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Spectrum sensing method based on a multi-scale feature fusion network

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Key words: Cognitive radios; Spectrum sensing; Deep learning; Multi-scale feature fusion

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Motivation

- Targeting the degraded spectrum sensing performance caused by severe SNR fluctuations, especially the limited feature extraction and inefficient feature utilization of traditional CNNs under low-SNR conditions, a novel spectrum sensing method based on a multi-scale feature fusion network (MSFFNet) is proposed, which effectively captures multi-scale information, suppresses redundant features, and significantly improves detection performance in low-SNR communication scenarios.

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Main idea

- MSFFNet for spectrum sensing: A novel multi-scale feature fusion network that extracts local and global spectrum features in parallel, significantly improving multi-scale signal perception under low-SNR conditions.
- AFSS + MLFFM: An adaptive feature screening and multi-level fusion strategy that emphasizes key features, suppresses redundancy, and enables effective cross-scale feature integration.
- Low-SNR evaluation framework: A multi-level mixed-SNR dataset and a Rayleigh fading channel model are constructed, demonstrating strong accuracy, scalability, and robustness of MSFFNet.

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Method

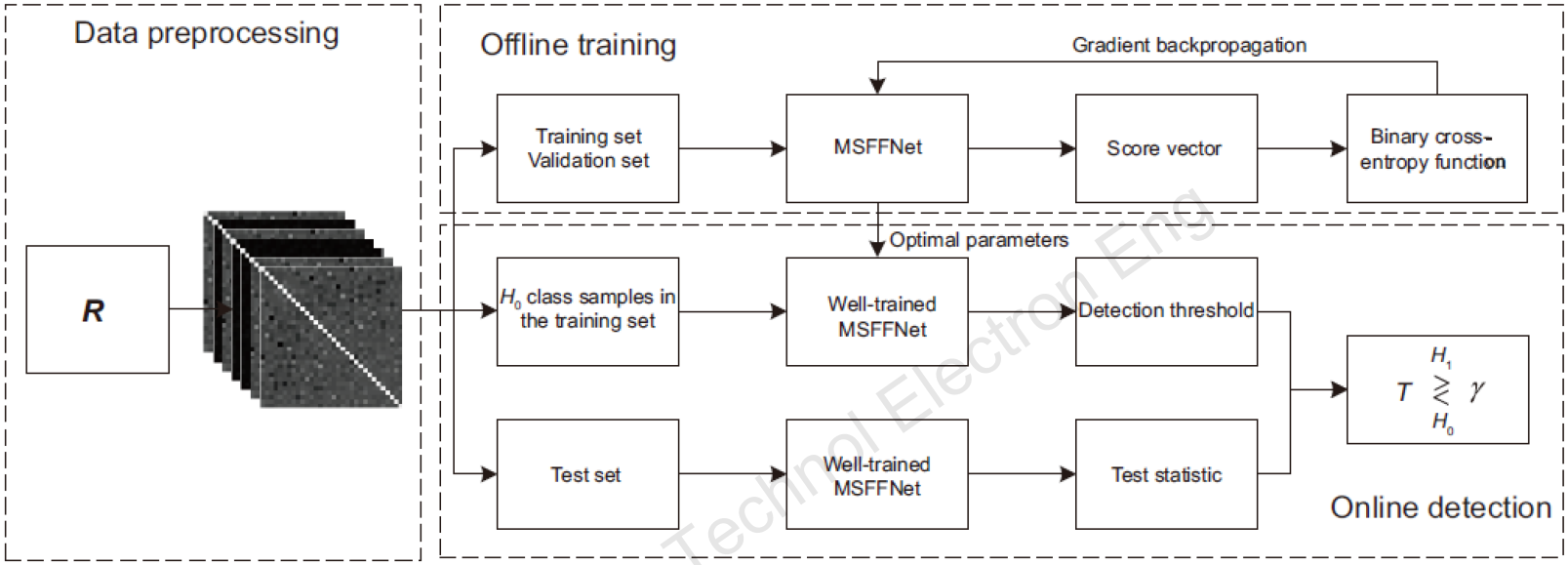


Fig. 1 Spectrum sensing system based on MSFFNet

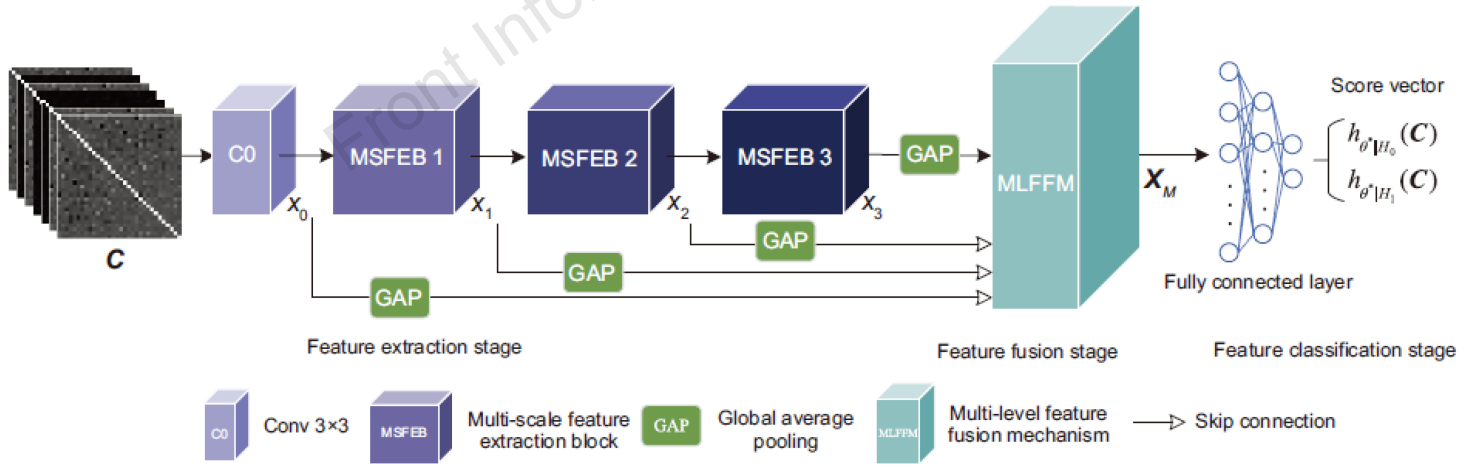
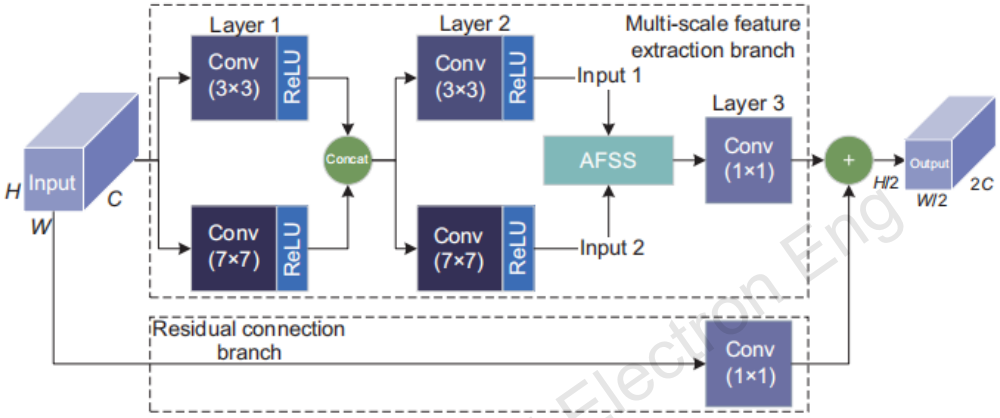


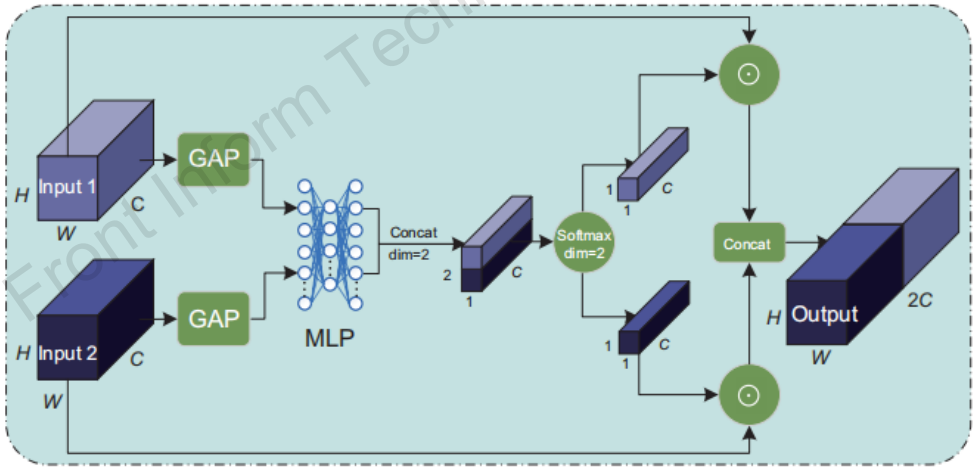
Fig. 3 MSFFNet model structure

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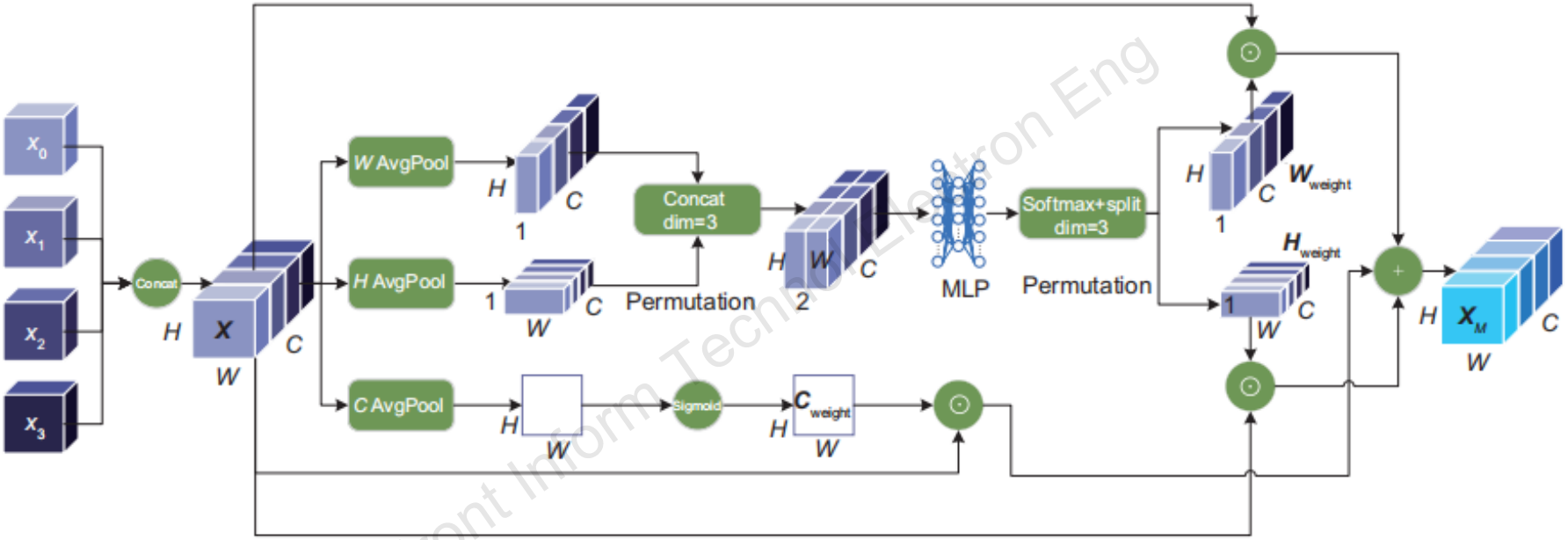
(a)



(b)

Fig. 4 Illustration of the multi-scale feature extraction (a) and AFSS in the MSFEB (b). ⊙: channel-wise multiplication

Method



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Fig. 5 Illustration of the MLFFM

Results

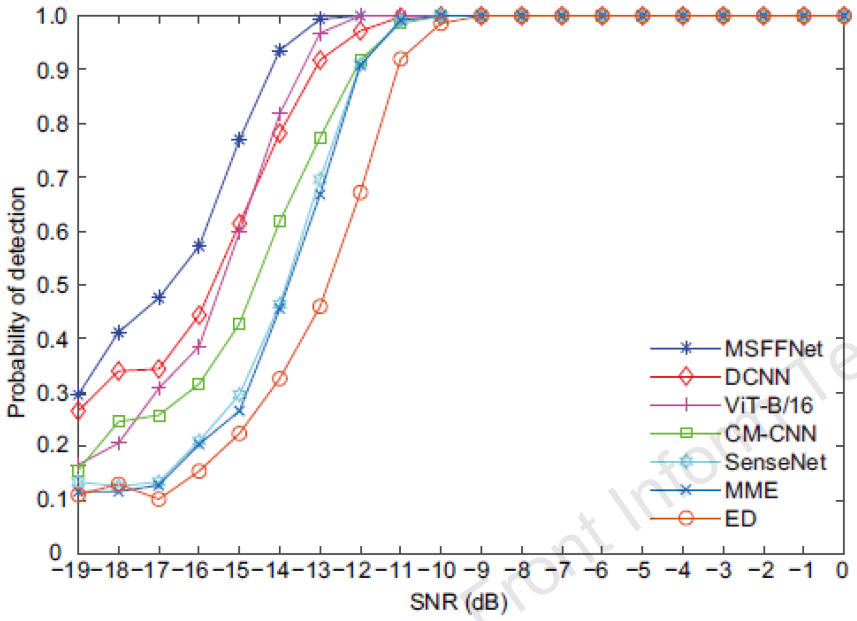


Fig. 7 P_d–SNR curves of the MSFFNet and six comparison methods

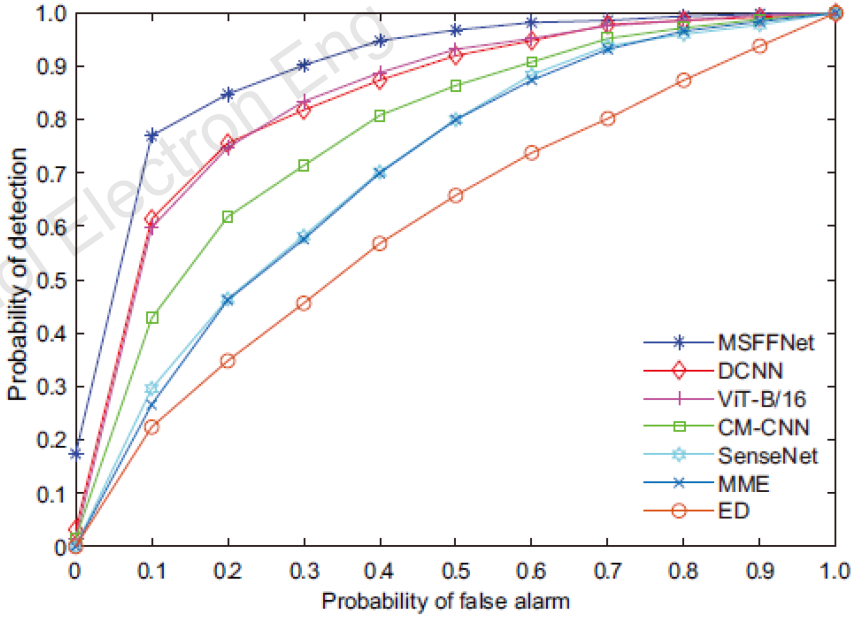


Fig. 8 ROC curves of the MSFFNet and six comparison methods

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Results

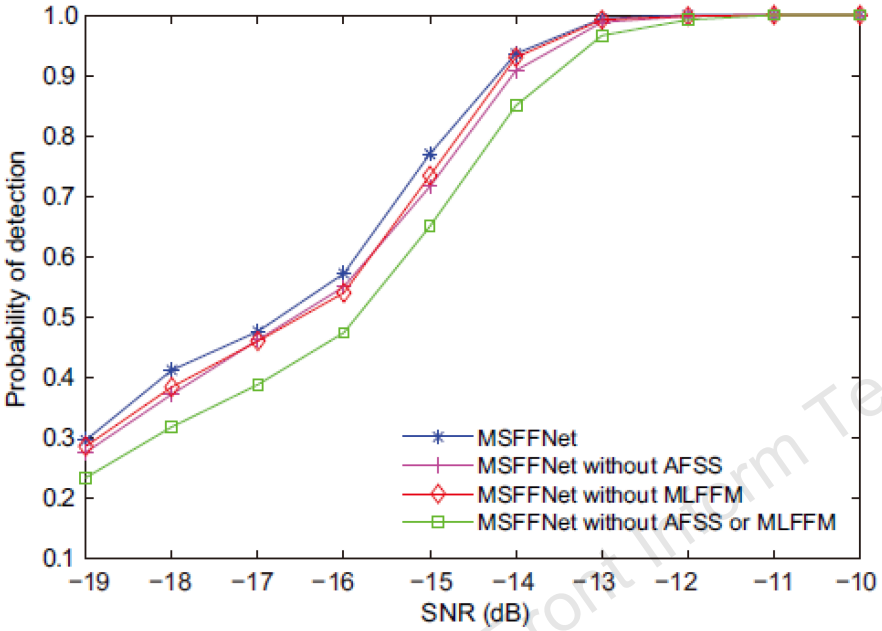


Fig. 9 Ablation simulation of the MSFFNet

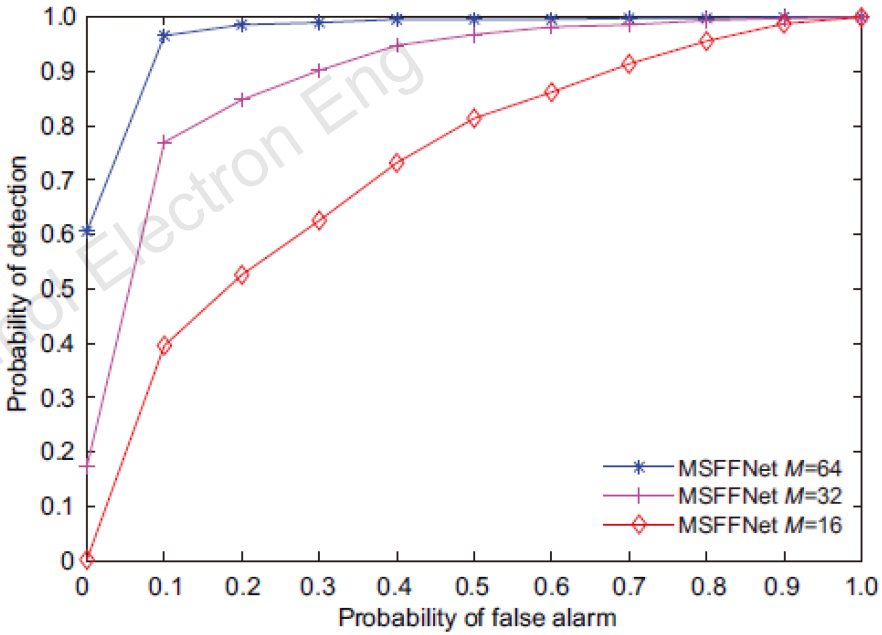


Fig. 10 ROC curves of the MSFFNet with different numbers of antennas

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Results

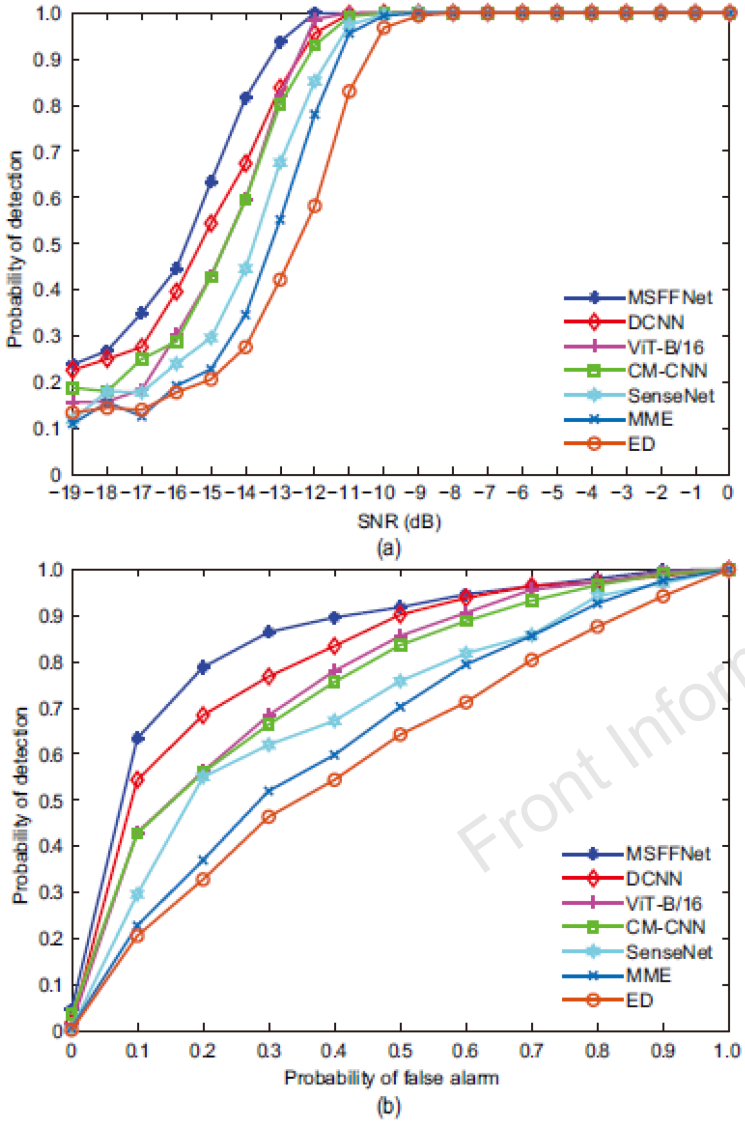


Fig. 12 Detection performance of spectrum sensing methods under colored noise: (a) P_{d}–SNR curves; (b) ROC curves

Table 4 Comparison of the complexity of spectrum sensing models

Model	Memory (MB)	N_{par} ($\times 10^6$)	N_{MACs} ($\times 10^6$)	P_{d}
SenseNet	17.89	4.21	5.32	0.464
DCNN	22.18	0.10	76.41	0.782
MSFFNet	104.49	22.22	969.62	0.936
CM-CNN	107.36	25.63	138.86	0.618
ViT-B/16	735.83	85.80	16 880	0.818

N_{par}: number of parameters; N_{MACs}: number of MACs

Table 5 Comparison of training and inference time for spectrum sensing models

Model	Training time (s)	Inference time (ms)
SenseNet	494	1
CM-CNN	596	2
DCNN	577	2
MSFFNet	851	4
ViT-B/16	4532	9

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Conclusions

In this work, we propose a novel spectrum sensing method based on a multi-scale feature fusion network (MSFFNet) to address the feature extraction limitations of traditional CNNs under low-SNR conditions. By integrating multi-scale feature extraction, adaptive feature screening, and multi-level feature fusion, the proposed method effectively captures local and global signal characteristics. Experimental results demonstrate that MSFFNet significantly outperforms existing sensing models in low-SNR scenarios at the same false alarm probability, providing useful insights for intelligent spectrum sensing in complex wireless environments.

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Kejun LEI received her BS degree in electronic information engineering from Jishou University, China, in 2002, the MS degree in circuits and systems from Hunan University, China, in 2007, and the PhD degree in electrical engineering from Hunan University, China, in 2018. She is currently a Professor and a Master's Supervisor in electronic information engineering at Jishou University. Her research interests include smart grids, digital signal processing, and cognitive radio.

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