MODELLING AND SIMULATION OF RECONFIGURABLE RF-ARCHITECTURES IN MULTIFUNCTION ANTENNA SYSTEMS

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ABSTRACT

This paper describes the function and development of a modelling and simulation tool for highly integrated multifunction antenna systems using reconfigurable RF-architectures. An example of system architecture is given. The main focus of this work is on the RF part of the system. Functional domain analysis, digital signal processing and modulation schemes are here treated only in a simplified manner.

INTRODUCTION

One of the challenges facing the military platforms today is to increase the number of onboard RF functions, including radar, electronic warfare, communication and navigation/positioning, without degrading their stealth capabilities. All these functions are today being performed by separate systems. Microwave-based reconfigurable multifunction systems, in this paper called multifunction antennas (MFA), capable of performing these functions, may become cost-effective alternatives to dedicated systems in the future. If factors such as weight, volume, radar cross section, cooling etc. are considered, then they become even more attractive, especially for small, mobile platforms.

It is important that MFA systems can be modelled in order to assist in choosing suitable architecture and relevant components that would make an acceptable compromise between the requirements imposed by the different functionalities. The simulator under development uses a generic system architecture that can be modified and reconfigured to allow for investigation of different functionalities and performance requirements. Components and blocks can be added or excluded. Once an architecture has been defined, the reconfigurability allows for the same system to perform multiple functions.

MULTIFUNCTION RF-SYSTEMS

An MFA is a wideband (instantaneous and multi-band) active phased array system using a single RF front-end to handle certain functions associated to radar, EW and communication. The system aperture can be of shared-aperture type or consist of several sub-apertures optimised for a specific frequency band or system function. Such a system does not only require a broadband behaviour in terms of apertures, T/R modules, beamforming and beamscanning, it also requires modular and reconfigurable architectures in order to, dynamically, reconfigure the array(s) to the required function(s) and to other parameters such as effective radiated power (ERP) and beamshape [1]. Figure 1 and 2 show schematic diagrams of a multifunction active phased array system [2].

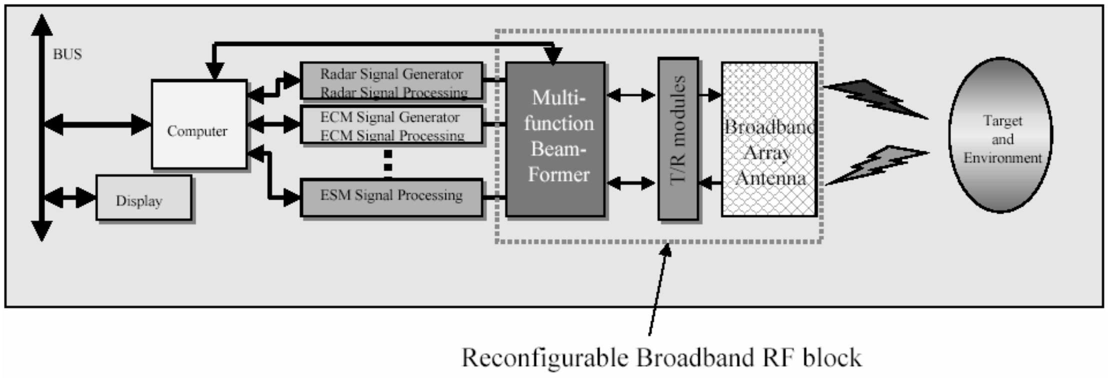

Figure 1. Schematic diagram for a multifunction active phased array system.

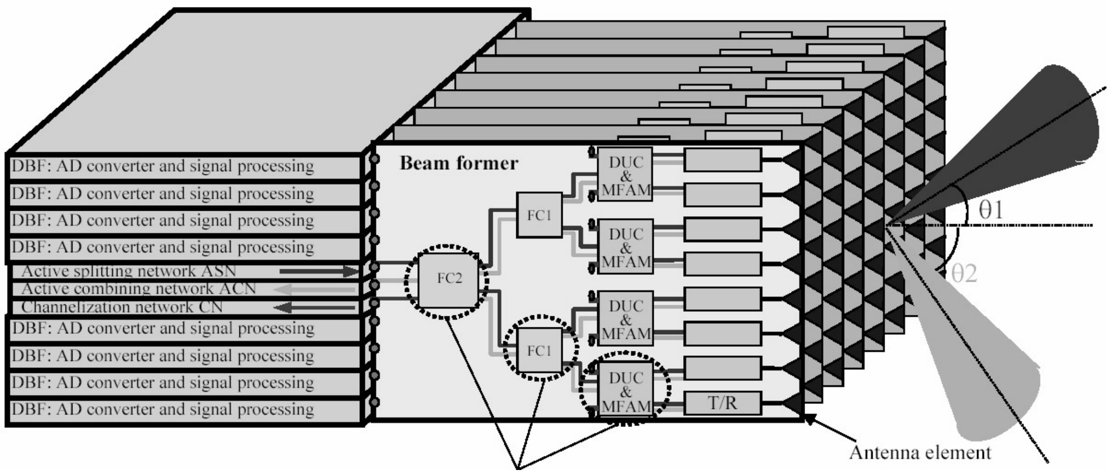

Figure 2. Broadband single RF system for multifunction array antenna

Key blocks such as FC1 and FC2 (active reconfigurable power splitters/combiners), MFAM (multifunction active matrice) and T/R module will have to be further studied and evaluated based on the requirements for a single RF system.

THE MFA SIMULATOR

At the time when this text is written, the simulator is still in development. Version 0, an experiment Matlab program that was built mainly to test ideas and to locate the pitfalls when building a MFA simulator, was developed at FOI in 2002 [3]. Since then, a redesign has been made and coding in C++ has started. The basic structure and some models have been implemented, but much work regarding implementation of the models and the functionality described in this paper is still in the implementation and verification stage.

When the simulator becomes functional it should be possible to use it as a tool for system and technology assessment. The main objective for a simulation is to investigate the performance of an MFA system in a certain scenario with focus on the limitations and conflicts that arises due to the choice of components, the system architecture and the strategy for resource management.

The scenarios in mind are fixed ones with little room for improvisation of the simulation units. The movements and the tasks requested from the MFA-systems should be determined before the simulation starts. There is nothing in the simulator design that prevents a higher degree of artificial intelligence or user interaction but we believe that if too many decisions are left to the simulation itself, then it is likely that the simulation outcome will be completely dominated by the decision making algorithms.

The system and scenario to simulate are defined by setup files in xml-format. Platforms are created by stating their type and parameters. Each platform has the possibility to include an MFA-system by specifying which components that are used, how they are interconnected, and by providing fine resolution schedules of how signals are to be processed for specific cases. It is typically done by choosing include files that contain subsystems.

Each system, subsystem or component is modelled by a three-fold representation. It has a hardware description defining characteristic parameters and interconnections. It has a functional description defining its actions in various situations, and it has a signal description that represents the signal state at certain places. It is assumed that the signals propagate without any instantaneous feedback loops, and that scattering due to mismatch can be neglected. If this is true, then the components can be treated as transfer functions from input to output as indicated by arrows in figure 3. It also becomes possible to use buffer stages to schedule the computations in an efficient way. If feedback loops or scattering are important, then they must be handled by component models that capture that feature internally.

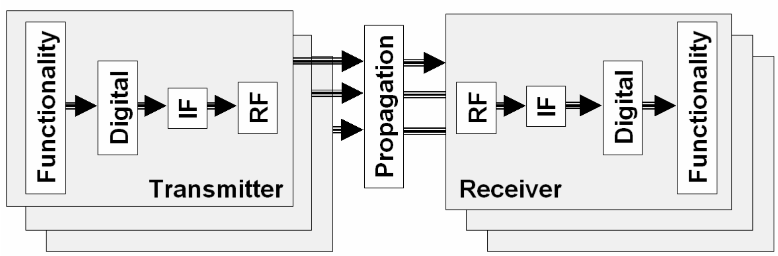

Figure 3. signal propagation model. The arrows represent hardware models and the rectangles represent signal instances. It is assumed that the signal at the output of a component can be computed as a function of the signals at the input side.

MODELLING OF T/R-MODULE RF-ARCHITECHTURES

In the simulator described above, models of the RF circuits and subsystems are necessary. All the included components can be described as either 2- or 3-port circuits. The 3-port circuits are mixers, power splitters/combiners and RF-switches. The interface to the digital domain is the A/D-converter (ADC). For both the transmit and receive mode, the system can be described as a cascaded chain of 2-port circuits. As a first approximation the 3-port circuits described above can be considered as 2-ports with one port terminated to the system impedance. In figure 4 an example of the receive mode is shown.

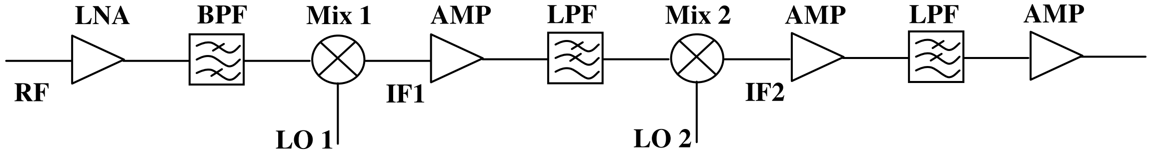

Figure 4. Receiver mode component chain.

This is to be considered as an example since the simulator would allow the user to modify or change the system before use. Using this description together with describing parameters for each circuit allows for a calculation of the total system performance. The parameters are noise figure (NF), gain/loss (G) and third order intercept point referred to input (I3i). For linear behaviour the corresponding s-parameters could be used as well. Spectral demands for the system are set by the selectivity of the filters and mixers and are included in the bandwidth definition for each component. The ADC is modelled using number of bits (n), least significant bit (LSB) and sampling frequency (fs). Each signal handled by the system is characterised by a signal bandwidth (fm). This system description has the advantage of being flexible and easy to modify. The disadvantage is that it does not cover all the aspects of the circuits involved. In most cases however, the description is sufficient to extract necessary system information for digital signal treatment and translation to functional performance. In table 1, typical system parameters for the components in figure 4 are shown.

Rx - Noise & Dynamic			
Rx Noise figure		**NF**	**3 dB**
Rx Gain		**G**	**40 dB**
Rx 3:e order intercept point reffered to input		**I3i**	**0 dBm**
Sampling frequency		**fs**	**500 MHz**
signal bandwidth		**B**	**7,5 MHz**
ADC n:o bits		**n**	**16**
ADC max voltage		**V_max**	**1024 mV**
ADC input impedance		**R**	**50 Ohm**
ADC LSB		**v**	**0,03125 mV**
ADC noise (1.5 LSB)		**Nq1.5**	**-99,59147434 dBm**
ADC quantisation noise (1 LSB)		**Nq1**	**-103,1132995 dBm**
Rx noise power input, over B		**Ni**	**-105,2493874 dBm**
Rx noise power output, over B		**No**	**-62,24938737 dBm**
Noise margin, No/Nq1.5		**Nm1.5**	**37,34208698 dB**
NFtot=NF+Nb/G/Ni			**3,000800821 dB**
Increase of noise figure, (NFtot-NF)			**0,000800821 dB**
Rx SFDR (Spurious Free Dynamic Range), over B		**SFDR_Rx**	**68,16625824 dB**
ADC Dynamic		**DR_ADC**	**98,0905112 dB**
Top margin (DR_ADC-SFR_Rx-Nm)			**-7,417834017 dB**

Table 1. Summary of system parameters for the RF-system shown in fig. 4.

DISCUSSION AND FUTURE WORK

More models have to be implemented and verified in order to proceed with the verification of the simulator. It might be possible to draw some conclusions regarding advantages, compromises and limitations of multifunction systems already at that stage, but then the models should be refined and extended. A good user interface is also needed before the program can come to practical use.

REFERENCES

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