# Sub-Nyquist Cognitive Radio System

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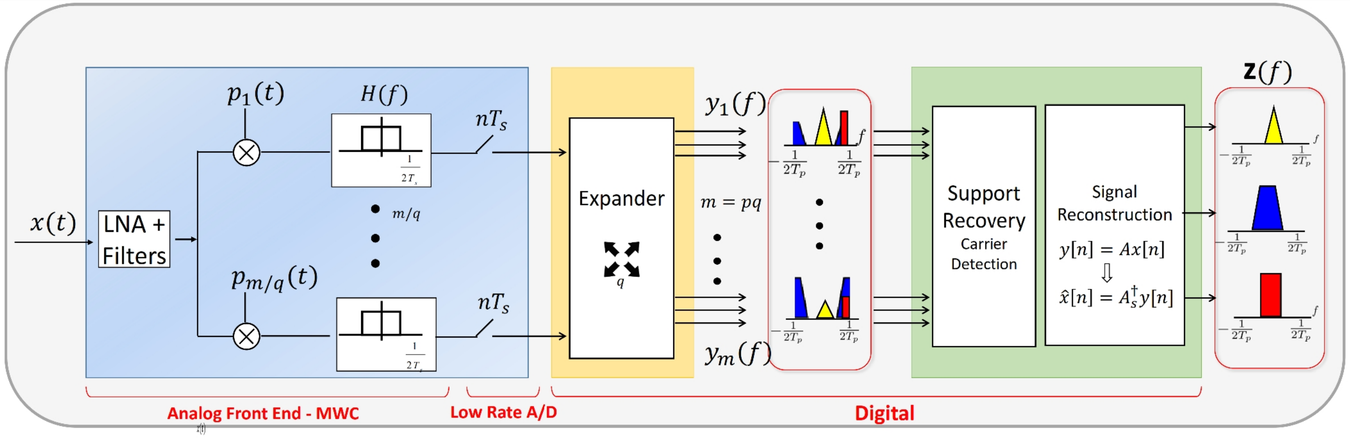
## Main Contributions

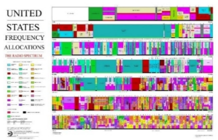
1. Implementing with proprietary hardware a true Sub-Nyquist Cognitive Radio prototype system.
2. Sampling a wideband signal of bandwidth up to 3GHz, at an effective rate of 360MHz – *Just 6% of Nyquist.*
3. Blind support recovery and complete signal reconstruction, without prior knowledge on broadcasted carriers.
4. Efficient calibration procedure that requires no prior knowledge on the system components, performed once off-line.

## The Modulated Wideband Converter (MWC)

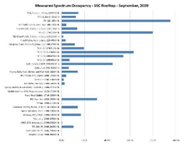



## Cognitive Radios

- Address the conflict between spectrum saturation and underutilization.
- Grant opportunistic and non-interfering access to spectrum "holes" to unlicensed users.
- Perform spectrum sensing task efficiently in real-time.




United States frequency allocation diagram.

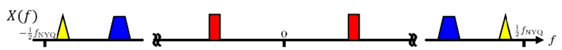


Typical measured spectrum occupancy percentage

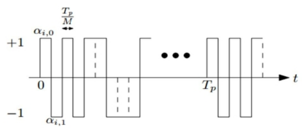
**For a wideband signal**
**Nyquist rate is not an option! → *Sub-Nyquist***

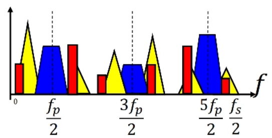
## Input Model & Analog Processing

- Input multiband model – *x(t)* with Nyquist rate $f_{\text{Nyq}}$ composed of $2N_{\text{sig}}$ bands each with max bandwidth $B$.




- The Modulated Wideband Converter (MWC) serves as an analog front-end: $M$ parallel channels alias the spectrum, so that each band appears in baseband.
- Aliasing is done by mixing with periodic sequences:




## Digital Support & Signal Recovery

- The theoretical transfer matrix

$$(\mathbf{A})_{i,l} = c_{i,l} = \frac{1}{T_p}\int_0^{T_p} p_i(t)e^{-j\frac{2\pi}{T_p}lt}\,\mathrm{d}t$$

- The vector $\mathbf{z}(f)$ that contains the spectrum of $x(t)$ divided into $f_p$ slices, and is defined using the DTFT of $x(t)$:

$$z_k(f) = X\big(f + (k - L_0 - 1)f_p\big),\ 0 \le k \le L_0,\ f \in \left[\frac{-f_p}{2}, \frac{f_p}{2}\right]$$

- The Orthogonal Matching Pursuit (OMP) algorithm is used to detect the transmitted signal carriers.
- the signal slices are then reconstructed by inverting the matrix A reduced to the recovered support:

$$\mathbf{y}[n] = \mathbf{A}z_s[n] \implies \boxed{\hat{z}_s(f) = \mathbf{A}_s^{\dagger}\mathbf{y}(f)}$$