

“Free-Space Loss” Is Not a Loss: The Vacuum Absorbs Nothing

— **92.4478** dB at **1** km and **1** GHz; doubling the distance and doubling the frequency both add the same **6.0206** dB — the frequency term comes not from space but from the receiving antenna, whose effective area scales as λ^2 — at **10** GHz that area is exactly **1/100** — [Paper 384]

Yuuki YAMAGISHI (山岸 勇輝)

Yamagishi Complexity Torus Lab, Japan

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— *From thinking to syncing.* —

Abstract

Radio waves are said to suffer a “loss” as the distance grows. This paper asks what is being lost—and the answer is that nothing is lost; what looks like loss is a fact about the receiver. No new theorem or law is claimed. First, free-space loss at **1** km and **1** GHz is **92.4478** dB (Section 2). Second, doubling the distance adds **6.0206** dB, which is $20 \log_{10} 2$ (Section 2). Third, and this is the core of the paper. Doubling the frequency adds exactly the same **6.0206** dB (Section 2). Fourth, yet the vacuum absorbs nothing at any frequency, and the radiated power density does not depend on frequency at all (Section 3). Fifth, the frequency term comes from the effective area of an isotropic antenna, $\lambda^2/(4\pi)$; at **10** GHz it is exactly **1/100** of its value at **1** GHz (Section 3). Sixth, the separator is “does the medium absorb, or is the receiving surface small”, and both are written in the same dB (Section 5).

Scope of this paper (scope note): No new theorem or law is claimed—the Friis transmission formula, free-space loss and effective aperture are all known. No electromagnetism is built—the theory of radiation resistance and directivity is not entered; it is only named. The atmosphere is not treated—rain attenuation, water-vapour absorption and the ionosphere are not the subject. Only propagation in vacuum is computed. No antenna is designed—the gain–area relation for aperture antennas is used, but no design method is given. Noise is not treated—receiver noise and G/T are not the subject. Multipath is not treated—reflection, diffraction and scattering are not the subject. Relation to earlier papers: Paper 356 showed that a current can flow and do no work—there too the word “loss” named two things. Paper 343 showed that the size of the hole does not enter the stress concentration—here the frequency does not enter space. Paper 300 showed that same-root and different-root can be decided—absorption by a medium and geometric dilution are different-root by that criterion. Paper 379 showed that the scale decides the ratio—here the reference antenna decides the “loss”. What is added is putting a number on the loss under six conditions, showing that distance and frequency give exactly the same 6.0206 dB, confirming through an area ratio that the frequency term comes from the λ^2 of the effective aperture, obtaining 205.1575 dB for a geostationary link, and placing the separator at “medium or receiving surface”.

1. Notation and the Question

Setting: write the free-space loss between isotropic antennas in dB.

$$L_{\text{dB}} = 20 \log_{10} d + 20 \log_{10} f + 20 \log_{10} \frac{4\pi}{c}$$

d is the distance in m, f the frequency in Hz, c the speed of light.

Observation 1.1

distance and frequency enter the formula in the same shape. Both carry $20 \log_{10}$ —double either one and the same amount is added.

Observation 1.2

but their origins differ. Distance, because the wave spreads over a sphere; frequency, because...—on the frequency side there is no reason on the vacuum’s part.

Observation 1.3

the vacuum absorbs nothing. It is transparent at every frequency——so where does the frequency term come from? This paper shows it with numbers.

Question: in “free-space loss”, what is being lost?

2. Distance and Frequency Give the Same 6.0206 dB

Computation 2.1: free-space loss for each condition (computed in this paper).

Distance [km]	Frequency [GHz]	Loss [dB]
1	1	92.4478
2	1	98.4684
1	2	98.4684
10	1	112.4478
1	10	112.4478
36000	12	205.1575

Observation 2.2

this is the core of the paper. The second and third rows agree to the last decimal at 98.4684 dB——doubling the distance and doubling the frequency add the same 6.0206 dB.

Observation 2.3

6.0206 is $20 \log_{10} 2$. Not a coincidence——the two carry the same coefficient in the formula.

Observation 2.4

the same happens at a factor of ten. Rows four and five are both 112.4478 dB——multiplying the distance by ten has the same effect as multiplying the frequency by ten.

Observation 2.5

the 92.4478 dB at 1 km and 1 GHz agrees with the standard value. An independently known figure——neither the formula nor the constants are off.

Observation 2.6

a geostationary link gives 205.1575 dB. 36000 km at 12 GHz——a dilution to about $1/(3 \times 10^{20})$.

3. The Frequency Term Comes from the Receiving Surface

Computation 3.1: effective area of an isotropic antenna (computed in this paper).

Frequency	Wavelength [m]	Effective area $\lambda^2/(4\pi)$ [m ²]
1 GHz	0.299792	7.152066×10^{-3}
10 GHz	0.029979	7.152066×10^{-5}
Ratio	—	0.01 (exactly 1/100)

Observation 3.2

the area ratio is exactly 1/100. Ten times the frequency means one tenth the wavelength, and the area goes as λ^2 —— $-10 \log_{10}(0.01) = 20$ dB, which matches the frequency term of Computation 2.1 exactly.

Observation 3.3

so the origin of the frequency term is identified. It is the receiving antenna, not space—the power density arriving at a given place does not depend on frequency.

Observation 3.4

only the distance term is genuine dilution. The wave spreads over a sphere, hence $1/d^2$ —this one does not vanish when the receiver is changed.

Observation 3.5

the frequency term, therefore, can be removed. Use an antenna of fixed aperture, such as a dish—and the higher frequency becomes the advantage instead. It is the choice of an isotropic reference that manufactures the f^2 .

Observation 3.6

the shape is that of Paper 379. There the scale decided the ratio—here the reference antenna decides the “loss”. In both, a convention on the measuring side makes the number.

4. The Same dB Writes Two Different Physics

Observation 4.1

genuine absorption is also written in dB. Rain attenuation, water-vapour absorption—there the energy becomes heat and is gone.

Observation 4.2

in free-space loss no energy is gone. It has only spread—integrate over the whole sphere and the transmitted power is still there.

Observation 4.3

the two are written in the same unit and can be added. A link budget does exactly that—which is why they stop being distinguishable.

Observation 4.4

the distinction appears when the receiver is changed. Absorption does not shrink with a bigger receiver—the frequency term of free-space loss disappears once the aperture is fixed.

Observation 4.5

they are different-root by the criterion of Paper 300. Absorption is set by the medium, dilution by geometry, the frequency term by the reference antenna—all three are called “loss in dB”, and there are three roots.

5. Separator: Does the Medium Absorb, or Is the Receiving Surface Small

Observation 5.1

separator—did the energy become heat, did it spread, or is the catching surface small.

Term	What happens	Origin	Change the receiver
Distance $20 \log d$	spreads over a sphere	geometry	stays
Frequency $20 \log f$	nothing happens	reference antenna	vanishes
Absorption (separate)	becomes heat	medium	stays

Observation 5.2

only the second row is “nothing happens”. Nothing changes on the wave’s side—and yet it is written in the same dB and added into the same formula.

Observation 5.3

the last column is the test. Does it vanish when the receiver is changed—a term that vanishes is not a property of the medium.

Observation 5.4

the separator can be moved. Switch to a fixed-aperture antenna and the frequency term does not merely vanish but reverses sign—the higher frequency becomes better. This is one reason satellite links use high frequencies.

Observation 5.5

to be honest—both 92.4478 dB and 205.1575 dB are referred to isotropic antennas. A real link adds the gains—what does not move is only the fact that the vacuum absorbs nothing.

Observation 5.6

one last thing—the word “loss” does not say what was lost. The same dB lines up what became heat, what spread out, and what was not caught—that quantities can be added does not make them the same kind.

6. Roll Call and Closing

1. 92.4478 dB at 1 km and 1 GHz (Computation 2.1): agrees with the standard value.
2. 6.0206 dB for double the distance (Observation 2.2): $20 \log_{10} 2$.
3. The same 6.0206 dB for double the frequency (Observation 2.2): identical to the last decimal.
4. The same 112.4478 dB at a factor of ten (Observation 2.4): the same effect.
5. 205.1575 dB for a geostationary link (Computation 2.1): about $1/(3 \times 10^{20})$.
6. Effective area is $\lambda^2/(4\pi)$ (Computation 3.1): $7.152066 \times 10^{-3} \text{ m}^2$ at 1 GHz.
7. Exactly 1/100 at ten times the frequency (Observation 3.2): matches the frequency term exactly.
8. Power density does not depend on frequency (Observation 3.3): space is not involved.
9. Fix the aperture and the frequency term vanishes (Observation 3.5): it becomes an advantage instead.

10. Addable does not mean same kind (Observation 5.6): there are three roots.

Closing: radio waves are said to suffer a “loss” as the distance grows—yet the vacuum absorbs nothing. Distance and frequency enter the formula in the same shape— $L_{\text{dB}} = 20 \log_{10} d + 20 \log_{10} f + 20 \log_{10}(4\pi/c)$, giving **92.4478** dB at 1 km and 1 GHz, which agrees with the standard value. Doubling the distance adds **6.0206** dB, and doubling the frequency adds exactly the same **6.0206** dB, to the last decimal. 6.0206 is $20 \log_{10} 2$; not a coincidence, but because the two carry the same coefficient in the formula. On the frequency side, however, there is no reason on the vacuum’s part—the vacuum is transparent at every frequency, and the power density arriving at a given place does not depend on frequency. The frequency term comes from the effective area of an isotropic antenna, $\lambda^2/(4\pi)$. That area is $7.152066 \times 10^{-3} \text{ m}^2$ at 1 GHz and $7.152066 \times 10^{-5} \text{ m}^2$ at 10 GHz—exactly **1/100**, and $-10 \log_{10}(0.01) = 20 \text{ dB}$ matches the frequency term of Computation 2.1 exactly. The origin is the receiving antenna, not space. The frequency term can therefore be removed—use an antenna of fixed aperture, such as a dish, and the higher frequency becomes the advantage instead. What manufactures the f^2 is the convention of taking an isotropic antenna as the reference. As in Paper 379, where the scale decided the ratio, a convention on the measuring side makes the number. The distance term, by contrast, is genuine dilution—the wave spreads over a sphere, hence $1/d^2$, and it does not vanish when the receiver is changed. Even so no energy is gone: integrate over the whole sphere and the transmitted power is still there. One thing does the separating—did the energy become heat, did it spread, or is the catching surface small. Only the frequency term is a term in which nothing happens on the wave’s side, and yet it is written in the same dB and added into the same formula. The test is whether it vanishes when the receiver is changed, and a term that vanishes is not a property of the medium. By the criterion of Paper 300 all three are different-root: absorption is set by the medium, dilution by geometry, the frequency term by the reference antenna. To be honest—both **92.4478** dB and **205.1575** dB are referred to isotropic antennas, and a real link adds the gains. What does not move is only the fact that the vacuum absorbs nothing. One last thing—the word “loss” does not say what was lost. The same dB lines up what became heat, what spread out, and what was not caught. That quantities can be added does not make them the same kind.

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Yuuki YAMAGISHI (山岸 勇輝)

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