SDR AT ASTRIUM – PART I: MILSATCOM, SPACE AND AVIATION

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ABSTRACT

The Paradigm Modem (PM) is a Secure SDR platform based on the SCA (v2.2) and developed for the UK`s Military Satellite Communication (MILSATCOM) service provision for Skynet 5. The application of derivatives of the PM technology base for MILSATCOM, Space and Aviation is considered in this paper. Some essential background to Astrium and its association with SDR for a period of ten years is given.

In the context of Space-based communications, the optimal and unconnected use of the four principal space orbits is a key motivation; examples of SDR for Space applications are provided. Astrium have been considering the utilisation of their SDR platforms for Airborne communications, specifically for supporting unmanned aerial vehicle (UAV) communications; an example of the application of SDR for Aviation is provided.

SDR`s flexibility at tactical communications optimised to scenario and channel conditions can be extended further to facilitate the efficient use of hybrid SATCOM Orbits, Services and Applications. In the longer term, SDR will enable SATCOM evolution to the future vision of Network Enabled Capability (NEC) Nodes.

KEYWORDS

Space, Airborne, UAV Communications, Waveforms, SDR, SCA, Communications System Design.

1. INTRODUCTION

This paper forms Part I of a two-part series; Part II provides some details on defence and civil applications [1]. The first European production MILSATCOM SDR system is the PM, which has been developed for the Skynet 5 System to support both UK and NATO armed forces. The PM's infrastructure is built upon SCA (v2.2) and has been augmented with a range of security measures in order to mitigate the security threats envisaged[2].

This paper discusses the application of SDR to space and aviation. SDR in its most basic sense is a reconfigurable platform offering the flexibility to support a wide range of waveforms, thereby enabling (at least in principle) a single platform to support a multitude of different waveforms. There are various issues which need to be resolved in order for this vision of dynamic waveform adaptation to be realised [3][4]. Dynamic waveform adaptation is generally perceived to be governed by an intelligent device such as a Cognitive Radio (CR), dependent upon the specific instantaneous scenario [5][6][7].

The capabilities to route, cross-band and bridge different waveforms are essential for network nodes such as UAVs. Efficient and robust tactical communications will be realised by hybrid multi-mode platform capabilities with in-service up-date features. These features will be essential to the realisation of future ground, airborne and space-borne network communication nodes. This will enable ready separation of system resources dependent upon specific instantaneous scenarios.

1.1 Organisation of the paper

This paper is organised into seven sections with Section 1 being the introduction. Section 2 provides some essential background of SDR and the SCA in the context of Astrium; this includes a brief review spanning ten years. This discussion provides some of the earlier images associated with a demonstrator programme in 1997 and one from 2000. Section 3 describes some high-level aspects of Astrium`s current suite of modems, which includes identification of the benefits of using SDR principles, in the context of platform diversification. Section 4 considers the issue of platform reconfigurability.

Section 5 addresses how these benefits can be best utilised for space applications; the scope for improvements are motivated by the need for improved communications given the various different satellite orbits, and associated features. The use of SDR for airborne applications is considered in Section 6, where aspects of waveform processing are separated and explored based on issues which Astrium have considered for suitability of their platform for airborne applications. Finally, Section 7 provides a summary of this paper.

2. ASTRIUM: A VERY BRIEF BACKGROUND

Astrium and their subsidiaries have been involved in MILSATCOM Research and Development (R&D)

programmes for a long time. In the time since 1997, some of the Astrium R&D activities in the SATCOM modem arena have been exploring software-driven radio principles. Some of the drivers for these programmes were to meet specific communications system objectives whereas others were to explore mechanisms of better utilising the longevity of such systems and assisting in mitigating obsolescence and maintainability issues. These aspects were being explored at a time prior to either the formal definitions (in the public domain) of either the SCA or the SDR.

This section provides a very brief background to Astrium`s R&D programmes, beginning ten years ago.

2.1 EHF Modem Demonstrator Programme

In 1997, Astrium embarked upon the EHF Modem Demonstrator (EMD) programme, which lasted approximately two years. Some high level features are provided in the following:

- Data Flow Architecture designed for COTS Multi-Processor DSP Boards
- Card level solution using standard bus and form-factor (6U x 160 VME)
- Custom cards where necessary but no ASIC's in bespoke designs
- Mix of COTS Technologies: ASSP, FPGA, DSP and GPP
- Flexible partitioning and overlapping of functions implemented in
    - ASSP, FPGA, DSP and GPP
- Dynamic hop by hop control of TX and RX pre-processing and processing functions in ASSP and FPGA.

Figure 1 provides an illustration of the system architecture for the EMD demonstrator programme, circa 1997 – 1999.

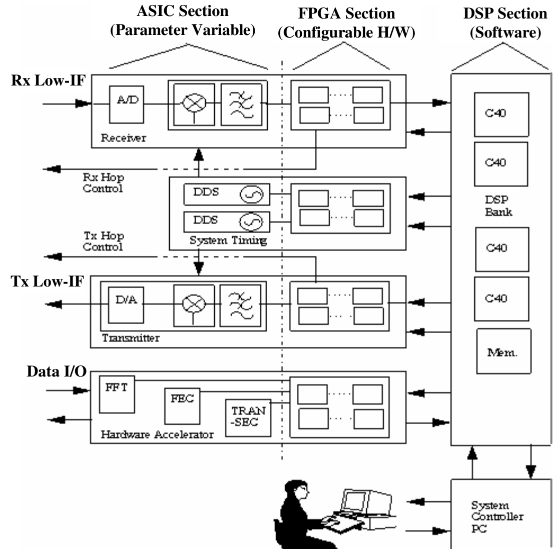

Figure 1: EMD Architecture c. 1997-1999

2.2 Astrium`s Second Demonstrator Programme

With the industry-wide adoption of SCA and SDR, Astrium sought to re-align its own architecture and mechanisms to those of the SCA (in practice Astrium were not too dissimilar although the terminology used did differ considerably). Figure 2 provides an illustration of the second demonstrator featuring SCA 2.0.

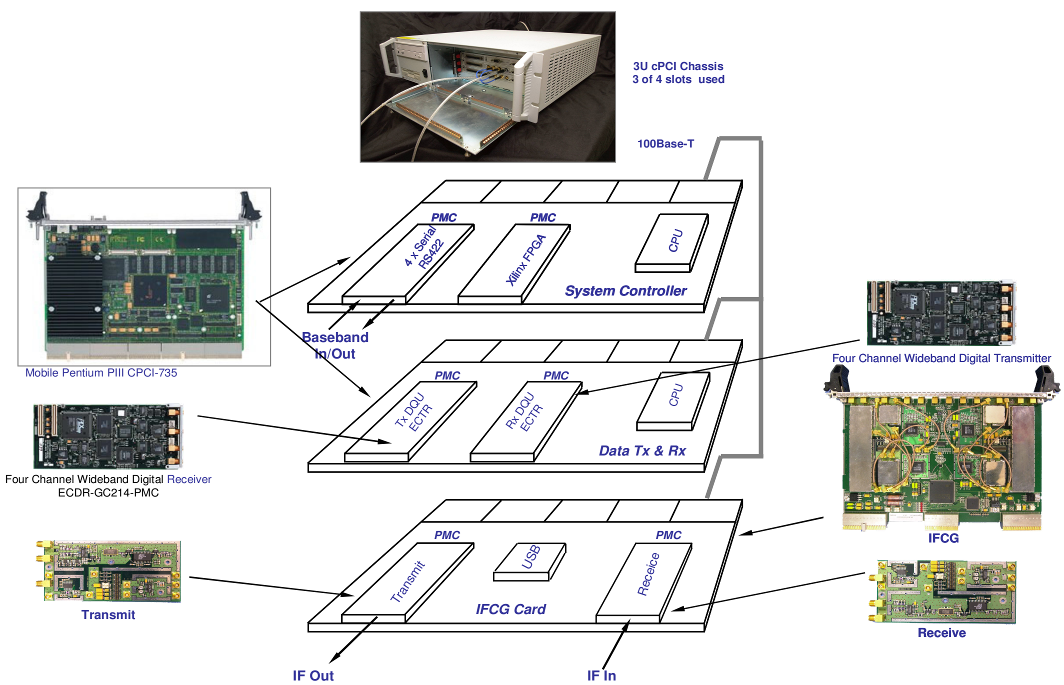

Figure 2: Second Astrium SDR Demonstrator: Alpha 1 (2001-2)

2.3 Demonstrator Programme Epochs

On average every two or three years Astrium has made significant advances. Astrium`s SDR R&D timeline is provided in Table 1.

Epoch	Description
1997 -1999	EMD H/W: ASSP, FPGA, DSP, GPP, VME bus S/W: UML model, CORBA, ADA95, C (DSP).
2000 -2001	PM Proof of Concept (POC); H/W: as EMD; S/W: Early PMPW waveform implemented in GPP; Demo at JWID 2001.
2002 -2003	PM Alpha 1 SCA 2.0 demonstrator; H/W: ASSP, GPP, cPCI bus; S/W: UML model, CORBA, JAVA, C (device driver)
2004 -2006	PM Alpha 2 SCA 2.2 programme / LC1000; H/W: FPGA, GPP, cPCI bus; S/W: UML model, CORBA, JAVA, C++, C (dev d.)
2007	First production MILSATCOM SDR based Modem in operation.

Table 1: Principal R&D Epochs

3. ASTRIUM`S SDR PLATFORMS

The PM is the UK MILSATCOM modem specifically developed for the UK Ministry of Defence (MoD) which contains provision for both communications security (COMSEC) and transmission security (TRANSEC). As a consequence of the SDR principles employed within the PM, Astrium have been able to make significant reuse (with adaptations to remove security sensitive aspects) of the PM technology to yield several COTS platforms. The current suite of SDR platforms includes the LC1000 and Proteus.

3.1 The Paradigm Modem (PM)

This modem features both high data rate waveforms (up to 8 Mbps) and highly resilient waveforms featuring varying grades of robustness and correspondingly differing levels of throughput.

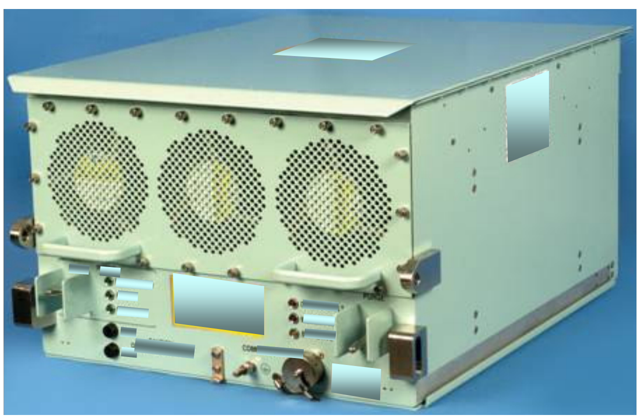

Figure 3: The Paradigm Modem (PM) – UK National Secure SDR System

3.2 LC1000

The LC1000 is the first low-cost EADS COTS SDR, and the LC1000 shares some H/W common to the Paradigm modem. The LC1000 is an ideal platform for third party waveform development.

Figure 4: The LC1000 Modem – Astrium`s Low Cost COTS SDR Platform

3.3 Proteus

Proteus is the other current EADS COTS SDR Platform – the highest specification variant of the LC1000.

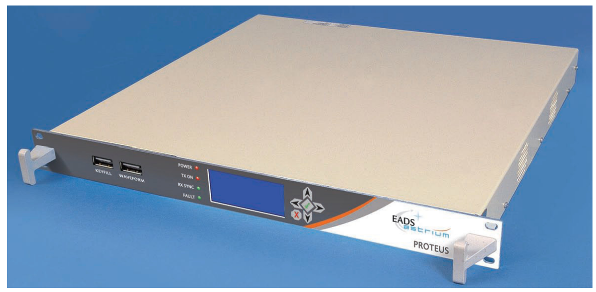

Figure 5: The Proteus Modem – Astrium`s Higher Functional COTS SDR Platform

The PM contains an architecture which provisions resilient communications through the use of orthogonal frequency hopping (FH) in circumstances where interference or jamming may be applied to the waveform. For non-hostile communications, the FH component of the waveform is not necessary, nor the associated orthogonalisation structure, which thereby reduces the overhead of the communication signal effectively increasing throughput.

An example of a module which is common among various Astrium SDR COTS platforms is the burst mode processor (BMP) node. The BMP node is situated towards the RF front end of the SDR platforms; Figure 3 provides a CE diagram description of the devices on the BMP node [8].

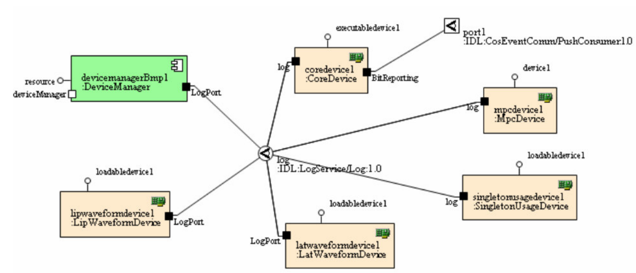

Figure 6: CE diagram describes the devices on the BMP node

4. PROVISIONING RECONFIGURABILITY

All of Astrium's SDR modems provide reconfigurability features to allow multiple waveforms to be supported by the platform. The notion of platform reconfigurability is shown in Figure 7 featuring one of Astrium`s SDR platforms.

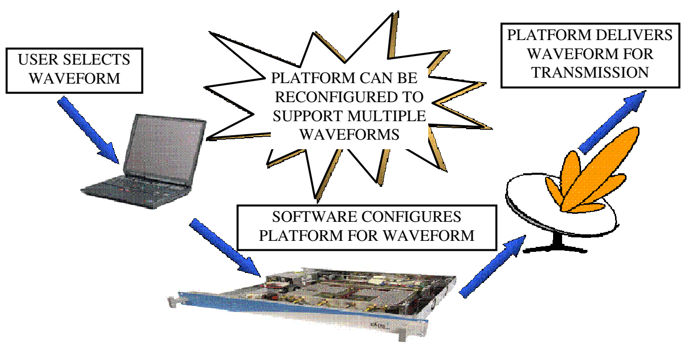

Figure 7: Illustrating Platform Reconfigurability

4.1 Flexibility Offered by both LC1000 and Proteus

The software-defined radio (SDR) nature of both LC1000 and Proteus implies:

- Expedient waveform development
- Optimal assessment and testing
- The system offers the flexibility to modify waveform parameters in terms of:
  - Physical layer (including modulation, error control coding)
  - Link and Network layers
  - Augmentation and Integration of the platform into a network is possible due the LC1000 and Proteus being SDRs.

5. SATELLITE COMMUNICATION

5.1 ORBITS: THE ESSENTIALS

Satellite communications utilise a variety of different orbits including the geostationary satellite, the quasi-zenith satellite, or the non-geostationary satellite. Typical communications applications use one or more of the following orbits [9][10]:

- Geo-synchronous earth orbit (GEO)
- Highly-elliptic earth orbit (HEO)
- Medium earth orbit (MEO)
- Low earth orbit (LEO).

Each of these orbits offers a range of different properties (e.g. coverage, path-loss) and they each have a specifically defined set of applications. Each of these features are briefly described in the following.

Traditionally, the different orbits are associated with different waveforms and payload architectures which are fixed to defined semi-static scenarios. This represents inefficient diversity in satellite system design and realisation. Some of the essential features for the different orbit types are presented in Table 2.

A key feature regarding a GEO satellite, compared to the other three types is that typically it is the largest and can carry the most complex payload. The essential feature of HEO satellite orbits is that it provides high latitude coverage; and an essential feature about LEO and MEO satellite orbits is that, due to the reduced range, the path-loss is significantly less than that of a GEO or HEO, however, this is at the expense of a need for a much greater number of satellites, as well as a need to cope with enhanced Doppler shift.

In addition, it is important to note that the different orbits provide different radiation environments to be tolerated by the space craft and payloads.

Orbit	Approximate Altitude (km)	Orbit Duration (Hours)	Typical Number of Satellites	*Typical Life span*	*Feature*	*Usage*
GEO	36,000	24	3-4	*> 15 years*	High Availability comms	Comms, meteorology
HEO	36,000 – 50,000	12-24	2-4	*2- 7 years*	High Latitude comms	Comms, surveillance
MEO	Several Thousand to 20,000; typical 10,000	5-12	Few - 10s	*5 – 10 years*	Global coverage & high visibility	Comms & Navigation
LEO	500 to Several Thousand; typical 1,000	1-2	Few - 100s	2 – 5 years	Global coverage, high visibility, low loss, low latency	Comms, surveillance & Science

Table 2: Essential features for the different orbit types

5.2 **SERVICES AND APPLICATIONS**

Satellite communications technology has expanded significantly over the course of the past twenty years, broadly in parallel to developments within the commercial wireless arena. Satellite communications technology has become instrumental to the provisioning of a broad range of services including:

- Communications
- Navigation
- Safety-of-life (SoL) and disaster recovery
- Intelligence, Surveillance Target Acquisition and Reconnaissance (ISTAR).

The advances in satellite communications technology have similarly enhanced services with the provisioning of substantially robust capability well beyond the classic backhaul capability, which include:

- Tactical local area networks - Provides a network infrastructure between various types of users
- World-wide information grid – Provides a capability for Internet Protocol Routing for a range of information classification.

5.3 SATCOM EVOLUTION AND FUTURE VISION

The design drivers for SATCOM are constantly evolving, commensurate with the pace of technological change. A key driver today is SDR. In the following, three sets of key points are presented, in order to gain a snap-shot of how the design drivers for SATCOM have evolved. Classical SATCOM usage (up to early 1990s):

- Transparent SATCOM
- Monolithic ground segment
- One modem type carrying one waveform type
- Separate modems to support CDMA, FHSS and FDMA
- Stream orientated communications.

Current SATCOM usage:

- Part of early Network Centric Warfare (NCW) vision
- Ground-segment SDR is available
- Potential for a new suite of waveforms
- Transponder architecture is fixed for the satellite lifetime
- One modem type supports multiple waveforms
- Waveforms can be adapted and new waveforms added over system lifetime.

Possible features of future SATCOM usage:

- More flexible/ adaptive digital transparent transponders
- Some degree of regenerative communications for special users
- On-board spectral monitoring
- On-board geolocation support.

The transparent payload architectures have been favoured for several decades (except for exceptional circumstances) due to the inflexible nature and design difficulties of regenerative architectures in space. The adoption of SDR principles in the spacecraft payload design may allow these issues to be addressed and the wider adoption of regenerative payloads for future communications satellites (Military and Civil).

The technology to overcome this major impediment is now beginning to emerge in research demonstrators [11]. Over the last five years, spaceborne digital processing (e.g. Inmarsat IV) has facilitated more complex and flexible transparent processing but principally realised in configurable application specific integrated circuits (ASICs); the functionality of the current generation of payloads is digital radio with only some elements of software reconfigurability to support some degree of flexible channelisation and coverage.

To realise this move from rear-haul to tactical internet, greater focus has been paid to the ground segment, where SDR is the key technology to enable the integration of a diverse range of IF and base-band equipments. SDR is a stepping stone between legacy systems and a future Network Enabled Communications (NEC) node; the figure below illustrates this concept.

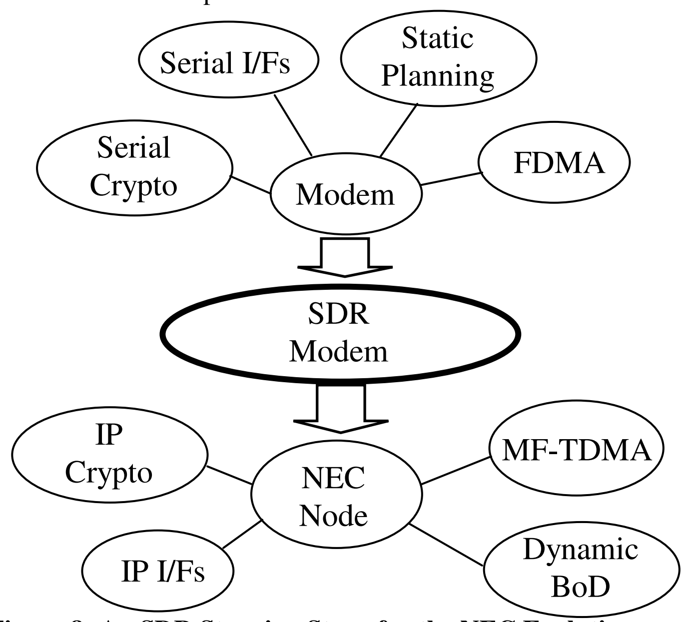

Figure 8: An SDR Stepping Stone for the NEC Evolution

6. EXAMPLE AIRBORNE APPLICATION

Some examples of communication system modifications and how the use of an SDR has supported these changes are provided in the following. Figure 9 provides an `in-side view` of the key functionality which requires modification in the context of a communication link to enable highly flexible communications.

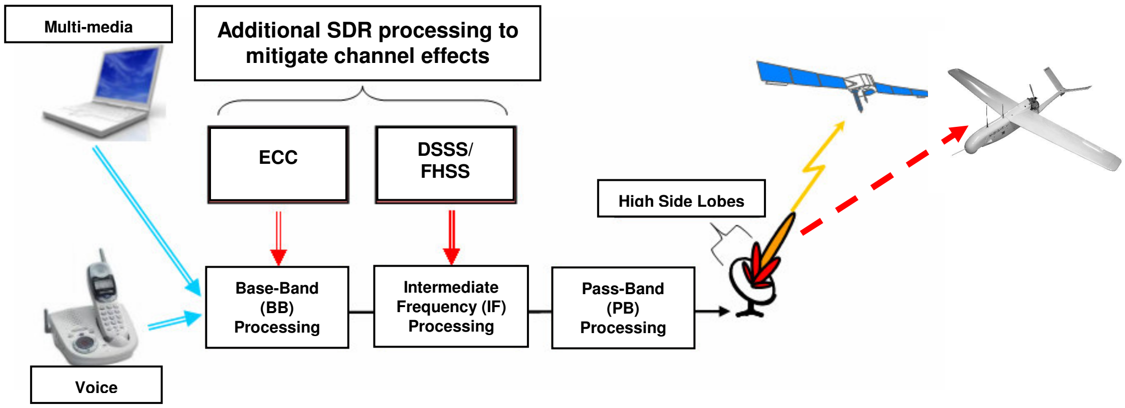

Figure 9: Airborne Forward Link Featuring SDR Augmentation to Control Various Channel Conditions

Astrium have been considering the use of Spread Spectrum (SS) techniques within one of the SDR platforms for both of these two issues:

- Mitigating high antenna side lobes
- Mitigating issues related to airborne communications.

The SDR processing at base-band and at the intermediate stage are illustrated within Figure 9; this includes Error Control Coding (ECC) and variants of SS techniques [12][13]. Multiple waveforms could then be supported which would allow the aircraft to switch from ITU compliant waveforms whilst flying over highly populated areas to higher capacity ones when the flight allows it. PFD (power flux density) is key to aircraft communications. Adjacent satellite and adjacent channel interference are major concerns. SDR could allow more dynamic use of a suite of optimal waveforms to meet the instantaneous flight characteristics instead of living with the compromise scenarios which currently exist.

7. SUMMARY

Some of the issues with SDR for SATCOM have been considered. Applying SDR in this application is particularly relevant due to the number of years that SATCOM systems are expected to provide service. SDR allows system modifications to incorporate new waveforms. This specific reason has been instrumental to Astrium`s ten-year history with SDR.

Some of the principal R&D demonstrator programmes at Astrium have been described in this paper; Astrium`s SDR efforts originated largely independently and in parallel with other similar efforts by organisations at the leading edge of this technology.

The flexibility of SDR in terms of platform and waveform adaptation has been described. Astrium has generated a range of COTS SDR platforms derived from the original Secure SDR PM platform. The motivations for SDR in Space include the efficient use of SATCOM Orbits, as well as Services and Applications. This will enable SATCOM evolution to the future vision of NEC Nodes.

8. REFERENCES

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