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Medium Power High Efficiency Ka Band

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Outline

Motivation

TWT Design

- Gun Design
- Delayline Design
- Collector Design

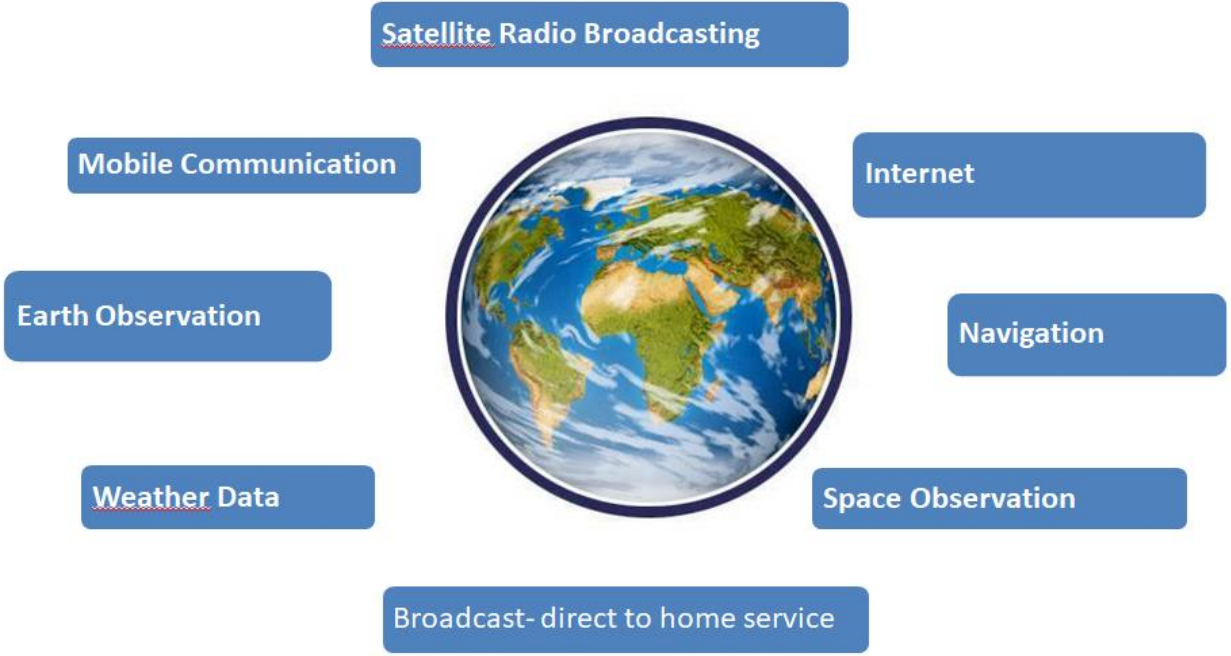
Performance at Saturation

3dB OBO performance

Conclusion

Motivation

In our daily communication, Rf Signals play an outstanding role



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Motivation

New Applications requires a continuous increase of data transfer for

- TV broadcasting (higher resolution of TV,..)
- New Video Formats with large bandwidth
- Navigation (connection between different systems)
- Earth observation (high resolutions needs more capacity and transfer to Gateways) + high level Space relais satellite (TDRSS/EDRSS)
- Internet, direct to home services

In last year an increase from a few kbps to several Mbps and Gbps

=> Goal Tbps

Need for modern communication:

Increase of RF power

enlarge bandwidth

high linearity and efficiency in back off

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Motivation

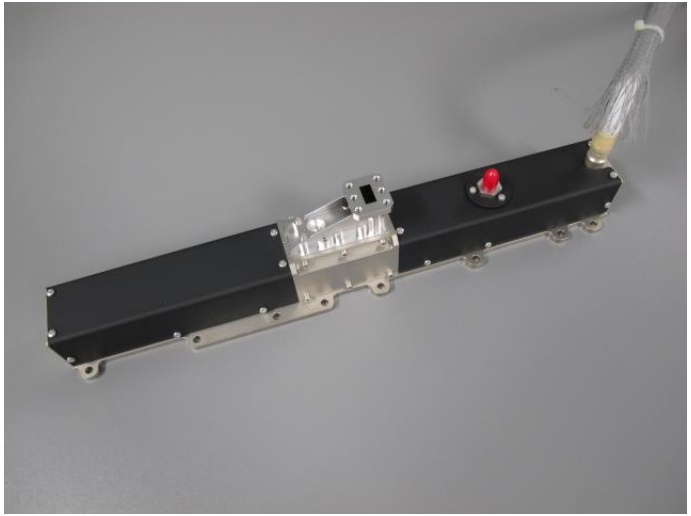
High data rate signals requires high output power back-off operation

Request

- Ka-Band TWT >100 W for VHTS – Satellite
- Efficiency improvement in OBO 3dB **(up to 10%)**
- Demand for high linearity with improved efficiency

Requirements

- Frequency Band: 17.7 GHz to 20.2 GHz
- Bandwidth: 2.5 GHz
- Output Power at Sat: 110 W amb BOL
- NOP: 3 dB OBO



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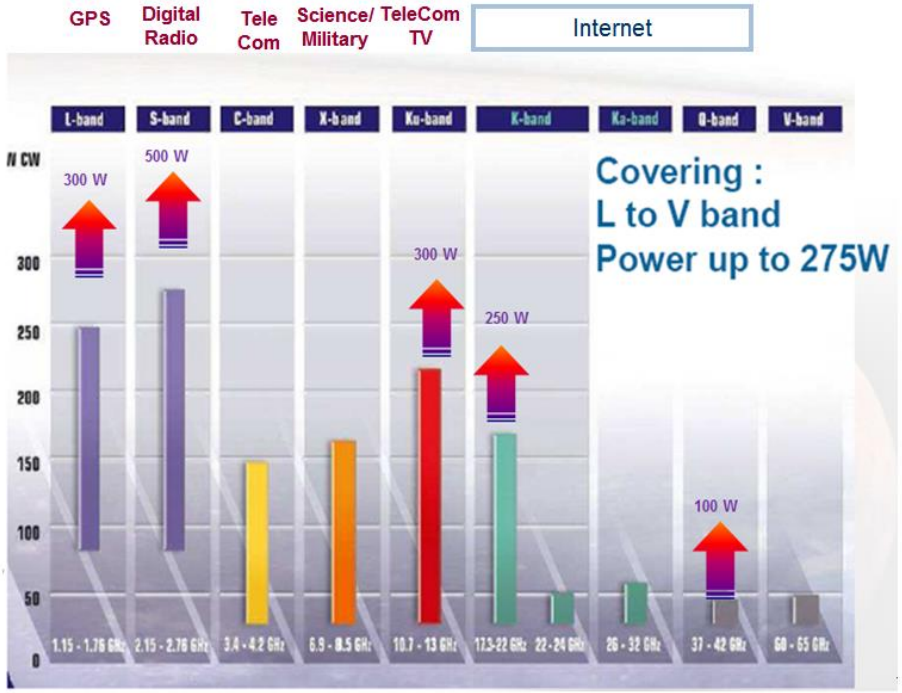
TWT design

TED has a long experience in the design of space TWT's

Amplifier Sub-systems



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In Orbit Experience: No. Of TWT's and Operating hours

Over the last years, THALES Deutschland (THALES Electron Devices) has delivered more than 1300 Ka-band TWTs using TL 20xxx design

- **Operated in orbit**: More than **1000** units (status Jan 2018)
  - 815 Low power conduction cooled
  - 319 High power conduction cooled
- Design life: 18 years
- **In orbit demonstrated life time (with the same Cathode design)** :
  More than 36 Mio hours

In Orbit Experience from 1972 to July 2018

Freq. Band	Cooling	Delivered TWTs (not yet launched)	TWTs in Orbit Qty (1)	TWTs in Orbit K. Hours (2)
S / L	CC	311	620	32,366
	RC	13	91	963
C	CC	747	3,323	203,183
X	CC	328	422	18,517
X	RC	0	25	0
Ku < 80 W	CC	125	1,636	132,746
Ku > 80 W	CC	252	3,699	213,465
	RC	732	5,705	281,118
Ka < 80 W	CC	346	924	43,177
80W< Ka <140 w	CC	391	1,278	41,944
80W< Ka <140 w	RC	662	1,352	38,518
140W< Ka <170 w	CC	152	0	0
140W< Ka <170 w	RC	0	0	0
Q-Band	CC	0	0	0
pulsed	CC	4	28	1,157
		4,063	19,103	1,007,156
		23,166		

Total delivered TWTs (at customer):	4,063
Total TWTs In-Orbit:	19,103
Total In-Orbit Operating Time (h):	1,007,155,503

Note 1 : Including redundant TWTs
Note 2 : Excluding redundant TWTs. Redundancy of 66% is assumed, if redundancy scheme is unknown
Note 3 : Launch dates as per Airclaims SpaceTrak CD-Rom

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TWT Design

Gun:

- Optimised for beam compression and focussing
- Positive Ion Barrier to protect Cathode and increased lifetime

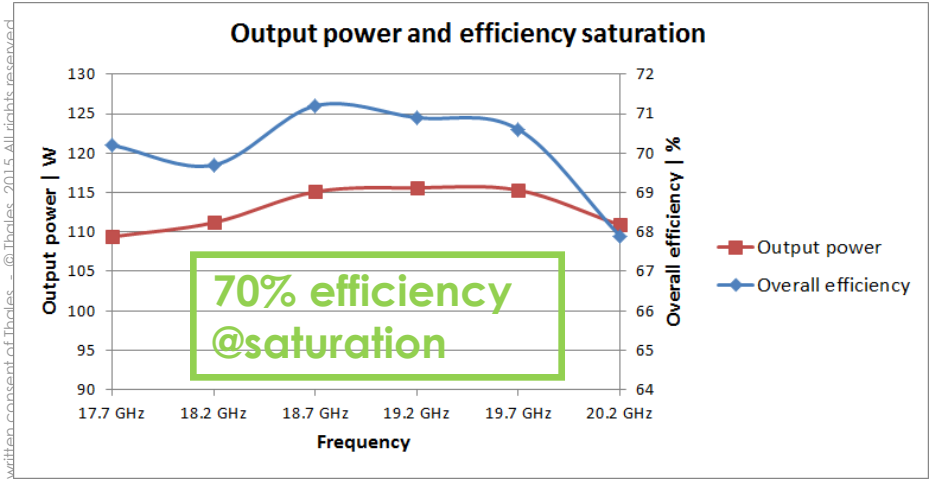
Delayline:

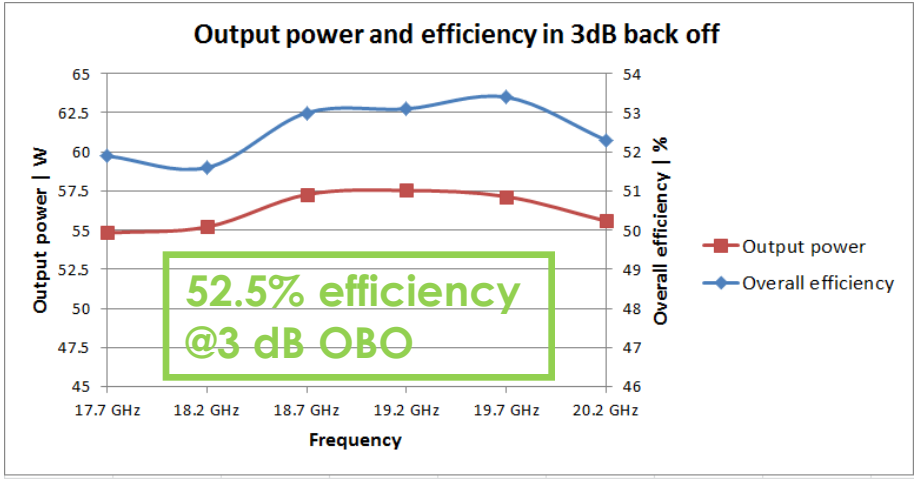
- Design for Bandwidth > 3GHz
- Improved efficiency
- Keeping well known linearities and stability

Collector:

- Significant improvement of Collector optics for >100W Output Power and improved efficiency

TWT – Performance @ Saturation





Values for 100W P2 class with 10dB overdrive specification

- P2 average :112.9W / 56.3W
- QDC average: 161.1W /107.1W (48.9W zero)
- Eta average: 70.1% @sat. / 52.6% @3dB output back-off

Back off values can be further optimized with reduced overdrive specification

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TWT Performance: Saturation

Flat behaviour of Pout over 2.5GHz

Good focussing

High efficiency over 2.5GHz

freq|GHz	17.7 GHz	18.2 GHz	18.7 GHz	19.2 GHz	19.7 GHz	20.2 GHz	--	
Ik|mA	66.02	66.02	66.02	66.02	66.02	66.02	66.02	
P2*|dBm	8.98	9.24	9.38	9.49	9.59	9.68		
P2|dBm	50.44	50.5	50.64	50.68	50.67	50.51		P2 av. [W]
P2|W	110.7	112.2	115.9	116.9	116.7	112.5		114.2
vp|dB	52.54	53.19	53.57	53.64	53.2	51.97		
Ih|mA	0.4	0.42	0.43	0.47	0.51	0.55	0.15	
Ig2|uA	13	12	13	15	17	18	2	Qdc av. [%]
Qdc|W	156.53	159.52	161.02	162.05	162.29	161.15	50.85	160.4
Qdiss|W	45.83	47.32	45.12	45.15	45.59	48.65	50.85	Eta av. [%]
ETA|%	70.7	70.3	72	72.1	71.9	69.8		71.1
ETA0|%	25.1	25.5	26.3	26.5	26.5	25.5		25.9
vpss|dB	59.52	60.21	60.51	60.51	59.86	58.52		Eta0 av. [%]

TWT Design

TWT Performance: -3dB OBO

Flat behaviour of Pout over 2.5GHz

Good focussing

High efficiency over 2.5GHz

freq|GHz	17.7 GHz	18.2 GHz	18.7 GHz	19.2 GHz	19.7 GHz	20.2 GHz	--	
Ik|mA	66.03	66.03	66.03	66.03	66.03	66.03	66.03	
P2*|dBm	5.97	6.22	6.35	6.44	6.53	6.65		
P2|dBm	47.43	47.48	47.61	47.63	47.61	47.48		P2 av. [W]
P2|W	55.34	55.98	57.68	57.94	57.68	55.98		56.8
vp|dB	58.32	59.05	59.39	59.46	58.91	57.7		
Ih|mA	0.25	0.25	0.25	0.25	0.26	0.26	0.16	
Ig2|uA	8	9	9	10	11	11	2	Qdc av. [%]
Qdc|W	106.46	107.89	108.38	108.41	107.74	106.6	50.96	107.6
Qdiss|W	51.12	51.91	50.7	50.47	50.06	50.62	50.96	Eta av. [%]
ETA|%	52	51.9	53.2	53.4	53.5	52.5		52.8
ETA0|%	12.6	12.7	13.1	13.2	13.1	12.7		12.9
vpss|dB	59.9	60.59	60.86	60.81	60.1	58.68		Eta0 av. [%]

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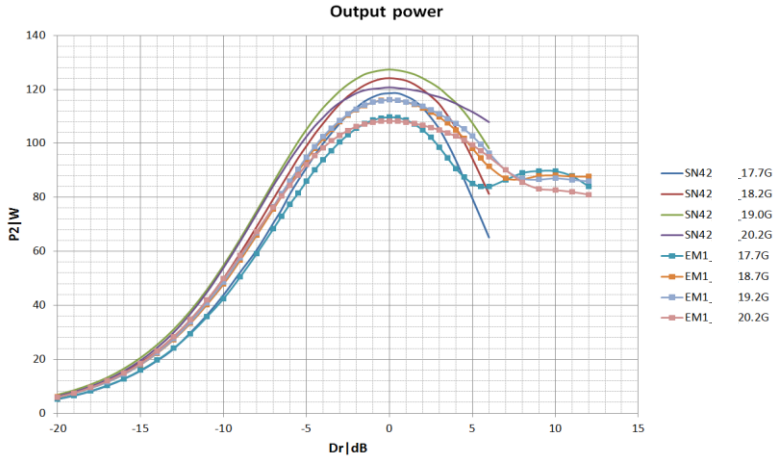
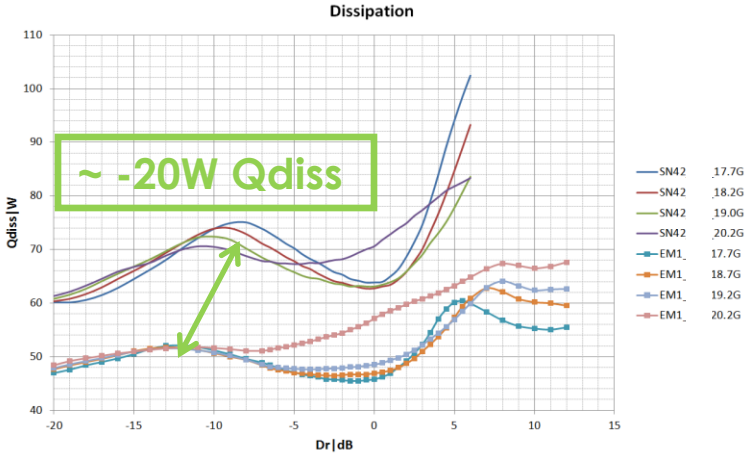
TWT Performance





Remark: P2 specification of TL 20073 :115W (+8W)
~+3.5W Qdis at saturation for TL20075S

Significant Qdiss improvement over complete AM/AM range

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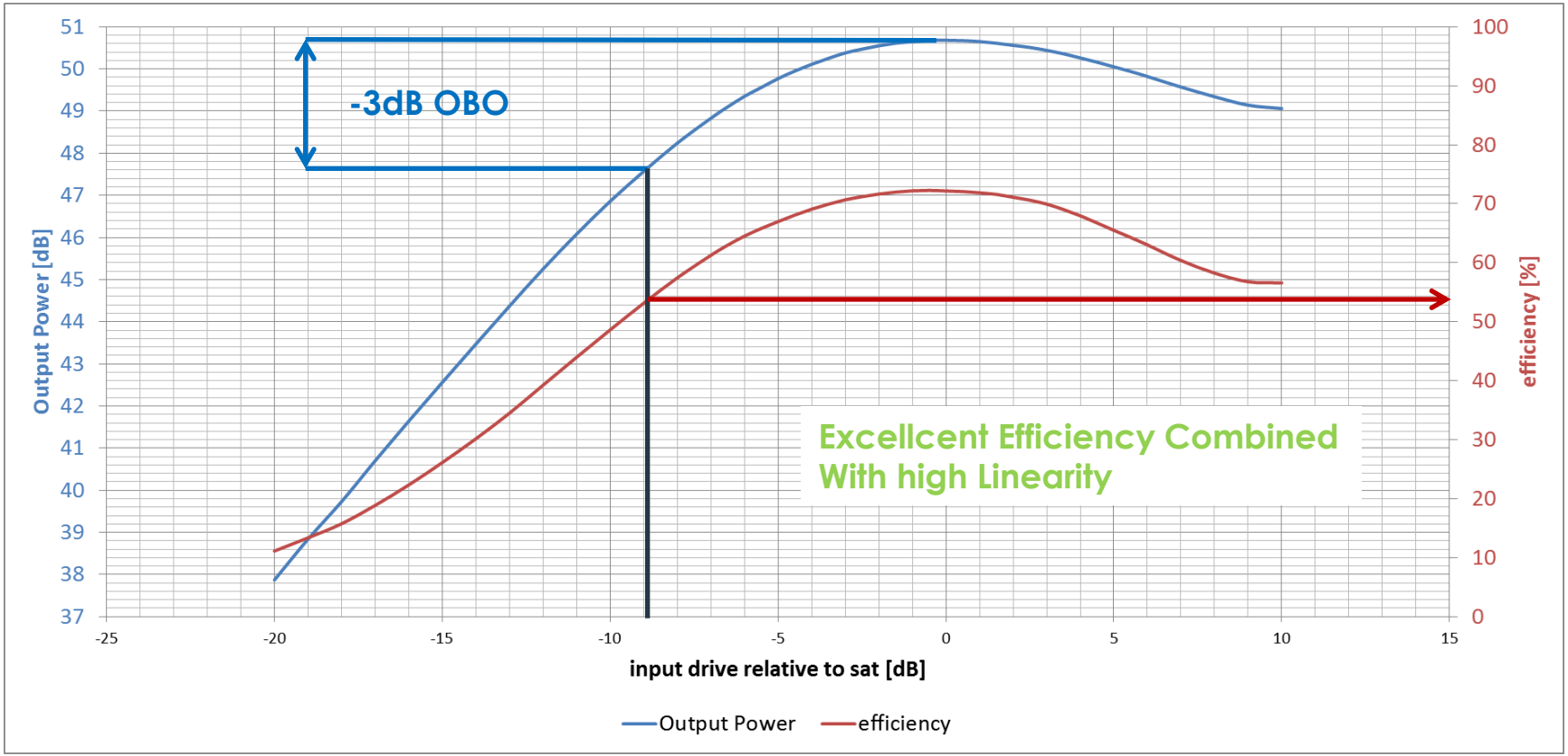
TWT Performance



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Conclusion

- Ka-Band TWT >100 W for VHTS – Satellite
- Improved efficiency in OBO 3dB
- high linearity with improved efficiency
- Frequency Band: 17.7 GHz to 20.2 GHz
- Bandwidth: 2.5 GHz
- Output Power at Sat: 107 W amb BOL

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Thank You