Comparative Analysis of Operational Satellites Using APRS: Link Parameters, Electronics, and Applications

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Resumen— El Sistema Automático de Reporte de Paquetes (APRS) sigue siendo un protocolo ampliamente utilizado en las comunicaciones satelitales, incluso décadas después de su desarrollo en la década de 1980. Este estudio se centra en el análisis de satélites en órbita terrestre baja (LEO) que operan con APRS, evaluando sus parámetros de comunicación, arquitecturas de sistema e interoperabilidad. El análisis abarca varios factores clave como la potencia de transmisión, las bandas de frecuencia, los esquemas de modulación y las unidades de procesamiento a bordo, con el objetivo de establecer bases de diseño para sistemas de comunicación de baja potencia capaces de interactuar con estos satélites sin necesidad de un lanzamiento propio. La comparación de satélites como DIWATA-2, LAPAN-A2, BRICSAT-2 y PSAT-2 resalta las adaptaciones del APRS para aplicaciones de telemetría, retransmisión de emergencia y radioaficionados. Los resultados de este estudio no solo validan la vigencia de APRS en misiones espaciales modernas, sino que también proporcionan lineamientos clave para el diseño de estaciones terrestres experimentales, así como futuras mejoras en la eficiencia de transmisión y procesamiento de datos en entornos satelitales.

Palabras Clave — APRS, Parámetros de enlace, AX.25, Electrónica, Comunicaciones satelitales.

Abstract- The Automatic Packet Reporting System (APRS) remains a widely used protocol in satellite communications, even decades after its development in the 1980s. This study focuses on the analysis of Low Earth Orbit (LEO) satellites that operate with APRS, evaluating their communication parameters, system architectures, and interoperability. The analysis covers several key factors such as transmission power, frequency bands, modulation schemes, and onboard processing units, with the aim of establishing design foundations for low-power communication systems capable of interacting with these satellites without the need for a dedicated launch. The comparison of satellites like **DIWATA-2**, **LAPAN-A2**, **BRICSAT-2**, and **PSAT-2** highlights APRS adaptations for telemetry applications, emergency relay, and amateur radio. The results of this study not only validate the relevance of APRS in modern space missions but also provide key guidelines for the design of experimental ground stations, as well as future improvements in transmission efficiency and data processing in satellite environments.

Keywords — APRS, Link Parameters, AX.25, Electronics, Satellite communications.

I. INTRODUCTION

APRS (Automatic Packet Reporting System) is a real-time digital communication network developed in the 1980s by Bob Bruninga (WB4APR) for amateur radio operators. It enables the exchange of tactical data, including station positions, weather updates, and emergency alerts, using the AX.25 protocol frame [1]. The flags marking the frame boundaries, along with the destination and source addresses (which contain callsigns and SSIDs), the control field, and the protocol ID indicate a UI-frame with no Layer 3 protocol. The information field contains APRS data, and finally, the Frame Check Sequence (FCS) is a code used for error detection [2].

Table 1.- AX.25 Frame

Flag	Destination Address	Source Address	Digipeater Addresses	Control Field	Protocol ID	Information Field	FCS	Flag
1	7	7	0-56	1	1	1-256	2	1

APRS must work everywhere to be a true resource for the mobile ham radio operator. In North America, the 144.39 MHz frequency is dedicated across the continent. In Europe, 144.80 MHz is used, and in Australia, 145.175 MHz [3]. APRS operates via both radio frequency and the Internet, with interconnected stations through iGATES. Mobile stations continuously transmit GPS data, while fixed stations typically send a beacon every 20–30 minutes. Messages can be relayed through up to four repeaters, covering distances of up to 500 km, depending on terrain. The integration of iGATES extends APRS reach globally, even in areas without Internet access [4] [5].

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The Automatic Packet Reporting System (APRS) has proven to be an efficient solution for communication in small satellites, thanks to its low processing requirements and its ability to operate with limited-resource hardware. Its implementation in CubeSats and other nanosatellites allows the transmission of telemetry, status messages, and scientific data using compact frames based on the AX.25 protocol. This is ideal for systems with power and memory constraints, as APRS optimizes bandwidth usage and simplifies integration with low-power radio frequency modules. Additionally, its extensive network of ground stations and orbiting repeaters enables real-time tracking and data collection, making it a versatile tool for educational missions, environmental monitoring, and emergency communications.

While APRS.droid [6], enhances APRS accessibility, it has limitations. It is designed for basic data transmission, such as location and short messages, and is not suitable for large or complex data transfers. Its functionality depends on network availability, either through APRS-IS (Internet) or local radio frequency coverage. In congested networks, data delays or losses may occur, and transmission frequency is subject to local regulations [7].

II. METHODOLOGY/DEVELOPMENT

The development of this article provides the fundamental parameters for designing communication systems capable of establishing links with real satellites operating with the Automatic Packet Reporting System (APRS). This is especially valuable in the research phase, where link validation and hardware optimization are essential. By taking advantage of the availability of operational satellites and the public information of their callsigns, it is possible to set up experimental ground stations that facilitate data reception and transmission via APRS. This approach not only allows for the evaluation of the performance of different radio and processing systems but also opens the possibility of developing new applications in telemetry, remote monitoring, and emergency communications, leveraging the global APRS infrastructure[i] [8].

To ensure a relevant and up-to-date comparison, the satellites included in this study were selected based on the following criteria:

- Operational Status: Only satellites currently in operation and actively transmitting APRS signals were considered.
- Application Type: Satellites were categorized based on their primary function, mainly Amateur, Telemetry and Tracking.
- Data Availability: Satellites with publicly accessible information regarding their communication parameters, hardware specifications, and applications were prioritized.
- Antenna Type and Configuration: Characteristics of the onboard antenna system.
- Latency and Packet Handling: Time delay between reception and retransmission of APRS messages.

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The study considered frequency bands (UHF/VHF), transmission power, and receiver sensitivity, which impact signal reach and reliability. The modulation scheme (AFSK 1200 baud, GMSK) and antenna configuration were also analyzed, as they influence coverage and efficiency. Additionally, latency and packet handling were examined, particularly in digipeater operations.

The onboard transceiver model, power consumption, and processing unit were assessed to determine energy efficiency and data handling capabilities. Integration with telemetry, command, and control systems was also considered to understand how APRS functions within the overall satellite architecture.

Satellites were categorized based on the type of data transmitted (positioning, telemetry, emergency beacons) and custom APRS adaptations for specific missions. Finally, interoperability with ground stations, satellites, and APRS digipeaters was evaluated to assess network efficiency.

This structured approach highlights how APRS remains a viable and versatile protocol in modern satellite operations.

A. DIWATA-2

The DIWATA-2 is a low Earth orbit satellite in active status, launched on October 29, 2018, as part of the PHL-Microsat program in the Philippines. It is primarily used as an earth imaging telescope, an amateur radio system through APRS signals, and as an emergency data relay point. Its data availability is publicly accessible and usable [9].

B. LAPAN-A2

The LAPAN-A2, launched on September 28, 2015, is an Indonesian satellite developed by ORARI (Indonesian Amateur Radio Organization). It is part of Indonesia's broader efforts in space exploration and technology development. LAPAN-A2 is primarily used for earth observation, providing valuable data for environmental monitoring. Additionally, it functions as an FM radio repeater, which is vital for enhancing communication capabilities in remote regions. The satellite also serves APRS data repeaters, making it an essential asset for amateur radio operators. The public availability of its data provides open access to telemetry and APRS signals for various application. [10]

Figure 1: LAPAN-ORARI (IO-86)- DIGIPTEATER APRS.

C. BRICSAT-2

The **BRICSAT-2**, launched on **June 25, 2019**, is a collaborative project among the **BRICS countries** (Brazil, Russia, India, China, and South Africa). This **LEO satellite** focuses on a mix of **earth observation** and **amateur radio communications** using APRS, with an additional role in **experimental technology** and **monitoring**. **BRICSAT-2** contributes to global scientific research through its **publicly accessible data**. The satellite is equipped with experimental systems to test new technologies, which supports a variety of research fields, especially in **space communication** and **satellite systems**. The ability to transmit data through APRS adds versatility to its communication capabilities, providing valuable connections for amateur radio enthusiasts and supporting international cooperation in space.

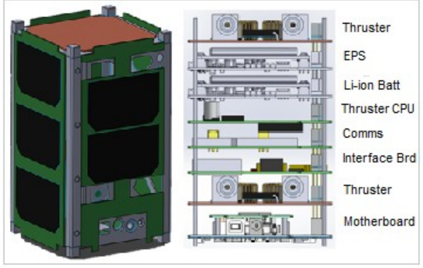

Figure 2: BRICSAT-2 (USNAP1) (NO-103).

D. PSAT-2

The PSAT-2 is a low Earth orbit satellite in active status, launched on September 27, 2017, by SpaceX Falcon 9. It is used by radio amateurs for APRS data and experimental technology. Its data availability is public [11].

Figure 3: PSAT-2 (NO-104) APRS/DTMF/VOICE.

E. Es'hail-2

Es'hail-2 *is a geostationary satellite launched on November 15, 2018, from the Kennedy Space Center. It is positioned in a geostationary orbit at 25.9° East. This satellite is notable for being the first to carry amateur radio transponders to geostationary orbit, enabling communication between amateur radio operators from Brazil to Thailand.*

Figure 4: Es´hail-2 Gestationary Satellite.

The satellite is equipped with two amateur radio transponders:

- **Narrowband linear transponder (250 kHz)**: Designed for conventional analog operations, such as SSB and Cw [11].
- **Wideband transponder (8 MHz):** Intended for experiments with digital modulation schemes and amateur DVB television.

Although Es'hail-2 is not specifically designed for traditional APRS operations, some amateur radio operators have experimented with transmitting APRS data through its transponders. These operations typically occur on the narrowband transponder using appropriate digital modes for data packet transmission.

Es'hail-2 uses frequencies different from those typically used for APRS. The narrowband transponder has an uplink at 2400.050 - 2400.300 MHz and a downlink at 10489.550 - 10489.800 MHz. These frequencies are in the 2.4 GHz and 10 GHz bands, respectively, which differ from the VHF/UHF frequencies commonly used in terrestrial APRS.

The inclusion of transponders in a geostationary satellite represents a significant milestone for the amateur radio community, offering new opportunities for experimentation and communication in higher frequency bands.

IV. Results and Discussion

In Table 2 It is possible to highlight the following operational parameters of the compared satellites.

Table 2: Satellite APRS Comparison

Name	DIWATA-2	LAPAN-A2	BRICSAT-2	PSAT-2
Data transmitted	Emergency relay point	Beacon packets	GPS	Telemetry, Position and Beacon
Adaptations of APRS	Message repeating	message repeating	Voice message	message repeating
Processing Unit	Satellite Central Unit (SCU)	LEON3	LEON (SPARC)	Digital Signal Processor (DSP)
Transmission power	5 W	3W	1W	10W
Frequency bands	145.900 MHz (VHF), 437.500 MHz (UHF)	145.825MHz (VHF) 435.880 Mhz (UHF)	145.825MHz (VHF) 437,605MHz (UHF)	145.825MHz (VHF)
Onboard transceiver	Amateur Radio Unit (ARU)	Handheld Transceiver (HT)	VHF Transceiver	TH-D7 Handheld Transceiver
Antenna Type	Monopole	Monopole	Monopole	Monopole
Receiver sensitivity	-120dBm to -140dBm	-120dBm to -140dBm	-120dBm to -140dBm	-120dBm to -130dBm
Modulation scheme	AFSK 1200 baud	AFSK 1200 baud	AFSK 1200 baud, GMSK.	AFSK 1200 baud
Interoperability	APRS digipeaters	Voice repeater (VR)	APRS digipeaters	APRS digipeaters and amateur radio
Integration with other subsystems	ADCS, C&DH, TT&C	ADCS	TT&C, ADCS	TT&C, ADCS

LEO satellites prioritize low power and efficient APRS message handling, while **Es'hail-2 represents an advanced model for stable, real-time communications**. This comparison confirms **APRS remains a viable choice for low-cost missions, but its future may involve higher-frequency, more resilient satellite communication systems**.

Although Es'hail-2 does not explicitly cater to traditional APRS applications, its use of **higher-frequency bands** and its **continuous, wide geographic coverage** provide a platform for expanding APRS functionality into new areas. Amateur radio operators can now experiment with **data transmission over extended distances** using digital modes suited to the satellite's available bandwidth. **Es'hail-2's innovative approach** to satellite-based amateur radio sets the stage for future developments in **data communication** and **telemetry**, offering new avenues for both hobbyists and scientific exploration.

These four satellites—DIWATA-2, LAPAN-A2, BRICSAT-2, and PSAT-2—highlight the growing trend of using small, low Earth orbit satellites for both scientific and amateur radio applications. Each satellite brings unique capabilities to the table, from earth observation and disaster monitoring to supporting amateur radio networks. One key takeaway is the diverse communication capabilities these satellites offer. While DIWATA-2 stands out for its imaging and emergency relay capabilities, LAPAN-A2 and PSAT-2 focus more on telemetry and APRS repeater functions. BRICSAT-2, with its role in experimental technology, introduces new avenues for testing advanced systems in space. Overall, these missions demonstrate how small satellites can be versatile platforms, integrating science, technology, and amateur radio to enhance both research and global communication infrastructure.

V. CONCLUSIONS

It is observed that most of the analyzed satellites use monopole antennas, suggesting that this type of antenna is an optimal choice due to its structural simplicity, ease of deployment, and adequate performance within the space and mass limitations of nanosatellites. Additionally, the operating frequencies in the VHF and UHF bands are consistent across all cases, with the frequency of **145.825 MHz** standing out as the standard for APRS. This facilitates compatibility with ground stations and other satellites that act as repeaters, establishing a common base for communications.

Regarding modulation, it is observed that the predominant use of **AFSK at 1200 baud** remains efficient for transmitting data packets over low-bit-rate links. This scheme provides a good balance between robustness and low energy consumption, which is crucial in systems with limited resources. Data transmission is carried out with power levels ranging from **1 W to 10 W**, indicating that APRS links require relatively low power levels to ensure effective communication, depending on altitude and the design of the ground station receiver.

One of the most variable aspects among the analyzed systems is the onboard processing unit. Some satellites employ advanced processors such as **LEON3** and **DSP** for data and signal management, while others integrate more general units, such as the **SCU**. This variability suggests that processing can be adapted to the specific requirements of each mission, allowing for everything from simple packet retransmission to more complex telemetry processing or even voice messages, as in the case of **BRICSAT-2**.

Based on the findings, it is possible to establish the foundations for designing a low-power satellite communication system that allows interaction with real APRS satellites without the need for a dedicated launch. This system should integrate several key components:

- **Monopole Antenna**: A monopole antenna tuned to the VHF band, preferably at **145.825 MHz**, which has been identified as a standard frequency for APRS, is crucial to ensure compatibility with satellites and ground stations.
- **Low-Power Transceiver**: A transceiver operating between **1 W and 5 W**, compatible with **AFSK at 1200 baud**, is recommended to transmit and receive data efficiently through low-bit-rate links.
- **Processing Unit**: The processing unit could be based on a **low-power microcontroller** or an **FPGA**, allowing flexibility in the implementation of protocols and data handling algorithms.
- **Telemetry Storage and Analysis Capabilities**: The integration of capabilities to store and analyze telemetry in real-time would be essential to validate link performance and assess communication stability with different operational satellites.

Furthermore, this study shows that, despite its age, APRS remains a relevant technology with innovative applications. An example of its evolution is the incorporation of new functionalities, such as **voice message transmission in BRICSAT-2**, which demonstrates opportunities to expand its capabilities beyond traditional telemetry.

This scenario opens the door to future research and developments in satellite communications, exploring the possibility of improving existing APRS systems or integrating them with other emerging technologies in the fields of nanosatellites and space communication networks.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the partial support of Secretaría de Investigación y Posgrado of Instituto Politécnico Nacional, through projects 20242752, 20240894, 20241163, 20240811 and 20241077, as well as the EDI and PIFI programs.

ETHICAL DISCLOSURE

It is declared that there is no conflict of interest in the publication of this article.

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