



MINISTÉRIO DA CIÊNCIA E TECNOLOGIA  
**INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS**

## ***Introdução ao DPCM para compressão de imagens da câmera PAN do CBERS-3&4***

***Desenvolvido por CAST, CRESDA***

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***Leila Maria Garcia Fonseca .....DPI/INPE***



**中国航天**



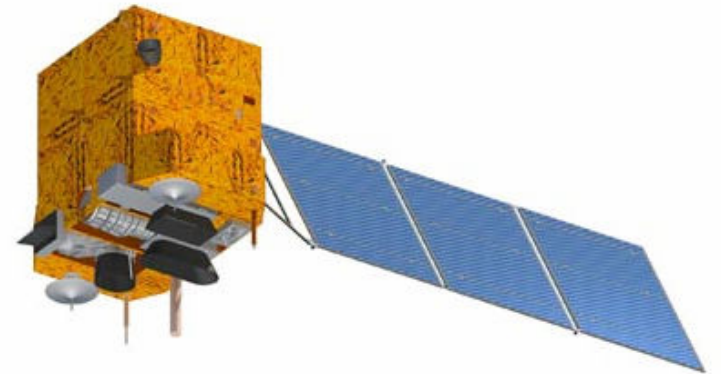
# **Introdução ao DPCM**

**DPCM do CBERS-03/04 (PAN)**

**Análise objetiva de qualidade**

**Análise visual de qualidade**

# CBERS-3&4



## Especificações técnicas CBERS-03/04

Payload	Band no.	Spectral range (μm)	Swath width (km)	Side-looking ability	Repetition cycle (days)	Spatial resolution (m)
Panchromatic & Multispectral Camera (PAN)	B01	0.51~0.85	60	±32°	3	5
	B02	0.52~0.59				10
	B03	0.63~0.69				
	B04	0.77~0.89				

Imagem da camera Pan CBERS-03/04 deve ser comprimida.

## Requisitos do compressor:

- ★ **Processamento** rápido;

  - Bom **desempenho** de compressão;

  - Boa **qualidade** da imagem recuperada;

- ★ **Baixa complexidade** computacional;

  - ★ **Fácil implementação** em FPGA.



# Modelos de Sistemas de Compressão de Imagem

# Métodos de Compressão



## Sem perda

Permite recuperar a  
imagem original

## Com perda

Permite maior compressão



# Métodos de Compressão



**Domínio espacial**

Métodos Preditivos

**Domínio da frequência**

Métodos baseados em Transformadas





# DPCM

**DPCM**

1950 ...

**JPEG**

Lossless JPEG

1992

1993

...

**JPEG-LS**

1999

2000

...

**CCSDS**

2005

2006

...

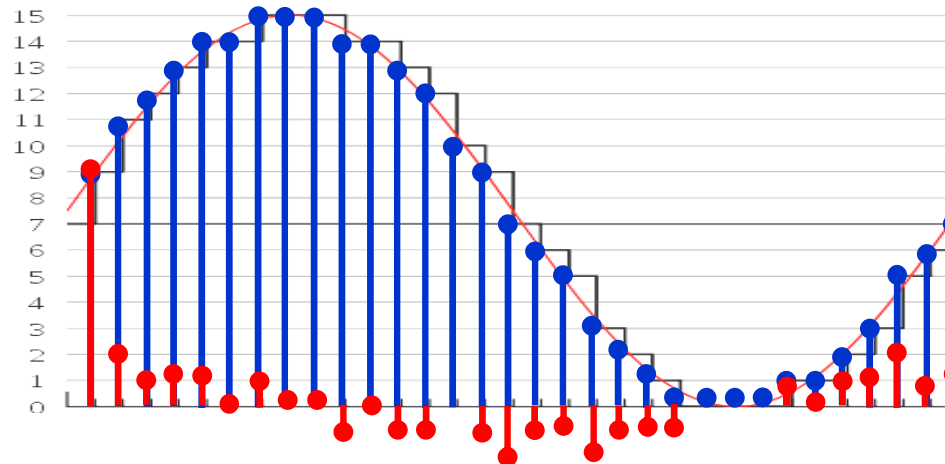
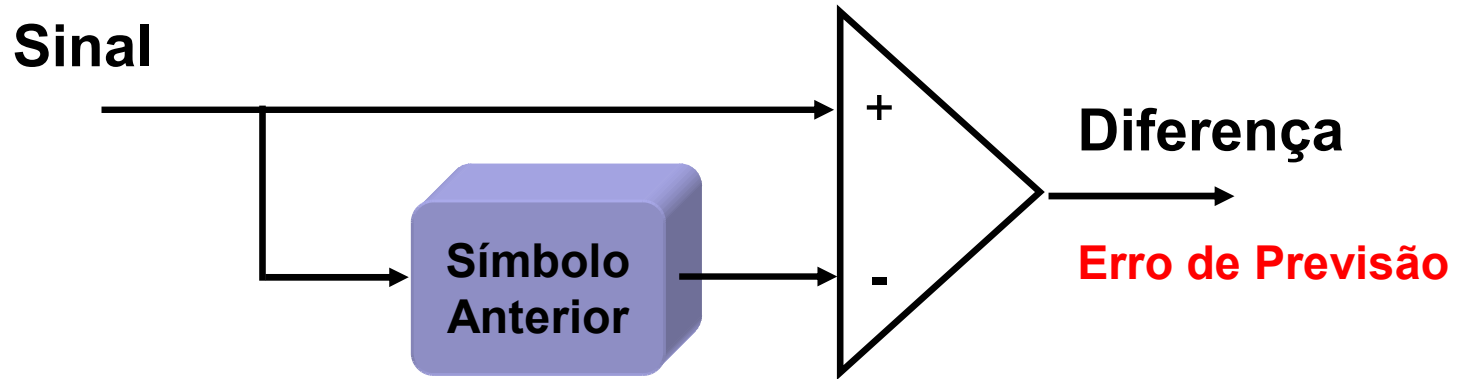
**JPEG-XR**

2009

**LOCO-I**

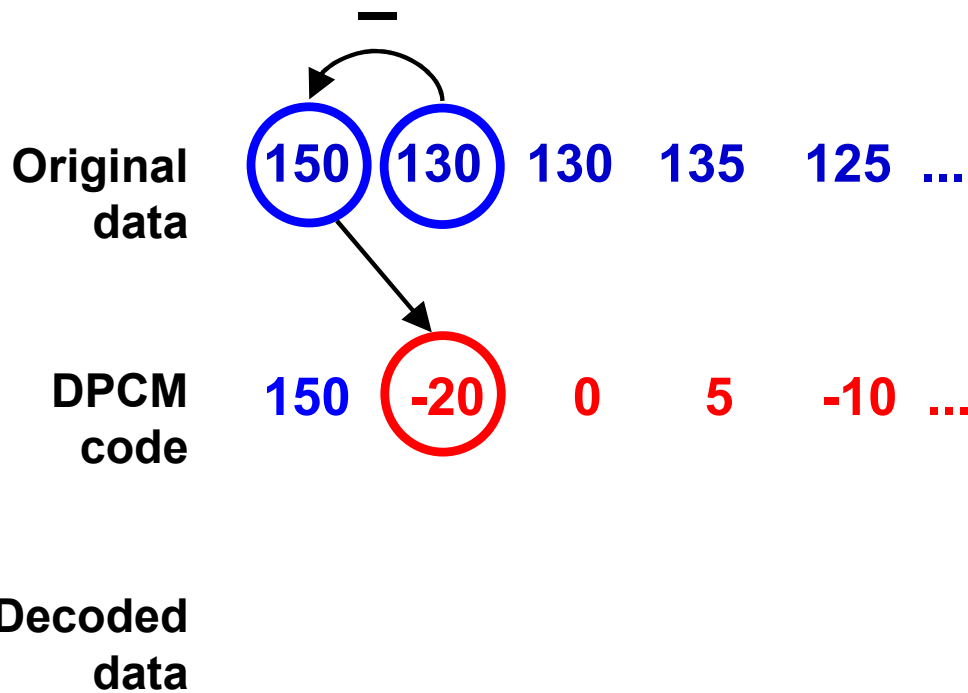
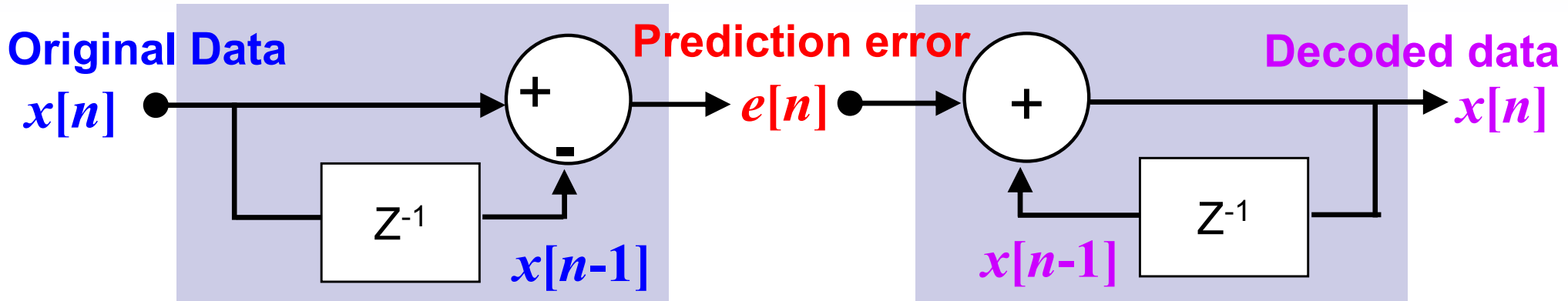
# DPCM

## Modulação por Codificação de Pulso Diferencial



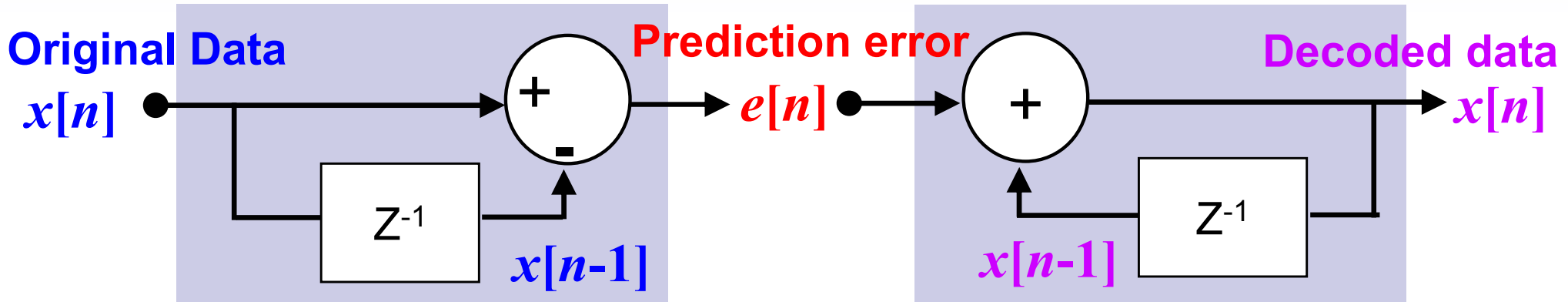
Sinal	9	11	12	13	14	14	15	15	15	14 ...
DPCM	9	2	1	1	1	0	1	0	0	-1 ...

# Compressor preditivo sem perda



$$e[n] = x[n] - x[n-1]$$

# Compressor preditivo sem perda



Original data    150   130   130   135   125 ...

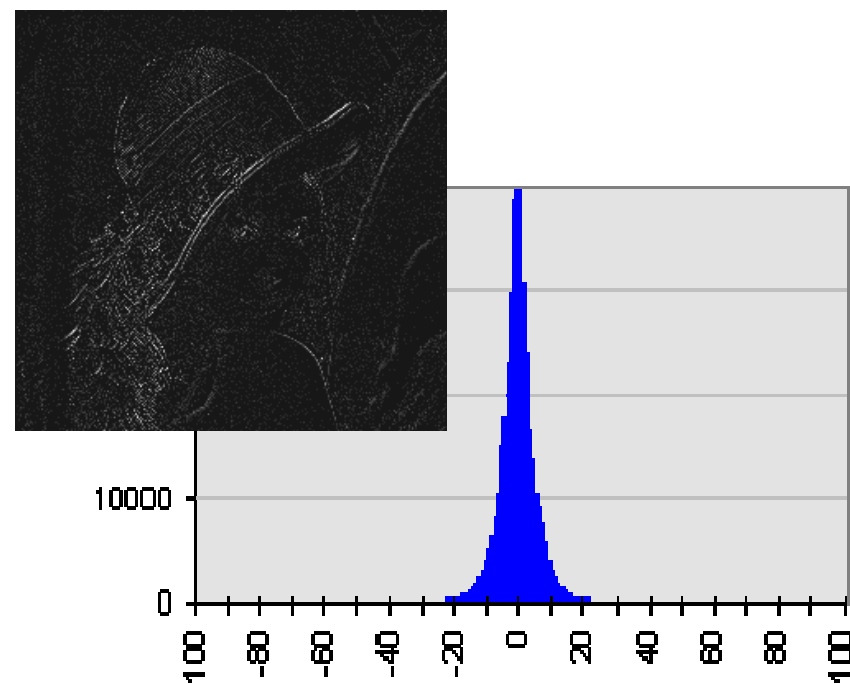
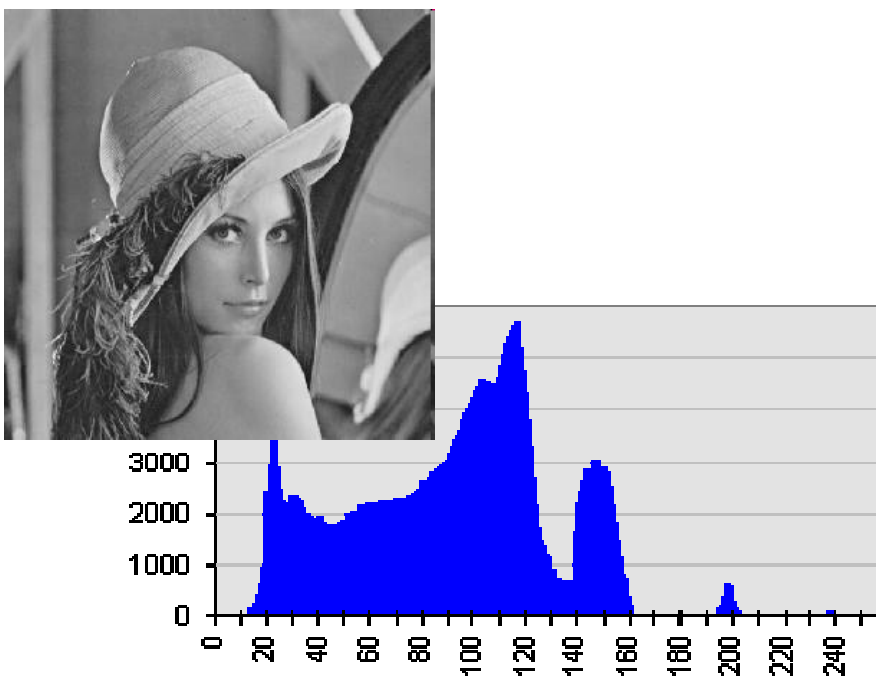
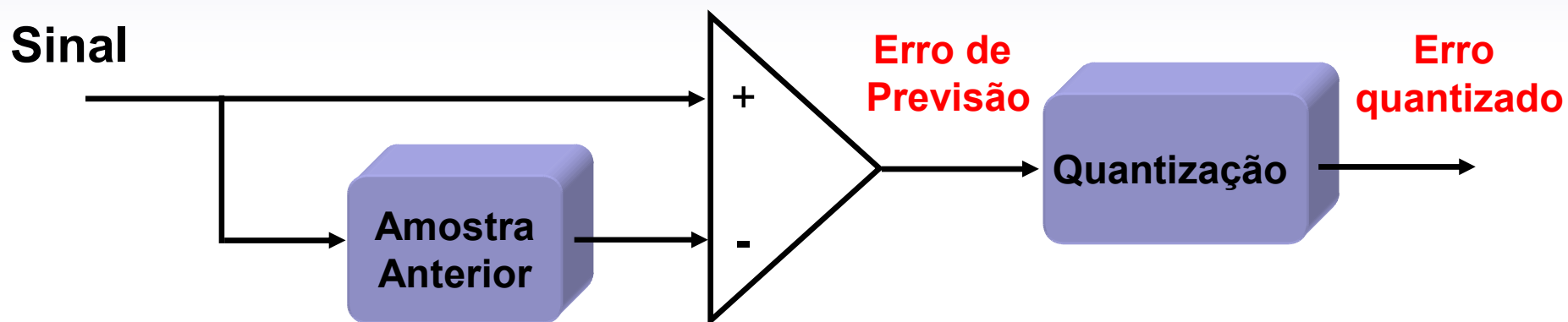
DPCM code    150   **-20**   0   5   -10 ...

Decoded data    **150**   **130**   130   135   125 ...

$$e[n] = x[n] - x[n-1]$$

$$x[n] = x[n-1] + e[n]$$

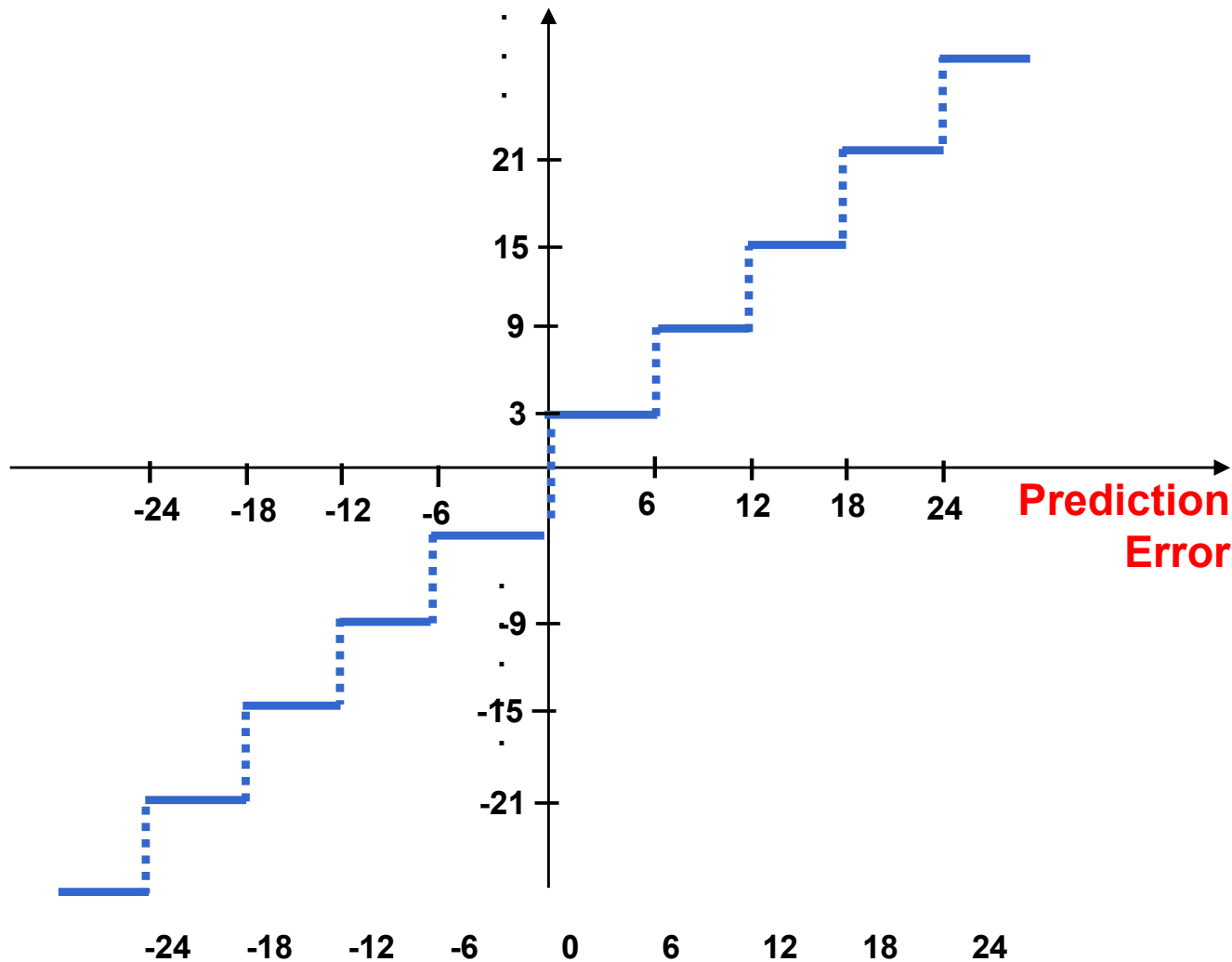
# Compressor preditivo sem perda



**Sem compressão**

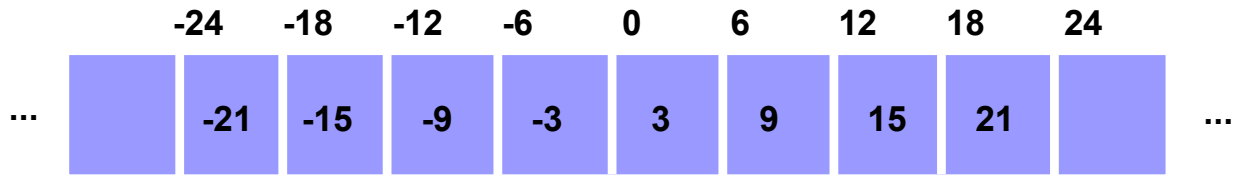
# Quantização do erro de predição

Quantized error

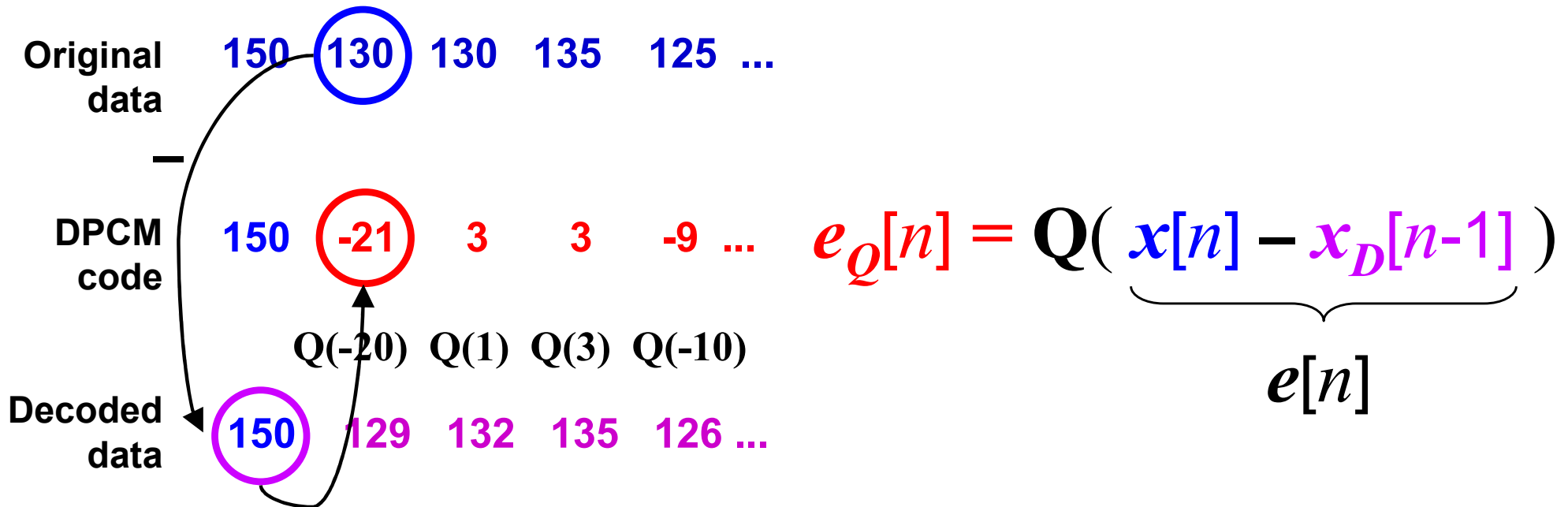
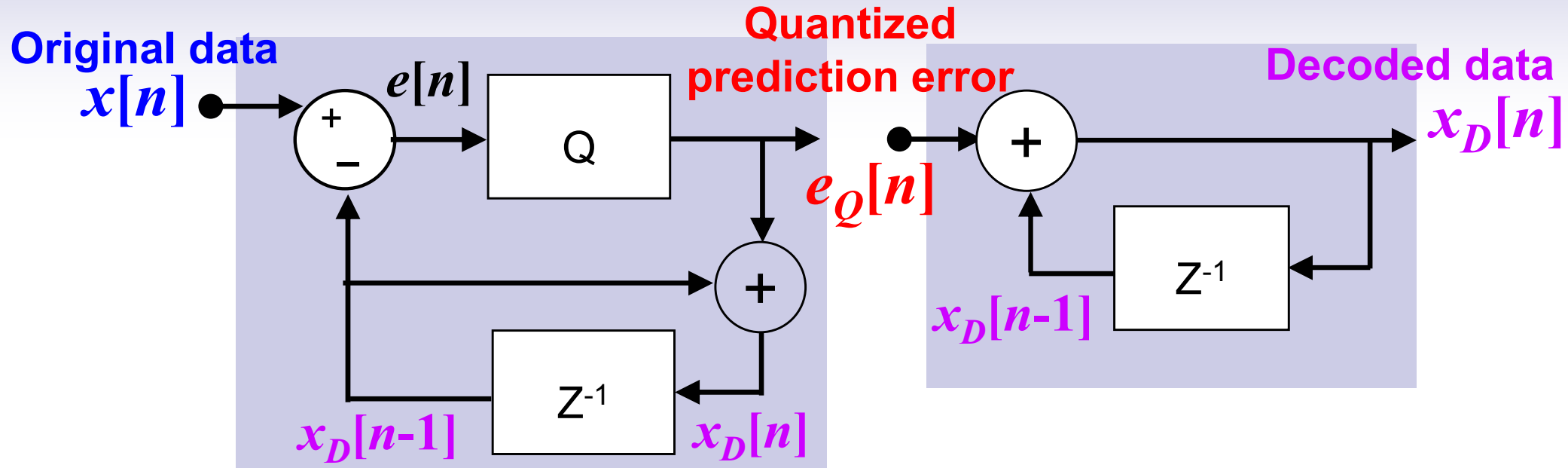


**Prediction error**   **Quantized error**

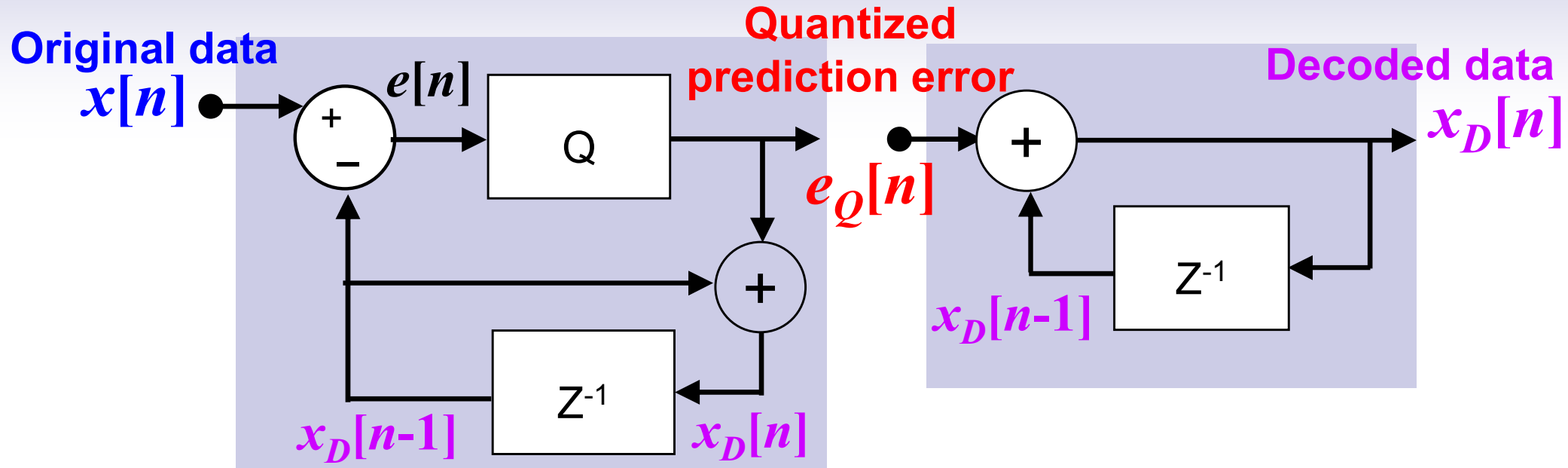
	.	.
	.	.
	.	.
[ 18, 23]		21
[ 12, 17]		15
[ 6, 11]		9
[ 0, 5]		3
[ -6, -1]		-3
[ -12, -7]		-9
[ -18, -13]		-15
[ -24, -19]		-21
	.	.
	.	.
	.	.



# DPCM



# DPCM



Original data    150   130   130   135   125 ...

DPCM code    150   **-21**   3   3   -9 ...

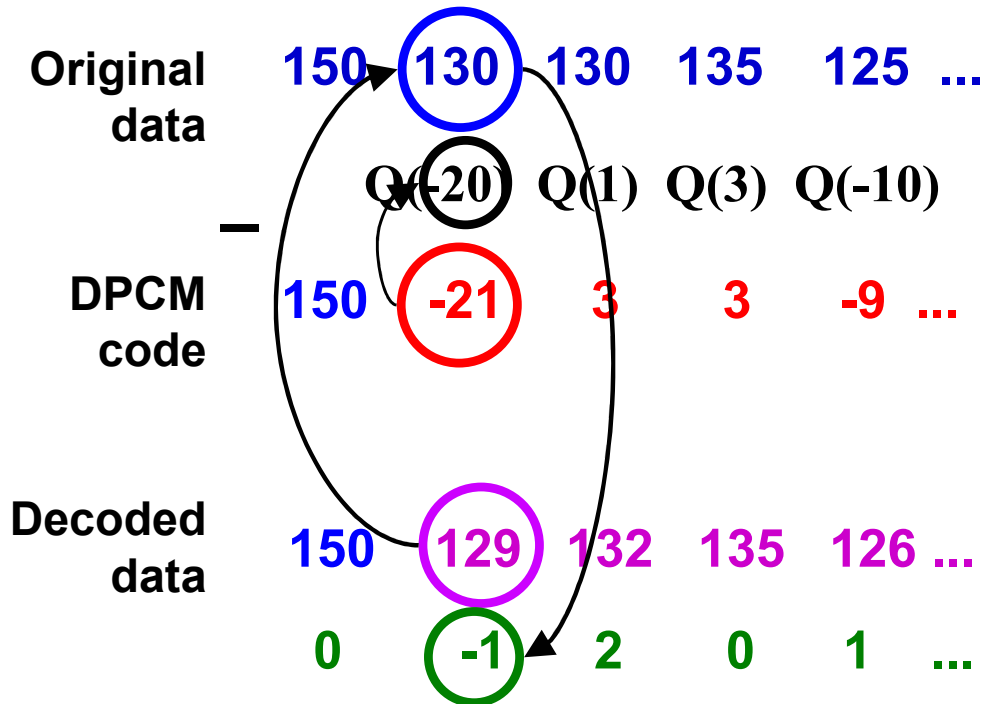
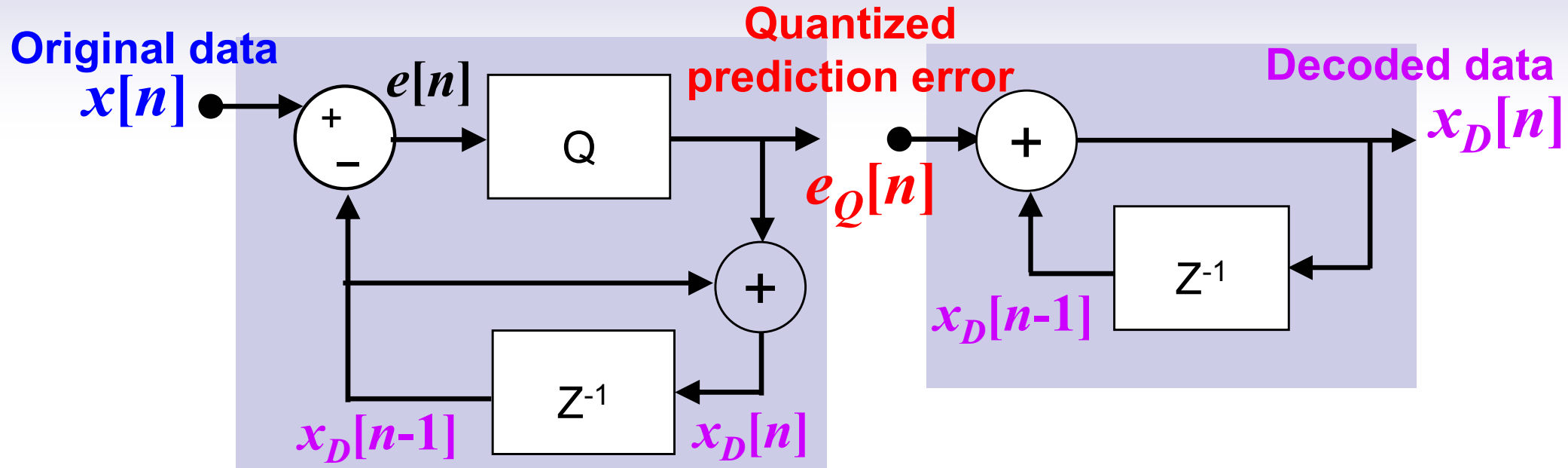
Decoded data    **150**   **129**   132   135   126 ...

*Decodificação dentro da codificação*

$$x_D[n] = x_D[n-1] + e_Q[n]$$



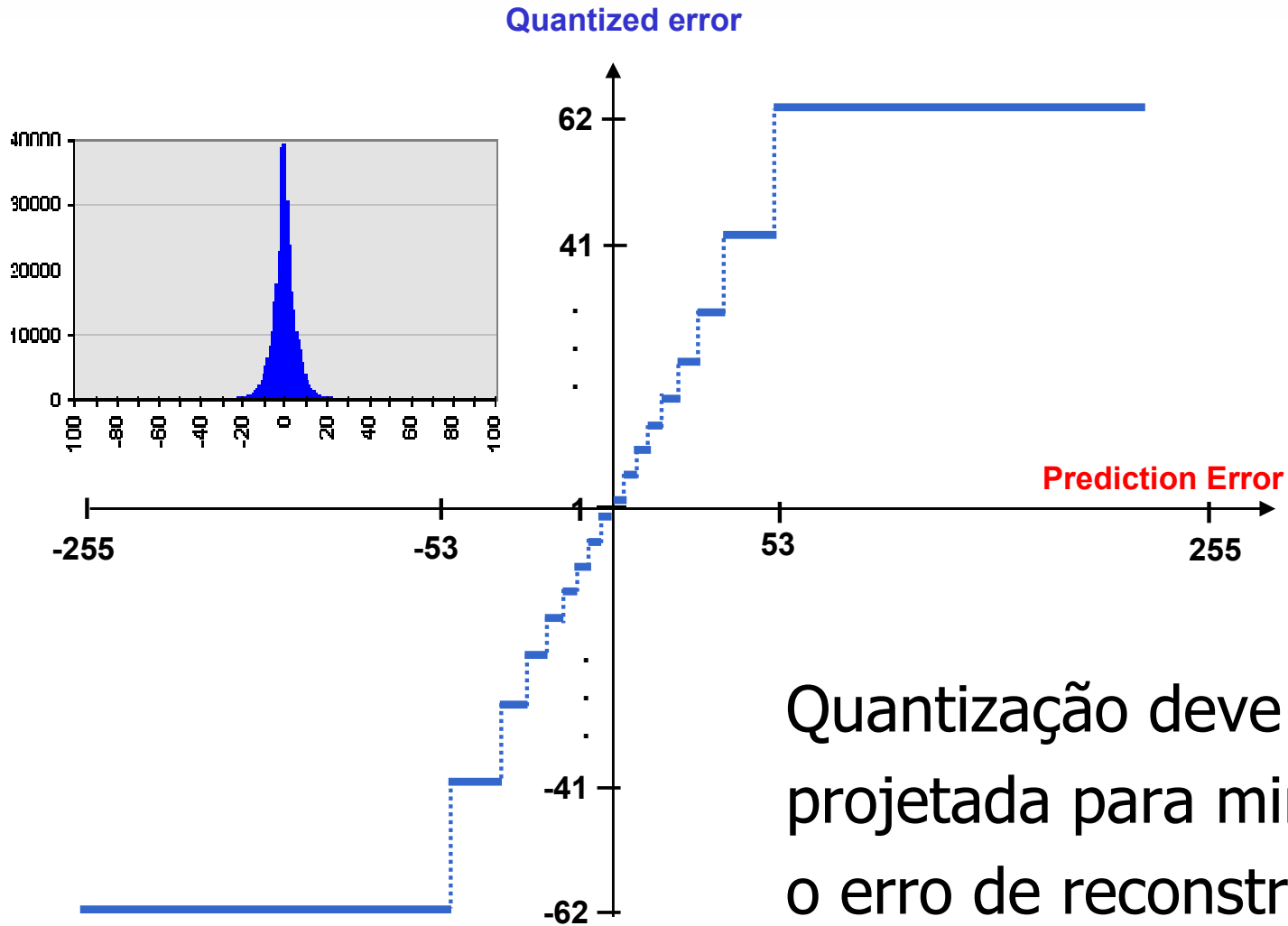
# DPCM



$$x_D[n] - x[n] = e_Q[n] - e[n]$$

Erro de reconstrução =  
Erro de quantização

# Quantização do erro de predição



# DPCM

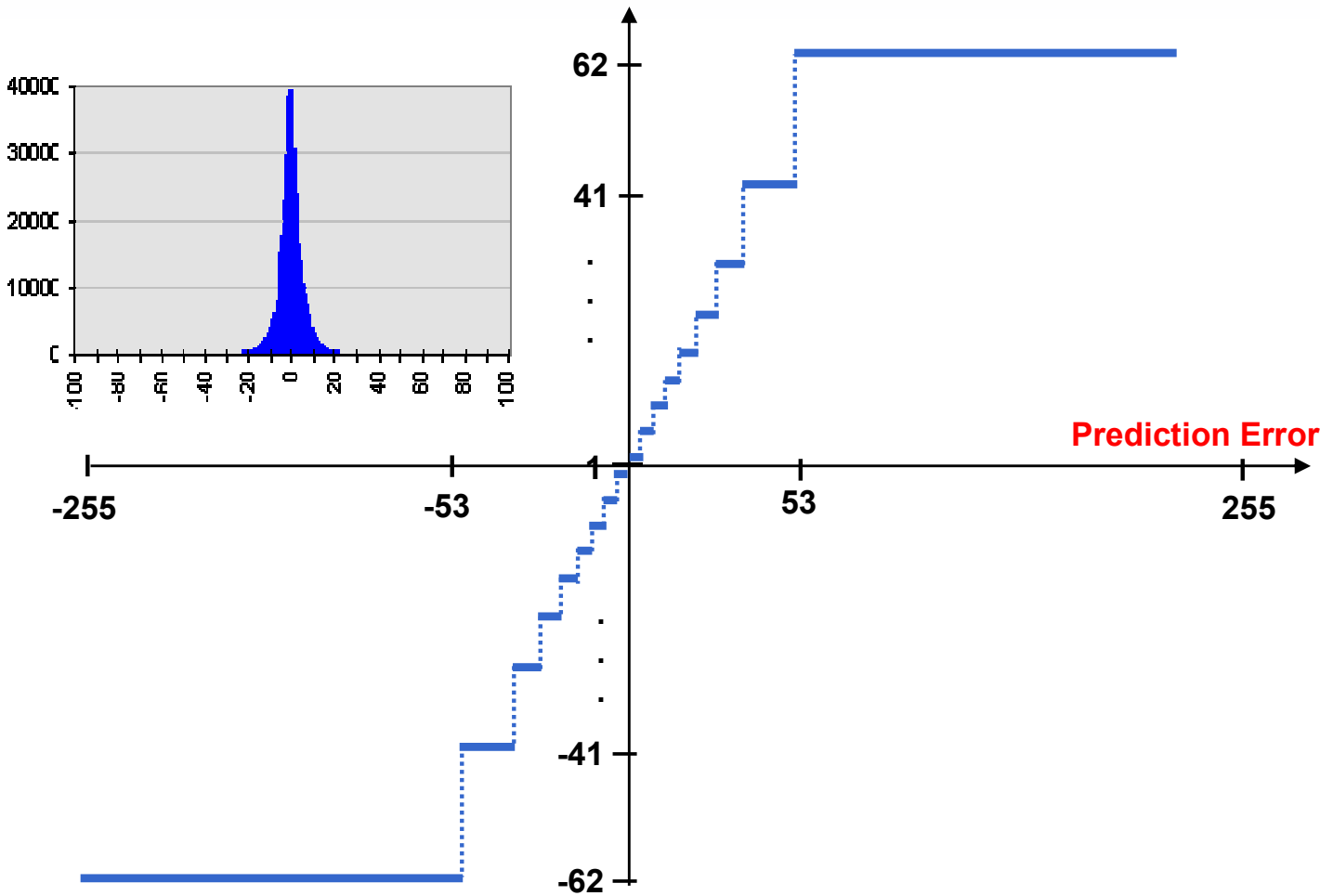
*Sub-System of PANMUX\_IRMSS  
Onboard CBERS 3 & 4 Satellites*



Source: Introduction to DPCM Encoding Algorithm in Data Transmission: Sub-system of PANMUX\_IRMSS Onboard CBERS 3&4 Satellites, CAST, CRESDA, August 3, 2010.

# Quantização do erro de predição

Quantized error

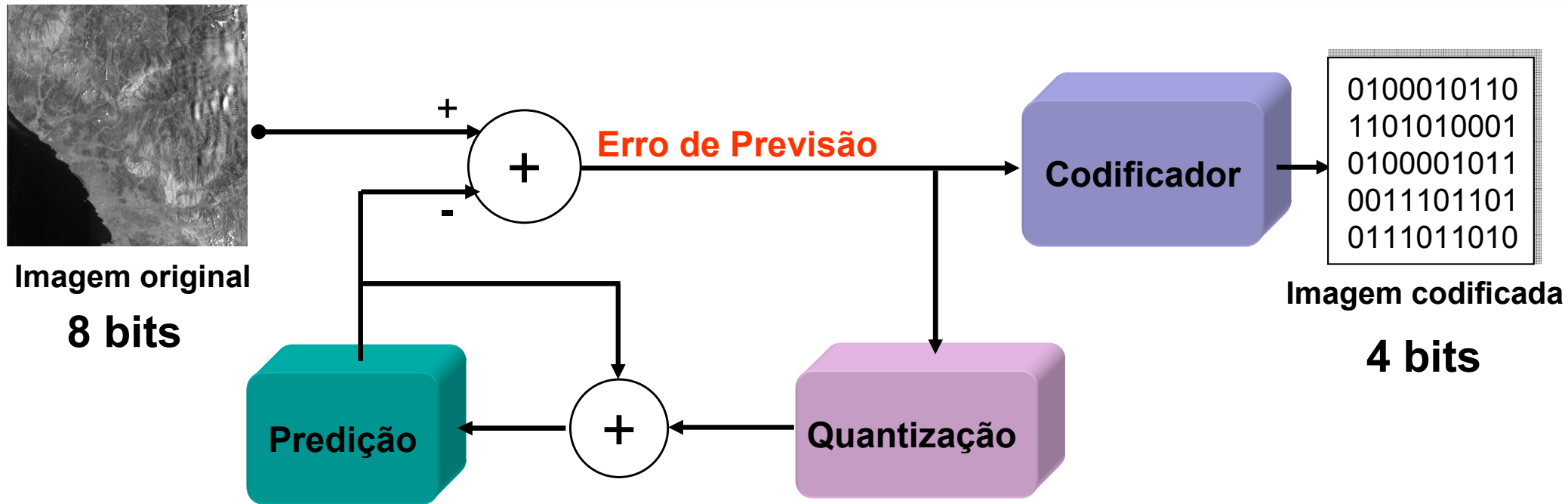


Prediction error	Quantized error	Code
[ 53, 255]	62	0111
[ 36, 52]	41	0110
[ 26, 35]	29	0101
[ 19, 25]	21	0100
[ 13, 18]	15	0011
[ 8, 12]	9	0010
[ 4, 7]	5	0001
[ 0, 3]	1	0000
[ -3, -1]	-1	1000
[ -7, -4]	-5	1001
[ -12, -8]	-9	1010
[ -18, -13]	-15	1011
[ -25, -19]	-21	1100
[ -35, -26]	-29	1101
[ -52, -36]	-41	1110
[ -255, -53]	-62	1111



4 bits

# Codificador DPCM

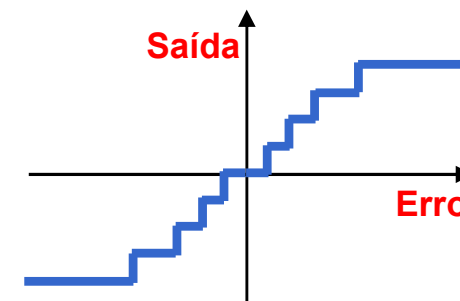
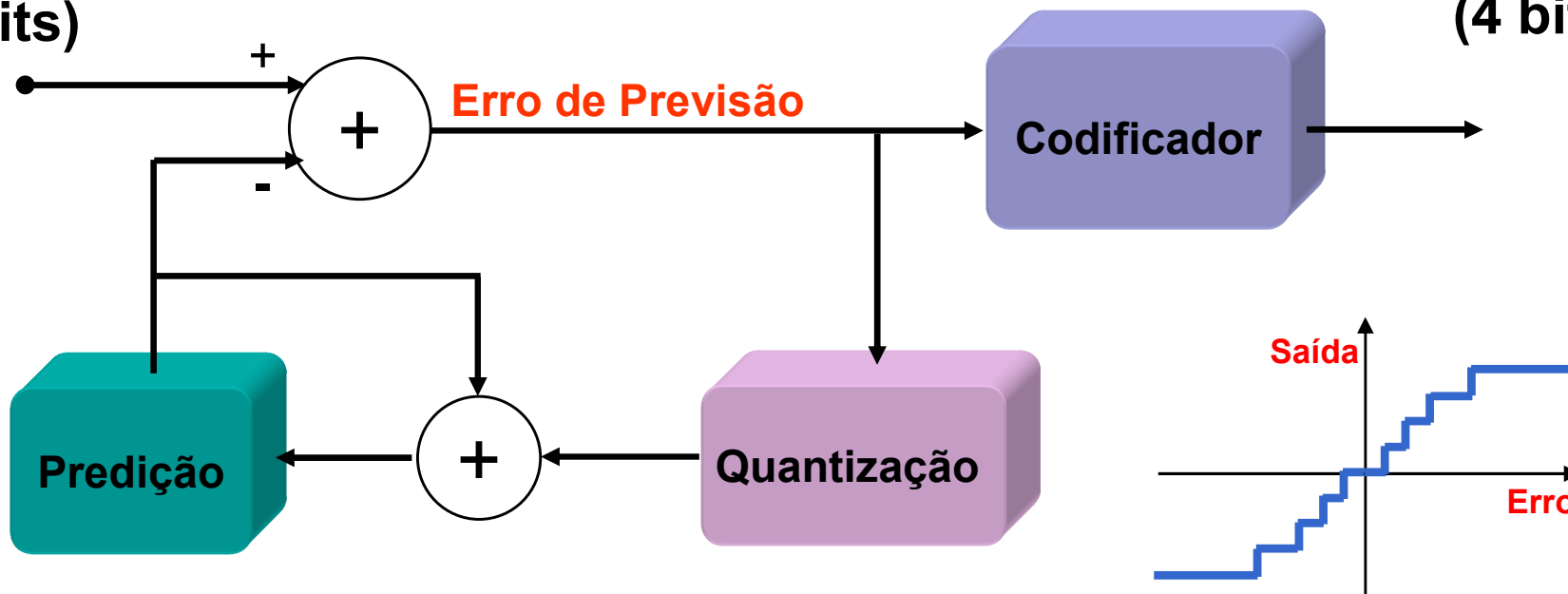


**Taxa de Compressão**  
**2:1**

# Codificador DPCM

Entrada  
(8 bits)

Saída  
(4 bits)



-233	-52	-35	-25	-18	-12	-7	-3	0	4	8	13	19	26	36	53	255
1111	1110	1101	1100	1011	1010	1001	1000	0000	0001	0010	0011	0100	0101	0110	0111	

Tabela de codificação do erro quantizado

# Codificador DPCM

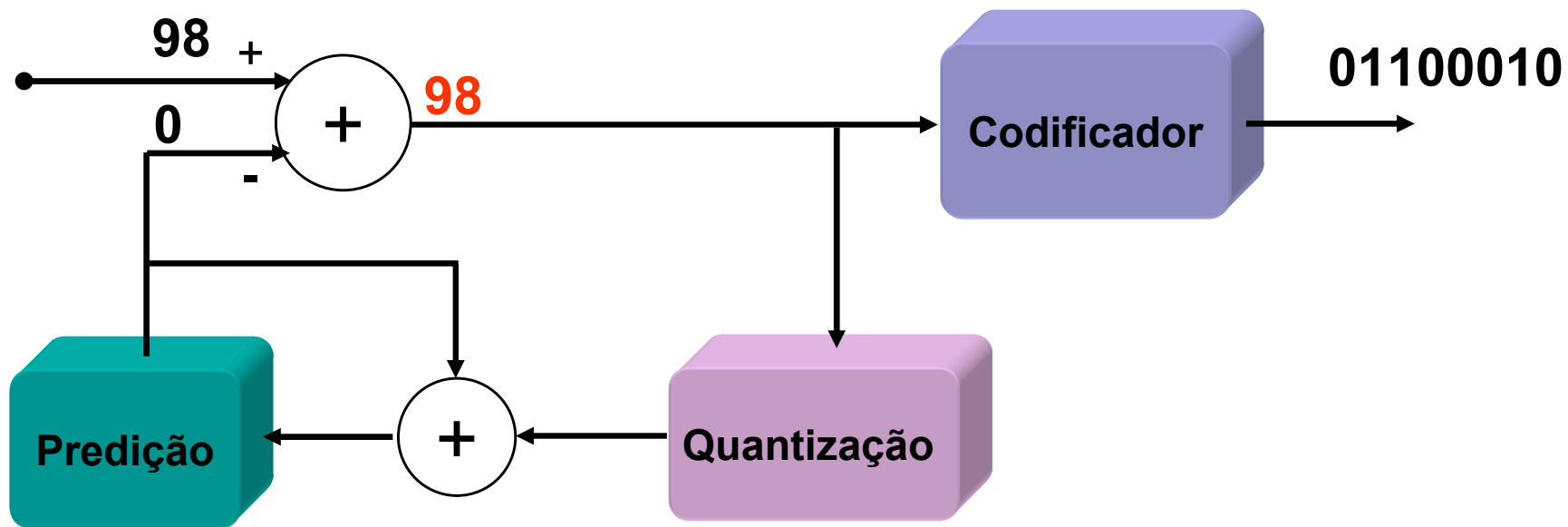
98

95

86

84

01100010



# Codificador DPCM

98

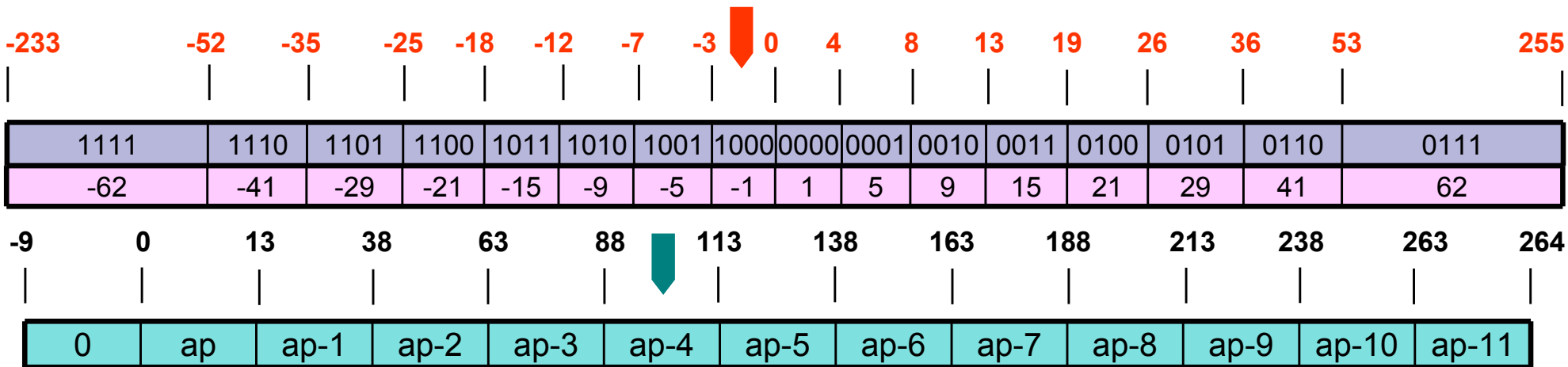
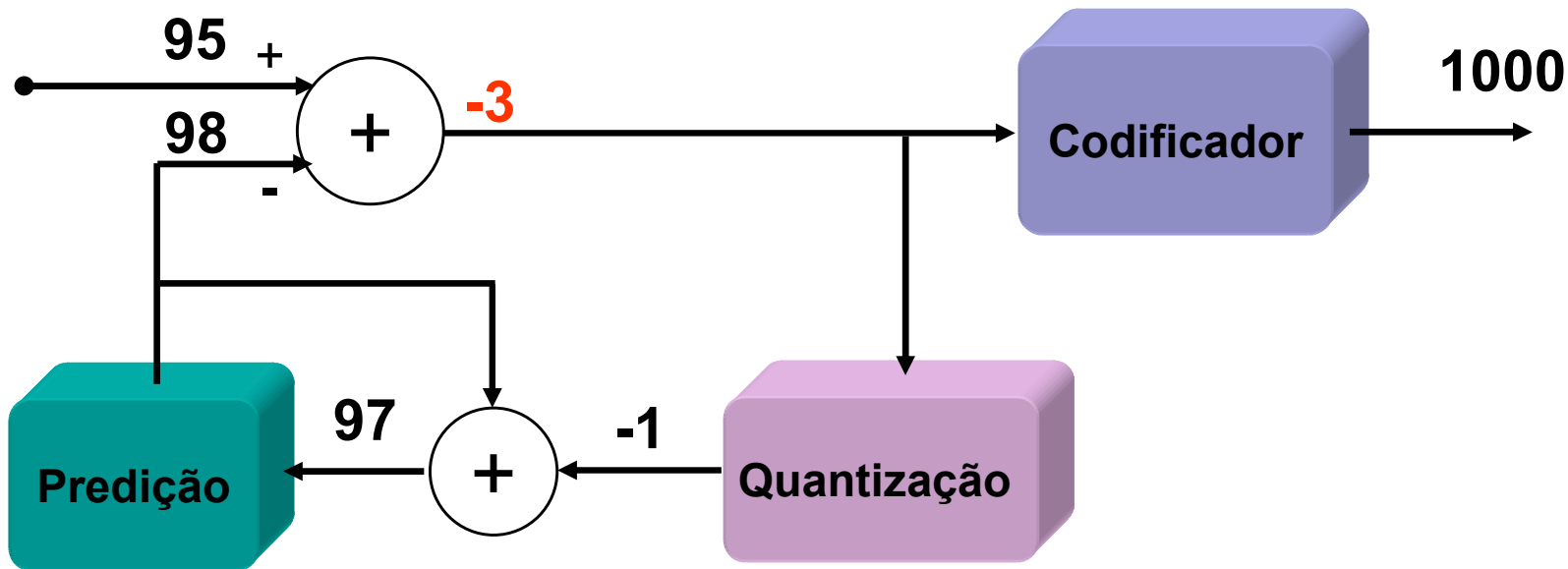
95

86

84

01100010

1000

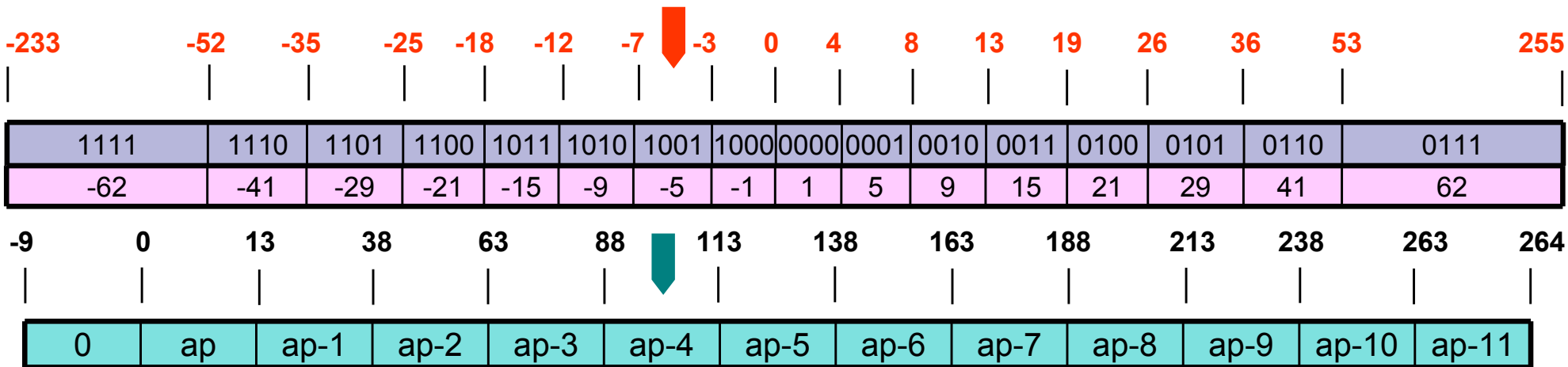
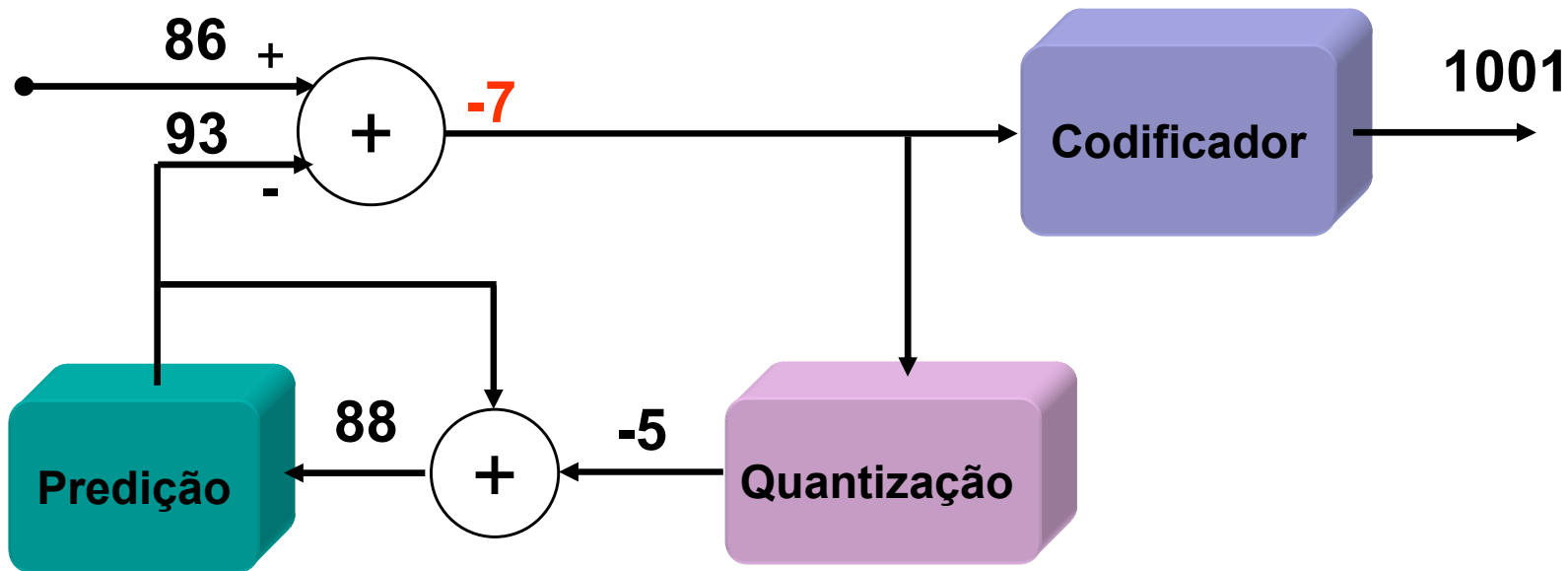




# Codificador DPCM

98    95    **86**    84

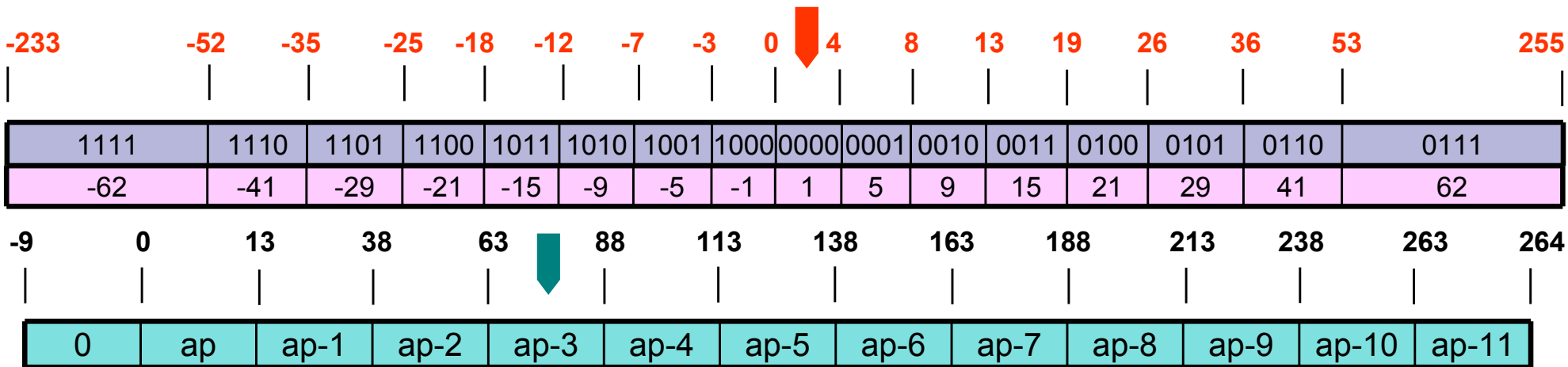
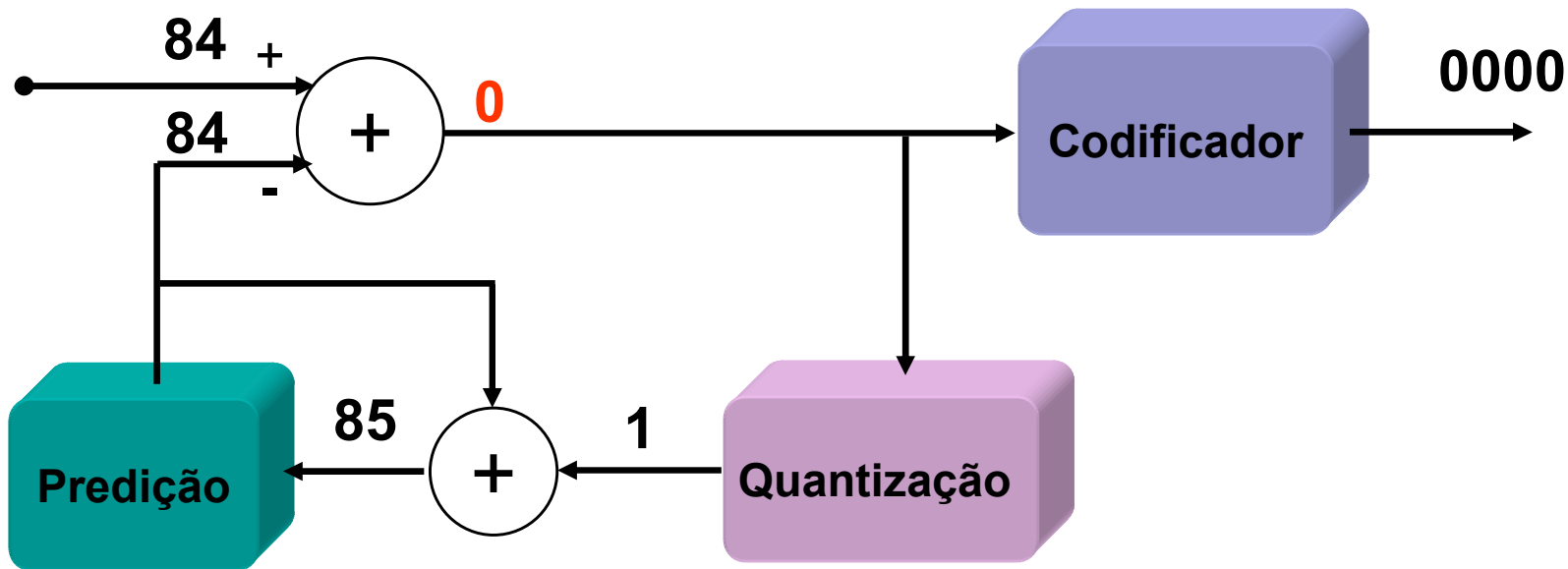
01100010    1000    1001



# Codificador DPCM

98    95    86    **84**

01100010    1000    1001    0000



# Codificador DPCM

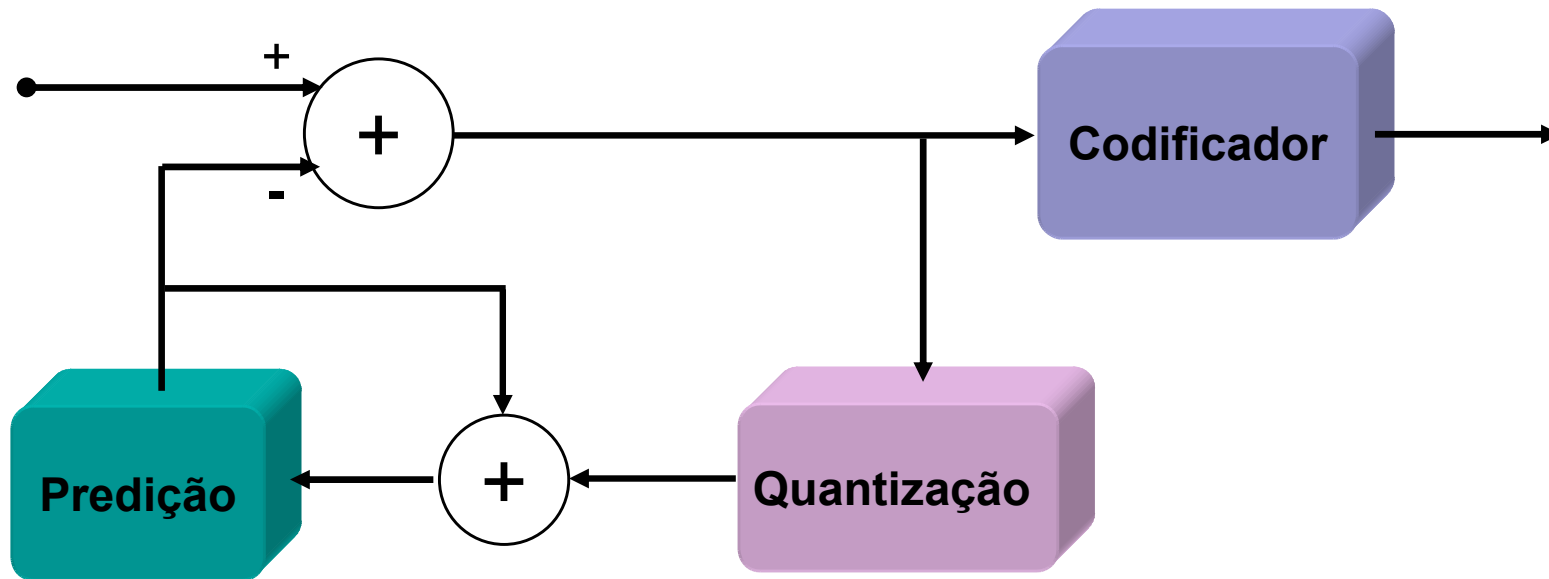
98

95

86

84

01100010 1000 1001 0000 ...

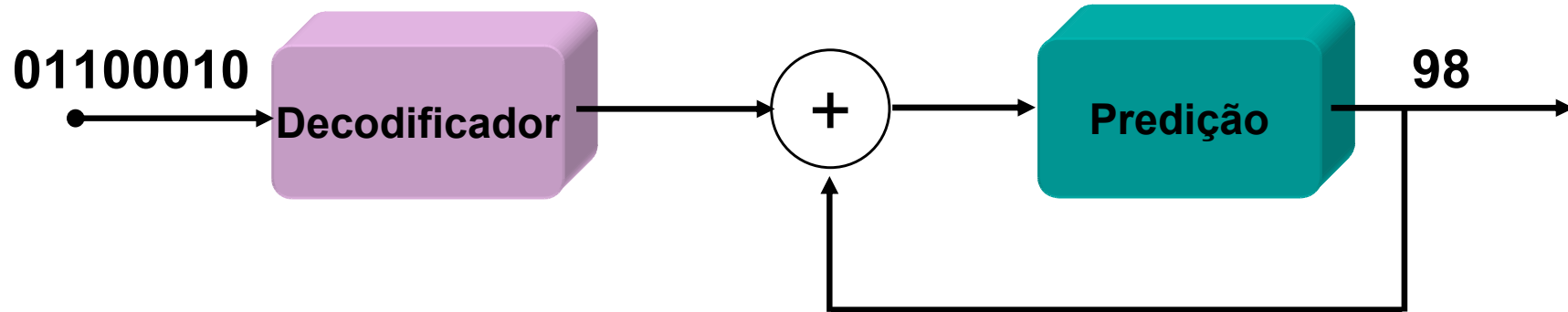


Fim da Codificação

# Decodificador DPCM

01100010 1000 1001 0000

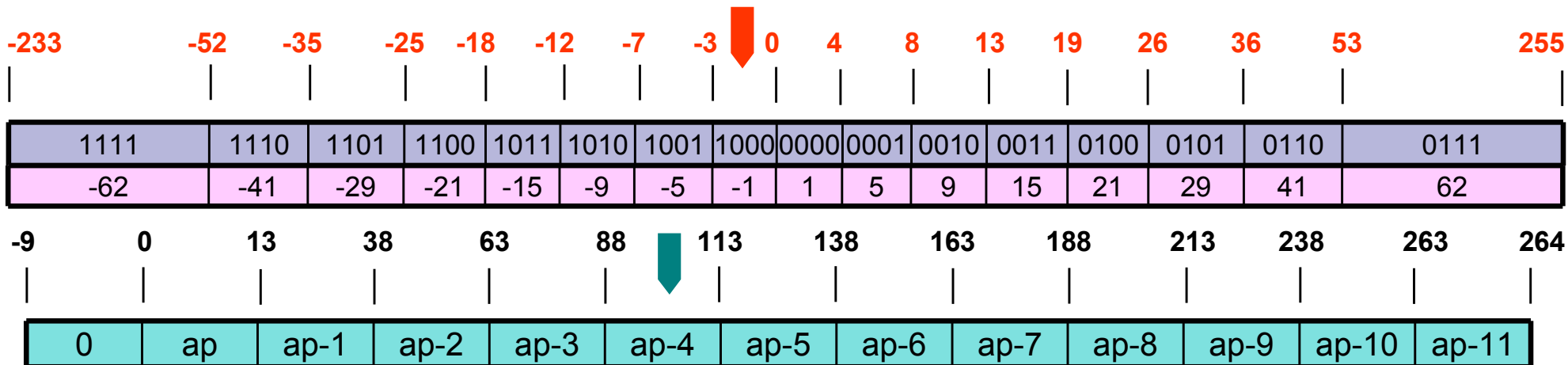
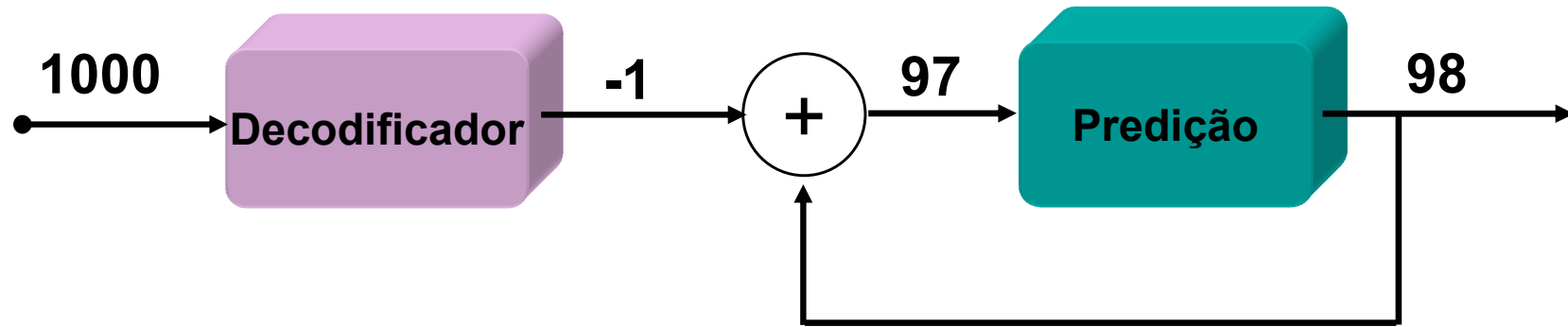
98



# Decodificador DPCM

01100010 **1000** 1001 0000

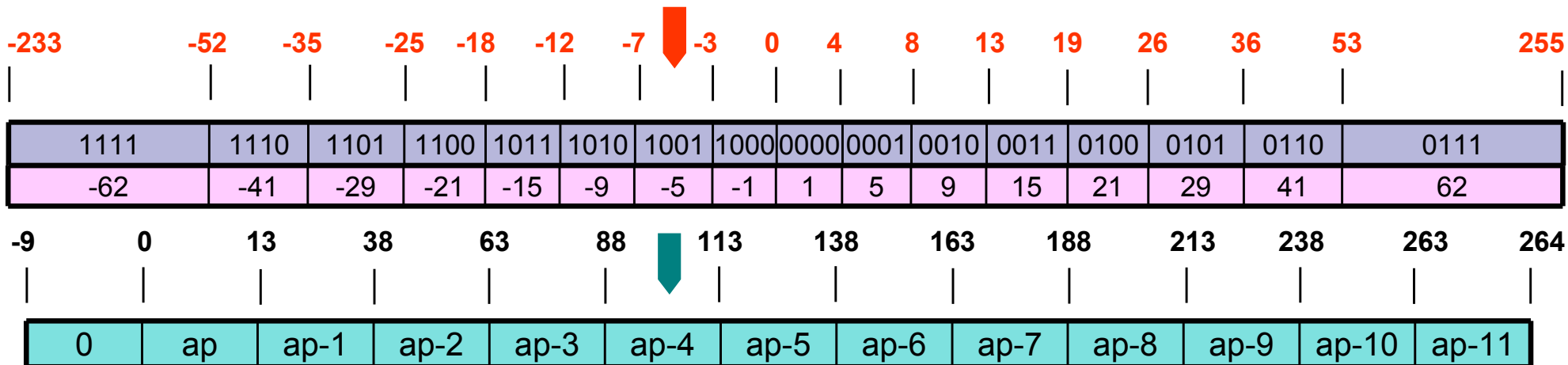
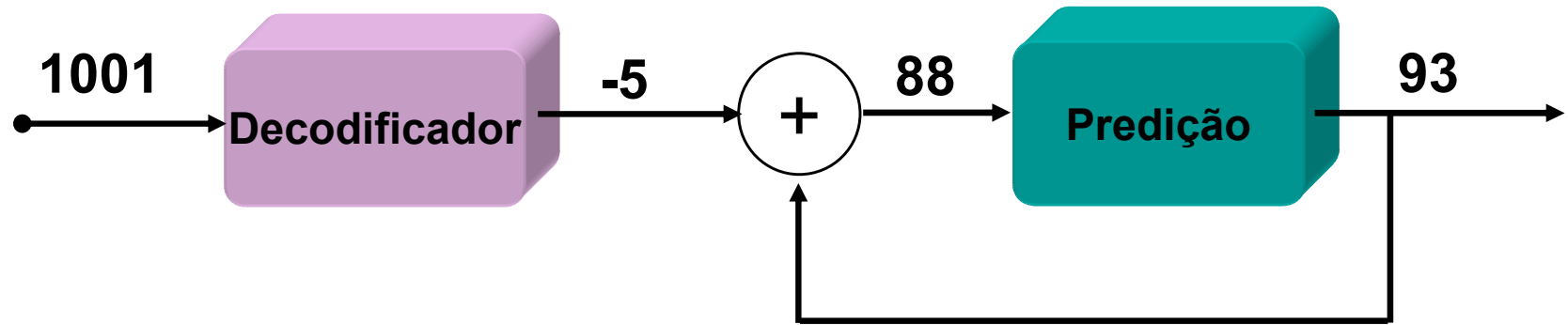
98



# Decodificador DPCM

01100010 1000 **1001** 0000

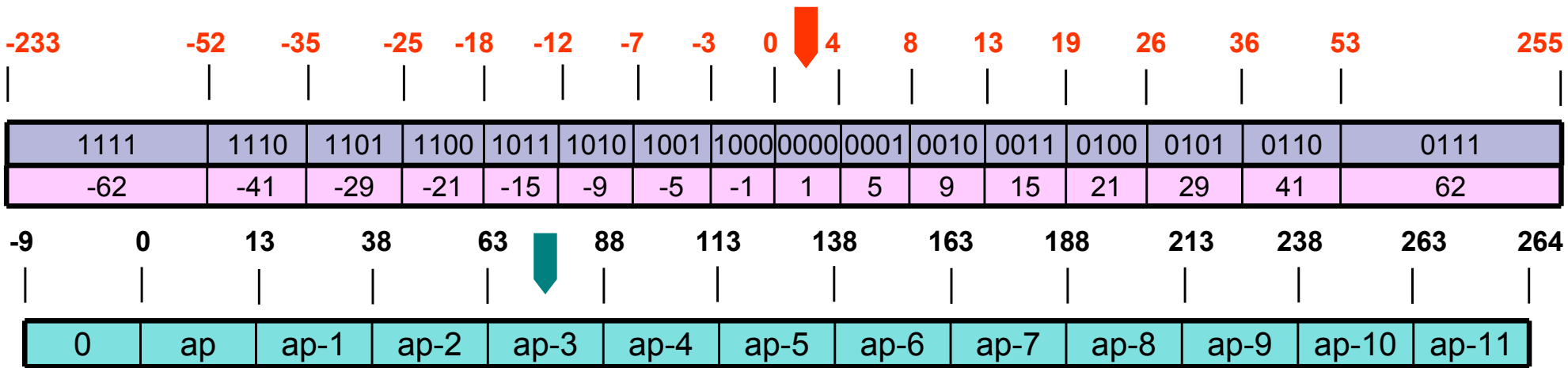
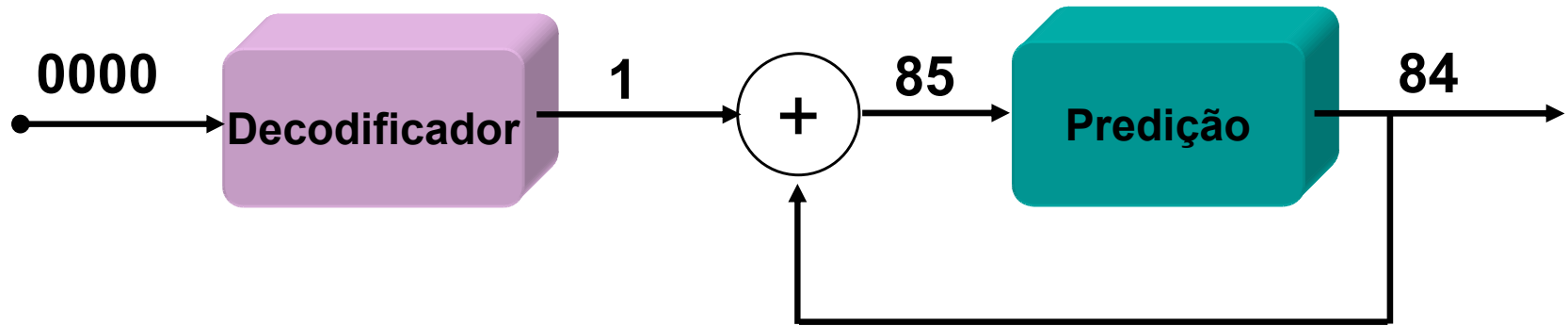
98 93



# Decodificador DPCM

01100010 1000 1001 **0000**

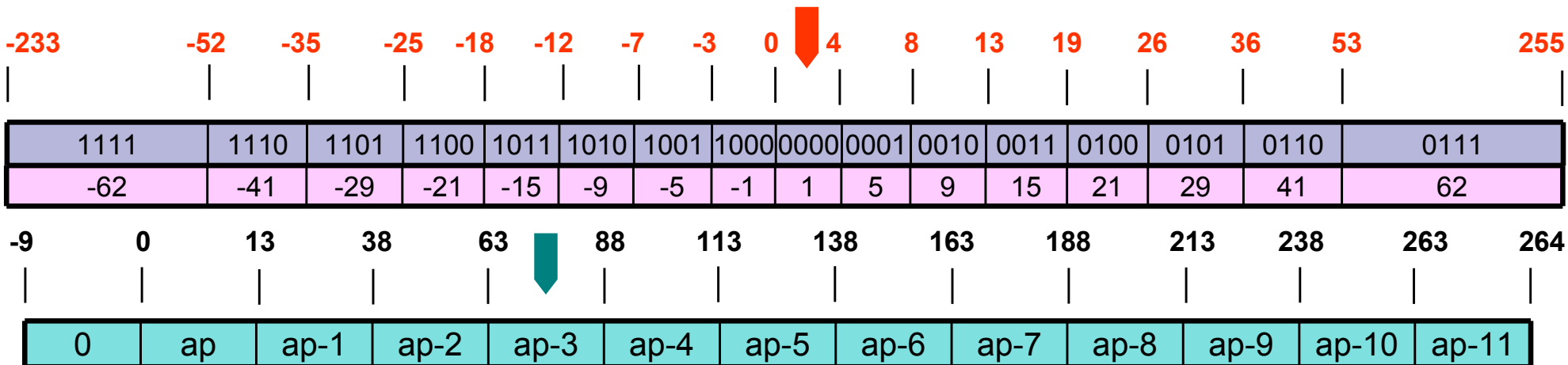
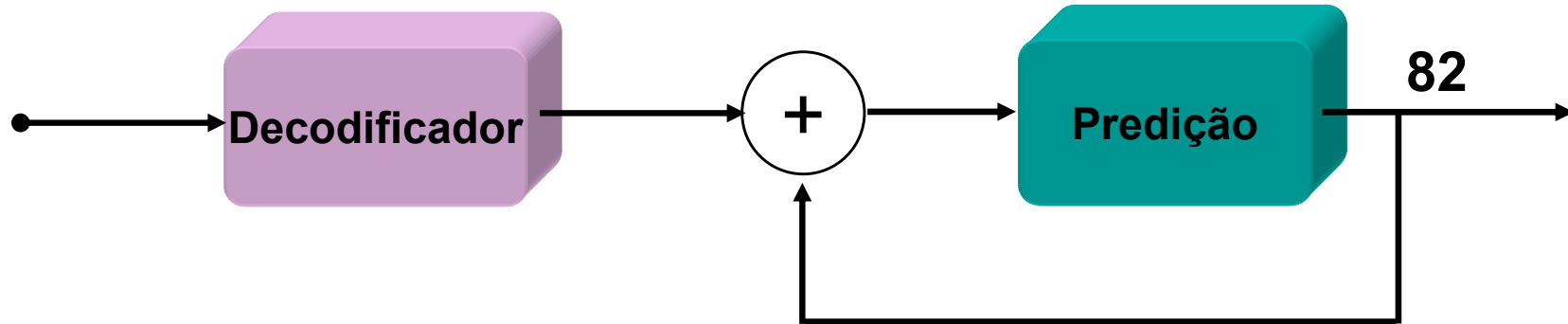
98 93 84



# Decodificador DPCM

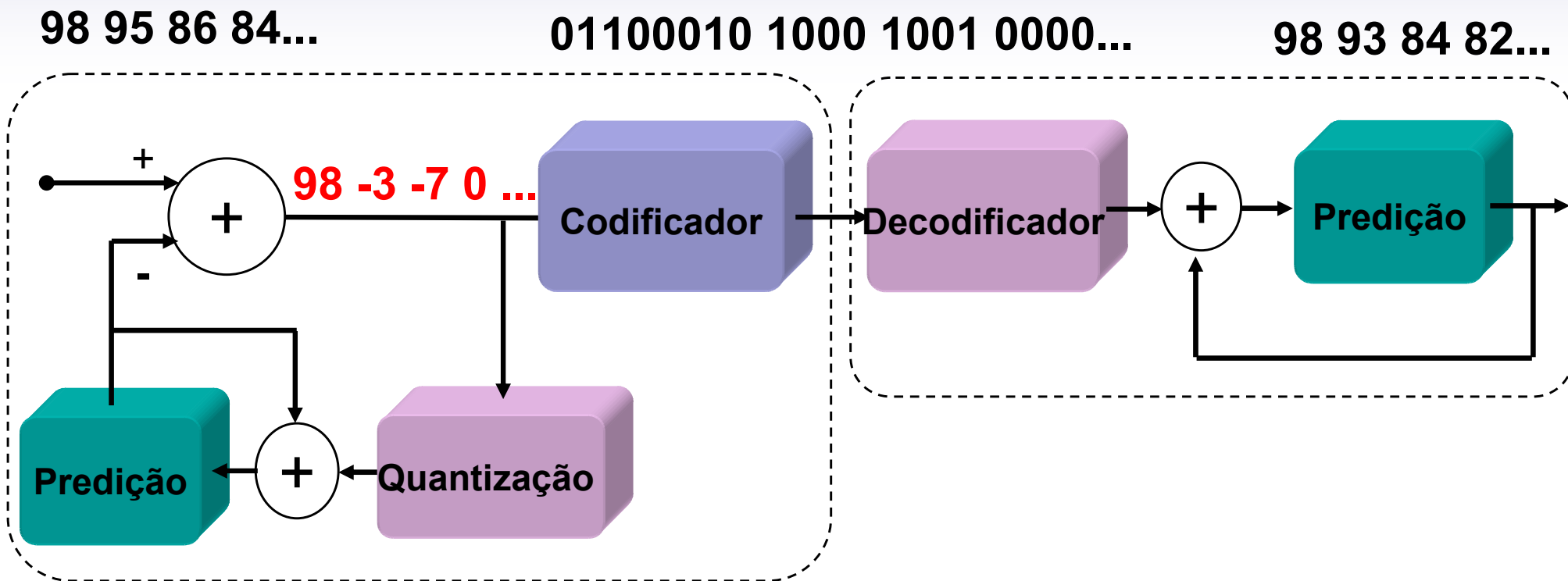
01100010 1000 1001 0000

98 93 84 82





# Sistema de Compressão DPCM



Baixa complexidade

Compressão com Perda

Taxa de Compressão 2:1



# Análise Objetiva de Qualidade

## PSNR

## Razão de Compressão

$$\text{Razão de Compressão} = \frac{\text{tamanho\_original}}{\text{tamanho\_comprimido}}$$

## Erro médio quadrático (MSE)

$$MSE = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} (a[x, y] - b[x, y])^2$$

*Imagem Original*                      *Imagem Recuperada*

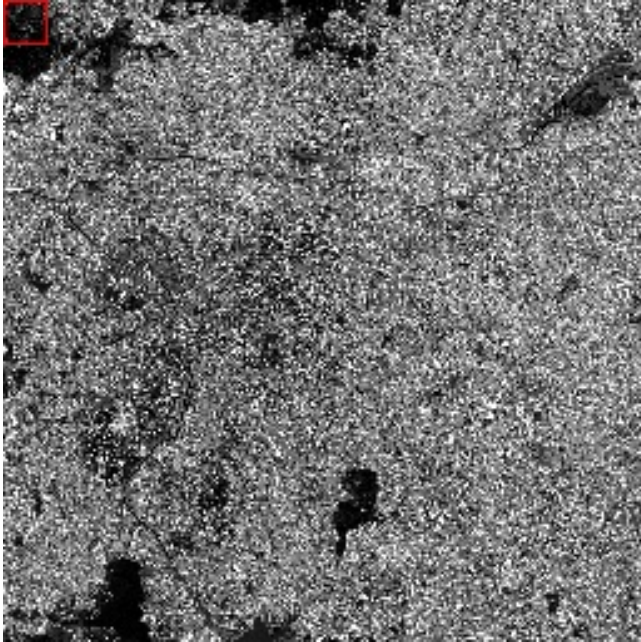


## Peak signal-to-noise ratio (PSNR)

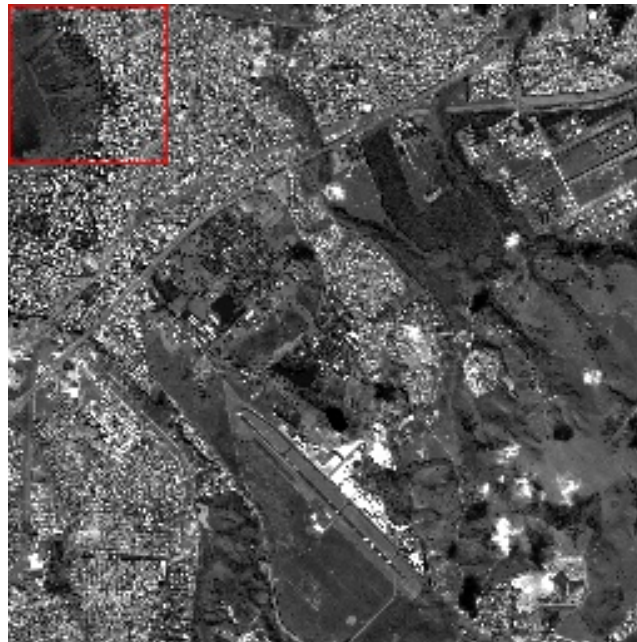
*B: nº de bits*

$$PSNR = 10 \log_{10} \frac{(2^B - 1)^2}{MSE} \quad (dB)$$

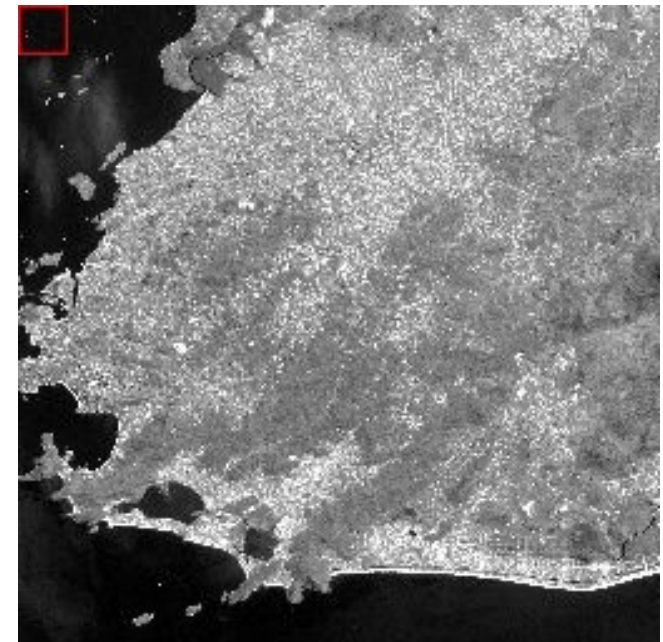
# Imagens simuladas



**SPOT**  
**São Paulo, SP**



**Quickbird**  
**S. J. Campos, SP**



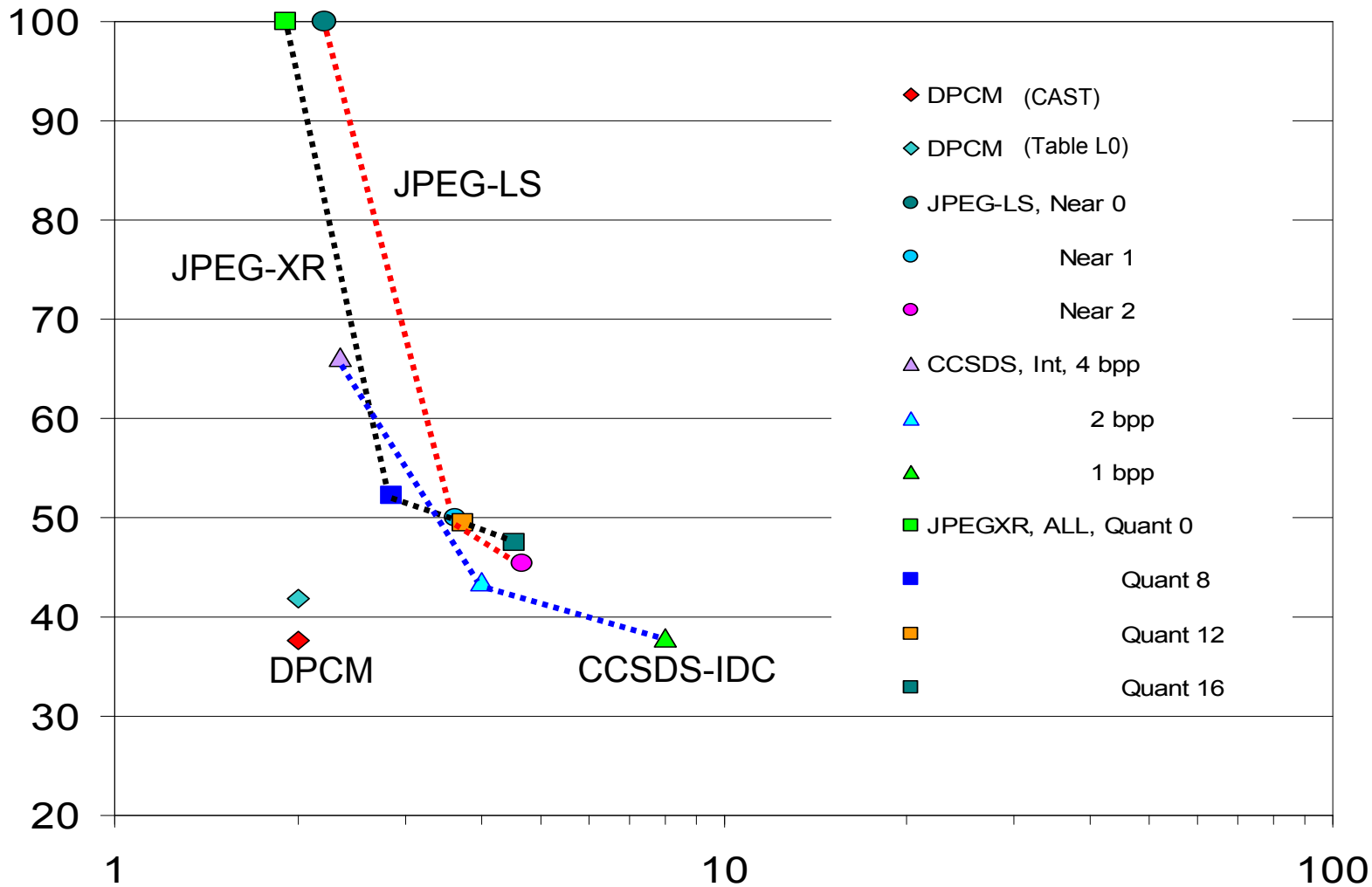
**RapidEye**  
**Niteroi, RJ**

# Análise Objetiva de Qualidade

PSNR(dB) x Compression Ratio

Qualidade ↑

PSNR (dB)



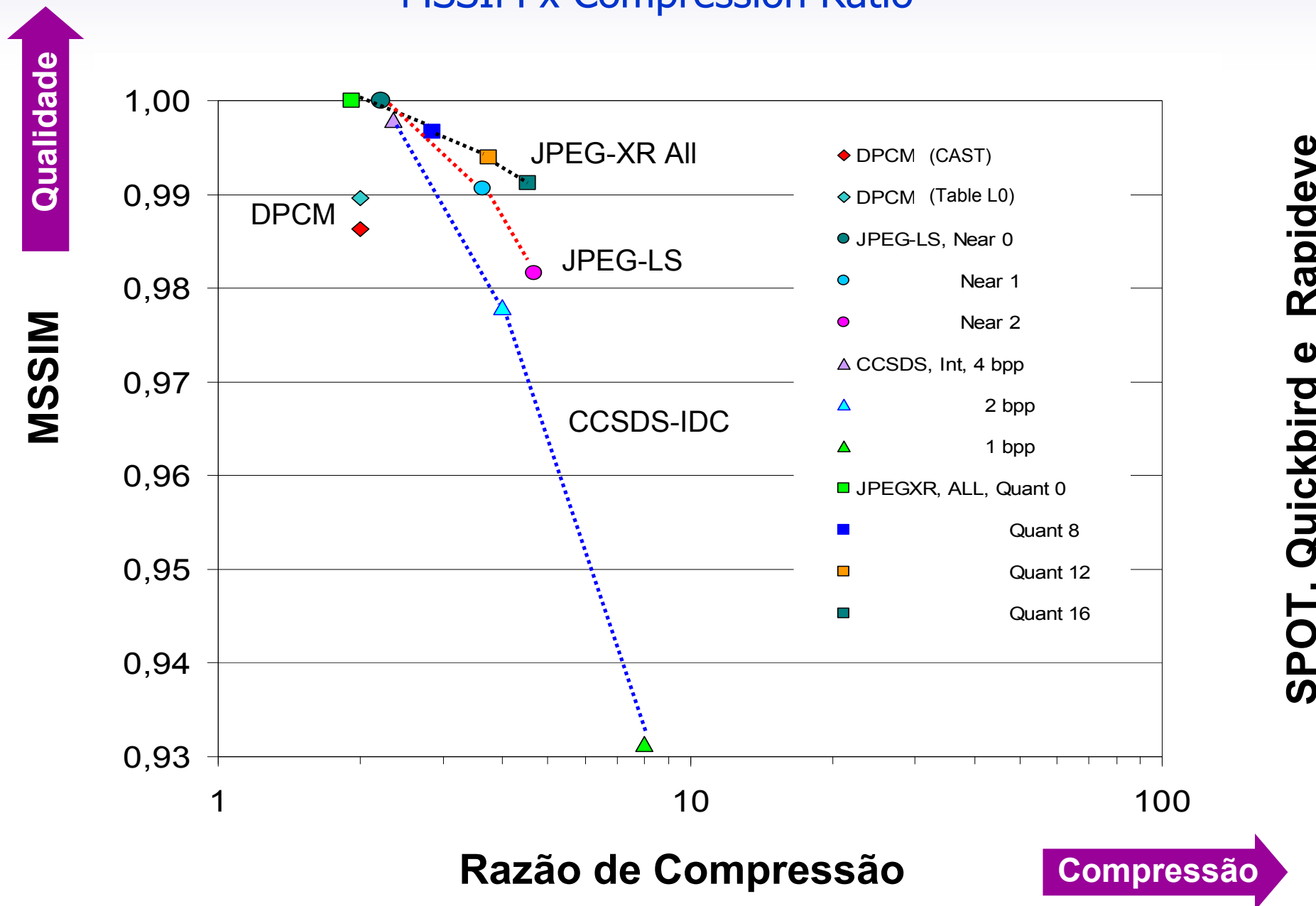
Razão de Compressão

Compressão →

SPOT, Quickbird e Rapideye

# Análise Objetiva de Qualidade

## MSSIM x Compression Ratio





# Análise Visual de Qualidade

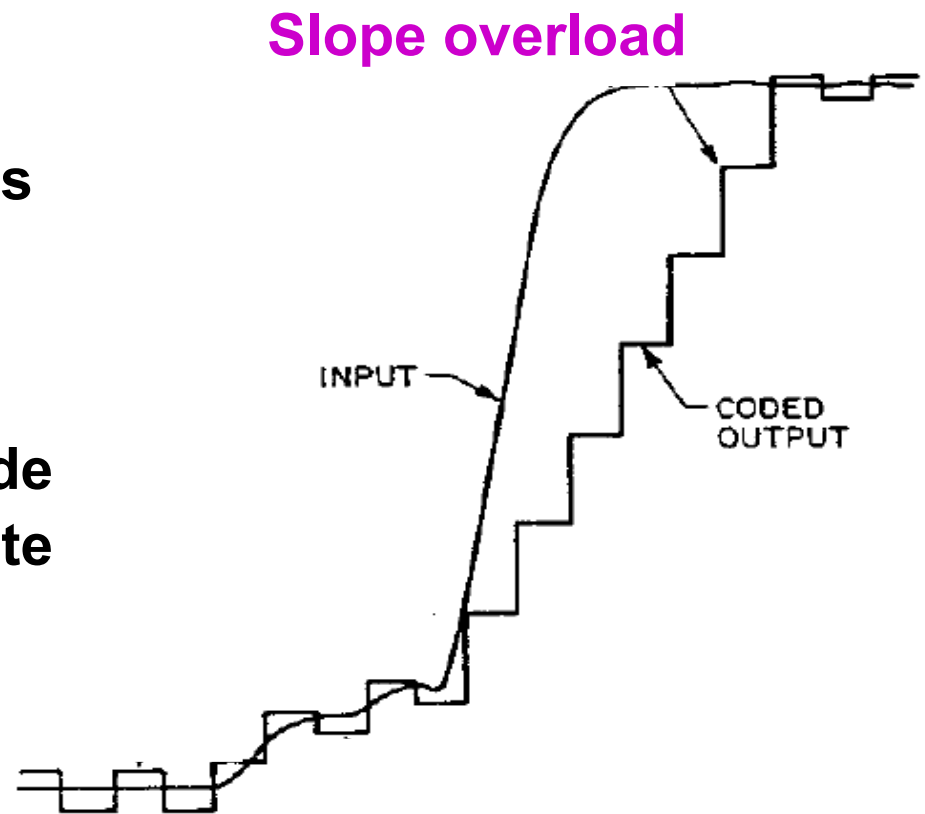
# Dois tipos de degradação podem ser gerados como resultado da quantização DPCM.

## Ruído granular

Ruído aleatório em áreas planas

## “Slope overload”

Suavização das bordas de alto contraste



Ruído granular



# Análise Visual de Qualidade

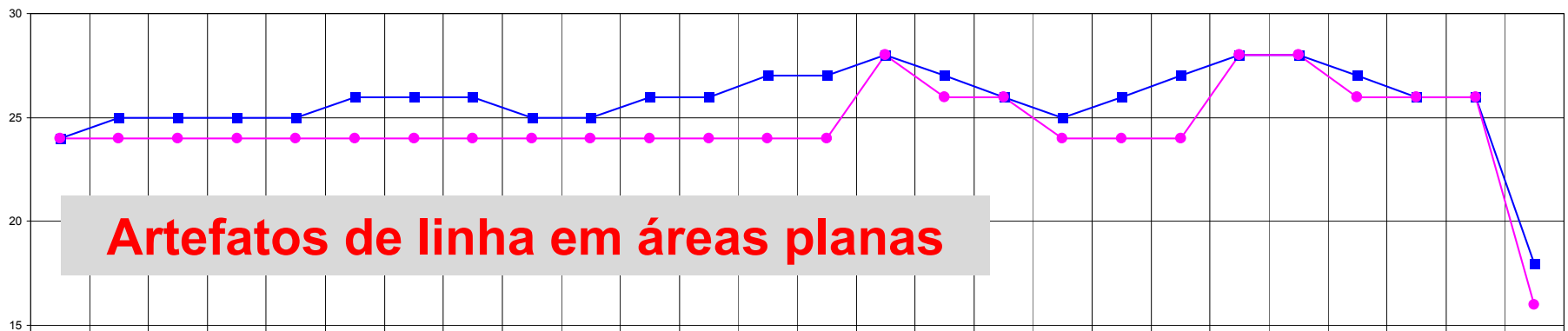
Quickbird  
S. J. Campos, SP



Imagem original



DPCM 2:1 (CAST)



# Análise Visual de Qualidade

HRC/CBERS-2B

Brasília, DF

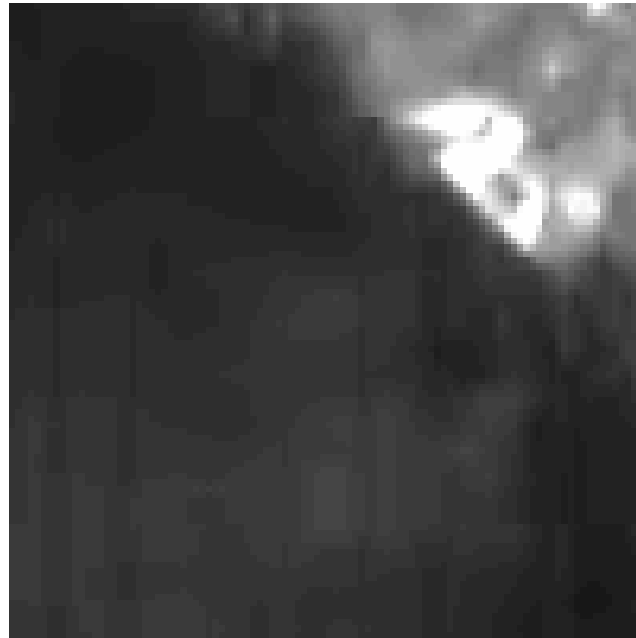
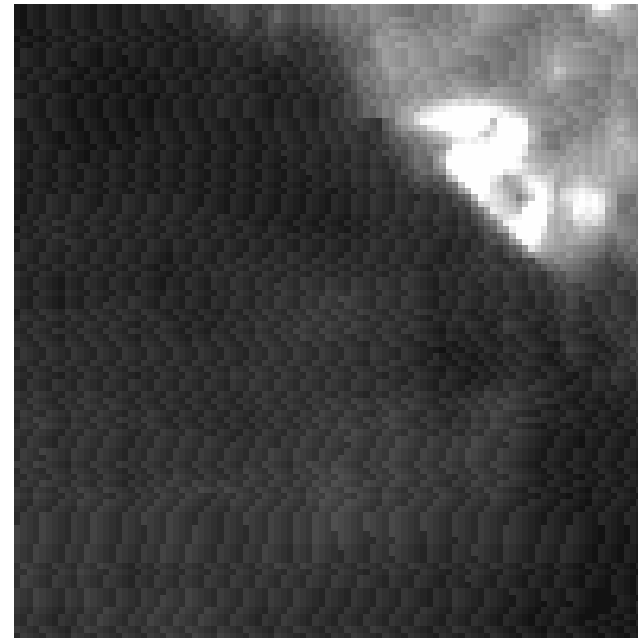


Imagem original



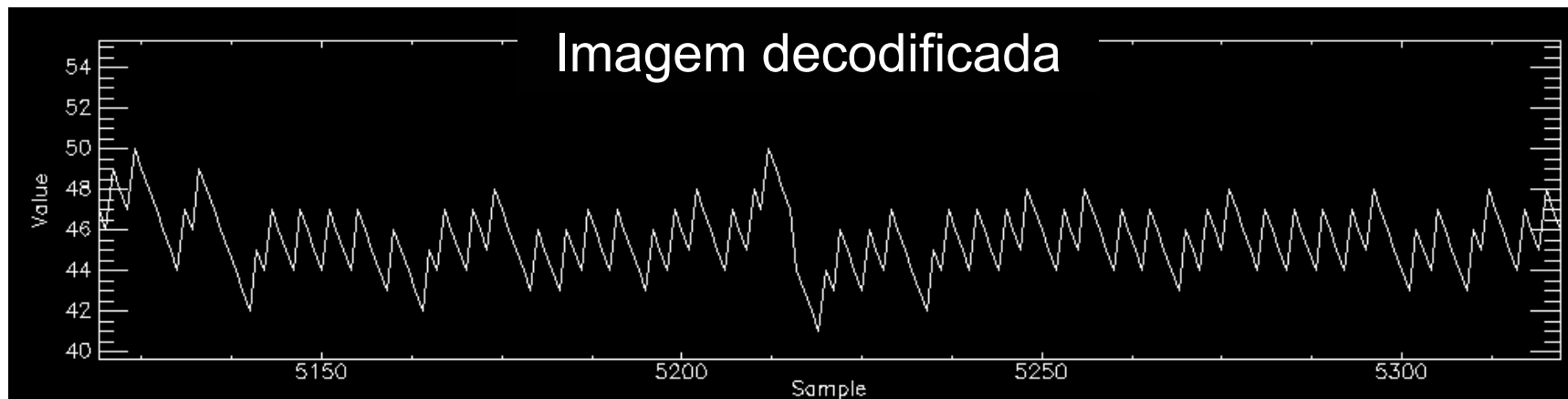
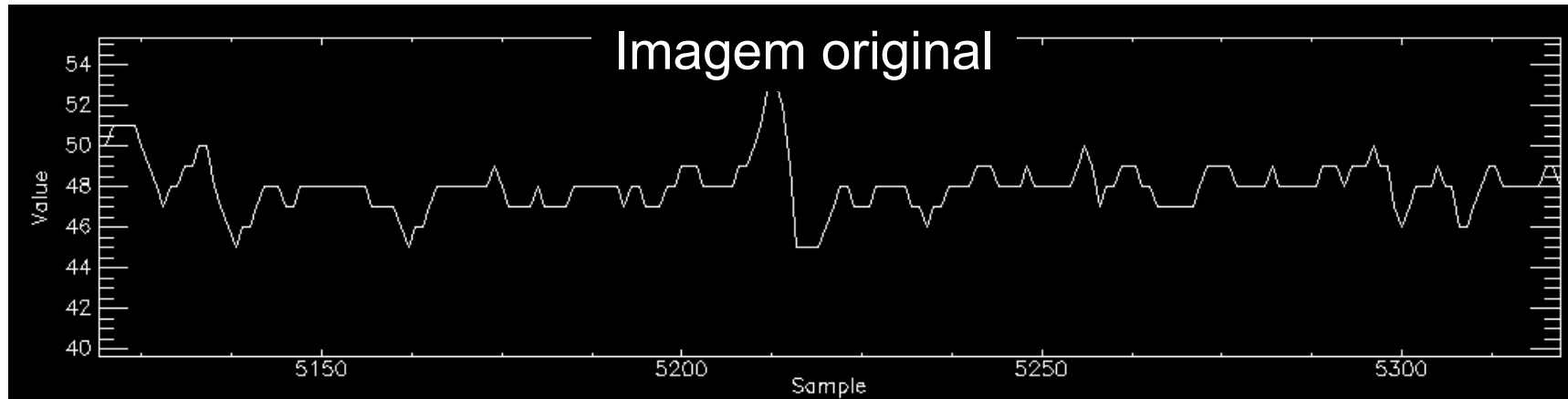
DPCM 2:1 (CAST)

**Ruído granular em  
áreas planas**

# Análise Visual de Qualidade

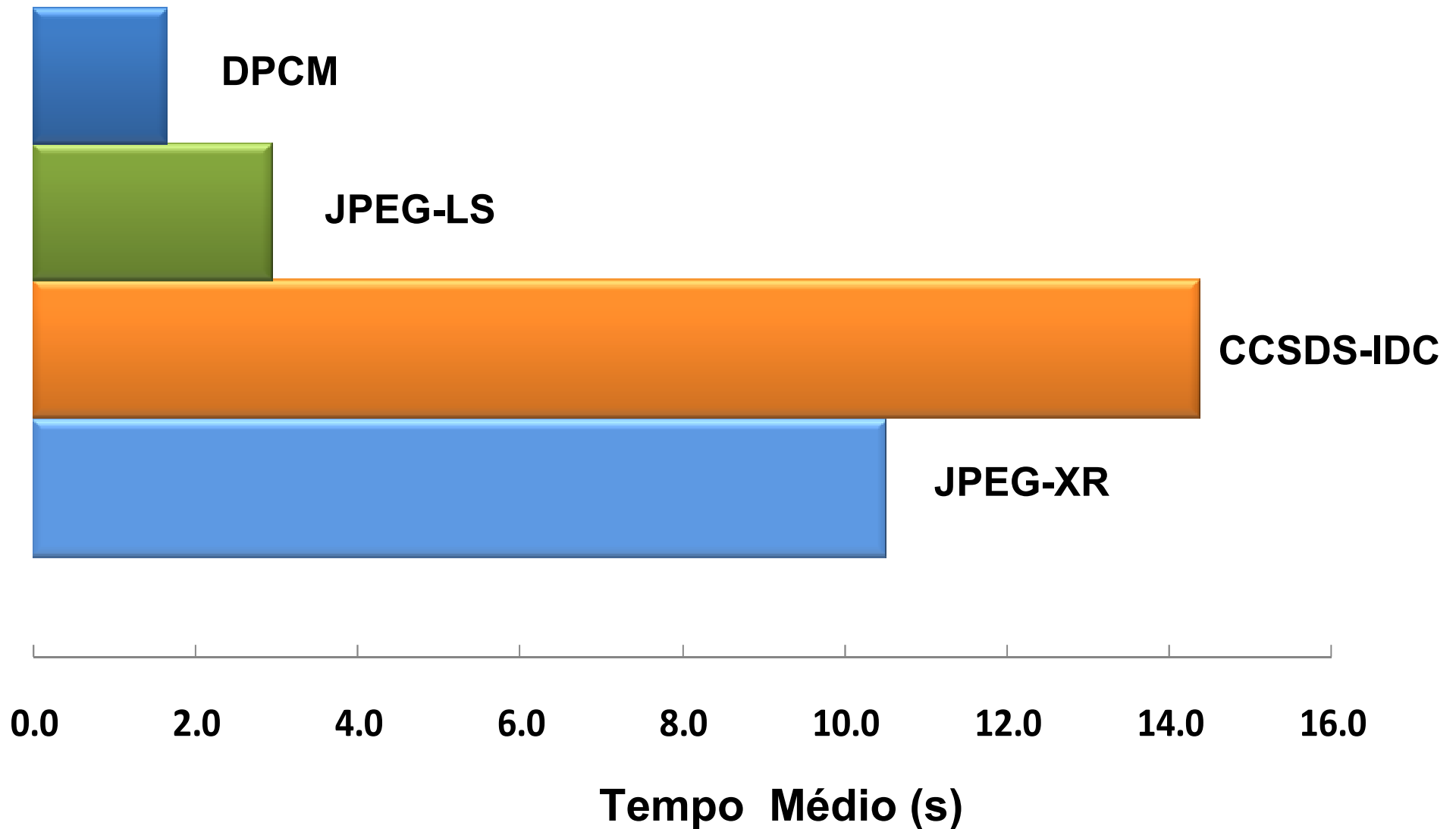
HRC/CBERS-2B

Brasília, DF



**Ruído granular em  
áreas planas**

# Tempo de Processamento



# *Principais referências*

China Academy of Space Technology, “**Introduction to DCPM encoding algorithm in data transmission sub-system of PANMUX IRMSS onboard CBERS 3&4 satellites,**” \*[S.I.]: CAST, (Wx CBERS03/04DPS.SM01), 2010.

Lilian N. Faria, Leila M. G. Fonseca, and Max H. M. Costa, “**Performance Evaluation of Data Compression Systems Applied to Satellite Imagery,**” *Journal of Electrical and Computer Engineering*, vol. 2012, Article ID 471857, 15 pages, 2012.  
doi:10.1155/2012/471857

<http://www.hindawi.com/journals/jece/2012/471857/>



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**INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS**

**Obrigada!**

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