Resonance Is Not Capture:
A Poynting-Theorem View of Tesla's Wireless Power Dream

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Abstract

Nikola Tesla's Wardenclyffe design may be read, in modern language, as a high-voltage resonant transmitter coupled to the Earth, atmosphere, and a distant tuned receiver. The seductive assumption is that sufficiently sharp resonance turns distance into a secondary issue: excite the planetary circuit, tune the receiver, and extract power. This note gives a compact electromagnetic obstruction to that view. Poynting's theorem forces an accounting in which the useful load competes not merely with detuning, but with ground dissipation, corona, dielectric loss, conductor heating, and uncaptured radiation. We formulate a small resonant-capture bound: for a passive single-mode system with load, environmental, and apparatus damping rates, the load efficiency is bounded by the fraction of modal damping assigned to the load. The theorem is elementary, but it cleanly separates two facts often confused in discussions of Tesla's scheme: resonance can increase stored energy, while capture determines where that energy goes. A Wardenclyffe-scale worked estimate, a distance bound, and two small numerical plots make the obstruction visible. We then describe two modern descendants that survive by changing the coupling problem: resonant near-field magnetic transfer and directed RF/microwave power beaming.

1 The beautiful wrong question

Tesla's wireless-power apparatus was not a vague wish for electricity without wires. In his 1900 patents, the transmitting system is explicitly described as an electrical transformer whose secondary is connected to ground and to an elevated terminal, with a distant receiving system similarly connected and tuned to the same oscillations [1, 2]. Wardenclyffe, the large Long Island tower begun in 1901, was intended as an enormous version of this idea: a roughly 187-foot tower with a 68-foot metal dome and a substantial underground grounding system [3].

In a modern sketch, the proposed power path was

$$\text{source} \longrightarrow \text{high-voltage resonator} \longrightarrow \text{Earth/air medium} \longrightarrow \text{tuned receiver} \longrightarrow \text{load.}$$

This picture is almost mathematically irresistible. A resonator stores energy. A tuned receiver responds selectively. A grounded transmitter suggests a natural return path. One sees the whole planet, for an instant, as a quiet circuit element waiting to be included.

The trouble is that the question "Can the receiver respond?" is not the same as the question "Can the receiver capture most of the input power?" Tesla's demonstrations and apparatus made the first question plausible. Wardenclyffe needed the second.

The distinction is the whole note.

2 Poynting bookkeeping

Let V be a volume enclosing the transmitter, the relevant part of the Earth/air channel, and the receiver. Poynting's theorem gives

$$\frac{\partial u}{\partial t} + \nabla \cdot \mathbf{S} = -\mathbf{J} \cdot \mathbf{E}, \tag{1}$$

where

$$u = \frac{1}{2}\epsilon|\mathbf{E}|^2 + \frac{1}{2}\mu|\mathbf{H}|^2, \qquad \mathbf{S} = \mathbf{E} \times \mathbf{H}. \tag{2}$$

For a time-periodic steady state, averaging over one cycle gives a power balance. The source power must be either delivered to the load, dissipated in material degrees of freedom, stored and released cyclically, radiated away, or reflected/mismatched before entering the intended mode. In the Wardenclyffe idealization, the balance has the form

$$P_{\text{in}} = P_{\text{load}} + P_{\text{coil}} + P_{\text{ground}} + P_{\text{corona}} + P_{\text{diel}} + P_{\text{rad}} + P_{\text{mismatch}}. \tag{3}$$

The Tesla-favorable approximation is essentially

$$P_{\text{in}} \approx P_{\text{load}} + \varepsilon, \qquad \varepsilon \ll P_{\text{load}}. \tag{4}$$

The modern electromagnetic accounting says that ε is not one small term. It is a cabinet full of knives.

For example, finite conductivity in the ground gives ohmic loss

$$P_{\text{ground}} = \int_{\text{Earth}} \sigma(\mathbf{x})|\mathbf{E}(\mathbf{x})|^2 \, dV. \tag{5}$$

The Earth conducts, but finite conduction is not a gift: it is a heating mechanism. Similarly, high electric fields near the elevated terminal may create corona or ionized air currents, with loss

$$P_{\text{corona}} = \int_{\text{ionized air}} \mathbf{J}_{\text{ion}} \cdot \mathbf{E} \, dV. \tag{6}$$

The tower is also an oscillating charge-current distribution, and so radiated power appears as outward Poynting flux,

$$P_{\text{rad}} = \oint_{S_\infty} (\mathbf{E} \times \mathbf{H}) \cdot d\mathbf{A}. \tag{7}$$

If this radiation is not intercepted and rectified by the receiver, it is a loss for power delivery even when it is perfectly real electromagnetic power.

The uncomfortable moral is simple:

$$\text{field existence} \neq \text{field capture}. \tag{8}$$

A lamp may glow at a distance while almost all of the supplied power has gone elsewhere.

3 A numerical parable

Since Wardenclyffe did not operate as a completed wireless-power station, the following numbers are not historical measurements. They are an order-of-magnitude parable for the difference between a Tesla-favorable loss model and a modern loss model. Normalize the input to

$$P_{\text{in}} = 200\,\text{kW}.$$

At a representative radio frequency and tower scale, one might model conductor and environmental channels by effective resistive or radiative losses proportional to a large circulating resonant current. The exact values are less important than the hierarchy: in the favorable model, environmental rates are small; in the modern model, they are not.

Power channel	Tesla-favorable model	Modern order-of-magnitude model
Useful load	176 kW	2 kW
Coil/conductor heating	4.5 kW	18 kW
Ground/Earth heating	4.5 kW	81 kW
Uncaptured radiation	1.8 kW	51 kW
Corona/ionized air	2 kW	20 kW
Dielectric loss	1 kW	5 kW
Atmospheric leakage	0.5 kW	3 kW
Detuning/weak coupling	5 kW	15 kW
Receiver-side loss	5 kW	5 kW
Total	200 kW	200 kW
Efficiency	88%	1%

The table should not be read as a reconstruction of Tesla's apparatus. It is a scale-separated reminder: if the Earth/air channel is a high-Q participant, the dream looks plausible; if it is a lossy open electromagnetic object, the denominator of the efficiency expression fills up before the receiver has eaten dinner.

A few back-of-the-envelope values produce the modern column. Take a large circulating resonant current

$$I_{\text{rms}} = 300 \text{ A}. \tag{9}$$

Three ordinary channels may then be written as

$$P_{\text{coil}} = I_{\text{rms}}^2 R_{\text{ac}}, \qquad P_{\text{ground}} = I_{\text{rms}}^2 R_{\text{ground}}, \qquad P_{\text{rad}} = I_{\text{rms}}^2 R_{\text{rad}}. \tag{10}$$

For an effective high-frequency conductor resistance $R_{\text{ac}} = 0.2\,\Omega$, the coil loss is

$$P_{\text{coil}} = (300)^2(0.2) = 18,000 \text{ W} = 18 \text{ kW}. \tag{11}$$

For a ground resistance $R_{\text{ground}} = 0.9\,\Omega$, the ground heating is

$$P_{\text{ground}} = (300)^2(0.9) = 81 \text{ kW}. \tag{12}$$

For radiation, model the tower crudely as a short vertical radiator. If $h = 57$ m and $f = 100$ kHz, then $\lambda = c/f \approx 3000$ m, and

$$R_{\text{rad}} \sim 160\pi^2 \left(\frac{h}{\lambda}\right)^2 \approx 160\pi^2 \left(\frac{57}{3000}\right)^2 \approx 0.57\,\Omega. \tag{13}$$

Thus

$$P_{\text{rad}} \approx (300)^2(0.57) \approx 51 \text{ kW}. \tag{14}$$

Already, before corona, dielectric loss, atmospheric leakage, and detuning are included, three mundane terms account for roughly

$$18 + 81 + 51 = 150 \text{ kW} \tag{15}$$

out of a 200 kW input. This is the arithmetic version of the complaint. The tower does not need to violate Maxwell's equations in order to fail. It only needs to obey them with ordinary material constants.

In the Tesla-favorable column one is effectively replacing the modern effective impedances by much smaller ones, for example

$$R_{\mathrm{ac}} \sim 0.05\,\Omega, \qquad R_{\mathrm{ground}} \sim 0.05\,\Omega, \qquad R_{\mathrm{rad,eff}} \sim 0.02\,\Omega. \tag{16}$$

At the same circulating current this gives only

$$(300)^2(0.05 + 0.05 + 0.02) = 10.8 \text{ kW} \tag{17}$$

in the three headline channels. That is the lost kingdom: not a different Maxwell theory, but different parameter values.

Aggregating the modern column into the notation of the theorem below gives

$$P_L = 2 \text{ kW}, \qquad P_E = 155 \text{ kW}, \qquad P_A = 43 \text{ kW}. \tag{18}$$

Hence

$$\frac{\gamma_E}{\gamma_L} = \frac{155}{2} = 77.5, \qquad \frac{\gamma_A}{\gamma_L} = \frac{43}{2} = 21.5, \tag{19}$$

and the resonant-capture bound gives

$$\eta \le \frac{1}{1 + 77.5 + 21.5} = 0.01. \tag{20}$$

The Tesla-favorable column instead has

$$P_L = 175.7 \text{ kW}, \qquad P_E = 8.8 \text{ kW}, \qquad P_A = 15.5 \text{ kW}, \tag{21}$$

so

$$\eta \le \frac{1}{1 + 8.8/175.7 + 15.5/175.7} \approx 0.88. \tag{22}$$

The two stories differ less in romance than in damping ratios.

4 The resonant-capture model

We now make the obstruction deliberately small. Suppose a passive linear time-harmonic system is driven near an isolated resonant mode of angular frequency ω_0. Let the time-averaged modal energy be

$$U = \frac{1}{4}\int_V \left(\epsilon|\mathbf{E}|^2 + \mu|\mathbf{H}|^2\right) dV. \tag{23}$$

Assume the mode loses power through three aggregate channels:

$$P_L = \gamma_L U, \tag{24}$$
$$P_E = \gamma_E U, \tag{25}$$
$$P_A = \gamma_A U. \tag{26}$$

Here P_L is useful load power, P_E is environmental loss, and P_A is apparatus loss. For the Tesla problem, P_E contains ground heating, atmospheric conduction, corona, and uncaptured radiation.

The apparatus term contains coil loss, dielectric loss, source mismatch, and receiver losses not delivered to the desired load.

This is just a branching model for modal energy. It is intentionally modest. It does not compute the γ_i from geometry; Maxwell's equations and material parameters do that. The model says only that, once energy has entered a resonant mode, different physical channels compete to remove it.

Theorem 1 (Resonant Capture Bound)**.** *Consider a passive single-mode resonant electromagnetic system with time-averaged stored energy U and loss channels satisfying* (24)–(26)*. If P_{in} is the total supplied input power and P_L is the useful load power, then the efficiency satisfies*

$$\eta = \frac{P_L}{P_{\text{in}}} \leq \frac{\gamma_L}{\gamma_L + \gamma_E + \gamma_A}. \tag{27}$$

Equality is approached only when all supplied power enters the intended resonant mode, with no reflection or source-side mismatch.

Proof. In time-averaged steady state, the net stored modal energy is constant. Therefore the power entering the mode equals the power leaving the mode through the available channels:

$$P_{\text{mode}} = P_L + P_E + P_A. \tag{28}$$

Since not all supplied power need enter the intended mode,

$$P_{\text{mode}} \leq P_{\text{in}}. \tag{29}$$

Thus

$$\eta = \frac{P_L}{P_{\text{in}}} \leq \frac{P_L}{P_L + P_E + P_A}. \tag{30}$$

Substituting $P_i = \gamma_i U$ gives

$$\eta \leq \frac{\gamma_L U}{\gamma_L U + \gamma_E U + \gamma_A U} = \frac{\gamma_L}{\gamma_L + \gamma_E + \gamma_A}. \tag{31}$$

This proves the claim. □

The same result can be written in Q-factor language. If

$$Q_i = \frac{\omega_0 U}{P_i} = \frac{\omega_0}{\gamma_i}, \tag{32}$$

then

$$\eta \leq \frac{Q_L^{-1}}{Q_L^{-1} + Q_E^{-1} + Q_A^{-1}}. \tag{33}$$

A low Q_E means environmental loss is fast. A low Q_L means load extraction is fast. Efficient delivery requires the right low Q: the load must be the dominant sink.

Corollary 1 (Sharper resonance is not capture)**.** *For fixed geometry, fixed material parameters, and fixed damping rates $\gamma_L, \gamma_E, \gamma_A$, tuning the drive closer to resonance may increase U but does not by itself improve the branching ratio in* (27)*.*

Proof. At fixed damping rates, increasing U multiplies P_L, P_E, and P_A by the same factor. The ratio in (27) is unchanged. □

This is the whole trap in a theorem small enough to hide in a coat pocket. A sharper resonance can make the fields larger. It cannot decide that the receiver, rather than the soil, the air, the conductors, or infinity, should absorb the energy. Resonance is storage. Capture is a branching ratio.

Figure 1 plots the bound in normalized variables. Write

$$r = \frac{\gamma_E}{\gamma_L}, \qquad a = \frac{\gamma_A}{\gamma_L}. \tag{34}$$

Then

$$\eta_{\max} = \frac{1}{1 + r + a}. \tag{35}$$

Moving left on the figure is not "better tuning." It is better capture: either the receiver has become a stronger sink, or the environment has become a weaker one. That is the design lever.

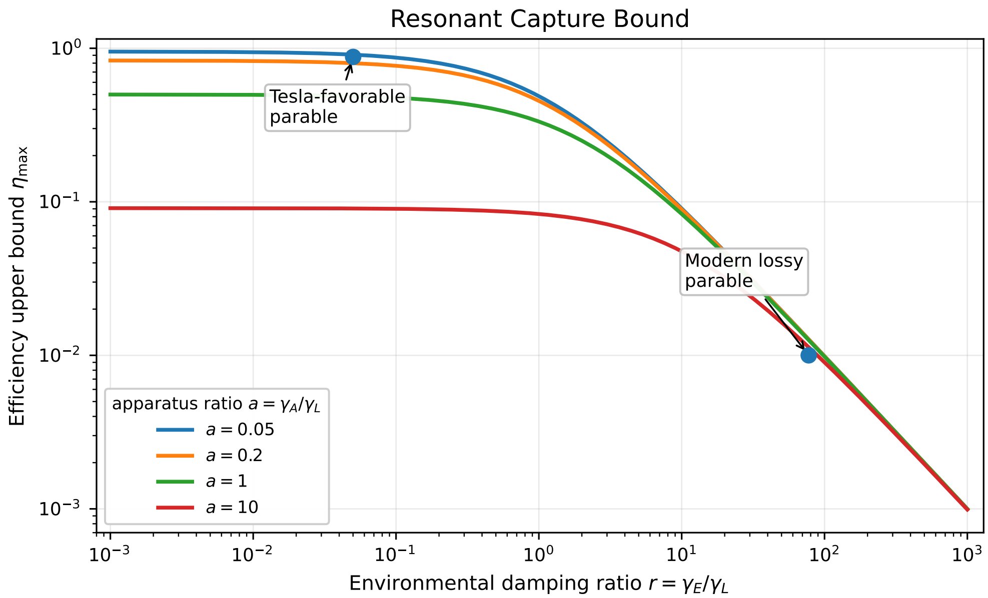

Figure 1: The resonant-capture bound in normalized form. The horizontal axis is the environmental damping rate relative to the load extraction rate. The curves show several apparatus damping ratios. The two marked points correspond to the numerical parable above. The plot is deliberately cruel: once the environment is the better absorber, resonance can make the system louder, but not more efficient.

5 A distance calculation: the two-foot joke

The preceding bound says that the receiver must be the dominant sink. A complementary estimate asks how quickly useful power collapses if the outgoing field is not guided, not beamed, and not captured by a privileged receiver. This is not a detailed Wardenclyffe simulation; it is the least romantic possible range calculation. It asks what remains when the tower's beautifully excited fields become an uncontrolled outward flux.

Theorem 2 (Uncontrolled-flux distance bound)**.** *Suppose a transmitter supplied with power $P_{\rm in}$ places at most $P_c = \eta_c P_{\rm in}$ into an outward electromagnetic channel spreading over solid angle Ω. Suppose a receiver at range R has effective collecting area $A_{\rm eff}$, conversion factor η_R, and no special directional advantage except a dimensionless concentration factor D. Then*

$$P_L(R) \le \eta_R \eta_c P_{\rm in} \frac{D A_{\rm eff}}{\Omega R^2}. \tag{36}$$

Consequently, to deliver a prescribed useful power P_*, the range must satisfy

$$R \le \left(\frac{\eta_R \eta_c P_{\rm in} D A_{\rm eff}}{\Omega P_*} \right)^{1/2}. \tag{37}$$

Proof. The average outward flux density at range R is bounded by the channel power divided by the area over which it is spread. With concentration factor D, the incident flux on the receiver is at most

$$S_R \le \frac{D P_c}{\Omega R^2}. \tag{38}$$

A receiver with effective area $A_{\rm eff}$ and conversion factor η_R therefore delivers at most

$$P_L \le \eta_R A_{\rm eff} S_R \le \eta_R \eta_c P_{\rm in} \frac{D A_{\rm eff}}{\Omega R^2}. \tag{39}$$

Solving this inequality for R gives (37). □

The theorem is intentionally simple. It is just Poynting flux divided over area. Its value is that it makes clear which lever is missing from the Wardenclyffe picture: without a guided mode or a beam, useful received power falls like R^{-2} before one even worries about receiver imperfections.

For a numerical parable, take the same 200 kW input as before. Let the lossy tower place about a quarter of that power into an outward electromagnetic channel,

$$\eta_c = 0.25, \tag{40}$$

let the receiver/conversion factor be

$$\eta_R = 0.5, \tag{41}$$

and take a modest effective collecting area

$$A_{\rm eff} = 1\,{\rm m}^2. \tag{42}$$

For an uncollimated hemispherical channel, put $\Omega = 2\pi$ and $D = 1$. Then (36) becomes

$$P_L(R) \lesssim \frac{0.5 \cdot 0.25 \cdot 200{,}000}{2\pi R^2} \approx \frac{3.98 \times 10^3}{R^2}\ {\rm W}. \tag{43}$$

Thus,

$$P_* = 10\,{\rm kW} \quad \Rightarrow \quad R \lesssim 0.63\,{\rm m} \approx 2.1\,{\rm ft}, \tag{44}$$

$$P_* = 1\,{\rm kW} \quad \Rightarrow \quad R \lesssim 2.0\,{\rm m}, \tag{45}$$

$$P_* = 100\,{\rm W} \quad \Rightarrow \quad R \lesssim 6.3\,{\rm m}. \tag{46}$$

At 100 m, the same crude bound gives only about 0.4 W for a $1\,{\rm m}^2$ receiver. This is the mildly comic version of the failure: a giant tower can be made to look as though it is transmitting power, while a useful small receiver is starved almost immediately.

The calculation should not be read as "Wardenclyffe literally had a two-foot range." Rather, it says that once the low-loss planetary mode is removed from the story, an uncollimated lossy tower is a catastrophically bad way to deliver industrial power to compact receivers. A glowing tube several meters away and a power grid across the Atlantic are separated not by poetry but by a square law.

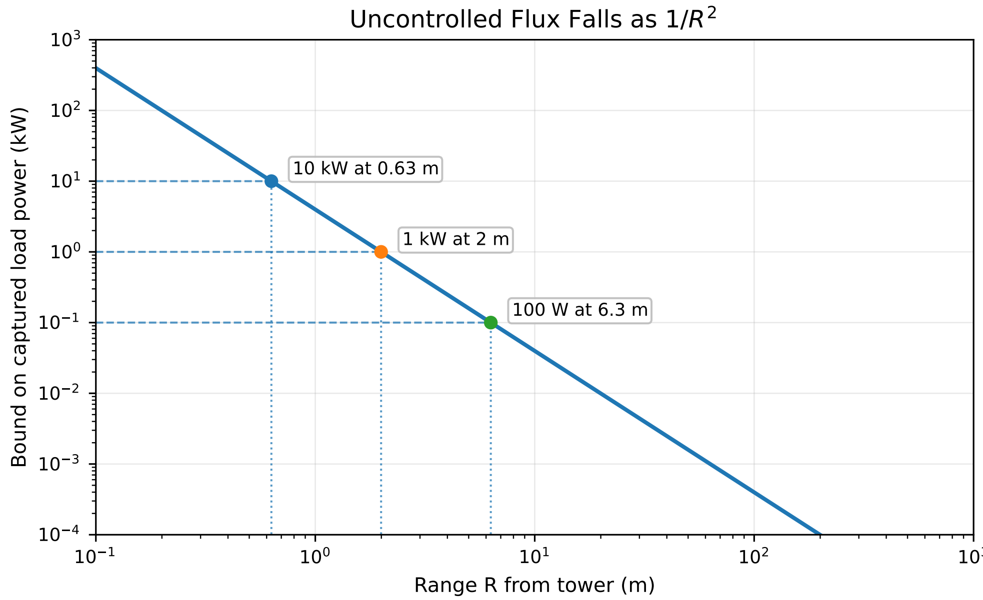

Figure 2: The uncontrolled-flux range estimate (43). With a 200 kW input, a 25 percent outward channel factor, a 50 percent receiver factor, and a $1\,\mathrm{m}^2$ effective receiver, industrial-scale useful power becomes local almost comically fast. The point of modern beaming is to change this plot by increasing D and A_{eff}; the point of near-field transfer is to avoid this spreading model altogether.

6 Why Wardenclyffe loses in this model

Tesla's conceptual bet may be expressed as

$$\gamma_L \gg \gamma_E + \gamma_A. \tag{47}$$

This is not silly if the medium is a low-loss guided structure and the receiver is strongly coupled. It is exactly the sort of inequality one would want for a useful resonant power system.

The Wardenclyffe difficulty is that the Earth/air channel is neither a clean wire nor a carefully fabricated waveguide. In the language of Theorem 1, the environmental rate has many contributions:

$$\gamma_E U = P_{\text{ground}} + P_{\text{corona}} + P_{\text{air}} + P_{\text{rad,uncaptured}}. \tag{48}$$

Each term is an ordinary Maxwellian object. There is no special historical exception for beautiful machines.

The modern reading of Tesla's failure is therefore not that resonance was wrong. It is that resonance was asked to do two jobs:

1. increase the energy stored in the transmitter-medium-receiver system;
2. ensure that the receiver captures most of that energy.

The first job is plausible. The second does not follow. If

$$\gamma_E \gtrsim \gamma_L, \tag{49}$$

then (27) gives poor efficiency no matter how poetically the tower rings.

This explains why small demonstrations can mislead. A distant receiver may respond, a lamp may glow, and an instrument may twitch. Such observations show

$$P_L > 0. \tag{50}$$

They do not show

$$\frac{P_L}{P_{\text{in}}} \approx 1. \tag{51}$$

A spectacular field effect can be a terrible power-transfer system. The ghost appears; the accountant remains unmoved.

7 First escape route: near-field resonant magnetic transfer

The first modern descendant keeps resonance but refuses both the Earth as the channel and the uncontrolled-flux assumption of Theorem 2. Instead, two resonators are placed close enough that their intended coupling is strong compared with environmental loss. A standard coupled-mode idealization is

$$\dot{a}_T = (i\omega_0 - \gamma_T)a_T + i\kappa a_R + s_{\text{in}}, \tag{52}$$

$$\dot{a}_R = (i\omega_0 - \gamma_R)a_R + i\kappa a_T, \tag{53}$$

where a_T and a_R are transmitter and receiver amplitudes, κ is the coupling rate, and γ_T, γ_R are internal loss rates. The useful transfer regime is governed by a dimensionless figure of merit of the form

$$U_c \sim \frac{\kappa}{\sqrt{\gamma_T \gamma_R}} \sim k\sqrt{Q_T Q_R}, \tag{54}$$

where k is a geometric coupling coefficient. This formula is the civilized descendant of Tesla's intuition: tune the systems together, but also make the receiver the dominant partner in the dance.

In terms of the capture bound, near-field resonant transfer tries to arrange

$$\gamma_L \gg \gamma_E, \tag{55}$$

not by commanding the environment to be gentle, but by making γ_L large. The field is concentrated in a controlled near-field region. The receiver is geometrically close and strongly coupled. The Earth is no longer being asked to serve as a continental violin string.

The modern experimental literature reflects this shift. Kurs et al. demonstrated nonradiative resonant wireless power transfer using self-resonant coils, reporting 60 W transferred with about 40 percent efficiency over distances greater than 2 m [5]. More recent wireless electric-vehicle demonstrations, such as work at Oak Ridge National Laboratory, have reported 100 kW transfer at 96 percent efficiency across a five-inch air gap using engineered electromagnetic coupling coils [6]. These systems are not planetary. That is their virtue.

Their loss function resembles

$$\mathcal{L}_{\text{near}} \sim \frac{P_{\text{coil}} + P_{\text{electronics}} + P_{\text{alignment}} + P_{\text{leakage}}}{P_{\text{in}}}. \tag{56}$$

The old environmental monster has been starved by geometry.

8 Second escape route: directed RF and microwave beaming

The second path makes the opposite confession. Radiation is not suppressed; it is promoted to the intended channel. In the notation of Theorem 2, it tries to make DA_{eff} large instead of hoping R^{-2} will be kind. In Wardenclyffe language, P_{rad} is mostly a loss. In power beaming, one seeks

$$P_{\text{rad}} \longrightarrow P_{\text{beam}} \longrightarrow P_{\text{rectenna}} \longrightarrow P_L. \tag{57}$$

The relevant mathematics is not Earth conduction, but aperture, beam spread, pointing, propagation, and rectification. For a transmitting aperture of diameter D, wavelength λ, and range R, the diffraction-limited angular scale is roughly

$$\theta \sim \frac{\lambda}{D}, \tag{58}$$

so the spot size at range is

$$w(R) \sim R\frac{\lambda}{D}. \tag{59}$$

The design problem is no longer "Can the planet ring?" It is

$$\text{What fraction of } \mathbf{S} \text{ crosses the receiving aperture?} \tag{60}$$

A schematic efficiency is

$$\eta_{\text{beam}} \approx \eta_{\text{tx}}\eta_{\text{prop}}\eta_{\text{aperture}}\eta_{\text{rectenna}}. \tag{61}$$

Equivalently,

$$P_{\text{uncaptured}} = \oint_{S_\infty \setminus A_R} (\mathbf{E} \times \mathbf{H}) \cdot d\mathbf{A}. \tag{62}$$

should be made small relative to the Poynting flux crossing the receiver aperture A_R. This is a more honest bargain with Maxwell's equations: the radiation term is not wished away, but shaped.

The 1975 Goldstone microwave power transmission experiment is the classical engineering demonstration. Dickinson's report describes a 24-square-meter rectenna array at a range of 1.54 km, operated at 2388 MHz, with measured DC output, RF input, efficiency, and temperature data; secondary summaries of the experiment report more than 30 kW of DC output and over 80 percent RF-to-DC conversion for incident microwave power [7, 8]. The experiment does not make long-range wireless power economically automatic. It does show the correct mathematical move: make the outgoing Poynting flux a designed beam rather than an uncontrolled loss.

The beaming loss function is therefore closer to

$$\mathcal{L}_{\text{beam}} = 1 - \eta_{\text{tx}}\eta_{\text{prop}}\eta_{\text{aperture}}\eta_{\text{rectenna}}. \tag{63}$$

This is not a small problem. It contains safety, weather, pointing, side lobes, aperture economics, and regulation. But it is a well-posed electromagnetic engineering problem. The receiver competes with aperture spillover and conversion loss, not with the whole wet planet.

9 Conclusion

Wardenclyffe did not fail because resonance is a fantasy. It failed because resonance is not capture. Poynting's theorem leaves no romantic loophole: input power must either reach the load, remain stored cyclically, dissipate locally, or leave through the boundary. Once the Earth, atmosphere, conductors, and radiative infinity are admitted as competing channels, the receiver's problem is not distance alone. It is competition.

The resonant-capture bound summarizes the first obstruction in one line:

$$\eta \leq \frac{\gamma_L}{\gamma_L + \gamma_E + \gamma_A}. \tag{64}$$

Sharper resonance can increase U. It cannot, by itself, change the fact that the modal energy is divided among sinks. The load must be made the dominant sink.

The distance bound summarizes the second obstruction: without guiding or beaming, compact received power decays like R^{-2}. The two most promising modern continuations do exactly what these inequalities demand. Near-field resonant magnetic transfer engineers strong local coupling so that γ_L beats environmental damping. Directed RF/microwave beaming accepts radiation, shapes it, and captures it with an aperture and rectenna. Both preserve a part of Tesla's vision. Both abandon the part that asked the Earth to be a benign circuit element.

Perhaps that is the cleanest modern epitaph for the tower:

Tesla had resonance. Modern systems engineer capture.

References

[1] N. Tesla, *System of Transmission of Electrical Energy*, U.S. Patent 645,576, issued Mar. 20, 1900. Available at https://patents.google.com/patent/US645576A/en.

[2] N. Tesla, *Apparatus for Transmission of Electrical Energy*, U.S. Patent 649,621, issued May 15, 1900. Available at https://patents.google.com/patent/US649621A/en.

[3] Tesla Science Center at Wardenclyffe, *Tesla's Wireless Power and the Wardenclyffe Tower*. Available at https://teslasciencecenter.org/teslas-wireless-power/.

[4] J. H. Poynting, On the transfer of energy in the electromagnetic field, *Philosophical Transactions of the Royal Society of London* **175** (1884), 343–361.

[5] A. Kurs, A. Karalis, R. Moffatt, J. D. Joannopoulos, P. Fisher, and M. Soljacic, Wireless power transfer via strongly coupled magnetic resonances, *Science* **317** (2007), 83–86.

[6] Oak Ridge National Laboratory, *Charging up the commute*, Mar. 12, 2024. Available at https://www.ornl.gov/news/charging-commute.

[7] R. M. Dickinson, *Performance of a High-Power, 2.388-GHz Receiving Array in Wireless Power Transmission Over 1.54 km*, Jet Propulsion Laboratory Technical Report, 1975. Available through NASA NTRS at https://ntrs.nasa.gov/citations/19760004119.

[8] W. C. Brown, Free-space microwave power transmission study and experiments, in *Solar Power Satellite Microwave Power Transmission and Reception*, 1977. Historical summary available at https://ssi.org/wp-content/fbs/sps-billbrown-1977/index.html.

[9] C. A. Balanis, *Antenna Theory: Analysis and Design*, 4th ed., Wiley, 2016.

[10] J. D. Jackson, *Classical Electrodynamics*, 3rd ed., Wiley, 1998.