Spectrum Sensing in POWDER

Boston C Terry

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The proposed spectrum sensing application addresses the need of POWDER systems to be able to determine spectrum offenders. POWDER users have the ability to transmit over the air at frequencies that could cause interference to primary users (PUs). Not only do we need to determine if users are intentionally transmitting on these bands, but we need to determine if their transmission is causing harmonic or other out-of-band emissions that could cause interference. For this reason, a monitoring SDR will tap into the RF chain after the power amplifier (PA). However, at this point, incident transmissions will also be present. The monitor SDR must be able to distinguish which emissions are generated by the user and which are incident.

To address the received versus transmit identification problem, a bi-directional coupler will be used to create two channels for the SDR. One channel will come from the side of the coupler associated with transmission. This channel will suppress, but not eliminate the received waveform. The other channel is associated with the receive or incident direction. We expect that the coupler will have a constant attenuation factor over time, but not necessarily over frequency. Thus, we can use information we know about the coupler to combine these two channels in such a way as to remove the incident energy from the combined signal.

We call the transmitter signal X and the received signal Y. On the side of the coupler, the signal corresponding to X is called X_s and for Y, Y_s. The signal received at the RX1 port of the SDR is X_s and for a given frequency band f is equal to:

$$Xs = aX + bY$$

The signal received at the RX2 port is Y_s and is equal to:

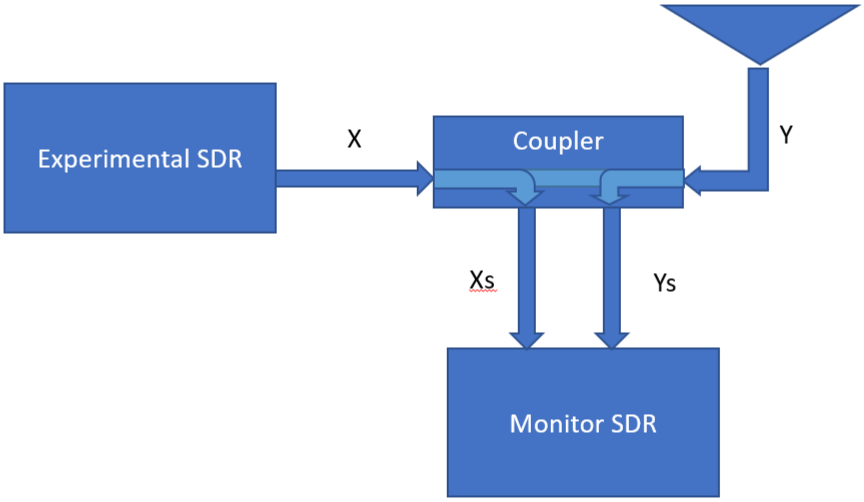
$$Ys = cX + dY$$

. More succinctly,

$$\begin{bmatrix} X & Y \end{bmatrix} \begin{bmatrix} a & c \\ b & d \end{bmatrix} = \begin{bmatrix} X_s & Y_s \end{bmatrix}$$

The sensing algorithm involves sweeping over all $f \in F$, where F is the set of all frequency bands that could potentially be used. The bandwidth of f is variable and will be determined later. We collect data at f, after having experimentally determined a,b,c, and d and use the following equation to remove isolate X.

$$\begin{bmatrix} X_s & Y_s \end{bmatrix} \begin{bmatrix} a & c \\ b & d \end{bmatrix}^{-1} = \begin{bmatrix} X & Y \end{bmatrix}$$



or

$$\begin{bmatrix} X_s & Y_s \end{bmatrix} \begin{bmatrix} d & -b \\ -c & a \end{bmatrix} \frac{1}{(ad-bc)} = \begin{bmatrix} X & Y \end{bmatrix}$$

We can thus isolate X and Y with the following linear equations:

$$\frac{1}{(ad-bc)}(dX_s - cY_s) = X$$

and

$$\frac{1}{(ad-bc)}(-bX_s + aY_s) = Y$$

It is likely that a,b,c, and d are functions of f. We can determine them for each f and then use the appropriate value as the monitor sweeps over F. It is also likely that a,b,c, and d are dependent on the couplers themselves. So, for each basestation, a calibration procedure could be determined where each BS or UE will receive a known signal, while transmitting another known signal, all while sweeping over a the frequency bands. They will these to determine a,b,c, and d.

Having isolated X, we can try to detect transmissions in restricted bands. This is a well-understood problem and we do not have to worry about channel conditions or detection of signals at low SNR values. A relatively simple solution is to collect power measurements at each frequency bin and store them for a number of time points. We then average for each bin and return a likelihood that a signal is present there. We then use a separate state machine to look at the averaged frequency bins and determine if sequential bands are occupied to determine the total bandwidth of the transmitted waveform. For higher bandwidths, higher power, and persistently occupied bands, there is a higher likelihood it is that the transmitter is causing the emissions and must be terminated if they are in a restricted band.

Some open questions to explore

1. How do we quantify residual incident signal Y left in X. In other words, how do we measure how well a,b,c, and d capture the relationship between X and Y?

2. How frequency dependent are the couplers? Are they close enough to constant that we only need one value for all frequencies.

3. Do a,b,c, and d depend on the antenna used at the output?

4. Do a,b,c, and d depend at all on the output power at the PA?

5. Further, how linear are the couplers? Is the linear model used above a good fit?

6. How fast can we collect over an entire band? Can we be confident that we can catch transient or bursty signals?

7. Once we have isolated X, we still have to be able to detect, with high probability, transmissions in a restricted band. What challenges exist for doing this.

8. Is it more efficient to average stay at a certain band and take more samples or to deal with the tune delay and try to sweep over F as fast as possible.