Sub-Nyquist Cognitive Radio System

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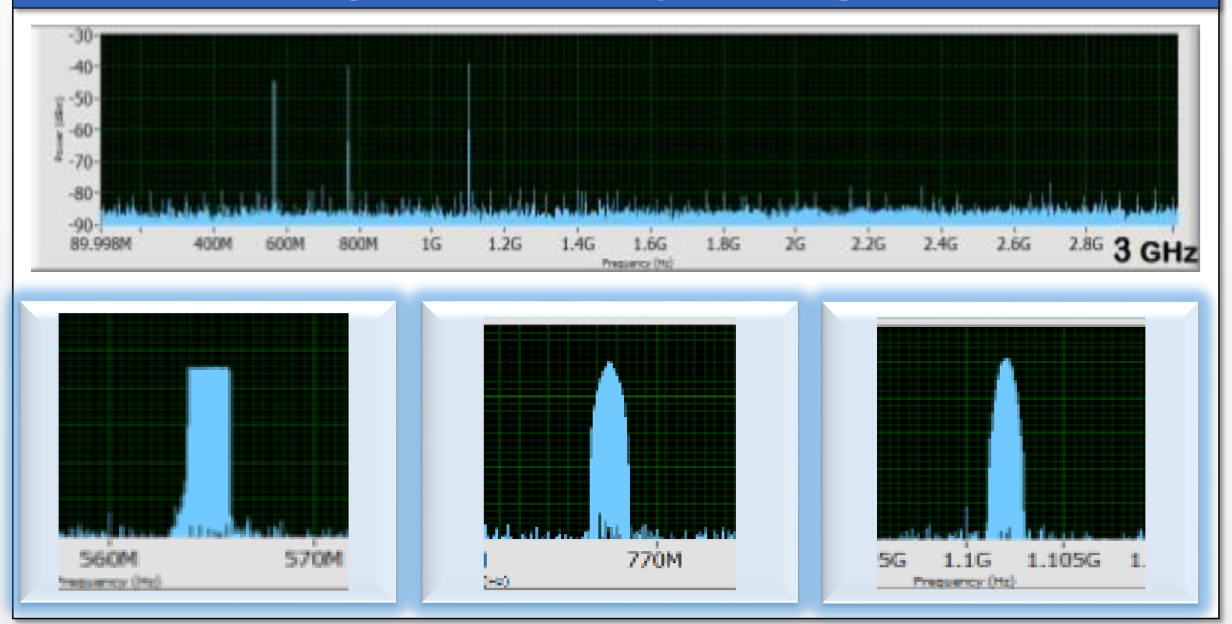
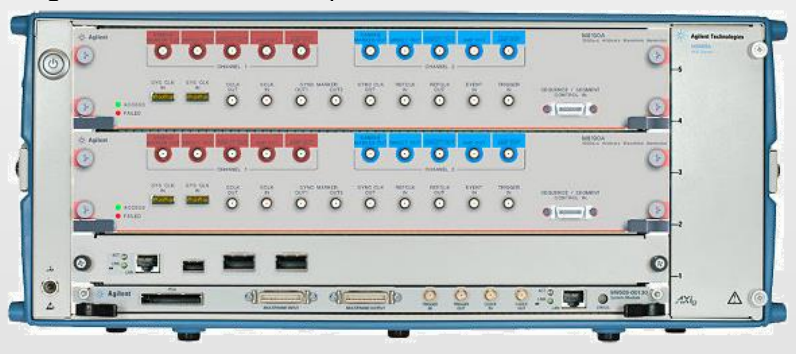
High Rate Input Signal



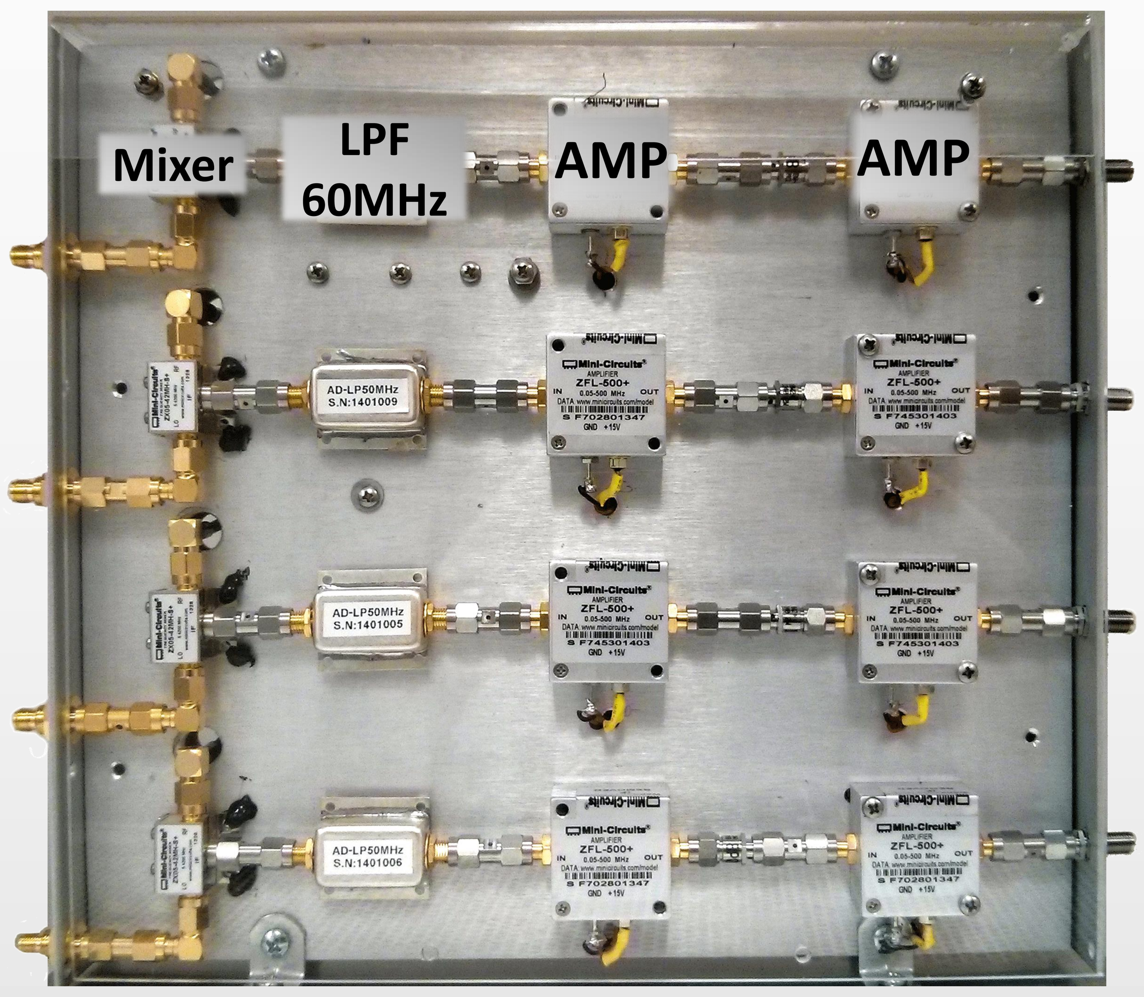
Agilent© Arbitrary Wave Generator M8190



Signal and Sequences Generator

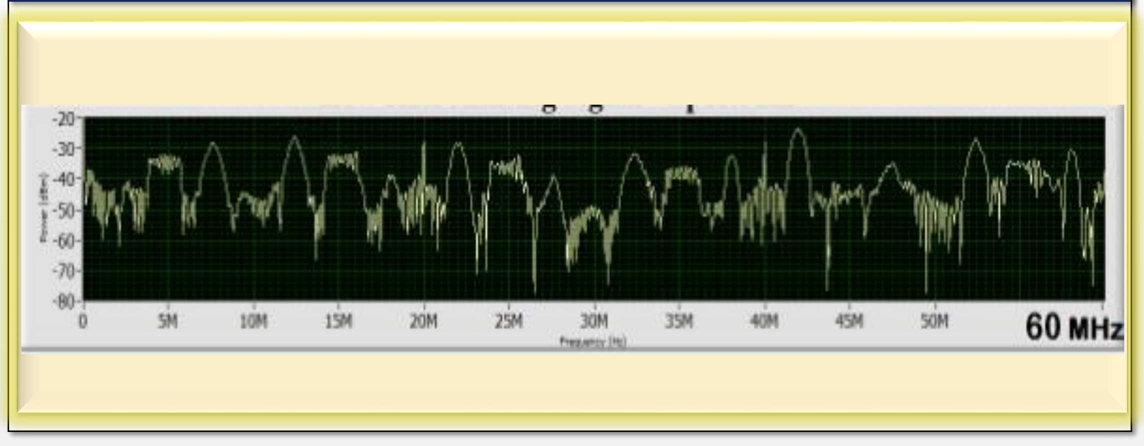
$x(t)$

$p_i(t)$



The MWC Card

Low Rate Aliased Signal



NI© PXIe-1065 with DC Coupled 4-Channel ADC

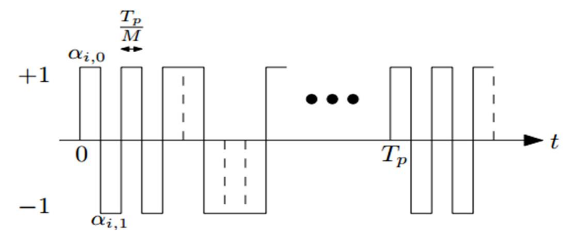
$y_i[n]$

Signal ADC + DSP

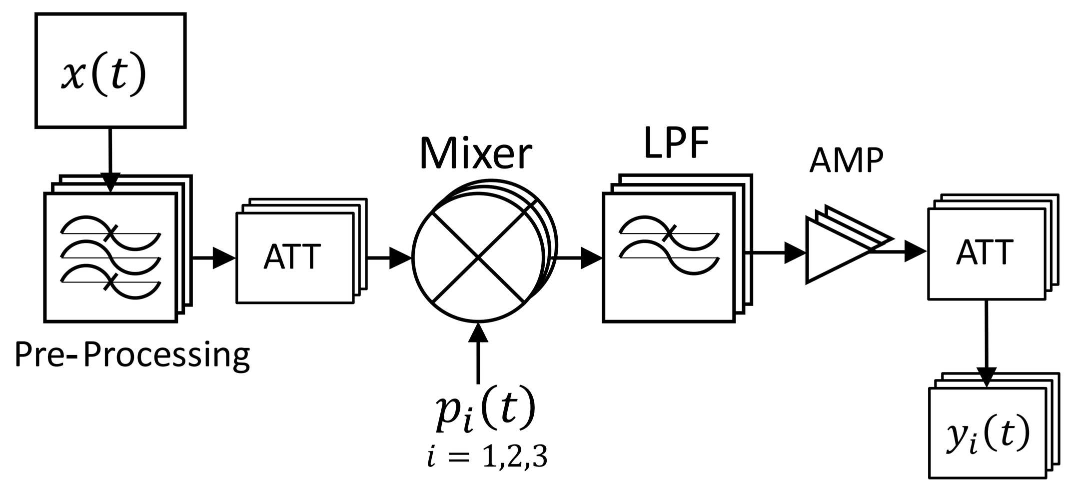
Mixing Series

- The mixing series are generated at high rate and alias the signal's bands to baseband.
- Alternate between ±1 at rate 6.1GHz.
- Generated using Agilent© Arbitrary Wave Generator M8190.

$p_i(t)$
$i = 1,2,3$



Analog Design

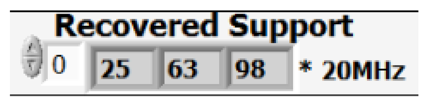


Digital Support & Signal Recovery

- The transfer matrix **A** is produced by the calibration procedure.
- 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:

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

- Support recovery and reconstruction occurs in real time



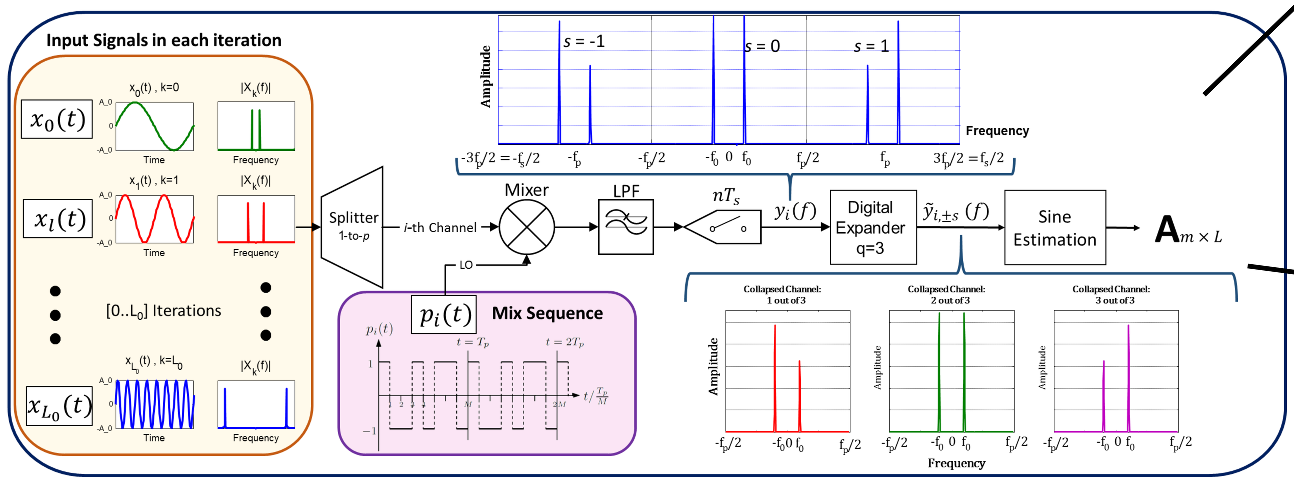
The Calibration Process

- The calibration process estimates the transfer function of the system, the matrix **A**.
- In the l-th step, a sine wave is injected to the system:

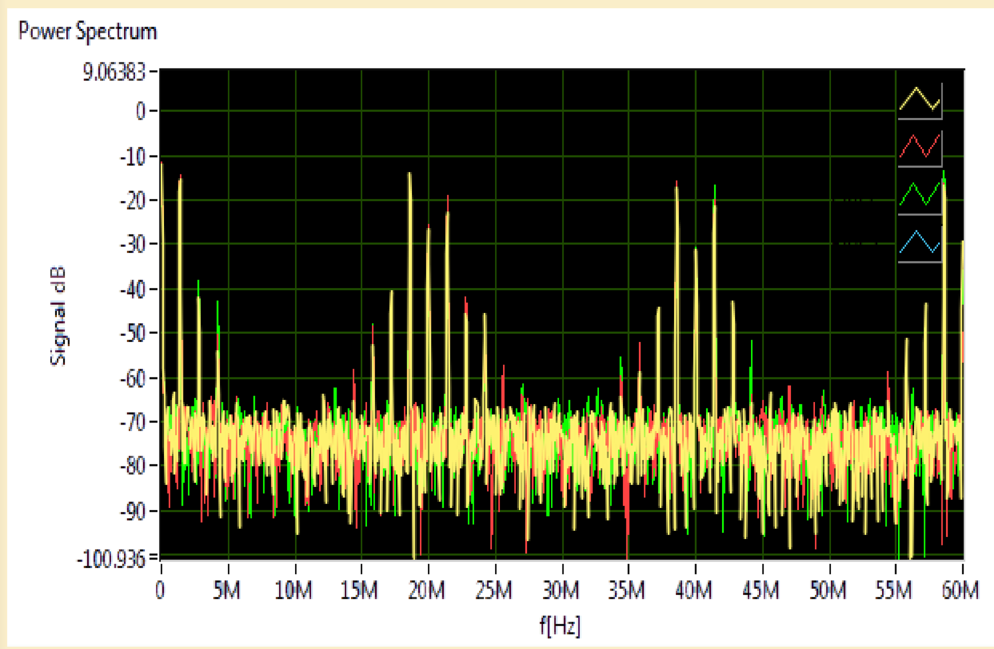
$$x_l(t) = \beta_0 \sin(2\pi f_p l + f_0)$$

- To recover the skewed coefficients of the expander we use linear combinations of the output samples.
- An estimation technique recovers the coefficients of the transfer matrix **A**.
- Least Squares (Trust Region method) minimizes the error according to:

$$\left[\hat{\beta}_0, \hat{\varphi}_0\right] = \arg\min_{\beta', \varphi'} \left\| \tilde{\Psi}_n - \beta' \sin\left(2\pi \tilde{f}_0 n + \varphi'\right) \right\|^2$$

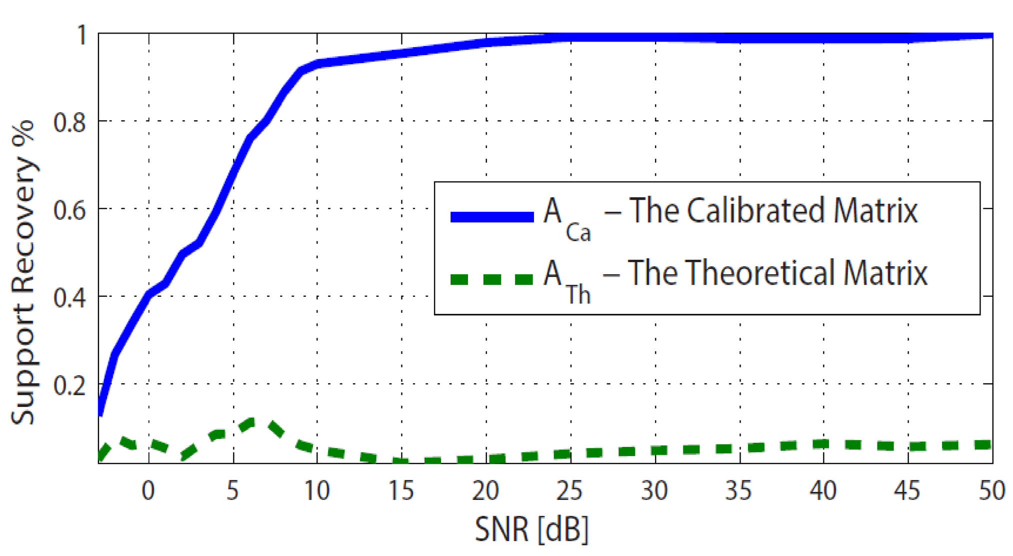


The autonomous calibration process flow chart.

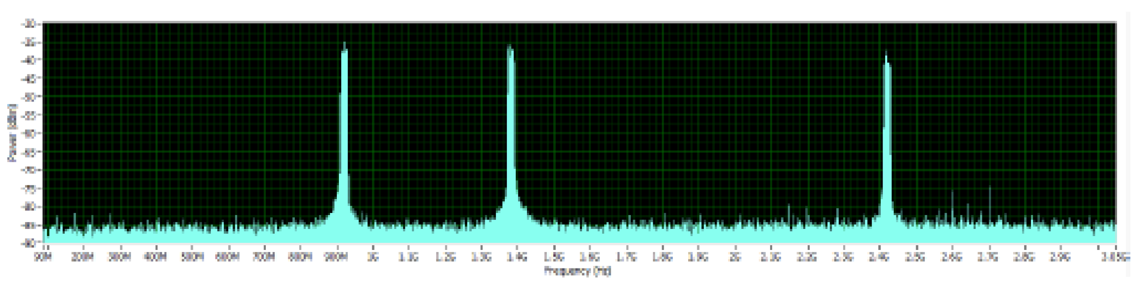


The Modulation of an input signal with T_p periodic series $p_i(t)$ as the mixer's LO input, adds additional redundant harmonics to the output mixed signal $y[n]$. When inserting sinusoid waves at rate $kf_p + f_0$, additional harmonics are present at $f = m_1 f_p \pm m_2 f_0, m_{1,2} \in \mathbb{Z}$

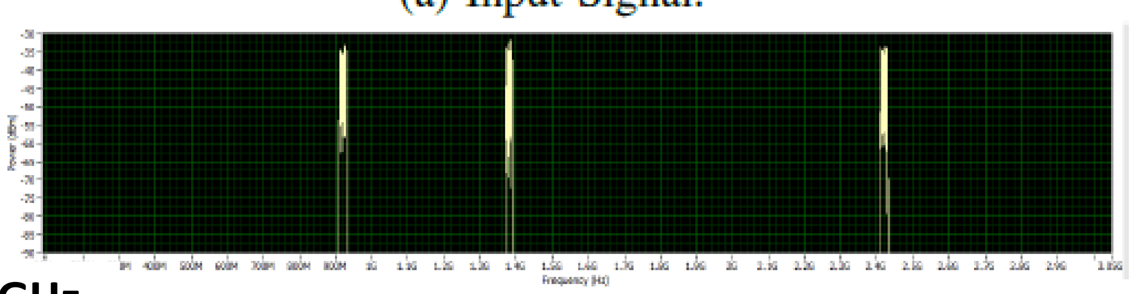
Results



Hardware reconstruction success percentage of the calibrated matrix $\mathbf{A}_{calibrated}$ vs. the theoretical $\mathbf{A}_{Theory}$.

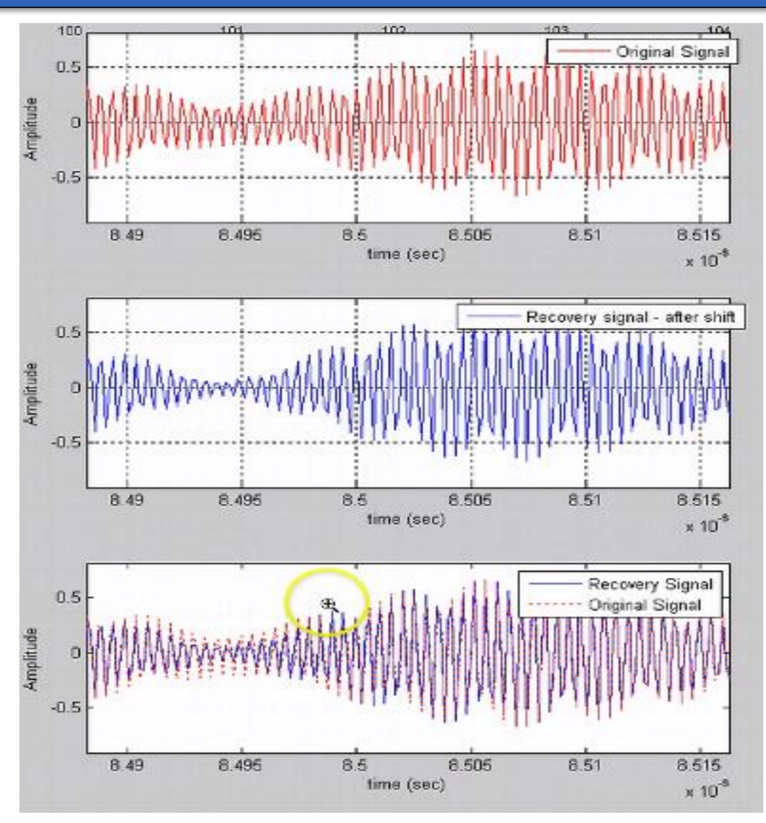


(a) Input Signal.



(b) Calibrated matrix full band reconstruction.

Correct support detection of the input signal, and full reconstruction, in frequency domain.



Full reconstruction in time domain

References

- Mishali, M., & Eldar, Y. C. (2010). From theory to practice: Sub-Nyquist sampling of sparse wideband analog signals. *Selected Topics in Signal Processing, IEEE Journal of*, *4*(2), 375-391.
- Cordeiro, Carlos, et al. "IEEE 802.22: the first worldwide wireless standard based on cognitive radios." *New Frontiers in Dynamic Spectrum Access Networks, 2005. DySPAN 2005. 2005 First IEEE International Symposium on*. IEEE, 2005.

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