ZTE 5G Massive-MIMO EMF Solution

Agenda

01 **Introduction to EMF**

- **EMF Concept, EMF and Health**
- EMF Exposure Limits

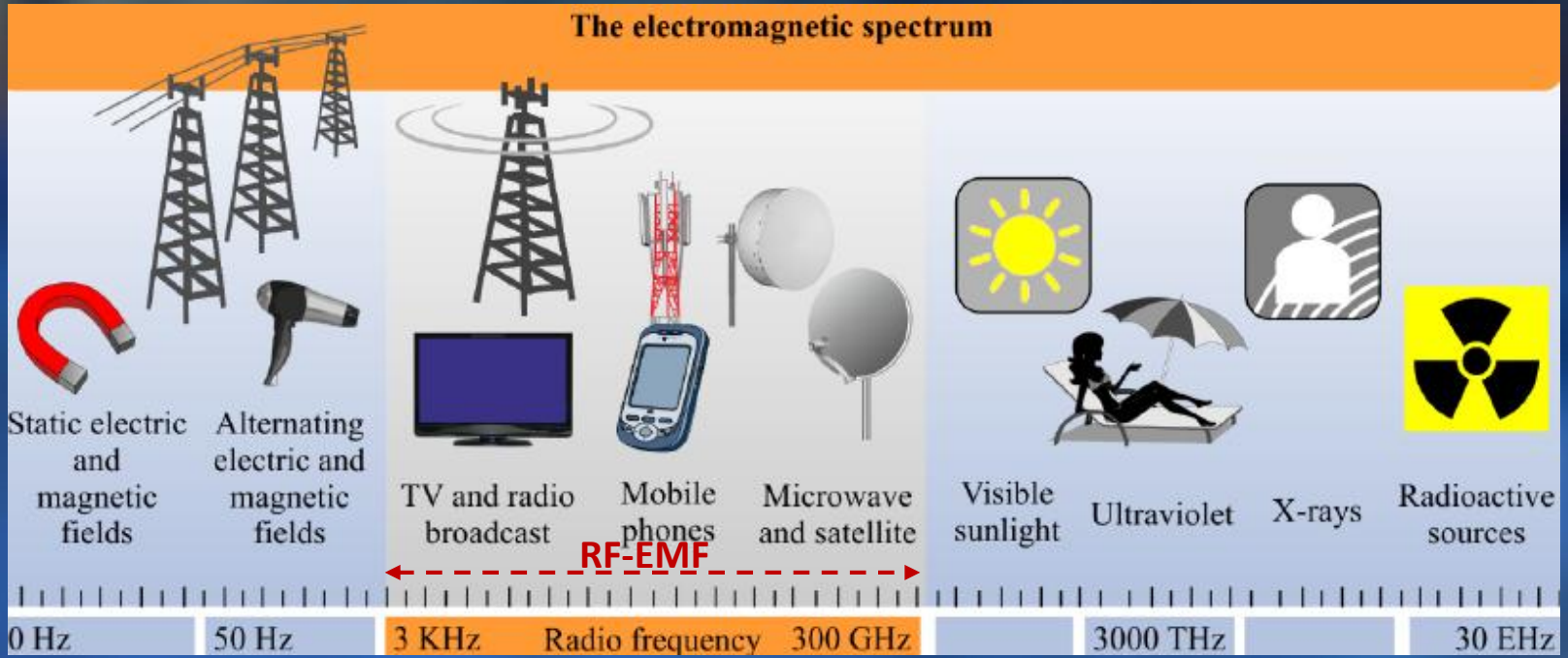
02 5G Massive-MIMO EMF Solution

- EMF Challenges of 5G Massive-MIMO
- EMF Evaluation
- ZTE Beam Level EMF Solution

EMF Concept

EMF (Electromagnetic Field) : waves of electric and magnetic energy moving together through space.

Often the term EMF is used to indicate the presence of electromagnetic radiation.



EMF and Health

- To protect public health , WHO established the International EMF Project, whose purpose is to assess the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz.

In terms of EMF and health the WHO notes:
"All reviews conducted so far have indicated that **exposures below the limits recommended in the ICNIRP (1998) EMF guidelines, covering the full frequency range from 0-300 GHz, do not produce any known adverse health effect**."

Information on base stations and health(WHO)
"Considering the very low exposure levels and research results collected to date, **there is no convincing scientific evidence that the weak RF signals from base stations and wireless networks cause adverse health effects**."
"Studies to date provide no indication that environmental exposure to RF fields, such as from base stations, increases the risk of cancer or any other disease."

Source: ITU-T K.91 - Guide on electromagnetic fields and health

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EMF Limits: ICNIRP 1998 EMF Guidelines

Occupational exposure limit
for adults who are generally exposed under known conditions and are trained to be aware of potential risk and to take appropriate precautions.

General public exposure limit
for individuals of all ages and of varying health status, and may include particularly susceptible groups or individuals.

Table 6. Reference levels for occupational exposure to time-varying electric and magnetic fields (unperturbed rms values).[a]

Frequency range	E-field strength ($V\ m^{-1}$)	H-field strength ($A\ m^{-1}$)	B-field (μT)	Equivalent plane wave power density S_{eq} ($W\ m^{-2}$)
up to 1 Hz	—	1.63×10^5	2×10^5	—
1–8 Hz	20,000	$1.63 \times 10^5/f^2$	$2 \times 10^5/f^2$	—
8–25 Hz	20,000	$2 \times 10^4/f$	$2.5 \times 10^4/f$	—
0.025–0.82 kHz	$500/f$	$20/f$	$25/f$	—
0.82–65 kHz	610	24.4	30.7	—
0.065–1 MHz	610	$1.6/f$	$2.0/f$	—
1–10 MHz	$610/f$	$1.6/f$	$2.0/f$	—
10–400 MHz	61	0.16	0.2	10
400–2,000 MHz	$3f^{1/2}$	$0.008f^{1/2}$	$0.01f^{1/2}$	$f/40$
2–300 GHz	137	0.36	0.45	50

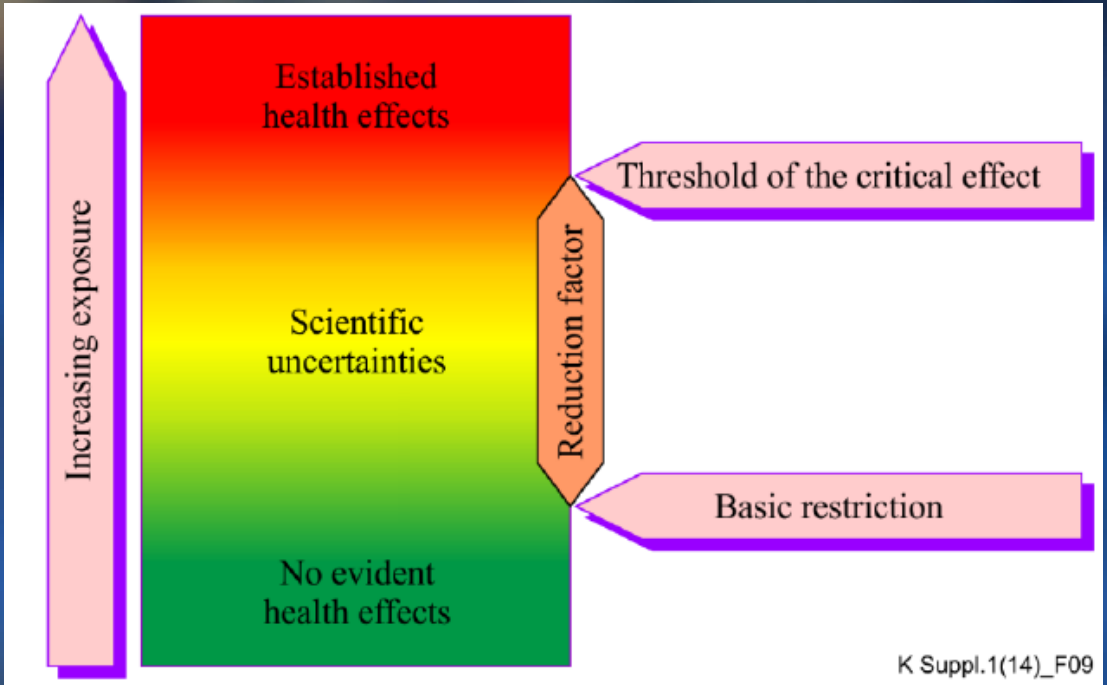
Table 7. Reference levels for general public exposure to time-varying electric and magnetic fields (unperturbed rms values).[a]

Frequency range	E-field strength ($V\ m^{-1}$)	H-field strength ($A\ m^{-1}$)	B-field (μT)	Equivalent plane wave power density S_{eq} ($W\ m^{-2}$)
up to 1 Hz	—	3.2×10^4	4×10^4	—
1–8 Hz	10,000	$3.2 \times 10^4/f^2$	$4 \times 10^4/f^2$	—
8–25 Hz	10,000	$4{,}000/f$	$5{,}000/f$	—
0.025–0.8 kHz	$250/f$	$4/f$	$5/f$	—
0.8–3 kHz	$250/f$	5	6.25	—
3–150 kHz	87	5	6.25	—
0.15–1 MHz	87	$0.73/f$	$0.92/f$	—
1–10 MHz	$87/f^{1/2}$	$0.73/f$	$0.92/f$	—
10–400 MHz	28	0.073	0.092	2
400–2,000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	$f/200$
2–300 GHz	61	0.16	0.20	10

Reduction Factor of Basic Restrictions in the Standards

The ICNIRP applies a safety factor of 10 to derive EMF worker exposure limits and a factor of 50 to obtain the guideline value for the general public.

ICNIRP Exposure limits and reduction factor



Basic restrictions for time varying EMF for 10K~10G RF-EMF.

Basic restrictions (SAR)

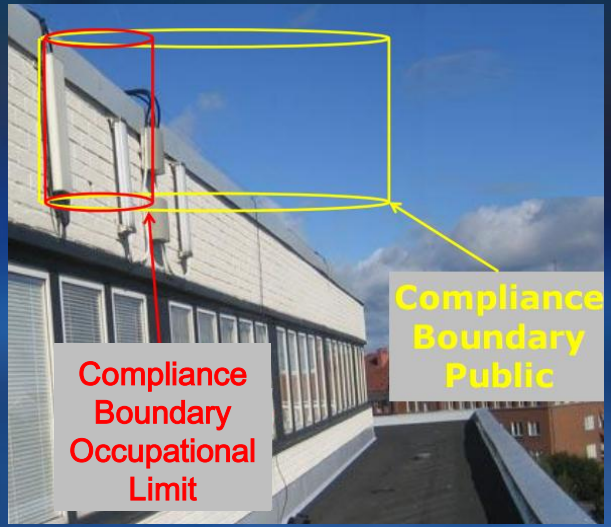
Workers	
Whole body exposure	0.4 W/kg
Local exposure – head and trunk	10 W/kg
Local exposure – limbs	20 W/kg
General public	
Whole body exposure	0.08 W/kg
Local exposure – head and trunk	2 W/kg
Local exposure – limbs	4 W/kg

All values averaged over 6 minutes
All local exposure is to be averaged over 10 g

EMF Exclusion Zones

For the sake of human health, areas exceeding a certain electromagnetic radiation intensity(exposure limits) is called exclusion zones. The border of exclusion zones is called Compliance Boundary.

Near the installation location of the base station, Compliance Boundary can be further divided into occupational limit and general public limit according to the intensity of electromagnetic radiation.



Occupational limit compliance boundary has higher electromagnetic radiation than public limit compliance boundary, only allows working personnel to short stay if necessary. Public limit compliance boundary doesn't allow general public to access.

EMF Exposure Limits of Different Countries

- RF-EMF exposure guidelines refer to the guidelines of ICNIRP or IEEE. Most countries adopted the International RF-EMF guidelines.
- The European Union also adopts the ICNIRP Guidelines as EMF Exposure Regulation into: Recommendation 1999/512/EC for general public exposure and Directive 2013/35/UE for worker exposure.
- Despite the EU Recommendation, there are some countries/regions in Europe that have imposed significantly lower EMF exposure limits, like Poland, Italy, Switzerland, Paris city and regions in Belgium.

	CURRENT EMF EXPOSURE LIMIT (JAN 2014)	SCOPE OF APPLICATION
ICNIRP	41 V/m (at 900 MHz)	All publically accessible places
Belgium (Brussels)	6V/m (at 900 MHz)	Living places
France (Paris)	ICNIRP based	Paris charter : -> 5V/m (eq. 900 MHz) for 2G+3G -> 7V/m (eq. 900 MHz) for 2G+3G+4G
Italy	6V/m	Indoor/outdoor living places
Lithuania	6.1 V/m	All publically accessible places
Poland	7 V/m	

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EMF Challenges of 5G Massive-MIMO

Greater Carrier Bandwidth Require Higher Tx Power

5G supports much bigger carrier bandwidth.

With the same power spectral density, the Tx power of a 5G base station would be much higher.

Massive-MIMO Array Antenna, Greater BF Gain

Large-scale array antenna will be widely used in 5G and achieve greater BF gain

The transmitted RF power is more concentrated in a specific direction.

For a typical 5G 64TR MM (maximum Tx power 200W and service beam antenna gain 25dBi), the service beam maximum EIRP can reach 78dBm.

EMF Difference: Massive-MIMO vs Traditional Marco Station

By focusing antenna beams, 5G Massive MIMO AAU can transmit required data only in the direction of the user and only during the time of usage, reducing the network interference and minimizing RF EMF exposure in unintended directions.

Traditional Marco

Massive MIMO

Traditional Antenna vs M-MIMO

Power is radiated throughout a wide range in a fixed spatial pattern	RF Power is radiated in specific directions, focused towards users sparsely located in the service area
Fixed area under coverage is constantly exposed to RF even if no users present	Radiated areas change dynamically to focus active users
EMF assessment considers constant RF power delivered permanently across coverage area	EMF assessment should account for power radiated in specific directions

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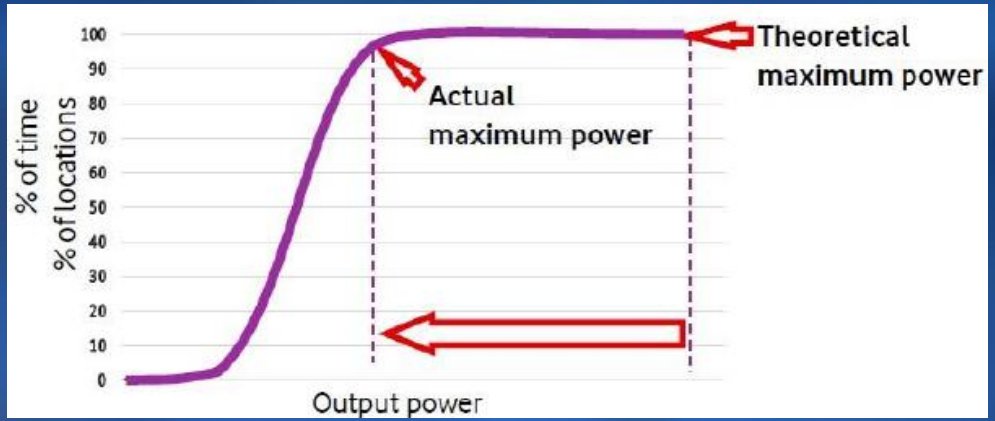
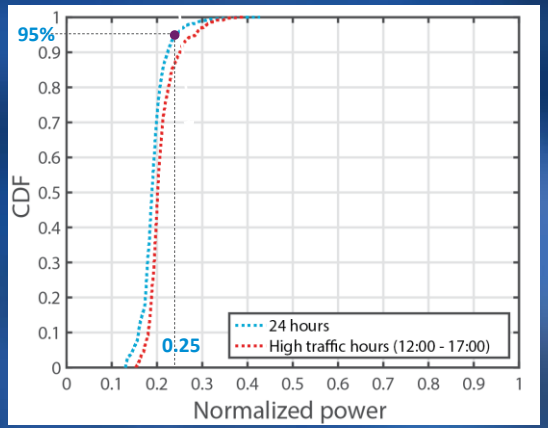
Statistics-based EMF Evaluation for 5G

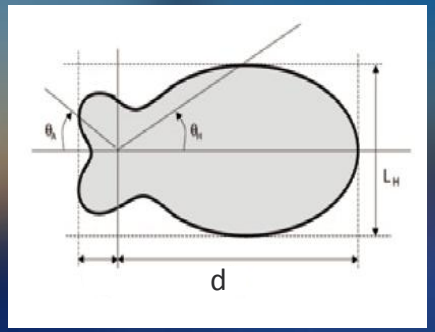
- Deterministic EMF evaluation is based on the theoretical maximum power of the AAU. But 5G AAU won't always transmitting with maximum power, and the actual transmitting power is usually much lower than the maximum transmitting capability.

- IEC defined guidelines (IEC62232 and TR62669) to consider realistic evaluations for 5G Network based on the "Actual maximum power" instead of the nominal one, defined as the 95th percentile of all measured values that contribute to the EMF emission. Signal variations both in space and time is considered and 6dB backoff is suggested compared to peak evaluation.





EMF Evaluation: A 5G MM AAU Example



Take a 3.5G 64T64R AAU as the example:

- Theoretical Peak EIRP: Theoretical Peak Tx Power 80/120/200W, Tx antenna gain 25dBi on main lobe
- Actual maximum EIRP: Based on the “Actual maximum power”, 6dB backoff of theoretical peak Tx power based on IEC technical report
- Exposure limit e(V/m): 61 V/m from the ICNIRP 98 international limits (public exposure)
- $d(m) = \frac{\sqrt{30 * EIRP(W)}}{e(V/m)}$

Configuration	64T64R				
	Theoretical Peak EIRP (dBm)	Actual maximum EIRP (dBm)	Actual maximum EIRP (W)	3.5GHz EMF public exposure Limit : e (V/m)	d (m)
5G MM 80W	74	68	6310	61	7.2
5G MM 120W	75.8	69.8	9549		8.8
5G MM 200W	78	72	15848		11.3

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Beam Level EMF Solution

Taking into account the 5% worst cases, the transmit power of the base station should be monitored to ensure the EMF security. If necessary, measures must be taken to limit the transmit power to meet the EMF requirements.

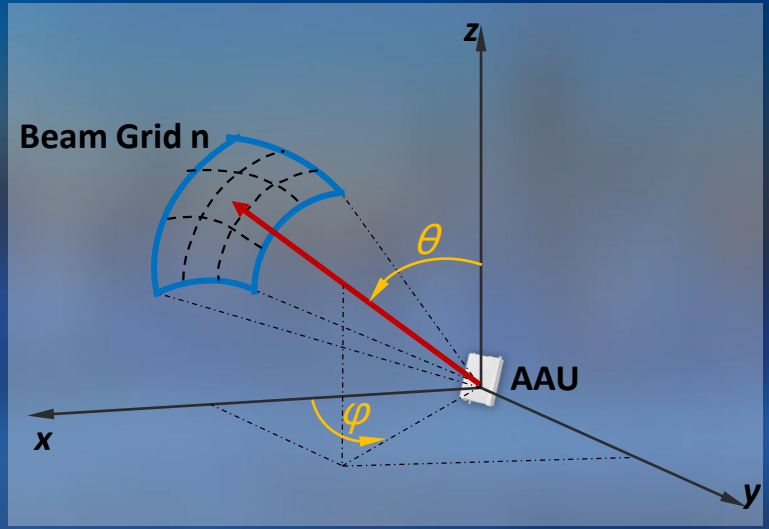
For 5G Massive-MIMO, ZTE provide beam level EMF monitoring & control :

1. EIRP per beam is calculated, including Tx antenna gain and beamforming gain.

2. Beam level threshold, including compliance boundary d and e(V/M), should be provided by the operator.

3. When PTx for some beam is above the given beam level threshold, measures will be taken to guarantee the EMF exposure limits won't be exceeded.

Beam Level EMF Solution – Beam Grid Design



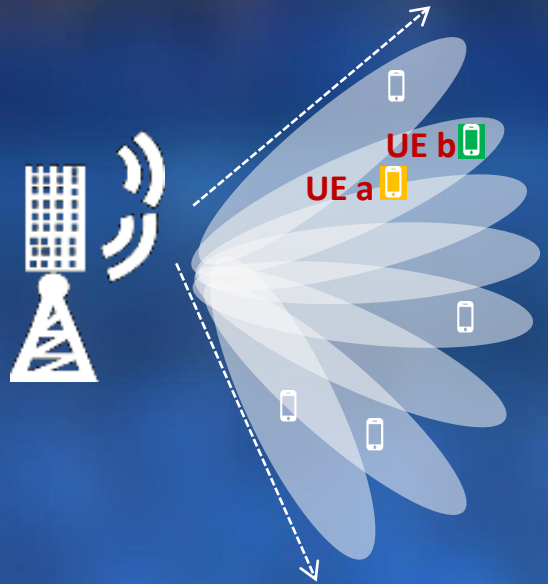
Beam Grid Design Consideration:

1. For typical macro site scenarios, more horizontal service beams give more accurate EMF exposure evaluation.
2. When mapping PTx for each UE to the beam grid, the energy projection for each beam is calculated.
3. Accumulated beam level PTx for all beams during time window.
4. The window size is configurable, 6min, 15min or 30min.

Beam Level EMF Solution – Power Control Strategy

Beam level power control is important for the solution.

1. When PTx for some beam is above the beam level threshold configured by operator, the alarm alerts.
2. Instead of directly reducing DL Tx power, ZTE propose to use different scheduler strategies for UEs of the beam to avoid EMF exceeding the limit, e.g. adjusting the scheduled RB in the frequency domain or reducing the scheduled TTI in the time domain.



- UE a and UE b are in the same beam grid.
- When the Tx power of this beam exceeds the predefined threshold and there is a EMF exposure risk, the resource scheduling reduce the DL PRBs for UE a &b, thus guaranteeing EMF security.

Comparison: Cell / Beam Level EMF Monitoring & Control

	Advantages	Disadvantages
Cell Level EMF Monitoring & Control	The EMF static evaluation method of existing 2/3/4G base station can be applied. Simple, easy to implement.	Power control is performed for the cell as a whole, and the loss of system capacity would be high in case of high load.
Beam Level EMF Monitoring & Control	The total transmit power of the BS is monitored at beam grid level. Power control is only performed for beam grid which have the risk of EMF exceeding the exposure limit, other beams won't not be affected.	EMF monitoring & control on beam level is required, the implement is more complex.

Summary ： ZTE 5G Massive-MIMO EMF Solution

- According to the IEC62232 statistical approach, perform EMF exposure evaluation based on "Actual maximum power" (95% CDF of all actual measured values) instead of the nominal one .

- To fulfill EMF requirements even in the 5% worst cases, ZTE 5G massive MIMO systems will support beam level EMF monitoring & control :
  - ➢ Step 1:
  - Monitoring the output power, including total power and power per beam, the measurement window size is 6-minutes intervals as it is the period of ICNIRP compliance.
  - Other measurement window sizes are also supported, such as 15-minutes and 30-minutes.
  - When the power in one of the beam grids exceeds a predefined threshold within the time windows, an alarm will be triggered.

  - ➢ Step 2:
  - The scheduler of Massive MIMO systems then reduce the power belong to the beam according to the exposure level, the power will be kept under the actual maximum limit.

Advantages:

1. Adopting a more realistic power values for EMF evaluation to avoid excessive restrictions on 5G deployments.
2. With beam level EMF monitoring & control, guarantee the EMF safety.

Thank You