



## Switched Band-Pass Filters for Adaptive Transceivers

Switched filters could be reconfigured to conform to diverse standards.

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Switched band-pass filters are key components of proposed adaptive, software-defined radio transceivers that would be parts of envisioned digital-data-communication networks that would enable real-time acquisition and monitoring of data from geographically distributed sensors. Examples of sensors to be connected to such networks include security cameras, radio-frequency identification units, and geolocation units based on the Global Positioning System. Through suitable software configuration and without changing hardware, these transceivers could be made to operate according to any of a number of complex wireless-communication standards that could be characterized by diverse modulation schemes, bandwidths, and data-handling protocols.

The adaptive transceivers would include field-programmable gate arrays

(FPGAs) and digital signal-processing hardware. In the receiving path of a transceiver, the incoming signal would be amplified by a low-noise amplifier (LNA). The output spectrum of the LNA would be processed by a band-pass filter operating in the frequency range between 900 MHz and 2.4 GHz. Then a down-converter would translate the signal to a lower frequency range to facilitate analog-to-digital conversion, which would be followed by baseband processing by one or more FPGAs. In the transmitting path, a digital stream would first be converted to an analog signal, which would then be up-converted to a selected frequency band before being applied to a transmitting power amplifier.

The aforementioned band-pass filter in the receiving path would be a combination of resonant inductor-and-capacitor filters and switched band-pass filters. The

overall combination would implement a switch function designed mathematically to exhibit desired frequency responses and to switch the signal in each frequency band to an analog-to-digital converter appropriate for that band to produce a digital intermediate-frequency signal for digital signal processing.

*This work was done by Ray Wang of Mobitrum Corp. for Stennis Space Center.*

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## Noncoherent DTTLs for Symbol Synchronization

At high signal-to-noise ratios, performances would approach those of coherent DTTLs.

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Noncoherent data-transition tracking loops (DTTLs) have been proposed for use as symbol synchronizers in digital communication receivers. [Communication-receiver subsystems that can perform their assigned functions in the absence of synchronization with the phases of their carrier signals ("carrier synchronization") are denoted by the term "noncoherent," while receiver subsystems that cannot function without carrier synchronization are said to be "coherent."] The proposal applies, more specifically, to receivers of binary phase-shift-keying (BPSK) signals generated by directly phase-modulating binary non-return-to-zero (NRZ) data streams onto carrier signals having known frequencies but unknown phases. The proposed noncoherent DTTLs would be modified versions of traditional DTTLs, which are coherent.

The symbol-synchronization problem is essentially the problem of recovering symbol timing from a received signal. In the traditional, coherent approach to symbol synchronization, it is necessary to establish carrier synchronization in order to recover symbol timing. A traditional DTTL effects an iterative process in which it first generates an estimate of the carrier phase in the absence of symbol-synchronization information, then uses the carrier-phase estimate to obtain an estimate of the symbol-synchronization information, then feeds the symbol-synchronization estimate back to the carrier-phase-estimation subprocess. In a noncoherent symbol-synchronization process, there is no need for carrier synchronization and, hence, no need for iteration between carrier-synchronization and symbol-synchronization subprocesses.

The proposed noncoherent symbol-synchronization process is justified theoretically by a mathematical derivation that starts from a maximum *a posteriori* (MAP) method of estimation of symbol timing utilized in traditional, coherent DTTLs. In that MAP method, one chooses the value of a variable of interest (in this case, the offset in the estimated symbol timing) that causes a likelihood function of symbol estimates over some number of symbol periods to assume a maximum value. In terms that are necessarily oversimplified to fit within the space available for this article, it can be said that the mathematical derivation involves a modified interpretation of the likelihood function that lends itself to noncoherent DTTLs.

The proposal encompasses both linear and nonlinear noncoherent DTTLs. The performances of both have