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Statistical analysis of the Radio Frequency Electromagnetic fields exposure induced by base stations with multiple Massive MIMO transmitters

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Abstract

Massive User MiMo antennas will be increasing used by future 5G networks to support the rise of traffic, is the In previous generations the network design used usual antennas to transmit signal in a large and constant angular sector.

1. Introduction

Future wireless communication networks are designed to enable smart connectivity and high throughput for all, anywhere, and at any time at the highest speed and efficiency so as to meet the overwhelming demand by today's society such as high-definition video streaming, or augmented reality as well as wide coverage and huge connectivity as required by massive Internet of Things (IOT).

With the fifth generation of networks (a.k.a 5G) the number of mobile connections should go methods that can be used to check if the by 2020 beyond the 25 billion with a traffic expected to be 1000 times higher than the present one, latency below 1ms. Densification, higher frequency band, beam-forming based on with phased array antennas and massive MIMO will play important roles in these future networks. With this kind of base station the signals is emitted in one or a few narrow beams that are oriented in the directions of the users. These later are moving so the direction of the beams will be variable in space and in time

Previous generations of network are using antennas transmitting signal in a large and constant angular sector. In this case The assessment of the exposure induced by the Radio Frequency (RF) electromagnetic fields (EMF) and the compliance zone (i.e. the exclusion zone) outside of which the RF EMF is below the ICNIRP limits [1] can be performed using the antenna gain and assuming maximum power.

With the mMiMo systems RF EMF exposure is time varying since the antenna's beams are time and space varying. In such as configuration assuming maximum power for each of the beams and estimate the RF EMF compliance boundary from the envelope of all possible beams, will lead to an unrealistic scenario.

Works are on going in international body such as IEC TC106 MT3 62232 [2] and SG SA4MM.

Recent papers ([3], [4]) have addressed this question looking at the maximum exposure corresponding to the exposure's quantiles of all possible exposure scenarios. These studies have been performed with one provider and one technology. In operating scenarios, the RF exposure can be generated by multiple independent transmitters linked to different operators and technologies Realistic output power of multi-technology radio base stations has been investigated [5] The approach used requests significant effort and do not take into account the results obtained with one provider and one technology. If this paper we propose a simplistic statistical method to handle such scenario. First a closed-form formula of the statistical distribution representing the mean to max ratio is investigated. After that the statistical distribution is used for multiple operators or technologies

2. Surrogate model of the statistical distribution representing the mean to max ratio.

As described previously the elevation and azimuth of the antenna beams are time varying with 5G and Massive MiMo. Previous studies [3], [4] have addressed this question looking at the maximum exposure corresponding to the 95th and 99th percentile of all possible exposure scenarios. The results that have been published shown that the ratio (of the time averaged SPD to the maximum SPD is in the range of 20% to 25% for 95th quantile and about 33% for the 99th quantile.

Since such analysis has been performed for one network provider it should be of interest to investigate the consequences on such ratio of multiple network providers in case of antenna sharing. Previous studies have investigated realistic output power of multi-technology radio base stations. The approach used is quite complex and requests significant effort. have been investigated

Several statistical distributions can be used to represent the random variations of quantities. Since we are dealing with SPD we have look for positive distribution having a finite support. The Beta distribution, positive and having a finite support, has been selected. the beta statistical, introduced by Karl Pearson [6] in early 1900's. has 2 parameters, $(\alpha\ and\ \beta)$ to control the shape of the Cumulative Distribution Function (CDF).

The equation 1 provides the mathematical expression of the probability density function (pdf) of the

Beta distribution as a function of the well known Gamma (a.k.a Γ) distribution (that is positive but non finite)

$$Beta(x,\alpha,\beta) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} x^{\alpha-1}(1-x)^{\beta-1}\mathbb{1}_{[0,1]}(x) \quad (1).$$

To be similar to the distribution obtained in [3] and [4] the distribution used in this paper has a support [0 1] and shape control set at 2 and 15. The random variable associated with a beta (2,15) distribution has been implemented over a set of 2.106 samples.

Table 1: Quantiles of Beta (2,15)

Quantiles	0%	0%	0%	0%	5%	9%
P/Pmax	.070	.103	.119	.137	.259	.330

The quantile are as in the table 1, the figure 1 shows the cumulative distribution function (cdf)

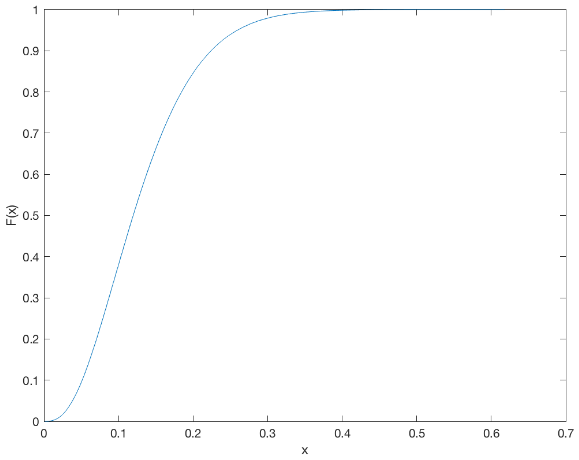

Figure 1. Cdf of the Beta distribution (2,15) (based on $2\ 10^6$ points)

3. Distribution of the mean to max ratio of multi technologies operated on the same base station

As stated in the introduction In operating scenarios, the exposure can be linked to multiple independent transmitters linked to different operators and technologies. The previous surrogate model of the statistical distribution representing the mean to max ratio for one signal can be used easily for independent multiple technologies.

In this paper we have considered on the one hand that the EMF exposure at a given location M that is proportional to the power emitted, depends on the value (possibly varying) of the gain in the direction and are independent. On the other hand we also considered all the maximum power emitted are the same and came from the same mMiMo antenna

For the multiple exposures we can consider a random variable that is the sum of independent variables following the beta distribution

$$Y = \sum_{i=1}^{N} X_i \quad (2).$$

As formulated in eq. 2 The random variable Y is the sum of the N random variables X_i. Each of these random variable have a beta distribution that mean that their CDF is given by eq 3:

$$F(x_i) = P_{beta(\alpha\beta)}(X_i < x_i) \quad (3).$$

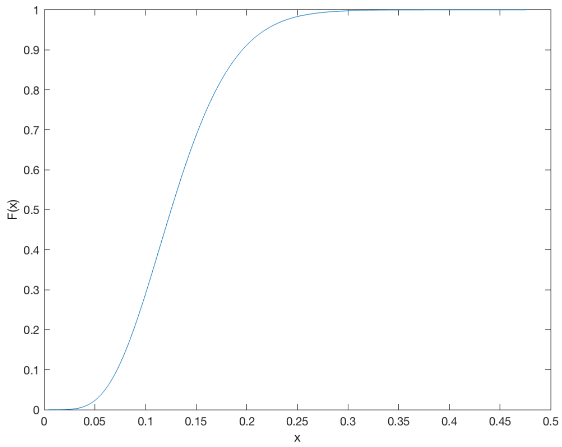

Figure 2. CDF of the a normalised sum of 2 emission.

The figure 2 shows the CDF of the sum of 2 independent distributions having the same CDF. The analysis has been performed fir up to 5 transmitters. The resulting percentiles are provided in Table 7.

Table 1: Percentiles resulting from the combination of 2 to 5 independent transmitters having the reference Beta distribution.

Percentiles	20%	40%	50%	60%	95%	99%
1 transmitter (reference)	0.07	0.10	0.11	0.13	0.25	0.33
2 transmitters	0.08	0.11	0.12	0.13	0.21	0.26
3 transmitters	0.07	0.10	0.11	0.12	0.19	0.23
4 transmitters	0.08	0.10	0.11	0.12	0.18	0.21
5 transmitters	0.08	0.10	0.11	0.12	0.17	0.20

The outcome of the statistical analysis shows that a power combination factor can be applied to the actual maximum transmitted power and other relevant percentiles. Examples of power combination factors are provided in

Table 3. Power combination factors applicable to the normalizer transmitted power CDF in case of combination of multiple independent identical transmitters

Percentiles	20%	40%	50%	60%	95%	99%
1 transmitter (reference)	1,00	1,00	1,00	1,00	1,00	1,00
2 transmitters	1,25	1,10	1,05	1,00	0,84	0,80
3 transmitters	1,13	0,99	0,94	0,90	0,76	0,72
4 transmitters	1,20	1,02	0,95	0,90	0,72	0,67
5 transmitters	1,25	1,03	0,96	0,90	0,69	0,63

4 Conclusions

In realistic configurations, RF exposure is often generated by multiple independent transmitters located on the same antenna. In such case, as shown in this study, the probability that multiple independent transmitters systems are delivering the actual maximum RF exposure on the same point at the same time is lower than for one single transmitter that is coherent with previous studies [4] As pointed out in section 3 one, important, assumption in the assessment of power combination factors is that all transmitters the same weight in the statistical combination (same maximum transmitted power, for all). Further studies are ongoing to study more general cases.

4 Acknowledgments

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5. References

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