

Lecture slides of the course
Information hiding & secret sharing

Audio Steganography

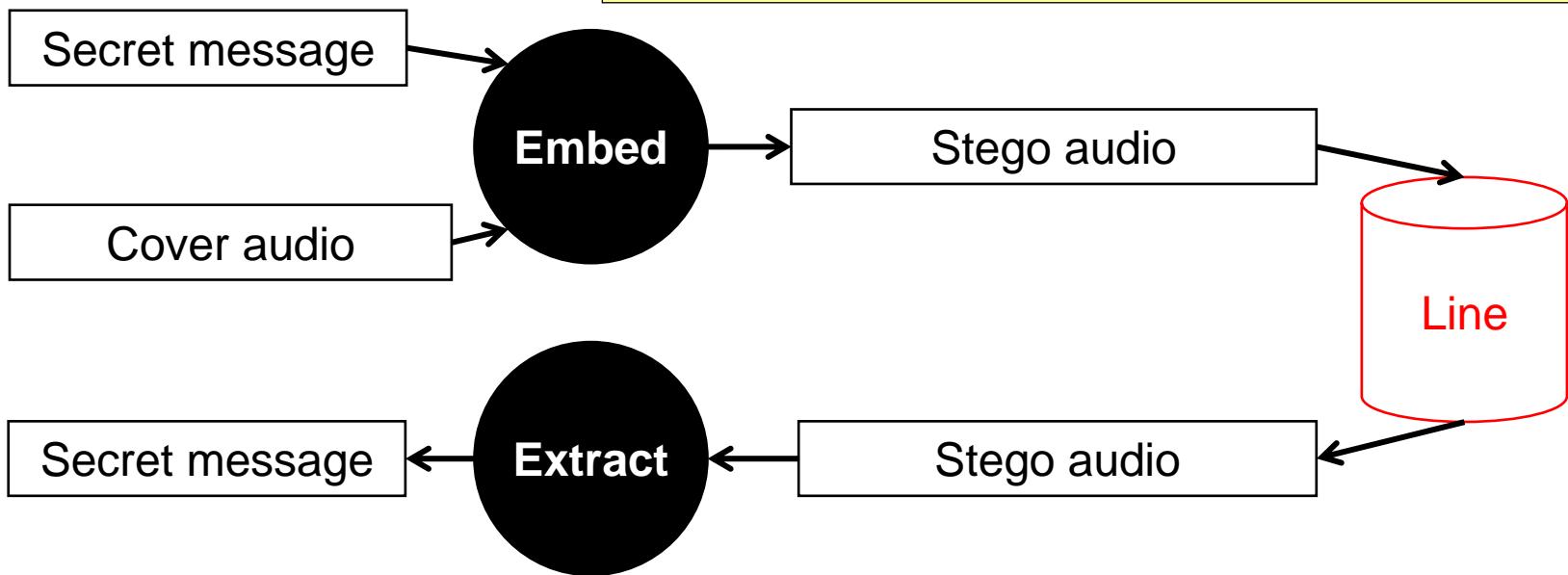
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Audio steganography

Desire:

- **Invisibility:** it must be difficult for a third person to know the existence of secret information in stego audio
- In addition, there are other desires: **capacity, robustness**



Audio staganography

Q: Where should the secret be embedded in the audio?

A: First, need to understand the sound...

How is sound represented in a computer?

- Try reading an audio file and see ... (demo)
- Sound is represented in the computer as a discrete sound wave.

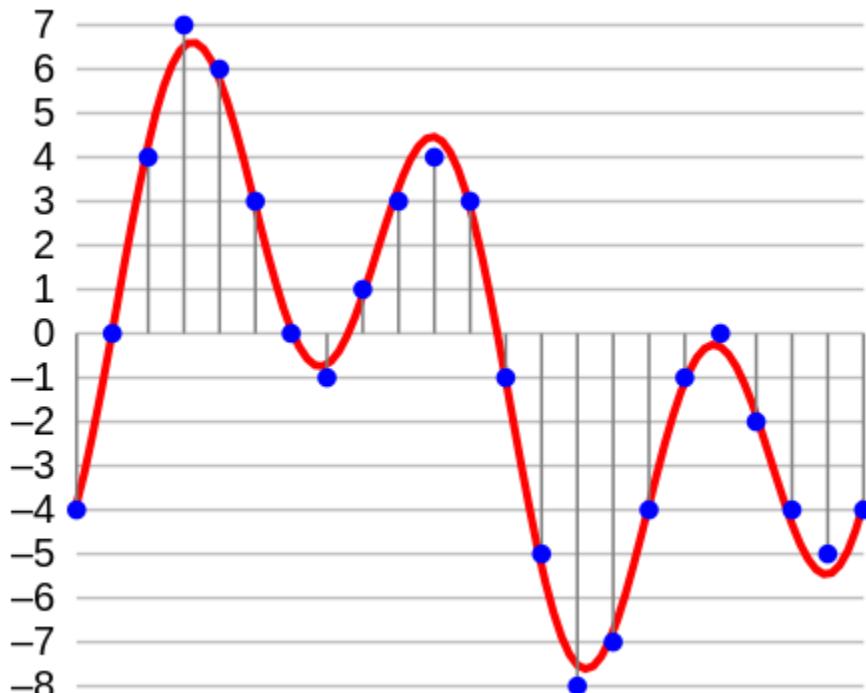
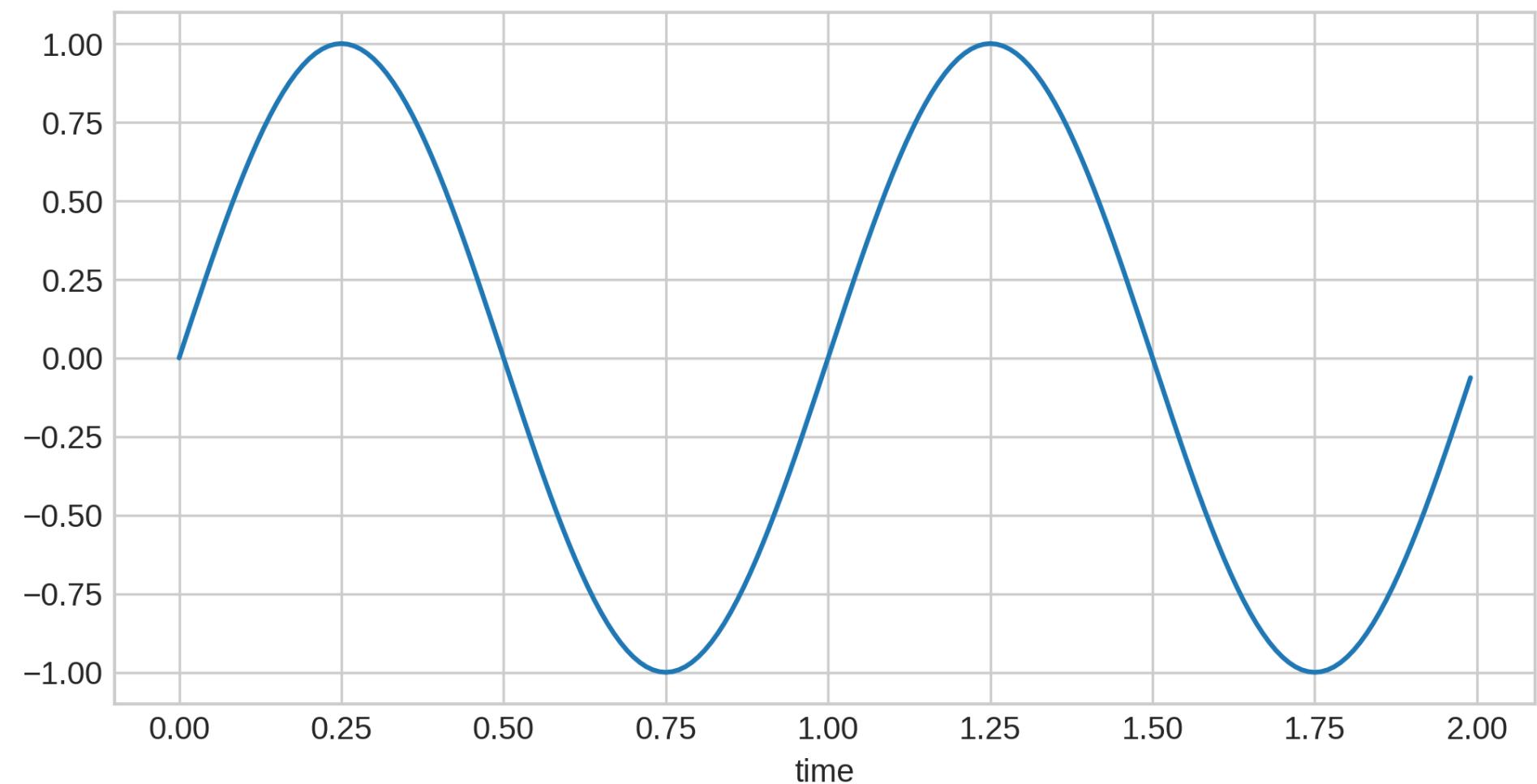


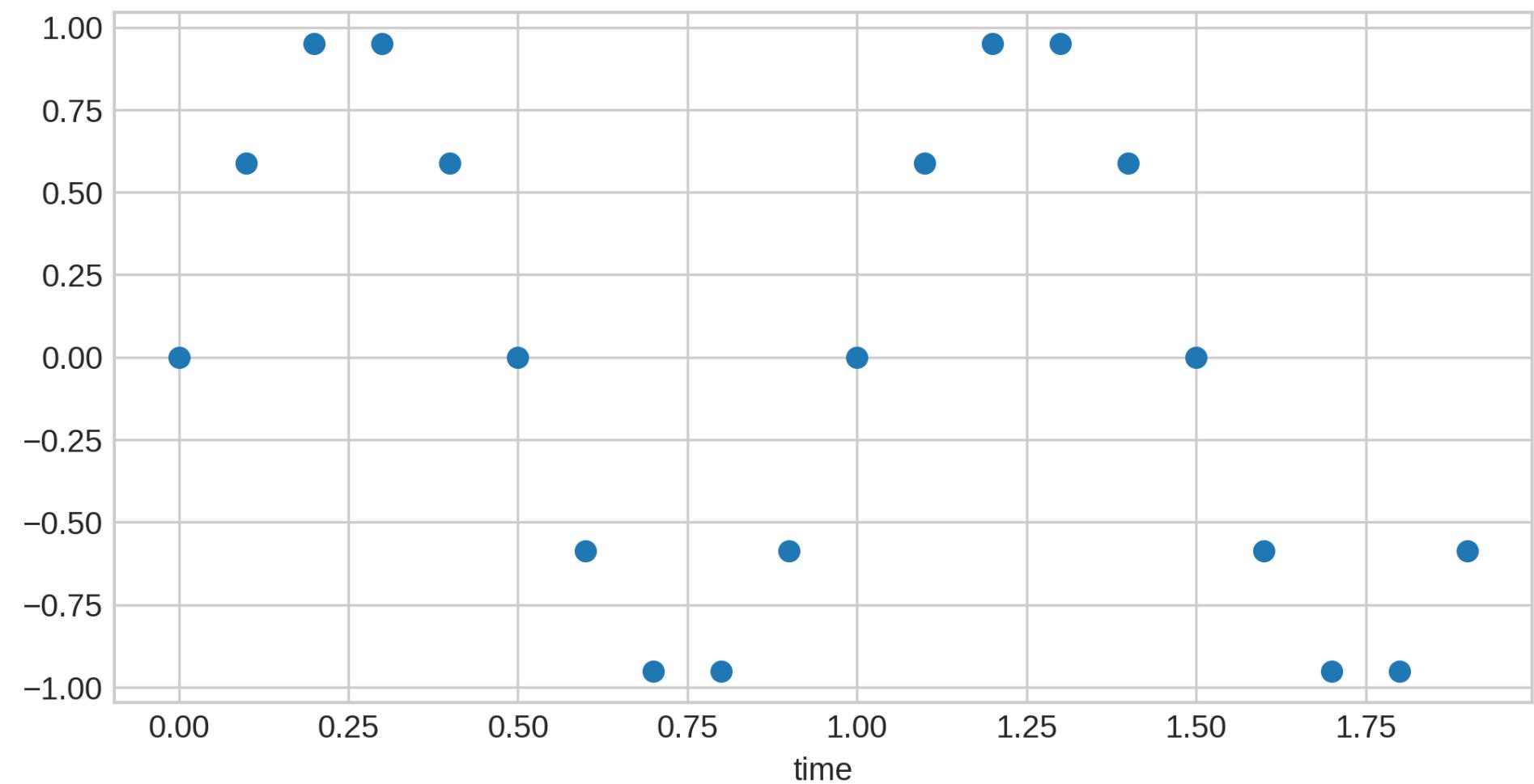
Image source:
https://en.wikipedia.org/wiki/Audio_bit_depth

- Red** line: original wave
Blue points: original wave is discretized
- Each point is called a sample
 - The degree of discretization in the **y** direction (intensity) is represented by **bit depth** (the number of bits used to store the intensity value of a sample).
 - The degree of discretization in the **x** dimension (time) is represented by the **sample rate** (number of samples/s).

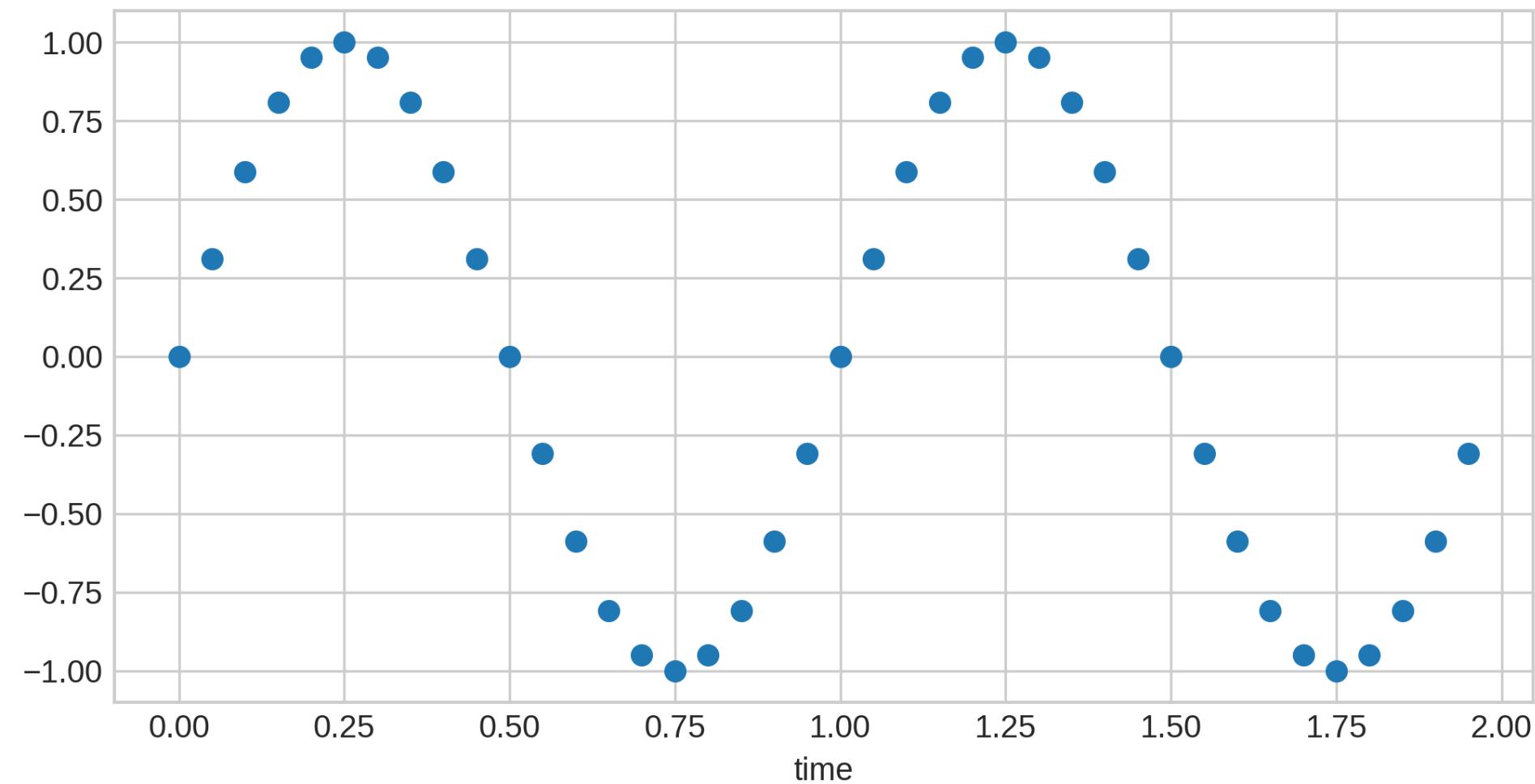
Original wave



Sample 20 points



Sample 40 points



How is sound represented in a computer?

- Audio files can be **mono** or **stereo**
 - Mono: one wave
 - Stereo: 2 different wave (same amplitude); when emit, one wave plays on the left speaker, one wave plays on the right speaker
→gives a more realistic feel
- Audio files can be **lossless** or **lossy**
 - Lossy: read data from file, edit data, write edited data to file, read data back up, the read data will not be the same as previously recorded data; for example: file *.mp3
 - Lossless: eg, file *.wav

How to hid secret message on audio file (lossless file like*.wav)

- The simple way is to hide the LSB bits of each sample
- Demo ...

Where to hid secret message on audio file

Other wave is using **echo**

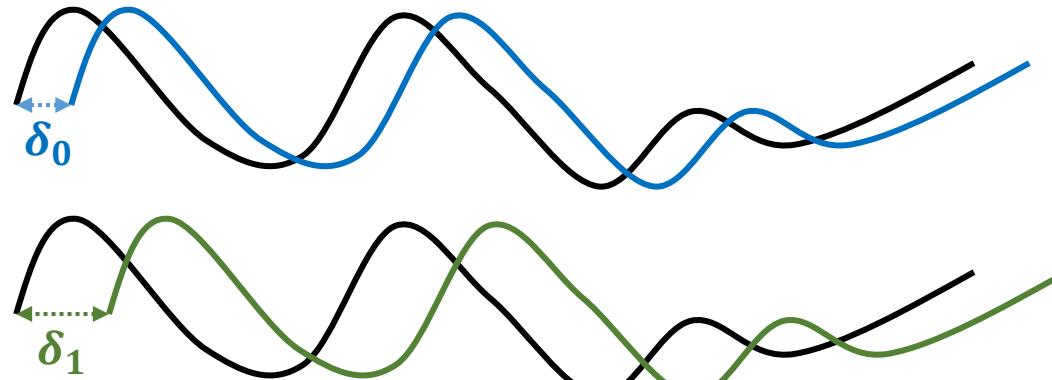
- What is Echo?
- How to use echo to embed secret message?
- How to extract?

What is echo?

- Watch [video](#)
- Demo create an sound with echo

How to use echo to embed secret bits??

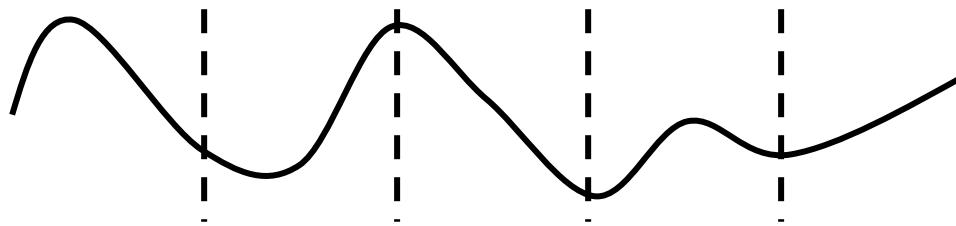
- To embed bit 0: add to cover audio an echo with delay δ_0
- To embed bit 1: add to cover audio an echo with delay δ_1
- With δ_0 and δ_1 small enough, human cannot hear echo.



- So only one bit can be embedded?
- How to embed multiple bits?

How to use echo to embed secret bits??

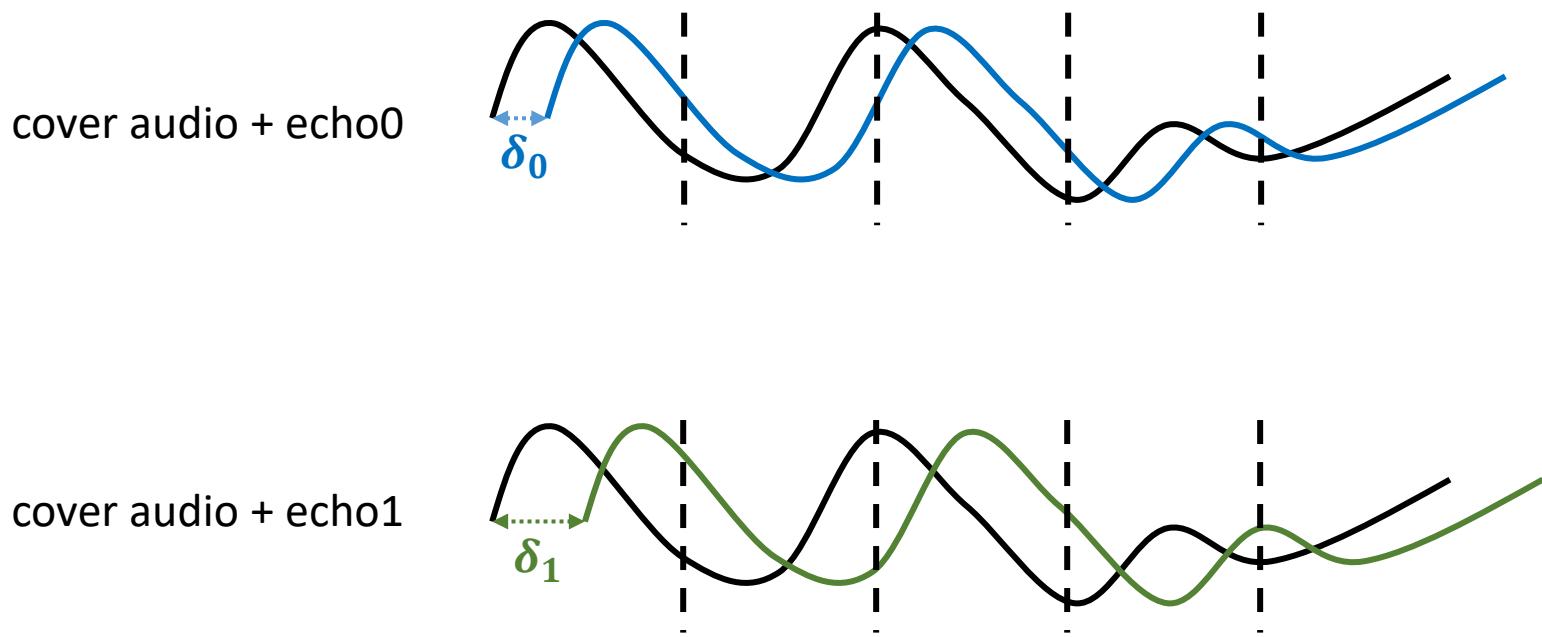
To embed multiple bits, we divide the cover audio into several segments and embed one bit in each segment by adding to that segment echo with delay δ_0 or δ_1



How to use echo to embed secret bits??

More detail about the embedding process :

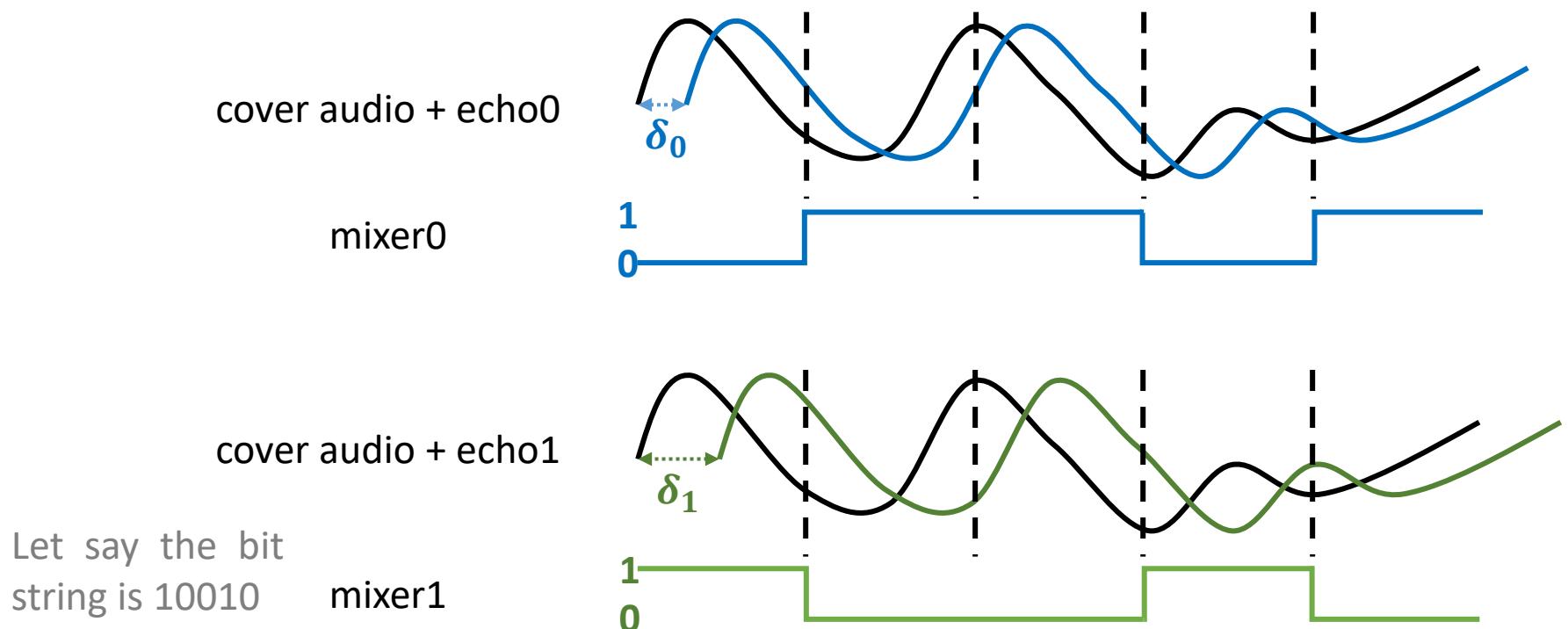
- Step 1: generates 2 cover audio, one with echo corresponding to bit 0, one with echo corresponding to bit 1



How to use echo to embed secret bits??

More detail about the embedding process :

- Step 2: create mixer0 và mixer1; mixer1 is created based on secret bit string, $\text{mixer0} = 1 - \text{mixer1}$



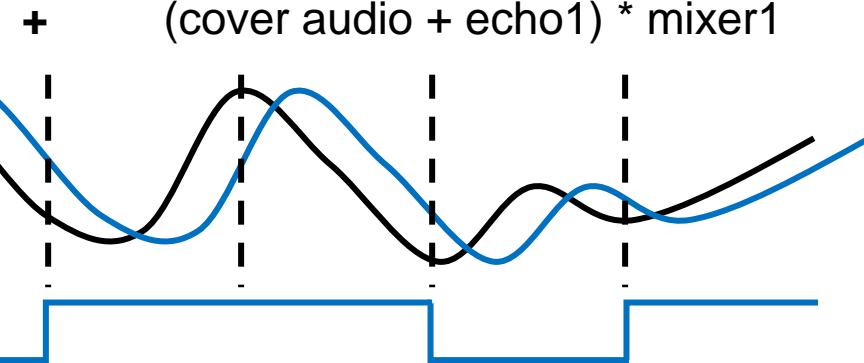
How to use echo to embed secret bits??

More detail about the embedding process ::

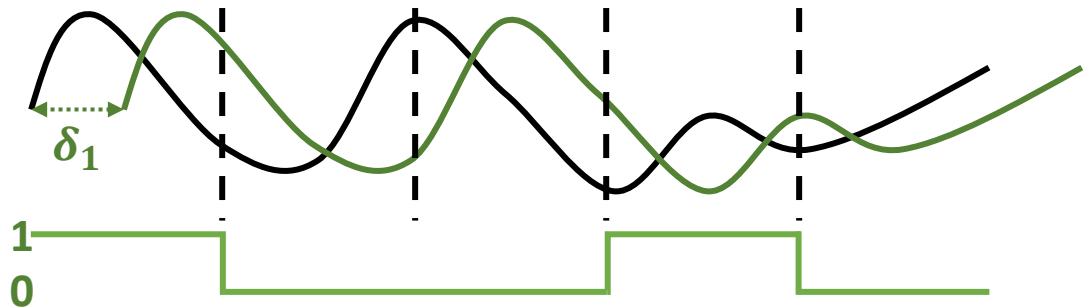
- Step 3: stego audio = $(\text{cover audio} + \text{echo0}) * \text{mixer0}$

$$+ (\text{cover audio} + \text{echo1}) * \text{mixer1}$$

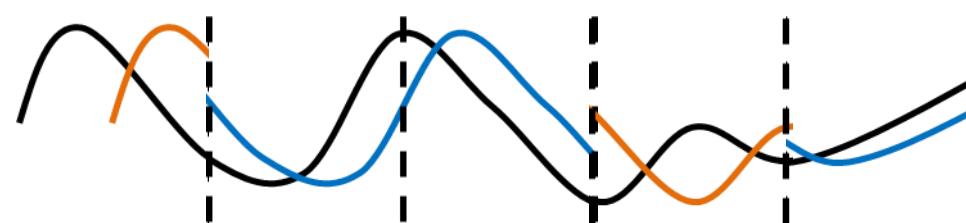
$$\begin{aligned} & \text{cover audio} + \text{echo0} \\ & * \text{mixer0} \end{aligned}$$



$$\begin{aligned} & + \\ & \text{cover audio} + \text{echo1} \\ & * \text{mixer1} \end{aligned}$$



stego audio



Input and output of the embedding process

- Input
 - message bits
 - cover audio
 - delta0, delta1
 - decay rate $\in [0, 1]$: scale ratio of the echo's intensity to the original sound wave
 - What do you gain and lose with a small decay rate??
- Output
 - stego audio

How to extract?

- To extract, it is necessary to know how many audio segments are divided when embedding
 - How can Bob and Alice exchange this information?
 - One way is that Alice and Bob can meet once and agree on the maximum length of the secret bit string → when embedding always divides into **the maximum length of the secret bit string + 1** audio track, add 100... to the secret bit string and embed over all audio tracks

How to extract?

- For an audio segment of stego audio, it is necessary to determine what delay echo is present
- Assume that there is echo at delay 0.5 s → bit 0 or bit 1?
- To know if it's bit 0 or 1, let's look at the echo delay in other audio tracks
 - there will be 2 delay values δ_0 (bit 0) and δ_1 (bit 1), but don't know where is δ_0 or δ_1
 - Alice and Bob choose that

$$\delta_0 < \delta_1$$

How to extract?

- Given a piece of stego audio, how can the echo delay be determined?
- Calculate autocorrelation
 - See demo

Correlation

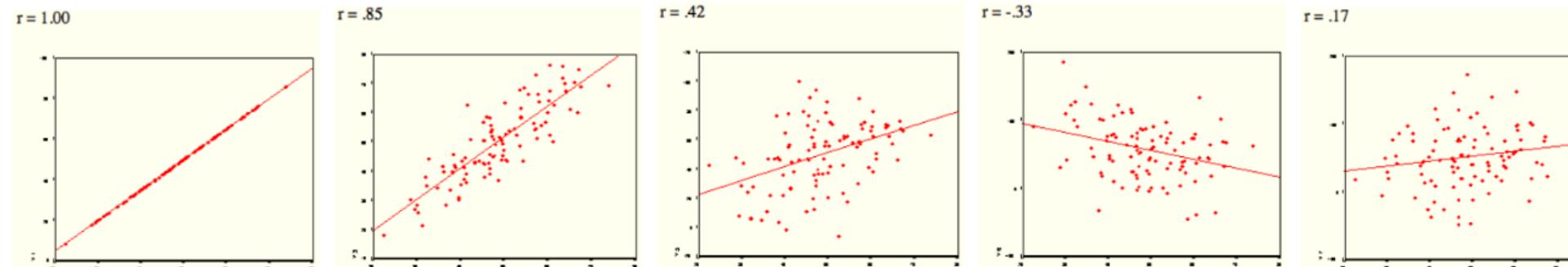
$$Var(X) = \sigma^2 = \sum(X - \mu_x)^2 / N]$$

$$\text{Cov}(x,y) = \frac{\sum (x_i - \bar{x}) * (y_i - \bar{y})}{N}$$

- Correlation

$$\rho_{x,y} = \frac{\text{Cov}(X, Y)}{\sqrt{Var(X)Var(Y)}}$$

- Range from -1 to 1



Autocorrelation

$$r_k = \frac{\sum_{t=1}^n (y_t - \bar{y})(y_{t+k} - \bar{y})}{\sum_{t=1}^n (y_t - \bar{y})^2}$$