INDIVIDUAL CHANNEL PHASE DELAY SCHEME

FIELD OF THE INVENTION

[0001] This invention relates to phase dependent demodulation and processing of analog signals, and more particularly to processing of an analog signal by generating and using a demodulation signal whose phase is controlled in relation to the analog signal.

BACKGROUND OF THE INVENTION

[0002] Various electronic devices use oscillating signals to sense external conditions. The external condition can be a user's voice, an incoming radio frequency communication, a user's touch of a button, a user's touch of a touch-screen display, the hover of a finger or another object over a proximity sensitive panel, etc.

[0003] Received signals that are used to sense external conditions and/or carry information such as audio, video or multi-touch data often pick up undesired noise in the process. Any wireless signal generated by, for example, a wireless device, such as a Bluetooth or WiFi signal may represent such a noise source. Noise makes processing of the signal to discover the external condition more difficult. Therefore, there is a continuing need for noise suppression circuits. In general, the major challenge in designing noise suppression circuits is the need to reduce portions of the signal considered to be noise in comparison to portions of the signal considered to include useful information.

[0004] Therefore, in order for a filter to be effective it often must be configured or tuned in phase and frequency to the signal it is processing. This requirement can cause difficulties when the signals being processed vary in some of their attributes. For example, if the signal being processed is not in phase with the demodulating signal, the dynamic range of the demodulator or filter is reduced therefore effectively reducing the signal to noise ratio, thus making the detection of the relevant signal more difficult.

[0005] Embodiments of the present invention are directed to demodulating an incoming signal by using a demodulation signal, while controlling the phase of the demodulation signal in relation to the incoming signal.

[0006] The incoming signal is comprised of the data of interest (for example data received from a touch sensitive panel) modulated onto a carrier and a noise component that may be present on the signal, can be processed by being mixed with the demodulation signal The mixing process generates signal components with frequencies that represent the sum and difference of the frequencies of the original signal components and signal components that have the same frequencies. Typically, if the demodulating signal has the same frequency as the incoming signal then, amongst others, signal components at DC and twice the original frequency are generated at the output of the mixer. Typically, following the demodulator stage, is a filter that has a pass band centered around one of the frequency components of interest. For example, if the carrier signal is 200 Khz, the modulation frequency is 10 Hz (this could for example be the rate at which the finger touches the multi-touch panel), the signal to be demodulated would look like a amplitude modulated signal, i.e. have a peak at 200 Khz and one peak each at 200 Khz−10 Hz and 200 Khz+10 Hz. If, for example, the signal is demodulated (mixed) with a **200**Khz signal, one of the components created is the difference of the components. Therefore there would a total of three components (in the absence of noise), 200 Khz−200 Khz=DC, 200 Khz−10 Khz−200 Khz=−10 Hz and 200 Khz+10 Khz+200 Khz=10 Khz. In the example above a subsequent low pass filter with a bandwidth of at least 10 Khz would follow the mixer stage to isolate the 10 Hz component. The amplitude of that 10 Khz component can carry useful information, such as, for example, a capacitance appearing at a touch sensitive panel.

[0007] However, in many cases, the phase of the incoming signal can vary as compared to the phase of the demodulation signal. Therefore, in some embodiments, the phase of the modulation signal is changed according to various variables (such as, for example, time) which indicate respective changes of the phase of the incoming signal. In some embodiments, an initialization period is implemented, during which one or more optimal phases of the modulation signal are detected and saved. The modulation signal may later be modified to match the optimal phases discovered during the initialization period.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** illustrates an exemplary computing system using a multi touch panel input device.

[0009] FIG. **2***a* illustrates an exemplary capacitive multi touch panel.

[0010] FIG. **2***b* is a side view of an exemplary capacitive touch sensor or pixel in a steady-state (no-touch) condition.

[0011] FIG. **2***c* is a side view of the exemplary capacitive touch sensor or pixel in a dynamic (touch) condition.

[0012] FIG. **3***a* illustrates an exemplary analog channel.

[0013] FIG. **3***b* is a more detailed illustration of a virtual ground charge amplifier at the input of an analog channel, and the capacitance contributed by a capacitive touch sensor and seen by the charge amplifier.

[0014] FIG. **3***c* illustrates an exemplary Vstim signal with multiple pulse trains each having a fixed number of pulses, each pulse train having a different frequency.

[0015] FIG. **4** is a diagram showing the rectification function of a mixer.

[0016] FIG. **5**A is a diagram of a portion of the multi touch panel.

[0017] FIG. **5**B is a diagram of a portion of the multi touch panel showing resistances and capacitances appearing at the electrodes.

[0018] FIG. **6**A is a diagram of an exemplary look-up table and an accompanying shift register and timing logic according to one embodiment of this invention.

[0019] FIG. **6**B is a timing diagram showing the various waves that can result from different tap-points of the shift register.

[0020] FIG. **7** is a diagram showing channel specific phase tuning logic according to one embodiment of this invention.

[0021] FIG. **8** shows logic for generation of phase selector signals according to one embodiment of this invention.

[0022] FIG. **9** is a flow chart showing a method of generating predefined row specific and column specific phase delay values.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0023] In the following description of preferred embodiments, reference is made to the accompanying drawings