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# ANALYSIS OF NEUTRON NOISE SPECTRA USING NEURAL NETWORKS

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## INTRODUCTION

Neural network architectures based on the back-propagation paradigm have been developed to recognize the features, and detect resonance shifts in, power spectral density (PSD) data. Our goal is to advance the state of the art in the application of noise analysis techniques to monitor nuclear reactor internals. The initial objectives have been to use PSD data, acquired over a period of about 2 years by PSDREC[1] (power spectral density recognition system), to develop neural networks that are able to

a. Differentiate between normal neutron power spectral density data and anomalous spectral data (e.g. malfunctioning instrumentation, etc.).

b. Detect significant shifts in the positions of spectral resonances while reducing the effect of small shifts. [In neutron noise analysis, shifts in the resonance(s) present in a neutron PSD spectrum are the primary means for diagnosing degradation of reactor internals.]

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Neural network systems referred to in this paper as spectral feature detectors (SFDs) and integral network filters (INFs) have been developed to meet these objectives. The performance of the SFDs is the subject of this paper.

## SPECTRAL FEATURE DETECTORS

Guidelines were adopted to develop networks that are simple, require no training when the system is on-line, and do not necessarily require *a priori* knowledge of the spectral patterns that may be encountered by the system.

Each SFD is trained to recognize the salient features typically used by a human to recognize a spectral signature—resonances (peaks), valleys, flat responses, or monotonically increasing or decreasing responses. The occurrence of these features at particular frequencies enables a spectrum to be recognized as "resembling a normal neutron noise spectrum." The neural network's ability to generalize allowed each feature to be recognized even when the signal was noisy or when the nature of a particular feature (such as the amplitude of a resonance) changed from those upon which the network was trained. The multiple neural network system was developed with an overlapping window structure. A 4-Hz window was used with 2-Hz overlapping (i.e., the windows were 0 to 4 Hz, 2 to 6 Hz, 4 to 8 Hz, etc).

Each SFD consists of a 10-neuron input layer (representing 10 frequency bins in a 4-Hz window), two hidden layers, and a 3-neuron output layer. The (binary) output from the set of networks constitutes a "binary feature signature" (BFS), which is used to detect the resonance regions in the spectrum. Each 3-bit pattern represents a particular feature seen by a network. A bit pattern of "111," for example, represents a resonance.

## TEST RESULTS

A 14-network system, covering a spectral range of ~30 Hz, was designed and tested with data from the ORNL PSD data library. Figure 1 shows a neutron spectrum and its BFS, along with a neutron spectrum (and its corresponding BFS) in which a resonance has disappeared in one frequency region. Figure 2 shows the spectral pattern (and corresponding BFS) obtained from a simulation of a failed sensor. This and other tests showed that changes in spectral patterns can be monitored accurately.

In a typical application the SFDs are used for spectral data validation, whereas actual data analysis is performed with the INFs.[2] Initial tests suggest that the method could be used as an alternative to the statistical pattern recognition technique employed in PSDREC. If used in conjunction with the INFs, it appears that this method can eliminate false alarms in PSDREC that may be due to slight shifts in the resonances. The system may be used as an embedded network in a design incorporating an expert system for signal validation and the automatic surveillance of reactor systems for internal structural degradation. Current work is directed toward this goal.

## REFERENCES

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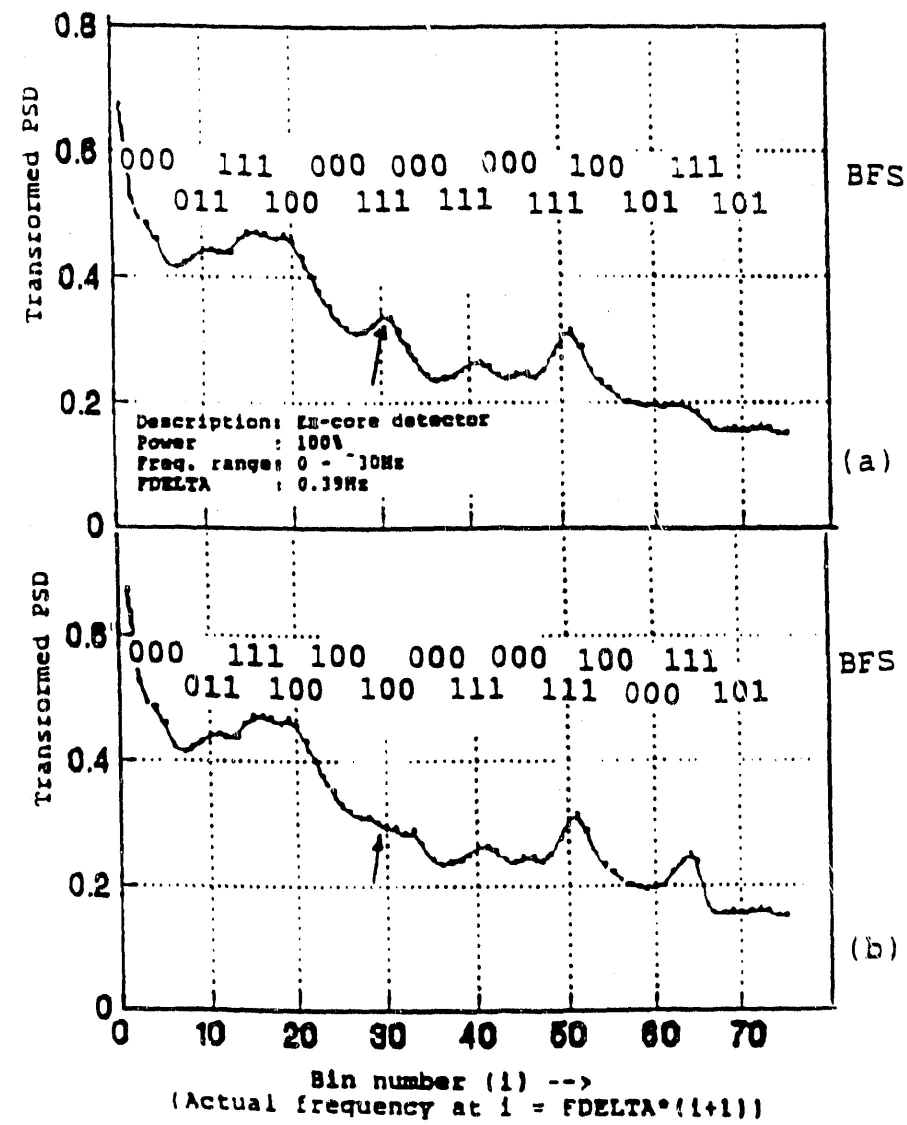
Fig. 1. a. Ex-core neutron PSD and the resulting BFS; b. The change in the spectrum (arrowed) was seen by the neural network system (see text).

Fig. 2. Spectral pattern (and corresponding BFS) obtained for a simulated sensor failure.

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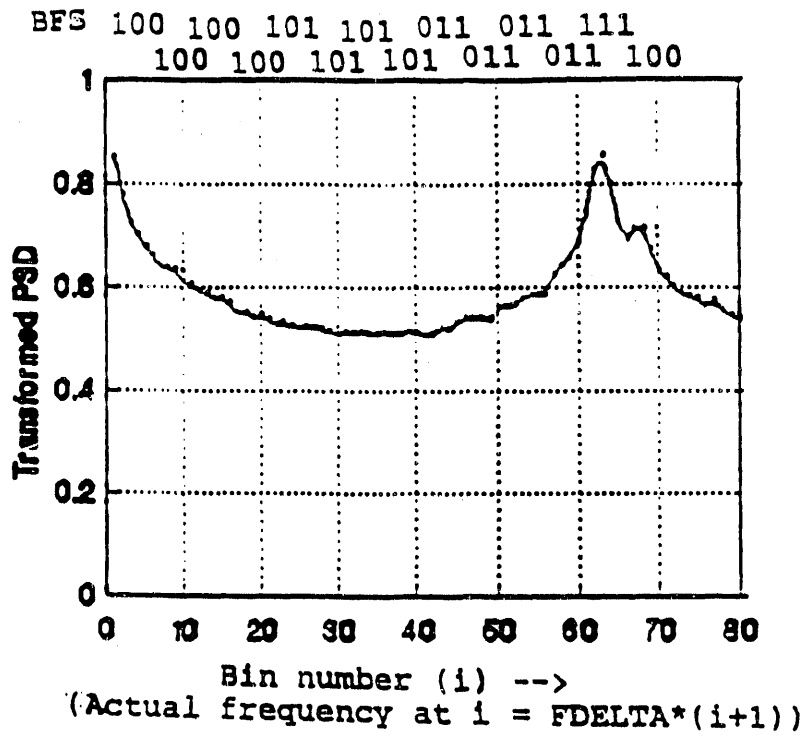


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