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Industrial Hygiene at 5G Speeds: Preliminary Field Measurements

AUTHORS

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INTRODUCTION

An industrial hygiene study was commissioned to assess the potential for exposures to radiofrequency radiation (RF) electromagnetic fields (EMF) at outdoor utility/telecommunications poles where utility workers engage in maintenance of telecommunications and wired infrastructure located in proximity to Fifth Generation Wireless Systems (5G) antennas installed by wireless phone carriers in three US cities. The power density (PD) was measured and compared with occupational exposure limits (OELs) published by regulatory (Occupational Safety and Health Association (OSHA), California OSHA (Cal/OSHA) and Federal Communications Commission (FCC) maximum permissible exposure (MPE) limits) and non-regulatory groups (American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV), and the Institute of Electrical and Electronics Engineers (IEEE) International Commission on Non-Ionizing Radiation Protection (ICNIRP) MPE), summarized in Table 1. The results were also used to delineate a safe approach boundary/exclusion zone outside of which the RF EMF exposure would be below the OELs.

RF is a part of the non-ionizing electromagnetic spectrum with frequencies from 3 kilohertz (kHz) to 300 GHz. The 5G wireless antennas reportedly operate in the range of 1 GHz to 50 GHz. The demands for 5G mobile transmission speeds are expected to increase over the coming years as the rollout of this new technology progresses. In general, there is limited scientific research available specific to 5G wireless technology. However, the principal concerns related to health effects, techniques and equipment for measurement, methods for performing predictive measurements, and exposure standards for RF have been documented and understood for decades. The main difference with respect to 5G wireless is that the frequency spectrum that is to be used has not been previously available for commercial telecommunications purposes.

Table 1. Standards and regulations–limits for occupational/restricted exposure

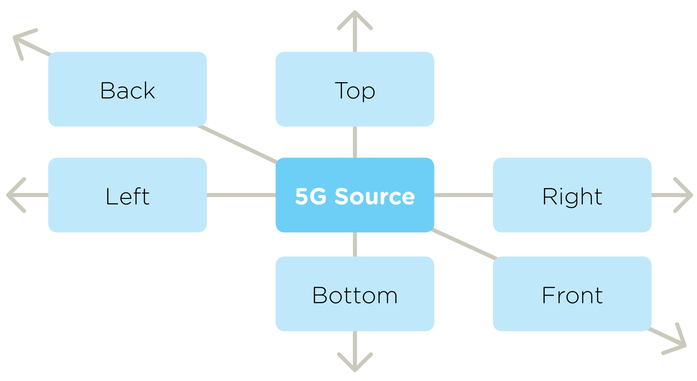
Guidelines	Frequency range MHz [GHz]	Power density (S) mW/cm²	Averaging time (minutes)
FCC[1]	300–1,500 [0.3–1.5] 1,500–100,000 [1.5–100]	f_M/300 5	6 6
IEEE[2]	400–2,000 [0.4–2] 2,000–300,000 [2–300]	f_M/400 5	30 30
ACGIH[3]	300–3,000 [0.3–3] 3,000–30,000 [3–30] 30,000–300,000 [30–300]	f_M/300 10 10	6 $34{,}000/f_M^{1.079}$ $68/f_M^{0.476}$
ICNIRP[4]	400–2,000 [0.4–2] 2,000–300,000 [2–300]	f_M/400 5	30 30
Cal/OSHA[5]	100–300,000 [0.1–300]	10	6
OSHA[6]	10–100,000 [0.01–100]	10	6

f_G = frequency in GHz
f_M = frequency in MHz
[1] FCC (1997)
[2] IEEE (2019)
[3] ACGIH (2016)
[4] ICNIRP (2020)
[5] Occupational Safety and Health of California (Cal/OSHA) (2018)
[6] 29 CFR 1910.97–Occupational Health and Safety Administration (1996)

METHODS

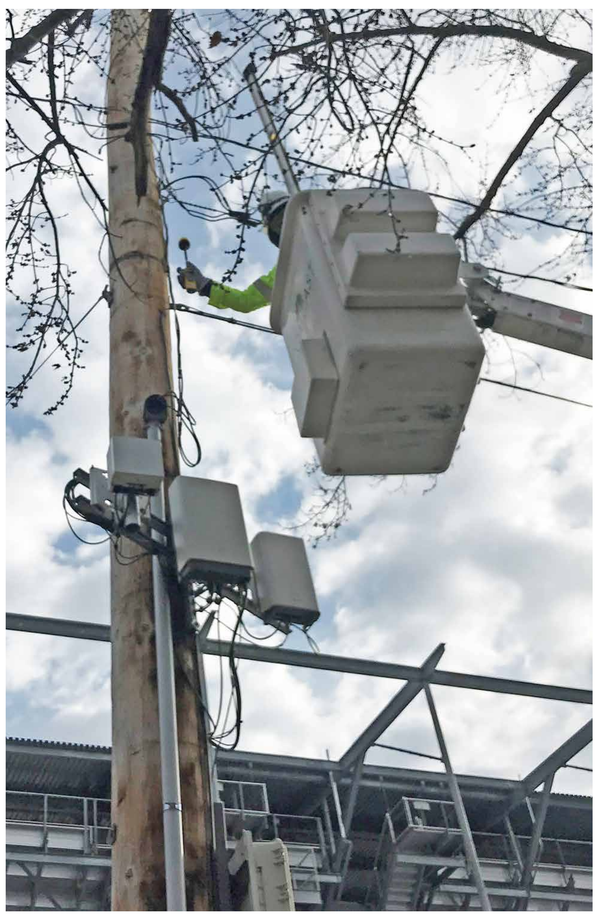
The authors coordinated with a telecommunications provider to identify locations of active 5G antennas in Sacramento, California, Houston, Texas, and Indianapolis, Indiana. Measurements of PD (reported in milliwatts per square centimeter [mW/cm²]) were collected at outdoor utility/telecommunications poles located in close proximity to active 5G antennas. A total of 20 data sets were collected at each of the regional locations (5 in Sacramento plus two background data sets, 8 in Indianapolis, and 5 in Houston). RF measurements were collected using a NARDA Broadband Field Meter NBM-520 with EF 5091 probe, which measures the PD of non-ionizing radiation from 1 GHz and 50 GHz, the frequency range of interest. The probe was calibrated at several frequencies, and the correction values are stored in an erasable programmable read-only memory (EPROM) chip in the probe and automatically considered by the NBM-520 instrument. NARDA instruments are calibrated at their labs which are accredited by the relevant national accreditation agencies and meet the general requirements for competence for calibration laboratories outlined in International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) 17025.

Figure 1. Direction of RF EMF measurements from antenna



RF EMF measurements were collected by a pole man at the following distances: 1.8 m, 0.9 m, 0.46 m, 0.24 m and at the 5G antenna (at the source) at different orientations, including right, left, front, back, top and bottom, as graphically depicted in Figure 1. There were some limitations in the accuracy of data collection. The meter requires use of a steady hand and RF EMF from other equipment (including power lines or 4G antennas) in the vicinity of the 5G antennas may result in interference with the measurements.

5G antenna

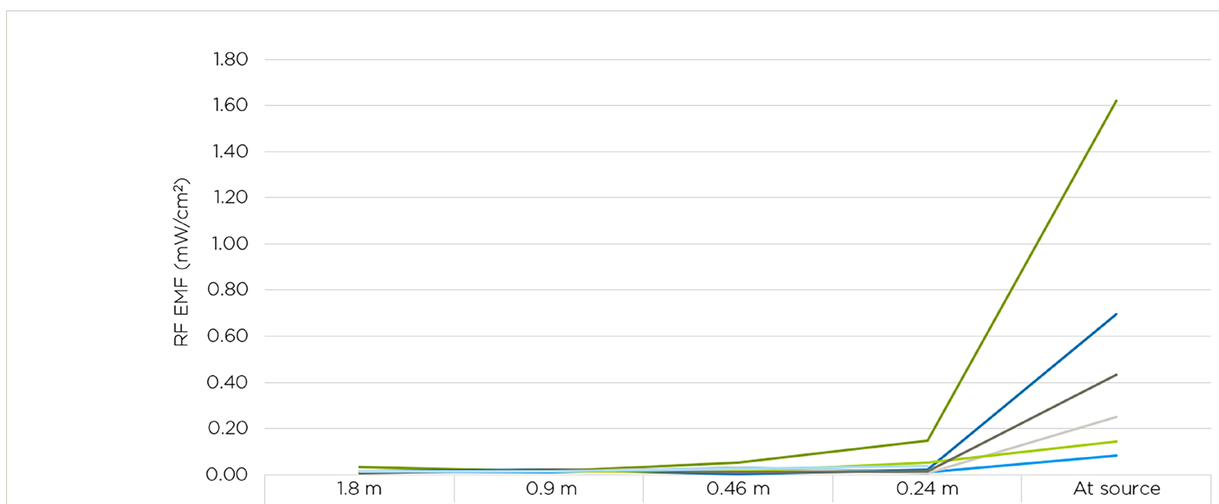


Measurement of PD collected at a 5G antenna

RESULTS

Aside from a few measurements collected at the 5G antenna (the source), all other measurements collected in Sacramento and Indianapolis at a distance from the source did not exceed the FCC MPE (for 60-minute time-weighted average) of 0.5 mW/cm². In Houston, 3 data sets were collected at 2 different 5G antennas at the same location and a number of the measurements of PD exceeded 1 mW/cm². Field observations at this location reported potential interference with the RF EMF instrument due to transmission power lines near the 5G antenna. The measured PD results by location are presented in Table 2.

Figure 2. PD measurements: Sacramento (n=5)



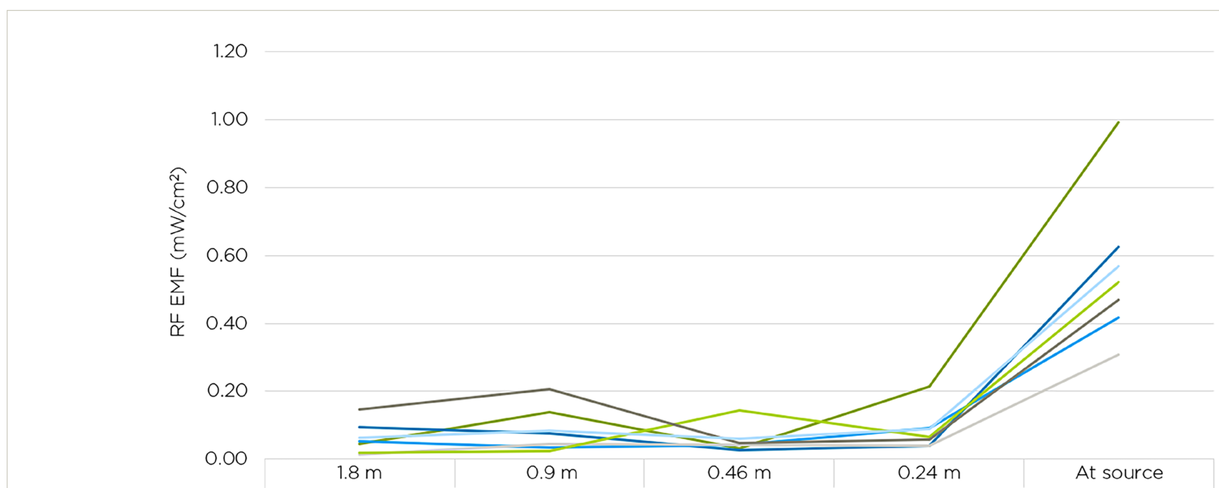
	1.8 m	0.9 m	0.46 m	0.24 m	At source
Back	0.0321	0.0135	0.0510	0.1463	1.6202
Bottom	0.0132	0.0233	0.0034	0.0225	0.6967
Front	0.0152	0.0089	0.0287	0.0089	0.0839
Left	0.0112	0.0127	0.0305	0.0050	0.2507
Right	0.0151	0.0140	0.0156	0.0515	0.1429
Top	0.0080	0.0205	0.0120	0.0124	0.4342
Average (all directions)	0.0152	0.0155	0.0254	0.0367	

Table 2. Average for all cities*

	Average RF RMF (mW/cm²)				
Direction	**1.8 m**	**0.9 m**	**0.46 m**	**0.24 m**	**At source**
Back	0.2806	0.0847	0.1534	0.3112	1.1044
Bottom	0.0823	0.0634	0.0491	0.0422	0.5603
Front	0.0565	0.0374	0.0543	0.0771	0.4130
Left	0.0315	0.0425	0.0690	0.0936	0.4979
Right	0.0209	0.0229	0.1077	0.0882	0.4566
Top	0.1005	0.1191	0.0661	0.0706	0.3803
Average RF EMF (mW/cm²)	**0.0905**	**0.0594**	**0.0833**	**0.1117**	**0.5614**
Background	0.0051	0.0292	0.0082	0.0806	

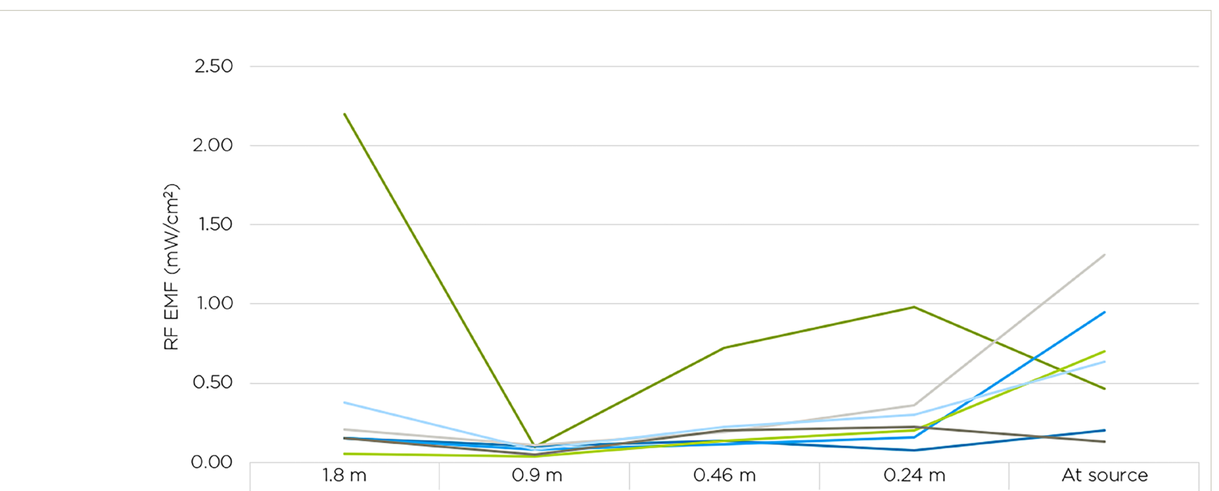
*Excludes Houston (n=2; outlier from instrument interference)

Figure 3. PD measurements: Indianapolis (n=8)



	1.8 m	0.9 m	0.46 m	0.24 m	At source
Back	0.0458	0.1388	0.0313	0.2139	0.9934
Bottom	0.0940	0.0772	0.0278	0.0411	0.6261
Front	0.0523	0.0351	0.0433	0.0908	0.4181
Left	0.0126	0.0463	0.0434	0.0393	0.3072
Right	0.0195	0.0242	0.1433	0.0648	0.5214
Top	0.1460	0.2061	0.0479	0.0580	0.4689
Average (all directions)	0.0640	0.0853	0.0608	0.0883	0.5681

Figure 4. PD measurements: Houston (n=3)



	1.8 m	0.9 m	0.46 m	0.24 m	At source
Back	2.2000	0.0991	0.7248	0.9818	0.4617
Bottom	0.1512	0.1027	0.1375	0.0774	0.2015
Front	0.1516	0.0800	0.1140	0.1587	0.9494
Left	0.2084	0.1093	0.1885	0.3613	1.3099
Right	0.0507	0.0372	0.1352	0.1994	0.7019
Top	0.1510	0.0495	0.2020	0.2245	0.1311
Average (all directions)	0.3741	0.0799	0.2237	0.3002	0.6356

DISCUSSION

The FCC MPE was chosen as the standard for comparison as it represented the lowest OEL for occupational exposure. The results of this preliminary data indicates there is a need to consider that there may be quite large variations in the PD depending on the power output of the 5G antenna, operating frequency, orientation relative to the location of the worker and the number of antennas in an array. Additionally, predictive data models suggest – when 5G antennas are operated at full power and there are multiple antennas in an array – that exposures to RF energy could be higher than the measured results from this initial assessment, requiring greater distances from the source to stay below OELs. As the 5G rollout continues, additional investigation appears to be prudent. Results of this study also indicate there may be variable safe approach distances for different antennas. Employers that may have workers that will be required to work in proximity to 5G antennas should consider establishing RF EMF safety programs, provide training for workers prior to assignment in work areas with 5G (or any other wireless antennas or transmitters), and use personnel monitoring, especially for work that will take place around live antennas or transmitters.