ORCA: A Multi-User Platform for Developing Commercial Communications

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Abstract. Commercial LEO satellite communications are now a reality. Functional systems are currently providing global voice and data services to a variety of customers, while several systems are still being developed and/or conceived. The early systems employed dedicated test spacecraft to minimize technical risk to the operational system. Several of these test satellites suffered failures that reduced their effectiveness. As current systems evolve and new systems are developed, there will be a continuing need to conduct research and development activities. While some of these activities are focused on developing specific hardware, much of the development is focused on assessing the performance of the Earth-Space radio link and associated software (modulation, compression, etc.) The Orbiting Radio Communications Asset (ORCA) provides a platform capable of serving the test and development needs of many users. ORCA provides continuous coverage of the radio spectrum up to 2.5 GHz, covering the primary Earth-to-Space communication frequencies for data as well as voice systems utilizing LEO constellations. The spacecraft can be configured to support various tests, including noise assessment and modulation testing. Users can obtain access to the satellite in a variety of ways and can schedule experiments to meet their needs. The current status of the spacecraft is presented, along with a description of the capabilities of the radio payload. Examples of possible uses are also highlighted.

ORCA Mission Overview

The ORCA mission will place a small satellite in a high inclination low Earth orbit that will cover the majority of populated regions of the Earth and provide at least three years of on-orbit operations. The spacecraft will be the first in a new line of high technology small satellites developed by neoStar Astronautics. The principle payload is a digitally programmable radio transceiver developed by Rockwell Collins. This payload will allow commercial users to test and validate various communication schemes including modulation waveforms, transmit power levels, and to study the effect of various atmospheric properties on radio transmissions. This payload will also allow background noise measurements to be taken over a wide spectrum of radio frequencies. Additional scientific investigations will study the properties of the ionosphere that effect radio communications and radio astronomy.

It is intended to launch ORCA satellite as a secondary payload. The current design is compatible with the Pegasus or Taurus launch vehicles but minor refinements would allow the spacecraft to be launched by the Ariane or Delta launch vehicles.

Mission development activities, including payload definition and the development of a demonstration system occurred during 1998 and 1999. ORCA mission capabilities are currently being publicized to secure both institutional and industrial funding. Launch of the ORCA spacecraft is anticipated in early 2002.

ORCA Radio Payload

The ORCA Radio Payload is shown schematically in Figure 1 below. The versatility of the radio payload allows the ORCA spacecraft to perform services for multiple customers.

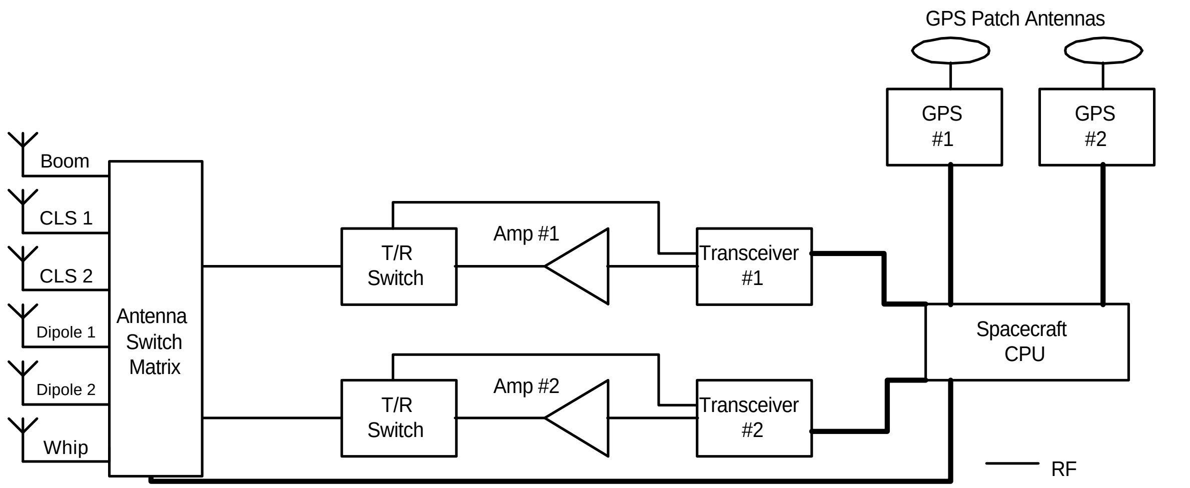

Figure 1. ORCA Radio Payload Block Diagram

Transceivers

The transceivers are modified Rockwell Collins receivers, with two identical and independent transceivers installed in the payload. The transceivers are direct conversion DSP receivers, routing incoming antenna signals through a multiband tracking preselector to a quadrature mixer, where a variable frequency synthesizer mixes the incoming signal to baseband where it is digitized and applied to DSP software for signal extraction. Command and data are routed to the spacecraft computer via a serial communications port.

The transmitter section utilizes a vector modulator to generate the modulation signal by beating a pair of quadrature baseband signals with a carrier signal at the selected transmit frequency.

Power Amplifiers

The power amplifiers are linear, fixed-gain amplifiers. Each amplifies the signal from the transceiver to the maximum rated output power of the amplifier. There are two identical amplifiers which provide up to 50 watts peak/10 watts average power at 2 MHz and 10 watts average/peak power at 2500 MHz. Balanced amplifier circuits minimize even-harmonic generation

Antenna Suite

The antenna suite consists of complementary antennas covering the entire operational frequency range of the ORCA payload. Each of the antennas may be connected to a desired transceiver or amplifier/transceiver combination via the antenna switch matrix. The antennas are immovably fixed to the ORCA bus, and cannot be steered or physically varied. ORCA is gravity-gradient stabilized, making it natural to reference the antenna directions to Earth horizon and Earth center.

Gravity Boom Low Frequency Monopole

The extendible gravity-gradient boom serves as a monopole antenna orthogonal to the center of the Earth (omnidirectional pattern broadside to monopole axis).

Low Frequency Dipoles

Two two-piece dipoles extend from the corners of the bus parallel to the horizon. The two dipoles are orthogonal to each other. The HF dipole is 16 feet in total length, the VHF dipole 4 feet. A resistive load in series with each dipole half provides a traveling wave response, presenting a controlled impedance to the power amplifiers over a one decade frequency range.

High Frequency Monopole

A short VHF/UHF broadband monopole is located on the bottom of the bus, orthogonal to earth and bottom-fed against the bus body (omnidirectional pattern broadside to monopole axis). A resistive load in series with the monopole provides a traveling wave response, presenting a controlled impedance to the power amplifiers over a one decade frequency range.

High Frequency Log Spiral Antenna

Two identical VHF/UHF directional log spiral antennas, right-hand circularly-polarized, are located on the bottom of the bus, orthogonal to the horizon (directive pattern orthogonal to horizon).

Table 1. ORCA Antenna Suite

	LF Monopole	HF Dipole	VHF Dipole	VHF Monopole	HF Log Spiral
Frequency range (MHz)	0-50	1-40	30-200	30-200	200-2500
Polarization	Vertical	Horizontal	Horizontal	Vertical	RHCP
Pattern Orientation	Earth tangent	Earth orthogonal	Earth orthogonal	Earth tangent	Earth orthogonal

Antenna Switch Matrix

The Rockwell Collins developed antenna switch matrix provides user-selected configuration of the inputs and outputs of the transceivers, power amplifiers and antennas. The matrix will handle the maximum allowable transmitter power for all configurations.

GPS

The dual GPS units provide very accurate time, position, and frequency for the ORCA payload. More specifically, accurate time is supplied to the ORCA spacecraft computer for use in timing command sequences. Navigational information is also available to the spacecraft computer. The highly accurate frequency reference output of the GPS receivers is applied to the transceivers as an external frequency standard to provide extremely precise frequency control of receive and transmit functions.

Spacecraft Description

The ORCA spacecraft has overall fundamental dimensions of 28 inches by 28 inches by 32 inches. The central body contains the spacecraft electronics and other hardware, and provides attachment locations for the antennas. The solar arrays are attached to the central body and will deploy to a fixed configuration once on-orbit. This configuration will provide approximately 90 W total continuous power, of which approximately 15 W will be continuously available to the payload with additional power being available by duty cycle management. Total spacecraft weight is 200 lbs.

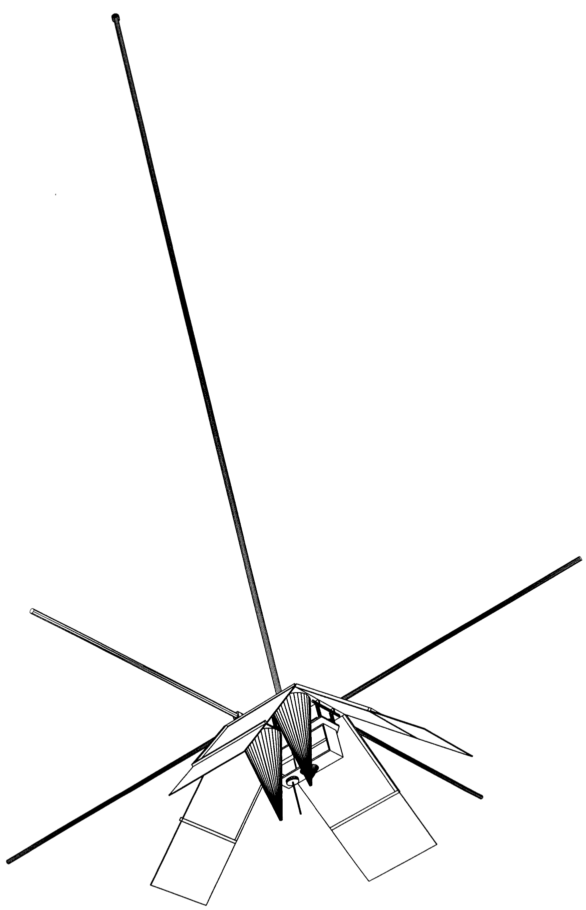

Figure 2. ORCA Spacecraft (Conceptual)

ORCA Applications

Scientific Applications

The ORCA spacecraft and radio payload are capable of performing a variety of applications of interest to the scientific community.

The primary scientific goal will be to provide a global radio frequency noise map. This map will provide the background noise level for radio frequencies from 30-2500 MHz commensurate with the level of sensitivity of the available antennas. This map will be compiled by the ORCA spacecraft when the spacecraft is not tasked for commercial use. This map will provide the data needed to assess the low Earth orbital environment for use by the radio astronomy community as well as provide data about global frequency use not currently available to the civil/scientific community.

The ORCA payload may also be used in conjunction with ground stations to conduct atmospheric sounding experiments. These experiments will allow the characterization of atmospheric effects on radio transmissions over a frequency range that has not previously been studied in detail.

Additional non-commercial applications are being explored, that would use the flexibility of the ORCA payload to provide demonstration of future capabilities. One particular application under consideration is multi-frequency search and rescue (SAR). The ORCA payload possess the capabilities required to make geo-location measurements from any radio transmission source. This could potentially provide the SAR community with additional geo-location data for hikers, motorists, or other "targets" that do not carry emergency location transponders (ELTs) or SAR radios.

Commercial Applications

The ORCA spacecraft and radio payload are designed to provide a variety of capabilities that cover the service frequencies of the current generation of LEO mobile communications systems. ORCA provides the greatest level of capabilities for VHF/UHF and higher frequencies utilized by mobile packet data and mobile voice. Future spacecraft are intended to provide similar services for the Earth-space link of next-generation broad-band data systems.

A variety of measurements and tests may be developed to suit the needs of commercial users within the frequency range of the ORCA payload. For many investigations, the users will program the ORCA payload and spacecraft via a simple forms-based interface. This interface generates a command script file that contains all of the needed information (time and location, transceiver configuration, antenna selection, etc.) and forwards this information to the ORCA command center for scheduling.

The ORCA payload may be programmed to emulate specific features of operational or conceptual systems. This includes not only the ability to transmit on a specific frequency, but the ability to transmit any desired modulation pattern over a test location or locations. With additional planning, the ORCA payload can also perform data compression, additional encoding, or other on-board signal processing. This feature allows the user to readily "field-test" new modulation, data compression, or encoding schemes. The spacecraft can store these settings on-board and repeat the test at various locations or at the same location multiple opportunities. Since ORCA is a time-shared resource, the tests can be structured to minimize costs (e.g. during business hours).

ORCA can also be configured to serve as a bent-pipe transponder. Receiving an uplink signal at a specified frequency and re-transmitting it at the same or a different frequency. This allows the user to test round-trip effects and to test modulation and/or encoding without programming the ORCA spacecraft. This mode allows the user complete privacy from the ORCA command center, as the spacecraft involvement is limited to power management, and no proprietary data is stored on-board the spacecraft. This mode does limit the test opportunities to those in-view of a transmit capable ground station.

ORCA can also conduct specific noise measurement or frequency usage assessments that are tailored to a user's requirements. While similar to the scientific radio noise map, these measurements are more focused, and allow the user to test specific parameters of interest, for example, FM modulation, a particular range of frequencies, or a particular location or time (Houston, Texas from 11:00 AM to 1:00 PM).

All of these example applications can be programmed using the ORCA Experiment Script Builder. An example screen from the demonstration version of this software is shown in Figure 3. The ORCA Experiment Script Builder allows the user to configure the ORCA spacecraft for a specific experiment (e.g. bent-pipe transponder) and select key parameters (such as time, location, frequency, bandwidth, and modulation) via a simple forms based interface. This allows the user to utilized the ORCA payload to without having to learn a complicated command language.

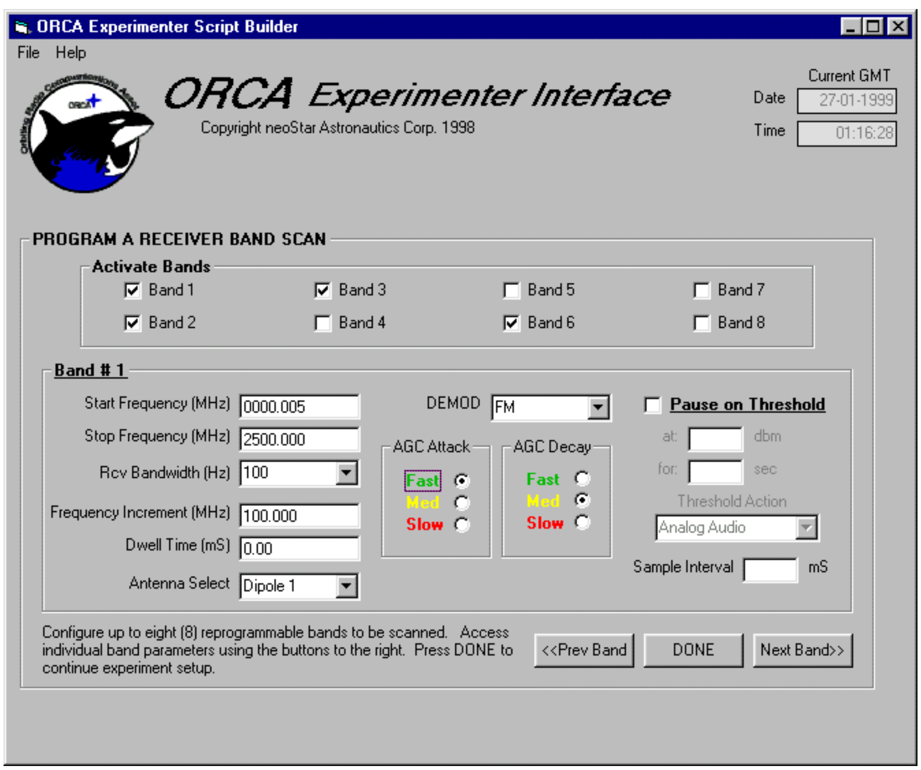

Figure 3. Example screen from ORCA Experiment Script Builder

Putting ORCA to Work

The ORCA mission is being led by the Iowa Space Grant Consortium in conjunction with Rockwell Collins and neoStar Astronautics. The Iowa Space Grant Consortium (ISGC) provides for the administration and management of the program. Rockwell Collins is providing the radio payload, and neoStar Astronautics is providing the spacecraft bus and is responsible for on-orbit operations. This unique arrangement provides protection to proprietary information for users and allows a diverse array of scientific and commercial users access to the ORCA resource.

ISGC is making ORCA available via the "sale" of "shares" to ORCA users. The purchase of ten shares allows participation as a partner. Partners are members of the ORCA steering committee, receive priority scheduling, and receive advance data from the scientific research conducted on ORCA. The purchase of a single share still allows use of the ORCA spacecraft, but provides more limited involvement in the development of the ORCA system and lower priority for scheduling.

Details regarding involvement in the ORCA mission may be obtained from William J. Byrd, Director, Iowa Space Grant Consortium, 408 Town Engineering, Iowa State University, Ames, IA 50011, phone 515-294-3106 or fax 515-294-3262.

Development Status

A demonstration version of the ORCA radio payload has been developed. This allows users to explore the capabilities of the ORCA payload utilizing a prototype user interface. Efforts continue to refine the scientific portion of the mission and secure a sponsored launch. Support and funding from ORCA users is also being solicited.

References

1. Cooper, D.G., Byrd, W.J., and Sternowski, R.H., "Overview of the Orbiting Radio Communications Asset (ORCA) Mission", Proceedings of the 12th Annual AIAA/USU Conference on Small Satellites, Logan, UT, September, 1998.
2. Iowa Space Grant Consortium, ORCA Experimenter's User Guide preliminary version 1.0, 23 June 1999.