Automatic gain control (AGC)
AGC in RF domain

- AGC controls variable gain amplifier (VGA) before ADC
- Low enough gain to avoid clipping of the received signal
- High enough gain so that weak signal levels do not fall below the noise floor of ADC
- In some applications (weather radar) AGC loop is too slow and other methods to expand dynamic range (parallel RF chains and ADCs) are required
AGC operating on the band-pass signal

(a) IF signal → ADC → resample process → AGC → DDS

- $r(n)$
- $r_o(n)$
- $\cos(\Omega_0 n)$
- $-\sin(\Omega_0 n)$

DSP symbol timing sync., carrier phase sync., decisions → bit decisions

(b) $r(n)$ → $r_o(n)$

$A(n)$

accumulator

$z^{-1}$

compute signal level

$\alpha$, $R$
AGC in digital baseband

- Many detection functions depend on signal level
  - Multilevel constellations like M-QAM
  - Phase error and timing error detectors
- Different options for the placement of AGC in baseband
AGC in digital baseband

- Amplitude update equation

- \( \alpha = \) step size
- \( R = \) reference value
- \( A[n] = \) gain
- \( A_{in}[n] = \) amplitude of the input signal
- Non-linear system
AGC in digital baseband


- Suppose input is a step function \( Cu[n], C > 0 \)
  \[ A[n + 1] = A[n](1 - \alpha C) + \alpha R, \; n \geq 0 \]
- First-order linear difference equation solved for \( A[n] \)
  \[ A[n + 1] = \frac{R}{C}(1 - (1 - \alpha C)^n)u[n] \]
- Steady state value is \( R/C \)
- Transient behavior is characterized by time \( n_0 \) when \( A[n] \) is \((1-e^{-1})\) times the steady state value
  \[ A(n_0) = (1 - e^{-1})\frac{R}{C} \quad n_0 \approx \frac{1}{\alpha C} \]
Example of AGC’s loop performance

1. Real part of the input signal
2. Input * gain
3. Gain
   - Convergence time is short when the signal is strong and long when the signal is weak
Log-based AGC in digital baseband

- Convergence can be made independent of the amplitude of input signal by log-based AGC
Log-based AGC

- **Amplitude update equation**
  \[ \log A[n+1] = \log A[n] + \alpha (\log R - \log |A[n]A_{in}[n]|) = \log A[n](1-\alpha) - \alpha \log \frac{A_{in}[n]}{R} \]

- **When input is a step function**
  \[ \log A[n+1] = \log A[n](1-\alpha) - \alpha \log \frac{C}{R}, \; n \geq 0 \]

- **Solving the difference equation**
  \[ \log A[n+1] = -\log \frac{R}{C} (1 - (1-\alpha)^n) u[n] \]

- **Time constant becomes**
  \[ n_0 \approx \frac{1}{\alpha} \]
Example of log-based AGC’s loop performance

1. Real part of the input signal
2. Input * gain
3. Gain
   • Convergence time is independent of the amplitude