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Radiated Spurious Emission Testing

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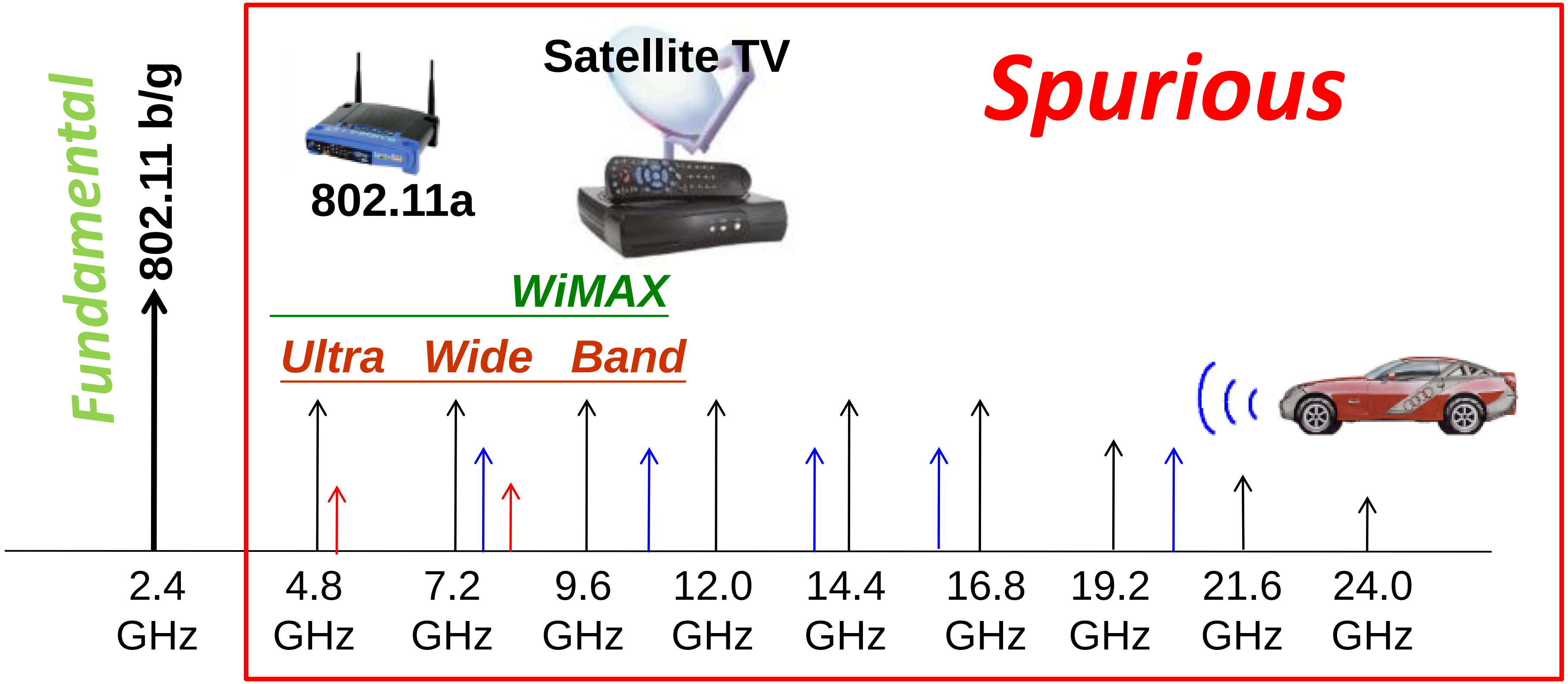
What is RSE?

- RSE = radiated spurious emission

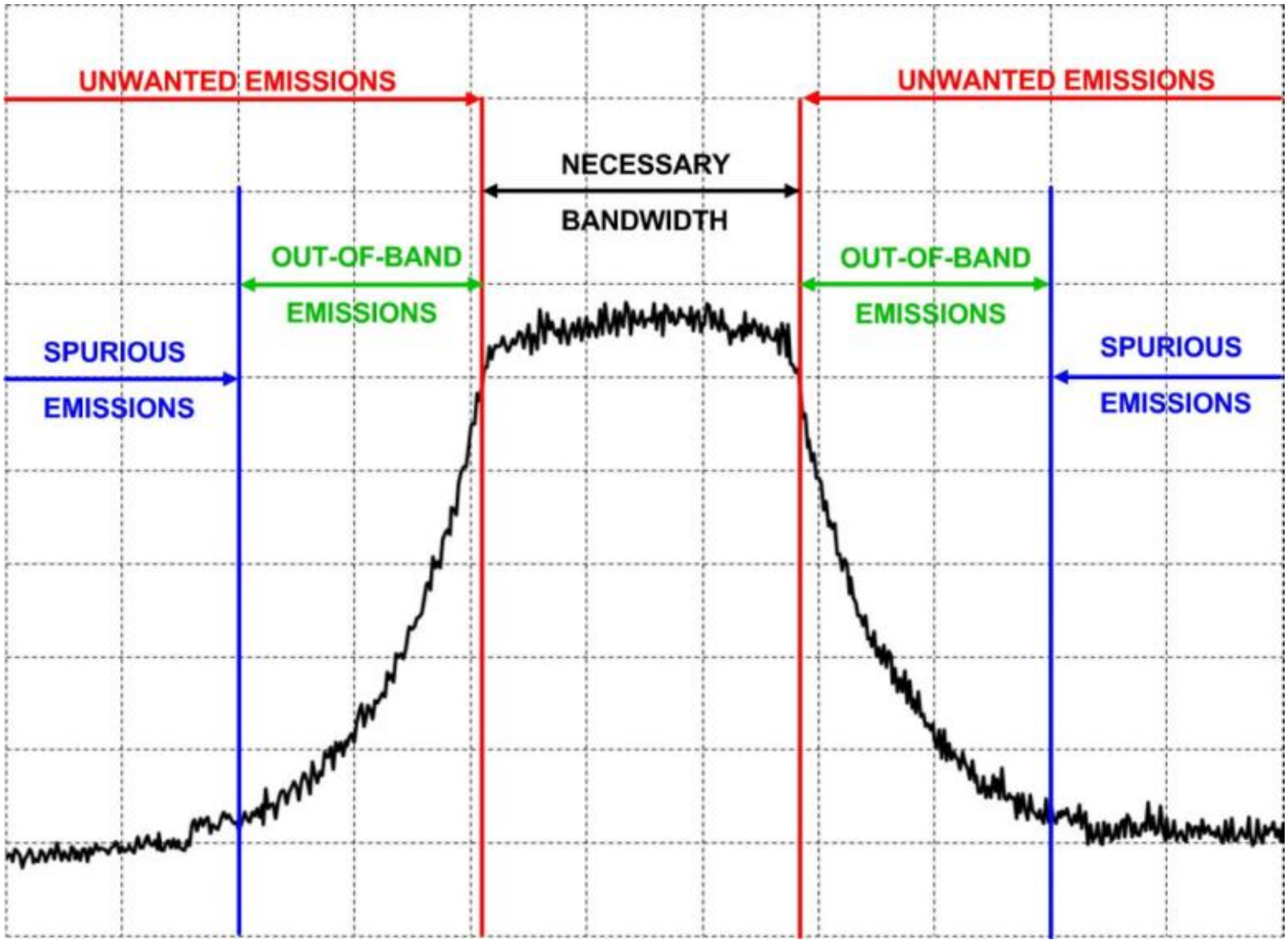
- Radiated → chamber
- Emission → EMI
- Spurious → intentional radiator

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.

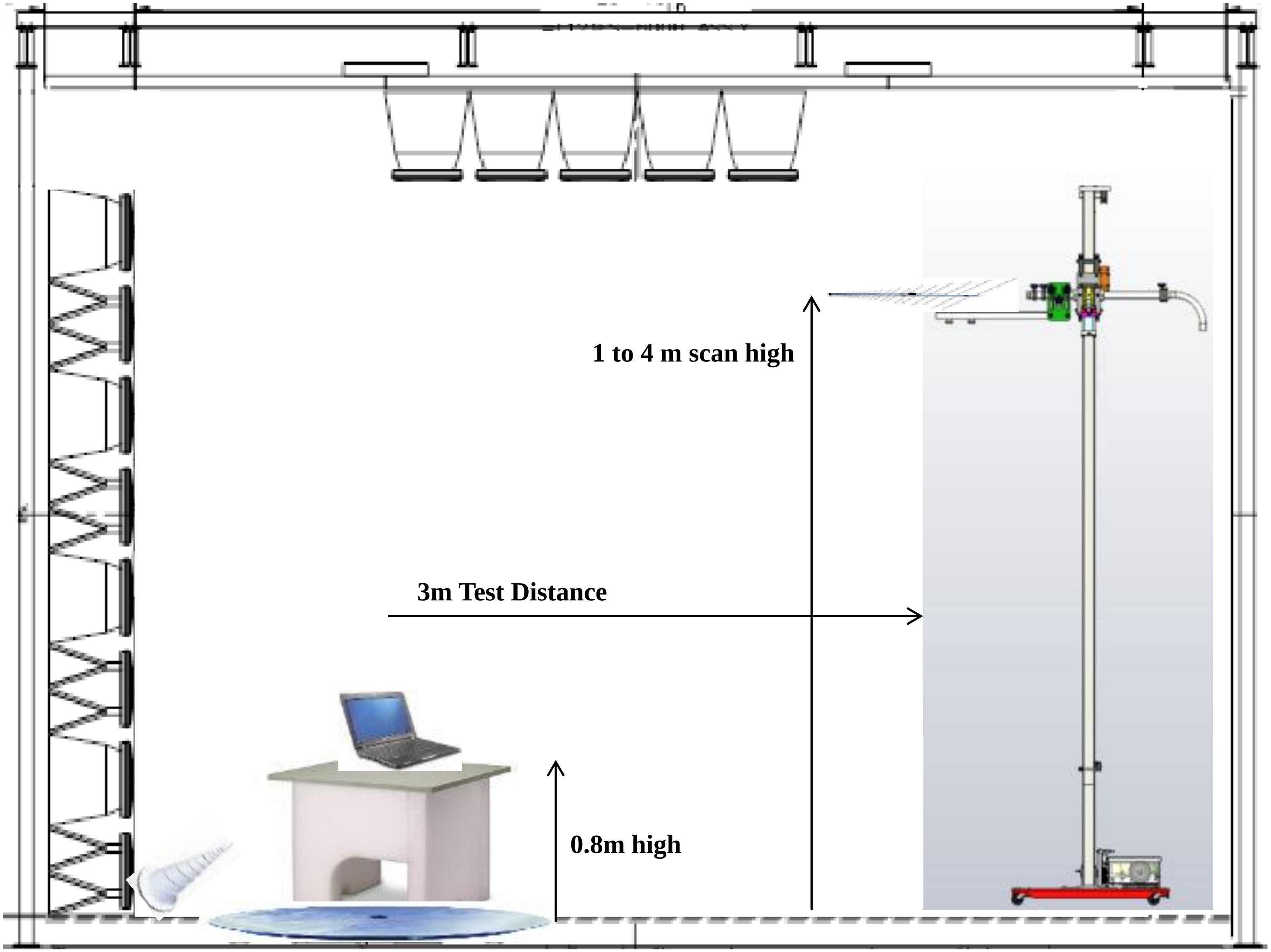
- In spurious emission measurements, the peak detector takes the place of the QP detector.

- All these differences make it necessary that for spurious emission measurements a spectrum analyzer or test receiver with spectrum analyzer functionality to be used rather than a pure EMC test receiver

Typical RSE Standards

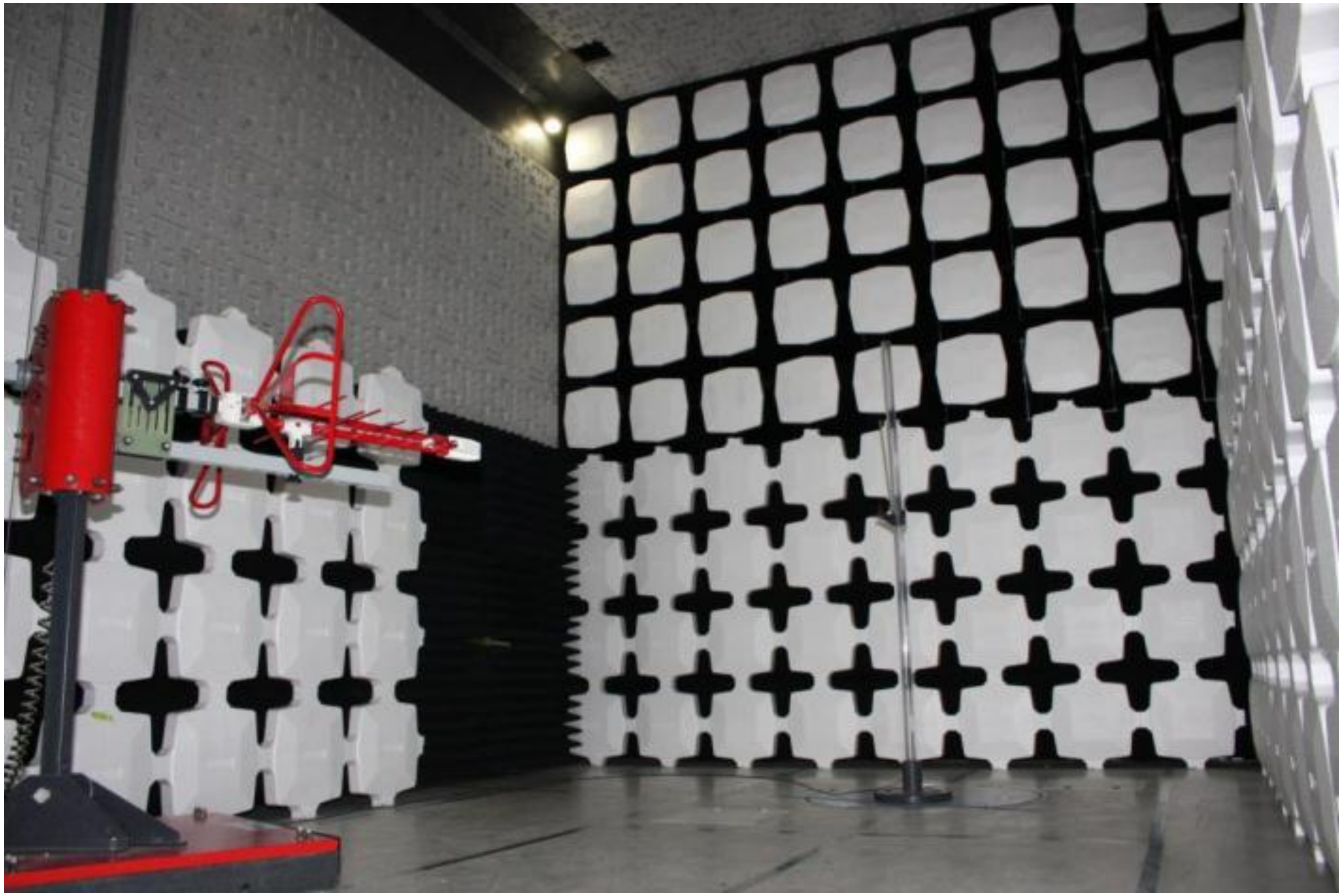
- FCC 15C/22/24/ (90)
  - Per 2.2.12 and 2.2.17 of TIA-603-C/D
- 3GPP standards define RSE for cellular technologies, such as 3GPP.51.010 for GSM (same std as EN 400 367-1)
  http://pda.etsi.org/pda/home.asp?wkr=RTS/TSGG-0351010-1v940
- ETSI EN 300 328 defines RSE for 2.4 GHz ISM band using spread spectrum modulation, up to 24 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
  - This implies EIRP measurement
    - → EIRP not function of test distance
    - → So, substitution calibration is required

Semi Anechoic Chamber



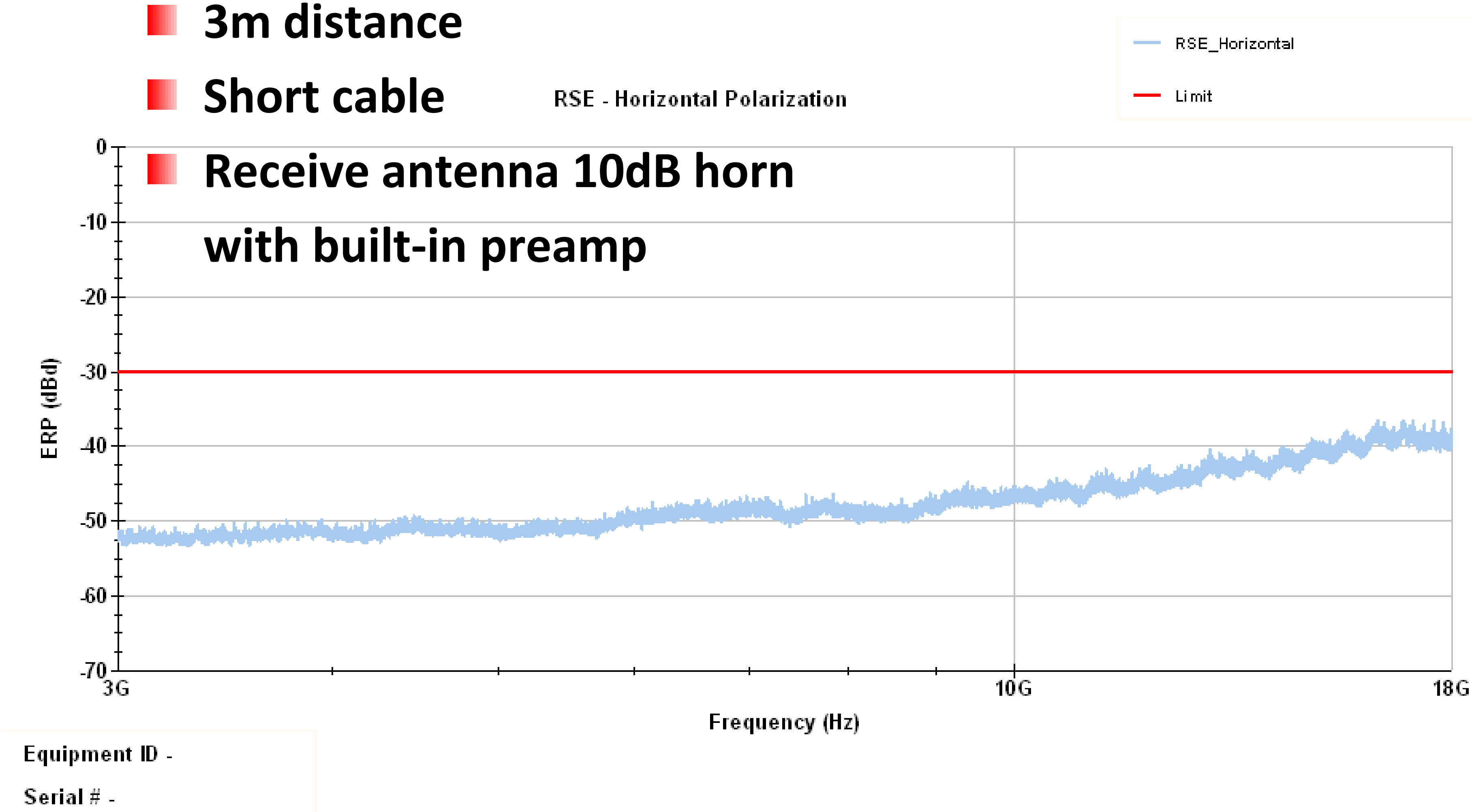
FCC Chamber

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.



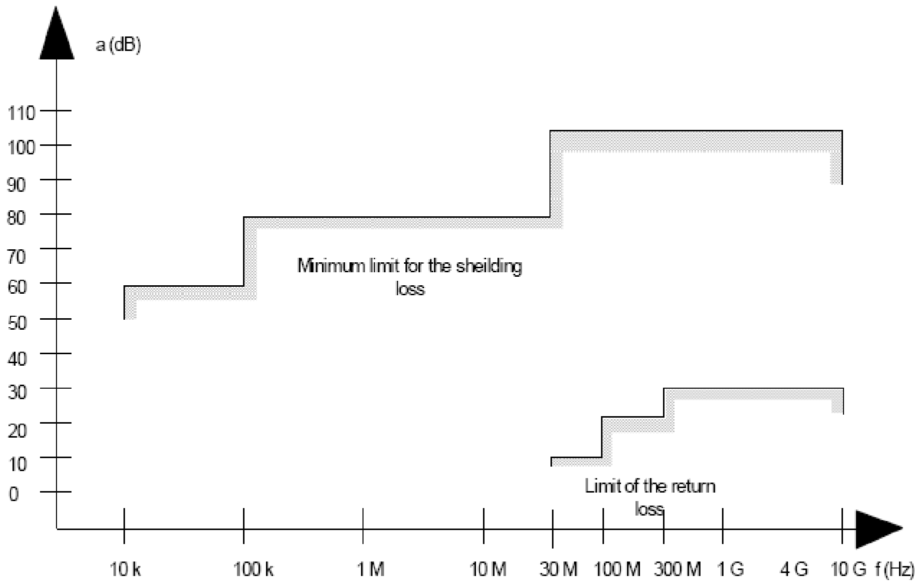
Noise Floor in FCC 3 meter chamber

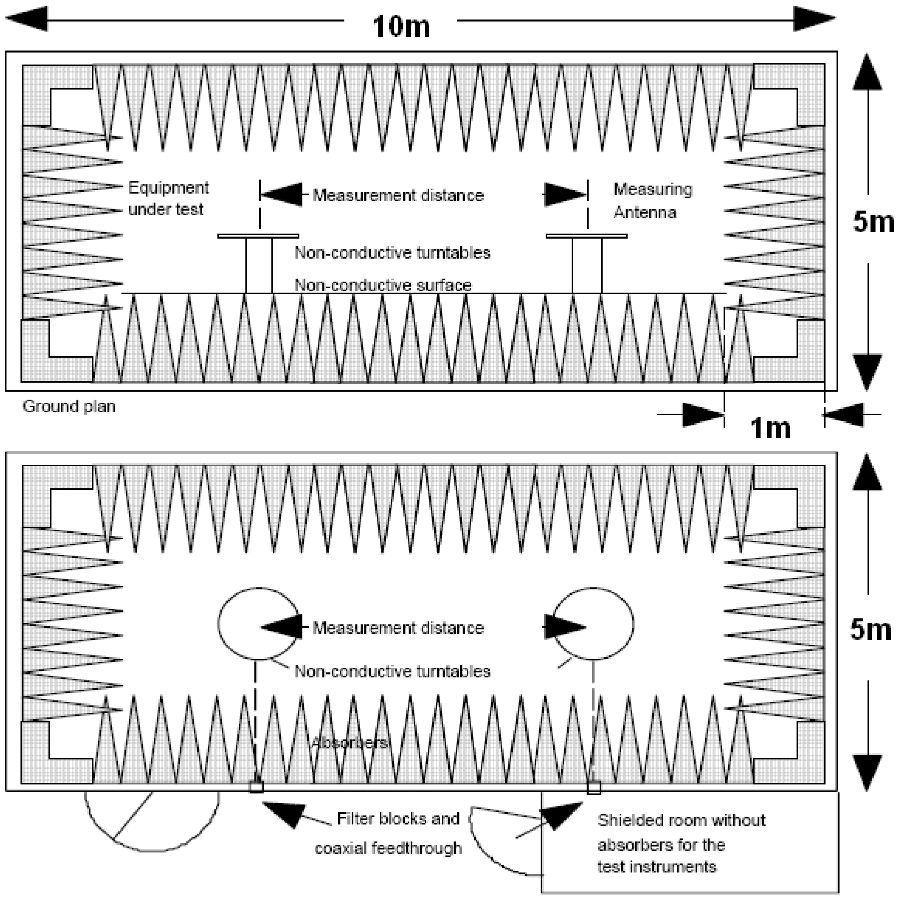
- 3m distance
- Short cable
- Receive antenna 10dB horn with built-in preamp



ETSI Chamber

The above mentioned standards (ETSI 300-328, ETSI 300-440) clearly define the *Reflectivity* of absorber and chamber size, not chamber performance.





ETSI Chamber

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

<table>
<tr><th rowspan="2">Rules FCC</th><th colspan="4">Frequency /Resolution Bandwidth</th><th rowspan="2">Power Limit (Ave.)</th></tr>
<tr><th>Freq (MHz)</th><th>RBW</th><th>Freq (MHz)</th><th>RBW</th></tr>
<tr><td>22.917 (850)</td><td rowspan="2">f_{low} - 1MHz < f < f_{low} & f_{up} < f < f_{up} + 1MHz;</td><td rowspan="2">≥1% of BW</td><td rowspan="2">$f \le f_{low}$ - 1MHz & $f \ge f_{up}$ + 1MHz</td><td>≥100 kHz</td><td rowspan="2">-13 dBm</td></tr>
<tr><td>24.238 (PCS) ; 27.53(g) (AWS)</td><td>≥1M Hz</td></tr>
</table>

FCC Spurious Testing, Handset Example

- 1. Connect the equipment with the EUT's antenna in a horizontal orientation.
  - 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.
- 2. 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!
- 3. Set the spectrum analyzer to measure peak hold.
- 4. Place the measurement antenna in a horizontal orientation. Raise the measurement from 1m up to 4 meters in steps and rotate the EUT 360 degrees at each height to maximize all emissions. Measure and record all spurious emissions (LVL) up to the tenth harmonic of the carrier frequency.
- 5. Replace the EUT with a horizontally polarized half wave dipole or known gain antenna. The center of the antenna should be at the same location as the center of the EUT's antenna.
  - Step is typically performed prior to testing and LOSS is recorded by test software

FCC Spurious Testing, Handset Example

- 6. Connect the 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).
  - Step is typically performed prior to testing and LOSS is recorded by test software
- 7. Determine the level of spurious emissions using the following equation: Spurious (dBm) = LVL (dBm) + LOSS (dB):
- 8. Repeat steps 4, 5 and 6 with all antennas vertically polarized.
- 9. Measurements are to be performed with the EUT set to the low, middle and high channel of each frequency band.

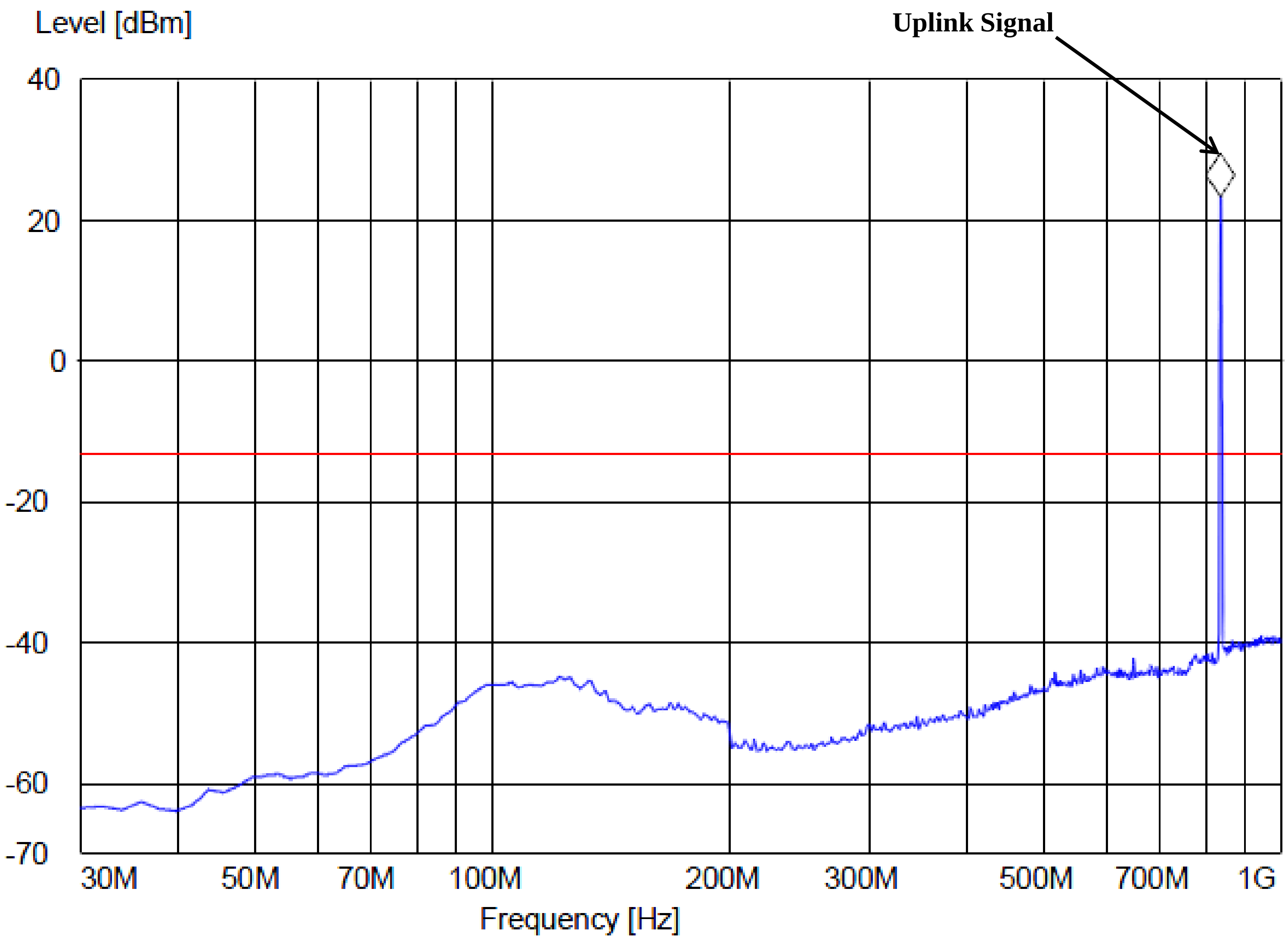
FCC 22.917 Emission limitations for cellular equipment

- The rules in this section govern the spectral characteristics of emissions in the Cellular Radiotelephone Service.
- (a) *Out of band emissions*. The power of any emission outside of the authorized operating frequency ranges must be attenuated below the transmitting power (P) by a factor of at least 43 + 10 log(P) dB.
- (b) *Measurement procedure.* Compliance with these provisions is based on the use of measurement instrumentation employing a resolution bandwidth of 100 kHz or greater. In the 1 MHz bands immediately outside and adjacent to the frequency block a resolution bandwidth of at least one percent of the emission bandwidth of the fundamental emission of the transmitter may be employed. A narrower resolution bandwidth is permitted in all cases to improve measurement accuracy provided the measured power is integrated over the full required measurement bandwidth (*i.e.* 100 kHz of 1 percent of emission bandwidth, as specified). The emission bandwidth is defined as the width of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, outside of which all emissions are attenuated at least 26 dB below the transmitter power.

FCC 24.238 Emission limitations for Broadband PCS equipment.

- The rules in this section govern the spectral characteristics of emissions in the Broadband Personal Communications Service.
- (a) *Out of band emissions*. The power of any emission outside of the authorized operating frequency ranges must be attenuated below the transmitting power (P) by a factor of at least 43 + 10 log(P) dB.
- *(b) Measurement procedure.* Compliance with these provisions is based on the use of measurement instrumentation employing a resolution bandwidth of 1 MHz or greater. However, in the 1 MHz bands immediately outside and adjacent to the frequency block a resolution bandwidth of at least one percent of the emission bandwidth of the fundamental emission of the transmitter may be employed. A narrower resolution bandwidth is permitted in all cases to improve measurement accuracy provided the measured power is integrated over the full required measurement bandwidth (*i.e.* 100 kHz of 1 percent of emission bandwidth, as specified). The emission bandwidth is defined as the width of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, outside of which all emissions are attenuated at least 26 dB below the transmitter power.

Example of FCC Spurious Test



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

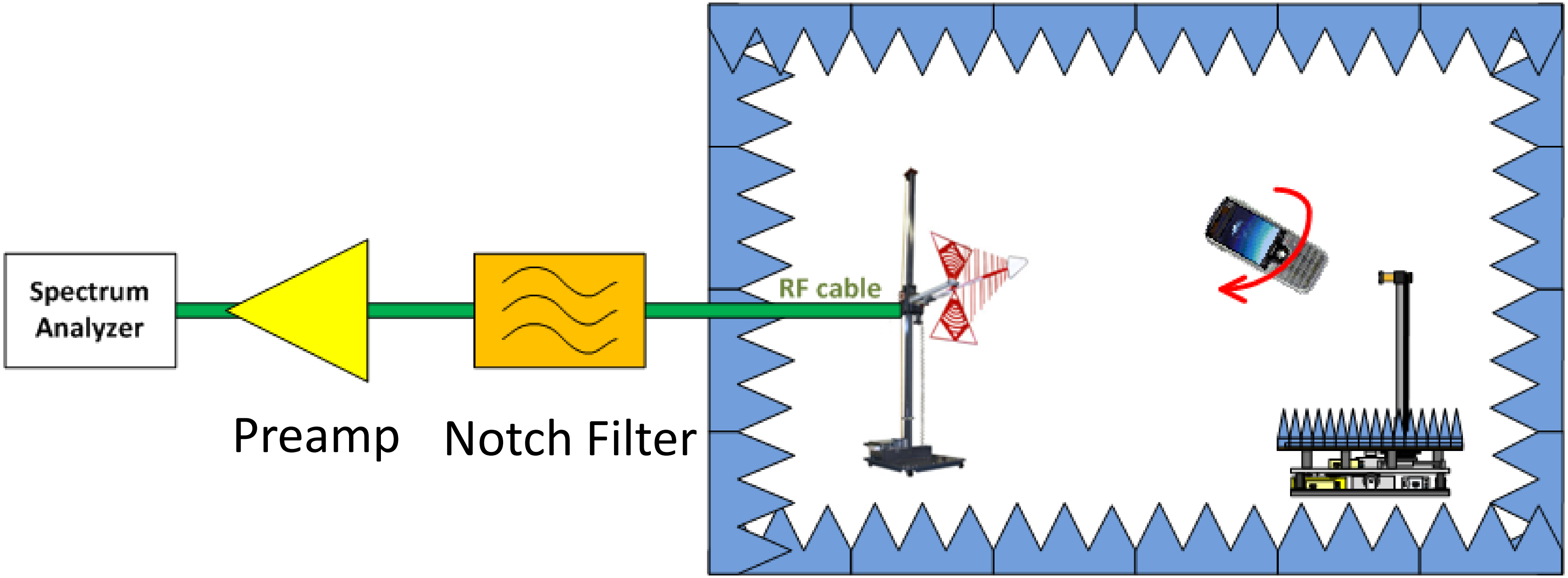
Freq. Range	CDMA (Cell and PCS Bands)
30 ≤f<1000 MHz	-36 dBm
1 ≤f<12.75 GHz	-30 dBm
Exclusive Band near fc to be exempt	

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 Wireless

- **Compliant EMC Solution**
  - For Measurement of the radiation and sensitivity of wireless devices under different signal protocols and frequency.
  - Main carrier frequencies used are:
  - 800MHz, 900MHz, 1.2GHz, 2.4GHz ....
  - When measuring broadband responses these carrier frequencies need to be included in the measurement path.
- **Pre Compliant MAPS Solution**
  - Pre compliant solution (above 200/700 MHz only)
  - Upper frequencies only

Filters for EMC and Wireless

Basic RSE System Diagram

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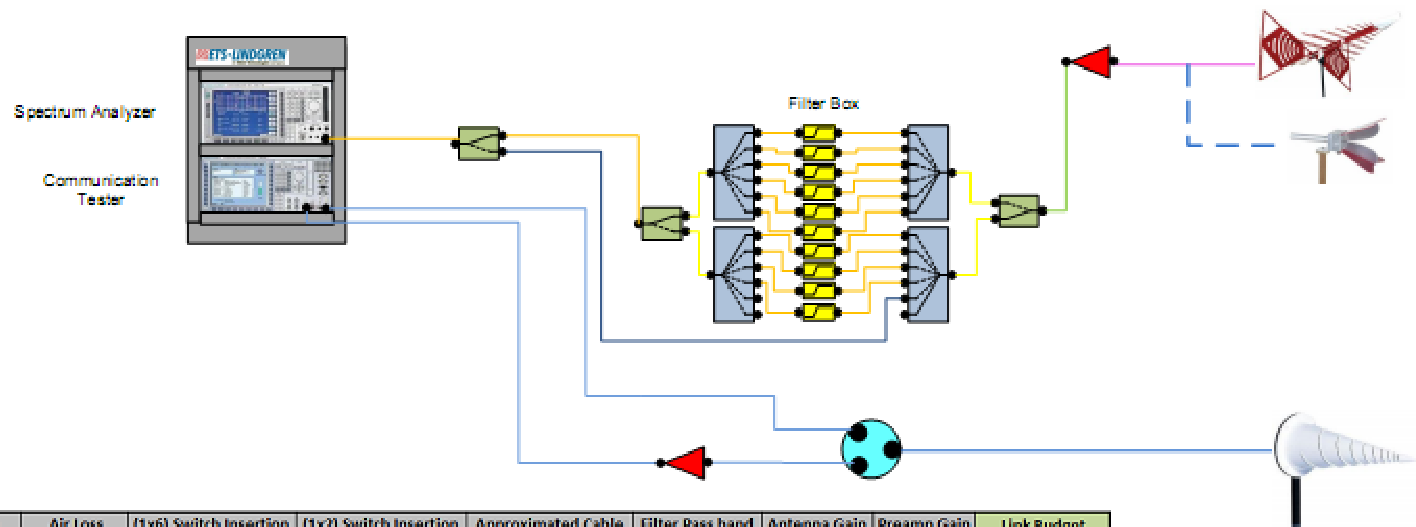
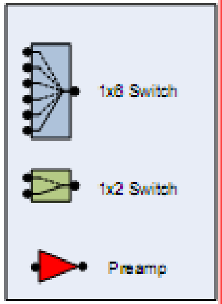
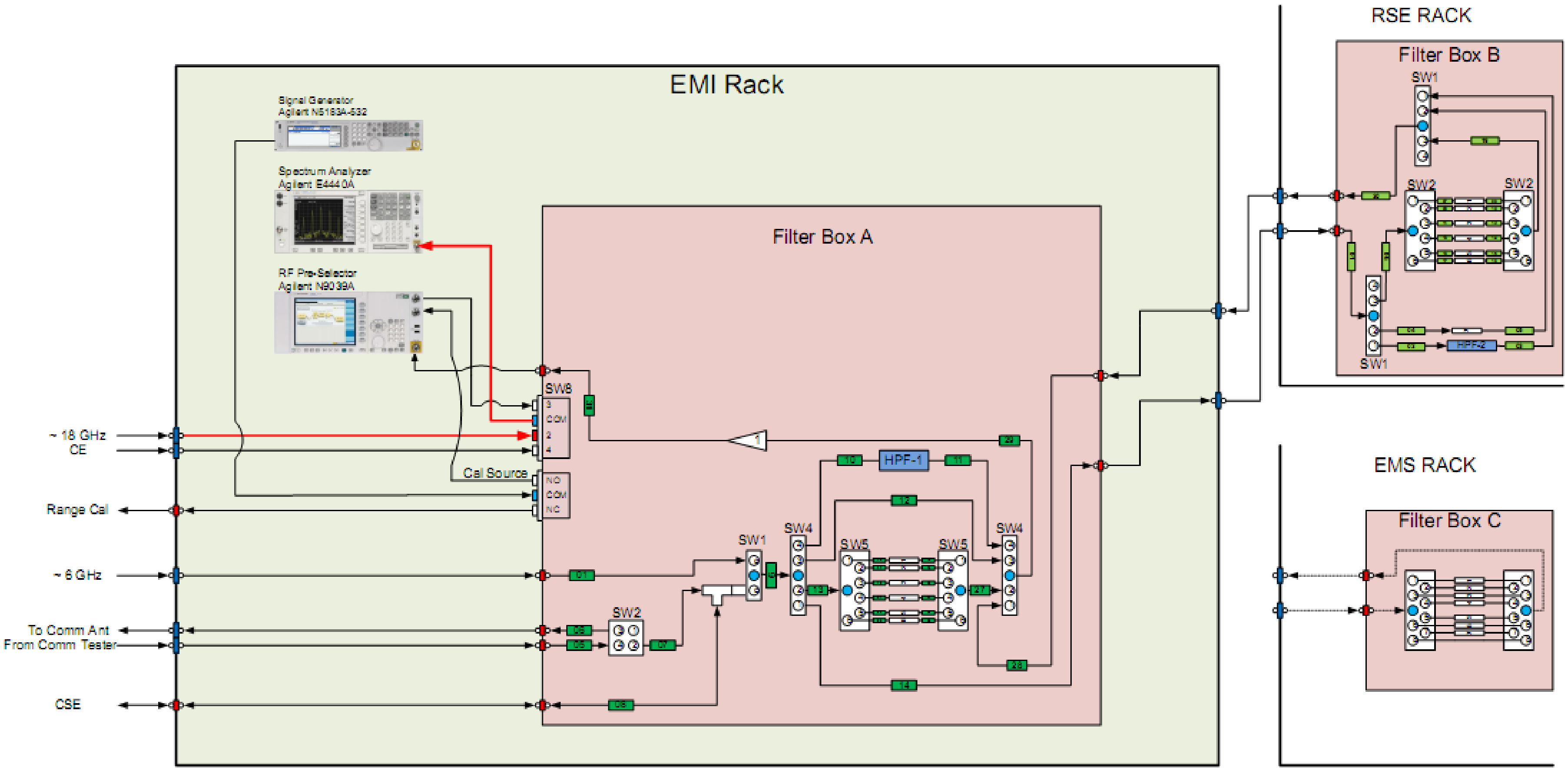
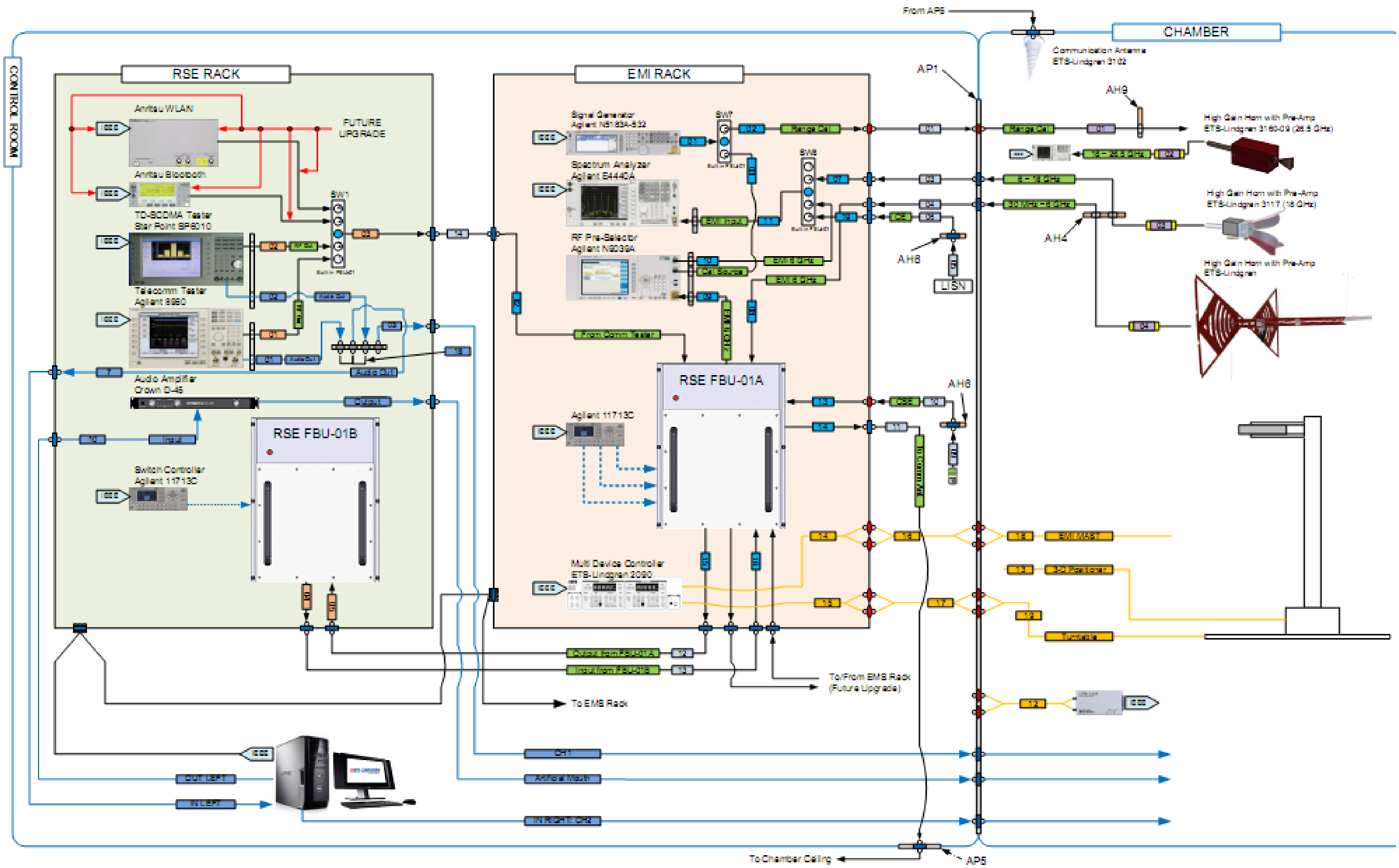


Freq (MHz)	Air Loss (dB)	(1x6) Switch Insertion loss (dB) *2	(1x2) Switch Insertion loss (dB) *3	Approximated Cable loss (dB)	Filter Pass band Loss (dB)	Antenna Gain (dB)	Preamp Gain (dB)	Link Budget
30	11.52662237	0.36	0.25	7	0.5	2	47	28.50337763
100	21.98419728	0.36	0.25	7	0.5	2	47	18.04580272
500	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



Filters for Wireless




CONTROL ROOM
RSE RACK
EMI RACK
CHAMBER
Anritsu WLAN
Anritsu Bluetooth
FUTURE UPGRADE
SW1
TD-SCDMA Tester
Star Point SP6010
Telecomm Tester
Agilent 8960
Audio Amplifier
Crown D-45
Output
Input
RSE FBU-01B
Switch Controller
Agilent 11713C
Signal Generator
Agilent N5183A-532
SW7
SW8
Spectrum Analyzer
Agilent E4440A
EMI Input
RF Pre-Selector
Agilent N9039A
From Comm Tester
RSE FBU-01A
Agilent 11713C
Multi Device Controller
ETS-Lindgren 2090
From AP6
AP1
Communication Antenna
ETS-Lindgren 3102
AH9
High Gain Horn with Pre-Amp
ETS-Lindgren 3160-09 (26.5 GHz)
High Gain Horn with Pre-Amp
ETS-Lindgren 3117 (18 GHz)
AH4
AH8
LISN
High Gain Horn with Pre-Amp
ETS-Lindgren
AH6
EMI MAST
Turntable
Output from FBU-01A
Input from FBU-01B
To/From EMS Rack
(Future Upgrade)
To EMS Rack
CH1
Artificial Mouth
OUT LEFT
IN LEFT
IN RIGHT/CH2
To Chamber Ceiling
AP5

Typical Notch Filter

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

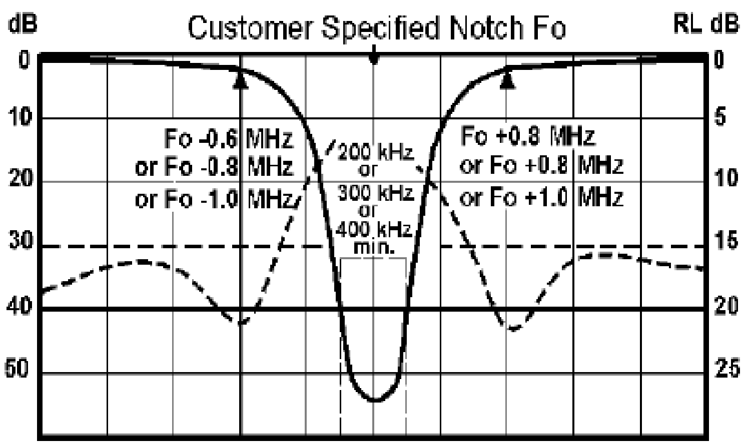
Wainwright Instruments GmbH

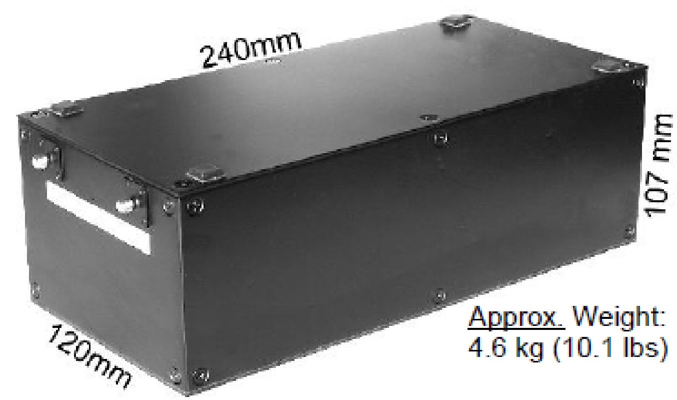
Widdersberger Str.14
82346 Andechs, Germany
Tel.: +49-8152-918230 Fax: +49-8152-918255
E-Mail: info@wainwright-filters.com
Internet: www.wainwright-filters.com

8 Resonator
Ultra Stable Cavity Design
WRCT Series

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

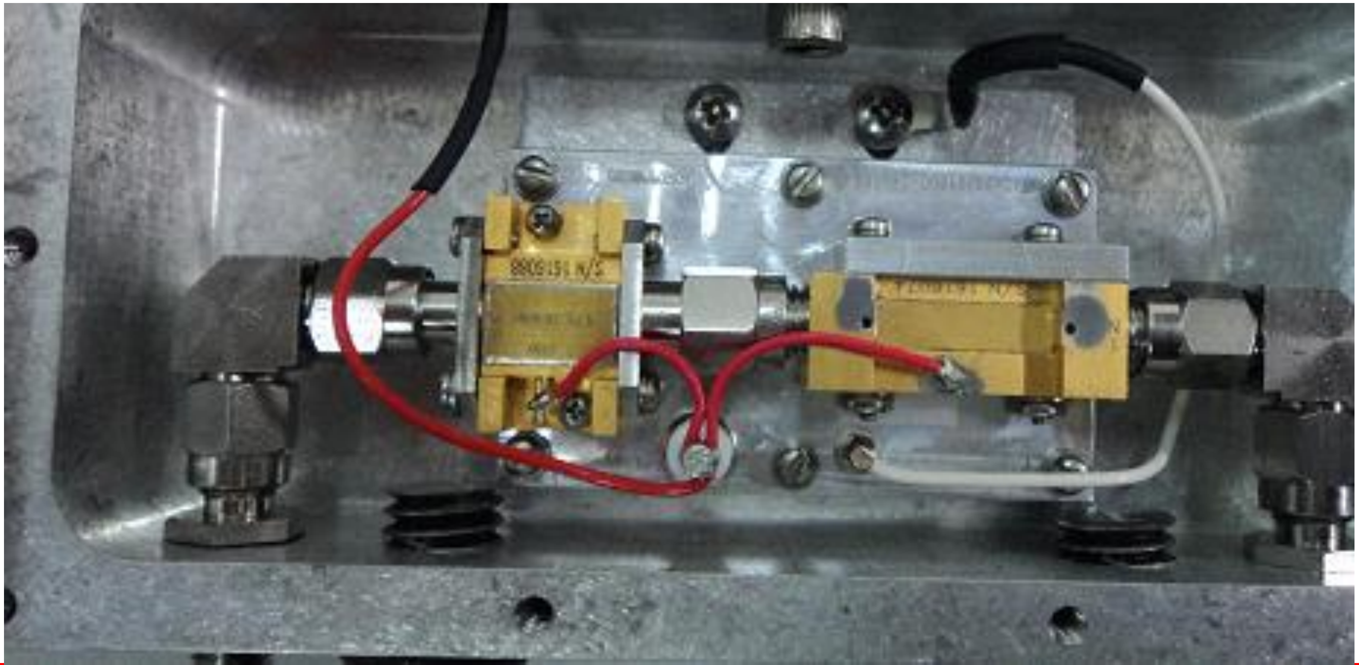
Model Number to be specified
(see below)





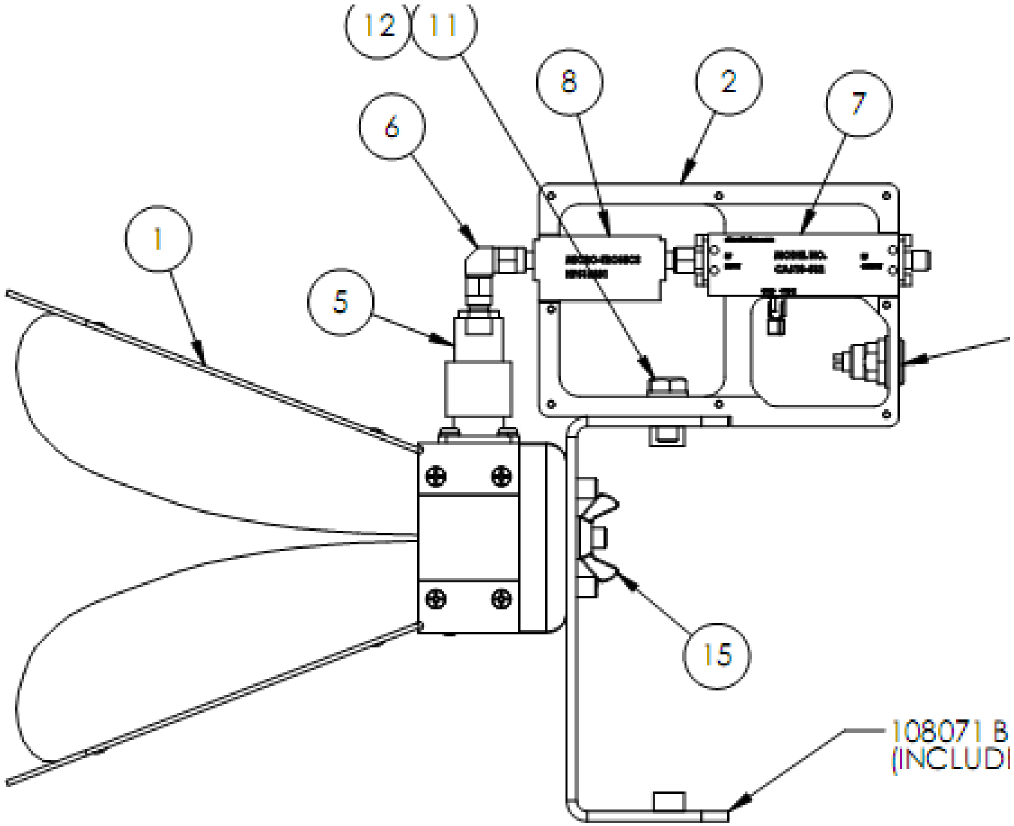
Preamp

- Preamp is essentially LNA (low noise amp) to boost up weak spurious to become detectable
- Carefully select preamp to have enough dynamic range
- Preamp is connected right after next to the receive antenna, after the notch filter, in good compliant RSE system.



Filters for EMC

- **EMC Solution for 2.7GHz or 6 GHz to 18 GHz**

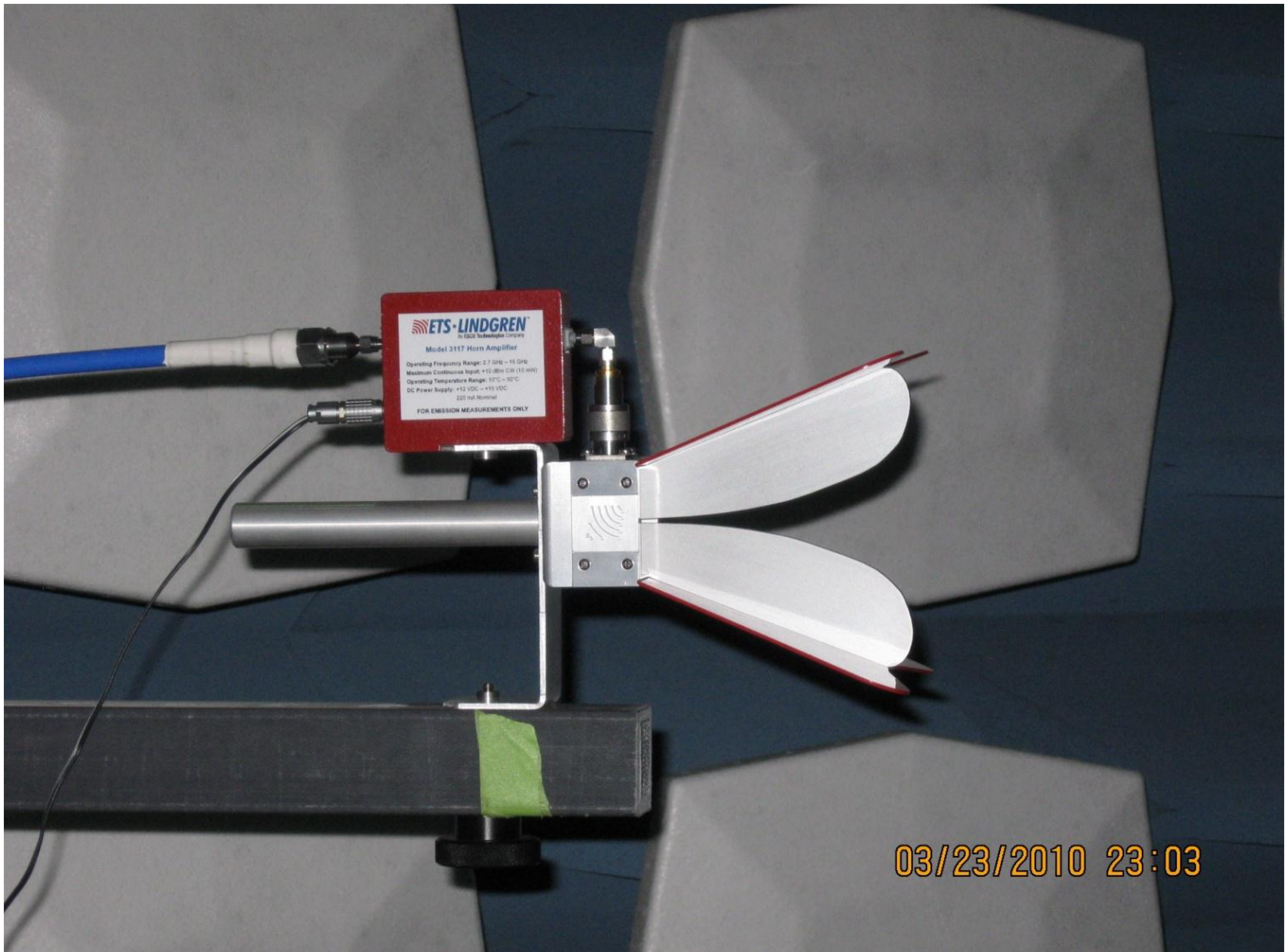


HPF filter used in series with Pre amplifier

Protects preamp from overload.

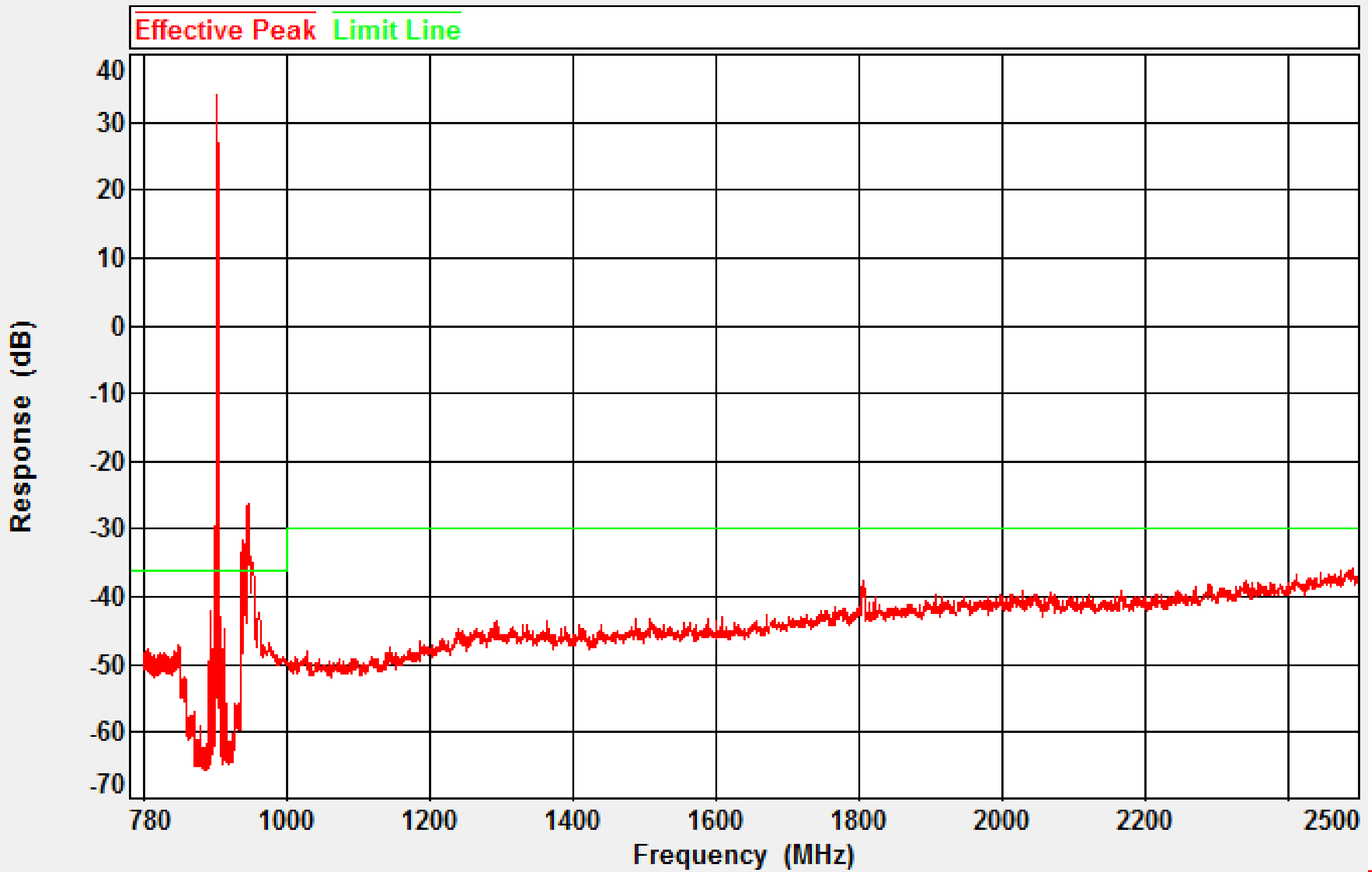
Filters for EMC

- **EMC Solution for 2.7GHz or 6GHz to 18 GHz**



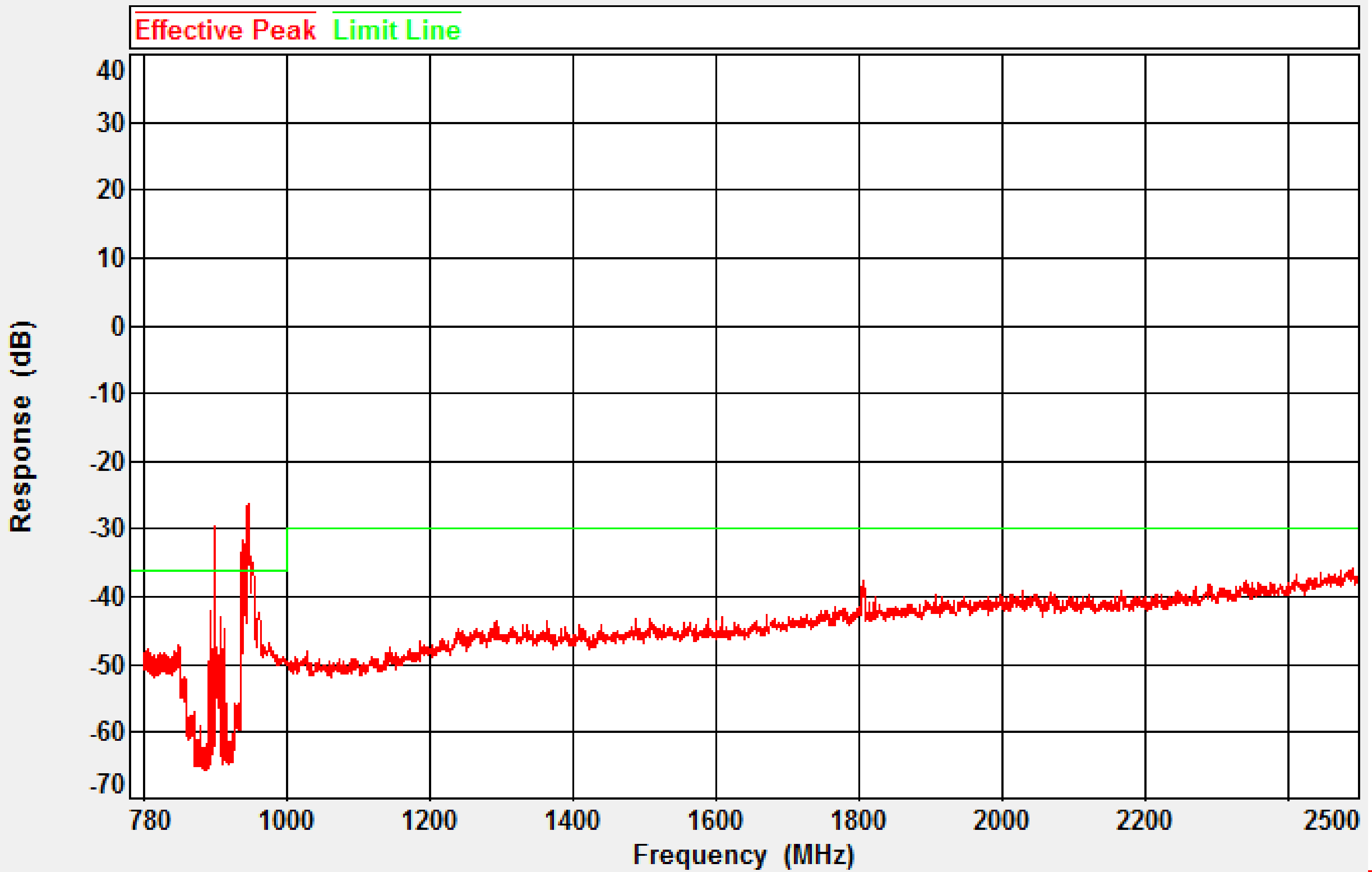
Measured Graph

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



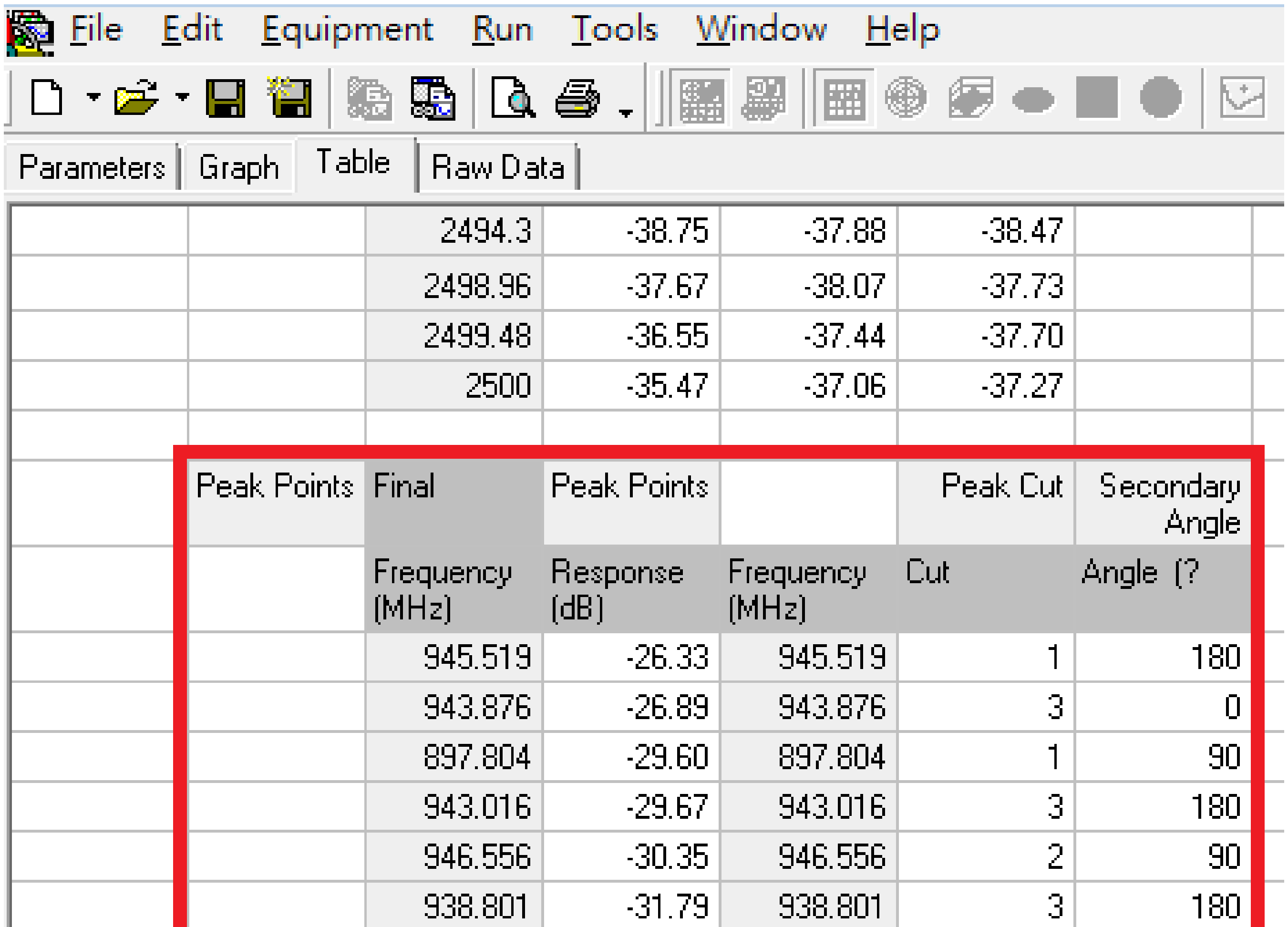
Exclusion Band

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



Table

- Table picks up peaks.



File	Edit	Equipment	Run	Tools	Window	Help

Parameters | Graph | Table | Raw Data

		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

Pre Test Calibration Methodology

- **The FCC has received several inquires regarding the acceptance of an adjunct methodology, whereby a signal generator is used to radiate a signal that is swept over a pertinent frequency range, and then recorded at a single point in space at a distance corresponding to the measurement distance required for compliance testing. A table of data collected from this site “pre-calibration” is then to be used to replace specific substitution procedures as described in Sections 2.2.12 (j) through (l) and/or 2.2.17 (c) and (d) of the TIA-603-C standard.**

Pre Test Calibration Methodology

- FCC Released a KDB 449343 (https://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?id=47471&switch=P) recognizing that there are labs using this method and prior to it being recognized by any industry standard or officially by FCC it is not acceptable at this point.

- There was a response submitted to try to get this methodology included as part of the FCC approved methodologies for this test.

Pre Test Calibration Methodology

- **EMC test labs have technically justified and used pre-test site calibrations to evaluate the field strength of radiated emissions in lieu of individual substitution measurements for each emission for many years.**

Pre Test Calibration Methodology

- **Procedure**
  - Reference Field Strength
    - The related regulatory compliance limit [e.g. -13 dBm / -20 dBm] should be used as the reference field strength for the pre-test site calibration.
    - However, as long the system sensitivity of the measurement system is adequate, labs are able to define their own reference field strength.
      - Labs should be capable of justifying their decision of reference field strength.

Pre Test Calibration, Procedure

- Measurement instruments used for path loss calibration do not need to be the same as ultimately used for measuring EUT radiated power
  - Swept frequency measurement under consideration
    - Network analyzer → Speed.
- It is very important that antenna locations, measurement antenna and related measurement cables to be the same for both the path loss calibration and EUT measurements.
  - If any of these elements change, then site calibration shall be verified before continuing with EUT testing
- A preamplifier can be utilized for testing even if it was not part of the path loss measurement.
- Correction Factor (CF) determined on the exact frequencies of the EUT emission testing or calculated using linear interpolation between site calibration frequencies

Pre Test Calibration, Procedure

- Set up the substitution measurement with the ref. point of the substitution antenna located in the position where the closest periphery of the EUT will be located during EUT measurements.
- The height of the substitution antenna should be at approximately the same height as the where center of the transmitter to be tested would be located.
- Set the test receiver settings and receive path parameters exactly as they will be used during emissions measurements.
- Connect a signal generator to the substitution antenna and set the level according
  - Pgen = Pref + Cable Loss - Antenna Gain [dBd]

    Where Pgen = signal generator setting [dBm]
    Pref = Reference Field Strength
    Antenna Gain [dBd] = Antenna Gain [dBi] - 2.15
    Antenna Gain [dBi] = 10*Log (Num Gain)

  - Scan antenna 1m to 4m to determine the height of the maximum received level.

Pre Test Calibration, Procedure

- Record the level of the received power [Prec] at the Receiver in dBm for that frequency and polarization.
- Perform the leveling of the signal generator power for each frequency with the receive antenna oriented in both the polarizations as described above.
- Calculate the system correction factor for each frequency in dB using the following equation:
- <u>Correction Factor [CF] = Pref [dBm] – Prec [dBm]</u>
- For example:

  At 4800 MHz for a frequency / polarization

  Prec = -34.8 dBm for a -13 dBm limit

  CF = -13 dBm – [-34.8 dBm] = <u>21.8 dB</u>
- Using Pre-Test Site Calibration Correction Factor to Determine EUT Emission Power
- EUT emission powers are calculated using the following equation:

  <u>Emission Power = EPrec dBm + CF</u>

  Where EPrec is the power of the emission measured at the test receiver during EUT measurements as defined in TIA 603C/D section 2.2.12.2 a - 2.2.12.2 g.
- This is the level to be compared against the regulatory limit as it is the emission power referenced back to the EUT on the test site.

Pre Test Calibration

- **Concerns**
  - Multitude of Correction Factors for variety of different EUT sizes, diameter, height and cable orientations.
    - Needs to be careful that right files are used or use methodology to reduce the error by performing a series of tests (or volumetric) for different path loss measurements and do 1/r distance correction to reduce the chamber associated ripple.
      - Maybe you can live then with one Correction Factor for the center and then just reduce the correction factor based on the radius of the EUT.
  - How sensitive the calibration factor determination is for set-up.
    - Do labs start taking short cuts if the set-up is “close enough” for the calibration factors already existing.
      - How to audit ?

QUESTIONS