



Boost economics in agile high throughput Satcom payloads

A white paper from e2v

The inexorable demand for bandwidth fuels the need for agile systems throughout data networks. Even Satcoms are undergoing transformative digital developments. Innovative architectures supported by new, ultra-wideband (UWB) data convertors are helping boost both their economics and data throughput.

Introduction

The inclusion of on-board processing (OBP) in modern, high throughput satellites (HTS) promises a new generation of highly agile, flexible, payloads. Traditionally, dumb, 'bent pipe' payloads acted as simple space based repeaters. Ideally, satcom operators would like to be able to dynamically allocate transport capacity - modifying mission profiles based on demand.

These are needs that vary on a seasonal, and daily basis. Therefore, an ability to steer spot beams based on capacity utilisation and traffic demand peaks, offers improved quality of service and lower delivery cost per customer.

Dynamic beam control using phased array antenna technology combined with agile frequency planning promises an unprecedented future. However, for this goal to be realised new approaches to payload design have to be undertaken.

In terrestrial communication networks, software defined radios are the workhorse for reliable, high capacity infrastructure. We are simply unaware of the complex channel and frequency hopping that occurs to maintain uninterrupted service. It just works. Now, imagine the impact of agile frequency management if applied to satcoms. That is the big idea currently being worked on by payload suppliers.

It is an idea exemplified by Intelsat's recently launched, Epic^{NG} satellite and by Eutelsat's soon to be realised Quantum project (launch 2018). The system engineering behind these place huge demands on electronics. Thankfully, new ultra-wideband data convertors are emerging at just the right time to help. This brief review considers:

1. The economic arguments for deploying more sophisticated payloads¹.
2. The benefits of using UWB convertors
3. How steerable antennas help mission agility

Satellite economics

Increased data throughput from better spectrum use, coupled with beam steering are principles to manage satellite economics. However, within the satellite industry, opinions divide on how best to meet customer needs and especially whether increased payload complexity really makes financial sense.

Everyone understands the benefits of flexibility - operators get to dynamically react to demand on the ground. But, there's a clear penalty to be paid in adding agile, signal processing. Flexibility usually imparts increased power consumption, complexity and cost penalties as well as a possible reduction in reliability. But, as argued here, there is growing evidence that the full digitalisation of satcoms is turning an economic corner; helped considerably by new components that enable flexible, software defined radio architectures.

¹ HTS Gateway Network optimization by using On-board Regenerative processor. 3rd ESA Workshop on Advanced Flexible Telecom Payloads. 21-24 March 2016 ESA/ESTEC. By Alessandro Le pera. Eutelsat SA.
Boost economics of agile, high throughput Satcom (HTS) payloads

Developing a satellite based communication infrastructure project is a high stakes game. It's all about launch weight. Oft cited costs to place 1 kg into geostationary orbit average around 50 k\$. So adding the extra weight for an OBP module is not cheap. However, over operational lifetime, it's clear that the flexibility afforded by an agile payload creates a new paradigm explored by Eutelsat in its recent 2016 ESTEC² paper. Eutelsat argues that flexibility has multiple benefits, specifically:

- **For operators**, given shifting market, political, regulatory environments coupled with a 15-year hardware lifecycle, it is impossible to balance system needs from a fixed platform. Re-configurability is a huge benefit to maximise utilisation over time.
Also more specifically, in an idea as developed by Alessandro Le Pera³ future HTS systems aim to reduce the cost of ground equipment by using OBPs that are designed to support the targeted HTS capacity with a reduced number of gateways.
- **For manufacturers**, traditionally flexibility has led to more complex flight hardware. Reconfigurable OBPs offers supply chain simplification coupled with easier test regimes whilst offering the prospect of forward compatibility (future proofing for customers).
- **For customers**, the promise of customer centred service management is a valuable idea. Customers need not predict the future. Instead capacity can be assigned and costed as needed. Service acquisition is thus de-risked.

So there are good reasons to consider an OBP approach. Perhaps not all of these benefits are so easily costed, but a logic emerges.

Furthermore, as we'll see, current component developments herald new system price points and performance capabilities. A single UWB ADC is now capable of replacing multiple RF mixers, and multiple baseband ADC banks to serve up savings in system cost, power consumption all whilst aiding system flexibility.

Faster UWB analog data convertor simplifies signal processing

Digitising radio spectrum is a task handled by high speed data convertors – Analog-to-digital (ADCs) used in the uplink and digital-to-analog convertors (DACs) in the downlink. In the role of signal conversion, data convertors fundamentally impact system performance. Converting RF signals into digital 'ones and zeros' enables an efficient, algorithmic approach to signal processing which provides for both backward and forward transport layer compatibility through system re-programmability.

Satellite telecoms payloads operate at Gigahertz (GHz) frequencies; Ka and Ku-band being most common. Traditionally, data convertor sample rate and bandwidths have been restricted to managing hundreds of megahertz. Often multiple RF mixer stages were required in the signal path to transform (up or down convert) microwave signals into readily sampled baseband signals of less than 500 MHz bandwidth. Because of this, older ADC devices tended to be limited to sampling signals in the first Nyquist zone (where $N1 = fs/2$). This constrains the per channel, RF carrier handling capacity. It's a limit only circumvented by adding extra ADC channels to handle the full signal bandwidth - raising design complexity and impacting reliability.

² Eutelsat Quantum-Class satellites, answering the Operator's need for flexibility. 3rd ESA Workshop on Advanced Flexible Telecom Payloads. 21-24 March 2016 ESA/ESTEC. by Dr Hector Fenech, Sonya Amos.

³ HTS Gateway Network optimization by using On-board Regenerative processor. 3rd ESA Workshop on Advanced Flexible Telecom Payloads. 21-24 March 2016 ESA/ESTEC. By Alessandro Le era. Eutelsat SA.
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Part number	Supplier	f_s max (MSPs)	Input -3dB BW (MHz)	SFDR (typ)	Total power (W typ)	Space grade?
EV12AD550	e2v	1500	4300	68dBc@-3dBFS/1498MHz 64dBc@-12dBFS/1900MHz (measured over temp)	4.6	Yes
ADC12D1800RF	Texas Instruments	1800	2700	71.7dBc@-0.5dBFS/498MHz 61dBc@-0.5dBFS/1448MHz (measured over temp)	4.22	No
ADC12D1600QML	Texas Instruments	1600	2700 not directly specified	63.3dBc@-0.5dBFS/248MHz (measured over temp)	3.88	Yes
AD9234-1000	Analog Devices	1000	2000	80dBc@-1dBFS/450MHz 78dBc@-1dBFS/1410MHz (measured at 25degC)	3.3	No
LTC2158-12	Linear Tech	310	1250	80dBc@140MHz (measured at 25degC)	0.76	No

Table 1: Comparison of currently available dual wideband 12-bit ADCs

Several commercial grade, wideband ADCs have been developed in recent years as detailed in Table 1. However, note that this list only contains two space grade parts. The ADC12D1600QML hints at an expanded bandwidth capability with a smattering of intermodulation specifications quoted at 2670 MHz input frequency. Curiously though, no dynamic specifications beyond 248 MHz input are included.

The benefit of a significantly increased signal bandwidth and sample rate in the multiple gigahertz range facilitates sampling in higher Nyquist zones eliminating the cost, weight and power penalties of extra RF mixer stages. This step can transform satellite economics by simplifying the signal path design (illustrated in figure 1). Furthermore, this results in the desired payload flexibility and impacts 'SWaP' (size, weight and power) plus cost and redresses reliability concerns.

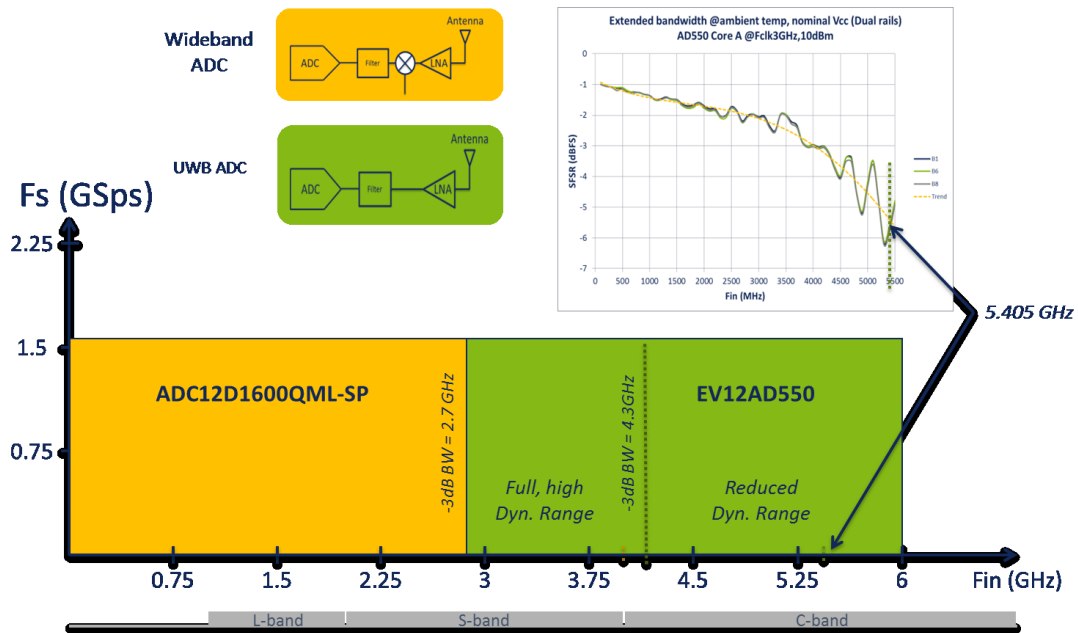


figure 1

Specialist e2v, has been pioneering novel UWB converters that push bandwidth limits for several years now. e2v has fingers in high speed data converter designs on both uplink and downlink sides of the signal chain. For uplinks, the new dual channel, 12-bit 1.5 Gbps ADC, the EV12AD550 will surely cause some excitement.

Featuring a pure, non-interleaved core design, this ADC is imbued with class leading dynamic specifications. Dual conversion cores, paired to a flexible input signal multiplexer enable it to sample in-phase or in opposition. It is also possible to support single channel interleaved, double sample rate operation (at 3 Gbps).

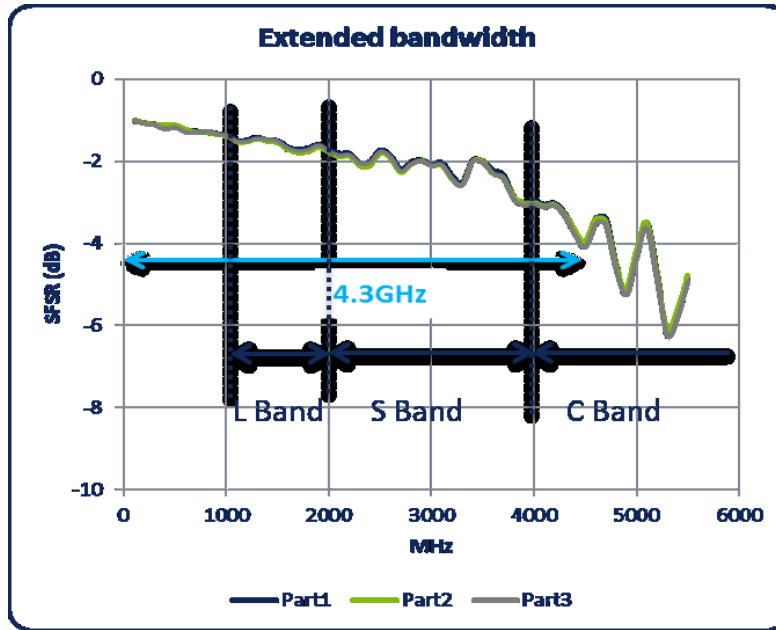


figure 2

This is a space grade, radiation hardened design that provides an impressive 4.3 GHz, 3 dB bandwidth (figure 2) on a competitive per channel power budget of just 2.3 W. A European sourced 0.13 μm BiCMOS process node provides the speed advantage. The EV12AD550 samples at up to 1.5 Gbps and can sample RF signals all the way into the fifth and sixth Nyquist zones ($N_5 = 3$ to 3.75 & $N_6 = 3.75$ to 4.5 GHz) and beyond.

A novel, high density hermetic package supports the RF design requirements. This package exploits an RF friendly aluminium nitride flip-chip package sourced from Kyocera (figure 3). With excellent thermal properties, including a coefficient of expansion closely matching silicon, there's minimal mechanical stress on interconnect bumps. This ensures stable over temperature and reliable performance throughout mission profiles.

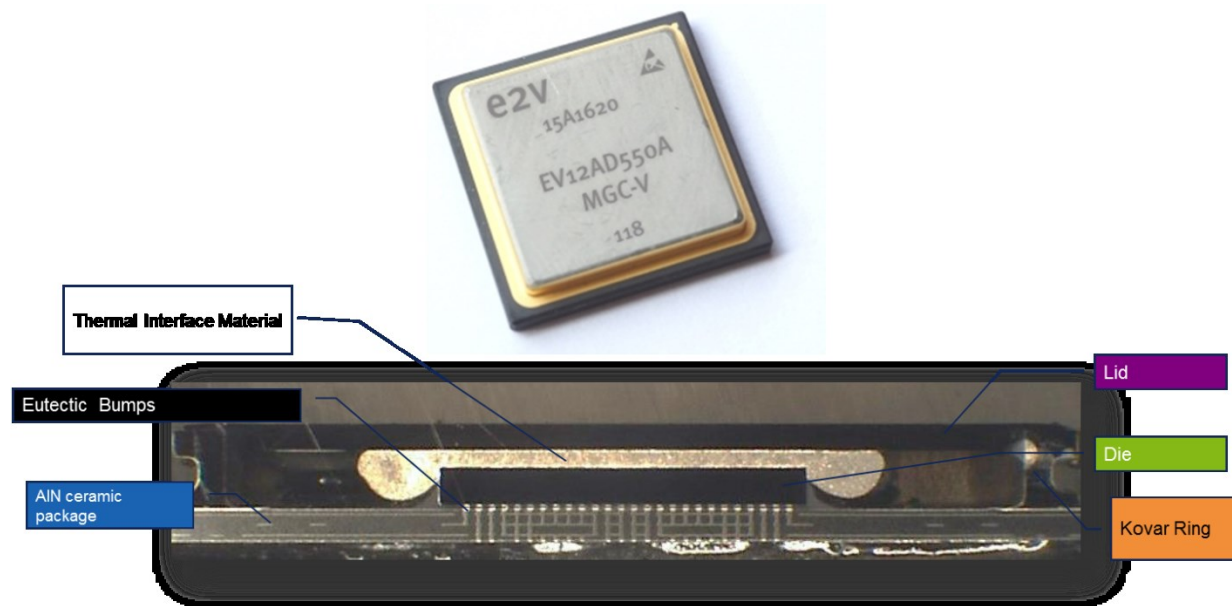


figure 3

Dynamic specifications

Spurious free dynamic range (SFDR) measures ADC dynamic performance by quantifying the maximum difference between an applied, pure, single frequency test tone and any sample spurs that appear in the post sampled frequency spectrum. Spurious signals are highly undesirable as they cannot be distinguished from low level information bearing signals. For the EV12AD550, when measured at worst case -1dBFS (that's 1dB down on full-scale) representing an input signal close to limiting, the first and second Nyquist zone SFDRs come in at a solid -80 dBc and -75 dBc respectively. Likewise, crosstalk between channels, even at 5 GHz is a minimal -80 dB.

So now the market has access to the first practical space grade ADC capable of directly sampling an S-band signal without extra down mixers. A single UWB device can now perform the role of multiple baseband converters, reducing overall payload cost and simplifying system design.

Steering RF signal beams

Electronic beam steering is a highly desirable satellite function as it allows for dynamic signal footprint changes as well as enabling frequency re-use across spot beams. Applying phased array techniques, it's possible to steer an RF beam from a series of fixed, multi-radiator antenna. In this way, operators gain more operational flexibility.

The most important design constraint when steering beams is understanding that phase (or time) difference between signals feeding multiple radiators establishes beam direction. Therefore, precise

time synchronization within the steering system is a must. That's not so easy to implement at gigahertz frequencies - even tiny phase differences affect performance. Here's where the EV12AD550 helps simplify system design.

A unique on-chip synchronization system has been designed to allow daisy chaining of multiple EV12AD550s to precisely manage sample timing offsets. Setting up the correct chained timing requires that three ADC timing functions be set via the SPI control interface:

- **Flagx** – indicates that the SYNC clock is in a meta-stable zone relative to the current sample clock
- **Edge_Selx** – selects which sample clock edge the SYNC pulse is locked to
- **Shift_Selx** – selects the integer number of clock pulse delays added to the SYNC pulse for each convertor in the daisy chain to deliver the required phased array timing

Once a 'phased' design has been prototyped, it is possible to calibrate system timing through a training sequence to ensure precise delay timing and repeatability. Figure 4 shows how three ADCs are connected to use the daisy chain control feature.

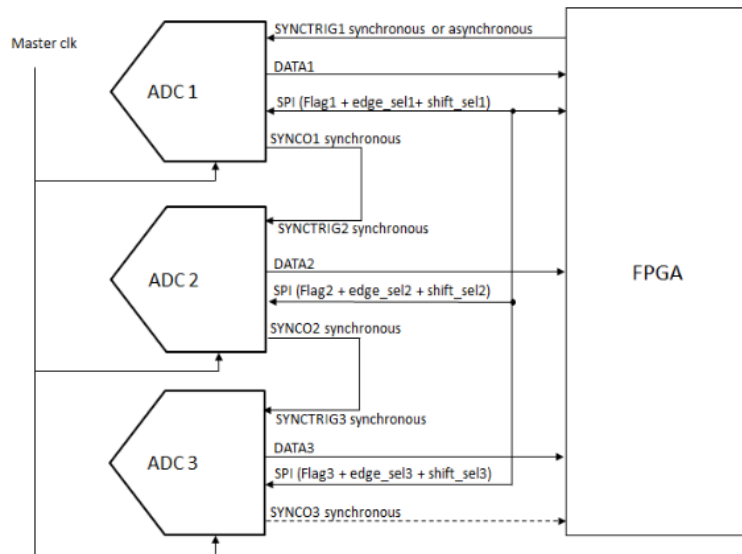


figure 4

Provisioning Agile payloads just got a lot easier

With the clever application of innovations, semiconductor suppliers continue impacting system design choices. A steady focus on UWB data conversion (both in ADCs and DACs) that eschews some historic approaches has recently lead e2v to make some major performance breakthroughs.

Increasingly now, the idea of direct to microwave (DTM) conversion is coming to fruition. Those fast moving suppliers quick to adopt revolutionary UWB convertors could soon be big beneficiaries in the competitive satcoms market. This latest crop of data convertors means that a new payload price point is achievable. Sceptics of the OBP approach may soon find themselves being left behind.