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Tesla: Inventor of Radio and Modern-Day AC

(Marconi and Edison notwithstanding.)

Popular beliefs in history are often not factual and cannot bear scrutiny. Such is the case for the history of electricity, which ultimately led to radio.

From the time man started his upward march toward an advanced technological society, only a few exceptional scientists have left indelible marks. Nikola Tesla was one of those few. Born in 1856 of Serbian parents in what was once the great Austro-Hungarian Empire, and educated at the Austrian Polytechnic School in Graz, he emigrated to the United States in 1884 and became an American citizen.

Tesla brought with him the secret of how to unleash an awesome power never imagined by his contemporaries … the power upon which, today, the entire world runs … polyphase alternating current (AC).

The illnesses Tesla suffered during his childhood almost killed him. Later, as an adult, the ridicule and rejection he suffered, after showering the world with many of nature's most elusive secrets, were severe enough to stifle most men, yet he remained dedicated to science. The great German philosopher Arthur Schopenhauer probably said it best when he stated: "All truth passes through three stages: First, it is ridiculed; Second, it is violently opposed; and Third, it is accepted as self-evident."

Such is the story of Nikola Tesla and his struggle to make AC the world standard. His rotating magnetic field principle, basic to all power generation and electric motors, is as eternal as the wheel. Indeed, it has become as common as the wheel, and without it, the world would be quite different.

The story of the rise of electric power is long, and no one man should have exclusive credit for its creation. Others, such as Hans Christian Oersted and Michael Faraday, made significant discoveries in electrical science. Their discoveries of electromagnetism and electromagnetic induction, respectively, were pivotal breakthroughs; without them, Tesla would not have been able to unleash the awesome power contained in the electrical genie Faraday discovered in 1831.

For 51 years after Faraday's discovery, investigators struggled to increase the electrical output of Faraday's embryonic generator. Gradually, magneto-electric generators became available, and by 1872 the direct current (DC) generator reached its peak of refinement.

Nevertheless, all such generators proved to be inefficient and troublesome, creating sparks and requiring frequent maintenance. Moreover, DC power was inherently inferior because its losses increase as a function of the inverse square of the voltage. End-use voltage has to be relatively low for safety reasons. With no inexpensive method of changing the voltage of DC electricity, the voltage of generation, transmission, and distribution of DC power had to be the same as the low voltage of use.

Unless massive copper bars as conductors are used to transmit all the amperes necessary to transmit a large quantity of power at low voltage, it is impractical to distribute DC a distance greater than 1/2 mile from the generating station. With AC power, the relatively inexpensive transformer changes the voltage from high voltage transmission (over pencil-thin conductors) to low voltage distribution … and use.

Nineteenth-century technologists believed DC power was their only option for harnessing Faraday's discovery. Everyone believed naturally occurring AC was useless … akin to a perpetual motion machine. Tesla's discovery of the rotating magnetic field principle proved everyone wrong. As the Circuit Court in Connecticut concluded in upholding Tesla's claim of invention against attacks on its novelty, "What

others looked upon as only invincible barriers ... he [Tesla] brought under control, and ... taught how to utilize in practical motors in distant cities the power of Niagara" [Westinghouse Elec. & Mfg. Co. v. New England Granite Co., Vol. 103, *Federal Reporter,* p. 951, at p. 972 (D. Conn.—1900); affirmed by the Circuit Court of Appeals, Second Circuit, 110 F 753 (CA2—1901)].

After Thomas Edison invented the incandescent bulb, he immediately sought investors to fund the construction of power stations, using existing DC technology to power his lamps. His promoters immediately dubbed him "The King of Electricity," but his role was strictly as an entrepreneur building larger generators than were already commercially available. Edison's brief foray into the power industry was nothing more than an anomaly, and he contributed nothing to the time line of scientific progress. His much-heralded Pearl Street Station in Manhattan produced the same DC as the much earlier arc-light DC central stations in San Francisco and other locations, so there can be no justification for scientific innovation. DC is merely a historic relic, and even its title does not belong to Edison.

While the rest of the world had their eyes fixed on Edison's promotion, Tesla was searching for a way to prove his AC theories. The answer came to him one day in 1882 as he was walking in a park reciting poetry. The idea appeared as a blinding flash in his mind, and he knew instantly that he had found the missing link in Faraday's great discovery ... how to extract the awesome electrical power contained in Michael Faraday's discovery 51 years earlier. Such was the power of his rotating magnetic field principle. Faraday's "new-born baby" suddenly became a giant in his mind. Moreover, Tesla never realized at the time how difficult a task he would have in overcoming ignorance and greed. Thomas Edison had spent millions of dollars of investors' money to promote existing, inefficient, DC technology, and he was not about to have his empire destroyed.

Tesla worked for Edison briefly, but he soon realized that Edison had fixed interests and that they were strictly entrepreneurial. Tesla had loftier goals, and they did not include wasting his time building Edison's power stations, which perpetuated a limited, inferior technology. He simply could not understand why Edison was unable to comprehend the superiority of his AC system.

George Westinghouse did not suffer Edison's shortsighted mentality. He knew Tesla had solved the energy problem that plagued scientists for more than 50 years, so he bought all of Tesla's patents on the polyphase AC system. Tesla had germinated the AC seed, and now it was the

81 C. Cls.] MARCONI WIRELESS TELEGRAPH CO. *v.* U. S. 671

Syllabus

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA v. THE UNITED STATES

[No. 33642. Decided November 4, 1935]

On the Proofs

Patents; improvements in wireless telegraphy; validity and infringement.—On the questions of validity and infringement of the following patents for improvements in wireless telegraphy, the court held as follows: Marconi reissue patent No. 11913, held not infringed. Lodge patent 609154, held valid and infringed. Marconi patent 763772, held invalid except claim 16, which is held to be infringed. Fleming patent 803684, held invalid and not infringed.

Royalty; construction of contract of sale.—Where a contract of sale to the United States of certain wireless telegraph stations by the owner of patents on the equipment thereof provided that the contract price was for compensation in full to the seller, and that the Government was not bound to pay the seller any further sum as payment, royalty or other compensation "on account of its patent rights involved in any of the apparatus" thereby transferred; the exemption of the Government from payment of royalty on account of such patent rights extended only to the use of the particular apparatus or equipment transferred in the sale.

Party entitled to sue for infringement.—The general rule as to the right to sue for the infringement of a patent is that the right rests with the one who was owner of the patent at the time the infringement occurred.

Infringement of combination.—A new combination of elements, presenting a new arrangement, and producing new and beneficial results does not infringe a former combination by using some of the elements thereof.

Validity of patent; application filed more than seven months after filing of foreign application.—A patent is not invalid under section 4887 Revised Statutes, as amended, because the application therefor was filed more than seven months after the filing of application for a foreign patent unless the invention was also first patented in the foreign country.

When invention "first patented" within meaning of section 4887 Revised Statutes.—As used in section 4887 Revised Statutes, the term "first patented" means the time when the patentee's rights to the patent become fixed and determined, which in Great Britain is the date when the patent is "sealed."

Laches of owner of patent in enforcing rights against infringers; effect upon subsequent owner.—Where there was such laches on the part of the owner of a patent in enforcing its rights against infringers that interested persons might well believe the patent had been abandoned, a subsequent owner of the patent is not

Fig. 1. *Excerpt from Marconi Wireless Telegraph Company of America v. the United States, 81 Ct. Cls.*

entrepreneur's turn to cultivate the power industry and reap its rewards.

Westinghouse, using Tesla's AC patents, joined with General Electric Company and in 1895 created the Niagara Power Project, the first large-scale hydroelectric generating station in the world. A mere 74 years later, man was walking on the moon. Such was the impact of Tesla's discovery. Now, virtually unlimited electrical and mechanical power is available anywhere.

Is it not classic irony that today our perception of electrical history is so flawed that Tesla's name is largely unrecognized, and we pay tribute to Thomas Edison, the man who fought bitterly to defeat the rise of the polyphase AC electrical power used almost universally throughout the world today? Even our premier museum, the Smithsonian Institution, hails Mr. Edison as the founding father of our electrical power system, and recognizes Tesla only as the inventor of the AC motor. Its curator even attributes Edison's incandescent lamp as being the catalyst for the second industrial revolution.

It was not the lamp that industry needed; it was the mechanical muscle of Tesla's AC motor and the power to make it run that sparked the second industrial revolution. But the greatest triumph of the polyphase AC system was that its use permitted the integration of utility systems to permit taking advantage of overwhelming scale economies in generation. No more was it necessary to have an isolated generating source for each different use of electric power.

Tesla's intellect was such that once he had solved the AC conundrum, he continued his investigations into the world above 60 cycles (AC) ... high frequency. A few years earlier, the brilliant Scottish mathematician, James Clerk Maxwell, established the laws of electrodynamics by formulating four equations defining electromagnetic theory. He concluded that it is possible to transmit energy by electromagnetic waves at the speed of light. Later, Professor Heinrich Hertz, in Germany, set out to interpret and prove Maxwell's work experimentally. His experiments proved those postulates — that electromagnetic waves are indeed propagated in air at the speed of light. Maxwell and Hertz had now laid the groundwork for someone to follow in their footsteps and create a system for transmitting and receiving intelligence.

Nikola Tesla was the first to recognize the need to investigate the properties of high frequency alternating currents ... probably because of Edison's attacks on his high voltage AC transmission system as unsafe. The so-called "skin effect" of high frequency reduced its danger; and this work with high frequency electric power led to his system of transmitting intelligence (radio).

Tesla invented a high frequency air core transformer capable of producing high voltages at very high frequencies. It became known as a Tesla coil. In doing so, he discovered the secret of

electrical resonance, a fundamental necessity in all electronic circuitry. Tesla again proved he was both scientist and technologist, someone who could discover new scientific truths that advanced earlier beliefs and then made them work in a practical way. In short, he was the link between the pure scientists and the technologists who followed.

History is not kind to Tesla, although all of us are the benefactors of his creative genius. The main reason his name is not a household word is that he left no industry or family to perpetuate his memory. Nevertheless, his legacy — whether or not we acknowledge it — is all around us in the electricity that powers our homes, schools, and factories, and in the AC motors powering the many machines that make our lives comfortable.

There is an overwhelming belief that Thomas Alva Edison was the chief architect of our electrical society, and that Marchese Guglielmo Marconi was the inventor of radio. Nonetheless, there is indisputable evidence clearly showing that Nikola Tesla was not only the father of polyphase AC electricity transmission, but also the father of radio.

Litigation again is helpful in establishing priority of invention of radio, just as it did for polyphase AC transmission. The granting of a patent, by itself, is not wholly determinative of invention because that is an *ex parte,* or one-sided proceeding. Usually no one is opposing its grant with facts (outside those readily available to the patent examiner), tending to show that the claims of the patent applicant were unwarranted. The patent examiner is some help in avoiding grants based on unwarranted claims of invention, but his study is limited to papers on file in the patent office or available to him without great effort and expense. Even concerning those, he is frequently dependent on the honesty of the lawyer for the applicant in bringing prior art to his attention.

In the case of radio, as well as electric power systems, two-party patent litigation, and sometimes other litigation, fortunately is available to help in determining priority of invention. Such litigation with respect to radio came to the U.S. Court of Claims when Marconi filed a claim against the government for the taking of his intellectual property involved in four patents; two claimed to be invented by him, one in which the claimed inventor was Sir Oliver Lodge and assigned to Marconi, and one by J.A. Fleming, also assigned to Marconi.

Four patents were involved. The first was a patent by Marconi for a two-circuit system for transmitting signals and receiving them remotely with one circuit in the transmitter and one in the receiver. A current analysis by an expert in electrodynamics (below) shows that this was not a viable system of radio communication.

The two-circuit patent was Re-issue No. 11,913 (Original No. 586,193), granted to Guglielmo Marconi on June 4, 1901, for transmitting electrical impulses and signals and the apparatus therefore.

The second patent was for a four-circuit system of wireless telegraphy, No. 763,772, granted to G. Marconi on June 28, 1904. This patent is the key to the invention of radio. The question for the court was whether the patent was properly issued to Marconi, who claimed to be its inventor, or whether its issuance was invalid because of prior art.

The third patent at issue was No. 609,154, for the use of a variable inductance in tuning a circuit to resonance with another, granted to O.J. Lodge on August 16, 1898; and the fourth patent was for a rectifier tube, No. 803,864, granted to J.A. Fleming on November 7, 1905. The total damages claim was for $6,000,000 — which in 1916 was a lot of money — and justified full development of the facts by the parties to the litigation.

The findings of fact and opinion of the lower court (Court of Claims) can be found in Marconi Wireless Telegraph Company of America v. The United States, 81 Ct. Cls. 671 (1935), affirmed in major part by the Supreme Court 320 US 1 (1943).

The Court of Claims decided that the government did not infringe on Marconi's two-circuit patent. The government's suppliers had not used that technology because long before World War I, it was already obsolete. It held that each of the components Marconi utilized in the two-circuit system was invented by others, but that possibly the combining of them justified a claim of invention for the two-circuit system (even though it was not a viable system of radio). Moreover, the four-circuit system had revolutionized the art. Clearly, the focus of the litigation in the Court of Claims was on the four-circuit patent.

During the more than three years after Marconi's initial filing of the key four-circuit patent on June 28, 1904 was rejected for prior art, new applications and petitions for revival were filed and rejected by reason of the prior art set forth in the Braun British patent, Lodge No. 609,154, and Marconi No. 627,650, but principally in Tesla No. 645,576.

In the early 1930s, the Court of Claims carefully analyzed Marconi's claim of invention of the four-circuit system. Its examination showed how patent office examiners time and again rejected Marconi's claim on the four-circuit system due to Tesla's prior patent for the identical apparatus, his "prior art." It held that it was not necessary even to consider the Stone claim, which was prior to Marconi's but after Tesla's, because Stone himself credited Tesla with its invention. [John Stone (1869–1943), one of the many early pioneers of radio, gave Tesla full credit for its invention.]

At long last, Marconi had persuaded the patent office to reconsider and grant the patent. Was it only by coincidence that this occurred just after the influential investment banker, Morgan, gave his backing to Marconi? Both the Court of Claims, and later the Supreme Court, in affirming the decision of the Court of Claims, remarked that the first examiners were correct, and there was no apparent justification for the *volte face* of the last examiner who granted Marconi the invalid patent on the four-circuit system (opinion of the Court of Claims on Liability, 81 Ct. Cls. 671, 760 to 768).

"It is sometimes said [by those denigrating Tesla's invention of radio] that Tesla's purpose was only to transmit electrical energy, but the electrical waves transmitted by any wireless system are merely one form of electrical energy. Moreover, the specification of Tesla's patent recited that the method of energy transmission would be useful when it was desired to transmit intelligible messages to great distances. In view of this statement, it is within the knowledge of those skilled in the art to interrupt the continuous generation of high frequency energy in the transmitting system by a telegraph key, and substitute for the current receiving instrumentalities disclosed in connection with the receiving system, a radio signal detector device."

The only thing left is to determine of what significance is the Court of Claims' marginal award of invention to Marconi for the two-circuit system.

First, the government's lawyer claimed that Marconi's two-circuit system was basically the same system used by Hertz to verify the theories of James Clerk Maxwell. Brief at 41.

Second, this is what Marconi's own lawyer said of the two-circuit system: "Marconi, in 1894, learned of the Hertz 1888 experiments and in 1896 filed an application in the United States, upon which was granted the patent which was reissued as 11,913. That patent, formerly in suit, described a sending station and a receiving station without any tuned circuits. This system would operate, but only at short distances, because there was too much waste of energy. The transmitting antenna would quickly, and not persistently, radiate the energy applied to it, with the result that the train of ether waves would be too short instead of being sustained. And at the receiving station, the antenna likewise would quickly absorb the received waves, instead of storing them up, and the antenna also would receive undesired waves from other transmitting antennas [citations omitted]. The Lodge patent formerly in suit was an improvement; both the transmitting and the receiving antennas being tuned with inductance, so that each would vibrate longer and the receiver would be more selective (inductance in an electrical system is the same as inertia in a physical system). Moreover, even with the Lodge patent, signaling only to short distances, about eighty miles, was all that was possible before the invention of the [four-circuit] system which enabled communication in 1901 over a distance of more than 6,000 miles [citations omitted]." Brief for Petitioner and Cross-Respondent, March, 1943, at p. 16.

According to the Corum brothers, who are prominent experimenters with Tesla coils, "Tesla's stroke of genius was to use tuned coupled coils, move the energy storage capacitance to the

81 C. Cls.] MARCONI WIRELESS TELEGRAPH CO. *v.* U. S. 677

Reporter's Statement of the Case

Marconi reissue #11913 and Lodge #609154, and assigned these patents, together with all claims for profits and damages by reason of past infringement, except for the same reservation previously mentioned.

These three assignments, being exhibit 362, are by reference made a part of this finding.

MARCONI REISSUE #11913

IX. The reissue patent #11913 relates to a—

"complete system or mechanism capable of artificially producing Hertz oscillations and forming the same into and propagating them as definite signals and capable of receiving and reproducing, telegraphically, such definite signals; * * *."

The embodiment shown by figs. 10 and 11 of the patent, reproduced below, is the basis of the alleged infringement.

Fig. 10.

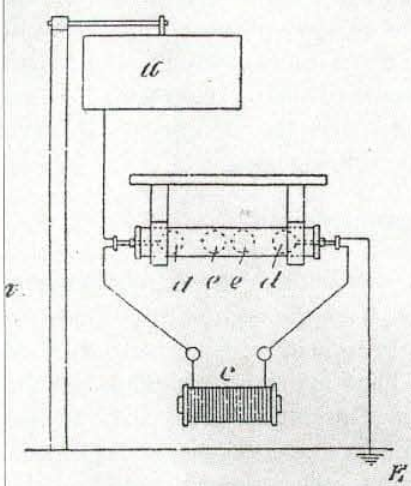
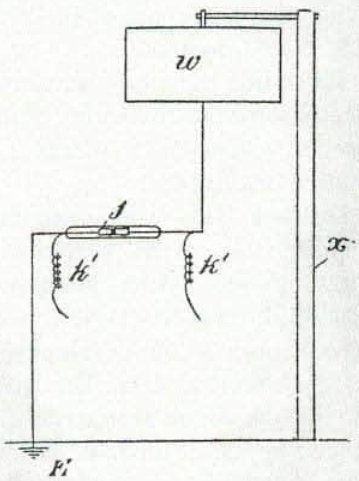


Fig. 11.



To one skilled in the art a transmitting station is shown at fig. 10, having a Morse key and battery in the primary circuit, not shown, of an induction or Ruhmkorff coil *c* or other source of high tension, high frequency current. A spark gap *d*, *e*, *e*, *d*, in the secondary circuit has one side grounded at *E* and the other side connected to an elevated wire and plate *u* insulated from the earth on the pole *v*.

The receiving station in fig. 11 has a coherer or imperfect electrical contact type detector *j* connected on one side to an elevated conductor *w* insulated from the earth, while

Fig. 2. *Another excerpt.*

primary side, and to add a ground connection. Tesla was the first to inductively couple the secondary circuit [where the capacitance must be small] to a tuned primary circuit, where the energy storage element [capacitance] may be huge by comparison. This remarkable innovation made possible the generation of RF signals immensely more powerful than Hertz's apparatus [and therefore the apparatus in Marconi's reissue patent] (*TCTUTOR* at page 13. J&K Corum, D. Edwards, Corum & Associates, Windsor, Ohio, 1988, ISBN 0-924758-01-5). According to the Corums, Hertz calculated his peak power at 16 kW. They concluded that his average radiated power was trifling. In contrast, at Colorado Springs, in 1899, Tesla's average power was in excess of 250 kW and his peak power exceeded 76 megawatts — a long way from Hertz in just a decade. *Ibid.*

Third, even Justice Frankfurter, who dissented bitterly in favor of Marconi, acknowledged that the two-circuit patent was not a significant factor in the innovation of radio: "That patent did not embrace many of the crucial claims here involved and its product cannot compare in commercial usefulness with that of the patent in suit." 320 U.S. 1 at 64, footnote 3.

The following technical evaluation will clearly show the unviability of the two-circuit system as a means for transmitting intelligence:

(1) Abstract. This work examines the characteristics of the two-circuit radio transmission and reception system (Patent Re-issue No. 11,913) used by Marconi prior to the development of the four-circuit system. The findings are that the circuit as described in the named patent is an unviable system of radio communication owing to a number of drawbacks (to be examined in detail). In particular, findings include a wide inherent bandwidth in the system (consider the implications of this in the usage of today's radio frequency allocations) and limitations on the signal and receptive power of the system as described in the patent (affecting coverage and transmission distance).

(2) Transmitter Characteristics (and their implications). The circuit diagram of the transmitter [Marconi Wireless Telegraph Company of America v. The United States — Fig. 10, 81 Ct. Cls. at p. 677] shows a conducting plate (u) suspended by insulating pole (v) to which is attached a vertically hanging wire connected to one end of spark gap (d,e,e,d). The other end of the gap is connected by a wire to earth. Across the spark gap is connected an AC power source (c) (see **Fig. 2**).

Observations

It is not obvious from the diagram of Marconi's two circuit apparatus (reproduced in the court's findings of fact) at exactly which point along the total length of the wire the spark gap is connected. This may have an influence on the resonant mode of the system (due to impedances associated with the power supply with respect to ground), but it is also true that any monopole resonator such as this will respond to a number of frequencies. (This is easily demonstrated both by doing a frequency sweep of such a circuit using a sweep generator and spectrum analyzer, and is also shown in graphic detail in a simple mechanical system — a metal ruler standing in a vise is an example of such a resonator.) It is assumed that the dominant 1/4-wave mode is being used.

Consequences

A conflicting set of requirements arises from the desirability of the system to be narrow band (selective) on one hand and a good radiator on the other. This is not necessarily an impediment to a good narrowband transmission (the antenna used in the typical AM station is unchanged except for the lack of a top-loading capacitance), and in modern radio stations the signal fed to the antenna is rigorously controlled with regard to frequency content.

In the transmitter in question, this is not so. The signal is generated by connecting a charged capacitance (upper wire + plate) to earth by a spark gap which conducts when the breakdown potential across it is reached. Conduction in the gap takes place extremely rapidly (spark propagation of up to 10^8 cm/s) [*High Power Electronics,* Sargent & Dollinger, pub. TAB Books, Inc., ISBN 0-8306-9094-8, Ch. 6.1, pp. 187–190] and is essentially a step function. The result is the generation of a broad spectrum of frequencies whose harmonic content and harmonic amplitudes may be described by a Fourier Series or similar [*Advanced Engineering Mathematics,* 5th Ed., Erwin Kreysig, pub. John Wiley and Sons, ISBN 0-471-88941-5, Ch. 5.3, pp. 211–216], all of which are available to excite the antenna in many resonant modes additional to the 1/4-wave fundamental.

The Q of a circuit containing a spark gap has been seen to be a severe limiting factor on the performance of resonators generally (particularly high Q ones — however, any unwanted losses in a radiating circuit that do not contribute to the radiation are undesirable). Not only does the gap dissipate energy (that could otherwise be usefully employed in radiation), but in extinguishing at low currents it suppresses further oscillation in the antenna before all energy in the circuit has been usefully employed.

Finally, the top capacitance is used as the primary energy store in the two-circuit system. Available system energy is described by the equation $E = 0.5CV^2$. To maximize transmission power, this energy must be maximized. An obvious ploy to increase available energy is to increase the voltage (V), because not only does energy scale as voltage squared, but antenna capacitance must be kept low enough to enable working at a desired frequency with good radiation efficiency. The geometry of the electrode dictates the voltage it can be charged to, and high voltages demand a large radius of curvature for the energy storage capacitance. It is clear that there are limitations on increasing both capacitance and voltage in this system.

Transmitter summary

In this transmitter, the sole resonant circuit is being asked to do two jobs with conflicting requirements. While

radiating efficiently, it is also required to achieve a high degree of harmonic suppression. The four-circuit system gets around this by separating these functions into two separate loosely coupled circuits, each performing a single function. Any circuit containing a spark gap has a very lossy harmonic generator built into it. Efficiency is not restricted to signal radiation alone, and the resonator (antenna) in this system is excited at a multitude of frequencies resulting in a wideband transmission. In the four-circuit transmitter, the gap is removed from the antenna circuit and incorporated into separate circuits, the degree of coupling between them defining the bandwidth of the circuit until the gap is quenched. Ideal quenching results in a single frequency output, a fact well known in early radio circles. This scheme, when used with close coupling, allows energy transfer from primary circuit to antenna to be effected with very few gap conductions ... and hence, losses.

The four-circuit system still suffers gap losses but enables the gap to be quenched (removed) from the antenna circuit while still allowing the antenna to ring at its natural frequency with better efficiency. The moment the gap stops conducting in the two-circuit system, all oscillations cease. There is a serious problem when trying to increase power in the system to a level suitable for long distance transmission. The requirements for the capacitor (u) to be small for radiation efficiency and large for energy storage clash badly. The voltage the capacitor can be charged to is limited by its size and shape — hence transmission power is also restricted. The four-circuit system overcomes this by allowing use of arbitrarily large primary storage capacitance charged to arbitrarily high voltages in a compact manner. Primary energy storage is removed from the aerial system.

(3) Receiver characteristics. The receiver circuit appears in Fig. 11 (Marconi Wireless Telegraph Company of America v. The United States, 81 Ct. Cls. At p. 677), shown in **Fig. 2**. Once again, a lossy element (coherer) appears in the antenna resonant circuit, losing energy and widening the antenna frequency response. The degree of coupling between the two resonant circuits in the four-circuit system defines overall system response and removes the lossy coherer from the antenna.

With that technical evaluation of the two-circuit system as background, we can turn to two portions of the Supreme Court opinion that are sometimes cited as preserving Marconi's priority of invention.

First, a sentence in the majority opinion at page 37. The sentence reads: "Marconi's reputation as the man who first achieved successful radio transmission rests on his original patent, which became Re-issue No. 11,913, and which is not here in question." The pronoun "which" has an ambiguous antecedent. It is not clear whether the matter "not here in question" is Marconi's reputation, or the validity of the two-circuit patent, Re-issue No. 11,913. It appears to the writer that it refers to the latter, which was not in issue because neither party sought review of the Court of Claims decision on the reissue patent since there had been a finding of no infringement. But even if it refers to the former, the statement would have significance only if the combination by Marconi of the elements invented by others played an important role in the progress of radio; and as it has been shown above, it did not. The two-circuit system could only transmit a few miles without the Lodge improvement, which increased the range to 80 miles. In contrast, the four-circuit system could reach 6,000 miles and lessened interference of other transmitters. The two-circuit system transmitter was identical to that of Hertz. The receiver merely substituted a coherer — invented by Branly — in the Hertz receiver, in lieu of the spark gap used by Hertz for experimental purposes.

The second citation is to the dissenting opinion of Mr. Justice Frankfurter. He commenced his dissent by pointing out the inadequacy of lawyers, such as himself, to follow a technical discussion. 320 U.S. 63, footnote 1. It is clear that he found it difficult to understand the facts, because he failed to cite a single one in support of his view that those prior in time to Marconi "did not have the 'flash' ... that begot the idea in Marconi which he gave to the world through the invention embodying the idea." Perhaps it was for this reason that he failed to persuade the majority. Just as in any other profession, lawyers and judges apply principles to facts to draw conclusions. The majority applied legal principles to facts and found that Tesla invented radio. Justice Frankfurter apparently reached the conclusion in his dissenting opinion in some other way.

Guglielmo Marconi deserves great credit for his vigorous promotion and business development of wireless telegraphy and radio, just as credit for promoting the polyphase alternating current system belongs to George Westinghouse — not the inventor, also Nikola Tesla.

Marconi evaluated the commercial opportunities arising from the inventions of Hertz and Tesla, and seized them. When Hulsmeyer, the inventor of radar, tried to sell his invention to shipowners, he had no success. Being a shrewd businessman, Marconi tied his customers with contracts so tight in exclusive dealing arrangements that shipowners were fearful of dealing with others to install radar systems for safety purposes because the systems also used Hertzian waves. "The very fact that all reports and documents referred to Hulsmeyer's [radar] discovery as based on a form of wireless telegraphy was enough to convince them [shipowners] that it was one and the same thing, however different its use, and shipping lines using wireless telegraphy in its accepted sense were mostly under contract to the Marconi monopoly. The terms of the Marconi License were strict and no one in those competitive times would dare risk a suit for breach of contract" [bracketed material added] (Pritchard, *The Radar War*, Thorsons Publishing Group, Wellingborough, Northamptonshire, NN8 2RQ, England, 1989, at p. 19).

Being a good businessman, Marconi

Continued on page 57

Tesla: Inventor of Radio and Modern-Day AC

continued from page 37

recognized the business advantages of a claim to invention of the products and services he was marketing as a check on his competition. In those days, most monopolies were formed by merging or buying up the competition, or by driving smaller competitors out of business through costly patent litigation where possible. Today, this is referred to by antitrust lawyers as nonprice predation and considered to be a restraint of trade.

For example, Edison had joined The Gramme Electrical Company in 1882, a group formed expressly not only to fix prices but also to engage in patent litigation against "outside" electric companies (*Electrical Review,* May 15, 1882). The Sherman Act was not enacted until 1890. It outlawed price fixing and other restraints of trade (but by 1890, the business was already pretty well concentrated). In sum, evidence available from historical documents simply does not support Marconi's claim of invention, but shows only a strong incentive for claiming invention.

Marconi's interest in wireless transmission of intelligence did not commence until 1894.

In 1866, an American dentist named Mahlon Loomis showed that one could detect signals between two mountains in Virginia. Loomis applied for and was granted a patent for wireless telegraphy in 1872, some 22 years before Marconi learned of Hertz's experiments.

In 1897, Marconi could only reach a distance of nine miles. Two years later, he sent messages across the English Channel (the English Channel is about 22 miles in width from Dover to Calais) (Bruno, *The Tradition of Technology,* Library of Congress, Washington, 1995, pp. 110, 241).

In contrast, despite a laboratory fire in 1895 that destroyed most of his equipment, less than two years later Tesla was transmitting from his Houston Street laboratory in New York City a distance of 30 miles up the Hudson River to West Point (*Nikola Tesla On His Work With Alternating Currents,* N. Tesla, ed. L.I. Anderson, Sun Publishing, 1992).

Tesla was so confident of his new four-circuit system that in 1899 he wrote a letter to his friend Robert Underwood Johnson proclaiming "how ... absolutely sure I am that I shall transmit a message [across the Atlantic] to the Paris Exposition without wire ...!" (microfilm letter, Tesla to Robert U. Johnson, August 16, 1899, Library of Congress).