Implementation of a Simulated Model for the Evaluation of Electromagnetic Disturbances in Anechoic Chamber

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***Abstract*— the 5G wireless network is going operate within the environment of other electrical, electronic and electromagnetic devices. The 5G network owns the ability to transmit large amounts of data at high speeds, taking the growing demand for equipments connectivity which increase the operating frequencies and give as results the rapid propagation of parasitic signals. This rapid propagation is causing network malfunctions and equipments failure in some critical operations.**

For that it is necessary to study the functioning of these equipments within an electromagnetic environment and to answer the questions: is it compatible or not? And is it sufficiently immune to electromagnetic disturbances from other equipments or its environments in a more generally way?

To perform this study, the implementation of a test bed model is investigated. In this work, an interest is taken to the radiated electromagnetic disturbances. The test bed model use the anechoic chamber which absorbs any kind of electromagnetic radiation and leave just the radiation which comes from the antenna, and also it allows to measure the disturbances in near field and in far field.

This article aims to predict a model of measurement test bed based on anechoic chamber, in order to study the influence of radiated electromagnetic disturbances in case of emissivity. The implemented model use the real dimensions of the RITM laboratory anechoic chamber.

Keywords*— *electromagnetic compatibility, 5G, electromagnetic disturbances, anechoic chamber, horn antenna, frequency band, emissivity.

I. Introduction

Beyond speed improvement, the 5G should facilitate the emergence of a huge ecosystem in which networks can ensure the communication needs of a billion connected objects, taking into consideration a balanced compromise between speed, latency and the cost.

And as the electromagnetic fields, wave propagation and signal transmission are part of the fundamentals of wireless network, and while we consider the deployments of 5G service to enhance connectivity to broadband services, and as, the demand for connectivity to network access is increasing daily from all works of life. This desire requires capabilities such as power, interference and reliability as well as electromagnetic effects which include: electromagnetic compatibility (EMC), electromagnetic interference (EMI) and electromagnetic pulse (EMP) which can result in network malfunction.

Therefore, being compatible in an electromagnetic environment means two things:

- Limit the disturbances from the device, in order to not disturb other equipments in the same electromagnetic environment.
- Be able to function properly when a device generates disturbances in the proximity

To check the EMC of a device, we started by verifying that the device works properly in the presence of disturbances. in the measurements tests we injects disturbances(in conduit mode and in radiated mode) on the device, and we check that it operates normally, To perform measurements tests several equipments are needed, such as anechoic chamber, transmitting antennas, receiving antennas, spectrum analyser, vector network analyser, an RSIL…

On the other hand, the devices under test are cheeked to evaluate the disturbances level. This evaluation is made by measuring the device electromagnetic field at a defined distance.

According to the standards the disturbances must not exceeds a defined level.

Standards are published for each device class. These standards specify the frequency of the measurements, the distance between the source and the receiver, the level of the measurement…

This paper aims to study the radiated electromagnetic disturbances, in terms of radiated emissions and immunity.

Radiated emissions tests are the most problematic tests because it is often difficult to predict all interactions between components. The tests must be implemented in a large chamber, protected against all external disturbances and the facades are specially designed to absorb the EM waves and avoid reflections (anechoic chamber).

This paper is organized in three parts:

- Presentation of the technical criteria's required by the EMC standard in relation with 5G standard for the implementation of tests bed model.
- Implementation of a measurement test bed model.
- Results and discussions.

II. TECHNICAL CRITERIA'S REQUIRED BY THE EMC STANDARD IN RELATION WTH THE 5G STANDARD FOR THE IMPLEMENTATION OF TESTS BED MODEL

A. Radio frequency technical details

This paper aims to study the radiation of electromagnetic disturbances in the context of the EMC applied to the 5G technology.

5G technology is seen by some as a key technology that could deliver mobile telecommunication throughput of several gigabits of data per second.

For the frequencies provided for the 5G can be divided into three broad categories: low frequencies (<1 GHz), the average frequencies (1 GHz<f<6 GHz), and the highest (above 20 GHz), the first band of frequencies is already exploited by the previous generations (2G/3G/4G) and other technologies, it represents a good compromise between flow and capacity of cover. On the other hand, the high frequency band (>20 GHz) poses a limited propagation problem: the range is only a few hundred meters, the transmission is often only possible in direct line, without obstacle between the transmitter and the terminal, and they will therefore be usable only in very dense urban area. For that we chose to work with the second frequency band (1 GHz<f<6 GHz) with a central frequency of 3.3 at 3.8 GHz. For the types of devices used there are two categories:

Class A device: a device that is marketed for use in a commercial, industrial or business environment. A "class A" device should not be marketed for use by the general public. It should contain a warning notice in the user manual stating that it could cause radio interference. For example "warning operation of this equipment in a residential environment could cause radio interference".

Class B device: a device that is marketed for use in a residential environment and may be also be used in a commercial, business or industrial environments. NOTE: a residential environment is an environment where the use of broadcast radio and television receivers may be expected within a distance of 10 m of the device concerned, for our case we chose to work with class B devices.

The frequency range and peak limits for class B devices are figured in the following tables:

Frequency range	Quasi-peak limits-3m
30Mhz-88Mhz	40dB µV/m
88 Mhz-216 MHz	43.5dB µV/m
216Mhz-960Mhz	46 dB µV/m
960-1Ghz	54 dB µV/m

Table 1: peak limits for the frequency range [30MHz-1GHz].

Frequency range	Average limits-3m	Peak limit-3m
1Ghz and Up	54 dB µV/m	74 dB µV/m

Table 2: peak limits for a frequency up to 1GHz.

NOTE: The (dB µV/m) represents the amplitude of a radio wave is measured using the density of electric field by a field meter, it can be graduated in Volt/meter and milivolt/meter or more generally in microvolt/meter, as the variation of the electric field can be great, so we also use the decibel compared to microvolt/meter.

The formula used to convert a field to a level is as follows:

$$E\ Db\mu V/m = 20 \log (E)$$

Therefore to study the influence of radiated electromagnetic disturbances we need some equipments such as EUT, antenna, also the design of the anechoic chamber.

B. Choice of transmitting antenna

According to the chosen frequency band (1 GHz-6 GHz), they exist several types of antennas like: Yagi antenna, parabolic antenna, horn antenna…, but each of them has advantages and disadvantages.

Antenna	Advantage	Disadvantages
Horn antenna	➢ High gain ➢ Wide bandwidth ➢ Polarization purity	His foot print
Yagi antenna	➢ High gain ➢ Wide bandwidth	Its becomes more selective when we increasing the number of stands which results in the decrease of the bandwidth
Parabolic antenna	➢ High gain ➢ More directive	Low bandwidth

Table 3: The advantages and disadvantages for different antennas admitted for the frequency range [3GHz-4GHZ].

For all these reasons the choice of the use of the horn antenna is made, because in the centimeter and millimeter waves' domain, the transmission line may be constituted by a wave guide, to effect the transmission between the guide and the free propagation medium. The used antennas are constituted by guide elements in the section increasing progressively, and which are known as electromagnetic horns.

The horn antennas are very popular in the microwave band (>1 GHz), they provide high gain, low SWR, relatively wide bandwidth, and they are not difficult to achieve.

The main qualities of these types of antennas are the purity of polarization which allows its use to characterize the polarization of other antennas, its wide bandwidth (compared to the resonant antennas) and important gain.

The circular cylindrical horn antennas are a circular wave guides whose section increases gradually before ending with a circular radiating opening, it is possible to obtain the radiation pattern (either in the plane H or in the plane B or both).

Circular wave guides form a special class of transmission line: they are constituted of a single conductor with the advent of coaxial lines increasing quality of dielectrics with very low losses.

The circular wave guides are confined to very particular applications, they are found especially in:

- The transport of microwave signals over intermediate distances.

- The interconnections between the power stage and the transmission antenna.

C. *Choice of equipement under test*

To study the influence of radiated electromagnetic disturbances we need an equipment under test, which will undergo the maximum of radiation coming from the antenna that is in our case a horn antenna in the case of emissivity, and therefore see if he is sufficiently immune against these disturbances . For that, we chose as equipment under test a metal box with a slot and a coaxial feed.

The influence study of radiated electromagnetic disturbances in the case of emissivity will be done inside an anechoic chamber model which has as dimensions:

External dimension including structure (L*l*H) in meter	(9.76*6*3.48) meter
Dimension of the faraday cage (L*l*H) in meter	(6.60*5.80*3.20) meter
Dimension between absorbents (L*l*H) in meter	(8.00*4.20*1.60)

Table 4: Dimensions of the anechoic chamber of RITM laboratory (in progress).

For emissivity measurements, the measurement distance is the length between the center of the antenna and the point before the equipment under test.

It is necessary to perform the measurements in a far field this is valid if two conditions have been made on the measuring distance L:

- The first is related to the wave length used: L≥ λ in the case where we consider a localized source, we are in a far field zone.
- The second is related to the dimensions of the equipment under test: L≥2(D)^2/λ where D is the largest dimension of the antenna, this applies for large equipment such as D> λ.

Following the dimension of the chamber and the CISPR-16-3 standard the measuring distance to measure in the anechoic chamber is 3 meters.

III. Implementation of a Measurement Test Bed Model

After having identified the different elements that will be used to simulate the complete test bed model and study the influence of radiated electromagnetic disturbances on the equipment in the case of emissivity, so this paragraph will be dedicated to the conception and simulation of the equipment under test, transmitting antenna and the complete test bed..

A. *Conception and Simulation of the equipement under test*

This example shows the EMC calculation of a metal box with a slot and a coaxial feed, the electric field outside the metal box in a distance of 3 meters.

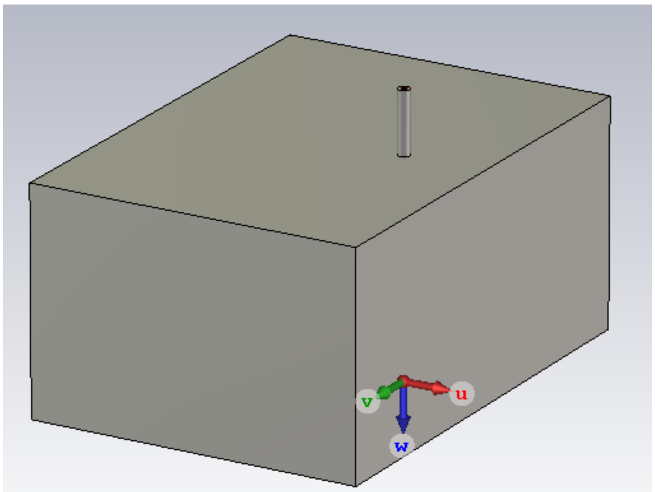

Figure 1: Model of the equipment under test

The structure is generated using basic bricks and cylinders, it consists of a metal housing filled with air, on top of the housing a coaxial feed is mounted off-center- the inner conductor of this coaxial line is connected to a thin cylindrical wire which is terminated by a 50 ohm resistor (lumped element) at the ground of the box. A slot in the metal housing is modeled by a brick of a vacuum metal, about the current that is cradling in the stem or (lumped element) is given by the following figure:

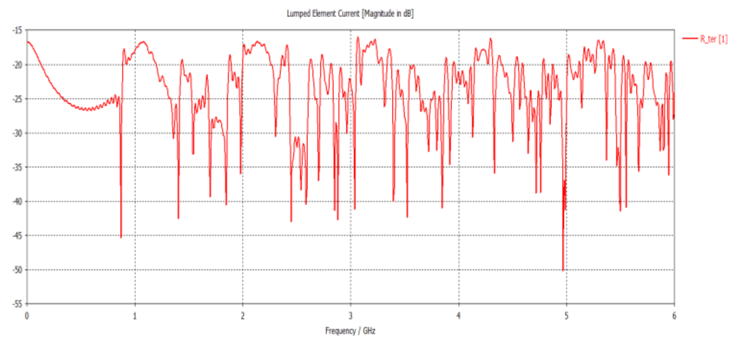

Figure 2: The equipment under test current flowing.

The amplitude of the current is given in decibel with a frequency up to 6 GHz; the current flowing in this stem is the current before the disturbance of the box and for the central frequency that equals 3.2 GHz the current is nearly equal to -17 decibel.

And to eliminate the reflections of the equipment under test, the parameter S must be equal at least to -10 decibel:

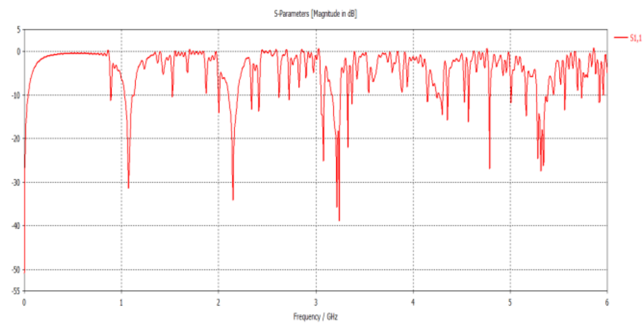

Figure 3: Reflection coefficient magnitude of the EUT.

As we see in the figure, representing the reflections coefficient at the box which equals -37 decibel for the central frequency, which indicates that the box absorbs all electromagnetic radiations that comes from the antenna.

B. Conception and simulation of the transmitting antenna

This example present the calculation of a horn antenna that it use the principal of radiation aperture, the horn shape ensuring the gradual adaptation of the electromagnetic wave between the coupling point and the radiation surface.

The measurements are made in far field (Fraunhofer area), and it is essential that the EUT receives a wave as flat as possible, that is a wave whose amplitude and phase must be uniform over the entire area occupied by the antenna to be tested.

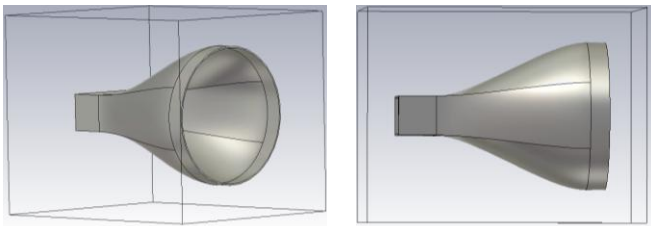

Figure 4: the simulated horn antenna.

Concerning the adaptation of the antenna, the following figure shows the amplitude of the reflection coefficient in the frequency range (1 GHz-12 GHz).

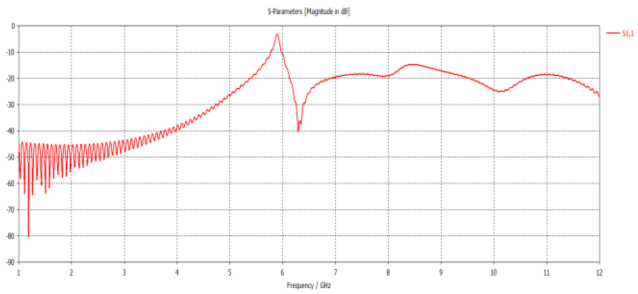

Figure 5: Reflection coefficient magnitude of transmitting antenna

As we can observe in the figure that the amplitude of reflection coefficient S (1, 1) for the central frequency used is equal to -42 decibel which implies that the antenna is adapted and therefore we have the transmission of the maximum electromagnetic radiations.

And as each antenna has its radiation pattern which is obtained by the measurement of the electric field, measurements are made in two mains planes which are called plane E and plane H. By definition the plane E is the plane where the electric field is maximum, it is also the collinear plane to the vector electric field on the antenna, whose component Eɵ is then maximum, by analogy the plane H is the plane perpendicular to the plane E where the magnetic field is maximal, in this plane the electric field vector is then carried by EΦ

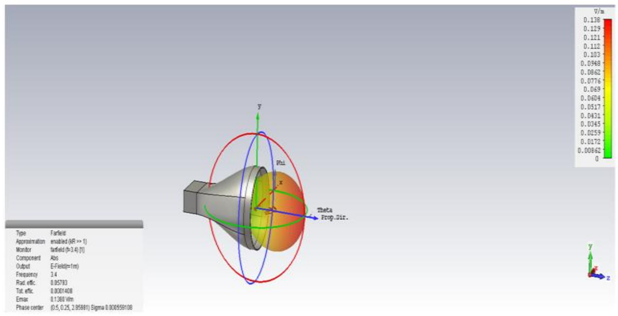

Figure 6: the 3D horn antenna radiation pattern.

The directivity of the antenna in the horizontal plane which corresponds to the width of the main lobe which is calculated by the angular width of each side of the lobe whose intensity decreases by half, a decrease of 3 decibel, in our case the amplitude of the main lobe is 27.5 V/m so the energy is focused in a specified direction.

The angle of aperture of an antenna is the direction angle for which the radiated power is half of the radiated power in the most favorable direction.

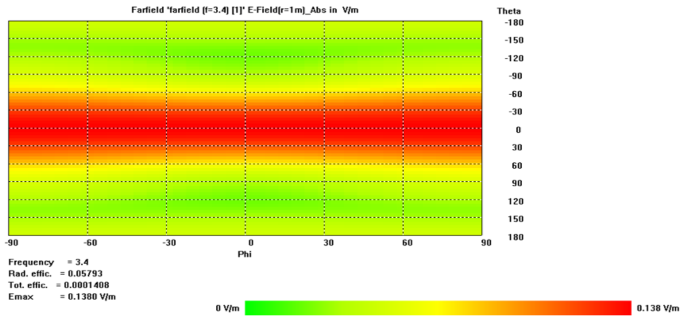

Figure 7: the 2D horn antenna radiation pattern.

For our case the opening angle varies from -60 to 60 theta but concentrated from -30 to 30 so the opening angle is 60 theta in the far field.

C. Implementation of test bed based on Anechoic chamber

An electromagnetic anechoic chamber, which is a faraday cage whose walls are covered in our case by pyramids of polyurethane foam loaded with a complex based on carbon, absorbing the electromagnetic waves and preventing their awakening in order to measure the electromagnetic disturbances.

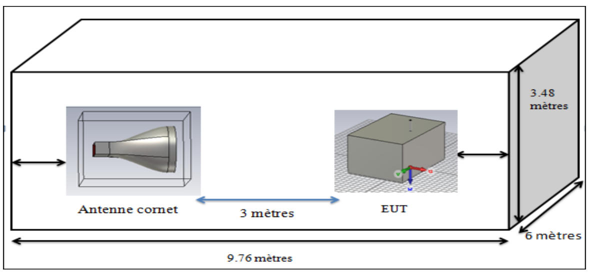

Figure 8: Overview of the simulated complete test bed.

In the case above we have to model a totally anechoic chamber because of two reasons, first because we have to work with a frequency range f>1Ghz and in this case it is preferable to work with a totally anechoic room to avoid any kind of reflections, the second reason is to place EUT directly on the ground.

For the design of our chamber we used a parallelogram whose walls are loaded with losses that act as absorbers whose purpose is to absorb all the electromagnetic waves that are in the room, for the disposition of the antenna and EUT are facing each other with a distance of 3 meters to measure in far fields.

IV. Results and Discussions

After the assembly of all the elements in the anechoic chamber (antenna, box), and after the verification of the functioning of each equipment in the selected frequency band, we start the global simulation of the chamber by the ejection of the electromagnetic radiation coming from the antenna on EUT (metal box), and we found the following results.

A. The results of the parameters retrieve in the global simulation.

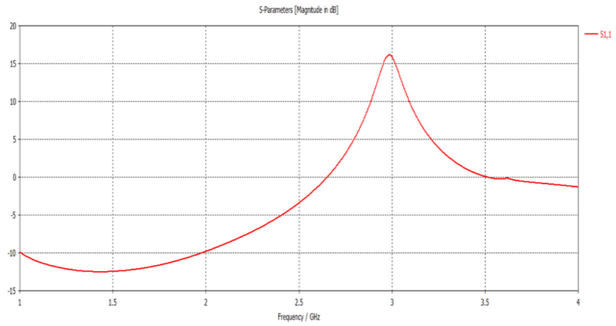

Figure 9: Reflection coefficient magnitude of the EUT after the disruption.

This figure represents the recovery of the parameter “reflection coefficient” at the stem, and as we have mentioned in the article that to have a good adaptation of the equipment the (S1, 1) must equal at least -10 decibel in our case, after the disturbance of the stem, we notice that the amplitude of (S1, 1) in the frequency range chosen (3Ghz-4Ghz) varies from 15 to 0 decibel, and according to the relation:

$$S1, 1+S1.2=1$$

A zero reflection coefficient result a total transmission in the metal stem and proves the results already found for the box. Therefore as a result the stem absorbs the maximum of the electromagnetic radiation coming from the antenna, and this is the process required to study the influence of radiated electromagnetic disturbances.

For the second parameter to recover is the current at the

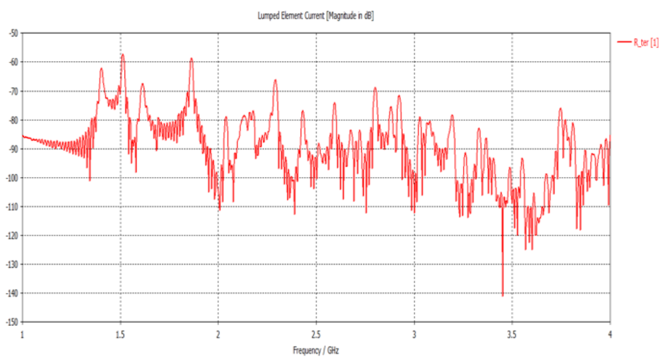

Figure 10: The equipment under test current flowing after the disruption.

Always in the case of the electromagnetic disturbance, we are now sure that the stem absorbs the maximum of the electromagnetic radiation coming from the horn antenna and to see the influence of this disturbance on the stem we recover as parameter, the current that flows in the stem, and after a comparison in the same frequency band (3Ghz-4Ghz), between the current before and after the disturbance, we note that there is a degradation of the current, its amplitude varies from (-85 decibel until -140 decibel) whereas before the disturbance its varies from (-17 decibel to -43 decibel), so the result is a clear attenuation of the current and it can be seen that the radiation from the antenna produces a deterioration of performances at the level of the EUT.

V. Conclusion

The development of 5G and the discovery of new frequency ranges have advantages like: massive connectivity, reduced latency, throughput…, so the 5G will be a totally new and versatile network, providing the interference with all current and evolving generations of future wireless technologies.

But, it also represents a major disadvantage is that the 5G requires the installation of many antennas very close to each other, and we also speak about a mellimetric waves that will require a installation of antennas very close together every 100 meter to 200 meter !!!

In addition, four frequency bands are planed: 700 MHz, 1400 MHz, 3.6 GHz, and 26 GHz!!!

This result an electromagnetic interferences and also an electromagnetic disturbances. For that, it is necessary to develop the standards of the EMC and other techniques fight against these disturbances, so we can use the 5G with security.

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