Application Brief

Design Considerations and Challenges for Future User Terminals

Phil LaVerde

Constant connection to the internet has become a near necessity in the world of today. Because staying online is now arguably a requirement for modern life, the expectation of access has moved far beyond the home or office. People want to be connected no matter where they go; for example, airlines and cruise lines rapidly upgrade their fleets to offer seamless Wi-Fi. The need for connection no matter the location has created a need for user terminals to be deployed where terrestrial networks cannot reach. These user terminals support vital applications by establishing secure data channels for rural homes, commercial aircrafts, passenger ships, and remote industrial infrastructure. These terminals are also heavily deployed by military forces and emergency responders to establish secure command centers and restore critical communication lines during natural disasters.

A user terminal is one of the building blocks of the satellite communications (Satcom) network. Satcom utilizes three distinct components to establish global connectivity: the ground station, the communications payload, and the user terminal or equipment, as shown in Figure 1. Ground stations are hubs that directly interface with the data network and transmit data to and from the satellite. The satellite payload operates in orbit, acting as a medium between the ground stations and the user terminals to enable constant, two-way communication.

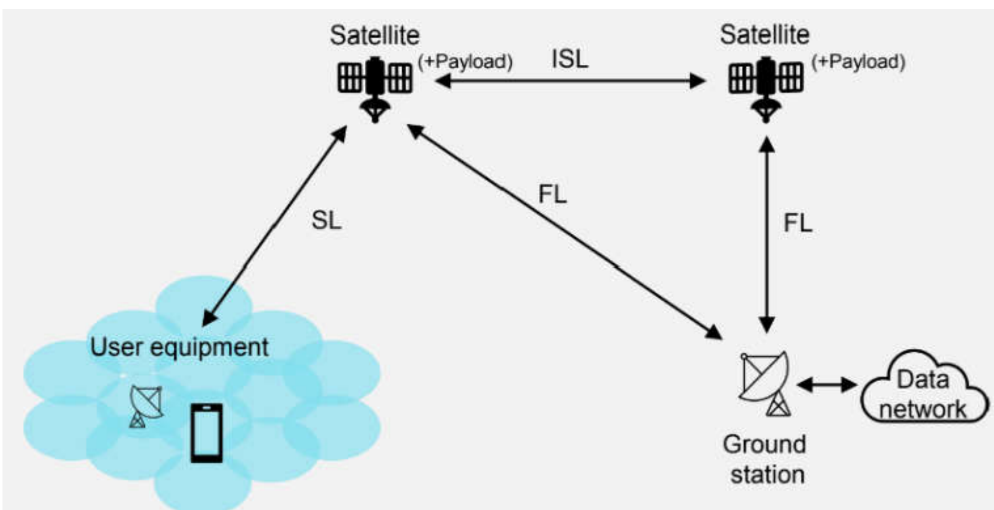

Figure 1. Satcom Ecosystem

User terminals are modems that serve as an interfacing link between satellite infrastructure and individual end users. User terminals perform several functions to maintain reliable connectivity. The terminal maintains line-of-sight alignment by either physically driving a reflector dish, or electronically steering the beam using a phased-array architecture. Once aligned, user terminals convert digital data from user devices into radio frequency signals, amplify the signals to sufficient power levels, and transmit the signals into space. Simultaneously, the terminals capture weak consumer downlink signals from orbit, process the signals through a low-noise amplifier (LNA) to filter out ambient RF noise, and demodulate the frequencies back into digital data. Table 1 provides a breakdown of three user terminal subtypes and the differentiating factors.

Table 1. User Terminal Types

	Fixed	Mobile	Portable
Description	Permanent hardware mounted to buildings or ground infrastructure.	Terminals mounted on vehicles, ships, or aircraft.	Tactical or emergency systems designed for single-person deployment without infrastructure.
Use Cases	• Commercial broadband • Enterprise terminals	• In-flight connectivity • Maritime navigation • Vehicles	• Manpack • Flyaway • Satellite phones
Common Bands	• L-band • S-band • C-band • Ku-band/Ka-band		

Market Trends and Technology Drivers

Multi-orbit hybridization: Hybrid designs are emerging due to the influx of LEO satellites as mentioned above. Hybrid terminals can switch between low-latency LEO links for interactive traffic, and high-capacity GEO beams for bulk data transfer, optimizing performance based on real-time network conditions and service requirements.

Flat-panel ESAs: Flat-panel, electronically-steered phased arrays (ESAs) are becoming more popular across the market with the increase in LEO satellites. Flat-panel systems steer RF beams electronically without moving parts, giving them lower profiles for easier installation and the ability to track multiple LEO satellites at once with multiple beams. According to the Yole Group market report on RF for Satcom, around 5,000 LEO satellites are being launched per year, up from just 1,600 in 2021.

Non-Terrestrial Networks (NTN): 3GPP Release 17 made NTN a major trend by introducing the first official standards for direct satellite-to-cellular connectivity. By embedding satellite capabilities into standard cellular systems, this technology effectively eliminates the traditional boundaries of geographic coverage. The service link from the satellites can be received by a user terminal or by a mobile phone. Current mobile technology primarily supports emergency SOS texting, location sharing, and limited data messaging in remote areas without terrestrial coverage. The unified framework addresses the challenge of data isolation for critical operations in extreme environments, including offshore energy platforms, maritime shipping lanes, and isolated agricultural fields.

Multi-Band and Multi-Orbit Support

Multi-band and multi-orbit capabilities allow a single terminal to communicate across different frequency bands (for example, L, S, Ku, Ka) and satellite orbits (GEO, MEO, LEO). This flexibility enables seamless switching between constellations to access the best available coverage, while providing resilience when individual satellites or networks experience outages or congestion. The need for these capabilities is driven by scaling satellite deployments and demanding data applications. Each different orbit has distinct advantages in terms of latency, coverage area, and cost. Terminals with the ability to access multiple orbits offer customers greater flexibility and resilience.

TI has transceiver designs, such as the AFE8128 and AFE7769D, that are capable of multi-band and multi-orbit operations. The AFE8128 leverages numerically controlled oscillator (NCO)-based RF sampling architecture to enable multi-band operation without requiring multiple RF chains or external mixing stages. Four independent RF phase-locked loops (PLLs) enable the AFE7769D to support multi-band architectures, combining L/S/C band operation into a single transceiver. Such frequency flexibility allows terminals to dynamically switch between satellite constellations and frequency bands without hardware reconfiguration.

Frequency Hopping

Frequency hopping is the rapid switching of radio signals across multiple frequency channels according to predetermined patterns. This capability is essential for military variants of this application because frequency hopping protects against jamming, interception, and interference, while commercial systems use frequency hopping to dynamically avoid congested spectrum and keep reliable connections in congested electromagnetic environments. TI has transceiver designs that feature fast frequency hopping: the AFE812x family has this technology incorporated to provide an uninterrupted signal. A visualization of frequency hopping on an RF output is shown in Figure 2.

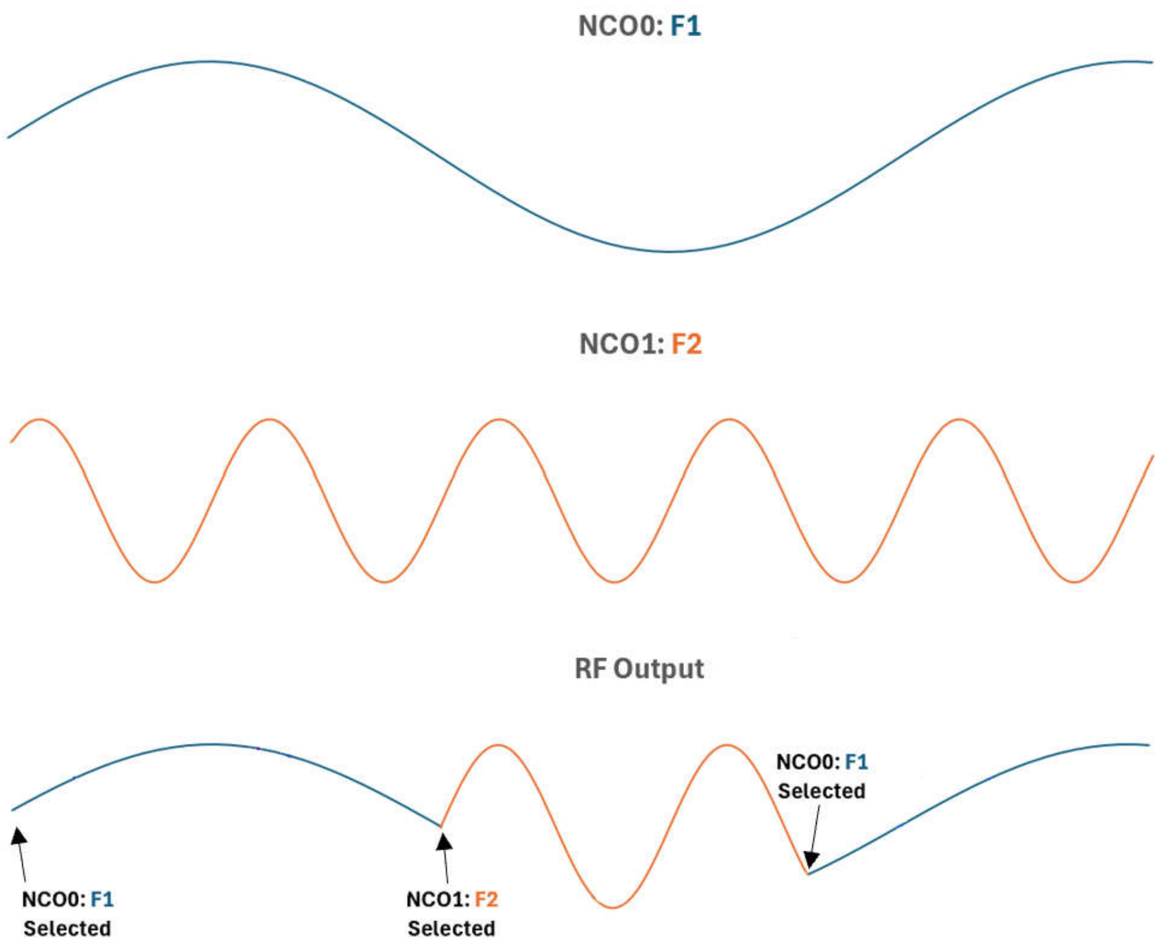

Figure 2. Example of Phase Continuous Frequency Hopping

Size, Weight and Power-Cost (SWaP-C)

SWaP-C optimization focuses on minimizing the physical footprint, mass, and energy consumption of ground hardware while driving down manufacturing costs. This efficiency directly dictates whether a terminal can be deployed on restricted platforms. Size optimization is crucial for terminals designed for small vehicles or airborne designs. While large enterprise terminals on building rooftops or ships can plug directly into a main power grid, power optimization becomes critical for emergency and tactical terminals. In addition to the need for energy efficiency, these portable designs also need to consider size and weight. TI's AFE7769D features integrated digital pre-distortion (DPD) and linearizes the power amplifier (PA) in a system, while crest factor reduction (CFR) reduces signal peaks to prevent PA saturation. Together, these advanced signal conditioning techniques improve transmit signal quality, maximize power amplifier efficiency, and directly reduce power consumption. This device contributes to the consolidation of system level bill-of-materials, further addressing the size and cost challenges of user terminals.

Conclusion

As the satcom market expands, the expectation for seamless, non-stop connection drives the evolution of user terminals. With LEO and MEO constellations rapidly expanding alongside existing GEO networks, user terminals can no longer rely on rigid, single-orbit architectures. Next-generation satellite terminals must support multi-orbit operation while meeting strict size, weight, and power requirements to remain viable across aerospace, military, and commercial platforms. Achieving this level of adaptability requires advanced hardware integration. Ultimately, these chip-level advancements provide the efficiency, agility, and resilience necessary to power the next era of satellite networks.

References

- Yole Group. (2026). *RF for SatCom 2026*. https://admin.yolegroup.com/static/sample/yintr26564-rf_for_satcom_2026-product_brochure.pdf
- 3GPP. (2025, July 4). *Non-Terrestrial Networks (NTN)*. https://www.3gpp.org/technologies/ntn-overview
- International Telecommunication Union. (2025, October 15). *Internet use*. https://www.itu.int/itu-d/reports/statistics/2025/10/15/ff25-internet-use/
- Texas Instruments, *Multi-AFE Synchronization using AFE7769D for Large Phased Array Antenna Systems*, application note.

Trademarks

All trademarks are the property of their respective owners.