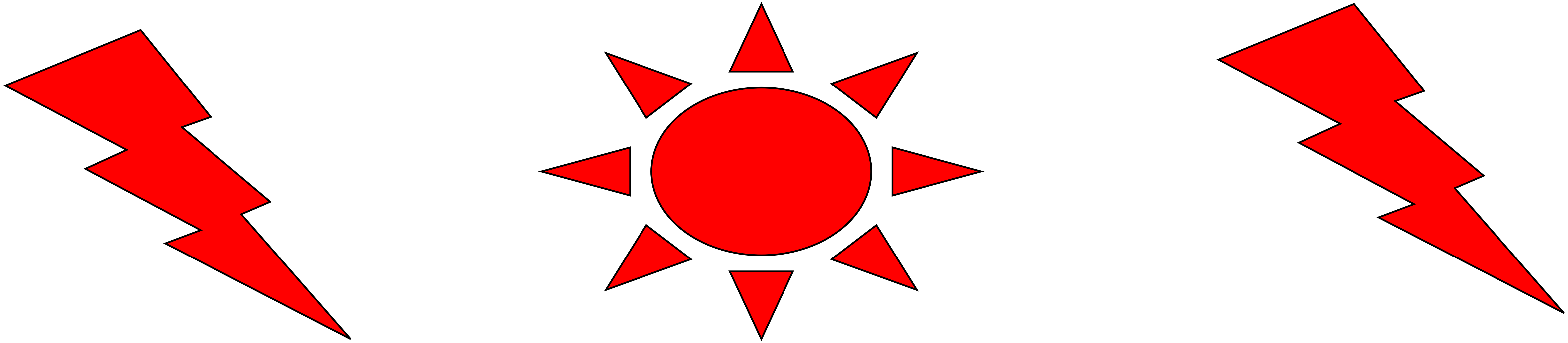
RADHAZ



Neil Blaho AA3EO - Background

- Boeing Electromagnetics Group. (30+ years)
- E3 Technology Group, Aircraft testing, etc.
- Associate Technical Fellow for Electromagnetic Environmental Effects. (ATF E3)
- BSEE 1982 Northeastern University, Electromagnetics.
- 43 years in aircraft aerospace.
  - (F-5, F-20, B-2, A-12, F-22, RAH-66, V-22, CH-46, CH-47, MH-139)
  - Draper Lab., Lincoln Lab., Northrop Aircraft, Northrop B-2, McDonnell Douglas, Boeing Helicopters.
- EMI, Antennas, Radar, RCS, Lightning, ESD, RF testing, HPM, SOF testing, etc.
- FCC Radio-Telephone license w/Radar endorsement.
- 52 years in analog/digital electronics.
- Hobby: Amateur Radio, Call Sign: AA3EO

RF RADIATION HAZARD

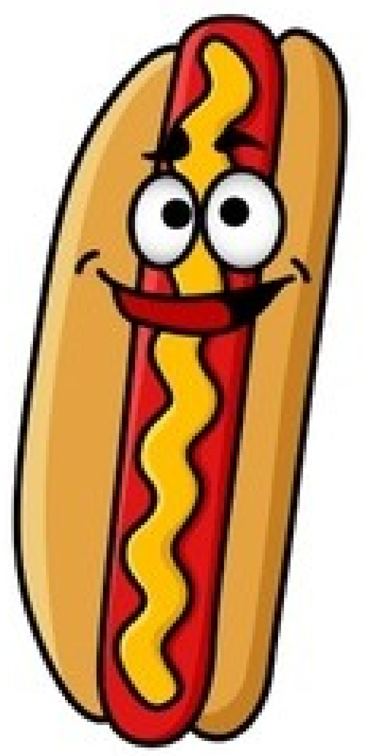
- What is the radiation hazard to radio operators from RF transmissions?
- What are the safety requirements?
- What are typical operator situations?
- What are the safe distances?
- What can Hams do for protection?

Ham Equipment

- Radio operators use RF mostly from 3 to 450 MHz.
- Typical radios run from 2 to 1000 watt output.
- Typical antennas run from rubber duckies to Yagis.
- Typical coax loss from 0 to 6 dB.
- Typical operator distance is 0 to 100 feet.

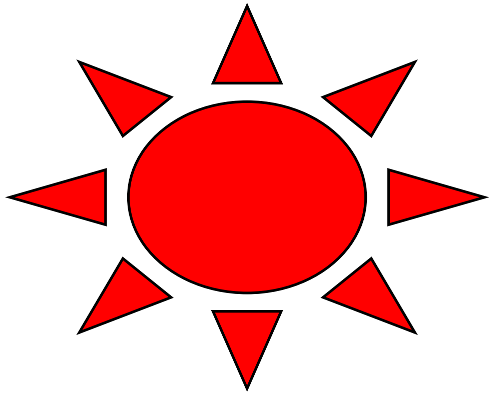
WHAT is the RADIATION HAZARD?

- Exposure of RF to a radio operator.
- Humans absorb RF the same way a resistor absorbs heat.
- “Root Mean Squared” power absorption
  - Summation of the effects of the waveform.
- Yes, we look like a hotdog to RF.
- RF energy is not nuclear energy
- Non-ionizing!



WHAT Are RADIATION HAZARD Effects?

- Length of exposure is critical.
  - More time equals more energy absorbed.
- Body absorbs unevenly based on frequency.
  - Different organs absorb heat differently.
  - Eyes are the most sensitive.
- Percentage of body exposure.
  - Partial or total body exposure?
- Heating disrupts the oxygen transfer.
  - Hemoglobin above 104 degrees.



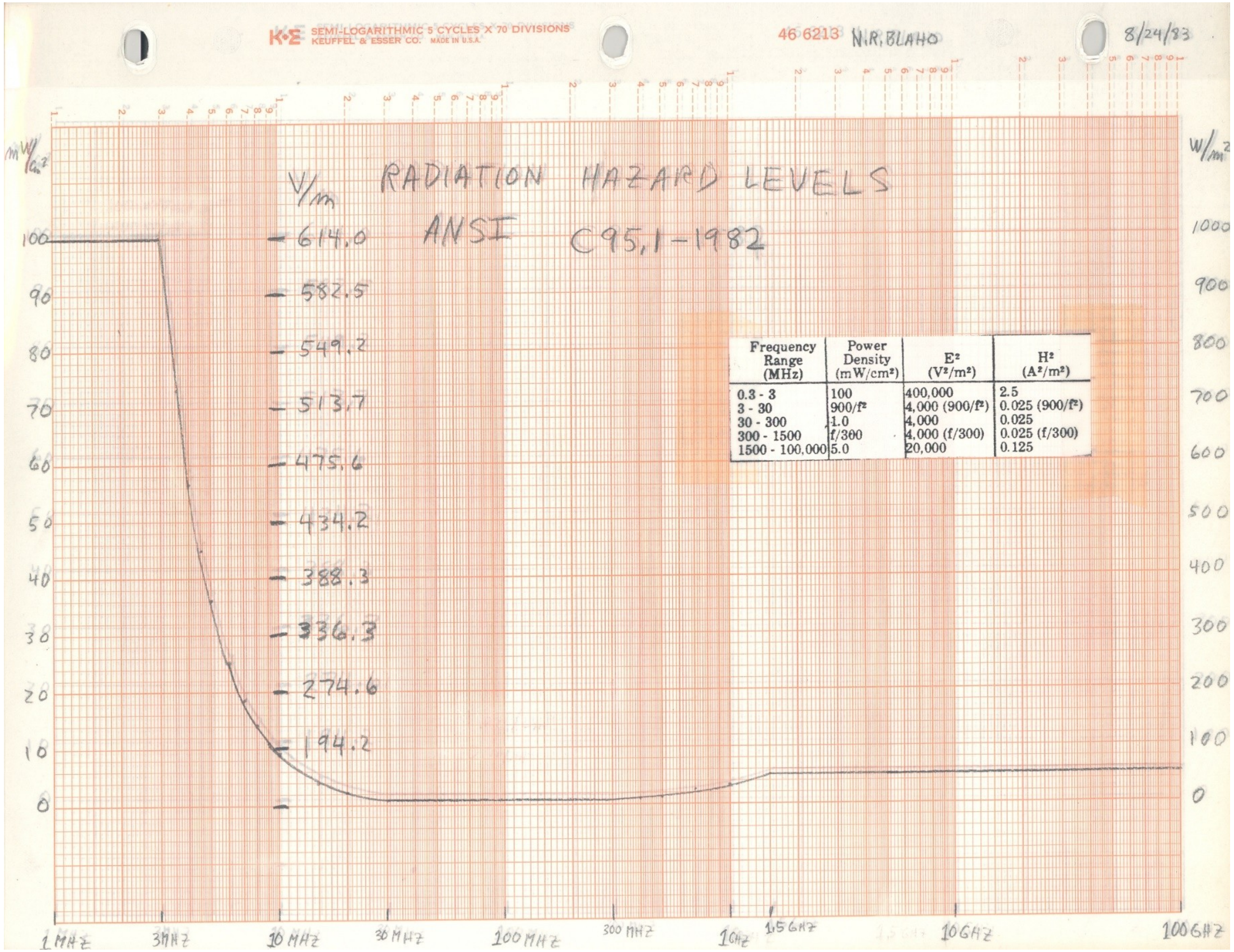
MEDICINAL RADIATION?

- Practice called DIATHERMY.
  - Target organs with antennas and specific frequencies.
  - Kill cancer by depriving cells of oxygen.
  - Not used anymore.
  - Frequency, power and targeting issues.
- MRI: Magnetic Resonance Imaging
  - Up to 1 GV/m pulse.

WORLD RF SAFETY STANDARDS

- OSHA – Occupational, General US standard.
- ANSI-C95.1-2019 – General US standard.
- TB-MED-523 – ARMY & AIR FORCE standard.
- ICNIRP – Occupational & Public, UK.
- International Commission on Non-Ionizing Radiation Protection
- SAFETY CODE 6 - Occupational & Public, Canada.
- DoDI 6055.1 NAVY RADHAZ

ANSI-C95.1-1982



Frequency Range (MHz)	Power Density (mW/cm^2)	E^2 (V^2/m^2)	H^2 (A^2/m^2)
0.3 - 3	100	400,000	2.5
3 - 30	$900/f^2$	4,000 ($900/f^2$)	0.025 ($900/f^2$)
30 - 300	1.0	4,000	0.025
300 - 1500	f/300	4,000 (f/300)	0.025 (f/300)
1500 - 100,000	5.0	20,000	0.125

RF SAFETY STANDARDS

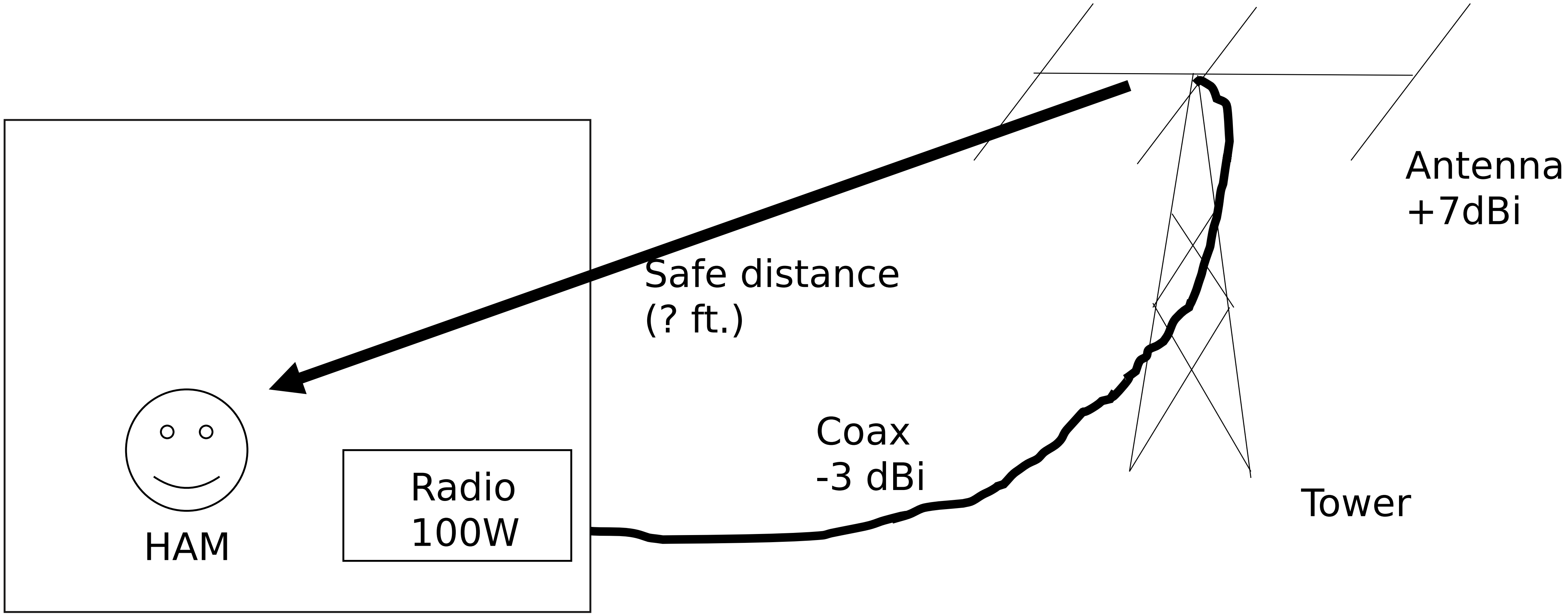
- OSHA – Based on human effects.
- Eyes are the most susceptible organ.
- 614 V/m causes eye heating which leads to cataracts.
- Restriction of oxygen hemoglobin transfer.
- Fine vascular organs.
- 61.4 V/m is a x10 safety factor. (20 dB)

RF SAFETY STANDARDS

- OSHA – Applicable to public and workers.
- Exposure level vs time:
  - 0 hour (denied access) 194.2 V/m (10 dB safety factor)
  - 6 minutes 61.4 V/m (20 dB safety factor)
  - 1 hour 8 V/m (38 dB safety factor)
- Calculate safe distances?
  - Function of power, time and level.
  - Note: OSHA levels are frequency independent.
  - Yes, cellphones are limited to 8 V/m.

TYPICAL STATION EXAMPLE

- Determine safe distance



ARRL RF SAFETY STANDARDS

- On-line calculator.
- https://www.arrl.org/rf-exposure-calculator
- Input your station parameters and determine safety distance.
- Added feature allows for modulation duty cycle.

ARRL On-Line Calculator

RF Exposure Calculator

- FCC RF-Exposure Regulations -- the Station Evaluation
- ARRL RF Safety Committee
- **RF Exposure Calculator**
- RF Exposure Calc Instructions
- Changes in the FCC RF Exposure Reguations

The FCC has changed its RF-exposure rules, eliminating service-specific exemptions from the need to do a routine RF-safety evalaluation and replacing those exemptions with a formula that applies to all radio services. See the FAQ on the ARRL RF-Exposure page for more information. The rules did not change the exposure limits nor the two-tiered exposure environments for controlled and uncontrolled exposure. The controlled limits generally apply to amateurs and members of their household if those people have been given instructions by the amateur about RF safety. The uncontrolled limits apply in all other circumstances, such as exposure to the general public.

To use the RF Exposure Calculator, fill-in the form below with your operating power, antenna gain, and the operating frequency. Depending on how far above ground the RF source is located, you might want to consider ground reflections — and then click "Calculate".

You may need to run the calculator multiple times to get a complete picture of your situation, i.e. take into account the antenna's lobes and directionality.

View detailed instuctions for each parameter. (opens in new tab/window)

Parameters

- Power at Antenna: (Need help with this?) 50 (watts)
- Mode duty cycle:
  Carrier Always On, i.e., for Tuning Up (duty cycle=100%)
- Transmit duty cycle: (time transmitting)
  You transmit for 5 minutes then receive for 10 minutes (and repeat).
- Antenna Gain (dBi): (Need help with this?) 7
- Operating Frequency (MHz): 14

☑ Include Effects of Ground Reflections

If you would like to receive future announcements of any FCC news related to RF-exposure or the requirements for amateurs to evaluate their stations, you may **optionally** provide an email address.

Email Address:	(optional)
Comments:	(optional)

Calculate

Results for a controlled environment:

Maximum Allowed Power Density (mw/cm^2): 4.5918
Minimum Safe Distance (feet): 3.1579
Minimum Safe Distance (meters): 0.9625

For an uncontrolled environment:

Maximum Allowed Power Density (mw/cm^2): 0.9184
Minimum Safe Distance (feet): 4.4660
Minimum Safe Distance (meters): 1.3612

Print Results

ARRL RF calculator

- Example Calculation: 14 MHz, 100W, -3 dB, +7 dBi, Tuning.
- ARRL safe zone: 4.6 ft.
  - “Duty Cycle” of modulation is a safety factor.
- ARRL uses roughly 61.4 V/m limit (6 minute)
  - Similar to OSHA
  - Similar to ANSI-C95.1-1982
  - Close to Safety Code 6 (Canada) RF worker levels.
  - DoDI 6055.1 (NAVY) plus 3 dB safety margin.
  - NAVY PEL calculator: 6 minutes.
  - “Controlled Environment” safety distance.
  - No ground effects (reflections)

REAL LIFE SCENARIO

- Use ARRL/OSHA calculator.
- **HF radio station with three element beam.**
- 100W, 7 dBi antenna, 3 dB cable loss.

- 0 hr. 1.5 ft.
- 6 min. 4.6ft.4.6 ft.
- 1 hr. 35.5 ft.

- “Hidden safety factor” (RF has a low duty cycle.)

REAL LIFE SCENARIO

- Use ARRL/OSHA calculator.
- **HF radio station with three element beam plus amplifier.**
- 1000W, 7 dBi antenna, 3 dB cable loss.

- 0 hr. 4.6 ft.
- 6 min. 14.6ft. 14.6 ft.
- 1 hr. 112.2 ft.

- Note: Antenna is 30 ft. from the ground and aimed to the horizon. (Side lobe: Divide distances by 3.)

REAL LIFE SCENARIO

- Use ARRL/OSHA calculator.
- **VHF radio station with handheld.**
- 5W, -6 dBi antenna, 0 dB cable loss.

- 0 hr. 0.1 ft.
- 6 min. 0.32 ft. 0.3 ft.
- 1 hr. 2.5 ft.

REAL LIFE SCENARIO

- Use ARRL/OSHA calculator.
- **VHF/UHF radio station with seven element beam.**
- 50W, 14 dBi antenna, 6 dB cable loss.

- 0 hr. 1.6 ft.
- 6 min. 5.2 ft. 5.2 ft.
- 1 hr. 39.8 ft.

- Note: Antenna is 30 ft. from the ground and aimed to the horizon. (Side lobe: Divide distances by 3.)

REAL LIFE SCENARIO

- Use ARRL/OSHA calculator.
- **Mobile VHF/UHF radio station with whip antenna.**
- 50W, 1 dBi antenna, 2 dB cable loss.

- 0 hr. 0.5 ft.
- 6 min. 1.8 ft. 1.8 ft.
- 1 hr. 14.1 ft.

REAL LIFE SCENARIO

- Use ARRL/OSHA calculator.
- **Cellphone.**
- 0.125 W, -7.7 dBi antenna, 0 dB cable loss.

- 0 hr. 0.013 ft.
- 6 min. 0.043 ft. 0.043 ft. (0.5 in)
- 1 hr. 0.327 ft.

- Remember: Voice duty cycle is 30%

SUMMARY

- ARRL calculator is reasonable to use.
- You can read a dozen RF safety papers and they all come to the same conclusions.
    1. No proven cancer threat.
    2. We need more money for research.

- Radio operator common sense is the best defense.

Table 8—MPE for the upper tier (people in controlled environments) (see Figure 3 for graphical representation)

Frequency range (MHz)	RMS electric field strength (E)[a] (V/m)	RMS magnetic field strength (H)[a] (A/m)	RMS power density (S) E-field, H-field (W/m^2)	Averaging time $\|E\|^2$, $\|H\|^2$ or S (min)
0.1–1.0	1842	$16.3/f_M$	$(9000, 100\,000/f_M^2)$[b]	6
1.0–30	$1842/f_M$	$16.3/f_M$	$(9000/f_M^2, 100\,000/f_M^2)$	6
30–100	61.4	$16.3/f_M$	$(10, 100\,000/f_M^2)$	6
100–300	61.4	0.163	10	6
300–3000	–	–	$f_M/30$	6
3000–30 000	–	–	100	$19.63/f_G^{1.079}$
30 000–300 000	–	–	100	$2.524/f_G^{0.476}$

NOTE—f_M is the frequency in MHz, f_G is the frequency in GHz.

[a]For exposures that are uniform over the dimensions of the body, such as certain far-field plane-wave exposures, the exposure field strengths and power densities are compared with the MPEs in the Table. For non-uniform exposures, the mean values of the exposure fields, as obtained by spatially averaging the squares of the field strengths or averaging the power densities over an area equivalent to the vertical cross section of the human body (projected area), or a smaller area depending on the frequency (see NOTES to Table 8 and Table 9 below), are compared with the MPEs in the Table.

[b]These plane-wave equivalent power density values are commonly used as a convenient comparison with MPEs at higher frequencies and are displayed on some instruments in use.