NOAA GOES DCS UPLINK SPECTRUM SHARING

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ABSTRACT

The National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite (GOES) Data Collection System (DCS) receives environmental data from approximately 28,000 Data Collection Platforms (DCPs) that transmit up to the GOES spacecraft in the Ultra-High Frequency (UHF) band between 401.7 Mega-Hertz (MHz) and 402.1 MHz. The radio spectrum around 402 MHz is also available to commercial satellite companies and several have recently begun using the spectrum. There are questions regarding whether the shared use of the spectrum by small satellites may pose an interference problem to the NOAA DCS program and if so how such issues might be mitigated. This paper discusses some of the pertinent technical issues regarding the performance of the DCS system, reviews some of the known commercial satellite systems sharing the spectrum and briefly discusses some of the issues that spectrum sharing creates.

KEYWORDS

NOAA DCS, small satellites, spectrum sharing, command and telemetry, interference.

INTRODUCTION

Approximately 28,000 environmental monitoring stations in the western hemisphere communicate their data through the two Geostationary Operational Environmental Satellites (GOES) operated by the National Oceanic and Atmospheric Administration (NOAA). These monitoring stations transmit data up to the GOES satellites, usually once an hour in a 10 second window, on one of 532 available channels in the frequency band between 401.7 Mega-Hertz (MHz) and 402.1 MHz[1] [1]. The individual channels are 750 Hertz (Hz) wide and the most common symbol rate used is 150 symbols per second[2] (SPS). The 28,000 monitoring stations are referred to as Data Collection Platforms (DCP) and typically transmit using 10 Watts into a wide-beam antenna. The GOES transponder relays these Ultra-High-Frequency (UHF) uplink transmissions back down to earth in an L-band transmission near 1680 MHz. The one-way service is called the NOAA Data Collection System (DCS). The two satellites are positions strategically, one over the east part of the hemisphere and the other over the western part of the hemisphere. The 532 channels are split into odd and even channels, with odd channels assigned to GOES east and even channels assigned to

[1] Randomly-timed messages are also possible, as well as more frequent regular transmissions.

[2] Eight Phase Shift Key (PSK), rate 2/3, Trellis Coded Modulation (TCM) is used to sustain an effective 300 Bits Per Second (BPS) data rate. 600 SPS (1200 BPS) service is possible by combining multiple adjacent channels.

GOES west. However, there is overlapping coverage so many DCP transmissions are often received by both the east and the west GOES.

During DCS operations, the GOES transponder output power for the L-band downlink is shared among the channels that are occupied by individual DCP transmissions at any given time. This means the dynamic range of the L-band downlink receivers on the ground have to accommodate significant gain changes during the reception of each channel. When many channels are simultaneously transmitting, then the power per channel at the receiver can be dramatically reduced. Fortunately, the DCS system was specifically designed to accommodate the power variations associated with this dynamic channel usage. The GOES transponder includes a bandpass filter to limit out-of-band, undesired, adjacent channel signals from entering the transponder and consuming some of the available DCS L-band downlink power. The bandpass filter response on the new GOES east DCS transponder is shown in Figure 1[3] [2].

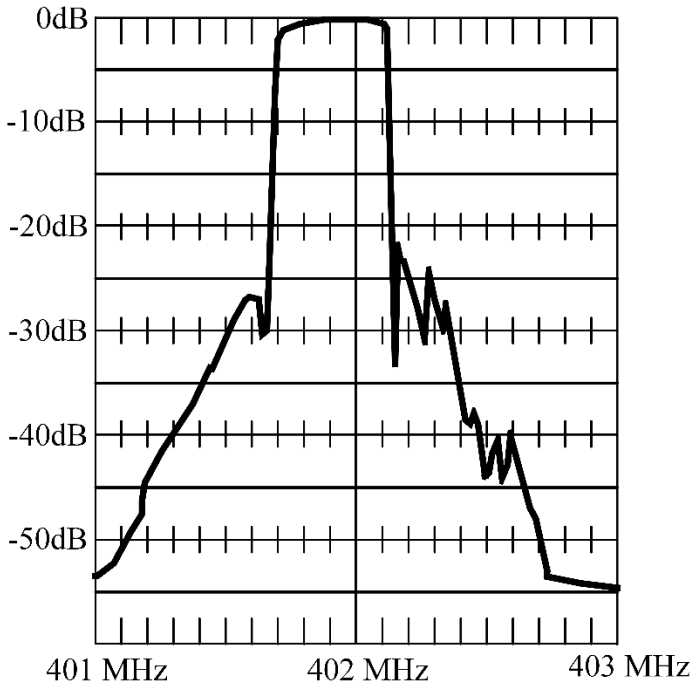

Figure 1. GOES DCS transponder bandpass filter response.

SPECTRUM REGULATIONS

The regulations that govern the use of the spectrum around the NOAA DCS uplink are limited mainly to space-related activities. In the United States (US), the federal government is afforded primary use of the 2 MHz between 401 and 403 MHz for meteorological and earth exploration applications that transmit from the earth to space. This is precisely how the NOAA DCS system

[3] The figure was traced from the filter response provided by the reference. The trace is the worst-case maximum from the on-orbit tests at hot and cold temperatures. In addition, the trace has been translated to UHF from L-band to facilitate comparisons with signals that share the spectrum.

uses the spectrum. Non-federal meteorological and earth exploration applications can also transmit from the earth to space in this spectrum but they are considered secondary users and therefore they must not cause interference to any primary federal users, like the NOAA DCS program. There is one other permitted use of part of this spectrum that should be noted. Between 401 and 402 MHz both federal and non-federal entities can use this spectrum for space operations transmitting from space to earth. Both federal and non-federal entities have primary status for this service and are both protected from secondary users causing them interference. When interference occurs between two primary users of the same spectrum the two parties are expected to resolve the issue through a mutual effort. These spectrum allocations are summarized in Figure 2[4].

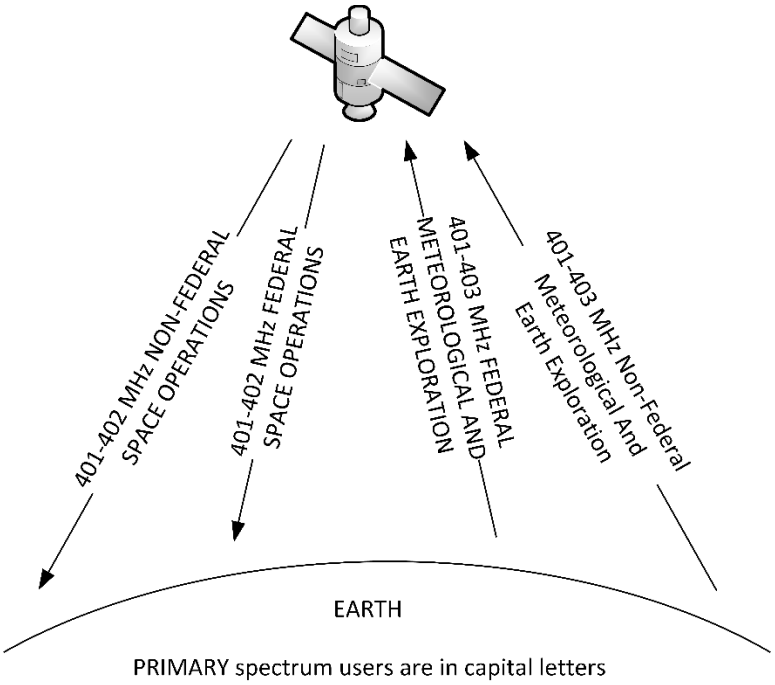

Figure 2. Spectrum allocations at 401-403 MHz.

SHARING THE SPECTRUM

In recent years technological advancements in electronics, communications, energy storage, and rocket science have made the deployment of a large number of small satellites possible. In 2008 there were approximately 15 launches of small satellites[5] but by 2017 the number of launches increased to 300 [3]. There are currently two large constellations of small satellites as well as several small constellations that are actively using the spectrum between 401 and 403 MHz. Many of these satellite owners also operate their own earth stations. However, there are also earth station service providers that sell earth station access to satellite owners who do not have enough earth

[4] One other application permitted in the US between 401-403 MHz is the deployment of radiosondes for atmospheric testing. These low power devices are suspended from balloons for temporary operations and communicate back down to the ground.

[5] Less than 50 kilograms.

stations of their own to provide the required coverage needs for the satellite's mission. To identify the satellites utilizing the 401 to 403 MHz spectrum near the US, a multilayer search of the Federal Communications Commission's (FCC) databases was conducted. The databases that were searched included the Office of Engineering Technologies Experimental license database and the International Bureau database where both satellite earth station, and satellite space station searches were conducted. The results from these searches were combined and are presented below in Table 1. The transmit power levels in the table are given in effective isotropic radiated deci-Bel Watts (dBWi).

			401-403 MHz	
Name	**Constellation Description**	**Earth Stations**	**Uplink**	**Downlink**
Planet Labs	~ 160 small satellites on orbit. Authorized for ~ 600 satellite deployments.	6 earth stations in North America, see also Denali 20020	N/A	Space operations, 60 kHz at 401.3 MHz, -2dBWi
Spire	~ 56 small satellites on orbit. Authorized for ~ 128. Pending request to operate 175 satellites by deploying 1000 satellites over 15 years.	~ 15 earth stations in North America	Waiver granted for Space operations: 15 kHz between 402.6 and 402.8 MHz, 30 dBWi	Space operations: 15 kHz between 402.6 and 402.8 MHz, 0 dBWi
Astro Digital	Authorized for 1 small satellite. Pending request to operate 30 satellites by deploying 100 satellites over 15 years.	1 earth station: Moffett Field, CA.	Waiver granted for space operations: 40 kHz between 402.88 and 402.92 MHz, 41 dBWi	N/A
Blue Origin	Short duration high altitude flights.	1 earth station: Van Horn, TX	N/A	High altitude flight downlinks 401.1 – 401.3 MHz, 13dBWi 401.7 – 401.9 MHz, 13 dBWi
Astranis	1 Experimental Communications Satellite with plans for a large constellation.	Fairbanks, AK, see also RBC Signals	Waiver granted for space operations: 150 kHz between 401.6 and 401.75 MHz, 29 dBWi	Space operations: 150 kHz between 401.6 and 401.75 MHz, 0.84 dBWi
Denali 20020 Earth Station Services	Earth Station operation in support of Planet Labs	Brewster, WA	N/A	Receive only: Space operations, 60 kHz at 401.3 MHz, -2dBWi
RBC Signals Earth Station Services	Earth Station operations in support of Astranis	7 US locations but only one (Prudhoe Bay) supports Astranis	Waiver granted for space operations: 150 kHz between 401.6 and 401.75 MHz, 29 dBWi	Receive only: Space operations: 150 kHz between 401.6 and 401.75 MHz, 0.84 dBWi

Table 1. The shared spectrum at 401 – 403 MHz.

CONCLUSIONS

For the DCS program, the data in Table 1 creates two areas of concern. First, the co-channel operation of the Astranis experimental satellite could pose a singular interference risk given that its earth stations are uplinking with almost 900 Watts. Fortunately, the Astranis earth station location at Fairbanks, Alaska has very limited opportunities to direct its uplink signal toward the GOES spacecraft. Being even further north, the RBC Signal earth station at Prudhoe Bay that also supports Astranis has even fewer opportunities to communicate in the direction of a GOES spacecraft.

The second area of concern is more challenging to assess and may require an ongoing effort to monitor small satellite licensing. There are an increasing number of satellites operating a downlink within a few hundred kilo-Hertz (kHz) of the GOES DCS spectrum. In addition, several small satellite systems use powerful uplink transmitters that are also just a few hundred kHz away from the GOES DCS spectrum. While the GOES DCS transponder bandpass filter provides significant attenuation to these signals, the concern is that as more satellites are launched and the aggregate of these signals increases, an interference problem at the input to the DCS transponder may start to occur that will begin to impact earth station reception of the DCS channels.

REFERENCES

[1] Noblis Incorporated, "GOES Data Collection Platform Radio Set (DCPRS) Certification Standards for 300 bps and 1200 bps", Version 2.0, June 2009, prepared under NOAA/NESDIS contract DG133E-07-CQ-0030.

[2] Original filter response provided by Philip Whaley, NOAA DCS RF Systems Specialist, email correspondence, April 17, 2018.

[3] Space Works Enterprises, " 2018 Nano/Microsatellite Market Forecast, 8th Edition", 2018, Atlanta, GA.