05-November-2019

SRI International S-band High Altitude Balloon Radar Experiment

This document describes SRI International's high altitude balloon radar experiment and the need for Special Temporary Authority (STA) license through the FCC.

Experiment Overview

SRI has been testing an experimental S-band radar system on high altitude balloons under FCC License 0526-EX-ST-2019, Call Signs WM9XAS. SRI is seeking a new FCC license to test this same experimental S-band radar system on a high altitude balloon near Crestview, FL during the period of December 12th and June 11th, 2020. This window allows for ground testing of the instrument prior to flight and also accommodates potential slip in the test schedule.

The radar system is designed to generate synthetic aperture radar (SAR) for the purpose of characterizing the ground backscatter for various Earth Science applications. The radar system is built by SRI International and consists of a custom transmitter, receiver unit, and antenna unit. In addition to the radar, the balloon payload will include a 900 MHz communication link that allows data and control command transfer between the airborne balloon and a nearby ground station. Also, on board is an Iridium and Inmarsat communication link that allows telemetry transfer between the airborne balloon and Iridium or Inmarsat satellites.

The balloons planned ascent is expected to be near Foley, AL, latitude/longitude of approximately 30N to 31.75N, 87W to 88.5W . Dauphin Island Airport and Bay Minette Airport are other potential launch sites. The chosen launch site will depend on the wind predictions in the days leading up to the event. While aloft, the balloon will fly at altitudes between 5,000 and 65,000 ft, with a nominal altitude of approximately 60,000 ft. The anticipated area of operation is between 29.25N to 32N latitude, 83.5W to 89W longitude. The radar will operate periodically over the flight path, transmitting once about 3 minutes for every 10 minutes while aloft. The balloon-ground station links will be operated more regularly over the flight path to upload payload commands and downlink radar data and telemetry. Because the intent of the experiment is to image the ground, the radar antenna will always be pointed at an elevation angle below the horizon.

Balloon Payload Radar Description

The SRI radar consists of a custom S-band transmitter and receiver unit designed and built by SRI International. The radar transmits a pulsed linear FM chirp signal over **2.93625 to 3.35GHz**, having an instantaneous BW of **200 MHz** bandwidth. The transmitter outputs the waveform with an average power of about 60 W. A maximum 21 dBi gain antenna is used with the transmitter, resulting in an EIRP of 7500 W average. The radar will operate with a maximum pulse repetition frequency (PRF) of 4000 Hz, a maximum pulse width of 100 microseconds, and a duty cycle of 10%. The radar antenna has a beamwidth of 10 deg in the azimuth (horizontal) plane and 20 deg in the elevation plane. The directive antenna will be pointed at a depression angle between 10 and 90 deg below the horizon. Figure 5 shows a schematic of the SRI S-band radar system. Prior to launching the balloon, the radar will be tested on the ground at the launch site to check EMI emissions and verify instrument readiness.

The radar transmitter has the following emission mask, which was measured in the laboratory with a spectrum analyzer at 1 MHz resolution bandwidth

- -3 dB bandwidth: 200 MHz
- -20 dB bandwidth: 215 MHz
- -40 dB bandwidth: 228 MHz
- -50 dB Bandwidth: 240 MHz

Spurious and harmonic emission measurements were also made of the radar transmitter outputs:

- Spurious emissions over 2.93625 to 3.13625 GHz: -50 dBc
- Spurious emissions out of band: -50 dBc
- Harmonics: -50 dBc

The radar center frequency is tunable up to 3.35 GHz; the emission mask and spurious/harmonic measurements translate with the center frequency.

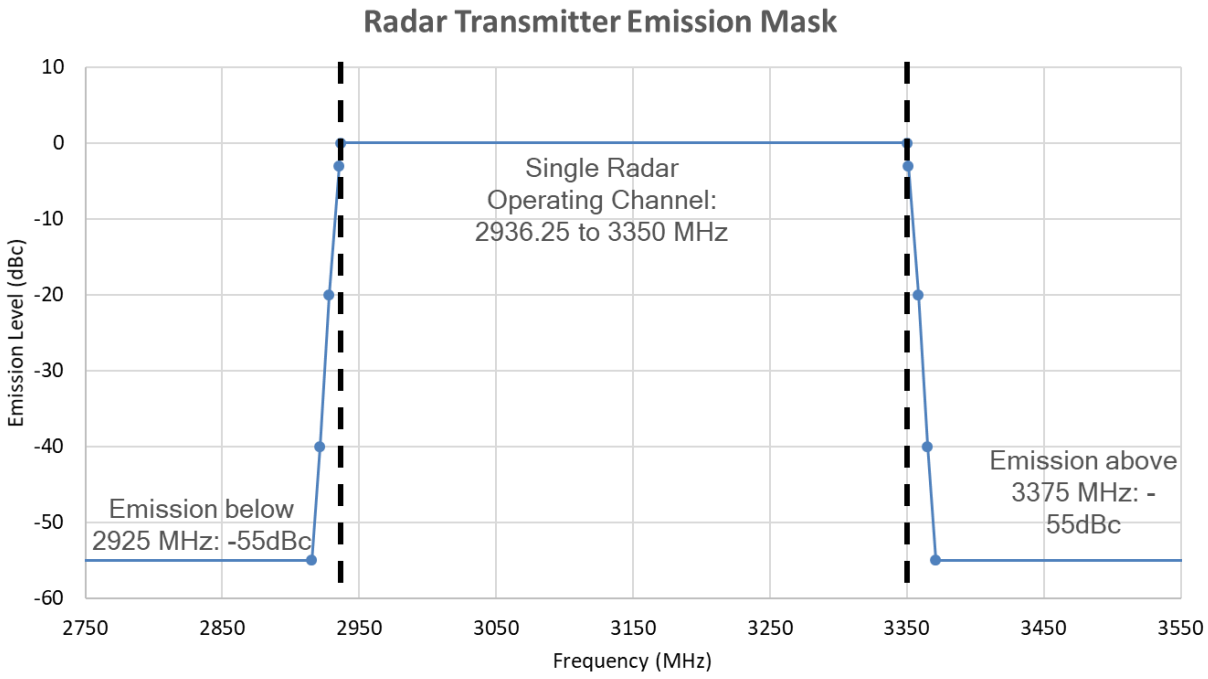

Figure 1. Radar Transmitter Emission Mask

UHF Ground-Balloon Communication Link Description

While the balloon is airborne, SRI will maintain communication with the balloon radar payload via a 900 MHz ISM-band communication link. Both the ground station and the balloon will utilize a Digi XLR Pro commercial transceiver that operates over 910 to 920 MHz. The transceiver utilizes a chirp spread-spectrum waveform to minimize interference with other transceivers. For the ground station, the transceiver unit will output an average power of 1 W and be connected to a 13.5 dBi gain antenna for an average EIRP of 22 W. For the balloon side of the link, the transceiver unit will output an average power

of 1 W and be connected to a 3 dBi gain antenna for an average EIRP of 2 W. While the balloon is aloft SRI will operate a mobile ground station that will follow the balloon flight path on the ground and maintain periodic communication with the balloon payload. SRI will utilize a maximum of two mobile ground stations along the balloon flight path at a time.

L Band Satellite-Balloon Communication Link Description

The Iridium link is a commercial off the shelf satellite communications solution. The Iridium link uses Time-Division Multiple Access (TDMA) and Frequency-Division Multiple Access (FDMA) transmission schemes, with a Differentially Encoded Quadrature Phase Shift Keyed (DEQPSK) modulation scheme. The Iridium satellite constellation operates from 1616MHz to 1626.5MHz. The balloon will have two of these Iridium links. Each of these links average RF power is ~7W, and a standard 3dBi "Hockey Puck" antenna is connected, giving a EIRP of ~14W. The beamwidth is ~145 degrees.

The Inmarsat satellite link is also a commercial off the shelf satellite communications solution (Cobham Aviator UAV 200 Modem with SwiftBroadband phased array antenna). A technical description of the Inmarsat link can be found at https://licensing.fcc.gov/myibfs/download.do?attachment_key=-94644 .

Balloon Flight Path

The balloon will likely launch from a site near Foley, AL. Dauphin Island, AL and Bay Minette, AL are also candidate launch sites. The balloon will ascend to its nominal operating altitude of 60,000 ft. SRI is requesting the STA license to operate the radar and comm link at any location within the anticipated area of operation between 29.25N to 32N latitude, 83.5W to 89W longitude at balloon altitudes up to 65,000 ft. SRI also plans to operate the balloon radar and comm link while the balloon ascends from the launch site at altitudes between 5,000 and 65,000 ft. The anticipated ascending area of operation is between 30N to 31.75N latitude, 87W to 88.5W longitude. During the experiment, SRI operators will be able to disable the radar and/or radio transmitter at any time. Transmission of the radar and/or radio can be stopped by contacting either of the following SRI personnel:

- Scott Williams: 650-455-6925
- Simon Lee: 805-801-9223

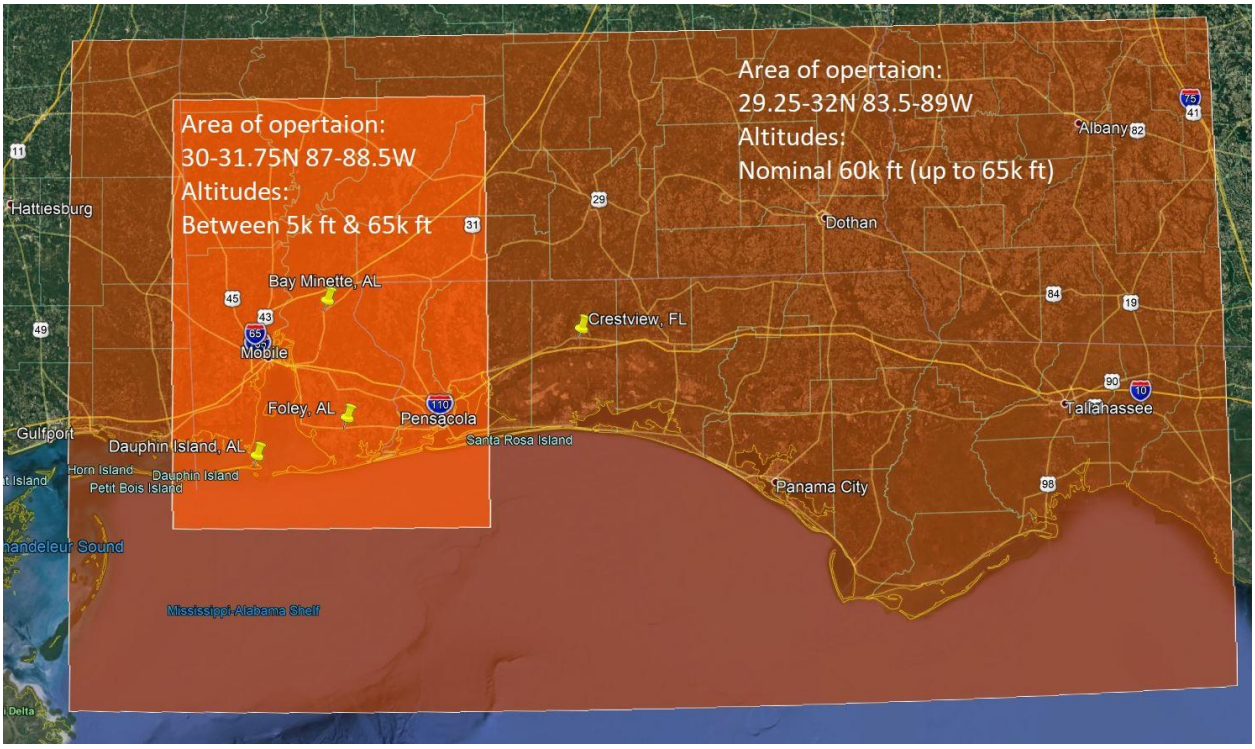

Figure 2. Balloon launch site near Foley, AL (anticipated), expected flight path, and area of operation at altitudes between 5,000 and 65,000 ft over 30N to 31.75N, 87W to 88.5W, and up to 65,000 ft altitude over 29.25N to 32N, 83.5W to 89W. Nominal operation altitude is 60,000 ft.

As seen in Figures 3 and 4 below, the radar antenna has a narrow beam in the azimuth direction.

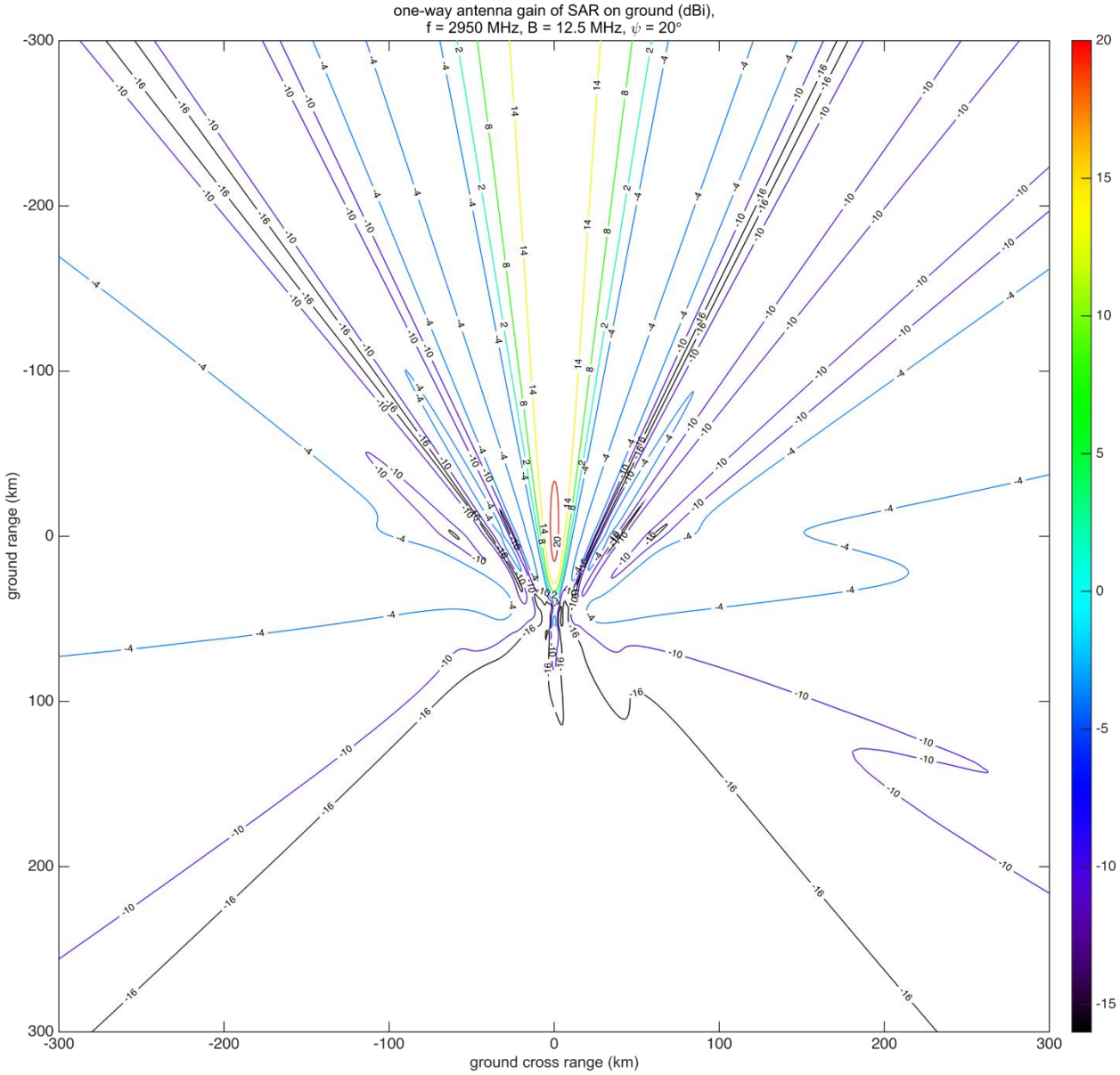

Figure 3. SRI Radar Antenna Beam Projected to Ground, 20 deg Grazing Angle

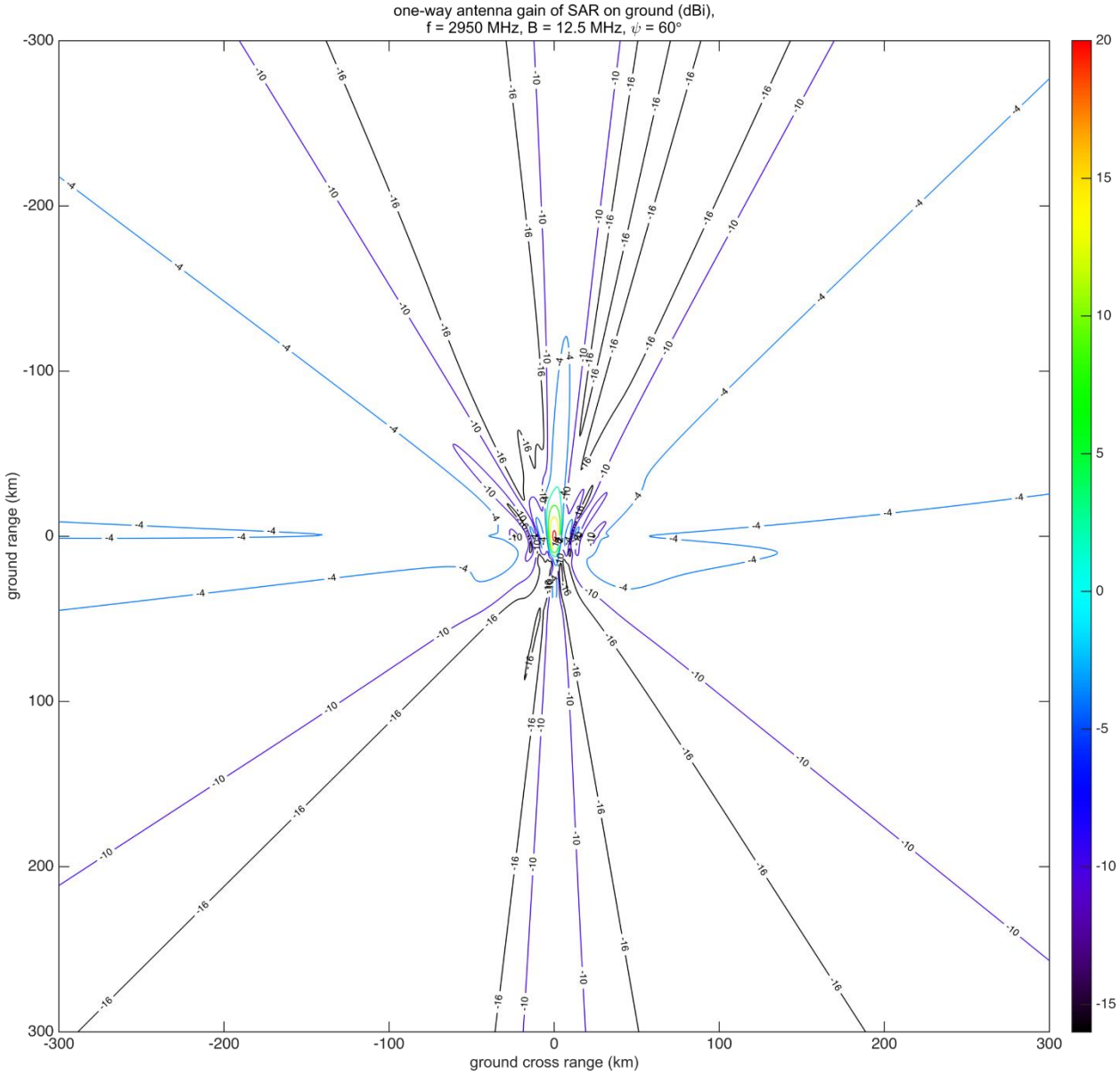

Figure 4. SRI Radar Antenna Beam Projected to Ground, 60 deg Grazing Angle

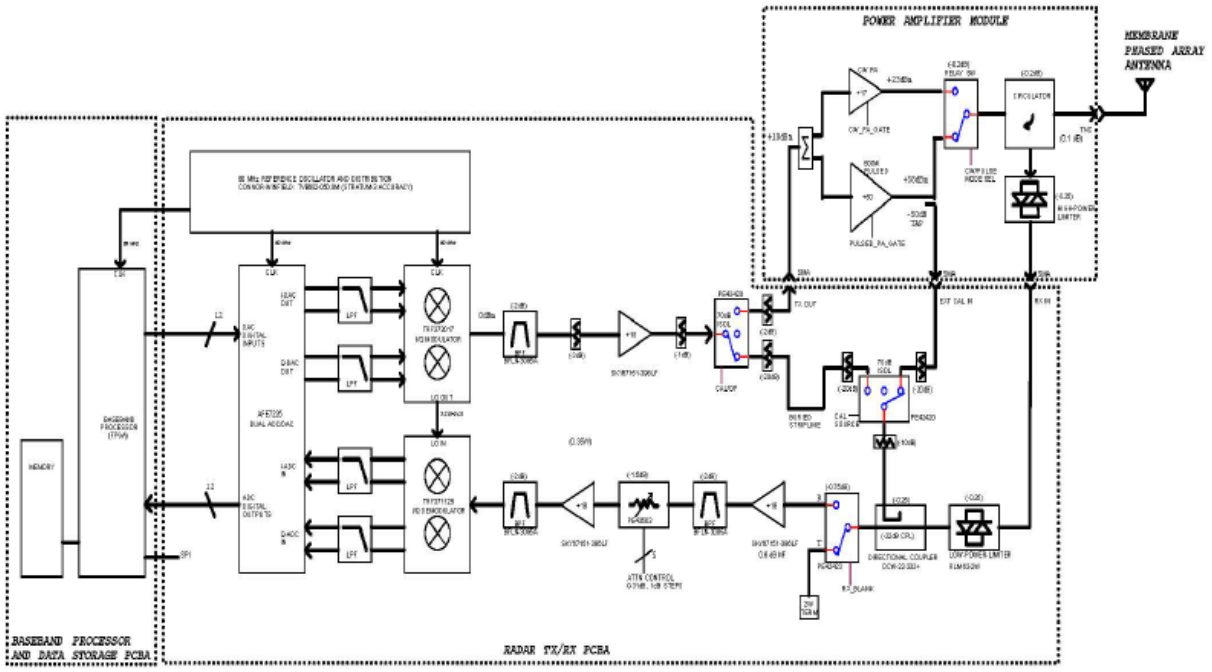

Figure 5. SRI International Experimental S-band Radar System

Table 1. Balloon Radar and Comm Link Transmitter Parameters

	Balloon Radar Transmitter	**UHF Balloon Comm Link Transmitter**	**UHF Ground Station Comm Link Transmitter**	**Balloon Satellite Link Transmitter (Iridium)**	**Balloon Satellite Link Transmitter (Inmarsat)**
Frequency Range	2.93625 to 3.35 GHz	910 to 920 MHz	910 to 920 MHz	1616 to 1626.5 MHz	1626.5-1675 MHz
Bandwidth	200.0 MHz	10 MHz	10 MHz	10.5 MHz	50 MHz
Emission Designation	200MM3N	10M0F3D	10M0F3D	10M5M7D	50K0D7W
Waveform Type	Pulsed linear FM chirp	Chirp Spread Spectrum	Chirp Spread Spectrum	Differentially Encoded QPSK	16-QAM
Transmit Power, Avg	60 W	1 W	1 W	7 W	Max 5 W (Adjusted to maintain EIRP)
Transmit Antenna Gain	21 dBi	3 dBi	13.5 dBi	3 dBi	Max 10 dBi (Varies with direction to Satellite)
EIRP, Avg	7500 W	2 W	22 W	14 W	10 W
Transmitter Part Number	SRI custom	Digi XLR Pro	Digi XLR Pro	9522B DataMODEM RST600B and RockBlock MK2	Inmarsat Cobham Aviator UAV 200 Modem
Antenna Part Number	SRI custom	L-Com HG903RD-SM	KP Performance KPPA-900DP-FP	Iridium Aero Antenna	Internal phased array for Inmarsat Class 4 SwiftBroadband