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Q) Find the fourier transform of

$$x(t) = \begin{cases} 1 & -T \le t \le T \\ 0 & \text{else everywhere} \end{cases}$$

(t) time → Continuous (a, c, d)

(n) number → discreate (b)

b) $x(n) = \delta(n)$

Q) $x(t) = 2\pi\, 10t$

Q) $x(t) = \cos 2\pi (20t) + \sin 2\pi (25t)$

Continuous ⟶ discreate

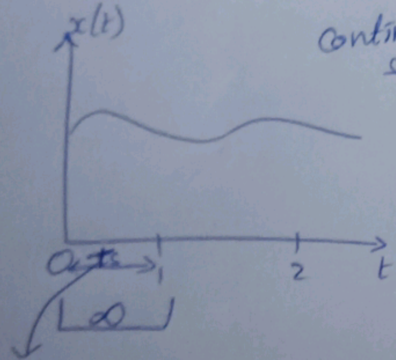
Sampling

time → independent

$x(t)$ → dependent

(Similarity of the signal with complex exponential)

Fourier transform



Continuous time signal

Sampling interval

CT $\xrightarrow{\text{Sampling}}$ DT

CT ⇓ CTFT   DT ⇓ DTFT

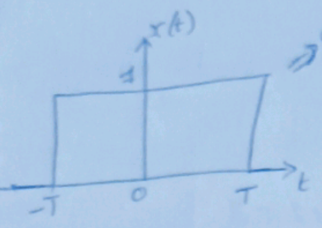
$\langle x(t), e^{j\omega t} \rangle$ $\langle x(n), e^{j\omega n} \rangle$

inner product

(Integral)

$$\int_{-\infty}^{\infty} x(t) e^{-j\omega t}\, dt \qquad \sum_{n=-\infty}^{+\infty} x(n) e^{-j\omega n}$$

Q) $x(t) = \begin{cases} 1 & -T \le t \le T \\ 0 & \text{otherwise} \end{cases}$

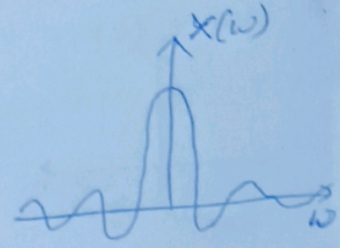


$\Rightarrow$ rectangular pulse

$$\frac{e^{i\theta} + e^{-i\theta}}{2} = \cos\theta$$

$$\frac{e^{i\theta} - e^{-i\theta}}{2j} = \sin\theta$$

$\xRightarrow{FT}$



CTFT:-

$$\langle x(t), e^{jwt} \rangle = \int_{-\infty}^{\infty} x(t) e^{-jwt}\, dt$$

$$= \int_{-T}^{+T} 1 \cdot e^{-jwt}\, dt$$

$$= \left[\frac{e^{-jwt}}{-jw}\right]_{-T}^{T}$$

$$= \frac{e^{-jwT} - e^{+jwT}}{-jw}$$

$$= -\left(\frac{e^{-jwT} - e^{jwT}}{jw}\right)$$

$$= \frac{e^{jwT} - e^{-jwT}}{jw}$$

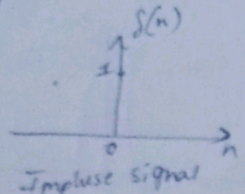
$$= \frac{2j\sin wT}{jw}$$

$$= \frac{2\sin wT}{w}$$

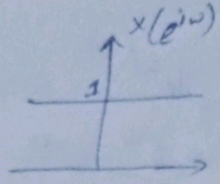
Multiplying & dividing T

$$= \frac{2T\sin wT}{wT} = (2T)\operatorname{sinc}(wT)$$

Q)



$\xrightarrow{FT}$



$$X(e^{j\omega}) = \sum_{n=-\infty}^{\infty} x(n)\, e^{-j\omega n} = \sum_{n=0} x(0)\, e^{-j\omega(0)} = \sum_{n=0} 1 \times 1 = 1$$

Q) $x(t) = \cos\omega_0 t$

$e^{-j2\pi ft}$

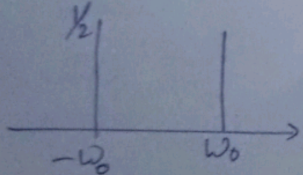
$\underbrace{\int x(t)\, e^{-j\omega t}\, dt}_{\text{Similarity} \to \text{Inner product}}$

$\langle x(t)\, e^{j\omega t} \rangle$

$\langle \cos\omega_0 t\; e^{j\omega t} \rangle$

$\left\langle \left(\frac{e^{j\omega_0 t} + e^{-j\omega_0 t}}{2}\right) e^{j\omega t} \right\rangle$

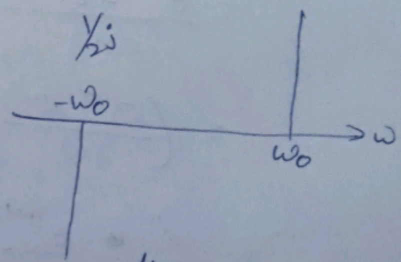
$\frac{1}{2}\left[\langle e^{j\omega_0 t}\, e^{j\omega t} \rangle + \langle e^{-j\omega_0 t}\, e^{j\omega t} \rangle \right]$



$\langle \sin\omega_0 t\; e^{j\omega t} \rangle$ → angular frequency

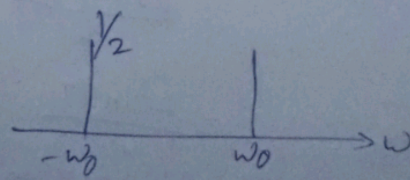
$\left\langle \left(\frac{e^{j\omega_0 t} - e^{-j\omega_0 t}}{2j}\right) e^{j\omega t} \right\rangle$

$\frac{1}{2j}\left[\underbrace{\langle e^{j\omega_0 t}\, e^{j\omega t} \rangle}_{\omega_0} - \underbrace{\langle e^{-j\omega_0 t}\, e^{j\omega t} \rangle}_{-\omega_0 t} \right]$



⇓

magnitude

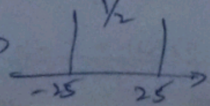


Q) $x(t) = \cos 50\pi t$

$\langle \cos 50\pi t \,.\, e^{j2\pi ft} \rangle$

$\left\langle \frac{e^{-j50\pi t} + e^{j50\pi t}}{2} \,.\, e^{j2\pi ft} \right\rangle$

$\frac{1}{2}\left[\langle e^{-j50\pi t} \,.\, e^{j2\pi ft} \rangle + \langle e^{j50\pi ft} \,.\, e^{j2\pi ft} \rangle \right]$. ⇒



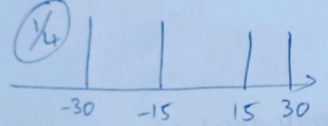
Q) $x(t) = \cos 30\pi t + \cos 60\pi t$

$$<(\cos 30\pi t + \cos 60\pi t)\, e^{j2\pi f t}>$$

$$<\left[\frac{e^{j30\pi t} + e^{-j30\pi t}}{2}\right] + \left[\frac{e^{j60\pi t} + e^{-j60\pi t}}{2}\right] e^{j2\pi f t}>$$

$$\frac{1}{4}\left[<(e^{j30\pi t} + e^{j60\pi t})\, e^{j2\pi f t}> + <(e^{-j30\pi t} + e^{-j60\pi t}) . e^{j2\pi f t}>\right]$$

15 30



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Quasi Periodic:

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Short time fourier transform (STFT)

magnitude
frequency
time

Spectogram

Energy(time, frequency)

Signal to be analyzed

$$STFT_f^u(t', u) = \int_t [f(t) . w(t - t')] . e^{-j2\pi u t}\, dt$$

time Parameter

frequency Parameter

windowing function

centered at $t = t'$

* window is to long ⟶ FT
* window is toshort ⟶ time resolution is best. frequency resolution is not better.

If window signal is increases then in the fourier tranform of an signal we can say the Particular frequency.

Σ overlap can be there in the signal.

Heisenberg (or uncertainty) principle:-

$$\Delta t \cdot \Delta f \geq \frac{1}{4\pi}$$

Time resolution

Frequency resolution.

Spectrogram

Narrow   wideband

1/4/20

* The two dimensional function $|X(n,\omega)|^2$ is called the spectrogram.

Formants

dark-high
white-low

Speech → Rectangular pulse Multiply → FFT → Spectrum

Hz

Amplitude

"20-30 msec"

50% overlap

hone Signals

Phoneticians

5/6/24

ॐ

Classification of speech, speech signal characteristics.

Sound
- not restricted → Vowels
  - Based on tongue place
  - Dipth
  - Semi vowels
- restricted in vocal track → Consonants (combination of speech sound)
  - unvoiced
  - voiced — vocal folds vibrate periodically

Consonants
- stop & release → stops
  - unvoiced
  - voice
- high restriction → fricatives
- stop & high restriction → Affricatives

velar (back side)
Alveolar (muscle behind the ~~tounge~~ teeth)
Dental (teeth)
bilaber (tounge)

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ॐ

Time domain features intro & short time energy :-

- TD (fourier)
  - STE (short time energy)
- FD (STFT, spectogram)
  - (Formal frequency)
- cepstual domain

Speech $\xrightarrow{FT}$ spect $\xrightarrow{FT}$ cepstual domain

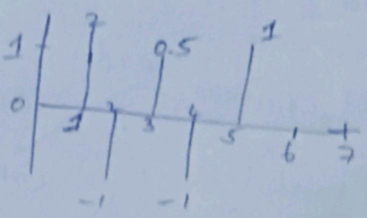
Energy = $(\text{signal})^2$ & Sum of it.

$$E_n = \sum_{m=-\infty}^{\infty} \left[x[m]\, w[\hat{n}-m] \right]^2$$ It is variane over the time

Q) For a speech signal sample at 16KHZ how many samples will be there inside the analysis window if the window size is taken for 20ms. Overlapping 50%.

S) 320 Samples. $\frac{320}{2} = 160$

Q) Find the short time energy for the signal given in the figure. windowsize → 4, overlap → 50%.

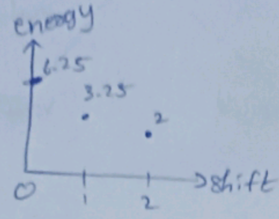


1+4+1+1+0.25

$e(0) = 1+4+1+0.25 = 6.25$

$e(1) = 1+0.25+1+1 = 3.25$

$e(2) = 1+1+0+0 = 2$



0-3
2-5
4-7
rectangle - 1

Average energy $= \text{Avg } e(0) = \frac{6.25}{4}$

$\text{Avg } e(1) = \frac{3.25}{4}$

$\text{Avg } e(2) = \frac{2}{4} = \frac{1}{2} = 0.5$

Part A:-
Calculate Average magnitude fun?
Calculate Zero crossing Count?
~~Calculate~~ repeat all these parameters if hamming window is

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Short time Processing:-

$$Q_{\hat{n}} = \left(\sum_{m=-\infty}^{\infty} T(x[m])\, \hat{w}[n-m] \right)\Big|_{n=\hat{n}}$$

Hardware

$$x[n] \rightarrow \boxed{T(\,)} \xrightarrow{T(x[n])} \boxed{\tilde{w}[n]} \rightarrow Q_{\hat{n}}$$

linear or non-linear transformation — window sequence.

⇐ In software, this process is reverse. first is window function then we use the energy function.

Short time energy – (voice & no-voice signal)
average Magnitude
Zero crossing
AutoCorrection.
pitch/Fundamental frequency

magnitude = 1 through the signal then it is known as rectangular window.

Hamming window (raised cosine window):-

$$h[n] = 0.54 - 0.46\cos(2\pi n/(L-1)) \quad 0 \le n \le L-1$$

Note:-
each frame should be 20-30ms

Short time Average Magnitude:-

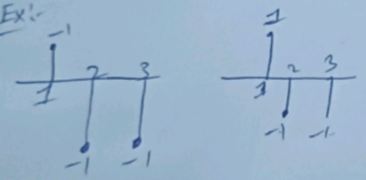
* short time energy is very sensitive to large signal levels due to $x^2[n]$ term

$$M_{\hat{n}} = \sum_{m=-\infty}^{\infty} |x[m]|\, \tilde{w}[\hat{n}-m]$$

Zero crossing:-

$$\text{sign}(n) = \begin{cases} 1 ; x(n) \ge 0 \\ -1 ; x(n) < 0 \end{cases} \qquad Z = \frac{1}{2N}\sum_{n=0}^{N-1} |\text{sign}(s(n)) - \text{sign}(s(n-1))|\, w(n-m)$$

Ex:-



$[1-(-1)]$ for 1-2 sec $= 2$ (where there is an zero crossing)

$[-1-(-1)]$ for 2-3 sec $= 0$ (No-zero crossing)

* zero crossing are more in unvoiced regions.