Rake receiver

If, in a mobile radio channel reflected waves arrive with small relative time delays, self interference occurs. Direct Sequence (DS) Spread Spectrum is often claimed to have particular properties that makes it less vulnerable to multipath reception. In particular, the rake receiver architecture allows an optimal combining of energy received over paths with different. It avoids wave cancellation (fades) if delayed paths arrive with phase differences and appropriately weighs signals coming in with different signal-to-noise ratios.

The rake receiver consists of multiple correlators, in which the receive signal is multiplied by time-shifted versions of a locally generated code sequence. The intention is to separate signals such that each finger only sees signals coming in over a single (resolvable) path. The spreading code is chosen to have a very small autocorrelation value for any nonzero time offset. This avoids crosstalk between fingers.In practice, the situation is less ideal. It is not the full periodic autocorrelation that determines the crosstalk between signals in different fingers, but rather two *partial*correlations, with contributions from two consecutive bits or symbols. It has been attempted to find sequences that have satisfactory partial correlation values, but the crosstalk due to partial (non-periodic) correlations remains substantially more difficult to reduce than the effects of periodic correlations.

The rake receiver is designed to optimally detected a DS-CDMA signal transmitted over a dispersive multipath channel. It is an extension of the concept of the matched filter.

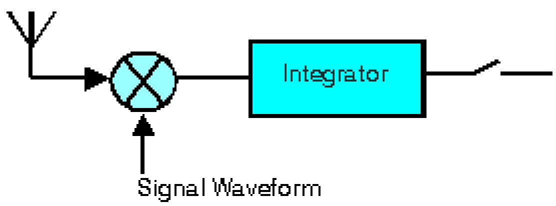

Figure: Matched filter receiver for AWGN channel.

In the matched filter receiver, the signal is correlated with a locally generated copy of the signal waveform. If, however, the signal is distorted by the channel, the receiver should correlate the incoming signal by a copy of the expected received signal, rather than by a copy of transmitted waveform. Thus the receiver should estimate the delay profile of channel, and adapt its locally generated copy according to this estimate.

In a multipath channel, delayed reflections interfere with the direct signal. However, a DS-CDMA signal suffering from multipath dispersion can be detected by a rake receiver. This receiver optimally combines signals received over multiple paths.

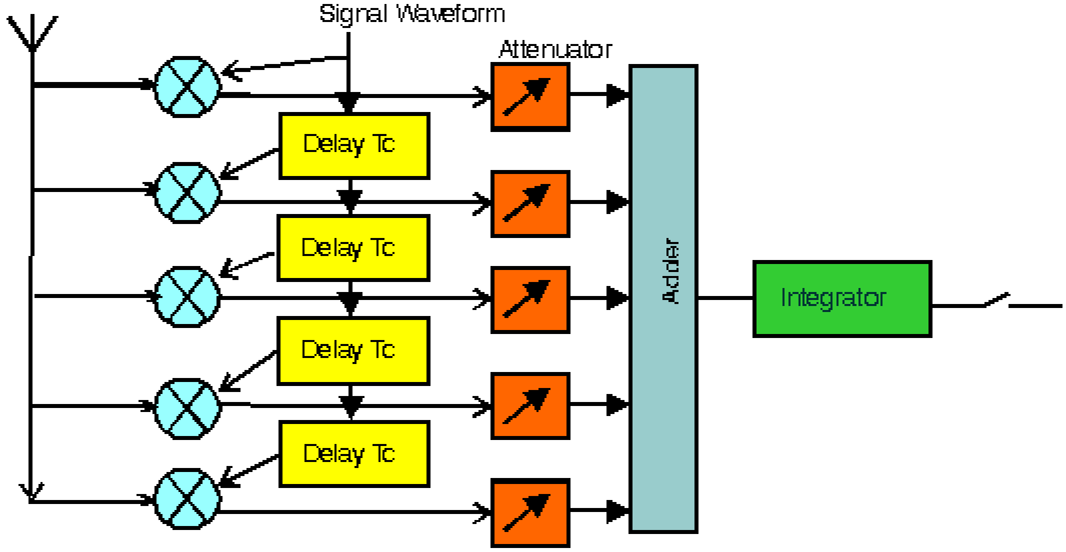

Figure: Rake receiver with 5 fingers

Like a garden rake, the rake receiver gathers the energy received over the various delayed propagation paths. According to the maximum ratio combining principle, the SNR at the output is the sum of the SNRs in the individual branches, provided that

- we assume that only AWGN is present (no interference)
- codes with a time offset are truly orthogonal

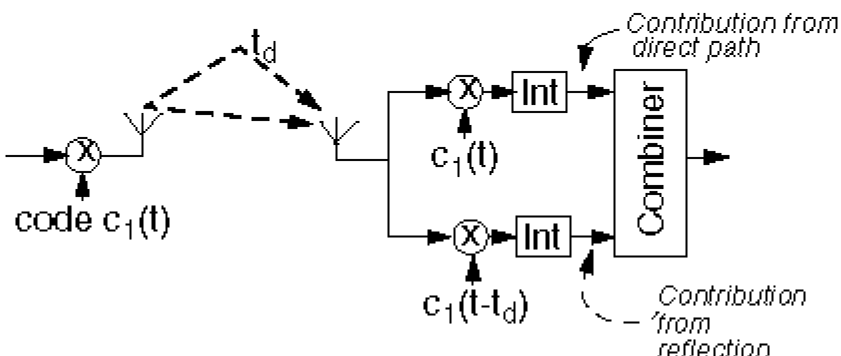

Figure: Rake Receiver

Different reflected waves arrive with different delays. A rake receiver can detect these different signals separately. These signals are then combined, using thediversity technique called maximum ratio combining.

Signals arriving with the same excess propagation delay as the time offset in the receiver are retrieved accurately, because

$$\sum_{n=1}^{N} c_1^2(nT_c + t_d) = \sum_{n=1}^{N} c_1^2(nT_c) = N$$

This reception concept is repeated for every delayed path that is received with relevant power. Considering a single correlator branch, multipath self-interference from other paths is attenuated here, because one can choose codes such that

$$\sum_{n=1}^{N} c_1(nT_c)\, c_1(nT_c + t_d) \cong 0$$

Rake Performance

A spread spectrum receiver with rake outperforms a simple receiver with a single correlator.

Rake Facts

- In an interference-free system, each attenuation/amplification coefficient in the Rake receiver is proportional to the received amplitude in the corresponding "bin" of the delay spread.
- One can compare the choice of the coefficients in the rake receiver with maximum ratio combining diversityreceiver.
- The rake receiver can also be used to support soft handovers in CDMA cellular networks.

Multiple Access Techniques for Wireless Communication

In wireless communication systems it is often desirable to allow the subscriber to send simultaneously information to the base station while receiving information from the base station. A cellular system divides any given area into cells where a mobile unit in each cell communicates with a base station. The main aim in the cellular system design is to be able to increase the capacity of the channel i.e. to handle as many calls as possible in a given bandwidth with a sufficient level of quality of service. There are several different ways to allow access to the channel. These includes mainly the following: 1) Frequency division multiple-access (FDMA) 2) Time division multiple-access (TDMA) 3) Code division multiple-access (CDMA)

Multiple Access Techniques are ways to access a single channel by multiple users. They provide multiple access to the channel. A “channel” refers to a system resource allocated to a given mobile user enabling the user to establish communication with the network (other users). Based on the type of channel, we can use a particular multiple access technique for communication.

The types of channel and the corresponding multiple access techniques are listed below:

- **Frequency Channels [FDMA - Frequency Division Multiple Access]** - Frequency band divided into small frequency channels and different channels are allocated to different users – like in FM radio. Multiple users can transmit at the same time but on different frequency channels.
- **Time-slot Within Frequency Bands [TDMA - Time Division Multiple Access]** – Each user is allowed to transmit only in specified time-slots with a common frequency band. Multiple users can transmit at the same frequency band at different times.
- **Distinct Codes [CDMA - Code Division Multiple Access]** – Users may transmit at the same time using the same frequency band but using different codes so that we can decode to identify a particular user.

Equalization, Diversity, and Channel Coding

•Introduction

•Equalization Techniques

•Algorithms for Adaptive Equalization

•Diversity Techniques

•Channel Coding

Introduction

•Three techniques are used independently or in tandem to improve receiver signal quality

•Equalization compensates for ISI created by multipath with time dispersive channels (W>BC) ¾Linear equalization, nonlinear equalization

•Diversity also compensates for fading channel impairments, and is usually implemented by using two or more receiving antennas¾Spatial diversity, antenna polarization diversity, frequency diversity, time diversity

•The former counters the effects oftime dispersion (ISI), while the latter reduces the depth and duration of the fades experienced by a receiver in a flat fading (narrowband) channel

•Channel Coding improves mobile communication link performance by adding redundant data bits in the transmitted message

•Channel coding is used by the Rx to detect or correct some (or all) of the errors introduced by the channel (Post detection technique)¾Block code and convolutional code

Equalization Techniques

•The term equalizationcan be used to describe any signal processing operation that minimizes ISI [2]

•Two operation modes for an adaptive equalizer: training and tracking

•Three factors affect the time spanning over which an equalizer converges: equalizer algorithm, equalizer structure and time rate of change of the multipath radio channel

•TDMA wireless systems are particularly well suited for equalizers Diversity Techniques

•Requires no training overhead

•Can provides significant link improvement with little added cost

•Diversity decisions are made by the Rx, and are unknown to the Tx

•Diversity concept ¾If one radio path undergoes a deep fade, another independent path may have a strong signal ¾By having more than one path to select from, both the instantaneous and average SNRs at the receiver may be improved, often by as much as 20 dB to 30 dB

•Microscopic diversityand Macroscopic diversity ¾The former is used for small-scale fading while the latter for large-scale fading ¾Antenna diversity (or space diversity).