KNOW YOUR EMF'S
RF AND MICROWAVE RADIATION

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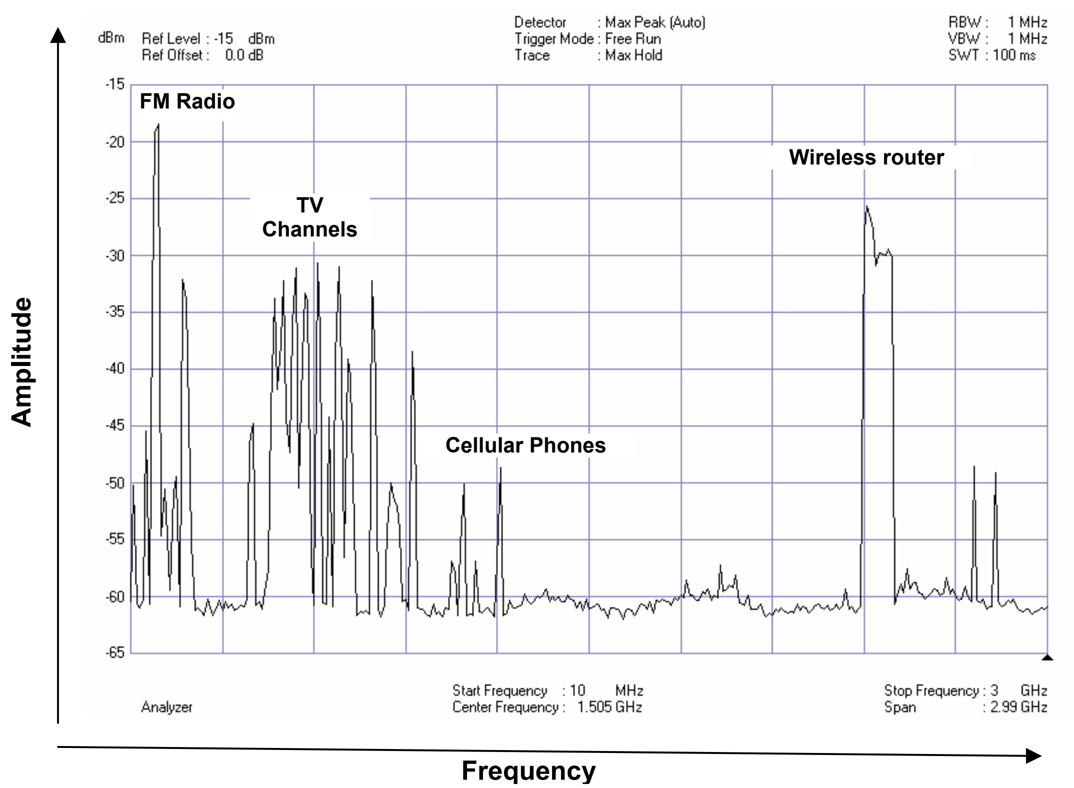
1. INTRODUCTION

Our electromagnetic environment has significantly changed over the last decade. New technologies and the wireless world are exposing us to unknown quantities of electromagnetic radiation. Bluetooth, WLAN, wireless, modulated and pulsed signals, time and code division multiplexing are now abundant in our daily lives. High frequency radiation is used for wireless signal transmission and is usually referred to as radio frequency (RF) and microwave radiation.

Graph 1: This spectrum analysis graph reflects conditions in a home office in San Diego



Let's start with the basics and untangle the subject of high frequency fields. We will look at the sources, physics, measurement technologies, reference values and mitigation methods.

2. THE FREQUENCY SPECTRUM

Radiation is energy that is propagated through space in waves or particles. The most common forms of radiation are x-rays, microwaves, light waves, and radio waves. We differentiate the types of radiation depending on the frequency. Frequency is the rate of polarity change per second and expressed as Hertz (Hz). Our electrical power system in the United States runs on a 60 Hz frequency. Cell phone communication utilizes the 800-900 MegaHz (MHz) or 1.8-1.9 GigaHz (GHz) frequency ranges.

Graph 2: This spectrum analysis represents conditions present in an office with a cell tower in the parking lot

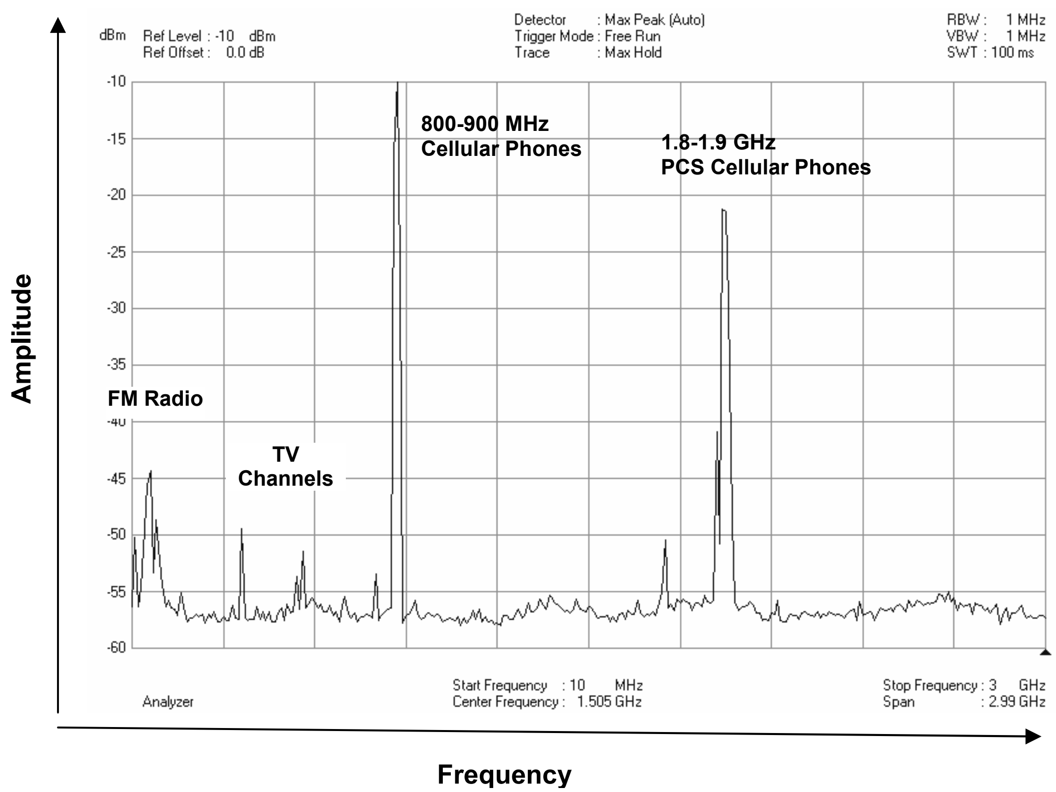
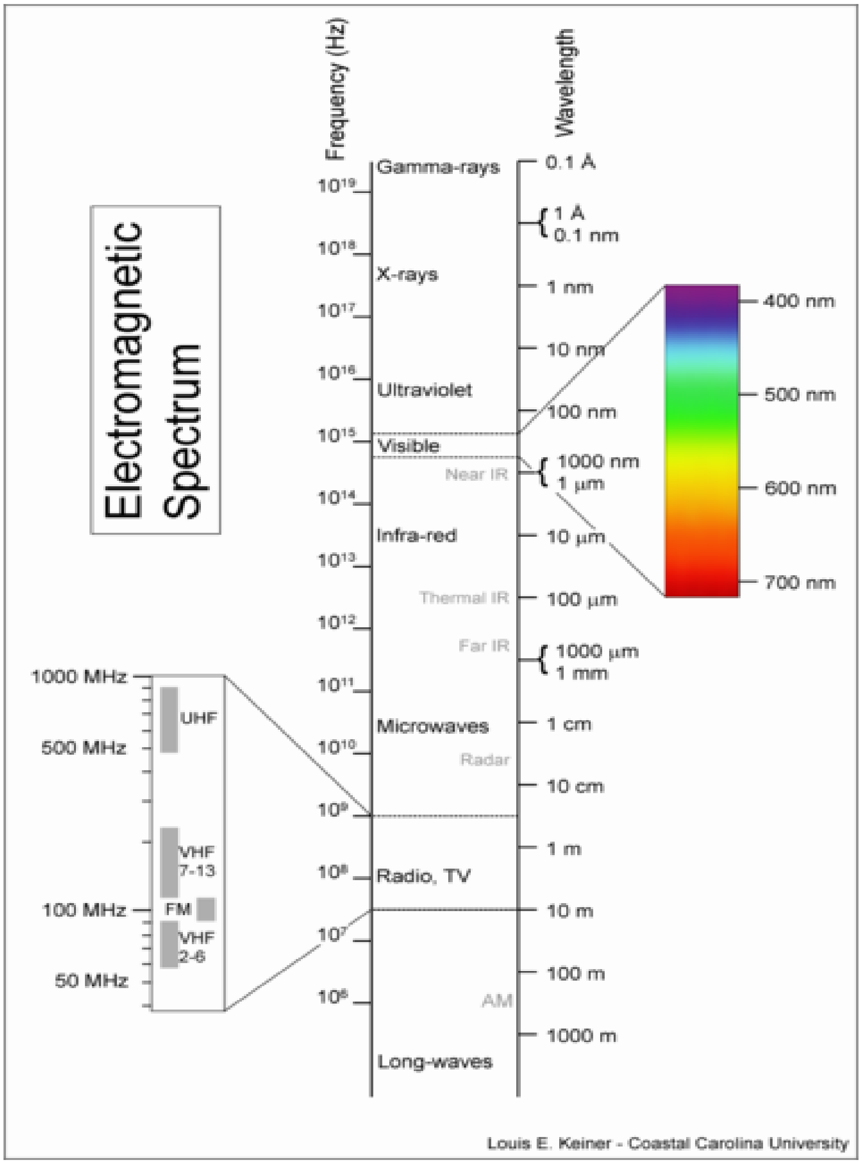


Table 1: Common Units Used for High Frequency Radiation

Unit	Symbol/Unit	Frequency	Frequency
1000 Hz	1 kHz (kiloHertz)	1000 Hz	10^{3}
1000 kHz	1 MHz (MegaHertz)	1000.000 Hz	10^{6}
1000 MHz	1 GHz (GigaHertz)	1000.000.000 Hz	10^{9}
1000 GHz	1 THz (TeraHertz)	1000.000.000.000 Hz	10^{12}
1000 THz	1 PHz (PetaHertz)	1000.000.000.000.000 Hz	10^{15}
1000 PHz	1 EHz (ExaHertz)	1000.000.000.000.000.000 Hz	10^{18}
1000 EHz	1 ZHz (ZettaHertz)	1000.000.000.000.000.000.000 Hz	10^{21}

Diagram 1: Electromagnetic Spectrum



Radio Spectrum and Wave Length

ELF	SLF	ULF	VLF	LF	MF	HF	VHF	UHF	SHF	EHF
3 Hz	30 Hz	300Hz	3kHz	30kHz	300kHz	3MHz	30MHz	300MHz	3GHz	30GHz
30 Hz	300Hz	3kHz	30kHz	300kHz	3MHz	30MHz	300MHz	3GHz	30GHz	300Ghz

EL	Extremely low	SL	Super low	UL	Ultra low
VL	Very Low	L	Low	M	Medium
H	High	VH	Very high	UH	Ultra High
SH	Super high	EH	Extremely high		

10 kHz	100 kHz	1 Mhz	10 MHz	100 MHz	1 GHz	10 GHz	100 GHz
30 km	3 km	300 m	30 m	3 m	30 cm	3 cm	3 mm

Table 2: Frequencies and Associated Usage

Frequencies	**Services**
0 Hz	Earth magnetic field, Direct Current, magnets
50-60 Hz	Electrical power in buildings and appliances
400 Hz	Power system in airplanes
3 kHz-30 kHz	Submarine communication
10 – 20 kHz	Door openers, anti-theft devices
535- 1700 kHz	AM Radio
30-50 MHz	Walkie-Talkies, analog cordless phones, amateur radio
88-108 MHz	FM Radio
54-806 MHz	Television
800-940 MHz	Cellular phones, paging, anti-theft, cordless phones
941-944 MHz	Government services
950-1610 MHz	Aviation navigation and transponders, radar, maritime
1240-1300	Amateur radio
1610 MHz	Satellite phone uplinks
1850-1990 MHz	PCS cellular phones
2483 – 2500 MHz	Satellite Phone downlinks
2.4 GHz	WLAN, Bluetooth, spread spectrum, cordless phones
5.2 GHz	New digital cordless phones
3-30 GHz	Radar, data transmission
28-29 GHz	Wireless cable TV?
38.6-40 GHz	High-speed data links
0.3 THz-400 THz	Infrared
400-750 THz	Visible light
750 THz-30 PHz	Ultraviolet light
30-300 EHz	x-ray
30 EHz-30ZHz	Gamma radiation

Cellular Communication Systems
Basically, two different systems exist for cellular phone communication in the US:

- Time Division Multiple Access TDMA
- Code Division Multiple Access CDMS

and the European version of TDMA referred to as GSM.

2. THE HEALTH EFFECTS DEBATE

The health effects related to high frequency exposures are as controversial as that of low frequency EMF or mold exposures. The scientific community is divided. The traditional and current regulatory approach is to acknowledge only the thermal (heating) effect on human tissue and exposure regulations are based on this concept.

However, over the last decade a significant number of studies have shown other potential effects such as increased and altered cell proliferation, influences on hormones, heart, circulatory, and nervous system. These are currently not recognized by the regulatory authorities. From an international view point, a number of countries have lowered the permissible public exposure levels significantly. Recommendations by concerned scientists and physicians call for even lower threshold levels. In August of this year the *BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF)* published a comprehensive analysis of existing research and recommends prudent avoidance of excessive EMF's. You can obtain a copy at www.bioinitiative.org .

3. TESTING METHODS

Identification and measurement of high frequency fields is far more intricate then low frequency EMF's. Testing equipment and measurement results are frequency specific and specific instrumentation to measure specific parameters. At our disposal we have:

Spectrum Analyzers

Spectrum analyzers can be used to sweep specific frequency ranges, identify individual sources of that specific frequency and provide information about the strength and the type of the signal. Currently common spectrum analyzers cover frequency ranges between 100 kHz and 3 GHz. Specific antennas are required to ascertain specific frequency ranges Advantages of spectrum analyzers are: that they are selective for a specific amplitude and frequency, capable of making peak value measurements, identifying pulse modulated signals and are very sensitive. The disadvantages are that they are expensive, and complicated to operate.

Broad-spectrum Meters

Broad spectrum meters are used to ascertain overall radiation levels. They do not identify the individual sources, frequency or their amplitude but provide a sum of all high frequency sources. They are commonly used for FCC compliance measurements. They usually do not allow for the differentiation between, AM or FM radio, TV communication, cellular frequencies or wireless communication devices. The advantages are that they capture all signals, provide total power level, fast results, are simple to operate and relatively inexpensive. Disadvantages are that they can not differentiate frequencies or capture pulse modulation, and are not very sensitive.

Scanning Devices

A large number of inexpensive scanning devices have come onto the market. They provide audible sounds or LED light to indicate fields. However, the type or specific strength of radiation can not be determined. In the hands of inexperienced individuals misinterpretations or measurement errors are common occurrences. However, they can be useful to detect the presence of elevated fields.

In conclusion, spectrum analyzers with the appropriate antennas are the most useful instrumentation for high frequency evaluations. We can measure the magnetic or electric portion of the signal.

4. Data Evaluation

Magnetic field measurements are expressed as power density in nanoWatt per square centimeter (nW/cm^2), electric field measurements in volt/per meter (V/m).

Table 3: International regulatory threshold limits, references and guidelines

Entity	**Power Density**
Regulatory – FCC/ANSI – USA	579,000 nW/cm^2
Regulatory – Italy, Poland, Hungary, Bulgaria	10,000 nW/cm^2
Regulatory – Switzerland	4,500 nW/cm^2
Recommendation – Ecolog Hannover, Germany (2003)	300 nW/cm^2
Recommendation – Salzburg Resolution, Austria (2000)	100 nW/cm^2
Recommendation – STOA – EU Parliament (2001)	10 nW/cm^2
Average range in metropolitan areas	0.5 – 2 nW/cm^2
Background levels in residential areas	0.05 -0.5 nW/cm^2
Necessary for cellular phone reception	0.0001 nW/cm^2

Table 4: A study conducted in Germany in 2002 of indoor environments in proximity to cellular base stations yielded the following distribution:

Percentiles	**Power Density**	**Percentiles**	**Power Density**
10	<1 nW/cm^2	60	30 nW/cm^2
20	2 nW/cm^2	70	50 nW/cm^2
30	4 nW/cm^2	80	100 nW/cm^2
40	10 nW/cm^2	90	320 nW/cm^2
50	20 nW/cm^2	95	630 nW/cm^2

5. Case Histories

Office Building

A cellular base station (small pole with 6 antennas) is located in the parking lot of a two-story medical office building in the Los Angeles area. 12 additional antennas are being installed on the roof of the building. The tenants want to establish a base line prior to the activation on the new roof-mounted antennas. See spectrum analysis Graph2 on page 2. The table below shows the measurement results in representative office.

Table 5: Measurement Results for Power Density in nW/cm² from different Sources

Location	Cellular Total
Reception – 1st. floor approximately middle of building	10 nW/cm²
Physician's office – 1st. floor in center of building	3 nW/cm²
2nd. floor corner offices – closest to antenna pole	437 nW/cm²
Medical office – 2nd. floor at interior	76 nW/cm²
Office – 2nd. floor at middle of the building	34 nW/cm²
2nd. floor corner office – furthest away from antenna pole	235 nW/cm²

It is expected that the levels on the second floor offices will increase with the activation of the roof-based cellular base station.

Residential Building

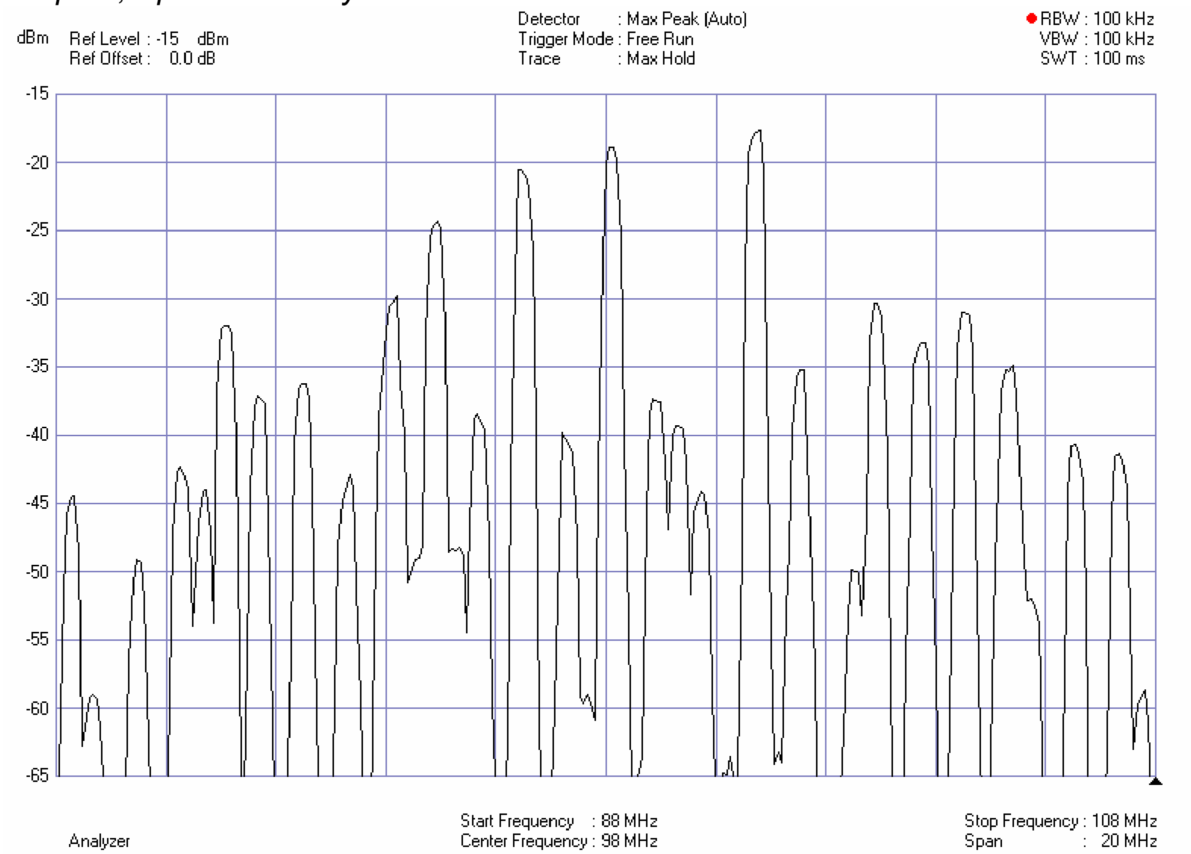
A single story home located halfway down Mount Soledad in San Diego. A new cellular base station was established on the roof of a recreation center across the street. Measurements were performed prior to activation to establish a baseline. A significant number of transmission antennas for radio, TV, cellular, public and military communication are located on top of Mt. Soledad.

Table 6: Measurement Results for Power Density in nW/cm² from different Sources

Location	FM Radio and TV	Cellular Phone	Paging	PCS Phone	Portable Wireless Phone	Total
Family room	53	0.1	1	0.1	439	493.2
Master bedroom	21	0.1	2	0.1	0.1	23.3
Front yard	47	0.1	0.1	0.1	0.1	47.4

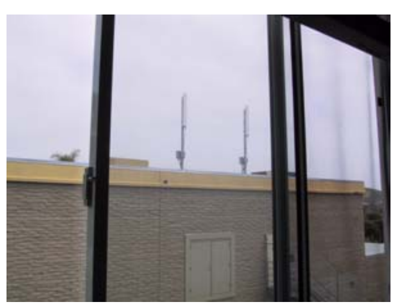
The strongest signals outside signals (highest amplitude) were associated with FM radio and TV transmission towers. However, the highest radiation source was 2.4 GHz from the wireless phone base station in the family room, which was used as an office. See spectrum analysis Graph 1 on page 1.

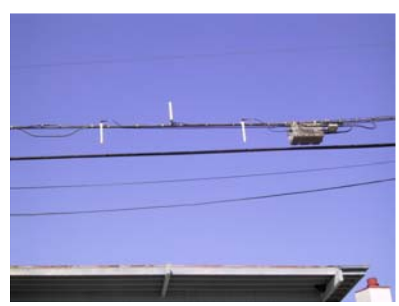
Graph 3; Spectrum analysis of FM radio stations



6. SUMMARY

We are constantly increasing our high frequency exposure load by the increased usage of wireless communication networks such as cell phones, baby monitors, WLAN (wireless local area networks), Bluetooth and other applications. Careless in-house wireless network installations can become a significant source of microwave radiation in a building. Care should be taken on how and where we install and use wireless networks within our indoor environments, especially in bedrooms, and areas where we spent a significant amount of time.





Cellular base stations ("Hot Spots") are being established inside commercial buildings, on street lamp posts and on towers across from residential buildings. In situations where outside sources such cellular base stations are a significant and unavoidable source, selection of certain construction materials can reduce exposures significantly.

In existing building the options are more limited. However, a number of shielding materials are available. For example, the application of metal-based UV shielding films on the windows will usually reduce the levels from outside emission sources by 30 to 35 decibel (dB).

If shielding of indoor environments is taken into consideration, it should always be conducted in conjunction with spectrum analysis measurements to identify the significant source frequencies and amplitude, to choose the most effective materials for that frequency and to verify successful mitigation.

The determining factors for the exposure from high frequency source are:

- **Distance to the antenna site**
- **Line of sight to the antenna site**
- Type of antennas, e.g. omni directional or directional antennas
- Number, power, and orientation of the antennas
- Capacity of the antenna site (no of channels / frequencies)
- Height difference between location and antenna site
- Type of building construction / type of window glass
- Total reflection of the environment

The pprecautionary principles also needs to apply to high frequency radiation. In a press release issued on August 1, 2007, the Germany Department for Radiation Protection discourages the use of wireless local area networks (WLAN), i.e. wireless internet routers in homes and businesses. It warns that inappropriately placed wireless internet routers can create high levels of microwave radiation. It recommends the use of hard-wired internet assess systems instead.