SDSU MASTERS of HOMELAND SECURITY

GEOL600 SENSOR NETWORKS

INTRODUCTION

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EM Spectrum
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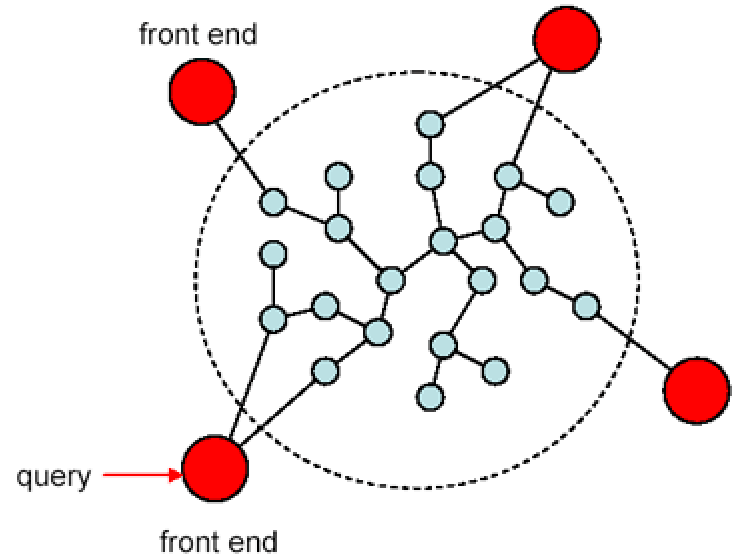
OVERVIEW of SENSOR NETWORKS



A **sensor network** (SN) consists of many spatially distributed sensors, which are used to monitor or detect phenomena at different locations such as temperature changes, pollutant levels, etc. Usually, each sensor is intended to be physically small and inexpensive, thus making it possible to produce and deploy them in large numbers.

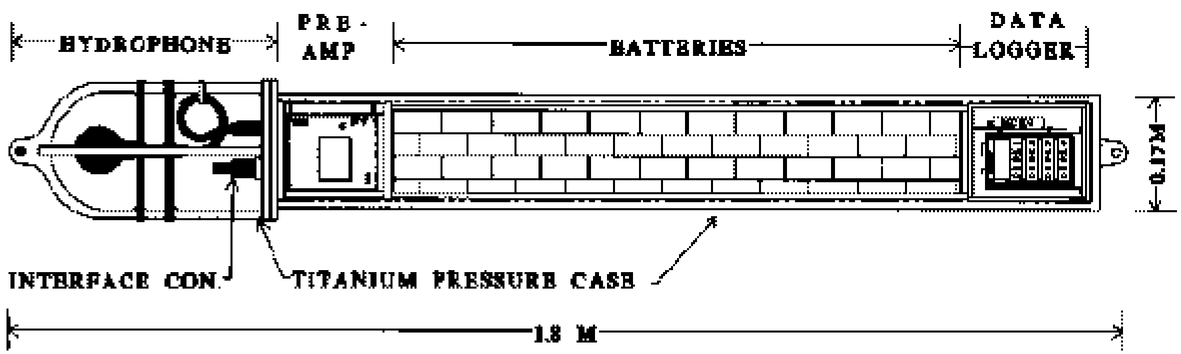
A sensor is equipped with a radio transceiver, a small microcontroller, and an energy source, usually a battery.

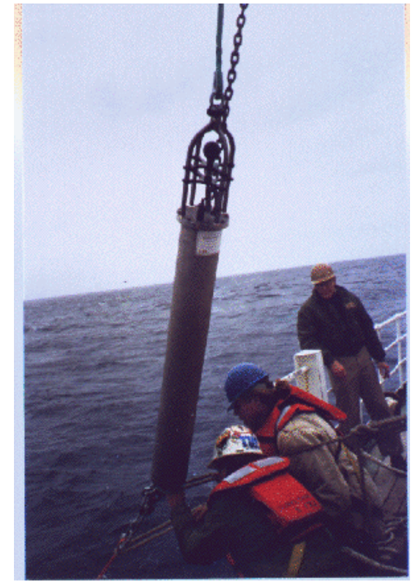
For sensors to be small and low-cost, resources in terms of energy, memory, computational speed and bandwidth are severely constrained.
The sensors use each other to transport data to a monitoring entity.

Sensor networks involve technologies from three relative areas:
sensing, communication, and computation (hardware, software, algorithm).

Applications

Sensor networks are applied in a wide variety of areas, such as environmental monitoring, video surveillance, traffic monitoring, air traffic control, industrial and manufacturing automation, etc.





Brief History

Early sensor networks were applied for military purposes, **Sound Surveillance System** (SOSUS).

Modern research on sensor networks started around 1980. DARPA **Distributed Sensor Network**(DSN)

Smaller computing chips, more capable sensors, wireless networks and other new IT technologies are spurring development.

COMMERCIAL SN APPLICATIONS (2005)

CROSSBOW www.xbow.com

Crossbow Technology, Inc. is a leading supplier of inertial sensor systems, including MEMS gyro and FOG gyro-based Inertial Measurement Units, AHRS, and Vertical Gyros for Aviation, Land, and Marine Applications. Crossbow also produces MEMS accelerometers (single and tri-axial), magnetometers, tilt sensors (inclinometers), vibration, seismic and other instrumentation sensors. Crossbow develops and produces wireless sensor networks and wireless data-loggers based on the "Smart Dust" concept and utilizing UC Berkeley's TinyOS

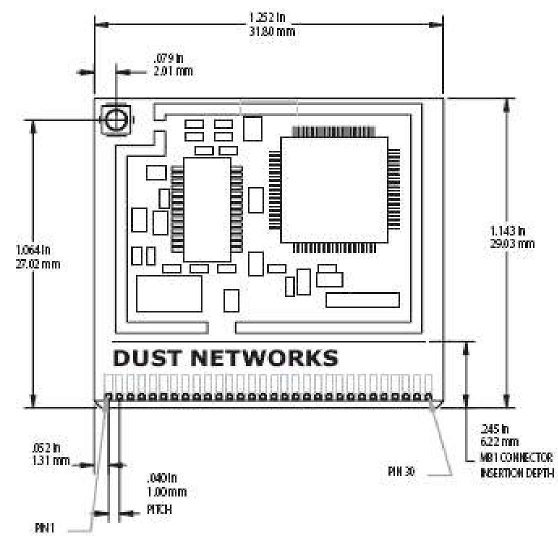
MOTE

MICA2DOT

DUST NETWORKS www.dust-inc.com

Dust Networks™ provides wireless mesh networking systems to solution providers, integrators and OEMs for enterprise-class monitoring and control applications. Dust Networks' SmartMesh™ Networks combine sophisticated mesh networking software and low-power wireless nodes to provide unmatched reliability, manageability and ease of installation. Dust Networks' premier product – the SmartMesh networking system – lowers the barrier to deploying sensing and control solutions, and provides unprecedented access to information about the physical world; information that will be used to increase occupant comfort in buildings, to reduce energy consumption, to reduce machine downtime in factories, and to allow companies to monitor and control processes and systems for increased efficiency and enhanced profitability

DIMENSIONS

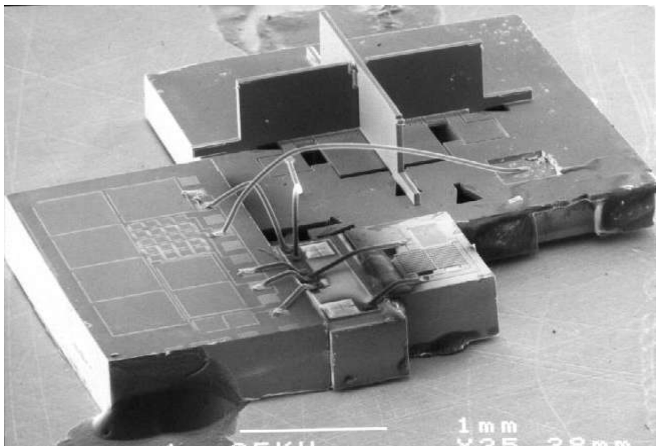


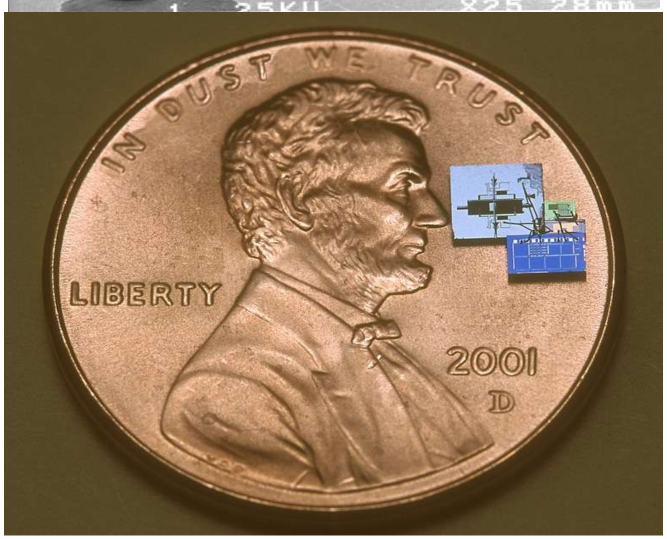
M1010 mote

SMARTDUST PROJECT

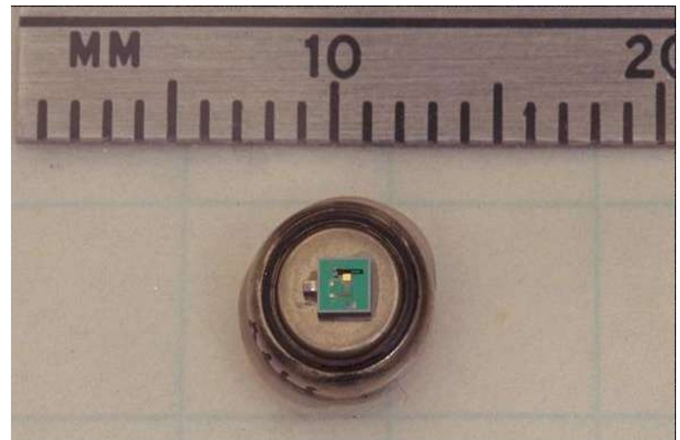
The goal of the Smart Dust project is to build a self-contained, millimeter-scale sensing and communication platform for a massively distributed sensor network. This device will be around the size of a grain of sand and will contain sensors, computational ability, bi-directional wireless communications, and a power supply

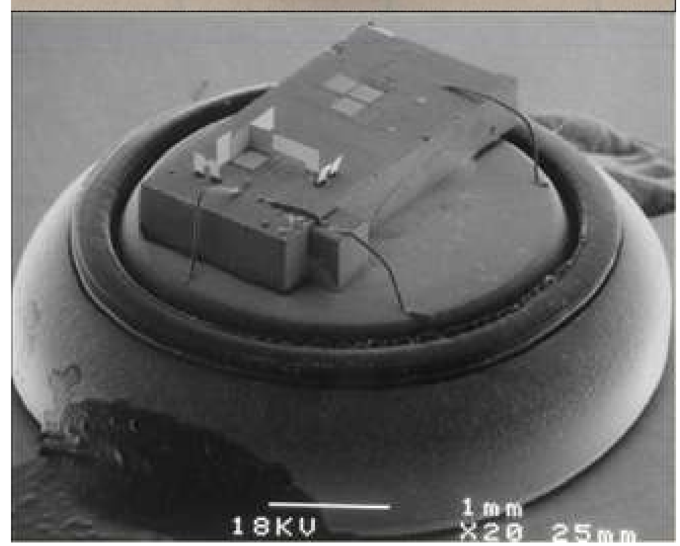
GOLEM DUST
solar powered bidirectional coms & sensing





DAFT DUST
63mm^3 bidirectional coms mote





www-bsac.eecs.berkeley.edu/archive/users/warneke-brett/SmartDust/index.html

BATTERIES

Store energy and make it available in an electrical form. Batteries usually consist of electrochemical cells , which can be combined in series to provide higher voltages.

Disposable (primary cells)

- Zinc-carbon battery
- Alkaline battery
- Silver-oxide battery
- Lithium battery

Rechargeable (secondary cells)

- Lead-acid battery
- Gel battery
- Nickel-Cadmium battery
- NiMH battery
- Li-ion battery
- Li-Polymer battery

Standard 9-volt battery

Battery Capacity

The capacity to store charge is often expressed in ampere hours. A battery that can provide 1 A of current for 1 hour, has a real-world capacity of 1 A·h.
If it can provide 1 A for 100 hours, its capacity is 100 A·h. But...
While a battery that can deliver 10 A for 10 hours can be said to have a capacity of 100 A·h, that is not how the rating is determined by the manufacturers.

Their rating is based on tests performed over 20 hours with a discharge rate of 1/20 (5%) of the expected capacity of the battery. So a 100 ampere-hour battery is rated to provide 5 A for 20 hours.
When discharging at 1/20 of their capacity, batteries are more efficient than at higher discharge rates.

To calculate the 5% discharge rate of a battery, take the manufacturer's ampere-hour rating and divide it by 20. For a AA cell rated at 1300 mA h the 5% discharge rate from which the rating was derived is 1300 mAh / 20 h = 65 mA.

Battery Power

A 500 mAh battery could produce 5 mA for 100 hours, or 10 mA for 50 hours, or 25 mA for 20 hours, or (theoretically) 500 milliamps for 1 hour.
However, batteries are not quite that linear. But milliamp-hour ratings are somewhat linear over a normal range of use. Using the amp-hour rating, you can roughly estimate how long the battery will last under a given load.

Four 1.25V, 500 mAh batteries arranged in series, gives 5V (1.25 x 4) at 500 mAh.
Arranged in parallel, gives 1.25 V at 2,000 (500 x 4) mAh.

en.wikipedia.org/wiki/Battery_(electricity)

MICROCONTROLLERS

A microcontroller is a computer-on-a-chip optimized to control devices.
It is a type of microprocessor emphasizing self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor used in a PC.

A typical microcontroller contains all the memory and I/O interfaces needed, whereas a general purpose microprocessor requires additional chips to provide these necessary functions.

Microcontrollers are a component in many kinds of electronic equipment (embedded system). They can be found in almost any electrical device, washing machines, microwave ovens, telephones, etc.

Microcontrollers are dedicated to one task and run one specific program. The control program is stored in ROM (read-only memory) and generally does not change.

Microcontrollers are often low-power devices. A desktop computer is almost always plugged into a wall socket and might consume 50 watts of electricity. A battery-operated microcontroller might consume 50 milliwatts

Most microcontrollers today are based on the von Neumann architecture, which defines the four basic components required for an embedded system.

A single microcontroller integrated circuit includes:
CPU core
Memory for program (ROM or Flash memory) and for data (RAM),
Timers (customizable and watchdog timers),
I/O lines to communicate with external peripherals and complementary resources

A typical microcontroller will have a built in clock generator and a small amount of RAM and ROM (or EPROM or EEPROM), meaning that to make it work, all that is needed is power, some control software and a timing crystal.

I/O (input/output) devices, such as analog-to-digital converters, timers, UARTs or specialized serial communications interfaces like I²C, Serial Peripheral Interface and Controller Area Network. Often these integrated devices can be controlled by specialized processor instructions.

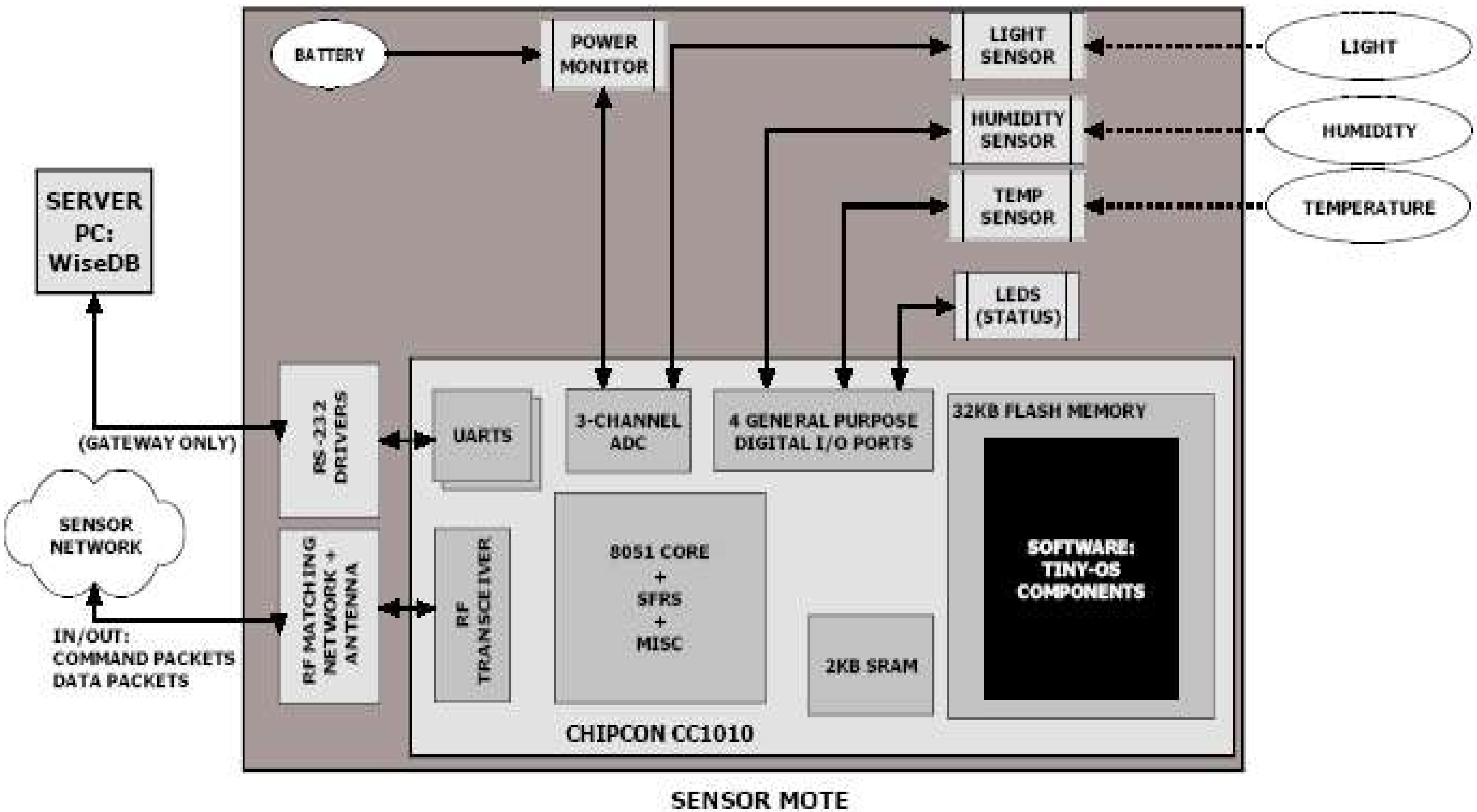
Some modern microcontrollers include a built-in high-level programming language; BASIC is quite common for this.

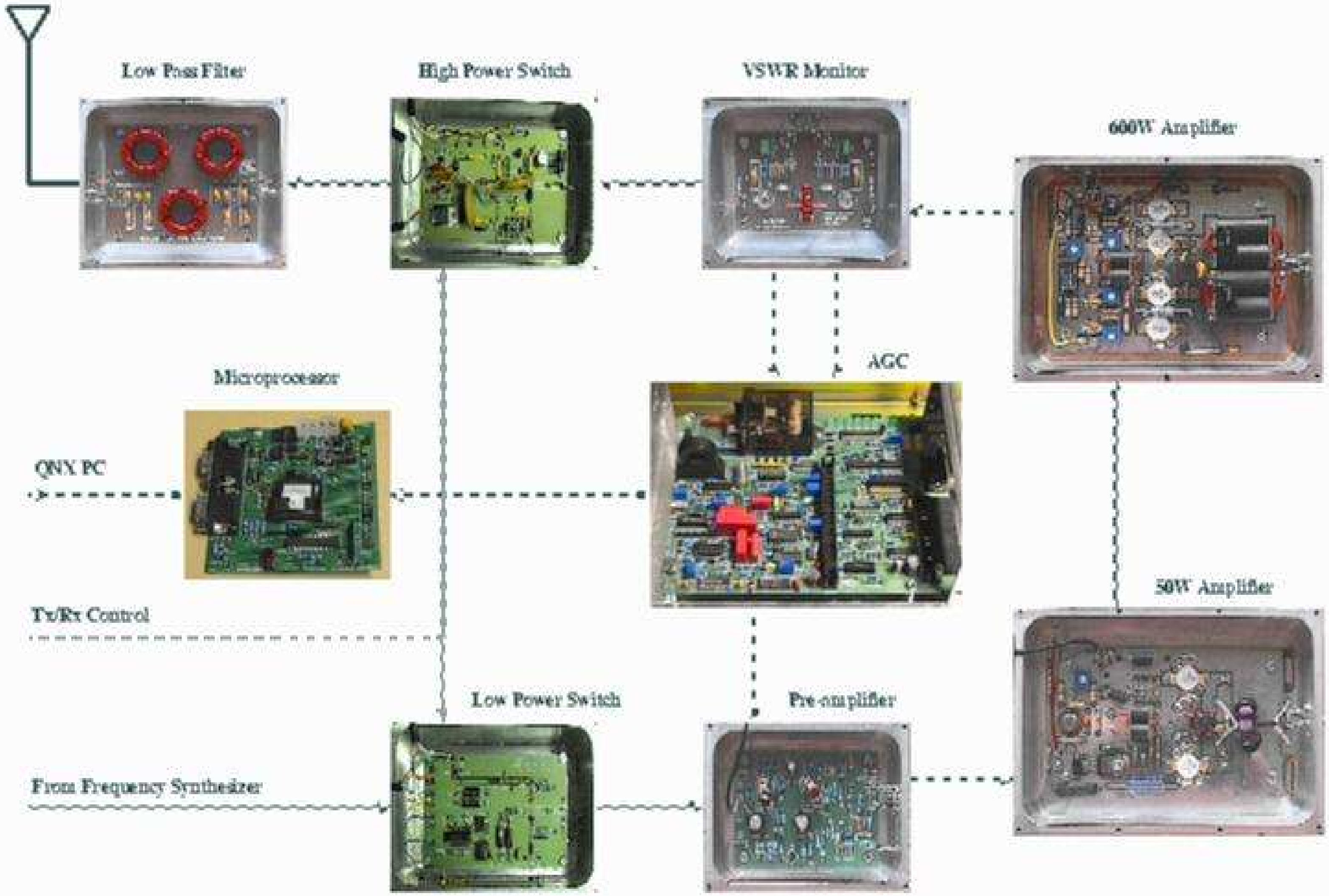
en.wikipedia.org/wiki/Microcontroller

BLOCK DIAGRAMS

The block diagram is a simple pictorial representation of a system/sub-systems linked to illustrate the relationships between components/subsystems.

In many cases detailed drawings and/or hardware are not available, the block diagram serves to visualize the system and identify its interdependencies.

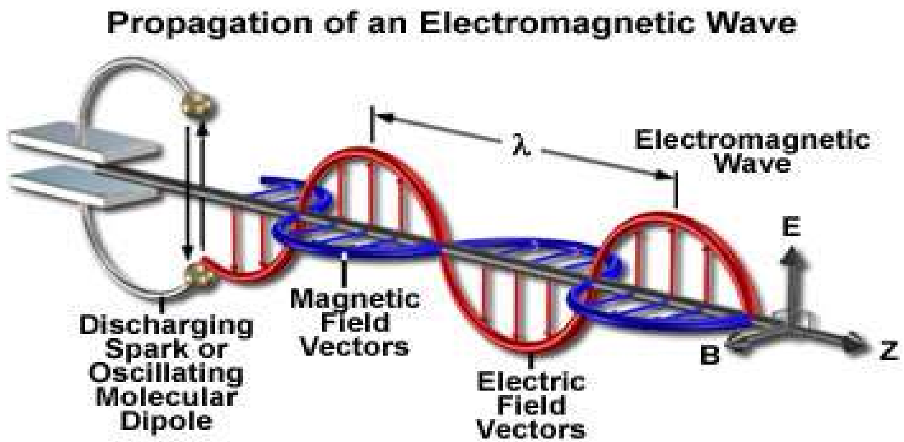




TIGER Transmitter

RADIO / RF COMMUNICATIONS

Radio is a technology that allows the transmission of signals by modulation of electromagnetic waves with frequencies below those of light.

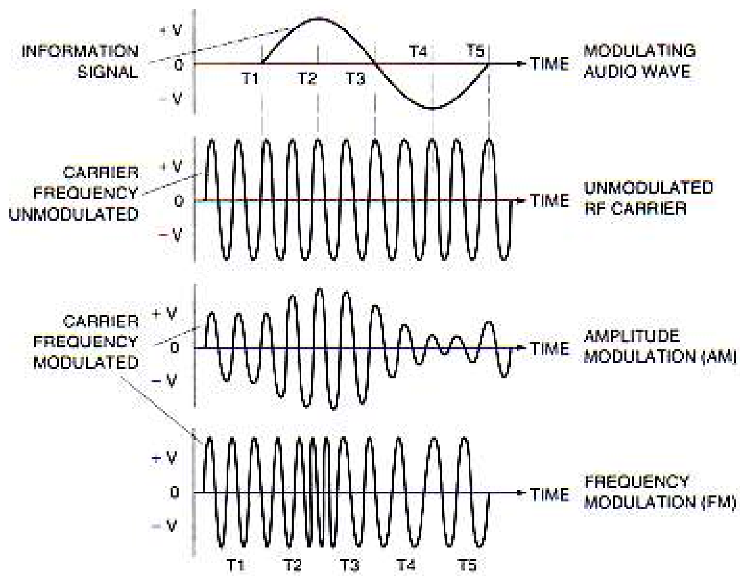


Radio waves are a form of electromagnetic radiation, and are created whenever a charged object accelerates with a frequency that lies in the radio frequency (RF) portion of the electromagnetic spectrum.

Electromagnetic radiation propagates by means of oscillating electric and magnetic fields that pass through the air and the vacuum of space equally well, and does not require a medium of transport.

When radio waves pass a wire, their oscillating electric or magnetic field (depending on the shape of the wire) induces an alternating current and voltage in the wire. This can be transformed into audio or other signals that carry information. Although the word 'radio' is used to describe this phenomenon, the transmissions which we know as **television**, **radio**, **radar**, and **cell phone** are all in the class of radio frequency emissions.

MODULATION



Modulation is the process of combining an information signal with the carrier of a radio signal.
There are many ways to modulate a signal:

Amplitude Modulation (AM) occurs when a voice signal's varying voltage is applied to a carrier frequency. The carrier frequency's amplitude changes in accordance with the modulated voice signal, while the carrier's frequency does not change.

Frequency Modulation (FM) occurs when a carrier's CENTER frequency is changed based upon the input signal's amplitude. The carrier signal's amplitude is unchanged.
FM is more immune to noise than AM

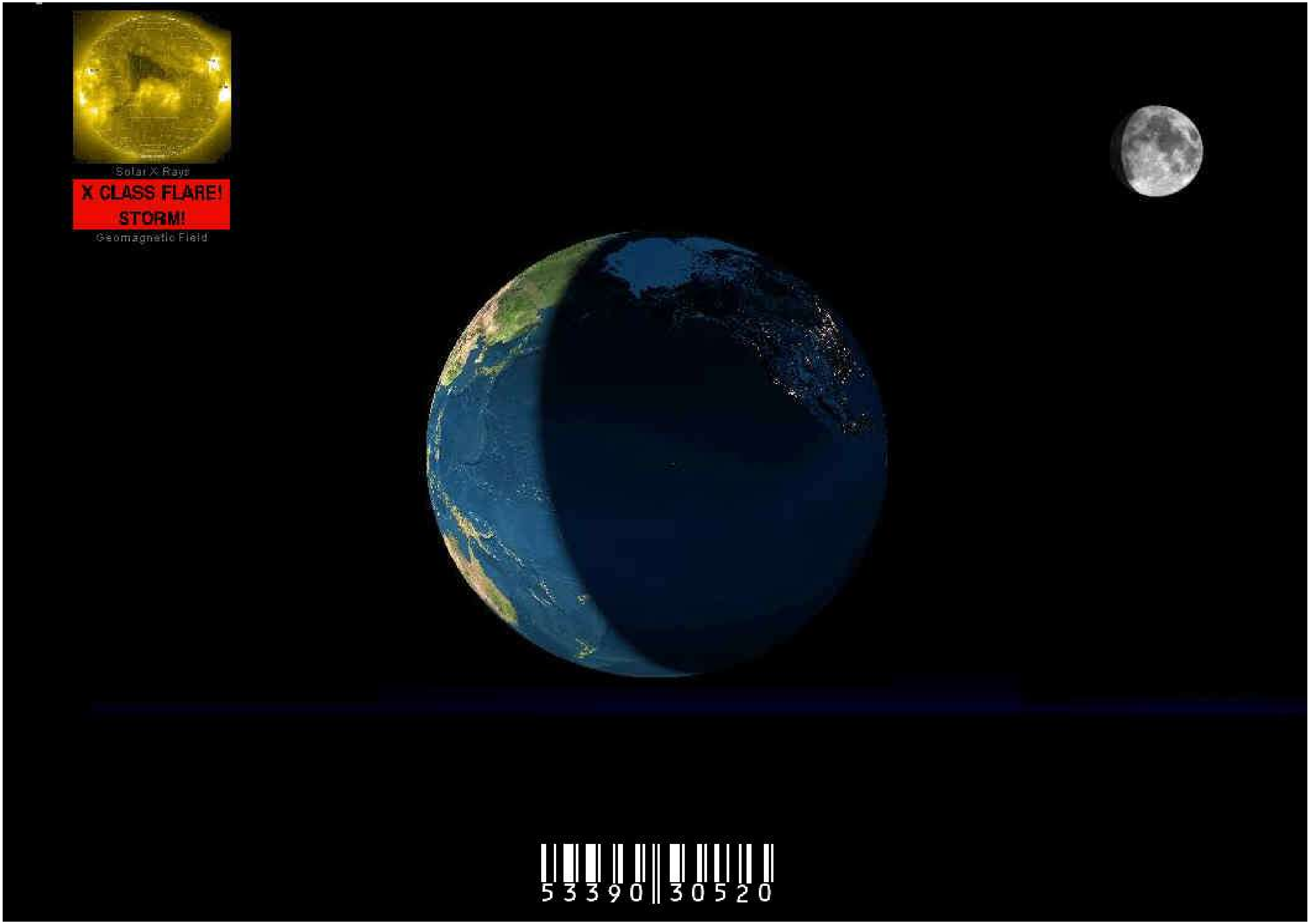
Phase Modulation is similar to Frequency Modulation. Phase of the carrier changes. Easily adaptable to data modulation.

Pulse Modulation (PM)

With Pulse Modulation, a "snapshot" (sample) of the waveform is taken at regular intervals. There are a variety of Pulse Modulation schemes:

Pulse Amplitude (PAM) , Pulse Code Modulation (PCM)

Pulse Frequency (PFM) , Pulse Position (PPM), Pulse Width Modulation (PWM)



OUR ELECTROMAGNETIC ENVIRONMENT

Current Solar Data (from NOAA)

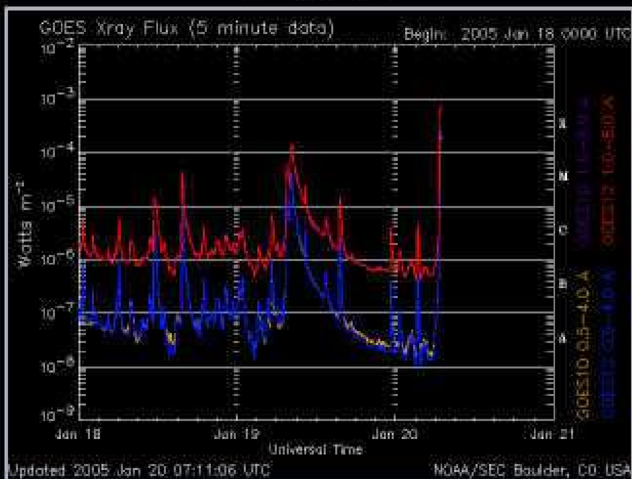
Solar X-rays: **X CLASS FLARE!**

Geomagnetic Field: **STORM!**

53390 30520

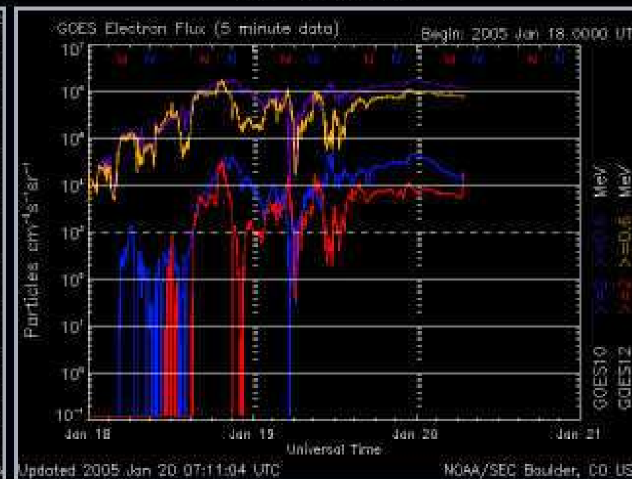
Jan 19 2005 2330 PST

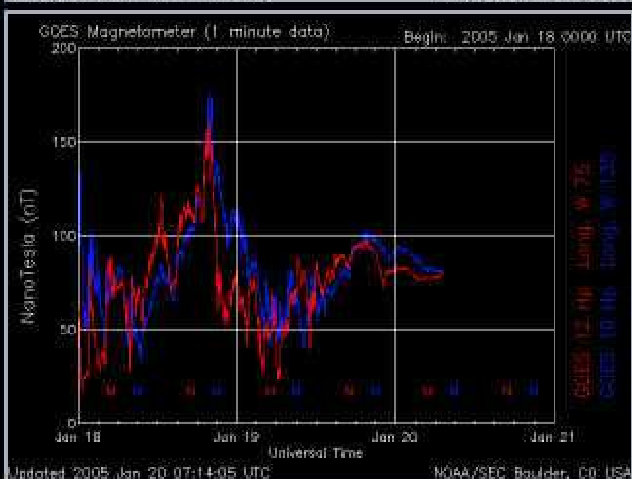
X-Ray Flux



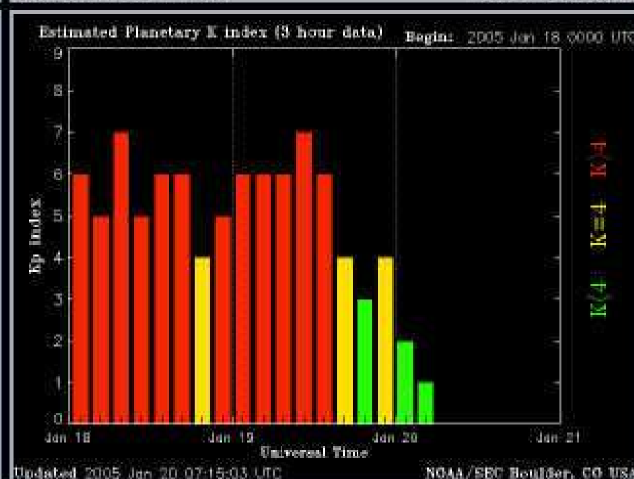
Satellite Environment (combined)

Electron Flux

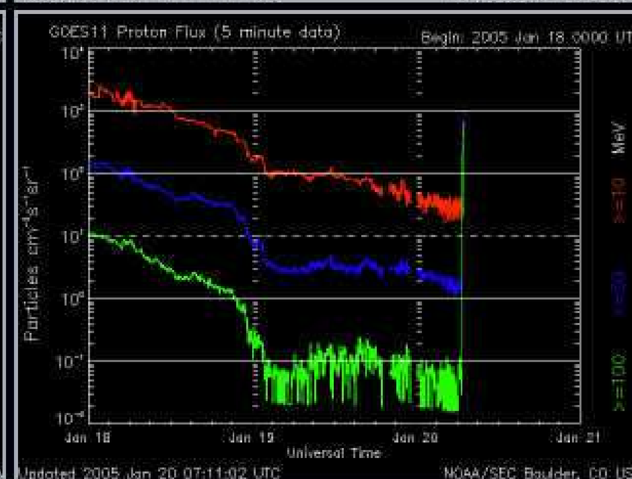




Magnetometer

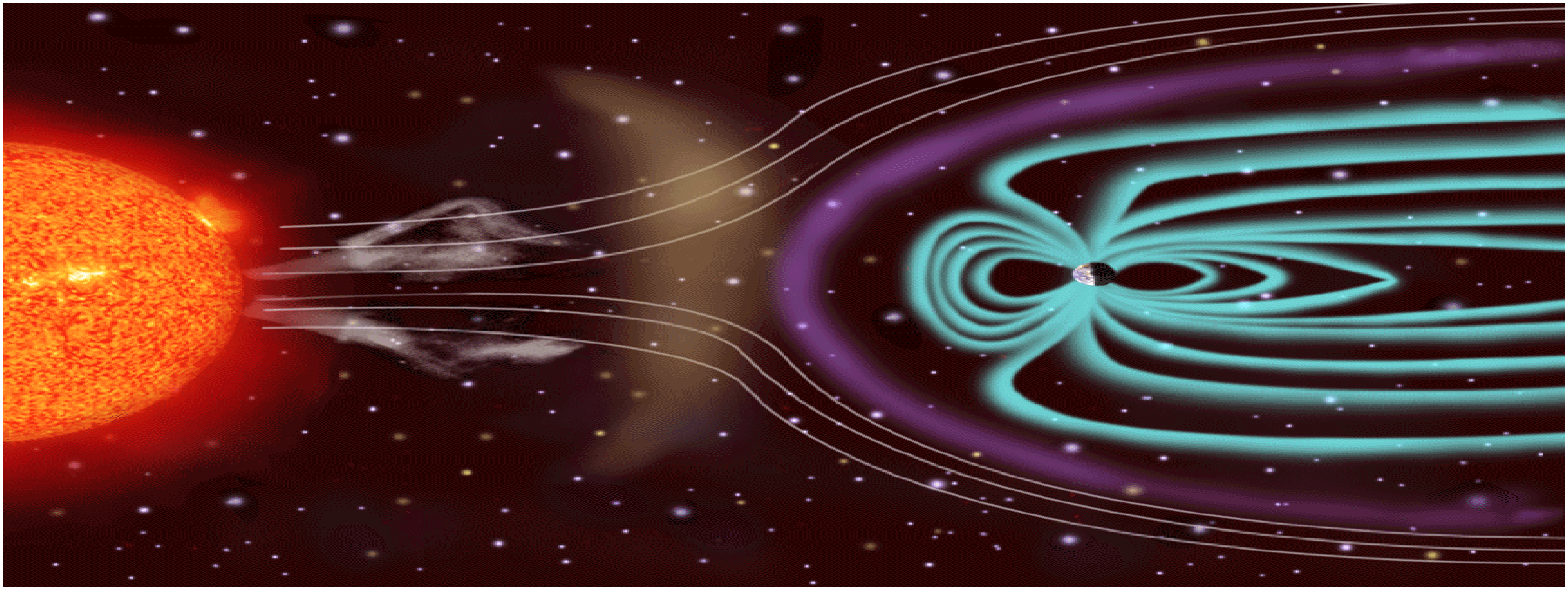


Estimated Kp Index



GOES 8 Proton Flux

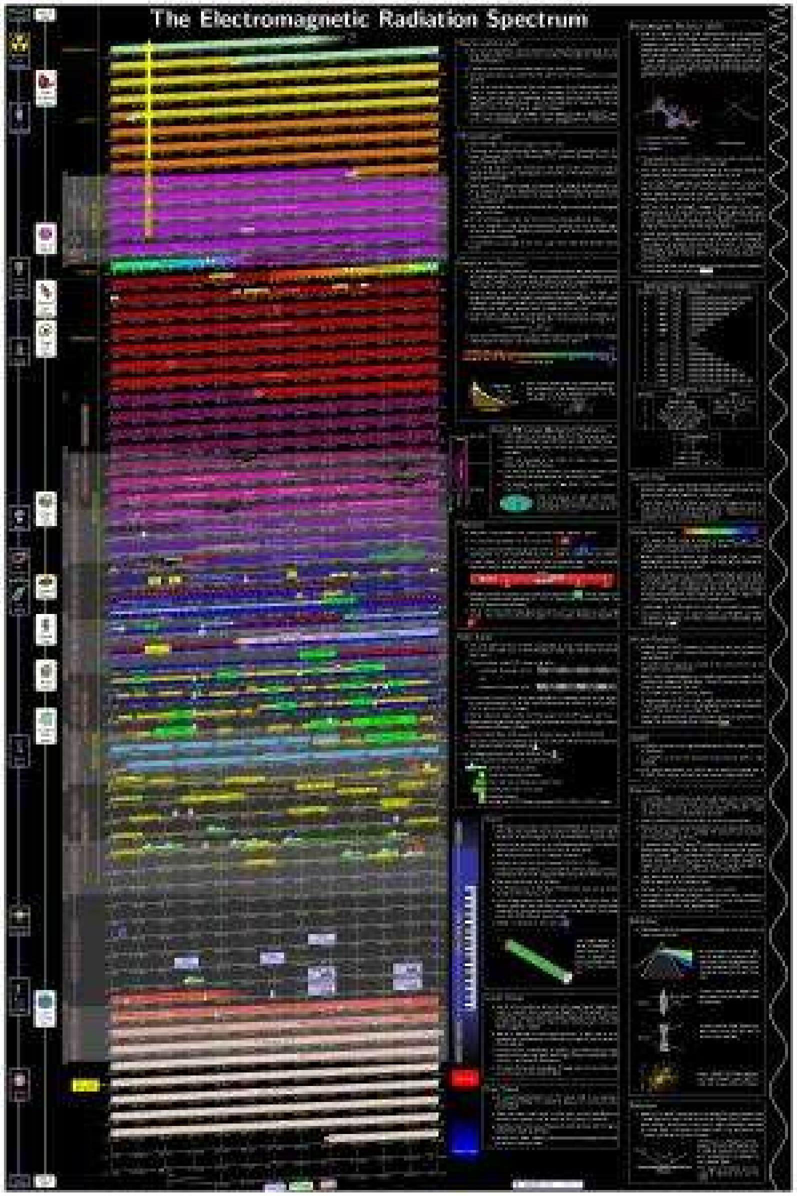
http://www.n3kl.org/sun/noaa.html



Solar disturbances can cause:

1. **Geomagnetic Storms** -- disturbances in the geomagnetic field caused by gusts in the solar wind that blows by Earth.
   Causes: Coronal Mass Ejections (CMEs)
   Affects: power systems, spacecraft operation, radio propagation, navigation, migratory animals, auroras
   Scale & measurements: Geomagnetic Storm Scale ("A" index values range from 0 to 400 Nanoteslas; K & Kp index values range from 0 to 9, anything over 5 can have effects on Earth)
2. **Solar Radiation Storms** -- elevated levels of radiation that occur when the numbers of energetic particles increase.
   Causes:
   Affects: radiation hazard to astronauts & high-flying planes, satellite operations, communications systems
   Scale & measurements: Solar Radiation Storm Scale (proton/ion flux levels; anything over 10 can have affects on Earth)
3. **Radio Blackouts** -- disturbances of the ionosphere caused by X-ray emissions from the Sun.
   Causes: M-class and X-class solar flares
   Affects: high frequency radio, navigation systems
   Scale & measurements: Radio Blackouts Scale (based on x-ray brightness; only M- and X-class flares can affect Earth)

EM SPECTRUM



We live in an electromagnetic environment, and make use of it with both natural and manufactured transducers.

Known ranges of EMR organized by octaves

IONIZING RADIATION

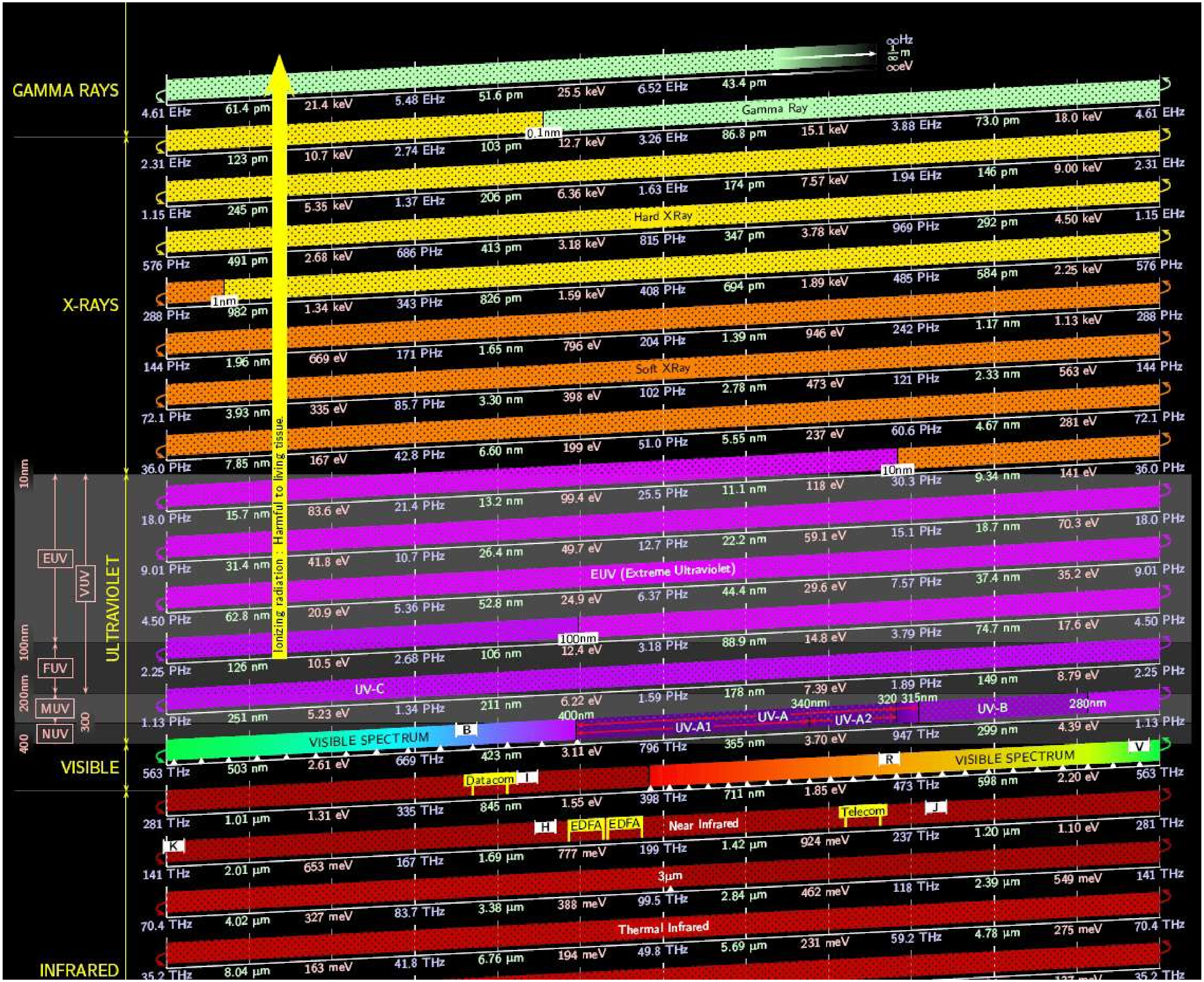
- gamma rays
- X-rays
- ultraviolet light

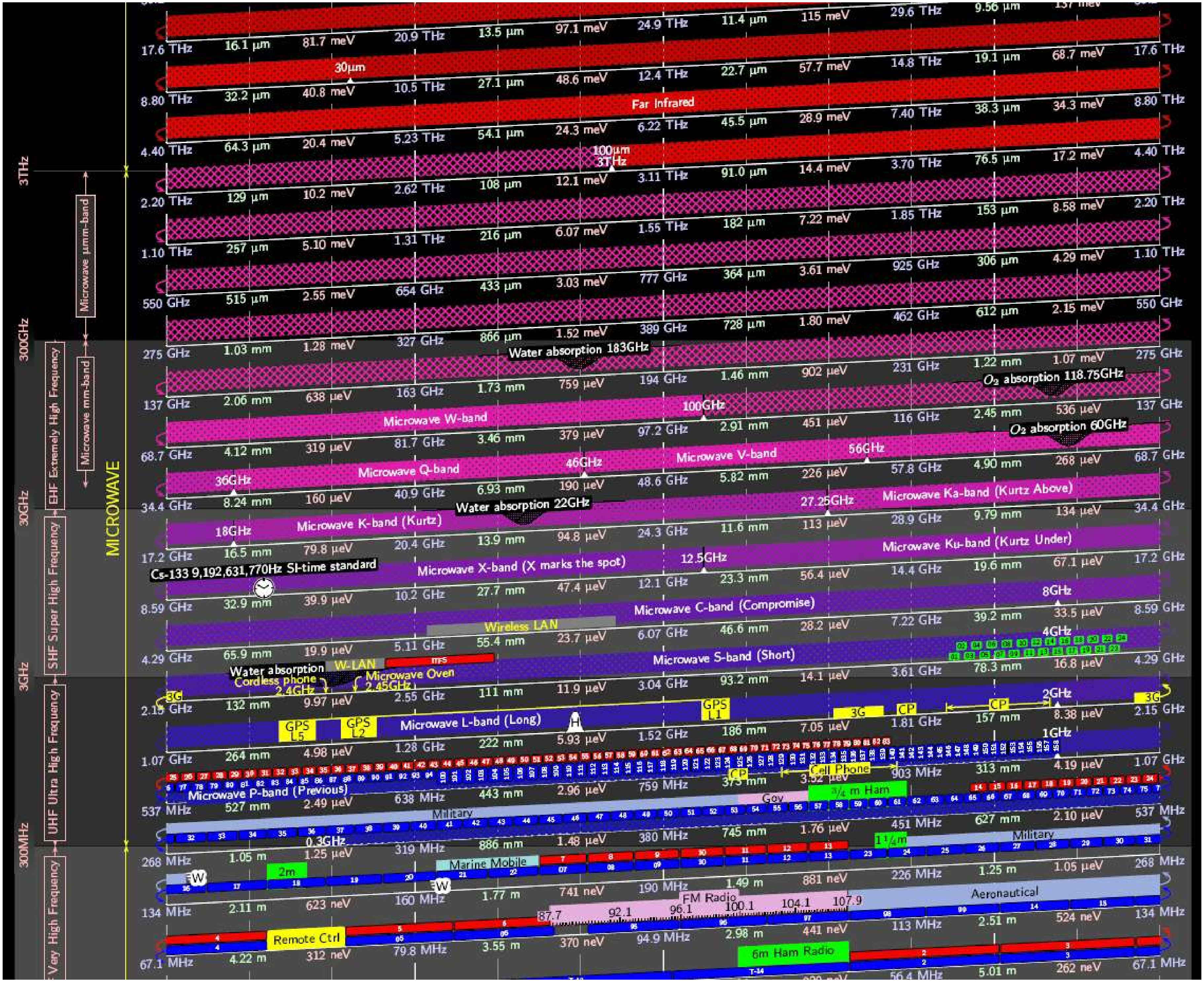
NON IONIZING

- visible light
- infrared
- microwaves
- radio waves (ULF, VLF, LF, MF, HF, HAM, VHF, UHF, SHF, EHF)
- cosmic microwave background radiation
- brain waves

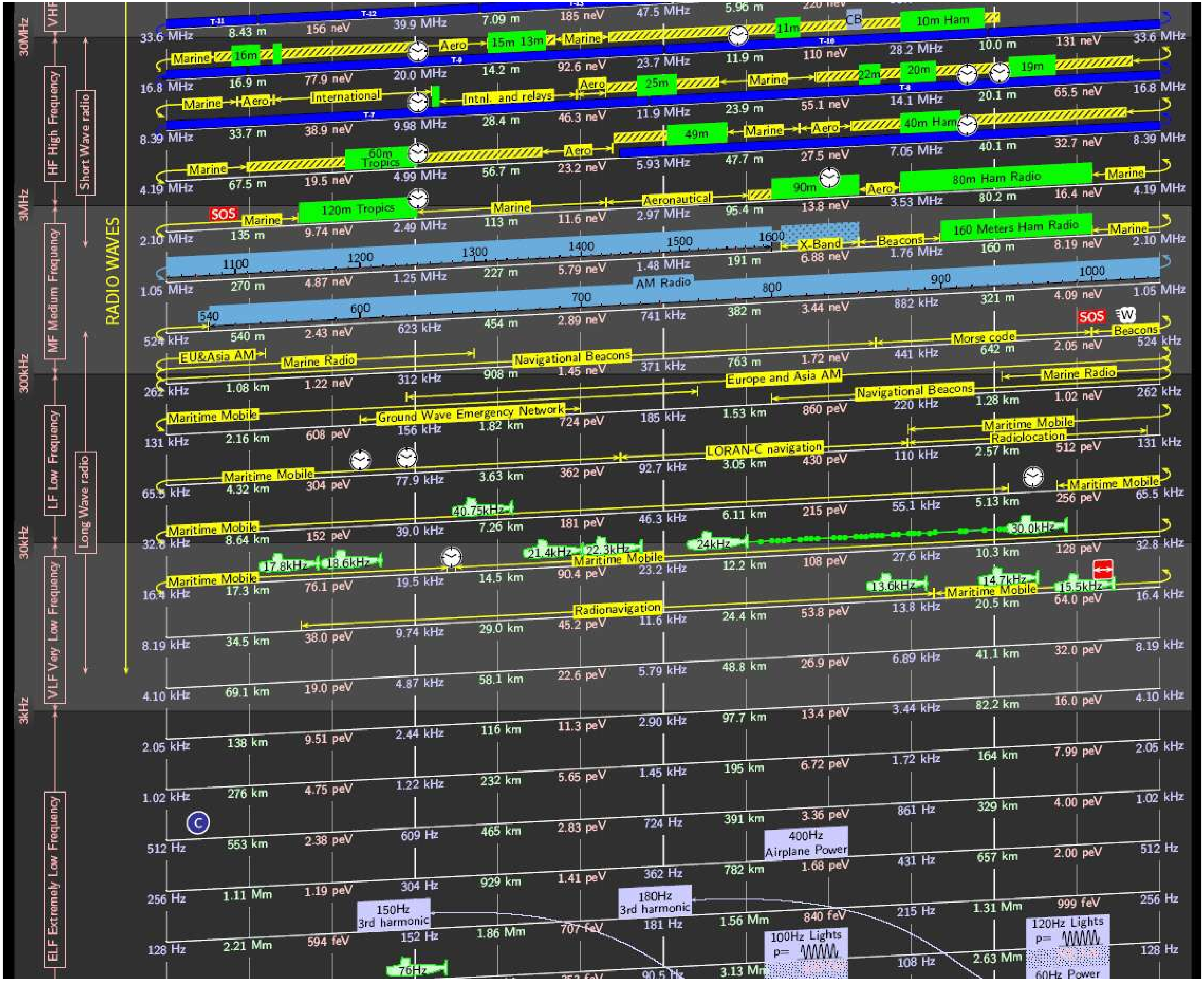
Reference poster by AnthonyTekatch

Available for purchase at Unihedron.com
or for download PDF file (932k)

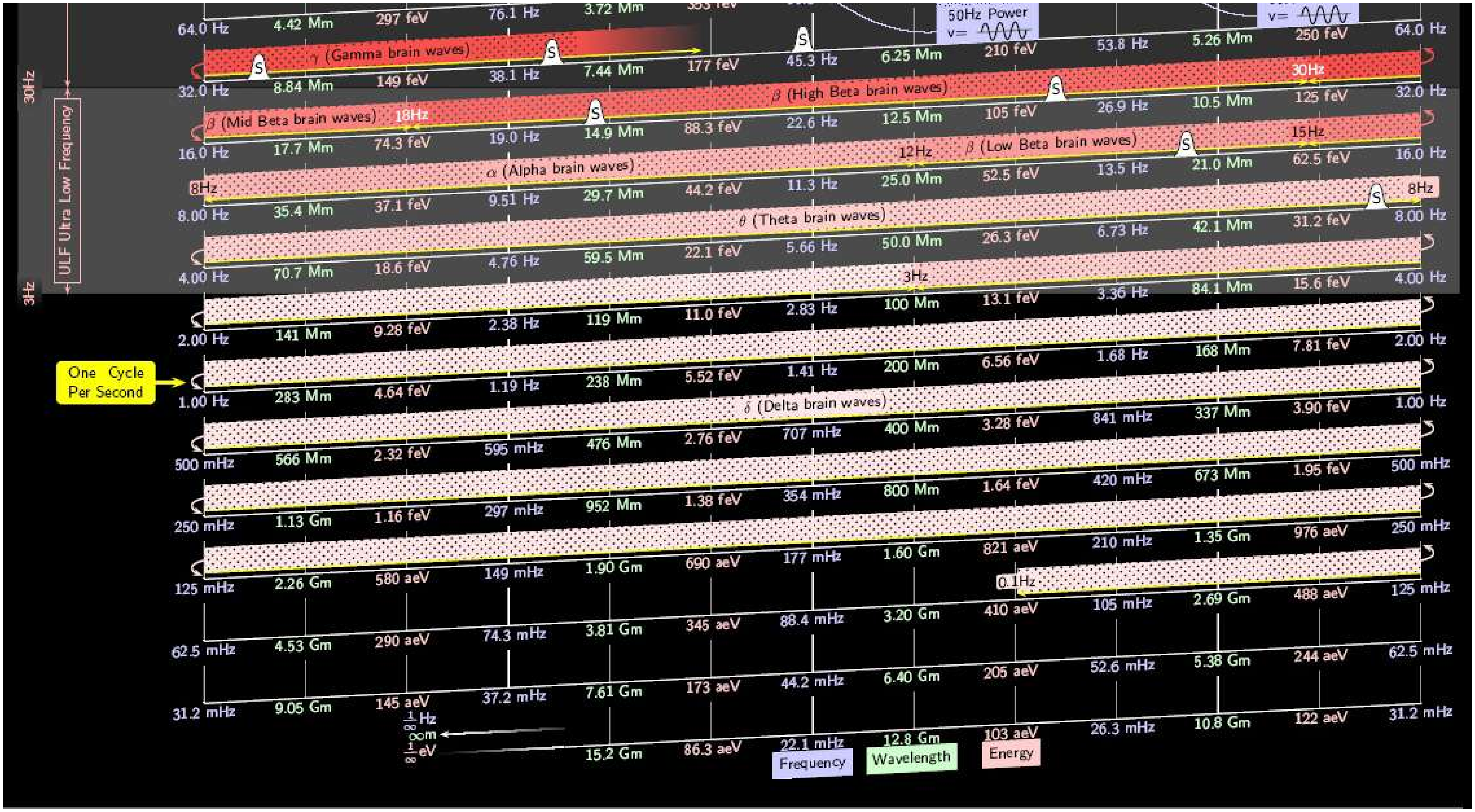

GAMMA RAYS
X-RAYS
ULTRAVIOLET
VISIBLE
INFRARED
Gamma Ray
0.1nm
Hard XRay
1nm
Soft XRay
10nm
EUV (Extreme Ultraviolet)
100nm
UV-C
UV-B
UV-A
UV-A1
UV-A2
400nm
340nm
320 315nm
280nm
VISIBLE SPECTRUM
Datacom
EDFA
Telecom
Near Infrared
3μm
Thermal Infrared
Ionizing radiation : Harmful to living tissue.
EUV
VUV
FUV
MUV
NUV
10nm
100nm
200nm
300
400



3THz
300GHz
30GHz
3GHz
300MHz
MICROWAVE
Microwave μmm-band
Microwave mm-band
EHF Extremely High Frequency
SHF Super High Frequency
UHF Ultra High Frequency
Very High Frequency
17.6 THz
8.80 THz
4.40 THz
2.20 THz
1.10 THz
550 GHz
275 GHz
137 GHz
68.7 GHz
34.4 GHz
17.2 GHz
8.59 GHz
4.29 GHz
2.15 GHz
1.07 GHz
537 MHz
268 MHz
134 MHz
67.1 MHz
30μm
Far Infrared
100μm
3THz
Water absorption 183GHz
O2 absorption 118.75GHz
100GHz
Microwave W-band
O2 absorption 60GHz
Microwave Q-band
46GHz
Microwave V-band
56GHz
36GHz
Water absorption 22GHz
27.25GHz
Microwave Ka-band (Kurtz Above)
18GHz
Microwave K-band (Kurtz)
Microwave Ku-band (Kurtz Under)
Cs-133 9,192,631,770Hz SI-time standard
Microwave X-band (X marks the spot)
12.5GHz
8GHz
Microwave C-band (Compromise)
Wireless LAN
4GHz
Water absorption
W-LAN
Cordless phone
2.4GHz
Microwave Oven
2.45GHz
Microwave S-band (Short)
3G
GPS L1
CP
2GHz
GPS L5
GPS L2
Microwave L-band (Long)
1GHz
Cell Phone
Microwave P-band (Previous)
Gov
3/4 m Ham
Military
0.3GHz
1 1/4 m
2m
Marine Mobile
FM Radio
87.7
92.1
96.1
100.1
104.1
107.9
Aeronautical
Remote Ctrl
6m Ham Radio



RADIO WAVES
VHF
30MHz
HF High Frequency
Short Wave radio
3MHz
MF Medium Frequency
300kHz
LF Low Frequency
Long Wave radio
30kHz
VLF Very Low Frequency
3kHz
ELF Extremely Low Frequency
33.6 MHz
16.8 MHz
8.39 MHz
4.19 MHz
2.10 MHz
1.05 MHz
524 kHz
262 kHz
131 kHz
65.5 kHz
32.8 kHz
16.4 kHz
8.19 kHz
4.10 kHz
2.05 kHz
1.02 kHz
512 Hz
256 Hz
128 Hz
10m Ham
CB
11m
15m 13m
Marine
16m
Aero
International
Intnl. and relays
25m
22m
20m
19m
49m
40m Ham
60m Tropics
90m
80m Ham Radio
SOS
120m Tropics
Aeronautical
160 Meters Ham Radio
X-Band
Beacons
AM Radio
540
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
Morse code
EU&Asia AM
Marine Radio
Navigational Beacons
Europe and Asia AM
Maritime Mobile
Ground Wave Emergency Network
Radiolocation
LORAN-C navigation
40.75kHz
30.0kHz
24kHz
21.4kHz
22.3kHz
17.8kHz
18.6kHz
13.6kHz
14.7kHz
15.5kHz
Radionavigation
400Hz Airplane Power
180Hz 3rd harmonic
150Hz 3rd harmonic
100Hz Lights
120Hz Lights
60Hz Power
76Hz



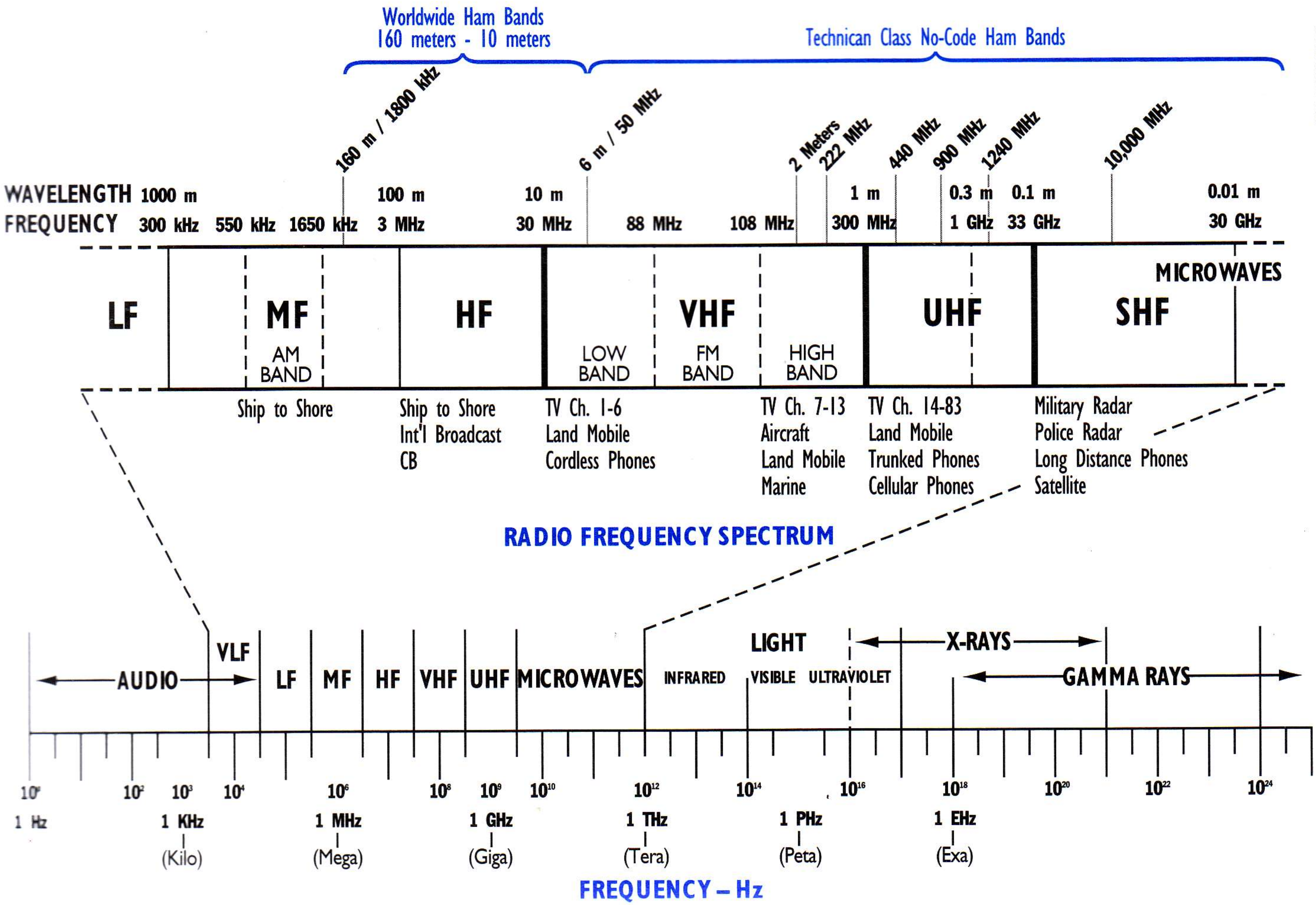
$$c = f \lambda$$

ms^{-1} Hz . m For EM, c = 299 792 458 ms^{-1}

freq = 299792 458 / wavelength wavelength = 299792458 / freq

LOW FREQUENCY – LONGER WAVELENGTH | HIGH FREQUENCY – SHORTER WAVELEGNTH

RADIO FREQUENCIES



In the United States, the FCC (Federal Communications Commission) decides who is able to use which frequencies for which purposes, and issues licenses to stations for specific frequencies.

Common frequency bands include the following:

AM radio - 535 kHz to 1.7 MHz

Short wave radio - bands from 5.9 MHz to 26.1 MHz

Citizens band (CB) radio - 26.96 MHz to 27.41 MHz

Television stations - 54 to 88 MHz for channels 2 through 6

FM radio - 88 MHz to 108 MHz

Television stations - 174 to 220 MHz for channels 7 through 13

Every wireless technology has its own band. For example:

Garage door openers, alarm systems, etc. - Around 40 MHz

Baby monitors: 49 MHz

Radio controlled airplanes: Around 72 MHz

Radio controlled cars: Around 75 MHz

Wildlife tracking collars: 215 to 220 MHz

MIR space station: 145 MHz and 437 MHz

Air traffic control radar: 960 to 1,215 MHz

Global Positioning System: 1,227 and 1,575 MHz

Deep space radio communications: 2290 MHz to 2300 MHz

RF COMMUNICATIONS

IEEE 802.11 (WiFi)WLAN
Wireless LAN technology including Wi-Fi.

IEEE 802.15 WPAN / ZIGBEE
Wireless Personal Area Networking

IEEE 802.16 WiMAX WMAN
Wireless Metropolitan Area Networking
and WiMAX technology

HiperLAN,HiperLAN2
Wireless LAN technology.

Bluetooth
Short-range radio

CDMA
Code Division Multiple Access

UMTS / 3G
Universal Mobile Telephony System
Third Generation Mobile

GPRS
General Packet Radio Service

GSM
General System for Mobiles

UWB
Ultra Wide Band

Satellite
Communications, TV, Remote Sensing

Radar
Radio Detection and Ranging

GPS
Global Positioning System

BIOLOGICAL EFFECTS of RF ENERGY

Biological effects can result from exposure to RF energy.

Thermal effects
Exposure to very high levels of RF radiation can be harmful due to rapid heating of biological tissues and increases in body temperature. This is the principle by which microwave ovens cook food. In humans, the eyes and the testes, are particularly vulnerable to RF heating because of the relative lack of available blood flow to dissipate the excessive heat load.

Non-Thermal effects
At relatively low levels of exposure to RF radiation, i.e., levels lower than those that would produce significant heating, the evidence for production of harmful biological effects is ambiguous and unproven. Several years ago research reports began appearing in the scientific literature describing the observation of a range of low-level biological effects. However, in many cases further experimental research has been unable to reproduce these effects. Furthermore, there has been no determination that such effects constitute a human health hazard.

It is generally agreed that further research is needed to determine the generality of such effects and their possible relevance, if any, to human health. In the meantime, standards-setting organizations and government agencies continue to monitor the latest experimental findings to confirm their validity and determine whether changes in safety limits are needed to protect human health.

www.fcc.gov/oet/rfsafety/rf-faqs.html

Assignment 1

Value 25/100

To obtain FCC certification for use of Technician Class radio frequencies. (Element 2)

Students are to provide instructor with their FCC issued callsigns no later than 2 weeks before the end of the semester.

Table 2-1. Technician Class No-Code Operating Privileges

Wavelength Band	Frequency	Emissions	Comments
6 Meters	50.0–54.0 MHz	All modes	Sideband voice, radio control, FM repeater, digital computer, remote bases, and autopatches. Even CW. (1500 watts PEP output)
2 Meters	144–148 MHz	All modes	All types of operation including satellite and owning repeater and remote bases. (1500 watt PEP output)
1¼ Meters	222–225 MHz	All modes	All band privileges. (1500 watt PEP output)
70 cm	420–450 MHz	All modes	All band privileges, including amateur television, packet, Internet linking, FAX, and FM voice repeaters. (1500 watt PEP output.)
33 cm	902–928 MHz	All modes	All band privileges. Plenty of room! (1500 watt PEP output.)
23 cm	1240–1300 MHz	All modes	All band privileges. (1500 watt PEP output)
13 cm	2300-2310 MHz 2390-2450 MHz	All modes	Amateur television

Obtaining the technician class license will provide valuable experience in radio communications techniques and RF transmission

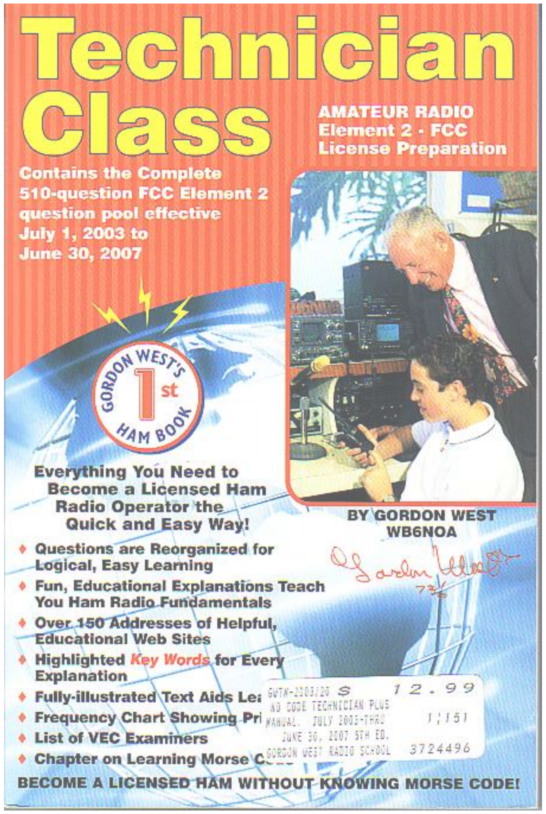
HAM Radio Operators also provides backbone communications during emergencies, and as such being familiar with their methods and resources will prove beneficial.

Possible resources:

Gordon West, WB6NOA
Element 2 FCC License Preparation handbook

Test questions online

www.arrl.org/arrlvec/tech2003.txt

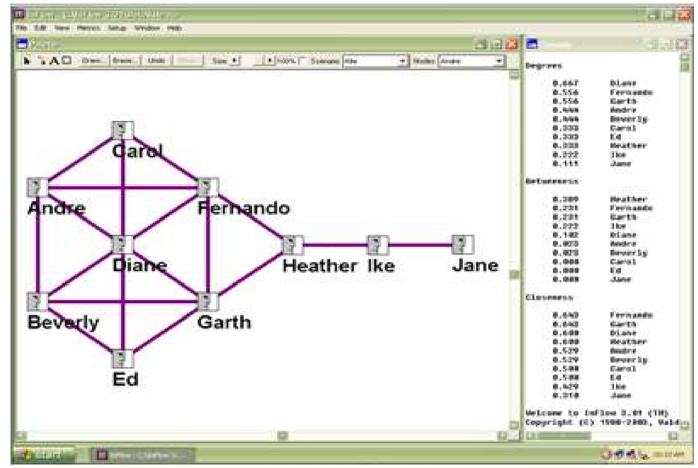


Assignment 2

Value 15/100

Social Engineering – Social Networking

Social networks operate on many levels, from families up to the level of nations, and play a critical role in determining the way problems are solved, organizations are run, and the degree to which individuals succeed in achieving their goals.

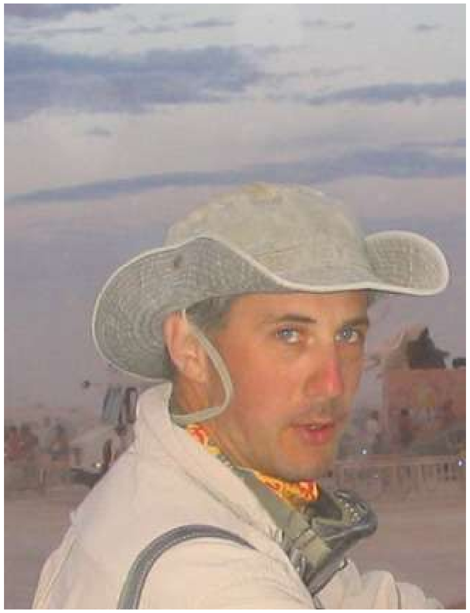


Aim: To build and expand a social network using existing Internet technology.

Tool: LinkedIn is a networking tool that helps you discover inside connections to recommended job candidates, industry experts and business partners.
Students interested in being invited to submit email to instructor, else can register at www.linkedin.com

Because of the technical nature of Sensor Networks and other systems, students are to infiltrate either their parent organizations or totally new groups, identify and develop working relationships with two (2) technically proficient people who are willing to assist students with technical matters, ranging from , but not limited to: hardware construction to software development.

Students are to submit completed personal Resource ID form in electronic format by week 2, and completed Resource IDs for identified support personnel no later than 2 weeks before the end of semester.



Steve BIRCH

B.Sc.hons (biochem/zool)
Ph.D. (biomedical engineering)

SYSTEMS INTEGRATOR
SENIOR TESTING SCIENTIST

SDSU . MINDTEL DST

email sbirch@projects.sdsu.edu
vox 858 353 8808
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http:// projects.mindtel.com

Systems Integrator | Senior Testing Scientist

SDSU | Mindtel DST (2002 – now)

Providing hardware and software evaluation and integration, merging new technologies for use by Intelligence, Homeland Defense and others. Also conduct webmaster / networking infrastructure / systems administration / troubleshooting as ongoing day to day duties and exercise communications infrastructure deployments.

Developments / Field deployments
-SRA Op. Talavera:[2004]
-USN StrongAngel 2: [2004]
-DARPA Grand Challenge: [2004]
-OSD Burningman: [2002,2003,2004]
-San Diego Sheriff: Imperial Beach Sandcastle competition,
 El Cajon MotherGoose parade: [2003, 2004]
-SRA gameroom: [2003]
-SANDIA National Labs : Mentor-Pal system: [2003]
-Iraq conflict support reachback [2003]
-DERIS [2003]
-VOC (Virtual Operations Center),
-SDSU Vizlab: [2003]
-NRO KnowledgeFountain: [2002]
-DARPA HumanID: [2002]
-ControlPod: [2002]

Web & Systems Engineer
Neuroflex 1999 – September 2001

Solely responsible for all IT management and infrastructure requirements for a dotcom internet startup company

o Network Engineer
o Resource Manager
o Systems Administrator -- UNIX -- Windows
o Webmaster / Web & Interface Designer / Marcom

Designed content and graphics for website, product graphical user interfaces and back end navigation and functionality for web-based product distribution

EXAMPLE OF RESOURCE ID FORM

Top guide:
0.4 in from top

Center guide
5.5 in from left

Left guide
0.4 in from left edge

Right guide
0.4 in from right edge

Verdana 15 point

Verdana 10 point

RESOURCE ID TEMPLATE
letter size page 8.5x11”

Bottom guide
0.4in from edge