Write or Radiate: Inscribed Mass vs. Electromagentic Channels

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WINLAB Research (Infostations redux)

- Infostations:
  - Delay tolerant? $\Rightarrow$ transmit when near base!
- Channel Quality
  - How good can that RF channel be? $\Rightarrow$ really good!
- Interference Avoidance, Pricing & Spectrum Management
  - Interference hurts $\Rightarrow$ deal with it!

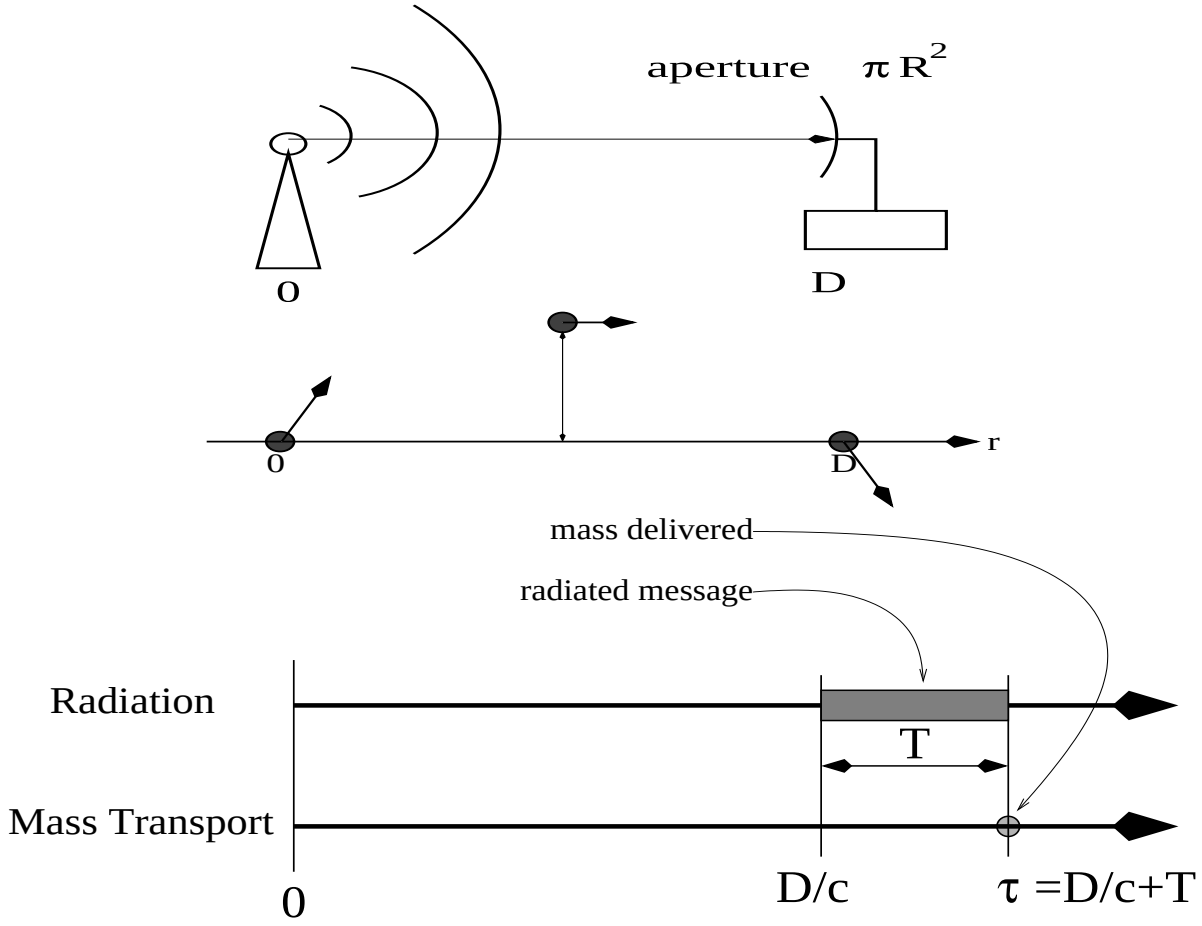
Some Observations

- RF Interference is bad
- Storage density is increasing
- Channel good when nearby
- Can tolerate delay
- Forget RF!
  - Write message down
  - Toss it to recipient
- Completely ridiculous ..... right?

A Little Empirical Rigor

- **Optical Lithography** with SiO_2: 3.85×10^{18} bits/kg
- **E-beam Lithography** with SiO_2: 1.54×10^{21} bits/kg
- **STM with Xenon on Nickel**: 1.74×10^{22} bits/kg
- **RNA**: 1.8×10^{24} bits/kg
  - 1 bit per $nm^3 \rightarrow 1\mathbf{mm}^3 = 10^{18}$ **bits!**
- And maybe a lot more room at the bottom

A Little Analytic Rigor



Parameters and Definitions

- B: message size (bits).
- $\tilde{\rho}$: mass information density for inscribed information (bits kg^{-1}).
- W: bandwidth available for radiated communication (Hz).
- $A = \pi R^2$: effective receiver aperture (m^2).
- D: distance to receiver (m).
- N_0: background noise energy (W Hz^{-1}).
- τ: message deadline (s)
- T: radio messaging time (s).
- $\delta = \frac{\tau c}{D}$: ratio of τ to the light travel time.

Radiation to Transport Energy Ratio

$$\text{Define: } \Omega = \frac{E_r}{E_w}$$

$$E_w \approx \tfrac{1}{2}\tfrac{B}{\tilde{\rho}}\left(\tfrac{c}{\delta}\right)^2, \quad E_r = TWN_0\tfrac{4\pi D^2}{A}\left(2^{\frac{B}{TW}} - 1\right)$$

$$\Omega \geq \left[\frac{\tilde{\rho}N_0}{c^2}\right]\left[\frac{4\pi D^2}{A}\right](2\ln 2)\,\delta^2 \quad .$$

for infinite bandwidth W and $\delta \gg 1$

Directed Radiation

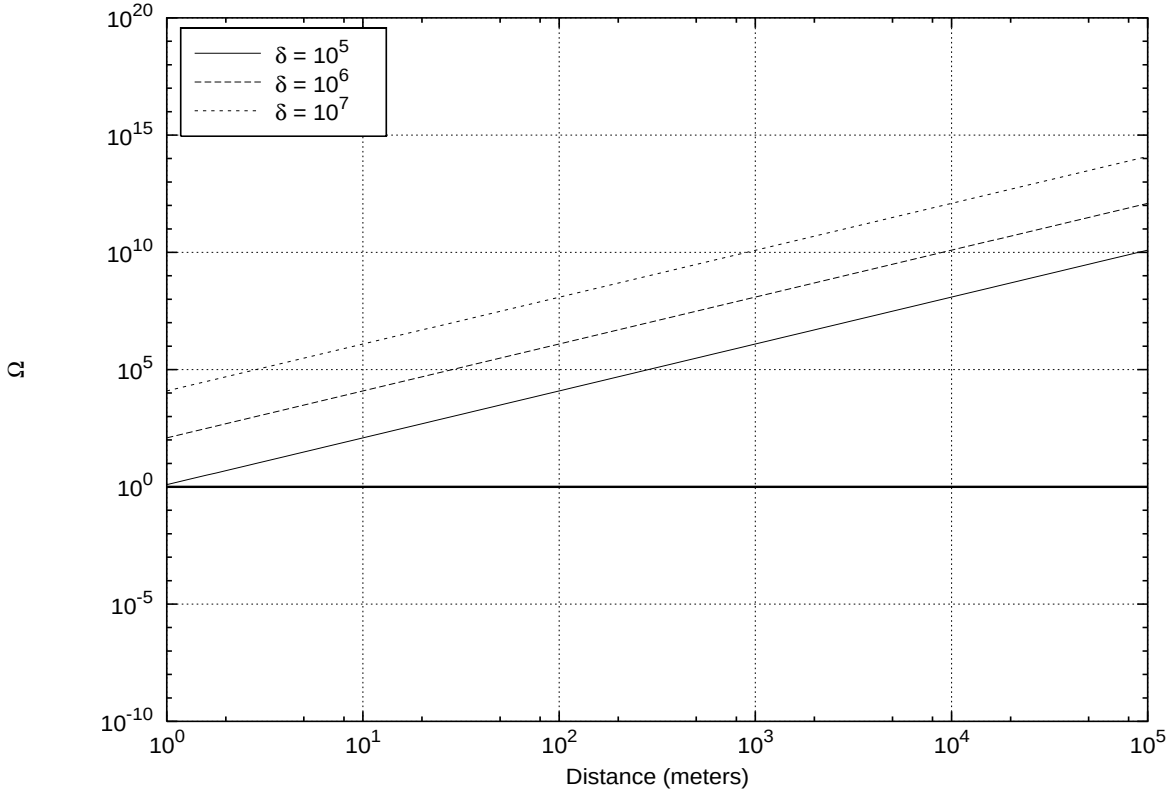
$$G_{\max} = \frac{8\pi^2 R^2}{\lambda^2}$$

Critical $\tilde{\rho}$ Values

(0.05 m)	$2.15 \times 10^{36} \left[\frac{D\delta}{1 \text{ meter}}\right]^{-2}$ bits kg^{-1}	$D \geq 0.37$ m
(Arecibo)	$1.74 \times 10^{52} \left[\frac{D\delta}{1 \text{ meter}}\right]^{-2}$ bits kg^{-1} $1.95 \times 10^{20} \left[\frac{D\delta}{1 \text{ light year}}\right]^{-2}$ bits kg^{-1}	$D \geq 3.3 \times 10^6$ m
(Earth)	$5.71 \times 10^{70} \left[\frac{D\delta}{1 \text{ meter}}\right]^{-2}$ bits kg^{-1} $6.38 \times 10^{38} \left[\frac{D\delta}{1 \text{ light year}}\right]^{-2}$ bits kg^{-1}	$D \geq 6.0 \times 10^{15}$ m

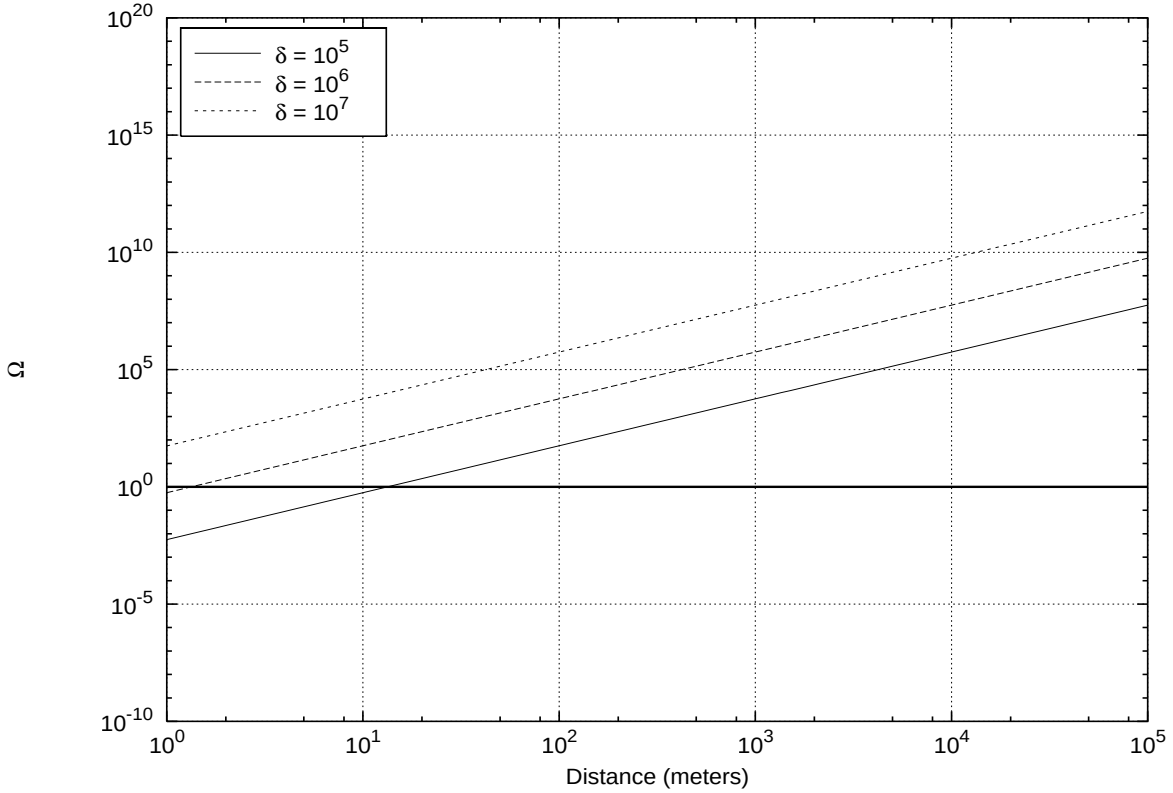
Table 1: Critical $\tilde{\rho}$ for $\lambda = 0.03$ m

Ω vs. Distance: point to point no gain



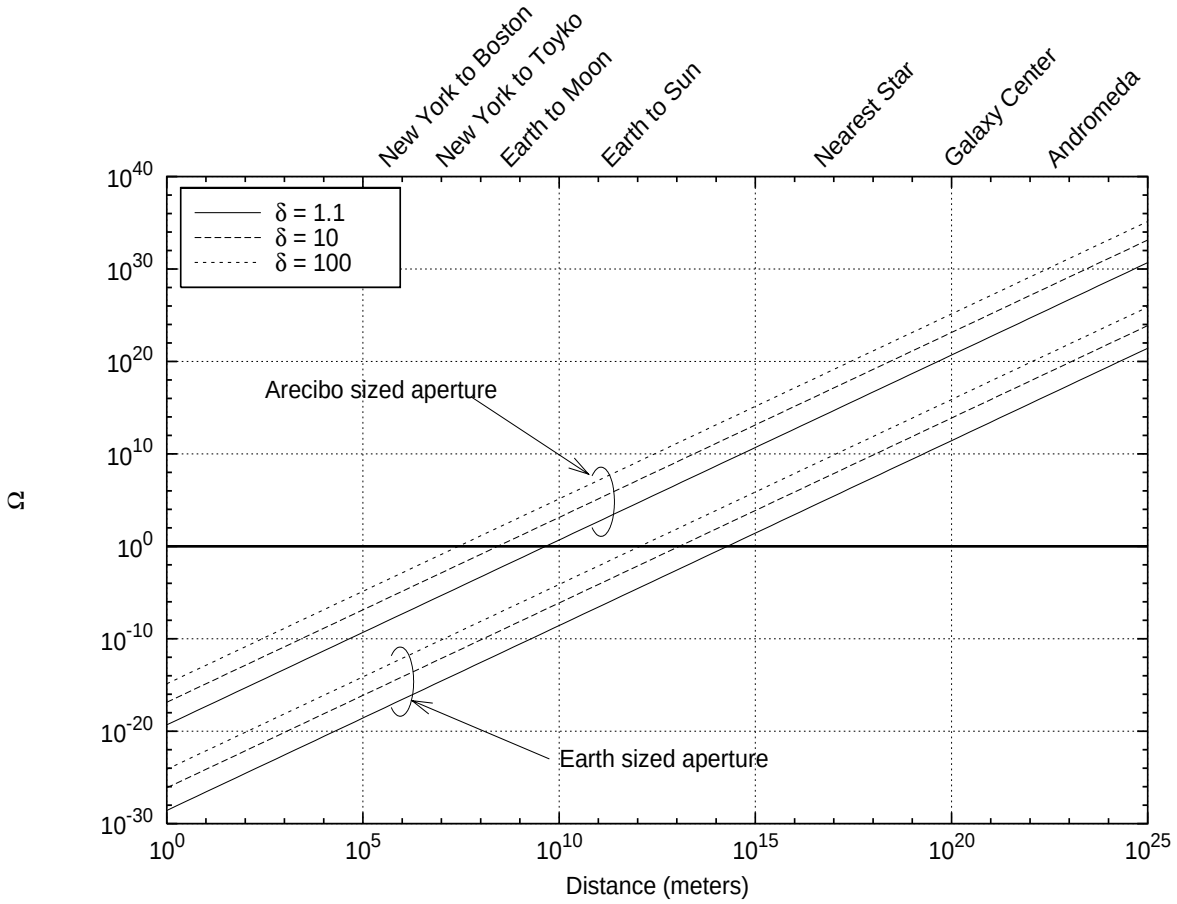
Terrestrial

Ω vs. Distance: point to point with gain



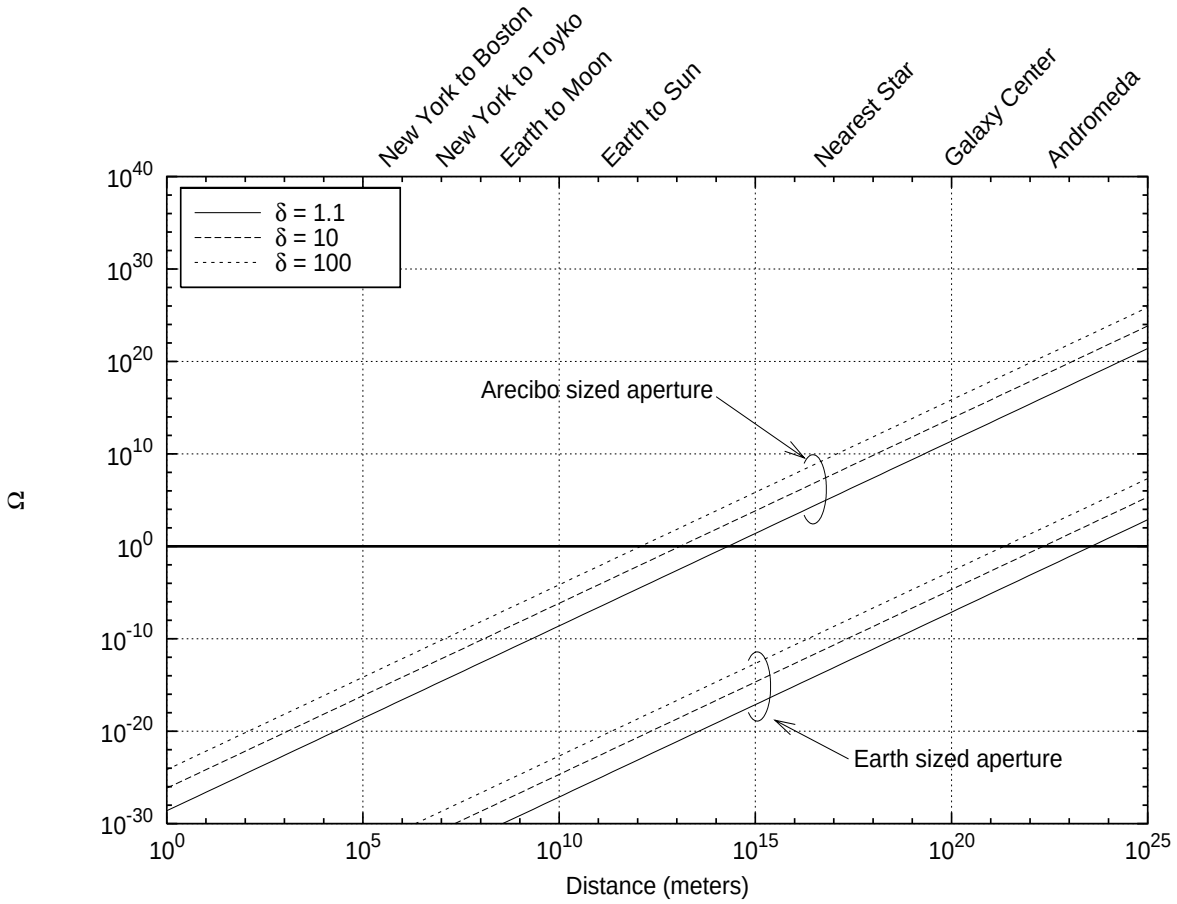
Terrestrial

Ω vs. Distance: point to point no gain



Interstellar

Ω vs. Distance: point to point with gain



Interstellar

Other Issues

- **Mass Inscription/Readout Energy**
  - Landauer said it can be reversible
- **Mass Inscription/Readout Time**
  - Landauer said it can be arbitrarily fast
- **Broadcast**
  - Blind Broadcast: mass stinks
  - Directed Broadcast: mass can win
  - Multicast: mass almost always wins
- **Message Corruption**
  - How do high energy insults disrupt inscriptions?

Delay Tolerant Punchlines

- It's often (MUCH MUCH) better to throw dust/pebbles
- Network Issues
  - Pebbles are non-interfering
  - Pebble net throughput scales well
  - Delays reasonable (Boston/NYC: $\approx$ 270 seconds ballistically)
- Practical value
  - Terrestrial: maybe some, maybe none
  - Interstellar: dust, not spectrum for SETI
- Learn more:

  http://www.winlab.rutgers.edu/$\sim$crose/papers/masschannel17.pdf