# Radiated Emissions Test Approach

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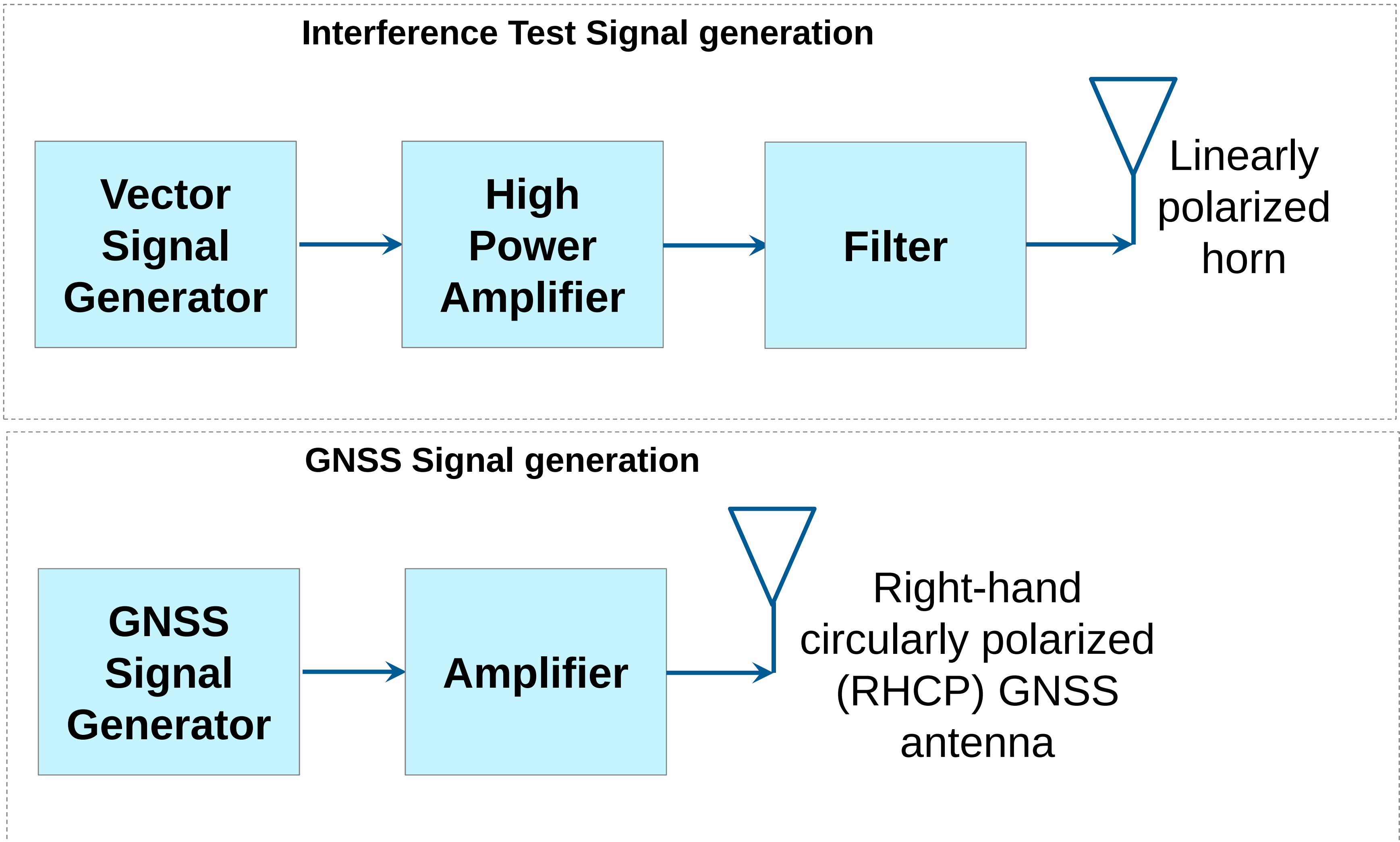
# Overview

- **Draft Department of Transportation (DOT) "Test Plan to Develop Interference Tolerance Masks for GNSS Receivers in the L1 Radiofrequency Band (1559 – 1610 MHz)" provides high level overview of radiated emissions test setup**
- **Presentation provides preliminary details on test setup and execution**
- **Finalization of test setup and procedures will include consideration of:**
  - Opportunities and constraints of selected test facility
  - Availability of equipment from participating organizations
  - Comments received from DOT Request for Comments on Test Plan

# Signal Generation Approach

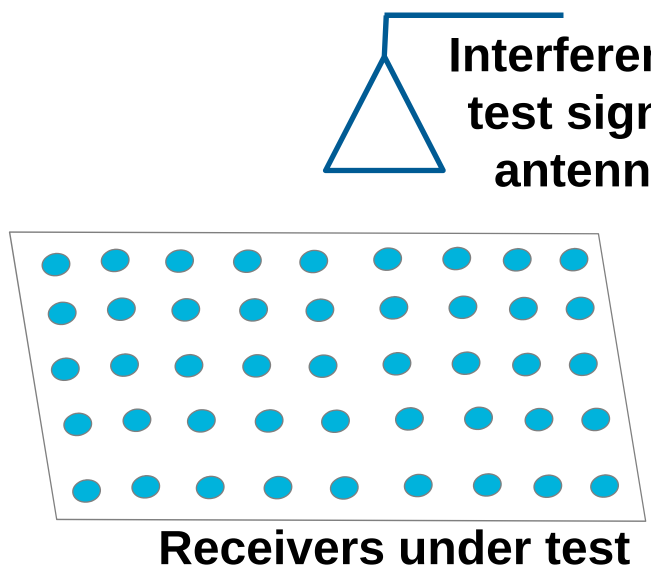


# Interference Test Signal Generation

- **Per test plan (Section VI), two types of signals will be generated:**
  - Signal Type-1: Bandpass white noise with a bandwidth B = 1 MHz
  - Signal Type-2: Bandpass white noise with a bandwidth B = 10 MHz
- **These signal types can be readily generated with a vector signal generator (VSG) having arbitrary waveform generation capability**
  - At center frequencies within [1475, 1675 MHz]
  - Could alternatively emulate Long Term Evolution (LTE) signal for Type-2 with appropriate VSG package
- **Filtering required to achieve out-of-band emissions (OOBE) compliant with Section IX of Test Plan**
  - Type-2 – to the extent practicable, OOBE at or below:
    - -100 dBW/MHz in 1559 – 1610 MHz for downlinks referenced to a downlink peak effective isotropic radiated power (EIRP) of 32 dBW
    - -95 dBW/MHz in 1559 – 1610 MHz for uplinks, referenced to a peak EIRP of -7 dBW
  - Type-1 – lowest practical level

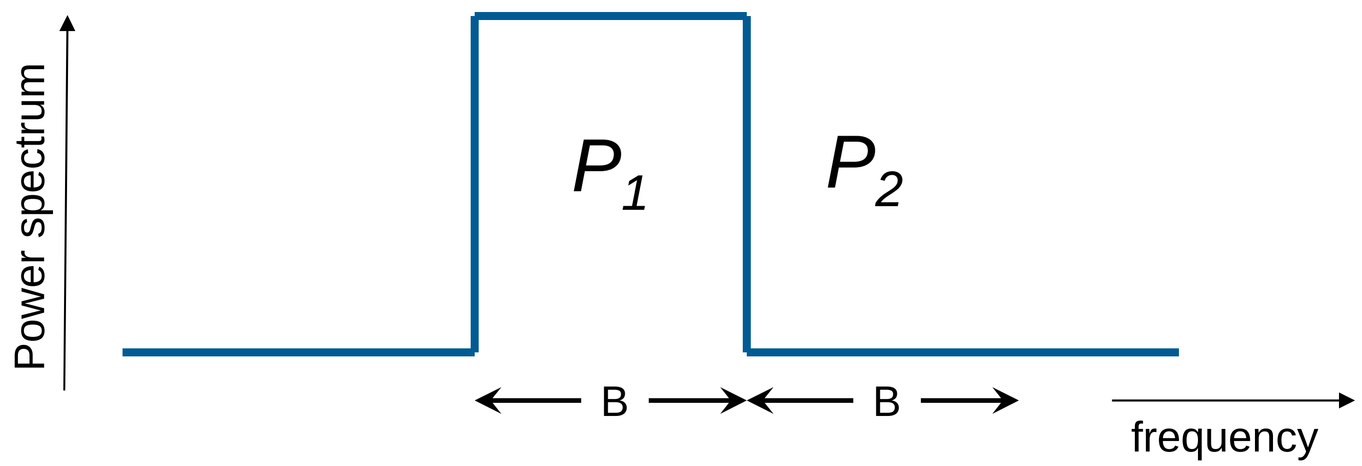
# High Power Amplifier (HPA)

- **For a large chamber, antenna-antenna distance can be up to 20 m**
  - Required antenna half-beamwidths of ~20 degrees
  - ~63 dB path loss
- **To achieve -5 dBm received power for all test positions, average HPA output power of ~30W required**
  - Assumes 15 dBi antenna gain, 2 dB cable/filter losses
  - Higher peak HPA output required for high interference test signal peak-to-average-power-ratio (PAPR)



# Interference Test Signal Generation - Filtering

- **ACLR (see figure below) is ratio of power $P_1$ of desired signal measured in bandwidth $B$ to OOBE power $P_2$ measured in the same bandwidth**
- **Typical VSG adjacent channel leakage ratio (ACLR) is in the range of 65 – 75 dB**
- **After further amplification, ACLR is degraded further**
  - ~55 dB seen in earlier GPS adjacent band interference testing
- **ACLR of 122 dB is needed for downlink, 72 dB for uplink**
  - Cavity filter following amplifier can provide this ACLR



# Cavity Filters

- **Recommended for discrete center frequencies in test plan**
  - 1475, 1490, 1505, 1520, 1525, 1530, 1535, 1540, 1545, 1550, 1675 MHz (downlink)
  - 1620, 1625, 1630, 1635, 1640, 1645, 1660 MHz (uplink)
- **Cavity filters provide excessive attenuation for uplink OOBE**
  - Very difficult to obtain filters providing exactly the target OOBE level for each center frequency
  - Could potentially add target OOBE level back using noise source
- **Characteristics:**
  - 9.8 MHz equiripple bandwidth with not-to-exceed +/-0.5 dB ripple
  - Not-to-exceed 1 dB insertion loss
  - 65 dB attenuation at center frequency +/-20 MHz and 20 dB attenuation at center frequency +/-7 MHz
  - Average power handling of 50 W

# GNSS Signal Simulator

- **Modern GNSS signal simulators capable of emulating many 1559 – 1610 MHz signals used by civilian receivers**
  - GPS L1 C/A-code, L1C, P(Y)-code
  - Satellite-based Augmentation System (SBAS) C/A-code
  - GLONASS L1
  - BeiDou B1
  - Galileo E1 Open-Service
  - QZSS L1

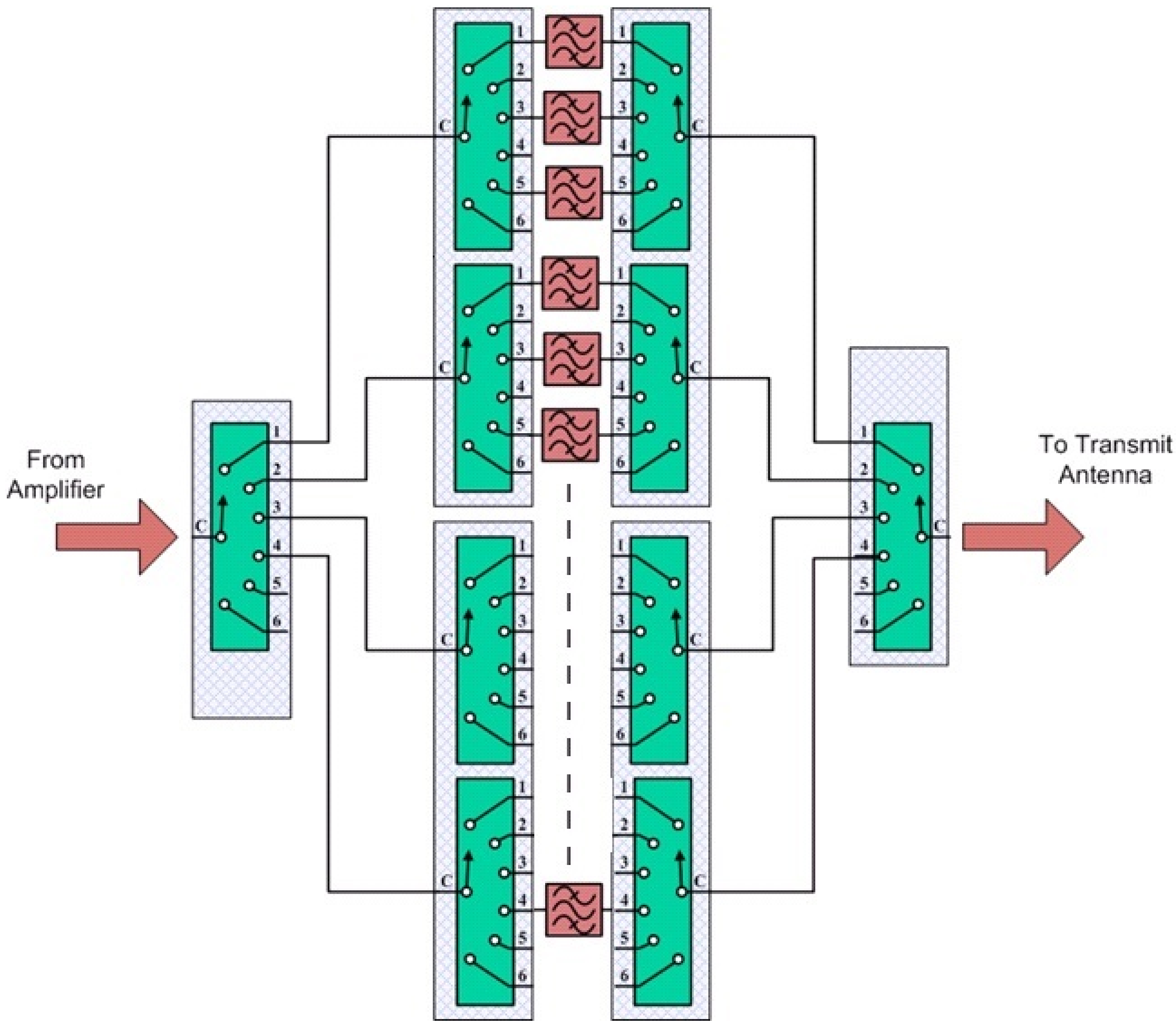
# Calibration and Test Monitoring

- **Interference and GNSS signals to be calibrated at select points across receiver grid**
  - Comparison of calibrated levels with link budget to ensure received power levels match expectations
- **Continuous monitoring of test intended to provide record of signals generated and assist with post-processing**
- **Interference signal generation confirmation desirable to provide record of transmitted signal**
  - Signal collection at test point prior to transmit antenna for real-time feedback and recording of transmitted signal characteristics
  - Transmission monitor to safeguard unintended signal settings and potential equipment damage
- **Monitoring of GNSS signals with control/characterized receiver direct from GNSS simulator and equipment located on chamber grid**

# Test Automation

- **Test automation considered critical for efficient test verification, execution and repeatability**
- **Instrumentation control for signal generation environment is a significant development item**
  - Requirement to provide software (SW) control of VSG, filter switches, HPA and GNSS simulator
  - Functionality needs to set signal type, radiofrequency (RF) path, power level, dwell durations…etc. and monitor these parameters
- **Concept for signal generation defined and SW control architecture to support automation being developed**
  - Test components such as VSG, RF filters and switches identified to support signal types and power levels

# Representative Signal Generation RF Switch Network and Filter Configuration



# Receiver Data Format Requirements

- **Receiver data requested in Receiver Independent Exchange (RINEX) format or National Marine Electronics Association (NMEA) 0183 standard**
  - Other data formats to be worked with Volpe to ensure conversion into ASCII format (TBD)
- **Time reference for test will be GPS time (seconds of week) as estimated from GNSS simulator signals**
  - GPS time will be reference for interference signal generation and recorded with interference signal attributes
- **Sample receiver data files with GNSS signals to be tracked requested in advance from test participants to support tool development**
- **Test conducted in daily blocks to assist on-site processing for identification of potential test/collection issues**