

Universidade de São Paulo  
Instituto de Física de São Carlos  
Analysis and Pattern Recognition

## **Projeto 2**

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# 1 Introdução

Nesse trabalho foram abordados os mesmos autômatos do projeto anterior com a adição do autômato da figura 2 do CDT(Costa's Didatic Texts). Para cada um deles foi abordado cinco conjunto de medidas, as quais são explicadas na seção posterior.

## 2 Conjunto de Medidas

1. Número de bursts e média, desvio padrão, entropia e evenness dos tamanhos dos bursts em cada split signal.
2. Número de distâncias intersímbolos e média, desvio padrão, entropia e evenness das distâncias intersímbolos em cada split signal.
3. Média e desvio padrão das magnitudes do espectro de potência da transformada de Fourier discreta de cada split signal (rotina para FFT).
4. Média e desvio do grau e coeficiente de aglomeração de grafos dos sinais originais, obtidos pelo método de visibilidade, que deve ser implementado.
5. Coeficiente alpha do DFA da integral do sinal.

## 3 Autômatos Analisados

Para cada autômato foi escolhido uma letra do alfabeto de A a E. Sendo três deles com apenas dois nós, outros sendo a junção dos anteriores com algumas alterações. E por fim, o último sendo um autômato de quatros nós.

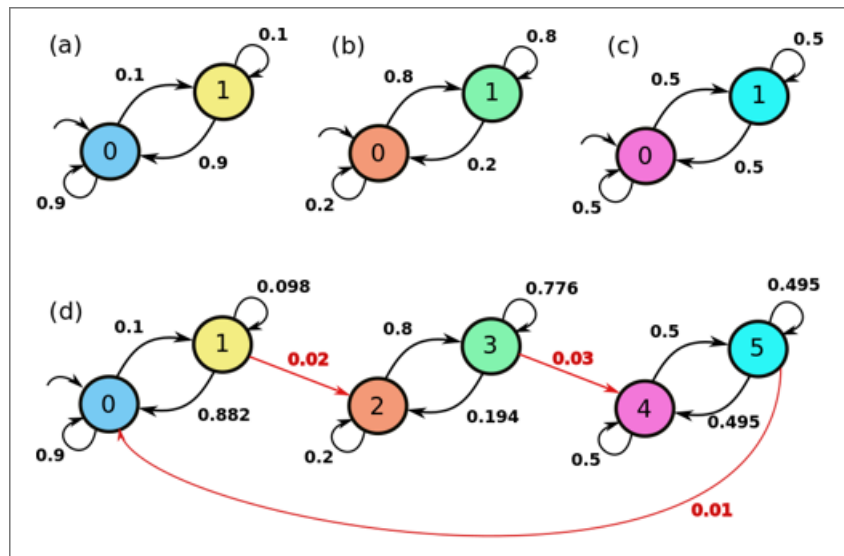


Figura 1: Autômatos A, B, C, D

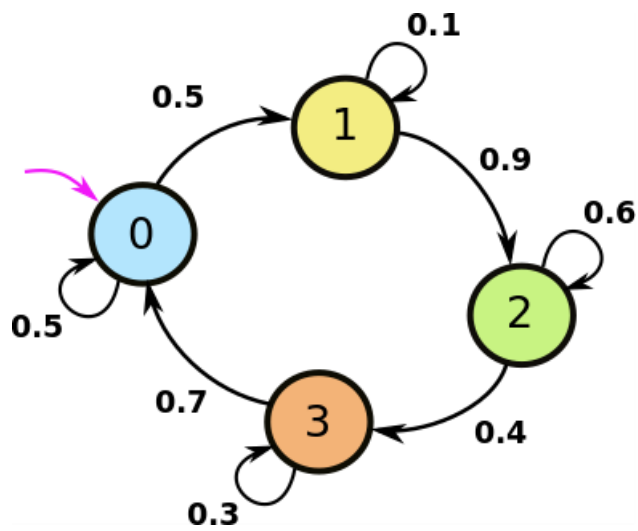
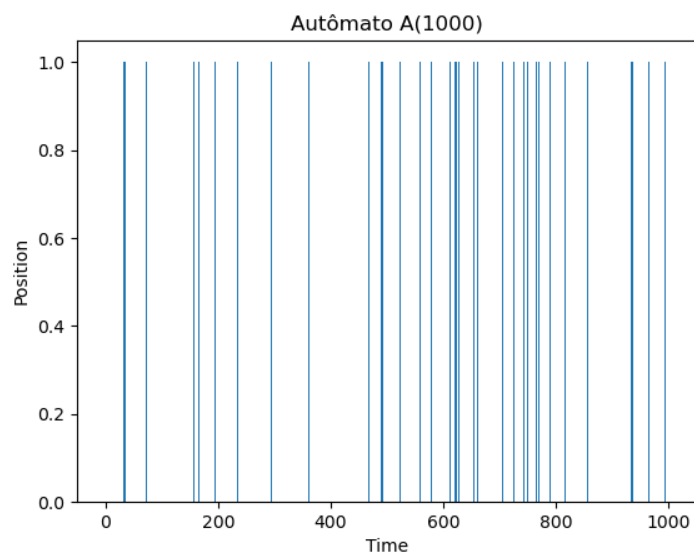


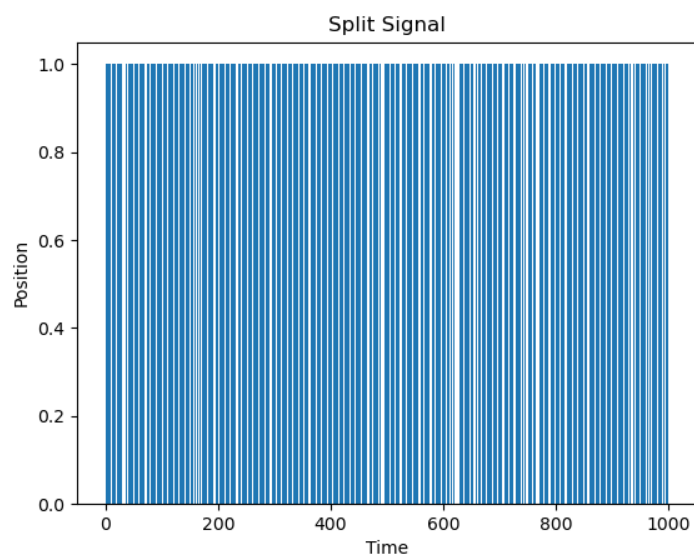
Figura 2: Autômato E

## 4 Autômatos

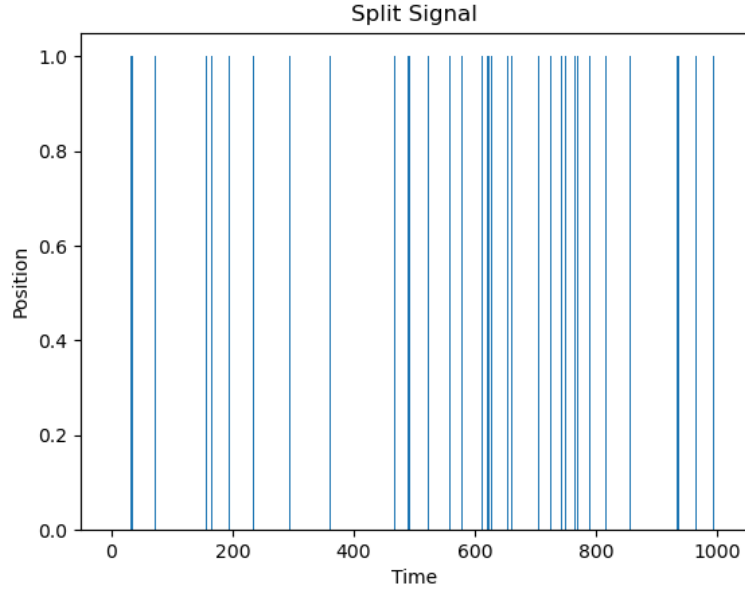
### 4.1 Estudo de A



*Figura 3: Sinal Original*



*Figura 4: Symbol 0*



*Figura 5: Symbol 1*

#### 4.1.1 Burst-Based Features

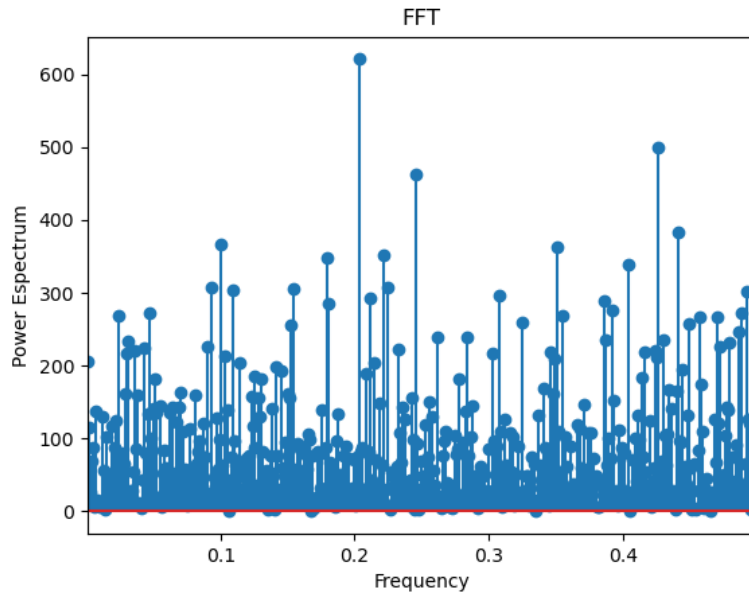
$$\text{Node 0} \rightarrow \begin{cases} \text{Número de Bursts} = 85 \\ \text{Média} = 10.69 \\ \text{Desvio Padrão} = 10.1 \\ \text{Entropia} = 4.4451 \\ \text{Evenness} = 21.782 \end{cases}$$

$$\text{Node 1} \rightarrow \begin{cases} \text{Número de Bursts} = 84 \\ \text{Média} = 1.095 \\ \text{Desvio Padrão} = 0.3679 \\ \text{Entropia} = 0.4368 \\ \text{Evenness} = 1.3536 \end{cases}$$

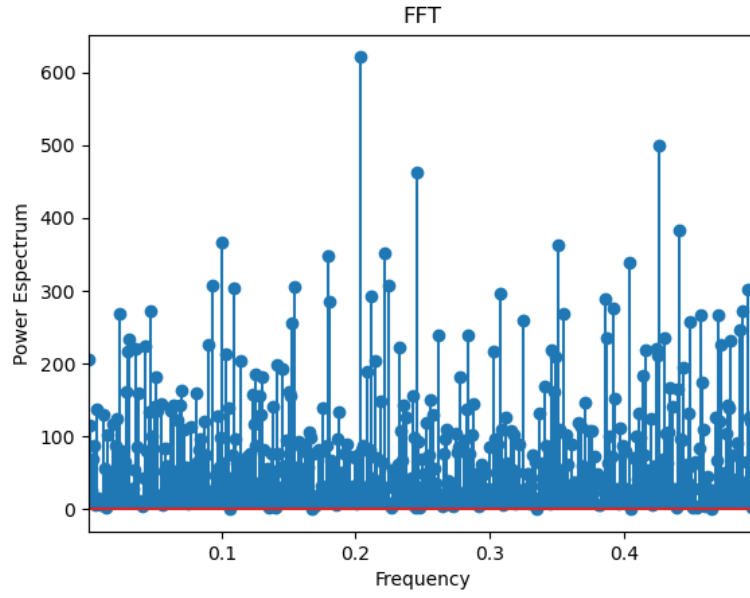
### 4.1.2 Intersymbol-Based Features

$$\begin{aligned} \text{Node 0} &\rightarrow \begin{cases} \text{Número de Intersymbols} = 84 \\ \text{Média} = 1.101321 \\ \text{Desvio Padrão} = 0.336 \\ \text{Entropia} = 0.4852 \\ \text{Evenness} = 1.399 \end{cases} \\ \text{Node 1} &\rightarrow \begin{cases} \text{Número de Intersymbols} = 84 \\ \text{Média} = 10.725 \\ \text{Desvio Padrão} = 10.086 \\ \text{Entropia} = 4.46241 \\ \text{Evenness} = 22.0456 \end{cases} \end{aligned}$$

### 4.1.3 Fast Fourier Transform



*Figura 6: Symbol 0*

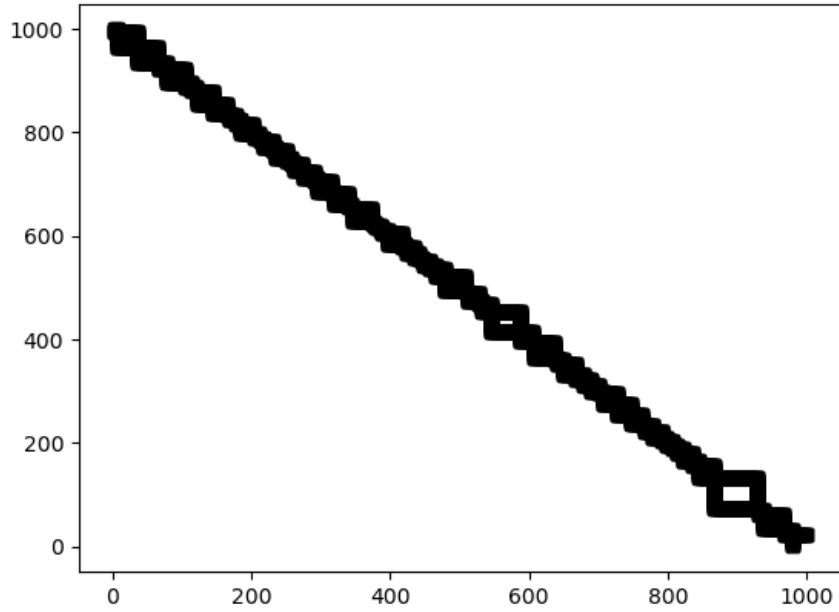


*Figura 7: Symbol 1*

$$\text{Node 0} \rightarrow \begin{cases} \text{Média} = 909.00 \\ \text{DesvioPadrão} = 26113.73 \end{cases}$$

$$\text{Node 1} \rightarrow \begin{cases} \text{Média} = 92.0000 \\ \text{DesvioPadrão} = 277.59 \end{cases}$$

#### 4.1.4 Network-Based Features

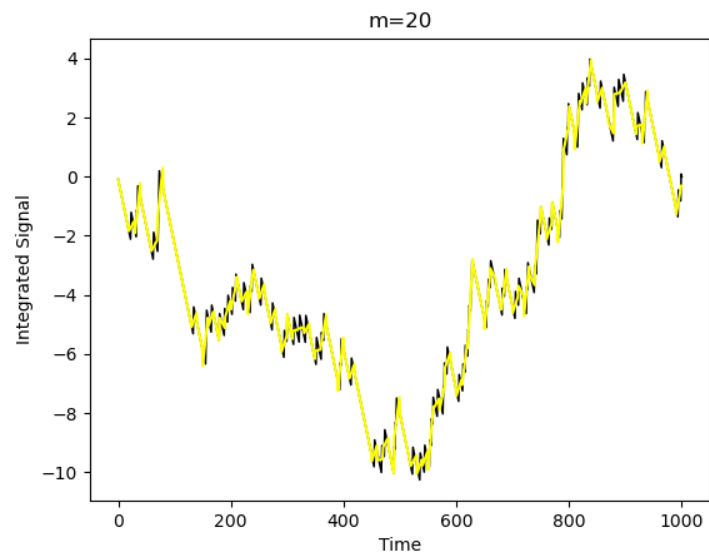


*Figura 8: Metodo da Visibilidade*

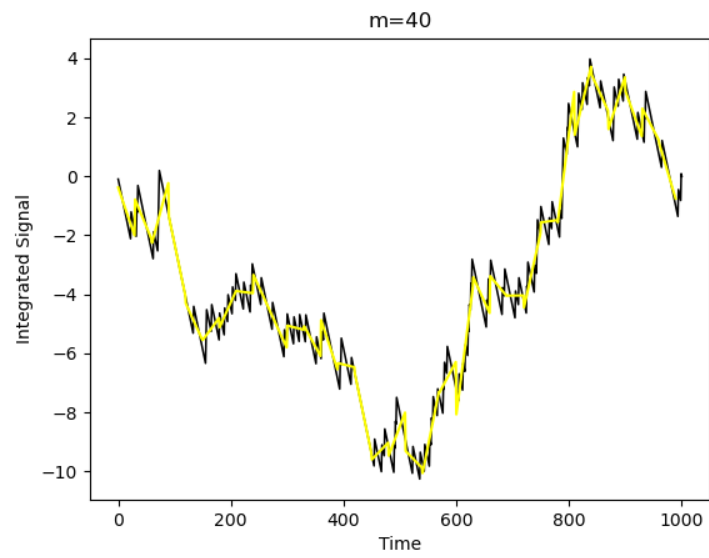
$$\text{Grafo} \rightarrow \begin{cases} \text{MédiaDegree} = 3.4125 \\ \text{DesvioPadrão} = 6.6662 \\ \text{MédiaClustering} = 0.73779 \\ \text{DesvioPadrão} = 0.4307 \end{cases}$$



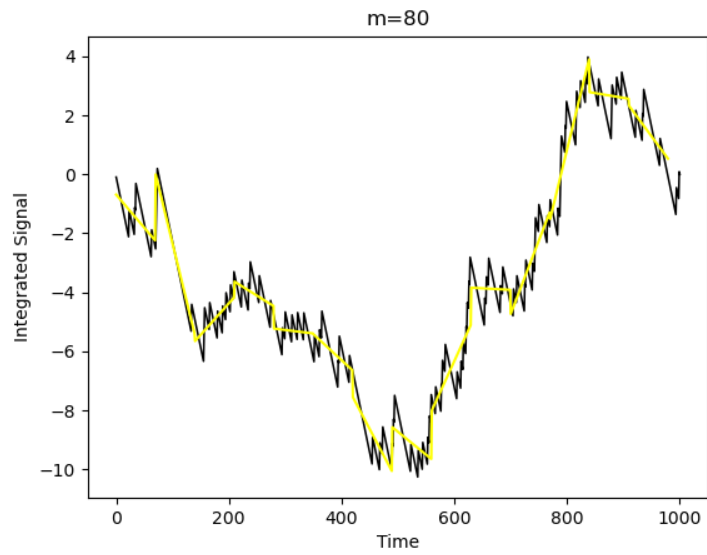
#### 4.1.5 Self-Affinity Features (DFA)



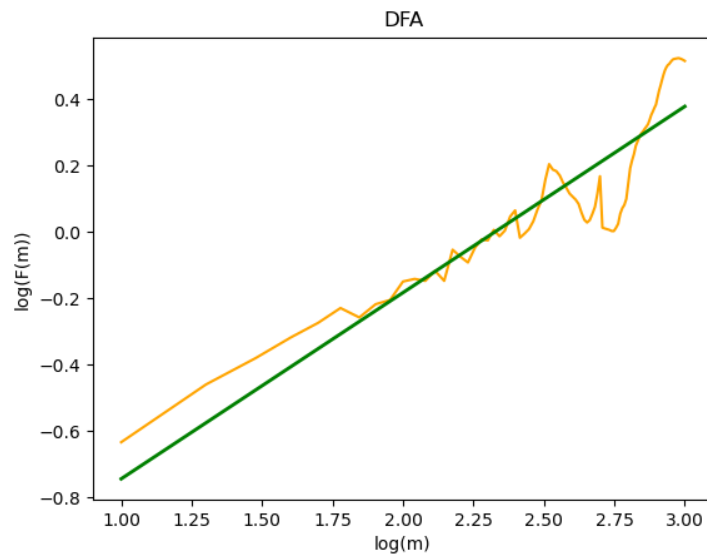
*Figura 9: DFA*



*Figura 10: DFA*



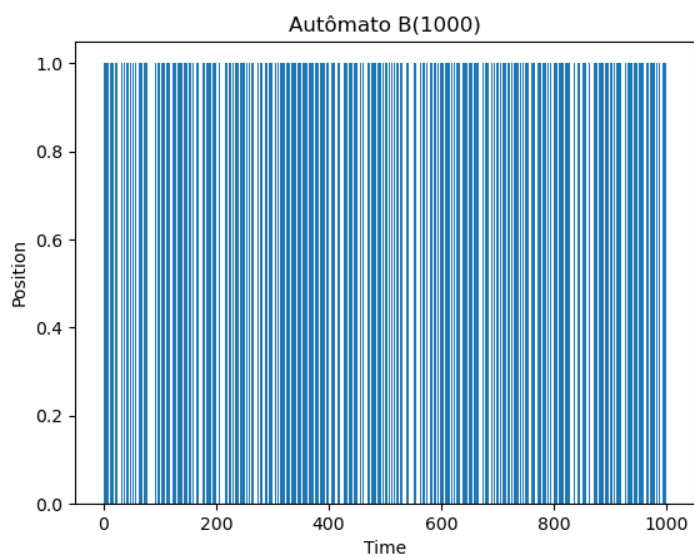
*Figura 11: DFA*



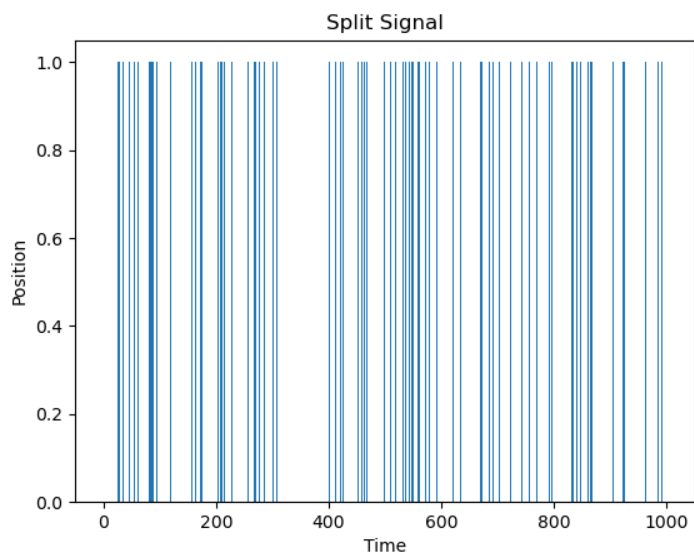
*Figura 12: DFA*

$$\text{DFA} \rightarrow \left\{ \text{Alpha} = 0.56157 \right.$$

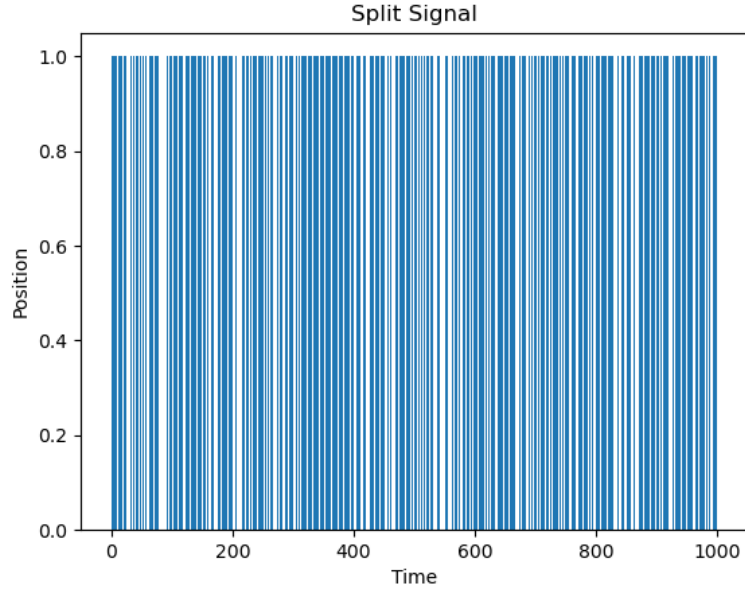
## 4.2 Estudo de B



*Figura 13: Sinal Original*



*Figura 14: Symbol 0*



*Figura 15: Symbol 1*

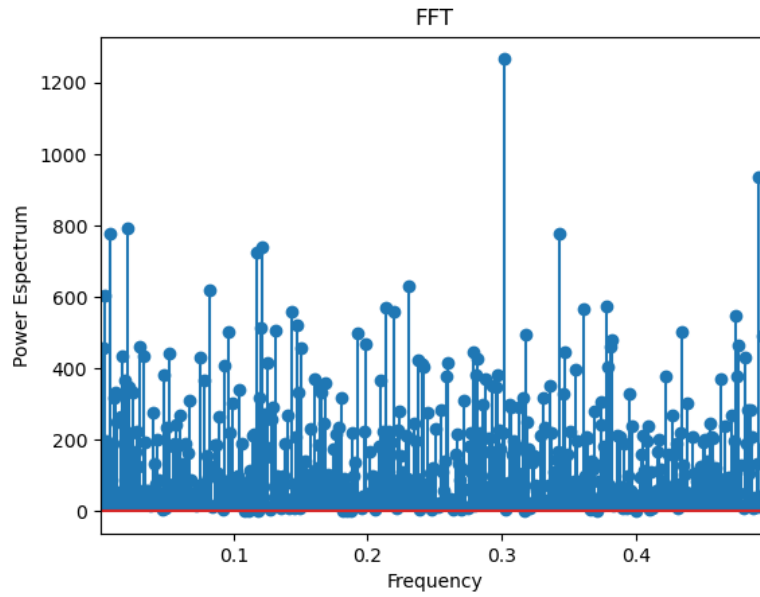
#### 4.2.1 Burst-Based Features

$$\begin{aligned}
 \text{Node 0} &\rightarrow \begin{cases} \text{Número de Bursts} = 157 \\ \text{Média} = 1.2993 \\ \text{Desvio Padrão} = 0.5713 \\ \text{Entropia} = 0.9895 \\ \text{Evenness} = 1.9855 \end{cases} \\
 \text{Node 1} &\rightarrow \begin{cases} \text{Número de Bursts} = 157 \\ \text{Média} = 5.076433 \\ \text{Desvio Padrão} = 5.0896 \\ \text{Entropia} = 3.4924 \\ \text{Evenness} = 11.254 \end{cases}
 \end{aligned}$$

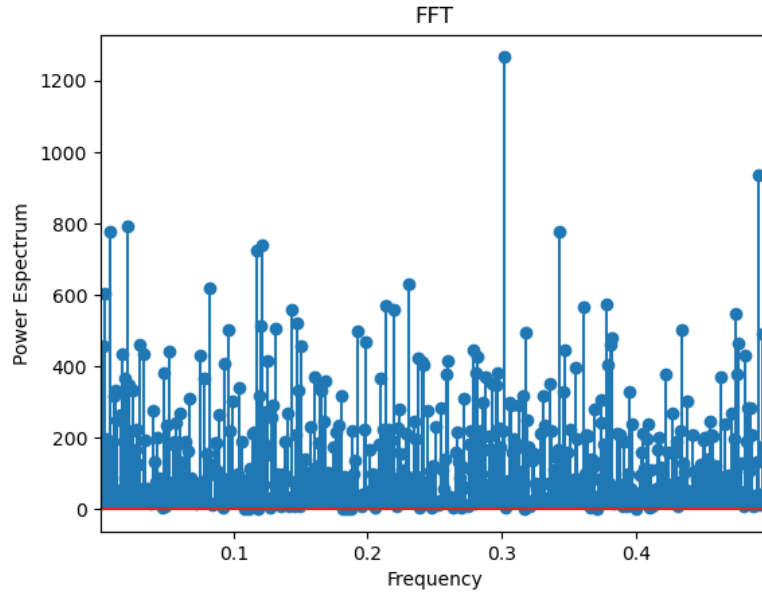
### 4.2.2 Intersymbol-Based Features

$$\begin{aligned}
 \text{Node 0} &\rightarrow \begin{cases} \text{Número de Intersymbols} = 157 \\ \text{Média} = 4.91133 \\ \text{Desvio Padrão} = 4.961 \\ \text{Entropia} = 3.46692 \\ \text{Evenness} = 11.0572 \end{cases} \\
 \text{Node 1} &\rightarrow \begin{cases} \text{Número de Intersymbols} = 157 \\ \text{Média} = 1.2550 \\ \text{Desvio Padrão} = 0.5754 \\ \text{Entropia} = 0.9084 \\ \text{Evenness} = 1.877077 \end{cases}
 \end{aligned}$$

### 4.2.3 Fast Fourier Transform



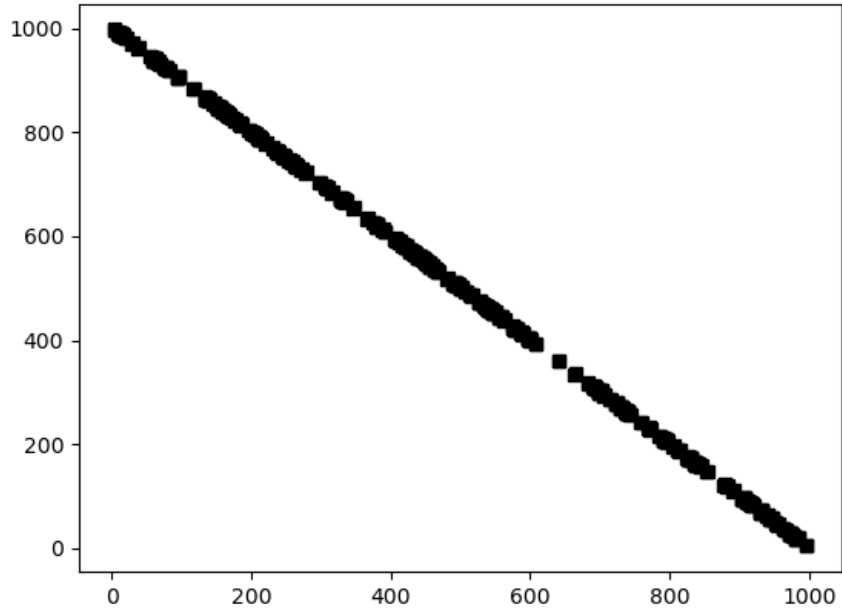
*Figura 16: Symbol 0*



*Figura 17: Symbol 1*

$$\begin{aligned} \text{Node 0} &\rightarrow \begin{cases} \text{Média} = 203.9999 \\ \text{DesvioPadrão} = 1320.282 \end{cases} \\ \text{Node 1} &\rightarrow \begin{cases} \text{Média} = 797.000 \\ \text{DesvioPadrão} = 20072.55 \end{cases} \end{aligned}$$

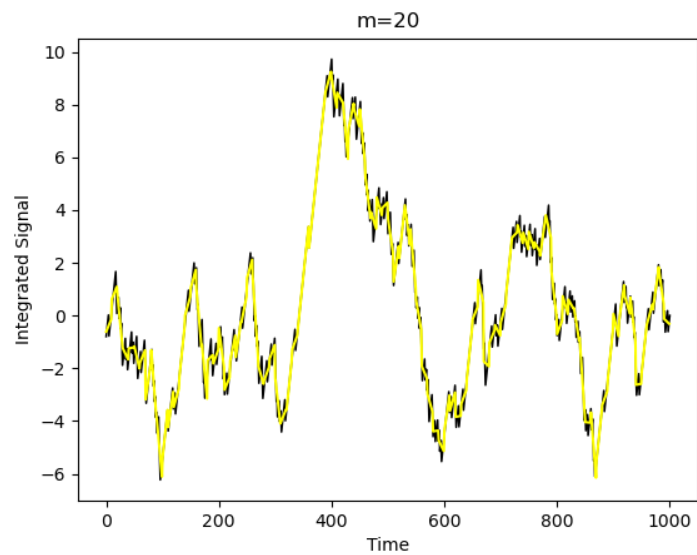
#### 4.2.4 Network-Based Features



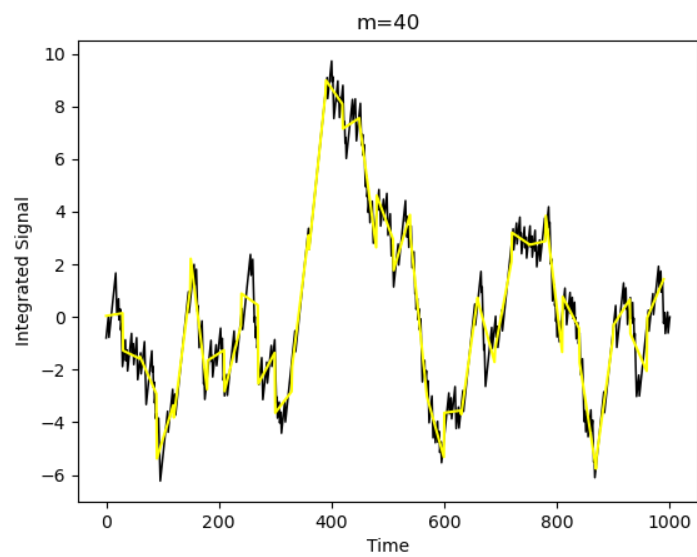
*Figura 18: Metodo da Visibilidade*

$$\text{Grafo} \rightarrow \begin{cases} \text{MédiaDegree} = 0.4995 \\ \text{DesvioPadrão} = 0.78628 \\ \text{MédiaClustering} = 0.013919 \\ \text{DesvioPadrão} = 0.101431 \end{cases}$$

#### 4.2.5 Self-Affinity Features (DFA)

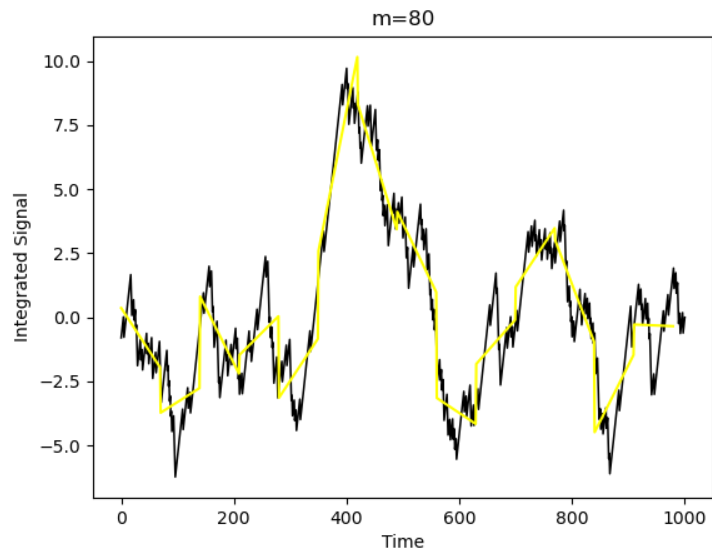


*Figura 19: DFA*

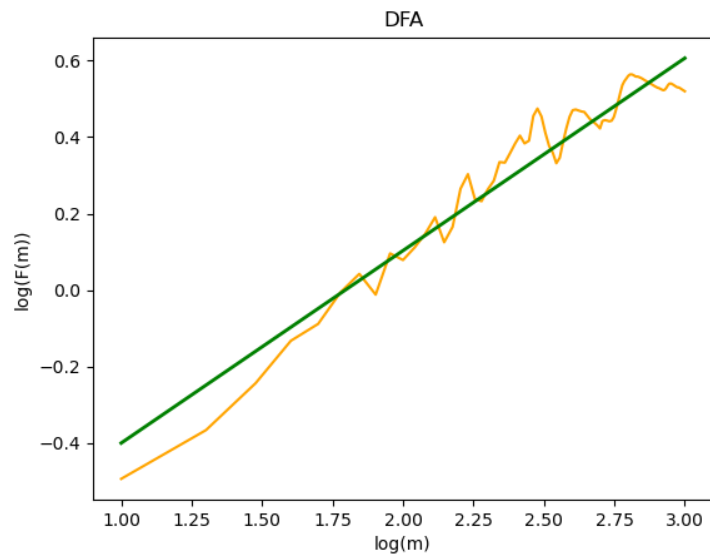


*Figura 20: DFA*





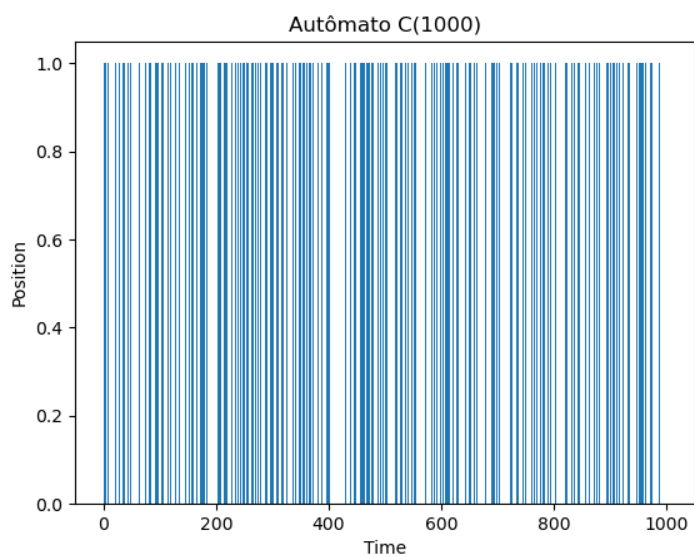
*Figura 21: DFA*



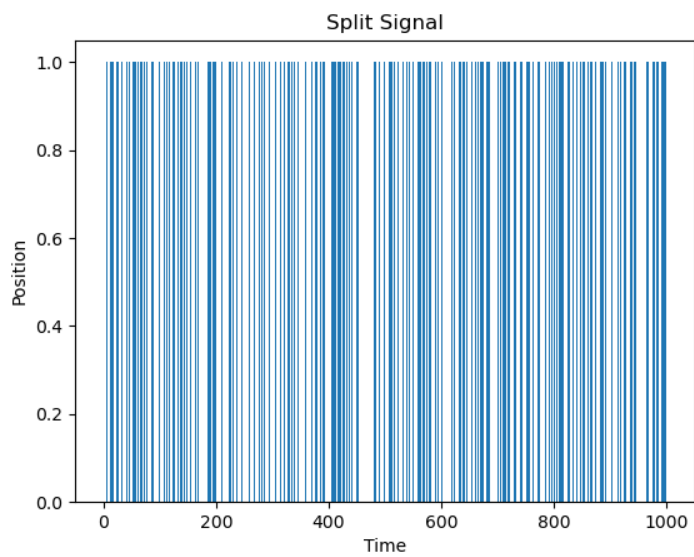
*Figura 22: DFA*

$$\text{DFA} \rightarrow \left\{ \text{Alpha} = 0.503128 \right.$$

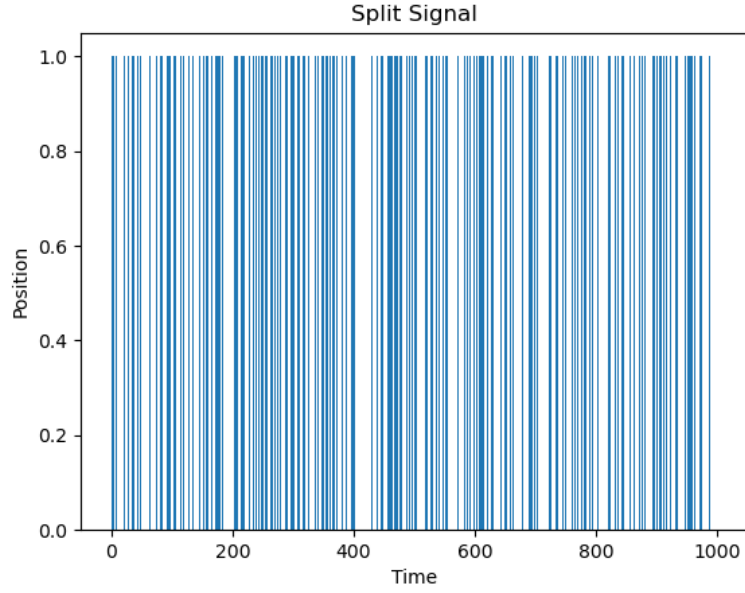
### 4.3 Estudo de C



*Figura 23: Sinal Original*



*Figura 24: Symbol 0*



*Figura 25: Symbol 1*

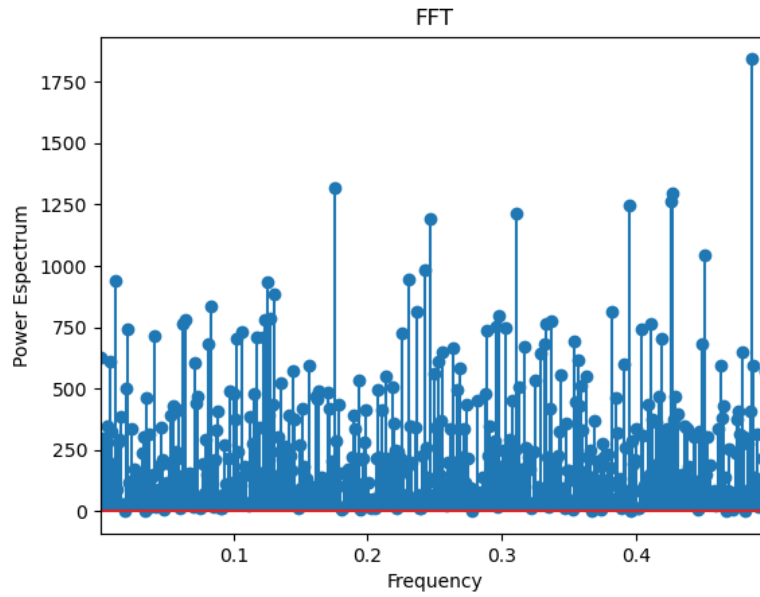
#### 4.3.1 Burst-Based Features

$$\begin{aligned}
 \text{Node 0} &\rightarrow \begin{cases} \text{Número de Bursts} = 255 \\ \text{Média} = 2.031372 \\ \text{Desvio Padrão} = 1.4523 \\ \text{Entropia} = 2.0148 \\ \text{Evenness} = 4.0413 \end{cases} \\
 \text{Node 1} &\rightarrow \begin{cases} \text{Número de Bursts} = 254 \\ \text{Média} = 1.9015 \\ \text{Desvio Padrão} = 1.3285 \\ \text{Entropia} = 1.8778 \\ \text{Evenness} = 3.67538 \end{cases}
 \end{aligned}$$

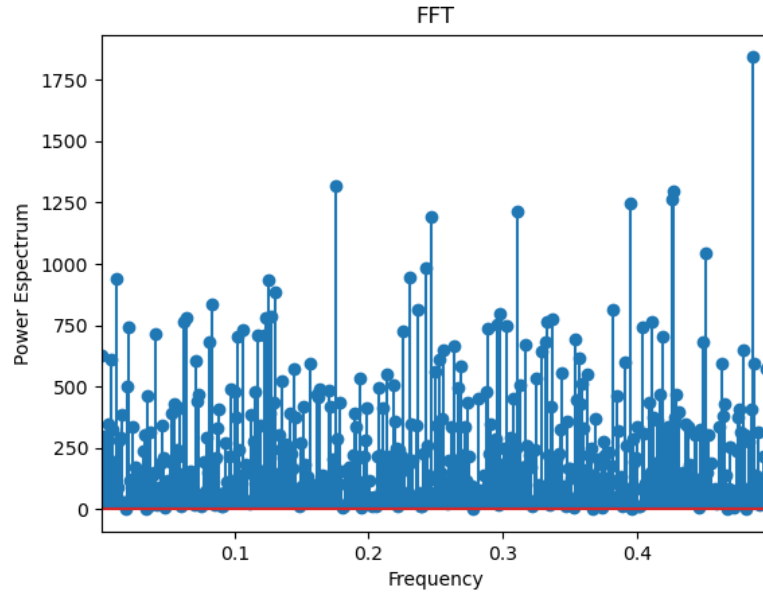
### 4.3.2 Intersymbol-Based Features

$$\begin{aligned}
 \text{Node 0} &\rightarrow \begin{cases} \text{Número de Intersymbols} = 254 \\ \text{Média} = 1.93423 \\ \text{Desvio Padrão} = 1.3307 \\ \text{Entropia} = 1.9223 \\ \text{Evenness} = 3.7904 \end{cases} \\
 \text{Node 1} &\rightarrow \begin{cases} \text{Número de Intersymbols} = 254 \\ \text{Média} = 2.06846 \\ \text{Desvio Padrão} = 1.46528 \\ \text{Entropia} = 2.05807 \\ \text{Evenness} = 4.164298 \end{cases}
 \end{aligned}$$

### 4.3.3 Fast Fourier Transform



*Figura 26: Symbol 0*

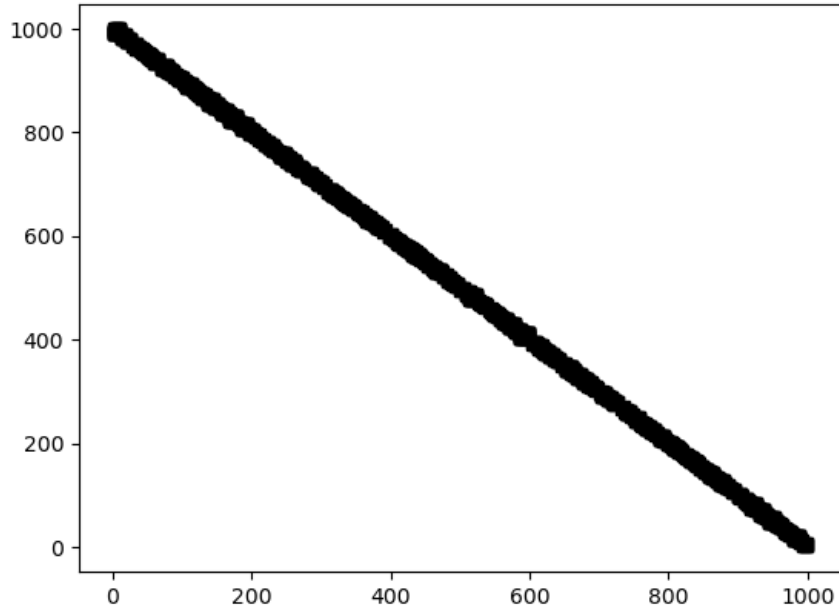


*Figura 27: Symbol 1*

$$\text{Node 0} \rightarrow \begin{cases} \text{Média} = 517.999 \\ \text{DesvioPadrão} = 8476.765 \end{cases}$$

$$\text{Node 1} \rightarrow \begin{cases} \text{Média} = 482.999 \\ \text{DesvioPadrão} = 7369.97 \end{cases}$$

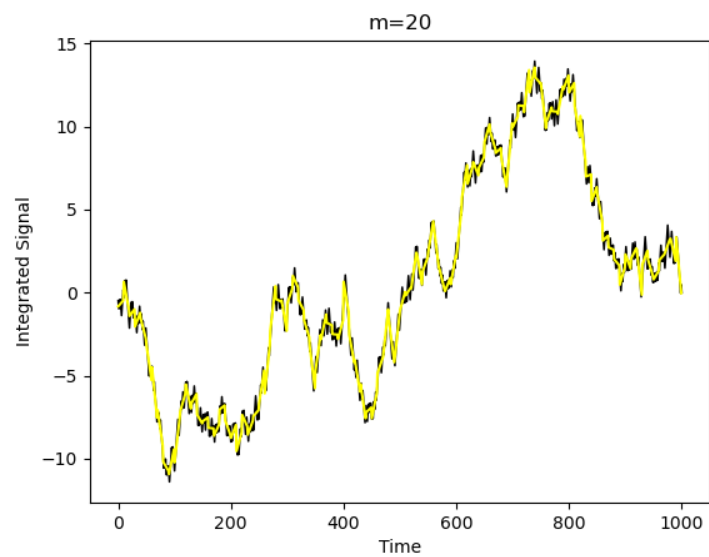
#### 4.3.4 Network-Based Features



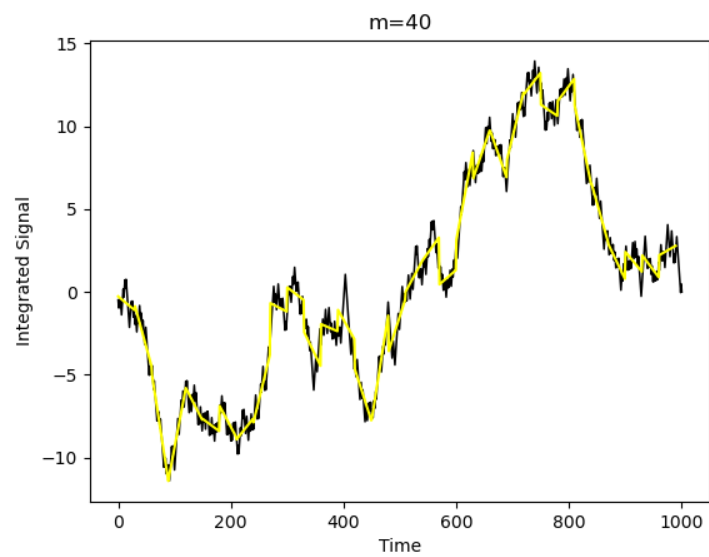
*Figura 28: Metodo da Visibilidade*

$$\text{Grafo} \rightarrow \begin{cases} \text{MédiaDegree} = 1.55244 \\ \text{DesvioPadrão} = 1.561888 \\ \text{MédiaClustering} = 0.16173 \\ \text{DesvioPadrão} = 0.3375 \end{cases}$$

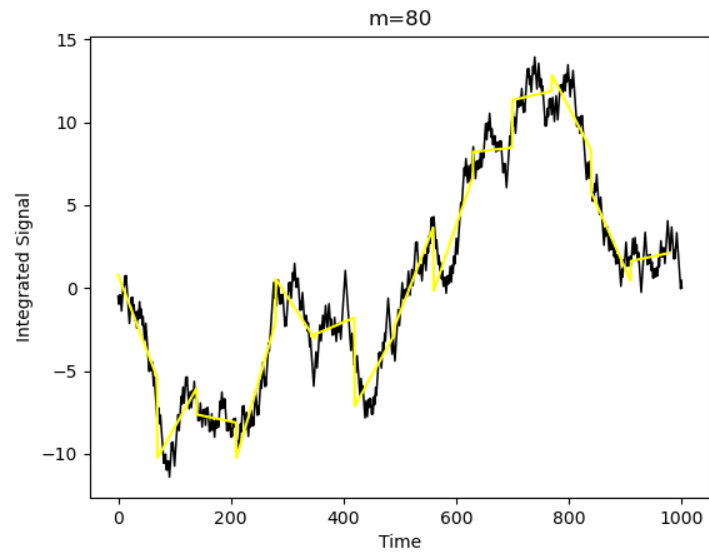
### 4.3.5 Self-Affinity Features (DFA)



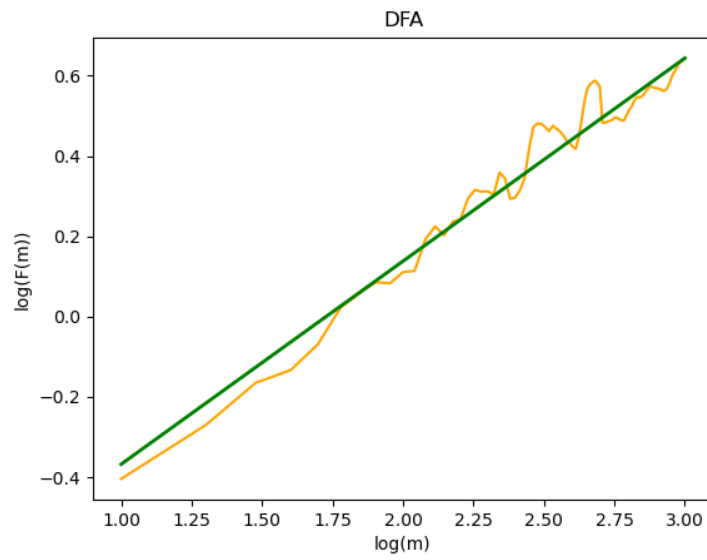
*Figura 29: DFA*



*Figura 30: DFA*



*Figura 31: DFA*

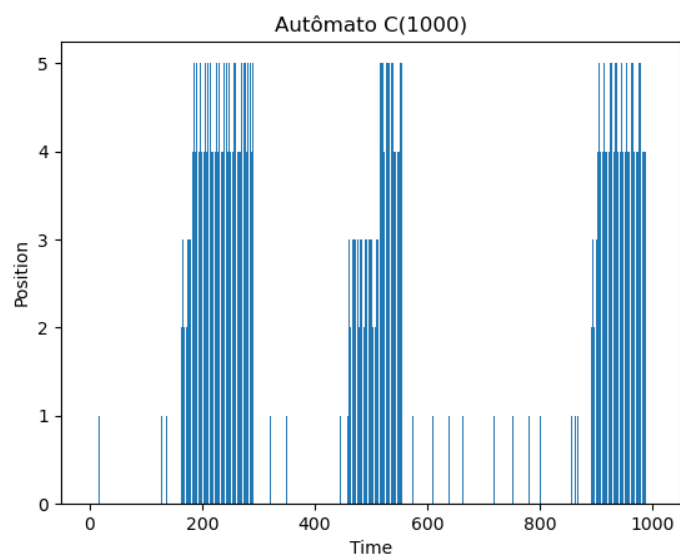


*Figura 32: DFA*

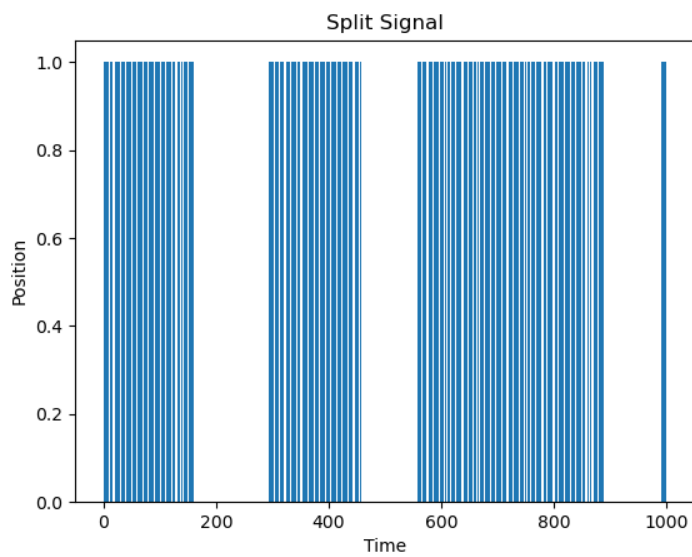
$$\text{DFA} \rightarrow \left\{ \text{Alpha} = 0.505775 \right.$$



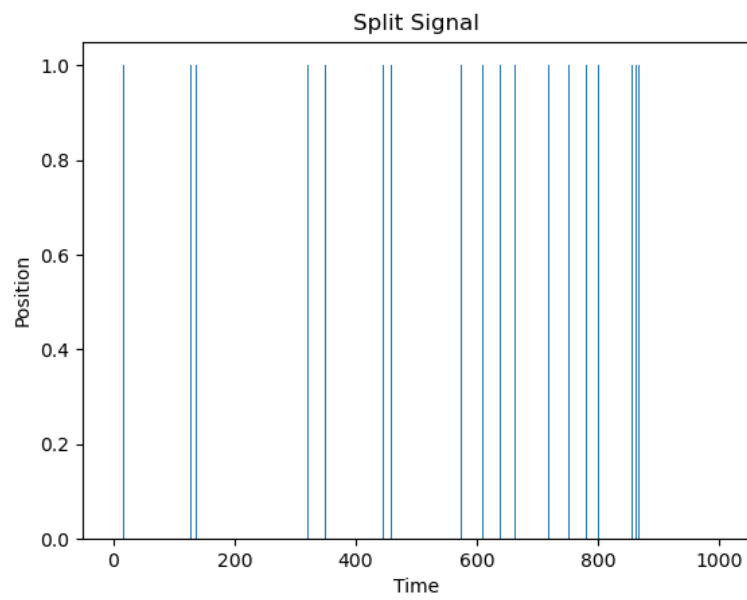
## 4.4 Estudo de D



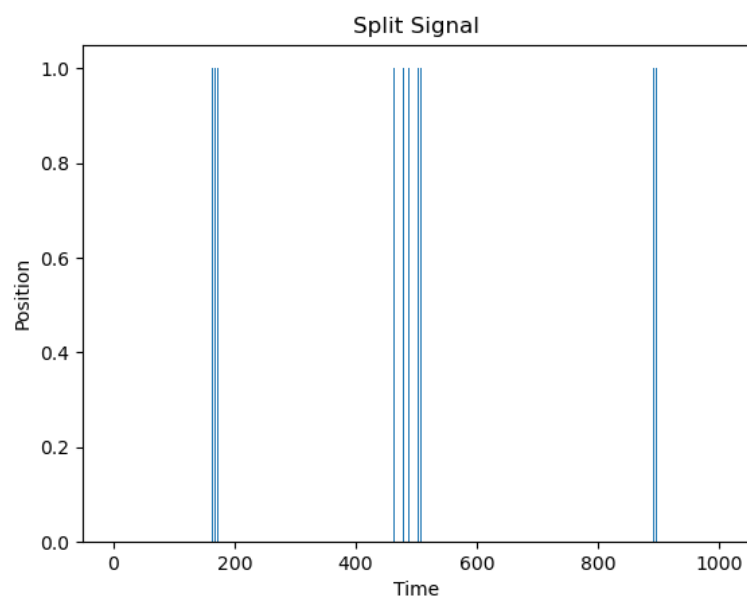
*Figura 33: Sinal Original*



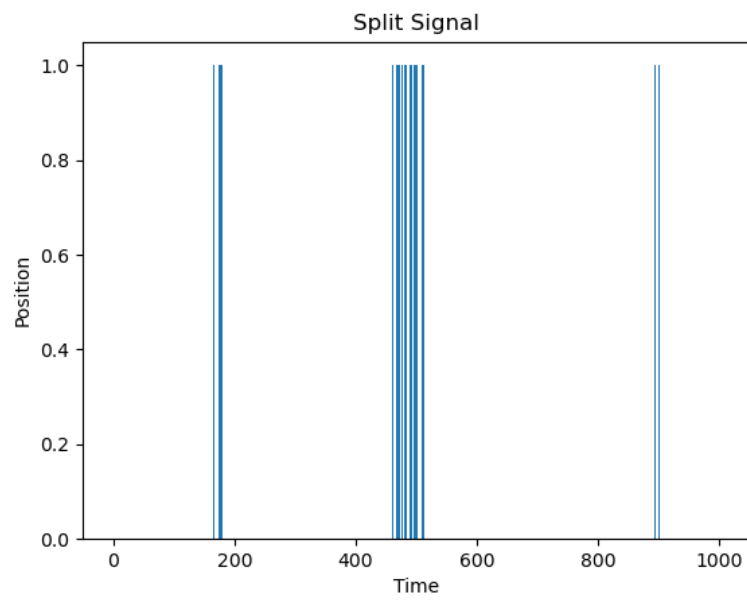
*Figura 34: Symbol 0*



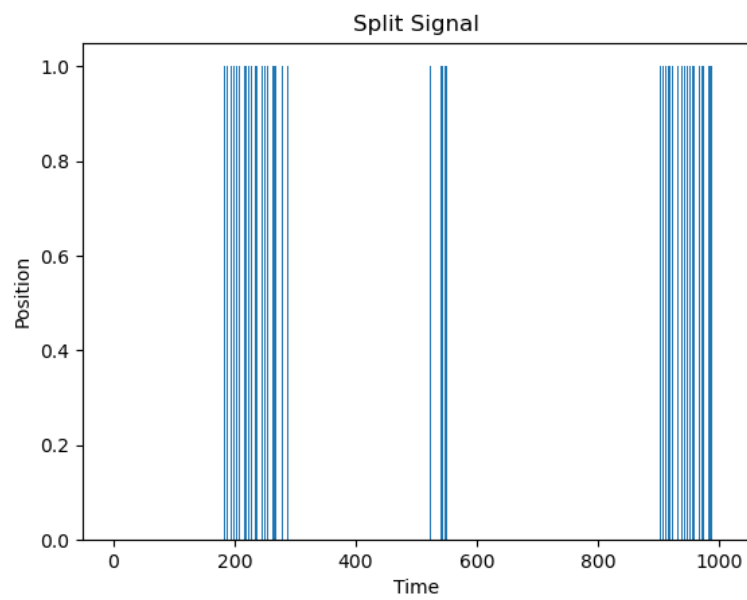
*Figura 35: Symbol 1*



*Figura 36: Symbol 2*



*Figura 37: Symbol 3*



*Figura 38: Symbol 4*

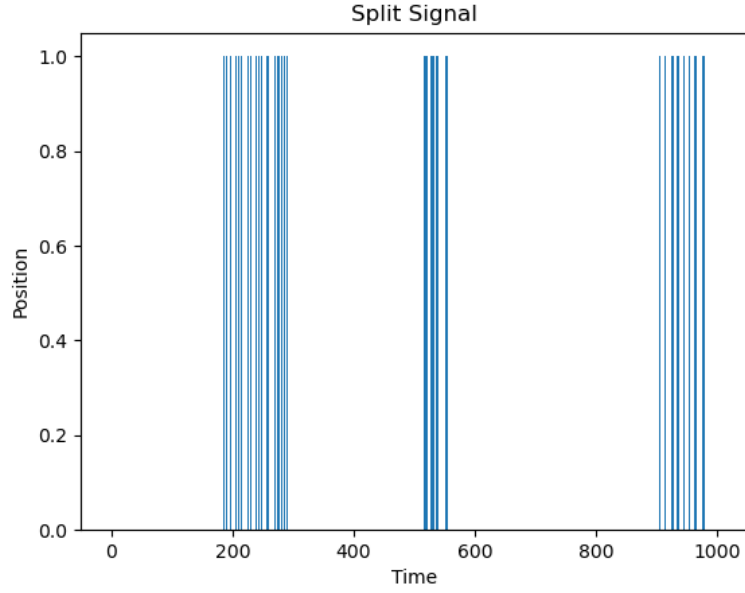


Figura 39: Symbol 5

#### 4.4.1 Burst-Based Features

$$\text{Node 0} \rightarrow \begin{cases} \text{Número de Bursts} = 59 \\ \text{Média} = 10.440 \\ \text{Desvio Padrão} = 9.307 \\ \text{Entropia} = 4.125 \\ \text{Evenness} = 17.4588 \end{cases}$$

$$\text{Node 1} \rightarrow \begin{cases} \text{Número de Bursts} = 58 \\ \text{Média} = 1.06896 \\ \text{Desvio Padrão} = 0.2556 \\ \text{Entropia} = 0.3620 \\ \text{Evenness} = 1.285251 \end{cases}$$

$$\text{Node 2} \rightarrow \begin{cases} \text{Número de Bursts} = 16 \\ \text{Média} = 1.3125 \\ \text{Desvio Padrão} = 0.6020 \\ \text{Entropia} = 1.0140 \\ \text{Evenness} = 2.0196 \end{cases}$$

$$\text{Node 3} \rightarrow \begin{cases} \text{Número de Bursts} = 16 \\ \text{Média} = 3.75 \\ \text{Desvio Padrão} = 3.0876 \\ \text{Entropia} = 2.57781 \\ \text{Evenness} = 5.97036 \end{cases}$$

$$\text{Node 4} \rightarrow \begin{cases} \text{Número de Bursts} = 68 \\ \text{Média} = 1.75 \\ \text{Desvio Padrão} = 1.0420 \\ \text{Entropia} = 1.6908 \\ \text{Evenness} = 3.22845 \end{cases}$$

$$\text{Node 5} \rightarrow \begin{cases} \text{Número de Bursts} = 68 \\ \text{Média} = 1.80882 \\ \text{Desvio Padrão} = 0.99637 \\ \text{Entropia} = 1.703078 \\ \text{Evenness} = 3.255950 \end{cases}$$

#### 4.4.2 Intersymbol-Based Features

$$\text{Node 0} \rightarrow \begin{cases} \text{Número de Intersymbols} = 68 \\ \text{Média} = 1.6260 \\ \text{Desvio Padrão} = 7.63712 \\ \text{Entropia} = 0.51649 \\ \text{Evenness} = 1.4304 \end{cases}$$

$$\text{Node 1} \rightarrow \begin{cases} \text{Número de Intersymbols} = 68 \\ \text{Média} = 14.32786 \\ \text{Desvio Padrão} = 23.682 \\ \text{Entropia} = 4.17837 \\ \text{Evenness} = 18.1057 \end{cases}$$

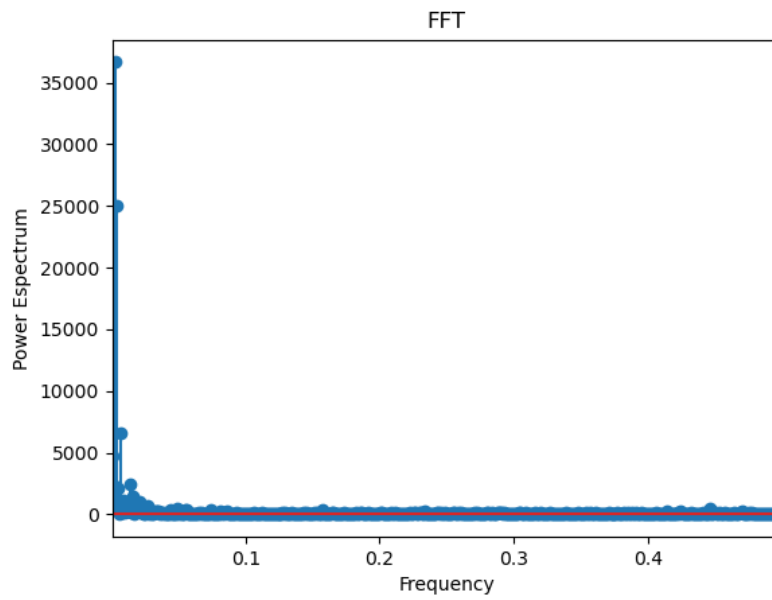
$$\text{Node 2} \rightarrow \begin{cases} \text{Número de Intersymbols} = 68 \\ \text{Média} = 36.8 \\ \text{Desvio Padrão} = 102.6889 \\ \text{Entropia} = 2.8414 \\ \text{Evenness} = 7.1673 \end{cases}$$

$$\text{Node 3} \rightarrow \begin{cases} \text{Número de Intersymbols} = 68 \\ \text{Média} = 12.49152 \\ \text{Desvio Padrão} = 60.8617 \\ \text{Entropia} = 1.2470 \\ \text{Evenness} = 2.3735 \end{cases}$$

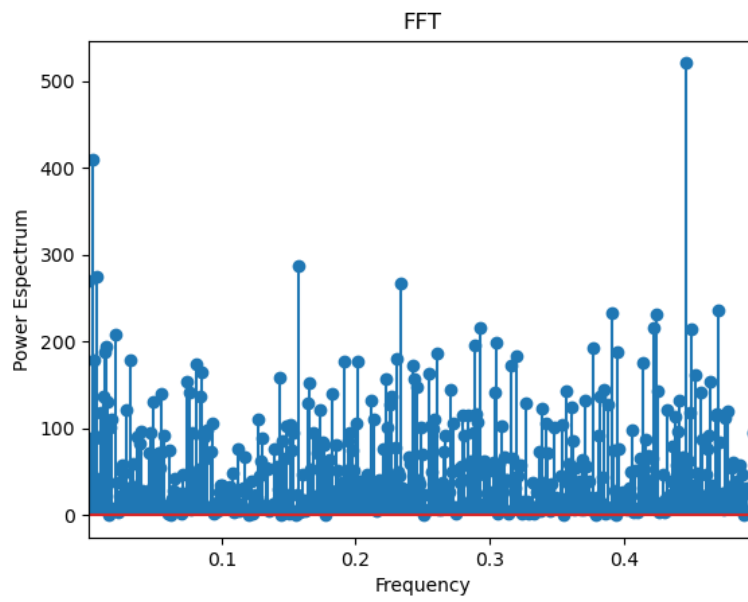
$$\text{Node 4} \rightarrow \begin{cases} \text{Número de Intersymbols} = 68 \\ \text{Média} = 6.8389 \\ \text{Desvio Padrão} = 37.7347 \\ \text{Entropia} = 2.05328 \\ \text{Evenness} = 4.15049 \end{cases}$$

$$\text{Node 5} \rightarrow \begin{cases} \text{Número de Intersymbols} = 68 \\ \text{Média} = 6.6229 \\ \text{Desvio Padrão} = 37.150 \\ \text{Entropia} = 2.02853 \\ \text{Evenness} = 4.079916 \end{cases}$$

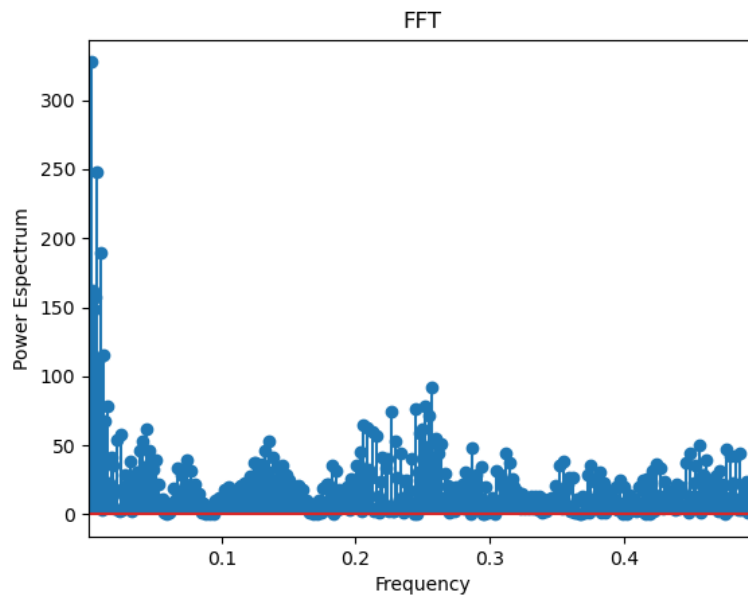
#### 4.4.3 Fast Fourier Transform



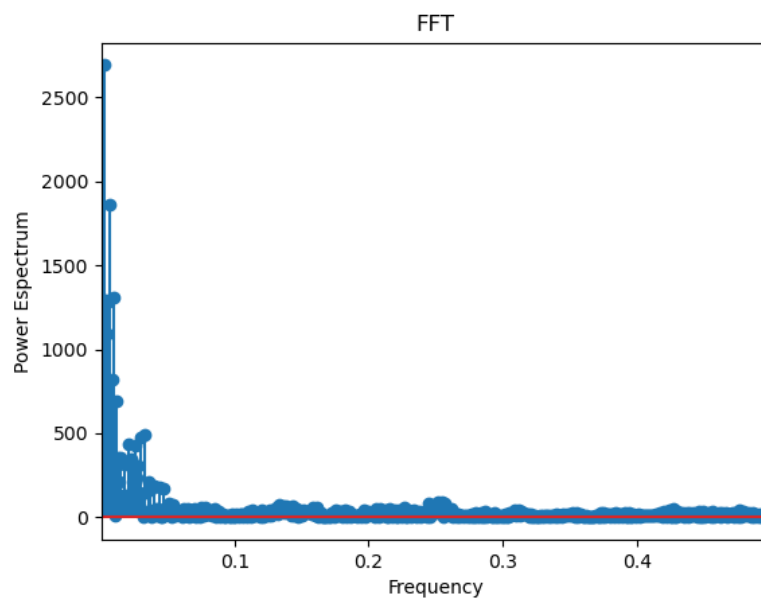
*Figura 40: Symbol 0*



*Figura 41: Symbol 1*

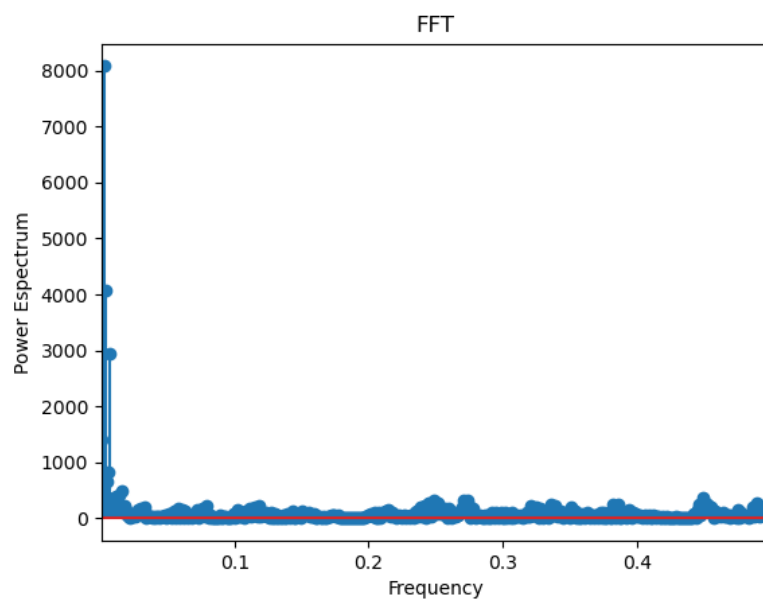


*Figura 42: Symbol 2*

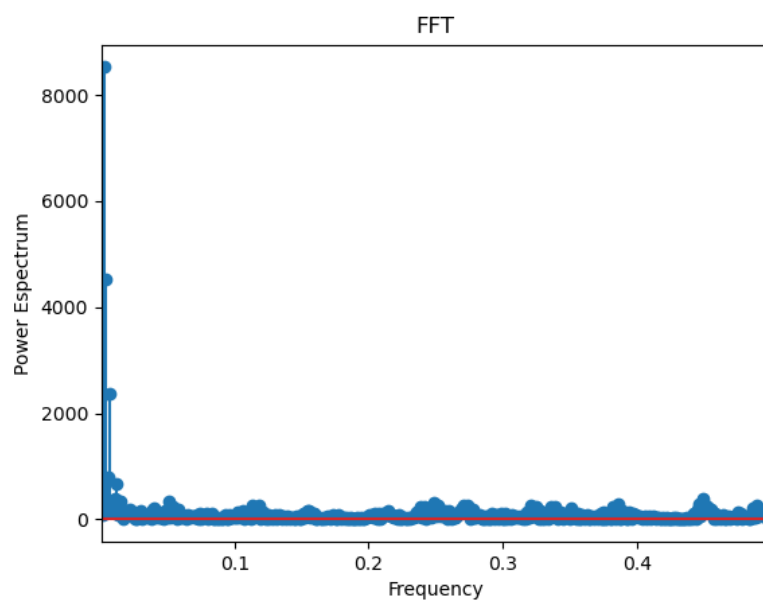


*Figura 43: Symbol 3*





*Figura 44: Symbol 4*



*Figura 45: Symbol 5*

$$\text{Node 0} \rightarrow \begin{cases} Média = 615.99999 \\ DesvioPadrão = 12154.490 \end{cases}$$

$$\text{Node 1} \rightarrow \begin{cases} Média = 61.99999 \\ DesvioPadrão = 134.0147 \end{cases}$$

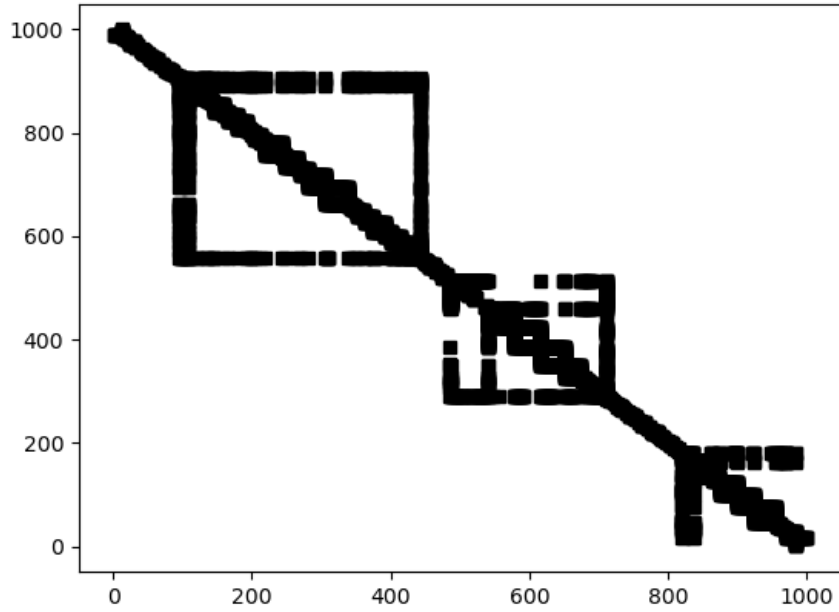
$$\text{Node 2} \rightarrow \begin{cases} Média = 20.999999 \\ DesvioPadrão = 30.93470 \end{cases}$$

$$\text{Node 3} \rightarrow \begin{cases} Média = 60.00 \\ DesvioPadrão = 233.0971 \end{cases}$$

$$\text{Node 4} \rightarrow \begin{cases} Média = 119.000 \\ DesvioPadrão = 619.4912 \end{cases}$$

$$\text{Node 5} \rightarrow \begin{cases} Média = 123.000 \\ DesvioPadrão = 658.822 \end{cases}$$

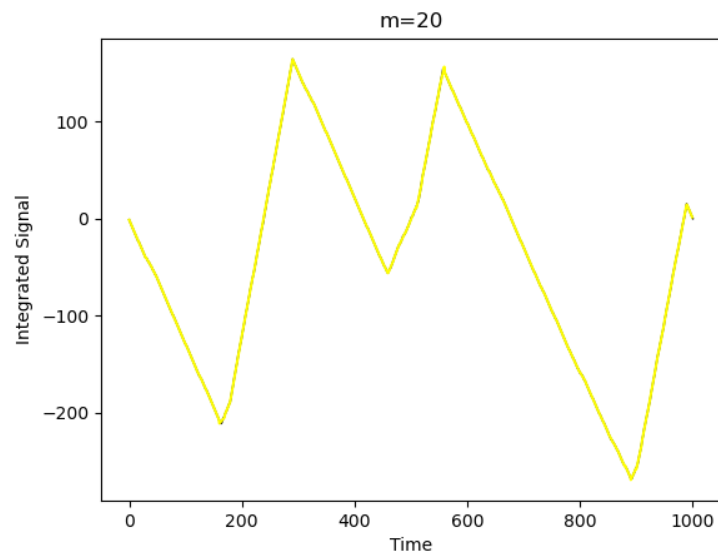
#### 4.4.4 Network-Based Features



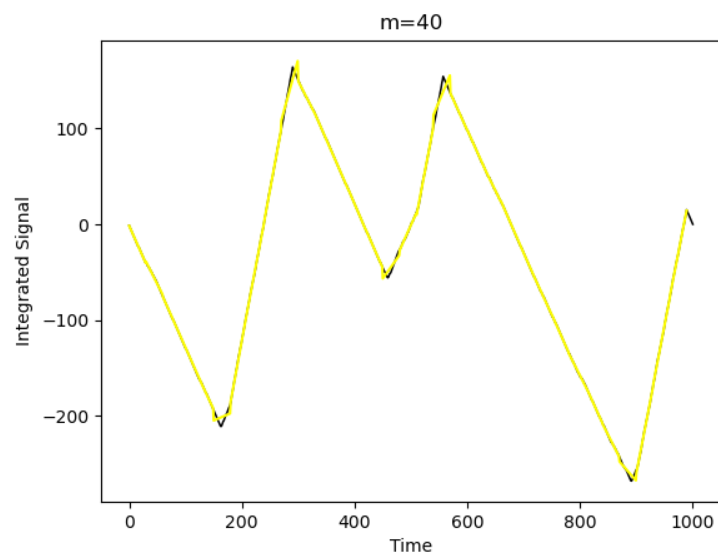
*Figura 46: Metodo da Visibilidade*

$$\text{Grafo} \rightarrow \begin{cases} \text{MédiaDegree} = 3.97402 \\ \text{DesvioPadrão} = 8.98539 \\ \text{MédiaClustering} = 0.55207 \\ \text{DesvioPadrão} = 0.4633976 \end{cases}$$

#### 4.4.5 Self-Affinity Features (DFA)



*Figura 47: DFA*



*Figura 48: DFA*

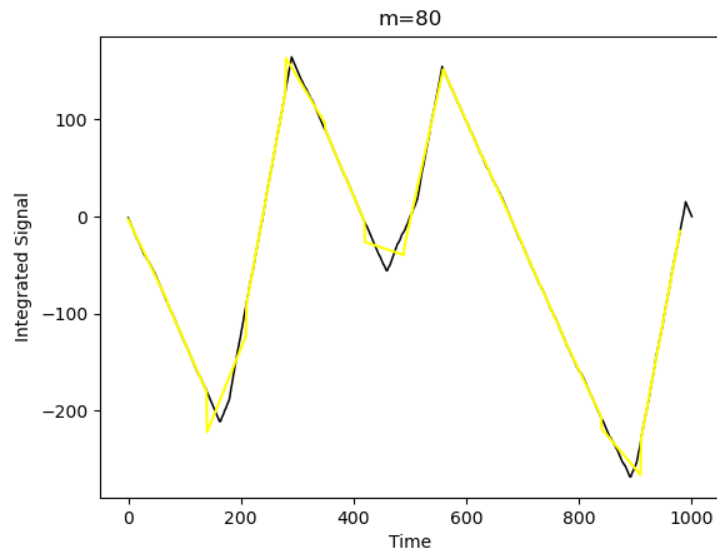


Figura 49: DFA

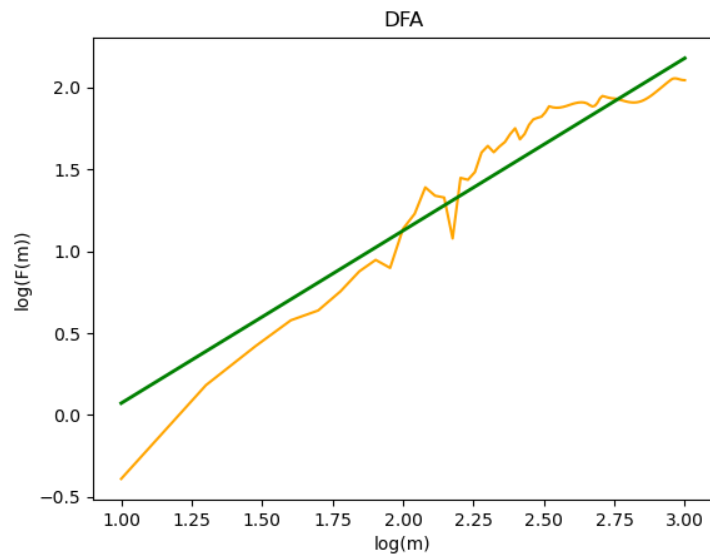
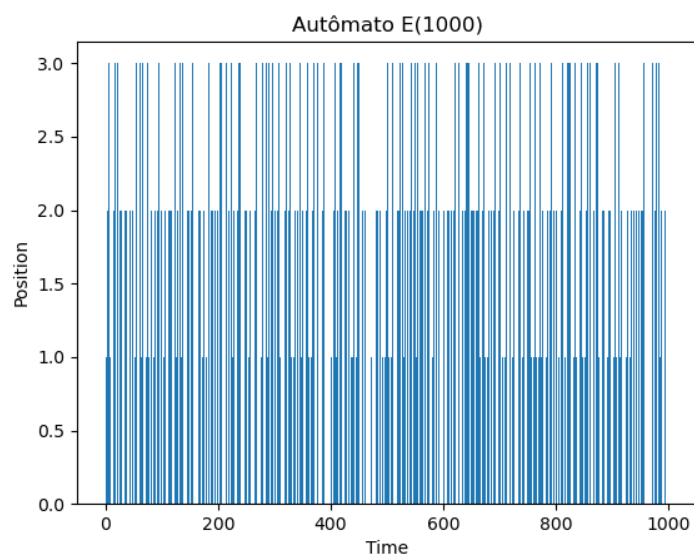


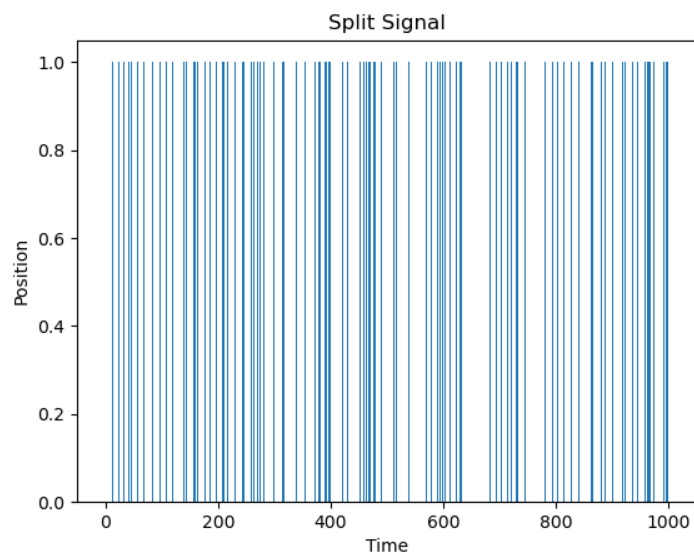
Figura 50: DFA

$$\text{DFA} \rightarrow \left\{ \text{Alpha} = 1.05241437 \right.$$

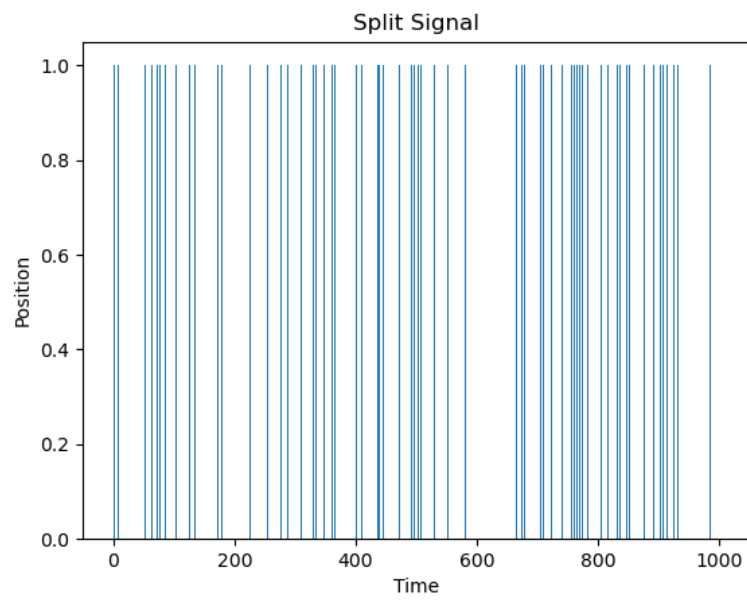
## 4.5 Estudo de E



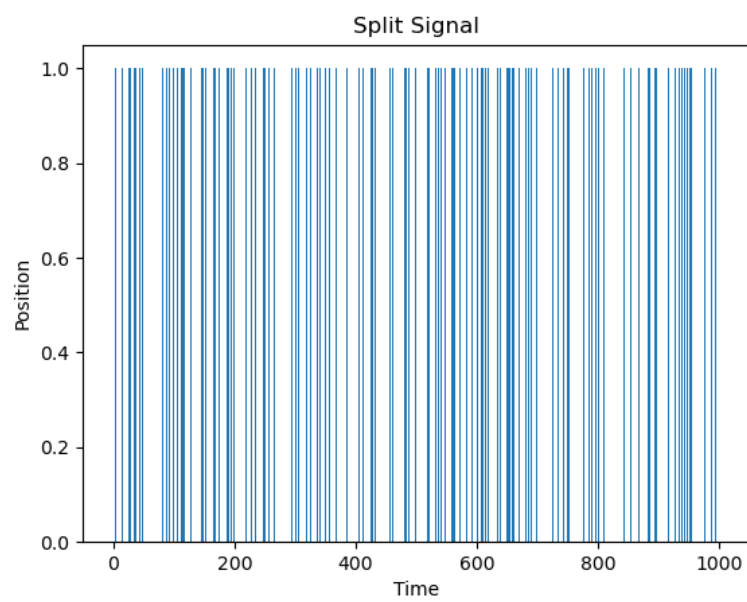
*Figura 51: Sinal Original*



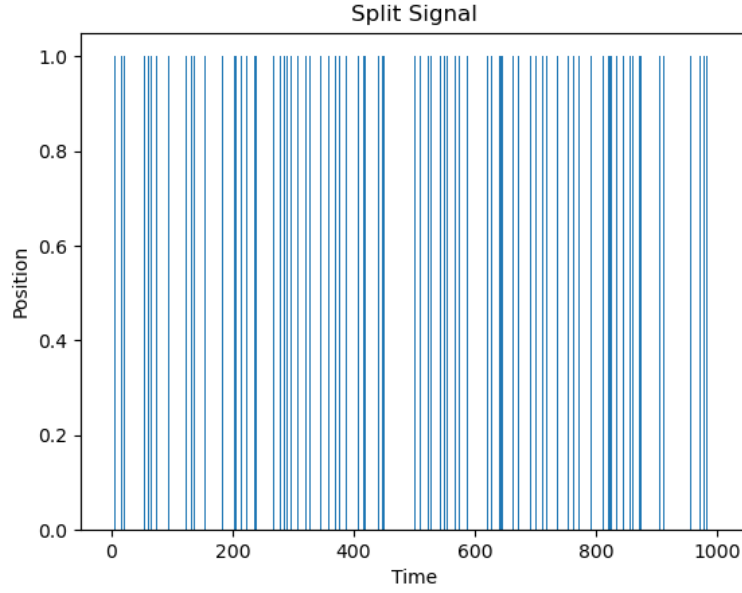
*Figura 52: Symbol 0*



*Figura 53: Symbol 1*



*Figura 54: Symbol 2*



*Figura 55: Symbol 3*

#### 4.5.1 Burst-Based Features

$$\begin{aligned}
 \text{Node 0} &\rightarrow \begin{cases} \text{Número de Bursts} = 147 \\ \text{Média} = 1.85034 \\ \text{Desvio Padrão} = 1.500 \\ \text{Entropia} = 1.790 \\ \text{Evenness} = 3.4586 \end{cases} \\
 \text{Node 1} &\rightarrow \begin{cases} \text{Número de Bursts} = 146 \\ \text{Média} = 1.10273 \\ \text{Desvio Padrão} = 0.3469 \\ \text{Entropia} = 0.48841 \\ \text{Evenness} = 1.4028 \end{cases} \\
 \text{Node 2} &\rightarrow \begin{cases} \text{Número de Bursts} = 146 \\ \text{Média} = 2.3630 \\ \text{Desvio Padrão} = 1.6268 \\ \text{Entropia} = 2.2851 \\ \text{Evenness} = 4.8741 \end{cases}
 \end{aligned}$$



$$\text{Node 3} \rightarrow \begin{cases} \text{Número de Bursts} = 146 \\ \text{Média} = 1.527397 \\ \text{Desvio Padrão} = 1.121 \\ \text{Entropia} = 1.36750 \\ \text{Evenness} = 2.5802 \end{cases}$$

#### 4.5.2 Intersymbol-Based Features

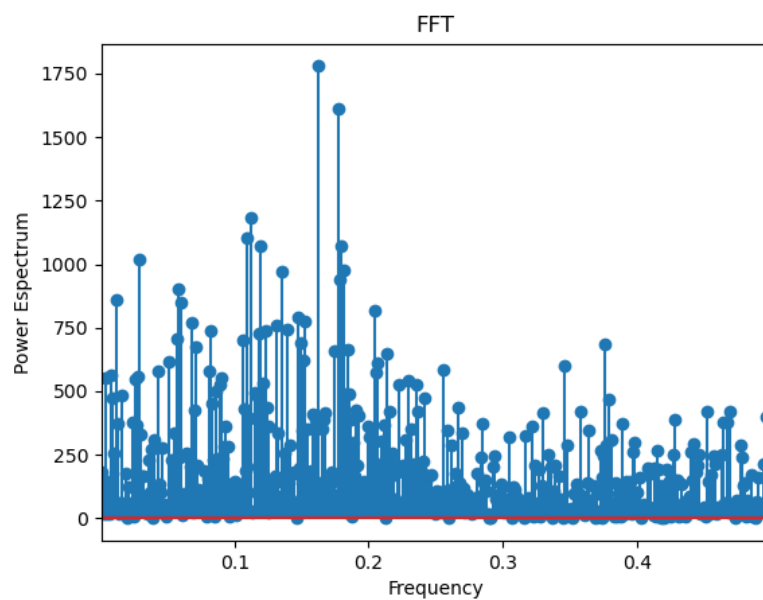
$$\text{Node 0} \rightarrow \begin{cases} \text{Número de Intersymbols} = 146 \\ \text{Média} = 3.69003 \\ \text{Desvio Padrão} = 2.8427 \\ \text{Entropia} = 2.41941 \\ \text{Evenness} = 5.34955 \end{cases}$$

$$\text{Node 1} \rightarrow \begin{cases} \text{Número de Intersymbols} = 146 \\ \text{Média} = 6.1937 \\ \text{Desvio Padrão} = 1.46528 \\ \text{Entropia} = 3.11963 \\ \text{Evenness} = 8.69170 \end{cases}$$

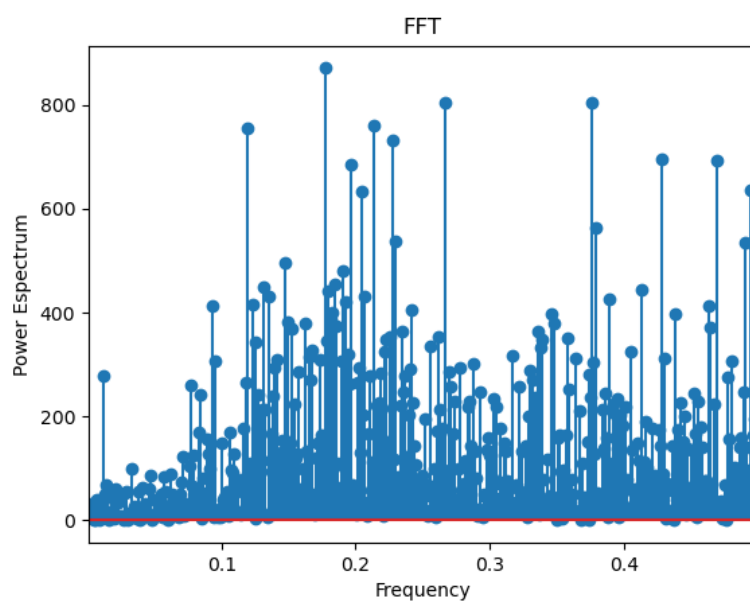
$$\text{Node 2} \rightarrow \begin{cases} \text{Número de Intersymbols} = 146 \\ \text{Média} = 2.8808 \\ \text{Desvio Padrão} = 2.5303 \\ \text{Entropia} = 1.9773 \\ \text{Evenness} = 3.937679 \end{cases}$$

$$\text{Node 3} \rightarrow \begin{cases} \text{Número de Intersymbols} = 146 \\ \text{Média} = 4.454954 \\ \text{Desvio Padrão} = 3.08627 \\ \text{Entropia} = 2.77699 \\ \text{Evenness} = 6.854225 \end{cases}$$

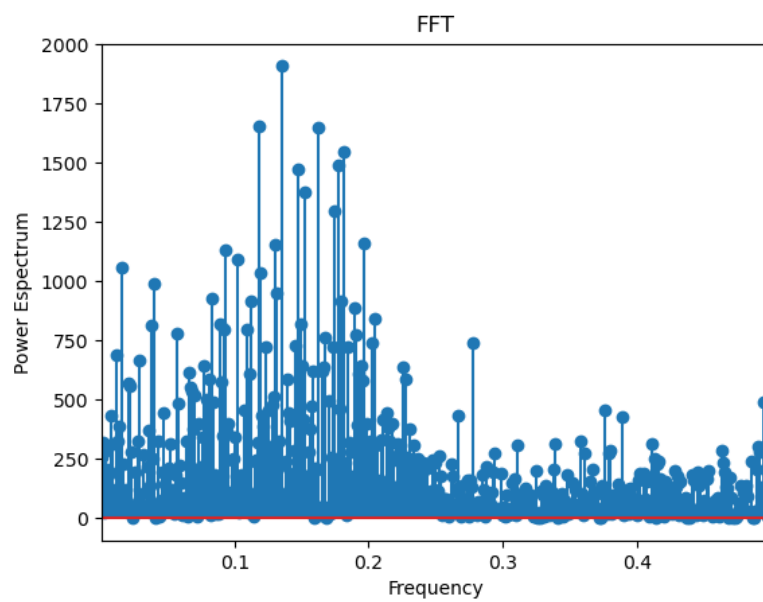
#### 4.5.3 Fast Fourier Transform



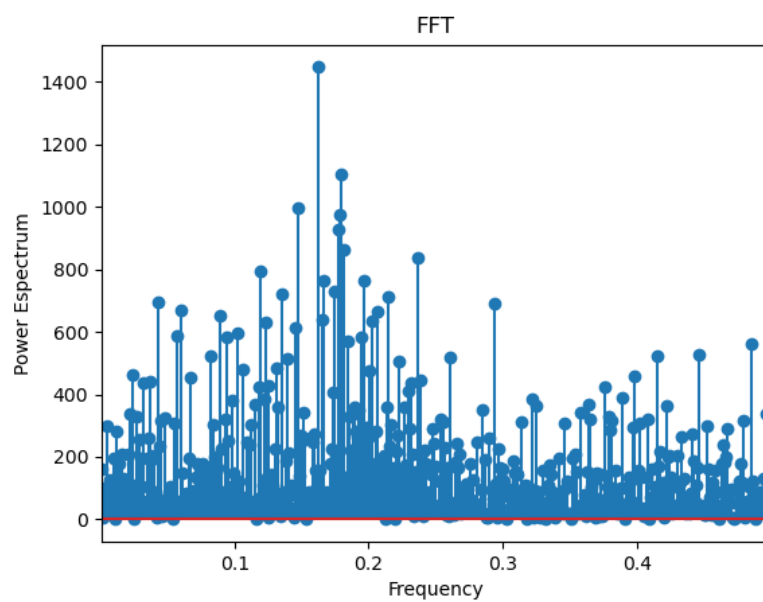
*Figura 56: Symbol 0*



*Figura 57: Symbol 1*



*Figura 58: Symbol 2*



*Figura 59: Symbol 3*

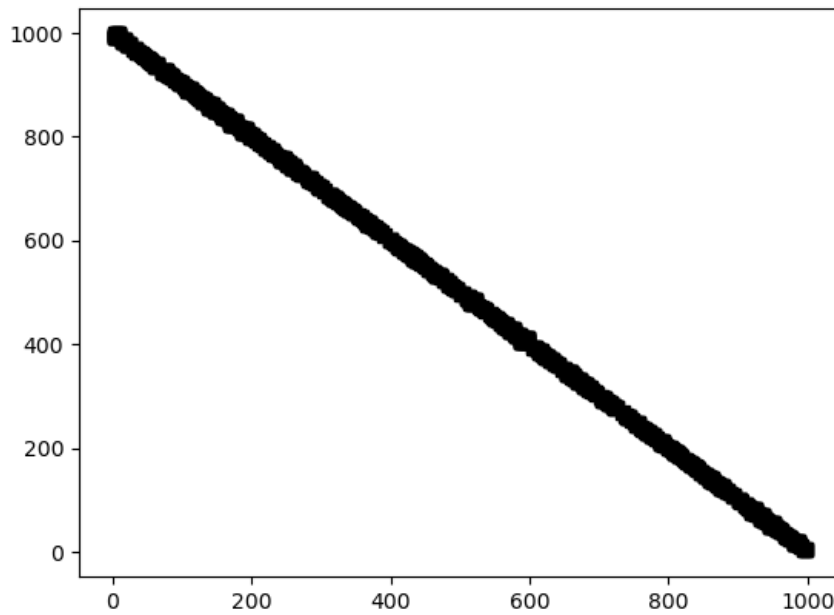
$$\text{Node 0} \rightarrow \begin{cases} \text{Média} = 271.99999 \\ \text{DesvioPadrão} = 2343.925 \end{cases}$$

$$\text{Node 1} \rightarrow \begin{cases} \text{Média} = 160.99999 \\ \text{DesvioPadrão} = 828.4138 \end{cases}$$

$$\text{Node 2} \rightarrow \begin{cases} \text{Média} = 344.99999 \\ \text{DesvioPadrão} = 3765.399 \end{cases}$$

$$\text{Node 3} \rightarrow \begin{cases} \text{Média} = 222.99999 \\ \text{DesvioPadrão} = 1577.6528 \end{cases}$$

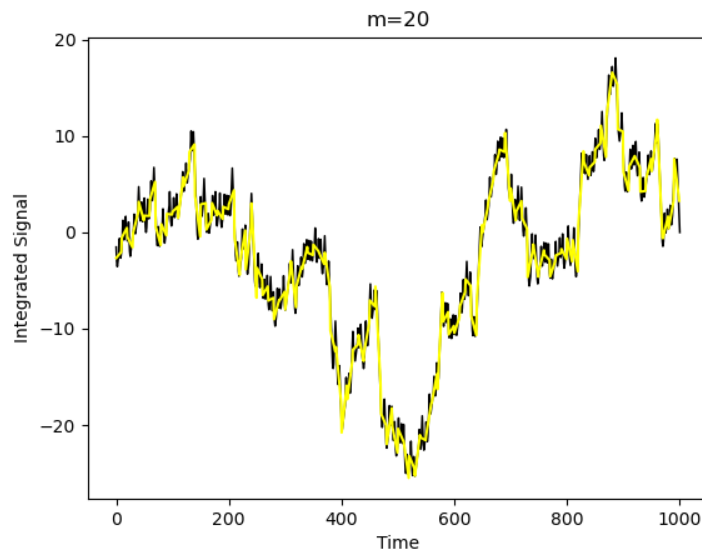
#### 4.5.4 Network-Based Features



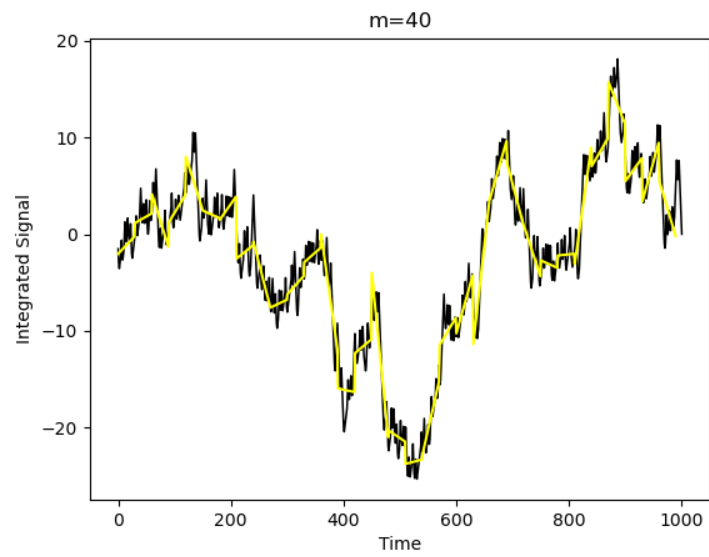
*Figura 60: Metodo da Visibilidade*

$$\text{Grafo} \rightarrow \begin{cases} \text{MédiaDegree} = 2.5694305 \\ \text{DesvioPadrão} = 2.626294 \\ \text{MédiaClustering} = 0.27943007 \\ \text{DesvioPadrão} = 0.3867404 \end{cases}$$

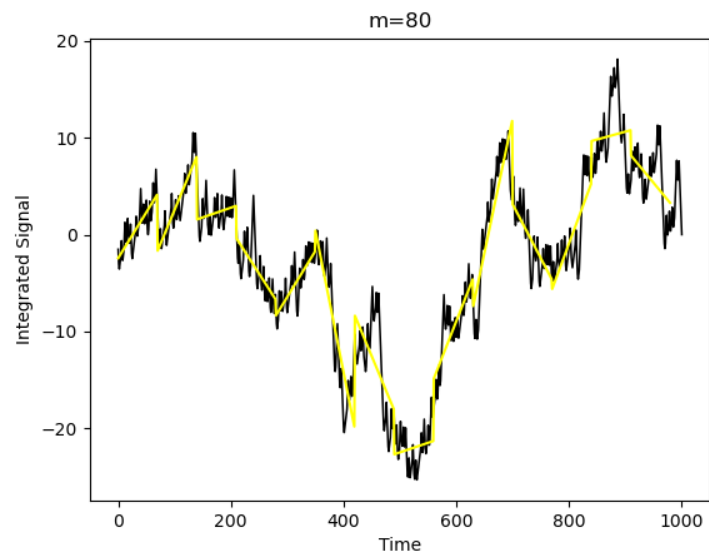
#### 4.5.5 Self-Affinity Features (DFA)



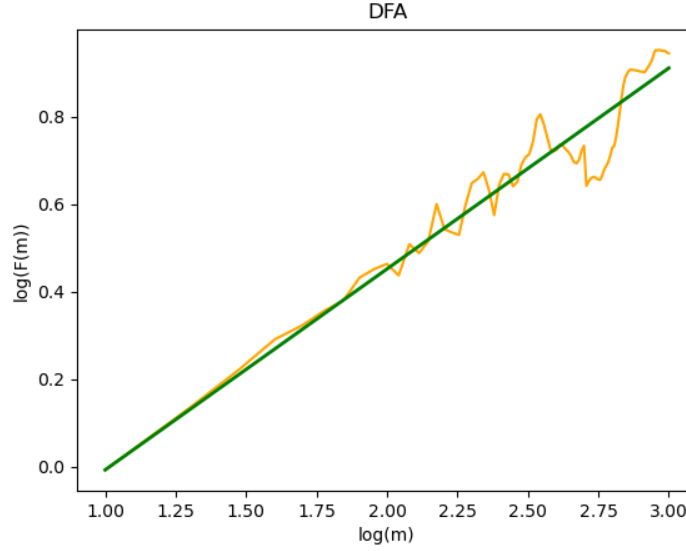
*Figura 61: DFA*



*Figura 62: DFA*



*Figura 63: DFA*



*Figura 64: DFA*

$$\text{DFA} \rightarrow \left\{ \text{Alpha} = 0.4587943 \right.$$

## 5 Referências

[1]CDT-23, [https://www.researchgate.net/publication/339800429\\_Discrete\\_One-Dimensional\\_Signals\\_A\\_Brief\\_Catalogue\\_of\\_Features](https://www.researchgate.net/publication/339800429_Discrete_One-Dimensional_Signals_A_Brief_Catalogue_of_Features)DT – 23

[2]CDT-17, [https://www.researchgate.net/publication/337103890\\_Linear\\_Least\\_Squares\\_Versatile\\_Curve\\_and\\_Surface\\_Fitting](https://www.researchgate.net/publication/337103890_Linear_Least_Squares_Versatile_Curve_and_Surface_Fitting)DT – 17

[3]CDT-2, [https://www.researchgate.net/publication/324312765\\_What\\_is\\_a\\_Complex\\_Network](https://www.researchgate.net/publication/324312765_What_is_a_Complex_Network)DT – 2

[4]Luís M. da Silva, Éverton. Programa que cria as imagens e realiza os calculos necessários. <https://github.com/everttonmendes/Analysis-and-Pattern-Recognition/commit/243d77120fb3e12974424a0199bc1a25da494b0b>