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Contribution to WG1 *: Definition of cognitive algorithms for adaptation and configuration of a single link according to the status of external environment*

Application of an Algorithm for Channel and Noise Estimation to Spectrum Sensing in a Cognitive Radio Context

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Introduction: This extended abstract proposes an application of an existing algorithm to spectrum sensing in a cognitive radio context. This algorithm, presented in [1], has been originally designed for the joint and iterative estimation of the channel and the SNR in an OFDM case. In the following, the system model, the algorithm and preliminary results are presented.

I. System model

Let us assume a secondary user (SU) that senses a given band of frequency in order to detect a primary user (PU). We denote **U** the vector containing the OFDM signal samples in the frequency domain that are received by the SU, after the cyclic prefix removal and the discrete Fourier transform (DFT) of size M. According to the absence or the presence of the PU, the usual hypothesis test is considered:

$$\begin{cases} H0 : \boldsymbol{U} = \boldsymbol{W} \\ H1 : \boldsymbol{U} = \boldsymbol{H}\underline{\boldsymbol{C}} + \boldsymbol{W} \end{cases}$$

where $\boldsymbol{W}$ is the zero-mean additive white Gaussian noise vector of variance σ^2, $\boldsymbol{H}$ is the channel frequency response and $\underline{\boldsymbol{C}}$ is the transmitted OFDM symbol. The SU is supposed to be perfectly synchronized with the signal of the PU.

II. Proposed detector

The principle of the original algorithm [1], under the hypothesis ***H1***, is to iteratively estimate the channel frequency response $\boldsymbol{H}$ and the noise level σ^2 by means of the minimum mean square error (MMSE) criterion. At each iteration i, the estimated channel feeds the noise variance estimation and vice versa. For i>0, the estimation steps are expressed as follows:

$$\widehat{\boldsymbol{H}}_{(i)}^{LMMSE} = \underline{\boldsymbol{R}}_H(\underline{\boldsymbol{R}}_H + \hat{\sigma}_{(i-1)}^2\underline{\boldsymbol{I}})\widehat{\boldsymbol{H}}^{LS},$$

$$\hat{\sigma}_{(i)}^2 = \frac{1}{M}E\{||\widehat{\boldsymbol{H}}^{LS} - \widehat{\boldsymbol{H}}_{(i)}^{LMMSE}||^2\},$$

where $\widehat{\boldsymbol{H}}^{LS}$ et $\widehat{\boldsymbol{H}}_{(i)}^{LMMSE}$ are the least square (LS) and linear-MMSE (LMMSE) channel estimations [2], $\underline{\boldsymbol{R}}_H$ is the channel frequency covariance matrix and E{.} is the mathematical expectation. Under ***H1***, we proved that the noise variance estimation is very accurate.

Under the hypothesis ***H0***, the steps are naturally the same. In that case, the LS estimation $\widehat{\boldsymbol{H}}^{LS} = \boldsymbol{W}\boldsymbol{C}^{-1}$ returns just noise. It is then possible to analytically show that the algorithm converges, and the estimated noise variance is very close to its true value. This property is ensured if the initialization value $\hat{\sigma}_{(i=0)}^2$ is chosen relatively high. This characterization matches the recommendation concerning the initialization made under ***H1*** [1]. Thus, as the algorithm has a similar behavior for each hypothesis ***H0*** and ***H1*** (i.e. it does not diverge), it can be used as a detector.

Since the algorithm estimates the noise variance under both hypotheses, we propose the following metric $\mathcal{M} = M_2 - \hat{\sigma}^2$ to define the decision rule, with M_2 the second-order moment of the received signal. As we assume an accurate noise variance estimation, we get $\mathcal{M} = \sigma^2 - \hat{\sigma}^2 \approx 0$ under ***H0***, and $\mathcal{M} = P_s - \hat{\sigma}^2 \approx P_s$ under ***H1***, with P_s the signal power. By fixing a threshold ς, we define the decision rule

$$\begin{gathered} HO, if\ \mathcal{M} < \varsigma \\ H1, else. \end{gathered}$$

III. Simulations results

We now evaluate the performance of the detector by means of the receiver operating curves (ROC), displaying the detection probability versus the false alarm probability. Two different SNR values (-10 dB and 0 dB) are considered, and the proposed detector is compared to the basic energy detector.

We observe that, whatever the SNR value, the proposed detector outperforms the energy detector, since the latter is inefficient in Rayleigh channels. Furthermore, the proposed detector is able to reach the perfect detector, for SNR=0dB.

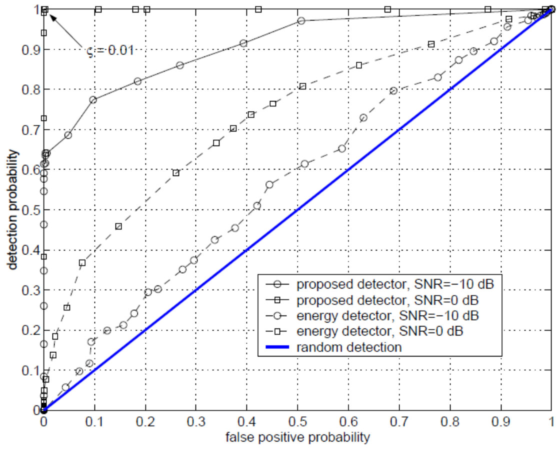

Fig. 1 ROC curves of the proposed detector

Conclusion: This abstract presented a spectrum sensing method based on an iterative algorithm designed for the joint channel and SNR estimation. This algorithm has then different applications (sensing, estimations) with a unique structure, so it perfectly comes in the scope of cognitive radio.

[1] V. Savaux, Y. Louët, M. Djoko-Kouam and A. Skrzypczak “Application of a Joint and Iterative MMSE-based Estimation of SNR and Frequency Selective Channel for OFDM Systems” *EURASIP JASP*, accepted in July 2013-08-29

[2] O. Edfors, M. Sandell, J.-J. van de Beek, S. K. Wilson and P. O. Börjesson “OFDM Channel Estimation by Singular Value Decomposition”, *IEEE Transactions on Communications*, vol. 46, no. 7, pp. 931 – 937, July 1998