ECSTUFF4U for Electronics Engineer

DTFT properties

We already know about what is DTFT. In this section, we will study some properties of DTFT to know a better understanding of this topic. We know that x (n) and X (ω) are Fourier transform pair and denoted as given below,

If $x(n) \xleftrightarrow{DTFT} X(\omega)$

1. Linearity :

Fourier transform of a linear combination of signals then it will be the same as the linear combination of the Fourier transform of each of the individual signals.

If $x_1(n)$ is $\xleftrightarrow{DTFT} X_1(\omega)$ and $x_2(n)$ is $\leftrightarrow X_2(\omega)$ then

$a_1 x_1(n) + a_2 x_2(n)$ is $\xleftrightarrow{DTFT} a_1 X_1(\omega) + a_2 X_2(\omega)$

2. Time shifting :

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Time shifting shows that a shift in time is equivalent to a linear phase shift in frequency domain. Since the frequency content depends only on the shape of a signal generated, which is basically unchanged in a time shift, then only the phase spectrum will be altered. This property is given below :

If

$x(n)$ is $\xleftrightarrow{DTFT}$ $X(\omega)$ then

$x(n-k)$ is $\xleftrightarrow{DTFT}$ $e^{-j\omega k} X(\omega)$

3. Frequency shifting :

If

$x(n)$ is $\xleftrightarrow{DTFT}$ $X(\omega)$ then $e^{-j\omega_0 n} x(n)$ is $\xleftrightarrow{DTFT}$ $X(\omega - \omega_0)$

4. Time reversal :

If

$x(n) \xleftrightarrow{DTFT} X(\omega)$ is then

$x(-n)$ is $\xleftrightarrow{DTFT}$ $X(-\omega)$

5. Differentiation :

It is a complicated differentiation equation, it is the easiest way to understand a better way to this topic, the equation is given below. It is apparent with this property that converting to the frequency domain may allow the frequency domain may allow us to convert these complicated differential equations to easy simpler equations involving multiplication and addition. This property is given below :

If

$x(n) \xleftrightarrow{DTFT} X(\omega)$ then

$n\,x(n) \xleftrightarrow{DTFT} d/d\omega\, X(\omega)$

6. Parseval's theorem :

If $x_1(n)$ is $\xleftrightarrow{DTFT}$ $X_1(\omega)$ and $x_2(n)$ is $\xleftrightarrow{DTFT}$ $X_2(\omega)$ then

Parseval's relation tells us that the energy of a signal is totally equal to the energy of its Fourier transform.

$$\sum_{n=-\infty}^{\infty} x_1(n)\, x_2(n) \text{ is } = 1/2\pi \int_{-\pi}^{\pi} X_1(\omega)\, X_2(\omega)\, d\omega$$

7. Convolution theorem :

Convolution is one of the big reasons for converting signals to the frequency domain since convolution in time becomes multiplication in frequency domain.

If $x_1(n)$ is $\xleftrightarrow{DTFT}$ $X_1(\omega)$ and $x_2(n)$ is $\xleftrightarrow{DTFT}$ $X_2(\omega)$ then

$x_1(n) * x_2(n)$ is $\xleftrightarrow{DTFT}$ $X_1(\omega) . X_2(\omega)$

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