CGMS

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Direct Broadcast Beyond 2015

NOAA-WP-28 presents a summary of the direct readout plans for future NOAA environmental spacecraft. The transition of the NOAA direct readout services is taking place across several spacecraft constellations. This will encompass many years of development, coordination and implementation. Replacement of the analog Weather Facsimile (WEFAX) with the new digital LRIT, in 2005, started a transition period that will culminate with the implementation of the EMWIN/LRIT service on the GOES-R spacecraft constellation, combined with the transition from today's GVAR to the GOES Re-Broadcast (GRB) service on GOES-R. NOAA's current direct broadcast services will change dramatically in data rate, data content, frequency allocation and field terminal configurations. The geostationary and polar-orbiting environmental satellite constellations will employ new downlink frequency allocations, larger bandwidths, and faster data rates. Environmental data users must employ new field terminal receivers unique to that particular broadcast service.

Direct Broadcast Beyond 2015

1. Introduction

The National Oceanic and Atmospheric Administration (NOAA) is in the process of transitioning its current direct broadcast services to the most up-to-date digital formats. The new Global Specifications for Low Rate Information Transmission (LRIT) and the Advance High Rate Picture Transmission (AHRPT) digital formats are intended to improve the quality, quantity, and availability of meteorological data from direct broadcast meteorological satellites.

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2. Current Broadcast Services

The current direct readout services are derived from satellite sensor data from NOAA's GOES and POES systems. NOAA's geostationary (i.e., GOES) direct readout services include Low Rate Information Transmission (LRIT), Emergency Managers Weather Information Network (EMWIN), Data Collection System (DCS) and GOES VARiable (GVAR) broadcasts. The polar orbiting (i.e., POES) direct readout services include the analog Automated Picture Transmission (APT) and digital High-Rate Picture Transmission (HRPT) transmissions.

LRIT is a communications transponder service provided through the GOES spacecraft. This low-rate digital service involves the retransmission of low-resolution geostationary and polar orbiter satellite imagery or other meteorological data through the GOES satellites to relatively low cost receiving units within hemispheric receiving footprint of the satellite. The low-resolution geostationary and polar satellite images are produced at the NOAA Environmental Satellite Processing Center (ESPC) facility in Suitland, Maryland. This imagery is produced from the retransmitted GVAR data streams received at the facility from the GOES spacecraft . The ESPC ingests these retransmitted GVAR data streams through a Front End Processor. Based on an automated schedule, the data is subset into areas, reduced in spatial resolution, if necessary, and enhanced according to predefined look-up tables. The resultant LRIT products and imagery (IR and visible) are referred to as sectors which are spatial subsets of the full earth disc corresponding to an area of interest to weather forecasters. The generated sectors are then transmitted from the ESPC as digital product via dedicated communications lines to the Wallops Command and Data Acquisition Station (WCDAS) for transmission through the GOES spacecraft.

On the current operational spacecraft (GOES 10/11/12/13) and the planned launch missions of GOES O/P (GOES 14/15), the LRIT service will remain a128 kbps service. The current LRIT service also contains a copy of the EMWIN data and a copy of the consolidated DCS data stream, both of which are also currently transponded in their own service domains. A combined EMWIN/LRIT service at 400 kbps will be deployed on the GOES-R series spacecrafts (GOES-R will no longer have a dedicated EMWIN transponder, and the continuance of DCS being embedded in the LRIT stream is under review). The LRIT service complies with the CGMS Global Specification for LRIT/HRIT (i.e., CGMS Document Number CGMS 03, Issue 2.6, dated August 12, 1999).

With its two operational GOES satellites, NOAA currently acquires raw data from its two primary instruments used to carry out the main mission. The Imager is a multi-channel instrument that senses radiant energy and reflected solar energy from the Earth's surface and atmosphere. The Sounder is a multi-channel instrument that provides data through vertical atmospheric temperature and moisture profiles, surface and cloud top temperatures, and ozone distribution. Raw data from these instruments is down-linked to the ground to be processed into GVAR formatted data. The GVAR data is up-linked to its corresponding GOES satellite, together with auxiliary data inputs from additional ground equipment, for global re-broadcast to users.

The GVAR data format is primarily used to transmit Imager and Sounder meteorological data. Other functions of GVAR data include transmission of calibration data, satellite navigation data, administrative and operational text messages. The GVAR format was developed as an evolution of the Mode-AAA format used for the early spin-stabilized GOES spacecraft and which would have severely limit the capabilities for data decimination from the Imager and Sounder of the newer three-axis stabilized spacecraft platform. The Mode-AAA format used a fixed-length transmission. The GVAR format supports variable scan line lengths. The last GVAR mission will be supported by GOES-P scheduled for launch in October 2009.

The APT service provides a reduced resolution data stream from the AVHRR instrument. Any two of the AVHRR channels can be chosen by ground command for processing and ultimate output to the APT transmitter. A visible channel is used to provide visible APT imagery during daylight, and one IR channel is used constantly (day and night). A second IR channel can be scheduled to replace the visible channel during the night time portion of the orbit. The analogue APT signal is transmitted continuously and can be received in real time by relatively unsophisticated, inexpensive ground station equipment while the satellite is within radio range overhead. The characteristics of the transmitted signal remain unchanged in the NOAA KLM satellite series from those in the TIROS-N series (NOAA 8 through NOAA 14), while there is a minor change in the data format to account for a sixth channel on the AVHRR/3 instrument beginning with NOAA-K (a switchable channel 3 or 3A). NOAA will continue to support the afternoon (PM) polar-orbiting mission with its APT service through NOAA N'. The HRPT system provides data from all spacecraft instruments at a rate of 665,400 bps. The S-band real time transmission consists of the digitized unprocessed output of five Advanced High Resolution Radiometer (AVHRR) channels, plus the TIP (HIRS, SBUV, SEM, DCS instruments) data and Advanced Microwave Sounding Unit (AMSU) data (AMSU-A and AMSU-B on NOAA 15 through 17 and AMSU-A and Microwave Humidity Sounder (MHS) on

NOAA 18 and N'/19). All information necessary to calibrate the instrument outputs is also included in the data stream. The last of the APR-pm and HRPT missions will be supported by NOAA-N' scheduled for launch in February 2009.

3. Future Direct Readout Services

As future environmental satellites improve their monitor and observing capabilities, they will produce far more data than the current satellite series. The geostationary and polar-orbiting environmental satellite constellations will employ new downlink frequency allocations, larger bandwidths, and faster data rates. Environmental data users must employ new field terminal receivers unique to that particular broadcast service.

NPOESS

Over the last nine years, NOAA has been developing the National Polar-orbiting Operational Environmental Satellite System (NPOESS). With a planned delivery of the first operational satellite in 2013, NOAA will begin launching NPOESS spacecraft into three orbital planes (0530, and 1330 equatorial nodal crossing times) to provide a single, national system capable of satisfying both civil and national security requirements for space-based, remotely sensed environmental data. The advanced technology visible, infrared, and microwave imagers and sounders that are being developed for NPOESS will deliver higher spatial and temporal resolution data to meet user validated requirements for 55 atmospheric, oceanic, terrestrial, and solar-geophysical parameters enabling more accurate short-term weather forecasts and severe storm warnings, as well as serving the data continuity requirements for improved global climate change assessment and prediction. Early flight-testing of instruments is planned to reduce development risk and to demonstrate and validate global imaging and sounding instruments, algorithms, and pre-operational ground processing systems through the NPOESS Preparatory Program (NPP) prior to delivery of the first NPOESS spacecraft.

NPOESS spacecraft will also simultaneously broadcast two types of real-time data to suitably equipped ground stations. These direct broadcast/real-time ground stations (or field terminals) will be capable of processing NPOESS RDRs into EDRs by utilizing IDPS software appropriate for the type of field terminal. The NPOESS High Rate Data (HRD) broadcast will be a complete, full resolution data set containing all sensor data and auxiliary data necessary to generate all NPOESS EDRs and is intended to support users at regional hubs. The HRD broadcast will be transmitted at X-band frequencies, at a data rate of about 20 Mbps, and will require a bandwidth of nearly 50 MHz, with a receive antenna aperture of at least 2.0 meters in diameter. The NPOESS Integrated Program Office (IPO) has reviewed alternative spectrum availability and has determined that the WARC-97 EESS X-band allocation at 7750-7850 MHz is suitable for this application.

The NPOESS Low Rate Data (LRD) broadcast will be a subset of the full NPOESS sensor data set and is intended for NOAA and worldwide users of field terminals (land and ship-based, fixed and mobile environmental data receivers operated by DoD users and surface receivers operated by other federal agencies, worldwide weather services, and other international users). Some data compression (Lossy or Lossless) may be employed for the LRD link. The LRD L-band broadcast will provide data at a rate of about 4.0 Mbps (nominally 3.88 Mbps) at 1702.5/1706.5 MHz with full CCSDS convolutional coding, Viterbi decoding, and Reed Solomon encoding/decoding into a tracking receive antenna aperture of at least 1.0 meter diameter. The LRD broadcast will be available on two selectable channels to accommodate multiple NPOESS spacecraft in the same orbit during life-cycle replacement. The NPOESS LRD broadcast parameters (frequency, bandwidth, data rate, and data content) have been selected to satisfy NOAA requirements for low-rate, real-time direct broadcast, as well as be closely compatible with the broadcast parameters for the Advanced High Resolution Picture Transmission (AHRPT) format that has been accepted and approved by the Coordinating Group on Meteorological Satellites (CGMS) and will be used on the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Metop spacecraft.

The NPOESS LRD service will include data required to satisfy the U.S. user-specified highest priority EDRs for real-time broadcast. These EDRs are listed in priority order in the following table:

	High Priority EDRs, In Priority Order from Highest to Lowest
1	Imagery Threshold Attributes: 0.8 km horizontal spatial resolution (HSR) worst case across scan for at least one visible and one IR band. Day/night band at night with 2.7 km HSR Provide Day and Night capability for the Field Terminal User** to: -Interpret High, Mid, and Low Cloud Types -Detect all Fog Types (Valley, Coast, etc.) -Distinguish Between Snow & Clouds -Detect Coastal Water Mass Features (coastal fronts, eddies, river plumes, etc.) -Detect Dust/Aerosol/Haze/Smoke ** The users intend to primarily exploit the LRD Imagery by manual methods (Interpretation, Detection, and Distinction) of inspection of processed images.
2	Atmospheric Vertical Temperature Profile (Surface to 100 mb only) Measurement Accuracy Threshold Attributes: Surface to 700 mb: 2.5K/1 km 700 mb to 300 mb: 1.5 K/1 km 300 mb to 100 mb: 1.5K/3km. Measurement Accuracy attributes applies to clear and cloudy conditions.
3	Atmospheric Vertical Moisture Profile (Surface to100 mb only)
4	Global Sea Surface Winds (Speed and Direction)
5	Cloud Base Height
6	Cloud Cover/Layers
7	Pressure (Surface/Profile
8	Sea Surface Temperature (SST)

Fifteen additional lower priority EDRs will also be included in the LRD broadcast. While the eight high priority EDRs will be produced at the LRD "objective" level of performance, including data latency of two minutes for imagery EDR processing and 15 minutes or less for the other EDRs, these lower priority EDRs will be produced between threshold and objective levels with less stringent latency requirements.

Lower Priority EDRs (no particular order)	
	Aerosol Optical Thickness
	Albedo
	Cloud Effective Particle Size
	Cloud Liquid Water
	Cloud Optical Thickness
	Cloud Top Height
	Cloud Top Temperature
	Land Surface Temperature
	Ocean Wave Characteristics – Significant Wave Height
	Precipitation Type/Rate
	Perceptible Water
	Snow Cover/Depth
	Soil Moisture (Surface)
	Suspended Matter
	Total Water Content

GOES-R

NOAA has initiated a program to introduce a new advanced imager with significantly improved performance to GOES satellites in year 2014. The new imager has been named the Advanced Baseline Imager (ABI). The ABI will have 16 spectral bands. The 0.59-0.69 micron visible resolution band will be improved to 0.5KM with all other bands being 2km. The new imager scanning rate will be significantly increased to provide a full disc every 5 minutes ("Mode-4), or 4 full discs per hour (one every 15 minutes) plus 12 CONUS scans (one every 5-minutes) and up to two mesoscale areas with a 1 minute refresh each (120 total per hour) ("mode-3). The ABI will provide key performance parameters cloud and moisture imagery for Full Disk, Continental United States (CONUS), and Mesoscale coverage for monitoring, forecasting and severe weather warning. Additional instruments include Space Environment In-Situ Suite (SEISS), Extreme Ultraviolet Sensor/X-Ray Sensor Irradiance Sensors (EXIS), Solar Ultraviolet Imager (SUVI), Magnetometer (MAG), and.Geostationary Lightning Mapper (GLM).

The GOES I-P series (currently GOES 8-13, plus O and P) imager and sounder raw data downlink is 2.6 Mbps. The corresponding entire Level 1b data stream, 2.11 Mbps, is uplinked to the GOES I-N series satellite for broadcast as GVAR data. GVAR data is broadcast in L-band (1685.7 MHz), with binary phase shift keyed (BPSK) modulation.

The GOES-R instrument raw data downlink (includes imager, lightning mapper, and four space environmental instruments) is expected to be approximately 71 Mbps. The corresponding entire Level 1b data stream will be in the order of 31 Mbps. The goal is to downlink the entire Level 1b data stream as GOES Re-Broadcast (GRB) data.. This will require significant changes to the GOES spacecraft communication system, some changes to the processed data sites, and the introduction of new data formatting. Because of the large data rate the GVAR format will no longer be used.

The GOES-R Program Office (GPO) has developed a Government Reference Architecture that provides a workable solution to the GOES-R GRB requirements. To minimize the impact on the user, the GRB will continue to be transmitted in L-band, but use an expanded bandwidth (1682 MHz -1695 MHz). Emergency Managers Weather Information Network (EMWIN) has been combined with Low Rate Information Transmission (LRIT) and the separate EMWIN transponder eliminated from GOES-R/ LRIT and Data Collection Platform Report (DCPR) will be operated in the 1683 MHz to 1684 MHz range (see Figure 1).

Service	Current Frequency Spectrum	Current Data Rate	Future Frequency Spectrum	Future Data Rate
GVAR/GRB	1685.7	2.11 MHz	1690.0 MHz	31 Mbps
LRIT	1691 MHz	128 kbps	1697.4 MHz	400 kbps*
EMWIN	1692.7 MHz	9.6 kbps	1697.4 MHz	400 kbps*
DCS/DCPR	1694.5 MHz	100/300/ 1200 bps	1683.3 MHz	300/1200 bps

*Note: EMWIN and LRIT will have a combined service with a data rate of 400 kbps.

Figure 1 - Impact on Transmission Frequencies/Data Rates for GOES-R

To fit within the available bandwidth of 12 MHz (centered around 1690.0 MHz), the GRB service will employ dual polarization, having two signals (one right circular and the other left circular polarization). Understanding that the entire data downlink may not be of interest to every user, the GRB is expected to be formatted to allow all of the data similar to the current GVAR data to be transmitted on one of the polarizations— thus only one receiver will be required for this subset of data.. In addition to the traditional direct broadcast mode of GRB, Level 1b data will be available for distribution via terrestrial networks to authorized users in a "push/pull" mode as a data service, so that some users with less stringent data latency requirements can opt not to invest in new/updated Earth station receive systems. File sizes of all products are expected to be targeted for moderate line-rate web porting to support users with multi-megabit or Giga-bit connectivity. A key feature in the GPO transition plan is the development of a emulated GVAR (eGVAR) processed data stream containing selected full discs from GOES-R ABI, but relayed through the existing GOES-N/P series spacecraft at the 2.11 Mbps rate. This service will allow legacy GVAR users to transition more gradually to the new receive and processing systems required for GRB. However, operation of the GOES-R GVAR-like service is planned as a stop-gap measure and is not expected to continue indefinitely.

The GRB transmission format has not been defined; however, the intent is to take advantage of standard formats and technologies. The GVAR data transmission format was developed to allow full use of the capabilities of the advanced, three-axis stabilized spacecraft while retaining as much commonality as possible with receiving equipment in use from earlier spin-stabilized GOES spacecraft. The GVAR format is based on the operational visible and infrared spin scan radiometer atmospheric sounder (VAS) Mode-AAA format, which consisted of a repeating sequence of 12 fixed- length equal size blocks. The transmission of Mode-AAA blocks was synchronized with the spin rate of the earlier GOES spacecraft, that is, one complete 12 block sequence per satellite rotation. GVAR represented an evolution of Mode-AAA; GRB will represent a total change as impacted by the improved temporal and spatial, and measurement characteristics of the new instruments.

4. Conclusion

The direct readout services from NOAA spacecraft will change significantly over the next eight years. A summary of the spacecraft effects and field terminal changes is listed below:

<u>METOP</u>
APT service is not available
AHRPT format requires upgrades to existing HRPT field terminals or the purchase new station

<u>NOAA's POES Constellation</u>
APT frequency change in the 137.1 – 137.937 MHz frequency band
for NOAA-18 and N' spacecraft

<u>NOAA's NPOESS Constellation</u>
APT service will not available
HRPT will be replaced with the Low Rate Data (LRD) broadcast,
requires new L-band field terminal
High data Rate (HRD) service requires a new X-band field terminal

<u>NOAA's GOES Constellation</u>
GOES VARiable (GVAR) broadcast will be replaced with GOES Re-Broadcast GRB) service, requires new field terminal
GOES LRIT will be available, combined with EMWIN on GOES-R at a new higher data rate and new frequency.