



# BSM307

## İşaretler ve Sistemler

Dr. Seçkin Ari

z-Dönüştümü

# İçerik

- z-Dönüşümü
- Sınırlı İşaretler
- Sınırsız İşaretler

# z-Dönüştümü

- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n}$

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  - ◆  $x(n)$ : Ayrık zaman işaret

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  - ◆  $x(n)$ : Ayrık zaman işaret
  - ◆  $z = \sigma + j\omega$

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- $x(n)$ : Ayrık zaman işaret
  - ◆  $\exists n > 0$  iken  $x(n) \neq 0$  ve  $\forall n < 0$  iken  $x(n) = 0$  ise sağ taraflı

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  - ◆ Sayılabilir elemana sahipse, sınırlı
  - ◆ Sonsuz elemana sahipse, sınırsız

# z-Dönüşümü

- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n}$ 
  - ◆  $x(n)$ : Ayrık zaman işaret
  - ◆  $z = \sigma + j\omega$
- Yakınsama Bölgesi (YB)
  - ◆ Karmaşık düzlemede  $X(z)$ 'nin sınırlı değerler almasını sağlayan z değerlerini içeren bölge.

# Örnek 1

- $x(n) = \{ \underbrace{1}_0, 2, 5, 7, 0, 1 \}$  ise  $X(z) = ?$

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- $x(n) \rightarrow$  Sağ taraflı, sınırlı

# Örnek 1

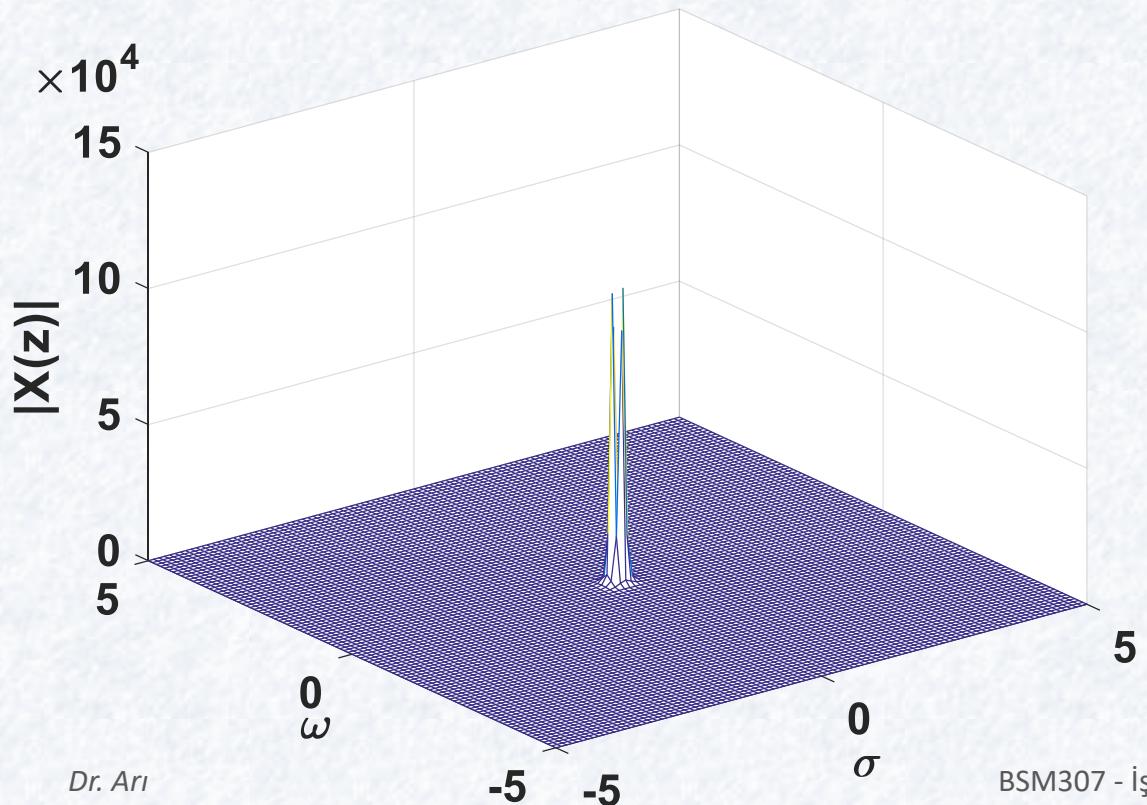
- $x(n) = \{ \underbrace{1}_0, 2, 5, 7, 0, 1 \}$
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# Örnek 1

- $x(n) = \{ \underbrace{1}_0, 2, 5, 7, 0, 1 \}$
- $X(z) = \sum_{n=0}^5 x(n)z^{-n} = 1 + 2z^{-1} + 5z^{-2} + 7z^{-3} + z^{-5}$

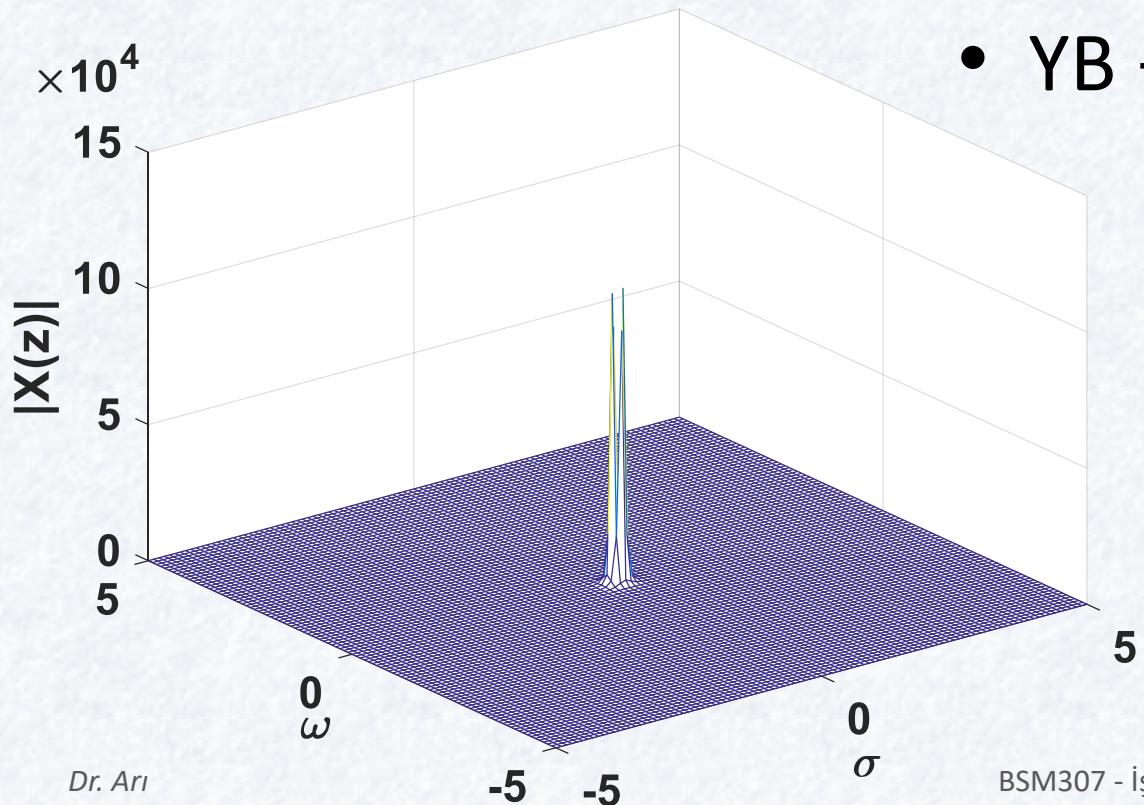
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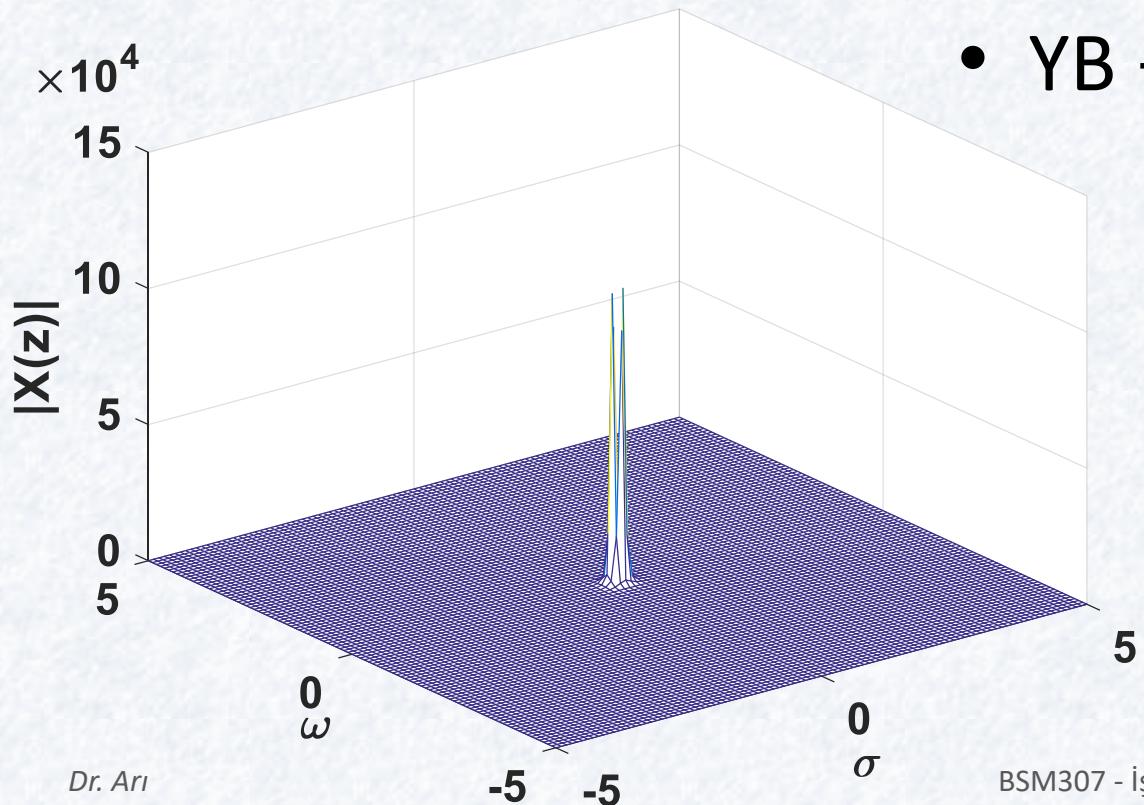
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• YB →

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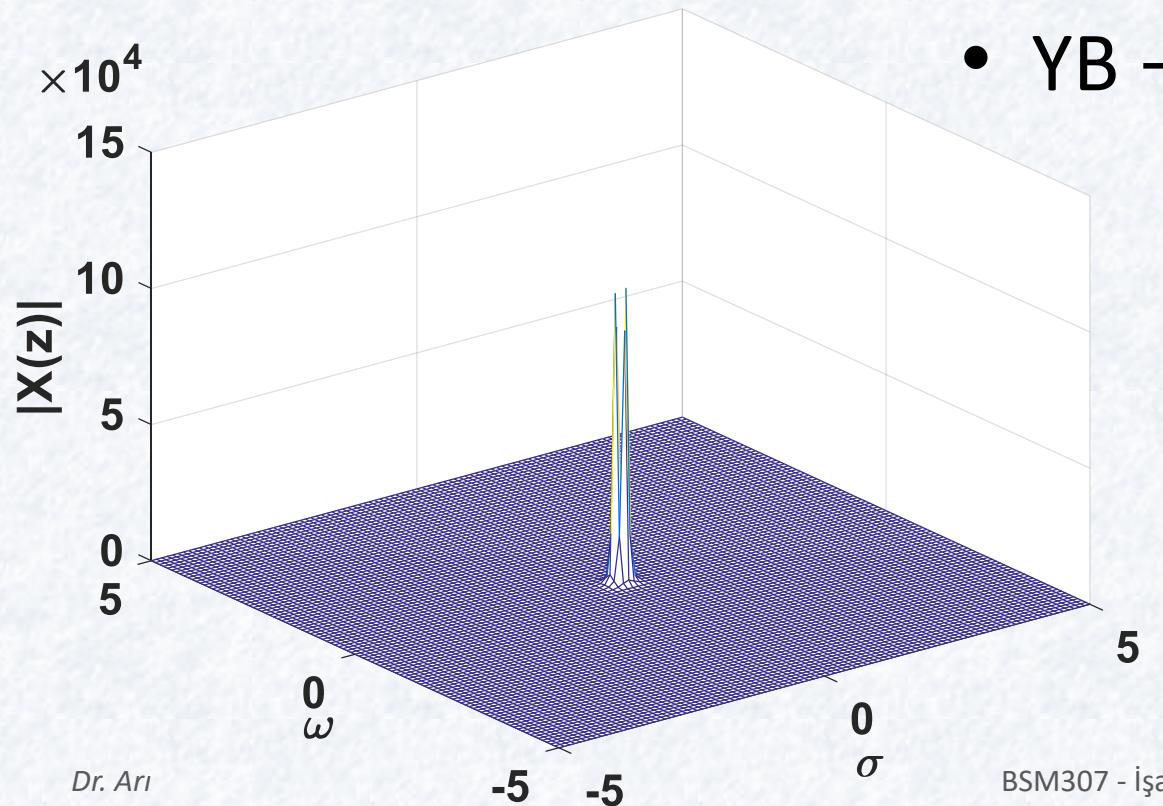
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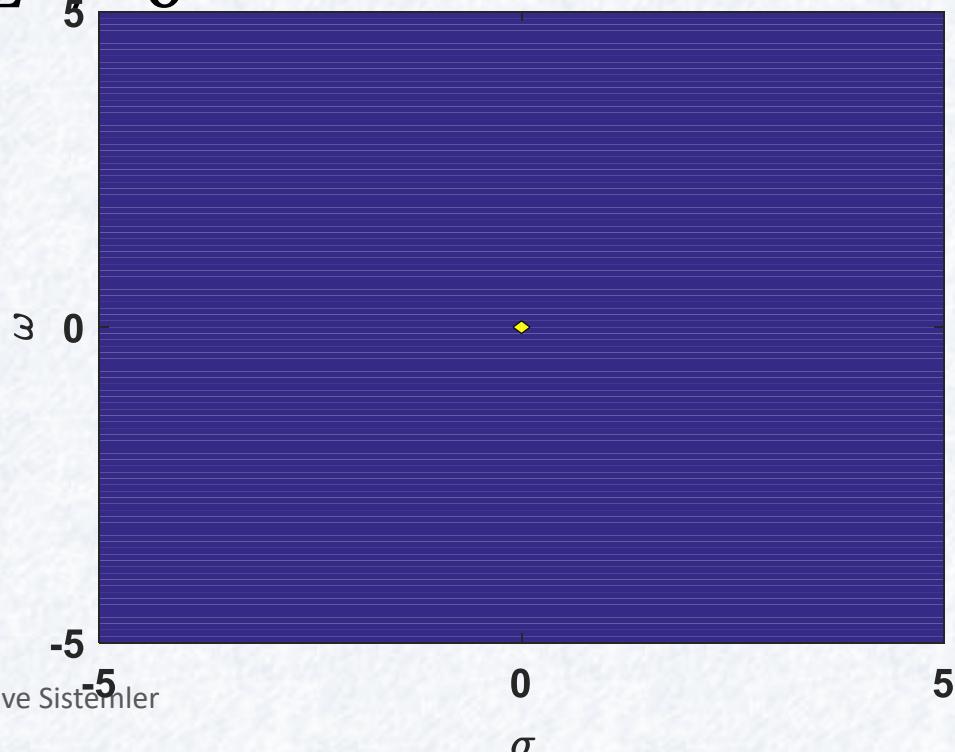
- YB  $\rightarrow z \neq 0$

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## Örnek 2

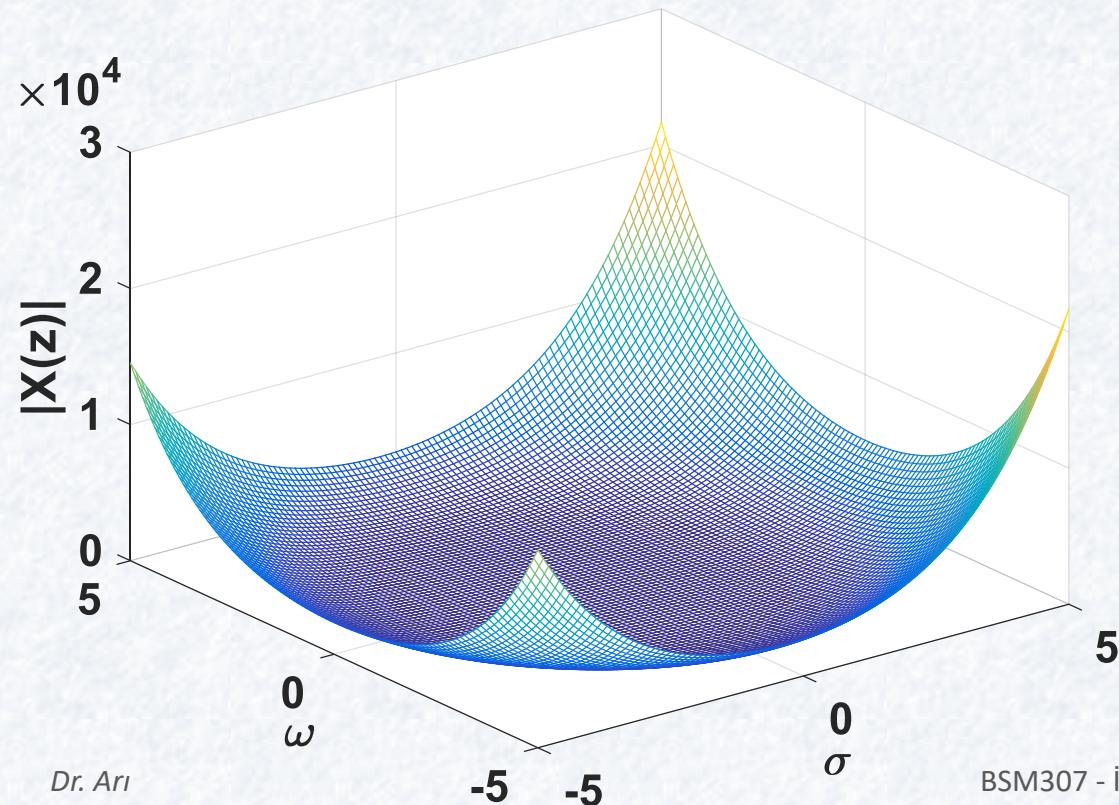
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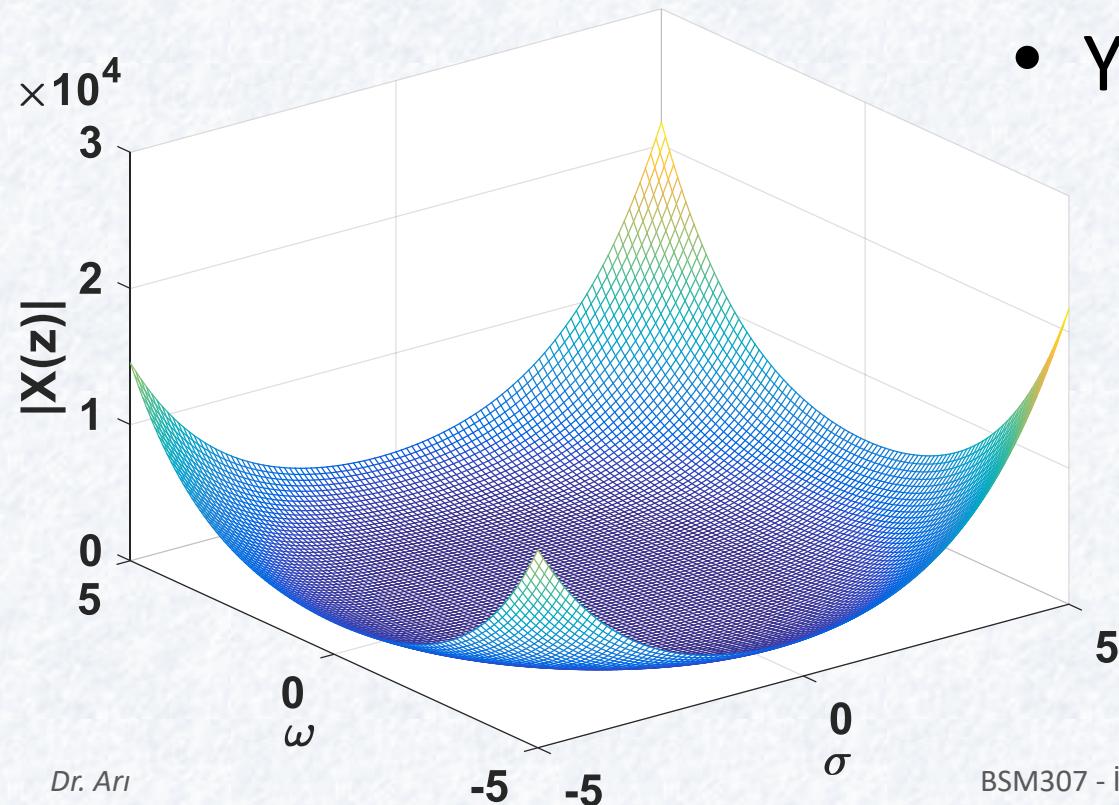
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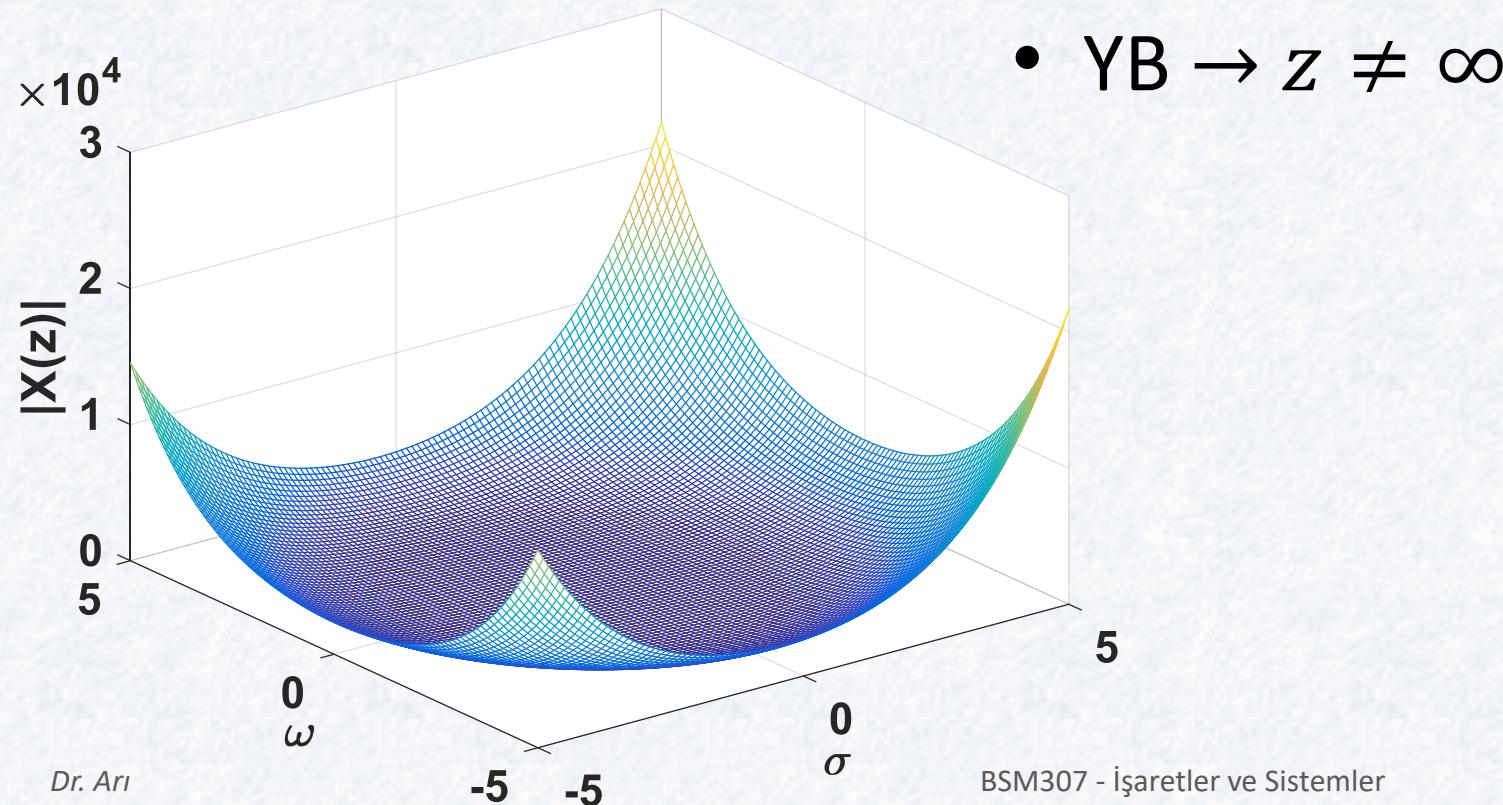
- $x(n) = \{1, 2, 5, 7, 0, \underbrace{1}_0\}$  ise  $X(z) = ?$
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• YB →

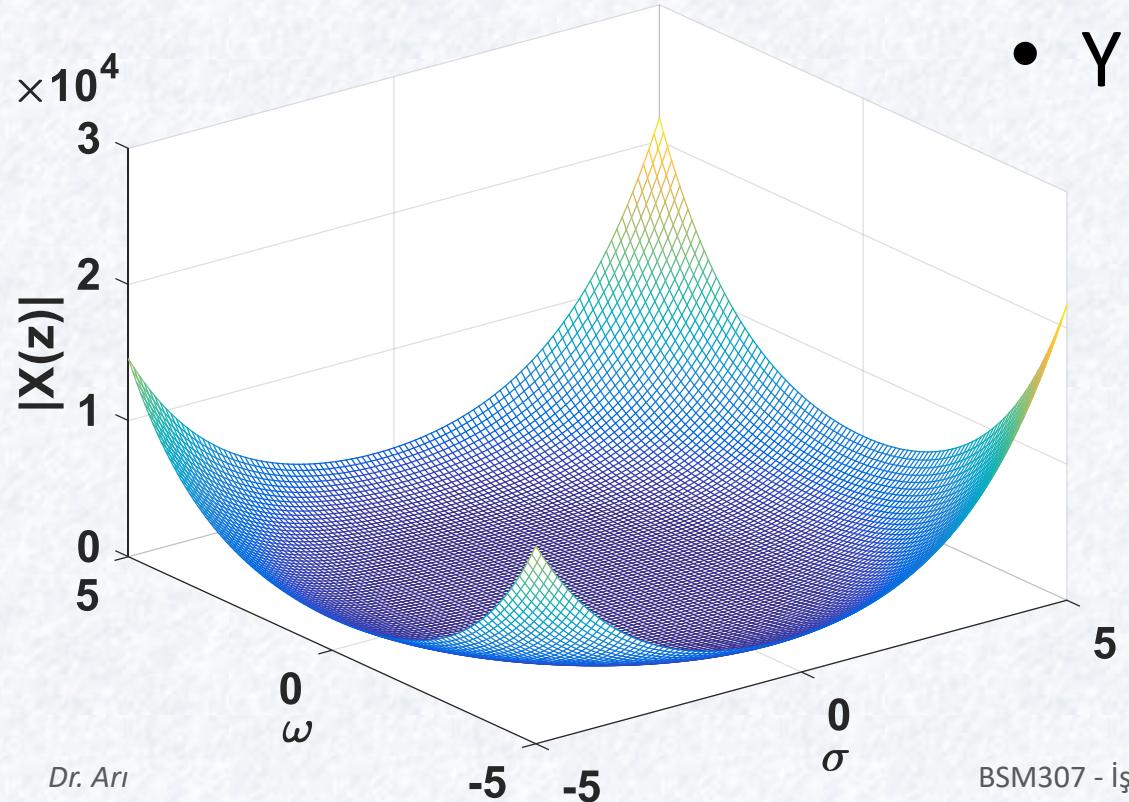
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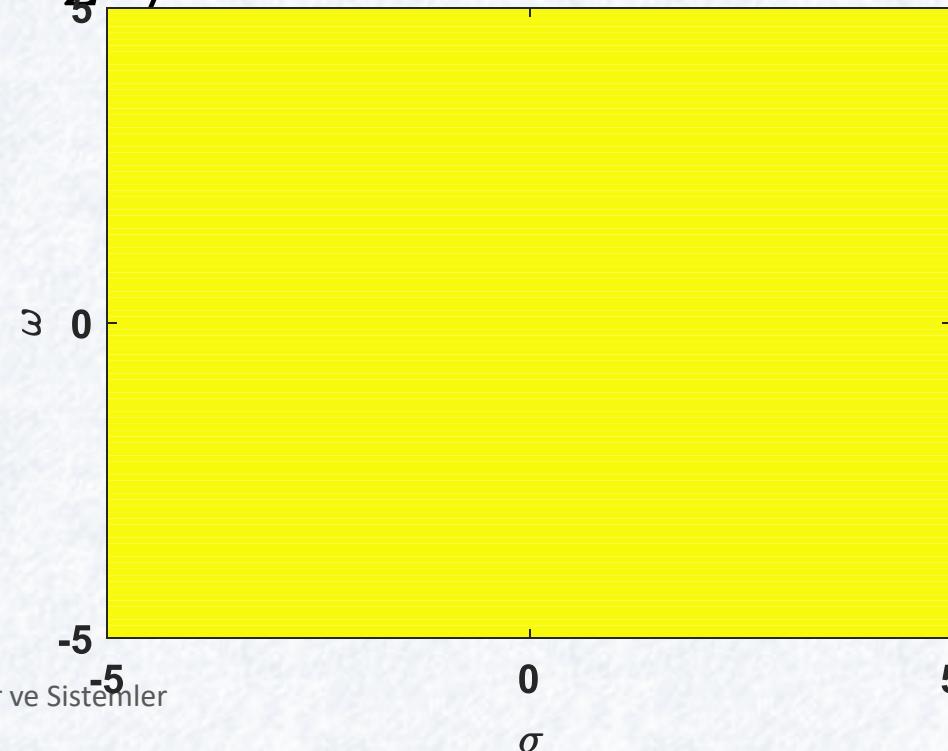


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- YB  $\rightarrow z \neq \infty$



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## Örnek 3

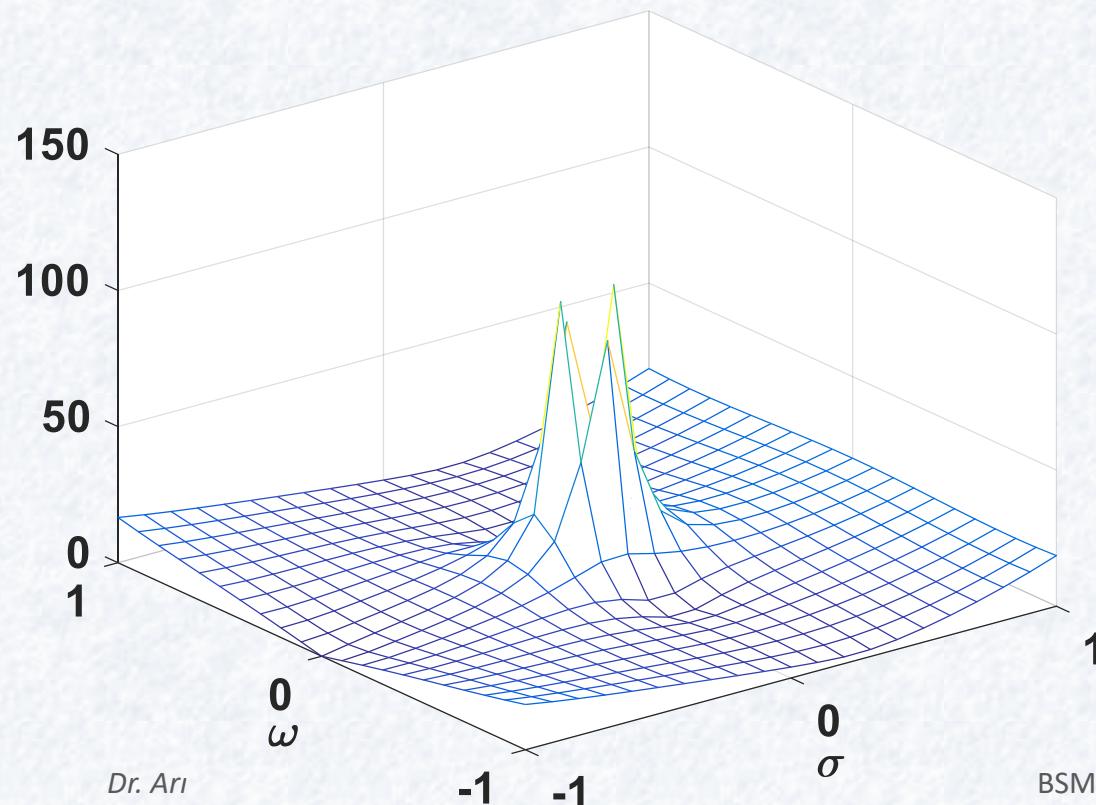
- $x(n) = \{1, 2, 5, \underbrace{7}_0, 0, 1\}$  ise  $X(z) = ?$
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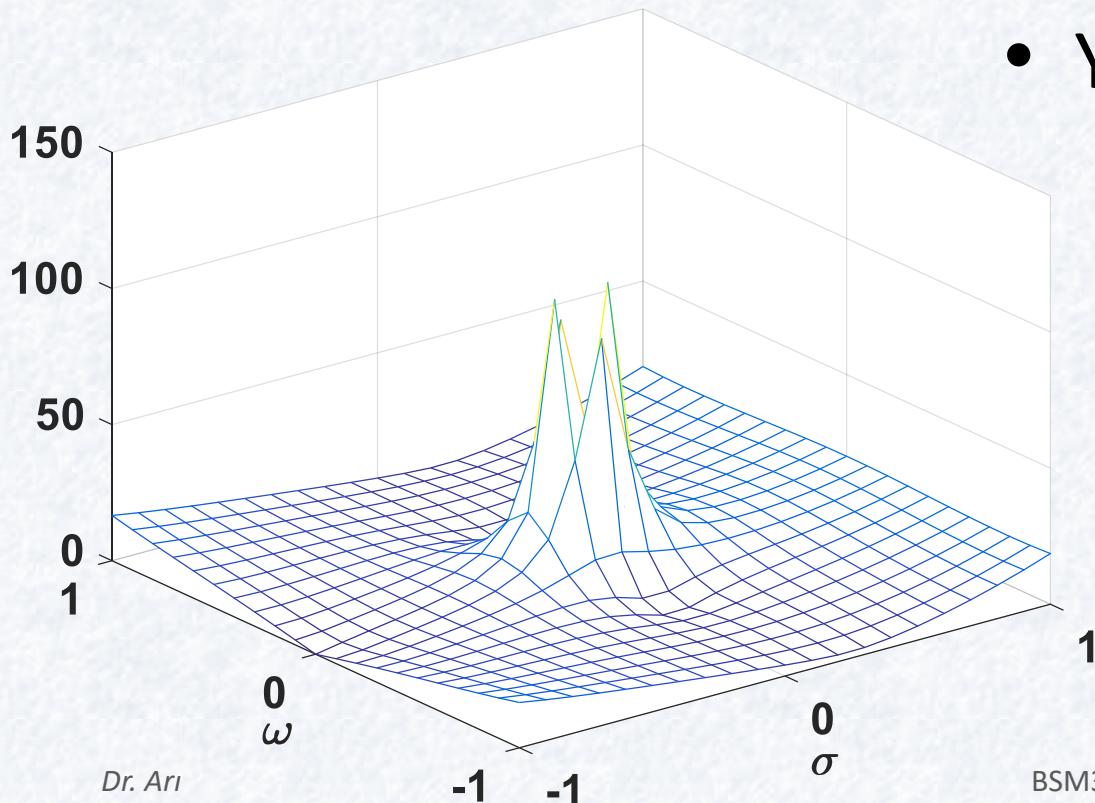
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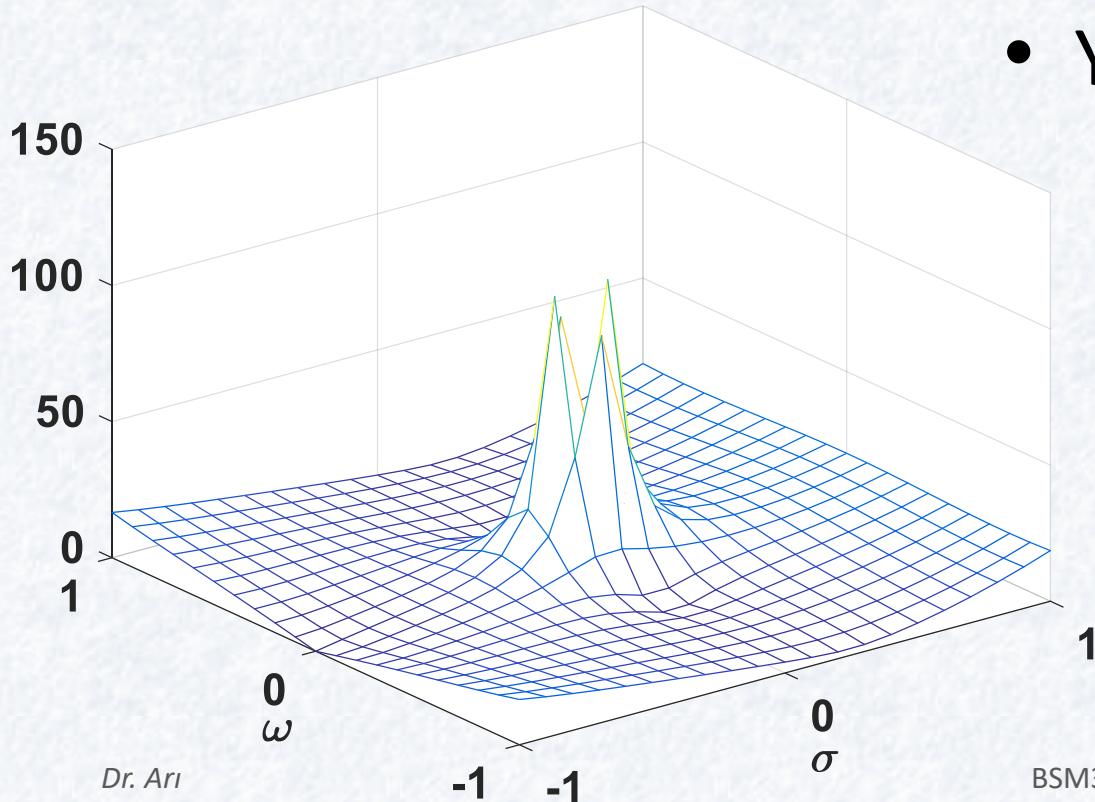
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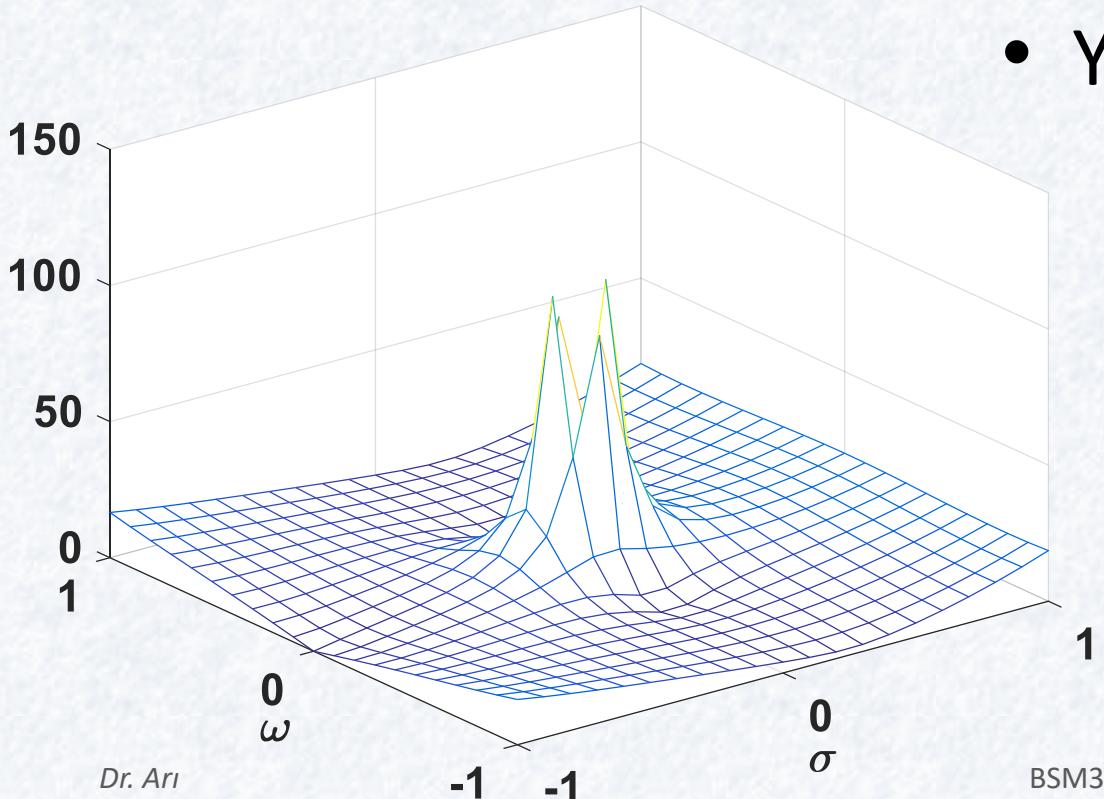
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- YB  $\rightarrow z \neq 0 \cap z \neq \infty$

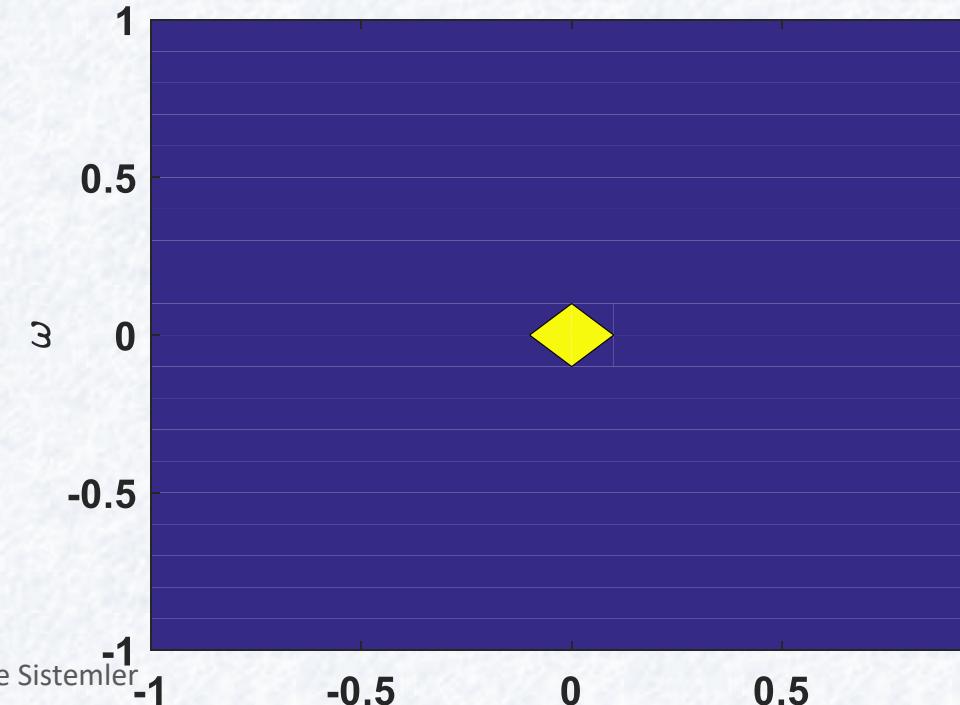


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# z-Dönüşümü

- Özeti

# z-Dönüşümü

- Özet

Ayrık Zaman İşaret	X(z)	Yakınsama Bölgesi
Sağ taraflı, Sınırlı	$z^{-\alpha}$ li terimler	$z \neq 0$

# z-Dönüşümü

- Özet

Ayrık Zaman İşaret	X(z)	Yakınsama Bölgesi
Sağ taraflı, Sınırlı	$z^-$ ' li terimler	$z \neq 0$
Sol taraflı, Sınırlı	$z^+$ ' li terimler	$z \neq \infty$

# z-Dönüşümü

- Özet

Ayrık Zaman İşaret	X(z)	Yakınsama Bölgesi
Sağ taraflı, Sınırlı	$z^-'$ li terimler	$z \neq 0$
Sol taraflı, Sınırlı	$z^+'$ li terimler	$z \neq \infty$
Çift taraflı, Sınırlı	$z^-'$ li ve $z^+'$ li terimler	$z \neq 0 \cap z \neq \infty$

## Örnek 4

- $x(n) = \delta(n)$  ise  $X(z) = ?$  ve  $YB=?$

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## Örnek 4

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- YB →

## Örnek 4

- $x(n) = \delta(n)$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} = \sum_{n=-\infty}^{\infty} \delta(n)z^{-n} = 1$
- YB  $\rightarrow$  Tüm karmaşık düzlem

## Örnek 5

- $x(n) = \delta(n - k)$  ve  $k > 0$  ise  $X(z) = ?$  ve  $YB=?$

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- $\text{YB} \rightarrow$

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- $x(n) = \delta(n - k)$  ise  $X(z) = ?$  ve YB=?
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- YB  $\rightarrow z \neq 0$

## Örnek 6

- $x(n) = \delta(n + k)$  ve  $k > 0$  ise  $X(z) = ?$  ve  $YB=?$

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- $x(n) = \delta(n + k)$  ve  $k > 0$  ise  $X(z) = ?$  ve YB=?
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## Örnek 6

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- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} = \sum_{n=-\infty}^{\infty} \delta(n + k)z^{-n}$

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- $x(n) = \delta(n + k)$  ve  $k > 0$  ise  $X(z) = ?$  ve  $YB=?$
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} = \sum_{n=-\infty}^{\infty} \delta(n + k)z^{-n} = z^k$

## Örnek 6

- $x(n) = \delta(n + k)$  ve  $k > 0$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} = \sum_{n=-\infty}^{\infty} \delta(n + k)z^{-n} = z^k$
- YB  $\rightarrow z \neq \infty$

# z-Dönüşümü

- Sınırsız, sağ taraflı işaretler

# z-Dönüşümü

- Sınırsız, sağ taraflı işaretler
- $x(n) = \alpha^n u(n)$

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- Sınırsız, sağ taraflı işaretler
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# z-Dönüşümü

- Sınırsız, sağ taraflı işaretler
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# z-Dönüşümü

- Sınırsız, sağ taraflı işaretler
- $x(n) = \alpha^n u(n)$
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# z-Dönüşümü

- Sınırsız, sağ taraflı işaretler
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- $X(z) = \sum_{n=0}^{\infty} (\alpha z^{-1})^n = \begin{cases} & |\alpha z^{-1}| \geq 1 \\ & \end{cases}$

# z-Dönüşümü

- Sınırsız, sağ taraflı işaretler
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- $X(z) = \sum_{n=0}^{\infty} (\alpha z^{-1})^n = \begin{cases} \infty, & |\alpha z^{-1}| \geq 1 \\ & \\ & |\alpha z^{-1}| < 1 \end{cases}$

# z-Dönüşümü

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- $X(z) = \frac{1}{1-\alpha z^{-1}}$ , YB →

# z-Dönüşümü

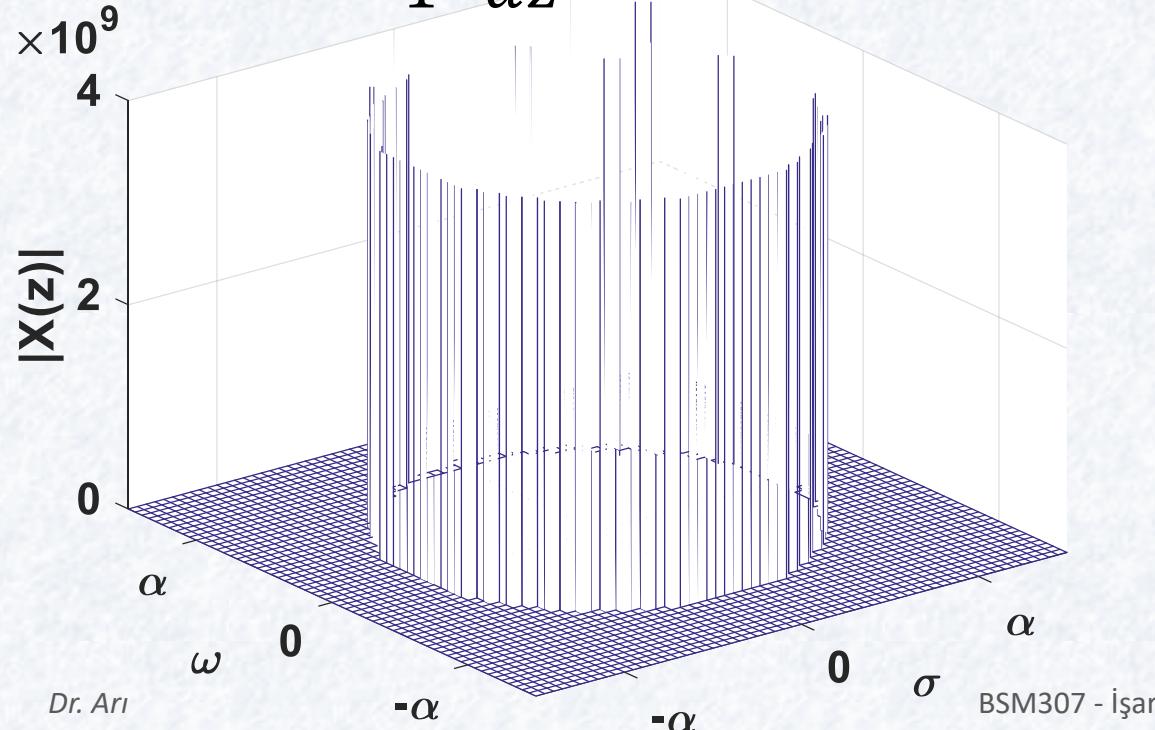
- Sınırsız, sağ taraflı işaretler
- $x(n) = \alpha^n u(n)$
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} = \sum_{n=0}^{\infty} \alpha^n z^{-n} = \sum_{n=0}^{\infty} (\alpha z^{-1})^n$
- $X(z) = \sum_{n=0}^{\infty} (\alpha z^{-1})^n = \begin{cases} \infty, & |\alpha z^{-1}| \geq 1 \\ \frac{1}{1-\alpha z^{-1}}, & |\alpha z^{-1}| < 1 \end{cases}$
- $X(z) = \frac{1}{1-\alpha z^{-1}}$ , YB  $\rightarrow |\alpha z^{-1}| < 1 \rightarrow$

# z-Dönüşümü

- Sınırsız, sağ taraflı işaretler
- $x(n) = \alpha^n u(n)$
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} = \sum_{n=0}^{\infty} \alpha^n z^{-n} = \sum_{n=0}^{\infty} (\alpha z^{-1})^n$
- $X(z) = \sum_{n=0}^{\infty} (\alpha z^{-1})^n = \begin{cases} \infty, & |\alpha z^{-1}| \geq 1 \\ \frac{1}{1-\alpha z^{-1}}, & |\alpha z^{-1}| < 1 \end{cases}$
- $X(z) = \frac{1}{1-\alpha z^{-1}}$ , YB  $\rightarrow |\alpha z^{-1}| < 1 \rightarrow |z| > |\alpha|$

# z-Dönüşümü

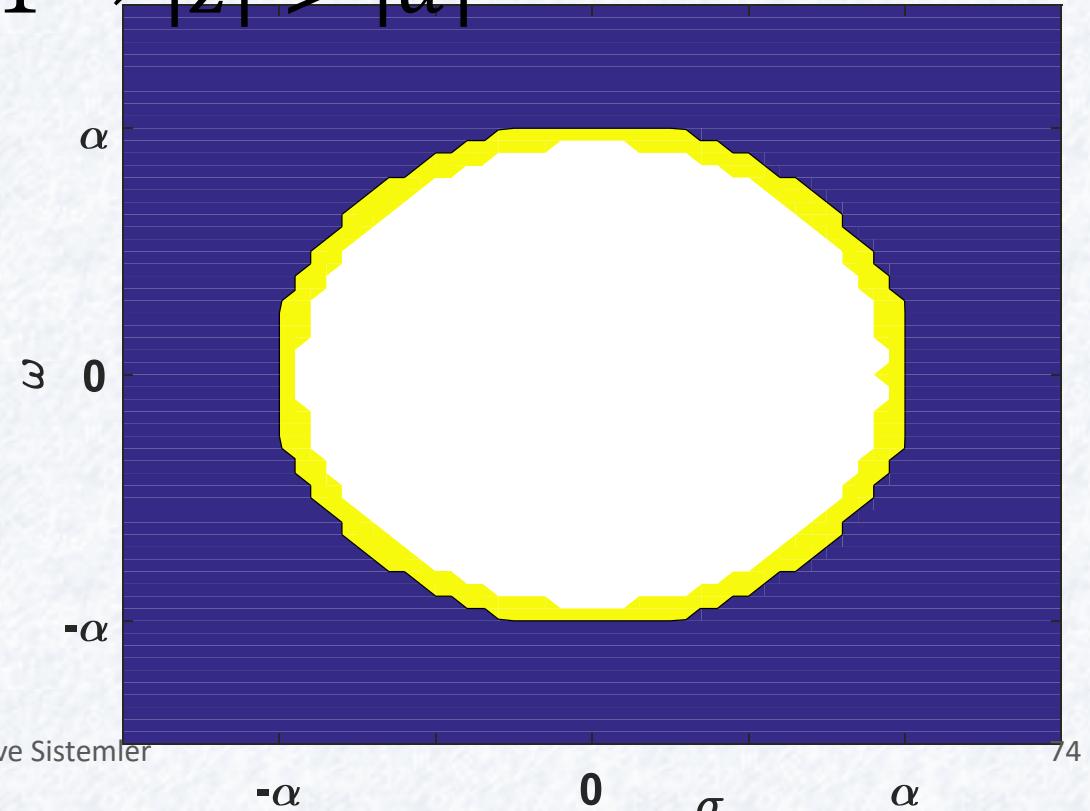
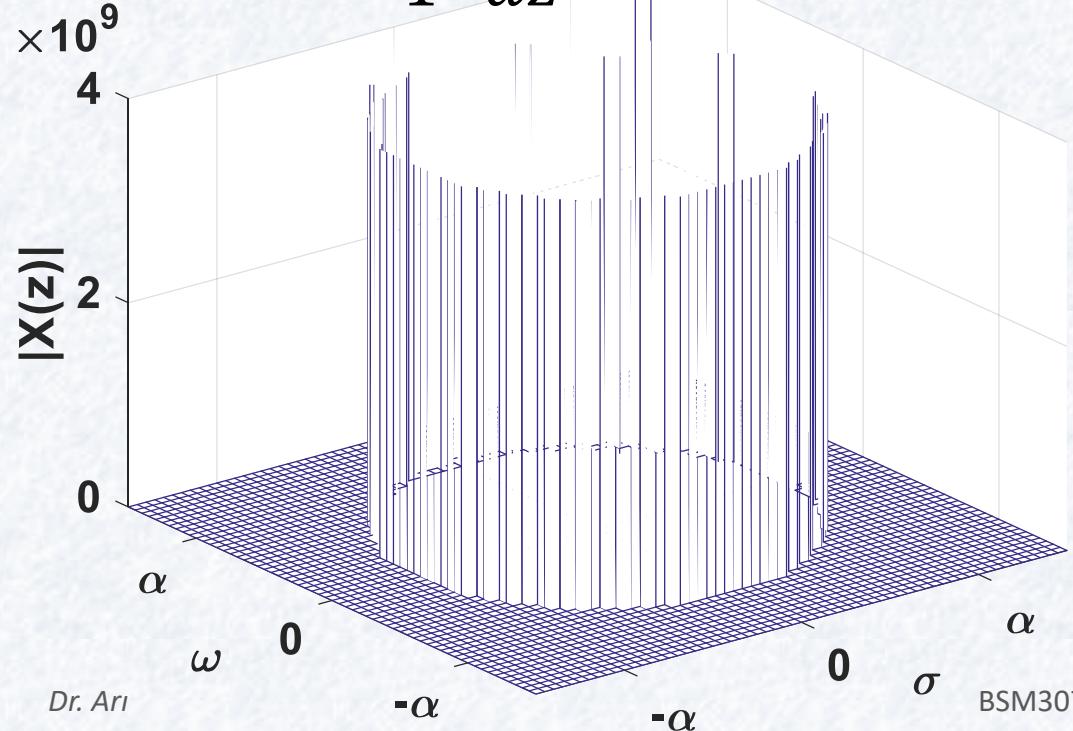
- Sınırsız, sağ taraflı işaretler
- $x(n) = \alpha^n u(n)$
- $X(z) = \frac{1}{1-\alpha z^{-1}}$ , YB  $\rightarrow |\alpha z^{-1}| < 1 \rightarrow |z| > |\alpha|$



# z-Dönüşümü

- Sınırsız, sağ taraflı işaretler
- $x(n) = \alpha^n u(n)$

- $X(z) = \frac{1}{1-\alpha z^{-1}}$ , YB  $\rightarrow |\alpha z^{-1}| < 1 \rightarrow |z| > |\alpha|$



# z-Dönüşümü

- Özet

Ayrık Zaman İşaret	X(z)	Yakınsama Bölgesi
Sağ taraflı, Sınırlı	$z^-'$ li terimler	$z \neq 0$
Sol taraflı, Sınırlı	$z^+'$ li terimler	$z \neq \infty$
Çift taraflı, Sınırlı	$z^-'$ li ve $z^+'$ li terimler	$z \neq 0 \cap z \neq \infty$
Sağ taraflı, Sınırsız $\alpha^n u(n)$	$\frac{1}{1 - \alpha z^{-1}}$	$ z  >  \alpha $

## Örnek 7

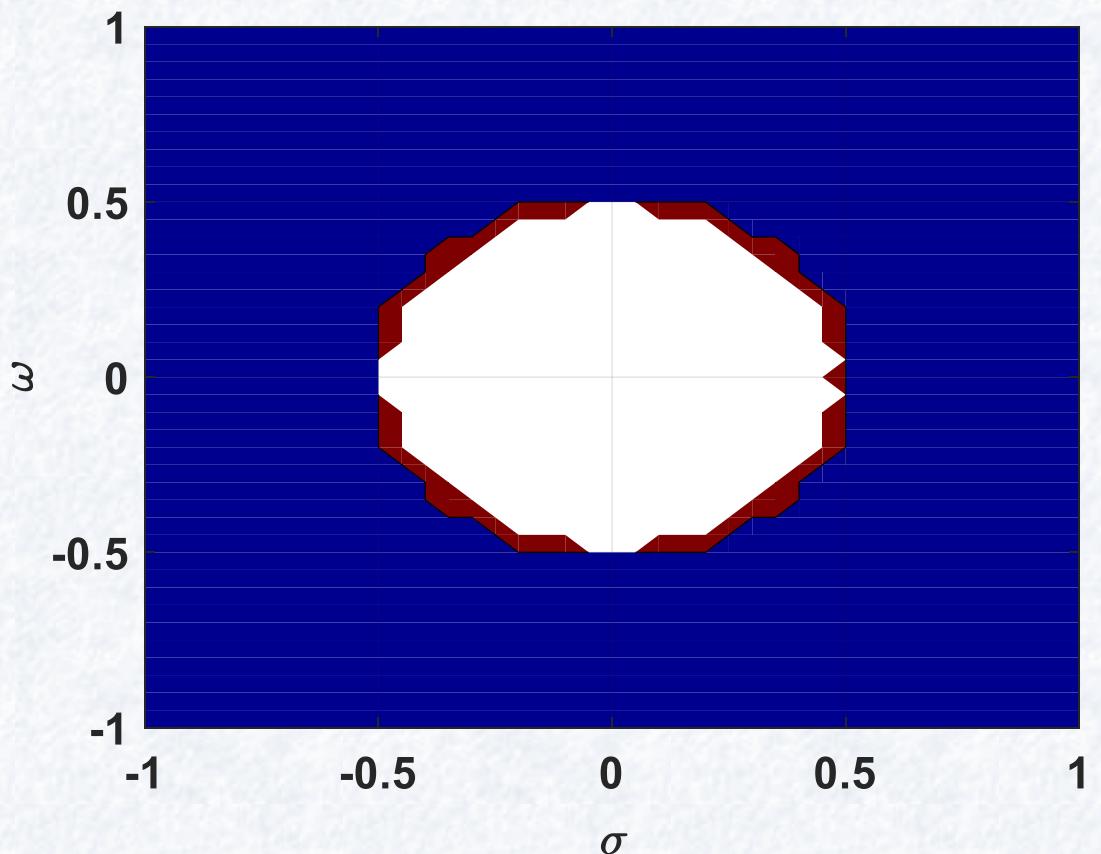
- $x(n) = \left(\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve  $YB=?$

## Örnek 7

- $x(n) = \left(\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve  $\mathcal{YB} = ?$
- $X(z) = \frac{1}{1 - \frac{1}{2}z^{-1}}$ ,  $\mathcal{YB} \rightarrow$

## Örnek 7

- $x(n) = \left(\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \frac{1}{1 - \frac{1}{2}z^{-1}}$ , YB  $\rightarrow |z| > \frac{1}{2}$



## Örnek 8

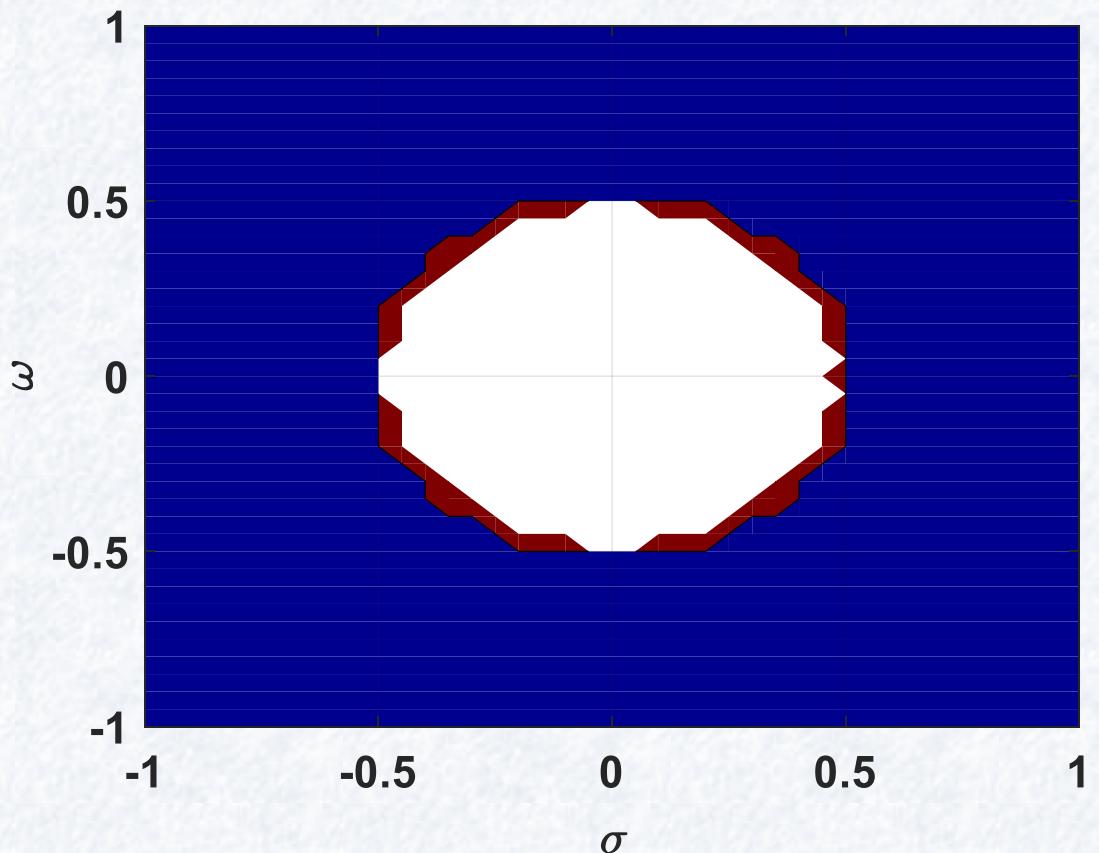
- $x(n) = -\left(\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve  $YB=?$

## Örnek 8

- $x(n) = -\left(\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve  $\text{YB}=?$
- $X(z) = \frac{-1}{1 - \frac{1}{2}z^{-1}}$ ,  $\text{YB} \rightarrow$

## Örnek 8

- $x(n) = -\left(\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \frac{-1}{1 - \frac{1}{2}z^{-1}}$ , YB  $\rightarrow |z| > \frac{1}{2}$



## Örnek 9

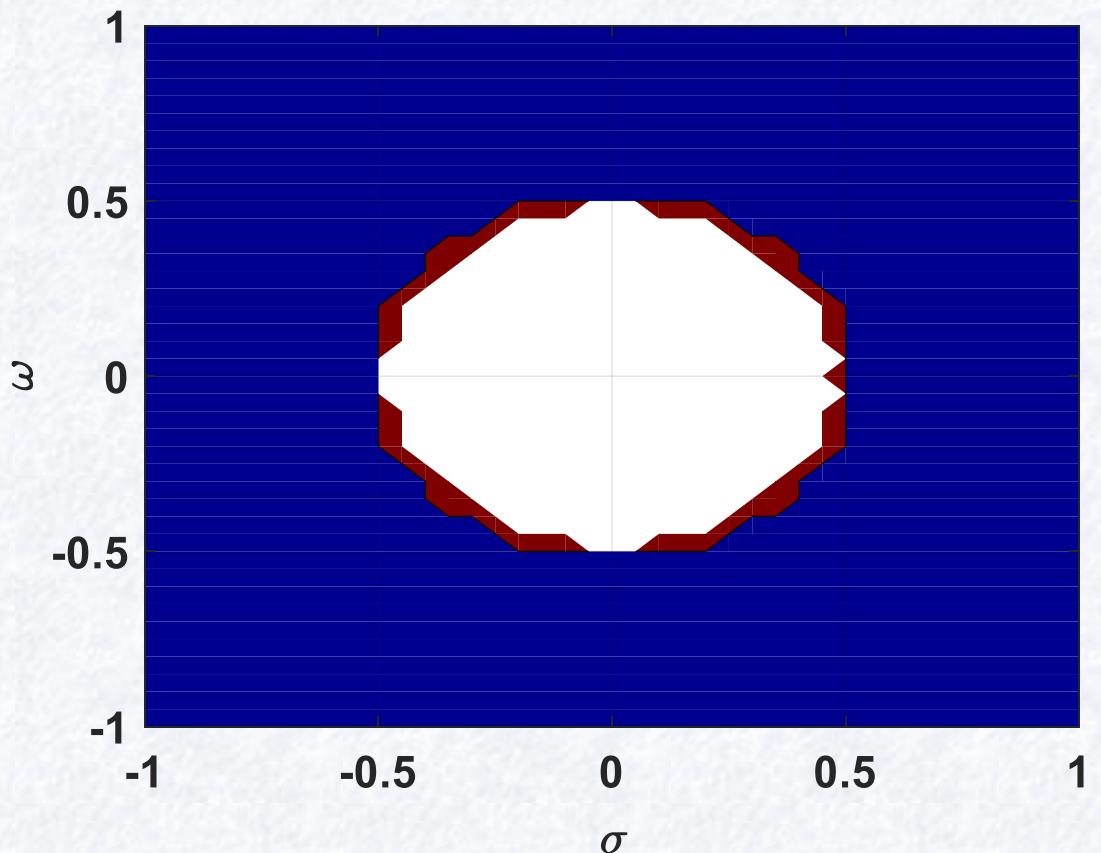
- $x(n) = \left(-\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve  $YB=?$

## Örnek 9

- $x(n) = \left(-\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve  $\text{YB}=?$
- $X(z) = \frac{1}{1 + \frac{1}{2}z^{-1}}$ ,  $\text{YB} \rightarrow$

## Örnek 9

- $x(n) = \left(-\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \frac{1}{1 + \frac{1}{2}z^{-1}}$ , YB  $\rightarrow |z| > \frac{1}{2}$



## Örnek 10

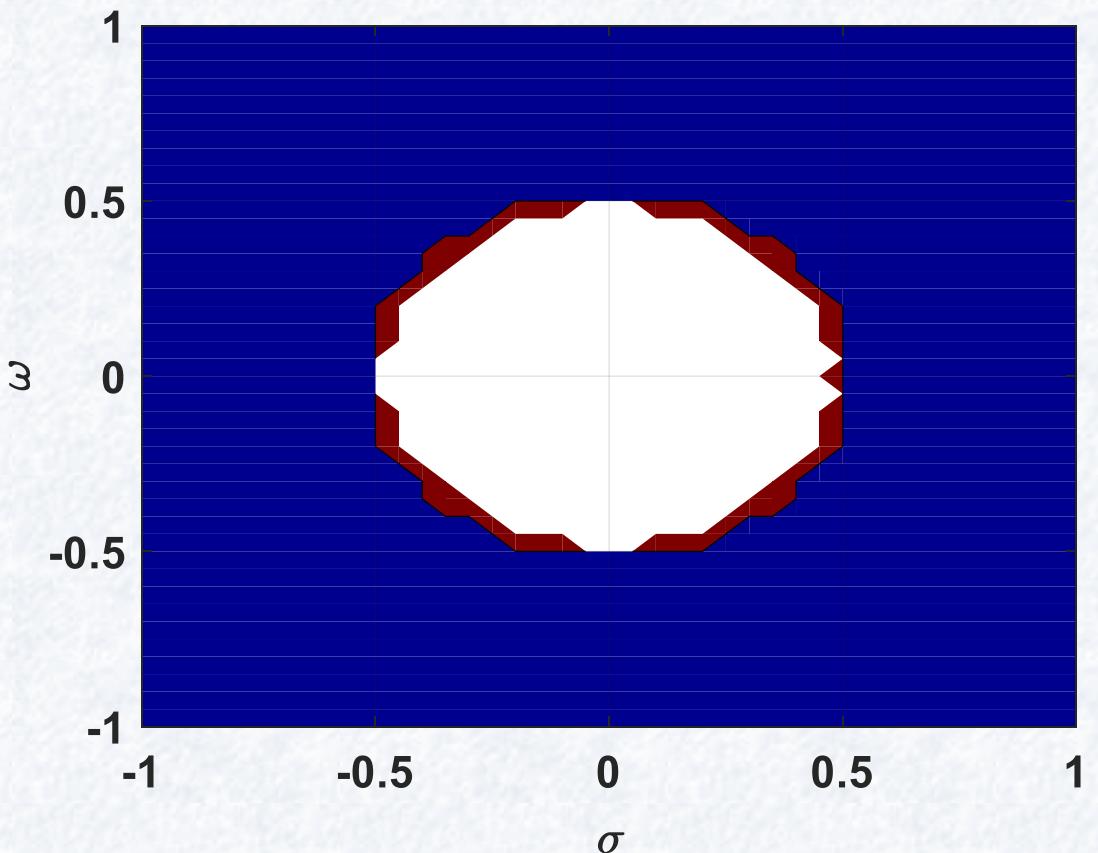
- $x(n) = -\left(-\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve  $YB=?$

## Örnek 10

- $x(n) = -\left(-\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve  $\text{YB}=?$
- $X(z) = \frac{-1}{1 + \frac{1}{2}z^{-1}}$ ,  $\text{YB} \rightarrow$

## Örnek 10

- $x(n) = -\left(-\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \frac{-1}{1 + \frac{1}{2}z^{-1}}$ , YB  $\rightarrow |z| > \frac{1}{2}$



# z-Dönüşümü

- Sınırsız, sol taraflı işaretler

# z-Dönüşümü

- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
- $X(z) =$

# z-Dönüşümü

- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
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# z-Dönüşümü

- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} = \sum_{n=-1}^{-\infty} \beta^n z^{-n}$

# z-Dönüşümü

- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n}$
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  - ◆  $n = -m$

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  - ◆  $n = -m$
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- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
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  - ◆  $n = -m$
- $X(z) = \sum_{m=1}^{\infty} \beta^{-m} z^m = \sum_{m=0}^{\infty} \beta^{-m} z^m - 1$

# z-Dönüşümü

- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
- $X(z) = \sum_{m=0}^{\infty} \beta^{-m} z^m - 1 = \sum_{m=0}^{\infty} (\beta^{-1} z)^m - 1$

# z-Dönüşümü

- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
- $X(z) = \sum_{m=0}^{\infty} \beta^{-m} z^m - 1 = \sum_{m=0}^{\infty} (\beta^{-1} z)^m - 1$
- $X(z) = \sum_{m=0}^{\infty} (\beta^{-1} z)^m - 1 = \begin{cases} & |\beta^{-1} z| \geq 1 \\ & \end{cases}$

# z-Dönüşümü

- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
- $X(z) = \sum_{m=0}^{\infty} \beta^{-m} z^m - 1 = \sum_{m=0}^{\infty} (\beta^{-1} z)^m - 1$
- $X(z) = \sum_{m=0}^{\infty} (\beta^{-1} z)^m - 1 = \begin{cases} \infty, & |\beta^{-1} z| \geq 1 \\ & \\ & |\beta^{-1} z| < 1 \end{cases}$

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- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
- $X(z) = \sum_{m=0}^{\infty} \beta^{-m} z^m - 1 = \sum_{m=0}^{\infty} (\beta^{-1} z)^m - 1$

- $X(z) = \sum_{m=0}^{\infty} (\beta^{-1} z)^m - 1 = \begin{cases} \infty, & |\beta^{-1} z| \geq 1 \\ \frac{1}{1-\beta^{-1}z} - 1, & |\beta^{-1} z| < 1 \end{cases}$

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- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
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- $X(z) = \frac{1}{1-\beta^{-1}z} - 1 =$

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- $X(z) = \frac{1}{1-\beta^{-1}z} - 1 = \frac{\beta z^{-1}}{\beta z^{-1}-1} = \frac{-1}{1-\beta z^{-1}}$ , YB  $\rightarrow$

# z-Dönüşümü

- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
- $X(z) = \sum_{m=0}^{\infty} \beta^{-m} z^m - 1 = \sum_{m=0}^{\infty} (\beta^{-1} z)^m - 1$
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- $X(z) = \frac{1}{1-\beta^{-1}z} - 1 = \frac{1}{\beta z^{-1}-1} = \frac{-1}{1-\beta z^{-1}}$ , YB  $\rightarrow |\beta^{-1} z| < 1$

# z-Dönüşümü

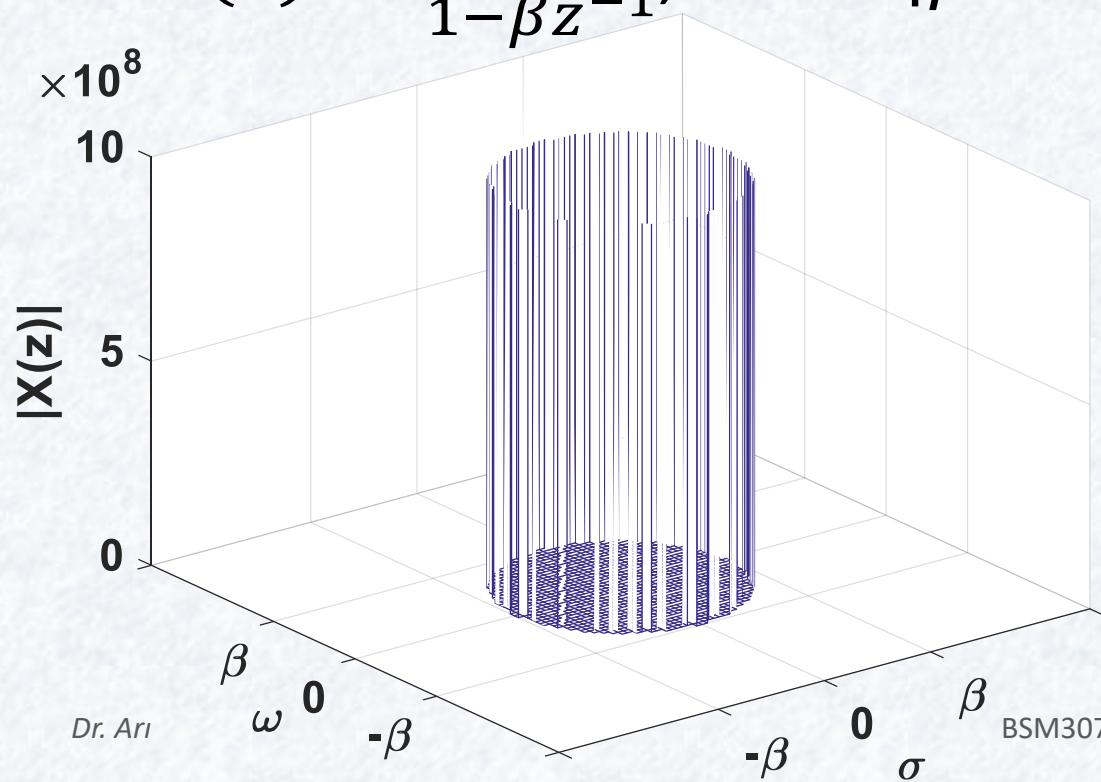
- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
- $X(z) = \sum_{m=0}^{\infty} \beta^{-m} z^m - 1 = \sum_{m=0}^{\infty} (\beta^{-1} z)^m - 1$
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- $X(z) = \frac{-1}{1-\beta z^{-1}}$ , YB  $\rightarrow |\beta^{-1} z| < 1 \rightarrow$

# z-Dönüşümü

- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
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- $X(z) = \frac{-1}{1-\beta z^{-1}}$ , YB  $\rightarrow |\beta^{-1} z| < 1 \rightarrow |z| < |\beta|$

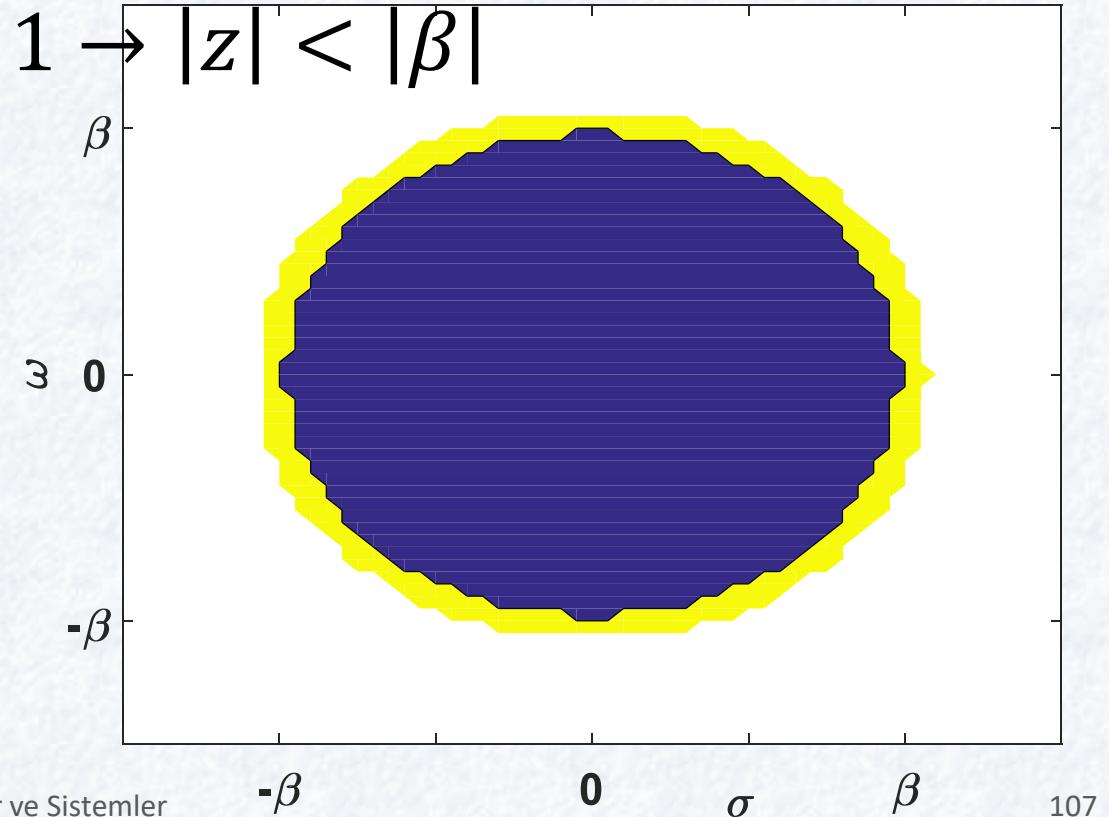
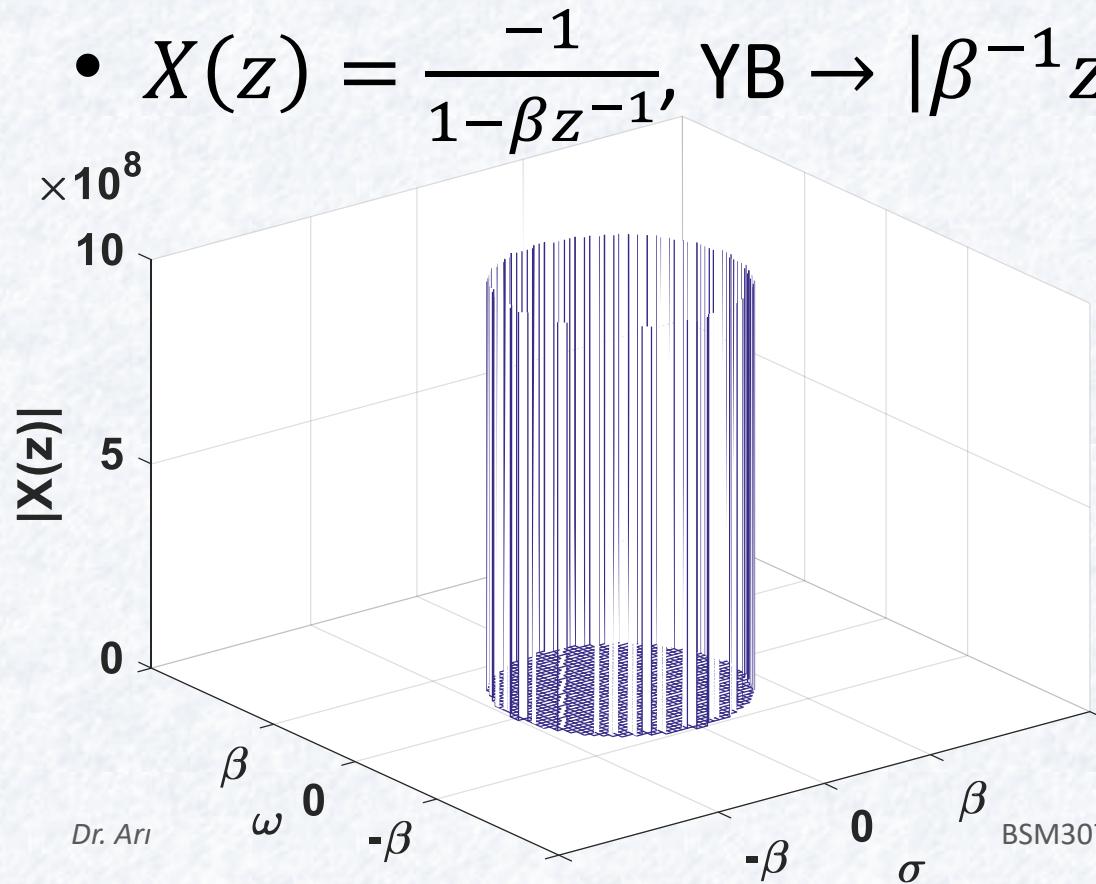
# z-Dönüşümü

- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$
- $X(z) = \frac{-1}{1-\beta z^{-1}}$ , YB  $\rightarrow |\beta^{-1}z| < 1 \rightarrow |z| < |\beta|$



# z-Dönüşümü

- Sınırsız, sol taraflı işaretler
- $x(n) = \beta^n u(-n - 1)$



# z-Dönüşümü

- Özet

Ayrık Zaman İşaret	X(z)	Yakınsama Bölgesi
Sağ taraflı, Sınırlı	$z^-'$ li terimler	$z \neq 0$
Sol taraflı, Sınırlı	$z^+'$ li terimler	$z \neq \infty$
Çift taraflı, Sınırlı	$z^-'$ li ve $z^+'$ li terimler	$z \neq 0 \cap z \neq \infty$
Sağ taraflı, Sınırsız $\alpha^n u(n)$	$\frac{1}{1 - \alpha z^{-1}}$	$ z  >  \alpha $
Sol taraflı, Sınırsız $-(\beta)^n u(-n - 1)$	$\frac{1}{1 - \beta z^{-1}}$	$ z  <  \beta $

## Örnek 11

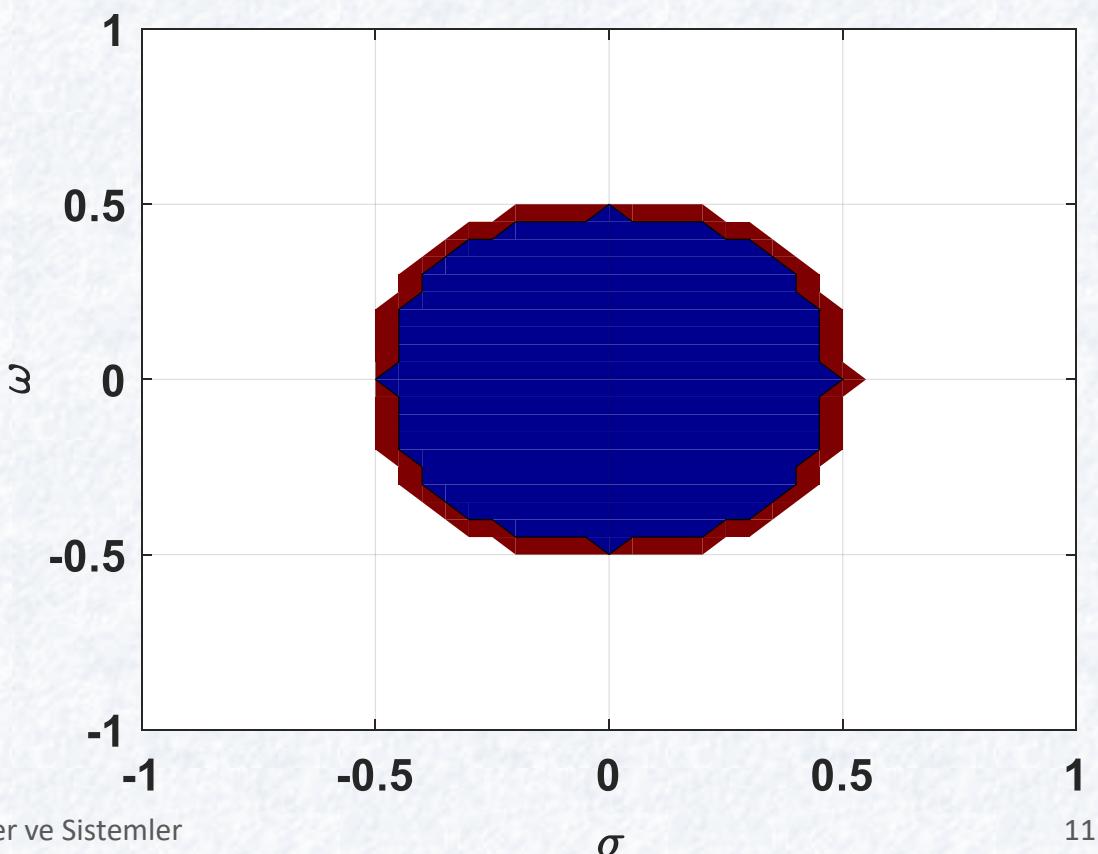
- $x(n) = \left(\frac{1}{2}\right)^n u(-n - 1)$  ise  $X(z) = ?$  ve  $YB = ?$

## Örnek 11

- $x(n) = \left(\frac{1}{2}\right)^n u(-n - 1)$  ise  $X(z) = ?$  ve  $\mathcal{YB} = ?$
- $X(z) = \frac{-1}{1 - \frac{1}{2}z^{-1}}$ ,  $\mathcal{YB} \rightarrow$

## Örnek 11

- $x(n) = \left(\frac{1}{2}\right)^n u(-n - 1)$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \frac{-1}{1 - \frac{1}{2}z^{-1}}$ , YB  $\rightarrow |z| < \frac{1}{2}$



## Örnek 12

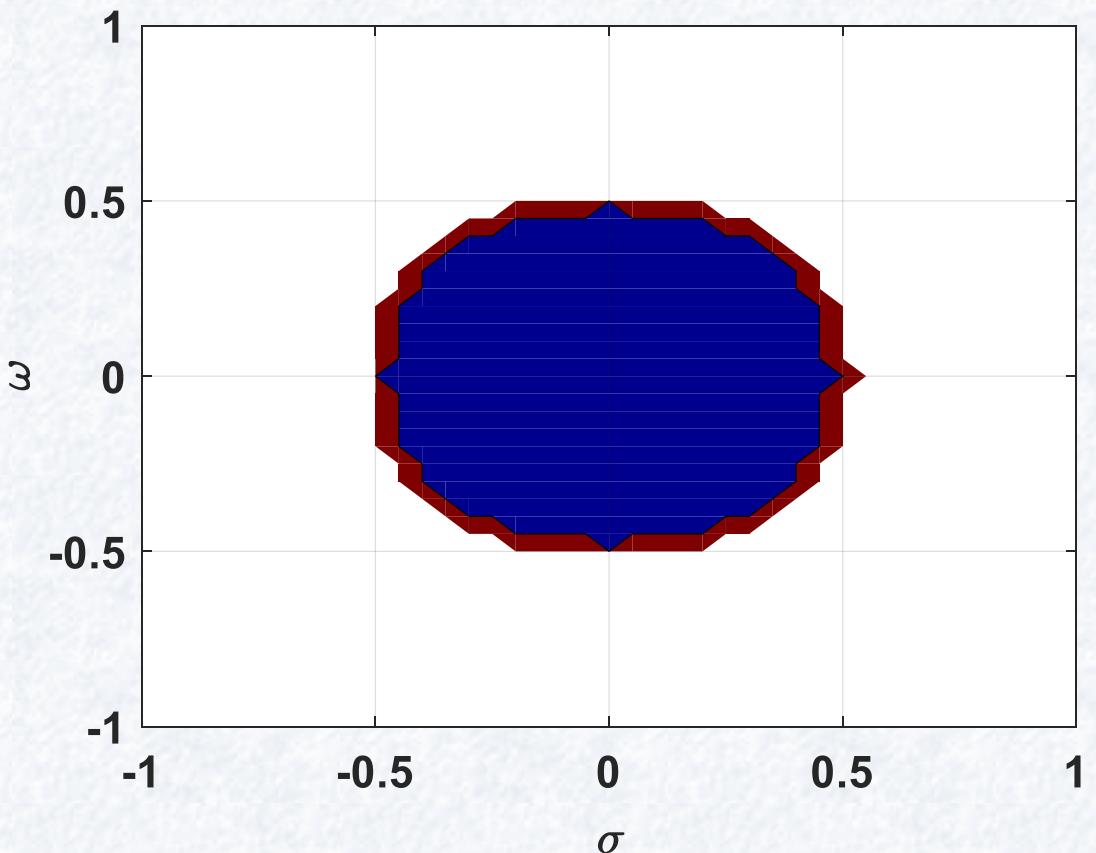
- $x(n) = -\left(\frac{1}{2}\right)^n u(-n-1)$  ise  $X(z) = ?$  ve  $YB=?$

## Örnek 12

- $x(n) = -\left(\frac{1}{2}\right)^n u(-n-1)$  ise  $X(z) = ?$  ve  $\text{YB}=?$
- $X(z) = \frac{1}{1-\frac{1}{2}z^{-1}}$ ,  $\text{YB} \rightarrow$

## Örnek 12

- $x(n) = -\left(\frac{1}{2}\right)^n u(-n-1)$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \frac{1}{1-\frac{1}{2}z^{-1}}$ , YB  $\rightarrow |z| < \frac{1}{2}$



## Örnek 13

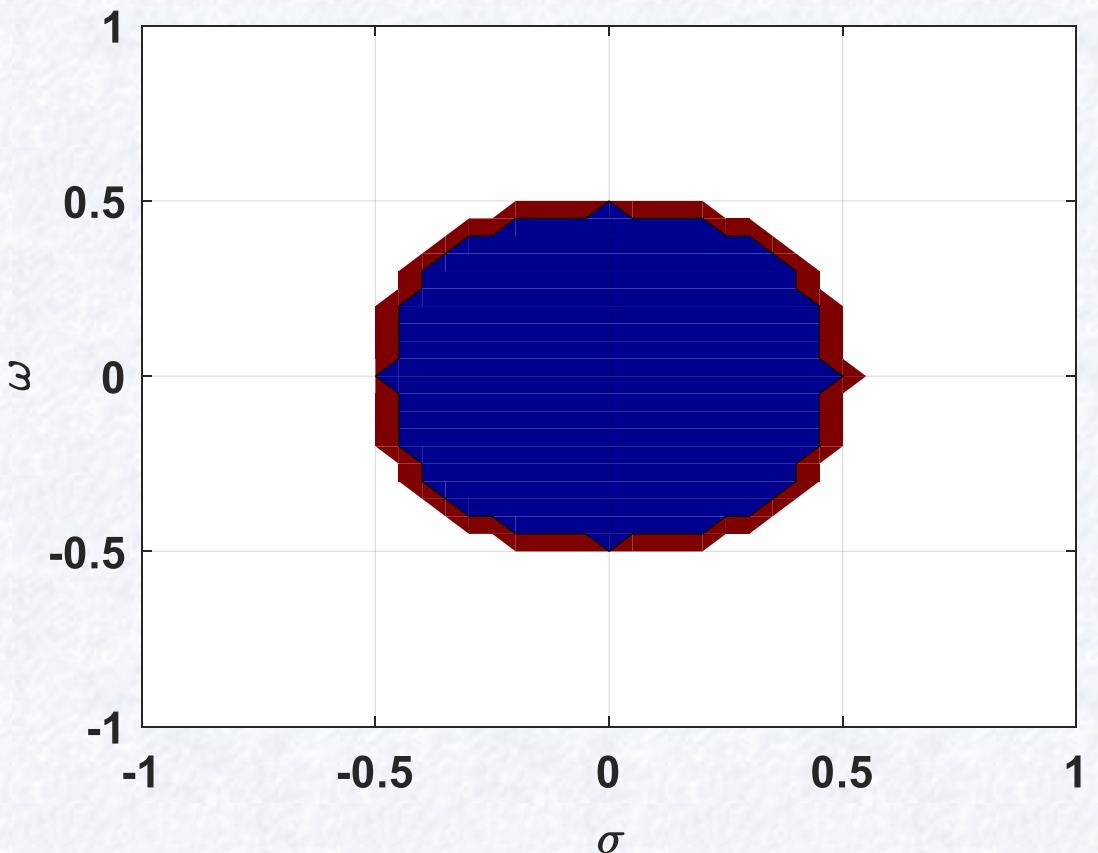
- $x(n) = \left(-\frac{1}{2}\right)^n u(-n - 1)$  ise  $X(z) = ?$  ve  $YB = ?$

## Örnek 13

- $x(n) = \left(-\frac{1}{2}\right)^n u(-n - 1)$  ise  $X(z) = ?$  ve  $\text{YB}=?$
- $X(z) = \frac{-1}{1 + \frac{1}{2}z^{-1}}$ ,  $\text{YB} \rightarrow$

## Örnek 13

- $x(n) = \left(-\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \frac{-1}{1 + \frac{1}{2}z^{-1}}$ , YB  $\rightarrow |z| < \frac{1}{2}$



## Örnek 14

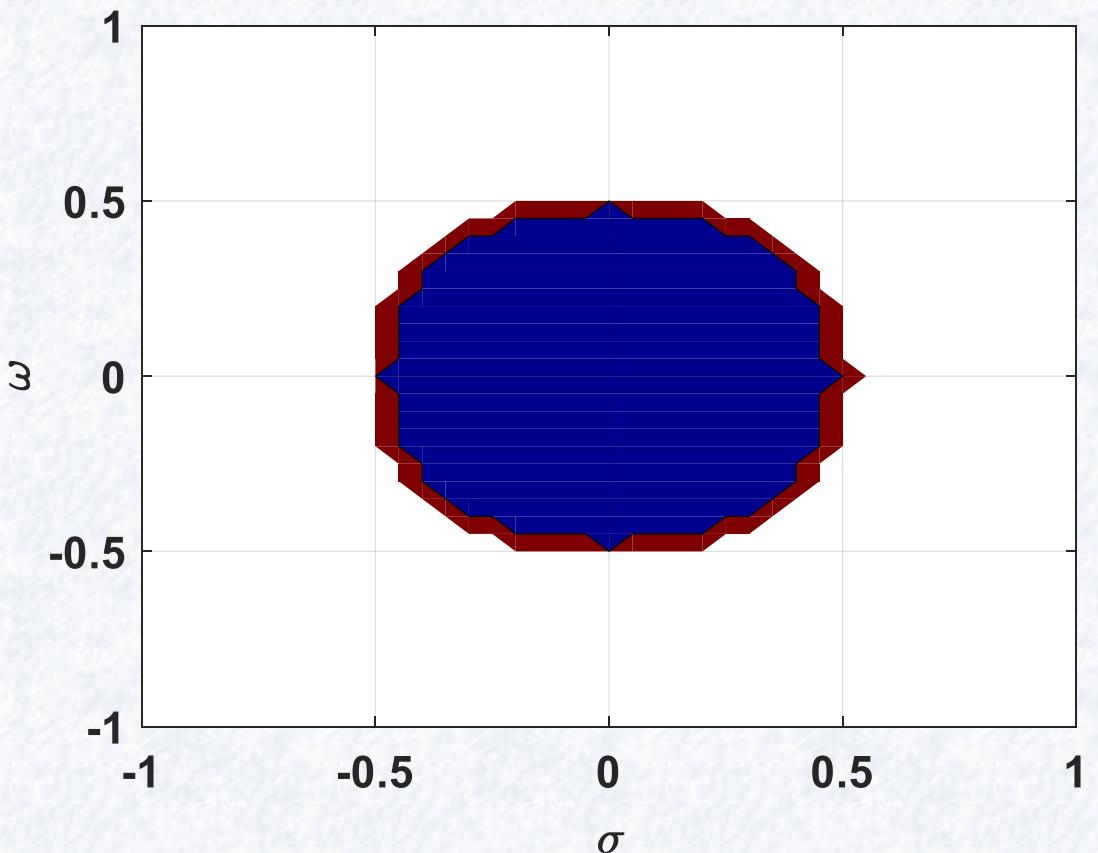
- $x(n) = -\left(-\frac{1}{2}\right)^n u(-n-1)$  ise  $X(z) = ?$  ve  $YB=?$

## Örnek 14

- $x(n) = -\left(-\frac{1}{2}\right)^n u(-n-1)$  ise  $X(z) = ?$  ve  $YB=?$
- $X(z) = \frac{1}{1 + \frac{1}{2}z^{-1}}$ ,  $YB \rightarrow$

## Örnek 14

- $x(n) = -\left(-\frac{1}{2}\right)^n u(n)$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \frac{1}{1 + \frac{1}{2}z^{-1}}$ , YB  $\rightarrow |z| < \frac{1}{2}$



# z-Dönüşümü

- Sınırsız, çift taraflı işaretler

# z-Dönüşümü

- Sınırsız, çift taraflı işaretler
- $x(n) = \alpha^n u(n) + \beta^n u(-n - 1)$
- $X(z) =$

# z-Dönüşümü

- Sınırsız, çift taraflı işaretler
- $x(n) = \alpha^n u(n) + \beta^n u(-n - 1)$
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n}$

# z-Dönüşümü

- Sınırsız, çift taraflı işaretler
- $x(n) = \alpha^n u(n) + \beta^n u(-n - 1)$
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} = \sum_{n=0}^{\infty} \alpha^n z^{-n} + \sum_{n=-1}^{-\infty} \beta^n z^{-n}$

# z-Dönüşümü

- Sınırsız, çift taraflı işaretler
- $x(n) = \alpha^n u(n) + \beta^n u(-n - 1)$
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} = \sum_{n=0}^{\infty} \alpha^n z^{-n} + \sum_{n=-1}^{-\infty} \beta^n z^{-n}$
- $X(z) = \frac{1}{1-\alpha z^{-1}} - \frac{1}{1-\beta z^{-1}}$

# z-Dönüşümü

- Sınırsız, çift taraflı işaretler
- $x(n) = \alpha^n u(n) + \beta^n u(-n - 1)$
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- $X(z) = \underbrace{\frac{1}{1-\alpha z^{-1}}}_{|z|} - \frac{1}{1-\beta z^{-1}}$

# z-Dönüşümü

- Sınırsız, çift taraflı işaretler
- $x(n) = \alpha^n u(n) + \beta^n u(-n - 1)$
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- $$X(z) = \underbrace{\frac{1}{1-\alpha z^{-1}}}_{|z|>|\alpha|} - \frac{1}{1-\beta z^{-1}}$$

# z-Dönüşümü

- Sınırsız, çift taraflı işaretler
- $x(n) = \alpha^n u(n) + \beta^n u(-n - 1)$
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} = \sum_{n=0}^{\infty} \alpha^n z^{-n} + \sum_{n=-1}^{-\infty} \beta^n z^{-n}$
- $$X(z) = \underbrace{\frac{1}{1-\alpha z^{-1}}}_{|z|>|\alpha|} - \underbrace{\frac{1}{1-\beta z^{-1}}}_{|z|}$$

# z-Dönüşümü

- Sınırsız, çift taraflı işaretler
- $x(n) = \alpha^n u(n) + \beta^n u(-n - 1)$
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} = \sum_{n=0}^{\infty} \alpha^n z^{-n} + \sum_{n=-1}^{-\infty} \beta^n z^{-n}$
- $$X(z) = \underbrace{\frac{1}{1-\alpha z^{-1}}}_{|z|>|\alpha|} - \underbrace{\frac{1}{1-\beta z^{-1}}}_{|z|<|\beta|}$$

# z-Dönüşümü

- Sınırsız, çift taraflı işaretler
- $x(n) = \alpha^n u(n) + \beta^n u(-n - 1)$
- $X(z) = \sum_{n=-\infty}^{\infty} x(n)z^{-n} = \sum_{n=0}^{\infty} \alpha^n z^{-n} + \sum_{n=-1}^{-\infty} \beta^n z^{-n}$
- $$X(z) = \underbrace{\frac{1}{1-\alpha z^{-1}}}_{\begin{array}{l} |z| > |\alpha| \\ |z| > |\alpha| \cap |z| < |\beta| \end{array}} - \underbrace{\frac{1}{1-\beta z^{-1}}}_{|z| < |\beta|}$$

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- $X(z) = \frac{1}{1-\alpha z^{-1}} - \frac{1}{1-\beta z^{-1}}$ , YB  $\rightarrow |\alpha| < |z| < |\beta|$
- $X(z) = \begin{cases} & |\alpha| < |\beta| \\ & \end{cases}$

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# z-Dönüşümü

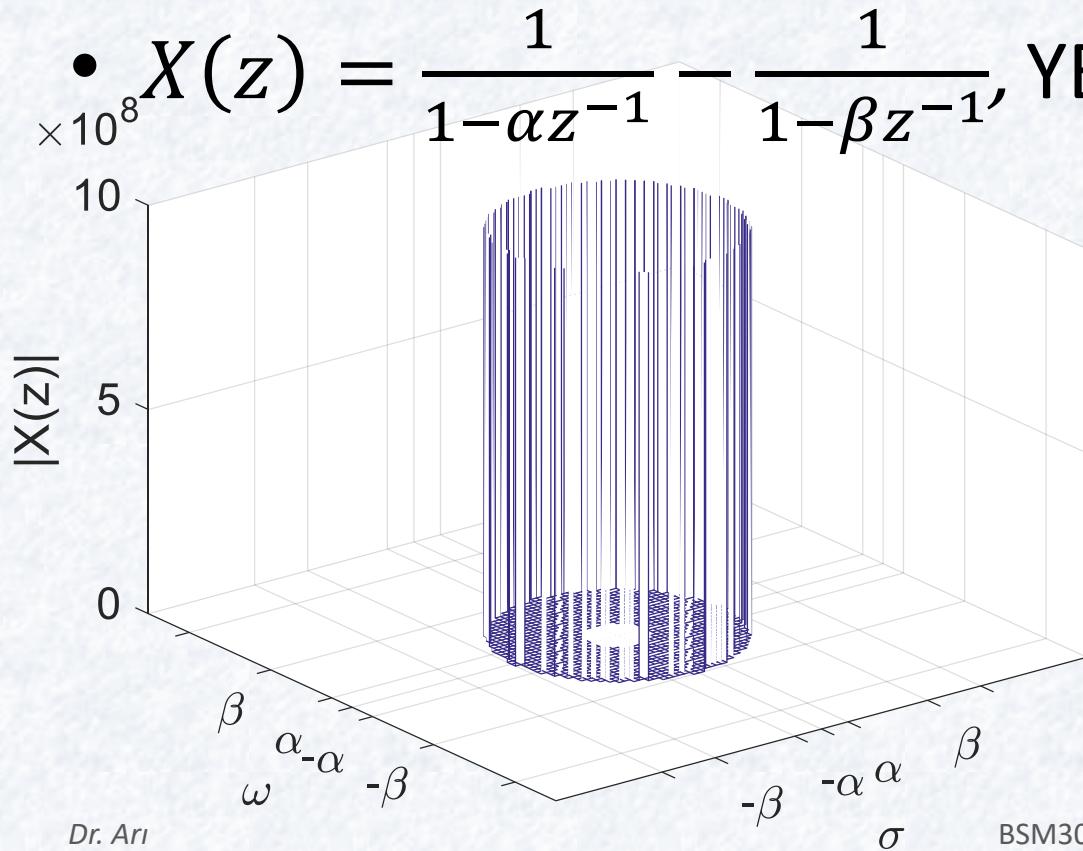
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- $$X(z) = \begin{cases} \frac{1}{1-\alpha z^{-1}} - \frac{1}{1-\beta z^{-1}}, & |\alpha| < |\beta| \\ & \\ & |\alpha| \geq |\beta| \end{cases}$$

# z-Dönüşümü

- Sınırsız, çift taraflı işaretler
- $x(n) = \alpha^n u(n) + \beta^n u(-n - 1)$
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- $$X(z) = \begin{cases} \frac{1}{1-\alpha z^{-1}} - \frac{1}{1-\beta z^{-1}}, & |\alpha| < |\beta| \\ \text{Geçersiz} & |\alpha| \geq |\beta| \end{cases}$$

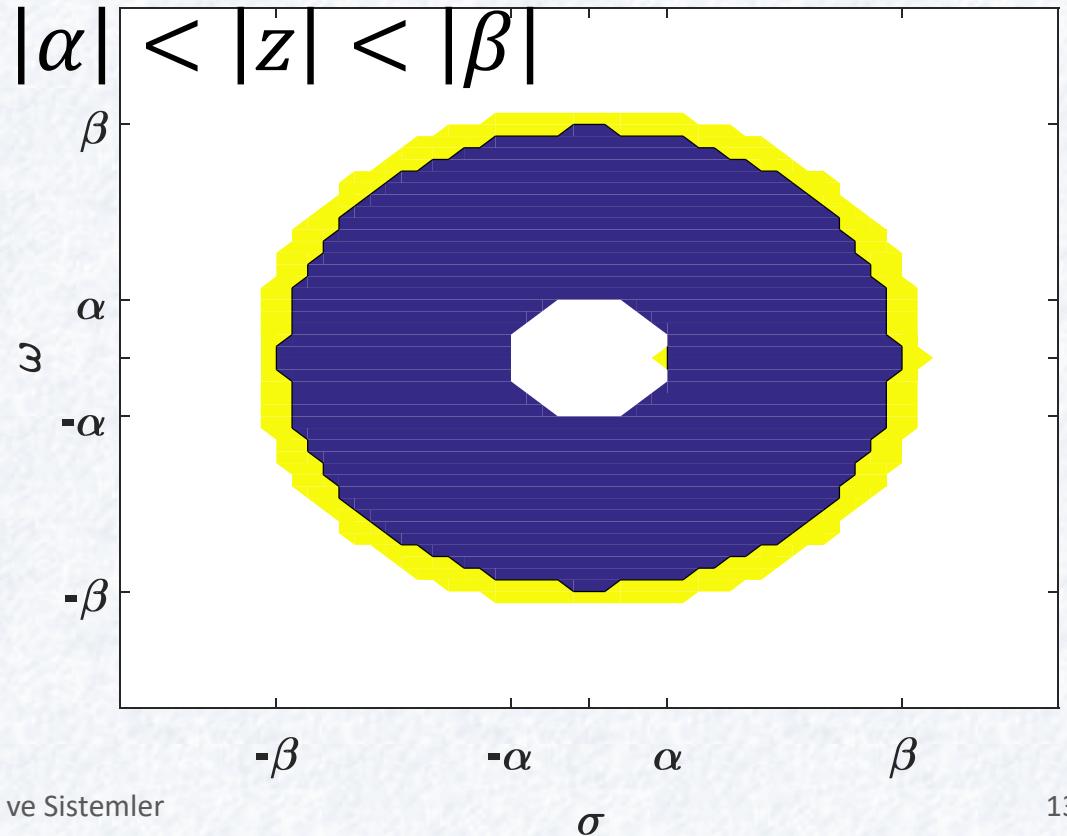
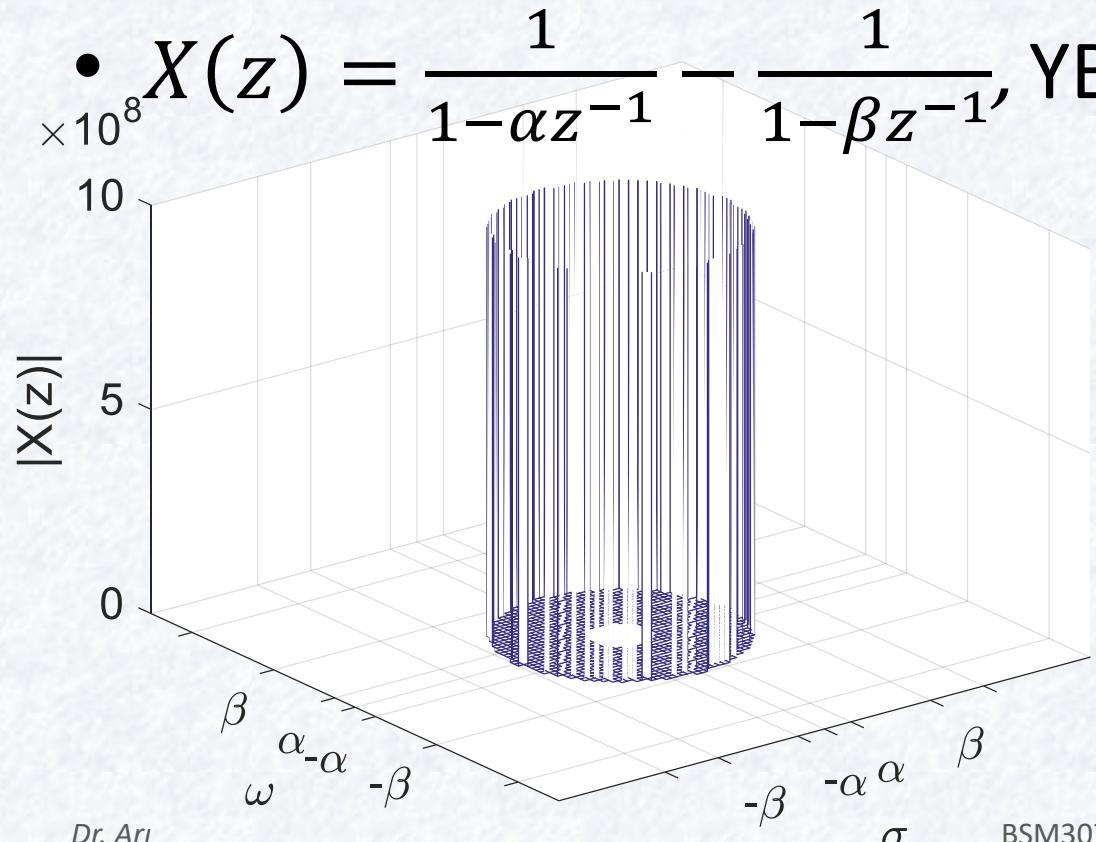
# z-Dönüşümü

- Sınırsız, çift taraflı işaretler
- $x(n) = \alpha^n u(n) + \beta^n u(-n - 1)$
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# z-Dönüşümü

- Sınırsız, çift taraflı işaretler
- $x(n) = \alpha^n u(n) + \beta^n u(-n - 1)$



# z-Dönüşümü

- Özet

Ayrık Zaman İşaret	$X(z)$	Yakınsama Bölgesi
Sağ taraflı, Sınırlı	$z^-$ ' li terimler	$z \neq 0$
Sol taraflı, Sınırlı	$z^+$ ' li terimler	$z \neq \infty$
Çift taraflı, Sınırlı	$z^-$ ' li ve $z^+$ ' li terimler	$z \neq 0 \cap z \neq \infty$
Sağ taraflı, Sınırsız $\alpha^n u(n)$	$\frac{1}{1 - \alpha z^{-1}}$	$ z  >  \alpha $
Sol taraflı, Sınırsız $-(\beta)^n u(-n - 1)$	$\frac{1}{1 - \beta z^{-1}}$	$ z  <  \beta $
Sol taraflı, Sınırsız $\alpha^n u(n) - (\beta)^n u(-n - 1)$	$\frac{1}{1 - \alpha z^{-1}} + \frac{1}{1 - \beta z^{-1}}$	$ \alpha  <  z  <  \beta $

## Örnek 15

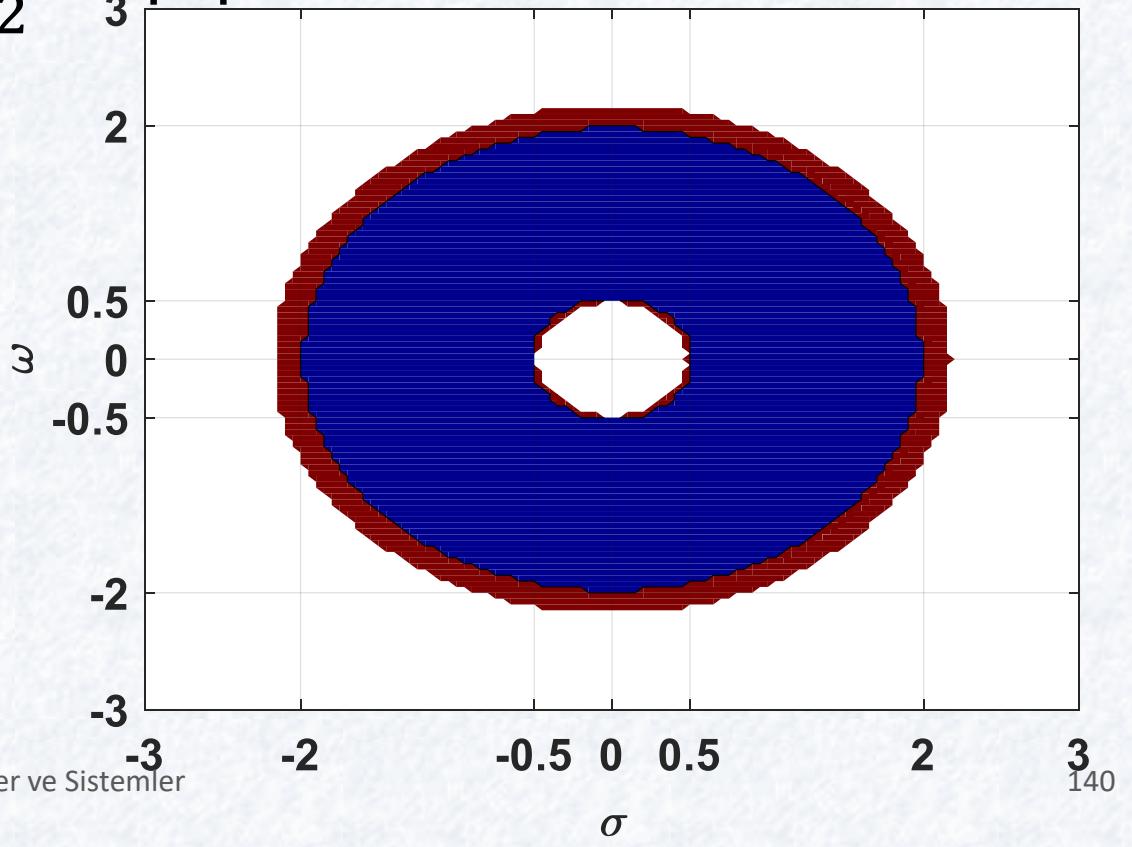
- $x(n) = \left(\frac{1}{2}\right)^n u(n) + (2)^n u(-n - 1)$  ise  $X(z) = ?$  ve  $YB = ?$

## Örnek 15

- $x(n) = \left(\frac{1}{2}\right)^n u(n) + (2)^n u(-n - 1)$  ise  $X(z) = ?$  ve  $\mathcal{YB} = ?$
- $X(z) = \frac{1}{1 - \frac{1}{2}z^{-1}} - \frac{1}{1 - 2z^{-1}}$ ,  $\mathcal{YB} \rightarrow$

## Örnek 15

- $x(n) = \left(\frac{1}{2}\right)^n u(n) + (2)^n u(-n - 1)$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \frac{1}{1 - \frac{1}{2}z^{-1}} - \frac{1}{1 - 2z^{-1}}$ , YB  $\rightarrow \frac{1}{2} <_3 |z| < 2$



## Örnek 16

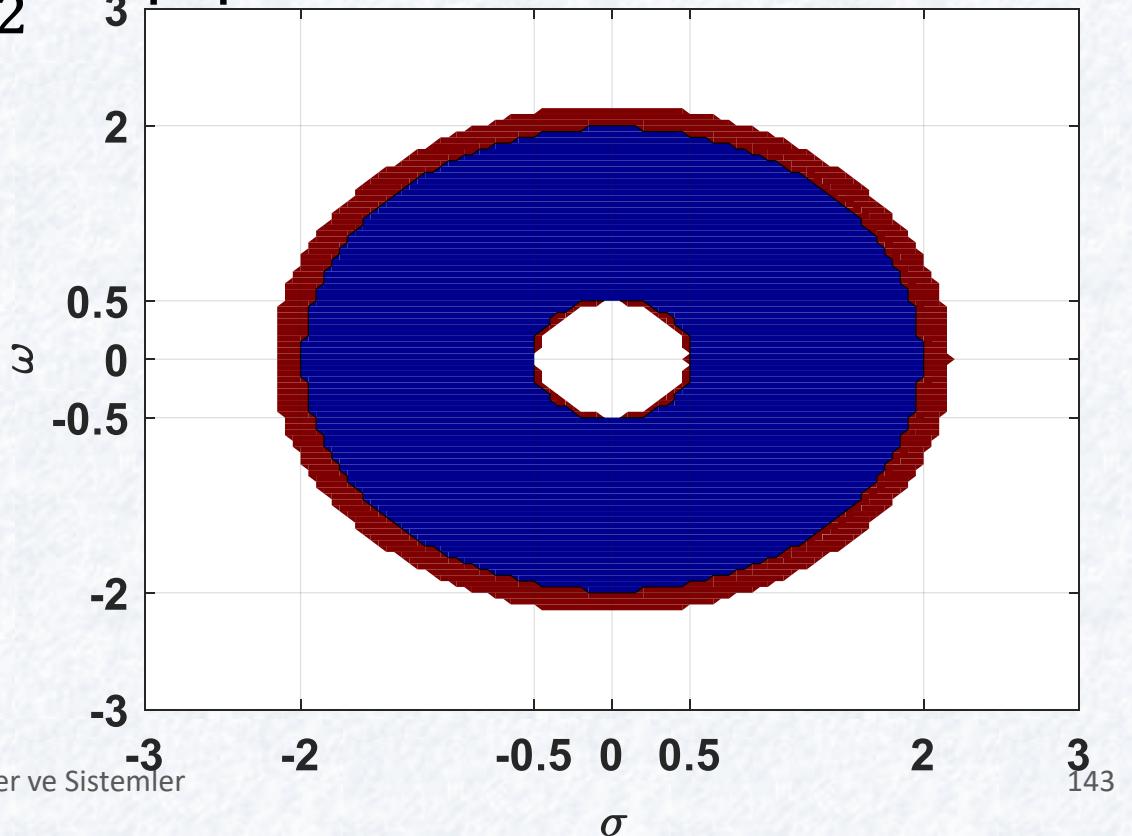
- $x(n) = -\left(\frac{1}{2}\right)^n u(n) - (2)^n u(-n - 1)$  ise  $X(z) = ?$  ve  $YB = ?$

## Örnek 16

- $x(n) = -\left(\frac{1}{2}\right)^n u(n) - (2)^n u(-n - 1)$  ise  $X(z) = ?$  ve  $YB = ?$
- $X(z) = \frac{-1}{1-\frac{1}{2}z^{-1}} + \frac{1}{1-2z^{-1}}$ ,  $YB \rightarrow$

## Örnek 16

- $x(n) = -\left(\frac{1}{2}\right)^n u(n) - (2)^n u(-n-1)$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \frac{-1}{1-\frac{1}{2}z^{-1}} + \frac{1}{1-2z^{-1}}$ , YB  $\rightarrow \frac{1}{2} <_3 |z| < 2$



## Örnek 17

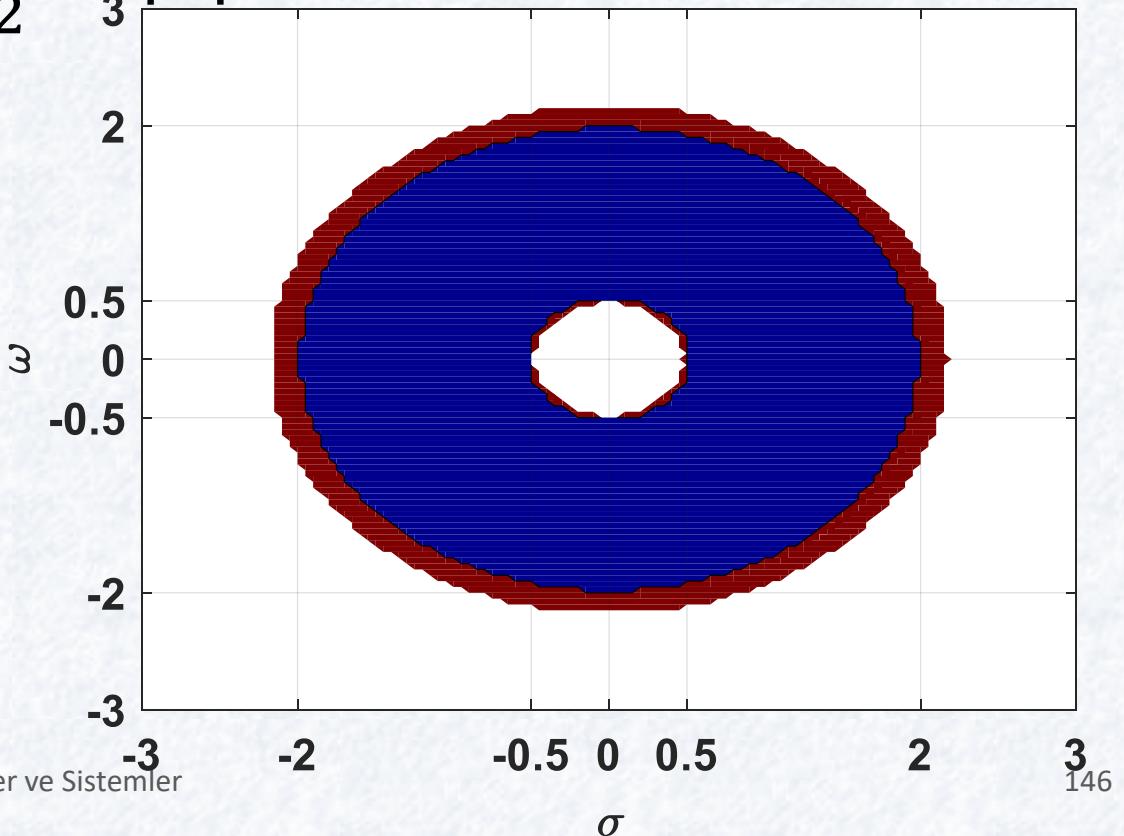
- $x(n) = \left(-\frac{1}{2}\right)^n u(n) + (-2)^n u(-n - 1)$  ise  $X(z) = ?$  ve  $YB = ?$

## Örnek 17

- $x(n) = \left(-\frac{1}{2}\right)^n u(n) + (-2)^n u(-n - 1)$  ise  $X(z) = ?$  ve  $YB = ?$
- $X(z) = \frac{1}{1+\frac{1}{2}z^{-1}} - \frac{1}{1+2z^{-1}}$ ,  $YB \rightarrow$

## Örnek 17

- $x(n) = \left(-\frac{1}{2}\right)^n u(n) + (-2)^n u(-n - 1)$  ise  $X(z) = ?$  ve YB=?
- $X(z) = \frac{1}{1+\frac{1}{2}z^{-1}} - \frac{1}{1+2z^{-1}}$ , YB  $\rightarrow \frac{1}{2} <_3 |z| < 2$



## Örnek 18

- $x(n) = -\left(-\frac{1}{2}\right)^n u(n) - (-2)^n u(-n-1)$  ise  $X(z) = ?$  ve  $YB = ?$

## Örnek 18

- $x(n) = -\left(-\frac{1}{2}\right)^n u(n) - (-2)^n u(-n-1)$  ise  $X(z) = ?$  ve  $\text{YB} = ?$
- $X(z) = \frac{-1}{1+\frac{1}{2}z^{-1}} + \frac{1}{1+2z^{-1}}$ ,  $\text{YB} \rightarrow$

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- $x(n) = -\left(-\frac{1}{2}\right)^n u(n) - (-2)^n u(-n-1)$  ise  $X(z) = ?$  ve YB=?
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