

WARDENCLYFFE · SHOREHAM, NEW YORK · 1901–1917

How Does Tesla's Tower Work?

The Wardenclyffe transmitter, read out of its own four patents: what the machine did, where Tesla believed the current came back, and which half of the scheme the arithmetic refuses.

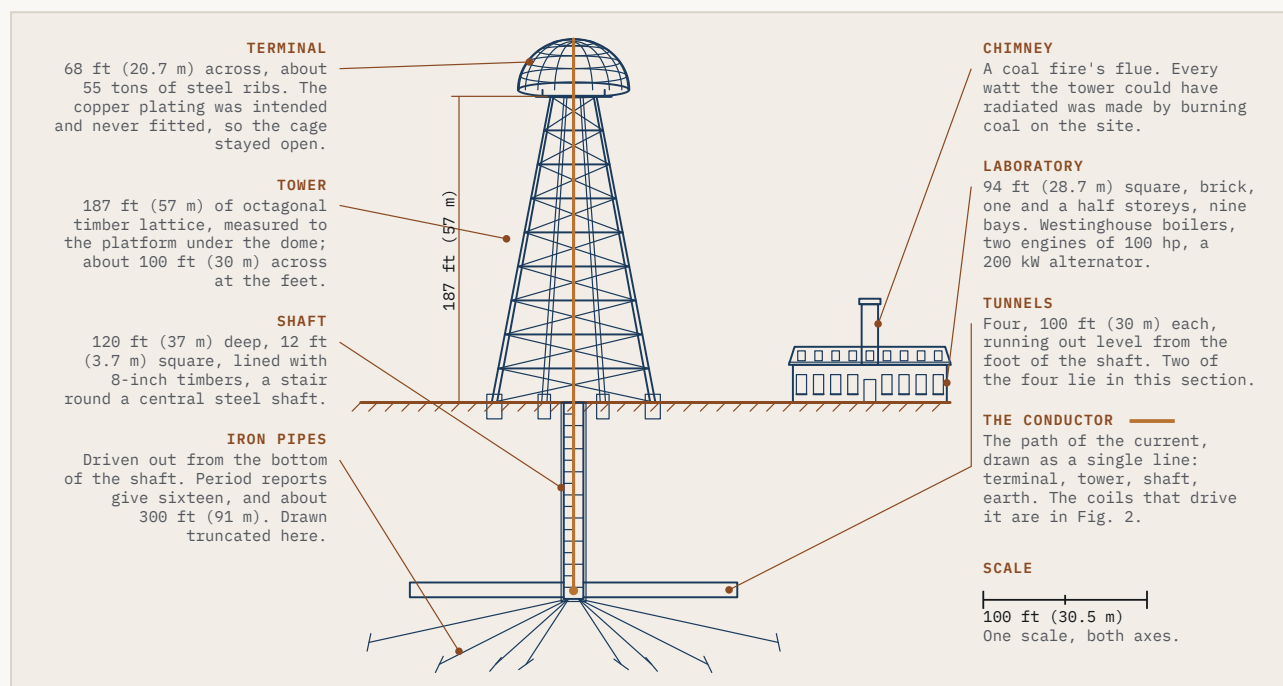


Fig. 1 – The installation in section, drawn to one scale. The lattice stood 187 ft (57 m) to the platform under its 68 ft (20.7 m) dome, over a shaft sunk 120 ft (37 m) into the sand with four tunnels running out level from the foot; the brick building beside it, 94 ft (28.7 m) square, held the boilers, the steam engines and the 200 kW alternator that were to drive it. Drawn for this document from the dimensions in the sources on page 14. The iron pipes are drawn truncated and the distance between tower and building is schematic; everything else is to the one scale.

The Tesla Record

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UNITS

Measurements are given as the sources give them, with metric equivalents in parentheses: 187 ft (57 m). Dates are written out in full: 21 November 2023.

THE FOUR DOCUMENTS

US 645,576 · *System of Transmission of Electrical Energy*, granted 20 March 1900.

US 649,621 · *Apparatus for Transmission of Electrical Energy*, granted 15 May 1900. A division of the same 1897 application as 645,576.

US 787,412 · *Art of Transmitting Electrical Energy Through the Natural Mediums*, granted 18 April 1905.

US 1,119,732 · *Apparatus for Transmitting Electrical Energy*, granted 1 December 1914.

Titles and dates transcribed from the patent faces. All four are in the public domain.

ANSWERED FIRST, THEN SHOWN

The short answer

Wardenclyffe was a transmitter. It was not a generator, and its inventor never said it was.

A coal fire made the electricity. A steam engine turned an alternator of 200 kilowatts. Transformers raised the pressure to something like 60,000 volts and charged banks of condensers. The condensers discharged across a spark gap into a primary coil of a few turns. That primary rang a much larger secondary tuned to the same frequency, and the voltage climbed, because the two circuits agreed on a frequency. The top of the secondary ran up the tower to a steel dome 68 ft (20.7 m) across. The bottom of it went into a shaft 120 ft (37 m) deep.

All of that is ordinary high-voltage engineering, done at an unusual size. The invention is what Tesla believed happened next. He held that a current pushed into the ground at a low enough frequency travels *through* the planet rather than leaking away near the electrode, that it reaches the far side and comes back, and that a transmitter tuned to the round trip therefore sets up a standing wave in the earth itself, with crests and nodes in fixed places. Any station anywhere with a ground rod, a matching coil and an elevated terminal could then take the note off it, the way a second tuning fork picks up the first. Messages would ride on that oscillation. So, he later argued, would power.

That is the mechanism, stated as fairly as it can be. The signalling half of it was aimed at something real: very low frequency energy does travel round the world. The power half cannot be made to work, for reasons that are arithmetic rather than opinion, set out in section 6. Neither half was demonstrated at Shoreham. No measurement of any transmission from the tower survives — no log, no reading, no observation.

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WHERE THE PLANT CAME FROM

Westinghouse supplied the boilers, the engines and the dynamos, and sued for the unpaid bill in 1912. Judgment: \$23,500.

200 KW IN HIS OWN UNITS

$$200 \text{ kW} \div 745.7 = 268 \text{ hp}$$

The plant Tesla described in January 1905 was to *transmit* 10,000 horse-power (7.5 MW). The generating plant actually installed at Shoreham was about two orders of magnitude short of his own stated design target.

CONDENSER

The period word for a capacitor: two conductors separated by an insulator, storing charge. The steel tanks on the site held banks of them.

SECTION 1 • THE MACHINE

What was the machine?

The tower was the top end of a chain of ordinary machinery. Every stage in the chain is documented, either in a patent or in the equipment list for the site.

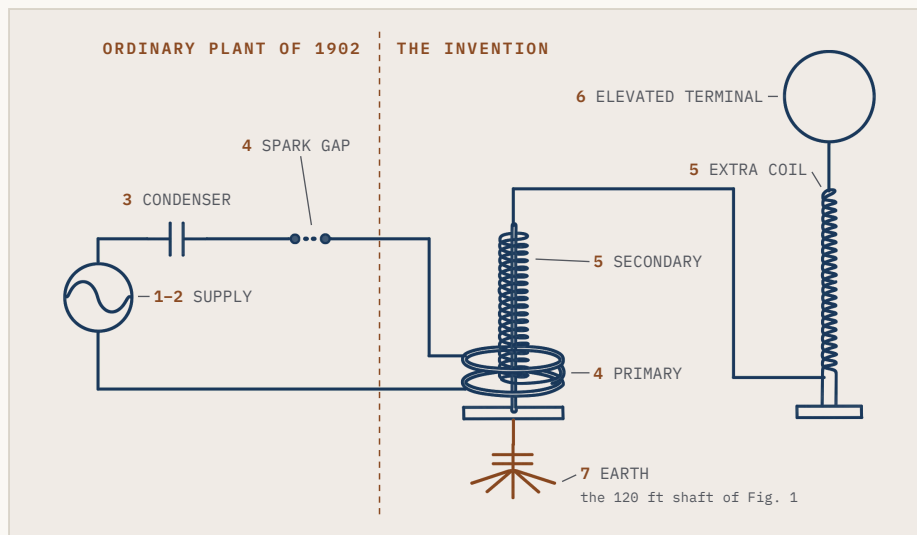


Fig. 2 – The path of the energy, in seven stages. The numbers are the stages below and overleaf; stages 1 and 2 stand behind the one source symbol. Three windings, not two: the extra coil is documented at Colorado Springs. Drawn for this document.

- 1 THE FIRE.** A steam plant stood inside the brick laboratory beside the tower: Westinghouse boilers, two steam engines of 100 horsepower each being installed in November 1901, and a direct-connected Westinghouse alternator rated at 200 kilowatts. The chimney on that building is the flue of a coal fire. It is the most useful object on the site, because it means the tower could not be switched on until somebody had bought coal — and there was a documented stretch when nobody could.
- 2 RAISING THE PRESSURE.** The alternator fed four Westinghouse transformers. The compiled equipment records for the site put the high side at around 60,000 volts.
- 3 STORAGE.** That current charged banks of condensers held in steel tanks, together with the regulating coils that fed the primary circuit.
- 4 THE SPARK.** The condensers discharged through a primary coil of a few turns. This is the step that converts a modest *continuous* power into an enormous *momentary* one: energy is gathered slowly and spent in a very short interval. A spark transmitter is a machine for doing exactly that. It is also the answer to a charge often laid against Tesla — that a 200-kilowatt plant could not possibly produce the ten million horse-power he wrote about. It could, for an instant, and instantaneous power is what he meant by *activity*. Section 8 sets out the arithmetic that is a genuine problem.

**WHY THE COILS WERE
THE SIZE OF ROOMS**

$$\lambda = c \div f$$

At the top of the permitted band, 20,000 cycles a second:

$$\lambda = 14,990 \text{ m} \approx 15 \text{ km}$$

A quarter of that in wire is

$$\approx 3,750 \text{ m (12,300 ft)}$$

of winding. Every frequency the patent allows is lower, so every wavelength – and every coil – is longer.

NOT 300 FEET DEEP

The shaft is 120 ft (37 m). The figure of about 300 ft (91 m), which appears in otherwise careful accounts, belongs to the iron pipes driven *outward* from the bottom of it.

NEVER PLATED

No evidence has been located that the copper skin was ever fitted. Photographs of the finished structure show the ribs bare, and the sources that mention copper describe it as an intention.

5 THE RESONANT RISE. The ringing primary drove a much larger secondary tuned to the same frequency, and at Colorado Springs a third winding as well – the *extra coil*, resonant with the rest. The voltage climbs because the circuits agree on a frequency, not because a mysterious force is involved. The patents fix a design rule for it: the length of the thin-wire coil “should be approximately one-quarter of the wave length of the electric disturbance in the circuit.”

6 THE TERMINAL. The top of the secondary went up the tower to a hemispherical steel rib-cage 68 ft (20.7 m) in diameter – 34 ft (10.4 m) in radius – generally put at 55 tons (50 t), which was to be closed in with copper plate so that the whole became one smooth insulated conducting ball. The reason for the size and the smoothness is stated flatly in the last of the four patents: “the smaller the radius of curvature the greater, for a given electric displacement, will be the surface-density and, consequently, the lower the limiting pressure to which the terminal may be charged without electricity escaping into the air.” The dome is a device for stopping the charge bleeding off into the sky. It is not an ornament and it is not a mystery.

7 THE GROUND. The bottom of the secondary went into a shaft 120 ft (37 m) deep and 12 ft (3.7 m) square, lined with 8-inch timbers, with a spiral stairway winding round a central steel shaft. Iron pipes were driven out from the bottom into the surrounding ground – period reports give sixteen pipes and a figure of about 300 ft (91 m) – and four tunnels of 100 ft (30 m) ran out from the foot. If the earth is to be the return conductor, the connection to it cannot be an afterthought. It has to be built as seriously as the terminal in the air, and it was.

Read as a circuit, the arrangement is a capacitor with one plate in the sky and the other underfoot. Driven at the right rate, it pumps charge onto the dome and off it again, and pushes a matching current into and out of the earth at the tower’s foot.

That is the whole of the hardware. None of it is exotic, and none of it makes energy. The four patents are titled, in order, a *system of transmission*, an *apparatus for transmission*, an *art of transmitting* and an *apparatus for transmitting*. Transmission is a delivery problem. Somebody, somewhere, still has to burn the coal.

Which leaves the question the whole scheme turns on, and the one a reader usually arrives with.

THE DOCUMENT THIS IS BUILT ON

US 787,412, *Art of Transmitting Electrical Energy Through the Natural Mediums*, filed 16 May 1900 (Ser. 112,034), renewed 17 June 1902, granted 18 April 1905 – the patent in which the earth-conduction premise is stated in Tesla’s own words, read together with US 645,576, US 649,621 and US 1,119,732. Full scans of all four are linked in the sources on page 14; the whole US grant list is at teslainfo.org/patents/.

THE BENCH EVIDENCE,
1897

The air-conduction claim rests on a laboratory observation stated in the patent itself: an insulating tube “of a length of fifty feet or more” (15 m) held at 120 to 150 millimetres of mercury, through which the discharge passed freely. Rarefied air conducts. Tesla had watched it conduct on his own bench.

WHAT THE CLAIMS CLAIM

In US 787,412, claims 1, 2, 3, 5 and 6 all claim the establishment of *stationary electrical waves in the earth*. Claim 6 goes as far as “shifting the nodal and ventral regions of these waves.” The patented invention is literally a standing wave in the planet.

DATED BY ITS OWN FILING

US 1,119,732 was filed on 18 January 1902, while the brickwork at Shoreham was still going up. The leakage was a problem before the tower was finished.

SECTION 2 · THE RETURN CIRCUIT

Where does the current come back?

A transmitter of this kind is half a circuit. The tower is the half you can see. Something has to carry the current back, and the four patents give three different answers.

Read in order of filing, they show a man changing his mind about the hardest question in his own scheme — which is why quoting one patent at a time produces three incompatible versions of what Wardencllyffe was.

1897 – THE RETURN PATH IS THE AIR

The earliest of the four, US 645,576, answers through the atmosphere. Its terminals are to be raised as high as possible, the specification going so far as to propose “a balloon at an elevation suitable for the purposes of transmission”, and the impulses are to be of an electromotive force sufficient “to render the air strata at or near the elevated terminal conducting.” Current then passes through those strata to a distant station tuned to them. The upper air is the wire.

1900 – THE RETURN PATH IS THE EARTH

By US 787,412 the emphasis has moved decisively downward. This is the document that states the premise most plainly, and the two sentences that carry the whole scheme are these:

the terrestrial globe may in a large part or as a whole behave toward disturbances impressed upon it in the same manner as a conductor of limited size ... the planet behaves like a perfectly smooth or polished conductor of inappreciable resistance

US 787,412, specification, filed 16 May 1900, granted 18 April 1905.

From that premise the rest follows: “the phenomenon of stationary waves with maxima and minima in definite fixed positions is produced.” Note what kind of statement *inappreciable resistance* is. It is not a measurement. It is an assumption, and section 6 is largely about what happens when it is dropped.

1902 – THE CHARGE ESCAPES ON THE WAY

The last of the four, US 1,119,732, opens by admitting the trouble: difficulties “in confining considerable amounts of electricity to the conductors and preventing its leakage over their supports, or its escape into the ambient air, which always takes place when the electric surface density reaches a certain value.” Its whole remedy is geometric — large radii of curvature everywhere, which is what the dome is for.

THE THREE ANSWERS, SIDE BY SIDE

1897 · US 645,576	The upper air, made conducting by the impulses themselves.
1900 · US 787,412	The body of the earth, as a conductor of limited size and inappreciable resistance.
1902 · US 1,119,732	No new path. Now the problem is the charge escaping before it goes anywhere.

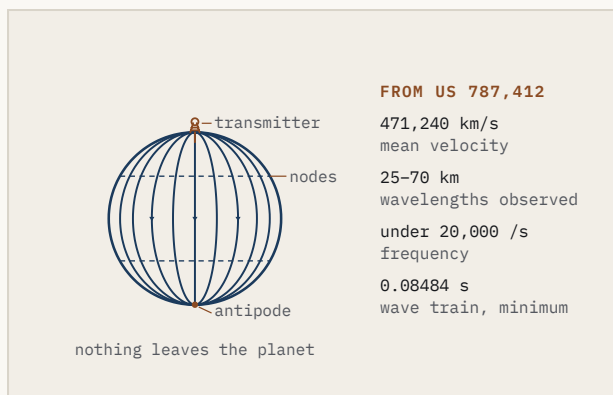


Fig. 3 – What Tesla believed was happening. A current driven into the ground reaches the far side of the planet and returns, and a transmitter tuned to that round trip holds a standing wave in the earth. The four figures beside it are his own, from US 787,412. Diagram drawn for this document.

ON “SCALAR WAVES”

The phrase appears in none of the four patents. It belongs to a much later literature. Invoking it does not rescue the scheme, because the objections in section 6 are objections about where the energy goes, and they apply to any carrier that conserves energy.

HELD TO THE END

Tesla was still denying that his system radiated in 1919, twelve years after Zeenneck and ten after Sommerfeld had worked out propagation over a finitely conducting earth.

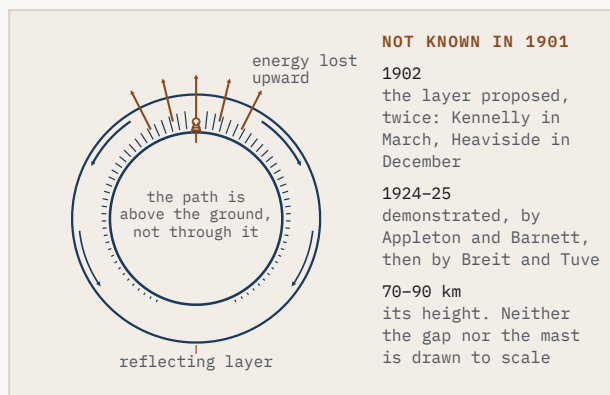


Fig. 4 – What is actually happening. Energy at these frequencies does circle the earth, guided in the gap between the ground and the ionised layers overhead, at roughly 70 km by day and 85 to 90 km by night. That layer was demonstrated in 1924-25. Diagram drawn for this document.

WHAT THE PATENTS DO NOT SAY

Two later reconstructions circulate, both offered by readers closing the circuit on Tesla’s behalf. One fires a collimated ultraviolet or X-ray beam upward from the dome to burn a conducting corridor to the rarefied upper air. The other has the charge on the dome ionising the air above it spontaneously, handing the current to the high atmosphere by electrostatic induction.

Neither is in the specifications. No drawing, claim or note has been located in which Tesla describes either arrangement. Both supply a return path that the patents supply differently – and the aperture at the crown of the dome, sometimes offered as evidence for the first, proves nothing: the dome was a bare rib cage, open everywhere, because the copper skin was never fitted.

The chronology settles it. The conducting layer such a corridor would have to reach was not known to exist while the tower was going up. It was *proposed* in 1902, independently, by Kennelly in March and Heaviside in December, to explain how Marconi’s signal had crossed the Atlantic at all, and *demonstrated* by Appleton and Barnett in 1924 and Breit and Tuve in 1925. In 1901 there was no ionosphere to aim at.

His own answer never wavered after 1900, and he put it in print:

the transmission thru the earth is in every respect identical to that thru a straight wire ... the signals picked up by the instruments must actually be induced by earth currents – not etheric space waves

Nikola Tesla, “The True Wireless”, *The Electrical Experimenter*, May 1919, pp. 28-30, 61-63, 87. Spelling as published.

That is the answer to the question this document is named for. The return path is the ground; the air above a certain height was the earlier answer, and survived only as a secondary return. Wardencliff was not an early radio station that ran out of money. It was a different theory of how a signal crosses the world, and the difference between it and the theory that turned out to be true is drawn above.

THE DOME AS A CAPACITOR

An isolated sphere of radius r has

$$C = 4\pi\epsilon_0 r$$

With $r = 10.36$ m (34 ft):

$$C \approx 1.15 \text{ nF}$$

To resonate that at 20,000 cycles a second:

$$L = 1 \div (2\pi f)^2 C \approx 55 \text{ mH}$$

A large coil, but an entirely buildable one.

The design is arithmetically coherent. It is the premise that fails, not the engineering.

Q, IN ONE LINE

The quality factor is how many times energy sloshes back and forth before losses eat it. High Q , large rise. Low Q , no rise at all.

WHERE IT SURVIVES

The resonant transformer itself was sound and is still built: lecture and museum demonstration, leak-testing of vacuum in glass and neon work, high-voltage insulation testing.

SECTION 3 • RESONANCE

What is resonance doing here?

Resonance multiplies voltage. It does not multiply energy, and it collapses when the resonator is lossy. Almost every confused claim about Wardenclyffe comes from mixing up the first sentence with the second.

A tuned circuit builds a large oscillation out of small pushes delivered in step, the way a child on a swing goes higher on small shoves timed to the swing. Nothing is created. Energy is accumulated, cycle by cycle, and how much accumulates before losses eat it is set by the resonator's quality factor.

The Colorado Springs machine — the *magnifying transmitter* — was an air-cored resonant transformer scaled up to the size of a building: a primary about 50 ft (15 m) across running round the wall of the shed, a secondary within it, and a third winding, the extra coil, resonant with the rest and joined at its top to the elevated terminal. The third coil is the real point of difference from a lecture-bench Tesla coil, and it is genuinely clever: it raises the terminal to a very high potential at the chosen frequency *without* raising the voltage across the insulation of the first two windings.

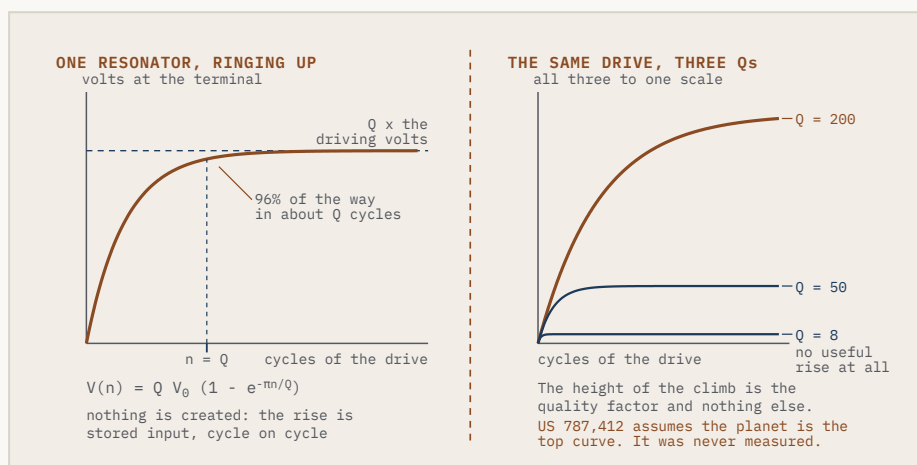


Fig. 5 – Resonance, drawn honestly. Left: one resonator driven at its own frequency climbs toward Q times the driving volts, and is 96 per cent of the way there after about Q cycles. Right: the same drive into three resonators, so the heights stand as the quality factors do. A lossy resonator does not ring, however well it is tuned. The two panels are scaled differently and each says which. Drawn for this document.

Now put the two halves together. The planetary claim in US 787,412 is a claim that the earth is a resonator, and the sentence that makes it work is the one calling the planet a conductor of *inappreciable resistance*. In the language of this section, that is an assumption that the planetary resonator has an enormous Q . The assumption does all of the work in the scheme, and it is the one thing in the patent that was never measured.

The transmitter at the near end is not the weak part. The arithmetic in the margin shows a machine that was correctly sized for the job it was designed to do. What fails is the thing it was designed to drive.

THE STATION

Knob Hill, east of Colorado Springs, May 1899 to January 1900. A wooden shed about 50 × 60 ft (15 × 18 m) with a roll-back roof section, and a mast about 142 ft (43 m) carrying a copper-sheathed wooden ball about 30 in (76 cm) across. The current was supplied free by the local electric company.

THE RECORD

About five hundred pages of dated entries and close to two hundred drawings, 1 June 1899 to 7 January 1900, published in facsimile in 1978. A daily notebook is a different kind of object from a memoir: it records the runs that failed, on the day they failed.

NOT LOCATED

Any measurement from the July 1903 tests at Shoreham. No log, no instrument reading, no observation by a third party with an instrument. Newspaper reports of flashes are the whole of the record.

SECTION 4 • THE EVIDENCE

What did Tesla actually demonstrate?

The earth-conduction claim was not arrived at in an office. Tesla believed he had measured it, and the place he believed he had measured it was Colorado Springs.

The decisive entry is dated 3 July 1899. A heavy storm passed over the station and moved away eastward. As it receded, his receiving instruments did not simply fade: by his account they passed through a repeating series of maxima and minima, going quiet and then recovering, until the storm was some 300 km off. He read that pattern as nodes and antinodes — as evidence that the discharges were setting up a standing wave in the earth itself, with fixed places of strength and weakness. He regarded it for the rest of his life as the most important thing he ever found, and it is the observation that US 787,412 rests on.

The same observation has a different explanation now. A receiver watching a source that is moving away sees exactly that pattern of fading and recovery when the wave travelling along the ground interferes with waves returning from the conducting layers of the upper atmosphere. That explanation was unavailable in 1899, for the plain reason that nobody yet knew there was a layer up there to reflect anything.

The measurement was real. The inference was the error. That is the fair verdict, and it is a different verdict from the one usually handed down in either direction.

WHAT THE RECORD DOES NOT CONTAIN

What the notes hold is settings, readings and sketches. What they do not hold is energy delivered at a distance. No independent measurement of the transmitter's output exists, and whether the extra coil was ever operated at the terminal voltages claimed for it is not settled by anything located.

One episode from the station is well documented and worth stating accurately, because it is usually told bigger than it was. High-frequency currents driven back into the supply destroyed the insulation of the generating company's dynamos some miles away; Tesla described the failure himself in *The Electrical Experimenter* in August 1917. No contemporary Colorado Springs newspaper report of a city-wide blackout has been located. The station never ran again after 7 January 1900. The building was pulled down in 1904 and the timber sold to satisfy a judgment of \$180.

At Shoreham the evidential position is thinner still. Neighbours reported flashes and noise from the tower at night in July 1903, and the press picked the reports up — the *New York Sun* of 17 July 1903 has “all sorts of lightning were flashed from the tall tower and poles last night.” That is the entire surviving record of the tower in operation. Tesla and his staff left in the autumn of 1906.

APPROXIMATE FIGURES

The parcel is given as about two hundred acres in the modern accounts and in the compiled 1901 local reporting; the 1968 local history, closest to the county records, prints no acreage at all. The building is 94 ft square in the site's own historical material and "100 feet square" in the *Port Jefferson Echo* of February 1902.

NOT LOCATED

The March 1901 agreement itself. No text or scan of the instrument has been found in any public repository. Every account of its terms – the \$150,000, the fifty-one per cent, the scope – is secondary, and the accounts agree with one another.

SECTION 5 • THE BUILD

What was built, and what it paid for

Land	About 200 acres at Shoreham, Suffolk County, taken in 1901 from James S. Warden, a lawyer and land-company director who wanted a reason for people to settle there. The place is named Wardencllyffe for him.
Announced	<i>Port Jefferson Echo</i> , 2 August 1901: a contract closed for a "wireless telegraph plant and electrical laboratory", work to start in thirty days.
Building	Brick, 94 ft (28.7 m) square, one and a half storeys, nine bays by nine, side-gabled, central chimney. Boiler room, engine and dynamo room, machine shop, laboratory.
Architects	McKim, Mead & White; the partner on the job was Stanford White. The tower was drawn by an associate in his office.
Tower	187 ft (57 m), octagonal timber lattice, members cut on the ground and hoisted, about 100 ft (30 m) across at the base.
Dome	Hemispherical steel rib-cage, 68 ft (20.7 m) in diameter, about 55 tons (50 t). Designed to be plated in copper; never plated.
Shaft	120 ft (37 m) deep, 12 ft (3.7 m) square, timber-lined, spiral stair, iron pipes driven outward, four tunnels of 100 ft (30 m).
Plant	Westinghouse boilers; two 100 hp steam engines installing November 1901; a direct-connected 200 kW Westinghouse alternator; four transformers; condenser tanks; regulating coils.
Worked	Tesla worked at the laboratory from 1902 to 1906; the tower was standing by early 1903.

WHAT THE MONEY WAS FOR

In June 1900 *The Century Magazine* carried a long and extremely confident essay by Tesla on the transmission of energy. Among the people it reached was J. Pierpont Morgan, who in March 1901 contracted to advance \$150,000 for a controlling interest – the figure normally given is fifty-one per cent – in the wireless patents and in whatever the venture produced.

What that bought, in a banker's language, was **transatlantic wireless telegraphy**. Not electricity delivered to houses: messages, and the businesses that hang off messages. Tesla's published prospectus is specific, and astonishing to read now. A subscriber station was to distribute universal time by "simple inexpensive clocks requiring no attention and running with nearly mathematical precision"; "stock-tickers, synchronous movements and innumerable devices of this character could be worked in unison all over the earth"; instruments would indicate "the course of a vessel at sea, the distance traversed, the speed, the hour at any particular place, the latitude and longitude." Elsewhere he describes the interconnection of telegraph exchanges, private transatlantic telephony, and the reproduction of writing and pictures at a distance.

Those are information services, and they are the businesses Morgan already owned or financed. They are also, item by item, a description of what wireless would in fact be used for. He was wrong about the physics and right about the demand.

THE CLAIMS CAME AFTER THE MONEY

The sweeping public statements – power “in unlimited amounts, to any terrestrial distance and almost without loss”, an activity of ten million horse-power – were published in March 1904 and January 1905, after Morgan had already refused to advance anything further. They were in part an attempt to restart the funding.

NOT LOCATED

Any government order to demolish the tower, from any department, in a century of looking. What exists on paper is the mortgages, the 1915 transfer of the deed and the 1922 appeal record.

WHY IT STOPPED

The 1903 correspondence is the closest thing to a transcript of the collapse. On 8 April Tesla wrote about costs; on 22 April he tried gratitude, thanking Morgan for help given “at a time when Edison, Marconi, Pupin, Fleming, and many others openly ridiculed my undertaking.” Then, on 3 July, having explained at last that the plant was to transmit power and not only intelligence, he wrote:

If I would have told you such as this before, you would have fired me out of your office. Will you help me or let my great work – almost complete – go to pots?

Nikola Tesla to J. P. Morgan, 3 July 1903. Quoted from a published transcription of the Wardenclyffe correspondence; the originals were not examined.

Morgan answered on 14 July without argument: “I should not feel disposed at present to make any further advances.” He gave no reason, then or later. Read together, the letters show something unlike the legend: Tesla is telling a man who bought a telegraph company that he has been building something else, and asking him to fund it. The word that appears nowhere in the exchange is *suppression*.

One other event decided matters, eleven hundred miles to the north-east. On 12 December 1901, on Signal Hill above St John’s, Newfoundland, Marconi reported hearing the three dots of the Morse letter S sent from Cornwall on a kite-borne aerial. That reception has never been independently verified. It made no difference. What decided where the money went was not whether the letter S crossed the Atlantic but that the newspapers, the investors and the cable companies believed it had – on a kite and a length of wire, while Shoreham consumed a fortune in brick, steel and steam plant.

FROM PROJECT TO DEBT

1904, 1908	The property mortgaged twice, to the proprietor of the Waldorf-Astoria, against unpaid hotel bills.
1906	Tesla and his staff leave in the autumn; neighbours notice the plant abandoned without notice.
1912	Westinghouse takes judgment for machinery supplied: \$23,500.
1915	The deed passes to the hotel company against a debt of about \$20,000.
4 July 1917	A New York steel contractor dynamites the tower for scrap. The charge does not bring it down and the work runs on to Labour Day. The scrap realises \$1,750 above the cost.
20 April 1922	Tesla loses his appeal on the foreclosure judgment.
1939	The site is leased to a photographic-materials works – the mundane reason the laboratory survived at all. Somebody kept the roof on.

The wartime rumour – that the government ordered the tower destroyed because German agents were using it – was current at the time and has never been supported by a document. A creditor sold timber and steel to recover a debt, in a war, when scrap was worth having. The duller explanation did not circulate because the mortgages and the foreclosure had been kept off the public record.

GROUND RESISTIVITY

Not a constant of nature. A few ohm-metres in wet clay; hundreds to thousands in dry sand, granite and permafrost. It varies by orders of magnitude across a single continent, and it changes with the weather.

WHERE THE LOSS HAPPENS

An earth return works at all because the cross-section is enormous. But the resistance of a real path is dominated by the region close to the electrode, where the current is crowded into a small volume before it spreads. That crowded volume is where energy is turned into heat, and heat does not come back.

SECTION 6 • THE PHYSICS

Why the power half cannot work

Four objections. Each is sufficient on its own, and none of them is an objection to Tesla's competence. They are objections to a specific, testable engineering claim, which is the only kind of claim worth arguing with.

1 • THE RETURN PATH IS NOT WHERE THE PATENTS PUT IT

US 645,576 asks for conducting air at a height a balloon can reach, on the strength of a tube 50 ft (15 m) long at a hundred-odd millimetres of mercury. The atmosphere does not become usefully conducting at balloon heights. It becomes conducting tens of kilometres higher. A mast of 187 ft (57 m) is not a shortened version of a 50-kilometre one; it is a different problem.

2 • THE EARTH IS A CONDUCTOR, BUT A LOSSY ONE

The premise of US 787,412 is a planet of "inappreciable resistance." Real ground is nothing of the kind, and the losses are concentrated exactly where the scheme puts its electrodes. Everything the patent claims about standing waves follows from that one unmeasured assumption, and nothing survives without it.

3 • THE GEOMETRY CANNOT BE ARGUED WITH

This is the objection that no improvement in materials or engineering can touch. A transmitter designed to establish an oscillation over the whole planet has, by construction, divided its output across the whole planet. A receiving station collects only the share that crosses its own small aperture. Tesla's own arithmetic gives it away: one per cent of ten million horse-power is "amply sufficient to girdle the globe" — but girdling the globe is the opposite of delivering to a customer.

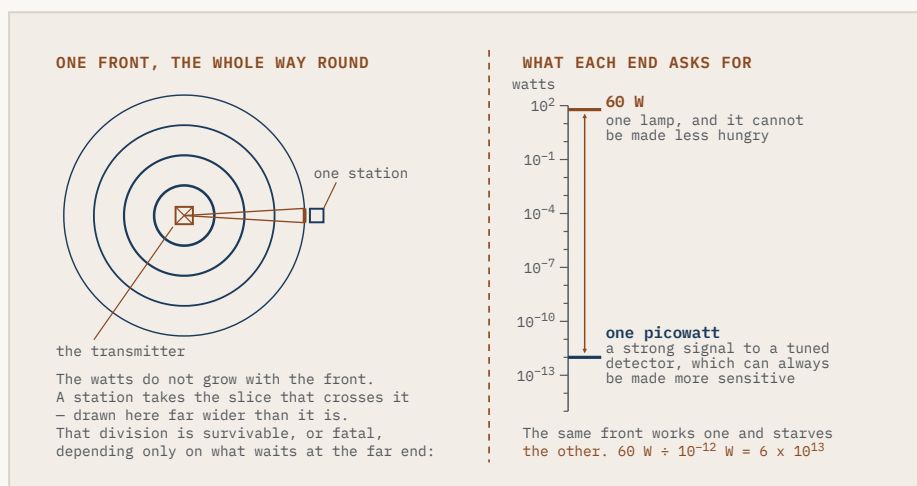


Fig. 6 — Why the same premise supports telegraphy and refuses power. Left: the watts do not grow with the front, so a station takes only the slice that crosses it. Right: what each end asks of that slice. A receiver survives the division: it can be made more sensitive, and only has to tell a dot from a dash. A lamp cannot, and needs the actual watts. Drawn for this document.

HOW SMALL THE TOWER IS, ELECTRICALLY

At 20,000 cycles a second, $\lambda = 14,990$ m.
The tower is 57.0 m:

$$h \div \lambda = 0.0038$$

For a short monopole over a ground plane,

$$R_T = 40\pi^2(h \div \lambda)^2$$

$$R_T \approx 5.7 \text{ m}\Omega$$

Ideal top loading – which is what the dome is – can raise the effective height toward twice and R_T toward four times:

$$\approx 23 \text{ m}\Omega$$

Against coil, ground-system and corona losses of the order of ohms, the radiating efficiency is of the order of one per cent.

THE METERING OBJECTION

A scheme in which anyone with a ground rod and a tuned coil can draw from the common oscillation has no meter in it. That is a real flaw in the business proposition, and it is commercial rather than physical. No document has been located in which Morgan, or anyone else at the time, gives it as a reason for anything.

4 • THE TOWER IS ELECTRICALLY TINY

At any frequency the patents allow, the wavelength is 15 km or more, and a radiator 187 ft (57 m) high is about one two-hundred-and-sixtieth of it. The arithmetic is in the margin. A structure of those proportions radiates a few milliohms' worth against losses measured in ohms; nearly everything put into it sloshes back and forth as stored energy and leaves as heat and glow. This is not an incidental defect. It is precisely the problem US 1,119,732 was filed to fight, the dome was the fix, and the fix was not sufficient.

THE EMPIRICAL CEILING, AND IT IS NOT A SIMULATION

There is one full-scale test of Tesla's regime, built by people with a century of additional engineering and a superpower's budget. To reach submerged submarines the United States Navy built an extremely-low-frequency transmitter, using the earth and the ionosphere as the guiding structure – which is Tesla's territory exactly. Two sites in Wisconsin and Michigan drove earthed antenna lines 14 and 28 miles (23 and 45 km) long on a combined input of about 2.6 megawatts, and radiated on the order of 8 watts. That is three parts in a million. A three-letter code group took about fifteen minutes to send. The system was operational from 1989 until 2004.

It worked, as a communications channel, which is the point. It is not a power grid, and no better hardware makes it one, because the loss is in the channel and not in the machinery at either end. Tesla's signalling instinct is vindicated by that installation. His power claim is refuted by the same installation, using the same numbers.

WHERE THE POPULAR ACCOUNT UNDERSTATES HIM

- The prospectus is a startlingly accurate forecast of what wireless would be used for: global time synchronisation, market data distributed in unison, position and speed at sea, facsimile, private transatlantic voice. He was describing network services in 1904.
- The transmitter itself was sound and original. The three-coil arrangement raises terminal voltage without stressing the earlier windings; the dome's radius of curvature is a correct solution to corona; the 120-foot shaft treats the earth connection as seriously as the aerial, which plenty of later radio engineers failed to do.
- He made the scheme checkable. Cranks do not print velocities, wavelengths and time intervals in granted patents, and they do not leave five hundred pages of dated measurements for anyone to read. Wardencllyffe can be called wrong, rather than merely doubted, precisely because Tesla published numbers.
- The Colorado Springs observation was real. Something in the propagation of that receding storm did produce maxima and minima. Explaining it needs an ionosphere he did not have.

SECTION 7 • THE LEDGER

Proposed, demonstrated, never worked

THE ELEMENT	WHAT TESLA PROPOSED	WHAT WAS DEMONSTRATED	WHAT NEVER HAPPENED
The resonant transmitter	A three-coil air-cored transformer raising a terminal to a very high potential at one frequency.	Built and run at Colorado Springs and at Shoreham. The principle is sound and is still used.	Nothing. This part worked, it is his, and it is not in dispute.
The earth as a resonator	A standing wave in the planet with fixed nodes. US 787,412, claims 1, 2, 3, 5, 6.	One observation, 3 July 1899: maxima and minima as a storm receded.	No standing wave in the earth has been measured. The 1899 pattern has another explanation.
Transatlantic telegraphy	A handful of plants covering the world; the World System prospectus, 1904-05.	Nothing from Shoreham. Flashes and noise in July 1903, unmeasured.	No signal was ever reported received from the tower, by anyone.
Power without wires	Power "in unlimited amounts, to any terrestrial distance and almost without loss."	Lamps lit within a laboratory, at laboratory distances.	No usable power delivered at any distance, then or since, by this method.
The copper dome	A smooth plated sphere to hold charge without corona loss.	The steel rib-cage was erected in 1903.	The plating was never fitted. The tower stood unfinished until it was demolished.

SECTION 8 • CORRECTIONS

Eight things the popular account gets wrong

THE CLAIM	STATUS	WHAT THE RECORD HOLDS
Wardenclyffe would have given the world free, unlimited energy.	FALSE	Every document in the scheme describes transmission; none describes generation. A coal-fired plant with a 200 kW alternator stood on the site, and the chimney is still there.
The government destroyed the tower to suppress it.	FALSE	No order from any department has ever been produced. The paper trail is two mortgages, a Westinghouse judgment, the 1915 deed and a scrap demolition in 1917.
Tesla discovered the Schumann resonance in 1899.	FALSE	His own published interval of 0.08484 s implies 11.79 Hz; the cavity fundamental is 7.83 Hz. Crediting him with it means discarding the only number he printed. Schumann derived it in 1952.
Morgan withdrew because wireless power could not be metered.	UNVERIFIABLE	The flaw is real; the attribution is not. No letter, interview or report has been located in which anyone puts that objection to Morgan. His refusal gives no reason at all.
The tower was finished and Tesla operated it.	FALSE	The dome was never plated, no measurement of any transmission survives, and Tesla left in the autumn of 1906.
A 200 kW plant could not make ten million horse-power, so he was lying.	FALSE	Activity, in his usage, is instantaneous power, and a spark discharge delivers an enormous one from a modest continuous supply. The checkable problem is different: 200 kW is 268 hp, against his own 1905 target of 10,000 hp.
The Supreme Court ruled in 1943 that Tesla invented radio.	TRUE BUT MISATTRIBUTED	320 U.S. 1 was a money case about the government's wartime liability. It invalidated Marconi's tuning claim on prior art that was mostly Stone's and Lodge's; Tesla is one of three. teslainfo.org/marconi-v-united-states-1943/
The tower was a death ray.	FALSE	A straight conflation. Teleforce – a charged-particle beam – was announced in July 1934, seventeen years after the tower came down. Nothing connects the two.

SECTION 9 • THE SITE

What stands at Shoreham today

Stated as at August 2026. The tower has not existed since 1917. What survives is sixteen acres of the property and the brick laboratory on it, owned since 2013 by the Tesla Science Center at Wardenclyffe and listed on the National Register of Historic Places in July 2018 (ref. 100002744). A fire on 21 November 2023 took the roof, the chimney cap and the cupola; the 1901 brick shell held, and the damage was put above \$3 million. Restoration continues and the laboratory is not open. A purpose-built visitor centre, the first on the site, was dedicated on 11 July 2026. Current visiting arrangements are published at teslasciencecenter.org.

Sources, and what could not be found

PRIMARY DOCUMENTS

- Nikola Tesla, **US 645,576**, *System of Transmission of Electrical Energy*, filed 2 Sep 1897 (Ser. 650,343), granted 20 Mar 1900. patents.google.com/patent/US645576A
- Nikola Tesla, **US 649,621**, *Apparatus for Transmission of Electrical Energy*, filed 19 Feb 1900 (Ser. 5,780), a division of Ser. 650,343, granted 15 May 1900. patents.google.com/patent/US649621A
- Nikola Tesla, **US 787,412**, *Art of Transmitting Electrical Energy Through the Natural Mediums*, filed 16 May 1900 (Ser. 112,034), renewed 17 Jun 1902, granted 18 Apr 1905. patents.google.com/patent/US787412A
- Nikola Tesla, **US 1,119,732**, *Apparatus for Transmitting Electrical Energy*, filed 18 Jan 1902 (Ser. 90,245), renewed 4 May 1907, granted 1 Dec 1914. patents.google.com/patent/US1119732A
- Nikola Tesla, *Colorado Springs Notes, 1899–1900*, Nolit, Belgrade, 1978 – facsimile of the daily record.
- Nikola Tesla, “The Problem of Increasing Human Energy”, *The Century Magazine*, vol. LX no. 2, June 1900, pp. 175–211.
- Nikola Tesla, “The Transmission of Electrical Energy Without Wires”, *Electrical World and Engineer*, 5 March 1904, pp. 429–431.
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- Nikola Tesla, “The True Wireless”, *The Electrical Experimenter*, May 1919, pp. 28–30, 61–63, 87.
- Nikola Tesla, “Tesla’s Views on Electricity and the War”, *The Electrical Experimenter*, August 1917 – the damaged dynamos.
- Tesla–Morgan correspondence, 8 and 22 April, 3 and 14 July 1903, from published transcriptions. Originals not examined.
- *Port Jefferson Echo*, 2 Aug 1901 and Feb 1902; *Brooklyn Eagle*, 8 Feb 1902; *New York Sun*, 17 Jul 1903 – as quoted in compiled chronologies.
- “Tesla, at 78, Bares New ‘Death-Beam’”, *The New York Times*, 11 July 1934, p. 1.
- *Marconi Wireless Telegraph Co. v. United States*, 320 U.S. 1 (1943), decided 21 Jun 1943. supreme.justia.com/cases/federal/us/320/1/
- *Wardenclyffe Laboratory*, National Park Service; National Register of Historic Places ref. 100002744, listed 27 Jul 2018.
- Marc Seifer, *Wizard: The Life and Times of Nikola Tesla*, Birch Lane, 1996.
- J. S. Belrose, “Fessenden and Marconi: Their Differing Technologies and Transatlantic Experiments”, *IEEE 100 Years of Radio*, conf. pub. 411, September 1995, pp. 32–43.
- J. Zenneck, *Annalen der Physik* 23 (1907), 846–866; A. Sommerfeld, *Annalen der Physik* 28 (1909), 665–736 – propagation over a finitely conducting earth.
- A. E. Kennelly, “On the Elevation of the Electrically-Conducting Strata of the Earth’s Atmosphere”, *Electrical World and Engineer*, 15 Mar 1902; O. Heaviside, “Telegraphy”, *Encyclopædia Britannica*, 10th ed., 1902.
- E. V. Appleton and M. A. F. Barnett, “Local Reflection of Wireless Waves from the Upper Atmosphere”, *Nature* 115 (1925), 333–334; G. Breit and M. A. Tuve, pulse-sounding work of 1925.
- W. O. Schumann, *Zeitschrift für Naturforschung A* 7 (1952), 149–154; M. Balser and C. A. Wagner, “Observations of Earth–Ionosphere Cavity Resonances”, *Nature* 188 (1960), 638–641.
- D. L. Jones, “Sending Signals to Submarines”, *New Scientist*, 4 July 1985, pp. 37–41 – the US Navy extremely-low-frequency system.
- Longer treatments of sections 5, 6 and 8: teslainfo.org/wardenclyffe-what-the-tower-was-for/ and teslainfo.org/what-tesla-actually-proposed-wireless-power/

LOOKED FOR AND NOT FOUND

- The March 1901 Morgan agreement itself. No text or scan in any public repository; all accounts of its terms are secondary.
- Originals of the 1903 letters. Published transcriptions only.
- Any document giving Morgan a reason for stopping, metering or otherwise.
- Any government order to demolish the tower, from any department.
- Any evidence that the dome was ever plated in copper.
- Any measurement from the July 1903 tests at Shoreham.
- Any Colorado Springs newspaper report of a city-wide outage attributed to the station.
- Any figure near 7.8 cycles a second anywhere in Tesla’s published wireless patents. US 787,412 implies about 11.8.
- Any specification, drawing or note describing a beam projected upward from the dome, or a corridor of ionised air above it.

FURTHER READING AND TECHNICAL LITERATURE

- Leland I. Anderson, “Wardenclyffe – A Forfeited Dream”, *Long Island Forum*, Aug 1968, pp. 146–149, and Sep 1968, pp. 169–172.
- W. Bernard Carlson, *Tesla: Inventor of the Electrical Age*, Princeton, 2013.

ARITHMETIC

- Every calculation in the margins was computed for this document from figures in the sources above, with its formula shown – $\lambda = c/f$; $C = 4\pi\epsilon_0 r$; $L = 1/(2\pi f)^2 C$; $R_x = 40\pi^2 (h/\lambda)^2$ – so a reader can redo them.