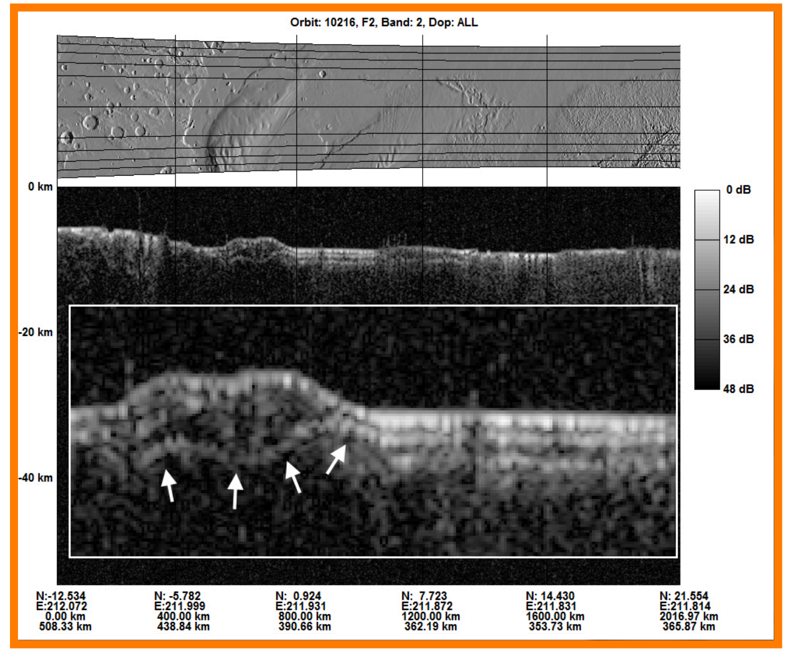
Sounding Radars 101

Roger Phillips
Isaac Smith

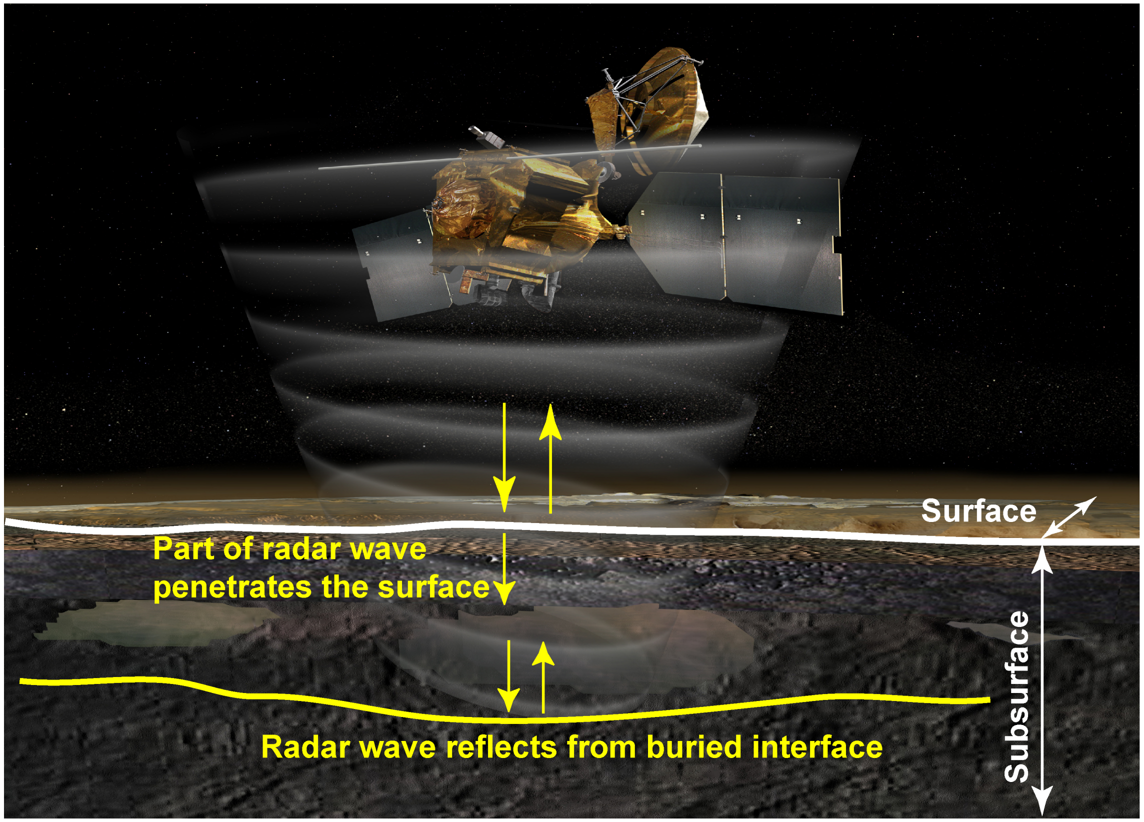


If you already know that

distance = velocity×time

you're in great shape, though really

2×distance = velocity×time

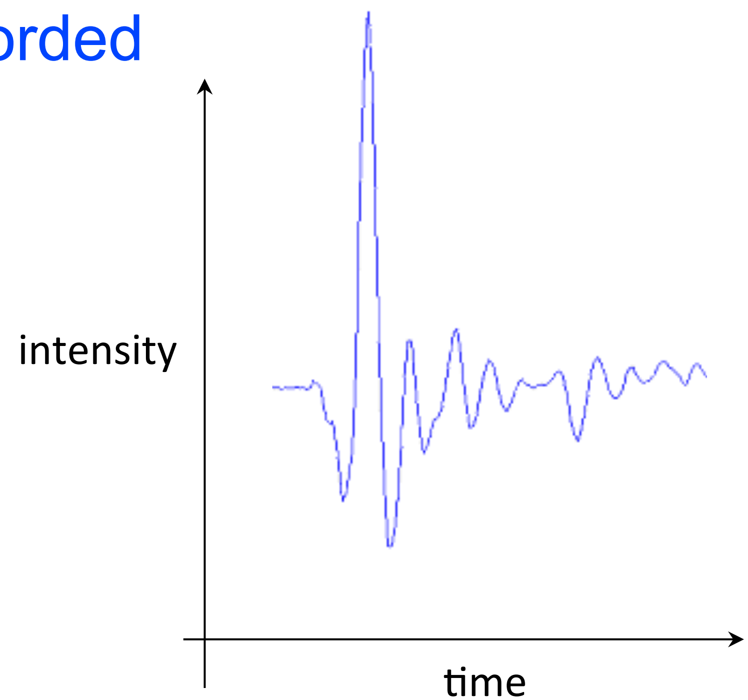


What is radar doing?

Pulse of energy sent

Some energy is reflected

Intensity and time are recorded



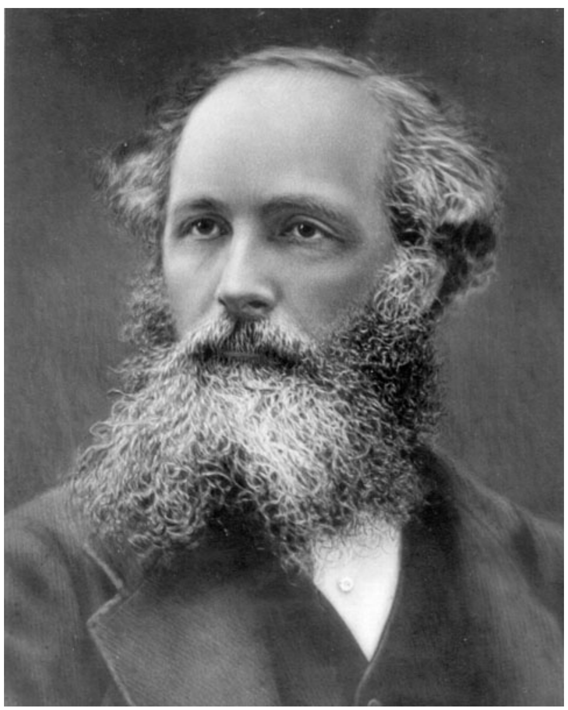
Two Way Time (TWT)

Signal travels away from transmitter

Reflects off of a surface

Travels back to receiver

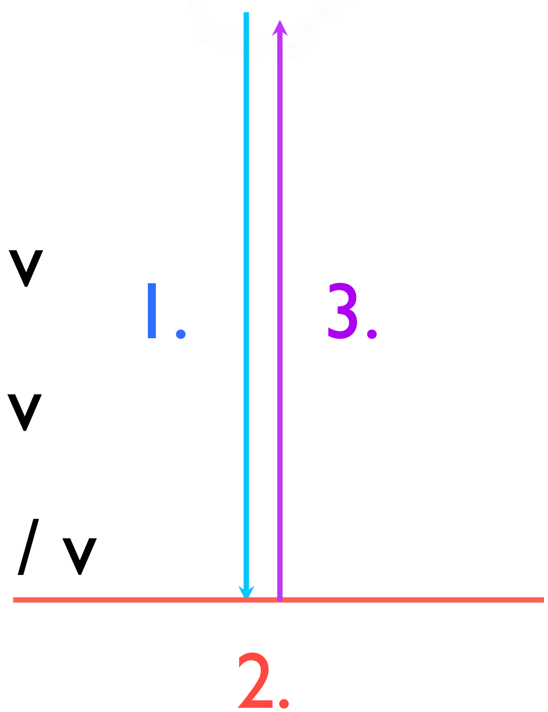
Jack in 20 years



Step 1 time = h / v

Step 2 time = h / v

total time = 2 x h / v



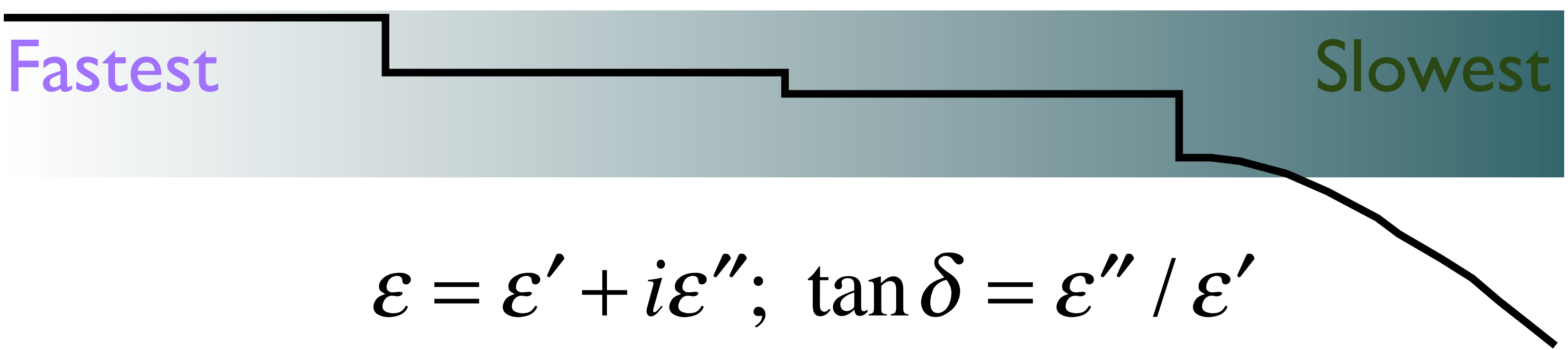
$$V = \frac{1}{\sqrt{\mu\varepsilon}} \approx \frac{1}{\sqrt{\mu_0 \varepsilon' \varepsilon_0}} = \frac{V_0}{\sqrt{\varepsilon'}}$$

Velocities in Media

Signal Velocity depends on real part of permittivity, ε'

$$V \approx V_0 / \sqrt{\varepsilon'}$$

Space	CO_2	H_2O	Rock
$V_0 = \dfrac{3\times10^8}{\sqrt{1}}$	$V = \dfrac{3\times10^8}{\sqrt{2.1}}$	$V = \dfrac{3\times10^8}{\sqrt{3.15}}$	$V = \dfrac{3\times10^8}{\sqrt{\sim 4 \text{ to} 12}}$



$$\varepsilon = \varepsilon' + i\varepsilon''; \;\; \tan\delta = \varepsilon'' / \varepsilon'$$

Basic quest is for depth, but estimates of ε' & $\tan\delta$ constrain composition and porosity

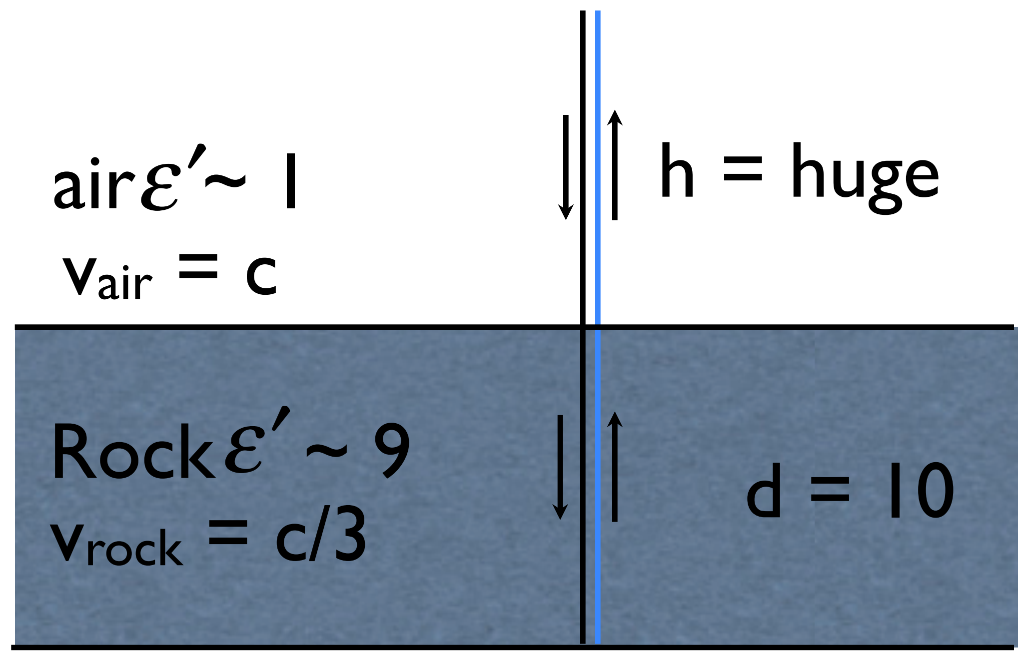
Signal return time

$t = d / v$

$$t_{air} = 2h / v_{air}$$

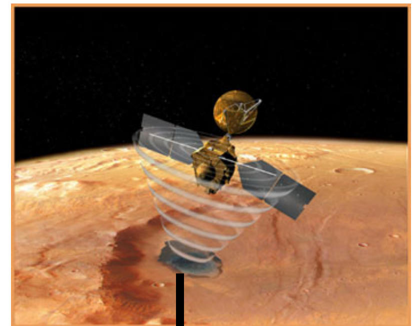
$$+ \quad t_{rock} = 2d / v_{rock}$$

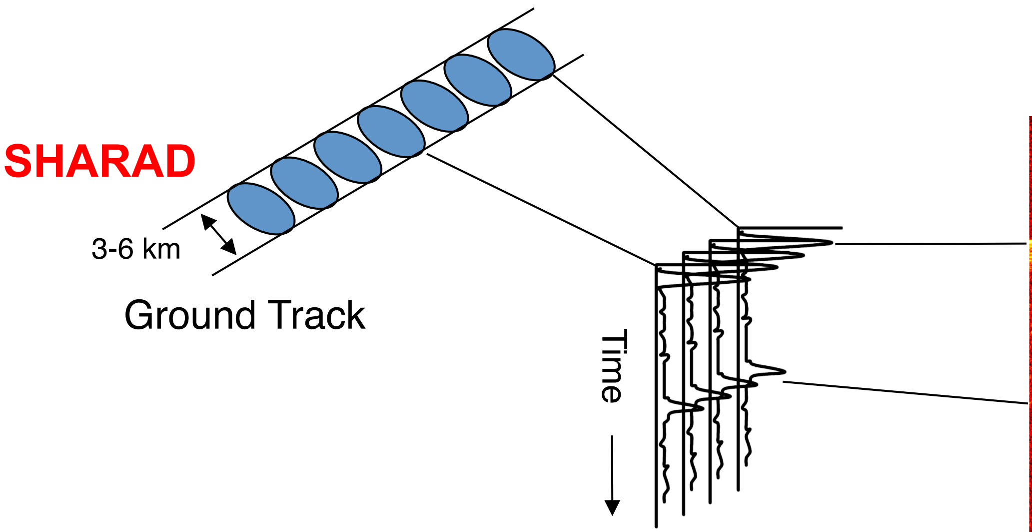
$$\text{total time} = t_{air} + t_{rock}$$



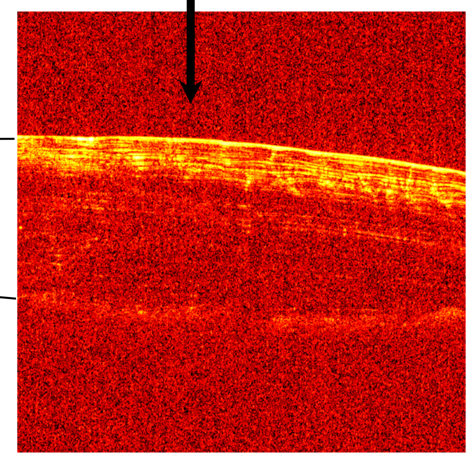
These are really relative permittivities; i.e., divided by ε_0

Build a radargram





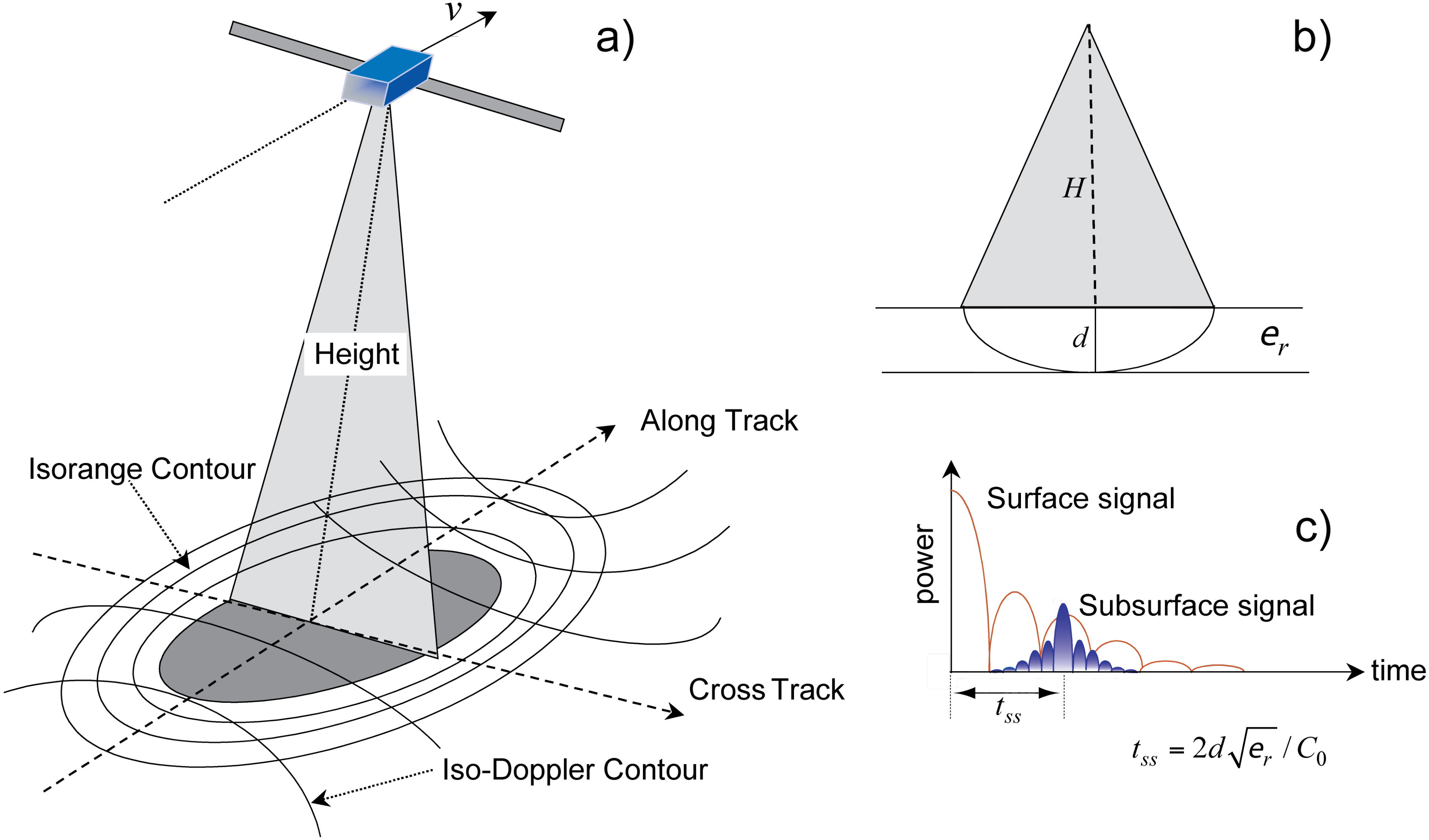
Each interface returns a reflection



Radargram

Stack individual echo traces along track to build up a **radargram**

Horizontal resolution

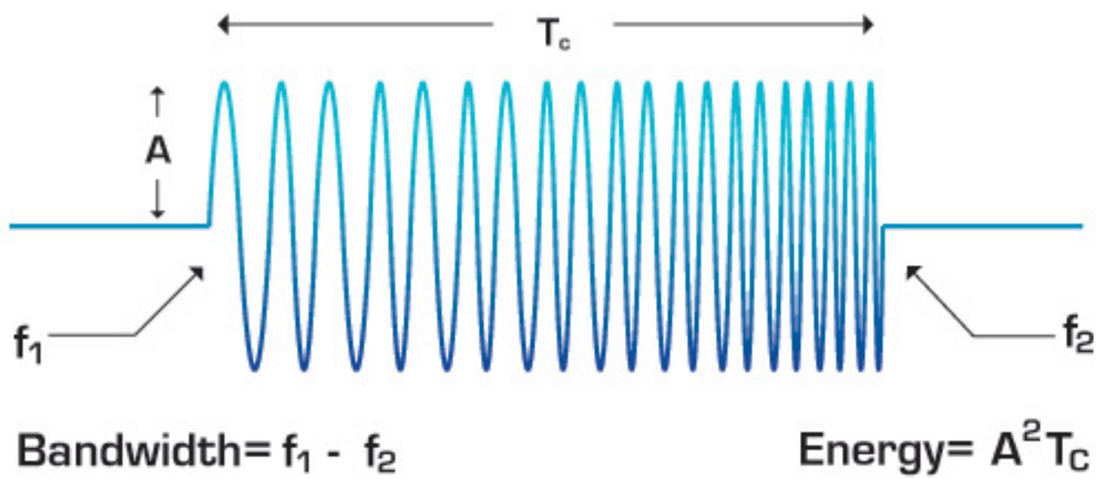


Vertical resolution

Time-bandwidth product ~ unity;

$$\Delta t \Delta f \sim 1; \quad \Delta t \sim 1/\Delta f; \quad \Delta h \approx \frac{V_0}{2\sqrt{\varepsilon'}} \frac{1}{\Delta f}$$

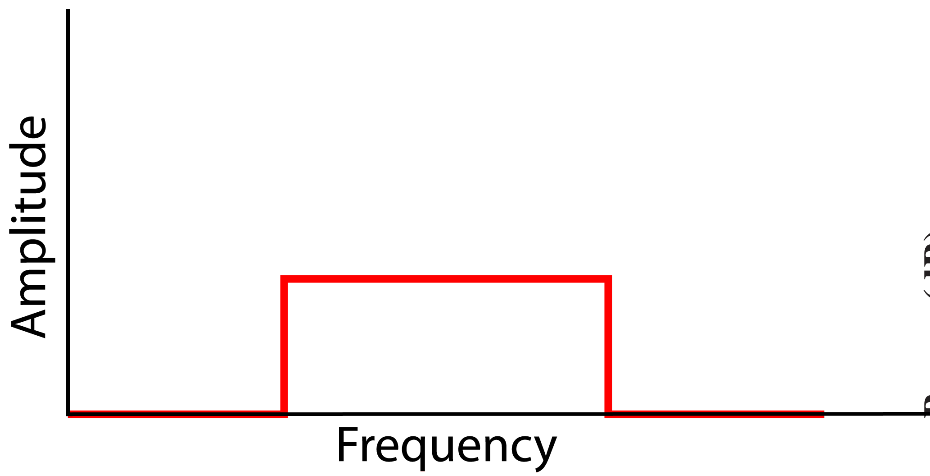
Transmitter signal is a chirp, which enhances output energy by spreading the bandwidth over time, $E = A^2 \times t$; $A^2 = P$

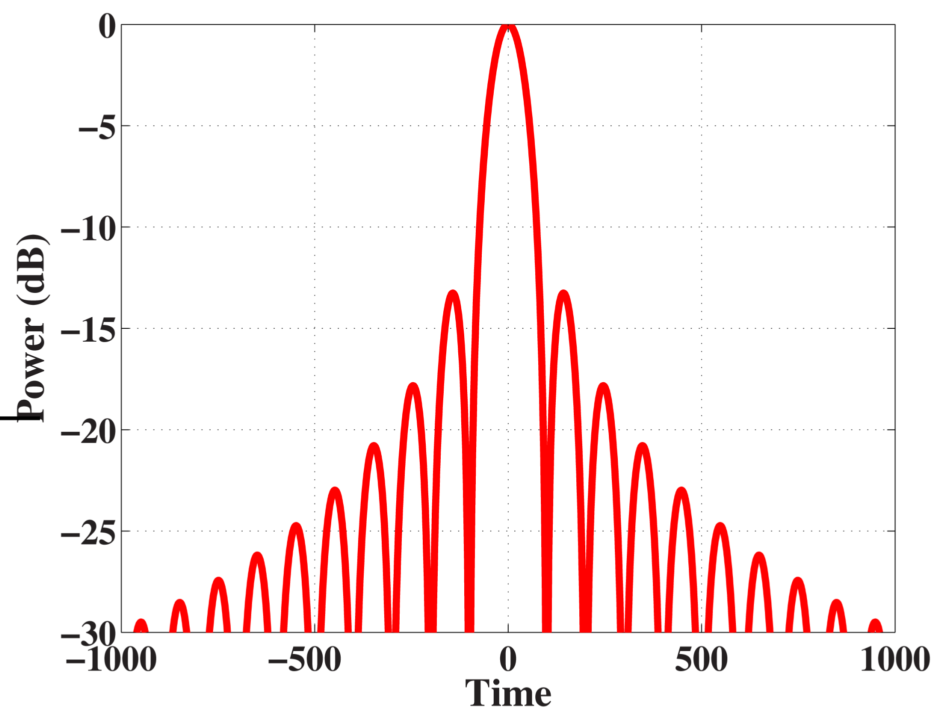


There is a price to be paid for this.

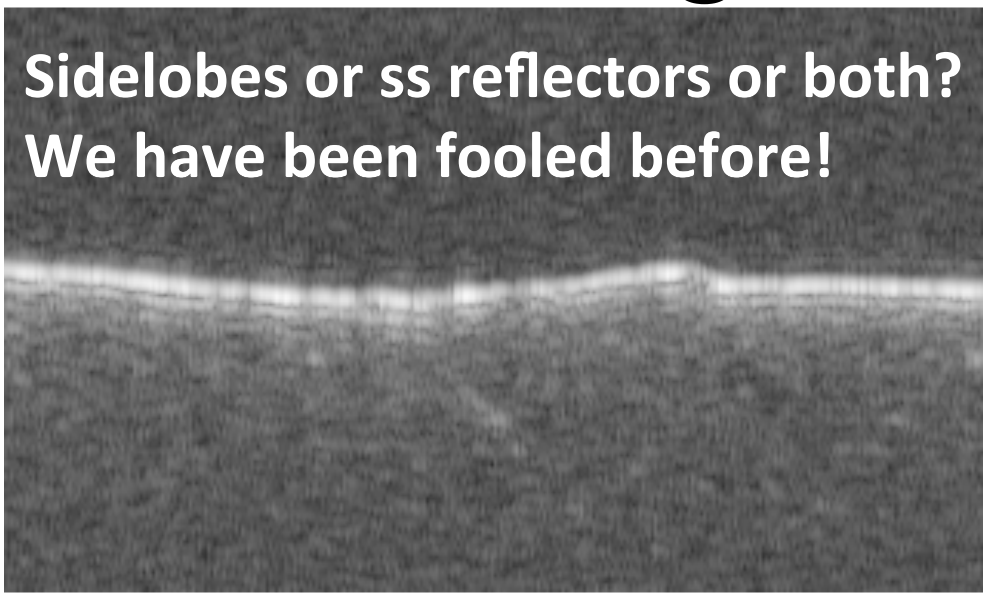
Dreaded Sidelobes

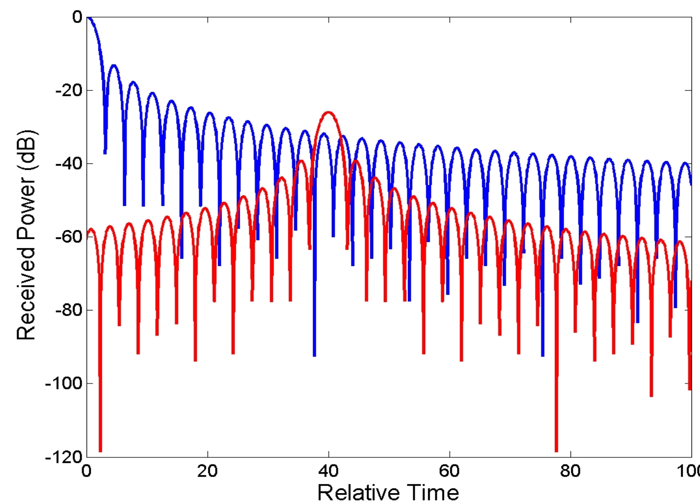
- Chirp signal has sharp cutoffs in frequency domain
- Rectangle (box car) ⟷ FT sin(x)/x (sinc function)



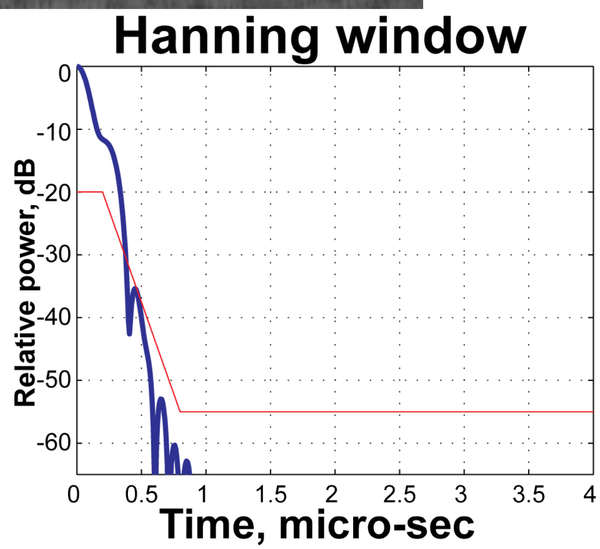


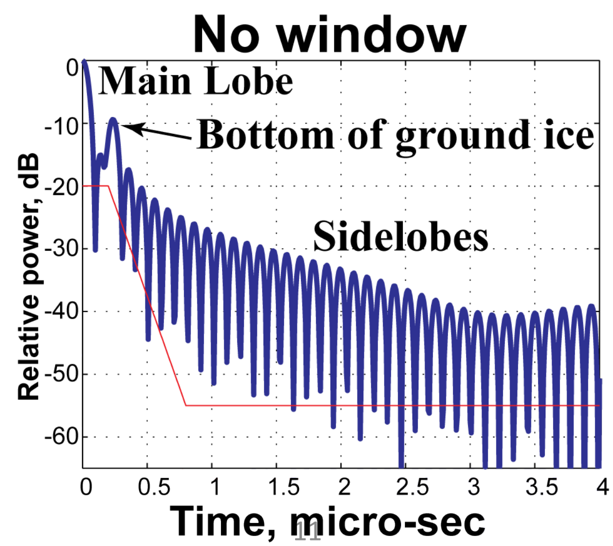
Reflected signal not so simple

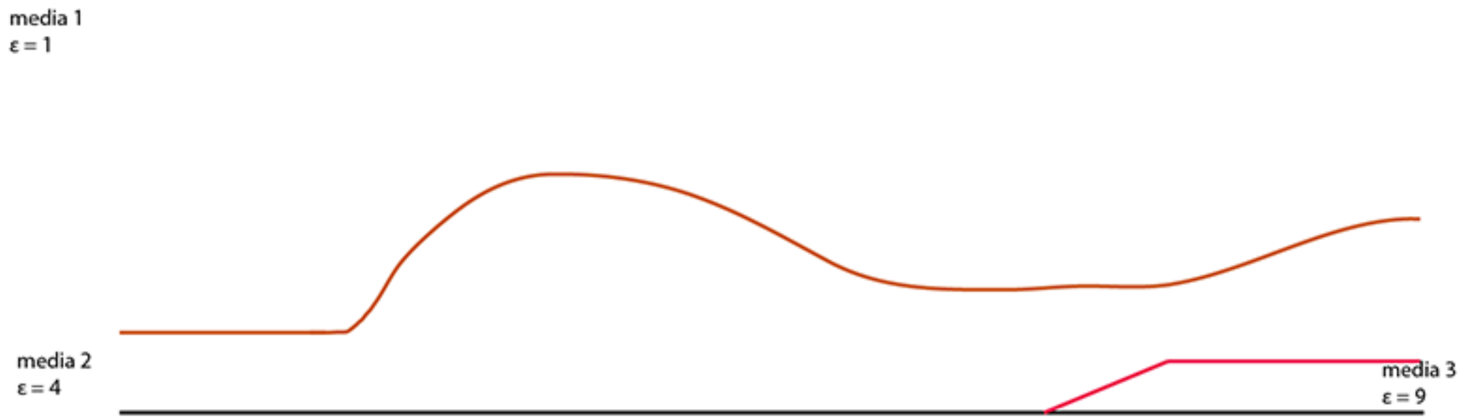




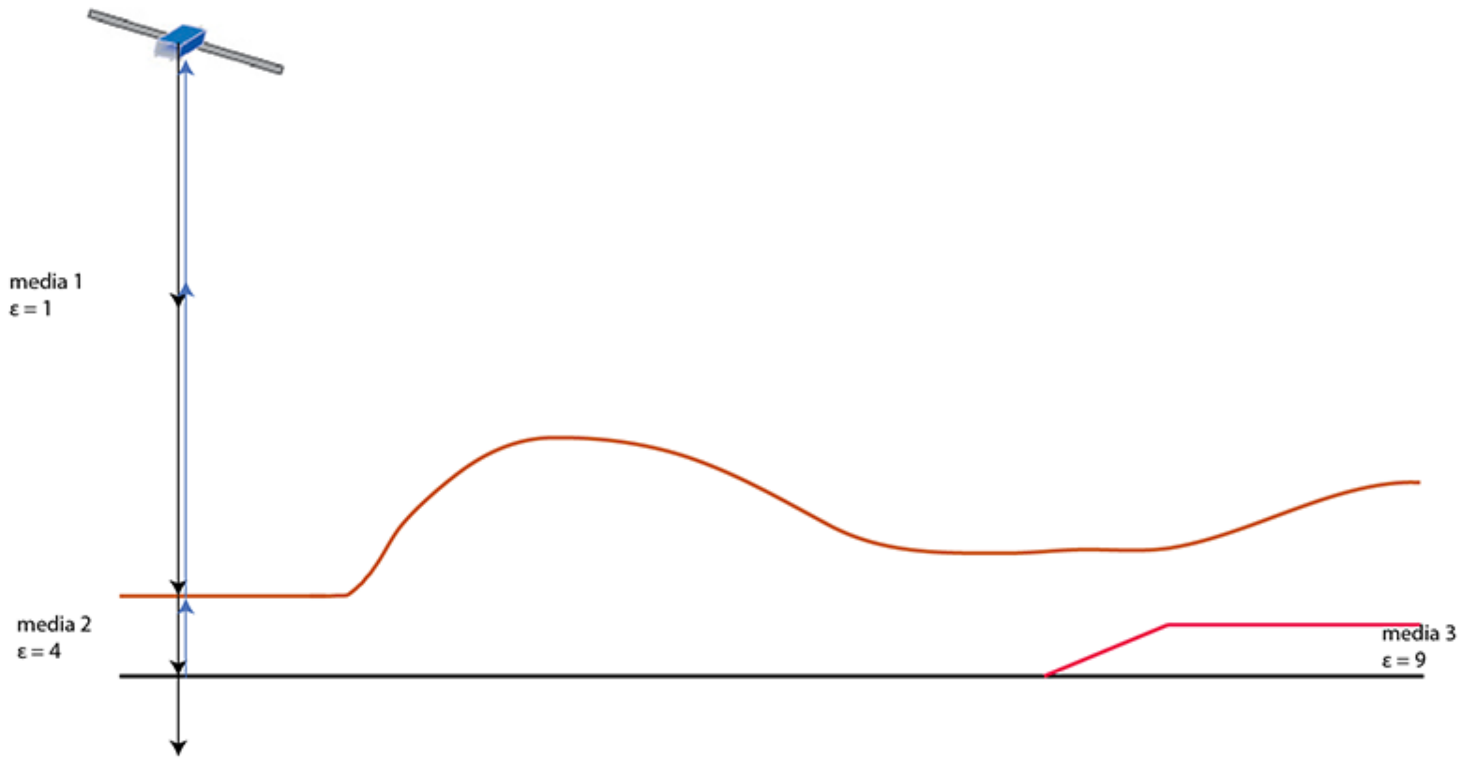
Tradeoff in weighting to suppress sidelobes & resolution







media 1
ε = 1
media 2
ε = 4
media 3
ε = 9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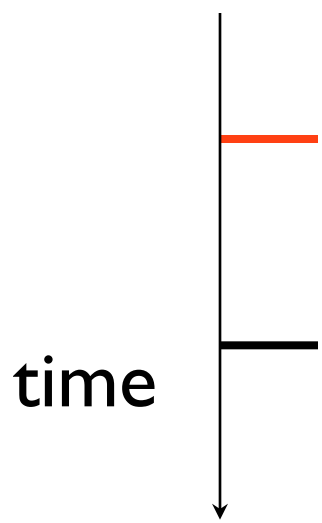
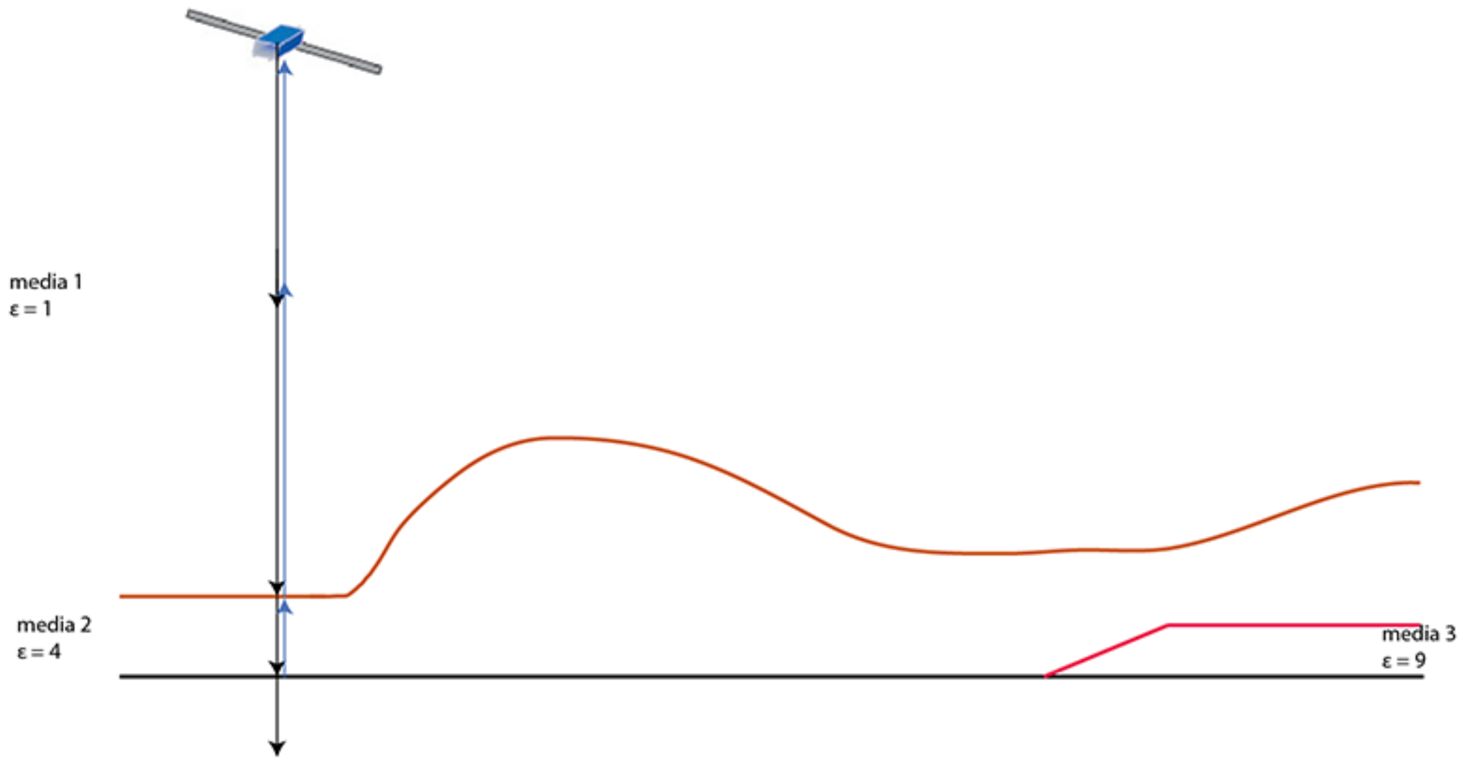

time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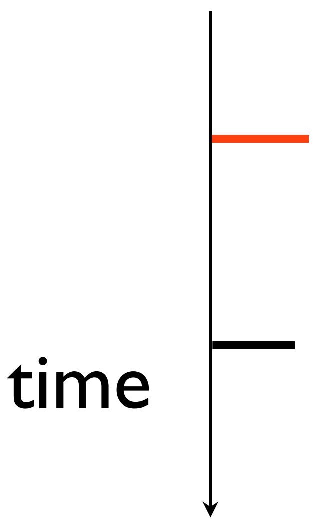
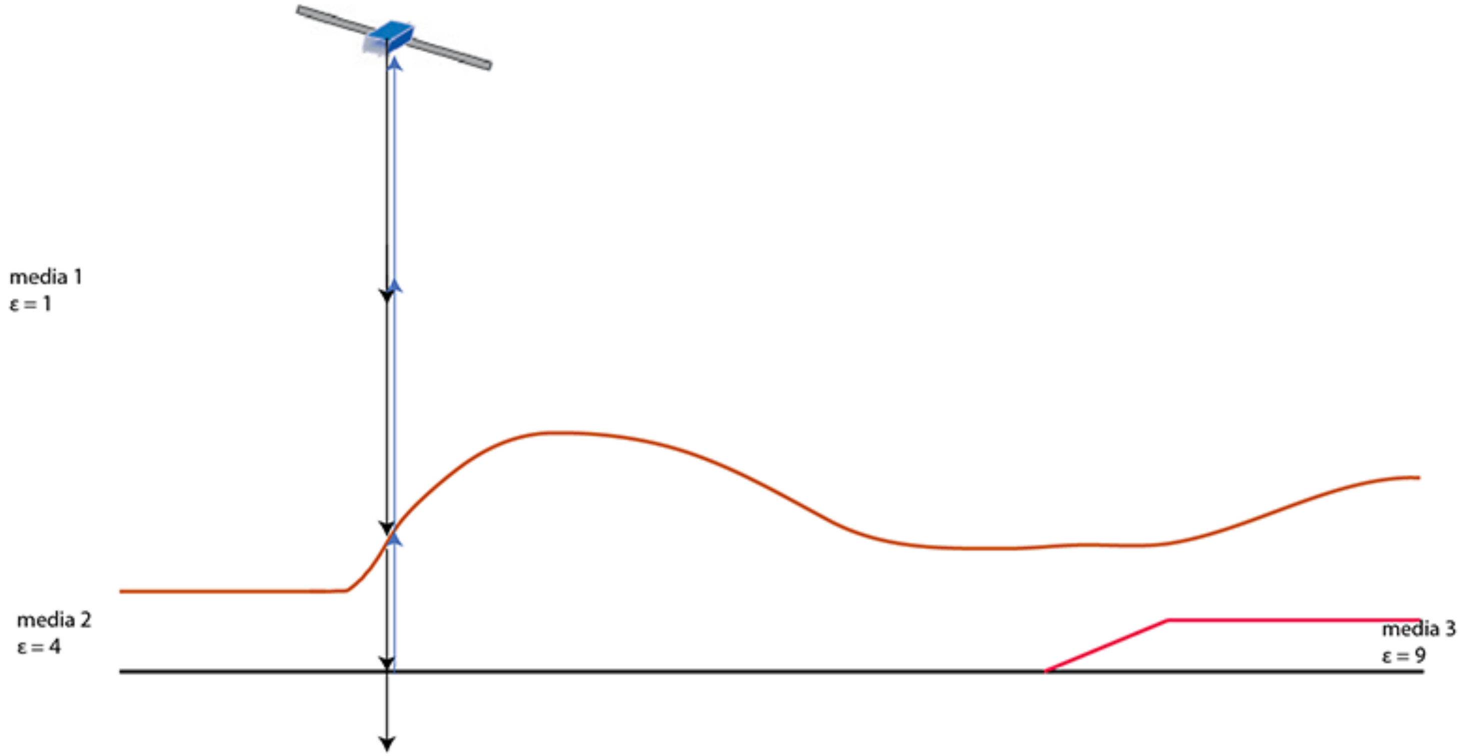
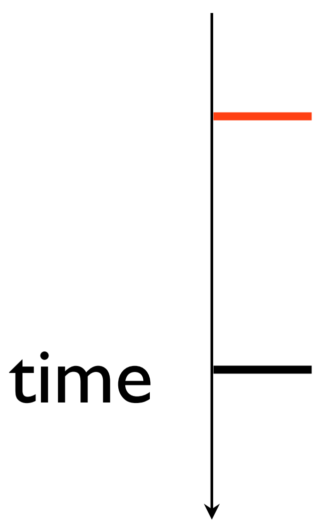
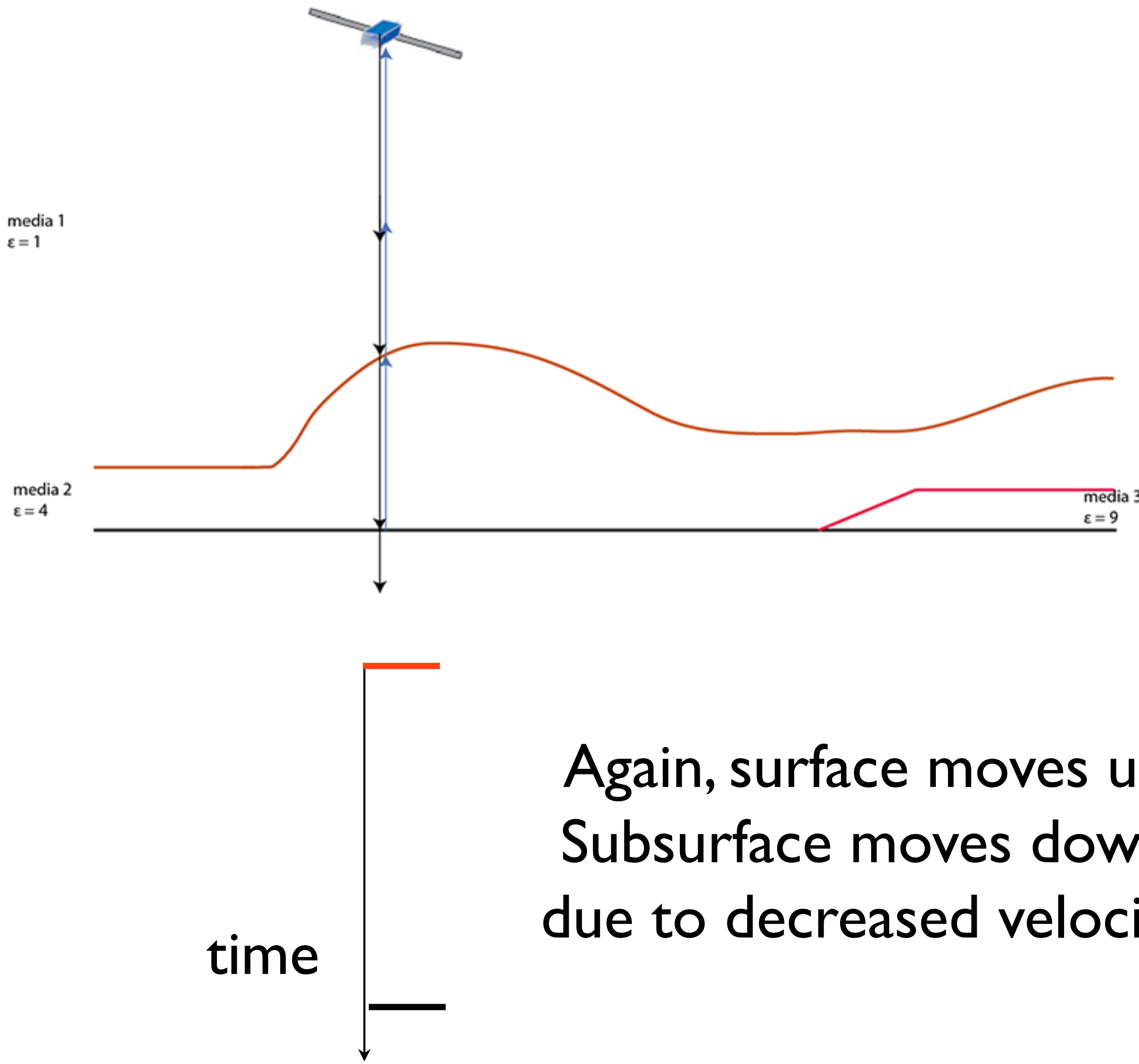

time

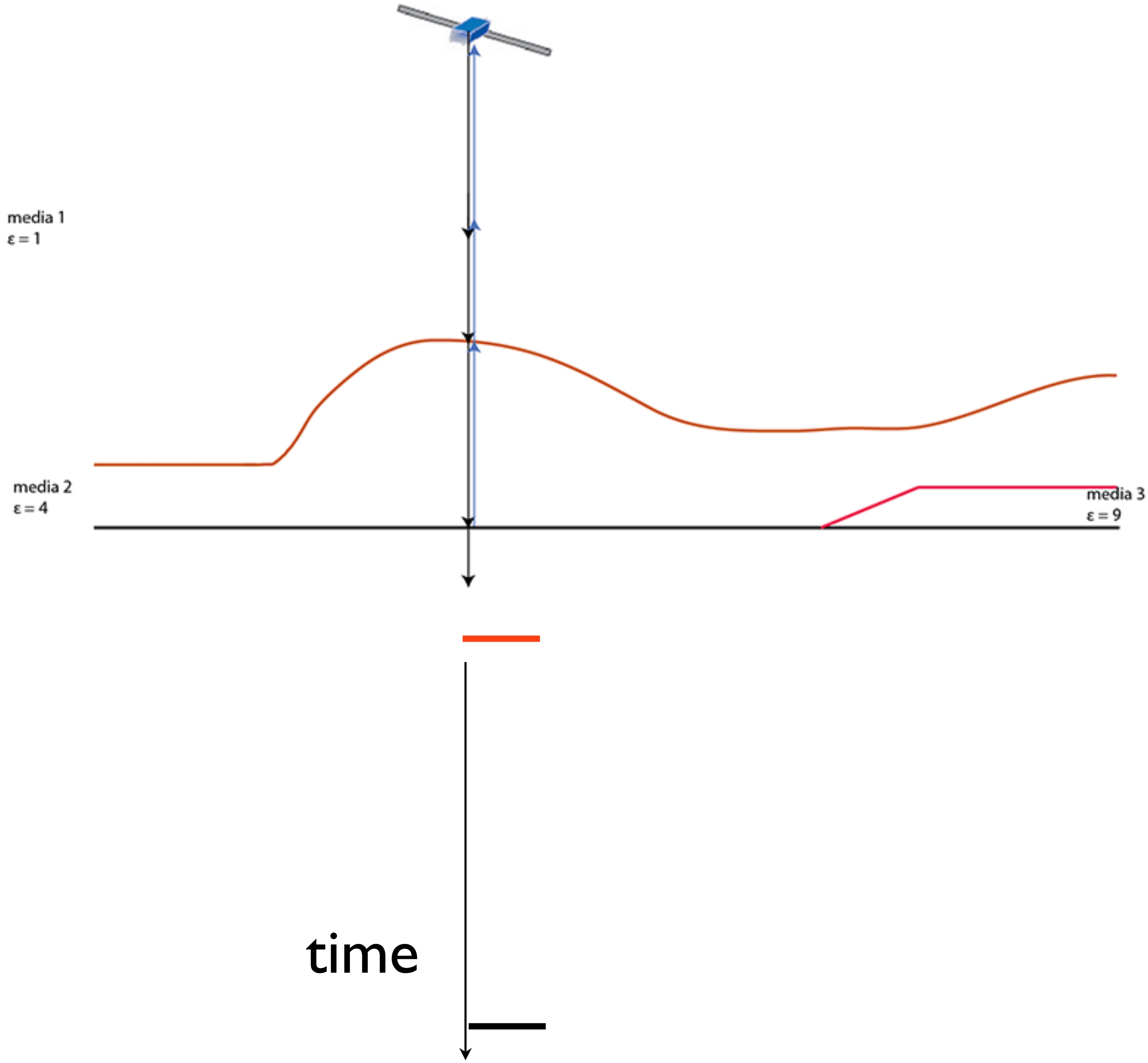




Surface moves up
Subsurface moves down
due to decreased velocity



Again, surface moves up
Subsurface moves down
due to decreased velocity



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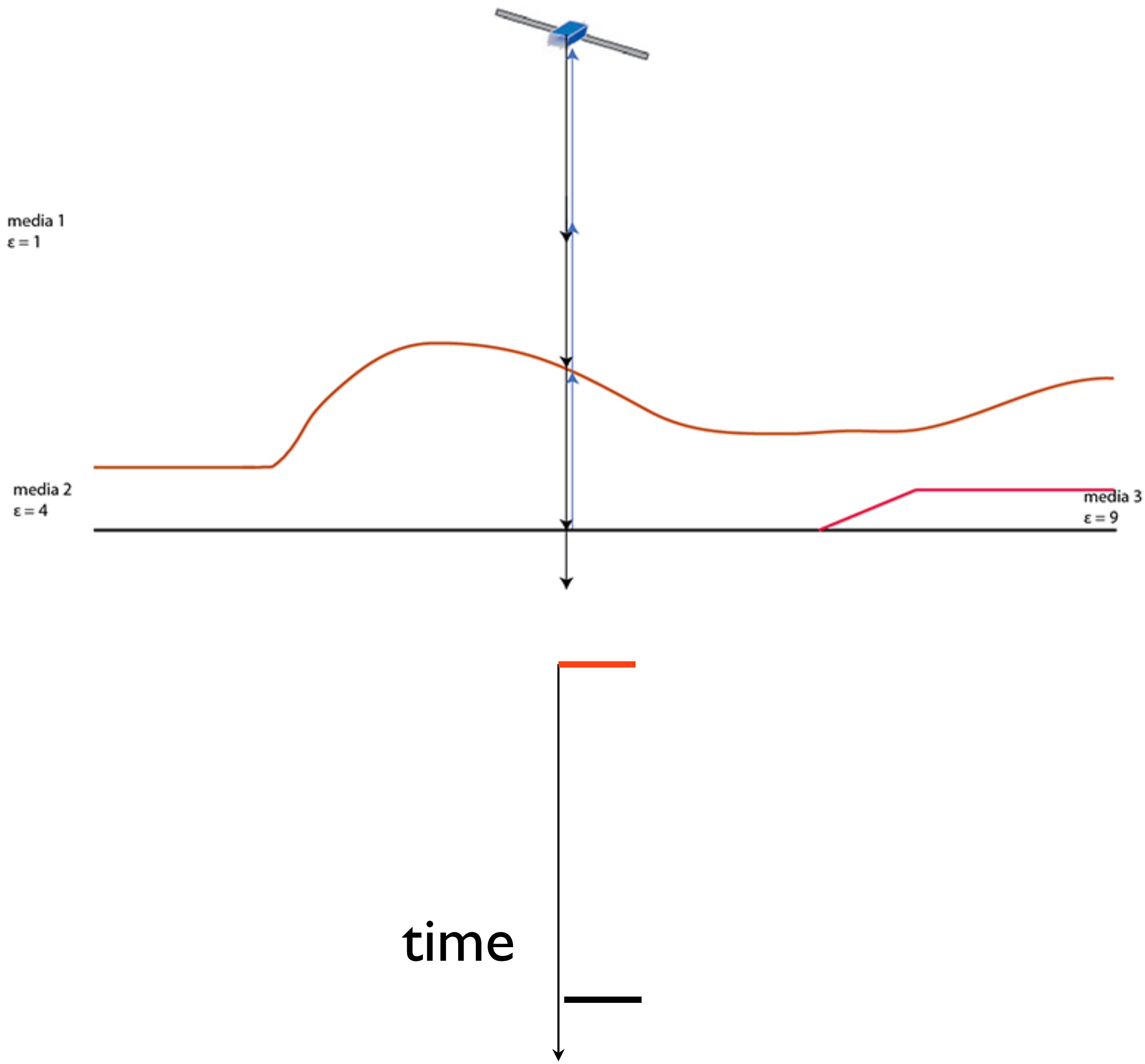
time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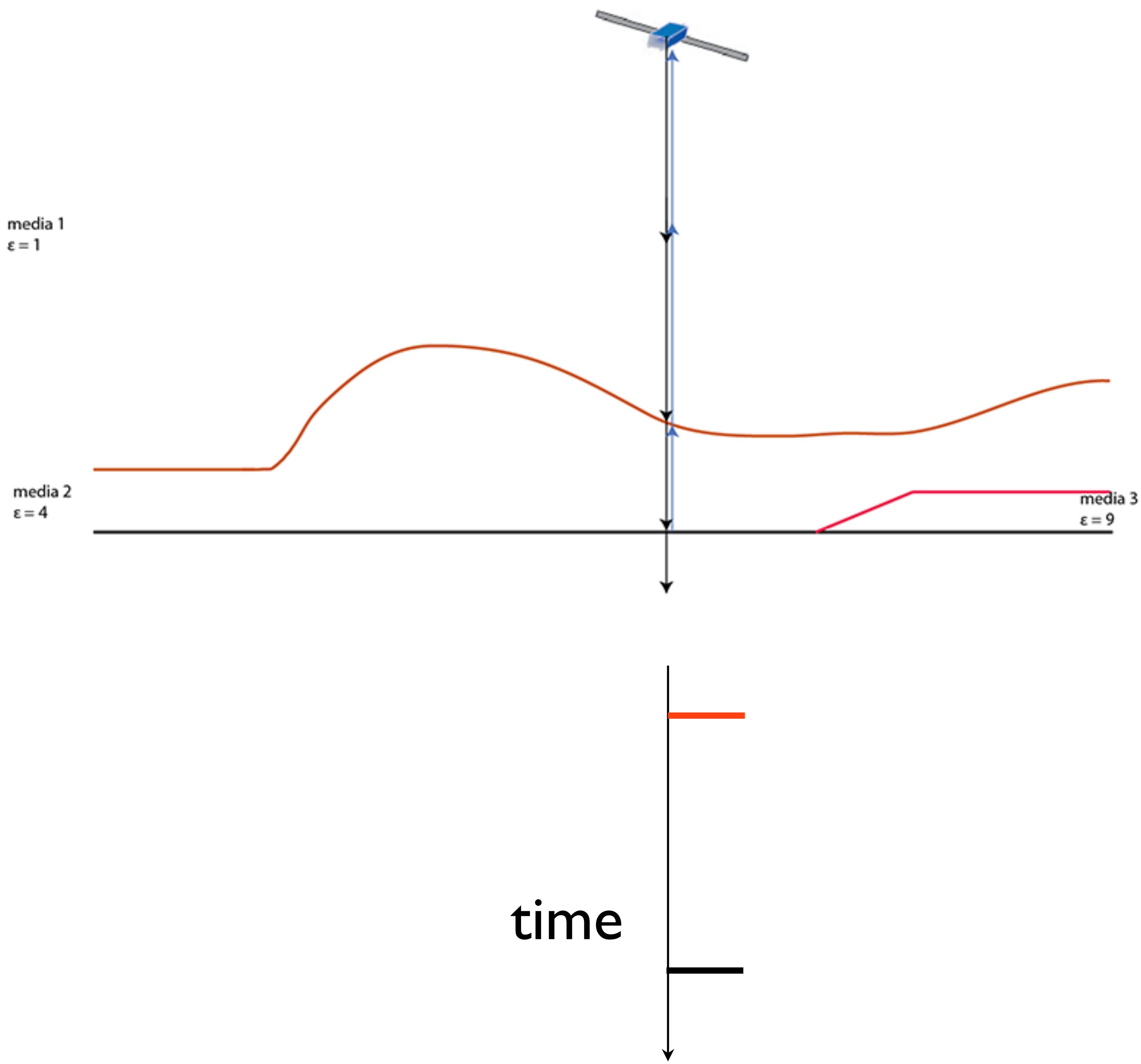
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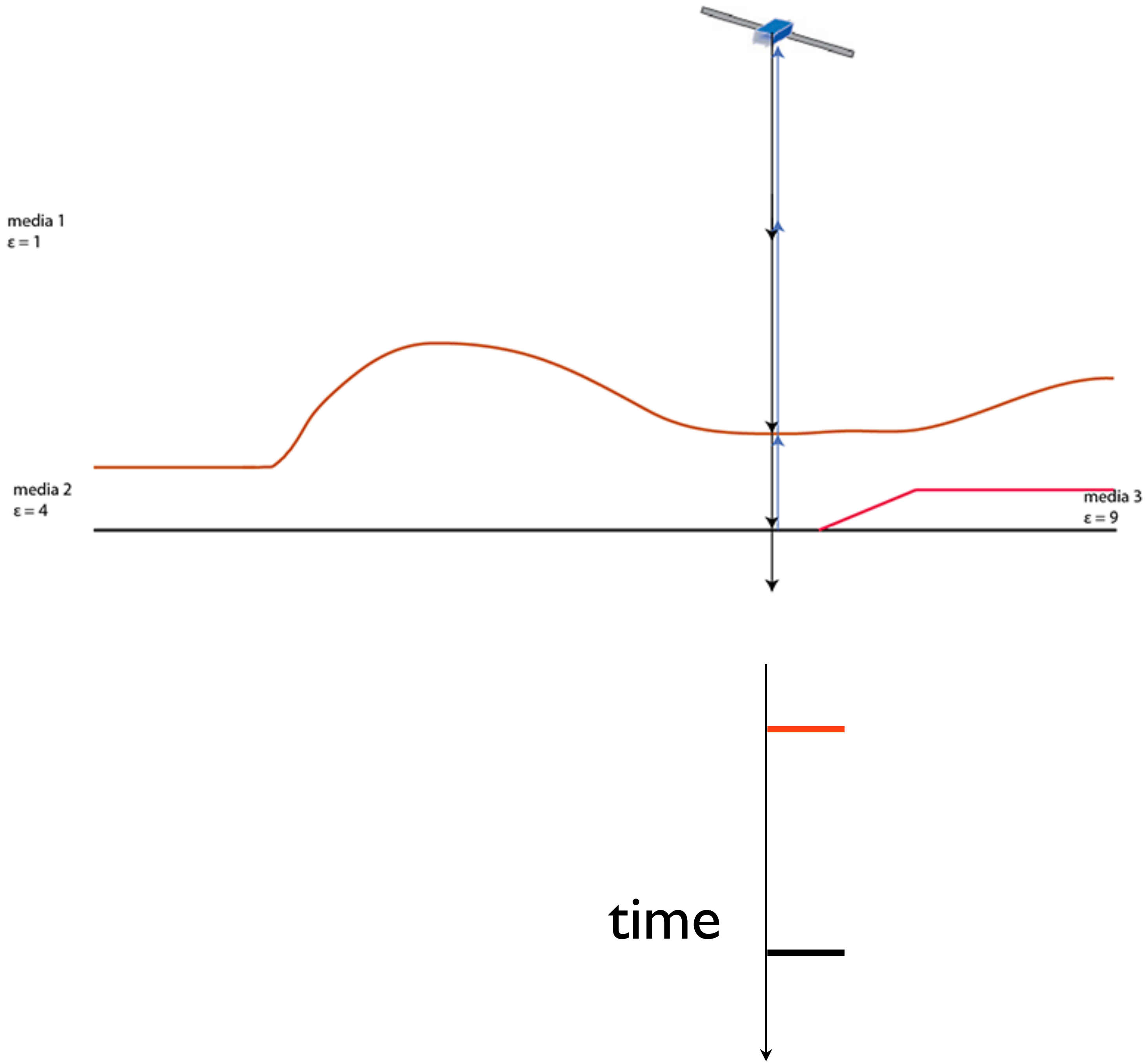
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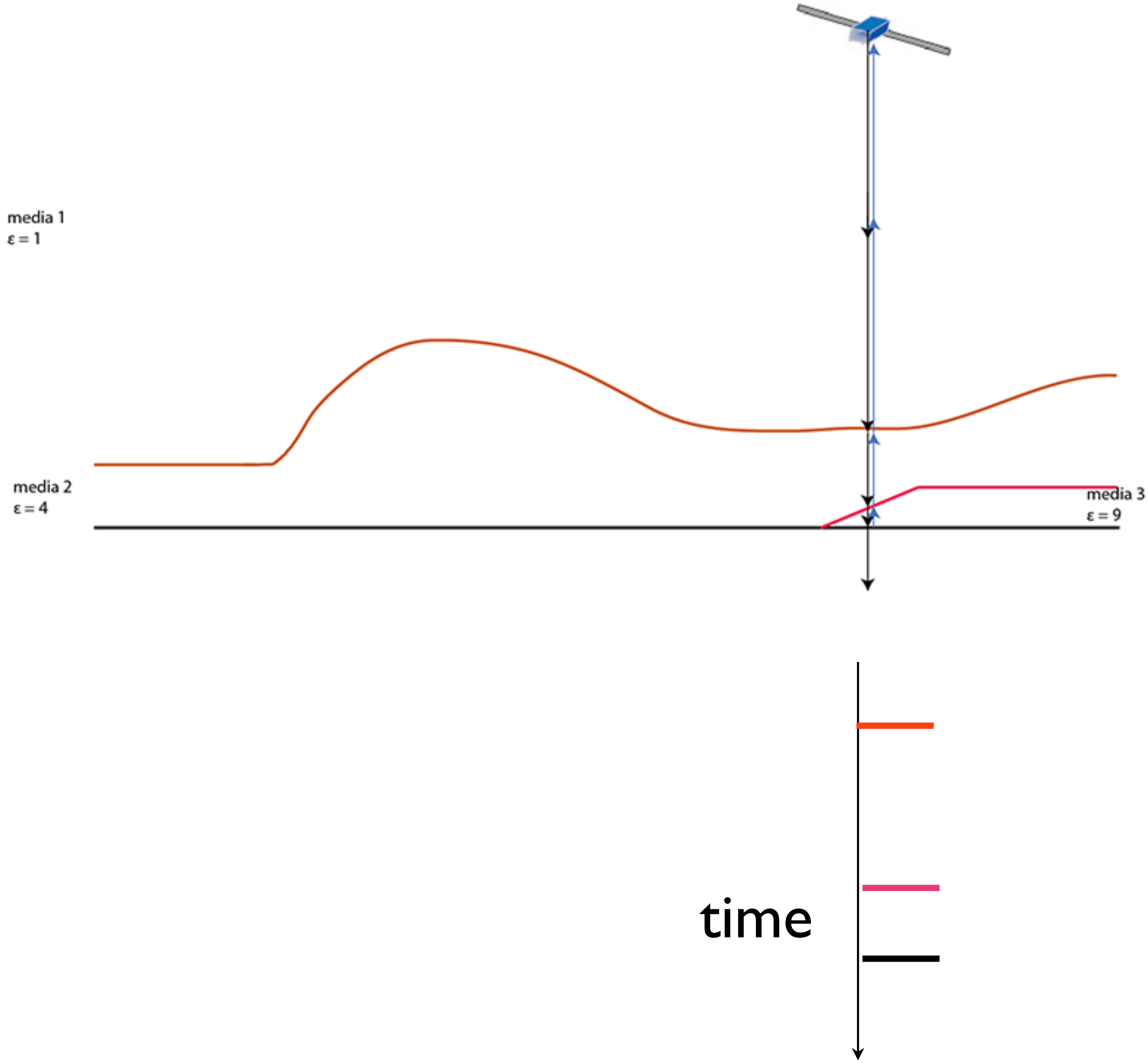
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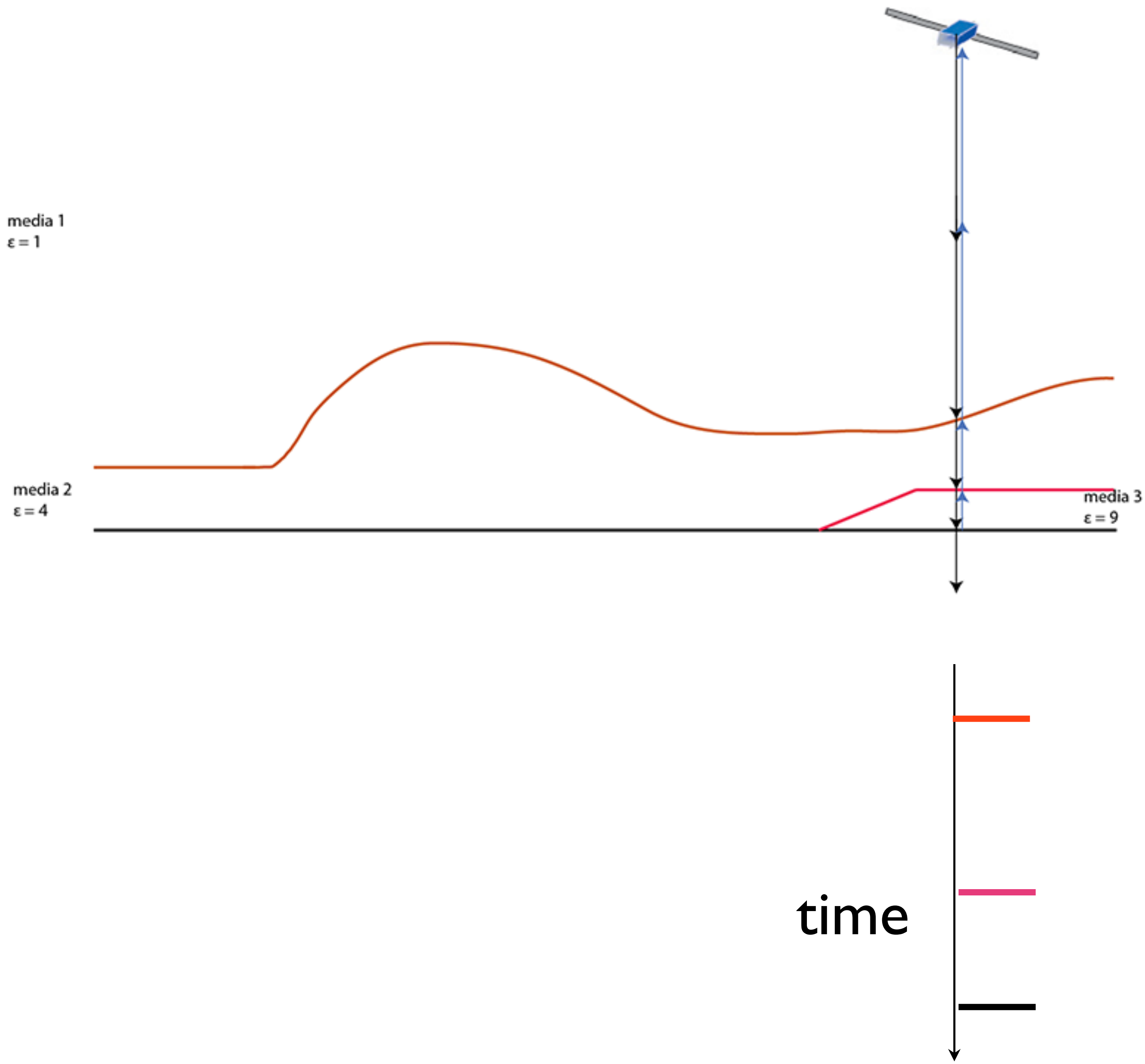
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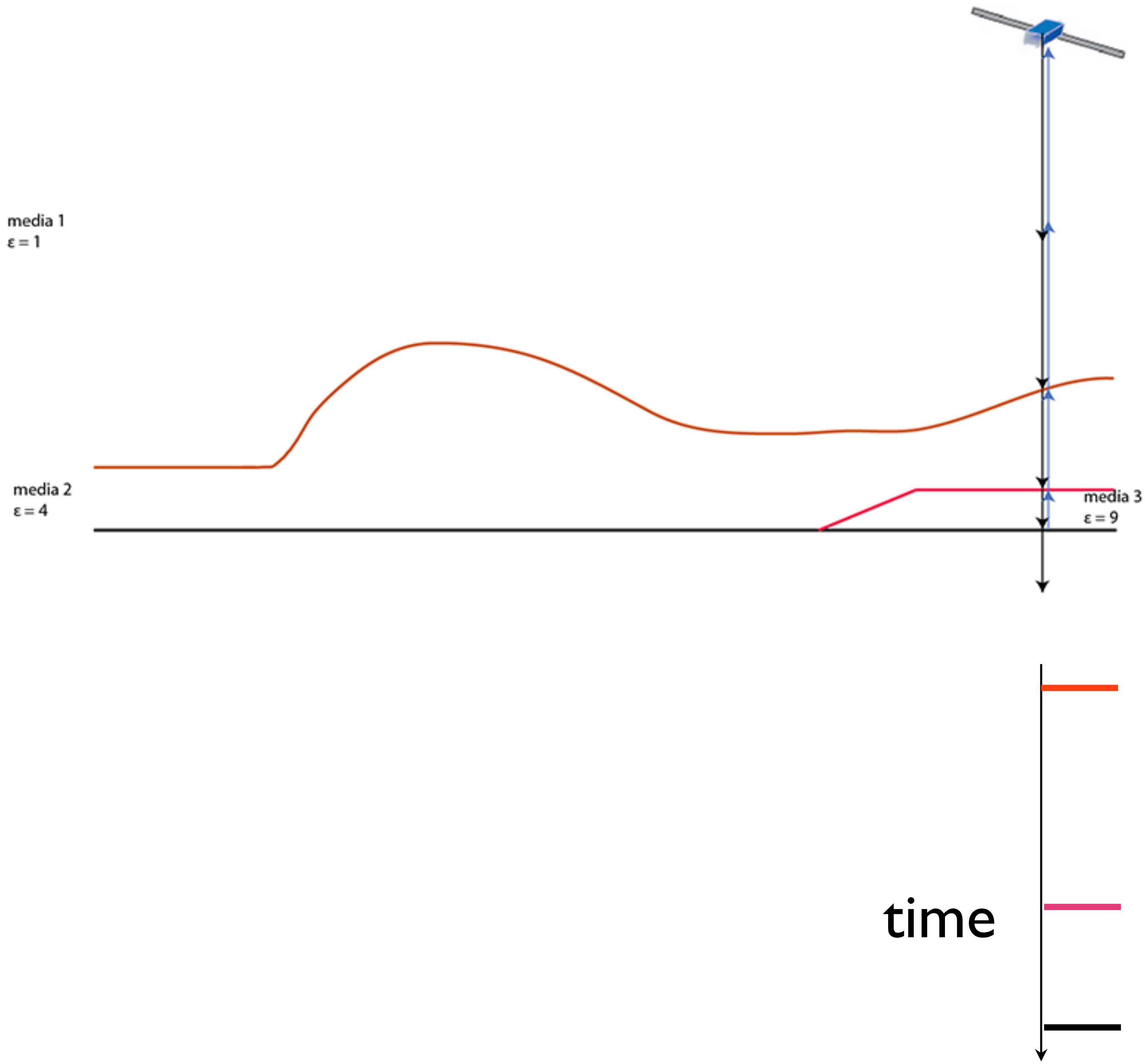
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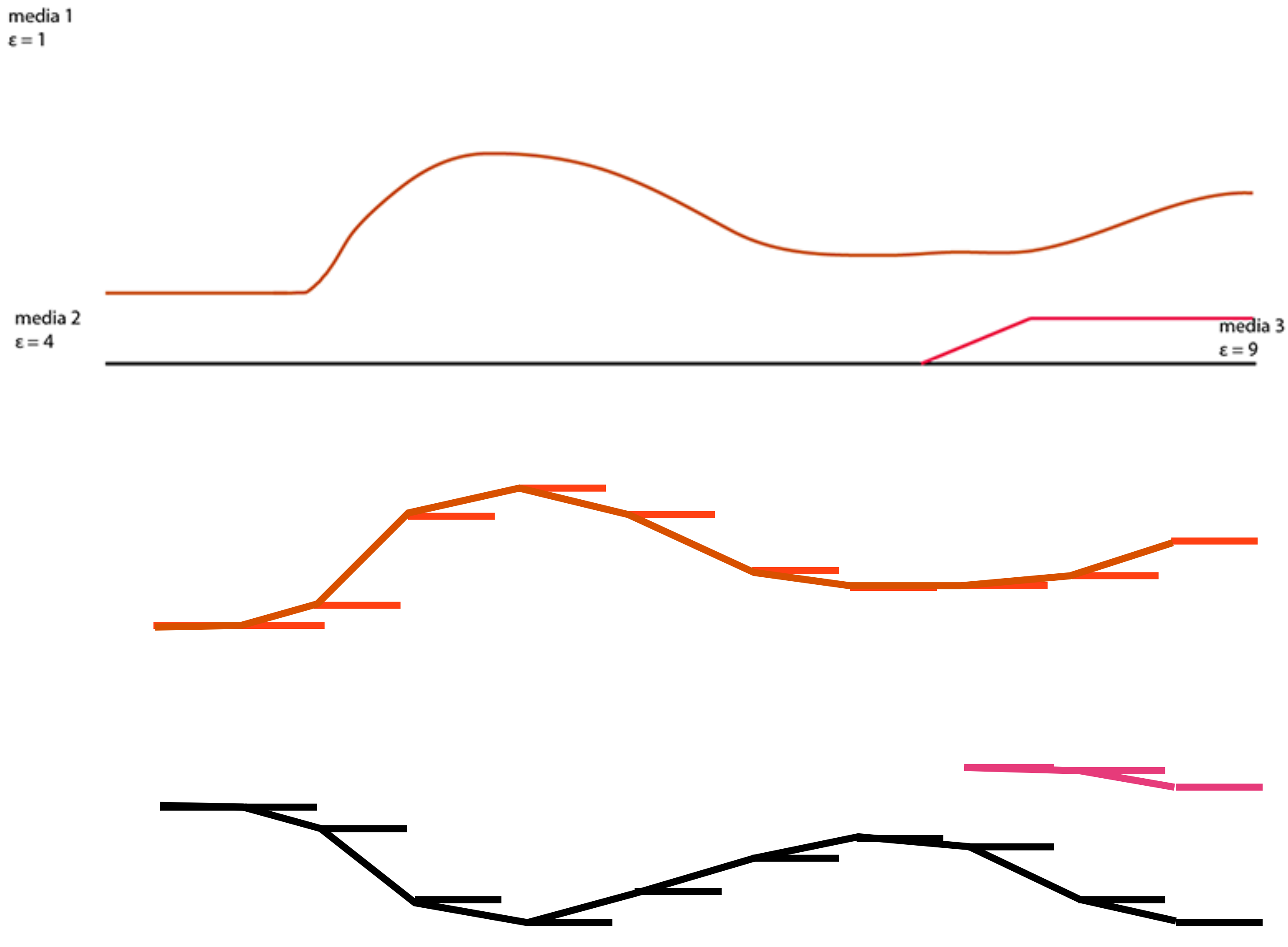
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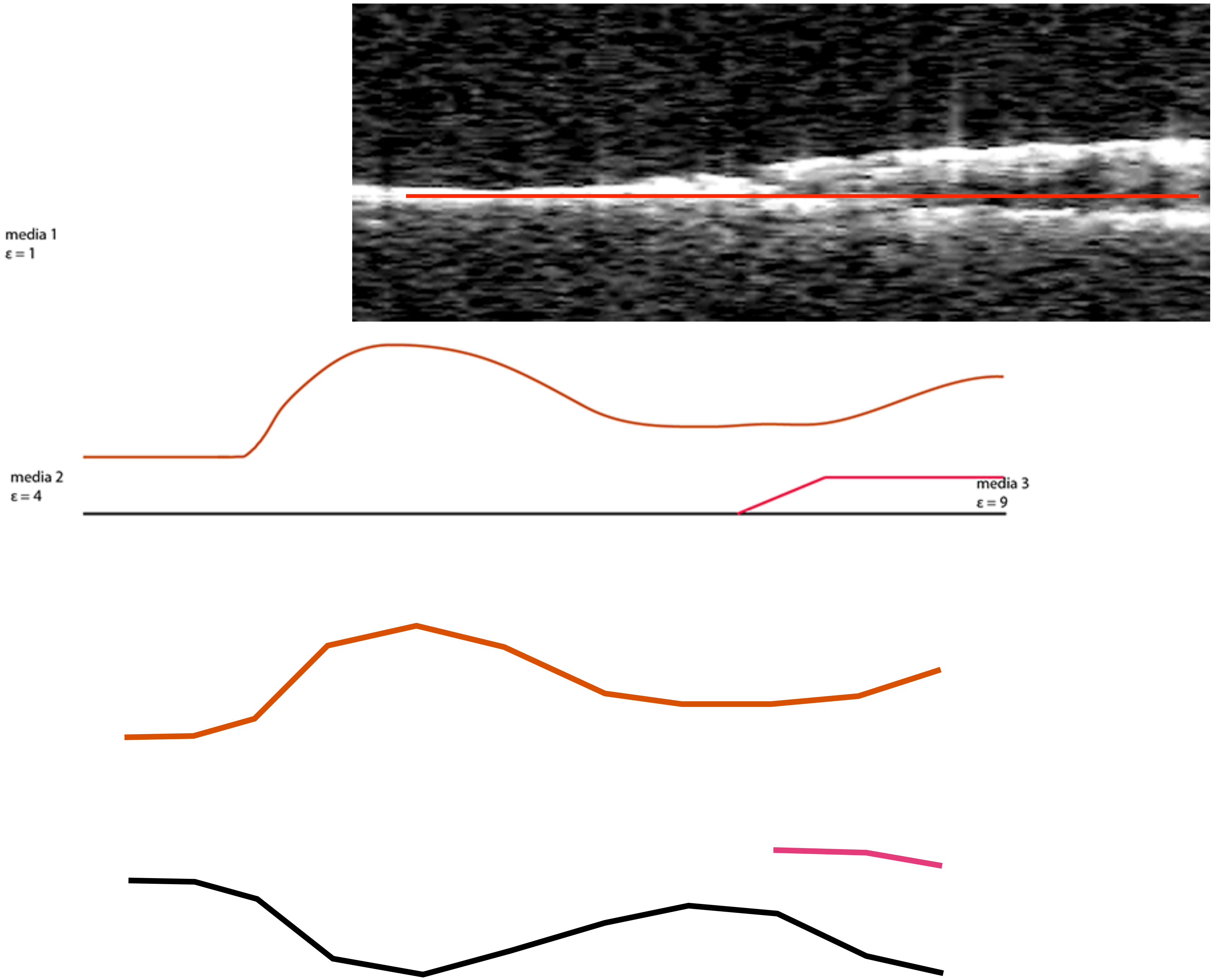
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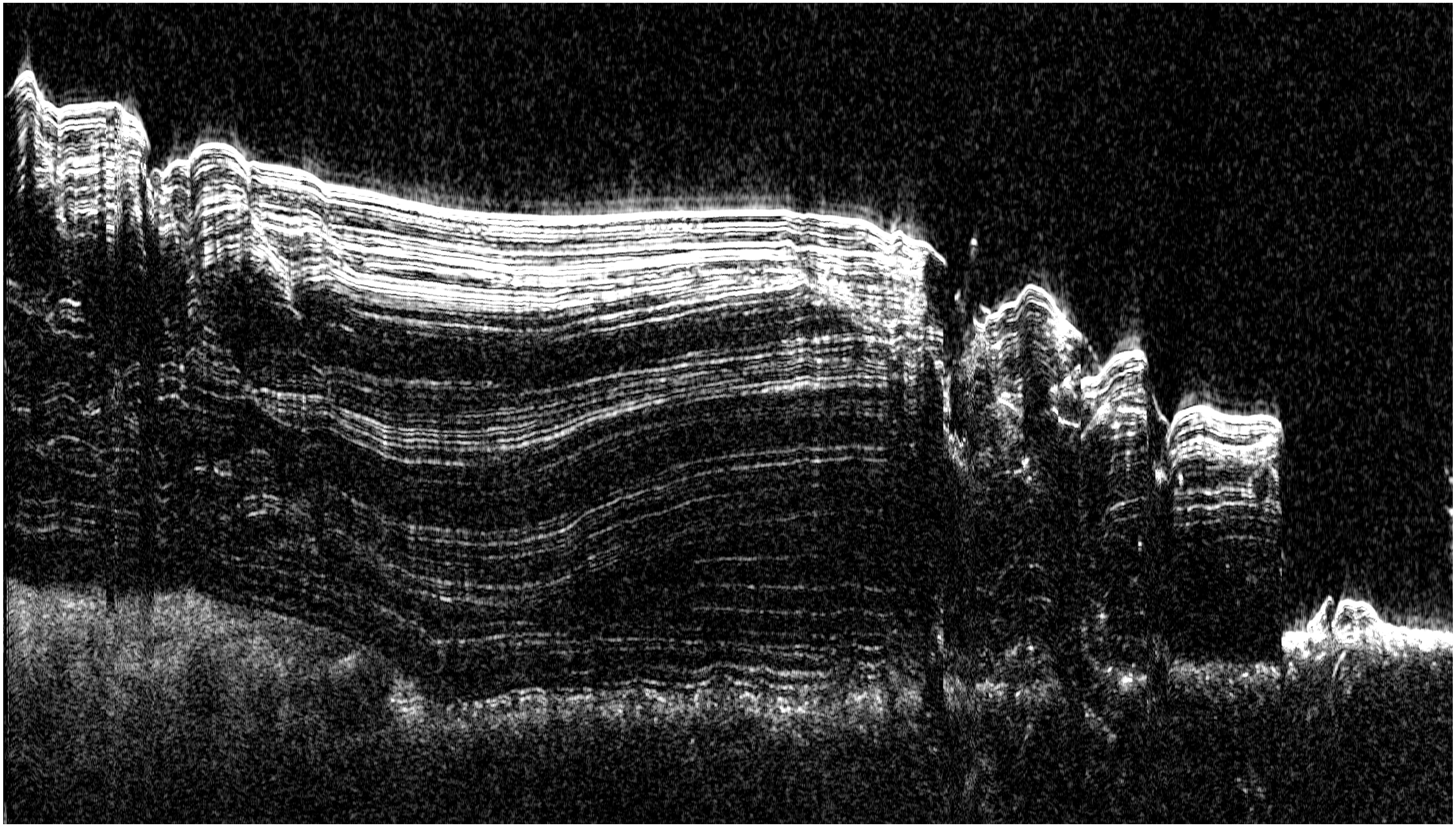
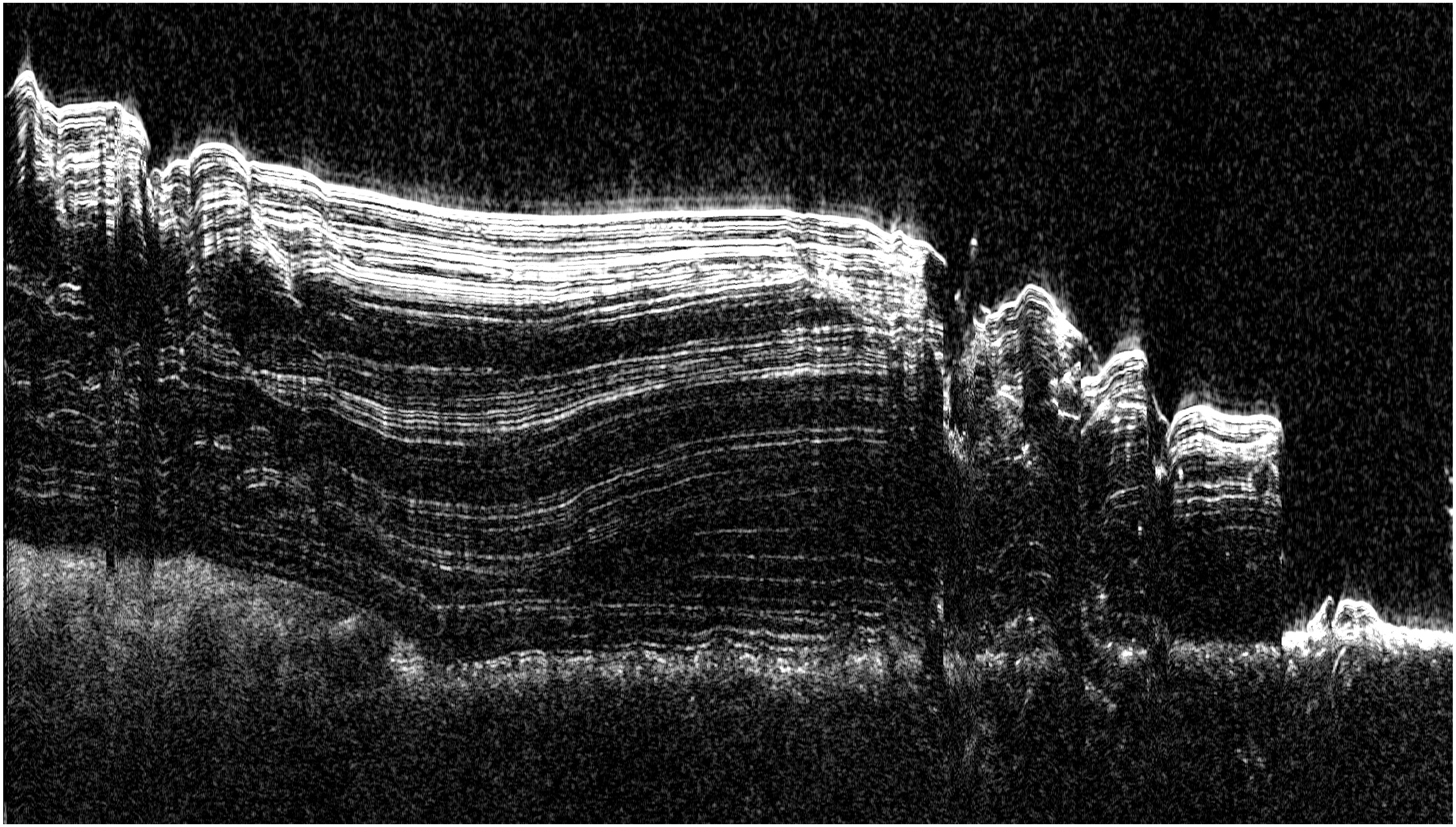
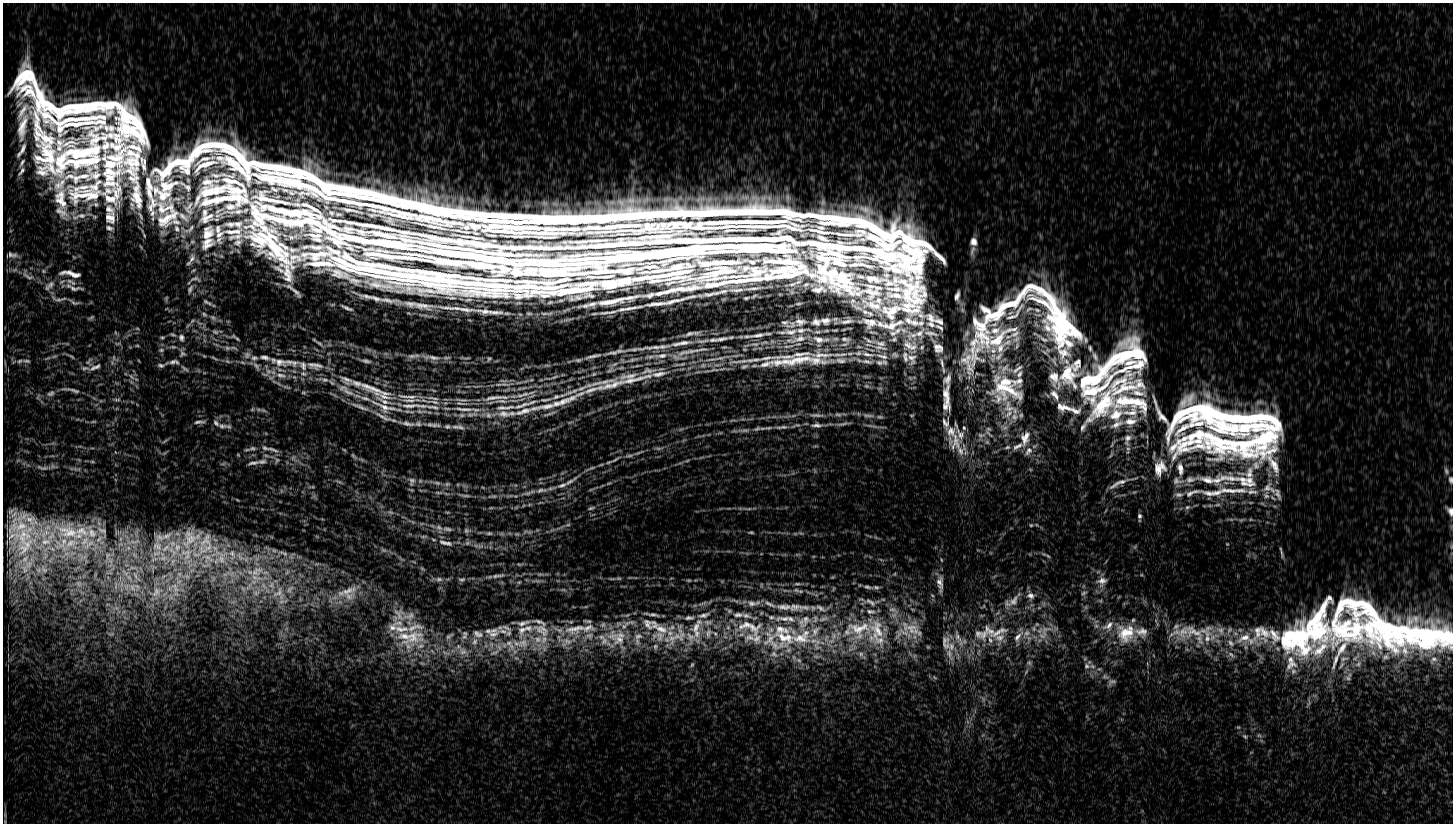


ε' 3.8

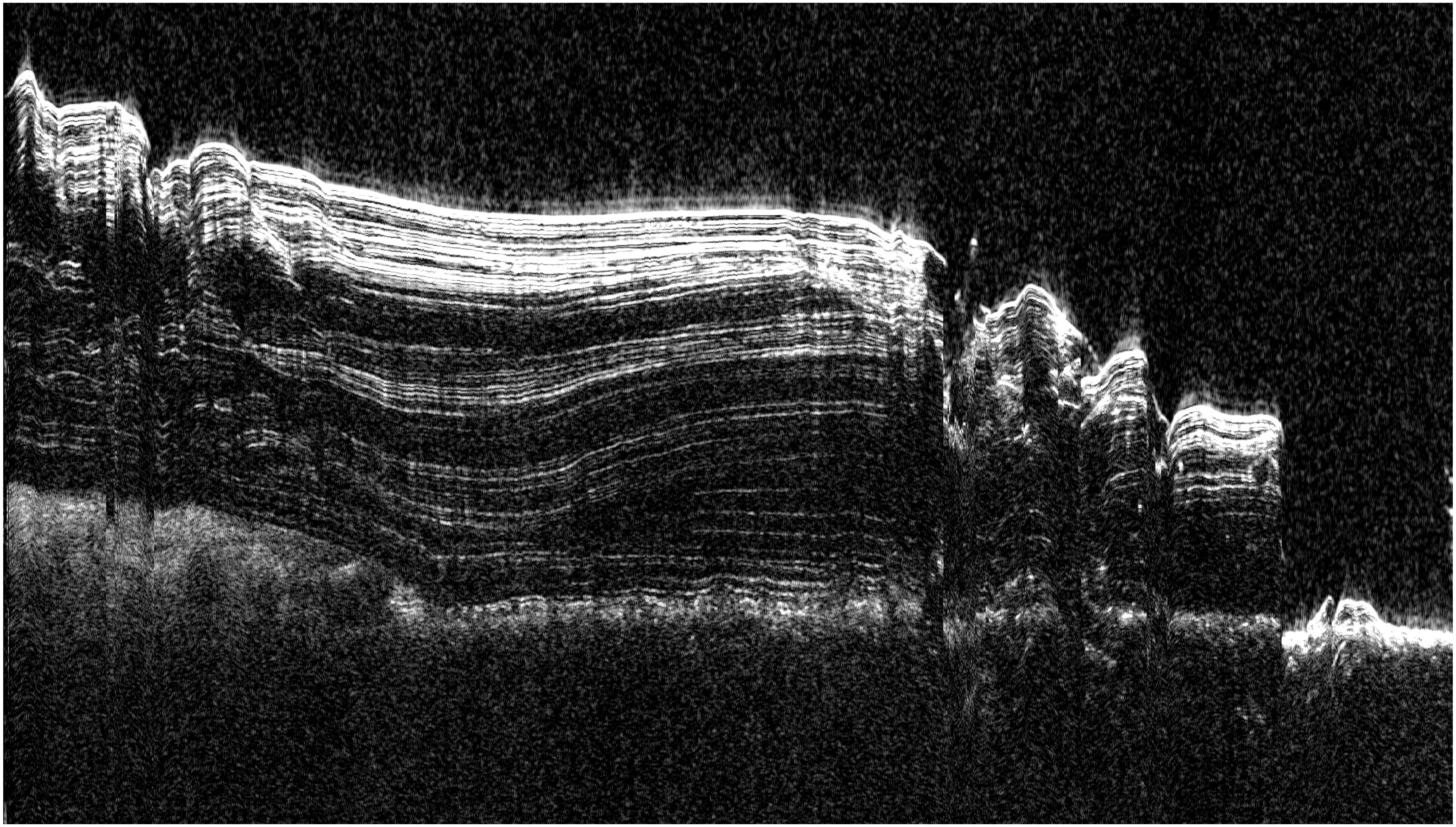
This + next 4 slides: time to depth w/ different ε'



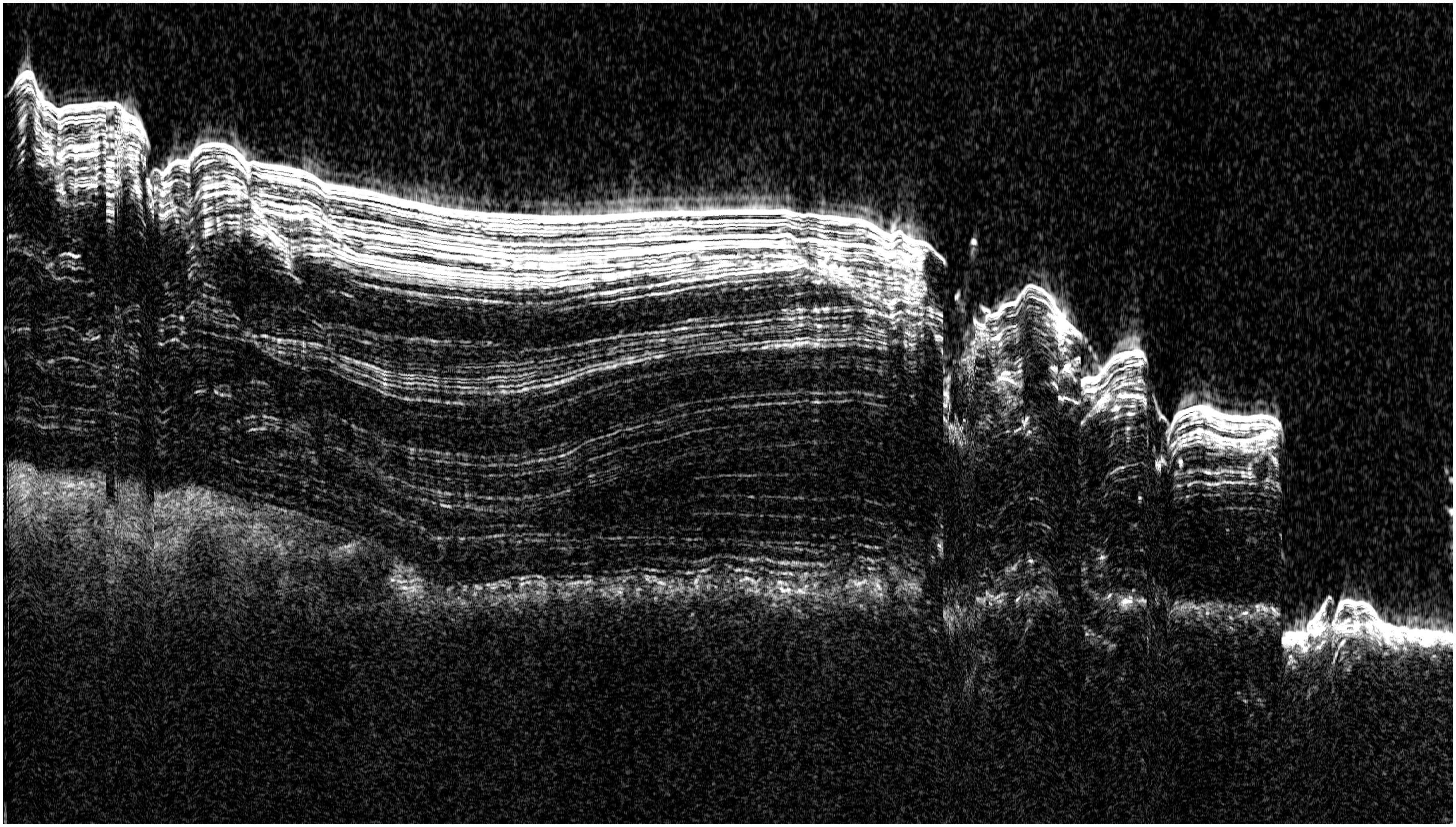
ε' 3.4



ε' 3.0

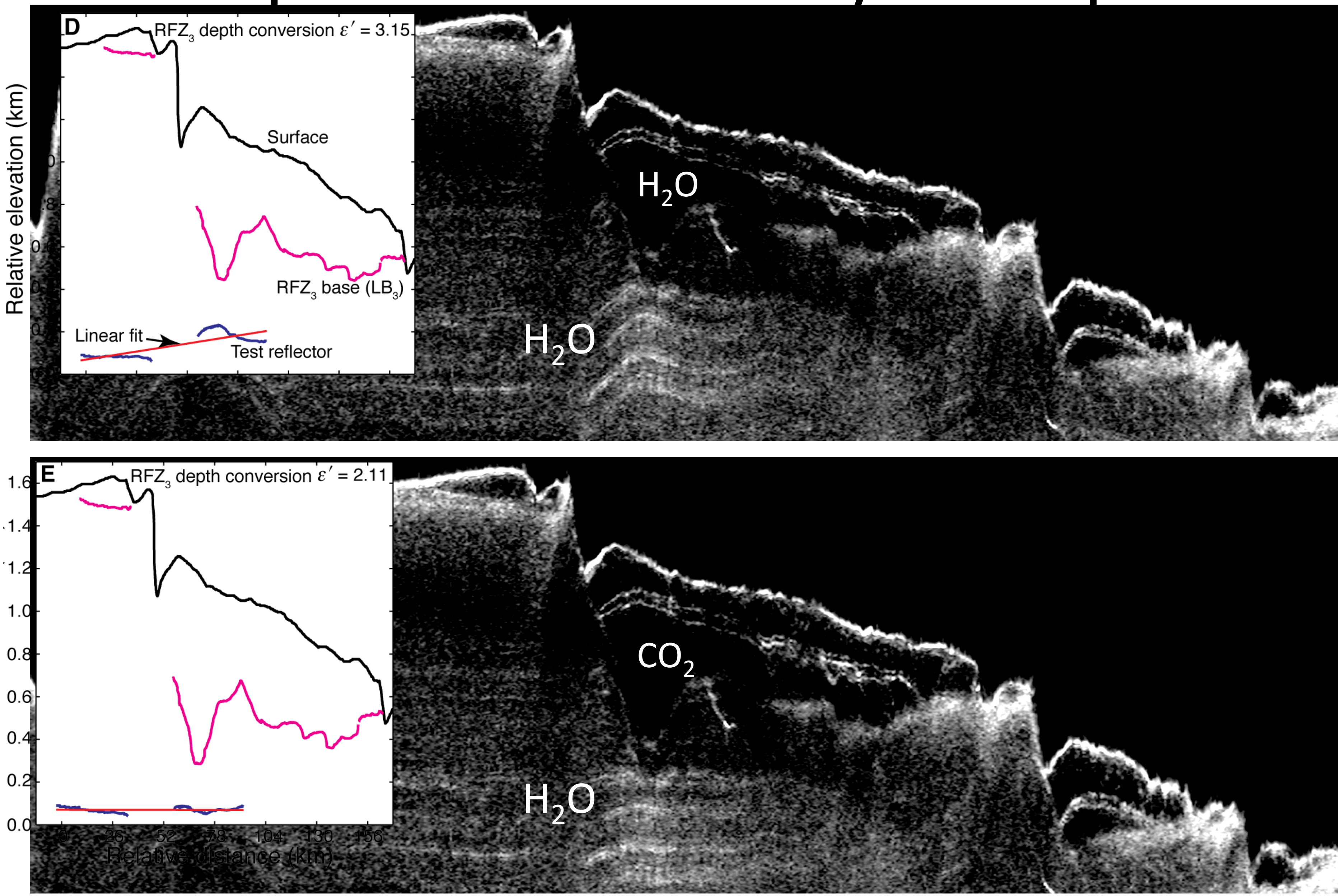


ε' 2.6

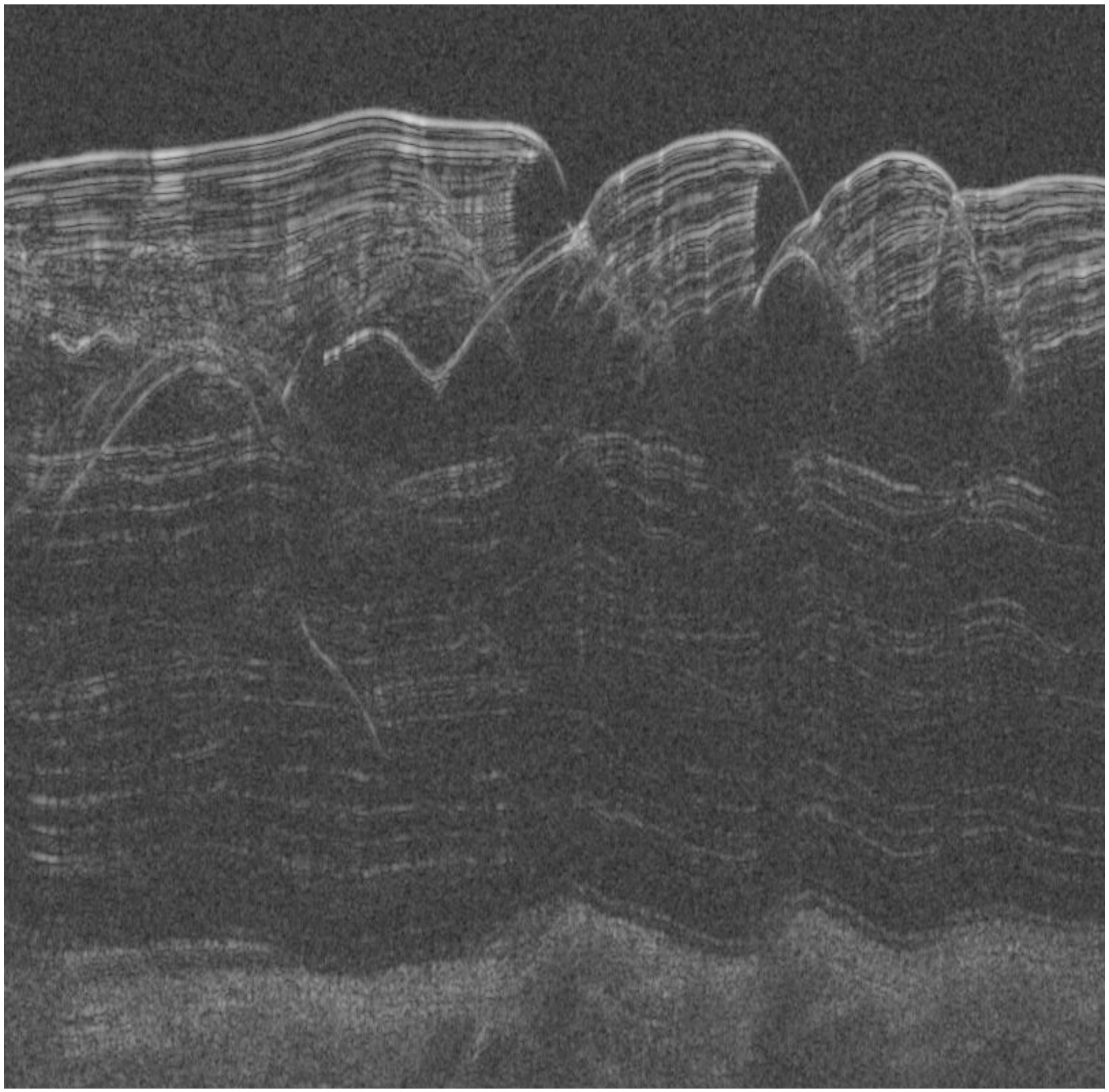


ε' 2.2

Depth conversion w/ multiple ε'



How deep is a reflector?



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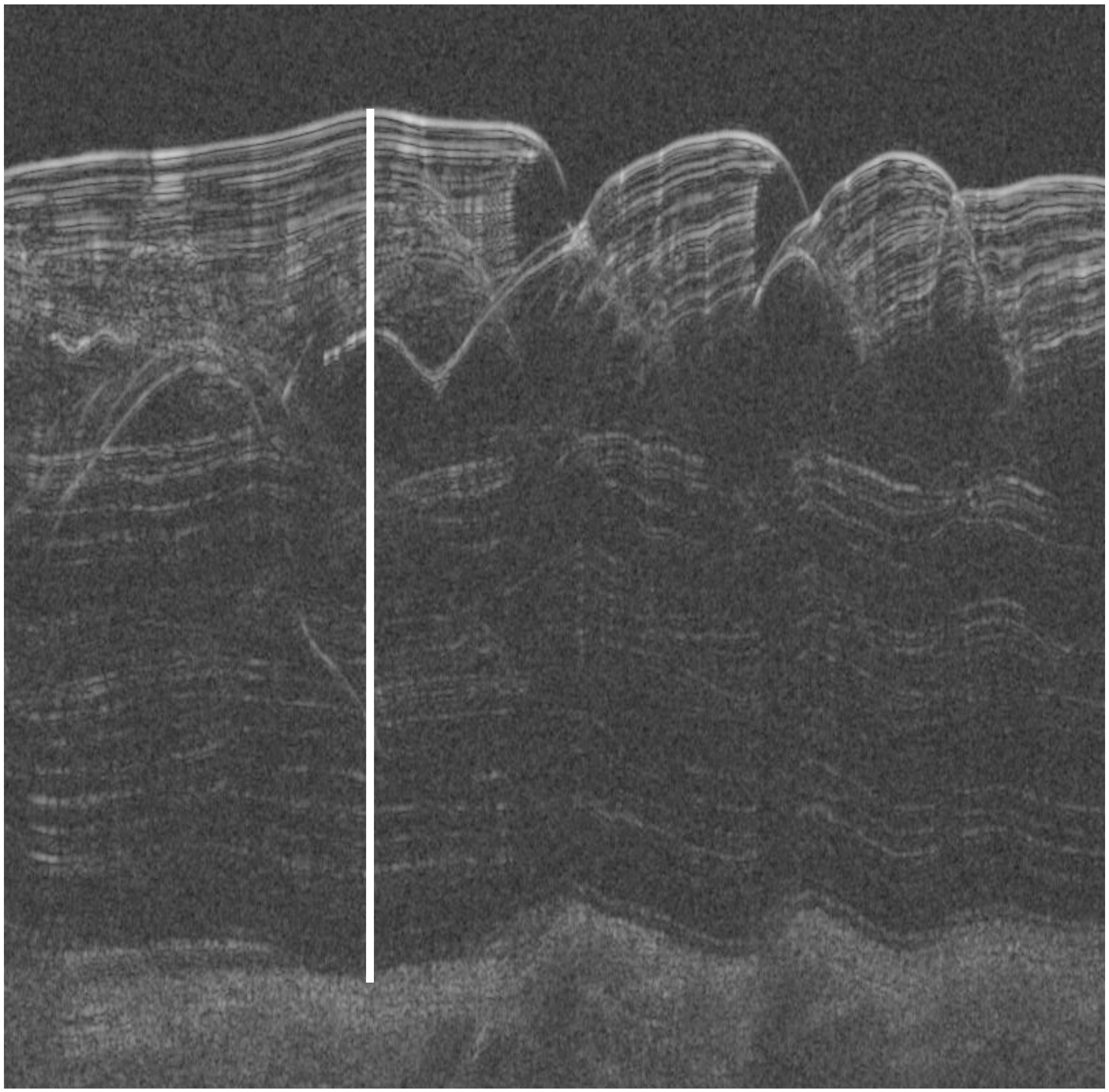
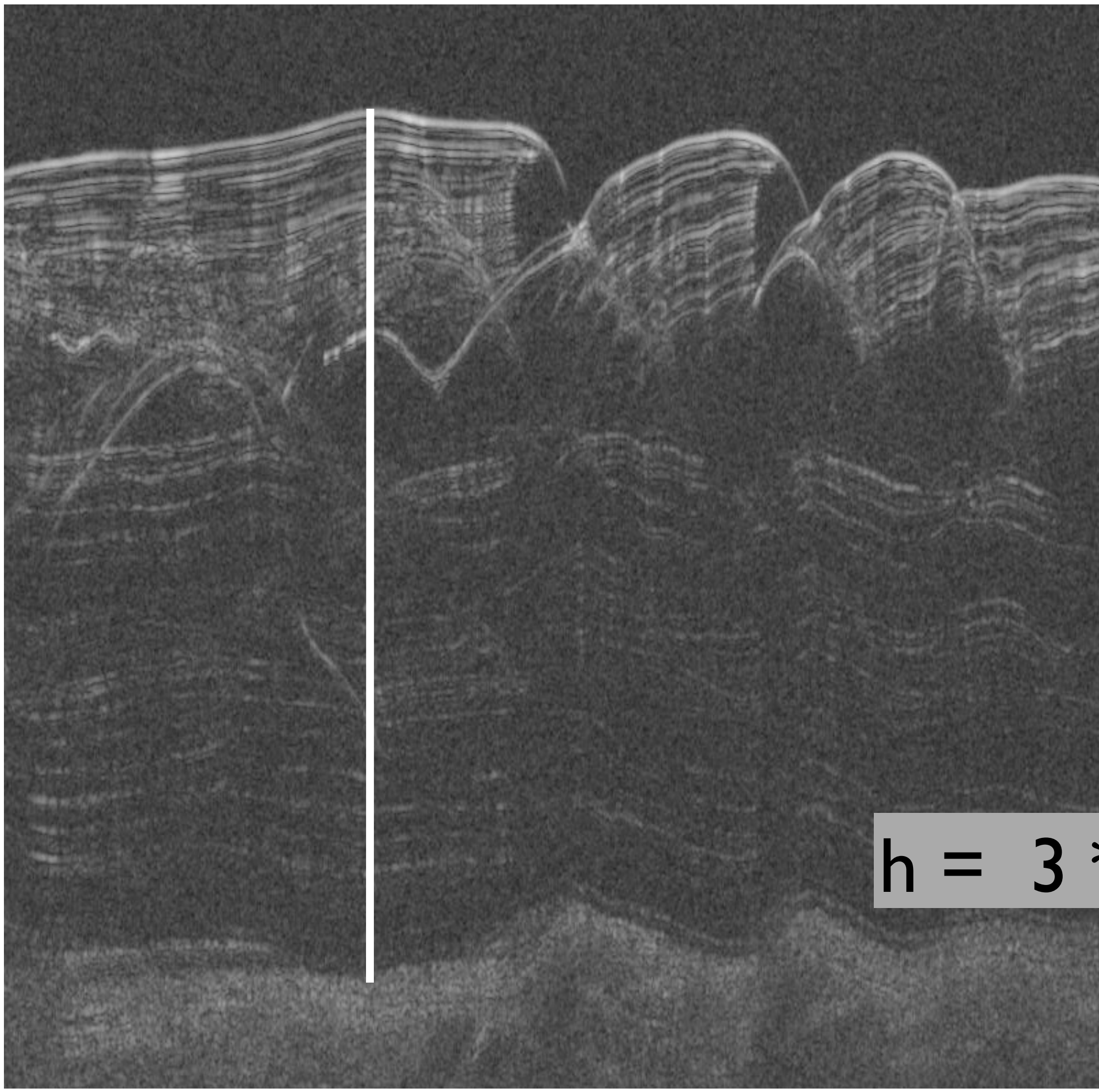


631 pixels

x 37.5 ns per pixel

23.7 μs TWT

How deep is a reflector?



23.7 μs TWT

11.8 μs OWT

$h = v * OWT$

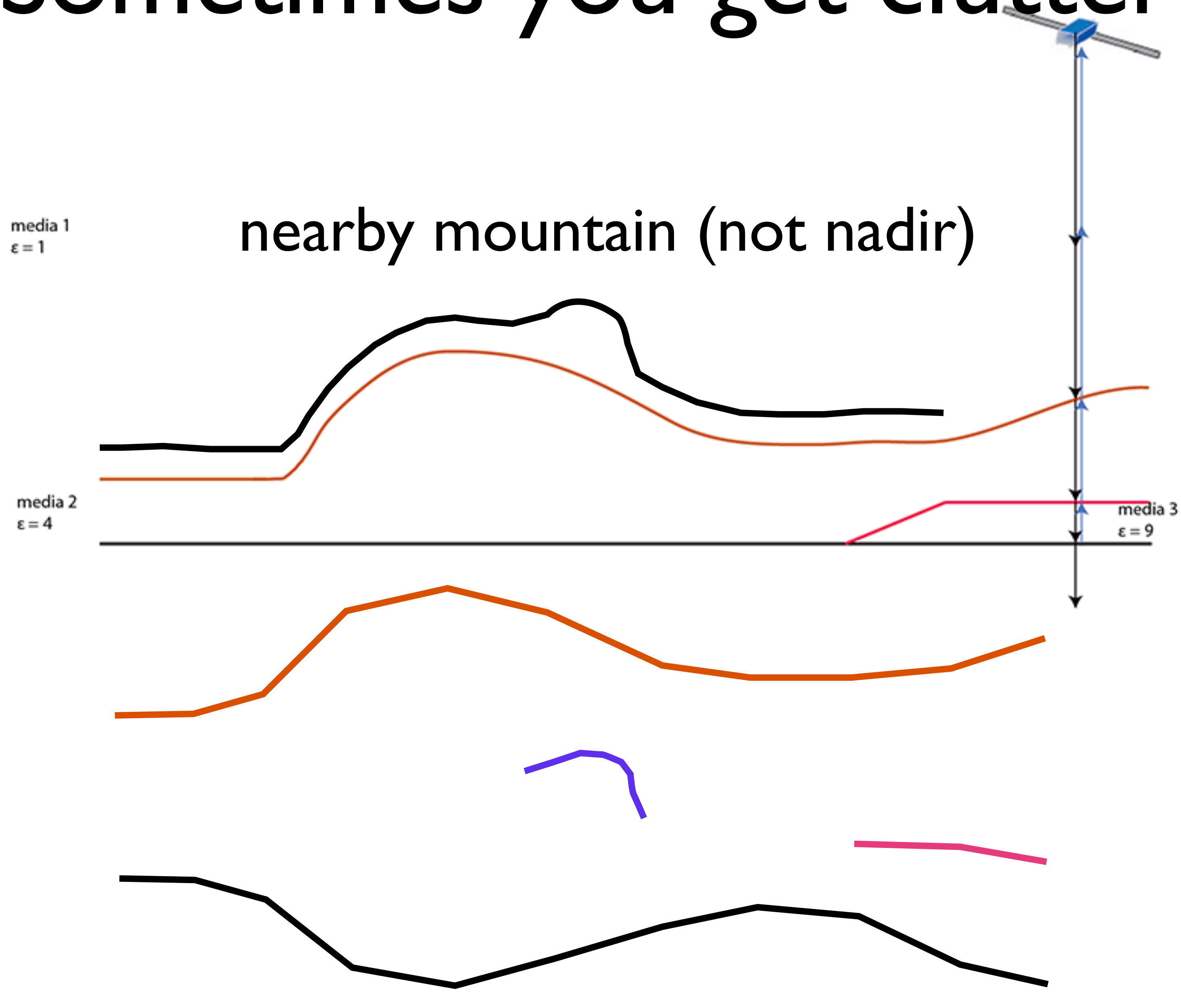
$v = c / \sqrt{3.15}$

$c = 3 \times 10^8$ m/s

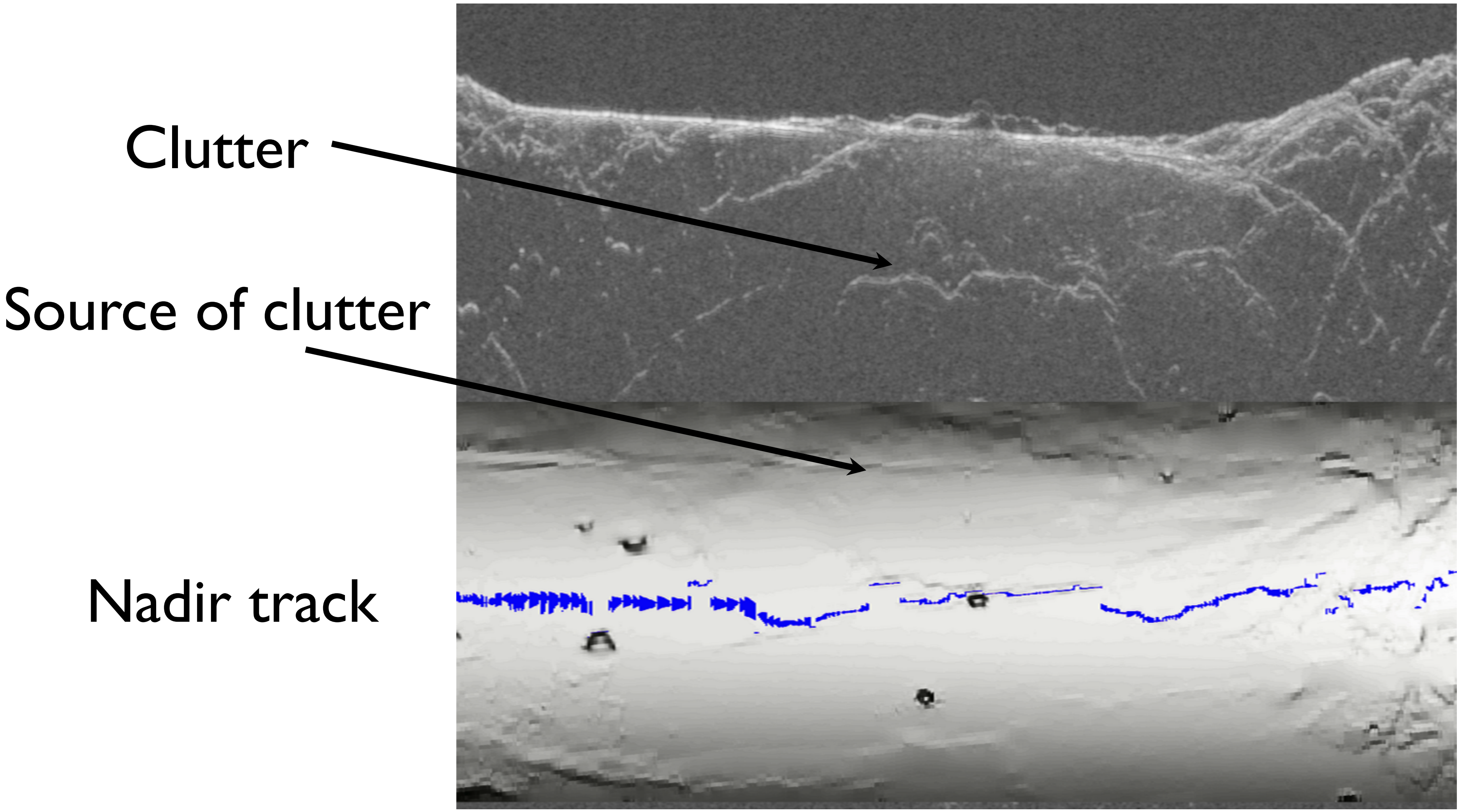
$h = 3 * 10^8 / \sqrt{3.15} * 11.8\ \mu s$

$h = 2000$ m

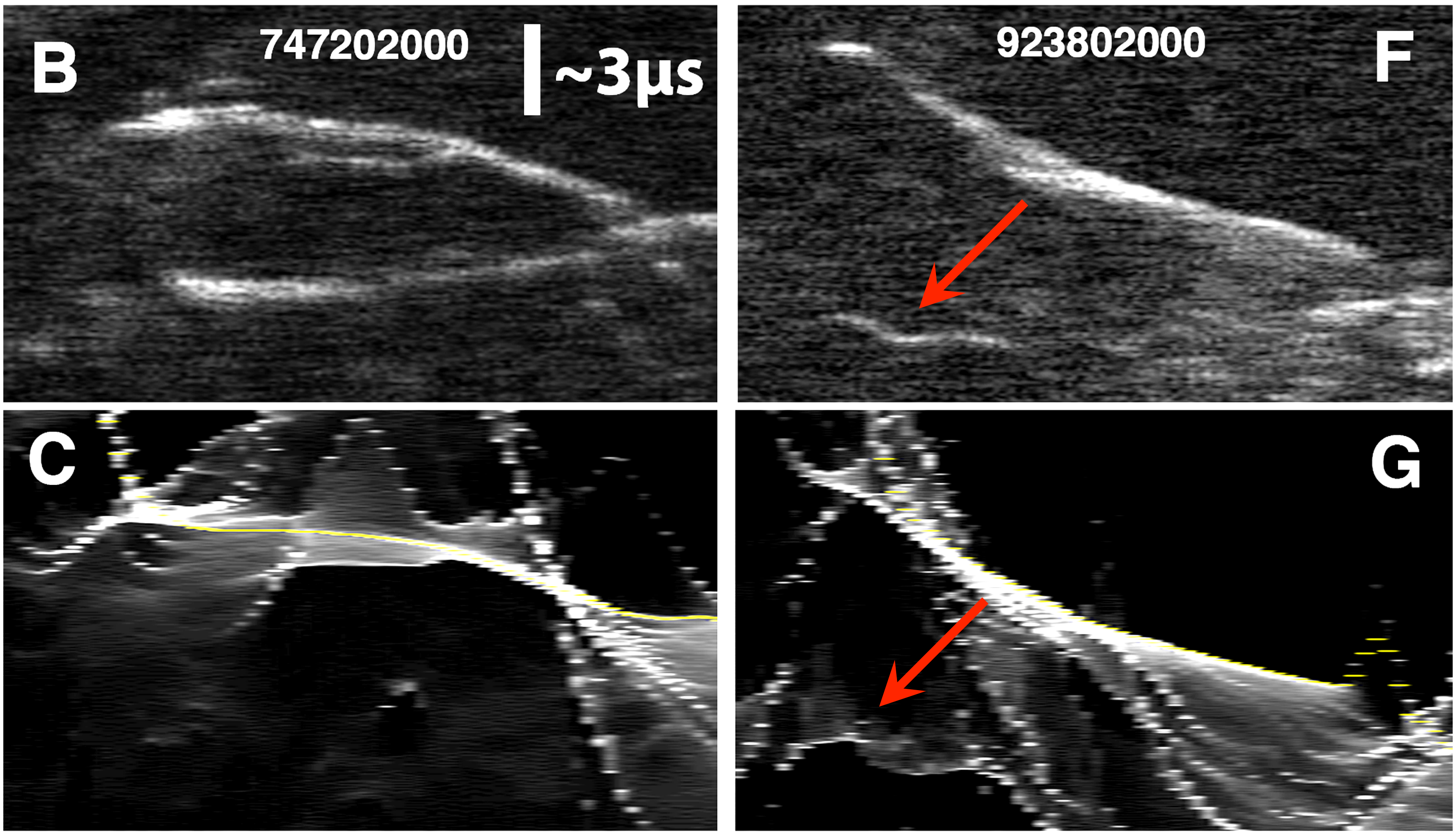
Sometimes you get clutter



Sometimes you get clutter



Sometimes you get clutter



SHARAD Comparison with MARSIS

	MARSIS	SHARAD
Frequency Bands	1.3-2.3 MHz, 2.5-3.5 MHz, 3.5-4.5 MHz, 4.5-5.5 MHz	15-25 MHz
Vertical Resolution ($\varepsilon' = 5$)	~100 m (1 MHz BW)	~10 m (10 MHz BW)
Penetration Depth	> 3 km in ice-dominated material	Few 100 m in rock Up to 2 km in ice
Horizontal Resolution (along-track x cross-track)	5-9 km x 15-30 km	0.3-1 km x 3-6 km
Processing	Mostly on-board	Mostly on the ground

Congratulations!
You have passed
Sounding Radars 101