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TESLA'S EGG OF COLUMBUS, RADAR STEALTH, THE TORSION TENSOR, AND THE "PHILADELPHIA EXPERIMENT"

by

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"Can we learn to think in 4-dimensions? This, and *negative time*, involve dreaming of the wildest sort, with no support whatsoever as yet from anything we see or record on our delicate instruments."

Vannevar Bush,
March 2, 1967****

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****Bush, V., Science Is Not Enough, Morrow and Co., 1967, pg. 168.

"Gentlemen,... we are facing a crises such as the world has never seen before [WWI], and until the situation clears, the best thing we can do is to devise some scheme for overcoming the submarines, and that is what I am doing now. (Applause)"

Minutes of the 7th AIEE Edison Medal
Presentation to Nikola Tesla, May 18, 1917

ABSTRACT

In this paper we follow the thread leading from Tesla's spinning "Egg of Columbus" demonstration, through his proposal of a large rectangular helix disposed about the hull of a ship for U-boat detection, to Arnold Sommerfeld's discussion of magnetically biased ferrites creating electromagnetic stealth for WW-II submarines. By calculation, the required magnetic field to reduce a ship's radar reflection to less than 1%, at L-Band (1.5) GHz, is in excess of 15,000 A/m. Fields this order of magnitude would appear to fulfill the requirements of a "Philadelphia Experiment". Such intense fields would create green mist and cavities in salt water, and magnetophosphenes and Purkinje patterns in humans, particularly if driven at frequencies in the range of 10 - 125 Hz, as was available from the synchronous generators on WW-II electric drive ships. We conclude that with the knowledge available, the DSRB (under Vannevar Bush) would have been derelict not to have conducted such an experiment.

Finally, we present speculation on temporal bifurcations. Assuming Hehl's hypothesis that localized Cartan Torsion tensors are generated by ferromagnetic spin, we propose two physical experiments which distinguish temporal anisotropy arising from anholonomity (the Sagnac effect) from that arising in the torsion of the 1929 version of the unified field (Eddington's "crinkled manifold").

Disclaimer

This paper stands unique among our publications both on Tesla and on the conventional aspects of electromagnetism and relativity. In this regard it is partly speculative. (And, only partially at that, since we report on some of our experimental findings that can be verified by independent laboratory examination). Before wading too deep into a controversial subject like that before us, it is common for respectable folk to acknowledge their limitations. We need to make some kind of professional "disclaimer". Let us express it this way: we offer this little study in the spirit of an engineer and some physicists having some fun [in the sense of Arthur Eddington,[1][2] Joseph Slepian,[3]* Jearl Walker,[4]** Edwin Abbot,[5] George Gamow,[6] or even Arthur C. Clark], looking at published statements, attempting to stay within the bounds of engineering technical propriety, and saying, "What if ...?" Since the theoretical analyses make specific physical predictions, it follows that our assertions can be experimentally examined by disinterested (but technically qualified) third parties, and that we haven't strayed too far from the scientific method in our amusing pastime. Taken in that spirit, our passing entertainment should also provide recreational diversion for skeptics, grad students, the lunatic fringe, engineers, and men of honor.

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*Slepian wrote a delightful series of "Electrical Essays" for engineers. Start with the one cited and read either forward or backward several years.

**Walker wrote about physics problems, "I am not so interested in how many you can answer as I am in getting you to worry over them."

PART I - RADAR AND ROTATING FIELDS

Introduction

During the 1992 International Tesla Symposium, the authors took the opportunity to once again visit the site of Tesla's Colorado Springs laboratory and nearby Prospect Lake, where many of Tesla's experiments were conducted in 1899. While walking around the Monument in War Memorial Park our conversation turned to the book by William Moore and Charles Berlitz on the Philadelphia Experiment. A colleague at Battelle had introduced us to the story in fall of 1989. One of the presentations at the last ITS Symposium concerned the topic, and as we walked we began to ponder out loud how we might rationally explain such an experiment. The following is the result of our reveries.

The world of magnetics, today is extremely complex. During the 1940's and 50's high field magnetics became "big physics", and it would be impossible for the authors in this small space to even attempt a modern analysis of this topic. Instead, we believe that there is some merit to *employing the sort of physical arguments, both classical and relativistic, that would have been available by scientists of the decade preceding* the Philadelphia Experiment. This is not a discussion of anything even remotely like the Navy's new "Sea Shadow".[7]

It has been asserted that the initial Philadelphia Experiment took place "sometime between July 20 and August 20, 1943."[8] Simply put: in the experiment(s) a big coil of wire was wrapped around a large ship, the ship became invisible in a foggy green mist, and a lot of people on board were hurt. (Some thought they went through a rip in the fabric of the space-time continuum, were teleported from the Philadelphia shipyards to Norfolk, Virginia, and saw alien humanoids). The respected names identified with with the experiment include Albert Einstein (1879-1955),* Rudolph Ladenburg (1882-1952), John Von Neumann (1903-1957) [and his Gottingen dissertation advisor, David Hilbert (1862-1943)], Nikola Tesla (1856-January 7, 1943), Oswald Veblin (1880-1960), Burtrand Russell (1872-1970), Gabriel Kron (1901-1968), Vannevar Bush (1890-1974) and a host of other recognized men of renown whose common interest seems to include, among other things, an historical association with things of interest to the Navy, and submarine detection in particular. The Department of the Navy has officially identified the experiment as mythical, having its genesis in a 1955 book on UFO's,[9] not Naval science.[10] Perhaps the story really was mythological. However, if

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*Einstein served as a consultant for the R&D Division of the US Navy Bureau of Ordnance from May 31,1943-June 30,1946. Interestingly, according to the FBI Einstein file [QC 16 ESU55; OCLC #13720407; Title #3892869], Einstein was in Philadelphia during the time of the alleged Philadelphia Experiment. (On the evening of August 10, 1943 he spoke before the Philadelphia section of the "Friends of Soviet Russia".)

that's the case, then our hats are off to the brilliant scientists that spun this gossamer web of fantasy - for no ordinary laymen could have done it.

Why Tesla?

It is now common knowledge that Tesla had attempted to market his radio controlled craft (the "telautomaton"; Patent* 613,809) to the US Navy.**[11][12] Tesla was the first to advocate the electric drive for naval vessels.[13] He was the first to suggest that electric drive war ships could be used in peacetime to supply shore power during emergencies.[14] (They were, of course. See the comments below). And, as is evident from Tesla's quote at the top of this article, he was again dealing with the Navy during World War I. It was during this time that he met in Washington with Assistant Secretary of the Navy Franklin Delano Roosevelt. Roosevelt's mentor, Josephus Daniels, was Secretary of the Navy.*** (It was also during this time that university professor and future Director of OSRD (Office of Scientific Research and Development), Vannevar Bush, was just starting research on submarine detection for the Navy.) From Tesla's files, we know that a few years later, during the 1920's, the Navy in Philadelphia (specifically John B. Flowers, Electrical Engineer), was examining Tesla's work. Anderson has noted that, "Tesla was engaged... at the E.G. Budd Mfg. Co. in Philadelphia from 1925-1926."[15] And, we also know that when Tesla died in 1943, Naval Intelligence officers accompanied MIT EE Professor John G. Trump (a Bush colleague also in the employ of OSRD) as he secretly examined Tesla's papers.

We think that not only can the Philadelphia Experiment be tracked to statements which Tesla published during World War I, and were grasped by men like Bush, but that the physics of the experiment can actually be traced back to Tesla's invention of the rotating magnetic field. Furthermore, to us to there appears be a legitimate link between Tesla's rotating fields and the Torsion tensor which appears in Einstein's 1927-29 Unified Field Theory publications. This connection was first identified and published by Gabriel Kron at GE (Schenectady) during the 1930's. Return with us

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*For which Tesla has been identified as the Father of robotics.

**In 1916 Tesla said, "I vainly attempted to persuade them to accept. I perfected the machine in 1898, and tried everything in my power to have it adopted... After the patent expired a few months ago Congress appropriated [$750,000] and I have now the pleasure of simply looking on while others are using my inventions, which I could not persuade people to adopt. This is usually so." [Anderson, 1992, pg. 19.] "I tried to persuade the Navy... it was absolutely impossible to find listeners..." [Anderson, 1992, pg. 158.]

***Both Daniels and FDR advocated absolute legal control of the electromagnetic spectrum by the Navy.

now to 1887 and Tesla's first rotating field patent (#381,968; Applied for October 12,1887; Issued May 1,1888).

Polyphase Currents and Rotating Fields

The creation of the rotating magnetic field was "purely the work of scientific imagination". It has been identified as the greatest creation of the human mind since the invention of the wheel. Tesla's discovery of polyphase currents and "an invisible wheel made of nothing but a magnetic field" (the phrase is due to Reginald Kapp)[16] was the turning point from the past into the 20th century. Tesla stands at the focal point of the important electrical discoveries of the 20th century. At the conferral of the AIEE's highest award of honor, B.A. Behrend remarked,

> "Were we to seize and to eliminate from our industrial world the results of Mr. Tesla's work, the wheels of industry would cease to turn, our electric cars and trains would stop, our towns would be dark, our mills would be dead and idle."[17]

When Tesla died in 1943, Yale University EE professor Charles F. Scott observed,

> "The evolution of electric power from the discovery of Faraday in 1831 to the initial great installation of the Tesla polyphase system in 1896 is 'undoubtedly the most tremendous event in all engineering history'."[18]

And, the connection to the relativity of rotation (an issue still not put to rest today) was not overlooked: Yale physicist Leigh Page once said,

> "The rotating armatures of every generator and every motor in this age of electricity are steadily proclaiming the truth of the relativity theory to all who have ears to hear."[19]

Let us follow this central thread that runs through Tesla's professional career back to its origin.

While Tesla had constructed the first rotating field apparatus in the summer of 1883 (one year before both he, and the Statue of Liberty, arrived from France), it was not until 1887 that a company was formed to exploit the phenomenon. However, Tesla was unable to raise capital to commercially introduce his invention. (The enterprise was 'undercapitalized'.) He finally found a skeptical Wall Street lawyer that was somewhat interested, and this is the conversation as Tesla retells it.

> Tesla: "Do you know the story of the Egg of Columbus? ...Well, what if I could make an egg stand on the pointed end without cracking the shell?"* "If you could do this

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*As Columbus had done when getting Queen Isabella to pawn her jewels for three ships to sail in.

> we would admit that you had gone Columbus one better." "And would you be willing to go out of your way as much as Isabella?" "We have no crown jewels to pawn," said the lawyer, who was a wit, "but there are a few ducats in our buckskins and we might help you to an extent."[20]

Tesla arranged for a demonstration the next day. He placed a copper-plated egg on a wooden plate above his rotating magnetic field (there is a photograph of the apparatus in the Secor article). As soon as the windings were energized the egg began to spin. [Tesla's spinning egg is, in fact, a macroscopic analog of the Einstein-de Haas effect investigated almost thirty years later. The materials in Einstein's WWI experiments spin because of molecular 'amperian currents' (although later Einstein did suggest using high frequency '*rotating magnetic fields*' to Barnett). In Tesla's experiments they spin because of induced eddy currents. See part V below.]

> "... to their astonishment, it stood on end, but when they found that it was *rapidly spinning* their stupefaction was complete*... No sooner had they regained their composure than Tesla was delighted with their question: '*Do you want any money?*'... That started the ball rolling. Tens of millions of horsepower of Tesla induction motors are now in use all over the world and their production is rising like a flood... Rotating fields of 15,000 horsepower are now being turned out... and ship propulsion by Tesla's electric drive which, according to Secretary of the Navy Daniels' statement, has proved a great success."[21]

The electrical circuit which Tesla employed for the egg of Columbus used two phase AC energizing the coils in quadrature and the source frequency was varied from 25 to 300 cycles, "*the best results being obtained with currents from 35 to 40 cycles.*"** The story was also mentioned in Fleming's eulogy of Tesla.[22]

In 1893, 6 years after demonstrating the egg of Columbus to the attorneys and business investors in New York, a large egg demonstration was constructed for Tesla by Albert Schmid and Charles H. Scott, at the time both of Westinghouse. (Scott, subsequently an EE professor at Yale, served as President of both the AIEE and, later, the IRE.) The egg occupied part of the Westinghouse exhibit in the Electricity Building at the great Chicago World's Fair. The 1893 Fair celebrated the 500th anniversary of Columbus' discovery of the new world and, ostensibly, it was intended to launch

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*The language used to describe the striking effect his 1892 lecture-demonstration had on the Royal Institution in London, was, "The scientists simply did not know where they were when they saw it." (Anderson, 1992, pg. 95)

**Note that Tesla has recognized that he can characterize different spinning eggs with certain gyromagnetic resonance frequencies!! This was in 1887.

society into the 20th century. There is a photograph of Tesla's exhibit in the Martin book.[23] This was only a few months before Lord Kelvin was to choose the Tesla polyphase system for Niagara Falls, and 3 years before the first Niagara Falls plant was turned on.

While Tesla had been active in RF generation in the early 1890's, the close of the decade saw him making great strides in the realm of high voltage RF power processing. These experiments culminated in a cluster of patent applications and the construction of the Wardenclyffe laboratory. Mention should also be made of his turbine development and intense engineering consulting practice just prior to WWI. From the comments above it is clear that he was actively promoting his patented ideas.

Tesla's Reflections on Radar and Ships Wrapped in Coils of Wire

Just after receiving the AIEE's Edison medal (May 18, 1917), Nikola Tesla granted an interview to H.W. Secor of the Electrical Experimenter magazine. (Secor's article was published in August of 1917.) The topic of discussion turned to the detection of German U-boats (U-boat = Unterseeboot = submarine), which had caused so much distress to the allies. The US had entered the war in April of 1917. Tesla's concerns centered around the detection of submarines, in particular the possibility of non-ferrous hull detection. Listen as, filtered by the pen of a journalist, Tesla narrates the electrical preparation of the ship:

> "Now, suppose that we erect on a vessel, a large rectangular helix or an inductance coil of insulated wire. Actual experiments in my laboratory at Houston Street (New York City), have proven that the presence of a local iron mass, such as the ship's hull, would not interfere with the actions of this device. To this coil of wire, measuring perhaps 400 feet in length by 70 feet in width (the length and breadth of the ship*) we connect a source of extremely high frequency and very powerful oscillating current."[24]

We think that Vannevar Bush was aware of this suggestion, and it is our thesis that these words are the seed that later blossomed as the "Philadelphia Experiment". The article then goes on to describe an RF technique which subsequently became quite popular (though not on such a grand scale) for metal detectors and for tuning the reactance of RF coils in transmitters and receivers. Upon further prodding by Secor, Tesla discussed a high peak power *microwave radar* for operation at wavelengths "... of but a few millimeters". (X-Band radar at 10 GHz has a wavelength of 30 mm.)

Tesla desired that the ship be able to provide sufficient electrical power, and he states this in

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*According to Jane's Fighting Ships (1967-68, pg. 408), the Eldridge (DE-173) was 306 feet long by 37 feet at the beam, and had a draft of 14 feet. Its main engines were GM diesels, electric drive, 2 shafts, 4.5 Mw.

the interview:

> "The average ship has available from say 10,000 to 15,000 HP. ... The electric energy would be taken from the ship's plant for a fraction of a minute only, being absorbed at a tremendous rate **by suitable condensers** and other apparatus, from which it could be liberated at any rate desired."

Clearly, Tesla was contemplating the use of pulsed currents* in the coils around the ship. Remarkably, vessels wrapped in coils were observed during WW-II (perhaps for mine sweeping or even degaussing studies). [According to Moore, Francis Bitter, of MIT, recalled witnessing "a relatively large ship carrying ... a bar magnet going from the bow ... way aft. This bar magnet had coils wound around it which passed current produced by big motor generators."[25]] By the way, the Eldridge's generator was rated at 4,600 kVA and could deliver 6,000 HP. Two generators, as described in the book, could deliver more than 12,000 HP (almost 9 Mw).

It is not clear that Mr. Secor even fathomed what Dr. Tesla was speaking about. How much of what was published in the article were Tesla's ideas and what was added (or deleted) by Secor is not transparent. (We have the same problem with O'Neill's colorful biography.) After Tesla's brief discussion of sonar, Secor mixes together the RF magnetic detection process and the "electric ray" radar technique. While Secor's version of Tesla's disclosures might sound, today, like oversimplified impractical popularizations, Secor was quick to conclude his 1917 article with the disclaimer, "... several important electrical war schemes will shortly be laid before the War and Navy Departments by Dr. Tesla, the details of which we naturally cannot now publish."[26] Margaret Cheney has observed that, at the time, Thomas Edison

> "... had been named to direct the new Naval Consulting Board in Washington, *with the primary job of finding a way of spotting U-boats*. Tesla's idea, if even brought to Edison's attention, would almost certainly have been discounted."[27]

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*"I will tell you the secret of all these wonderful displays. ... Consider a large gun which hurls a projectile of a ton a distance of 18 or 20 miles. If you figure the horsepower at which the gun delivers energy, you will find that it amounts to from 6 to 12 or 15 million horsepower. ... With the methods which I have devised, with my transformer, it is not at all difficult to get rates of energy many times that. ... in the plant on Long Island, if I wanted to operate, I could have just reached a rate of 1 billion horsepower. ... That wonderful thing can be accomplished through a condenser. The condenser is the most wonderful electrical instrument ... You store less energy in the condenser than in the gun, but whereas a gun will discharge ... in 1/50 of a second, a condenser can discharge the energy in 1 millionth of this time. ... all these effects which elicited great wonderment of the profession, were always produced by damped waves, because with the undamped waves it would not have been possible to attain any such activities." [Tesla on His Work With Alternating Currents, by L.I. Anderson, 1992, pp. 112-113.]

It should also be noted that Vannevar Bush was involved in the same endeavor:

> "During 1917-18 [Bush] was engaged in research on submarine detection in connection with the United States Navy special board on submarine devices."[28]

In 1917, Bush, fresh out of graduate school,* was a newly appointed assistant professor of electrical engineering at Tufts College in Medford, Massachusetts and consulting for the American Radio and Research Corporation. [AMRAD was a J.P. Morgan venture, built on the Tufts campus, which manufactured "thousands of transmitters and receivers" during WWI.[29]] Bush was one of the guiding lights for a spin-off company which, in 1925, was renamed Raytheon.** (In 1941 Raytheon became the prime source for the new Navy Search Radar.[30]) Bush joined the MIT EE Department faculty (his specialty, initially, was electrical power and subsequently operational calculus and analog computers (the famous network analyzer)) and became Dean, and then Vice-President of MIT in 1931.*** He accepted the position of President of the Carnegie Institution of Washington in 1938 (and held the position until 1955). He was Science Advisor to the President and was appointed by Roosevelt as chairman of the National Defense Research Committee (July, 1940),**** as director of OSRD - the Office of Scientific Research and Development (1941), and as Chairman of the Joint Committee on New Weapons and Equipment of the Joint United States Chiefs of Staff (1942).[31]

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*Bush received a BS and an MS from Tufts College (1913), Doctor of Engineering jointly from MIT and Harvard (1916), and eventually 10 honorary doctorates from various colleges and universities. During his remarkable career, he was science advisor to several Presidents. He was Vice-President and Dean of Engineering at MIT in 1931, the year that he wrote to Tesla.

**Raytheon, in fact, (with 25% of the EE department involved) came to be known by the grad students at MIT in the late 1920's as "an extension of the Electrical Engineering Department." (See Reference 29.)

***Ever the entrepreneur, when Bush heard A.F. Joffe of the Polytechnic Institute of Leningrad present his ideas on a new super-dielectric for HV insulation, he rallied his investor friends and went to Leningrad and Moscow. (As described in his autobiography, Pieces of the Action (Morrow, 1970), the enterprise resulted in failure.)

****Recall that John G. Trump, accompanied by three Naval personnel, examined Tesla's personal papers when he died in January of 1943. Trump was Secretary of the Microwave Committee of the National Defense Research Committee from 1942 until 1944 when, as a member of General C.A. Spaatz's Advisory Special Group on Radar, he went to Europe as the Director of the British Branch of the (MIT) Radiation Laboratory. (See Electrical Engineering, Vol. 80, No. 5, May, 1961, pp. 364-365.) [General Spaatz, by the way, was Air Force Chief of Staff and headed the "very secret" committee on UFOs. According to Irving Langmuir, (Physics Today, October, 1989, pg. 48) Spaatz had confided, "You know it's very serious. It really looks as though there is something there." (Also see Physics Today, March 1990, pg. 13 and April, 1990, pg. 13.]

Vannevar Bush guided much of the Nation's weapons research during WWII. According to Frank B. Jewett* (President of the National Academy of Sciences), as head of OSRD Bush

> "... directed the mobilization of the entire civilian scientific and technical power of the nation and welded it together into the military establishment in the greatest industrial research and development man has ever known."[32]

Recall that Vannevar Bush, while Vice President of MIT, had sent Tesla birthday greetings in 1931:

> "Dear Dr. Tesla ... I wish to join to my own tribute of admiration for your unique career the congratulations of the Massachusetts Institute of Technology, where the contribution which your original genius has made for the benefit of mankind is fully appreciated."[33]

In 1943, Bush, like Tesla in 1917, received the AIEE's highest honor (at that time the Edison Award). Bush held about 50 US patents for various inventions. Let us move ahead from Tesla's suggestion, to place coils of wire on a ship, to radar and radar counter-measures (stealth).

Radar

It seems to be broadly recognized that, although Heinrich Hertz had observed RF standing waves resulting from metallic reflections, it was Nikola Tesla, in 1900, who was the first to propose the concept of radar.[34] According to NRL radar pioneer R.M. Page, it was Tesla who first "... suggested the use of electromagnetic waves to determine the relative position, speed, and course of a moving object."[35] The earliest patent issuing for radar appears to have been the British patent granted to German engineer Christian Hulsmeyer.[36] Certainly, Tesla's interview with H.W. Secor appears as an added note in the radar lore.[37] The acronym *radar* was an official code word adopted by the US Navy in November of 1940, the same month that the MIT Radiation Laboratory was organized for the exploitation of the microwave region for radar.

Sommerfeld on Electromagnetic Stealth During WW-II

In his authoritative two volume radar cross section handbook, George Ruck has pointed out the desirable features of radar absorbers.

> "The search for suitable radar absorbing materials (RAM) was initiated in the early 1940's both in the United states and Germany. Ideally, the optimum RAM would be a paint-like material effective at all polarizations over a broad range of frequencies and angles of incidence.

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*Edison Medalist in 1928. (Eleven years after Tesla.)

Unfortunately, such a material does not exist and the probability of its being developed is rather remote."[38]

Arnold Sommerfeld (1868-1951) presents a surprising discussion of German war research on stealth and radar absorbing materials in the optics volume of his famous Lectures on Theoretical Physics.[39] He relates that the case where the magnetic permeabilities between two media (air and target) are unequal ($\mu_1 \neq \mu_2$) is "of some historical interest".

> "***During the war*** **the problem arose to find, as a counter measure** ***against allied radar***, a largely nonreflecting ("black") surface layer of small thickness. This layer was to be particularly non-reflecting for perpendicular or almost perpendicular incidence of the radar wave. In this case the angle of incidence and the angle of transmission are both almost equal to zero. The problem is solved by making *the ratio of the two wave impedances* equal to unity:
>
> $$m_{12} = \frac{E_1/H_1}{E_2/H_2} = 1 \qquad (1)$$
>
> The criterion is, thus, not the index of refraction but the ratio of wave impedances."

Sommerfeld's suggestion is similar to the idea of making the radar target surface a "conjugate match" to eliminate radar reflections. If one could make the impedance of the second medium be the same as free-space, the target would become radar invisible. He continues:

> "In order to *'camouflage' an object against radar waves*, one must cover it with a layer for which this ratio of wave resistances has the value 1 *in the region of centimeter waves*. According to [the law of refraction and the boundary conditions] this means that if we call the constants of the desired material ε and μ and those of air ε_o and μ_o, then
>
> $$\frac{\epsilon}{\epsilon_o} = \frac{\mu}{\mu_o} \qquad (2)$$
>
> Hence, the problem concerns not only the dielectric constant but also the relationship between the dielectric constant and the permeability. A substance must be formed whose relative permeability $\mu_r = \mu/\mu_o$ is of the same magnitude as its relative dielectric constant $\varepsilon/\varepsilon_o$.

This case is discussed by Ridenour in Volume 1 of the famous MIT Rad Lab series,[40] and in a well known analytical reference by Weston.[41] Sommerfeld continues,

> But the problem is not yet solved. For at its back surface the layer borders on the object (metal) which is to be camouflaged, and this second surface still reflects strongly. Hence, the further condition must be imposed that *the layer should absorb sufficiently strongly*. This requires a complex rather than a real dielectric constant *and* because of the requirement (Eq. 2) *a corresponding complex permeability*. **The material** ***must, therefore, be ferromagnetic*** and must possess a strong hysteresis or a

> structural relaxation that acts correspondingly. Thus, a difficult technological problem was posed which, though not unsolvable, *required extensive preparatory work.*
>
> *Because of the urgent war situation*, the solution which *had* to be used resulted from the following considerations ..."

Sommerfeld then changes the course of his ideas. He proceeds to describe the reduction in radar reflection by a rather conventional means that does not build upon the requirement of Equation (2). Instead, what he discusses next is covering the surface with layers of lossy *dielectric* material, each strata being less than ¼ wavelength thick, neglecting entirely any effects attributable to μ. ("In this manner the reflected intensity could be reduced to 1% of the value given by Fresnel's formula ..."[42]) After the war, a number of papers were published by Sommerfeld's colleagues at Gottingen and Munich, in Zeitschrift fur Angewandte Physik, on the topic of radar absorption. (Just scan the magazine's annual index for 1956-1959.) Presumably, after the war the German workers were less constrained in publishing their research on the topic of RAM than Allied scientists.* Even at this late date most significant western RAM publications are classified, particularly those related to the stealth bomber technology.

In his 1947 MIT Rad Lab Volume, Ridenour comments that,

> "Absorbent materials have been produced in Germany for the radar camouflage of U-boats. The type of absorber that was actually put into service was of the interface kind. The dielectric constant and permeability were produced by a high concentration of spheroidal metal particles (carbonyl iron). The concentration of metal was 80% by weight, and values of dielectric constant and permeability were $\varepsilon = 7$, and $\mu = 3.5$.
>
> An absorber of the second kind was also developed in Germany. It consisted of a series of layers whose conductivity regularly increased with depth. The layers were separated by foam-type plastic whose dielectric constant was close to 1. The absorption was excellent from 4 to 13 cm [2.3-7.5 GHz]. However, the complete absorber was a rigid structure 2.5 inches thick, and it was never actually used."[43]

Is there any connection between the remarks of Sommerfeld and the supposed German version of the "Philadelphia Experiment", which has been rumored to have occurred at the Kiel Shipyards in Germany during World war II? Surprisingly, after hinting at ferromagnetic materials, Sommerfeld did not tell us how to produce magnetic radar camouflage. We will try our hand at supplying the missing details below. But first, we review conventional linear RAM.

Ferromagnetic Radar Absorbing Material

The more-or-less conventional approach to radar stealth is to either employ "shaping" of the

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*The American scientist of German origin, quoted by Dr. Rinehart in the Moore-Berlitz book (pp. 202-203) was clearly mistaken in his assessment of German military spirit.