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BROADCAST

Total Transmission

INNOVATION

SYSTEM EXPERTISE

GREEN POWER TECHNOLOGY

RELIABILITY

ENERGY SAVING

TRUST

2010'S THE DECADE OF OPPORTUNITIES FOR ENERGY SAVING FOR TV TRANSMITTERS?

Foreword:

- **Brief history on Radio broadcasting**
  - 1980's decade has seen the efficiency revolution for High Power Radio broadcasting Transmitters :

    ➔ ***30% to 35% overall efficiency increase*** with the arrival of "***high efficiency high level modulation techniques***"

    • PWM (Pulse Width Modulation)

    • PSM (Pulse Step Modulation) ***the well known Thomson Patented*** high efficiency modulation technique still in use today with SW transmitter and High Energy Power Supplies



  - 1990's decade has seen the arrival of Full Solid State High Power LW and MW transmitters

    ➔ a ***10 to 15% additional gain*** for the overall efficiency due to the arrival of the new generation of Full Solid State LW/MW High power transmitters combined with high efficiency modulation techniques

  - ***will 2010 decade see the same revolution for V/UHF TV transmitters?***

- **Opportunities are rising with the emergence of the following technologies and/or techniques**
  - Evolution in high power RF transistor technology
  - Improvements in DPD (Digital Pre-Distortion)
  - Applicable PAPR (Peak to Average Power Ratio) techniques
  - High efficiency modulation techniques

    ➔ ***The following presentation is trying to provide an answer to the question***

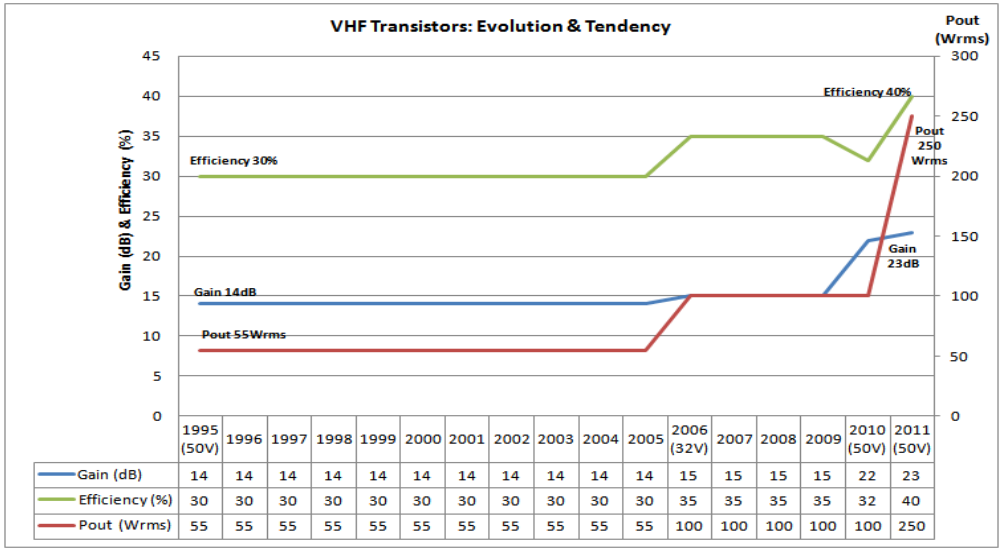
ENERGY SAVING & LIFE CYCLE COST REDUCTION FOR MODERN DIGITAL V/UHF TV TRANSMITTERS

- EVOLUTION IN HIGH POWER RF TRANSISTOR TECHNOLOGY
- IMPROVEMENTS IN DPD (DIGITAL PRE-DISTORTION)
- APPLICABLE PAPR (PEAK TO AVERAGE POWER RATIO) TECHNIQUES
- HIGH EFFICIENCY MODULATION TECHNIQUES
- NEW FEATURES IMPLEMENTATION ON DIGITAL TV TRANSMITTERS

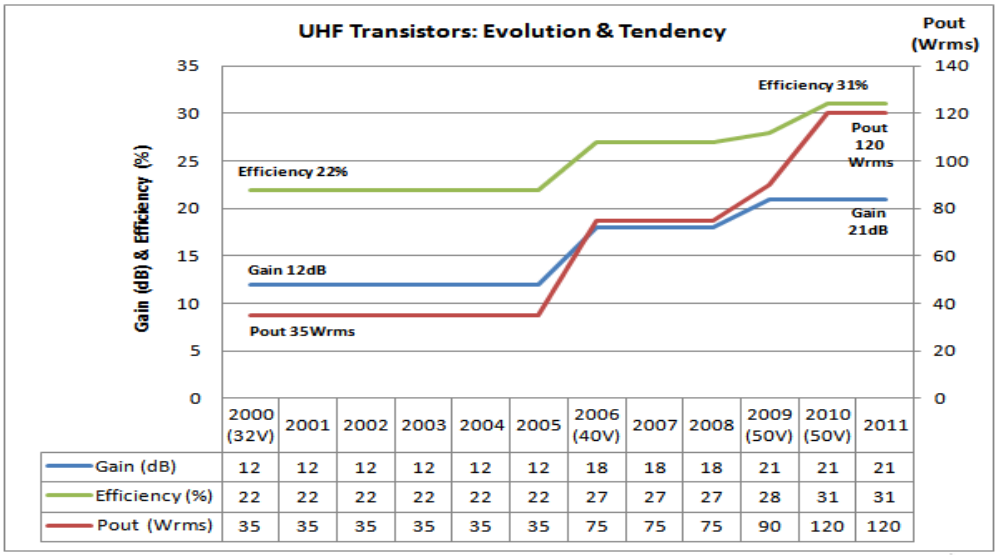
EVOLUTION IN HIGH POWER V/UHF RF TRANSISTOR TECHNOLOGY

Technical characteristics improvements with OFDM signal from 1995 to 2011

- **Output power increase**:
  - VHF: from 55Wrms to 250Wrms
  - UHF: from 35Wrms to 120Wrms
- **Thermal resistor decrease**
  - From 0.55°C/W to 0.15°C/W
- **Efficiency improvement with OFDM signal**
  - VHF: from 30% to 40%
  - UHF: from 22% to 31%
- **Ruggedness improvement**
  - From 10/1 to 65/1 VSWR
- **Linearity improvement**
  - From 25dB to 30dB
- **Gain increase**
  - VHF: from 14dB to 23dB
  - UHF: from 12dB to 21dB



	1995 (50V)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006 (32V)	2007	2008	2009	2010 (50V)	2011 (50V)
Gain (dB)	14	14	14	14	14	14	14	14	14	14	14	15	15	15	15	22	23
Efficiency (%)	30	30	30	30	30	30	30	30	30	30	30	35	35	35	35	32	40
Pout (Wrms)	55	55	55	55	55	55	55	55	55	55	55	100	100	100	100	100	250



	2000 (32V)	2001	2002	2003	2004	2005	2006 (40V)	2007	2008	2009 (50V)	2010 (50V)	2011
Gain (dB)	12	12	12	12	12	12	18	18	18	21	21	21
Efficiency (%)	22	22	22	22	22	22	27	27	27	28	31	31
Pout (Wrms)	35	35	35	35	35	35	75	75	75	90	120	120

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IMPROVEMENTS IN DPD (DIGITAL PRE-DISTORTION)

- **Comparison between Generations of Digital Exciters**
  - 1st Generation MODAP (1998)

EMMY Award
for DAP correction

  - 2nd Generation: SIRIUS (2004)

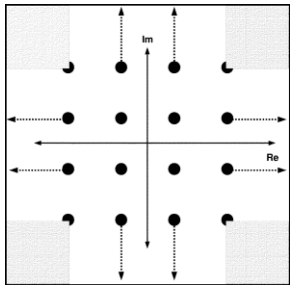
  - 3rd Generation: EXC3G (2011)

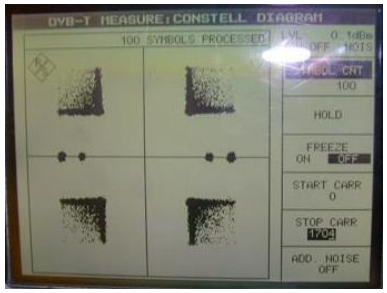
CRITERIA	1st Generation MODAP 1998	2nd Generation SIRIUS (2004)	3rd Generation EXC3G (2011)
Basic principle	Memory less	Memory less	With Memory effect
Main technology	DSP	FPGA	FPGA
NLC (Non Linear Correction) 7dB back off	0.5s computation 1 minute refreshing period 7dB efficiency	0.2s computation 5 seconds refreshing period 7dB efficiency	0.1s computation 2 seconds refreshing period 8dB efficiency
ALE (Adaptive Linear Equalization)	16 taps Filter 400 ns Group delay: 20ns >10db Ripple: ±0.2dB	64 taps Filter 1.6 µs Group delay: 20ns >10db Ripple: ±0.2dB	64 taps Filter 1.6 µs Group delay: 20ns >10db Ripple: ±0.2dB
Embedded PAPR techniques	No	No	Yes TR and ACE
Unbalanced shoulder equalization	No	No	Yes

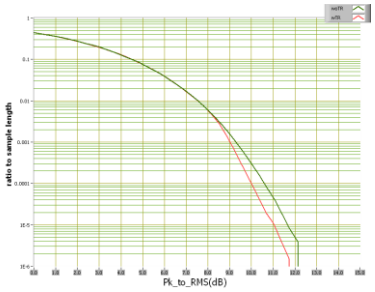
APPLICABLE PAPR (PEAK TO AVERAGE POWER RATIO) TECHNIQUES

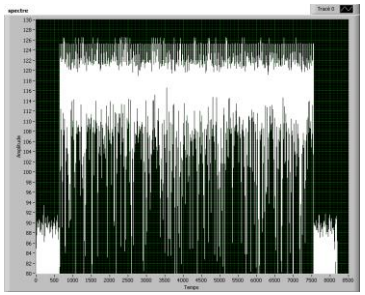
➢ Comparison between ACE et TR PAPR techniques

- ➢ ACE (Active Constellation Extension) is more efficient for low complexity constellation
- ➢ TR (Tone Reservation) is more efficient for high complexity constellation





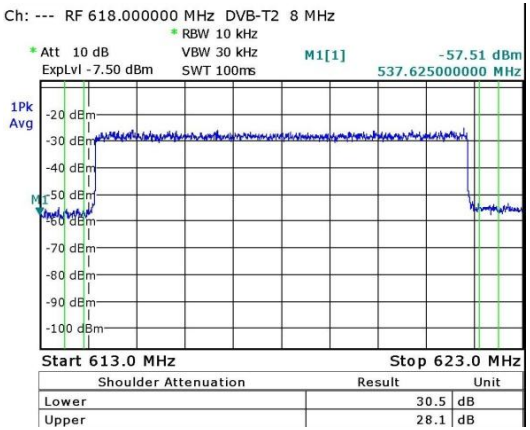


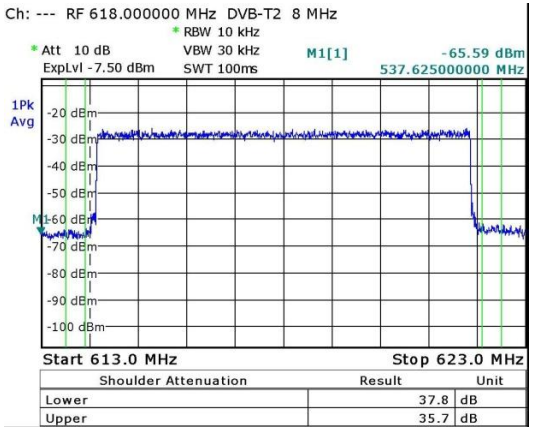


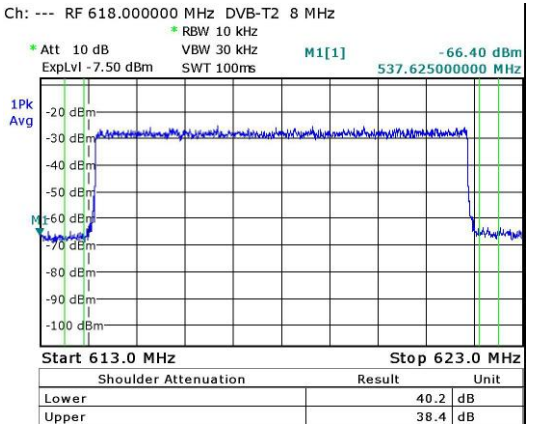
CRITERIA	ACE (Active constellation Extension)	TR (Tone Reservation)
PAR relative (to original signal)	8.7dB @ 10^{-5}	9.1dB @ 10^{-5}
rms gain	1.4dB(QPSK) 0.4dB (64QAM)	0.4dB (32K – 256QAM)
Bandwidth cost	0%	1%
Impact on Receiver	No	No
Power increase	<0.2dB	<0.2dB
DVB-T Backward compatibility	Yes	No
Complexity	Low to Medium (non iterative process)	High due to Iterative process

NEW GENERATION OF EXCITERS BENEFIT FROM BOTH DPD AND PAPR

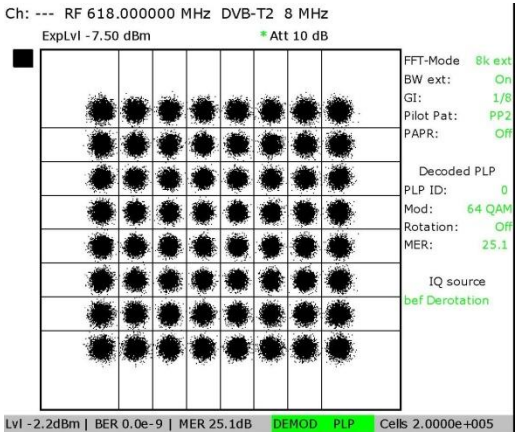
- **Shoulder improvement with a 7dB input back off: 10dB**
  - DPD is offering an averaging of 7dB
  - PAPR is delivering an additional 3dB average gain

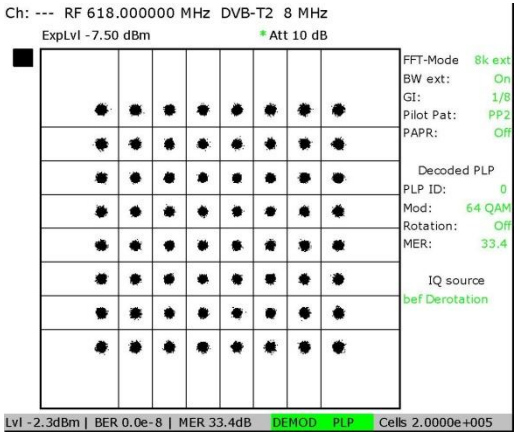


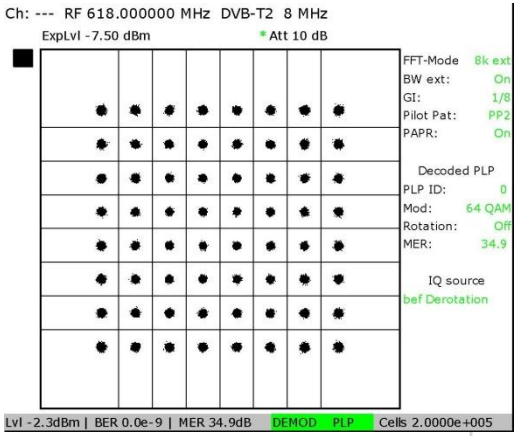




- **MER improvement with a 7dB input back off: 10dB**
  - DPD is offering an average gain of 8dB
  - PAPR is delivering an average additional gain of 2dB







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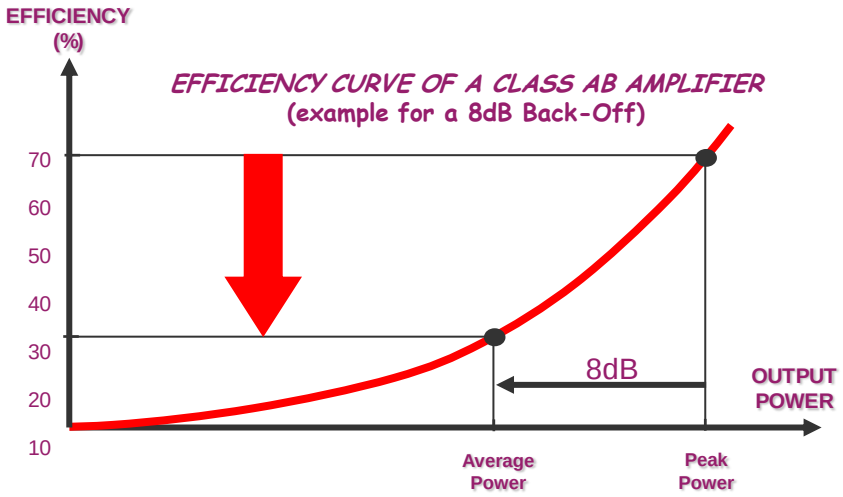
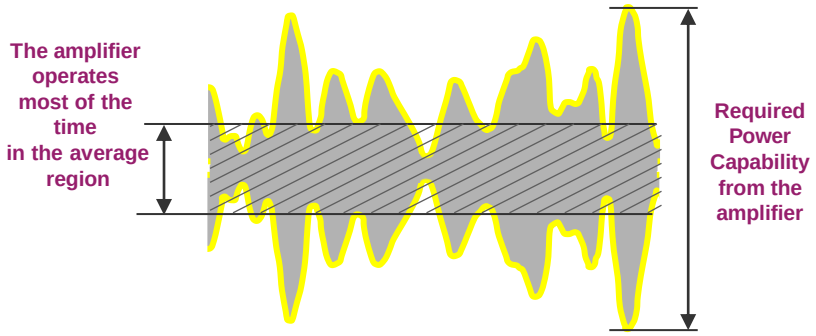
TV TRANSMITTER TODAY EFFICIENCY STATUS

- **Today state-of-the art modulation for digital TV RF amplifier**
  - Class AB with pre-correction
    - Feed forward technique at low output power: overall efficiency between 10% and 15%
    - Digital pre-distortion at higher output power : overall efficiency between 20% and 25%
- Due to the crest factor of the digital signal, in order to have acceptable performance specifically for out-of-band emission, the RF amplifier needs to operate with a 8dB to 10dB back-off far from its optimum operating point

but current Class AB RF Amplifier design has low efficiency at reduced power





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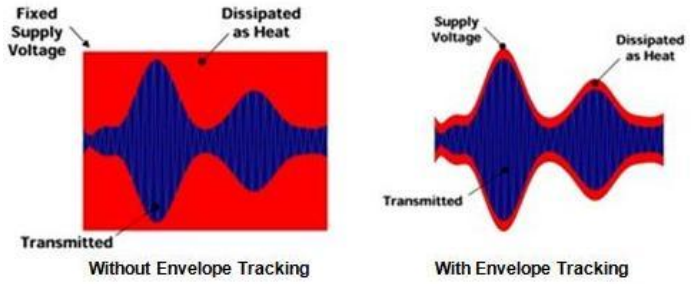
HIGH EFFICIENCY MODULATION TECHNIQUES

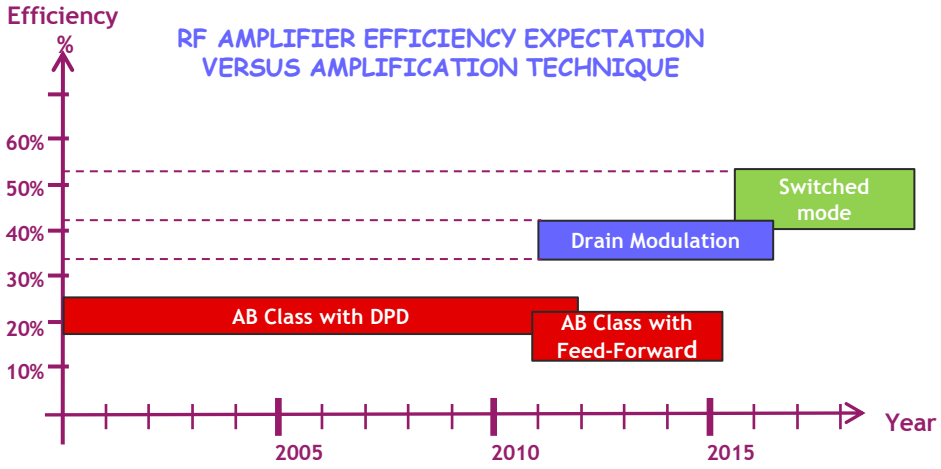
- **Promising modulation techniques applicable to VHF & UHF broadcasting are emerging some of them are already foreseen within the 2010 decade**
  - Doherty associated with DPD is already used in mobile phone base stations at higher frequency bands. This narrow band modulation technique (+/- 30 to 40MHz) is not really fitting the wide band operation required by traditional V/UHF TV Broadcasting (170 to 240MHz in VHF and 470 to 860MHz in UHF).
  - Drain Modulation also known as Envelop Tracking technique associated with DPD can be a candidate for short term applications including TV broadcasting
  - On-going advanced studies are conducted on Switched Mode. First prototypes of switched mode devices at low power are foreseen for 2015. Devices compatible with higher power for application in TV broadcasting could follow few years later.

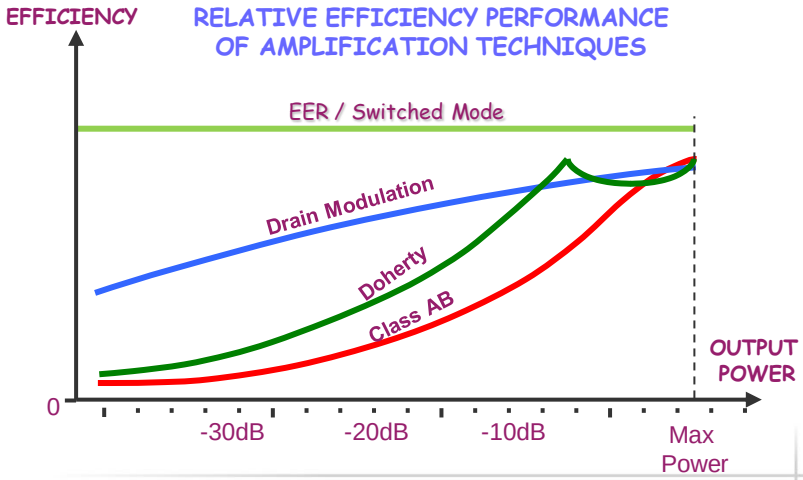


OPERA-Net
Power efficient Wireless

Optimising **P**ower **E**fficiency in mobile **RA**dio **Net**works

www.celtic-initiative.org/Projects/OPERA-Net





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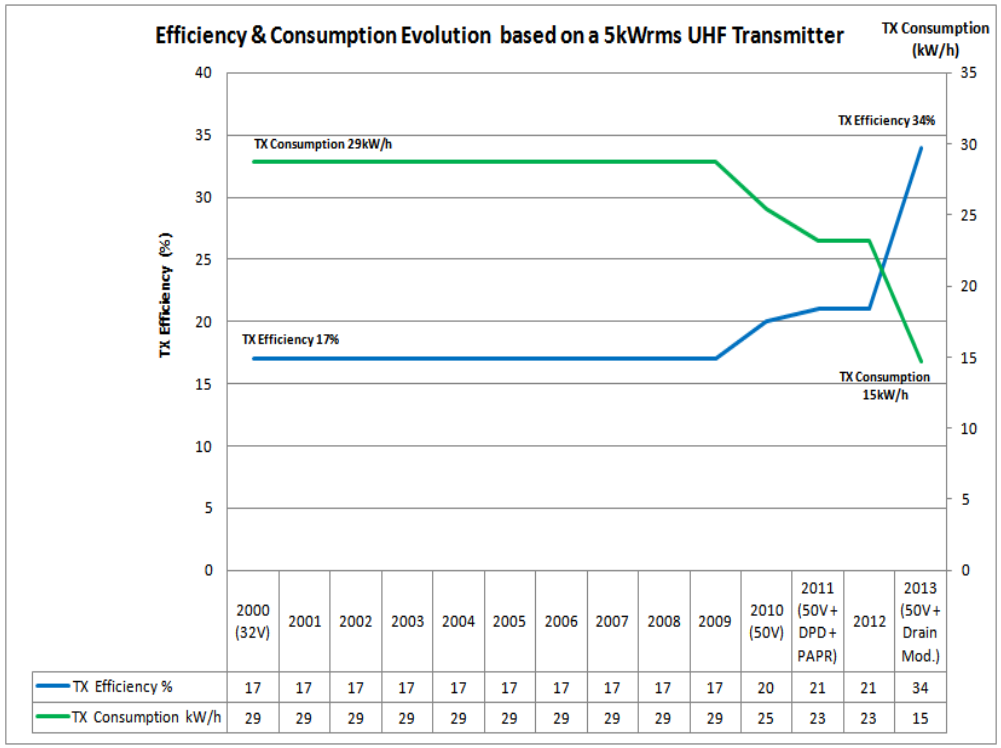
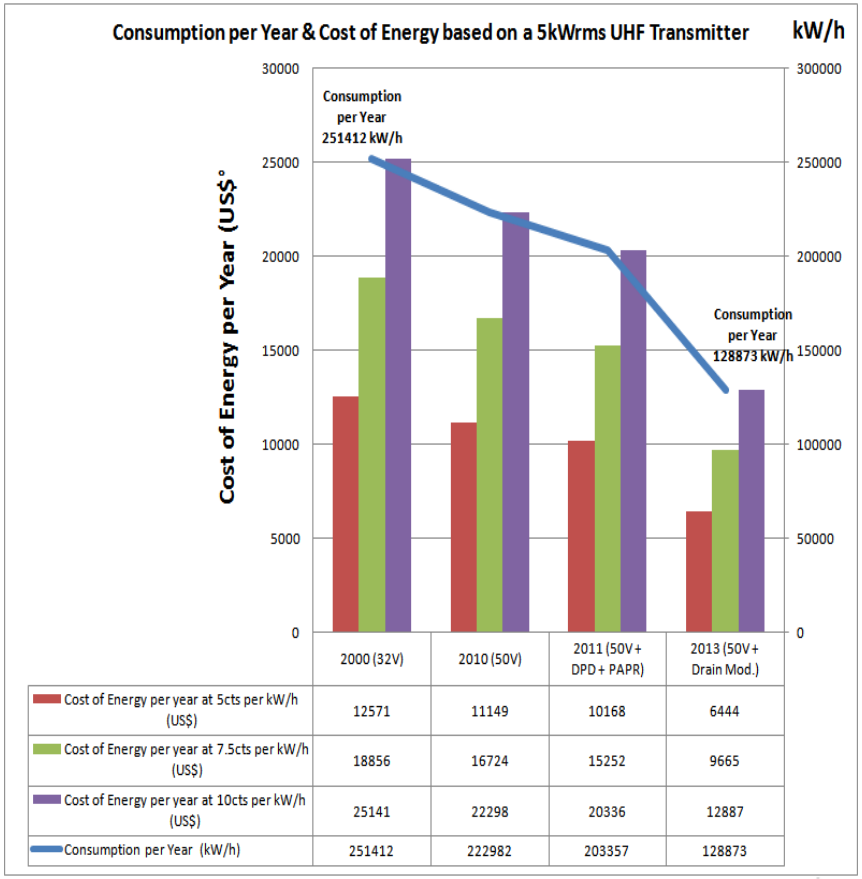
NEW FEATURES IMPLEMENTATION ON DIGITAL TV TRANSMITTERS

- **Possible improvements implementation according to the maturity of the new feature**
  - New generation of high power RF transistors: depend on Transistor Manufacturer NPI road map
  - PAPR: 2010/2011
  - High efficiency modulation technique
    - Drain modulation: 2012/2013
    - Switched mode: 2017/2018
- **Possible TV transmitter evolution time line**
  - Overall efficiency improvement
  - OPEX reduction



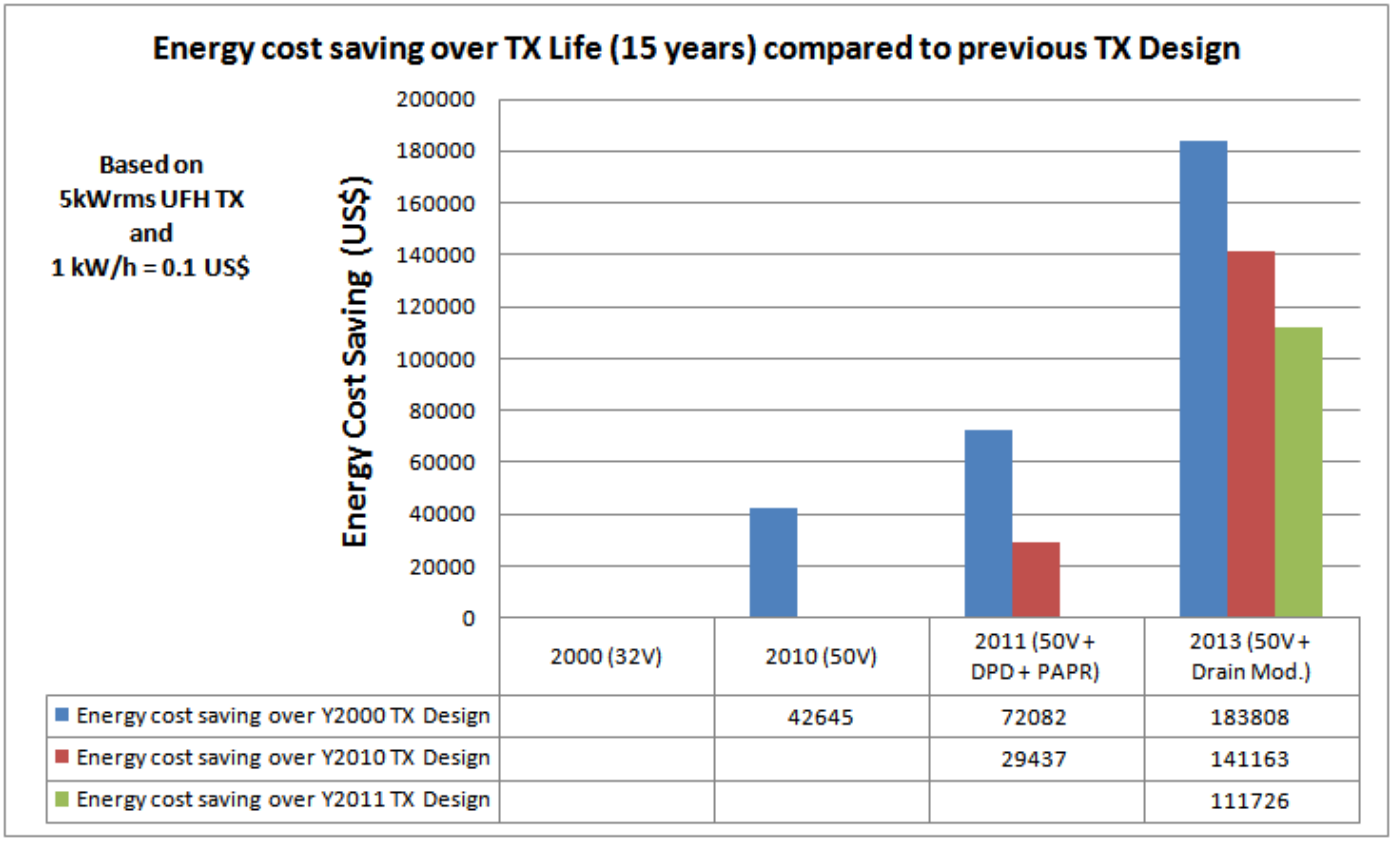
	2000 (32V)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010 (50V)	2011 (50V+ DPD+ PAPR)	2012	2013 (50V+ Drain Mod.)
TX Efficiency %	17	17	17	17	17	17	17	17	17	17	20	21	21	34
TX Consumption kW/h	29	29	29	29	29	29	29	29	29	29	25	23	23	15



	2000 (32V)	2010 (50V)	2011 (50V+ DPD+ PAPR)	2013 (50V+ Drain Mod.)
Cost of Energy per year at 5cts per kW/h (US$)	12571	11149	10168	6444
Cost of Energy per year at 7.5cts per kW/h (US$)	18856	16724	15252	9665
Cost of Energy per year at 10cts per kW/h (US$)	25141	22298	20336	12887
Consumption per Year (kW/h)	251412	222982	203357	128873

NEW FEATURES IMPLEMENTATION IMPACT ON CHOICE FOR THE FUTURE

- **Huge expected OPEX reduction heavily impact strategic decision for new investment in digital TV transmitters for the future**
  - Highest priority usually made on CAPEX should be revised
  - More important focus has to be done on Life Cycle Costs and Return On Investment (ROI)
  - On-going Regulation on Carbon Footprint reduction should amplify the phenomena



➔ ***According to the Price of Energy: Energy cost Saving between TX Generations and/or TX Designs could represent from 1 to 2 times CAPEX Over the TX Life***

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DIGITAL TV TRANSMITTER BENEFIT FROM NEW FEATURES

CONCLUSION:

- **Benefit from technology improvements and new features**
  - **Efficient DPD and PAPR provides**
    - An average gain of 3dB on shoulders
    - An average improvement of 2dB on MER
  - **New generation of transistors combined with high efficiency modulation techniques**
    - A 30% power increase at roughly constant cost/W
    - A 25% improved efficiency today and over 60% foreseen within the next few years
- **OPEX BENEFIT**
  - **Reduced energy costs**
  - **Improved reliability**
    - Decrease operating temperature
    - Reduced thermal stress
    - Reduced cooling system capacity
  - **Increase service availability**
    - Increase safety margin in operation:
  - **Environmental benefits**
    - Reduced carbon footprint

- **Two possibilities are offered**
  - Take advantage to reduce OPEX and to increase safety margin for the same coverage area
  - Take advantage to reduce CAPEX by increasing coverage area and reducing number of transmitters

➔ ***most of the time it will end in a compromise between the two possibilities according to the architecture of the TV Network***

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Thank you for your attention
Questions?

Visit Thomson Broadcast
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