UNIVERSITÉ DE SHERBROOKE

Comment se Propage un Signal Électro-Magnétique?
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Level 3: Impedance & Reflection [20min - 1h10]

Level 3: Impedance & Reflection [20min - 1h10]

- ✗ Type of source
- ✗ High/Low Impedance
- ✗ GPIO output circuit

Level 3: Impedance & Reflection [20min - 1h10]

Electric Permittivity [F/m]:

$$\varepsilon = \varepsilon_r \varepsilon_0$$

Magnetic Permeabililty [H/m]:

$$\mu = \mu_r \mu_0$$

Refractive Index:

$$n = \frac{\sqrt{\varepsilon\mu}}{\sqrt{\varepsilon_0\mu_0}} = \sqrt{\varepsilon_r \mu_r}$$

Nous avons initialement considéré ces valeurs comme étant des nombre réel $\mathbb{R}$.

Cela fonctionne tres bien pour definir des matériaux **sans pertes**.

Par contre, dans la vrai vie, ce sont des nombres complexe $\mathbb{C}$. Cela permet de définir des matériaux **avec pertes**

Indice de Refraction Complexe:

$$\tilde{n} = n + jk$$

Permittivitée Complexe:

$$\varepsilon = \epsilon_1 + j\epsilon_2 = (n + jk)^2$$

$$\epsilon_1 = n^2 - k^2$$

$$\epsilon_2 = 2nk$$

Indice de Refraction:

$$n = \sqrt{\frac{\sqrt{\epsilon_1^2 + \epsilon_2^2} + \epsilon_1}{2}}$$

Coefficient d'Extinction:

$$k = \sqrt{\frac{\sqrt{\epsilon_1^2 + \epsilon_2^2} - \epsilon_1}{2}}$$

mettre graphique sinusoidale ammortie

$$T = e^{-kl} \tag{1}$$

a valider

Level 3: Impedance & Reflection [20min - 1h10]

- PPPPP2
- Impedance dans le plan complexe
- Rappel qu'on ignore la conductance G.
- Propagation Constant (p.56)

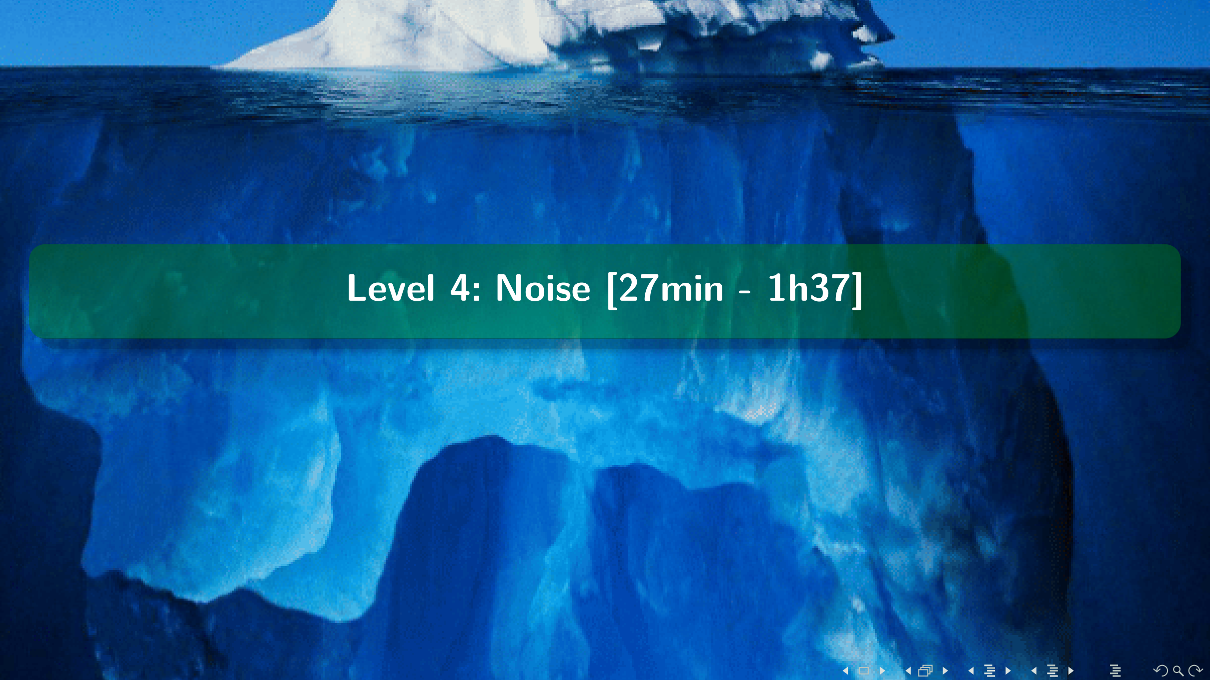
- ✗ L'Électricité prend le chemin avec la plus petite **Resistance**
- ✓ L'Électricité prend le chemin avec la plus petite **Impedance**

Level 3: Impedance & Reflection [20min - 1h10]

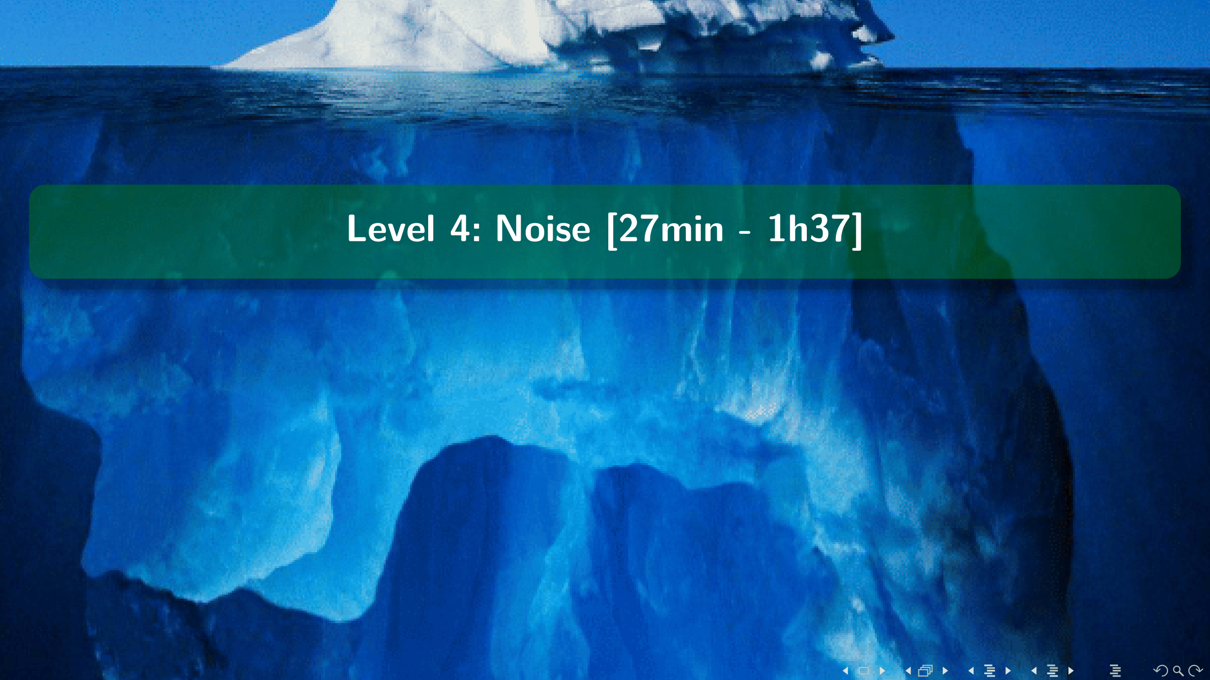
- Bounce Diagram
- Impedance Mismatch
- Item 3

Level 3: Impedance & Reflection [20min - 1h10]

- ✗ Equation de base
- ✗ Pertes en dB (exponential decay)



Level 4: Noise [27min - 1h37]



Level 4: Noise [27min - 1h37]

- Pourquoi c'est important
- Analogie des dB avec le stock market
- Item 3

Signal Power in dB

$$P_{Signal|\mathrm{dB}} = 10\log\frac{P_{\mathrm{Signal|W}}}{1\mathrm{W}} \tag{2}$$

Signal Power in dBm

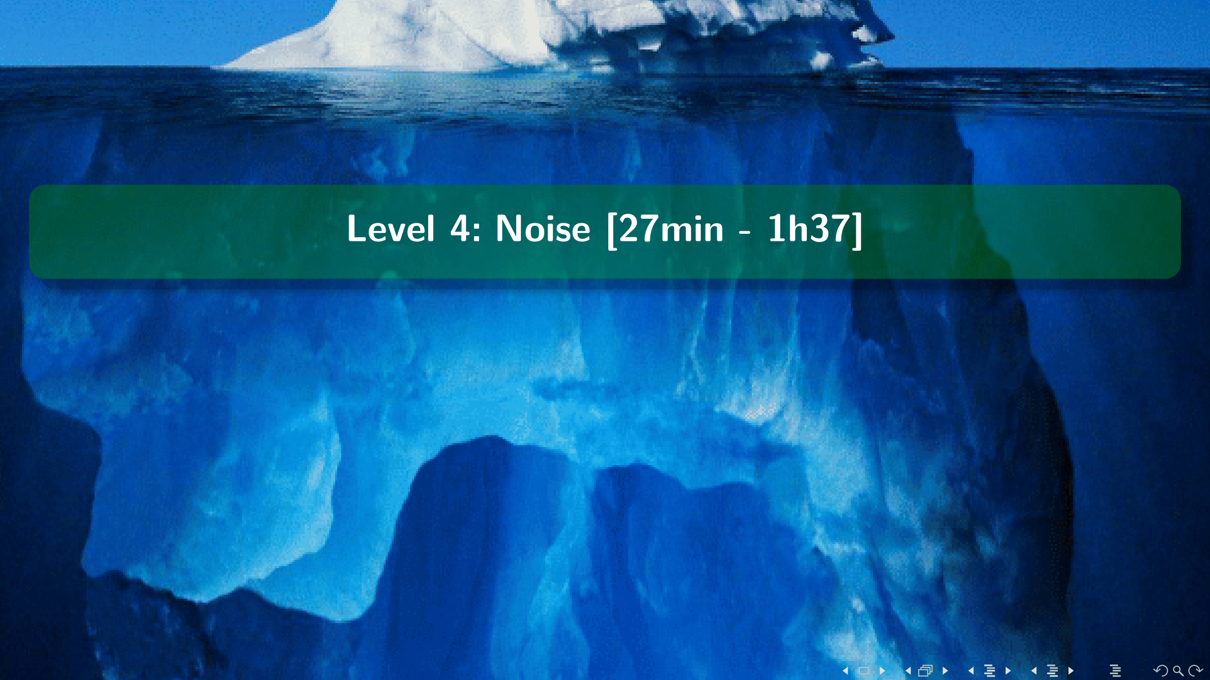
$$P_{Signal|\mathrm{dBm}} = 10\log\frac{P_{\mathrm{Signal|mW}}}{1\mathrm{mW}} \tag{3}$$

Voltage Gain

$$A_{V|\mathrm{dB}} = 20\log\frac{V_{out}}{V_{in}} \iff \frac{V_{out}}{V_{in}} = 10^{\frac{A_V}{20}} \tag{4}$$

Power Gain

$$A_{V|\mathrm{dB}} = 10\log\frac{P_{out}}{P_{in}} \iff \frac{P_{out}}{P_{in}} = 10^{\frac{A_P}{10}} \tag{5}$$



Level 4: Noise [27min - 1h37]

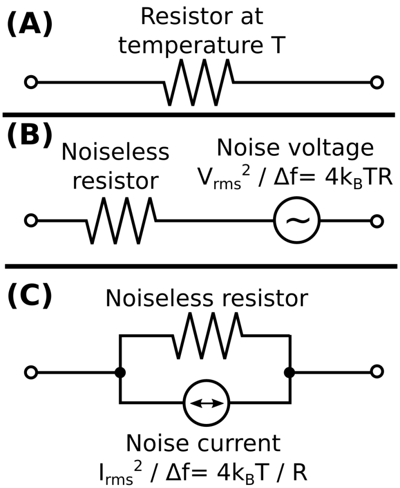
- ✗ Random Noise Source
- ✗ Noise Power
- ✗ Source of noise in a circuit

- ✘ Thermal Noise
- ✘ Environmental Noise
- ✘ Flicker Noise

Johnson-Nyquist Noise Equation:

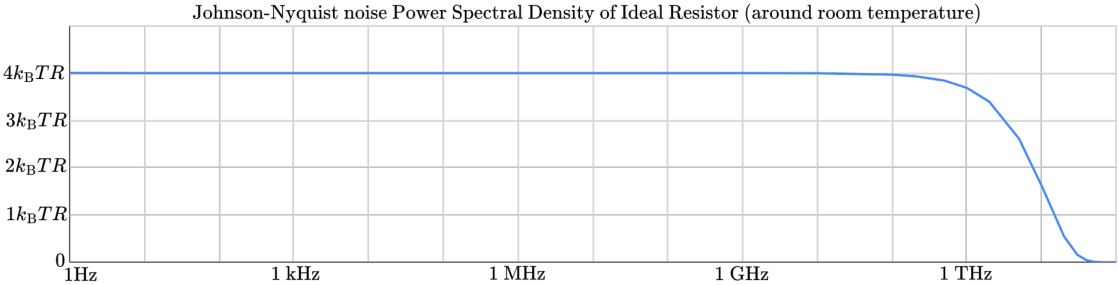
$$V_{rms} = \sqrt{4k_B TR\Delta f} \tag{6}$$

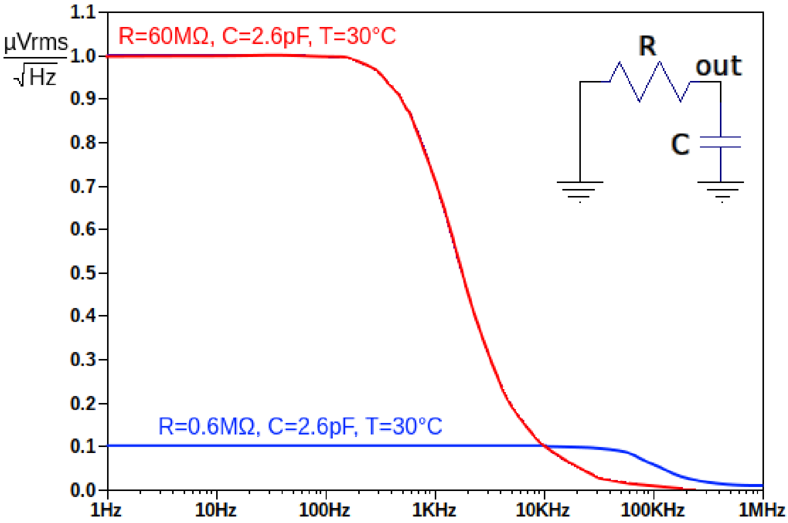
$k_b = 1.38 \times 10^{-23}$: Boltzmann Constant [J]
T: Temperature [K]
Δf: Frequency Range
R: Resistance [Ohm]



Valeurs pour 300k:

$$V_{rms} = 0.13 \cdot \sqrt{R\Delta f} \qquad [nV] \tag{7}$$





R=60MΩ, C=2.6pF, T=30°C
R=0.6MΩ, C=2.6pF, T=30°C
µVrms
√Hz
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1Hz
10Hz
100Hz
1KHz
10KHz
100KHz
1MHz
R
out
C

Bruit Condensateur:

$$V_{rms} = \sqrt{\frac{k_B T}{C}} \tag{8}$$

Bruit Inducteur:

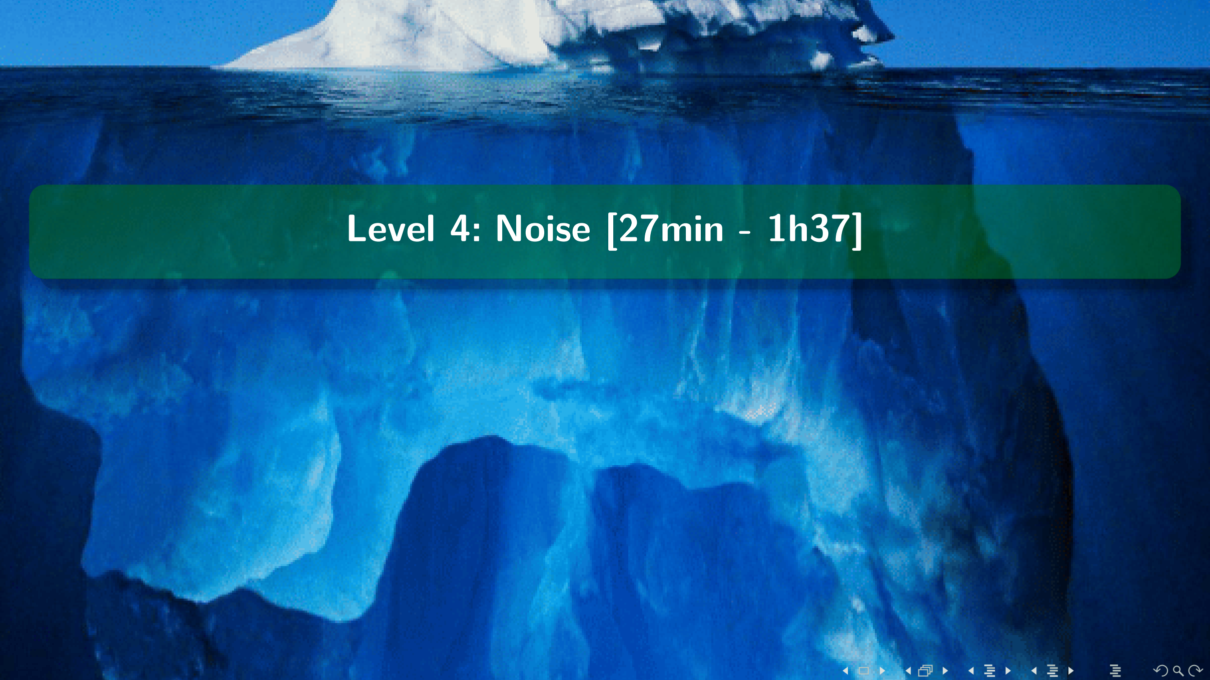
$$\overline{I_n} = \sqrt{\frac{k_B T}{L}} \tag{9}$$

Table 1: Niveau de bruit thermique pour differentes applications (wiki)

Source	Bandwith	Noise Power (300K)
Radio FM	10 kHz	-134 dBm
Bluetooth	1 MHz	-114 dBm
GPS	2 MHz	-111 dBm
WLAN 802.11	20 MHz	-101 dBm
WLAN 802.11n	40 MHz	-98 dBm
WLAN 802.11ac	80 MHz	-95 dBm
WLAN 802.11ac	160 MHz	-92 dBm

- **Atmospheriques:** Éclairs, Effets Corona, etc...
- **Industriel:** Lignes HV, Lampes Fluorescentes, etc...
- **Solaire:** Vents solaires
- **Cosmique:** Effets colectif des étoiles (8MHz-1.5GHz), CMB, Quasar, Pulsar, Chaos Gods
- **Psychologique:** Toi qui fait pas tes lectures

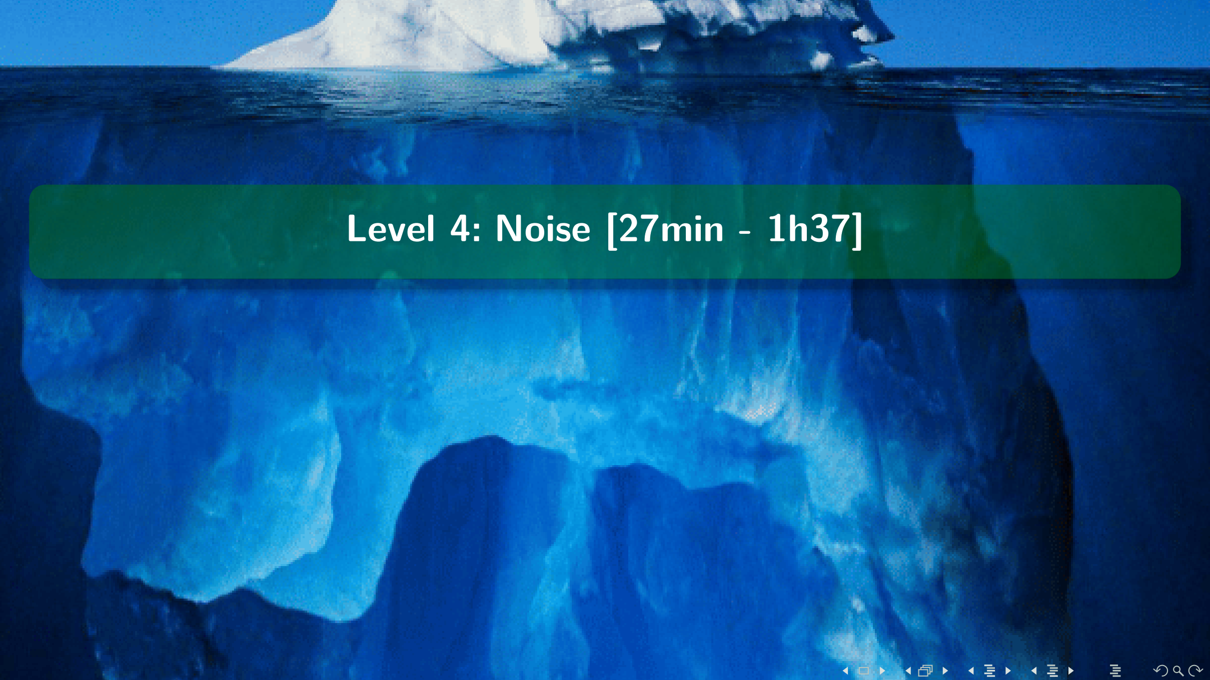
Level 4: Noise [27min - 1h37]



- ❌ Frequency dependant noise power
- ❌ Demo avec type de bruit (red, white, brown, etc..)

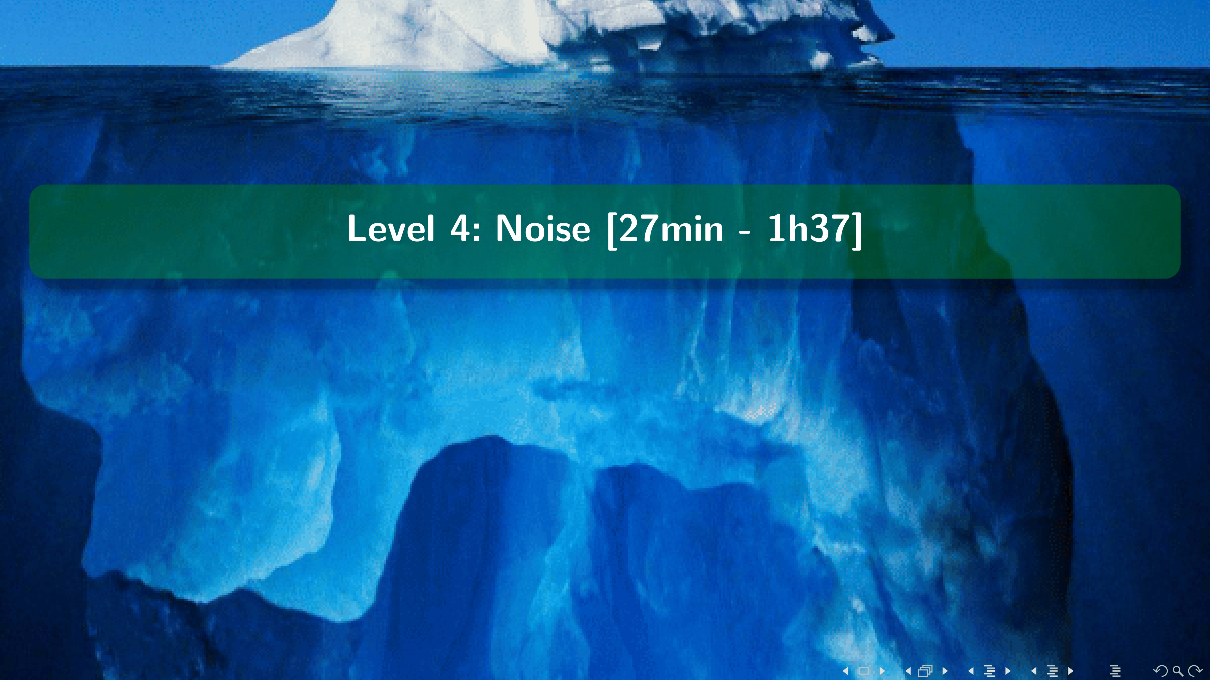
$$P_n = \lim_{T \to \infty} \frac{1}{T} \int_0^T n^2(t)\, dt \tag{10}$$

$$\int_0^\infty S_x(f)\, df = \lim_{T \to \infty} \frac{1}{T} \int_0^T x^2(t)\, dt \tag{11}$$



Level 4: Noise [27min - 1h37]

- Gauss representation in frequency domain of a sine wave
- Sinc function
- Item 3



Level 4: Noise [27min - 1h37]

- Why it matters
- How can you tell the SNR you need
- Shannon-Hartley Theorem
- Application: DAC,ADC
- Application: Example for Voyager 1 Detection Link

 Level 4: Signal to Noise Ratio (SNR) – Definition

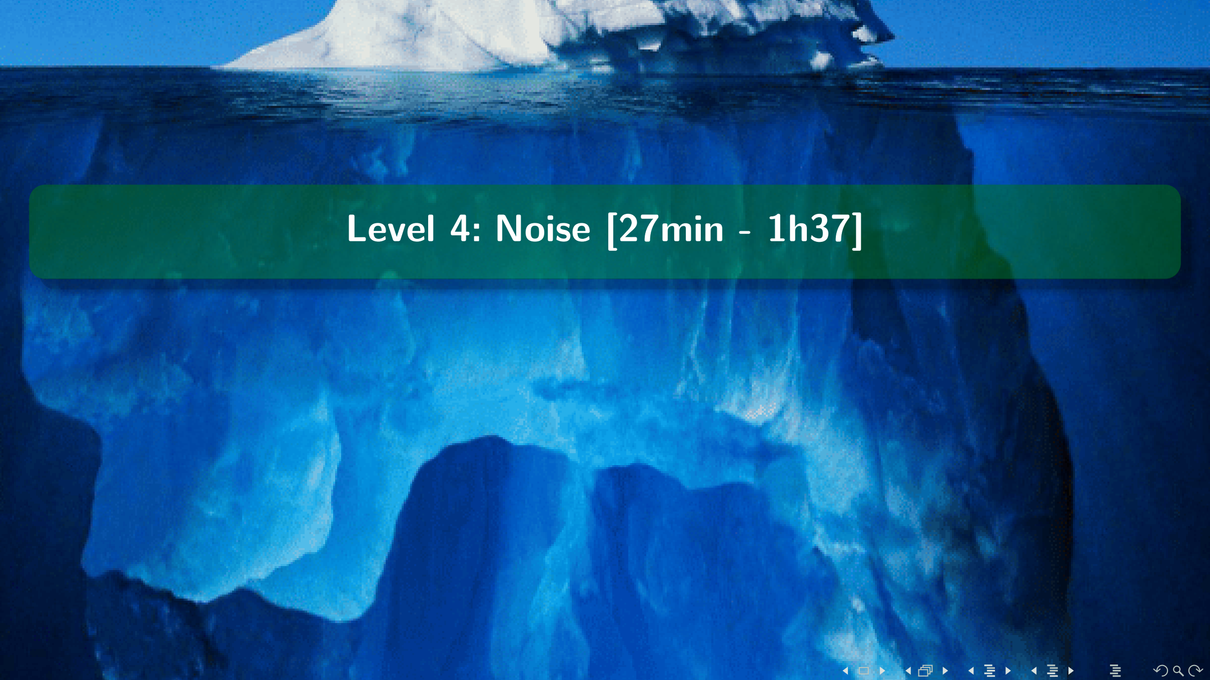
$$SNR = \frac{P_{\mathrm{Signal|W}}}{P_{\mathrm{Noise|W}}} = P_{\mathrm{Signal|dB}} - P_{\mathrm{Noise|dB}} \tag{12}$$

$$C = BW \cdot \log_2\left(1 + \frac{P_{\text{Signal}|\text{W}}}{P_{\text{Noise}|\text{W}}}\right) \tag{13}$$

- C: Canal Capacity [Bit/s]
- BW: Canal Bandwidth [Hz]

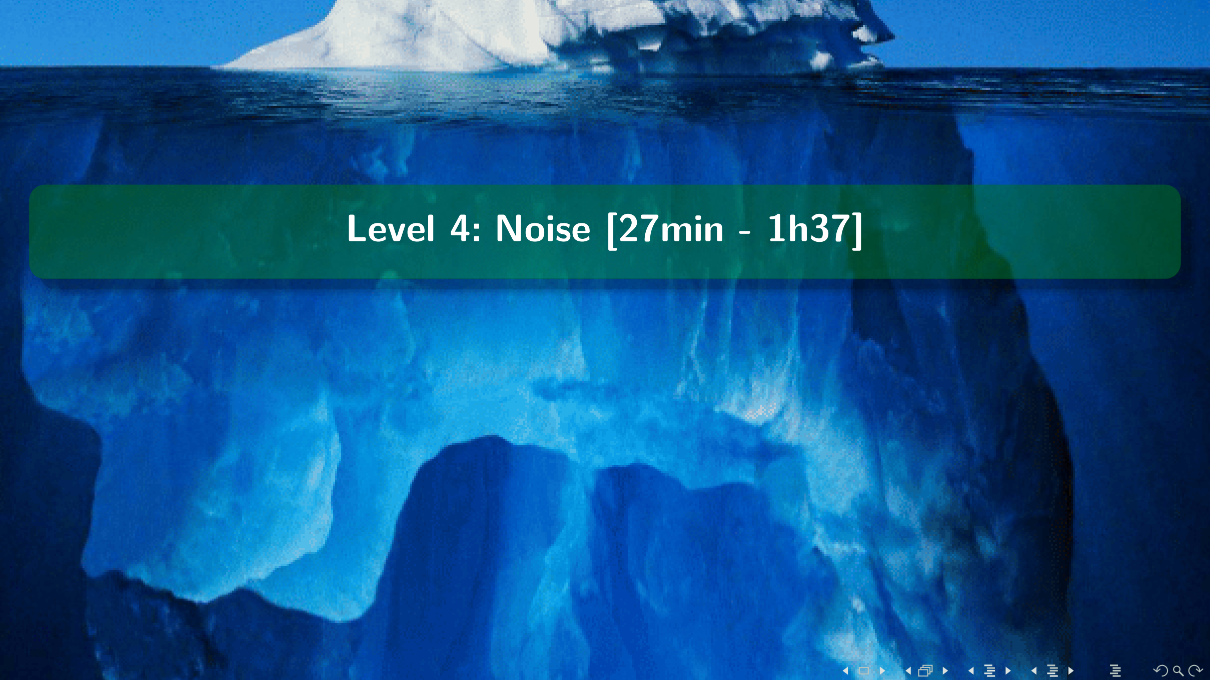
Mettre tableau avec resolution et SNR

Level 4: Noise [27min - 1h37]



- ✗ Item 1
- ✗ Item 2
- ✗ Item 3

Level 4: Noise [27min - 1h37]



- Item 1
- Item 2
- Item 3

Level 5: Crosstalk & Coupling [18min - 1h55]

Level 5: Crosstalk & Coupling [18min - 1h55] – Introduction

- Item 1
- Item 2
- Item 3

Level 5: Crosstalk & Coupling [18min - 1h55]

- Impedance du vide
-

Level 5: Crosstalk & Coupling [18min - 1h55]

- ✘ Radiation Pattern
- ✘ Radiation Lense

Level 5: Crosstalk & Coupling [18min - 1h55]

- ✗ Twisted Pairs
- ✗ Do Differential Pairs need GND?

Level 5: Crosstalk & Coupling [18min - 1h55]

- ✗ Item 1
- ✗ Item 2
- ✗ Item 3

Level 5: Crosstalk & Coupling [18min - 1h55]

- ✗ Item 1
- ✗ Item 2
- ✗ Item 3

Merci!

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