SYSTEMS &TECHNOLOGY RESEARCH

SDR-Based Inexpensive Radar Emulator System (SIREN) for Research and Development

RE: Antenna Registration Question 4: FCC Antenna Registration and Directional Antenna Information
File Number: 0650-EX-ST-2021
Confirmation Number: EL545579
Date: April 23, 2021

Experiment Overview

Systems & Technology Research (STR) is leading an effort to design, test, and produce ground-based low-cost radar threat emulators which may be employed to provide additional realism to DoD training exercises.

STR will be performing ground-based SIREN functional testing at mWAVE Industries LLC, in Windham, ME. at their outdoor far-field RF test range. The goal of these tests is to explore the boundary parameters of the SIREN systems including implemented far-field antenna and frequency characterization that cannot be conducted in indoor chamber environments.

Waveforms employed require the use of an 11 MHz IBW waveform in various test frequency ranges.

Although the requested operation frequency band is large (3.0-6.0, 8.0-11.0), we only require permissions to transmit 11 MHz wide waveforms in the following carrier frequency areas, to which are very flexible:
\> 3.0 GHz (lower region of the 3-6 GHz band)
~ 4.5 GHz (near center of the 3-6 GHz band)
< 6.0 GHz (upper region of the 3-6 GHz band)
\> 8.0 GHz (lower region of the 8-11 GHz band)
~ 9.5 GHz (near center of the 8-11 GHz band)
< 11.0 GHz (upper region of the 8-11 GHz band)

Specific information on the waveforms to test are listed in Tables 4 and 5 at the end of this document.

The system Peak ERPs are given as:
C-band (3-6 GHz): 26.5 dBw + 28 dBi = 54.5 dBW (282 kW)
X-band (8-11 GHz): 23 dBW + 36.8 = 59.8 dBW (955 kW)

Antenna beam patterns are 5deg horizontal and vertical (directional dish antenna).

The rest of this document will provide supplemental information used in antenna parameters within this request.

System Overview

The SIREN system operates across a wide frequency range. For the purposes of this test, we intend to use only capabilities in C and X band, denoted as SIREN-C and SIREN-X, which can operate anywhere in the 3 – 6 GHz, and 8 – 11 GHz bands, respectively. The arbitrary waveform generation is done with a software defined radio (SDR). C-band emissions are direct-output, whereas X-band switches in an RF upconverter. While the SDR is capable of generating an instantaneouse bandwidth (IBW) of ~100 MHz anywhere in the 3 – 6 GHz window (or 8 – 11 GHz post upconversion), functional testing will not use waveforms that exceed 11 MHz IBW.

The filtered signal from the SDR (or upconverter in the case of X-band) is passed to a high power amplifier (different specs for each band) . The transmission is then made from a solid band-dependent 3-ft diameter dish, which has electro/mechanic steering from an attached positioner module.

An overview of the system, seen in Figure 1, contains representative images of components to be used in the system, as well as a generalized block diagram. A summary of key parameters can be found in **Table 6,** at the end of this document.

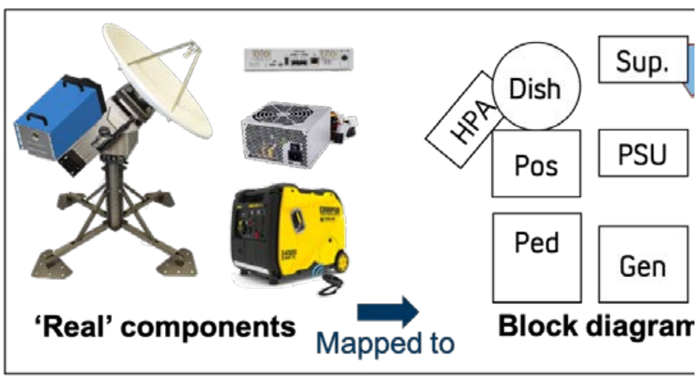

Figure 1: Block diagram of components to be used in the test. High power amplifier (HPA) is attached to an asymmetric parabolic reflector (Dish), and placed on the positioning system (Pos), which is supported by the pedestal (Ped). The power supply for the HPA (PSU) is placed off axis, along with supplementory electronics (Sup.).

Software Defined Radio

The Ettus USRP N300 is a software defined radio (SDR) that is designed to be used in a stand-alone configuration. The RF front-end consists of an AD9371 RFIC transceiver, which supports 2x2 MIMO operations, up to 100 MHz of instantaneous bandwidth, and a carrier frequency range between 10 MHz and 6 GHz.
Figure 2 displays the SDR module.

Figure 2: Ettus N300 product image.

Intermediate Frequency Response

The Tx frequency response for the for the 3–6 GHz output from the Ettus SDR employed is shown in **Figure 3**.

This radio supports transmit powers of 10 dBm or greater between 0.5 and 6 GHz, however, we will only be utilizing the 3–6 GHz range. Therefore, the maximum IF gain before the HPA is +19 dBm.

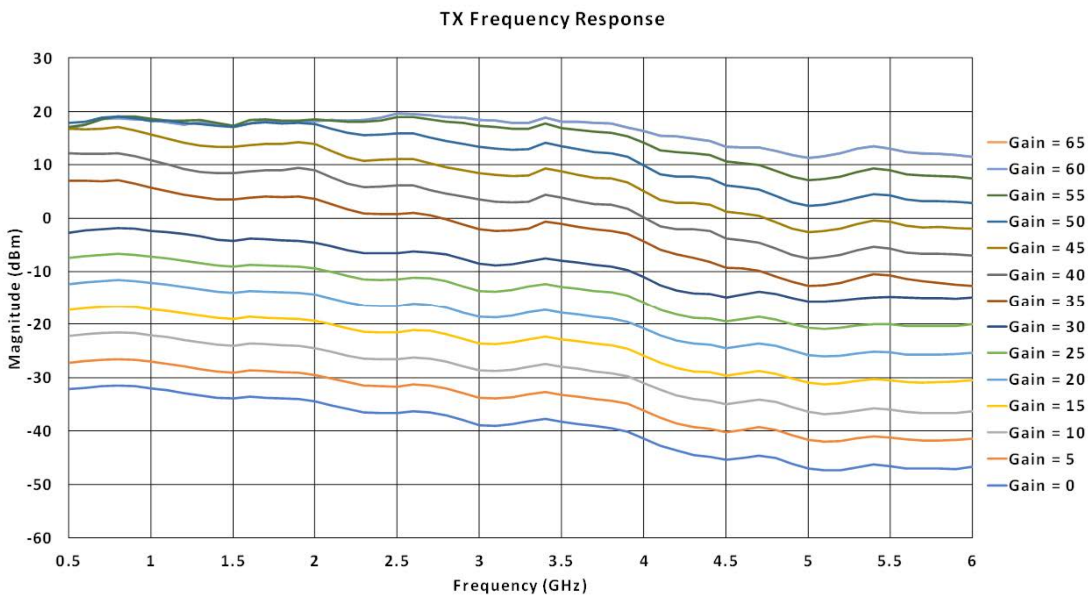

Figure 3: Frequency response of the SDR as a function of internal gain control

Upconverter: Used in X-band operation

The upconverter allows STR to expand the operational frequency range of the X-band system from the SDR's range of 10 MHz – 6 GHz to an RF band of 8–11 GHz. The upconverter's frequency response at the input (measured) and output (extrapolated) of the high power antenna is shown in **Figure 4**.

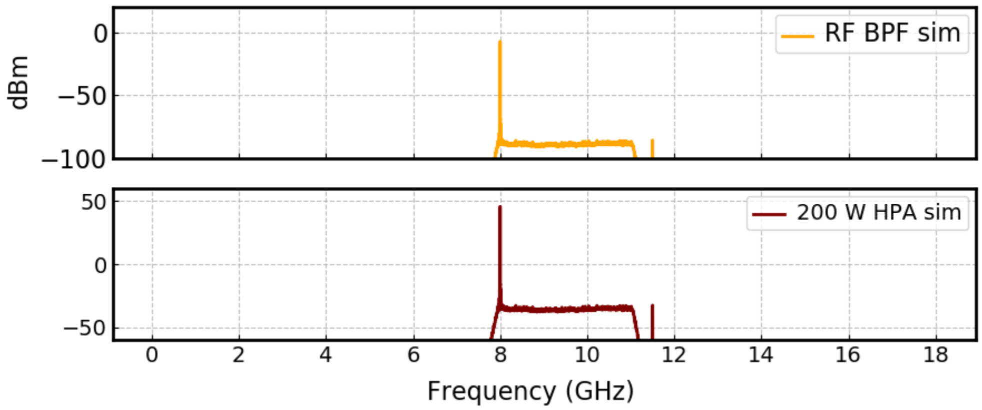

Figure 4: Measurements of the upconverter output for a given 8 GHz input waveform, before the HPA (orange) and after the X-band HPA (red).

High Power Amplifiers

Table 2 shows the relevant parameters of the High Power Amplifiers (for the C and X-band output) made by Quarterwave Corporation.

Table 2: HPA

Description	Value		Units
	C-band	X-Band	
Freq. Low	3	8	GHz
Freq. High	6	11	GHz
RF power out, max	450	200	Watts
	26.5	23	dBW

RF Transmitter Antennas (Dishes)

The parameters of the output antenna to be used (either in C-band or X-band operation) are shown in **Table 3**. The gain within each band is listed as 28.0 and 36.8 dBi (for C and X resepectively).

Table 3: Updated antenna parameters

Description	Value		Units
	C-Band	X-Band	
Size	3	3	ft
Freq. Low	3	8	GHz
Freq. High	6	12	GHz
Gain	28	36.8	dBi
3 dB Beamwidth	4.9	2.3	Degrees
Power Handling, Average	150	400	Watts
Power Handling, Peak	0.5	0.4	kW

System ERPs

Given the above, the following system parameters are given as:
C-band: 26.5 dBw + 28 dBi = 54.5 dBW (282 kW)
X-band: 23 dBW + 36.8 = 59.8 dBW (955 kW)

Test range

The test will be performed at the mWAVE facility in Maine, on a dedicated outside range. An arial view is shown in **Figure 4**. The Tx antenna will be directed towards the receiving dish during the entire duration of **ON** operation, with a beam width raging from 1–5 degrees, depending on the carrier frequency used.

Figure 5: Proposed test site and the Tx -> Rx configuration.

Antenna beam patterns

Below are the antenna beam patterns for the X-band system, as measured by MIT Lincoln Laboratory. The beam patterns for the C-Band system are currently being simulated by mWAVE, but designed to meet a 5 deg 3 dB mainlobe with the specified gain of 28 dBi.

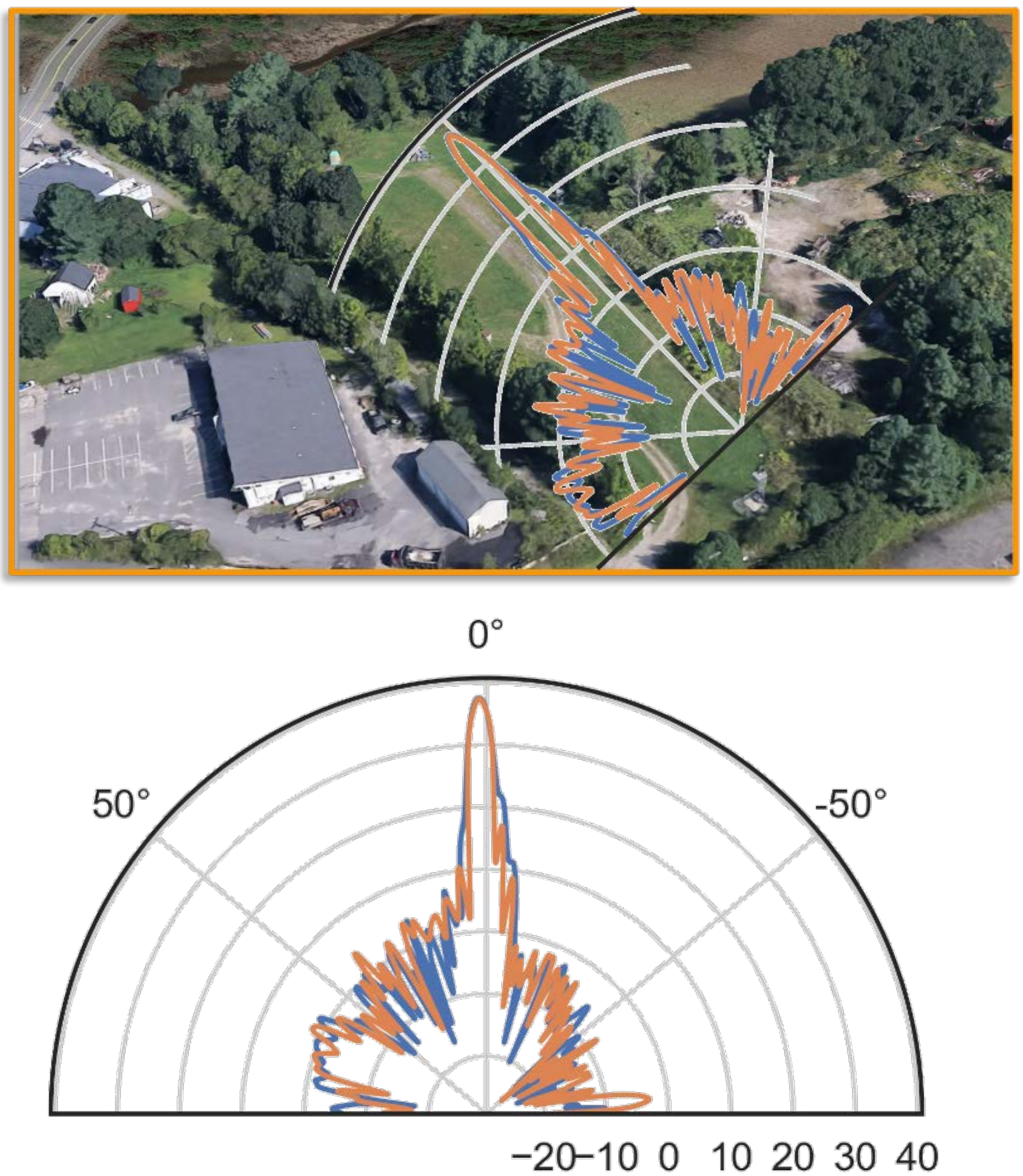

Figure 6: Antena beam patterns, at 8 GHz

Test Waveforms

The intended waveforms for SIREN-C and SIREN-X are listed below, in **Table 4** and **5,** respectively.

Table 4: SIREN C-band Test Waveform Parameters						
Test #	F Tx [MHz]	PW [us]	PRF [kHz]	Duty [%]	IBW [MHz]	WF Type
1	3	1	10	10	11	Unmodulated
2	3	100	10	20	11	LFM
3	3	0.1	10	5	11	Phase coded
4	4.5	1	10	10	11	Unmodulated
5	4.5	100	10	20	11	LFM
6	4.5	0.1	10	5	11	Phase coded
7	6	1	10	10	11	Unmodulated
8	6	100	10	20	11	LFM
9	6	0.1	10	5	11	Phase coded

Table 5: SIREX X-band Test Waveform Parameters						
Test #	F Tx [MHz]	PW [us]	PRF [kHz]	Duty [%]	IBW [MHz]	WF Type
1	8	1	10	10	11	Unmodulated
2	8	100	10	100	11	LFM
3	8	0.1	10	1	11	Phase coded
4	9.5	1	10	10	11	Unmodulated
5	9.5	100	10	100	11	LFM
6	9.5	0.1	10	1	11	Phase coded
7	11	1	10	10	11	Unmodulated
8	11	100	10	100	11	LFM
9	11	0.1	10	1	11	Phase coded