

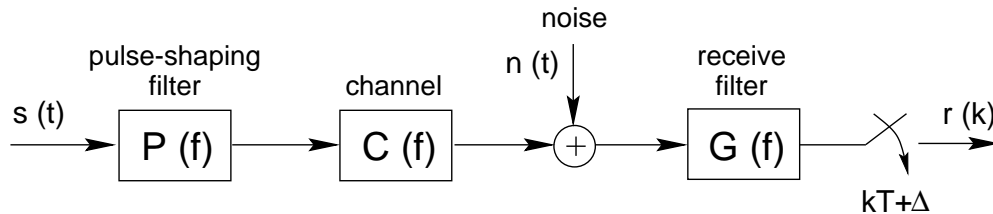
Blind and Semi-Blind Channel Equalization for Wireless Broadcast Channels

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Overview

- Baseband Communication System
- Baud-Timing
- Equalization
 - Linear Finite Impulse Response (FIR)
 - Linear Infinite Impulse Response (IIR)
 - Decision Feedback Equalizer (DFE)
- Trained Adaptation
 - *ISSUE 1: Training Signal Design*
- Blind Adaptation
 - *ISSUE 2: DFE Acquisition Strategies*
 - *ISSUE 3: Equalizer Sparsity*
 - *ISSUE 4: Unified Synchronization and Equalization*
- Closing Observations on Adaptive Signal Processing

Baseband Communication System



$$s(t) = \sum_{i=-\infty}^{\infty} s(i) \delta(t - iT - \epsilon)$$

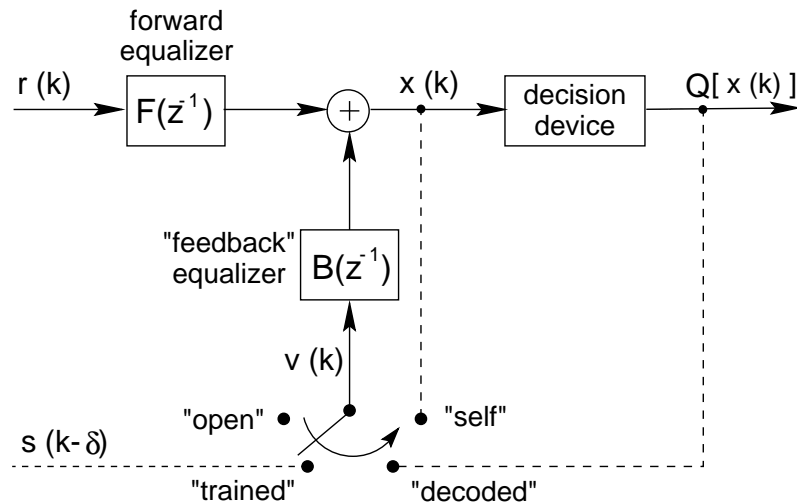
with real digital source, e.g., $s(i) = \pm 1$ or ± 3 or
complex digital source, e.g., $s(i) = \pm 1 \pm j$

- *Impairments:*
 - intersymbol interference
 - timing offset
 - channel noise
- *Noise-Free Objective:* distortionless delay with flat magnitude spectrum and linear phase spectrum
- *Solution:* adjust Δ and process $\{r\}$.

Baud Timing Recovery

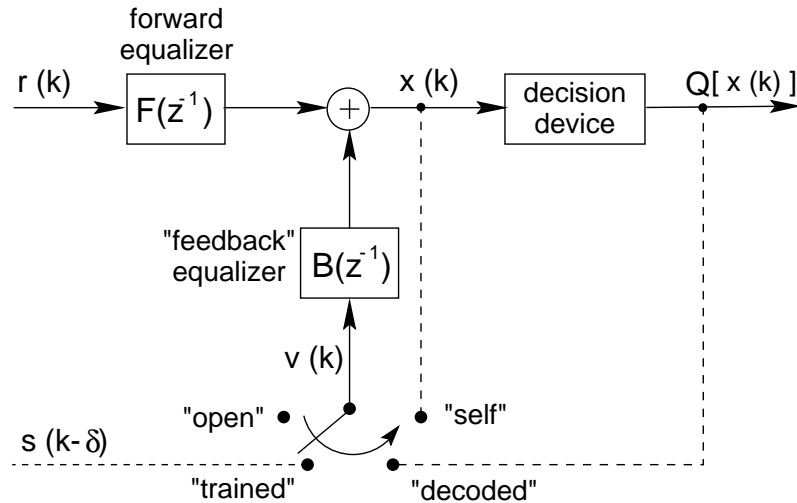
- *Matched Filter Output Maximization:* The choice of Δ over $-T/2 < \Delta < T/2$ that maximizes the power of the matched receive filter output achieves baud timing synchronization without (and with some) intersymbol interference.
- *Resampling for Δ Adjustment:* Assuming sampling frequency exceeds twice the highest frequency present in the receive filter output and using sinc functions as a basis for reconstruction of the analog receive filter output from $\{r(k)\}$, we can effectively adjust Δ without actually altering the sampler timing.
- *Separability from Equalization:* Baud timing is typically assumed to be performed prior to onset of successful $\{r\}$ filtering.

Linear FIR Equalizer



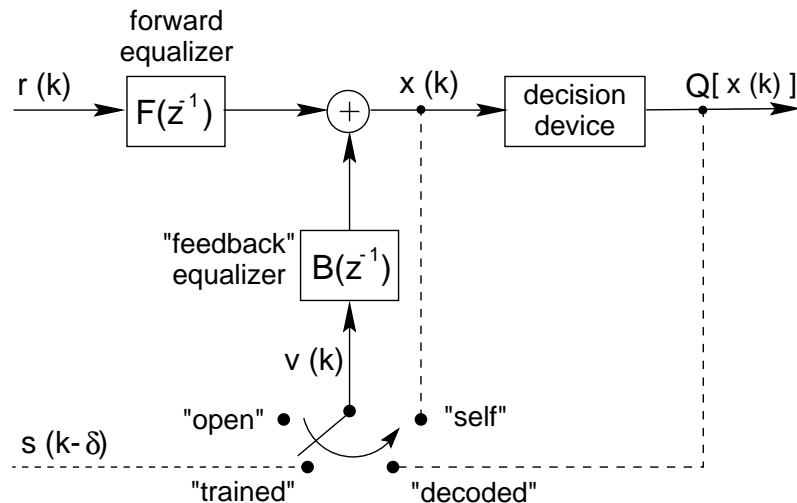
- *Switch Setting:* "open"
- *Feature:*
 - perfect zero-forcing equalization possible with oversampling
- *Issues:*
 - channel noise gain
 - long enough for accurate IIR delayed channel inverse approximation

Linear IIR Equalizer



- *Switch Setting:* "self"
- *Feature:*
 - parsimonious equalizer parameterization for minimum phase zeros in FIR channel
- *Issues:*
 - (temporary) instability
 - channel noise gain
 - delayed inverse approximation of maximum phase zeros in FIR channel

Decision Feedback Equalizer (DFE)



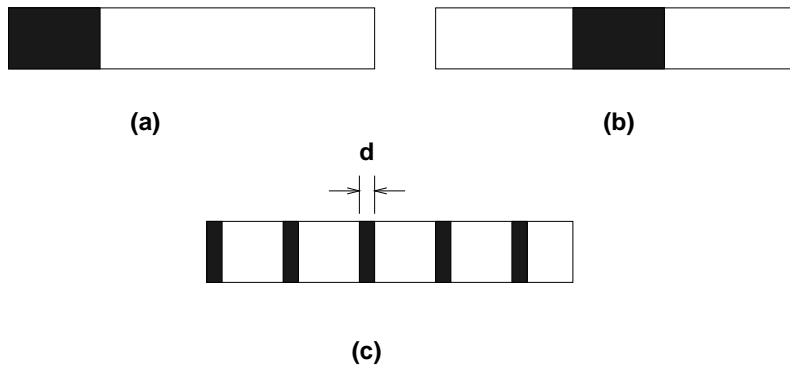
- *Switch Setting:* “decoded”
- *Features:*
 - parsimonious parameterization
 - reduced noise gain
 - in ideal case desired feedback polynomial matches that of IIR linear configuration
- *Issues:*
 - error propagation
 - design without perfect decision assumption

Trained Adaptivity

- *Circumstance-Dependence*: The “best” fixed filtering depends on the “channel” model.
- *Time Variation*: The channel model is expected to be time-varying.
- *Indirect Strategy*: First identify the channel, and then solve for the appropriate equalizer filter.
- *Need Input-Output Data*: Common system identification algorithms rely on the system’s input-output data records.
- *Training*: In a communication system, a training phase when the source signal is known at the receiver, offers up such an input-output record.
- *MSE*: The most popular adaptive algorithm minimizes the mean squared output prediction error.

ISSUE 1: Training Signal Design

- Which placement distribution is best?



- By which criterion?
 - minimizing average squared DFE recovery error
 - minimizing mean squared error over all channel estimators
 - minimizing Cramér-Rao lower bound on the mean square channel estimation error
 - maximizing channel capacity
 - minimizing bit error rate

Blind Direct Adaptivity

- *Direct Strategy*: MMSE channel identification algorithm can be converted to direct equalizer “identification” by using (delayed) training source as “system” output and received signal as “system” input.
- *Decision-Directed Adaptation*: When a training episode, or some other procedure, results in an acceptable, but not perfect, equalizer setting the decision device output can be used as a replica of the source sequence.
- *Tracking Versus Acquisition*: A decision-directed scheme can offer tracking capability, but will perform poorly if the close “initialization” assumption is violated.
- *Dispersion Minimization*: Dispersion minimization is a blind proxy for mean squared prediction error minimization.

ISSUE 2: Acquisition Strategies

- *Linear FIR Equalizer Cost Function Shape:*
 - Trained mean-squared error with known delay: ice cream cone
 - Trained simultaneous mean-squared error and delay optimization: egg carton
 - Blind dispersion minimization: egg carton, with minima near mean squared error egg carton minima
- *Multimodal Surface Gradient Descent:*
 - saddle stall and long convergence times
 - initialization dependent asymptotic performance
- *Blind DFE Cost Function Shape:* Much less is known about the blind DFE cost function surface, though it is also undeniably multimodal – making initialization-acquisition strategies a key practical issue.

ISSUE 3: Sparsity Exploitation

- *Performance Benefits:* Fewer active taps can lead to faster convergence and less misadjustment.
- *Performance Cost:* Zeroing out taps useful in intersymbol interference (ISI) reduction increases minimum achievable performance.
- *Practical Occurrence:* In a variety of settings, acceptable performance can be obtained with a few nonzero, nonuniformly spaced equalizer taps.
- *Tap Allocation:* How can you find which taps should be clamped to zero short of effectively solving for full answer and removing “unnecessary” ones?

ISSUE 4: Unified Synchronization and Equalization

- *Single Versus Multi-Tap Adjustment:* In those cases when adjustment of a single receiver variable can fully correct for some channel change, adapting a single parameter is far more efficient and robust than adjusting all of the equalizer tap weights.
- *Unification Claim:* To assist unified synchronization and equalization, a single common cost function should be used.
- *Blind Cost of Choice:* Several tasks can be phrased as (blind) dispersion minimization problems, including
 - equalization
 - timing recovery
 - phase derotation for carrier phase synchronization of complex sources

Adaptive Signal Processing

- APPLICATION
- ALGORITHM DEVELOPMENT
- BEHAVIOR ANALYSIS
- REALIZATION

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