

1994 Tesla Symposium at Colorado Springs

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

by

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and

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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-11 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-11 electric drive **ships**. We **conclude** that **with** the knowledge available, the DSRB (under Vannevar Bush) **would** have been derelict not to have mnducted 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 **anholonomy** (**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.

*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 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), Bertrand 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

*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 EG. 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 there appears to 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

*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. 19.1 "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 1890 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

*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**.'"*)

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

*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)

****Not 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

*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⁾

"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⁾

"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. 13.1

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 A d**) . 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.

[†]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:

$$m_{12} = \frac{E_1/H_1}{E_2/H_2} = 1 \quad (1)$$

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_0 and μ_0 , then

$$\frac{\epsilon}{\epsilon_0} = \frac{\mu}{\mu_0} \quad (2)$$

Hence, the problem concerns not only the dielectric constant but also the relationship between the dielectric constant and the permeability. A  must be formed whose relative permeability $\mu_r = \mu/\mu_0$ is of the same magnitude as its relative dielectric constant ϵ/ϵ_0 .

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 $\frac{1}{4}$ 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 $\epsilon = 7$, 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

*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.