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The Hughes JUPITER System

Features for Mobility Applications

Delivering Advanced Support for Aero, Maritime and Land Mobile Satellite Solutions

The satellite ground system platform from Hughes Network Systems, LLC (HUGHES) known as the JUPITER™ System sets the standard in the global communications industry for broadband satellite implementations over conventional and High-Throughput Satellites (HTS). The most widely deployed satellite ground system in the world, the next generation, Very Small Aperture Terminal (VSAT) platform powers networks over more than 40 satellites for consumer Internet, enterprise networks, mobile network operators, satellite network operators, and aeronautical and maritime service providers.

Featuring a flexible and robust gateway architecture with lights-out operation, enhanced air interface for bandwidth efficiency and performance, and high-throughput terminals, the JUPITER System enables operators to achieve the highest possible capacity and efficiency for any satellite broadband implementation. The foundational technology is the powerful JUPITER System on a Chip (SoC), a custom–designed VLSI processor employing a multi-core architecture and enabling 300 Mbps of throughput on every terminal in the system.

Now in its seventh major release, the JUPITER System constantly evolves to meet increasingly complex satellite networking demands. For instance, the latest versions include adaptive coding and modulation for the TDMA inroutes as well as significant enhancements for Layer 2 transport. And each successive generation is backward compatible with previous versions, delivering long-term and scalable value to operators worldwide. The JUPITER System operates on Ku- and Ka-band satellites with both HTS and non HTS (wide-beam) capabilities as well as conventional C-band satellites.

For mobility applications, the JUPITER System includes a set of features that enable aeronautical, maritime, land and transportable mobile applications with high performance and efficiency. This paper enumerates the features of the platform for an array of mobility applications, including in-flight and on-board passenger Wi-Fi, data networking, crew welfare, route planning, diagnostic networking, and much more.

Architecture Overview

Figure 1 illustrates the network elements of Hughes JUPITER System for mobility applications, including gateways, a Network Access Point (NAP), a Network Management System (NMS), an advanced air interface and mobility terminals.

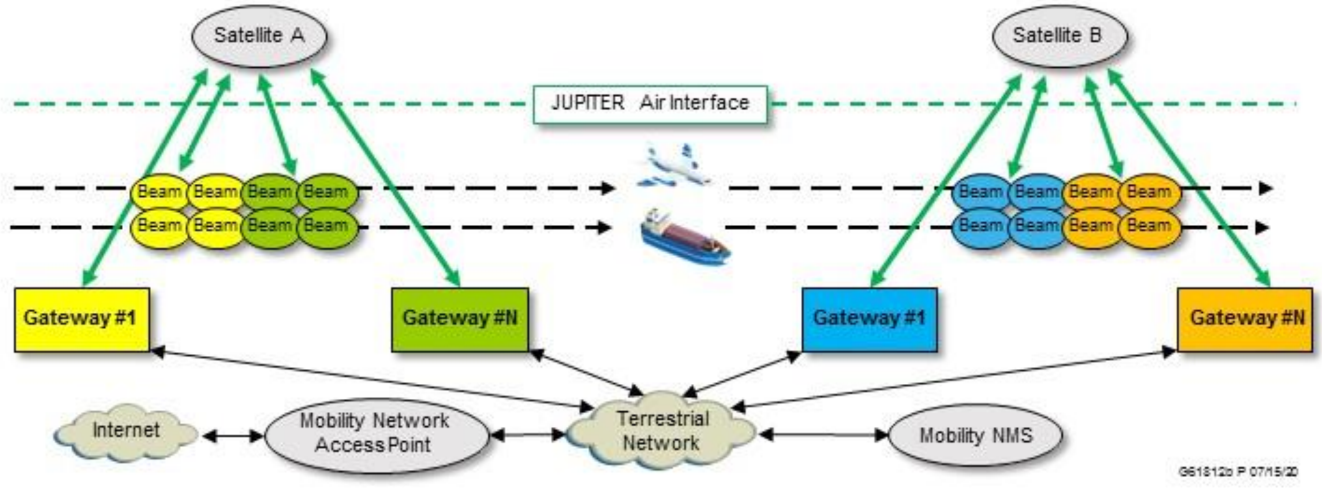

Figure 1. Architecture of the JUPITER System for mobility

- **Gateways (GW):** The system supports one or more GW sites that are a function of geographic locations defined by the satellite coverage footprint and specific beam mapping. The GW sites support the baseband satellite transmission and corresponding functional processing equipment that provide communications to one or more satellites. The baseband equipment connects to a customer-supplied RF Terminal (RFT) via standard L-band IF interface.
- **Network Access Point (NAP):** The system supports one or more NAPs that provide a centralized point of presence (POP) for connection to the Internet. Gateway sites are connected to the NAP through a terrestrial backhaul network. As a mobility terminal travels between GWs, the system provides a handoff between GWs and routes the data path to the common NAP such that consistent IP protocol connections are maintained. Optionally the NAP can be implemented in a distributed fashion in each of the GW stations. However, in this instance there will be loss of user connection when switching between GWs.
- **Network Management System (NMS):** The central NMS is the point from which gateway baseband elements and mobility modems are managed and may be installed at a gateway site or a centralized network operation center.
- **Satellite Air Interface:** The air interface supports a Time Division Multiplexing (TDM) outroute channel (download to aircraft) that is based on the DVB-S2X standard and provides highly efficient wideband operation with single carriers up to 250 MHz bandwidth with data rates exceeding 1 Gbps. The system also supports an MF-TDMA (multi frequency time division multiple access) inroute channel (upload from terminal) that is based on state-of-the-art LDPC FEC coding with dynamic encapsulation, Doppler compensation, and spectral spreading. Both outroute and inroute channels utilize ACM to maintain the highest efficiency and availability.
- **Mobility Terminals:** The JUPITER ModMan is an aero modem designed to be installed in the electronics bay of aircraft, conformant with appropriate standards and certifications. The HT2500 is the JUPITER terminal supporting maritime and land mobility services.

Mobility Application Features

The JUPITER System incorporates a variety of advanced features that enable mobility applications. The following is a description of some of these advanced features.

OpenAMIP Support

The Hughes mobility terminals support the industry-standard OpenAMIP specification which enables interoperability with most antenna controllers. The implementation is based on ARINC 791 OpenAMIP, with enhancements to address specific use cases for individual antennas and to provide additional status information.

Beam and Satellite Switching

The JUPITER mobility terminals perform automatic switching between beams on the same satellite and between beams on different satellites. When the gateways that serve the beams in question are managed by a common NMS and use a common NAP, end-to-end TCP/IP connectivity is maintained during beam switching.

Uninterrupted User Traffic

TCP connections are maintained through the course of beam switches with the use of a NAP (Network Access Point) which is a centralized point where the TCP connections are terminated, independent of which beam or gateway is used for transmission. The use of the centralized NAP allows terminals to switch between beams and gateways while maintaining end-to-end TCP/IP connections.

Owing to the slow-moving nature of maritime and land mobile terminals, the use of a centralized NAP is optional as the number of GW switching events will be limited. In these applications, the NAP functionality can be distributed in the GWs.

Global Roaming

The Global Roaming feature enables airplanes, vessels and vehicles to operate on any JUPITER System in the world (provided that roaming agreements have been established). The roaming agreements include such details as the service plans provided on the other systems.

Figure 2 shows the roaming architecture where terminals can roam between independent networks under the management of different NMSs, and with different NAPs. With this feature, there is no need for prior distribution of terminal keys to visitor networks and no need for prior configuration of roaming terminals in visitor networks.

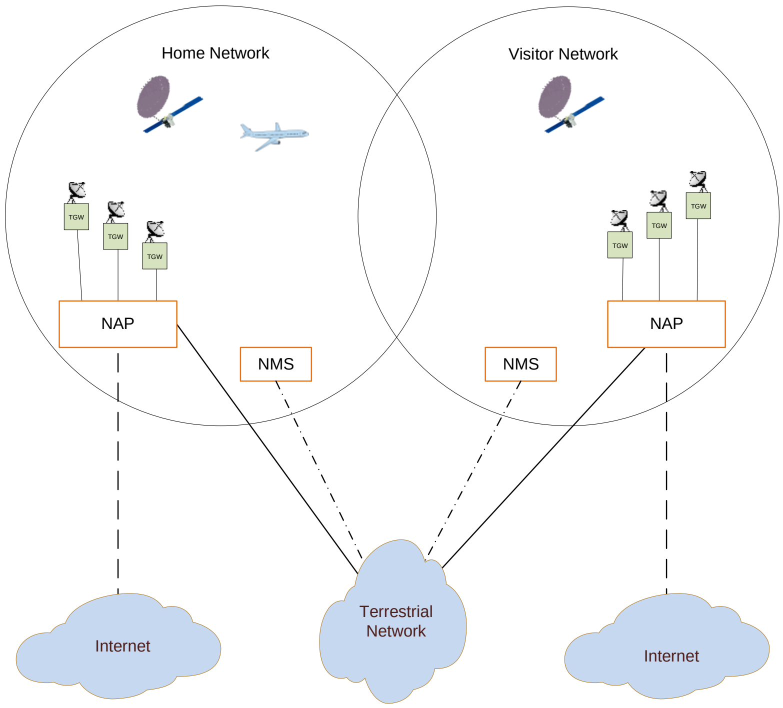

Figure 2. JUPITER System Roaming Architecture

Enhanced Power Control Algorithm

For mobility applications, the JUPITER System uses an enhanced power control algorithm that addresses the following:

- Mobile operation in which terminals are traversing beams quickly and therefore seeing rapidly changing link characteristics as the terminal moves from edge of beam to center of beam
- Requirements to prevent Adjacent Satellite Interference (ASI) by adhering to power spectral density limits
- Operation in a predominantly non-rain fade environment

Return Channel (Inroute) Spreading

Transportable and aero terminals typically use small form factor antenna systems. Due to their higher beam width, there is the potential for the transmit carriers to exceed the off axis EIRP limits and possibly cause adjacent satellite interference. The inroute spreading feature of the JUPITER System allows a terminal to maintain overall carrier transmit power while lowering power density, thus avoiding ASI. The spreading feature works in conjunction with the CLPC to provide optimal return channel carrier throughput.

Remote Terminal Active Doppler Compensation

Mobility terminals in the JUPITER System family can be configured to perform active transmit Doppler compensation. Navigation data is provided to the terminal through standard navigation data interfaces, (e.g., A-429 or NMEA) or through the navigation data facilities in OpenAMIP. Based on this navigation data, the terminal calculates the currently induced Doppler offset and provides an opposite frequency compensation to the terminal's transmit carrier.

Mobility Gateway Demodulator

As aeronautical terminals move at high rates of speed, Doppler frequency shifts are induced on their transmit carriers. These shifts are large enough to shift the terminal's transmit carriers outside of the capture and tracking range of the standard JUPITER gateway demodulator. As well as a larger observed absolute frequency offset, the frequency of the transmitted carrier is slewing during the reception of the burst by the gateway demodulator.

In the mobility system, the JUPITER gateway demodulator is enhanced as follows:

- The demodulator capture and tracking range is widened to handle the greater frequency offsets experienced with bursts from mobile terminals.
- The demodulator is optimized to track slewing carriers. The mobility demodulator can track carriers slewing up to the maximum rate expected on carriers at Ka-band during normal aircraft maneuvers.

In some situations, such as low-speed terminal operation, the capabilities of the standard gateway demodulator are sufficient to deal with all Doppler effects.

Regulatory Controls

The JUPITER mobility system allows management of the following regulator use cases:

- Limitation of terminal transmit power, per beam or regulatory area (e.g., country).
- Imposition of frequency constraints per beam and regulatory area and corresponding management of terminal allocation to allowed carriers. Terminals can be constrained to use only specific outroutes and/or inroutes based on beam or regulatory area.
- Allowed/barred terminal types per beam and regulatory area (e.g., country).
- Barred terminals per beam and regulatory area (e.g., country).
- PSD/ESD restrictions required to comply, e.g., asymmetric antenna patterns (skew limits) per beam and regulatory area (e.g., country).
- PSD limitation per beam and regulatory area (country) to comply with regulatory off-axis emissions limits.

DVB-S2X Forward Channels

The use of Adaptive Coding and Modulation (ACM) of the outbound channel enables the remote terminal to continually monitor the received signal level of the outbound channel and to dynamically request changes to the combination of coding and modulation. This allows the downstream channel to be optimized continually as the JUPITER mobile terminal travels through the various contours of the satellite footprint.

Return Channels with ACM

With the return channel ACM, the TDMA channel (uplink from the mobile device) is continually monitored by the hub and the JUPITER remote terminal is thus continuously advised of its optimal TDMA transmission modulation, coding and power levels. Similar to the DVB-S2/ACM for the outbound channel, this feature means that the TDMA channel is also continually optimized as the remote terminal travels through the various contours of the satellite footprint.

JUPITER System Mobility Routers

The JUPITER System works seamlessly with a variety of user terminals (routers). For mobility applications, Hughes offers the HT2500 Router for maritime and land mobility and the JUPITER Modman for aeronautical services, both of which are optimized for JUPITER System implementations.

HT2500 Router for Maritime and Land Mobility

The HT2500 router, shown in **Figure 3**, is a high-performance satellite router in a rugged 19" rack mount enclosure. The terminal supports dual cable IFL that enables use of an industry standard L-band interface to the outdoor unit, as well as operating on a wide array of operating frequencies with a variety of high-power BUCs. The HT2500 comes equipped with 4 GigE LAN ports and supports a variety of mobility related features including those detailed below.

Figure 3. HT2500 Router

NMEA Interface

For maritime applications, the HT2500 supports an NMEA serial interface. This interface is used for provisioning of navigation data and may also be used in some applications for antenna control.

Secondary Outroute Support

In some maritime installations, satellite blockage may occur due to the motion of the vessel, the location of the terminal's antenna, and the layout of the vessel's infrastructure. Secondary outroute support allows the HT2500 to be configured with a secondary outroute on a second satellite. When blockage occurs, the terminal automatically repoints to the secondary outroute on the secondary satellite and, no longer blocked, restores the link.

Uplink Power Calibration

In the maritime environment, many different vessel layouts are encountered, and thus there may be a lot of variety in the length of IF(intermediate frequency) cabling required to connect each HT2500 router with its corresponding antenna. This means that the path losses due over this cable may vary, as it will not be possible to use a standard set of cabling with known IF loss characteristics. The BUC power calibration facility provides a way to establish the IF cable loss value on the day of installation, thus providing the value needed to complete the installation process.

Persistent Outroute Acquisition Mode

In land mobility applications, link outages are more frequent than in the aero and maritime environments. Terminals may pass close to buildings, under bridges, close to trees, etc., and in all these cases cause brief link interruptions. For land mobile services, the HT2500 terminals are enhanced to be able to ride through these brief interruptions. When the carrier is lost, the enhancement prevents the terminal demodulator from quickly switching to reacquisition mode, freezing internal tracking loops to reacquire the carrier rapidly.

JUPITER ModMan Router for Aeronautical Mobility

The JUPITER ModMan (Modem Manager), shown in **Figure 4**, is designed to support commercial aeronautical Inflight Communications (IFC) applications. The ModMan consists of dual high-performance aero modems and a high-performance Intel-based server that can host additional airborne applications. One modem acts as the satellite router and supports throughput exceeding 300 Mbps. The second modem provides a second receiver for broadcast/multicast overlay applications. The ModMan is based on the ARINC 791 specification and complies with FAA DO-160 requirements. The ModMan has been successfully integrated and flight-tested with multiple Ka- and Ku-band aero antennas.

Figure 4. JUPITER ModMan

The ModMan supports a standard receive-only A-429 interface for reception of navigation data. The A-429 bus is a standard aviation bus that provides a variety of data labels, such as latitude, longitude, altitude, track angle, and other items.

Hughes Ku/Ka Band Aero Antenna

The Hughes aeronautical antenna, shown in **Figure 5**, delivers industry-leading RF performance and supports transmit/receive across the full bandwidth of all standard commercial Ka- and Ku-band satellites. The antenna has been specially designed to have low weight and a low profile, enabling compatibility with industry-standard aeronautical radomes. Mechanically, it incorporates features that enable precise, reliable tracking and rapid change from band to band.

The antenna system is based on ARINC 791 architecture and consists of four Line Replaceable Units (LRUs):

- Outdoor Antenna Equipment (pedestal, Ka and Ku apertures)
- Ka RF Unit (Ka KRFU)
- Ku RF Unit (Ku KRFU)
- Antenna Control Unit (KANDU)

The outdoor antenna equipment is mounted on top of the aircraft fuselage and incorporates two high-performances, back-to-back light weight apertures: one for Ka-band communications and a separate one for Ku-band communications. The KRFUs and KANDU are mounted inside the aircraft cabin above the headliner.

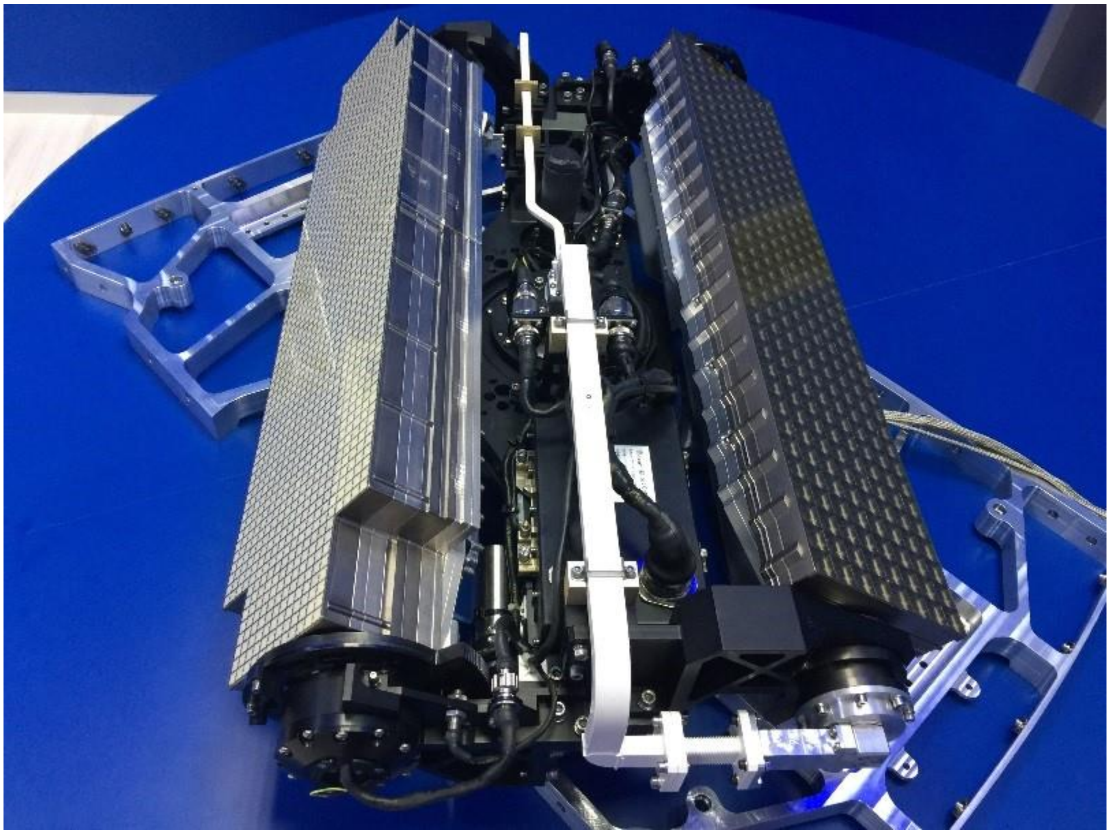

Figure 5. High-Performance Dual Band Aero Antenna