Universal Radio for Beamforming and Signal Detection without Carrier Knowledge

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Typical communication networks consist of a single radio-frequency (RF) carrier signal, modulated with an information signal. This information signal is extracted in a receiver by mixing the received signal with one or more local reference signals, generated within the receiver by a local oscillator (LO) or other circuit. The frequency of these reference signals must correspond with the received carrier frequency in a predetermined way. Simultaneously, the generation and distribution of reference signals is challenging, and can have unintended effects on the recovered signal. Increasingly, antenna arrays are employed to receive weaker signals by coherently combining the individual antenna element signals. However, producing the appropriate weights for each element signal requires knowledge of the signal's direction of arrival. Eliminating the need for any knowledge of the carrier signal or direction, and the need for local reference signals as well as phase shifters, all imply major receiver simplifications.

To this end, this paper proposes a "universal radio" capable of beamforming and down-converting incoming signals without *a priori* knowledge of the source location or frequency. This is accomplished by combining two innovations: 1) a self-steering array front-end, and 2) a frequency-independent receiver. Specifically, by leveraging symmetry in the aperture phase distribution, the self-steering front-end can cancel local phase mismatch to constructively combine element signals from an unknown angle of incidence. This can be done without a need for phase shifters. This produces gain in the signal reception, despite having omnidirectional sensitivity. Further, unlike conventional homo- or heterodyne receivers, which require a LO, the proposed system operates without prior knowledge of the carrier frequency. This is accomplished by applying a copy of the input signal in lieu of the LO for down-conversion.

Of course, for modulated signals the outputs are squared at baseband, leading to loss of phase and polarity information. This issue has prevented the extension of this type of receiver to communications applications. Besides basic amplitude modulations (ASK, OOK), such a receiver cannot recover data signals. To overcome this issue, we propose a novel digital zero-crossing detection, an approach that uses signal polarity to demodulate signals with Amplitude/Binary Phase Shift Keyed (ABPSK). We will also demonstrate that insertion of a time delay in one copy of the signal allows complex signals (QPSK, QAM) to be recovered in the same way.

At the conference, we will present the proposed architecture of the "universal radio," and will present design, simulation and measured results of signal recovery for modulated signals. To date, this is the first radio architecture capable of beamforming and down-conversion without *a priori* knowledge of the source location or frequency.