Probability Assignment

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Question: The frequency response $H(f)$ of of a linear time-invariant syatem has magnitude as shown in Fig. 0
Statement 1: The system is necessarily a pure delay system for inputs which are bandlimited to $-a \leq f \leq a$.
Statement 2: For any wide-sense stationary input process with power spectral density $S_X(f)$, the output power spectral density $S_Y(f)$ obeys $S_X(f) = S_Y(f)$ for $-a \leq f \leq a$.

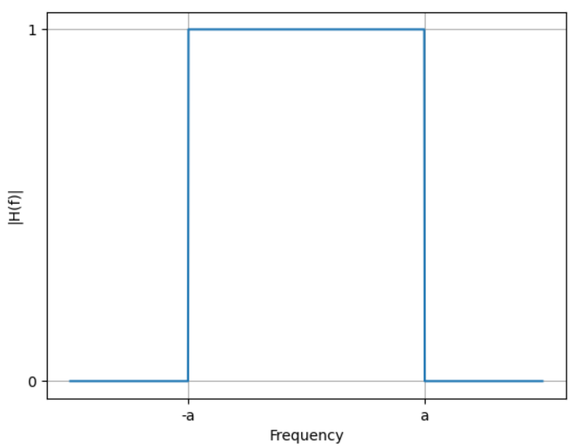

Fig. 0. $|H(f)|$ vs frequency

Solution:

1) Let us consider a delay LTI system with x(t) and y(t) as input and output signals in time domian. Let T_d be delay between input and output. So,

$$y(t) = x(t - T_d) \tag{1}$$

Appling fourier transform,

$$\int_{-\infty}^{\infty} y(t)e^{-2\pi f jwt}dt = \int_{-\infty}^{\infty} x(t - T_d)e^{-2\pi f jt}dt \tag{2}$$

$$= \int_{-\infty}^{\infty} x(t)e^{-2\pi f j(t+T_d)}d(t + T_d) \tag{3}$$

$$= e^{-2\pi f jT_d} \int_{-\infty}^{\infty} x(t)e^{-2\pi f jt}dt \tag{4}$$

$$Y(f) = e^{-2\pi f jT_d} X(f) \tag{5}$$

Here $Y(f)$ and $X(f)$ are output and input signals in frequency domian. Let $H(f)$ be

$$|H(f)| = \left|\frac{Y(f)}{X(f)}\right| \tag{6}$$

$$= \left|e^{-2\pi f jT_d}\right| \tag{7}$$

$$= 1 \tag{8}$$

Here, $|H(f)| = 1$ for all frequencies. But statement was for bandlimited input in $-a \leq f \leq a$. That is there is no input otherwise. So,

$$|H(f)| = \begin{cases} 1 & \text{if } -a \leq k \leq a \\ 0 & \text{otherwise} \end{cases} \tag{9}$$

From (9) and Fig. 0, $|H(f)|$ is same.So, system will act as pure delay system. Statement 1 is correct.

2) For wide-sense stationary LTI sytem,

$$S_Y(f) = |H(f)|^2 S_X(f) \tag{10}$$

Fron (9), for $-a \leq k \leq a$, $|H(f)| = 1$

$$S_Y(f) = (1)^2 S_X(f) \tag{11}$$

$$S_Y(f) = S_X(f) \tag{12}$$

STatement 2 is correct.