Radiated Spurious Emission Testing

Jari Vikstedt

jari.vikstedt@ets-lindgren.com

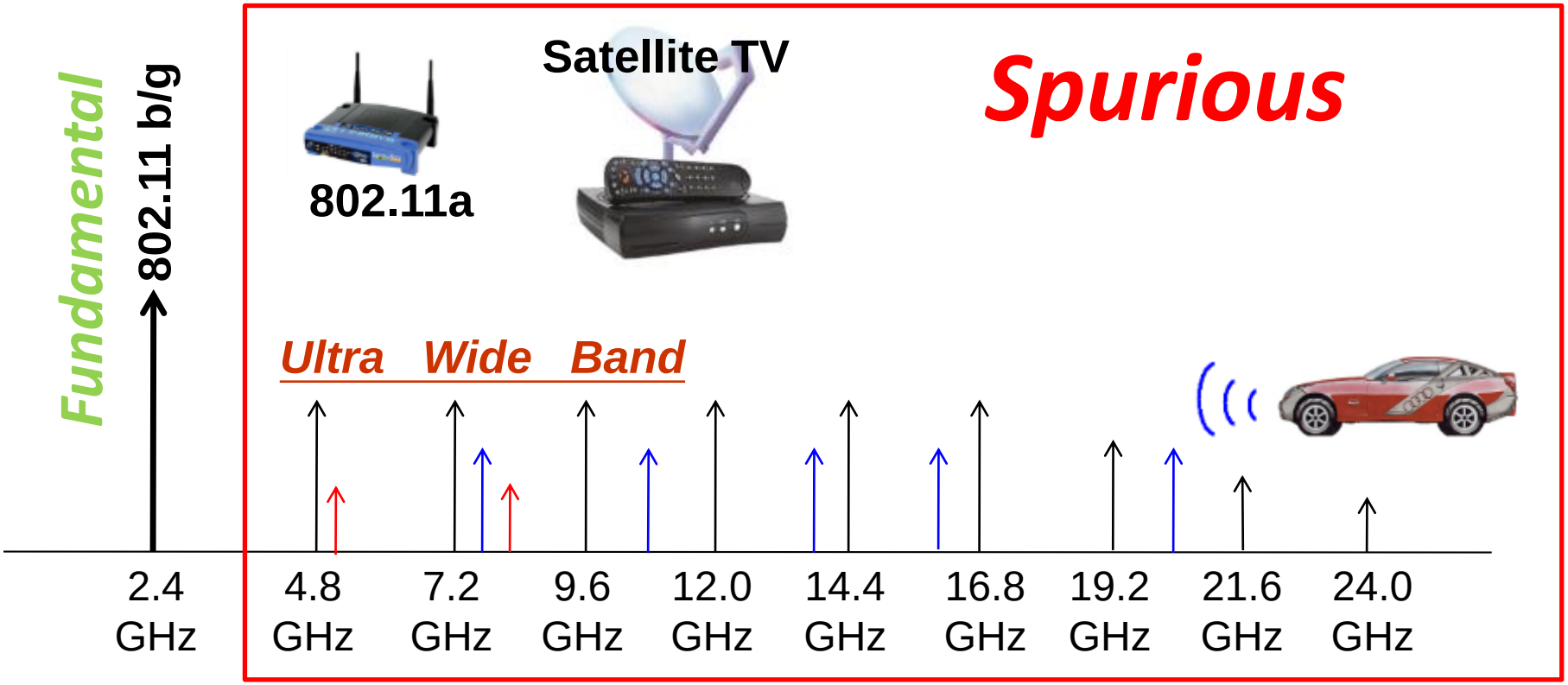
What is RSE?

- RSE = radiated spurious emission

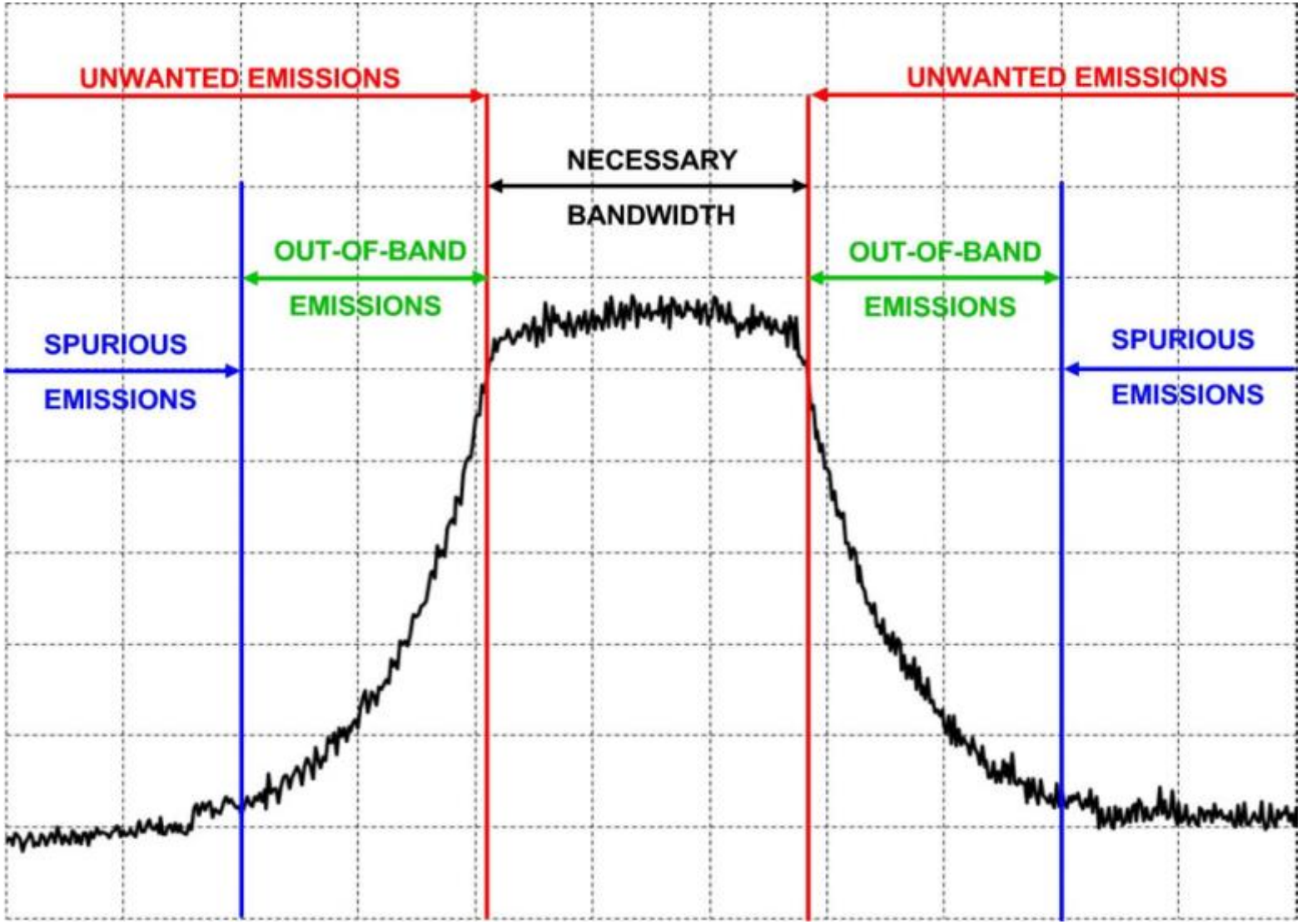
- Radiated → Shielded, Anechoic Chamber
- Spurious → Intentional Radiator
- Emission → EMI Measurements

Spurious

- **Spurious**, all emissions but the **fundamental (carrier)**
- **Spurious** can be harmonics, oscillations, mixing terms



Spurious Domain



Receiver vs. Spectrum analyzer

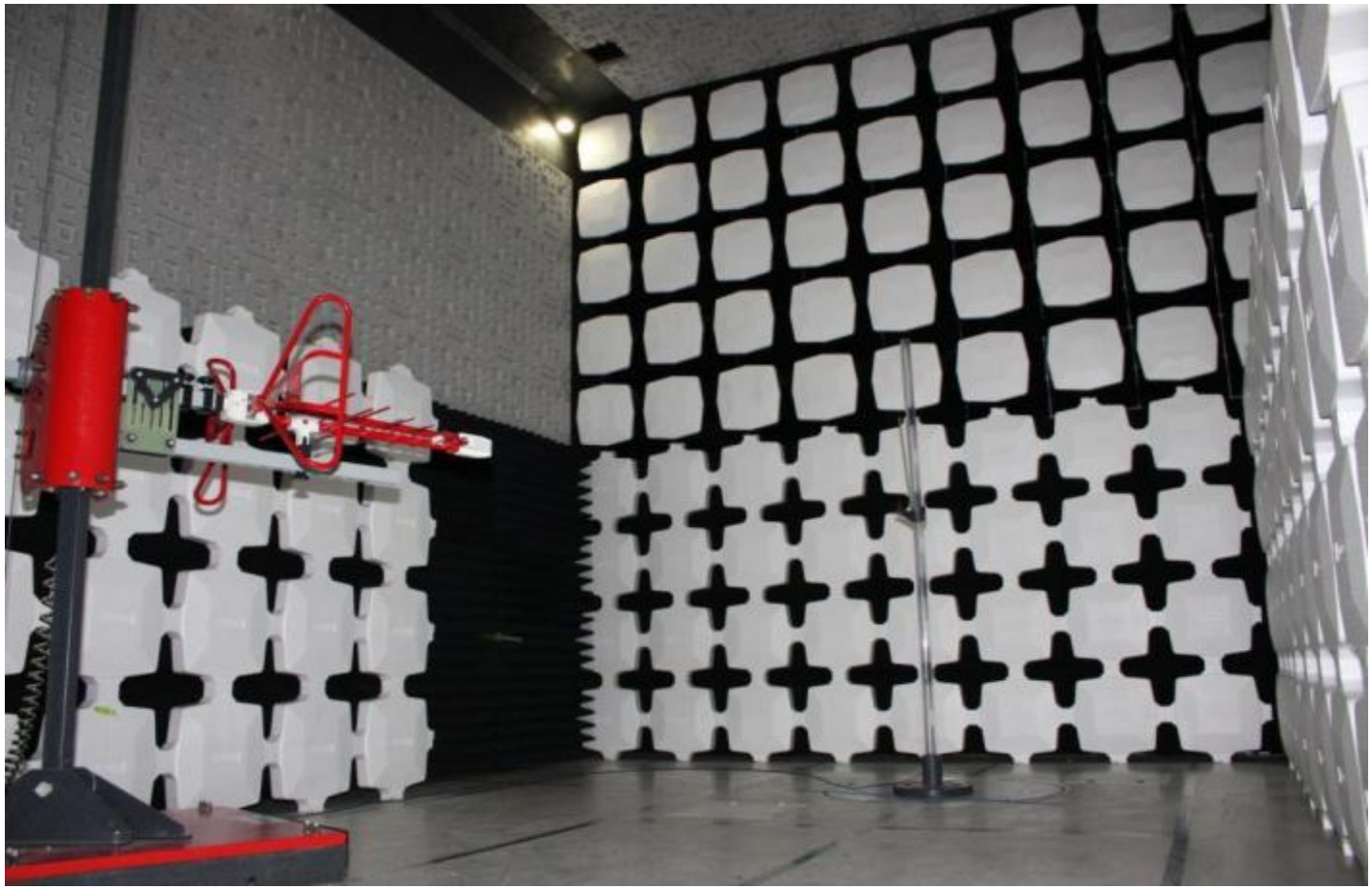
- Spurious Emission measurements differ from EMI measurements mainly in that BW's matching the useful signal have to be set on the receiver instead of the typical EMC bandwidths (e.g. 200 Hz, 9 kHz, 120 kHz).
- Also EMC BW's are referred to the 6 dB points of the IF filters, whereas the BW's for spurious emission measurements are referred to the 3 dB points.
- In spurious emission measurements PK detector is used in place of the QP detector.
- All these differences make it necessary that for spurious emission measurements a Spectrum Analyzer or Receiver with spectrum analyzer functionality to be used rather than a pure EMC test receiver

Typical RSE Standards

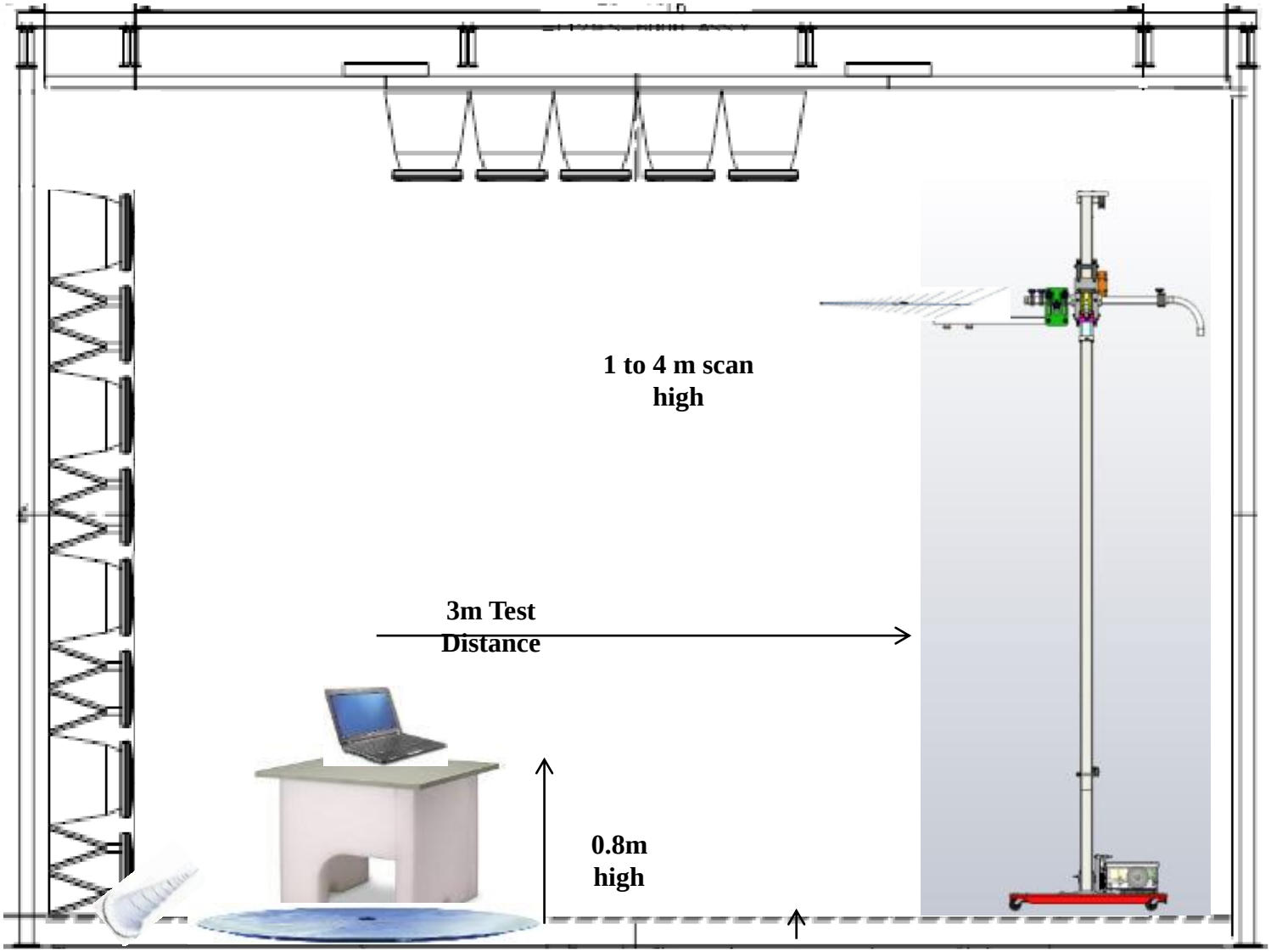
- FCC 15C/22/24/ (90)
- 3GPP standards define RSE for cellular technologies, such as 3GPP.51.010 for GSM
- ETSI EN 300 328 defines RSE for 2.4 GHz ISM band using spread spectrum modulation, up to 24 GHz
- ETSI EN 301 893 defines RSE for 5 GHz ISM band using spread spectrum modulation, up to 26 GHz
- ETSI EN 300 440 even defines RSE for equipments used to 40GHz, spurious measured to 100GHz
- Limit lines are given in dBm, not dBuV/m
  - This implies EIRP measurement
    - → EIRP not function of test distance
    - → So, substitution calibration is required

FCC Chamber

FCC does not deviate from general ANSI C63.4 spec when measuring the RSE, but simply reinforces the use of "typical" 3-meter EMC chamber.

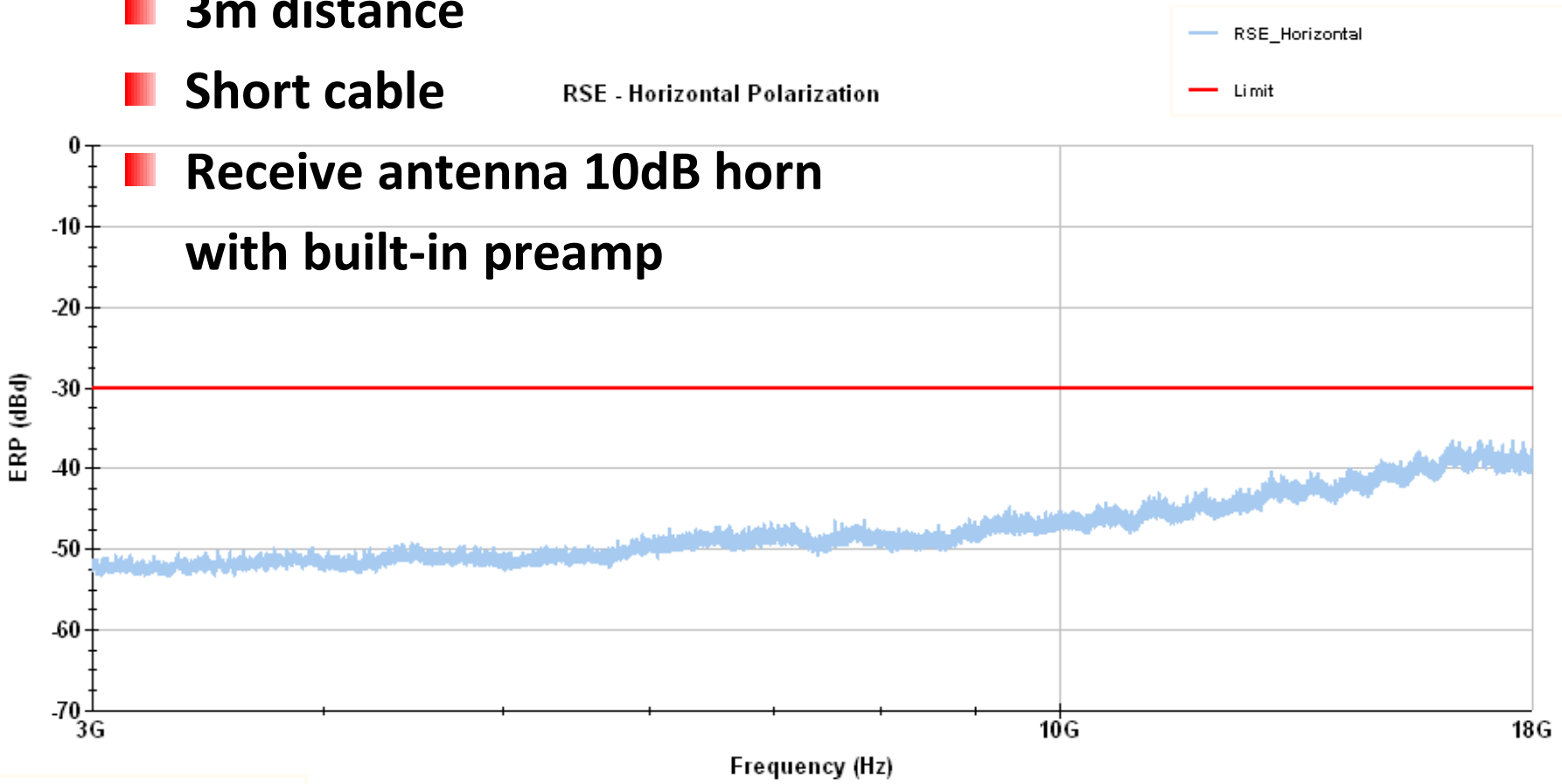


Semi Anechoic Chamber



Noise Floor in FCC 3 meter chamber

- 3m distance
- Short cable
- Receive antenna 10dB horn with built-in preamp



FCC

- **Intentional Emitters:**
  - f < 10 GHz: to the tenth harmonic of the highest fundamental frequency or to 40 GHz, whichever is lower.
    - In some cases the emissions from an intentional radiator must be measured to beyond the tenth harmonic of the highest fundamental frequency designed to be emitted by the intentional radiator because of the incorporation of a digital device.

- **FCC Rules Part 22 and 24 requirement for radiated spurious emissions is as follows:**
  - The ERP limit is –13dBm [derived from 43 +10log(P)]

FCC RBW/Limits

Rules FCC	Frequency /Resolution Bandwidth				Power Limit
	Freq (MHz)	RBW	Freq (MHz)	RBW	(Ave.)
22.917 (850)	f_{low} - 1MHz < f < f_{low} &	≥1% of BW	$f \leq f_{low}$ - 1MHz &	≥100 kHz	-13 dBm
24.238 (PCS) ; 27.53(g) (AWS)	$f_{up} < f < f_{up}$ + 1MHz;		$f \geq f_{up}$ + 1MHz	≥1M Hz	

FCC Spurious Testing, Example

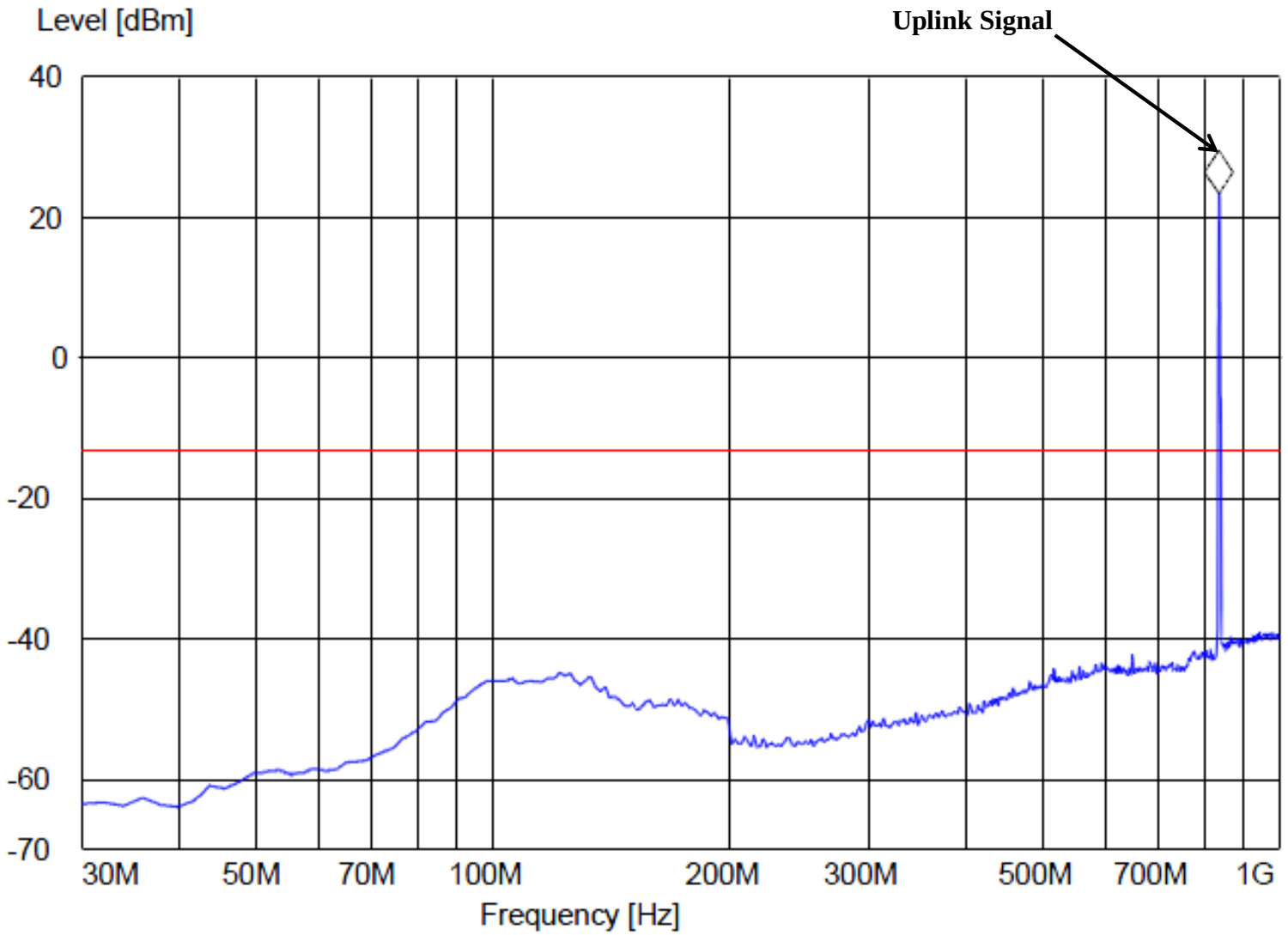
- Connect the equipment
  - If antenna element can be loaded with 50 ohm dummy load please do so or else take care not to overload the receiver/spectrum analyzer.
- Adjust the settings of the Radio Communication Tester to set the EUT to its maximum power at the required channel.
  NOTE, Requires communication antenna to maintain the link!
- Set the spectrum analyzer to measure peak hold.
- Measure EMI
  - a polarization (Horizontal or Vertical)
  - 1-4m Scan
  - Rotate EUT 0-360 degrees
  - Record level (LVL) up to 10^{th} harmonic

FCC Spurious Testing, Example

- Perform Substitution Test
  - Replace the EUT with a half wave dipole or known gain antenna.
  - Substitution antenna should be at the same location as the EUT.
  - Connect the known antenna to a signal generator with known output power and record the path loss in dB (LOSS). LOSS = Generator Output Power (dBm) Analyzer reading (dBm).
  - Determine the level of spurious emissions using the following equation: Spurious (dBm) = LVL (dBm) + LOSS (dB)

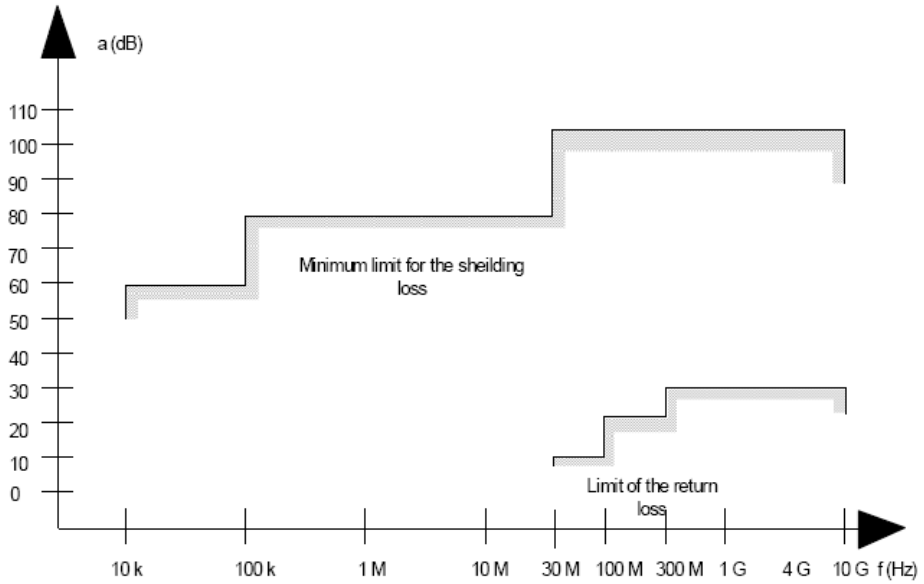
- Measurements are to be performed with the EUT set to the low, mid and high channel of each frequency band.

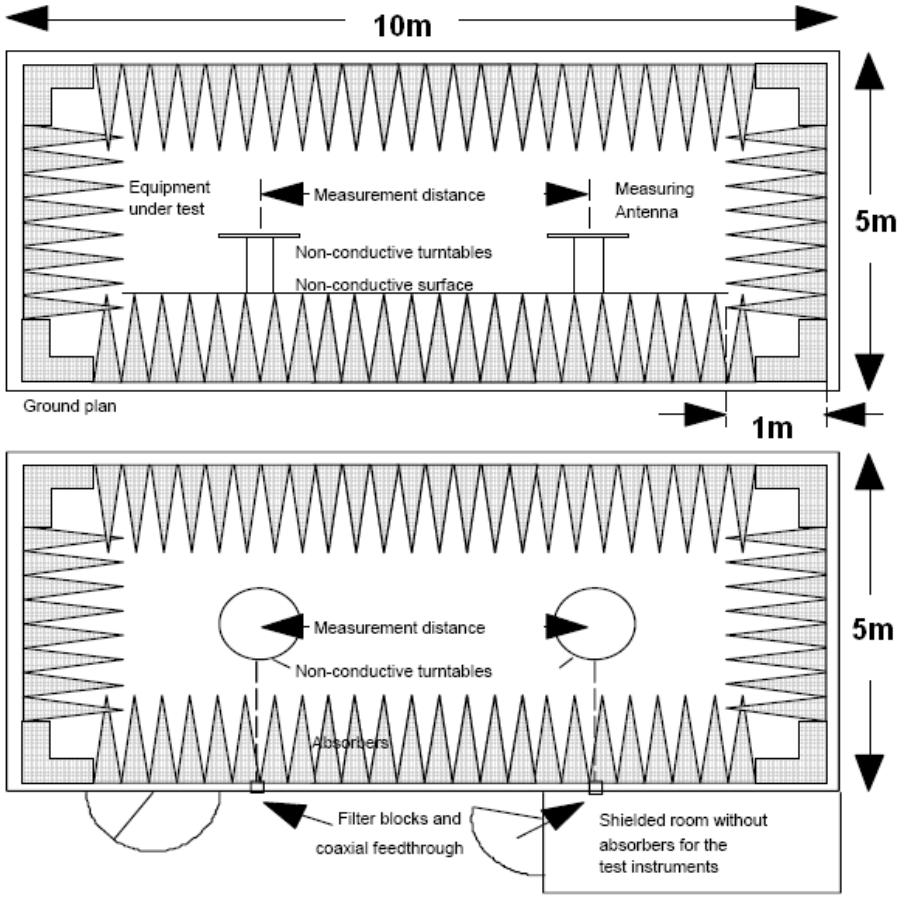
Example of FCC Spurious Test



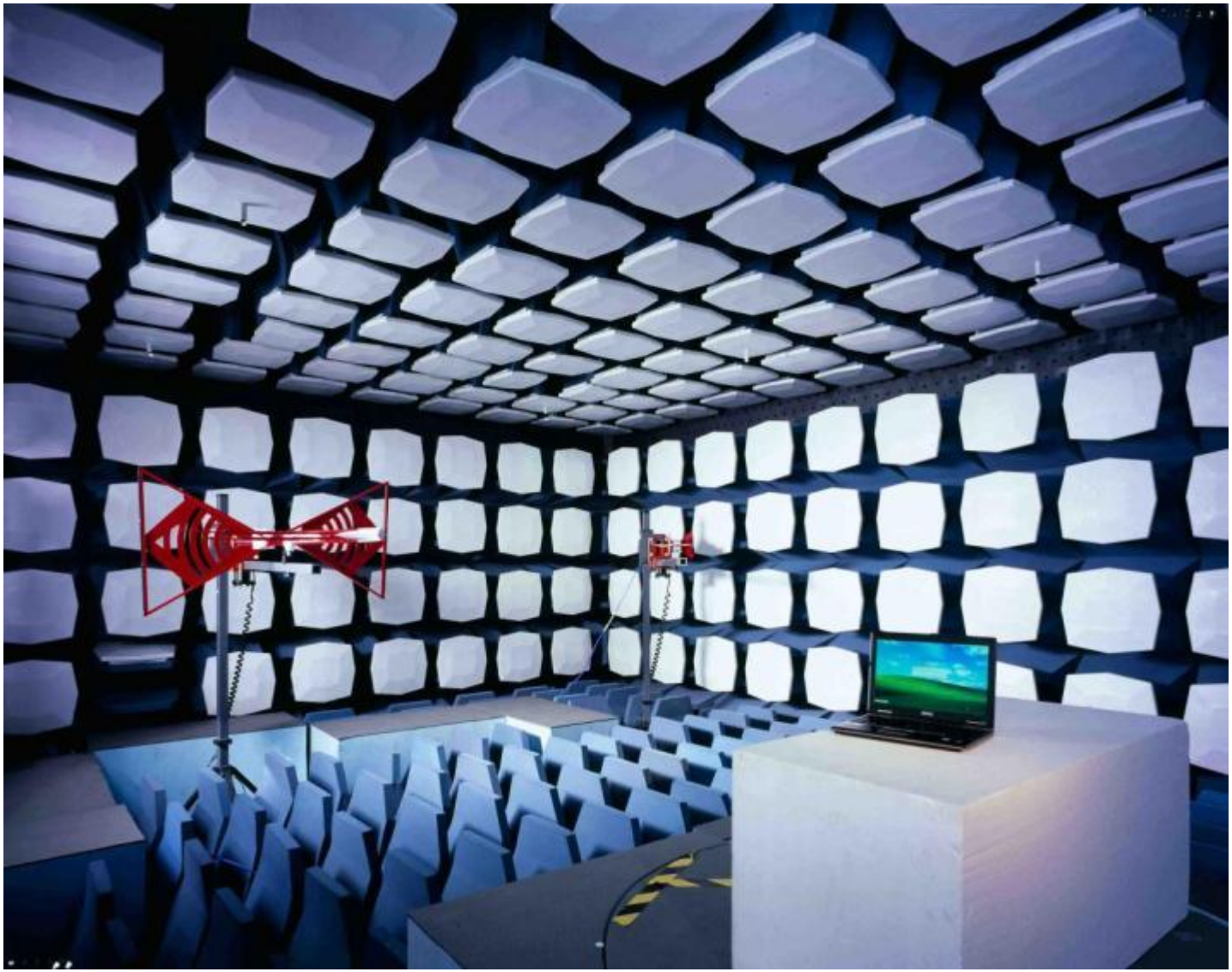
ETSI Chamber

The above mentioned standards clearly define the *Reflectivity* of absorber and chamber size, not chamber performance.





ETSI Chamber



ETSI Standard Basics

- EMI measured from 30MHz to 12.75GHz
- The receiving device is spectrum analyzer (3dB BW RBW), not EMI receiver (6dB BW RBW).
- No defined chamber performance test
- Only absorber requirement
- And suggested chamber size (10m x 5m x 5m)

ETSI RBW/VBW Settings

- Here is to given one example.

		GSM850 (CH190)		GSM900 (CH62)		GSM1800 (CH700)		GSM1900 (CH661)	
	fL/fH	824	849	880	915	1710	1785	1850	1910
	fo	836.6		902.4		1747.8		1880	
RBW	VBW	fstart	fstop	fstart	fstop	fstart	fstop	fstart	fstop
10k	30k	30	50	30	50	30	50	30	50
100k	300k	50	500	50	500	50	500	50	500
3MHz	3MHz	500	794	500	850	500	1680	500	1820
1MHz	3MHz	794	804	850	860	1680	1690	1820	1830
300k	1MHz	804	814	860	870	1690	1700	1830	1840
100k	300k	814	**824**	870	**880**	1700	**1710**	1840	**1850**
100k	300k	824	830.6	880	896.4	1710	1741.8	1850	1874
30k	100k	830.6	834.8	896.4	900.6	1741.8	1746	1874	1878.2
-	-	**834.8**	**838.4**	**900.6**	**904.2**	**1746**	**1749.6**	**1878.2**	**1881.8**
30k	100k	838.4	842.6	904.2	908.4	1749.6	1753.8	1881.8	1886
100k	300k	842.6	849	908.4	915	1753.8	1785	1886	1910
100k	300k	**849**	859	**915**	925	**1785**	1795	**1910**	1920
300k	1MHz	859	869	925	935	1795	1805	1920	1930
1MHz	3MHz	869	879	935	945	1805	1815	1930	1940
3MHz	3MHz	879	4000	945	4000	1815	4000	1940	4000

ETSI Limits

- Harmonics are mostly limited to -30dBm (in dBd), or -27.85dBm (in dBi) [dBd = dBi – 2.15]

Freq. Range (MHz)	Limit (ERP, dBm)	RBW (kHz)
30 – 1000	-36	100
1000-12,750	-30	1000

Freq. Range	GSM 850/900/1900 and GSM 400/700 (ERP in dBd)	GSM1800 (ERP in dBd)
30-1000 MHz	-36 dBm	-36 dBm
1000-4000 MHz	-30 dBm	(see separate limits)
1000-1710 MHz		-30 dBm
1710-1785 MHz		-36 dBm
1785-4000 MHz		-30 dBm

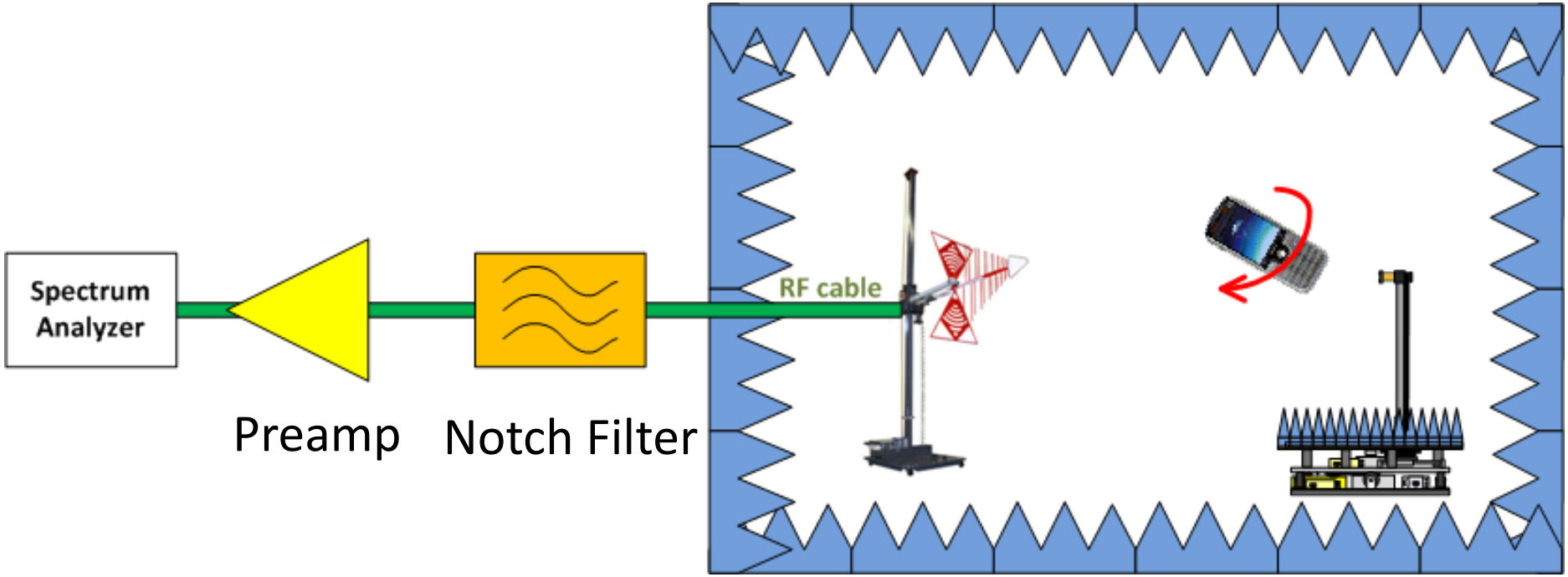
Freq. Range	CDMA (Cell and PCS Bands)
30 ≤f<1000 MHz	-36 dBm
1 ≤f<12.75 GHz	-30 dBm
	Exclusive Band near fc to be exempt

Freq. Range	WCDMA Band I,II,IV,VIII	TD-SCDMA
30 ≤f<1000 MHz	-36 dBm	-36 dBm
1 ≤f<12.75 GHz	-30 dBm	-30 dBm
	Exclusive Band near fc to be exempt	2013.4-2021.4 MHz

Freq. Range	WiFi ISM Band and Bluetooth (EIRP limit)
30 ≤f<1000 MHz	-36 dBm
1 ≤f<12.75 GHz	-30 dBm
1.8-1.9 GHz and 5.15-5.3 GHZ	-47 dBm

Basic ETSI RSE System Diagram

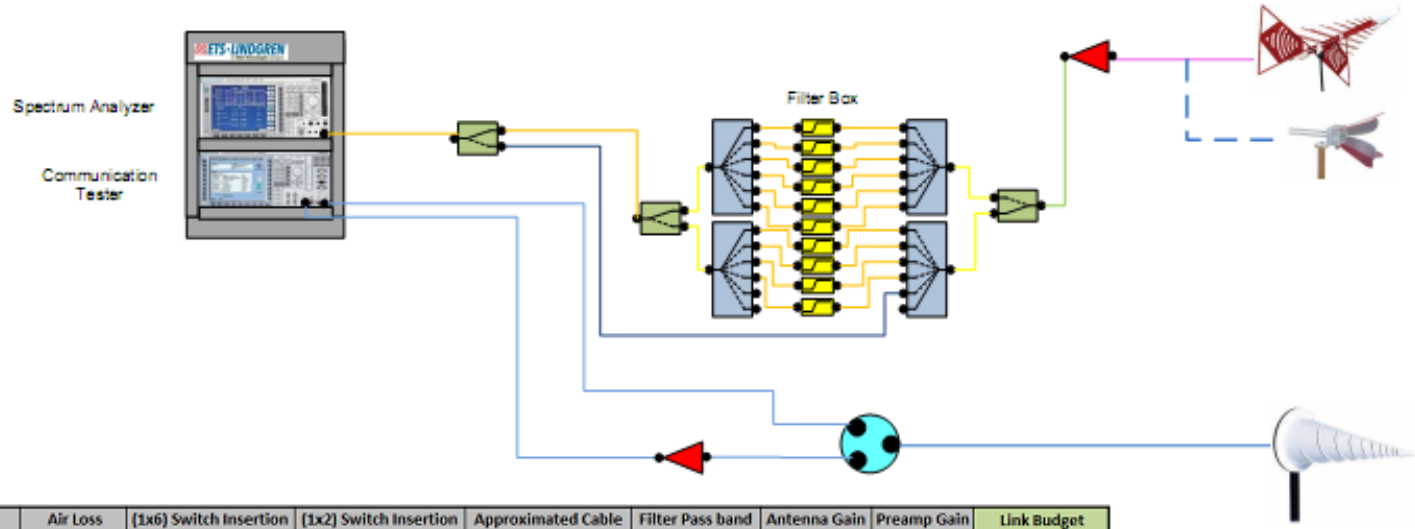
- 3D positioner for 3D measurement
- Notch Filter to remove fundamental carrier
- Preamp to increase dynamic range



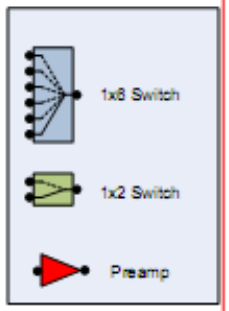
Filters for EMC and Wireless

Basic RSE System Diagram

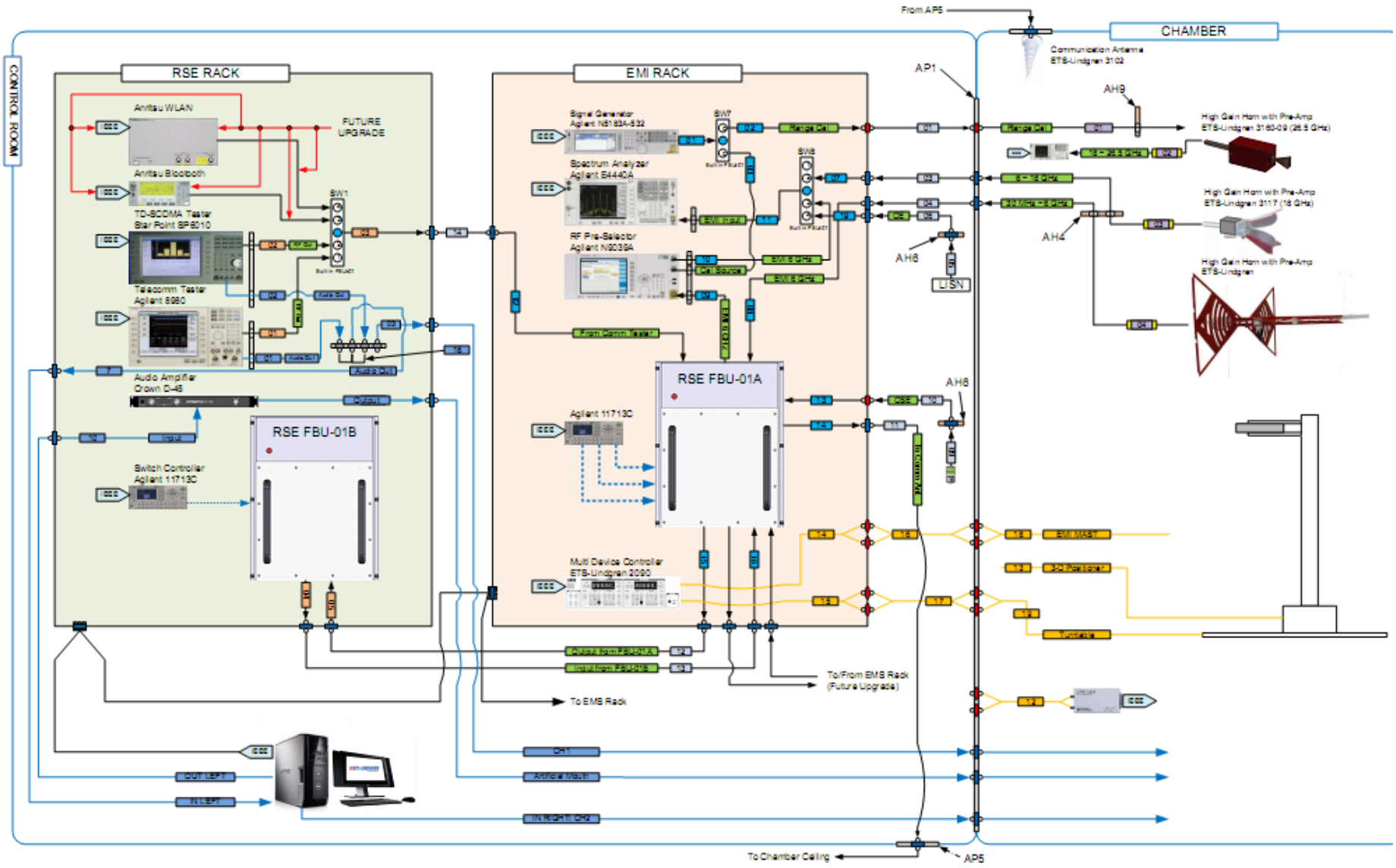
ETS·LINDGREN
An ESCO Technologies Company



Freq (MHz)	Air Loss (dB)	(1x6) Switch Insertion loss (dB) *2	(1x2) Switch Insertion loss (dB) *3	Approximated Cable loss (dB)	Filter Pass band Loss (dB)	Antenna Gain (dB)	Preamp Gain (dB)	Link Budget
30	11.52662237	0.36	0.25	7	0.5	2	47	28.50337763
100	21.98419728	0.36	0.25	7	0.5	2	47	18.04580272
500	35.96359737	0.36	0.25	7	0.5	5	47	7.066402633
1000	41.98419728	0.36	0.25	7	0.5	5	47	1.04580272
1500	45.50602246	0.36	0.25	7	0.5	5	47	-2.476022462
2000	48.00479719	0.36	0.25	7	0.5	7	47	-2.974797194
2500	49.94299745	0.36	0.25	7	0.5	7	47	-4.912997454
3000	51.52662237	0.36	0.25	7	0.5	7	47	-6.496622375
3500	52.86555817	0.36	0.25	7	0.5	7	47	-7.835558167
4000	54.02539711	0.36	0.25	7	0.5	8	47	-7.995397107
4500	55.04844756	0.36	0.25	7	0.5	8	47	-9.018447556
5000	55.96359737	0.36	0.25	7	0.5	10	47	-7.933597367
5500	56.79145107	0.36	0.25	7	0.5	10	47	-8.76145107
6000	57.54722229	0.36	0.25	7	0.5	10	47	-9.517222288



Drawn by: Faris Alhor
Date: Oct 14th, 2010



Typical Notch Filter

- Very sharp rejection band - 50dB rejections in 200kHz bandwidth
- To notch out the fundament which is strong enough to saturate receiver

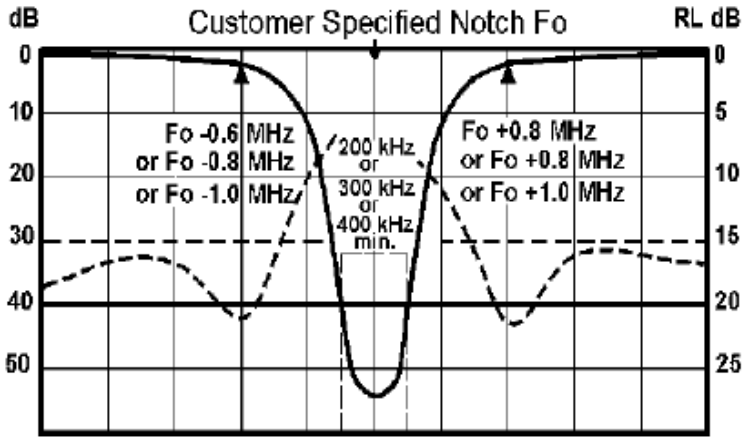
Wainwright Instruments GmbH

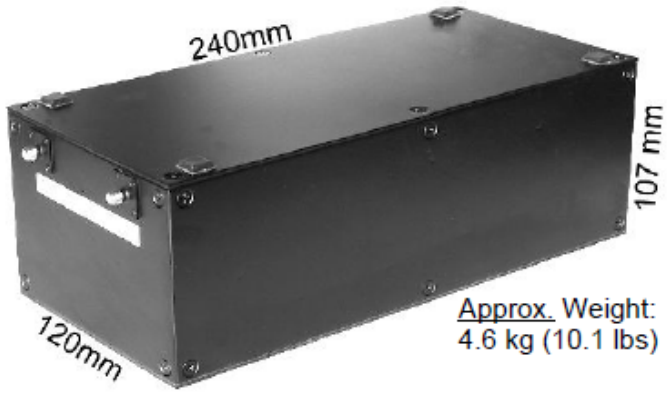
Widdersberger Str.14
82346 Andechs, Germany
Tel.: +49-8152-918230 Fax: +49-8152-918255
E-Mail: info@wainwright-filters.com
Internet: www.wainwright-filters.com

8 Resonator
Ultra Stable Cavity Design
WRCT Series

Notch Filter *(Fixed Frequency)*
with customer specified Notch Fo between 800 & 960 MHz

Model Number to be specified
(see below)

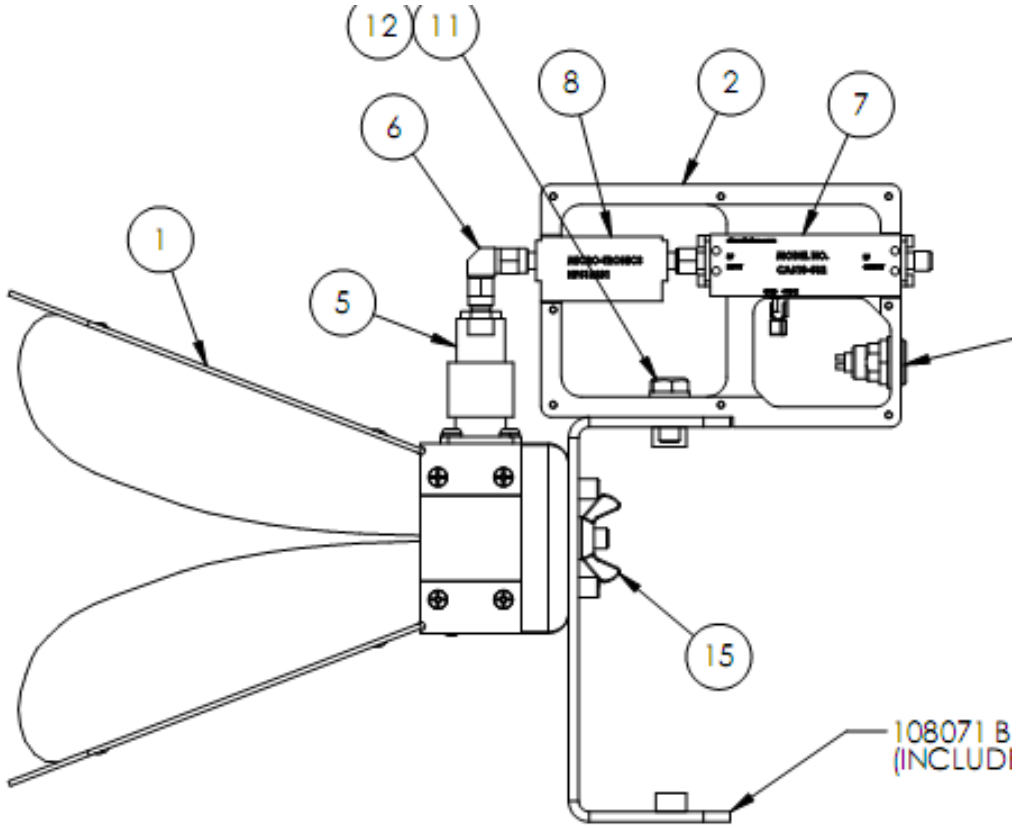




Approx. Weight:
4.6 kg (10.1 lbs)

Filters for EMC

EMC Solution for 2.7GHz or 6 GHz to 18 GHz

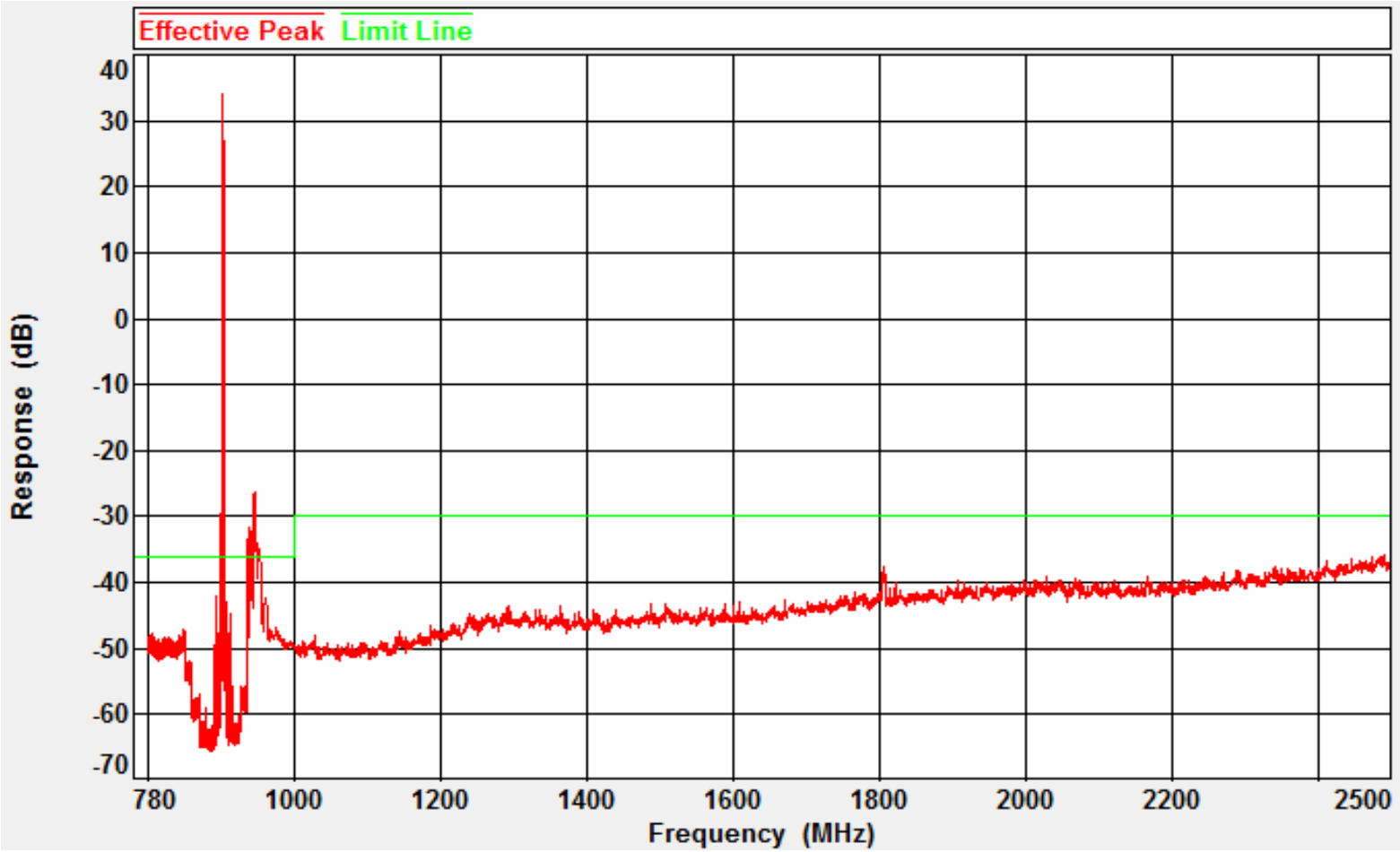


HPF filter used in series with Pre amplifier

Protects preamp from overload.

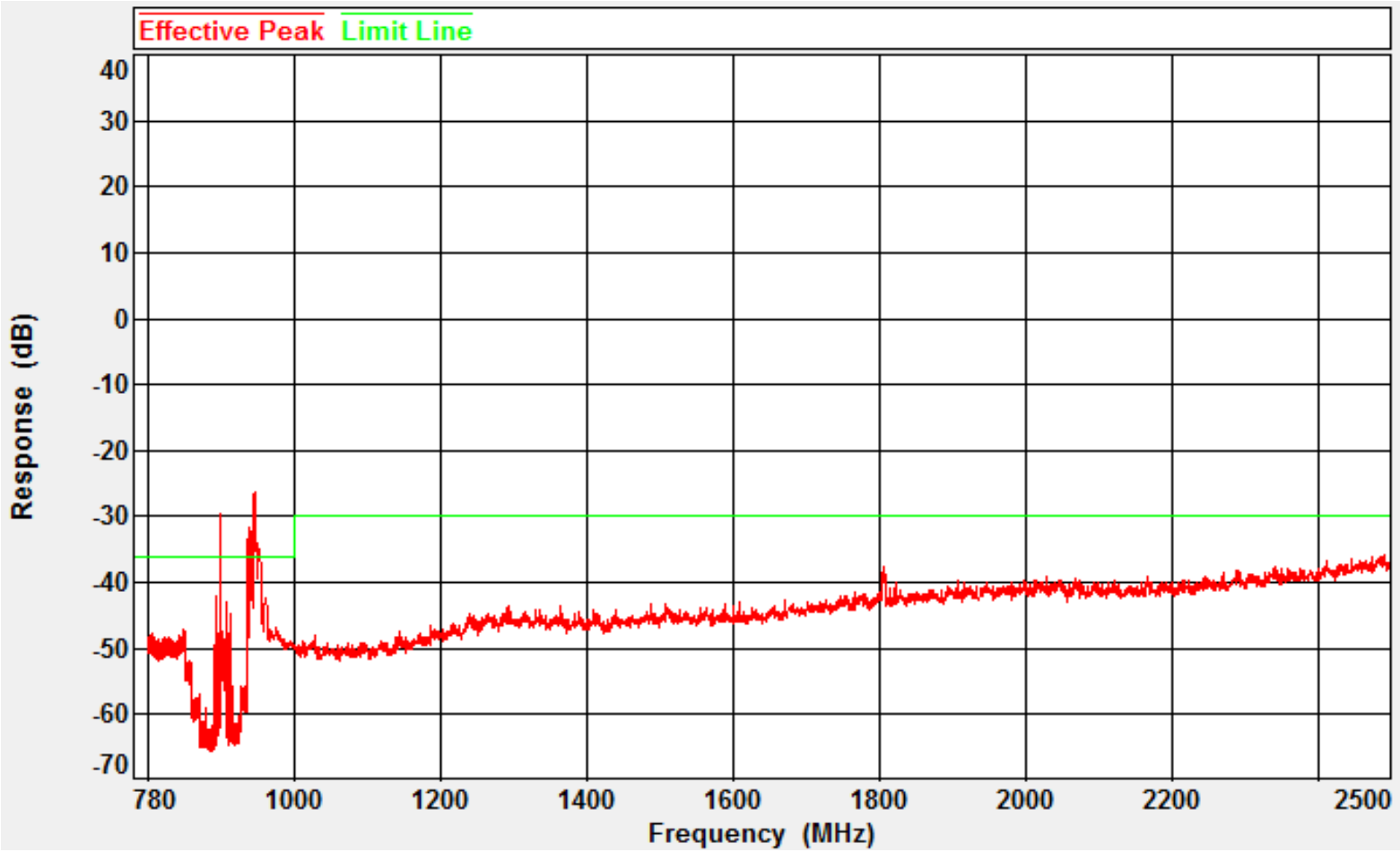
Measured Graph

- Limit line for GSM900 steps at 1GHz
- Fundamental TX carrier is strong.



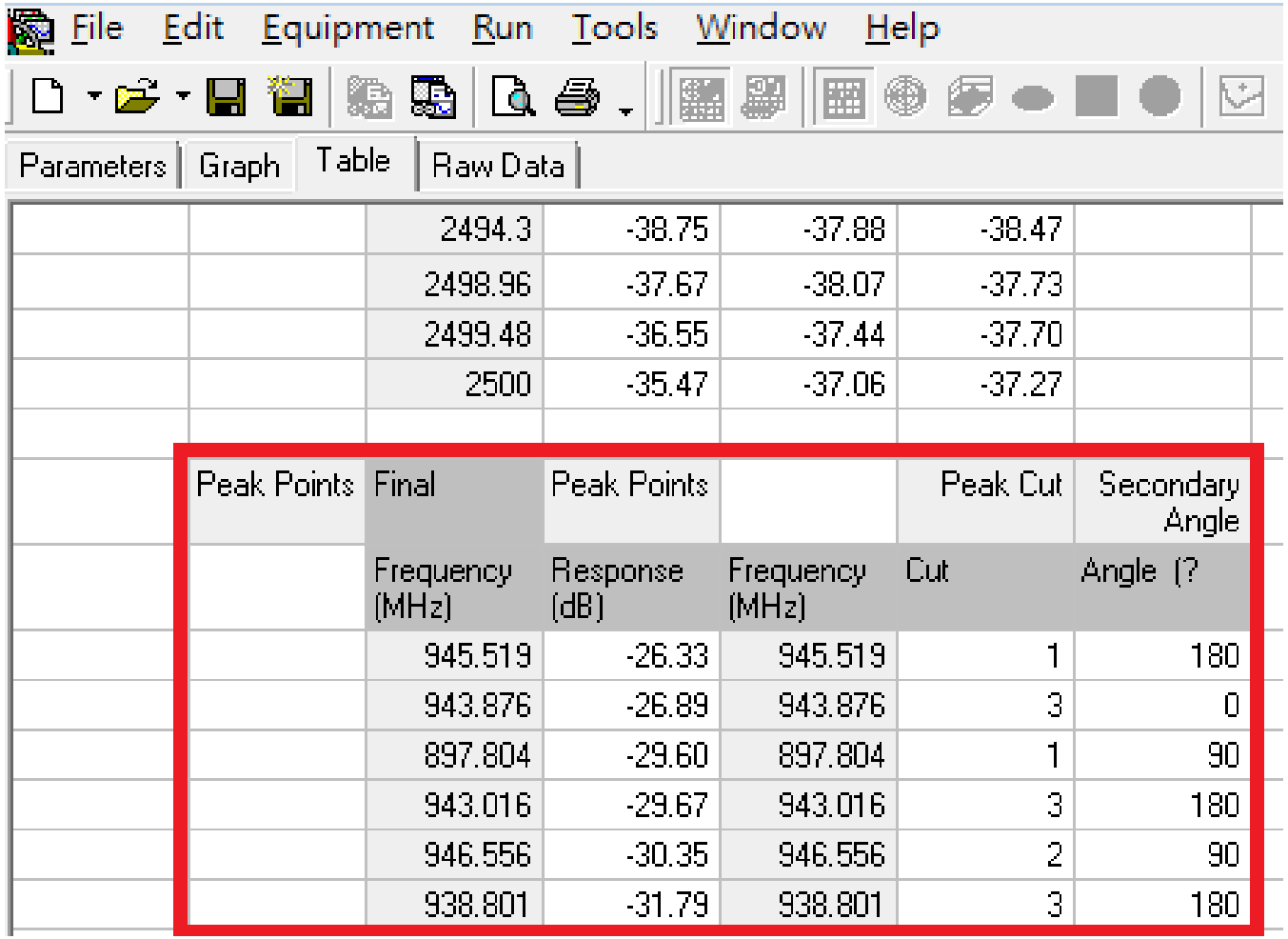
Exclusion Band

- The fundament of 902.4MHz is taken out by the BW of 3.6MHz.



Table

- Table picks up peaks.



		2494.3	-38.75	-37.88	-38.47	
		2498.96	-37.67	-38.07	-37.73	
		2499.48	-36.55	-37.44	-37.70	
		2500	-35.47	-37.06	-37.27	

Peak Points	Final	Peak Points		Peak Cut	Secondary Angle
	Frequency (MHz)	Response (dB)	Frequency (MHz)	Cut	Angle (?
	945.519	-26.33	945.519	1	180
	943.876	-26.89	943.876	3	0
	897.804	-29.60	897.804	1	90
	943.016	-29.67	943.016	3	180
	946.556	-30.35	946.556	2	90
	938.801	-31.79	938.801	3	180

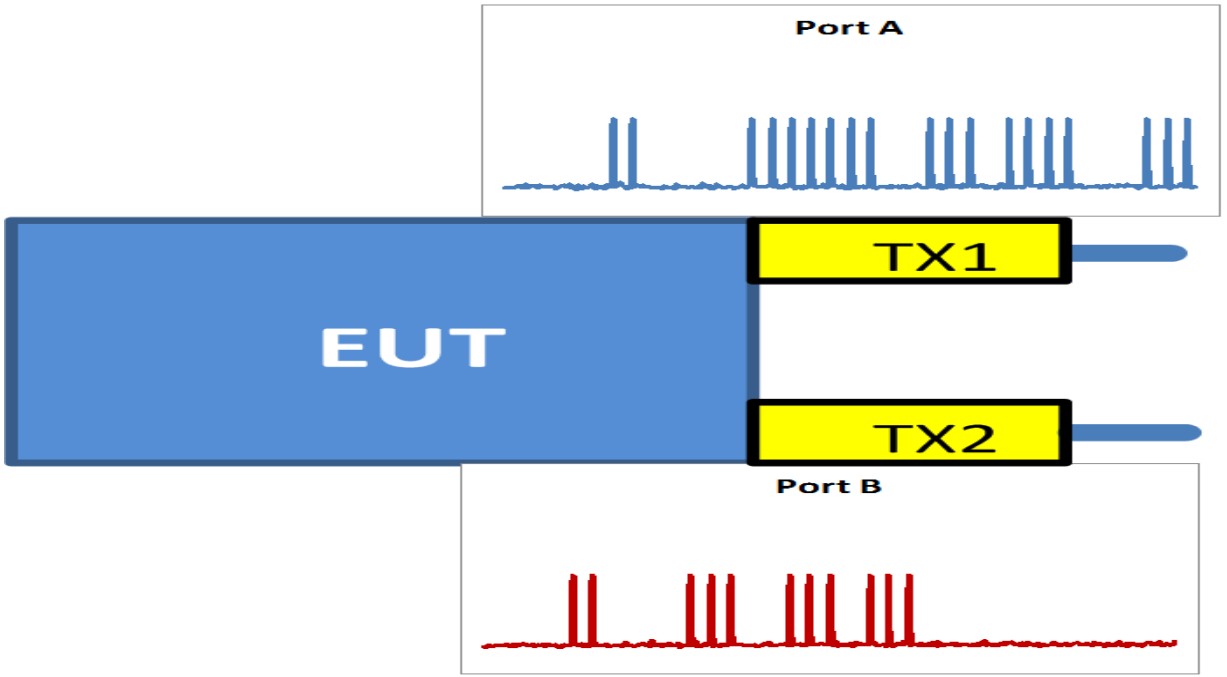
ETSI 300 328 and 301 893

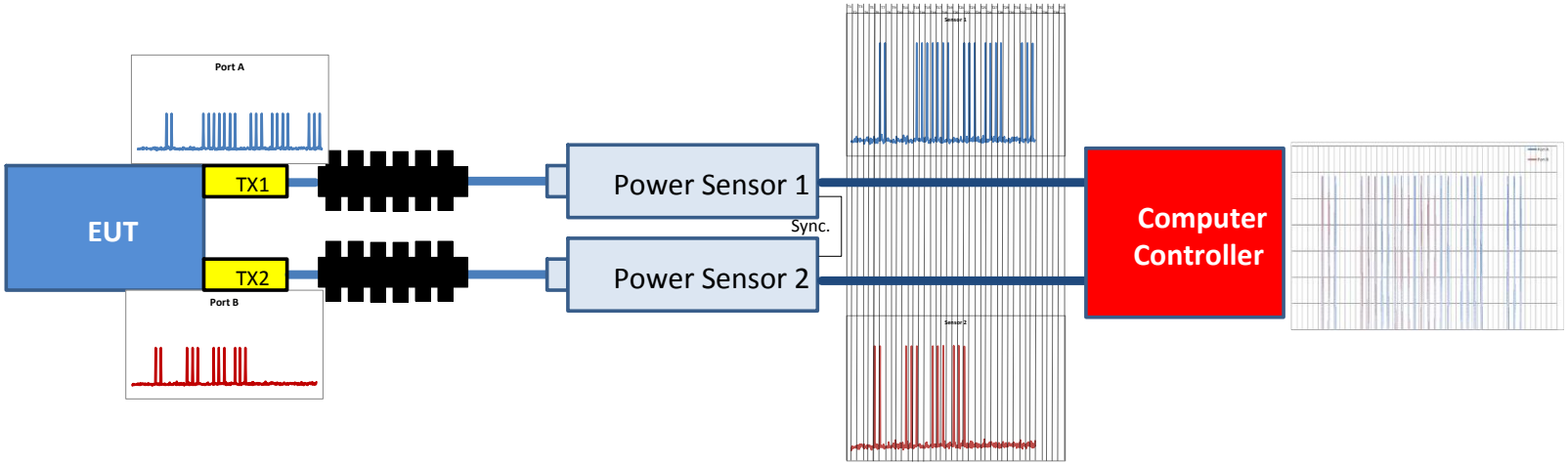
- **RF Output Power Measurement**
  - Consideration for MIMO (Multiple Input Multiple Output) devices are added.
  - Special burst power sensor is required to perform the test
  - Requires store a lot of data that is later post processed to get the output power

ETSI 300 328 and ETSI 301 893 Requirements

The ETSI standard defines simultaneously to be a minimum of 1 Mega-Samples per second (MS/s).

This requires the measurement system to be triggered "simultaneously" and acquire data every 1 µsec.





The multiple sensor measurements are combined in accordance with ETSI 300 328 and ETSI 301 893 The start and stop times of the individual burst must be recorded in order to determine the Power over the burst using the formula shown in the standard.

$$P_{burst} = \frac{1}{k}\sum_{n=1}^{k} F\,sample\,(n)$$

Legend:
P_{burst} = $Power_{rms}$ level burst
k = total number of samples
n = sample number

What are we measuring?

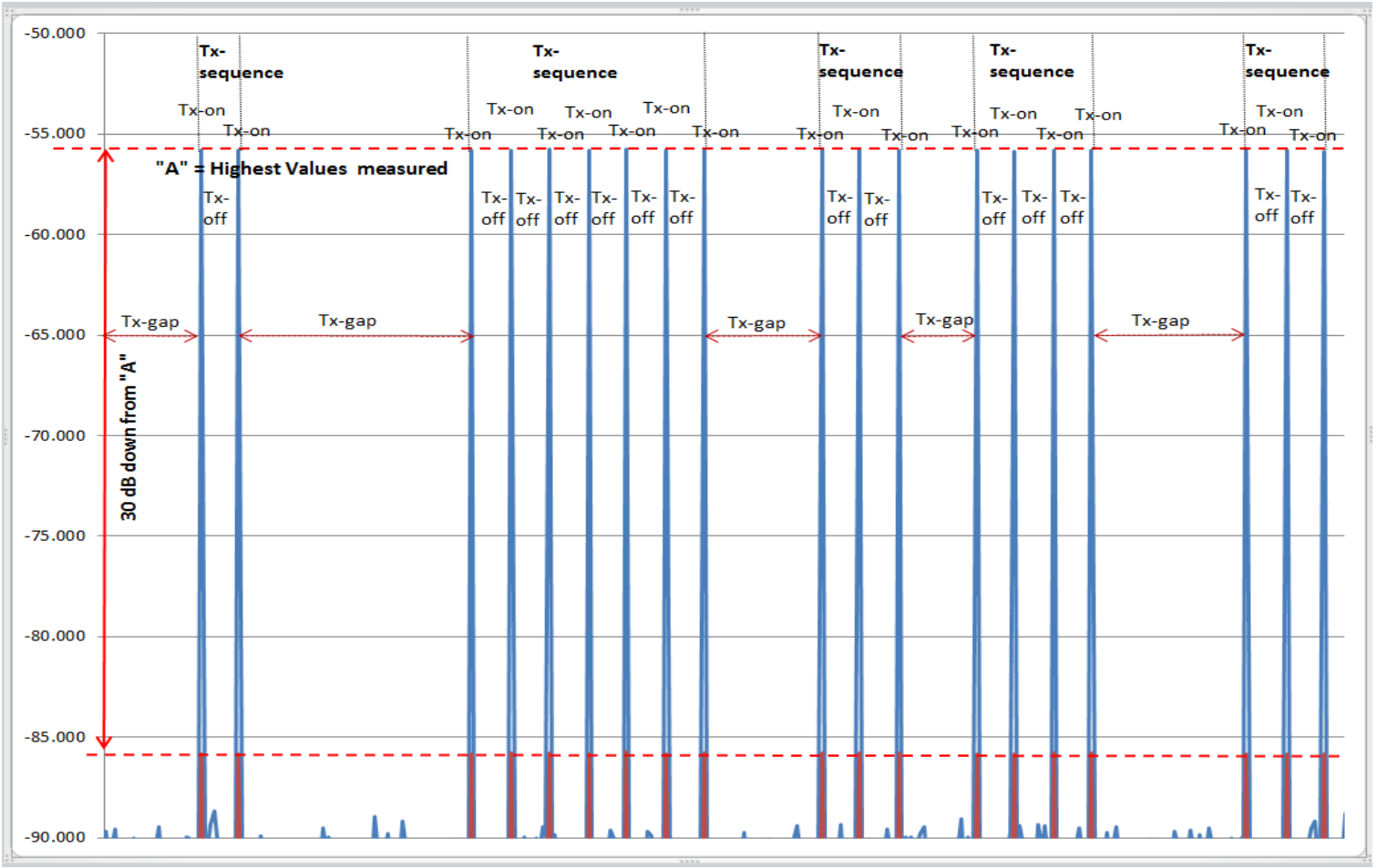
Transmit-on (**Tx-on**) is where the device is transmitting

Transmitter-off (**Tx-off**) is where the transmitter is not transmitting and the Tx-off time is less than the minimum transmit gap characteristics

Transmit gap (Tx-gap) is defined by the manufacturer depending on the product application with guidance provided by the standard

Transmit sequence (**Tx-sequence**) is defined the period where a single or multiple transmissions occur. The Tx-sequence follows a Tx-gap

Measurement Example - combined



What we Calculate?

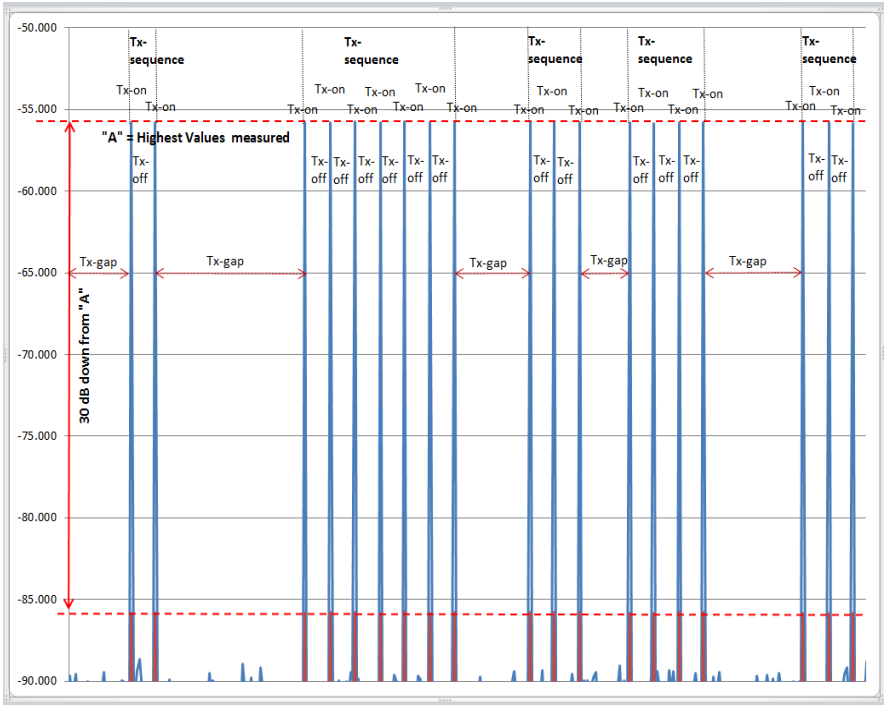
RF Power

$$Power\ (e.i.r.p.) = A(Power\ Burst\ Levels) + G\ (Antenna\ Gain) + Y\ (Antenna\ Beamforming\ Gain)$$

What we Calculate?

Duty Cycle

Is the sum of all Tx-On times between the end of first gap and the start of the last burst divided by the observation period.



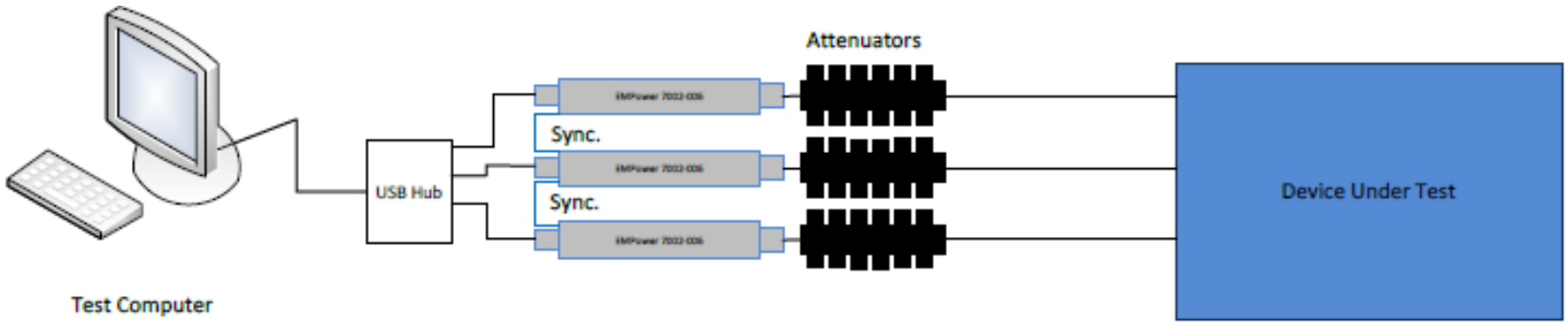
What we Calculate?

Medium Utilization

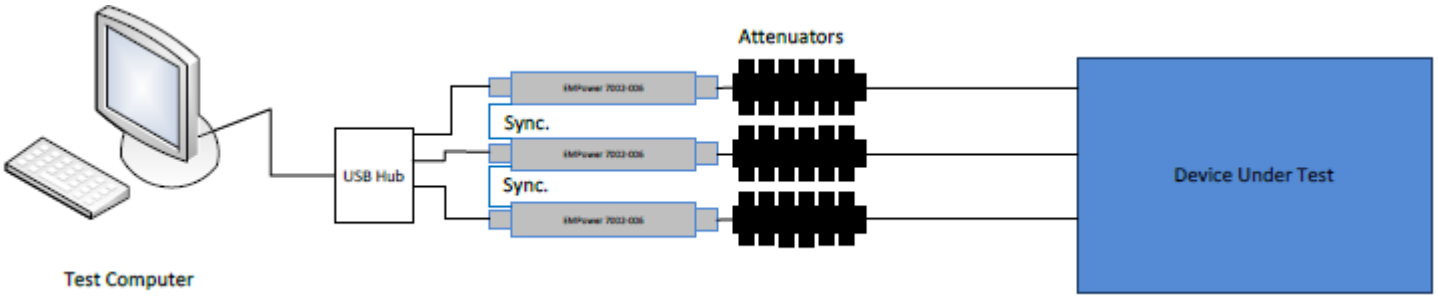
The goal here is to ensure equal access to the spectrum

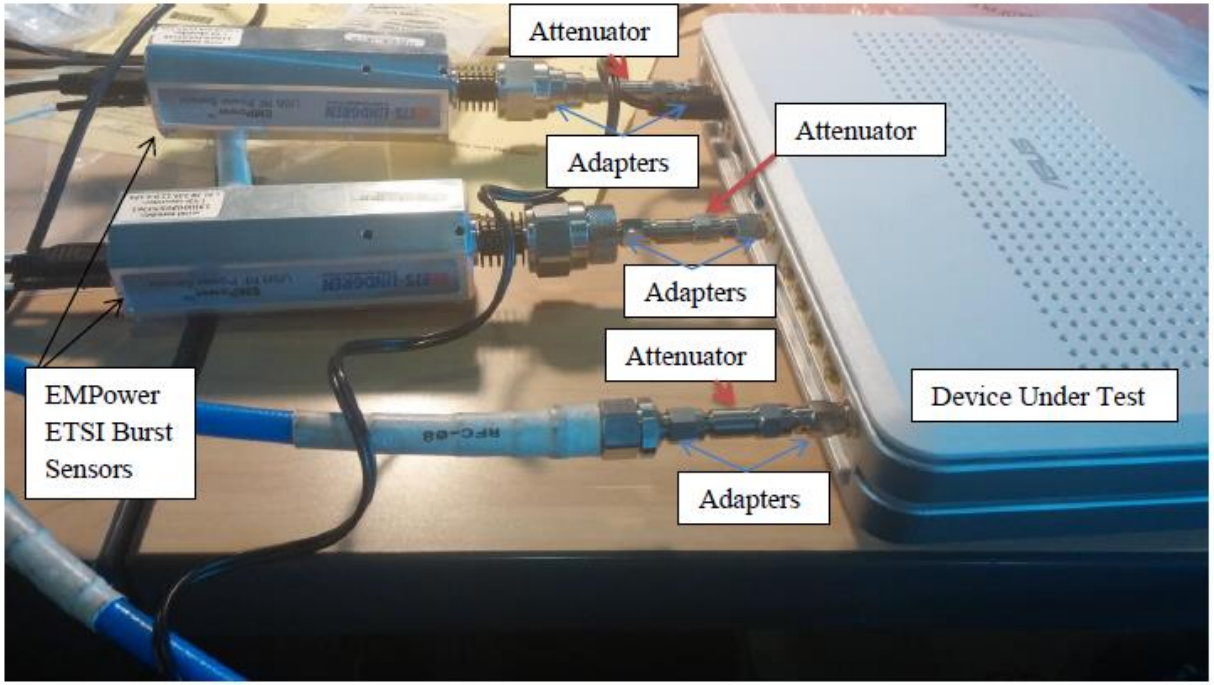
$$Medium\ Utilization = \left(\frac{\text{RF Power } (mW)}{100(mW)}\right) * Duty\ Cycle$$

Test Configuration Overview



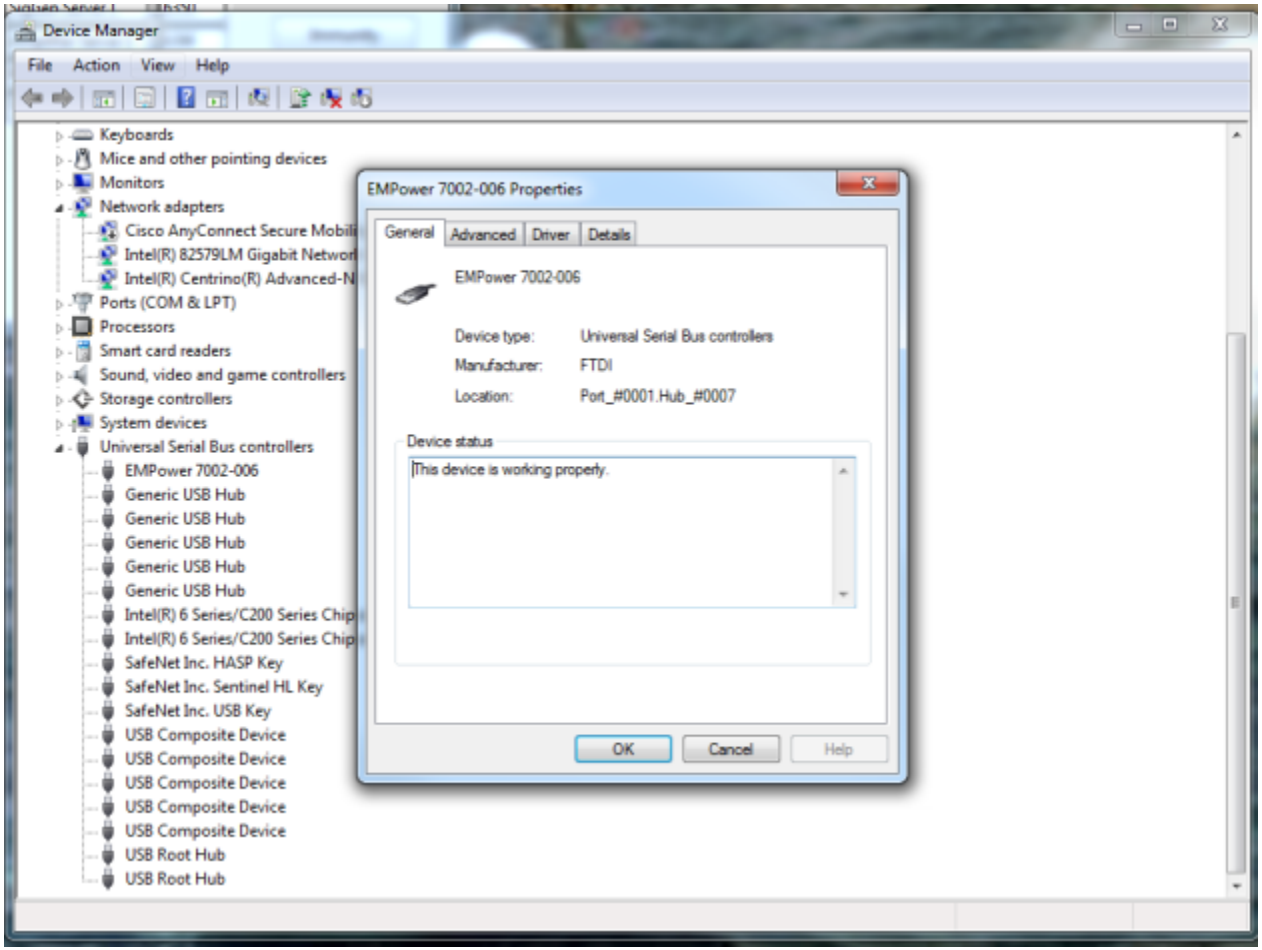
Configuration Overview



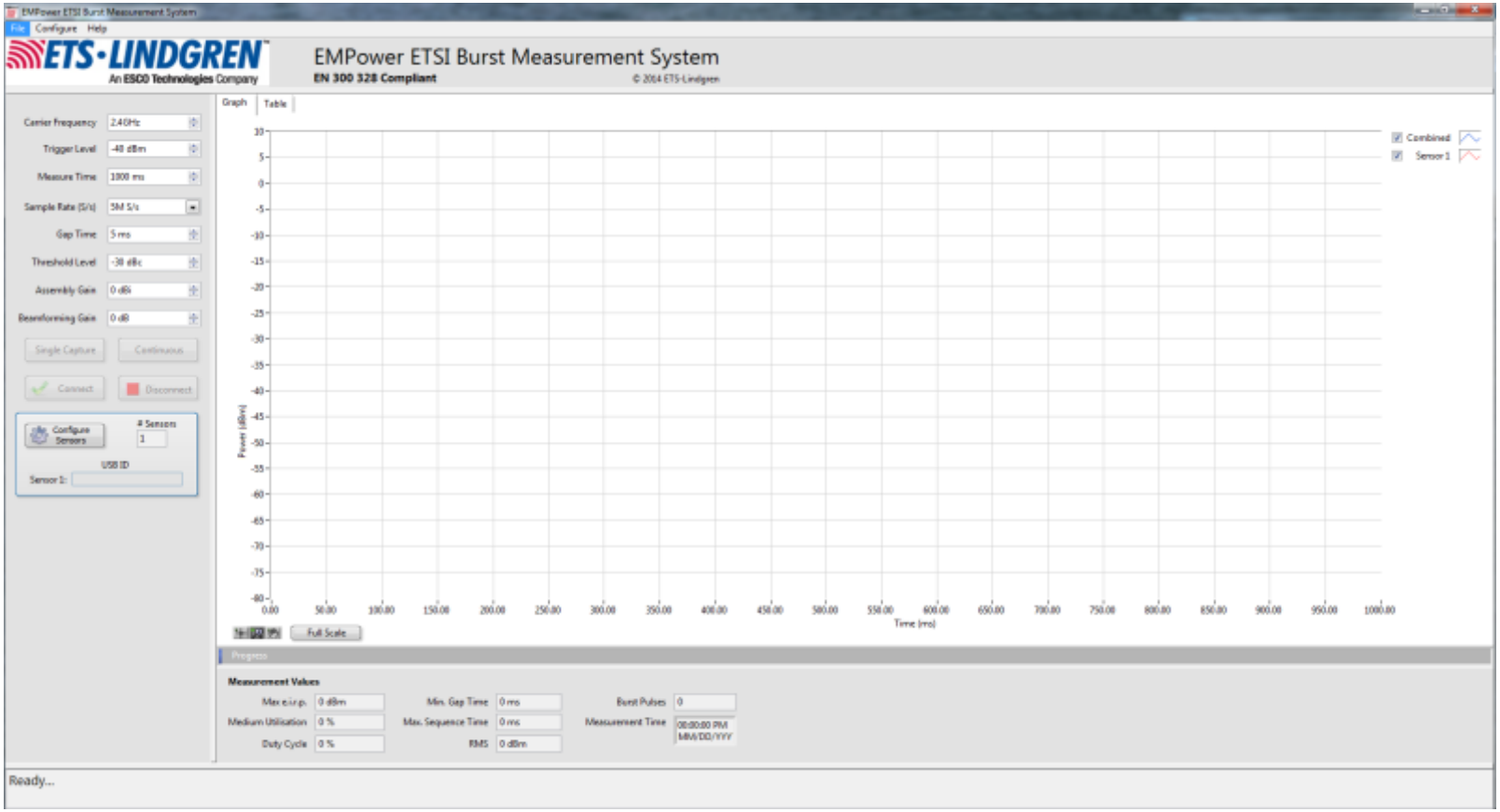


Configuration Sensor Connections

Configuration Sensor Connections



Software



QUESTIONS