КАФЕДРА ПРОЕКТИРОВАНИЯ ИНФОРМАЦИОННО-КОМПЬЮТЕРНЫХ СИСТЕМ

Основы программирования информационных систем

Преподаватель:
Олег Чеславович Ролич
кандидат технических наук, доцент

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Лабораторная работа 3

СПЕКТРАЛЬНЫЙ И СТАТИСТИЧЕСКИЙ АНАЛИЗ ДАННЫХ

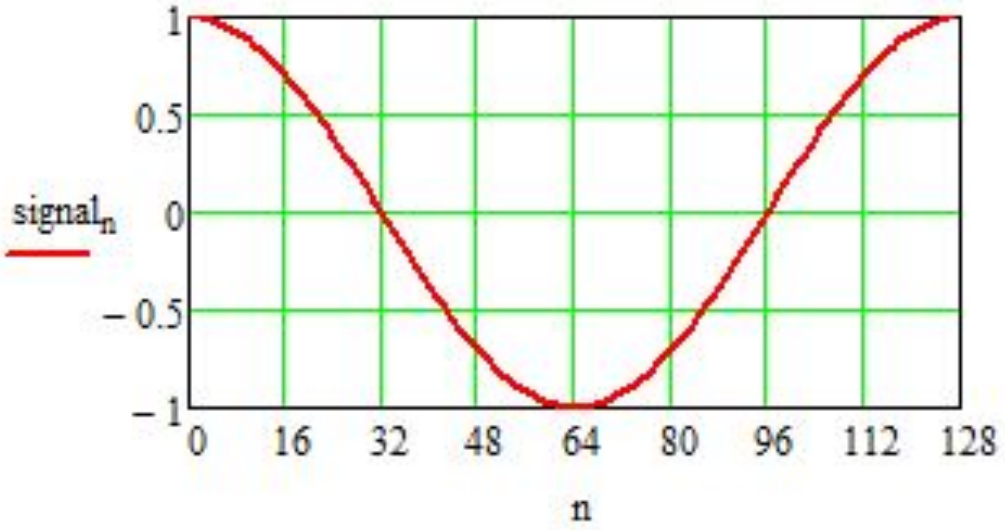
Спектральный анализ

$N := 128$

$n := 0..(N - 1)$

$$\cos\left(\frac{2\pi}{N}\cdot 1\cdot n\right) + \cos\left(\frac{2\pi}{N}\cdot 3\cdot n\right) + \cos\left[\frac{2\pi}{N}\cdot 9\cdot\left(n - \frac{N}{2}\right)\right]$$

$$signal_n := \cos\left(\frac{2\pi}{N}\cdot 1\cdot n\right)$$



$FS := FFT(signal)$

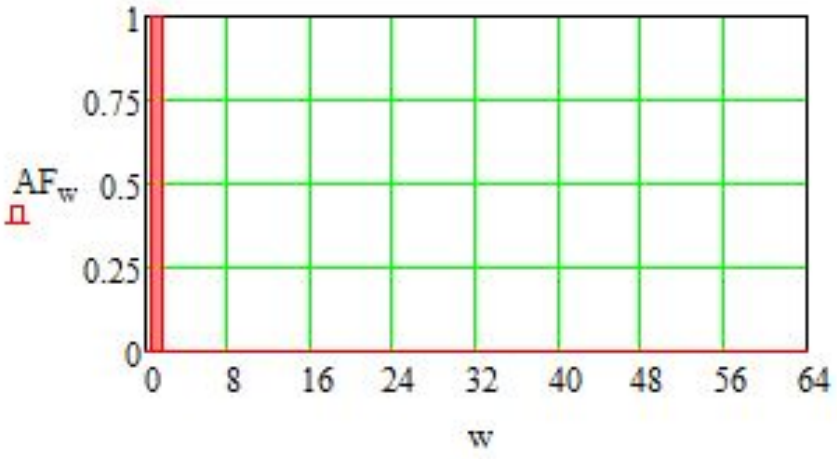
```
funAF(X) := | m ← rows(X)
            | for w ∈ 0..(m − 1)
            |   Y_w ← | 2·|X_w|  if (w ≠ 0)
            |         | |X_w|    otherwise
            | Y
```

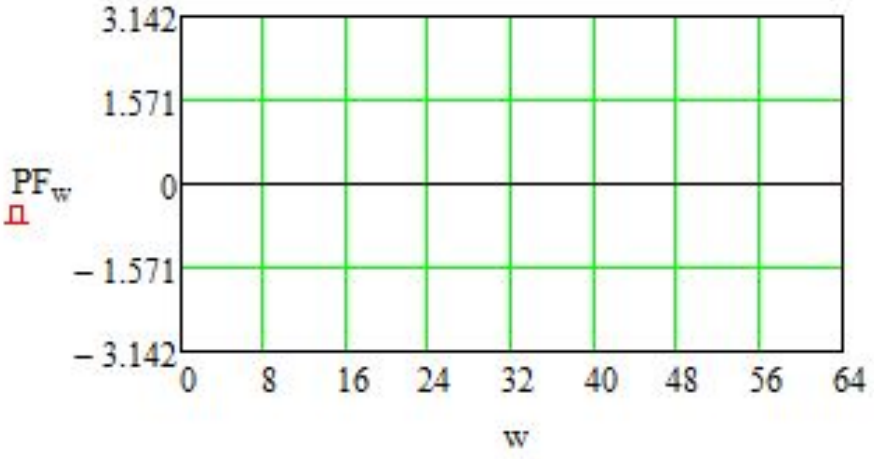
```
funPF(X, q) := | m ← rows(X)
               | n ← cols(X)
               | for i ∈ 0..(m − 1)
               |   for j ∈ 0..(n − 1)
               |     Y_{i,j} ← | arg(X_{i,j})  if (round(|X_{i,j}|, q) ≠ 0)
               |               | 0             otherwise
               | Y
```

$$w := 0..\frac{N}{2}$$

AF := funAF(FS)

PF := funPF(FS, 5)





ВЫПОЛНИТЬ АНИМАЦИЮ!!!

$\phi := FRAME$

$$signal_n := \cos\left[\frac{2\pi}{N}\cdot 3\cdot(n-\phi)\right] + 0.7\cdot\cos\left[\frac{2\pi}{N}\cdot 5\cdot\left(n-\frac{N}{3}\right)\right]$$

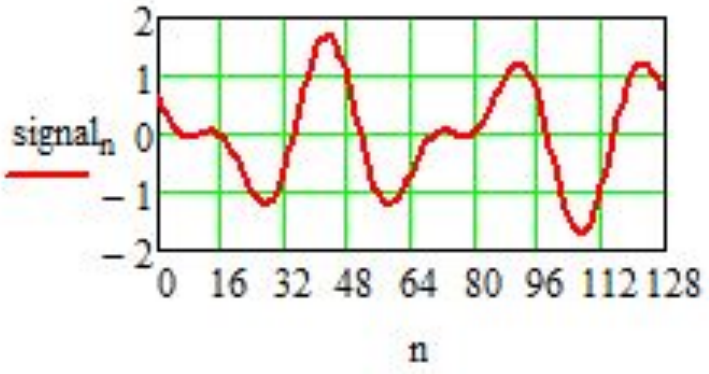
$FS := FFT(signal)$

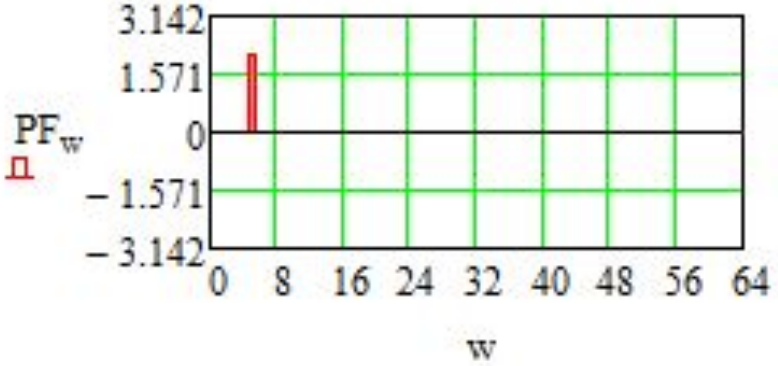
$AF := funAF(FS)$

$PF := funPF(FS, 5)$

Область анимации

Для FRAME от 0 до 128





Спектральный анализ wav-файла

Функция построения спектрограммы


```
Spectrogram(sprWidth, stream, start, step) :=
    for i ∈ 0.. (sprWidth − 1)
        for j ∈ 0.. N/2
            S_{i,j} ← 0
    for fr ∈ max(0, FRAME − sprWidth).. FRAME
        for n ∈ 0.. (N − 1)
            Win_n ← stream_{start+fr·step+n, 0}
        SWin ← FFT(Win)
        for j ∈ 1.. N/2
            for i ∈ (sprWidth − 1).. 1
                S_{i,j} ← S_{i−1,j}
            S_{0,j} ← |SWin_j|
        mxS ← max(S)
        for i ∈ 0.. (sprWidth − 1)
            for j ∈ 1.. N/2
                SPGR_{i,j} ← 255·S_{i,j}/mxS
    return SPGR
```

wavfile := "ALARM.wav"

M := READWAV(wavfile)

Header := GETWAVINFO(wavfile)

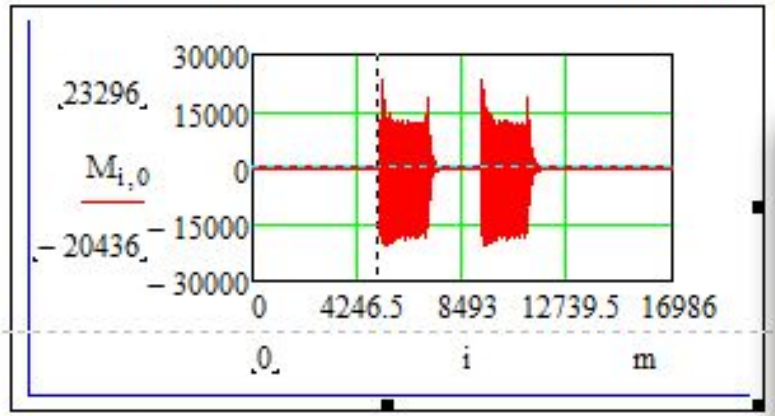
m := rows(M) = 16986

i := 0.. (m − 1)

Header = (1, 22050, 16, 44100)

M =

	0
0	0
1	0
2	0
3	0
4	1
5	1
6	-2
7	0
8	0
9	0
10	0
11	...

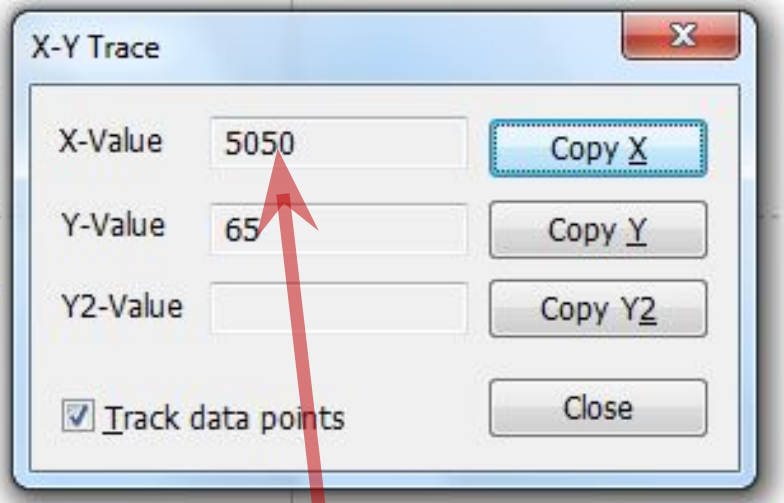


t_start := 5050

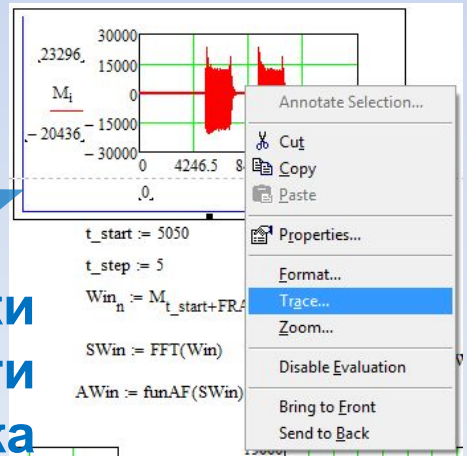
t_step := 5

Win n := M t_start+FRAME·t_step+n, 0

wav-файл выбирается из списка, доступного на текущем компьютере, например, в папке C:\Windows\Media



Примерное значение определяется с помощью трассировки
(для каждого wav-файла оно разное)



Вход в режим трассировки
нажатие правой клавиши мыши в области графика

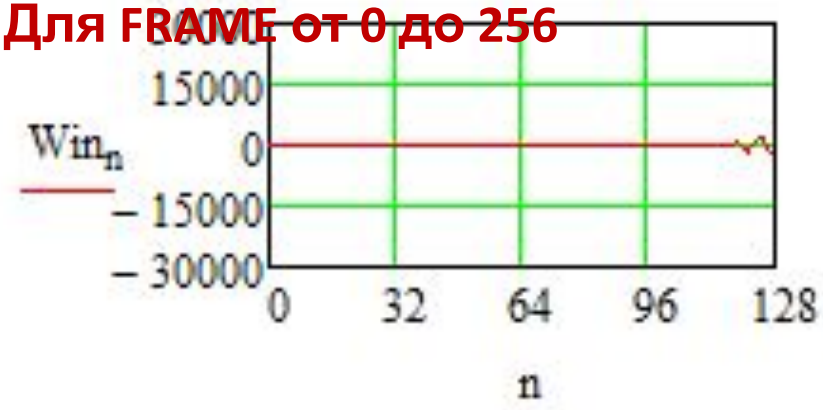
$SWin := FFT(Win)$

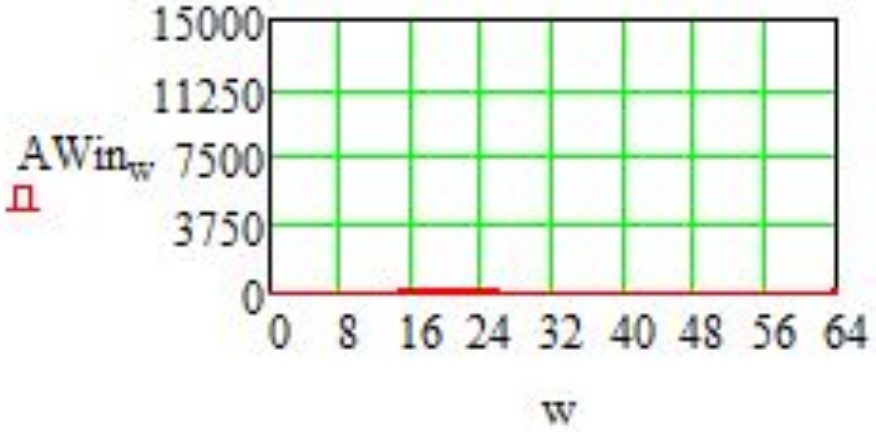
$AWin := funAF(SWin)$

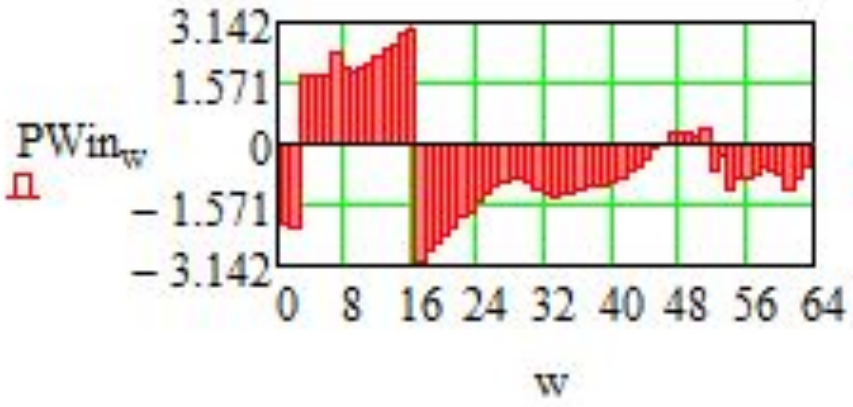
$PWin := funPF(SWin, 5)$

Область анимации

Для FRAME от 0 до 256







$Spectrogram(N, M, t_start, t_step)$

Способы управления объектами на примере органов чувств человека

Широтно-импульсное управление (ШИМ)

Период импульсной последовательности $pwmPeriod := 16$

Ширина отдельного импульса $pwmWidth = 10$

$k := 0..(pwmPeriod - 1)$

$$pulseFunc_k := \begin{cases} 1 & \text{if } (k < pwmWidth) \\ 0 & \text{otherwise} \end{cases}$$

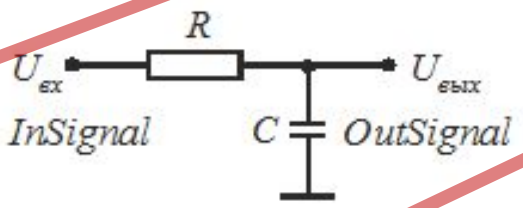
Скважность $\frac{pwmPeriod}{pwmWidth} = 1.6$

Коэффициент заполнения $\frac{pwmWidth}{pwmPeriod} = 0.625$

$InSignal_n := pulseFunc_{mod(n,pwmPeriod)}$

$R := 10^6$ $C := 10^{-4}$

$EyeH_w := \frac{1}{1 + i \cdot w \cdot R \cdot C}$



$OSpectrum_w := FFT(InSignal)_w \cdot EyeH_w$

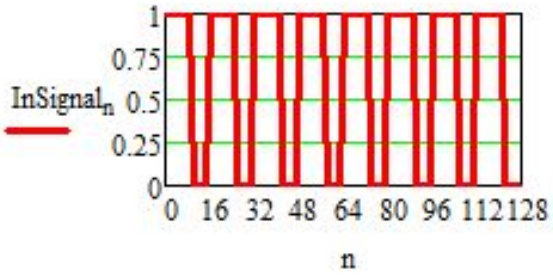
$OutSignal := IFFT(OSpectrum)$

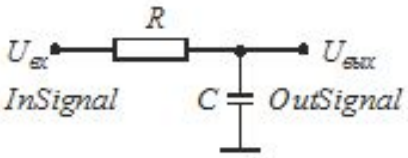
Регулирование ширины импульса

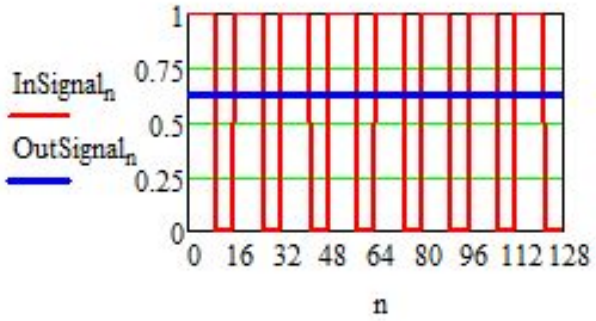
Ширина импульса равна 10

pwmWidth

pwmPeriod







Мнимая единица

1i

Компоненты MathCAD-BASIC

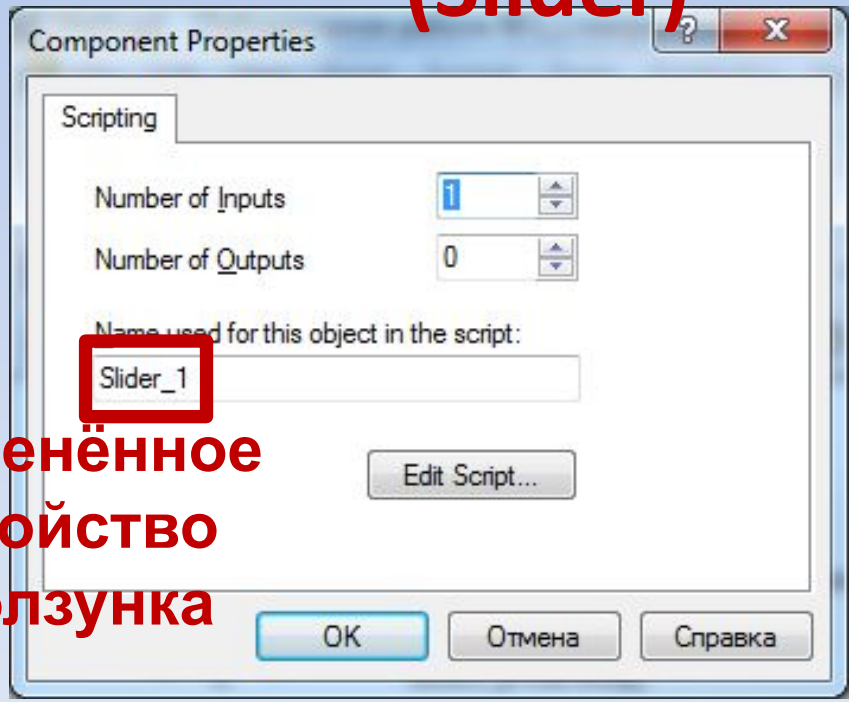
```
Sub Slider_1Event_Start()
  Rem TODO: Add your code here
End Sub

Sub Slider_1Event_Exec(Inputs,Outputs)
  T = Inputs(0).value
  Slider_1.MaxRange = T
  pwmWidth = Slider_1.Position
  If (pwmWidth <= 0) Then
    pwmWidth= 0
  ElseIf (pwmWidth >= T) Then
    pwmWidth= T
  End If
  Worksheet.SetValue "pwmWidth", pwmWidth
End Sub

Sub Slider_1Event_Stop()
  Rem TODO: Add your code here
End Sub


Sub Slider_1_ValueChanged()
  Slider_1.Recalculate()
End Sub
```

Скрипт для ползунка (Slider)



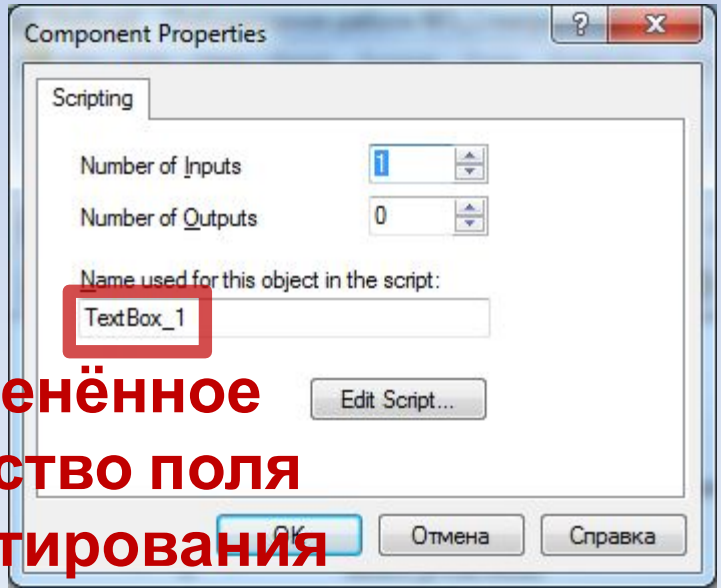
Изменённое свойство ползунка

Скрипт для поля редактирования (TextBox)

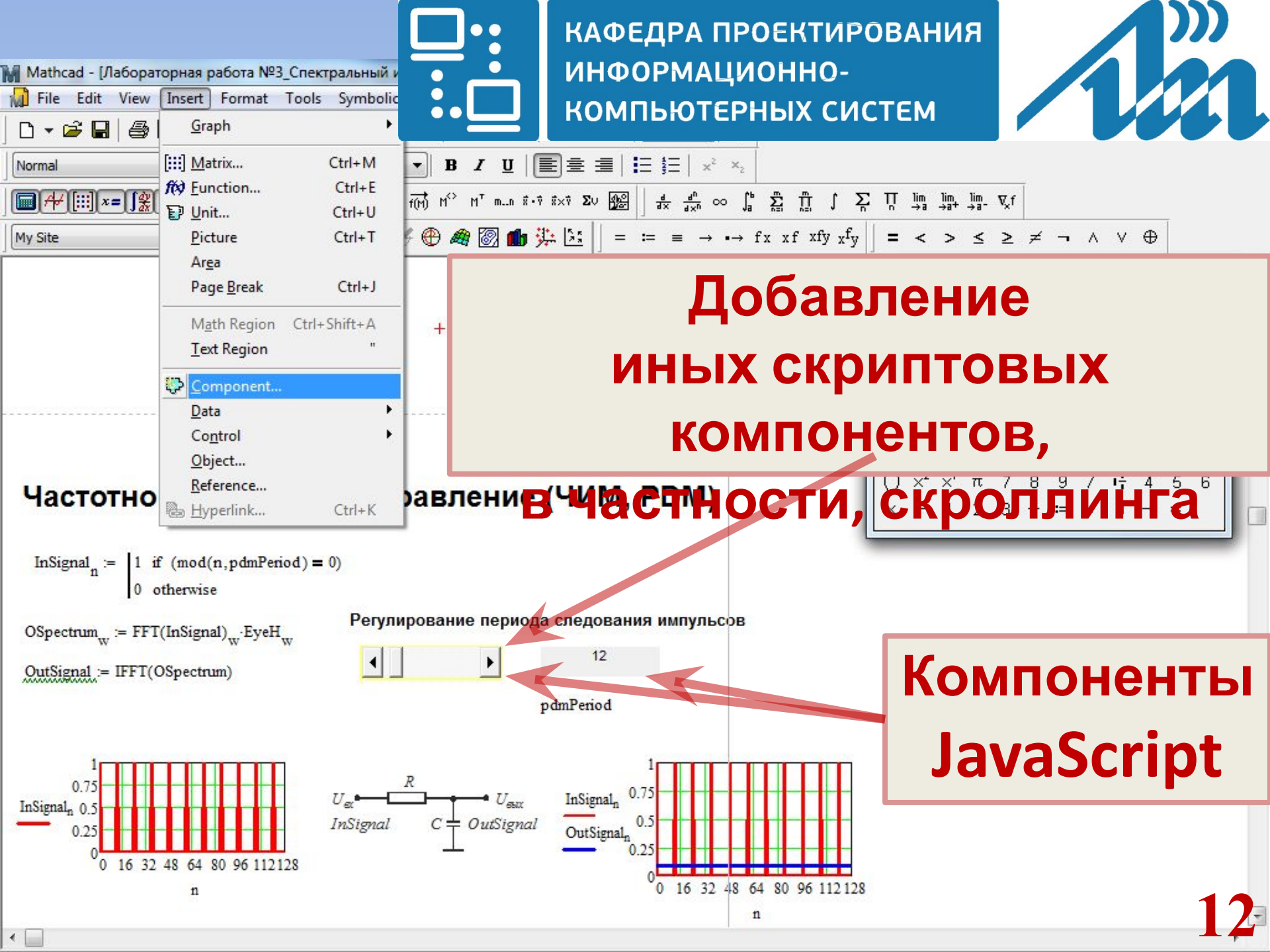
```
Sub TextBox_1Event_Start()
  Rem TODO: Add your code here
End Sub

Sub TextBox_1Event_Exec(Inputs,Outputs)
  TextBox_1.Text = "Ширина импульса равна " & Inputs(0).value
End Sub

Sub TextBox_1Event_Stop()
  Rem TODO: Add your code here
End Sub
```



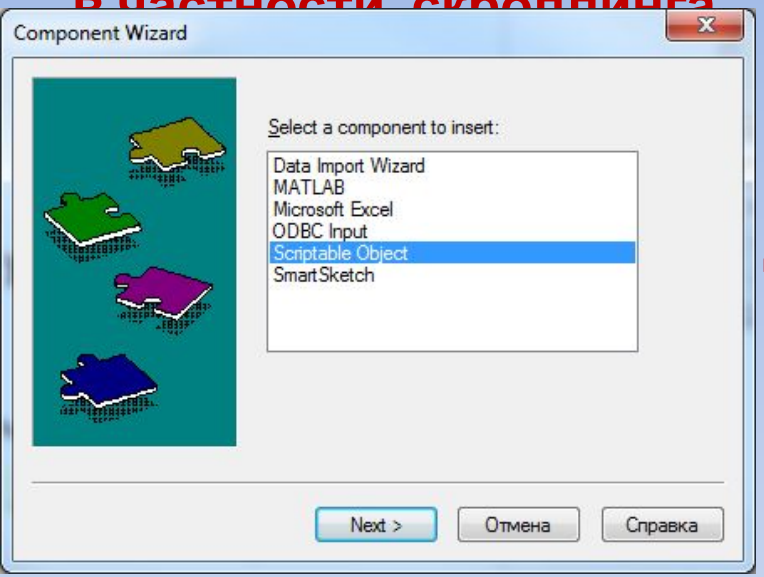
Изменённое свойство поля редактирования

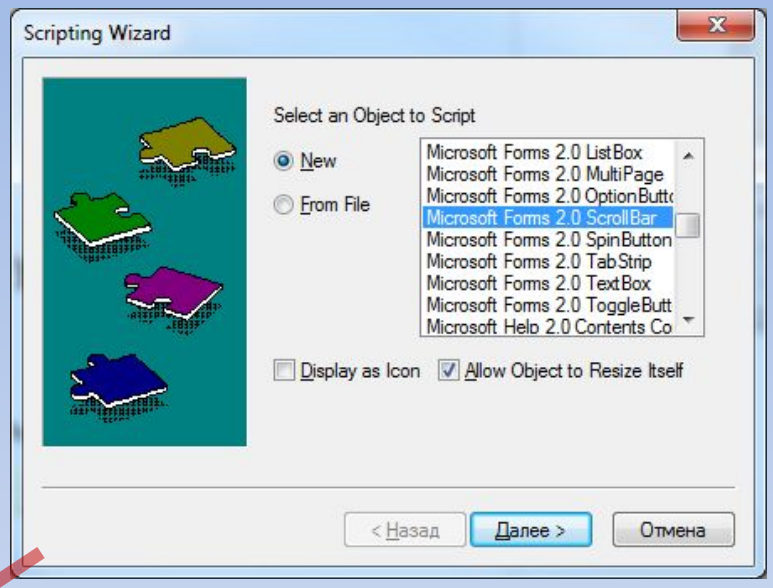


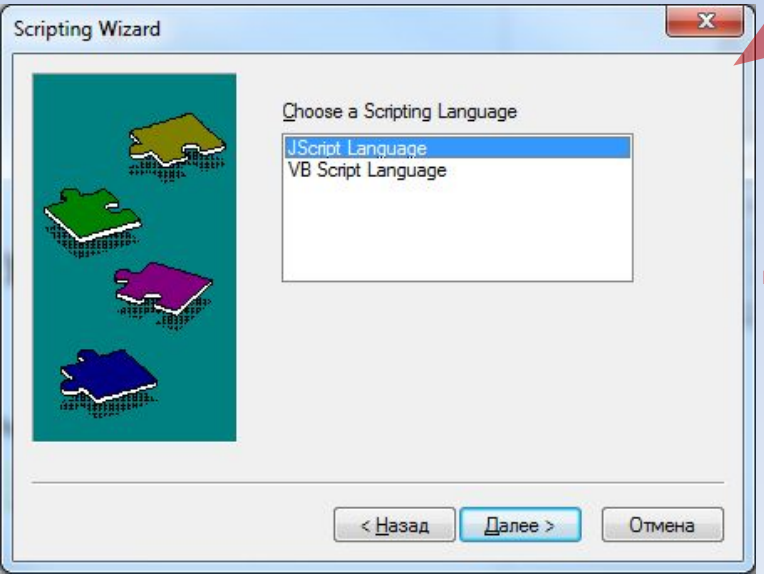
Добавление иных скриптовых компонентов, в частности, скроллинга

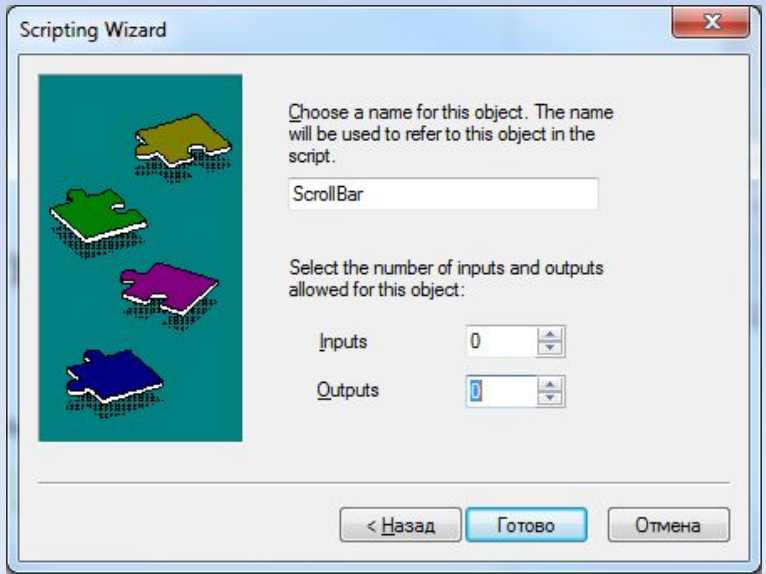
Компоненты JavaScript

Добавление иных скриптовых компонентов, в частности, скриптинга









Частотно-импульсное управление (ЧИМ, PDM)

$$InSignal_n := \begin{cases} 1 & \text{if } (mod(n, pdmPeriod) = 0) \\ 0 & \text{otherwise} \end{cases}$$

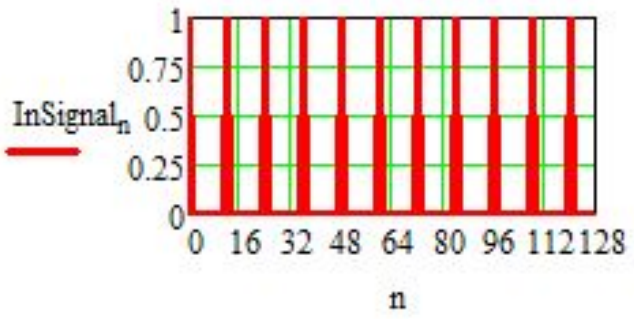
$$OSpectrum_w := FFT(InSignal)_w \cdot EyeH_w$$

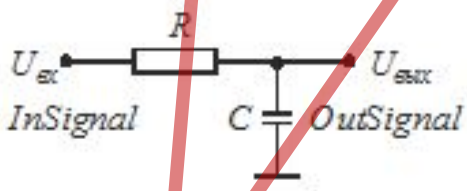
$$OutSignal := IFFT(OSpectrum)$$

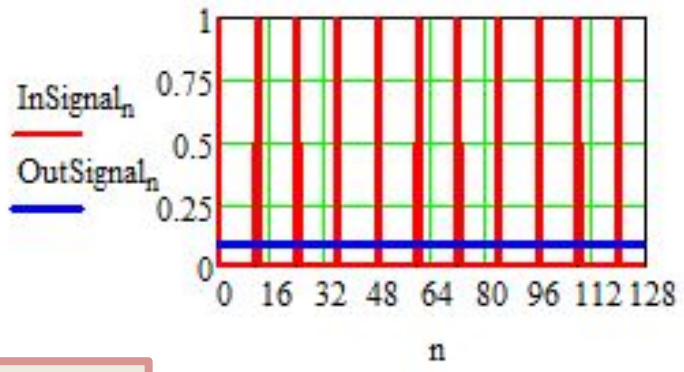
Регулирование периода следования импульсов

12

pdmPeriod







Компоненты JavaScript

JS-скрипт для скроллинга (ScrollBar)

```
function ScrollBarEvent::Start()
{
  // TODO: Add code here
  ScrollBar.Min = 1;
  ScrollBar.Max = 128;
}

function ScrollBarEvent::Exec(Inputs,Outputs)
{
  // TODO: Add code here
  Worksheet.SetValue("pdmPeriod", ScrollBar.Value);
}

function ScrollBarEvent::Stop()
{
  // TODO: Add code here
}
```

JS-скрипт для метки (Label)

```
function LabelEvent::Start()
{
  // TODO: Add code here
  Label.TextAlign = 2;
}

function LabelEvent::Exec(Inputs,Outputs)
{
  // TODO: Add code here
  // Label.Caption = Worksheet.GetValue("pdmPeriod");
  Label.Caption = Inputs(0).value;
}

function LabelEvent::Stop()
{
  // TODO: Add code here
}
```

Фазово-импульсное управление (ФИМ)

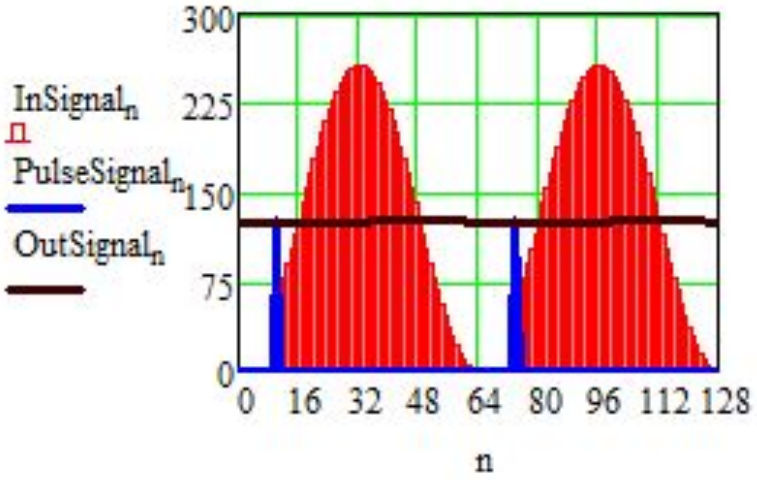
$$ContSignal_n := 128 \cdot \left[1 + \sin\left[\frac{2\pi}{N} \cdot (n - ppmPhase_0) \cdot ppmFreq\right]\right]$$

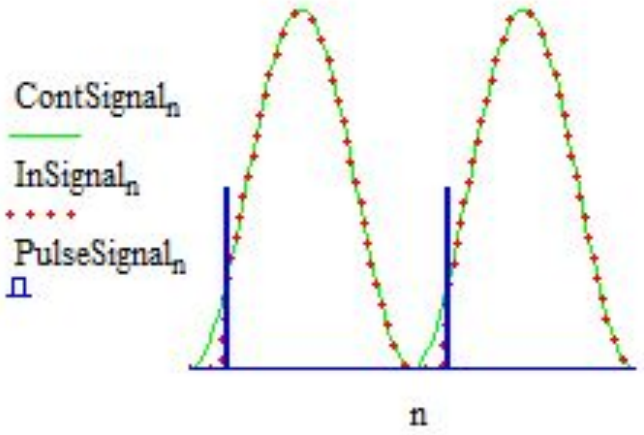
$$InSignal_n := \begin{cases} ContSignal_n & \text{if } \left(mod\left(n, \frac{N}{ppmFreq}\right) \geq ppmControlPhase\right) \\ 0 & \text{otherwise} \end{cases}$$

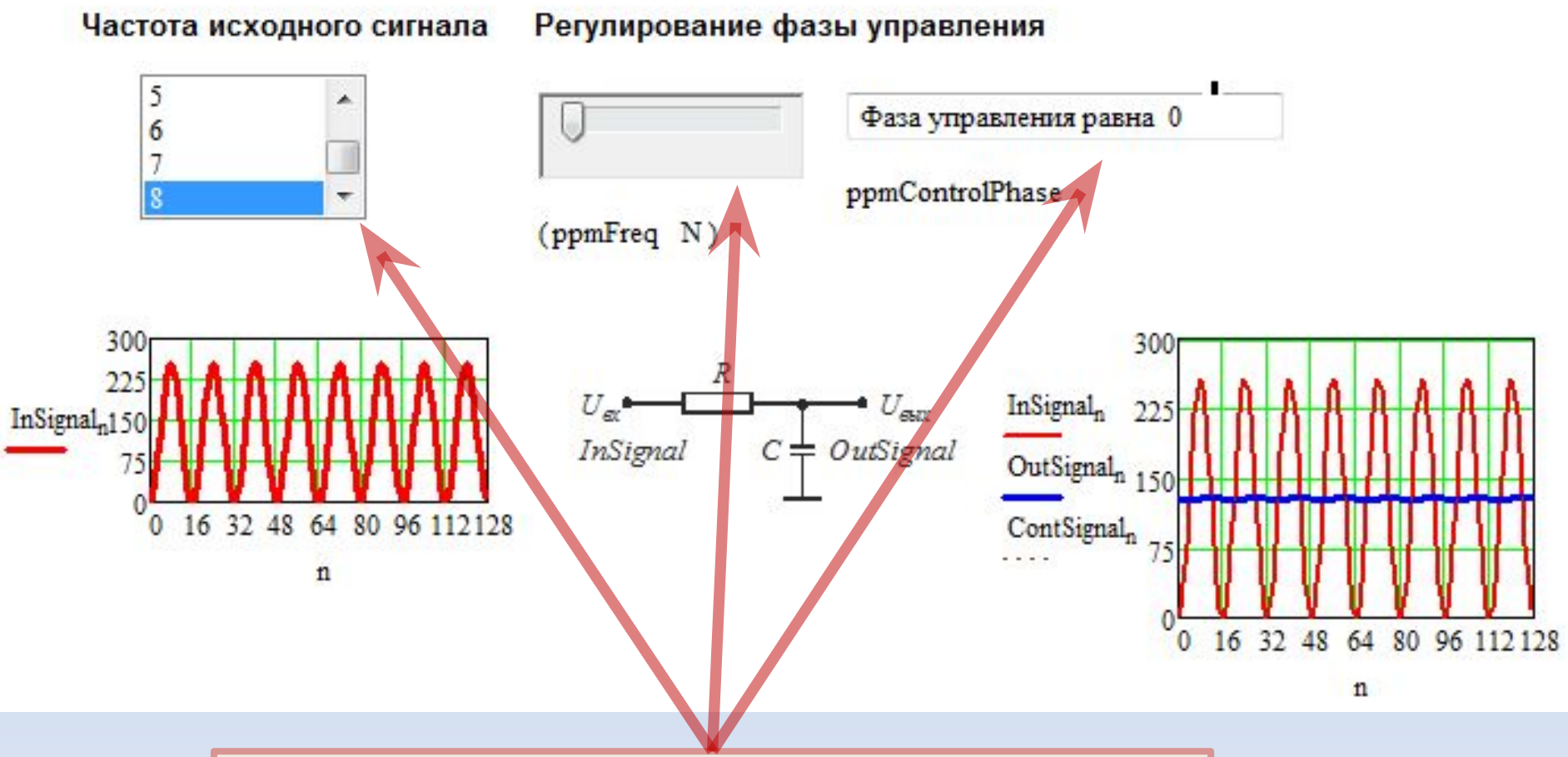
$$PulseSignal_n := \begin{cases} 128 & \text{if } \left(mod\left(n, round\left(\frac{N}{ppmFreq}\right)\right) = ppmControlPhase\right) \\ 0 & \text{otherwise} \end{cases}$$

$$OSpectrum_w := FFT(InSignal)_w \cdot EyeH_w$$

$$OutSignal := IFFT(OSpectrum)$$







Компоненты MathCAD BASIC

Скрипт (начало) для списка

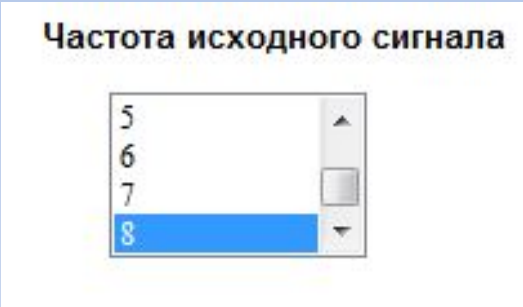
```
Rem Initialize List Box
ListBox_1.ResetContent()

x = Worksheet.GetValue("N")

If ListBox_1.Count = 0 Then
    For i = 1 To 8
        ListBox_1.AddString(i)
    Next
End If

Rem Initialize Selection If desired
ListBox_1.CurSel = 0

Sub ListBox_1Event_Start()
End Sub
```



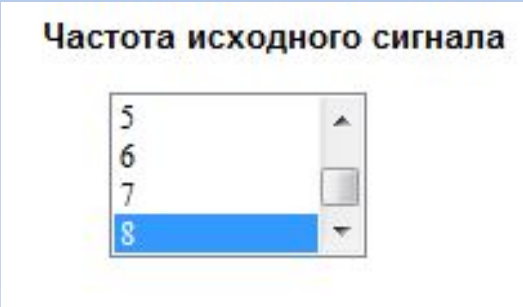
Скрипт (конец) для списка

```
Sub ListBox_1Event_Exec(Inputs,Outputs)
End Sub

Sub ListBox_1Event_Stop()
    Rem TODO: Add your code here
End Sub

Sub ListBox_1_SelChanged()
    Worksheet.SetValue "ppmFreq", ListBox_1.CurSel + 1
    Worksheet.SetValue "ppmPhase_0", x/4/(ListBox_1.CurSel + 1)
End Sub

Sub ListBox_1_DblClick()
End Sub
```



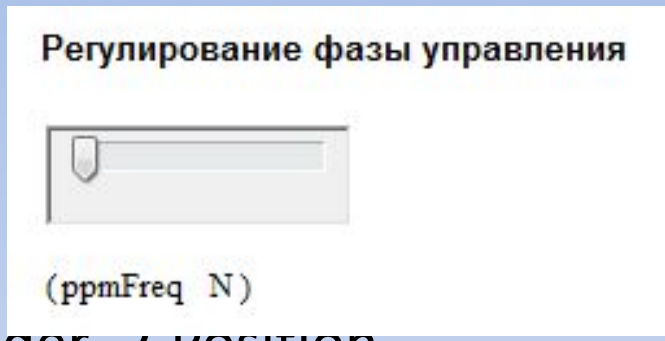
Скрипт для ползунка (Slider)

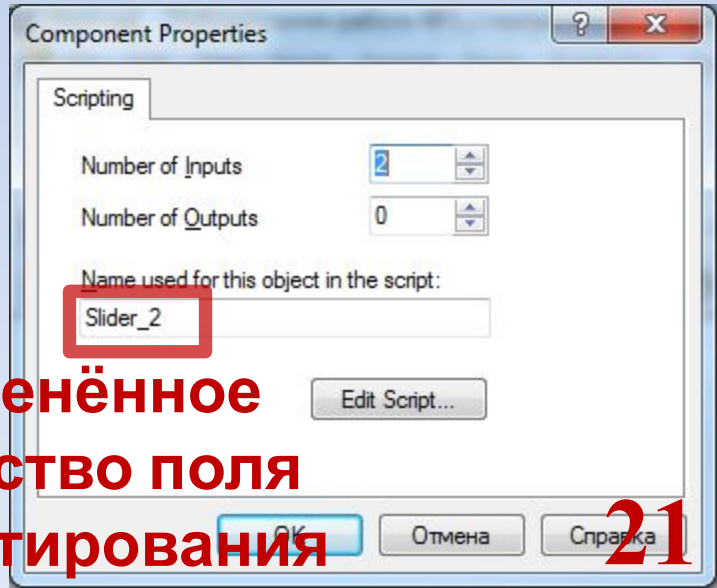
```
Sub Slider_2Event_Start()
  Rem TODO: Add your code here
End Sub

Sub Slider_2Event_Exec(Inputs,Outputs)
      ppmFreq = Inputs(0).value
      N = Inputs(1).value
      Slider_2.MinRange = 0
      Slider_2.MaxRange = N / ppmFreq
      Worksheet.SetValue "ppmControlPhase", Slider_2.Position
End Sub

Sub Slider_2Event_Stop()
  Rem TODO: Add your code here
End Sub

Sub Slider_2_ValueChanged()
  Slider_2.Recalculate()
End Sub
```





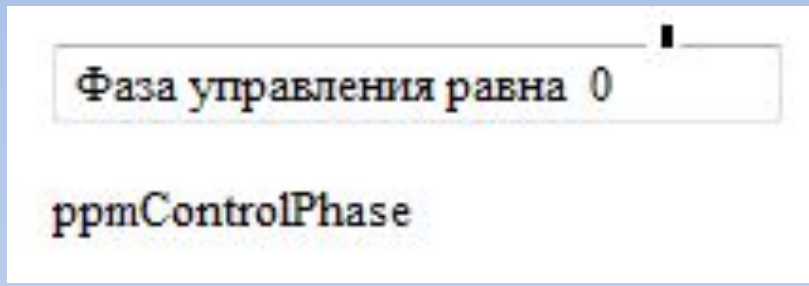
Изменённое свойство поля редактирования

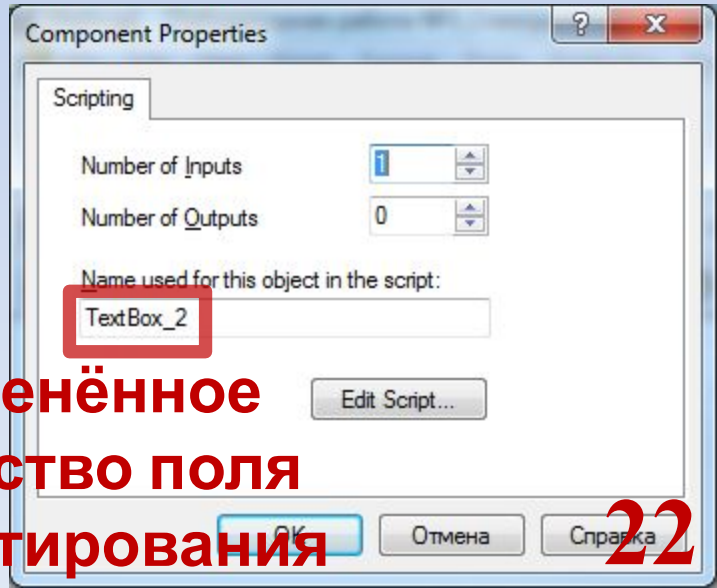
Скрипт для текстового поля

```
Sub TextBox_2Event_Start()
  Rem TODO: Add your code here
End Sub

Sub TextBox_2Event_Exec(Inputs,Outputs)
  TextBox_2.Text = "Фаза управления равна  " & Inputs(0).value
End Sub

Sub TextBox_2Event_Stop()
  Rem TODO: Add your code here
End Sub
```





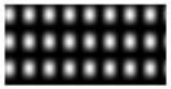
Изменённое свойство поля редактирования

Элементарный спектральный анализ изображения

$m := 32 \qquad n := 64$

$i := 0..(m-1) \qquad j := 0..(n-1)$

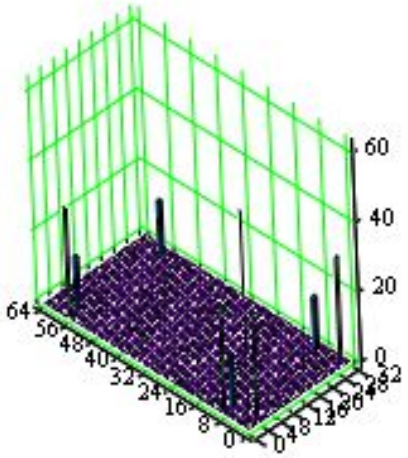
$$P_{i,j} := \text{floor}\left[63\cdot\left[1+\cos\left[\frac{2\pi}{n}\cdot 8\cdot\left(j-\frac{n}{7}\right)\right]\right]\cdot\left[1+\cos\left[\frac{2\pi}{m}\cdot 3\cdot\left(i-\frac{m}{9}\right)\right]\right]\right]$$



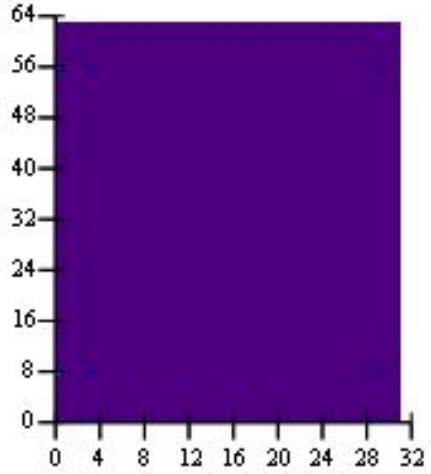
P

$FP := CFFT(P)$

$AFP_{i,j} := |FP_{i,j}| \qquad PFP := funPF(FP, 0)$



AFP



AFP

Статистический анализ

$N := 4096 \qquad i := 0..(N-1)$

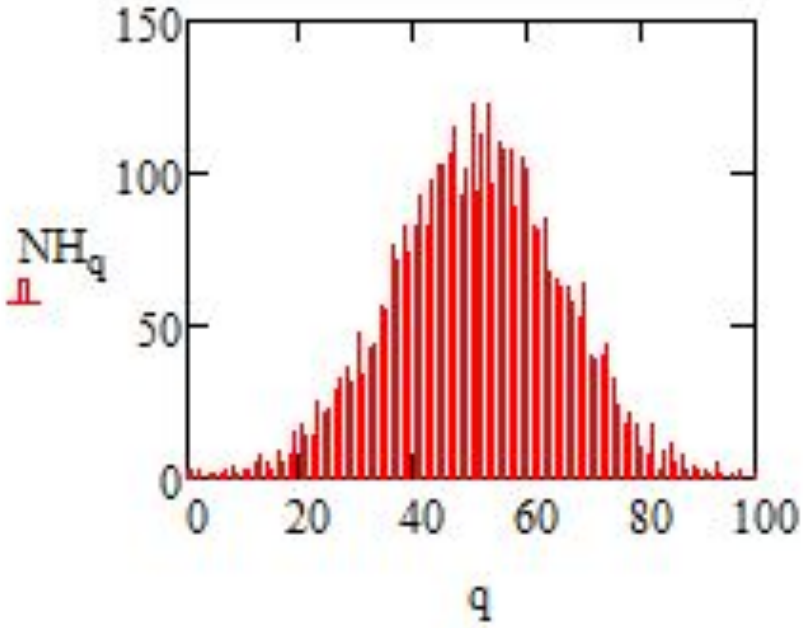
$Noise := morm(N, 0, 0.1)$

$$
\begin{aligned}
&NHist(X, Q) := \left|
\begin{array}{l}
mn \leftarrow \min(X) \\
mx \leftarrow \max(X) \\
\Delta \leftarrow \dfrac{mx - mn}{Q} \\
\text{for } q \in 0..Q \\
\quad H_q \leftarrow 0 \\
m \leftarrow \text{rows}(X) \\
n \leftarrow \text{cols}(X) \\
\text{for } i \in 0..(m-1) \\
\quad \text{for } j \in 0..(n-1) \\
\qquad H_{\text{floor}\left[\frac{(X_{i,j}-mn)}{\Delta}\right]} \leftarrow H_{\text{floor}\left[\frac{(X_{i,j}-mn)}{\Delta}\right]} + 1 \\
H
\end{array}
\right.
\end{aligned}
$$

$Q := 100$

$q := 0 .. Q$

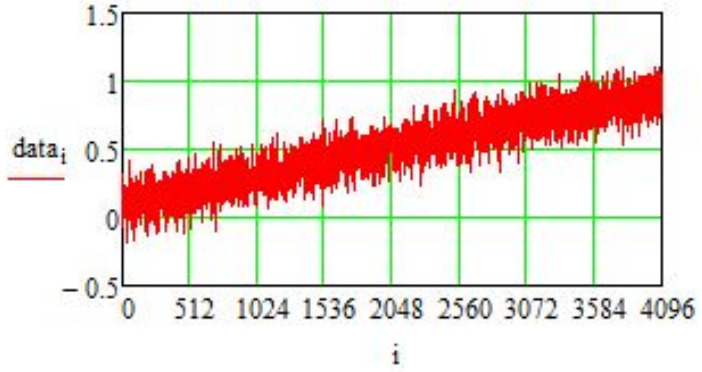
$NH := NHist(Noise, Q)$



$$\sum_q NH_q = 4096$$

Регрессионный анализ

$data_i := 0.0002 \cdot i + 0.1 + Noise_i$

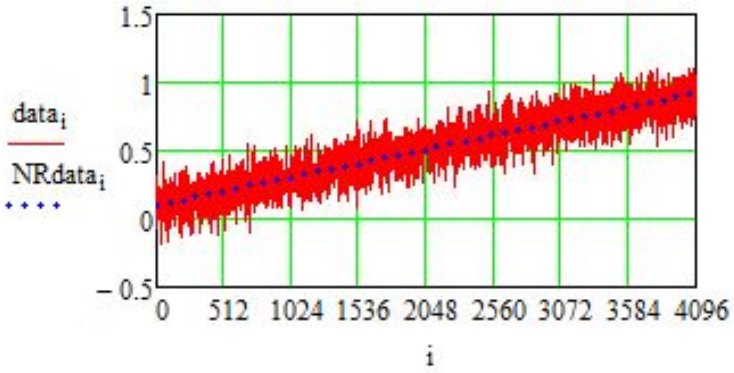


$x_i := i$

$Rdata := line(x, data)$

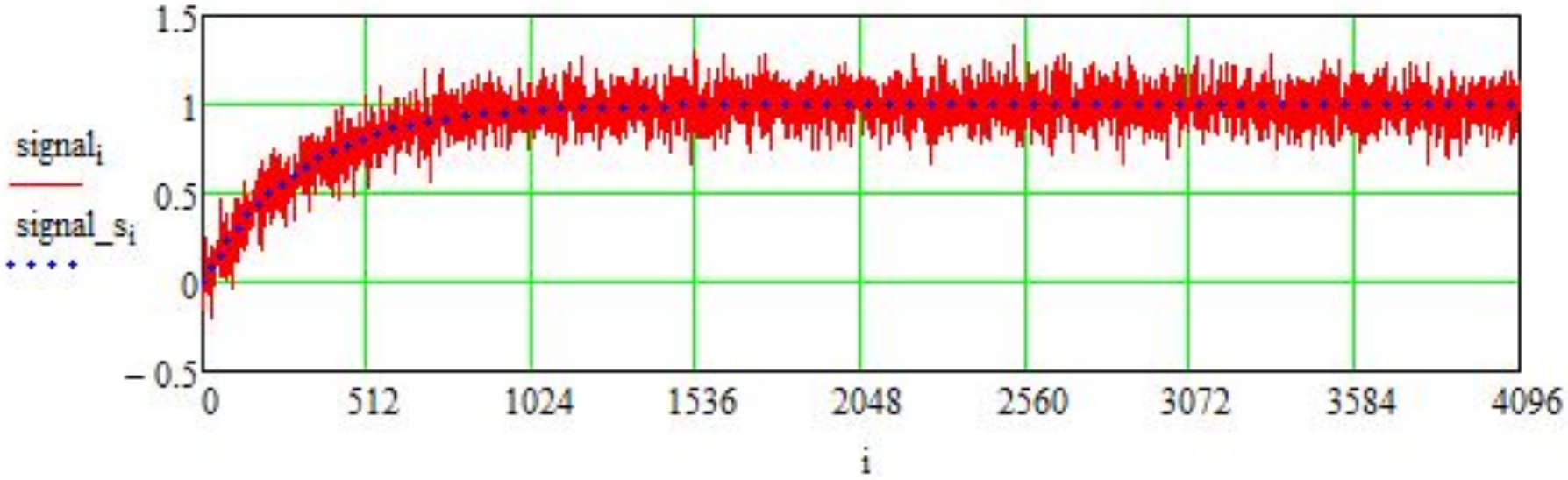
$$Rdata = \begin{pmatrix} 0.098272 \\ 0.000201 \end{pmatrix}$$

$NRdata_i := Rdata_0 + Rdata_1 \cdot x_i$



$$signal_i := 1 - e^{\frac{-i}{300}} + Noise_i \qquad signal_s_i := 1 - e^{\frac{-i}{300}}$$

$$\sum_i \left| signal_i - signal_s_i \right| = 323.832$$

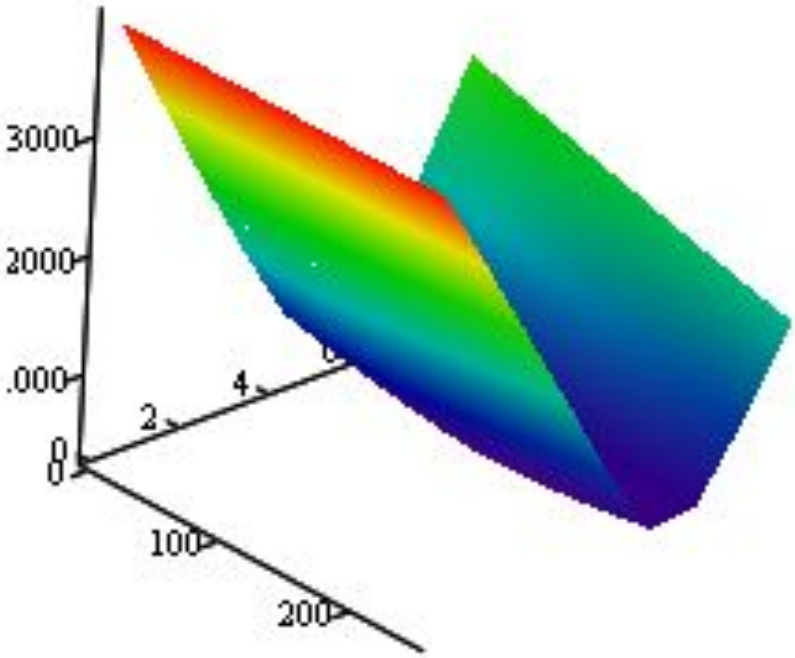


$$
\begin{aligned}
&\text{err}(X, a, bmax, bstep, Tmax, Tstep) := \\
&\quad N \leftarrow \text{rows}(X) \\
&\quad T \leftarrow 1 \\
&\quad kT \leftarrow 0 \\
&\quad \text{while } (T < Tmax) \\
&\qquad b \leftarrow 0 \\
&\qquad kb \leftarrow 0 \\
&\qquad \text{while } (b < bmax) \\
&\qquad\quad \Sigma\Delta_{kT,kb} \leftarrow \sum_{n=0}^{N-1} \left| X_n - a - b \cdot \left(1 - e^{\frac{-n}{T}}\right) \right| \\
&\qquad\quad b \leftarrow b + bstep \\
&\qquad\quad kb \leftarrow kb + 1 \\
&\qquad T \leftarrow T + Tstep \\
&\qquad kT \leftarrow kT + 1 \\
&\quad \Sigma\Delta
\end{aligned}
$$

bstep := 0.2 Tstep := 2

$$Err := err(signal, signal_0, 1.6, bstep, 500, Tstep)$$

min(Err) = 350.568



Err

$$fmin(X) := \left| \begin{array}{l} Y \leftarrow \begin{pmatrix} 0 \\ 0 \end{pmatrix} \\ mn \leftarrow X_{(Y_0), Y_1} \\ m \leftarrow rows(X) \\ n \leftarrow cols(X) \\ \text{for } i \in 0..(m-1) \\ \quad \text{for } j \in 0..(n-1) \\ \quad\quad \text{if } (X_{i,j} < mn) \\ \quad\quad\quad \left| \begin{array}{l} Y \leftarrow \begin{pmatrix} i \\ j \end{pmatrix} \\ mn \leftarrow X_{i,j} \end{array} \right. \\ Y \end{array} \right.$$

$$\mathrm{fmin}(\mathrm{Err}) = \begin{pmatrix} 129 \\ 5 \end{pmatrix}$$

$$T := \mathrm{fmin}(\mathrm{Err})_0 \cdot \mathrm{Tstep} = 258$$

$$b := \mathrm{fmin}(\mathrm{Err})_1 \cdot \mathrm{bstep} = 1$$

$$a := \mathrm{signal}_0 = -0.044$$

Результирующая зависимость

$$a + b \cdot \left(1 - e^{\frac{-i}{T}}\right)$$