Radio Frequency Interference Measurements of Industrial Machinery

# Description

The 2.4 GHz ISM band is shared by Wi-Fi, Bluetooth, Wireless HART, ISA100.11a, and several other industrial wireless systems. Our dataset contains comprehensive electromagnetic interference (EMI) measurements from machinery taken in various industrial environments. The measurements were taken at two frequencies: 900 MHz, 2.4 GHz. This dataset may be useful for understanding EMI emitters in factories and can be instrumental in developing interference mitigation strategies, aiding in RF band selection and enterprise frequency planning, improving wireless technology, and informing communications standardization activities such as the IEEE 3388 industrial wireless performance evaluation standard.

# Industrial Environments Measured

The interference measurements were taken in the following types of industrial environments:

* **Infrared Curing Machine**: Curing process using infrared radiation producing EMI across the 2.4 GHz band
* **Crane with an Unshielded VFD**: Overhead gantry crane operating at 900 MHz with an unshielded variable frequency drive (VFD) causing broadband interference
* **Microwave Dryer**: Two independent sets of measurements of a microwave oven baking machines used for a ceramic drying process. Multiple magnetrons are used with a power output of 1100 Watts each.
* **Unidentified Interference**: General recording of the 2400 MHz band capturing both wireless network traffic and an unidentified broadband RFI emitter possibly caused by an unshielded VFD.

# Equipment and Configuration

The following equipment was used to take these measurements:

* Wi-Spy DBx 2.4 & 5GHz Wi-Fi Spectrum Analyzer dongle capable of capturing spectrum recordings for signals above -115 dBm between 2400 MHz to 2500 MHz
* Legacy 900 MHz Wi-Spy dongle capable of capturing spectrum recordings for signals above -115 dBm between 862 MHz to 928 MHz

# Data Organization

The measurement data and supporting documentation is organized as described below.

**Top level (folder)**

* *analyze\_measurements.m*: M file script used to produce results
* *metadata.xlsx*: Descriptive metadata containing measurement parameters

**data (folder)**

* *<root\_file\_name>.csv*: measurement file containing power measured across frequency and time as a spectrogram.

Each CSV file is formatted as follows:

* + The first row contains the center frequency in KHz of each column of the spectrogram except for the first element. The first element of the first row indicates that the first column is a timestamp and merely states “Timestamp”.
    - Timestamp uncertainty is +/- 1 ms
  + Each subsequent row contains the timestamp of the measurement and the measured power level in dBm (Decibels relative to a mW) at each frequency.
    - Power measurement uncertainty is +/- 1 dBm

**figs (folder)**

For each measurement, a plot of the following perspectives is provided:

* **Power Spectrogram**: Presents the measured power across frequency and time as a color map. This perspective is used as a starting point to understand the behavior of the measured EMI.
* **Gross Power Spectrum**: Shows the summary peak and average power of the measured interference levels
* **Channel Utilization**: Presents how often the interference remains active in the measured band across frequency for different power thresholds
* **Activity Clustering Diagram**: Using image processing techniques presents connected regions of where the measured interference is active. These results can be used to determine interference patterns for developing testing strategies and test vectors.
* **Power Cluster Diagram**: Using a machine learning approach called DBSCAN, interference levels are clustered to determine the extent of the interference across the measurement band providing another perspective for developing testing strategies and test vectors.

**regions (folder)**

Contains the results of the Activity Clustering exercise using image processing techniques. Two files for each measurement are produced.

* *<measurement name> -allregs.csv*: Contains all connected regions
* *<measurement name> -lgregs.csv*: Contains all large, connected regions

**mat (folder)**

Contains the resulting MATLAB workspace produced when the measurement data files were processed. This folder can be helpful in understanding the underlying analysis while examining the code.

**@intfmeas (folder) and @latexreport (folder)**

Contains the MATLAB code written to process and report on the measurement files. MATLAB Version 2023a was used. The code may be incompatible with older versions of MATLAB.

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