

Reconfigurable Wireless Platforms for Spectrally Agile Coexistence

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NEED ADDRESSED

- RURAL BROADBAND

- **14.5M rural Americans lack broadband access**
 - Too expensive for many other rural Americans
- **Low population density and oftentimes difficult terrain hinders infrastructure development**
- **Impact:**
 - Higher unemployment/lower earnings
 - Fewer educational opportunities
 - Lower quality healthcare at higher cost

Technologies are needed to supply low-cost rural broadband communications

OPPORTUNITY/IMPACT

- FCC has approved rules for unlicensed use of Television White Spaces (TVWS) from 54-698 MHz
 - Long range, penetrates buildings & foliage
 - Highest availability in rural areas

- Initial U.S. rural broadband opportunity is \$100M-200M per year
 - White space device market projected to be ~\$10B/year

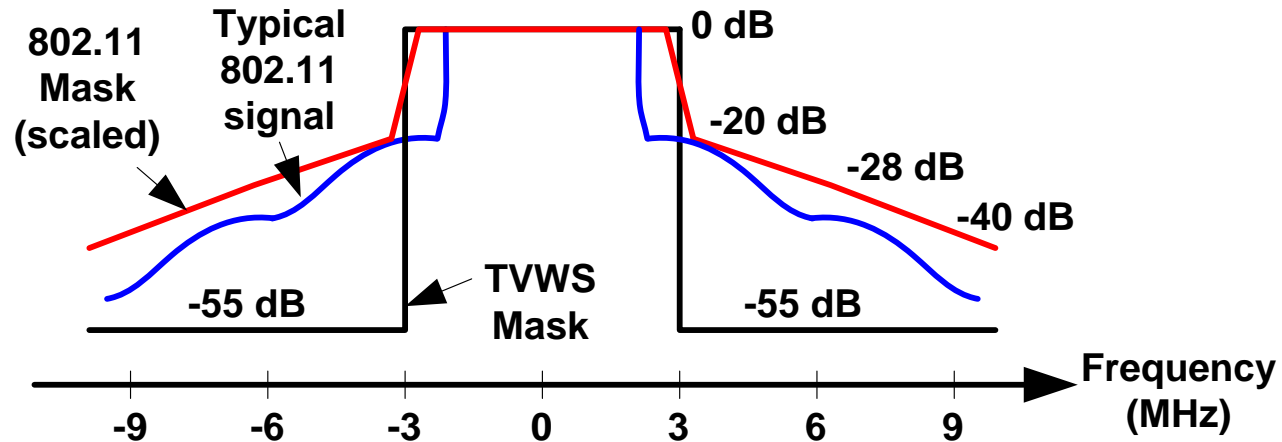


ISSUES

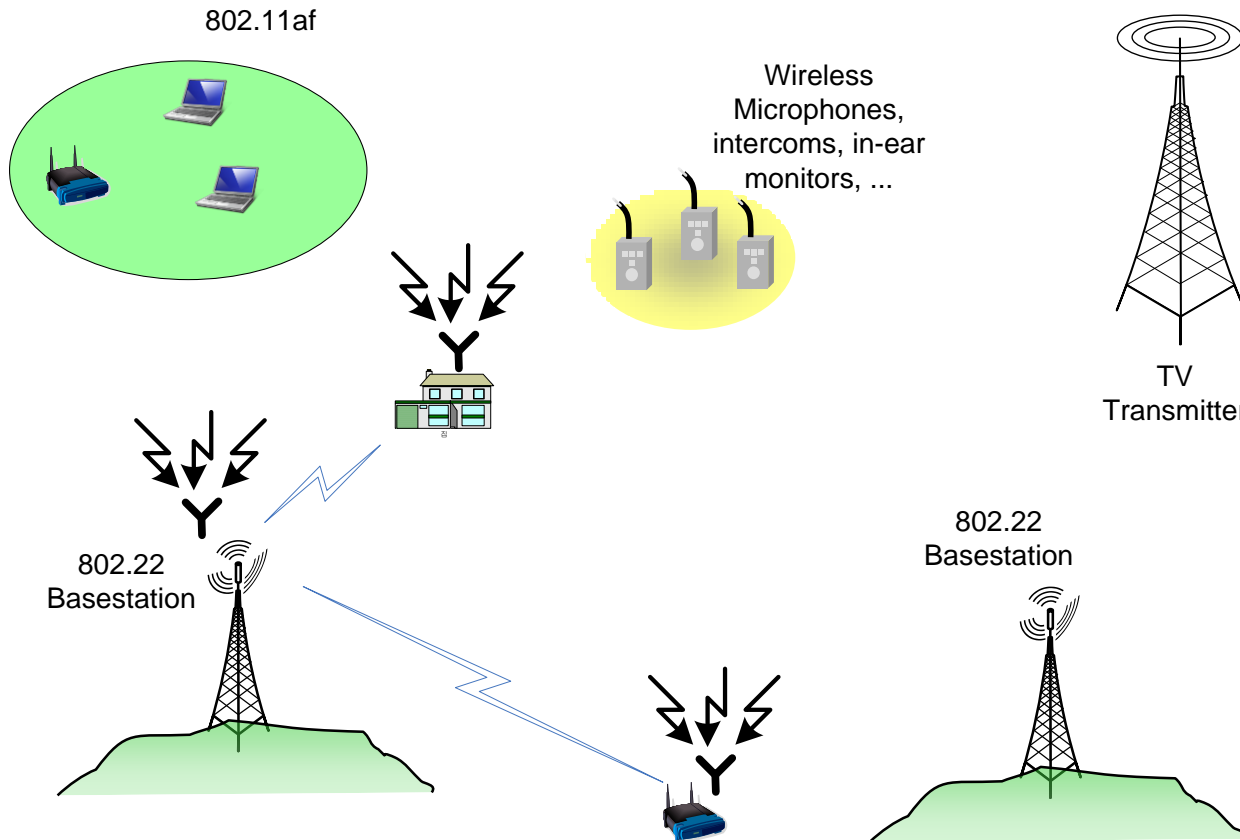
- **Current proprietary TVWS solutions cannot achieve economies of scale**
 - High cost
 - Lack benefit of community-wide innovations
- **No TVWS standard has achieved traction**
 - 802.22 best for long-range TVWS operation
 - Non-Contiguous Orthogonal Frequency Division Multiple Access (NC-OFDMA)
 - Alternatives (e.g., 802.11af, 802.15.4m) are not suitable for rural broadband
- **Technical challenges with 802.22 include:**
 - Out-of-Band (OOB) emissions
 - Coexistence with other TVWS networks
 - Interference mitigation
 - Operation in areas without internet and/or GPS
 - Sensing only operation

TVWS SPECTRUM MASK

- Cannot easily repurpose existing OFDM designs for TVWS operation
- New methods required to limit out-of-band (OOB) emissions

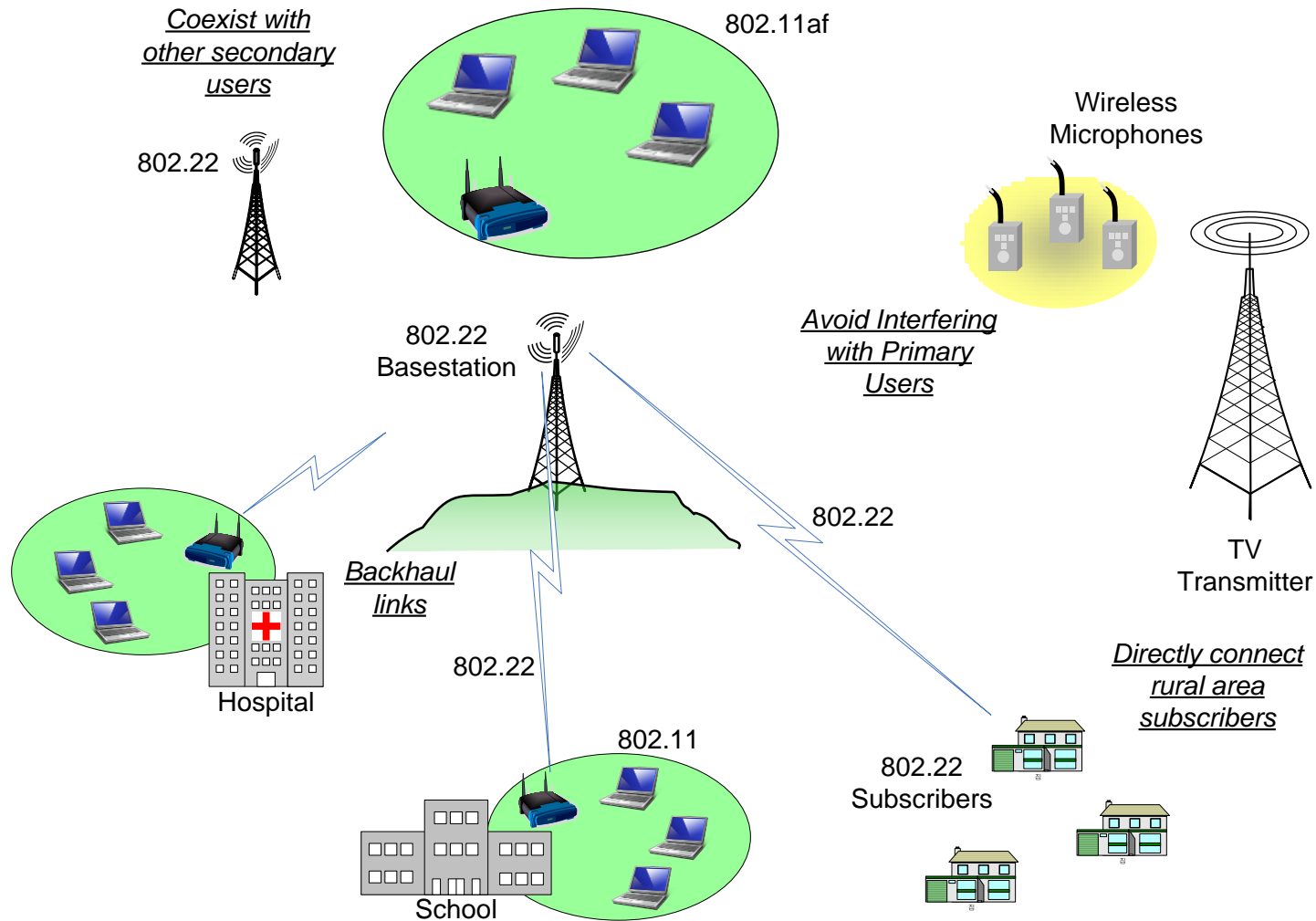


SPECTRUM SENSING



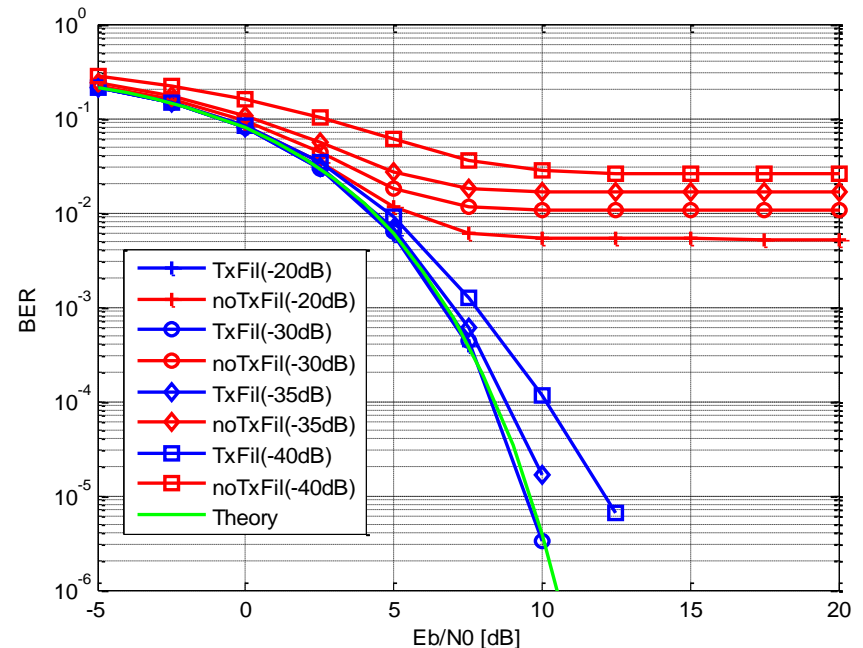
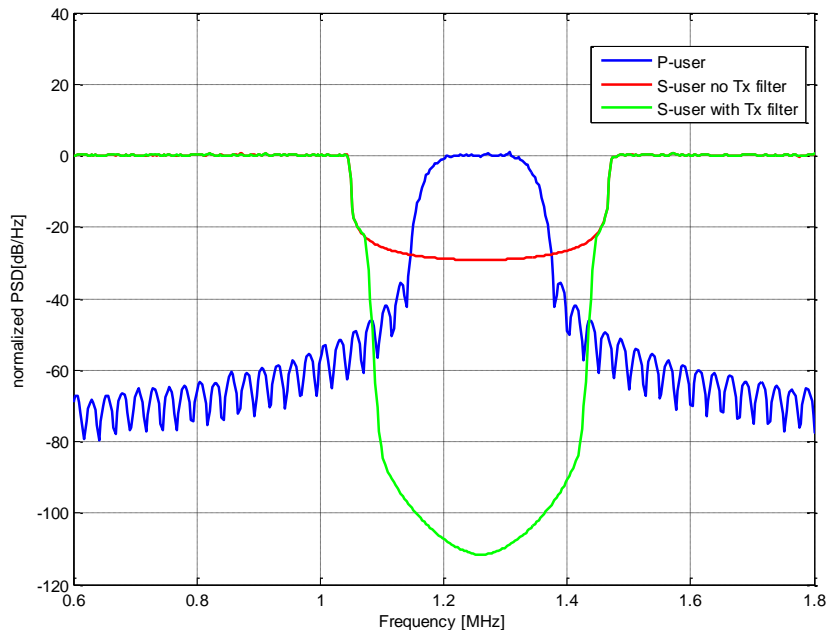
- **Sensing needed for:**
 - **Interference mitigation**
 - Distant TV transmitters
 - Unlicensed microphones
 - **Coexistence**
 - Other 802.22 networks
 - Other TVWS networks
 - **Sensing only operation**

RURAL BROADBAND SOLUTION USING 802.22



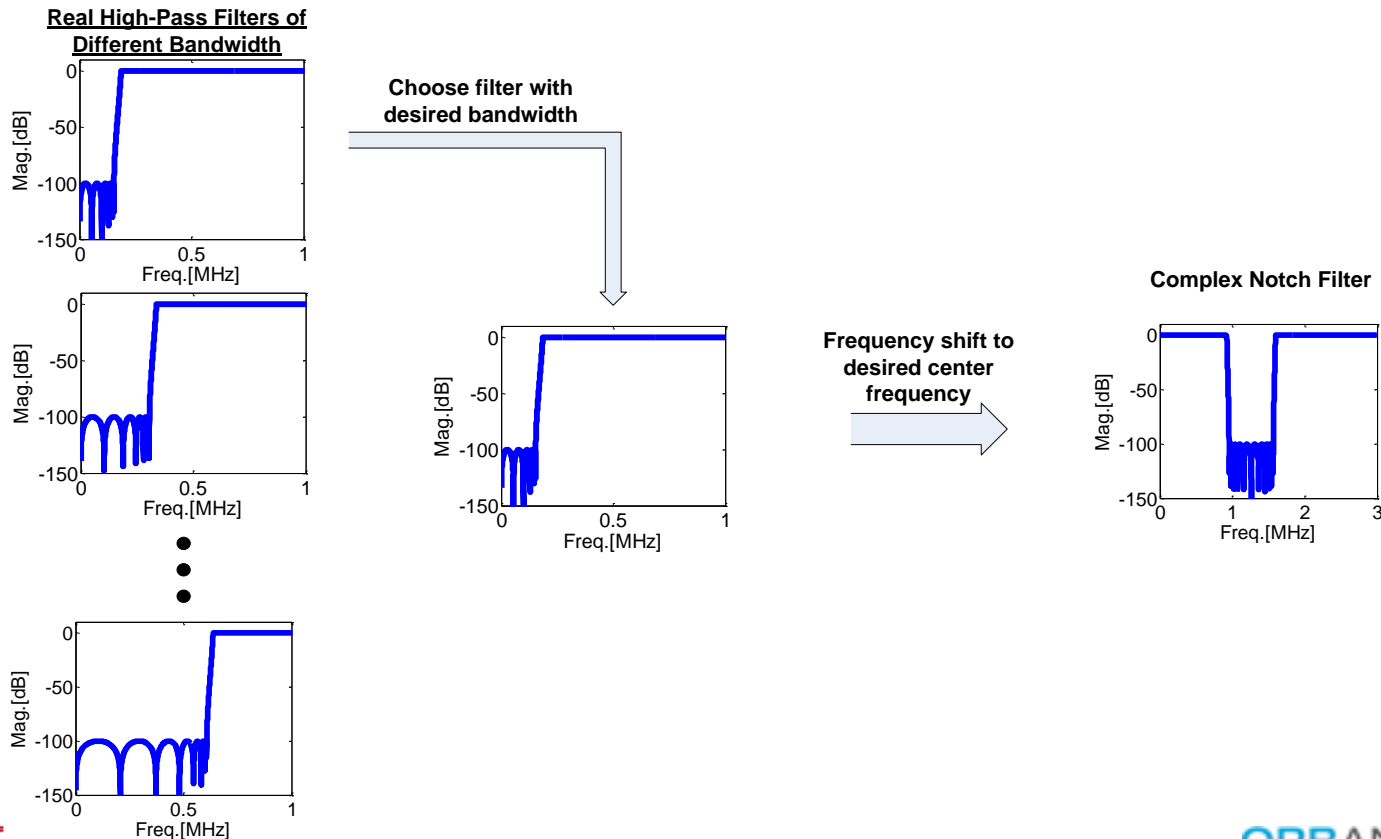
IIR FILTERING

- **Designed and demonstrated on FPGA tunable and practical IIR filters to:**
 - Mitigate in-band interference
 - Reduce OOB emissions



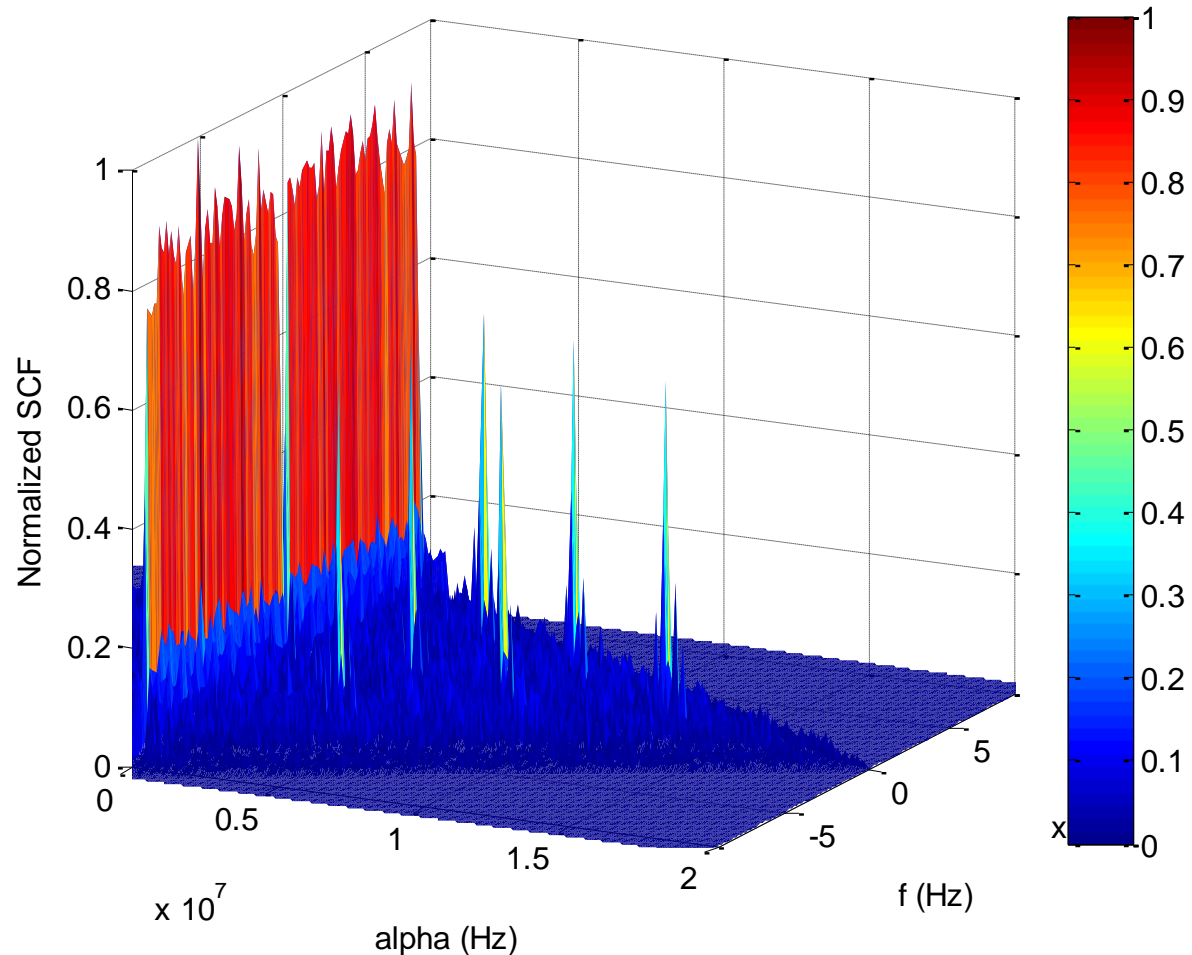
NOTCH FILTER CREATION

- Store high-pass IIR filters spanning range of bandwidths. Choose filter with desired bandwidth and frequency shift to create notch at desired center frequency.

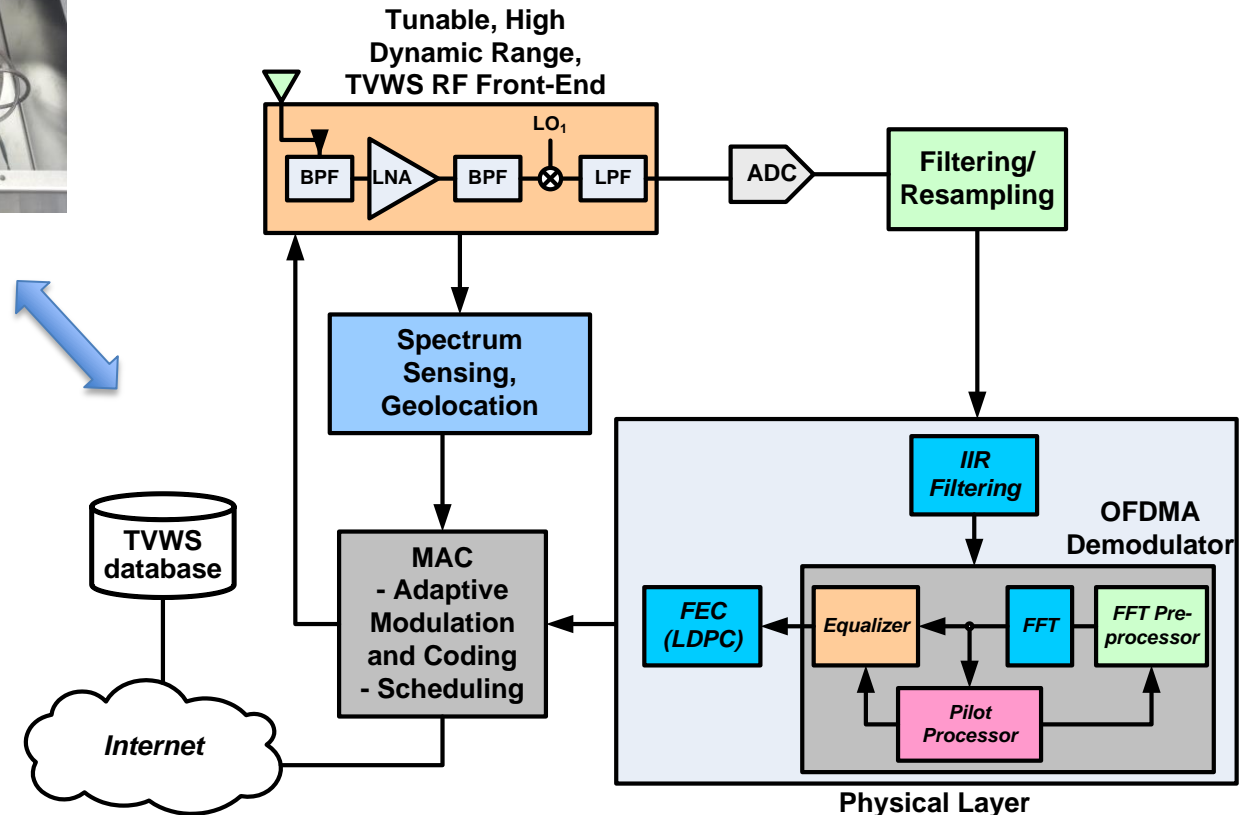


REDUCED COMPLEXITY SPECTRUM SENSING IMPLEMENTED ON FPGA

- **Cyclostationary processing for sensing OFDM:**
 - **Low-SNR operation even when noise and interference levels cannot be accurately estimated**
 - **Known signal features allow reduced bi-frequency search space**



RURAL BROADBAND PROTOTYPE



CONCLUSION

- Reduced complexity and effective filtering and sensing needed for practical and compliant TVWS solutions
- Proposed 802.22-based design promises low-cost, robust, and widespread rural broadband deployment

