PCM → prediction → residual → Rice coding → FLAC bits

Pulse Code Modulation (Raw audio file)

Step 1: Lets take 8 PCM samples $8 \times 16 = 128$ bits

$$x = [1000, 1010, 1025, 1030, 1020, 1015, 1018, 1022]$$

Step 2: $\bar{x}[n] = 2 \cdot x[n-1] - x[n-2]$

Predictor (order -2):

we store $x[0]$ & $x[1]$ raw [initial samples] ~~for decoding~~ ~~for~~

∴ (as we need atleast 2 samples to predict)

Step 3: For $n \geq 2$

→ $n = 2$

$\bar{x}[2] = 2 \cdot (1010) - 1000 = 1020$

residual

$e[2] = x[2] - \bar{x}[2] = 1025 - 1020 = +5$

→ $n = 3$

$\bar{x}[3] = 2 \cdot (1025) - 1000 = 1050$

$e[3] = -10$

→ $n = 4$

$\bar{x}[4] = 2 \cdot (1030) - 1025 = 1035$

$e[4] = -15$

→ n = 5:

$\bar{x}[5] = 2(1020) - 1030 = 1010$

$e[5] = +5$

→ n = 6:

$\bar{x}[6] = 2(1015) - 1020 = 1010$

$e[6] = +8$

→ n = 7

$\bar{x}[7] = 2(1018) - 1015 = 1021$

Residual $e[7] = 1022 - 1021 = +1$

$\therefore e = [+5, -10, -15, +5, +8, +1]$

Step 4:

Signed → Unsigned mapping (standard Rice map)

$$u = \begin{cases} 2e & e > 0 \\ -2e - 1 & e < 0 \end{cases}$$

u ↙ unsigned integers

(i.e, it maps $0 \to 0; -1 \to 1; +1 \to 2; -2 \to 3; \cdots$)

$e = +5 \Rightarrow u = 2(5) = 10$

$e = -10 \Rightarrow u = -2(-10) - 1 \Rightarrow 19$

$e = -15 \Rightarrow u = 30 - 1 = 29$

$e = +5 \Rightarrow u = 10$

$e = +8 \Rightarrow u = 16$

$e = +1 \Rightarrow u = 2$

$u = [10, 19, 29, 10, 16, 2]$

Step 5:

Rice coding with parameter $k=2$

quotient $q = [u/2^k]$ (written in unary: q zeros followed by 1)

Remainder $r = u \bmod 2^k$ (written in binary

with $k=2$, $2^k = 4$

→ $u=10$; $q = [10/4] = 2$; $r = 10 \bmod 4 = 2$

unary for $q=2$ → 00 1 (3 bits)

Remainder → 10 (2 bits)

Rice code bits → 00110 → total 5 bits

→ $u=19$; $q = [19/4] = 4$; $r=3$

unary for 4 → 0000 1 (5 bits)

Remainder → 11 (2 bits)

Rice bits → 0000 1 11 → 7 bits

→ $u=29$;; $q = [29/4] = 7$; $r=1$

unary for 7 → 0000000 1 = 8 bits

Remainder 01 (2 bits)

Rice bits: 00000001 01 → 10 bits

→ $u=10$ again → same as (1): 5 bits (00110)

→ $u=16$;; $q = [16/4] = 4$; $r=0$

00001 (5) + remainder 00 (2)

7 bits

→ u = 2; q = [2/4] = 0; r = 2

unary for 0 → 1 (Just a 1) = 1 bit

Remainder 10 (2 bits)

Rice bits: 1 10 → 3 bits

⇒ Total rice bits for residuals

= 5+7+10+5+7+3 = 37 bits

Step 6

Raw intial samples: 2 x 16 = 32 bits

Rice - coded residuals: 37 bits

total bits stored = 32+37 = 69 bits

Compare with raw PCM: 8 x 16 = 128 bits

→ compression ratio (raw/encoded) = 128/69 ≈ 1.855

→ Space reduction = (1 - 69/128) x 100 → 46.1% smaller

Step 7 Decoding

→ x[0] = 1000; x[1] = 1010

→ x[2] = 2·x[1] - x[0] = 2·1010 - 1000 = 1020

→ From bitstream decoder reads Rice code for 1st residual: unary: 00 1 then

remainder: 10 → q = 2; r = 2

Recover:

u = q·4 + r = 2·4 + 2 = 10

• even → e = u/2

• Odd → e = -((u+1)/2)

Reconstruct: x[2] = x̄[2] + e

= 1020 + 5

= 1025 // matches orginally