Measurements of radiation efficiency of mobile terminal antennas

Electromagnetics
and
Remote Sensing Lab
(ERSLab)

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Outline

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iPhone 4 reception issues

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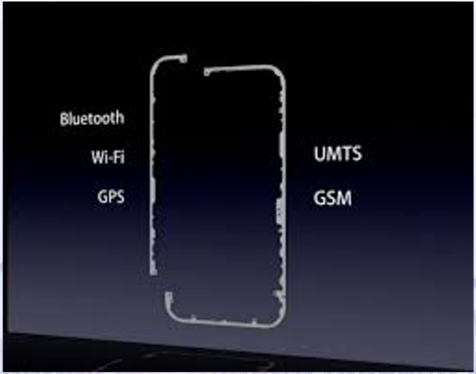
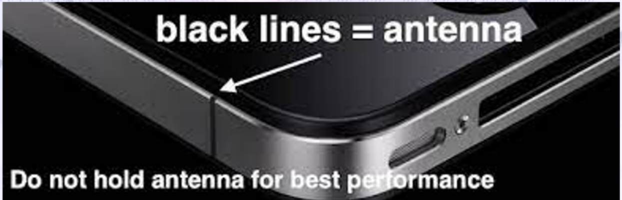




iPhone 4 reception issues

What the problem is

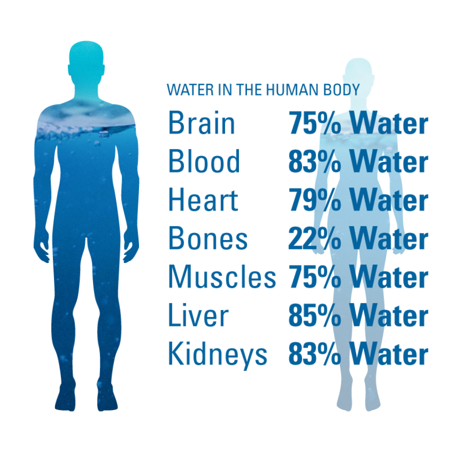
Apple's new antenna technology is failing when the bottom left corner of the iPhone 4 is touched. In that corner, as you can see in the picture, the two available antennas come close to meeting. When connected to each other by a person's hand (like when held in the left hand), some sort of interference occurs, causing the signal to degrade and eventually drop the call.

iPhone 4 reception issues

Apple's official response to the problem

Gripping any phone will result in some attenuation of its antenna performance with certain places being worse than others depending on the placement of the antennas. This is a fact of life for every wireless phone. If you ever experience this on your Phone 4, avoid gripping it in the lower left corner in a way that covers both sides of the black strip in the metal band, or simply use one of many available cases.

Human body



- The water content causes losses at microwave frequencies.
- Biological tissues call for a permittivity larger than the free space one causing a change in the impedance environment in the near-field zone of the antenna.

Outline

ERSLab

F. Nunziata

Introduction
Reception issues
Human body
Antenna's performance
Analysis of radiation performance
Parameters
Measurement setup
Anechoic chamber
Measurement configuration
Measurements
Reverberation chamber
Measurement configuration
Measurements

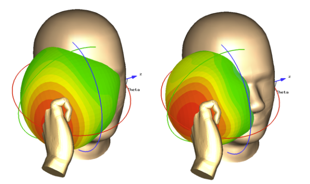
Antenna radiation efficiency

The presence of a user lossy tissue in close proximity to the mobile phone antenna can significantly deteriorate its performance

Detrimental effect

The detrimental effect of the human body depends on the design of the used antenna and factors e.g.; position of the fingers of the hand with respect to the antenna (hand grip), hand size, distance palm - mobile terminal.

Antenna radiation efficiency

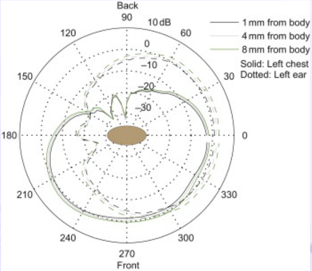


The human tissue affects:

- the input impedance of the antenna which, at once, affects the power input to the antenna itself;
- the radiation efficiency of the antenna that is reduced since part of the power radiated by the antenna is absorbed;
- the radiation pattern.

Outline

The antenna performance



Effects of the user on the antenna efficiency

The consideration of the user effect, due to the natural use of the mobile phones next to the human body, is an important step in the designing process of any antenna intended to be used for handsets.

Location of the antennas

The loss in antenna performance

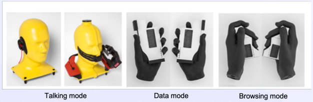
The performance of the mobile terminal antenna in proximity of user's analyzed in these different scenarios always differs due to the antenna placement on the chassis of a mobile phone

The index finger and hand palm

Hand's issues

Due to the use of multiple antennas in a mobile phone, the index finger of a user's hand caused the severest obstruction. Meanwhile, in the browsing mode, the antenna's radiation is obstructed by the thicker hand palm tissue.

Assessment of the radiation performance

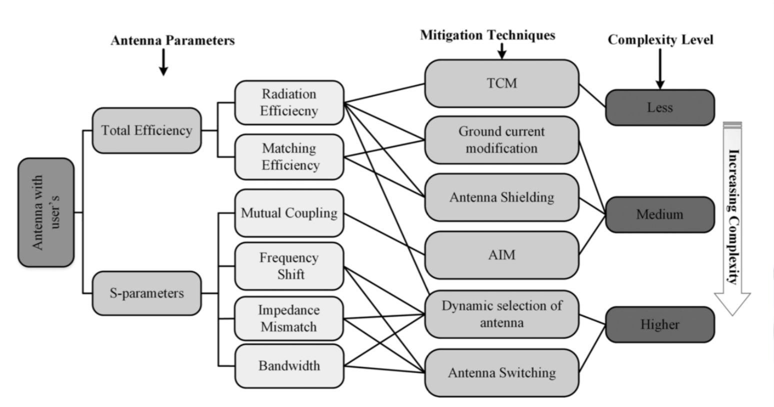


The radiation performance must be assessed according to the following configurations:

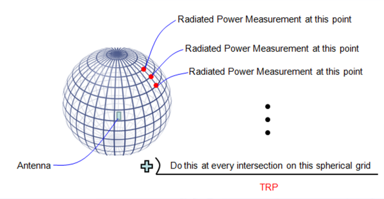
- Free space: The antenna under test (AUT) should be placed directly on a support made of low-dielectric material.
- Talking mode: The AUT is required to be placed against a head phantom or in a hand phantom.
- Browsing mode: The AUT is required to be placed in a hand phantom.

Outline

Antenna parameters to be monitored



Total Radiated Power (TRP)



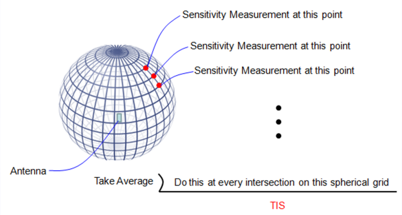
$$TRP = \frac{1}{4\pi}\int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi}(EIRP_{\theta}(\theta,\phi)+EIRP_{\phi}(\theta,\phi))\sin(\theta)d\theta d\phi$$

TRP

It accounts for the mobile phone's ability to radiate power and is given by the sum of all power radiated by the mobile device, regardless of direction and polarization.

The higher is the TRP, the better is the mobile's transmit performance

Total Isotropic Sensitivity (TIS)



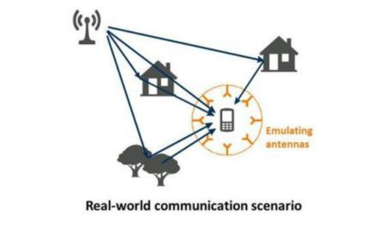
$$TIS = \frac{4\pi}{\int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi}\left(\frac{1}{EIS_\theta(\theta,\phi)} + \frac{1}{EIS_\phi(\theta,\phi)}\right)\sin(\theta)d\theta d\phi}$$

TIS

It accounts for the mobile phone's ability to receive power and is a measure of the minimum power which has to be received by the mobile device in order to maintain a reliable communication, assuming that the incident power is coming from all directions and for both polarizations.

The lower is the TIS the better is the mobile's performance

Over-the-air (OTA) test



OTA

It is a method used to predict the performance and reliability of a wireless device in the real world. The device is subjected to different test conditions to check how the device responds in various situations.

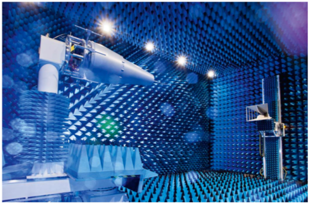
The lower is the TIS the better is the mobile's performance

Over-the-air (OTA) test

OTA

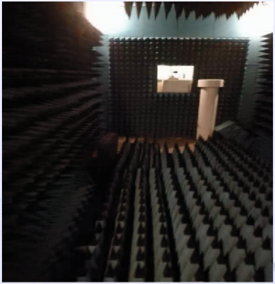
Open Area Test Site

Anechoic chamber



The device under test is placed in a free space environment inside a test chamber, where real-life situations are simulated.

Anechoic chamber

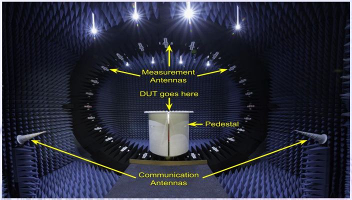


Anechoic chamber

It is a shielded room that has radio-wave absorbing material applied to the walls, ceiling, and floor. Chambers may be table top sized enclosures, but are normally room sized enclosures where engineers can walk in and work. The absorbers on the inside surfaces are often pyramidal shape.

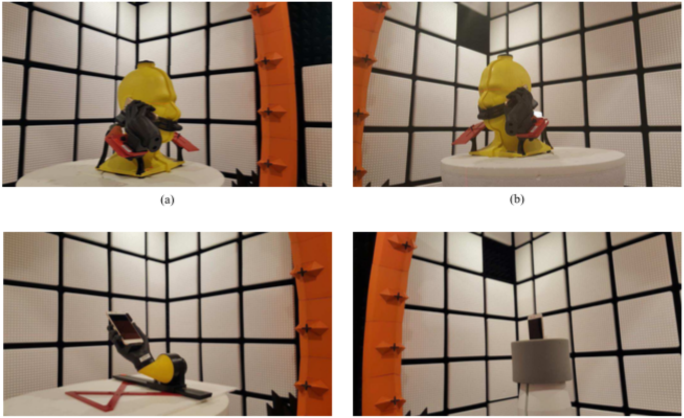
Outline

Measurement configuration



- An array of probes on a supporting ring.
- Radio-communication devices.
- It is time-consuming and expensive.

Measurement configuration



(a) (b) (c) (d)

Outline

Measurement process - TRP

- The mobile phone (MP) was set to transmit with the maximum allowed power for the studied mobile standard and frequency band.
- The power was measured successively by the probes distributed on the ring along elevation for each polarization.
- Then the mobile phone was rotated along azimuth and the power was again measured by the probes along elevation.
- The process continued until a sphere was covered (with 15° binning) and then the TRP value was evaluated.

Measurement configuration

Measurement process - TIS

- One probe at a time was set to transmit with certain power (for one polarization) a data signal to the phone and the BER was evaluated.
- Then the power was lowered with step of 0.5 dB and the BER was again evaluated.
- The process continued until BER reached a certain threshold. Thus, the minimum power needed to satisfy the specified BER was known for one direction and polarization.
- The procedure was repeated until all directions and both polarizations were tested, and then the TIS value was evaluated with 30° stepping.

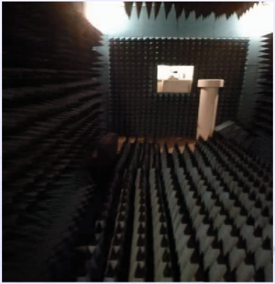
TRP

Mobile Phone	TRP (dBm)											
	GSM900			UMTS900			GSM1800			UMTS2100		
	FS	BHHR	BHHL	FS	BHHR	BHHL	FS	BHHR	BHHL	FS	BHHR	BHHL
Doro 7070	28.7	23.5	23.6	20.7	14.5	14.8	27.6	25.2	26.0	18.9	17.4	17.2
Samsung Galaxy S9	27.2	20.7	20.7	17.0	10.5	10.9	26.1	21.6	23.5	18.4	13.4	16.2
Samsung Galaxy S9+	27.6	20.5	20.3	18.1	11.5	10.0	26.0	18.8	21.7	18.6	11.8	15.8
Samsung Galaxy S8	27.4	19.9	20.9	16.9	10.4	10.9	25.8	21.3	22.7	19.7	13.8	17.1
Huawei P20 Pro	26.7	18.5	19.7	17.5	7.2	9.5	23.6	19.0	17.8	18.8	11.0	9.7
Nokia 7 Plus	24.7	17.8	15.0	15.6	9.8	6.0	24.6	20.7	19.9	19.5	14.7	15.3
iPhone 7	27.4	17.5	14.0	18.2	9.2	3.3	25.3	11.0	20.4	18.5	7.3	14.5
iPhone 8	26.8	17.4	10.5	17.9	9.1	-0.7	23.7	18.1	18.8	18.1	7.5	12.3
iPhone X	25.4	17.4	16.2	16.3	9.0	6.4	22.7	16.9	18.1	17.0	11.7	14.1
iPhone 8 Plus	26.2	17.3	7.7	17.7	8.3	-1.4	24.6	17.5	18.8	18.8	10.6	13.7
Sony Xperia XA2	27.8	17.3	18.0	18.9	8.1	9.6	22.5	19.9	16.8	18.0	14.9	9.8
OnePlus 6	25.6	16.3	12.8	16.1	6.8	2.9	24.1	20.6	16.6	16.5	12.9	9.4
Huawei P10 lite	29.7	15.8	15.1	20.2	7.9	6.7	25.9	19.0	19.3	19.6	11.9	12.9
Huawei P9 lite mini	27.0	14.6	16.2	18.8	5.1	7.3	26.3	23.1	20.5	16.4	13.2	14.0
iPhone Xs Max	20.5	14.4	15.2	15.9	-1.3	6.2	22.6	14.2	18.3	16.9	9.9	14.0
Huawei P10	28.0	12.0	18.2	18.7	3.5	9.3	25.9	11.5	19.6	18.8	13.6	10.8

TIS

Mobile Phone	TIS (dBm)											
	LTE700		LTE800		LTE1800		LTE2600		UMTS900		UMTS2100	
	FS	HR	FS	HR	FS	HR	FS	HR	FS	HR	FS	HR
Samsung Galaxy S9+	-94.8	-93.3	-94.8	-93.3	-98.6	-96.6	-91.9	-90.6	-108.4	-107.9	-110.5	-107.7
Samsung Galaxy S9	-95.5	-92.6	-94.5	-92.6	-98.9	-96.6	-91.7	-90.0	-106.5	-105.9	-110.2	-108.2
iPhone 8 Plus	-95.6	-91.7	-94.6	-91.5	-96.8	-94.5	-91.3	-88.3	-109.2	-108.4	-111.7	-108.7
iPhone 8	-96.2	-91.4	-95.6	-91.5	-97.0	-94.6	-90.8	-88.8	-109.5	-106.7	-110.0	-108.0
iPhone 7	-95.7	-91.2	-95.3	-91.3	-96.0	-91.9	-92.7	-90.5	-109.8	-106.3	-110.5	-106.9
Huawei P20 Pro	-93.6	-91.1	-92.9	-91.0	-98.1	-95.2	-89.5	-88.3	-107.7	-105.5	-110.4	-107.9
Samsung Galaxy S8	-94.0	-90.8	-95.0	-92.8	-97.5	-94.9	-93.0	-92.1	-107.2	-105.0	-108.1	-107.8
OnePlus 6	-93.3	-90.2	-93.3	-89.0	-96.6	-94.3	-93.3	-89.5	-107.1	-104.5	-109.7	-107.5
iPhone X	-94.2	-90.0	-94.6	-91.1	-94.2	-92.0	-89.7	-86.5	-107.3	-103.4	-109.1	-106.4
Huawei P10	-94.4	-89.7	-94.0	-90.8	-96.1	-92.2	-90.8	-89.4	-108.9	-106.4	-110.3	-108.5
Nokia 7 Plus	-93.6	-89.6	-93.0	-91.0	-95.1	-93.3	-88.3	-87.8	-106.4	-105.6	-107.4	-104.7
iPhone Xs Max	-94.4	-88.8	-93.5	-88.2	-96.2	-93.5	-93.0	-90.7	-106.8	-105.1	-107.4	-104.8
Doro 7070	N/A	N/A	-94.2	-91.2	-96.5	-95.3	-92.4	-89.8	-109.3	-105.2	-111.3	-108.7
Huawei P9 lite mini	N/A	N/A	-93.7	-88.8	-94.2	-93.1	-92.3	-91.1	-106.8	-98.4	-111.3	-109.9
Huawei P10 lite	N/A	N/A	-95.4	-92.6	-97.6	-94.1	-92.8	-89.6	-107.9	-104.8	-109.9	-106.5
Sony Xperia XA2	N/A	N/A	-94.7	-90.0	-95.3	-93.6	-90.1	-88.2	-108.1	-104.8	-107.9	-104.9

Reverberation chamber



Reverberation chamber

The RC is a large overmoded electromagnetic cavity in which the field is randomly perturbed. The field randomness can be achieved by several techniques that can be simply sorted into mechanical and electronic.

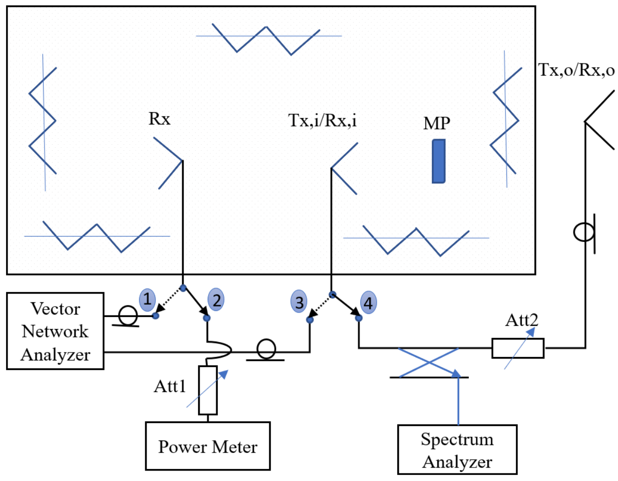
Outline

Reverberation chamber

A new measurement configuration has been proposed @Uniparthenope

- RC size: $6m \times 5m \times 4m$.
- Continuous stirring.
- External base station.

Sketch of the measurement configuration



Measurement configuration

The RF link branch

- The mobile phone (MP) is inside the RC and a RF coax link connect it (up/down link) with the actual base station.
- The coax links two TX/RX antennas that are located within the RC (Tx,i/Rx,i) and out of the University building (Tx,o/Rx,o).
- A direction coupled, which is inversely coupled with the down-link and directly coupled with the up-link is used to analyze (through the spectrum analizer) the frequency of the signal TX by the MP.

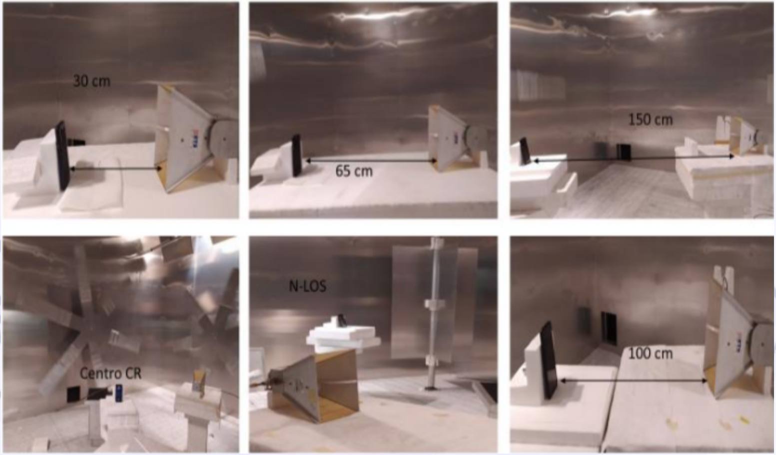
Measurement configuration

The measurement branch

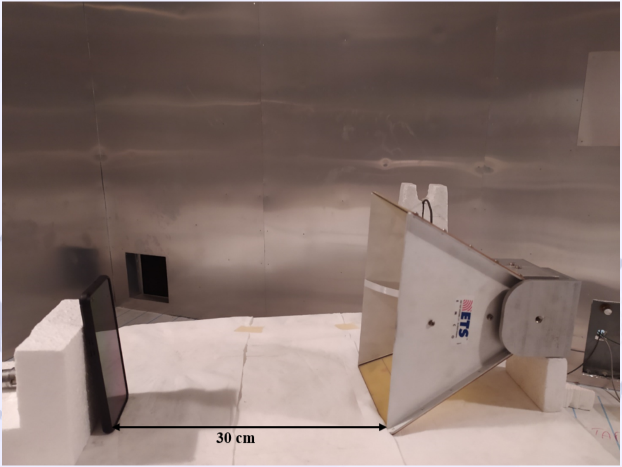
- It consists of a Rx antenna whose received power is measured by a power meter (PM) via a coax cable.
- The measurement configuration includes a vector Network analyzer that, connected to the Tx antenna (Rx,i) and the receiving one (Rx), allows measuring the RC insertion loss.

Outline

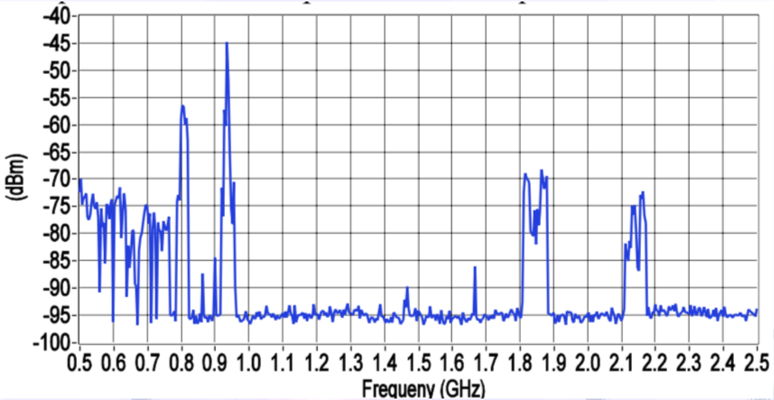
Measurement setup



Measurement setup



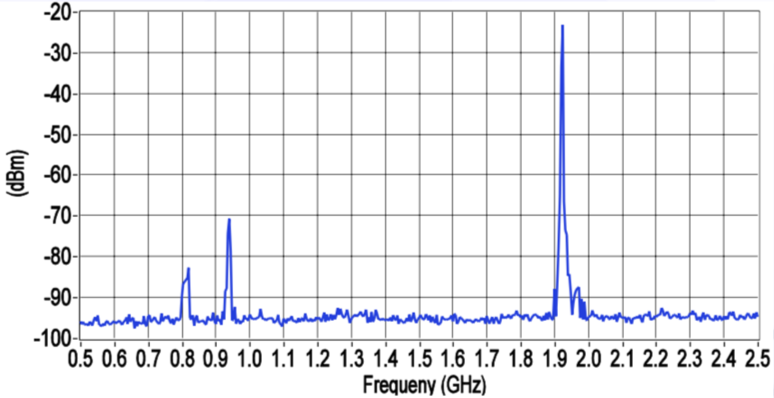
Spectrum measured by SA



The measured spectrum

Spectrum measured at the outer antenna where 4 bands can be observed.

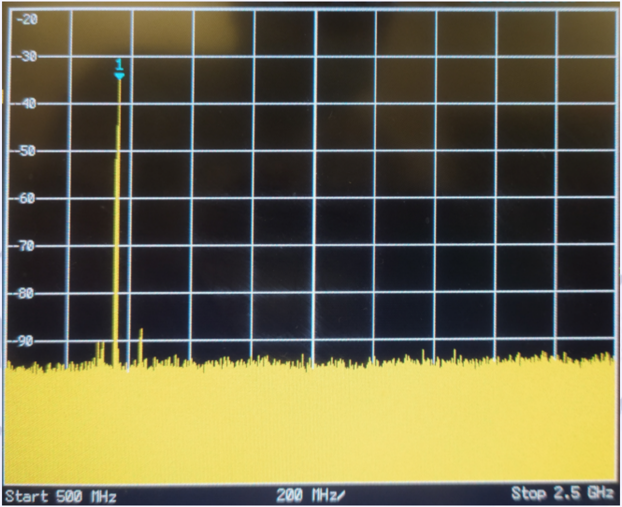
Spectrum measured by SA



The measured spectrum

Spectrum measured at the Rx antenna via the measurement branch.

SA output: Peak @ 900MHz - Vodafone



Measured TRP

REDMI 8 @900MHz
Vodafone

Position of the MPUT	TRP (dBm) measured by ATT2 = 0 dB	Att2 related to the max TRP value	MAX TRP (dBm)	RMU of MAX TRP (dB)
A	16.1	9	21.7	0.5
B	15.3	9	22.1	
C	13.4	9	21.7	
D	12.8	9	22.1	
E	12.3	11	22.5	
F	11.1	11	22.7	
G	14.8	11	23.2	
H	14.9	11	22.3	
I	15.0	11	22.6	
A	18.0 (measured by Att2 = 3)			
A	21.1 (measured by Att2 = 6)			

SAMSUNG 6 @ 900MHz
Vodafone

Position of the MPUT	TRP (dBm) measured by ATT2 = 0 dB	Att2 related to the max TRP value	MAX TRP (dBm)	RMU of MAX TRP (dB)
A	9.6	12	12.5	0.7
B	6.9	12	13.6	
C	8.1	12	11.5	
D	9.2	12	10.8	
E	8.9	12	12.1	
F	6.7	12	12.9	
G	11.2	12	12.2	
H	9.1	12	12.3	
I	7.4	12	11.8	

For further reading

- S.S. Zhekov and G.F. Pedersen, "Over-the-Air evaluation of the antenna performance of popular mobile phones", IEEE Access, vol. 7, pp. 123195-123201, 2019.
- R. Khan, A. A. Al-Hadi and P. J. Soh, "Recent Advancements in User Effect Mitigation for Mobile Terminal Antennas: A Review," in IEEE Transactions on Electromagnetic Compatibility, vol. 61, no. 1, pp. 279-287, Feb. 2019, doi: 10.1109/TEMC.2018.2791418.