



Architecture of an Autonomous Radio Receiver

The receiver would configure itself to receive an initially unknown signal.

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A program to develop an autonomous radio receiver compatible with a variety of digital communication schemes is underway. The proposed receiver, to be implemented largely in software, would configure itself to receive an incoming signal without much *a priori* knowledge of defining characteristics of the signal. These characteristics include the carrier frequency and phase, modulation type, modulation index, symbol timing, data rate, type of code, and signal-to-noise ratio.

Heretofore, radio receivers have been configured manually, on the basis of prior knowledge of the signals to be received. In situations in which prior knowledge of signal types is not available and/or it is necessary to receive signals of different types at different times, manual re-configuration can be impractical and excessively time-consuming. Such situations can be expected to arise increasingly frequently in spacecraft communications, military interception of signals transmitted by adversaries, and cellular telephony.

The proposed receiver would include estimating and classifying modules that would analyze the incoming signal to determine its defining characteristics and would then configure itself on the basis of the outputs of these modules. It is assumed that a signal to be received would arrive through a single channel, would be amplitude (pulse)- and/or phase-modulated, and may or may not include a residual carrier. Each of the estimating and classifying modules would be capable of recognizing one of the defining characteristics of such a signal.

The quality of the output of each module would be limited to the extent to which that module lacked knowledge of the outputs of the other modules. For example, it would not be feasible to classify the modulation type prior to classifying the data rate and obtaining the symbol timing. If one were to use conventional estimation and tracking designs, one would quickly encounter a "chicken and egg" problem: nearly every estimating module would

need the outputs of the other estimating modules before the receiver could make a maximum-likelihood estimate. The architecture of the proposed receiver would solve this problem by defining the order in which the modules could be operated, at least suboptimally, during the

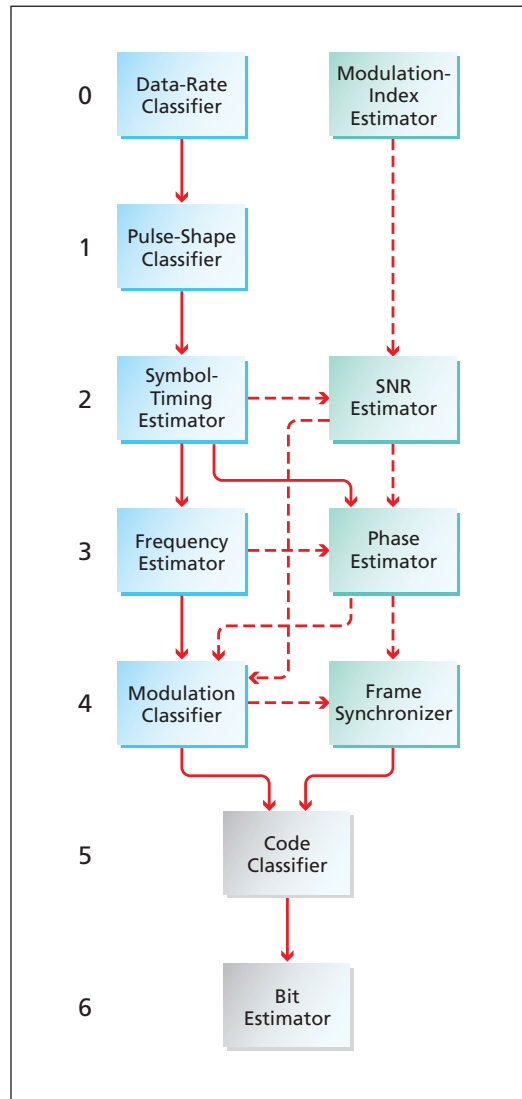
levels for which processing at some level, i , must be performed before processing at level $i + 1$.

The dashed arrows in the figure indicate additional dependencies that are not strictly required but could, if utilized, result in improved performance (possibly at the cost of increased latency). For example, the modulation classifier could operate noncoherently, without input from the phase-tracking loop, but if it waited for that input, its performance would be improved. This arrangement would implement a workable "boot-strapping" approach to estimating and classifying all of the parameters necessary for the proper operation of the entire receiver.

Initially, no module at a given level could make use of any signal attribute estimated at a level beneath it. This limitation would significantly adversely affect performance, and is inherent in any non-iterative autonomous signal-parameter-estimation algorithm. A fundamental innovation in the proposed receiver, intended to partly overcome this limitation, would be an iterative message-passing architecture: After each module completed its first estimate or classification in the proper boot-strap order, lower-level modules would send soft information to higher-level modules. In a second iteration, each module would make use of the soft information to improve its performance. After several iterations, the message-passing system would reach a reasonable convergence. It has been shown that systems like this one are typically quite robust, and can provide near-maximum-likelihood joint estimation and decoding performance.

This work was done by Jon Hamkins, Marvin Simon, Dariush Divsalar, and Samuel Dolinar of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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Estimating and Classifying Modules of the proposed autonomous receiver would operate in the order of dependency represented by this diagram.

first iteration of estimation. This order is depicted in the figure, wherein solid arrows indicate a strict dependency, meaning that the module at the head of an arrow cannot proceed without input in the form of the output of the module at the tail of the arrow. The modules would be arranged in the minimum number of