

Future-proofing satellite communications- how RF-over-IP technology reduces costs, simplifies deployment and improves security for ground-based operations

Digital Intermediate Frequency Interoperability (DIFI) will enable the satcom industry to transition from traditional analogue RF infrastructure to flexible, secure and scalable RF-over-IP connectivity across ground segment operations. Filtronic is developing high-throughput, high-bandwidth devices to digitise and de-digitise signals and support the industry-wide shift towards virtualised networks.

Digital Intermediate Frequency (DIF) or 'RF-over-IP' technology offers the opportunity for satellite data communications to scale up rapidly and cost-effectively, while preserving signal quality and improving resilience in the face of growing demand for data.

By encoding analogue RF signals into standard Internet Protocol (IP) packets, data can be transported more reliably and securely, at scale and with minimal signal degradation over fibre cables, even over long distances. In a digitised system, analogue RF signals are encapsulated as IP packets (digitised) at source and transmitted over standard ethernet connections to the antenna station. Here, signals are reconstructed back into RF (de-digitised), upconverted to the relevant frequency, and amplified for transmission via the antenna to satellites.

This approach removes the need for signals to be modulated and demodulated by modems and associated equipment at the antenna station. Using RF-over-IP not only streamlines signal transport, but also facilitates the integration of RF systems into modern digital infrastructures, marking a significant advancement in satellite communications technology.

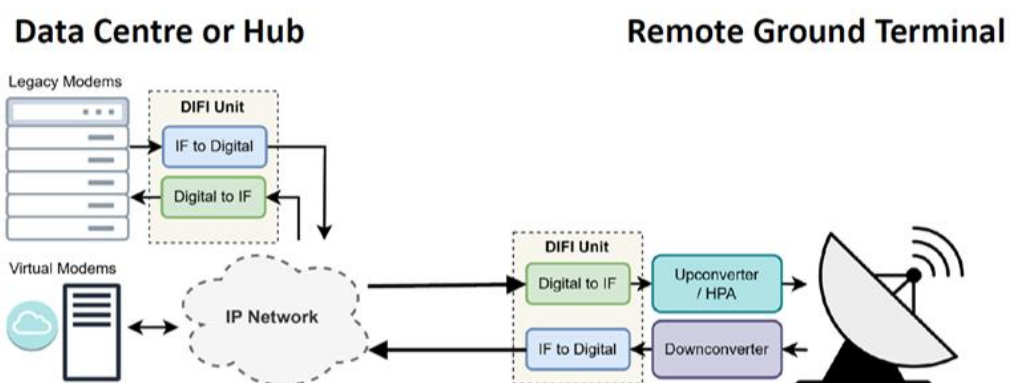


Figure 1: DIFI implementation

Why is digitisation needed in satellite communications?

The continued exponential growth in data traffic means that satellite communications need to rapidly increase capacity, resilience and security. The transition to DIFI directly addresses these pressures, particularly for operators wishing to move into higher mmWave frequencies which typically use wider bandwidth modulation such as at Ka, Q/V, E and W bands.

The huge growth in demand for data has seen the rapid expansion of LEO satellite constellations and high-throughput satellites (HTS) to deliver the necessary high-speed, high-capacity connectivity across non-terrestrial networks. However, current analogue ground systems are struggling to keep pace and cannot be scaled up quickly enough to meet future demand. These legacy hardware-heavy ground architectures are reaching their limits in terms of bandwidth, cost, capacity, scalability and flexibility.

Transforming to digital infrastructure and transitioning towards higher frequencies solves these issues and will enable satcom operators to rapidly and cost-effectively scale up their operations to meet growing demand.

How it works

Digital IF provides a streamlined, secure, high-capacity transport system for RF signals. In the ground segment of a traditional satcom system, antenna sites require routers, modems, IF matrices and cross-site cabling to handle incoming IF signals and convert them into RF signals for transmission up to satellites (see Figure 2a).

DIFI moves this capability back to the source of the data (for example, a data centre or hub) so that instead of sending the data to multiple antenna locations and modulating at the terminal, the data is sampled and encapsulated into IP packets at source using a single piece of digitisation hardware. In future this could even be a virtualised modem, since the RF to IP conversion can be done in the cloud.

The IP packets are transmitted over standard ethernet networks to the antenna station, where a simple de-digitisation unit reconstitutes the digital IP packets back into RF signals for transmission to satellites. This process happens in reverse for signals received by the antenna from satellites. It means that antenna terminals will no longer need to have routers, modems, cross-site cabling and associated infrastructure on site (see Figure 2b).

This is all replaced by a single digitiser/de-digitiser. This device extracts the RF signals from the incoming digital signals, which then pass through block upconverters (BUCs) and power amplifiers (SSPAs) to the antenna. In the other direction, RF signals received from satellites travel via low-noise amplifiers (LNAs) and block downconverters (BDCs) into the digitiser to be converted into IP packets for transmission to terrestrial destinations.

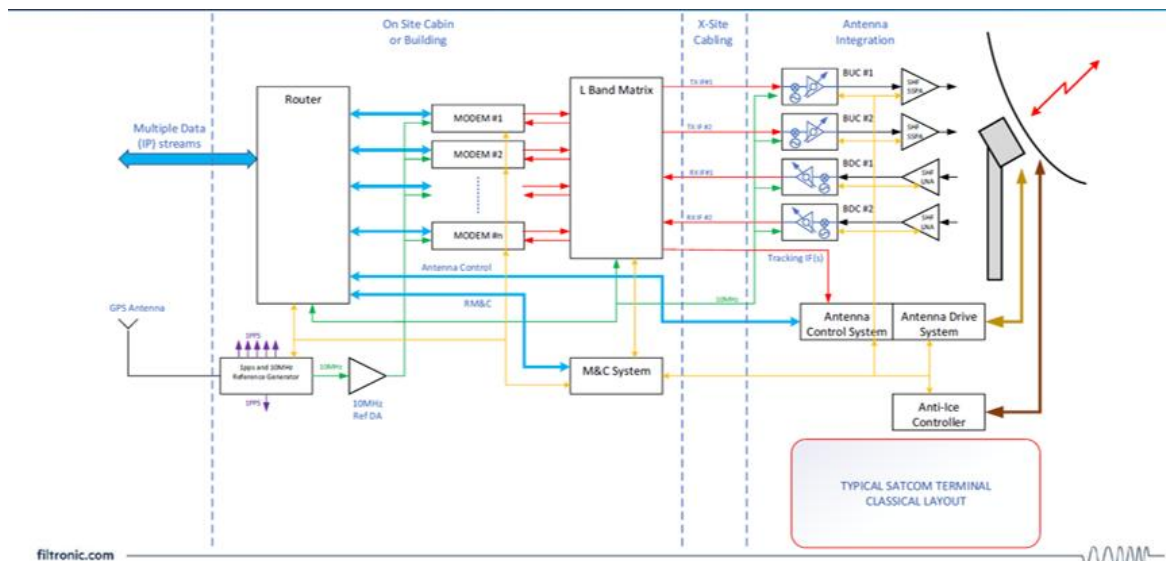


Figure 2a: Traditional satcom ground terminal layout (analogue system)

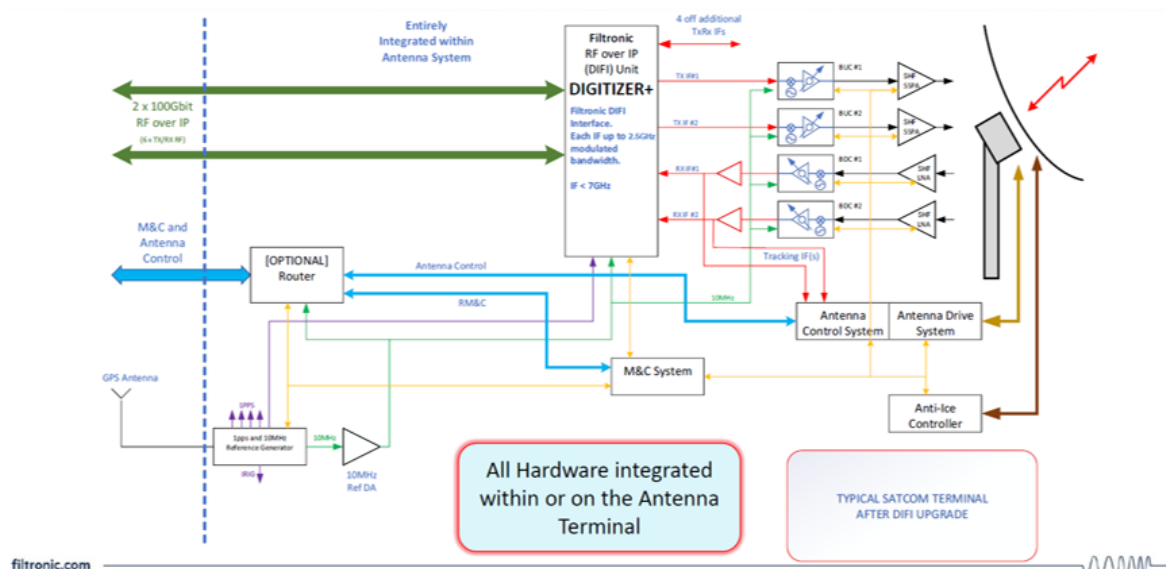


Figure 2b: Satcom ground terminal layout following DIFI upgrade

Advantages of digital over analogue RF systems

By eliminating a whole swathe of analogue hardware and cabling currently used to process signals at the antenna station, the switch to Digital IF reduces capital expenditure and operating expenditure, simplifies installation, operation and maintenance, improves signal quality and security, and increases network capacity.

– Capex savings

Much of the antenna terminal infrastructure, from baseband modems to IF/RF cross-site cabling, as well as some aspects of up and down conversion, can be replaced by a single digitiser/de-digitiser. This can be located close to the antenna, alongside existing

upconverters and downconverters – removing the need for a separate terminal building to house the analogue hardware.

The wholesale removal of hardware translates to significantly lower capital expenditure in the development of new ground-segment infrastructure. It also equates to a significant reduction in deployment times for these new assets, since DIFI equipment is much simpler and faster to install.

– Opex savings

For existing antenna sites that need to be upgraded for the Digital IF environment, the removal of legacy hardware and cabling results in long-term savings in operating and maintenance costs. With no need to retain a terminal building at the antenna site, ongoing rental and building-related costs are also eliminated. In practice, these savings in operational costs are more than sufficient to fund the conversion to DIFI.

– Signal quality

By digitising signals at source and de-digitising them close to the antenna, signal quality is maintained and losses in transmission significantly reduced. In analogue systems, IF signals sent over long distances inevitably experience degradation, due to losses in the coaxial cables.

– Improved security

Coaxial cables used in analogue systems can radiate signals, making them vulnerable to interception. Moving to RF-over-IP and transporting signals via ethernet cables significantly improves data security. Digital signals can be further encrypted, adding another layer of protection. The structure of DIFI networks also means that ground segment teams can focus their efforts on protecting one centralised secure facility where analogue signals are encapsulated as IP packets, rather than having to guard against vulnerabilities at each individual antenna site.

– Greater flexibility

In a digitised system, more aspects of signal transmission can be managed by software, rather than hardware, making it more flexible and easier to implement and upgrade. It also enables traditional RF systems to be integrated into modern digital cloud infrastructures.

– Increased capacity

Digitisation increases data capacity in the network, allowing satcom ground segment operations to scale up as demand for data increases. It means ground infrastructure can quickly ramp up capacity to keep pace with the expansion of high-throughput satellites (HTS) and LEO satellite constellations.

DIFI for industry-wide interoperability

To facilitate the widespread adoption of Digital IF systems, all participants in the satellite ground segment market need to adopt an agreed, universal digital RF/IF standard. This will enable full interoperability across all hardware in the sector.

The Digital Intermediate Frequency Interoperability (DIFI) consortium was established to support the digital transformation of space, satellite and related industries by providing just such a “simple, open, interoperable Digital IF/RF standard that replaces the natural interoperability of analogue IF signals and helps prevent vendor lock-in.”

As a member of the DIFI consortium, Filtronic has been closely involved in the evolution of the DIFI standard. Most of the industry has now adopted IEEE-ISTO Std 4900-2021 v1.3 July 2025 and members of the DIFI consortium, including Filtronic, are participating in regular interoperability trials.

High-throughput, high-bandwidth solution from Filtronic

To support the digital evolution of the satcom industry and open the door to RF-over-IP for satellite ground operations, Filtronic has developed an advanced digitiser/de-digitiser. By combining digitising and de-digitising functions in one unit, our device provides a compact solution that can be deployed both at antenna sites to toggle signals between analogue and IP formats, and at data sources on the ground to encapsulate RF signals as IP packets prior to transmission.

What sets our new device apart is the combination of wide bandwidth and high channel count. The platform features six transmit-and-receive RF channels, each capable of interfacing to carriers of over 2.5GHz of instantaneous bandwidth on IF carrier frequencies up to 6GHz. The RF signals can be sampled at 8 to 14-bit level and the encapsulated RF signals are transmitted over IP via a 100Gbit ethernet port. A second port can be enabled if additional data rates are needed. This exceptionally wide bandwidth provides a substantial performance advantage over existing solutions on the market.

Our solution has also been designed with a modular architecture, so it can be tailored to specific frequency bands and, where required, incorporate up/down conversion within the unit. An internal RF mezzanine board can be customised with tailored IF filtering for block upconverter and block downconverter applications, giving operators the flexibility to adapt the system to the specific needs of their ground segment.

Future-proofing the satcom ground segment

Digital IF is a pivotal technology for the future of satellite communications, and its adoption marks a major step forward in enabling truly virtualised, cloud-ready architectures.

Satcom industry technology suppliers must prepare to future-proof their products for an increasingly digitised environment. Every component, from solid-state power amplifiers and block upconverters to channelisers and digitisers will need to have built-in capability to interface with the DIFI ecosystem, enabling seamless interoperability across the wider satcom network.

In the near future, satcom operators will expect all ground segment hardware to be compatible with the DIFI environment, and for all equipment to conform to the agreed DIFI standard. This will allow operators to connect DIFI-enabled hardware from any manufacturer into their ground segment infrastructure, future-proofing their networks for secure, reliable performance in the emerging digital era.

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To find out more about the transition to DIFI and the possibilities of new RF-over-IP technology for the satcom industry, please contact Filtronic.

