

## Summary

By considering that an **immunity testing is a binomial process** [1], measurements performed with deterministic fields like a fully anechoic room (FAR) and measurements performed with random fields like a reverberation chamber (RC) can give very similar values.

## Motivation

The comparison of testing facilities is a subject of interest in the EMC community. The confidence intervals (generally  $\pm 3$  dB) provided by standard measurements [2, 3] does not allow a good agreement between the measurements.

### Solution

If the susceptibility of a device is a random variable, we can develop a **common statistical framework** to extract with a controlled uncertainty the susceptibility levels of the equipments tested in our lab.

## Statistical characterization of the susceptibility of a non-intentional emitter

In order to extract the statistics of the E-field radiated by a non-intentional emitter, we use a model of non intentional emitter used by P. Wilson [4].  $n$  random Hertz dipoles are placed arbitrary on a sphere of radius  $a$ .

We study the effects of the complexity (number of dipoles  $n$ ) and the electrical size  $ka = \frac{2\pi}{\lambda}a$  on the statistics of the radiated E-field.

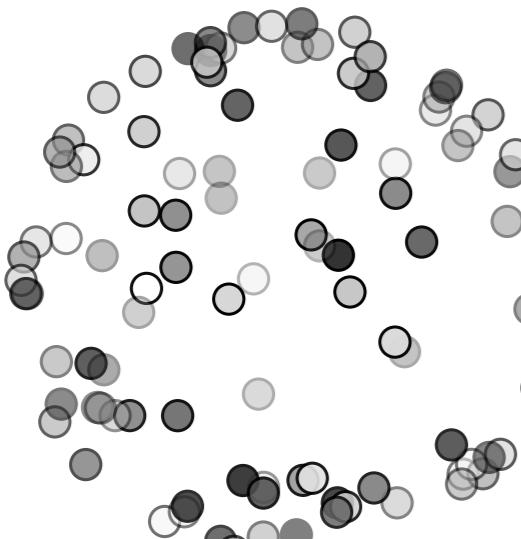
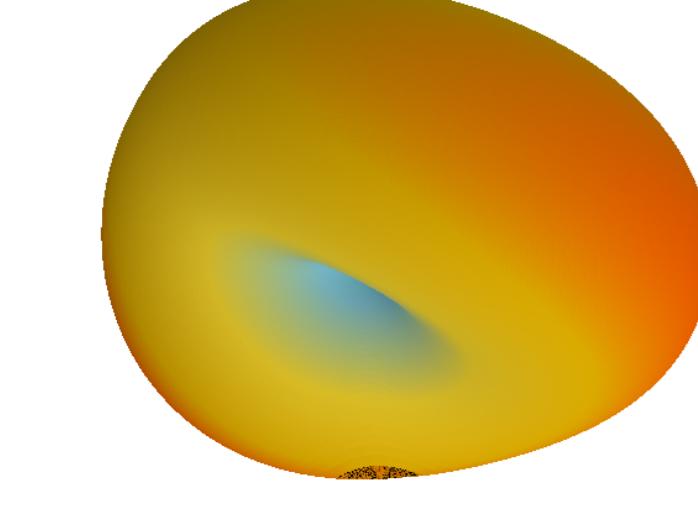
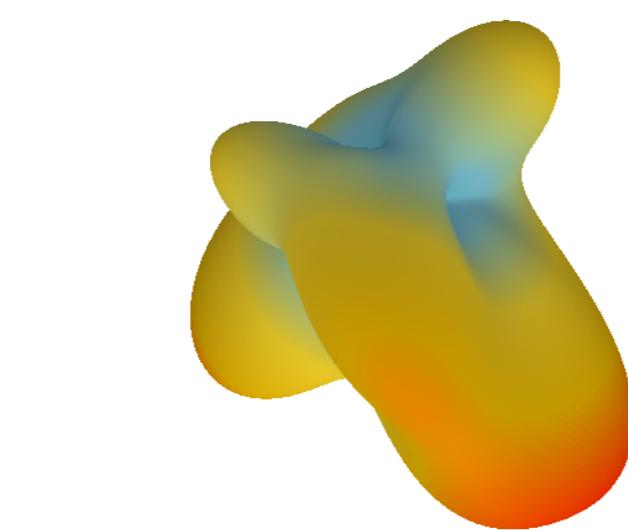


Figure : A non-intentional emitter



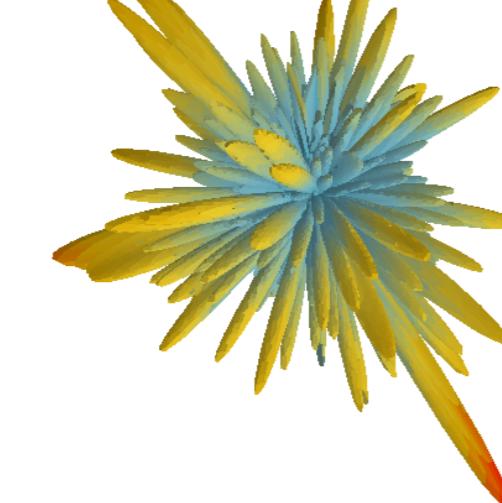
(a)  $f = 20$  MHz,  $ka = 0.4$ ,  $D \approx 1.6$



(b)  $f = 100$  MHz,  $ka = 2.1$ ,  $D \approx 2.3$



(c)  $f = 500$  MHz,  $ka = 10.5$ ,  $D \approx 5.2$



(d)  $f = 1000$  MHz,  $ka = 21$ ,  $D \approx 5.7$

Figure : Radiated power (linear values) of a random EUT with  $a = 1$  m and  $n = 100$  dipoles

Monte Carlo simulations can give an idea of the statistics of the E-field rectangular components:

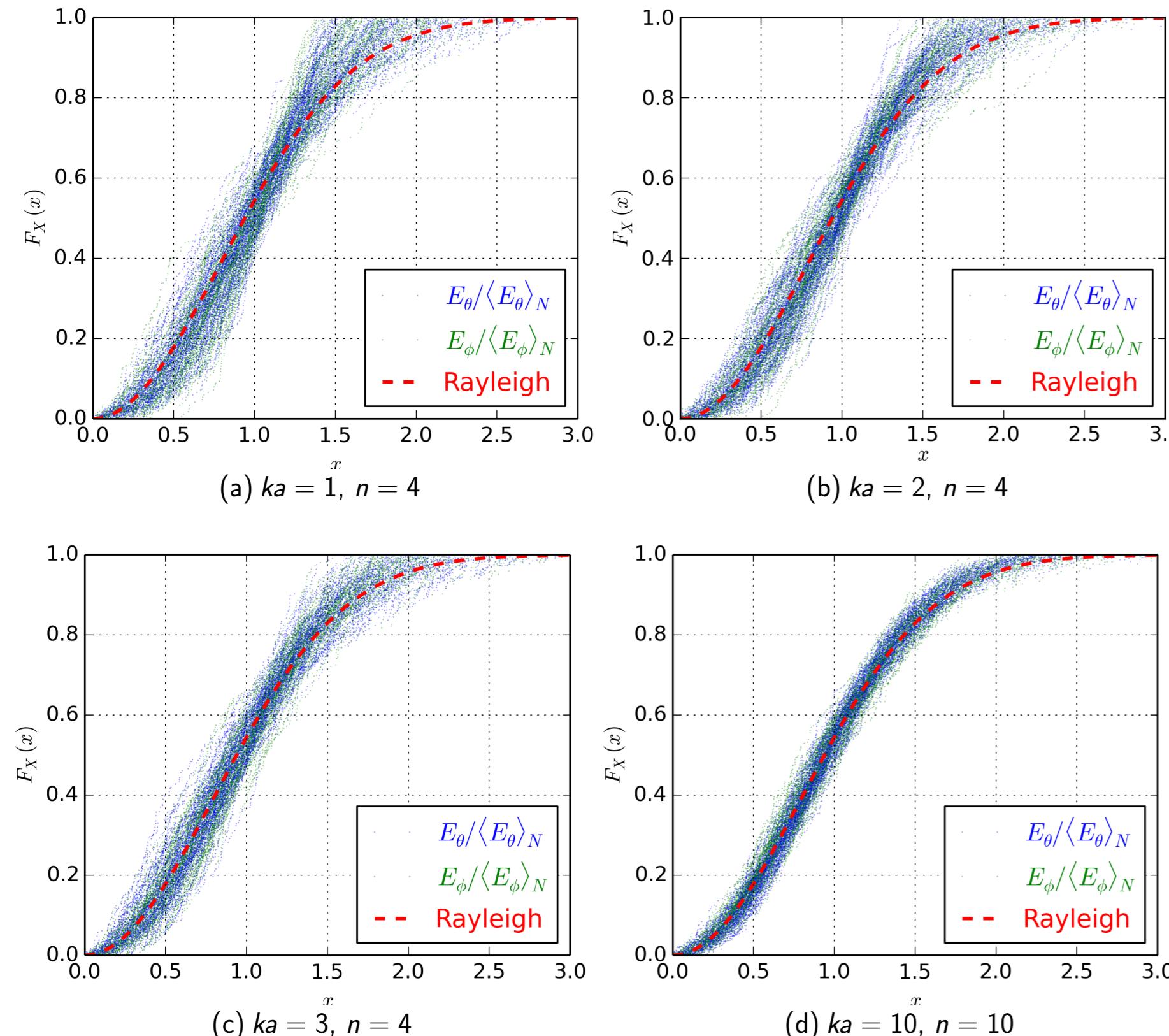


Figure : Cumulative distribution functions of the E-field rectangular components vs. theoretical Rayleigh distribution

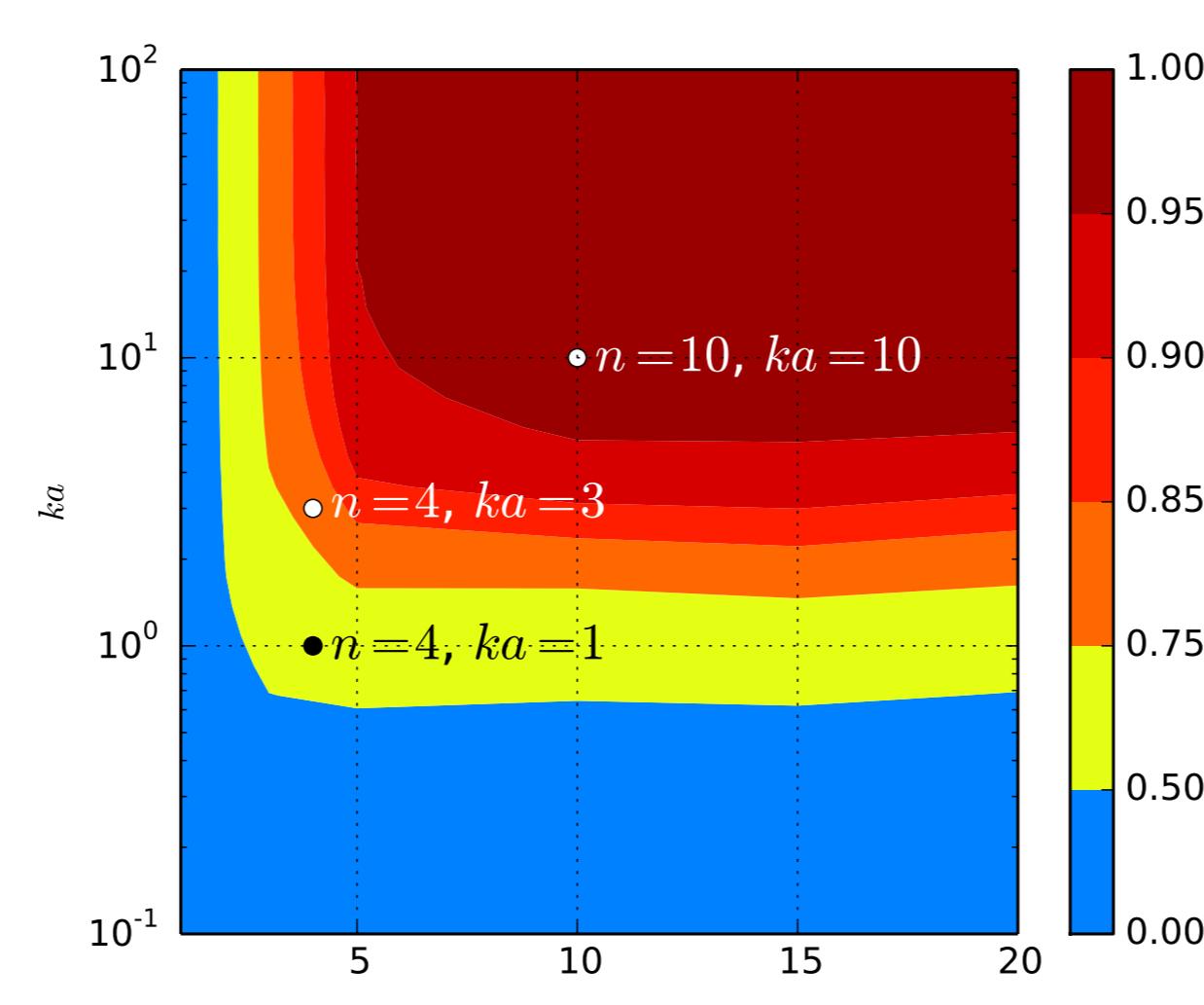


Figure : Probability to get a Rayleigh distributed E-field component according to the Anderson-Darling statistical test,  $10^5$  Monte Carlo trials for every point

## Statistical estimation of the susceptibility

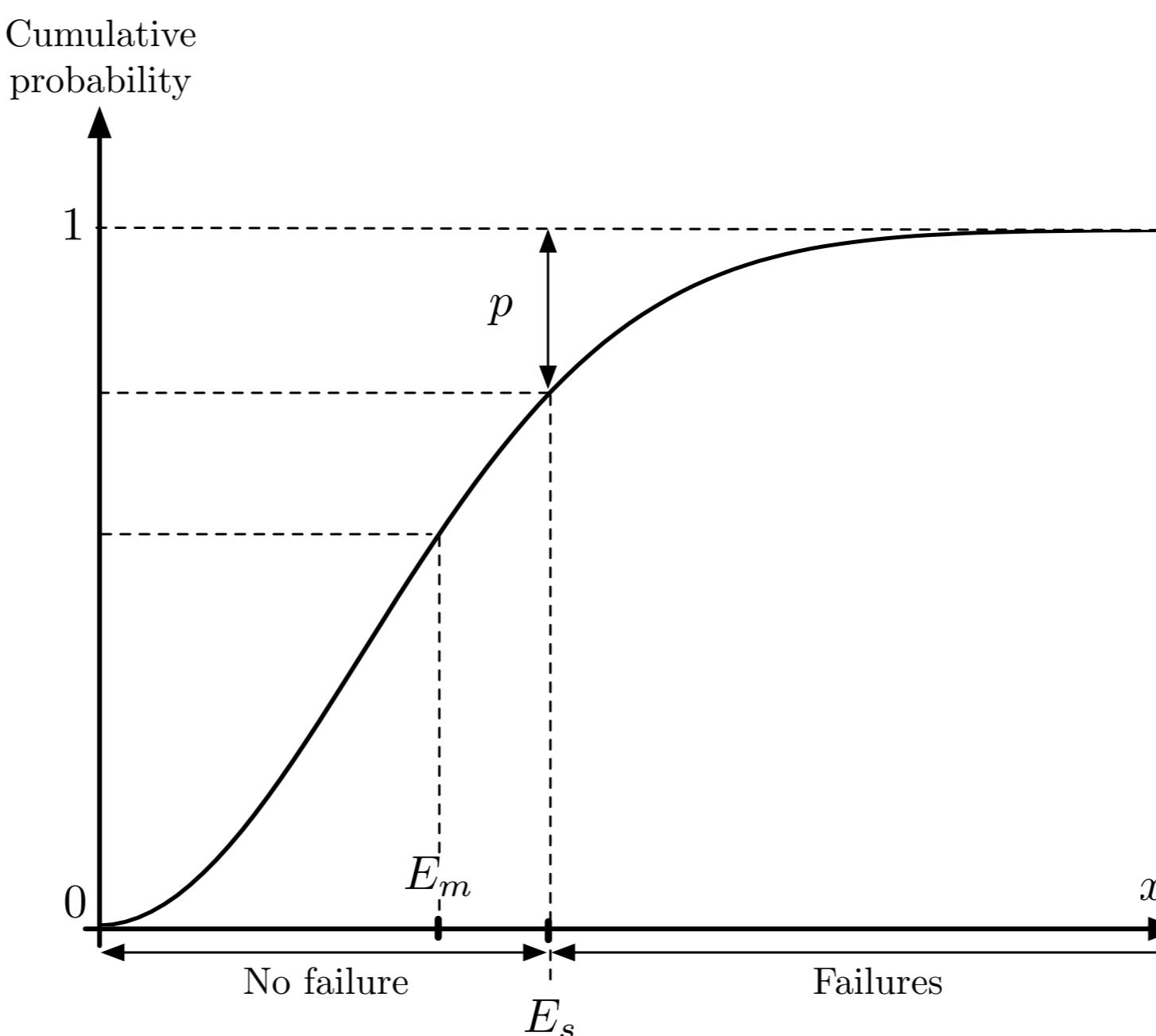


Figure : Statistical estimation of the susceptibility  $E_s$  [1] of an EUT if the impinging E-field components follows a Rayleigh distribution with mean value  $E_m$ .

$$\hat{E}_s = 2E_m \sqrt{\frac{\ln(1/\hat{p})}{\pi}}$$

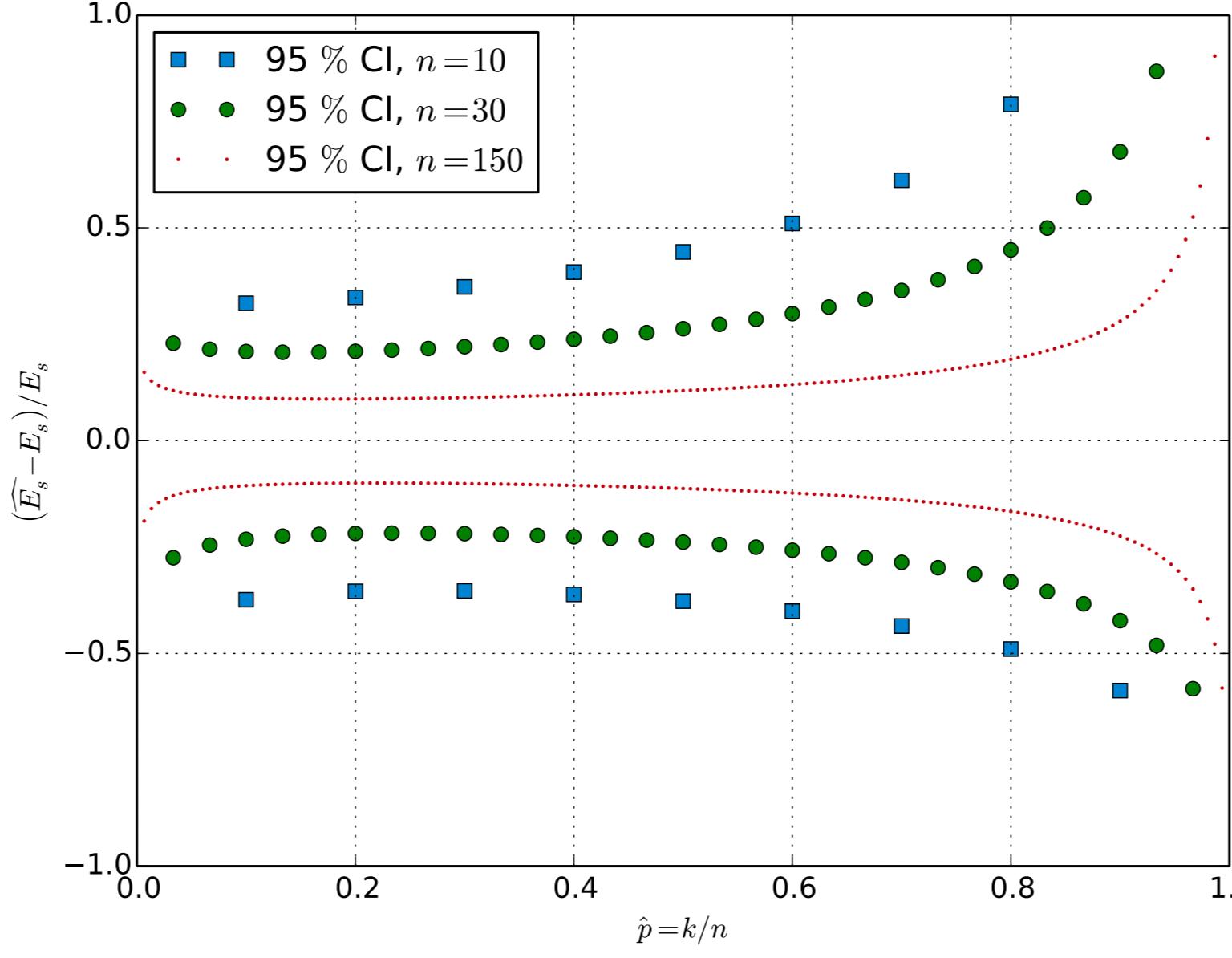
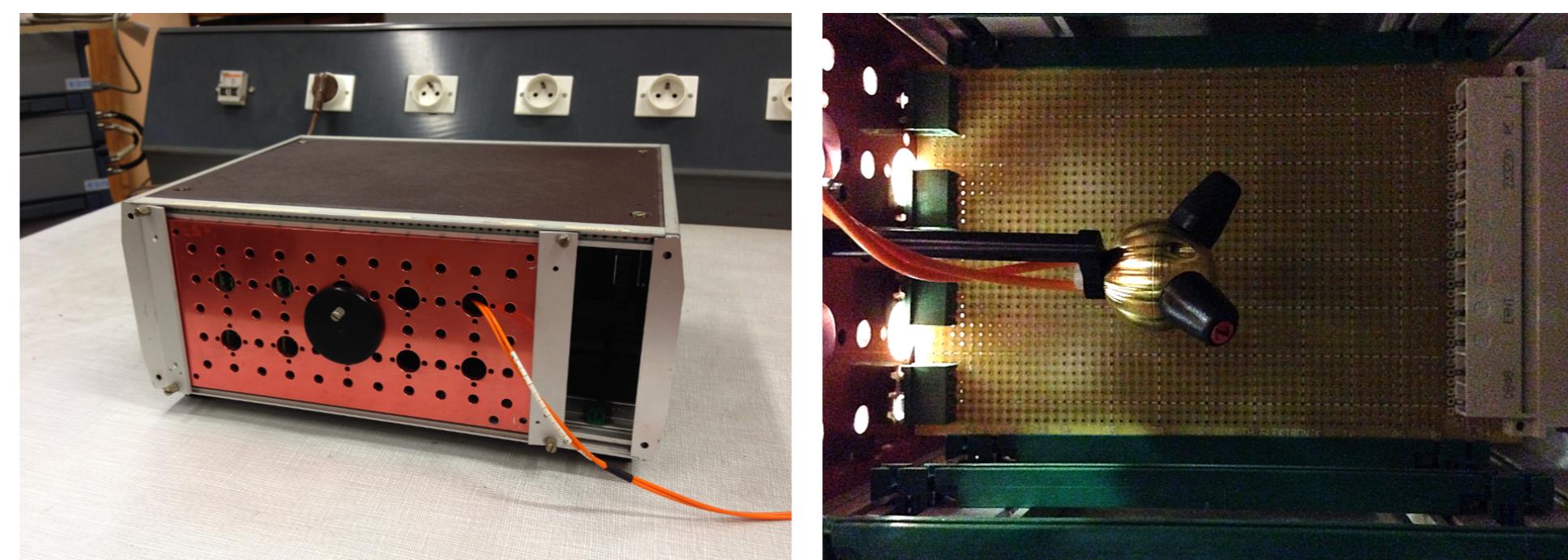


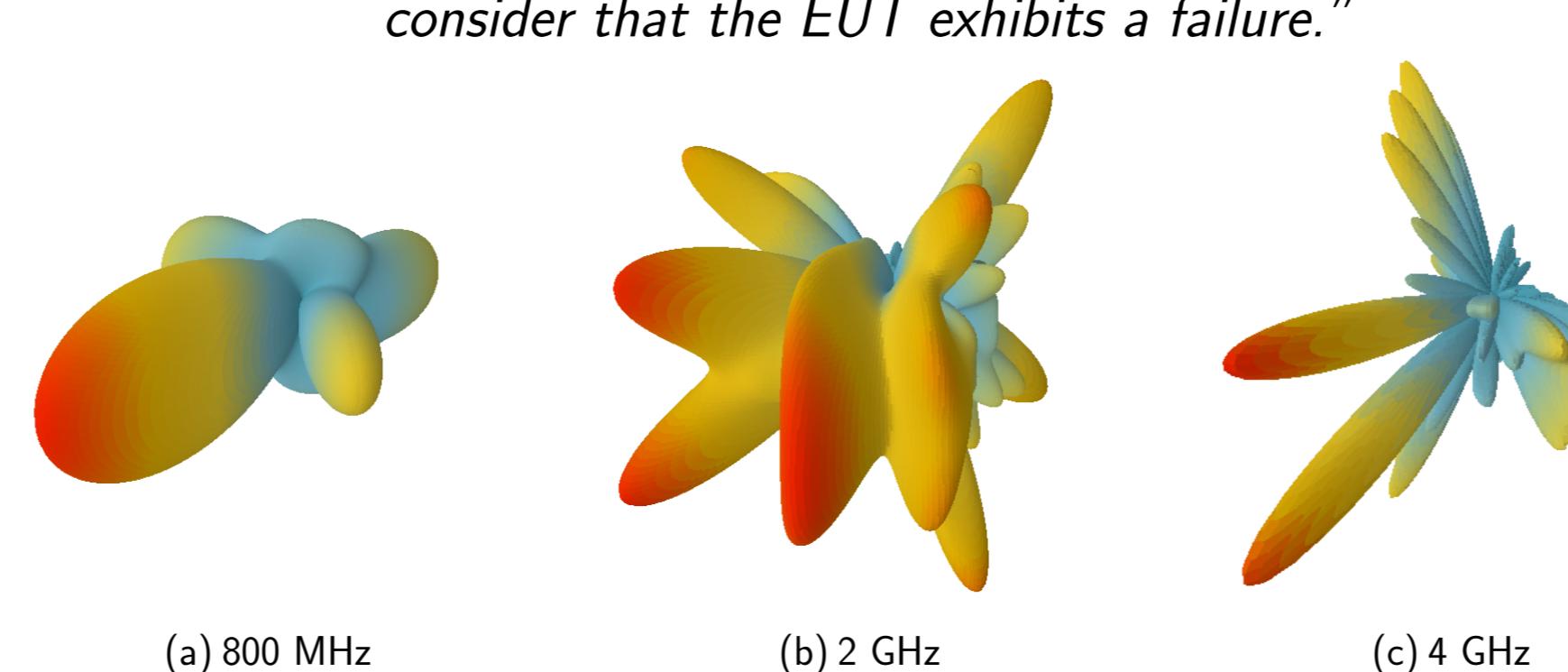
Figure : Confidence intervals of  $\hat{E}_s$ .

## A generic EUT



(a) External (a) and internal (b) views of the generic EUT.

"If the level on the z axis exceeds the critical value  $E_c = 10$  V/m, we consider that the EUT exhibits a failure."



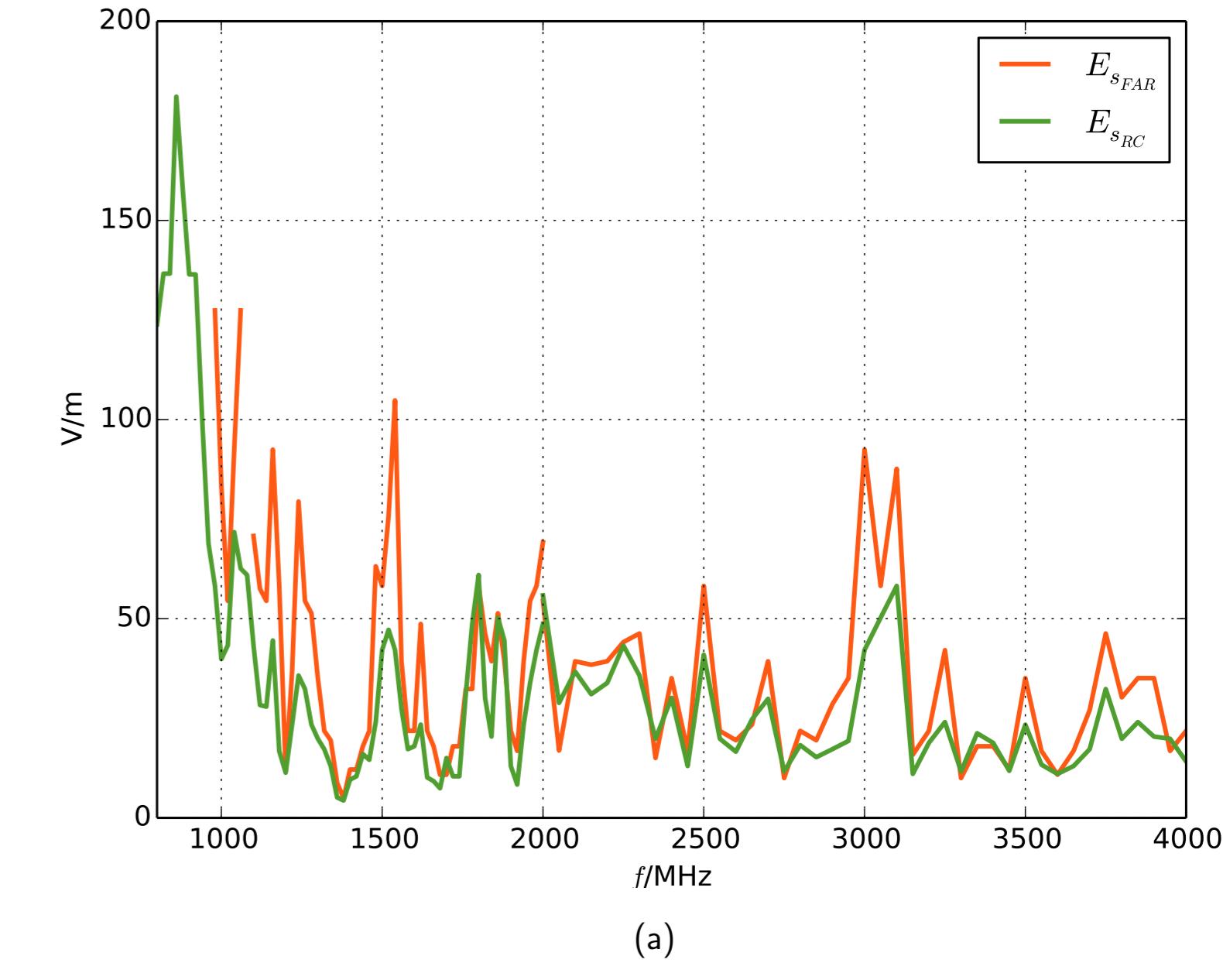
(a) 800 MHz (b) 2 GHz (c) 4 GHz

Figure : Radiation pattern (CST simulations).

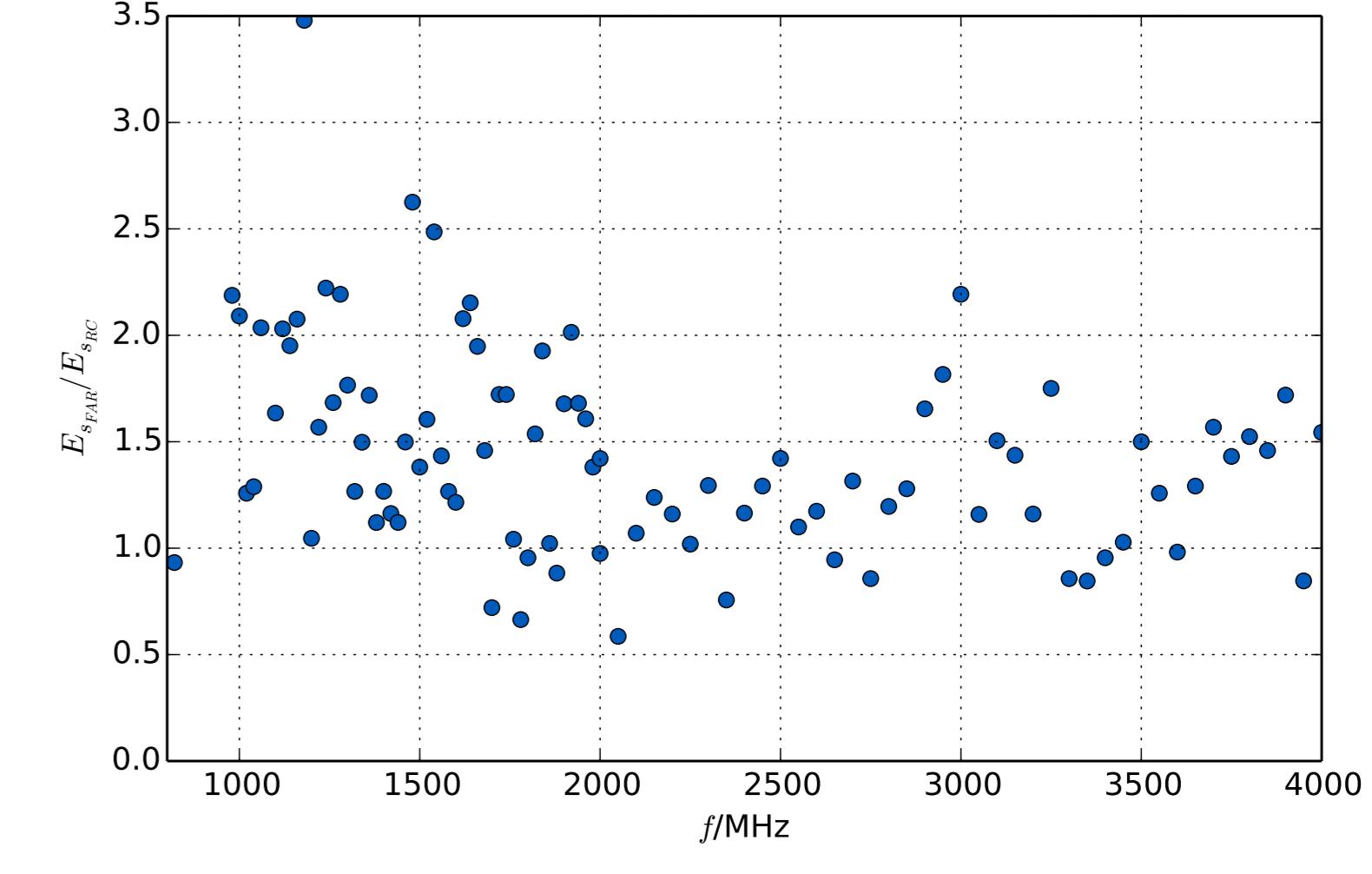
## Measurements

- Measurements are performed between 800 MHz and 4 GHz
- Calibration of the RC and the FAR is done for **every** frequency tested
- $n$  angles of incidence are randomly chosen for the FAR measurement.  $n$  stirrer positions in the RC
- Tested levels  $E_m$  are 5, 10, 20, 40, 80 V/m.

## Results

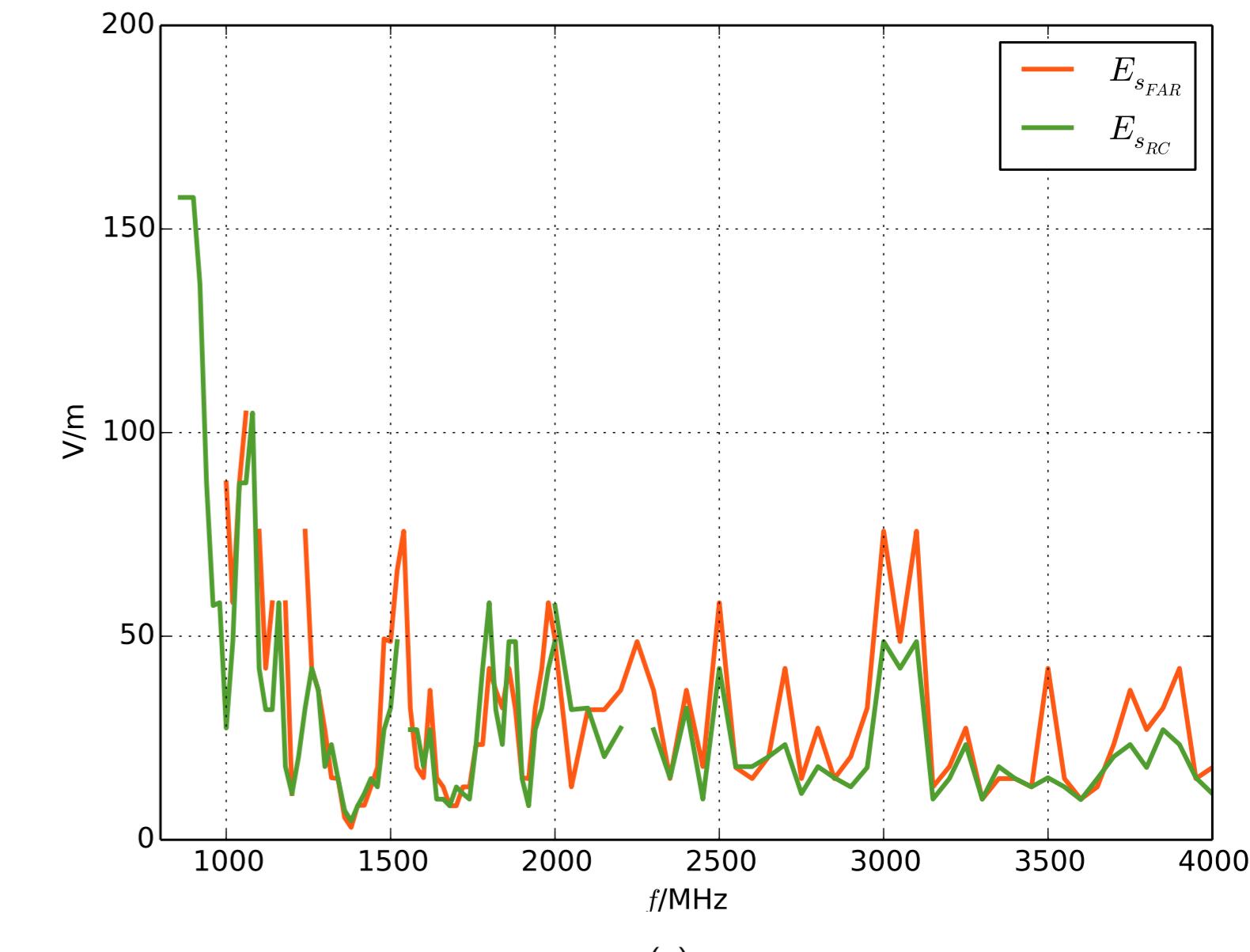


(a)

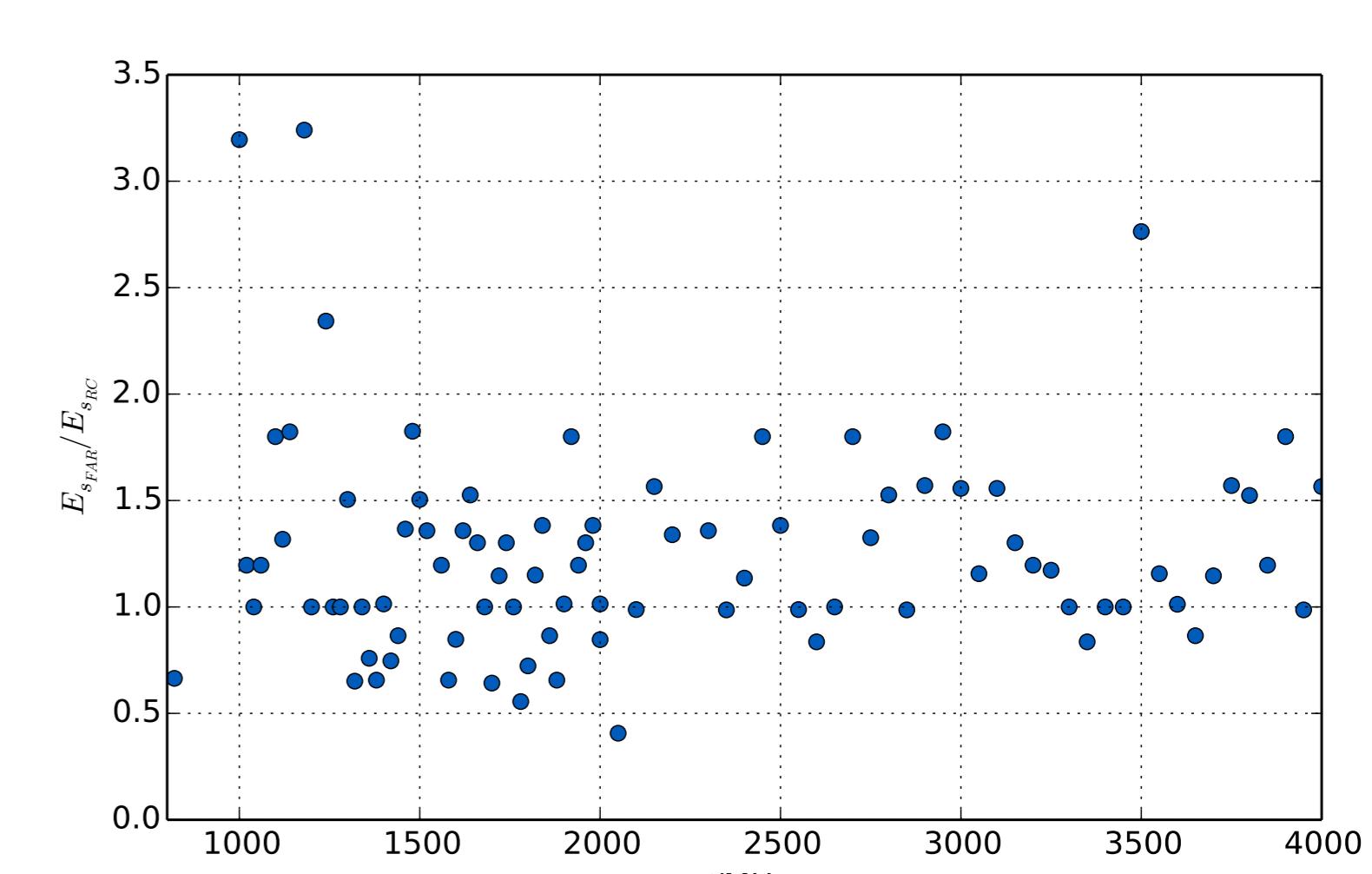


(b)

Figure : Susceptibility measurement with  $n = 30$  observations.



(a)



(b)

Figure : Susceptibility measurement with  $n = 10$  observations.

As long as the EUT is electrically large enough:

- Good agreement of the measurements
- With  $n = 10$ , the agreement is good enough for EMC purpose

## Conclusion

By using a common statistical framework for both the FAR and the RC and as long as the EUT is electrically large and complex, we can extract with a good agreement the immunity levels of an EUT. By giving a statistical dimension to FAR measurements, we can control and enhance the accuracy of the measurement.

## References

- [1] E. Amador, H. Krauthäuser, and P. Besnier, "A binomial model for radiated immunity measurements," *Electromagnetic Compatibility, IEEE Transactions on*, vol. 55, no. 4, pp. 683–691, Aug. 2013.
- [2] IEC, *IEC 61000-4-21 Ed. 2 : Testing and measurement techniques — reverberation chamber test methods*, IEC, Geneva, Switzerland, Feb. 2010.
- [3] ———, *IEC 61000-4-22 Ed. 1 : Testing and measurement techniques — radiated emissions and immunity measurements in fully anechoic rooms (FARs)*, IEC, Geneva, Switzerland, Nov. 2010.
- [4] P. Wilson, D. Hill, and C. Holloway, "On determining the maximum emissions from electrically large sources," *Electromagnetic Compatibility, IEEE Transactions on*, vol. 44, no. 1, pp. 79 – 86, feb 2002.

## Acknowledgments

Measurements and simulations made with:



Poster, data, scripts available at:

<https://github.com/manuamador/EMCEurope2014>

