Demo Abstract: A Compliance Monitoring System for Open SDR Platforms

Jie Wang
Washington University in St. Louis
jie.w@wustl.edu

Jacobus Van der Merwe
University of Utah
kobus@cs.utah.edu

Neal Patwari
Washington University in St. Louis
npatwari@wustl.edu

ABSTRACT

Next-generation wireless experimentation benefits from new large-scale open-access software defined radio (SDR) platforms. Each SDR's transmissions must be measured and monitored to guarantee spectrum compliance. The measured spectrum is, however, corrupted by external co-channel signals. Current approaches to remove external signals rely on impractical model calibration. This demo presents the *bidirectional incident/transmit signal separator* (BITSS), a system which estimates the linear system model, the SDR's transmit signal, and the signals received from other sources incident to the antenna, all on the fly and without *a signal prior* or system information. We implement and run BITSS on POWDER and evaluate its performance. The demo shows that BITSS enables separation over a range of signal parameters with high accuracy and alerts users and the operator whenever a spectrum violation occurs.

KEYWORDS

SDR platforms, source separation, compliance monitoring, spectrum violation

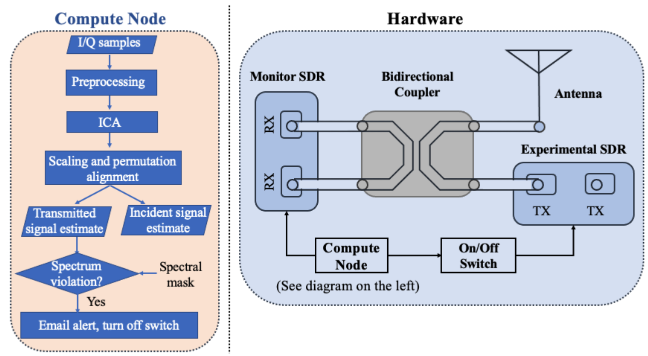

Figure 1: BITSS Overview

1 INTRODUCTION

Open wireless testbeds [1] provide an opportunity for researchers to experiment with next-generation wireless technologies in large-scale deployments of software-defined radio (SDR) devices. While providing a huge advantage in real-world experimentation, the experimental signals can, intentionally or unintentionally, be transmitted in an unauthorized band or at a power level higher than allowed. The testbed operator, who is legally responsible for RF spectrum compliance, may have no prior information about what the experimenter is transmitting. Thus robust monitoring of each SDR platform during every experiment is required.

A RF monitoring system can be a free-standing wireless monitor or one directly cabled to the SDR transmitter, but either raises a challenging signal mixture problem. Wireless RF monitors receive both attenuated transmitted signals and external co-channel signals, in some time- and frequency-varying combination. This makes it difficult to separate the two types of signals. Wired RF monitors are physically connected to the RF chain between a transmitter and its antenna using a coupler. This ensures strong signals from the SDR platform without as much loss as a wireless monitor. However, the signal mixture problem still exists. The antenna of the SDR transmitter is a bidirectional device which both emits the transmitted signal and receives any signal from external sources. A single wired monitor might measure a strong external signal in a band which is unauthorized to the platform user, for example due to a nearby cellular base station, and incorrectly shut down the experiment.

In this demo, we present the *bi-directional incident/transmit signal separator* (BITSS), a wired continuous RF compliance monitoring system. It can separate the platform's transmitted signal from any external co-channel signal with high accuracy. Based on its transmitted signal estimate, we can reliably determine whether or not the experiment is compliant with spectrum regulations.

2 SYSTEM ARCHITECTURE

An overview of BITSS is shown in Figure 1. The monitor and experimental SDR each links to a compute node via USB. A bidirectional coupler is connected between them to measure primarily forward- and backward- traveling signals on the RF chain. One of the mixed signals contains more of the transmitted signal while the other contains more of the signals from external sources incident to the platform's antenna. Continuously running software then separates the transmitted and incident signals from the two measurements.

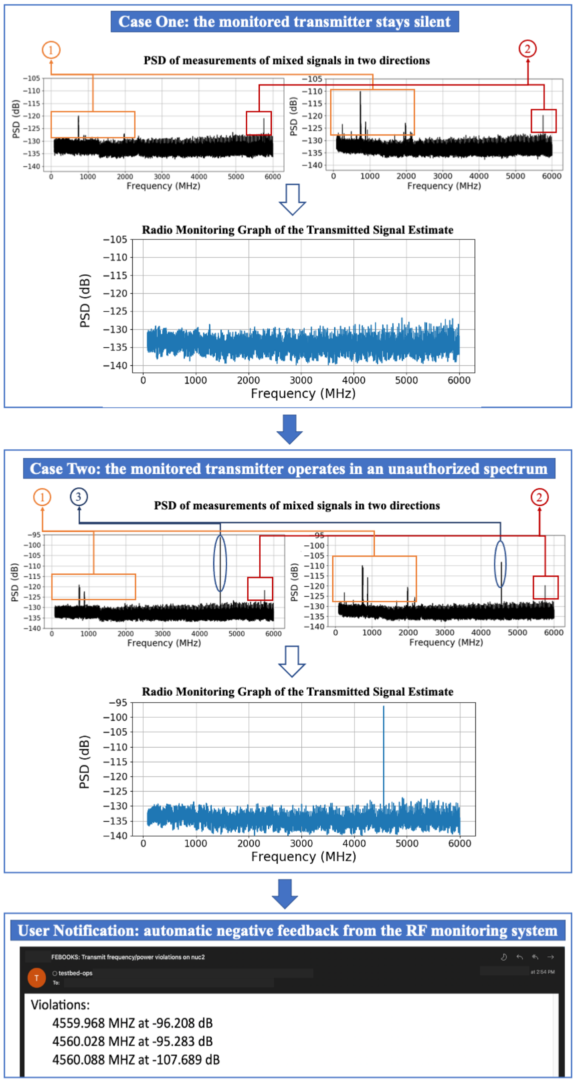

Figure 2: BITSS Workflow: ① incident signals from the environment; ② incident signals from a known external source; ③ transmitted signal at an unauthorized frequency.

The core of the BITSS software is the *frequency-domain independent component analysis (ICA) algorithm*. It models the mixture as an unknown linear combination, and assumes the transmitted and incident signals are independent and at most one of the source signals is Gaussian. However, a common problem with ICA is its scaling and permutation ambiguities. BITSS recovers the scale using the mixing matrix inverse and align the outputs to 'transmitted' and 'incident' via correlation and power difference of the raw measurements. The separated results and the regulation-generated spectral mask help the control compute to determine whether to alarm the user or disable the transmission with the on/off switch.

We demonstrate the workflow of BITSS in Figure 2. For case one, in which the SDR transmitter stays silent, two types of incident signals are shown in the power spectral density (PSD) of both directions. A radio monitoring graph given by BITSS can then visualize the separated transmitted signal across 100-6000 MHz. For case two, in which the SDR transmitter operates in an unauthorized band, we observe both incident and transmitted signals. The refreshed graph confirms that BITSS correctly estimates the transmitted signal. While combining the estimate and the spectral mask, the control compute alerts the user of illegitimate transmission.

3 DEMONSTRATION

BITSS has been continuously running on each monitor node in POWDER, an open wireless experimental testbed in Salt Lake City [2]. The SDRs being used are NI USRP B210s, which can transmit and receive in a 70–6000 MHz range. The compute node controlling each SDR is an Intel NUC which has I7-8650 processor and 32 GB of DDR4 RAM. The bidirectional coupler has two input and two output ports, one of which is connected to the TAOGLAS wide-band 4G LTE I-Bar antenna.

In the demo, we show a fully operational monitor continuously running BITSS. To evaluate its separation performance, a free-standing node is placed near the antenna to transmit *known* incident signals. The demo presents four source separation tests. Each verifies one setting including presence, types, carrier frequency and power of both signals. If the transmitted signal violates the spectrum mask set for the user, BITSS notifies the user via email of a spectrum violation.

REFERENCES

[1] 2018. Platforms for Advanced Wireless Research (PAWR) program. https://advancedwireless.org/ [Online; accessed 27-Sep-2021].

[2] Joe Breen, Andrew Buffmire, Jonathon Duerig, Kevin Dutt, Eric Eide, Mike Hibler, David Johnson, Sneha Kumar Kasera, Earl Lewis, Dustin Maas, Alex Orange, Neal Patwari, Daniel Reading, Robert Ricci, David Schurig, Leigh B. Stoller, Jacobus Van der Merwe, Kirk Webb, and Gary Wong. 2020. POWDER: Platform for Open Wireless Data-driven Experimental Research. In *ACM WiNTECH*. https://doi.org/10.1145/3411276.3412204