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EMF Policy in Brazil

WORKSHOP ON RECENT DEVELOPMENTS RELEVANT TO EMF POLICY FORMULATION

8TH MAY 2024

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Multidisciplinary Issue

- Two approaches: possible health effects and characterization of the EMF environment;
- WHO, ICNIRP and IEEE evaluates biological effects from this exposure;
- ICNIRP and IEEE establish exposure limits (i.e. exposure standards);
- ITU, IEC and IEEE establish measurement protocols (i.e. measurement standards);
- Law nr. 11,934/2009 establishes that the EMF exposure limits in Brazil will follow WHO Recommendations;
- Until there is no new recommended exposure limits, ICNIRP limits apply;
- Regulators (Telecommunications and Electric Power) are responsible to establish the assessment protocols.

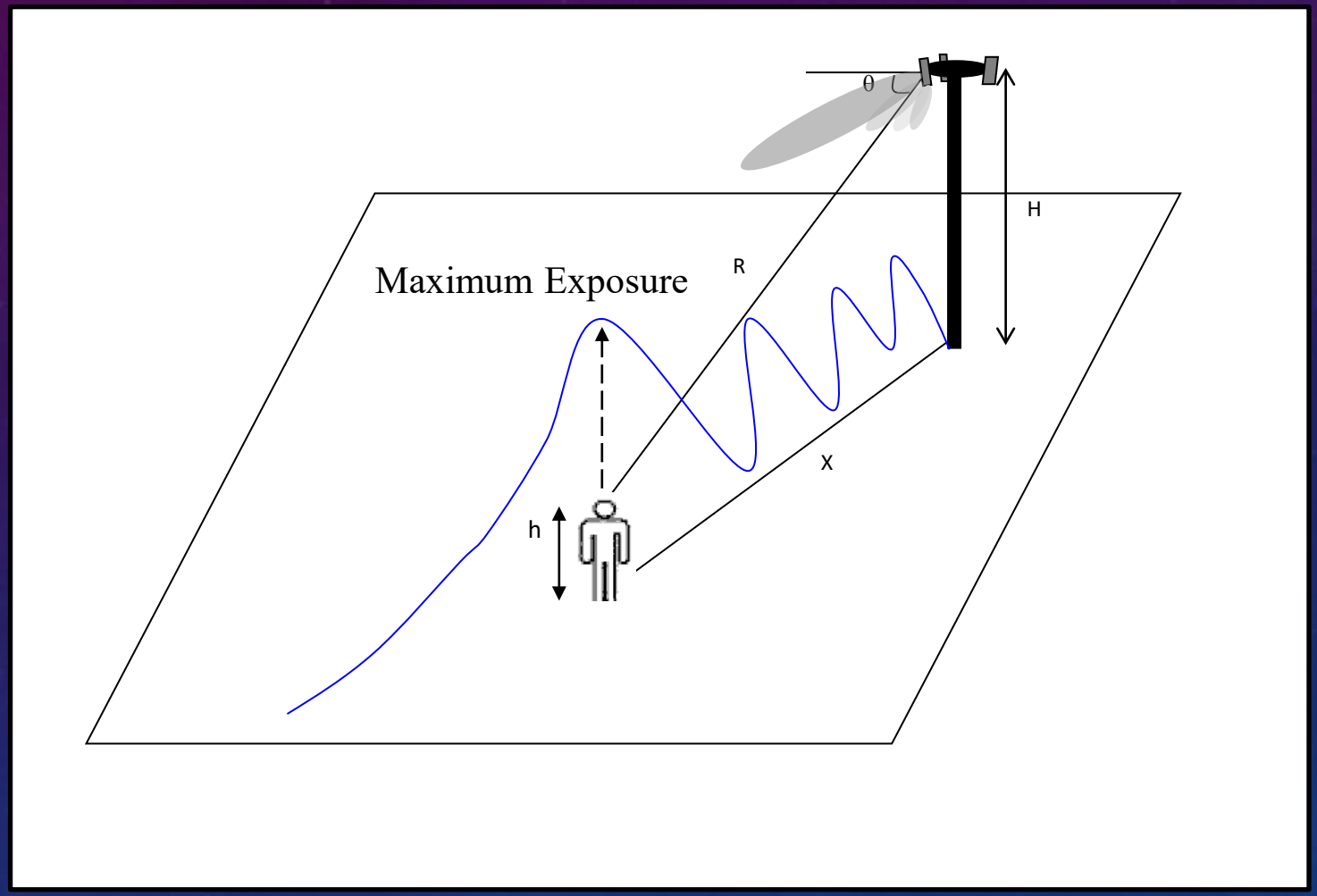
Law nr. 11,934/2009:

- Art.10 ... if a transmitting station is less than 500m from another station, then the tower has to be shared.
  - Exceptions: environmental harmonization, top of building, technical limitations.
- Art.13 ... all radiocommunication transmitting stations shall measure and re-assess the EMF compliance every five years.

Law nr. 11,934/2009:

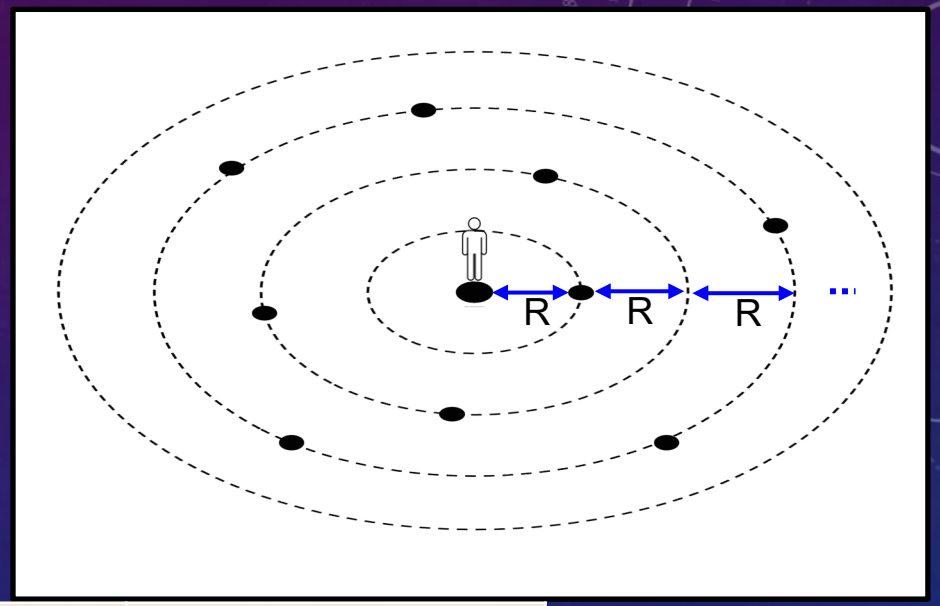
- ~~Art.10 ... if a transmitting station is less than 500m from another station, then the tower has to be shared.~~
  - ~~Exceptions: environmental harmonization, top of building, technical limitations.~~ (suppressed)
- Art.13 ... all radiocommunication transmitting stations shall measure and re-assess the EMF compliance every five years.

Environment Characterization: open space



Aggregated exposure due to multiple sources

- much complex and difficult to generalize
- was proposed a conservative simplified approach to show that the aggregated effect has an upper bound in real world
- was considered a series of concentric circles to generate a region that has constant density of stations



n-th circle	distance to center	area	total stations considered	density of stations	# stations in the n-th circle (formation rule)
1	R	πR^2	1	$\frac{1}{\pi R^2}$	1
2	2R	$\pi(2R)^2$	4	$\frac{4}{\pi(2R)^2} = \frac{1}{\pi R^2}$	3
3	3R	$\pi(3R)^2$	9	$\frac{9}{\pi(3R)^2} = \frac{1}{\pi R^2}$	5
...	...	...	...	...	...
n	nR	$\pi(nR)^2$	n^2	$\frac{n^2}{\pi(nR)^2} = \frac{1}{\pi R^2}$	$2n-1$

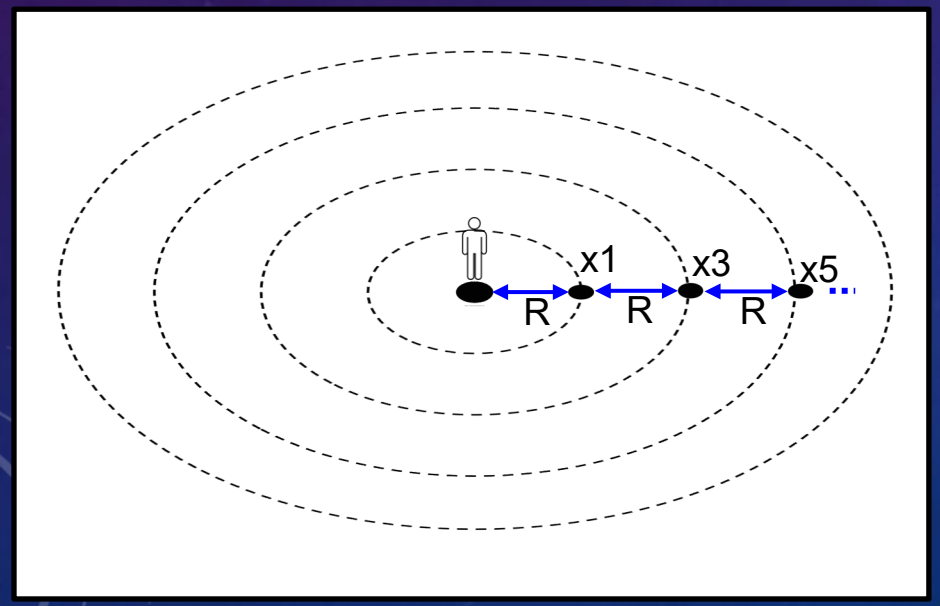
Aggregated exposure due to multiple sources

- Summation of the power flux-density due to n-th circular ring in free space

$$S = S_1 + S_2 + S_3 + \cdots + S_N$$

$$S = \frac{1 \cdot EIRP}{4\pi R^2} + \frac{3 \cdot EIRP}{2^2 \cdot 4\pi R^2} + \frac{5 \cdot EIRP}{3^2 \cdot 4\pi R^2} + \cdots + \frac{(2N-1) \cdot EIRP}{\mathrm{N}^2 \cdot 4\pi R^2}$$

$$S = \frac{EIRP}{4\pi R^2} \sum_{n=1}^{N} \frac{2n-1}{n^2}$$



when $N \to \infty$,

harmonic series dominate

DIVERGES!

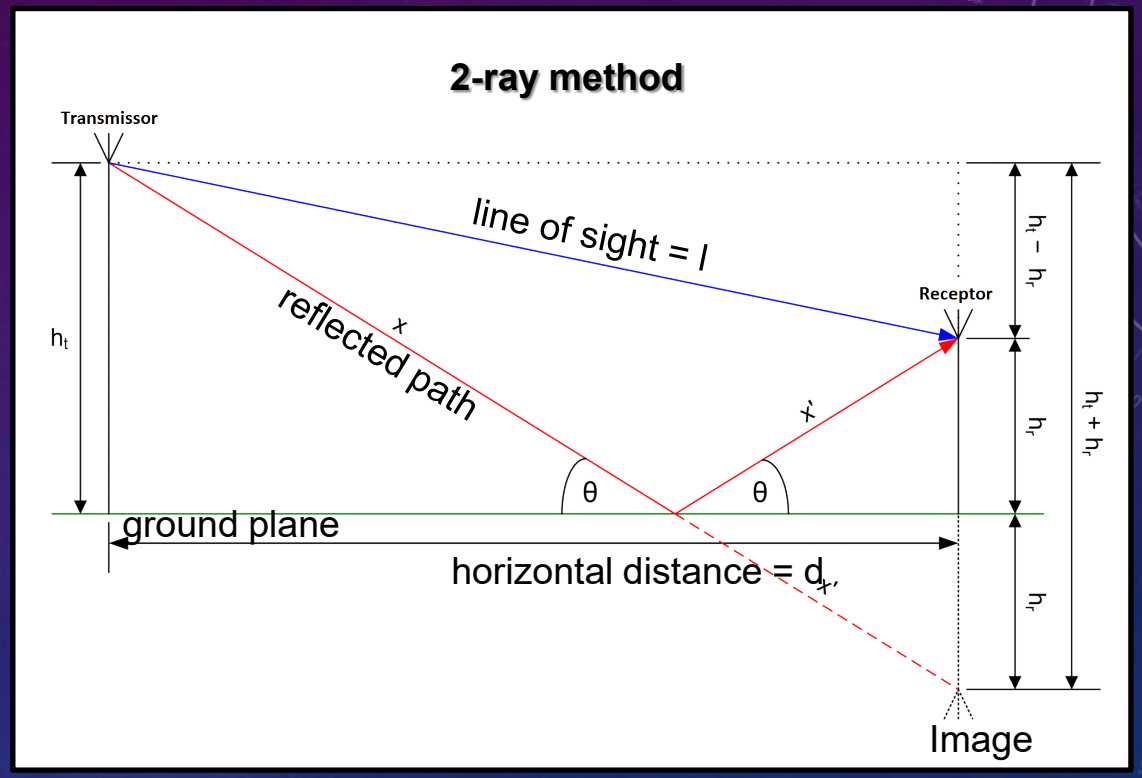
- but considering a more realist scenario…

Aggregated exposure due to multiple sources

- considering the 2-ray method
- noting that from the critical distance (d_c), the power decays with the fourth power

$$S^{2-ray} \approx \frac{4\pi\, EIRP\, h_t^2 h_r^2}{\lambda^2 d^4}, \qquad d \geq d_c$$

$$d_c = \frac{4 h_t h_r}{\lambda}$$



- power flux-density due to n-th circular ring:

$$S_n \approx \begin{cases} \dfrac{EIRP}{4\pi R^2} \cdot \dfrac{2n-1}{n^2}, & 0 < d < d_c \\ \dfrac{4\pi\, EIRP\, h_t^2 h_r^2}{\lambda^2 R^4} \cdot \dfrac{2n-1}{n^4}, & d \geq d_c \end{cases}$$

limited free-space like component

Aggregated exposure due to multiple sources

- Summation of the power flux-density due to n-th circular ring using 2-ray method

- $S_{TOT} = \sum_{n=1}^{N} S_n = \begin{cases} k_1 \cdot \frac{2n-1}{n^2}, & n = 1, 2, \cdots, M-1 \\ k_2 \cdot \frac{2n-1}{n^4}, & n = M, M+1, \cdots, N-1, N \end{cases}$

- $k_1 = \frac{EIRP}{4\pi R^2}$
- $k_2 = \frac{4\pi\, EIRP h_t^2 h_r^2}{\lambda^2 R^4}$
- $M = \left\lfloor \frac{d_c}{R} \right\rfloor$

- Consider infinitely many stations ($N \to \infty$), it can be rewritten by

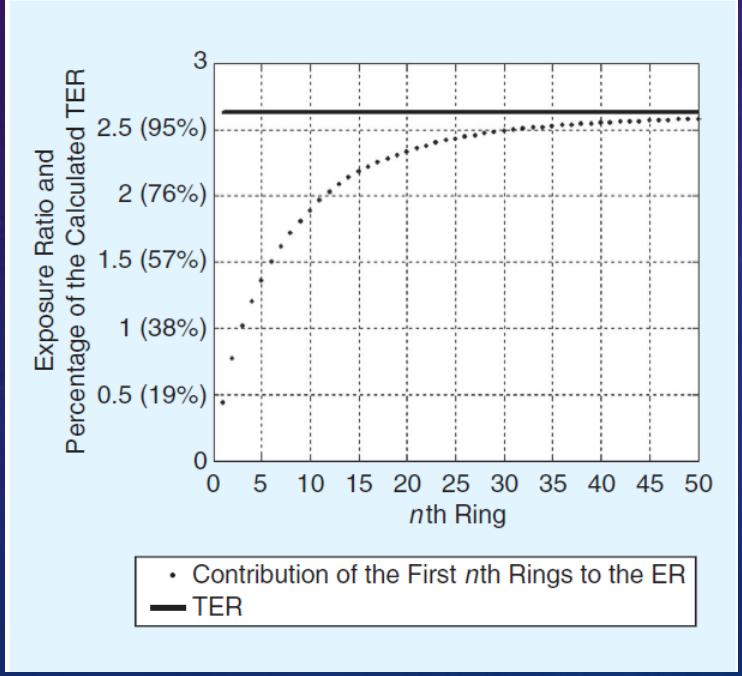
$$S_{TOT} = k_1 \sum_{n=1}^{M-1} \frac{2n-1}{n^2} - k_2 \sum_{n=1}^{M-1} \frac{2n-1}{n^4} + k_2 \sum_{n=1}^{\infty} \frac{2n-1}{n^4}$$

limited sum — converges

Aggregated exposure due to multiple sources

TABLE 1. THE BASE STATION TRANSMISSION FREQUENCIES.

FREQUENCY (MHz)	h_{BS} (m)	S_{calc} (W/m^2)	S_{icnirp} (W/m^2)	ER (%)
700	30	0.028	3.5	0.8%
850	30	0.029	4.25	0.7%
1,800	25	0.036	9	0.4%
2,100	20	0.035	10	0.35%
2,600	20	0.037	10	0.37%
		S_{tot}: 0.166		TER: 2.62%



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Radio-Frequency Electromagnetic Fields

Simultaneous exposure to infinite sources from typical base stations.

This article shows that simultaneous exposure to infinite electromagnetic field (EMF) sources from typical base stations transmitting at multiple frequency bands is lower than international limits. Considering a real base station density and conservative path loss models, we show that the power density at a given location can be modeled by a convergent infinite series. To validate this model, we apply it to Brasília, Brazil, and compare the results with measurements. While the proposed model shows that the exposure ratio (ER) will not exceed 2.62%, the highest measured value reaches 85% of this estimation.

INTRODUCTION

Radio-frequency (RF) EMFs radiated by cellular base stations concern the general public. Regulatory bodies are often questioned about exposure to RF EMFs and their adverse effects on human health [1]. In recent decades, this issue has been constantly studied to improve knowledge in the field and the quality of the information provided to the public. In 2020, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) updated its guidelines for human exposure to time-varying EMFs, which defines RF EMF limits intended to protect humans from established health effects [2]. The World Health Organization encourages the adoption of the ICNIRP EMF exposure limits [3].

To assess whether a particular location complies with the RF EMF reference level limits for whole-body exposure, the ICNIRP requires that the power density, electric field strength, or magnetic field strength be evaluated for frequencies from >30 MHz to 2 GHz. For frequencies >2 GHz, only the power density may be evaluated [2]. In general, the exposure assessment can be done by measurements and calculations [4], [5]. In the latter case, it is important to keep the precautionary principle in mind so that the computation does not underestimate the power density's true value. Measuring the electric field strength or power density in different locations might not be feasible. It is time consuming, and not every location is available (e.g., some roads and equipment are on private property). Whenever possible, the preference is to estimate the time average exposure to RF EMFs through a conservative approach.

Due to the characteristics of a transmitting antenna (i.e., its radiation diagram and tilt), the region of maximum exposure due to one macro base station is typically between 50 and 250 m

Digital Object Identifier 10.1109/MAP.2021.3106829
Date of current version: 9 September 2021

Regulation Issued by Anatel and EMF Map

Resolution nr.700/2018

Act nr. 17,865/2023

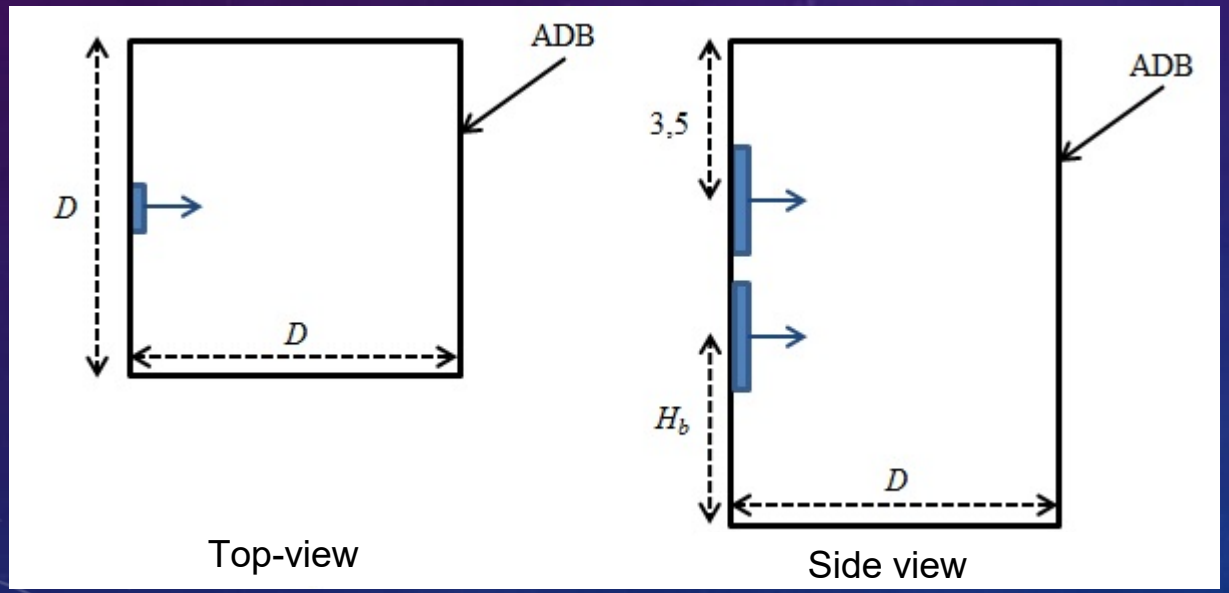
Theoretical Evaluation (partially based on Rec. ITU-T K.100)

EMF Exposure Map

Theoretical Evaluation (Based on Rec. K.100)

Step 1: Calculate ADB

ADB: Boundary surrounding an antenna (or set of antennas), which defines the maximum possible measurement area where the source is relevant.(5% exposure limit).

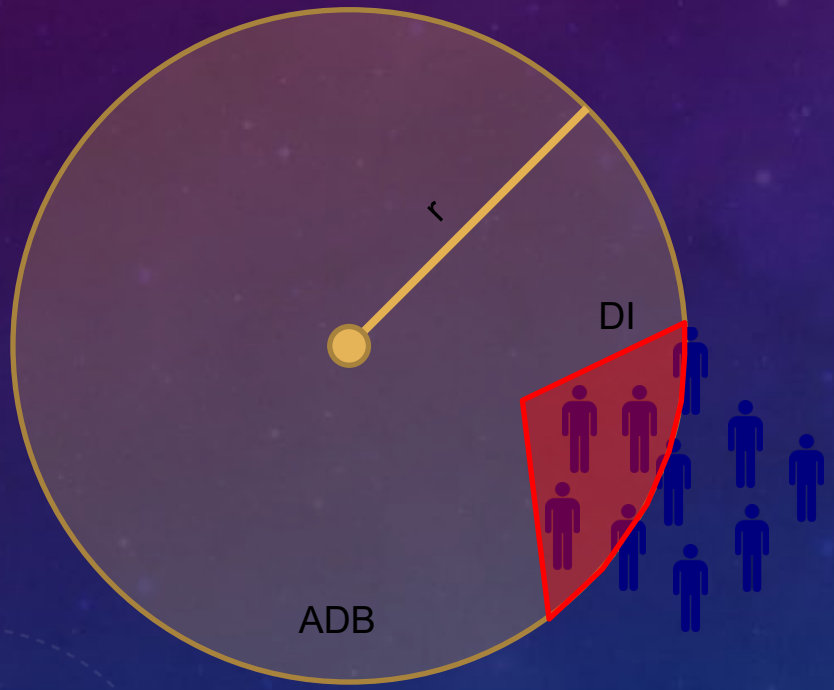


$$D = 1{,}3\sqrt{\sum_i \frac{EIRP_i}{S_{lim,i}}}$$

$$H_b = \max\left(3{,}5\,;\mathrm{D}\;tg(\alpha)\right)$$

Theoretical Evaluation (Based on Rec. K.100)

Step 2: Verify if DI exists



DI: The domain of investigation (DI) represents the area where a general exposure assessment shall be conducted. The DI is the part of the assessment domain boundary (ADB) of the EUT to which the general public has access.

If DI exists, then it is necessary to perform the EMF assessment on the field

Criteria to select the measurement points:

- DI
- Estimated maximum exposure
- Sensible areas (e.g., hospitals)
- Areas with many people

Final Comments

EMF assessment can be very time consuming → be as simple as possible in the regulation

Never in Brazil a base station was non-compliant with the EMF limits

Anatel has an Action Plan to carry out representative statistical sampling of stations that compliance with limits will be assed (L.11,934/09)

ITU-T and ITU-D have a very important role in disseminating good information and recommendations on human exposure to RF-EMF

Thank you!