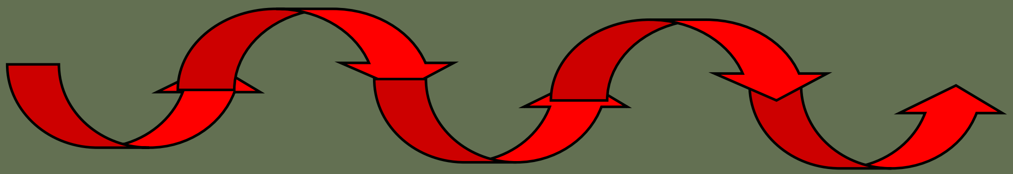
Safety with Radiofrequency Electromagnetic Radiation Fields



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RADIATION SAFETY ENGINEERING, INC.

Summary of Course Topics

- Radiation Basics
- Exposure Levels
- Analytical Methods
- Bioeffects
- ANSI Standard
- Examples of System Evaluations

RF Sources - Microwaves

- Klystrons
- Magnetrons
- Travelling wave tubes
- Thyratrons
- Cross field amplifiers
- Impatt Diodes

RF Sources – RF

- RF sealing machines
- CB and FM radio transmitters
- Radar
- RF induction heaters

Electromagnetic (EM) Radiation

- Definition

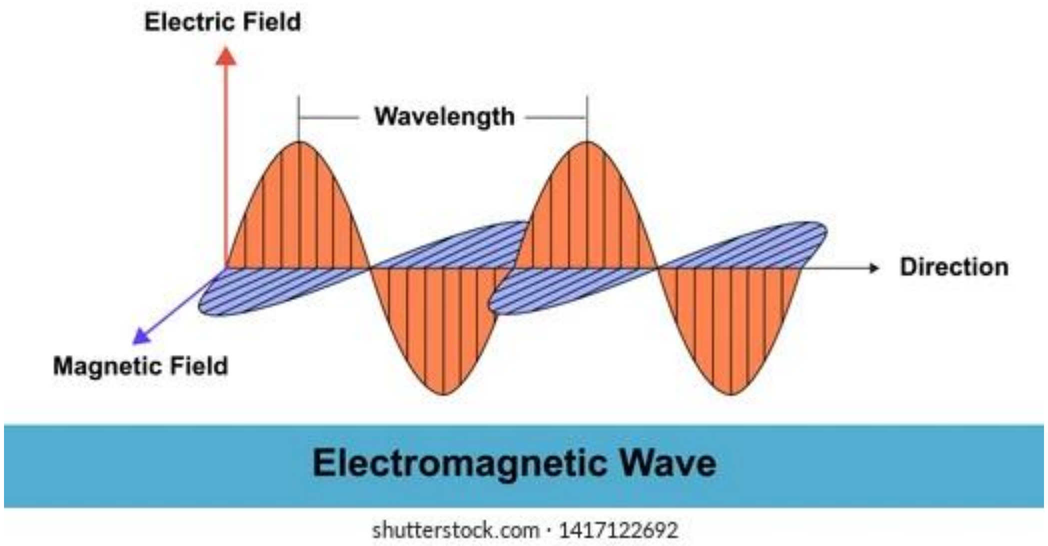
  Energy traveling through space or material in the form of electromagnetic waves

- Radiofrequency

  from 3 kHz to 300 GHz

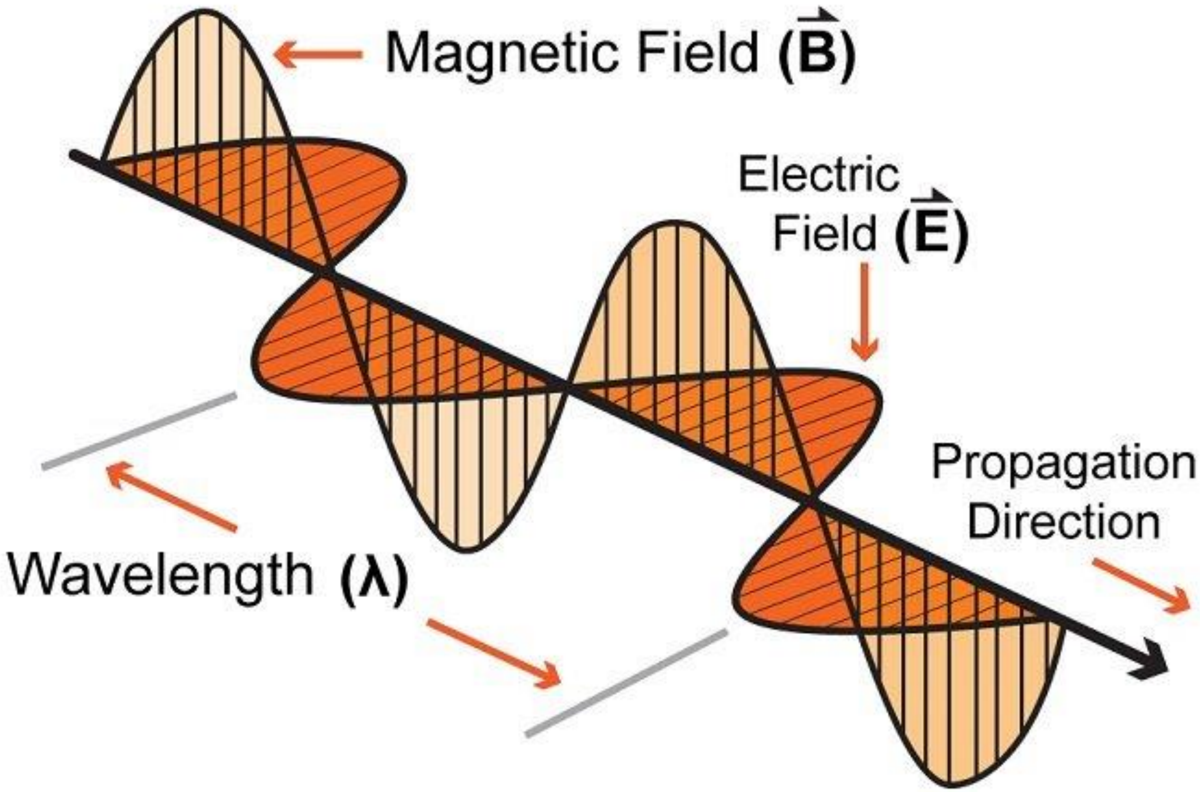
Electromagnetic (EM) Radiation

- EM Radiation



- Travels at speed of light in a vacuum
- Frequency determines how it interacts with matter

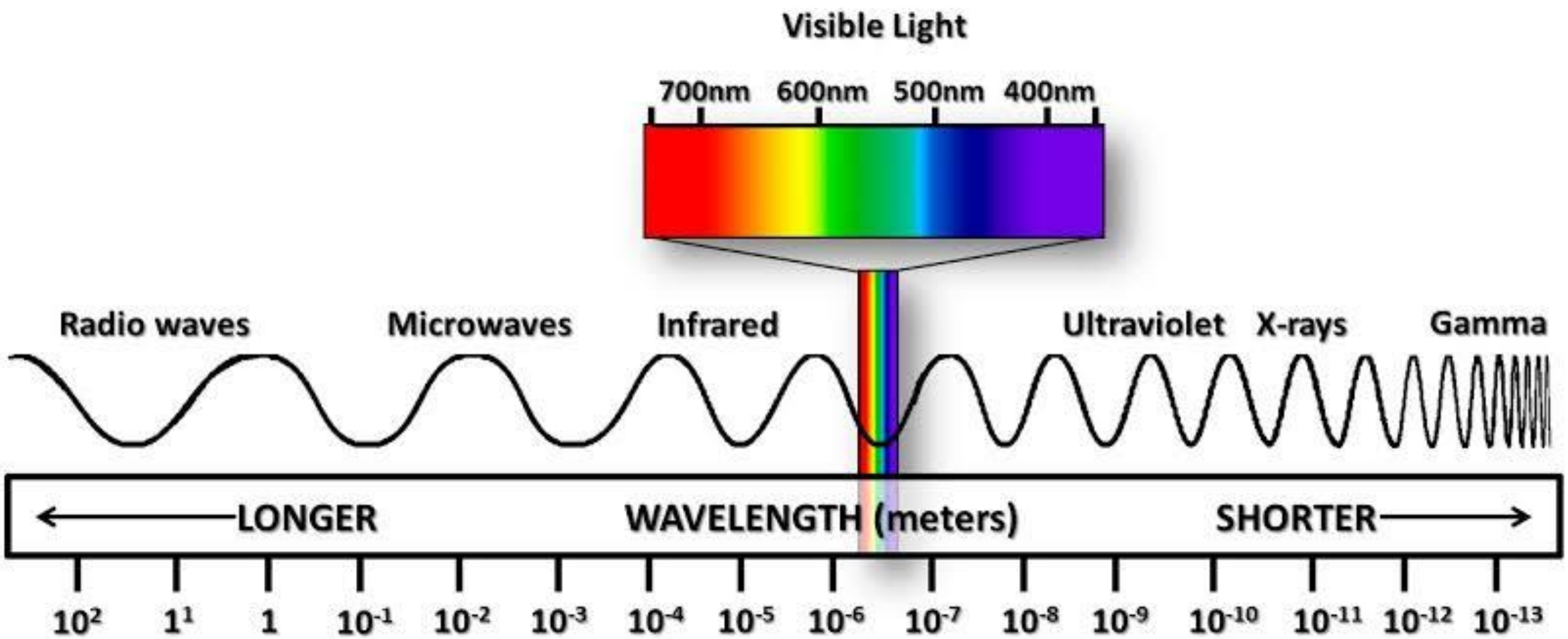
Propagated Electromagnetic Wave



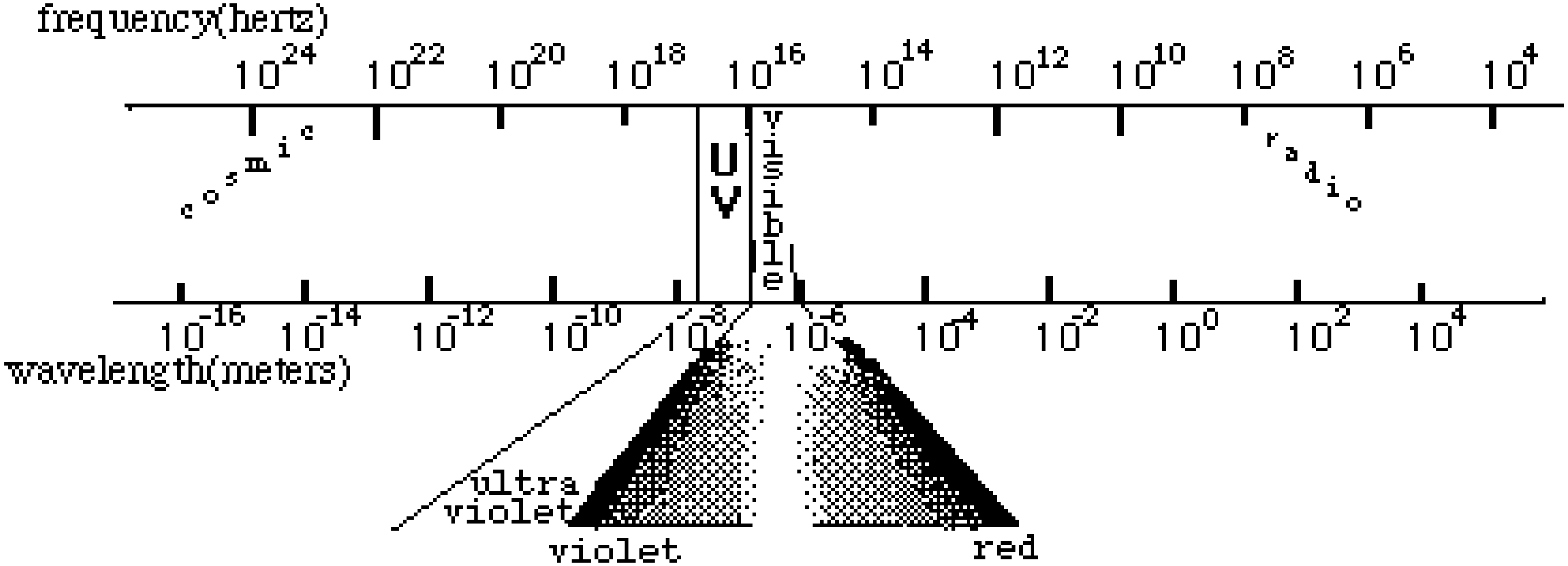
Non-Ionizing Radiation

- EM radiation that does not have sufficient energy to ionize human tissue
- Extents
  - EEG brain frequencies (<30 Hz)
  - Radiofrequency [Radio & TV] (3 kHz – 100 GHz)
  - Infrared light (0.7 – 100 µm)
  - Visible light (400 – 700 nm)
  - Ultraviolet light (180 – 400 nm)

Electromagnetic Spectrum



Wavelength vs. Frequency



Relationship between frequency and wavelength

$c = \nu\lambda$

Where c= speed of light (2.998×10^8 m/s)

ν = frequency (sec^{-1})

λ = wavelength (m)

So: $\lambda = \frac{c}{\upsilon}$ and $\nu = \frac{c}{\lambda}$

Example

What is the wavelength of a 3,000 MHz microwave?

$$\lambda = \frac{c}{\upsilon}$$

C= 3 x 10^{10} cm/sec

ν = 3 x 10^{9} Hz

$$\lambda = \frac{3\ x\ 10^{10}}{3\ x\ 10^{9}}$$

λ = 10 cm

Units - Decibels

Power and voltage ratios are normally expressed in decibels (dB)

$$dB = 10 \log_{10} (\text{Power Ratio})$$

$$dB = 20 \log_{10} (\text{Voltage Ratio})$$

Power with reference to one milliwatt

$$dBm = 10 \log_{10} (P/1mW)$$

Example

An antenna is stated to have a 12 dB gain. Express this value as a power ratio.

$$dB = 10 \log_{10}(\text{Power Ratio})$$

$$12 = 10 \log_{10}(\text{Power Ratio})$$

$$12/10 = 1.2 = \log_{10}(\text{Power Ratio})$$

$$10^{1.2} = \text{Power Ratio}$$

$$\text{Power Ratio} = 15.8$$

Units – Duty Factor

The ratio of the average power to the peak power is called the duty factor.

$$\text{Duty Factor} = P_{avg}/P_{peak}$$

Also, the duty factor is equal to the pulse width times the pulse repetition frequency. A duty factor of 1.0 corresponds to a continuous wave (no modulation).

Health effects are related to the average power density, with few exceptions.

Units - Power Density and ERP

For electromagnetic waves in free space, the power density is related to the electric field strength by the relationship:

$$PD\ (mW/cm^2) = E^2/3770$$

Where E = V/m

In the far field of any antenna the E and H fields are equal and orthogonal so only one needs to be measured to obtain the power density. Most often it is the E field that is measured.

Example

From Slide 28 which are the IEEE C95, 1999 exposure standards for Arizona, we see that the limit at 3000 MHz is 10 mW/cm2.

But no equivalent E field is listed. Yet our broadband exposure meter reads in V/M. What is this limit expressed in V/M?

$$PD\ (mW/cm^2) = E^2/3770$$

$$10\ (mW/cm2) = E^2/3770$$

$$37{,}700 = E^2 = SQRT\ (37{,}700)$$

$$E = 194\ V/M$$

Effective Radiative Power

The Effective Radiated Power is the transmitter power output (P_t) and the gain (G) of the antenna expressed as a factor (not dB).

$$ERP = G\ P_t$$

The units of ERP will be the same as P_t (e.g., watts, kW).

When the transmitter power is specified as the CW power output, it is appropriate to multiply by the Duty Factor as most applications modulate the transmitter power in some fashion.

Low duty factor applications that utilize strong brief pulses are now common.

Polarization

The polarization of an antenna is defined as the direction of the electric field vector component of the radiated field with regard to the earth. The types of polarization that are common are:

Linear polarization

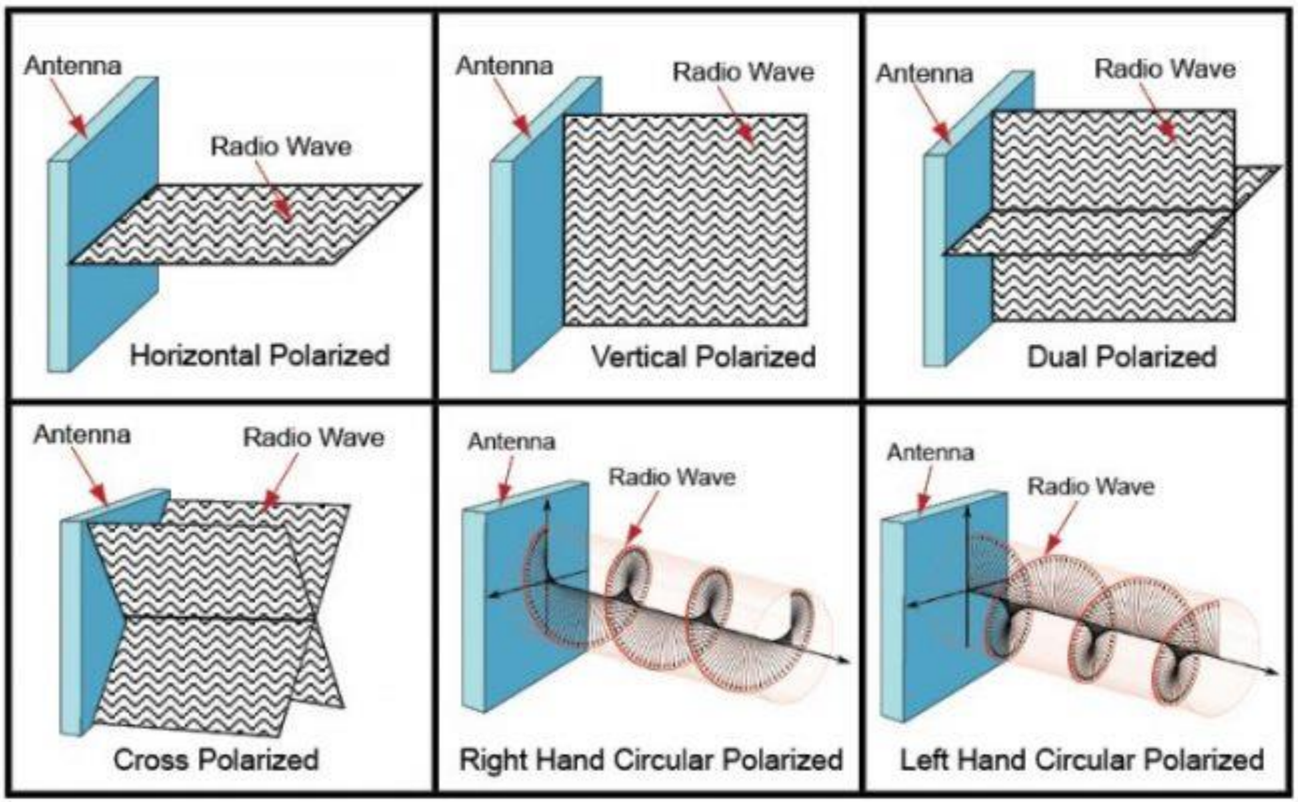
Elliptical Polarization

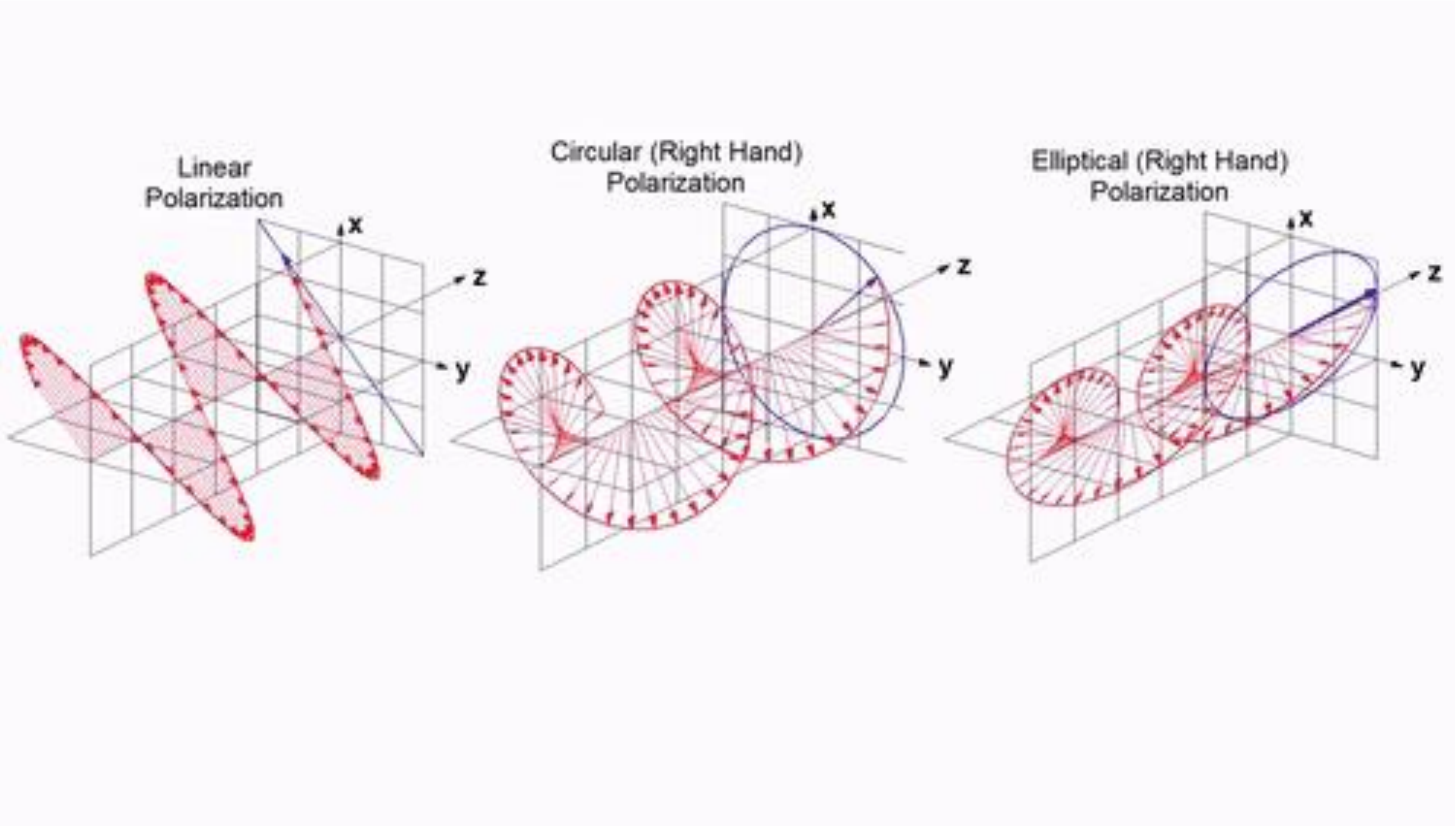
Circular Polarization

Sending and receiving antennas should have the same polarization for the best transfer of energy.

When measuring leakage fields, the polarization is rarely known.

Polarization Types





Polarization Types

RF Band Designations

Band	Designation		Frequency limits
4	VLF	very low frequency	3 kHz - 30 kHz
5	LF	low frequency	30 kHz - 300 kHz
6	MF	medium frequency	300 kHz - 3 MHz
7	HF	high frequency	3 MHz - 30 MHz
8	VHF	very high frequency	30 MHz - 300 MHz
9	UHF	ultra high frequency	300 MHz - 3 GHz
10	SHF	super high frequency	3 GHz - 30 GHz
11	EHF	extremely high frequency	30 GHz - 300 GHz

IEEE Radar Band Designations

#	Band Designation	Frequency Range
1	HF	3–30 MHz
1	VHF	30–300 MHz
2	UHF	300–3000 MHz
3	L	1–2 GHz
4	S	2–4 GHz
5	C	4–8 GHz
6	X	8–12 GHz
7	Ku	12–18 GHz
8	K	18–27 GHz
9	Ka	27–40 GHz
10	V	40–75 GHz
11	W	75–110 GHz
12	mm	110–300 GHz

Definitions

- Radiofrequency Protection Guides (RFPG) [ANSI C95.1]
  - RF field strengths or power densities that should not be exceeded without study:
    - consideration of reasons for doing so
    - estimation of increased energy deposition
    - consideration of increased risk of biological effects
- Specific Absorption Rate (SAR)
  - Time rate at which RF EM energy is imparted to body (W/kg)

RF Exposure Limits

RF Limits are listed in the Arizona Department of Health Services Bureau of Radiation Control regulations as an inclusion by reference. The limits are actually shown in ANSI C95.1, 1999 Edition entitled:

IEEE Standard for Safety Levels with Respect to Human Exposure to Radiofrequency Electromagnetic Fields, 3 kHz to 300 GHz.

These are occupational limits based on electric and magnetic field strength and power density averaged over a six-minute period. There is no cumulative exposure limit.

AZ Title 9 Rules

R9-7-1405. Radio Frequency Radiation: Maximum Permissible Exposure
A. A registrant shall not expose a person to radio frequency radiation that exceeds the applicable MPE specified in IEEE Std C95.1-1999, Institute of Electrical and Electronics Engineers Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300 GHz, 1999 edition, which is **incorporated by reference**, published by the Institute of Electrical and Electronic Engineers, Inc., 345 East 47th Street, New York, NY 10017, and on file with the Department. This incorporation by reference contains no future editions or amendments

The Occupational Exposure Rate Limits do not appear in the statutes!

IEEE C95 Standards

All IEEE C95 standards are available free from the IEEE GET website. See:

https://ieeexplore.ieee.org/browse/standards/get-program/page/series?id=82

Unfortunately, the C95.1, 1999 standard has been superseded so many times since then, it is no longer shown on the site. The most current standard is available, but the exposure limits shown in this current standard **are not** the ones incorporated in the Arizona Statutes.

IEEE 1999 RF Exposure Limits

Part A: Electromagnetic fields†				
Frequency range (MHz) **1**	**Electric field strength (E) (V/m)** **2**	**Magnetic field strength (H) (A/m)** **3**	**Power density (S) E-field, H-field (mW/cm^2)** **4**	**Averaging time $\|E\|^2$, $\|H\|^2$ or S (min)** **5**
0.003–0.1	614	163	(100, 1 000 000)‡	6
0.1–3.0	614	$16.3 / f$	$(100, 10\,000 / f^2)$‡	6
3–30	$1842 / f$	$16.3 / f$	$(900 / f^2, 10\,000 / f^2)$	6
30–100	61.4	$16.3 / f$	$(1.0, 10\,000 / f^2)$	6
100–300	61.4	0.163	1.0	6
300–3000	—	—	$f / 300$	6
3000–15 000	—	—	10	6
15 000–300 000	—	—	10	$616\,000 / f^{1.2}$

Note—*f* is the frequency in MHz.

Current C95.1 Exposure Limits

Table 8—ERLs for whole-body exposure of persons permitted in restricted environments (100 kHz to 300 GHz) [see Figure 4 for graphical representation]

Frequency range (MHz)	Electric field strength $(E)^{a,b,c}$ (V/m)	Magnetic field strength $(H)^{a,b,c}$ (A/m)	Power density $(S)^{a,b,c}$ (W/m^2)		Averaging time (min)
			S_E	S_H	
0.1 to 1.0	1842	$16.3 / f_M$	9000	$100\,000 / f_M^2$	30
1.0 to 30	$1842 / f_M$	$16.3 / f_M$	$9000 / f_M^2$	$100\,000 / f_M^2$	30
30 to 100	61.4	$16.3 / f_M$	10	$100\,000 / f_M^2$	30
100 to 400	61.4	0.163	10		30
400 to 2000	—	—	$f_M / 40$		30
2000 to 300 000	—	—	50		30

NOTE—S_E and S_H are plane-wave-equivalent power density values, based on electric or magnetic field strength respectively, and are commonly used as a convenient comparison with ERLs at higher frequencies and are sometimes displayed on commonly used instruments.

Other Standards

DoD Instruction 6055.11

Protecting Personnel from Electromagnetic Fields

More Standards – MIL-Std 464A

MIL-STD-464A
19 December 2002

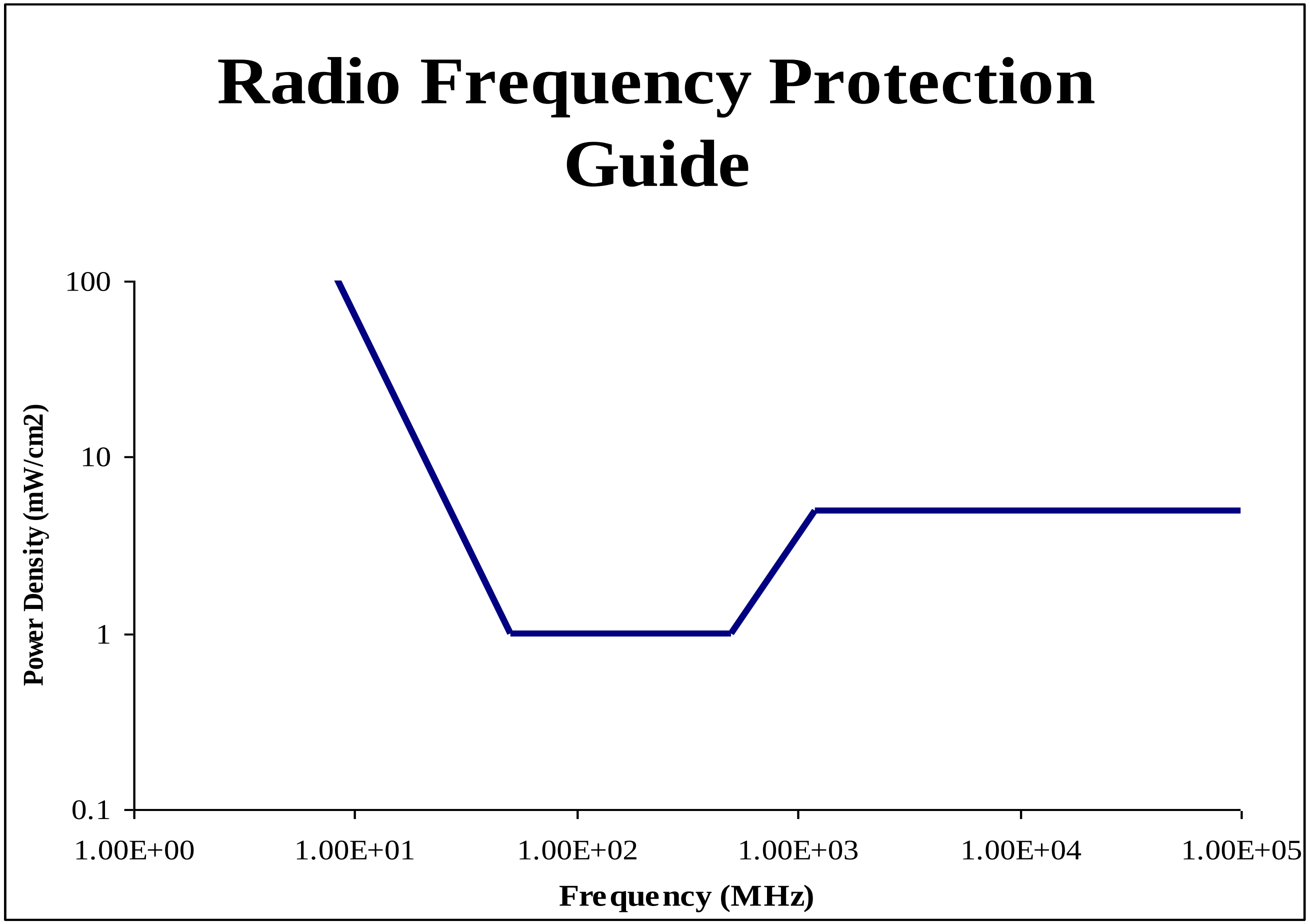
SUPERSEDING
MIL-STD-464
18 March 1997

DEPARTMENT OF DEFENSE
INTERFACE STANDARD

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS

REQUIREMENTS FOR SYSTEMS

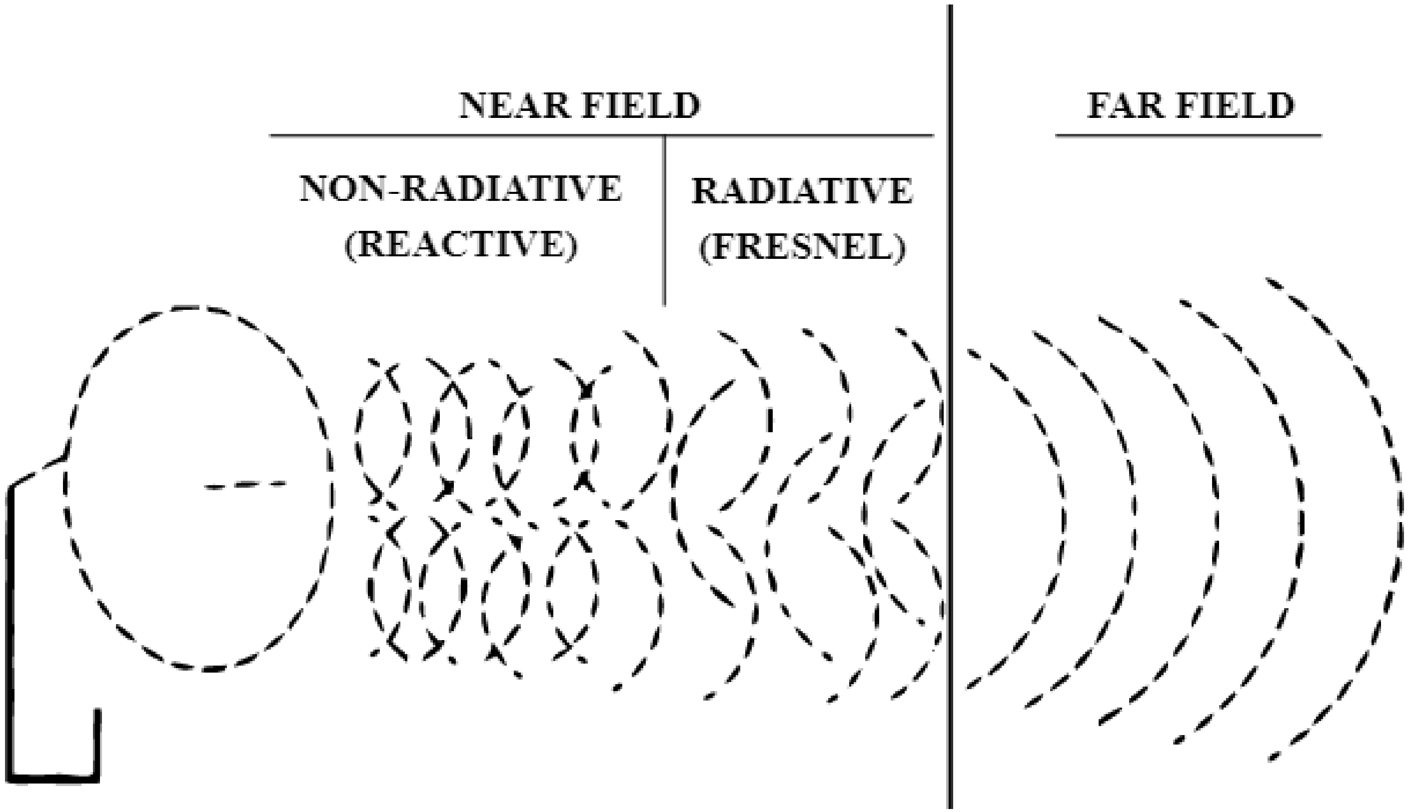
Radiofrequency Protection Guide



RF Measurements

- Human Exposure
  - Mean squared Electric field (E^2)
  - Mean squared Magnetic field (H^2)
  - Equivalent plane-wave power density
  - Frequency dependent
- Near Field Exposures
  - Mean squared Electric field (E^2)
  - Mean squared Magnetic field (H^2)

Antenna Regions



Antenna Regions (EPA)

$$\lambda = \frac{\text{Speed of Light}}{\text{Frequency}}$$

$$\text{Far Field} \geq \frac{2D^2}{\lambda}$$

$$\text{Radiating Near Field (Fresnel Region)} \leq \frac{2D^2}{\lambda}$$

$$\text{Reactive Near Field} \leq 0.62 \times \sqrt{\frac{D^3}{\lambda}}$$

Antenna Regions (Military)

End of Near Field

$R_1 = D^2/5.66\,\lambda$

End of Intermediate Field

$R_2 = D^2/2.83\,\lambda$

Avg Power Density in Near Field = $W_0 = P/A$

Max Near Field Power Density = $4W_0$

Intermediate Field Power Density = $W_{if} = 4W_0\,(R_1/R)$

Far Field Power Density = $W_{ff} = W_{if}\,(R_2/R)^2$

Power Density

Region	Region I	Region II	Region III
Region edges, measured from antenna where: λ = wavelength D = largest dimension of the antenna	$0..\max\begin{pmatrix}\lambda \\ D \\ \frac{D^2}{4\lambda}\end{pmatrix}$	$\max\begin{pmatrix}\lambda \\ D \\ \frac{D^2}{4\lambda}\end{pmatrix}..\max\begin{pmatrix}5\lambda \\ 5D \\ \frac{0,6D^2}{\lambda}\end{pmatrix}$	$\max\begin{pmatrix}5\lambda \\ 5D \\ \frac{0,6D^2}{\lambda}\end{pmatrix}..\infty$
$E \perp H$	No	Effectively yes	Yes
$Z = E/H$	$\neq Z_0$	$\approx Z_0$	$= Z_0$
Component to be measured	E and H	E or H	E or H

RF Measurements

In the near field of an antenna, the RF energy is concentrated at discreet nodes, and the E and H fields are not equal and orthogonal. Hazard analysis of an antenna system is normally done by calculation rather than measurement as the location of the nodes in front of the antenna is not known.

Similarly, leakage points from industrial sources (e.g., blank heaters) may not have equal and orthogonal E and H fields near the leakage point.

Measurements are normally made of the E and H fields with broadband isotropic probes and are compared to the ANSI Exposure limits (averaged over a six-minute period).

RF Isotropic Survey Probes

Measurement Accuracy

Broadband probes such as those shown previously, use orthogonal dipoles and loops to measure the radiated electric and magnetic fields, respectively. Since the polarization of the radiated field is not known, the coupling with the probes may not be perfect. Consequently, the accuracy of measurements in the field are rarely better than ± 2 dB.

Large safety factors are incorporated into the IEEE C95.1 exposure limits.

Regulations / Standards

- Time Averaging
  - Exposures (E field or H field) and Specific Absorption Rates may be averaged over 0.1 hours (6 min).
  - At occupational limits, a 6 min. exposure would result in energy deposition of 144 J/kg or less.
  - Equivalent to a SAR of 0.40 W/kg or less
  - Spatially and temporally averaged over the body

RF Warning Signs - Rules

A. A registrant shall post each point of access to a controlled area with caution signs of the type designated in Figure 1.

B. A registrant shall post operating procedure restrictions or limitations, used to prevent unnecessary or excessive exposure to radio frequency radiation, in a location visible to the operator.

C. A registrant shall place each warning sign or label so that an observer is not exposed to radio frequency radiation that exceeds the applicable MPE.

Shielding

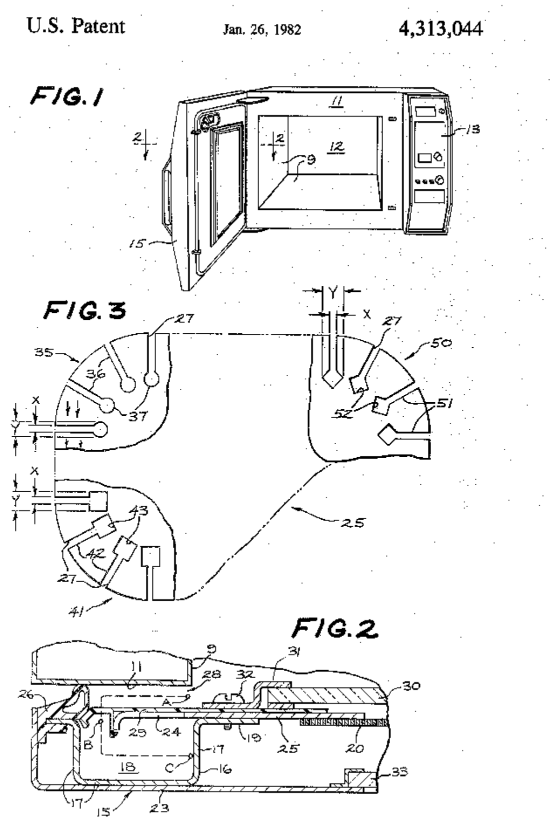
In situations where the power density in an occupied area cannot be reduced otherwise, shielding may be employed. An attenuation chart for various materials at different frequencies is shown below.

Material	1 – 3 GHz	3 – 5 GHz	5 – 7 GHz	7 – 10 GHz
60 x 60 Mesh Screen	20 dB	25 dB	22 dB	20 dB
32 x 32 Mesh Screen	18 dB	22 dB	22 dB	18 dB
16 x 16 window screen	18 dB	20 dB	20 dB	22 dB
¼” Mesh	18 dB	15 dB	12 dB	10 dB

¼ Wavelength Choke Seal

Microwave ovens and some other devices with doors utilize a ¼ wavelength choke seal to prevent the 2450 MHz microwaves from escaping the oven. The seal uses a recessed channel in the door that appears as an area of infinite impedance to stop the microwave energy from escaping.

The seal does not require electrical contact between the door and the oven opening.



Bioeffects

- Biological effects:
  - Largely related to the heating effects which is proportional to the SAR.
- Depth of penetration:
  - Depth at which intensity is reduced to 37% of the initial intensity
  - Approximately $\lambda/10$.

Bioeffects

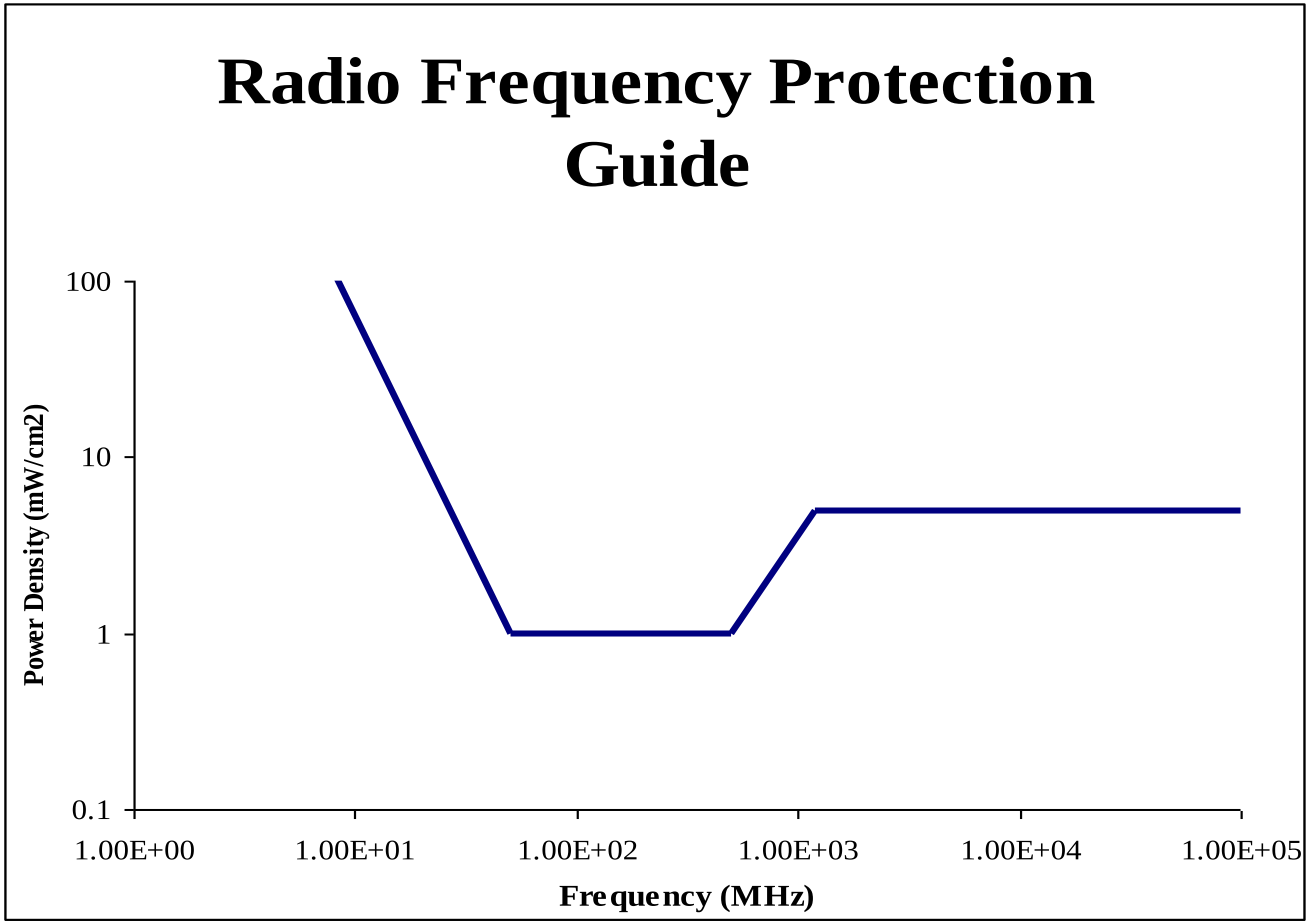
- Whole Body Resonance:
  - Height of Standard Man – 175 cm
  - Absorption rates approach maximal values
  - Long axis of body parallel to E field
  - Resonance occurs close to 70 MHz
- Example: 2450 MHz (microwave oven)
  - Absorb about half of the incident energy
- Example: 70 MHz
  - Sevenfold increase of absorption relative to that in the 2450 MHz field

Bioeffects

Whole Body Resonance:

- Recommended Maximum Protection Levels (MPLs) of field strength reduced
- Accommodates bodies from small infants to large adults

Radio Frequency Protection Guide



Bioeffects

Thermal effects:

- Elevation of core temperature.
- Cataracts observed at 80 – 120 mW/cm^2. The lens of the eye is the only avascular part of the body.
- Temporary impotency from elevated temperature of the testes.

Bioeffects

- Non-Thermal effects:
  - Reports from eastern block countries
  - Central Nervous System effects (bradycardia (slow heartbeat), tachycardia (fast heartbeat), headaches).
  - Reportedly observed at power levels below heating
  - Not well supported by western research except for frequencies that are exact multiples of natural brain frequencies (<30 Hz)
  - Higher frequencies that are modulated at exact multiples of the natural brain frequency have same effect

Electrostimulation

The difference between the IEEE C95.1 standards developed in 1999 that are incorporated into the AZ Statutes, and the most recent version of the standard shown previously are due to biological effects from electrostimulation of excitable nervous tissue.

The electrostimulation is caused by localized heating from short isolated pulses now common in many (particularly military) applications.

Trains of microsecond pulses generate a low duty factor and average power density, but can produce a high localized heating rate and electrostimulation of tissues.

Other Secondary Effects

Electromagnetic Interference (EMI) occurs when a radiated field interferes with the normal operation of a vulnerable piece of electronics. These effects can occur at field strengths far below the occupational limits discussed above.

The first generation of pacemakers were vulnerable to pulsed radiated fields (e.g. rotating air traffic control radars). All modern pacemakers are hardened against external fields.

Some avionics can malfunction in the presence of radiated fields such as the 5G antennas stationed near the flight path in airports.

EMI is a whole separate field which is not covered in this program.

Generation of X-Rays

High power klystrons used in various accelerator applications can also produce x-rays when in operation.

The x-ray production increases towards the end of life of the units when the control of the electron packets deteriorates.

If the area where the klystron operates is accessible, the external exposure rates should be measured periodically.

Summary of Course Topics

- Radiation Basics
- Exposure Levels
- Analytical Methods
- Bioeffects
- ANSI Standard
- **Examples**

Example 1

For an X Band Radar Set operating at 10 GHz with a 5-foot diameter parabolic dish with a 40 dB gain and a ERP of 2 kW, determine:

The near field power density.

The distance to the far field.

Assume a duty factor of 1.0 and no loss from the transmitter to the antenna.

Compare results to the RF Protection Guides.

Near Field

The near field (reactive region) is coherent radiation with most of the power concentrated at the nodes. The power density in the near field does not degrade substantially with distance from the dish. As the field degrades into the intermediate field (Fresnel region), the power density reduces linearly with distance from the antenna. Finally, in the far field, the power reduces with the square of the distance from the antenna and the E and H fields are equal and orthogonal. The maximum power density in the near field is:

$$W_{nf} = 4*P/A$$

The area of the 5-foot diameter dish is 18241 cm^2

$W_{nf} = 4*(2 \times 10^3 \text{ W}/18241 \text{ cm}^2) = 0.44 \text{ W/cm}^2$ in the near field.

$W_{nf} = 440 \text{ mW/cm}^2$

Intermediate Field

The power density in the near field is effectively constant and then becomes linear in the intermediate field and is:

$$W_{if} = 4W_0\,(R_1/R)$$

Where R is the distance from the antenna and R_1 is the distance to the end of the near field. R_2 is the end of the intermediate field.

$R_1 = D^2/5.66\,\lambda = (1.52\text{ m})^2/(5.66)(0.03\text{ m}) = 13.6$ *meters*

$R_2 = D^2/2.83\,\lambda = (1.52\text{ m})^2/(2.83)(0.03\text{ m}) = 27.2$ *meters*

$W_{if} = 4W_0\,(R_1/R) = 440\text{ mW/cm}^2(13.6/27.2) = 220\text{ mW/cm}^2$

Far Field

In the far field the E and H Fields are equal and orthogonal, and they fall off as the square of the distance. This in non-coherent radiation.

$W_{ff} = W_{if}\,(R_2/R)^2$

Where R is the distance from the antenna in the far field. Let's try 100, 200, and 400 meters from the antenna.

$W_{ff} = W_{if}\,(R_2/R)^2 = 220\,(27.2/100)^2 = 16.3\ \text{mW/cm}^2$

$W_{ff} = W_{if}\,(R_2/R)^2 = 220\,(27.2/200)^2 = 4.1\ \text{mW/cm}^2$

$W_{ff} = W_{if}\,(R_2/R)^2 = 220\,(27.2/400)^2 = 1.0\ \text{mW/cm}^2$

From Table 1 of the ANSI standard, we can see that the Maximum Permissible Exposure Level (MPEL) at 10 GHz is 10 mW/cm^2

Hazard Zone

Generally, it is important to calculate the distance to the far field and the distance where the power density drops below the MPEL. The Hazard Zone is then chosen as the larger of these two values.

For this radar system, the MPEL distance is the farther value, and the hazard zone would be set out to 130 meters.

It is obvious that the near and intermediate fields of this system exceed the MPEL. If this system is mounted such that personnel can easily access the space in front of the dish (e.g., a roof mount with a low beam angle), the space in front of the dish must be fenced or roped off to prevent access.

FCC Approved Systems

Virtually all communication systems have been approved by the FCC and have undergone a thorough analysis of power density throughout their operating range.

FCC licensed antennas do not need to be licensed or surveyed under State rules. Data on any FCC licensed system is available from the FCC or the manufacturer of the system.

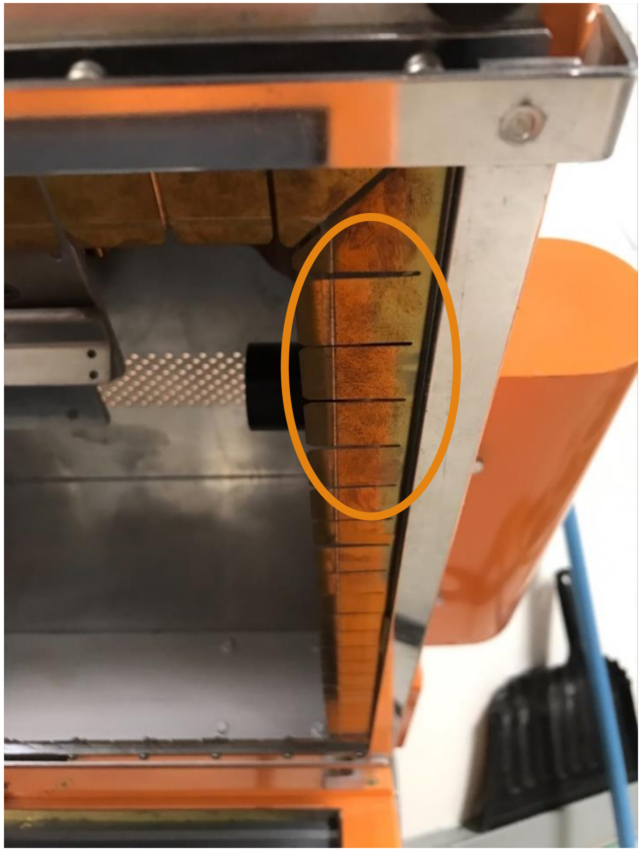
Some of these antennas have exclusion zones for a space in front of them. When roof mounted such that maintenance personnel may work in front of the antenna, the hazard zone should be marked off.

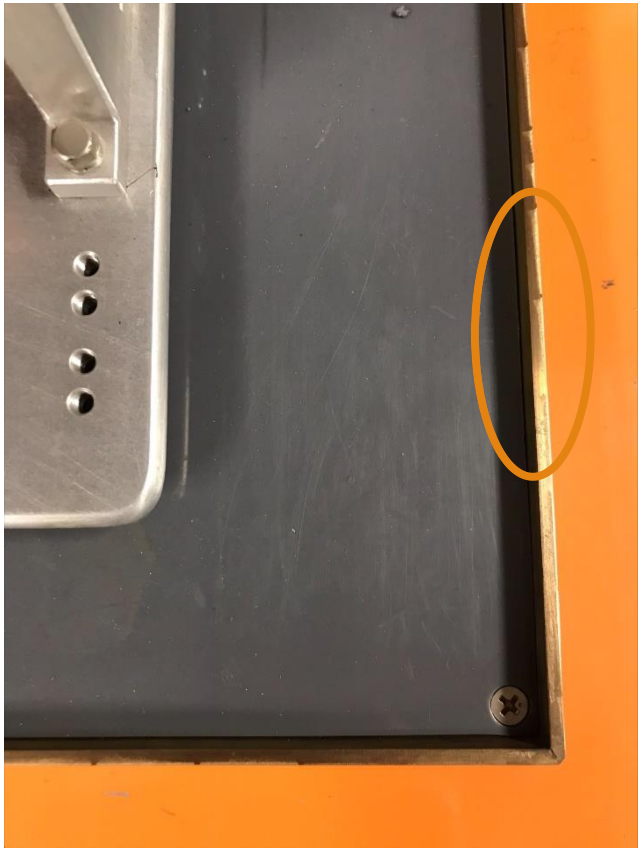
Example 2 – RF Blank Heater

RF Blank heaters take an ingot of plastic and heat it until it is soft where it can be placed in a molding machine to make plastic products.

This particular unit uses a metal-to-metal contact seal to prevent leakage of the RF radiation. Each copper finger in the lid must make electrical contact with the copper surface in the base.

RF Blank Heater





RF Blank Heater

This particular seal is fragile as any debris that stops any finger in the lid from making electrical contact with the base can produce a significant leak.

By contrast, modern microwave ovens use a quarter wavelength choke seal on the doors. The door gap appears as an area of infinite impedance to the microwaves and prevents leakage.

Since the field near a leakage point may or may not have equal and orthogonal E and H fields, both E and H field probes must be used with the results compared to the ANSI C95.1 limits.

RF Blank Heater

The blank heater operates at 73 MHz which gives an exposure limit of 61.4 V/m E field and 0.223 A/m H field. A survey of the unit yielded the following results for the E field (V/m).

Location	Head	Trunk	Feet
Front	<5	<5	<5
Right Side	22	240	720
Left Side	<5	<5	<5

RF Heater

A careful inspection of the metal contact seals showed that some molten plastic had fallen on the base contact bar and had prevented the copper finger in the lid from making electrical contact at that point.

Since the location was on the right side away from the operator, there was no overexposure of personnel.

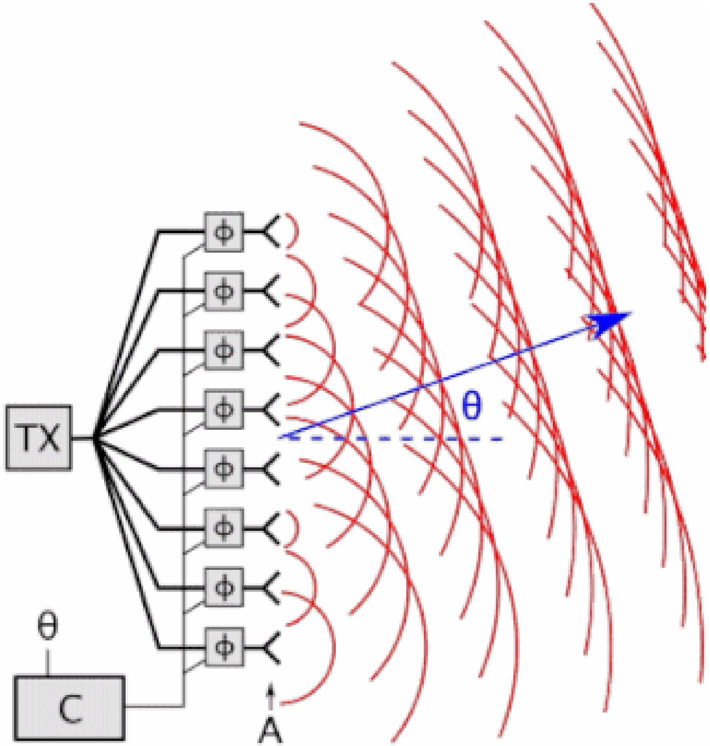
Seals such as these, waveguide seals, and rotating waveguide joints are also prone to leakage and should be checked periodically.

Dummy loads must always be used in a test environment.

Example 3 – A Phased Array

A phased array usually means an electronically scanned array, a computer-controlled array of antennas which creates a beam of radio waves that can be electronically steered to point in different directions without moving the antennas.

Very popular in military and commercial avionics.

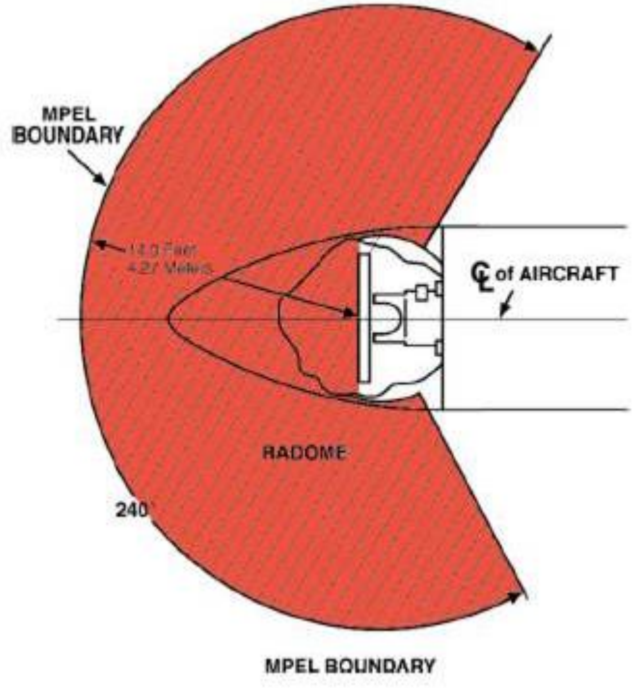


Phased Arrays

Since the beam location and shape are controlled by software, it is difficult to know where the beam is at any particular moment.

Manufacturers of these systems always provide a plot of the beam width, and intensity, and the stand-off to meet the IEEE/FCC exposure guidelines and the near/far field juncture.

This plot should be used to establish the safety hazard zone.



Other Common Sources

RF Induction Furnaces are commonly found in chemistry labs along with common muffle ovens.

A crucible is placed in the center of an RF coil and heats rapidly.

RF shielding protects the operator.

Damaged shielding can produce high exposure rates.

Other Common Sources

RF Heat Sealers use twin RF coils to heat whatever bag or fabric that is placed in between them.

Frequently they look exactly like common hot bar sealing machines

RF Plasma Ashers & Etchers

These systems use an RF source, generally at 13.56 MHz, to form a plasma which is used in the semiconductor manufacturing.

These systems normally can only exceed the RF exposure limits under a failure condition.

In newer designs, the RF generator is imbedded in the tool.

Regulatory Requirements

Regulatory requirements vary dramatically from state to state and from one Federal Agency to another. Many states have no RF rules. OSHA has no RF standards. In Arizona, radiating sources not covered under FCC or FAA must be registered with the Department of Health Services Bureau of Radiation Control and should be surveyed annually.

Training is also supposed to be offered to operators of the radiating equipment.

Other Resources

In addition to the IEEE standards and guides referenced earlier in this program, the FCC also has guidance documents available on a host of different communications related topics. See:

https://www.fcc.gov/general/radio-frequency-safety-0

The NCRP also has several Reports on RF Exposure.

NCRP Report No. 174, *Preconception and Prenatal Radiation Exposure: Health Effects and Protective Guidance*

NCRP Report No. 86, *Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields*

NCRP Commentary No. 18, *Biological Effects of Modulated Radiofrequency Fields*

Summary

We have reviewed the basics of RF radiation and its interaction with human tissue. We have also discussed the frequency dependent MPEL values established in ANSI Standard C95.1, 1999 which is incorporated into the Arizona Statutes.

Finally, we developed methods to assess RF exposure levels found around several types of radiating sources and industrial equipment, and demonstrated these methods with examples.

Quiz

For those of you that would like a certificate for the class, please complete the multiple choice quiz that was provided with your handouts.

The test is open book and open note.

Once complete, please scan or fax to the office where we will grade it and send the certificate to you.

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