COGNITIVE ANTENNA RADIO SYSTEMS FOR MOBILE SATELLITE AND MULTIMODAL COMMUNICATIONS

ESA/ESTEC, NOORDWIJK, THE NETHERLANDS
3-5 OCTOBER 2012

Norbert Niklasch [1]

[1] IABG mbH, Einsteinstrasse 20, D-85521 Ottobrunn, Germany, Email: niklasch@iabg.de

ABSTRACT

Advancing applications of wireless communications, especially mobile satellite communications require new concepts to cover the needs regarding capacity and increasing data transmission bandwidth.

In this paper the innovative concept of Software Defined Antenna Radio Systems SDARS is introduced.

SDARS combines the signal processing of the antenna radiation characteristic and the signal processing of the so called MODEM functionality in a single platform.

This innovative approach is a way to solve the demanding future communication needs for mobile users. The fundamental concept will be explained with special emphasis on the signal processing architecture.

To verify the applicability of the concept performance characteristics based on simulations and measured results are presented.

1 INTRODUCTION

Looking at the continuous growing application of wireless communication, the need for efficient, compact, configurable, multi-functional, and cost effective user equipment is easily visible.

Especially in the case of autonomous vehicles on ground, in the air or in space broadband data from sensors have to be sent to a processing center or data have to be exchanged between the vehicles. This results in the need to provide high data throughput rates and to operate different types of communication links in parallel at the same time.

Nowadays, it will be necessary to install several independent types of equipment to support this, which adds up to the overall weight, power consumption and cost. Multimodal communication although needed is not supported at all.

In classical approaches Antennas, Transmit-/Receive Systems and MODEMs are treated as separate items. When applying digital signal processing, similar types of algorithms and processing resources are necessary for antenna pattern, as well as for the Tx/Rx System or MODEM signal and data processing.

Taking this into account and to overcome the constraints and limitations inherent with classical user terminal configurations, IABG introduces the concept of Software Defined Antenna Radio Systems (SDARS), which represents the close integration of data, signal, waveform, and beam form processing in the digital domain.

Incorporating high performance parallel signal processing hardware and advanced algorithms, the baseline for the development of unique and innovative equipment, capable of being used in communication as well as in navigation or in any combined application, is formed.

Satellite links as well as links to other aerial vehicles or to the ground can be established based on the same baseline building blocks. Reconfiguration can be done during operation. Based on this set of building blocks different needs or requirements can be addressed by selecting the appropriate configuration.

The frequency sensitive surface, used to form the air interface for the free space wave, is built from so called antenna modules and can be adapted to the surface of the fuselage of the user vehicle as a conformal array installation. Using modules for different frequency bands, different types of services, like communication between vehicles or even navigation, can be supported.

Thanks to digital signal processing it is possible to generate multiple independent steerable beams, thus supporting MIMO techniques to improve the data throughput rate and enhance the availability of a service or to use different services at the same time, like vehicle to vehicle communication and a satellite link, for instance.

Beside classical communication functions, cognitive processing, like spectral monitoring, interference detection and mitigation as well as propagation channel condition adaptive data, waveform and beam form processing, can be applied to improve the overall performance and efficiency.

2 SOFTWARE DEFINED ANTENNA RADIO SYSTEMS

The IABG approach to address the needs for future innovative communication systems is called:

SDARS - Software Defined Antenna Radio Systems

The SDARS is an extension of the well-known SDR Software Defined Radio principle.

IABG applies a similar principle to implement the antenna functionality. The radiation characteristic of the antenna is generated and manipulated by means of digital signal processing. This allows a rich number of new features not available in today‘s antenna systems.

In addition the new SDARS concept introduces the marriage of antenna functionality and radio or modem functionality in one system unit to optimize the overall performance, reduce the required resources and supports the availability of new kind of services.

Following this approach it is possible to extend the Dimensions for Signal Processing and Control:

- Frequency Domain
- Time domain
- Coding/Signal Domain

by one additional domain:

- Space Domain

The actual implementation of this concept is based on a generic signal processing platform shown in Figure 1.

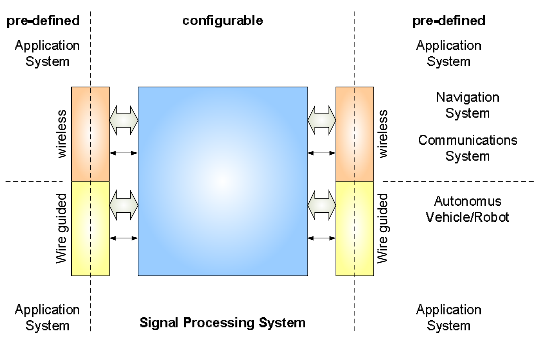

Figure 1. Signal Processing Concept

The kernel functions are implemented in a configurable and scalable signal processing system (HW-Platform), based on an innovative parallel processing architecture accompanied by adapted algorithms.

The application specific functions will be integrated via software modules.

The HW-components being adapted to the embedding system will be implemented at the designated interfaces.

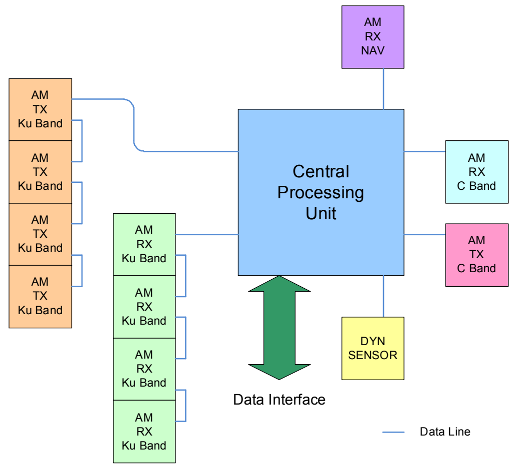

Figure 2. Multifunction Concept

3 BUILDING BLOCK PRINCIPLE

Based on the modular architecture und the implementation of the functionality in software, it becomes possible to realise application specific product solutions from building blocks, available from a hard- and software pool.

This supports a very flexible, customer oriented, and economically efficient approach.

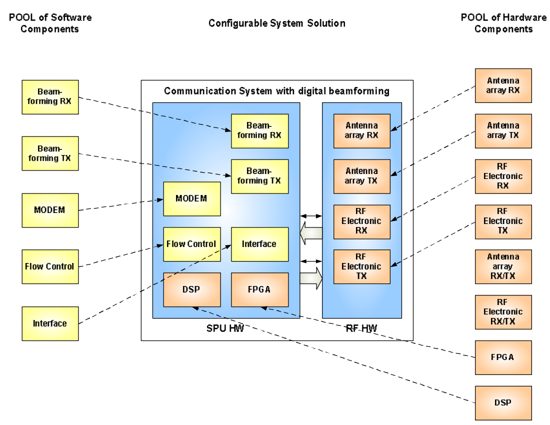

Figure 3. Building Block Concept

Further, the modular concept allows the arrangement of the final antenna array as required by the specific application. Large arrays can be built by combining sets of modules (Figure 4). Tilted modules, that support scan angles below the horizon can be placed around the four corners of a rectangle as shown in Figure 5 to cover the entire azimuth scan range. Conformal arrangements are also possible, see Figure 6.

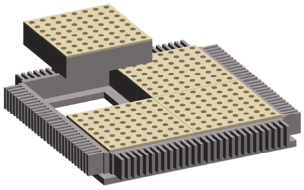

Figure 4. Large Arrays build from Modules

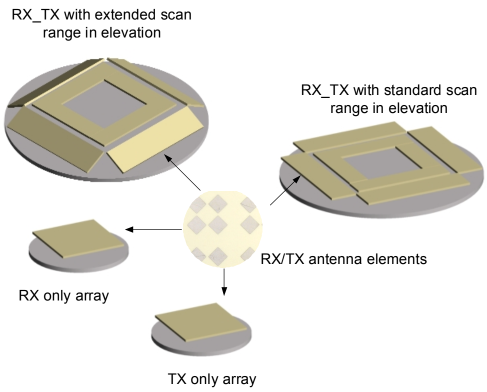

Figure 5. Arrangement of Antenna Modules for different Applications

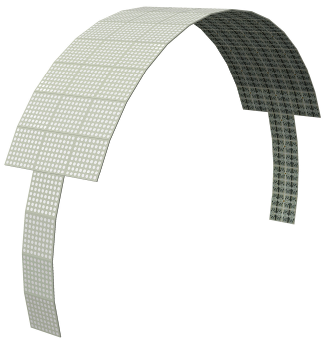

Figure 6. Conformal Arrangement of Antenna Modules

4 PROCESSOR ARCHITECTURE

To support high data throughput and multifunctional processing a highly parallel processing structure needs to be implemented for the digital signal processing functions. For the realisation of the SDARS concept a modified systolic array processing structure is envisaged.

In Figure 7 the general processing flow for a set of SDARS functions is presented.

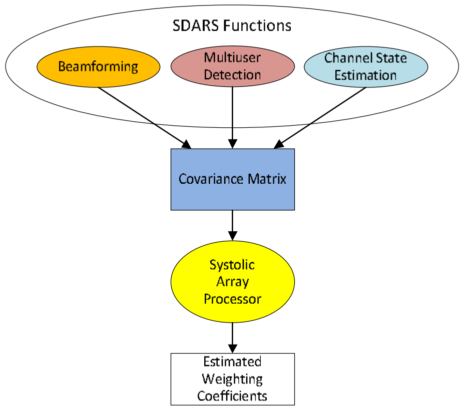

Figure 7. SDARS utilizing Systolic Array Processor

The application of a systolic array is a powerful method to support parallel processing of matrix type calculations. The systolic array is built up from basic processing elements shown in Figure 8. Each element performs a dedicated function and communicates with the neighbouring elements, keeping data transfer rates and throughput high.

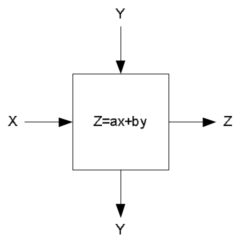

Figure 8. Systolic Array Processing Element [2]

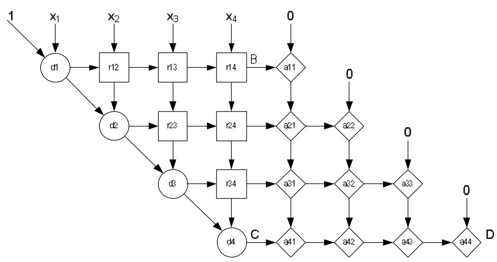

Figure 9. Principle of Systolic Array Processing [2]

In Figure 9 the arrangement of the basic processing elements to form the systolic processing array is shown.

As an example the implementation of an IIR Filter in a systolic array processor is shown in Figure 10. To derive the setup, first a signal flow diagram has to be generated and repeating identical processing structures have to be identified. These substructures are then allocated to the processing elements in the systolic array (Figure 11).

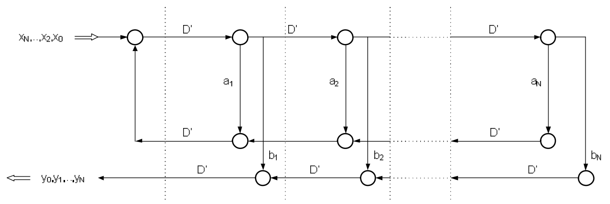

Figure 10. Signal Flow Graph of IIR Filter

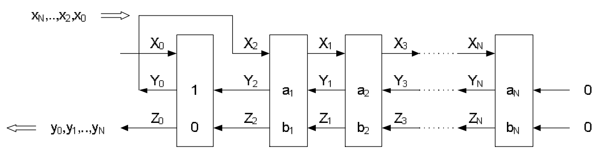

Figure 11. IIR Filter implemented in Systolic Array

The processing structure will be implemented in a FPGA, thus supporting re-configurability.

5 ARRAY AND SUBARRAY PROCESSING

Utilizing the concept of sub-array forming, it is possible to achieve a solution with a reduced number of signal processing channels in the digital proceeding part.

In Figure 12 the radiation patterns at different levels of signal processing are shown. The beige curve shows the radiation pattern of the array at the Module level, the red curve shows the radiation pattern at the sub-array level, and the green curve is the resulting radiation pattern at the final array. The blue curve represents the ETSI reference threshold for side-lobes in satellite communication systems [3],[4].

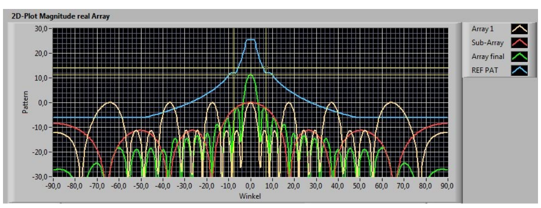

Figure 12. Superposition of Radiation Patterns at 0° Elevation

In Figure 13 the same results are plotted for a scan angle of 45° in elevation.

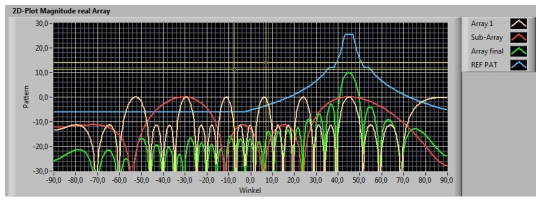

Figure 13. Superposition of Radiation Patterns at 45° Elevation

6 MODULE BUILD-UP AND TEST

To verify the concept described before, Modules in C-band (Figure 14) and Ku-band (Figure 15) have been manufactured and tested regarding the scan behaviour of the generated radiation characteristic.

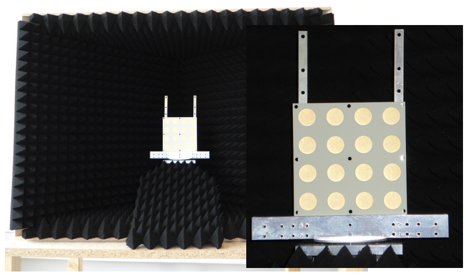

Figure 14. Antenna Module at C-Band

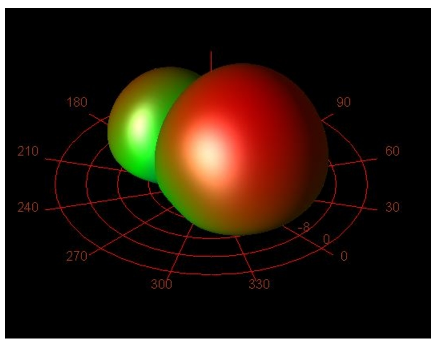

Figure 15. Radiation pattern of a 4x4 Element sub-array

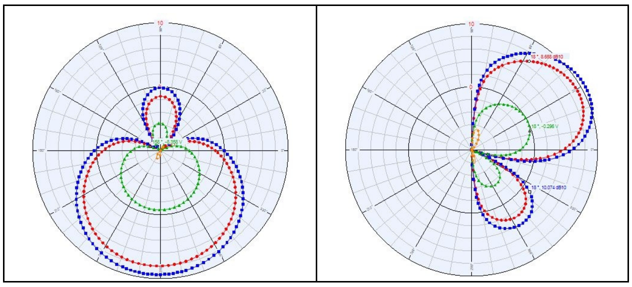

Figure 16. Azimuth and Elevation Cut of a sub-array

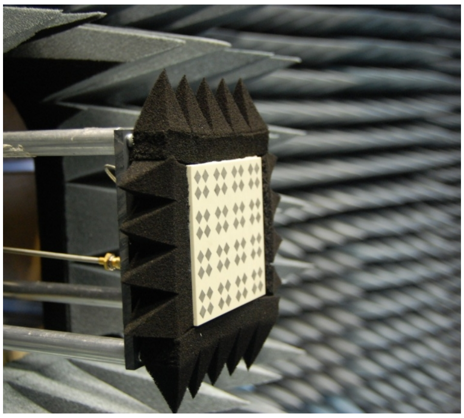

Figure 17. Antenna Module at Ku-Band

Measurement results of the radiation pattern of the Ku-band 8x8 Element Array module are shown in Figure 18 and Figure 19.

Scan angles up to 70° have been successfully measured.

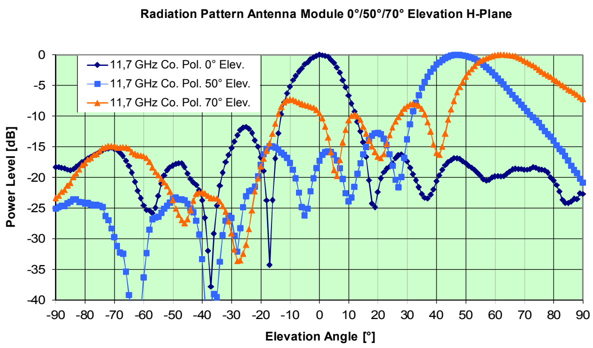

Figure 18. Co.Pol. Radiation Pattern of 8x8 Array Module for different Scan Angles

In satellite communication applications it is necessary to provide a good cross-polarisation discrimination, because different signals will be transmitted on orthogonal polarisations. Therefore notice the high cross-polarisation discrimination of > 35 dB even at 50° scan angle (Figure 19).

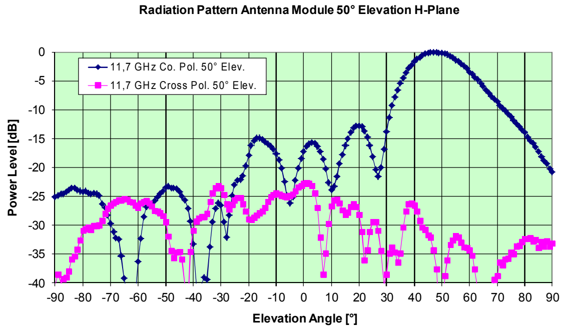

Figure 19. Comparison of Co. Pol. And Cross. Pol. Radiation Pattern of 8x8 Array Module

7 CONCLUSION

An innovative concept for realising Antenna Radio Systems to cope with the future demands from the mobile wireless communication community has been presented.

The advantages to apply the SDARS concept have been pointed out.

The feasibility of realisation has been proven by prototype implementations in C- and Ku-Band and the measurements performed.

Further activities will cover the realisation of larger arrangement of modules and operational tests in mobile satellite link applications.

8 REFERENCES

1. Niklasch, N. (2001). Aktive Antenne für die Multimediakommunikation über Satellit - WP 2500 Beamforming and Beamsteering. *Final Report FKZ 50 YB 0009.*

2. Lattice Semiconductor (2005). A Systolic Array Processor for Software Defined Radio. *Lattice semiconductor White Paper.* 7-14.

3. ETSI ETR 169 (1995). Satellite Earth Stations and Systems (SES); Common Technical Regulations (CTRs) in the satellite earth station equipment field.

4. ETSI TR 102 375 (2005): Satellite Earth Stations and Systems (SES); Guidelines for determining the parts of satellite earth station antenna radiation patterns concerned by the geostationary satellite orbit protection.