



T A R G E T
TOP AMPLIFIER RESEARCH GROUPS
IN A EUROPEAN TEAM

Course description: **Microwave Power Amplifier Linearisation Techniques**

Modules:

1. Overview of Microwave Power Amplifier Linearisation Techniques
2. Circuit Level Microwave Power Amplifier Linearisation
3. Microwave Power Amplifier feedback Linearisation
4. Microwave Power Amplifier feedforward Linearisation
5. Microwave Power Amplifier predistortion Linearisation
6. Other System Level Microwave Power Amplifier Linearisation Techniques
7. Implementation Issues of Microwave Power Amplifier Linearisation Techniques
8. Microwave Power Amplifier Linearisation Evaluation Criteria
9. PA Linearisation in some existing and upcoming Wireless Communication Systems

Audience:

These courses are designed for engineers working with wireless transmitters in system and circuit level design and implementation.

Preliminary Knowledge:

- Microwave power amplifier design and characterisation
- Telecommunication system level engineering



Our presenters:

Paolo Colantonio (Università di Roma, Tor Vergata, Italy)
Massimiliano Rossi (Università di Roma, Tor Vergata, Italy)
Máirtín O'Droma (University of Limerick, Ireland)
Joaquin Portilla (University of the Basque Country, Spain)
F. J. Casas (University of the Basque Country, Spain)
Michael Gadringer (Technische Universität, Wien, Austria)
Maurizio Pagani (CORITEL, Consorzio di Ricerca sulle Telecomunicazioni, Italy)
Andrea Meazza (CORITEL, Consorzio di Ricerca sulle Telecomunicazioni, Italy)
Anding Zhu (University College Dublin, Ireland)
Morten Olavsbraten (Norwegian University of Science and Technology, Norway)
Pere L. Gilabert (Universitat Politècnica de Catalunya, Spain)
Eduardo Bertran (Universitat Politècnica de Catalunya, Spain)
Simona Donati Guerrieri (Politecnico di Torino, Italy)
Gabriel Montoro (Universitat Politècnica de Catalunya, Spain)
Alberto Cesari (CNRS - Centre National de la Recherche Scientifique, LAAS, France)
Juan-Mari Collantes (University of the Basque Country, Spain)
Jordi Berenguer (Universitat Politècnica de Catalunya, Spain)
Marco Pirola (Politecnico di Torino, Italy)
Yiming Lei (University of Limerick, Ireland)
Martin Rupp (Technische Universität Wien, Austria)

Module 1 - Overview of microwave power amplifier linearisation techniques

Overview of microwave power amplifier (PA) linearisation techniques covering a selection of the following: PA non linear phenomena; efficiency-linearity tradeoff; distortion measurements; behavioural models; polar, Cartesian, Saleh, memory & memoryless polynomial models; Volterra Series; Hammerstein; separable kernel; Wiener; Parallel Wiener System; classification of linearisation techniques into circuit & system level, active and passive, adaptive and non-adaptive; digital and analog; BB, IF and RF; and overview of a range of schemes from each.

Presenters: P. Colantonio
M. O'Droma
M. Rossi
E. Bertran
A. Zhu
Duration: 3 hours

Module 2 – Circuit level microwave power amplifier linearization

Major circuit-level linearisation techniques: Harmonic terminations including Harmonic injection, Harmonic terminations, Harmonic feedback, harmonic feedforward and harmonic predistortion; Derivative Superposition and Transconductance Compensation; Dynamic Power Supply Approaches, Active Bias; Thermal compensation; Circuit-level predistortion; Circuit-level feedback; MM-wave linearity considerations.

Presenters: J. Portilla
A. Zhu
S. Donati Guerrieri
M. Olavsbraten
F. J. Casas
Duration: 3 to 8 hours

Module 3 - Microwave power amplifier feedback linearisation

Applied to PA linearisation feedback brings classic advantages of dynamic adaptable control theory to bear on the nonlinear distortion problem. However stability, robustness, bandwidth introduce constraints. This module will cover aspects from feedback fundamentals through to stabilisation, bandwidth modification, precision, sensitivity, control of noise, feedback disturbance effects, limitations, feedback amplifiers, stability issues, and implementation issues. Passive and active RF feedback, difference frequency & distortion feedback, Cartesian compensation, AM and error envelope feedback. Polar & Cartesian loop. Robust design issues. Adaptivity feedback signals. Introduction of modern control principles, H-infinity, & hyperstable.

Presenters: E. Bertran
M. Rossi
G. Montoro
J.M. Collantes
Duration: 3 to 8 hours

Module 4 – Microwave power amplifier feedforward linearisation

Feedforward (FF) is a classic wideband linearisation scheme for microwave and mm-wave PAs. This module will cover fundamental principles of FF linearisers through to issues such as effects of imbalances and imperfect cancellation; effects of imbalances on PAE; effects of loops maladjustments and delays at low wavelengths; error amplifier issues; stability; non-adaptive & adaptive loop controller; additional loops; optimising algorithms; mathematical modelling; FF combined with other linearisation techniques (feedback; predistortion both analog and digital); additional signal insertion schemes; ISM-Band & CDMA examples.

Presenters: M. Gadringer
E. Bertran
G. Montoro
P. L. Gilabert

Duration: 2 to 8 hours

Module 5 – Microwave power amplifier predistortion linearisation

Predistortion linearisation is today attracting much attention, both because of the wide range of schemes, the wide bandwidth, and potentially good stability. This module will examine various principles and schemes, including covering fundamentals; classifications; comparisons; analog & digital, adaptive & nonadaptive, BB, IF & RF, circuit and system level, etc. A selection of issues such as the following will be treated: polynomial (cubic) passive RF predistortion; gain expansion; gain and phase mismatch effects; alternative configurations; complex techniques; IF & RF circuit approaches including series diode, varactor diode, and antiparallel diodes. Active RF predistorters including using second order harmonics, 3rd & 5th order IMD products; MMIC implementation; Envelop RF predistorters; LUT & LOPA work functions. Digital baseband schemes; adaptive; direct and indirect learning architectures; LUT; function based; modelling approaches; Volterra, Wiener and Chebyshev series; hardware considerations.

Presenters: S. Donati Guerrieri
A. Zhu,
J. Portilla
P. L. Gilabert

Duration: 3 to 8 hours

Module 6 – Other system level microwave power amplifier linearisation techniques

Various other linearisation techniques or related issues: Kahn's envelope Elimination and Restoration principle, realisation using digital signal processing, delay distortion, bandwidth distortion, carrier feed through and its compensation. PAE. EE&R combined with AM-AM and AM-PM predistortion concept. Drain modulation. Doherty amplifiers: classical approach and alternative approach including load-pulling effect, mathematical analysis, maximum power, transducer gain, and efficiency.

Presenters: M. O'Droma
E. Bertran
P. L. Gilabert

Duration: 2 hours

Module 7 – Implementation issues of microwave power amplifier linearisation techniques

RF and IF device technology including in Cartesian feedback, polar loop, multiplicative feedback, I-Q demodulator: gain and phase adjustments, and nonlinearities, propagation delays, carrier phase shift, Gain-bandwidth products, four-quadrant multipliers; feedforward schemes – amplifiers, passive signal combiners/splitters, adjustable attenuators & phase shifters, delay and dispersion compensation networks. Properties of RF & IF devices: scattering matrix, effects of impedance mismatch, GT, GP, & GA gain definitions, linearity of RF and microwave devices, thermal noise. Technology issues: filtering, passive signal combiners/splitters, three port devices, four-port devices, adjustable attenuators and phase shifters. Delay lines and dispersion compensation networks. Mixers. MMIC implementation including cost, size, weight, complexity issues. Implementation methodology. MMIC technology issues – active and passive circuits review.

Baseband device technology – digital predistorter: components, implementation aspects related to IF & RF system behaviour. Distortion. Spurious outputs. Phase noise and frequency stability. ADC and DAC circuits. Sampling issues, clock jitter. Quantisation noise issues. Quantisation in table address calculations and in LUT. Distortion output quantisation. Stability and spurious oscillation issues including overview, stability in combined PAs, complex circuit stability, modal theor and advanced modal analysis. Combiners and dividers including Wilkinson, and Lange.

Presenters: M. Olavsbraten
 M. Pirola
 G. Montoro
 E. Bertran
 S. Donati Guerrieri
 J. Berenguer

Duration: 3 hours

Module 8 – Microwave power amplifier linearisation evaluation criteria

Evaluation criteria and standards. Review of typical relevant wireless communication system specifications. Common non-linearity measures including 1dB compression point; 2nd, 3rd order intercept points; harmonic distortion; intermodulation distortion; AM-AM & AM-PM Conversion Characteristics; Percentage linearisation. Modulation fidelity and spurious interference measures including ACPR, co-channel power ratio, NPR, multi-tone intermodulation ratio, EVM & BER, PAPR. Linking signal behavioural measures to nonlinear system's degree of nonlinearity. System level PA and PA lineariser behavioural modelling for linearisation benefit analysis; crest factor control in complex envelope modulation systems (e.g. OFDM & CDMA). PAE & its improvement. Examples.

Presenters: M. O'Droma
 Y. Lei
 S. Donati Guerrieri
 M. Olavsbraten

Duration: 3 hours

Module 9 – PA linearisation in some existing and upcoming wireless communication systems

Consideration of linearisation requirements and benefits in wireless communication systems which already exist or are planned will be the subject of this module. A selection of systems such as GSM-EDGE; 3G handsets & base stations (UMTS); WLAN systems (IEEE 802.11a, b & g and ETSI Hiperlan/2); Bluetooth; HomeRF; SWAP. Upcoming systems: LMDS/ IEEE802.16 & .16a/ ETSI BRAN. WirelessMAN- & WirelessHUMAN SC, SCa & OFDM PHY; HAPs & satellites; UWB {FCC (USA) & ETSI (Europe)}; IEEE 802.15.3a DS-CDMA and MB-OFDM proposals; IEEE 802.15.4a.

Presenters: M. Pagani
A. Meazza
M. Rupp
E. Bertran
A. Zhu
S. Donati Guerrieri
A. Cesari

Duration : 2 hours