ivor Catt [1] since 1982. It was initially posed to two Cambridge professors in electromagnetism who gave contradictory resolutions. None provided answers to explained why two authorities gave contradictory answers. Over the years, some attempts have been made but they did not seem to have been satisfactory. As recent as 2013, two Italian professors M. Pieraccini and S. Selleri [2] attempted yet another resolution published in the journal Physics Education. From the critique by Stephen J. Crothers [3], this attempt too may be unsatisfactory. The author here gives an answer to the Catt question that is based only on classical electromagnetic theory. Through investigation on the Catt question, a concomitant observation have been made that electrical interactions and electric power transfer over conducting conductors all are based on 'instantaneous_action_at_a_distance'.

1. INTRODUCTION

The Catt Anomaly - more correctly 'the Catt question' - is best explained in the words of Ivor Catt. The following is a quote from his website [1]; the figure 1 should help to clarify the passage:

> *Traditionally, when a TEM step (i.e. logic transition from low to high) travels through a vacuum from left to*

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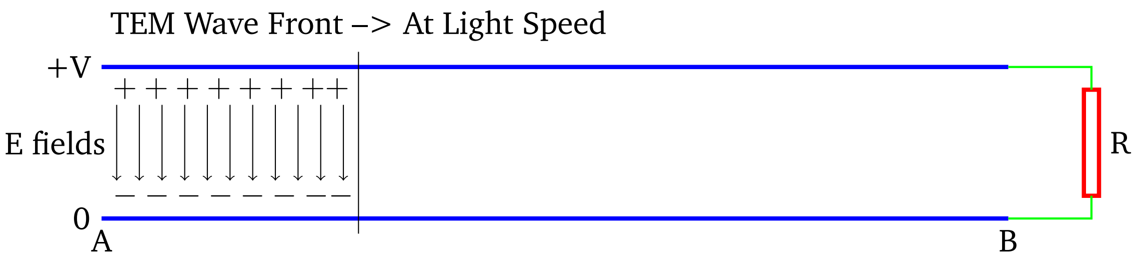

FIGURE 1. A step TEM wave propagation along a transmission line pair.

right, guided by two conductors (the signal line and the 0v line), there are four factors which make up the wave;

- *electric current in the conductors*
- *magnetic field, or flux, surrounding the conductors*
- *electric charge on the surface of the conductors*
- *electric field, or flux, in the vacuum terminating on the charge.*

The key to grasping the anomaly is to concentrate on the electric charge on the bottom conductor. The step advances one foot per nanosecond (light speed is about 1 foot per nanoseconds). Extra negative charge appears on the surface of the bottom conductor to terminate the new lines (tubes) of electric flux which appear between the top (signal) conductor and the bottom conductor.

Since 1982 the question has been: Where does this new charge come from? Not from the upper conductor, because by definition, displacement current is not the flow of real charge. Not from somewhere to the left, because such charge would have to travel at the speed of light in a vacuum.Conventional electromagnetic theory says that the drift velocity of electric current is slower than the speed of light.

Over the years, various accredited physicists [1] were asked by Ivor Catt to comment on the question; the answers received were contradictory. This seems to suggest that even the experts cannot find a one answer based on current classical electromagnetic theory. As recent as 2013, two Italian professors M. Pieraccini and S. Selleri attempted a resolution; their article appeared in the journal 'Physics Education' in 2013 [2]. From the critique by S.J.Crothers[3], it seems this recent attempt too have not settled the contradictory explanations surrounding the Catt question.

The author here gives an answer to the Catt question which is rather mundane and simple. It is based on no electromagnetic concept other than that of the traditional current flow; it is not a formulation of a new theory of current flow in conductors, but the same age-old classical current flow where the motion of the 'train' of electron charge carriers drift along at speed of the order of millimeter each second. The way to understand the Catt question is to first examine the simple textbook case of the discharge of a capacitor. The only peculiarity is we need the parallel plate capacitor to be a mile-long! From the analysis of the discharge of the mile-long capacitor,

[1] Professor M. Pepper, FRS, University of Cambridge, (1993), Neil McEwan (Dr.), Reader in Electromagnetics ,University of Bradford (1995), James W. Mink Ph.D.Chairman MTT-15 (IEEE) Dept. of Electrical and Computer Engineering, North Carolina State University (1995)

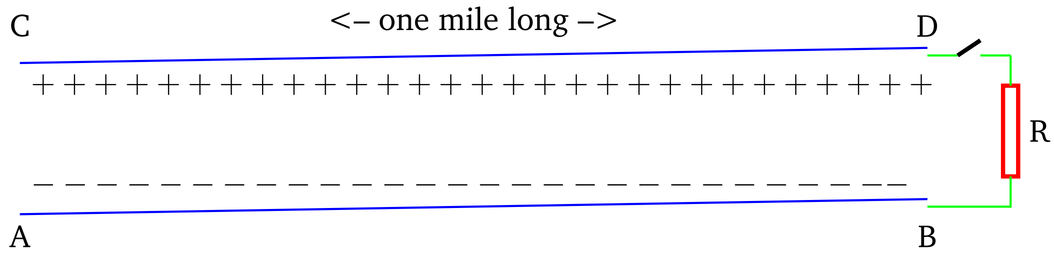

FIGURE 2. A fully +Q/-Q charged mile-long parallel plate capacitor

the Catt question reveals itself clearly - there is no anomaly, paradox nor mystery.

2. DISCHARGE OF A MILE-LONG PARALLEL PLATE CAPACITOR

[See figure 2] If the capacitor has dimension 1.6km x 1cm and distance apart of 1cm capacitor, it would be fully discharged within a few nanoseconds despite the fact that its length is unconventionally long for capacitors. The time of discharge of a capacitor is only dependent on its capacitance value and not its geometry. So the discharge of the surface charges here gives the illusion of electric charges moving very fast, very much faster than the classical drift velocity of electrons in current flow. Indeed, it is just an illusion. No electron moves or drifts at speed beyond the usual range of speed in any conventional current.The explanation of capacitor discharge is premised on IAAAD - electrical interactions follows "instantaneous_action_at_a_distance"; the mainstream notion of any upper limit on speed of information transmission does not apply.

The way the surface charges on the capacitor plates are neutralized is more as an accounting process of charge offsetting with the sea of free electrons within the conductor. On shorting the capacitor at the right end,a small -dQ of electrons enters the upper conductor giving a net increase in negative charge in the upper conductor. There is no exceptional congregation of electrons at the right end giving it any exceptionally large electron charge density over the rest of the conductor. Following IAAAD, there is a general increase in negative electron charge density that extends throughout the conductor - it extends right a mile away instantaneously to the left end of the conductor. What it means is the increase in negative charge in the sea of free electrons at the other end of the conductor is what offset the original excess positive surface charge at that left end of the conductor. So a flow of the conventional electron current at the right end of the conductor cause an almost instantaneous discharge of excess positive charge at the left end of the conductor. Such similar discharge of the excess charges extends throughout the mile-long capacitor giving

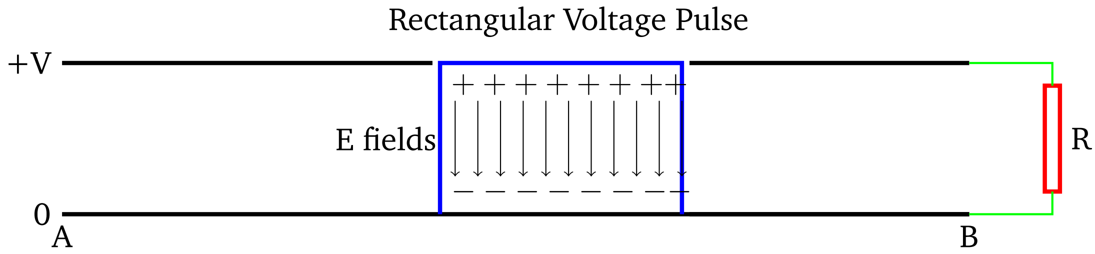

FIGURE 3. A Rectangular TEM wave propagation along a transmission line pair.

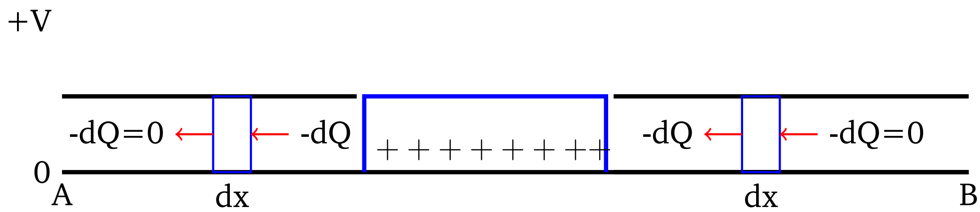

FIGURE 4. Top conductor; infinitesimal dx elements at back and front of wave pulse; drawn away from the wave for clarity

the illusion that electric charges move at an exceptionally high speed not found in classical electric theory.

The fact is that all currents involved in the discharge of a capacitor are classical currents only. Indeed, such currents are involved - and necessary - in the discharge process. This is so as the electric field within the conductor is not in a steady state during discharge; thus there must be electric current flow at all points of the conductors during discharge and these are only the usual classical currents of conventional electric theory.

3. Transmission Of A Rectangular Signal Pulse

[See figure 3 and 4]

We will answer the Catt question here not with the exact step signal originally posed with the question, but with a more general rectangular pulse signal along electric conductor wires. As the switch is ON for one nanosecond, the voltage pulse (or the corresponding current pulse) extends for about 1 foot along the conductor wire as it propagates along.

Figure 4 shows an infinitesimal element of the top conductor of length dx at the back-end of the wave train after the wave just leaves it.The -dQ charge is the amount of electron charge that enters from the right face of dx. Initially,when dx was still within the train pulse,it had a net positive charge. When it just leave the pulse train, electrons

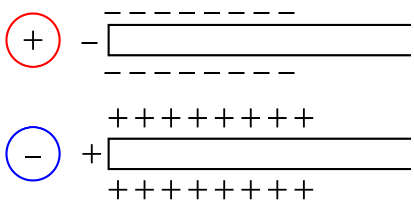

FIGURE 5. The battery terminals cause induced electrostatic charges in the conductor wires

from within the free electrons of the pulse enter into the dx element. There is no charge leaving the dx element and this is shown in the figure as -dq=0. Thus, the dx element has its initial net excess positive charge neutralized making the conductor element dx electrically neutral.

There is a corresponding right dx element as shown in the figure.This right element - before it gets assimilated into the pulse train - is electrically neutral. When it just 'enters' the train pulse, it gives up a charge -dQ into the free electrons of the pulse train; through this, the right dx element itself has a net positive charge. This is reflected as a net positive surface charge of the right element. This is the process by which the train pulse of positive charge gets propagated along the top conductor at near the light speed.

We can also examine the pulse as a current pulse with a constant current I corresponding to V. If we assume a lossless transmission condition, the conductor has zero resistance - an ideal perfect conductor. With such assumptions, the -dQ at the back-end of the wave and the front-end would be equal. In the time interval of dt, the current $I = -\frac{dQ}{dt}$. This shows that the pulse train is accompanied by an electric current - constant with our assumptions here. This current I has no unusual property outside of our electric theory; it is the same electric current of classical electric theory where the electron drift speed is in the order of millimeter per second despite the pulse train moving at near light speed.

4. HOW A BATTERY LIGHTS UP AN ELECTRIC BULB

[See figure 5] A battery has a positively charged and a negatively charged terminal. There is an electric field in its surrounding space. When a conductor is brought near a battery, electrostatic induction will causes surfaces charges to appear on its surface; this is necessary as such surface charge distribution is necessary to neutralize the electric field due to the terminals of the battery in order that the electric field within the conductor body is zero.

Figure 5 shows the induced charges on the conductor wires near the terminals before the switch is set 'ON'. There are already surface charges induced on the conductor wires even before the circuit is switched on. When the circuit is switch 'ON', a current will flow immediately through the battery; electrons will flow into the positive terminals in the top wire. As explained in the earlier section, a train of 'excess' positive surface charges will propagate towards the right at near the speed of light accompanying the TEM wave. At the bottom conductor wire, the train of charges will be negative. Currents will flow in the conductors where the wave front has gone passed. There will be no current flow in the conductor wires that are still ahead of the TEM wave front. In this way, the electric bulb will have a very small time delay to light up from the instant of the switch being set 'ON'.

5. Electric Power Transfer Is Instantaneous Through The Current

For DC circuits, TEM waves will be generated initially, but when the circuit reaches a steady state, there will not be any TEM waves responsible for transfer of power from the battery to the load. The only possible agent of energy transfer could only be the current of free electrons within conductors. This power transfer could only be instantaneous.

There is a prejudice in contemporary physics against the idea of 'instantaneous_action_at_a_distance'. It prefers the hypothesis that the light speed represents some sort of upper limit to all speed of information transfer. It assumes that all electrical interactions is limited to the speed of light. In classical electric theory, power - at least in the DC case - has no association with any phenomenon that has a velocity; without a vector of velocity, there cannot be a speed. Power is a scalar. So it is a misconception that we can have a speed of transfer of power. For the lack of any 'speed', the only possible hypothesis is that power transfer over electric conducting wires happen instantaneously.

There is a clear distinction between signal transmission over conductor guides and simple electric power transfer over power cables. In the former case, the signal speed is modeled by the telegrapher equation and the TEM wave has a finite speed near that of light. The signal is carried by the TEM waves. For electric power transmission - even in our AC distribution network - the telegrapher equation is irrelevant concerning transfer of power. The agent of electrical power transfer is the classical currents within the conductor carriers. What matters is the usual Kirchoff's law, Ohms law of classical electric theory. If there are any TEM waves in AC power transmission, it may be more of an unavoidable power loss through electromagnetic radiations and such should, instead, be minimized.

6. Conclusion

The Catt question could be answered from the the usual classical electromagnetic theory. There is no anomaly. The agent of electrical power transfer in conductors is the classical electric current. Electrical interactions and power transfer through conductors are all 'instantaneous_action_at_a_distance'.

References

[1] The Catt Question. http://www.ivorcatt.co.uk/x54c1.htm

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