Catt's Anomaly

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1. Introduction

It is undeniable that contributions to the advancement of science have not come only from people who remained within the boundary of the conventional vision of the world, but also from brave thinkers. These were people who denied the conformist views of their time, notwithstanding their being scholars, academicians, or amateurs and bizarre men away from academia, and often in contrast with it. Among the most celebrated, we can remember Nicolaus Copernicus (1473-1543), who overthrew the geocentric system in favor of the heliocentric system; Charles Darwin (1809-1882), with the theory of evolution; and Albert Einstein (1879-1955), with his revolutionary view of time and space; just to cite a few [1].

Besides these great confuters of conventional science who had success, there are many more who indeed fought for the wrong cause. Einstein's case was paradigmatic. Being a great innovator, he then become an enemy of even the newest theory of quantum mechanics (which he himself contributed to initiating!), and the uncertainty principle by Heisenberg. It is ironic that Einstein was also the target of many confuters for his theory of relativity, all of which of course failed, but who counted among them many very learned people. These included Quirino Majorana (1871-1957), full Professor of Physics and uncle to Ettore Majorana, who tried to disprove the postulate of light speed being a constant; and Herbert Dingle (1890-1978), President of the Royal Astronomical Society, who worked on many proofs to negate Einstein's special theory of relativity. Quantum mechanics, not less than relativity, has always been the subject of bold refutations. David Joseph Bohm (1917-1992), initially a brilliant quantum-mechanical physicist, spent half of his life elaborating an unsuccessful alternative view.

Ivor Catt is probably one of these [2], an engineer and amateur scientist. In the mid-1980s, the British company Anamartic, a spin-off of Sinclair, started to manufacture a solid-state memory based on an idea inspired by Catt. It won the "Product of the Year Award from the US publications *Electronic Design* (in October 1989) and *Electronic Products* (in January 1990), but finally wasn't a commercial success. For what concerns science, Catt argues not less than that classical electromagnetism is in a way wrong: in his opinion, electric charge doesn't exist!

Since 1982 [3], Catt has claimed to have found a fatal flaw in electromagnetism, which he named, with a sense of drama, "The Catt's Anomaly" [4]. It is a sort of "thought experiment" (a *gedankenexperiment*), in the tradition of twentieth-century physics, where Einstein, as already remembered, devised ingenious physical paradoxes capable of putting into crisis the fundamentals of the emerging quantum theory. Indeed, this is the aim of Catt: to crash the theory of electromagnetism [5, 6]. Actually, he has compared himself to Dingle rather than Einstein, but Catt specifies that his anomaly is easier to comprehend and more important than Dingle's twin paradox [4, 7]. The basic idea of the "thought experiment" of Catt is described in the next section.

2. The Anomaly

Let's consider a transmission line, connected to a load and a generator. At $t < 0$, the switch between the generator and the line is opened, and no field exists on the line, nor do currents, charges, or voltage drops (see the top of Figure 1). At $t = 0$, the switch closes. A transverse electromagnetic (TEM) wave begins to travel along the line at a speed *c*, which is, as is well known, the speed of light in the medium surrounding the conductors (Figure 1, bottom). As the TEM step pulse travels along the line, the lines of forces of the associated electric induction, **D**, are generated at the upper conductor and at the ends on the lower conductor.

The third of Maxwell's equations links the flux of **D** across a closed surface to the charge contained within said surface. If applied to a cylindrical volume, Ω, bounded by a surface, Σ, comprising a portion of one of the two conductors (Figure 1), the flux is clearly null. The electric charge is also null, if the volume has not yet been reached by the TEM wave. Once reached, the flux of **D** is not anymore null, and hence a charge, *Q*, must be present on the wire.

Now, this is what Catt calls an anomaly: where are these charges coming from? Electrons are the moving charges in metal. If the wave travels at *c*, electrons, which have a mass, cannot. However, classical electromagnetics requires that the electrons appear on the bottom conductor (and disappear from the top conductor) as if they could.

Catt starts from this consideration to negate the centrality of charges and currents as sources of the field in electromagnetism. He asserts that the fields are the primary cause, and that currents and charges are secondary effects. Catt tried to develop

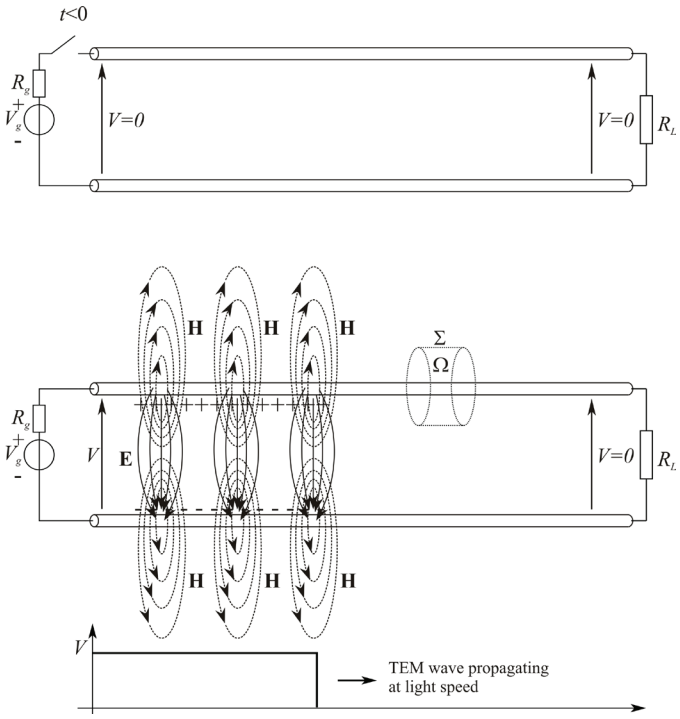

Figure 1. (top) A transmission line connected to a load and a generator, via an opened switch; (bottom) the same transmission line after the switch closes.

his own electromagnetic theory, which he named theory "C" [5], as opposed to the conventional electromagnetic theory, which he named theory "N." In his opinion, Catt's theory is an evolution of Heaviside's vision of electromagnetism (which he named theory "H"), in which energy is bound to the Poynting vector, and not to voltage and current waves.

The academic word did not take Catt seriously much. This was not only because most of Catt's publications were often in technical and not scientific journals. It was also because a scientific revolution – a paradigm shift – is a serious question, which has to be based on indubitable facts and verified predictions [1].

3. The Answers

Catt has claimed that no academic representative has ever replied in a satisfactory, written, public, manner to his raising this question. In his own book [4], he cites several personal communications. One is a 1993 letter by Sir Michael Pepper (born August 10, 1942), a renowned physicist active in semiconductors. Another communication – which Catt appreciated more – was in 1995 from Neil McEwan, then a Reader at the University of Bradford. Another communication was in 1997 from Brian David Josephson (born January 4, 1940), who received the Nobel Prize in Physics in 1973.

Catt promoted his "Anomaly" to the IEE (now the IET), obtaining an answer from its secretary, Philip E. Secker, in 1995. James W. Mink, Chair of the IEEE MTT-15 Microwave Field Theory Committee, also responded in the same year. Very few replies to Catt appeared in press, and then almost exclusively as very short letters in non-scientific journals, such as, for example [8] and [9].

Besides some wrong explanations incompatible with Gauss' Law, most of the answers agreed in considering the problem not to be an anomaly at all. They explained the phenomenon by resorting to the very high number of electrons in the metal, which can follow the TEM wave at a speed of c, generating an appropriate current, even if each single electron moved at a drift velocity much smaller than c. Indeed, what the theory requires is an appropriate current. However, current is the product of charge density and speed: where there is a high charge density, the speed could also be very slow. Physically, a current follows the field traveling at the speed c, but this current is due to a great number of slowly moving electrons. A possible analogy is the start of a marathon: the referee shoots the starting pistol, the sound of the bang propagates in the air, and each athlete begins to run when they hear it. The apparent effect is a wave of running athletes that propagates along the street at the speed of sound, even if obviously no one person can run so fast!

However, Catt declares he is unsatisfied by the answers. He purports to develop a new electromagnetic theory [5, 6], where charges are completely absent. Catt's point is indeed very interesting, inasmuch as it makes us think about the very basics of classical electrodynamics. However, in our opinion, Catt probably misinterprets the concepts of charge and field. The "Anomaly" is there because in his view, currents are the source of the TEM wave, and should be there *before* the wave they cause. Actually, charges are at the same time sources and effects: they generate the field, but are also subject to it. Thus, if a voltage generator is applied to a transmission line, it generates at its ends both a current and a field. Moving charges do generate a field that interacts with charges down the transmission line at a speed c, even if the charges themselves move much slower. It is not a matter of moving charges generating a TEM wave, or a TEM wave moving the charges. Instead, it is a continuous back and forth, from moving charges to TEM wave to new moving charges, and again to TEM wave, and so on.

4. References

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