9.5: End-to-End Performance Evaluation Methodology for TWTA-Based Satellite Flexible Payloads

Marinella Aloisio*, Piero Angeletti*, Enrico Colzi*, Salvatore D'Addio*, Roger Oliva Balague*, Enrico Casini**, Francesc Coromina*

*European Space Agency ESA/ESTEC
RF Payload and Systems Division
Keplerlaan 1, 2201 AZ, Noordwijk, The Netherlands
E-mail: Marinella.Aloisio@esa.int,
Piero.Angeletti@esa.int, Enrico.Colzi@esa.int,
sdaddio@esa.int, Roger.Oliva.Balague@esa.int,
Francesc.Coromina@esa.int

**NATO C3 Agency
Transmission and Network Services
Oude Waalsdorperweg 61, 2597 AK, Den Haag, The Netherlands
E-mail: enrico.casini@nc3a.nato.int

Abstract: *Reconfigurability of the RF power among different beams and channels is of primary interest in communications satellite systems for its potentiality in maximizing the payload bandwidth and power utilization over the satellite lifetime. The performance of reconfigurable payloads strictly depends on the architecture of the high-power section. We will compare two multi-amplifier architectures, one based on bias-adjustable Traveling-wave Tubes, the other based on Multiport Amplifiers. These architectures will be traded-off against their performance in terms of power flexibility and overall DC power efficiency by means of a suitable end-to-end figure-of-merit.*

Keywords: Communication satellites; traveling-wave Tube (TWT); flexible traveling-wave tube (flex-TWT); multiport amplifier (MPA); input back-off, linearity; efficiency; optimization.

Introduction

Due to the ever-evolving market requirements throughout a satellite lifetime, future broadband multimedia communication satellites will require highly flexible payloads. In this context, the payload design has to be tailored in order to effectively combine coverage, power and bandwidth flexibility while minimizing the overall DC power consumption and mass, at attractive costs for operators.

Among all the flexibility possibilities, RF power reconfigurability is an effective solution, able to handle traffic unbalances between different beams and their variation over the time. An ideal reconfigurable payload should allow redistributing the available RF power based on the real-time traffic needs. However, the achievement of this objective is strictly dependent on the high-power section architecture and antenna front-end. The desired on-board power flexibility can be obtained by realizing a common power pool from which each channel can adaptively draw the power it requires in a variable and fully reconfigurable manner. Several implementations can be considered depending on the level of integration of the power amplification stage with the beam forming section ([1]-[8]). In particular, we will focus our analysis on two different payload architectures, both based on self standing power sections, i.e., not integrated with the antenna. The first architecture is based Flexible Traveling-wave Tubes (Flex-TWTAs); the second on Multiport Amplifiers (MPAs) [9].

Flex-TWTAs are TWTAs in which the RF output power can be adjusted by an appropriate telecommand, which modifies the amplifier's bias conditions (anode voltage) [1]. Therefore the payload architecture based on Flex-TWTAs is capable of intrinsically realizing the power pooling at the level of satellite platform DC-power capacity. On the other hand, the architecture based on Multiport Amplifiers relies on the parallel amplification of a plurality of input signals by a stack of power amplifiers, usually TWTAs [2]-[4], which are preceded and followed by the input and output microwave networks (INET/ONET). In this case the power pooling is realized at RF power level.

Comparison of payload architectures

We have performed a comprehensive comparison of the two above-mentioned architectural solutions by thoroughly analyzing the payload impairments deriving from the TWTA nonlinearities and the power combining and isolation losses, as well as from the overall DC-RF conversion efficiency. The final objective was to evaluate the minimum DC power consumption capable of still guaranteeing the required quality of the end-to-end communication link. For this purpose it was necessary to properly dimension the entire payload and operate all on-board TWTAs at the optimum condition: the amplifiers saturation power and relevant operating points (i.e., the input back-off [8]) were optimized for the different high-power sections. The comparisons have been performed by means of an in-house ESA-developed software simulator [10], which is able to assess the impact of payload non-ideality on the end-to-end link performance by evaluating the Carrier-to-Interference (C/I) ratio. By means of such a figure-of-merit, the simulator allows estimating the useful signal power as well as the power of every in-band

interfering signal, by cross-correlating the expected signal with the actual received one.

We will show analyses performed with the in-house simulator and present the trade-off between the Flex-TWTA- and MPA-based architectures in terms of power flexibility and overall DC power efficiency, by means of a suitable end-to-end figure-of-merit. In addition, we will compare the two above-mentioned flexible architectures with classical non-flexible ones, in terms of power efficiency. Finally, we will show (Figure 1) and discuss the comparison between the results provided by the C/I figure-of-merit and those obtained with the TD-based optimization methodology, as discussed in [11].

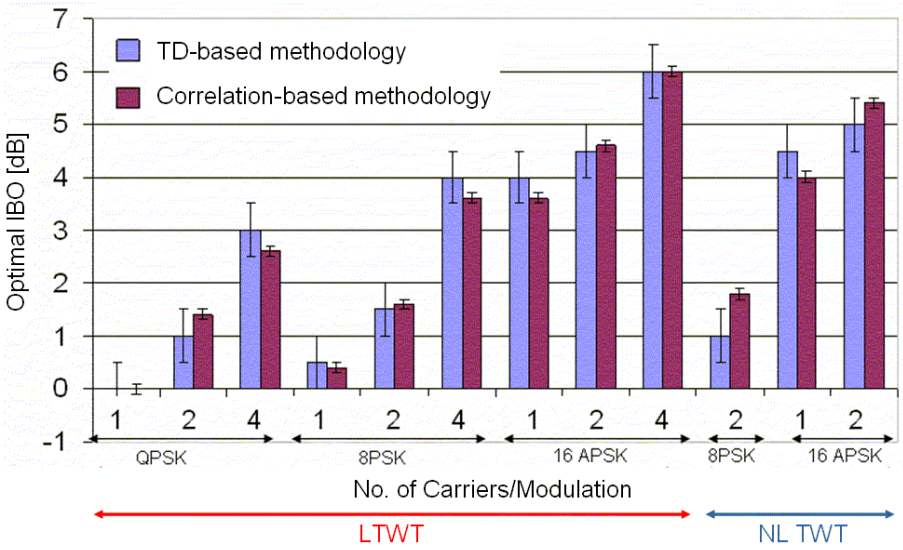


Figure 1. Results of our correlation-based optimization methodology as compared with those obtained with the TD-based methodology [11]. The optimal TWT IBO is obtained for a TWT without linearizer (NL TWT) and for a linearized tube (LTWT), for different modulation schemes and number of carriers.

References

[1] M. Khilla, W. Gross, H. Schreiber, D. Leucht, "Flexible Ka-Band LCAMP for In-Orbit Output Power Adjustable MPM", 23rd AIAA Int. Communications Satellite Systems Conf. (ICSSC), Rome, 2005

[2] W. A. Sandrin, "The Butler Matrix Transponder", COMSAT Technical Review, Vol. 4, No. 2, 1974

[3] S. Egami, M. Kawai, "An Adaptive Multiple Beam System Concept", IEEE Journal on Selected Areas in Communications, Vol. 5, No. 4, pp. 630-636, May 1987

[4] M. Lisi, "An Introduction to Multiport Power Amplifiers", Microwave Engineering Europe, pp. 43-48, Feb. 1992

[5] K. W. Spring, H. J. Moody, Divided LLBFN-HMPA transmitted architecture, US patent No. 4901085, Filed September 1988

[6] A. Roederer, M. Sabbadini, "A Novel Semi-Active Multibeam Antenna Concept", IEEE AP-S International Symposium Digest, pp. 1884-1887, 1990

[7] A. Roederer, "Semi-Active Multimatrix Reflector Antennas", Electromagnetics, Vol. 15, pp. 123-132, 1995

[8] A. Mallet, A. Anakabe, J. Sombrin, R.Rodriguez, "Multiport Amplifier Based Architecture versus Classical Architecture for Space Telecommunication Payloads", IEEE Transactions on Microwave Theory and Techniques, Vol. 54, No. 12, December 2006

[9] M. Aloisio, P. Angeletti, "Multi-Amplifier Architectures for Power Reconfigurability", in Proc. IVEC 2007, pp. 213-214

[10] P. Angeletti, E. Braunschwig, E. Casini, "Co-channel signal power measurement methodology in a communication and payload joint simulator", Proceedings of the 24th AIAA Int. Communications Satellite Systems Conference, (ICSSC), 2006

[11] M. Aloisio, E. Casini, A. Ginesi, "Evolution of Space Traveling-Wave Tube Amplifier Requirements and Specifications for Modern Communication Satellites", IEEE Trans. Electron Devices, Vol. 54, No. 7, July 2007, pp. 1587 – 1596.