

# *Determination of the Number of Statistically Independent Boundary Conditions of Mode-Stirred Chambers*

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- **Mode-Stirred Chambers:**
  - Cavity resonator
  - Changing boundaries by the tuner(s)
  - sufficient high mode density

⇒ get a statistical homogeneous field distribution

- **IEC 61000-4-21**



background: tuner (MSC Magdeburg)



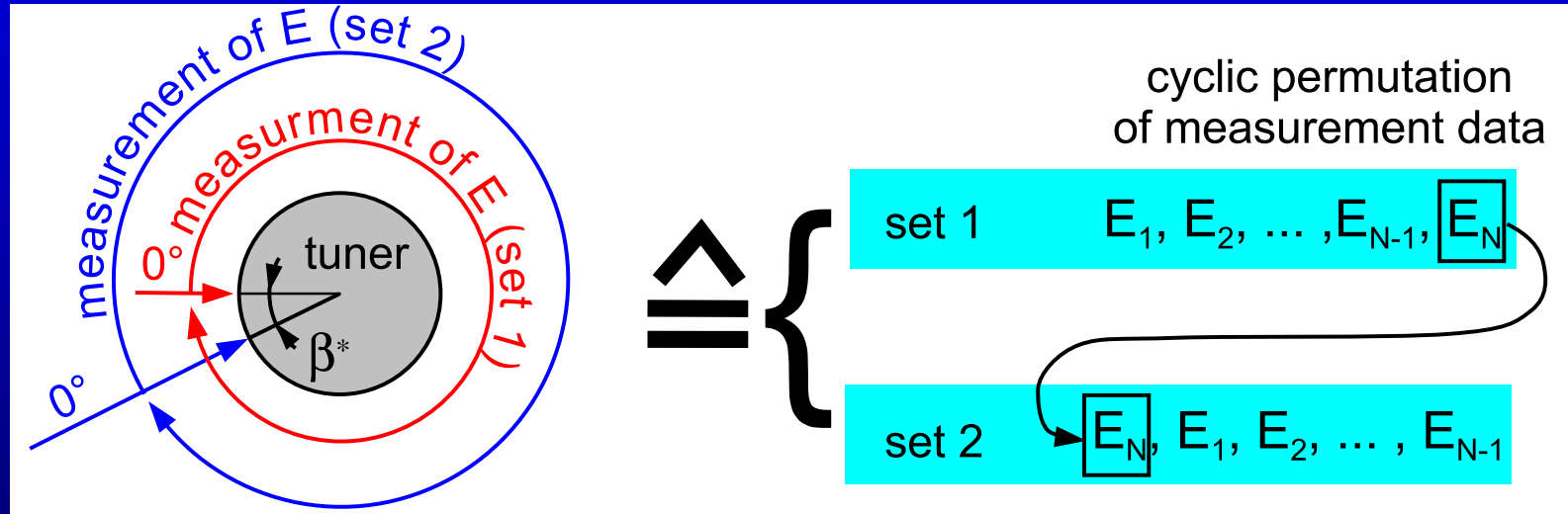
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- E-field measurements for a sample of tuner positions

⇒

$$\{E_1, E_2, \dots, E_{N-1}, E_N\}$$



- Determination of statistical independency by means of autocorrelation

$$r = \frac{\sum_{\nu=0}^{N-1} ((E_{\nu} - \langle E \rangle)(E_{\nu}^* - \langle E \rangle))}{\sum_{\nu=0}^{N-1} (E_{\nu} - \langle E \rangle)^2}, \quad -1 \leq r \leq 1$$

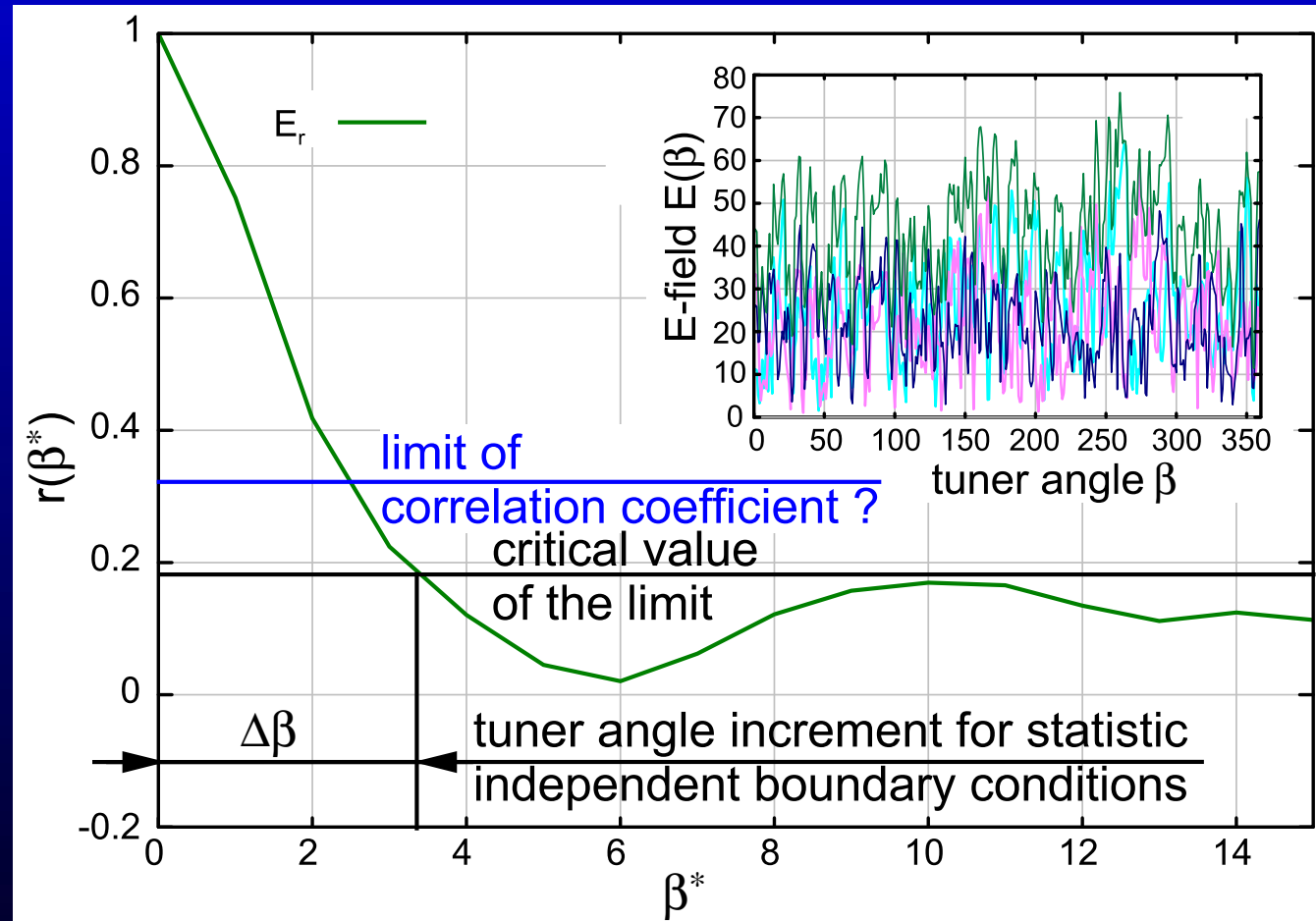
- $|r| = 1$  perfect correlated,  $r = 0$  perfect uncorrelated



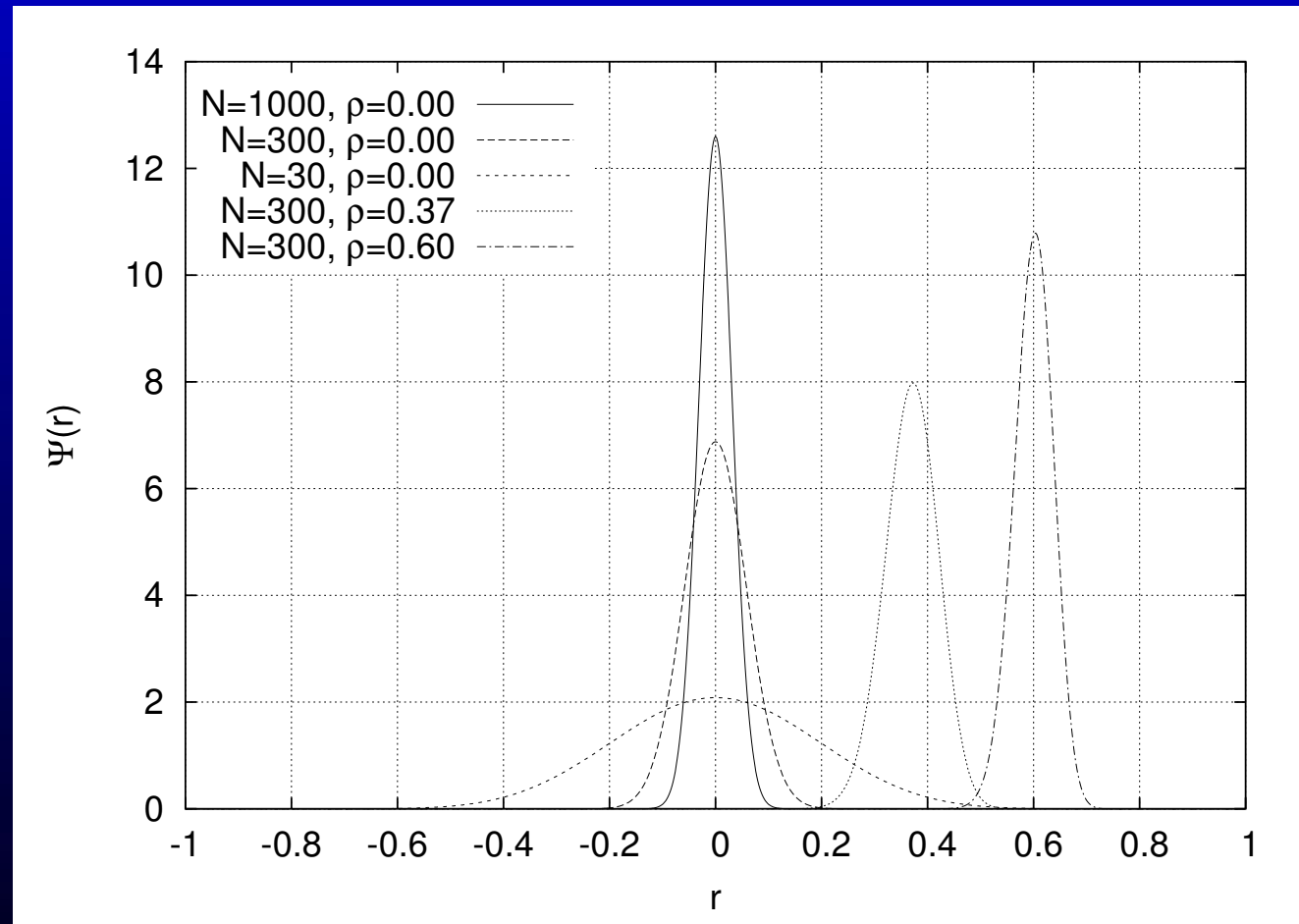
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- **Starting point:** Measurement is a sample of size  $N$ 
  - ⇒ Correlation coefficient is affected by statistical variations
  - true autocorrelation coefficient only if sample size  $N \rightarrow \infty$



$$\psi(r) = \frac{N-2}{\sqrt{2\pi}} \cdot \frac{\Gamma(N-1)}{\Gamma(N-\frac{1}{2})} \cdot \frac{(1-\rho^2)^{\frac{N-1}{2}} (1-r^2)^{\frac{N-4}{2}}}{(1-\rho r)^{N-\frac{3}{2}}} \left[ 1 + \frac{1+\rho r}{4(2N-1)} + \dots \right]$$



- Distribution known

from literature

$$\Rightarrow \Psi(r)$$

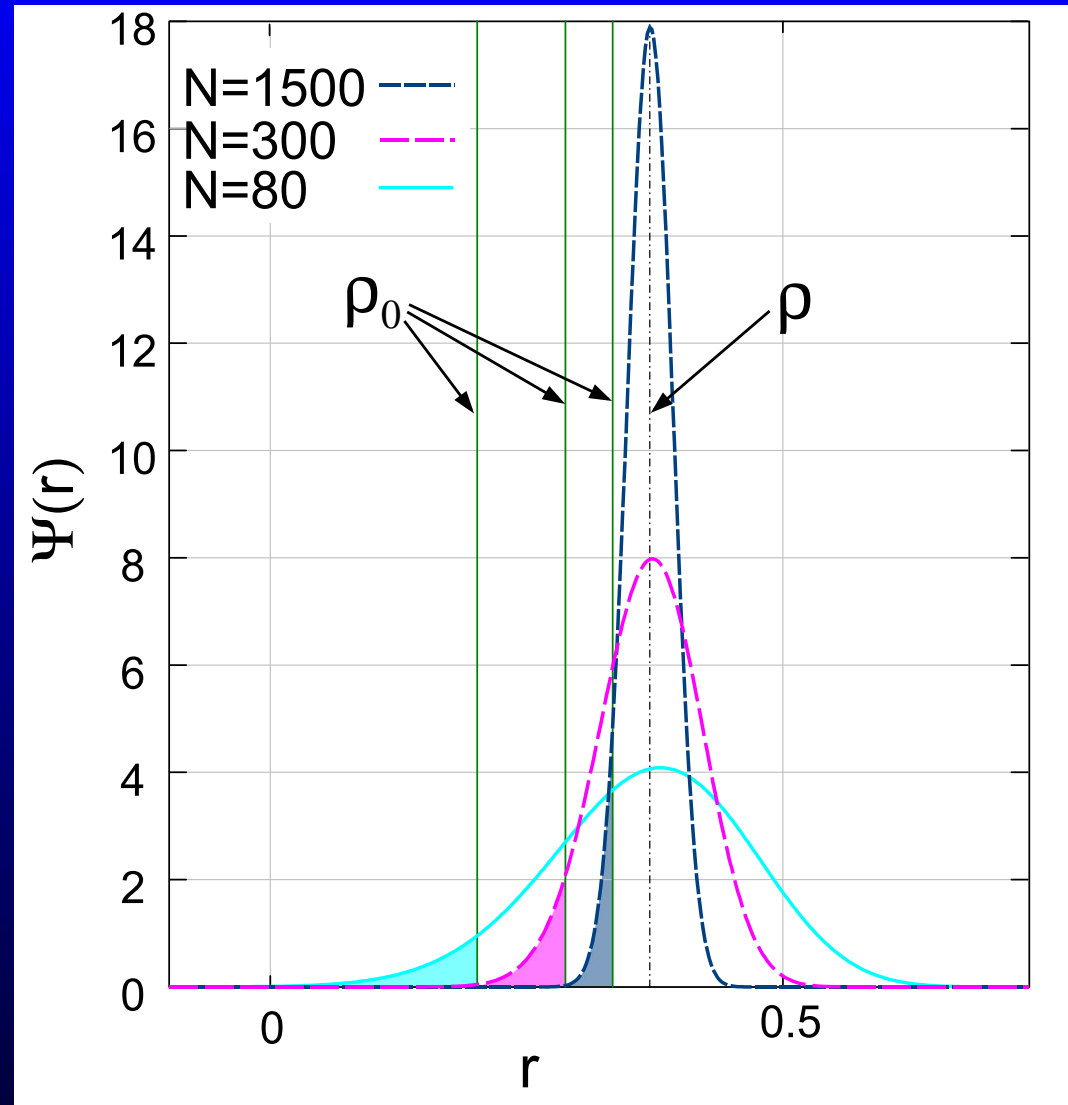
- $\rho$  – expected value

$\Rightarrow$  true value for  $N \rightarrow \infty$

- $N$  – sample size

- $\rho_0$  – limit

$$\alpha = \int_{-1}^{\rho_0} \Psi(r) dr$$



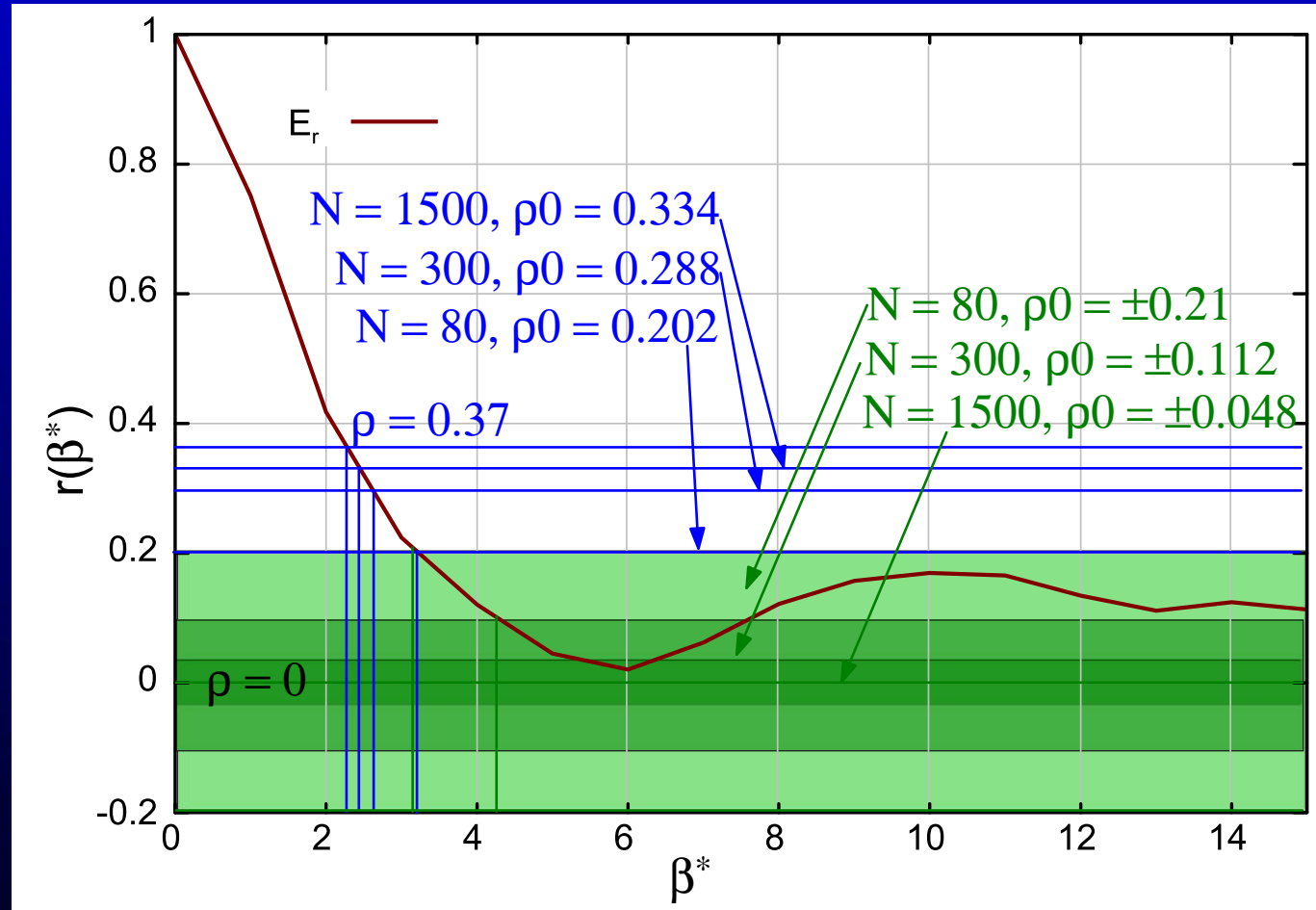
- $\alpha$  – probability for values less than  $\rho_0$  if the expected value is  $\rho$

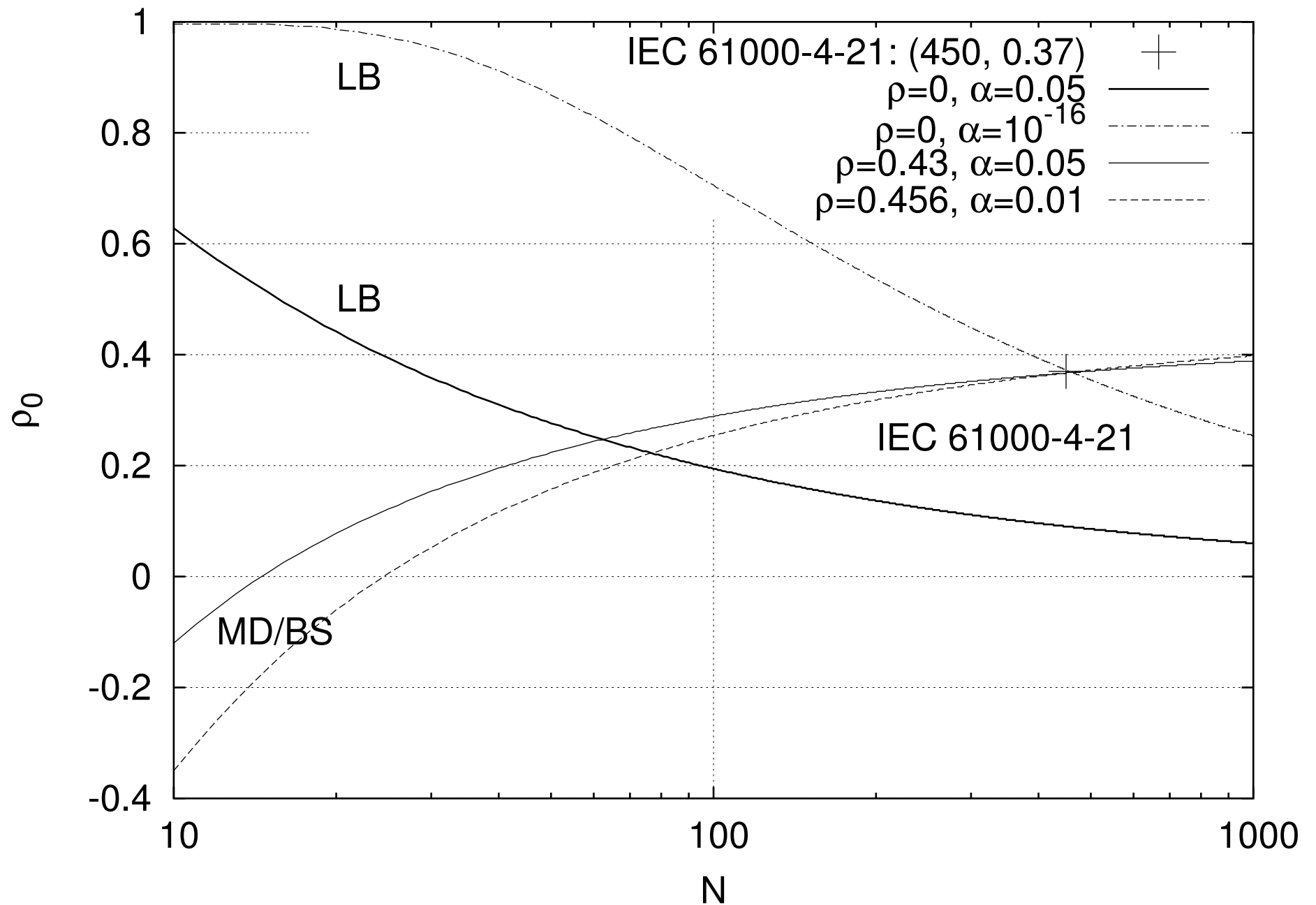


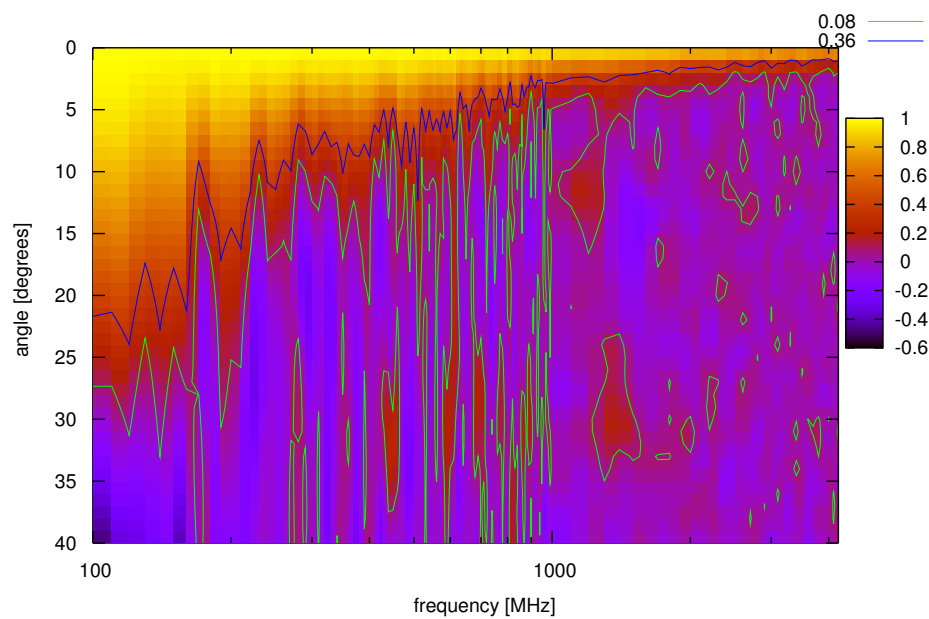
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- based on a publication of Lundén und Bäckström (IEEE EMC, 2000):
  - $\rho = 0$ ,  $\rightarrow$  perfect uncorrelated data
- MD/BS:
  - $\rho > \rho_{\text{critical}} > 0$ ,  $\rightarrow$  correlation stronger than  $\rho_{\text{critical}}$





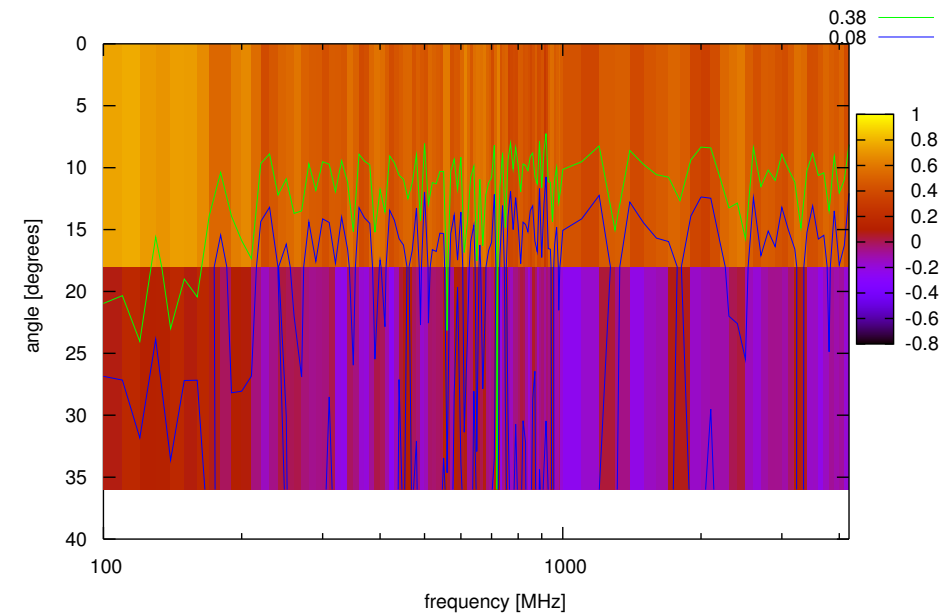
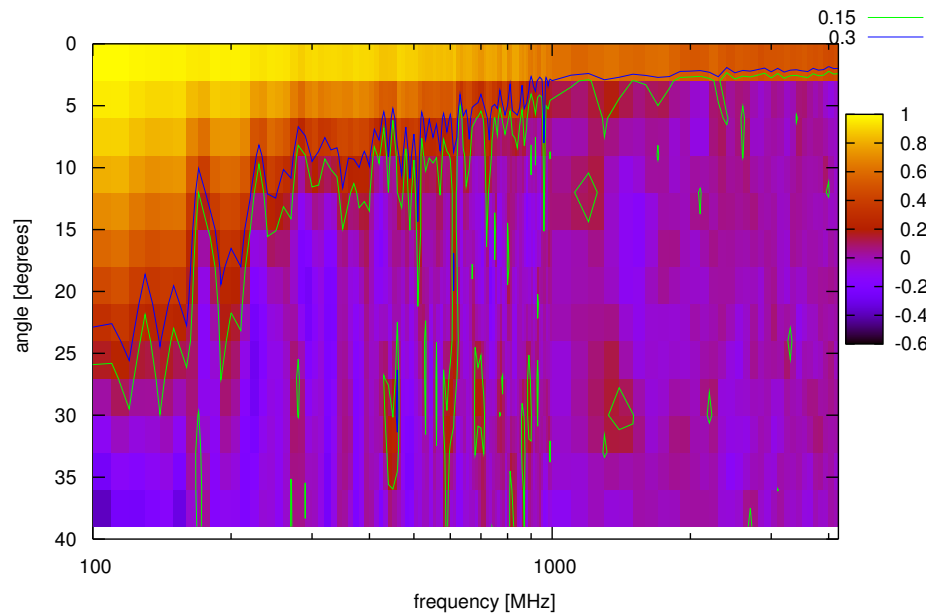


original data set:  $N = 360$  (1 degree)

reduced data sets:  $N = 120$  (3 degrees)  
and  $N = 20$  (18 degrees)

**for LB approach:** number of independent tuner positions **increase** with decreasing  $N$

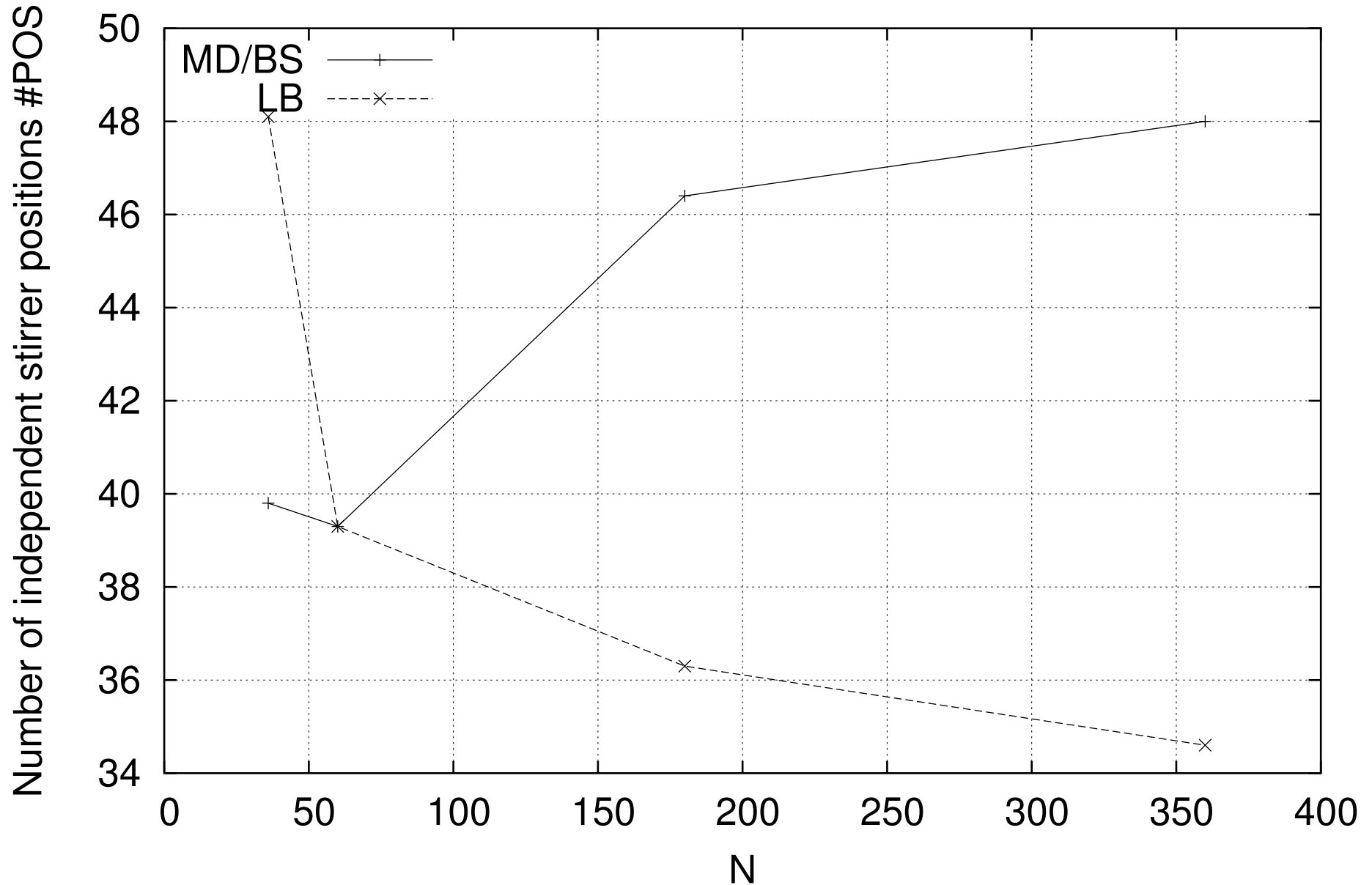
**for MD/BS approach:** number of independent tuner positions **decrease** with decreasing  $N$



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MSC MD:  $f = 200$  MHz, #POS for different  $N$ ,  $\alpha=0.05$



- **Insufficiency in the standard IEC 61000-4-21:**
  - Limit for the autocorrelation function  
only given for a fixed  $N$
- **Approach of Lundén und Bäckström:**
  - Pointed out that  $N$  has to be taken into account
  - Calculations are correct, but improper starting point ( $H_0$ )
- **Addendum of the standard:**
  - Explanation of the critical limit in  
its statistical context
  - normative specification of the expected value for  $\Psi(r)$



|                 | accept $H_0$ | reject $H_0$ |
|-----------------|--------------|--------------|
| $H_0$ correct   | no error     | alpha error  |
| $H_0$ incorrect | beta error   | no error     |

