

What's All This 5G Stuff, Anyhow?

Wesley Cardone, N8QM

November, 2021

What is the amateur radio operator expected to know?

Prepared for the Cascades Amateur Radio Club, W8JXN.org

Presentation Objectives

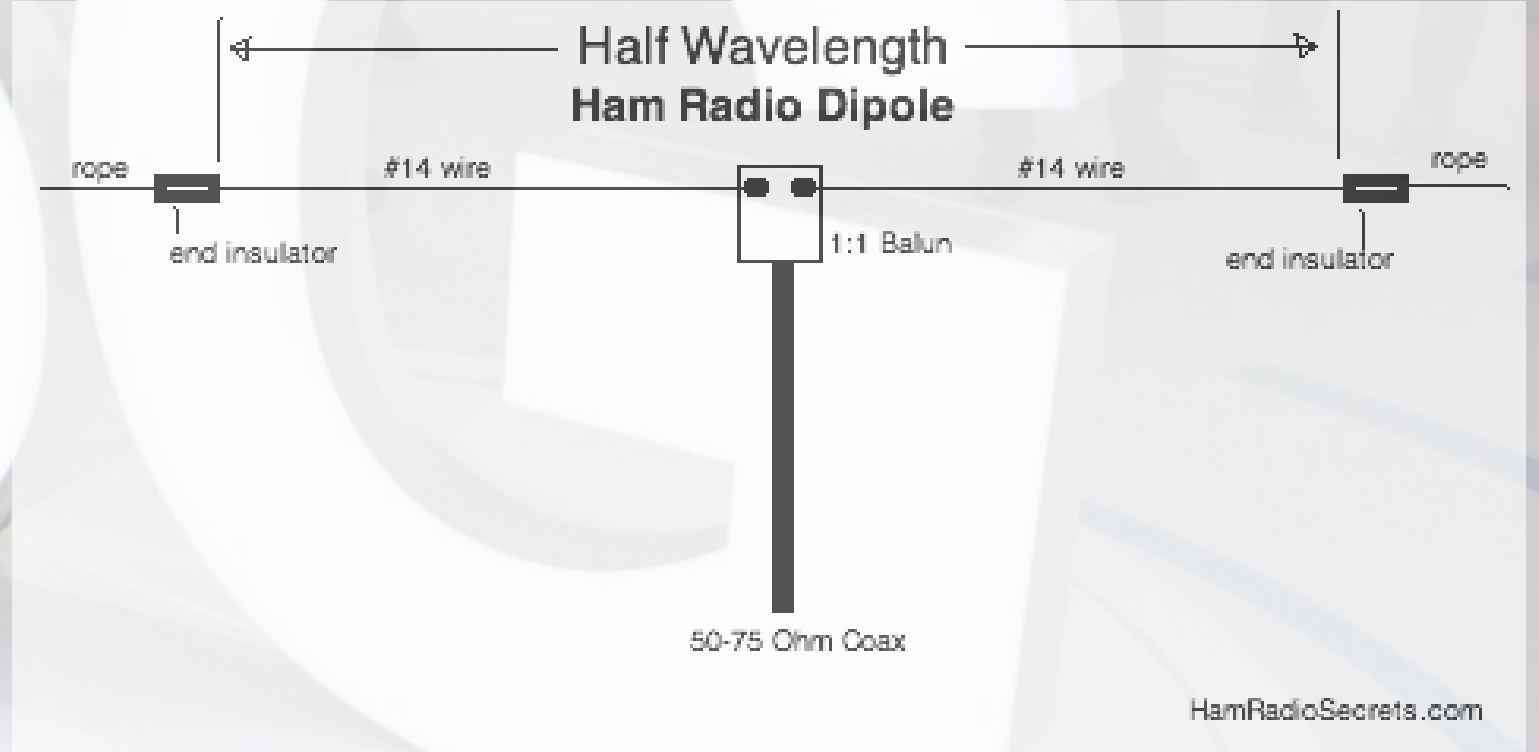
- Electromagnetics Amateurs Expected to Know
- Relevant forms of radiation
- Fields quantified
- Work—High School Physics
- Thermal Impedance
 - Resistance
 - Reactance
- Inexpensive instrumentation to measure EMS

Not Presented Herein

- Subjective concepts
- Conclusions

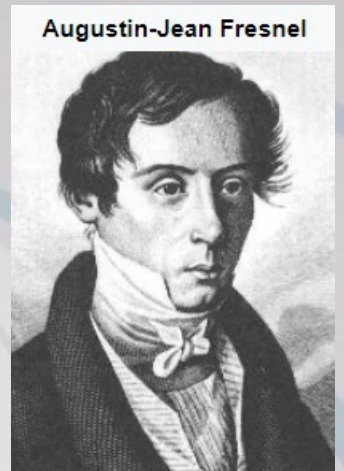
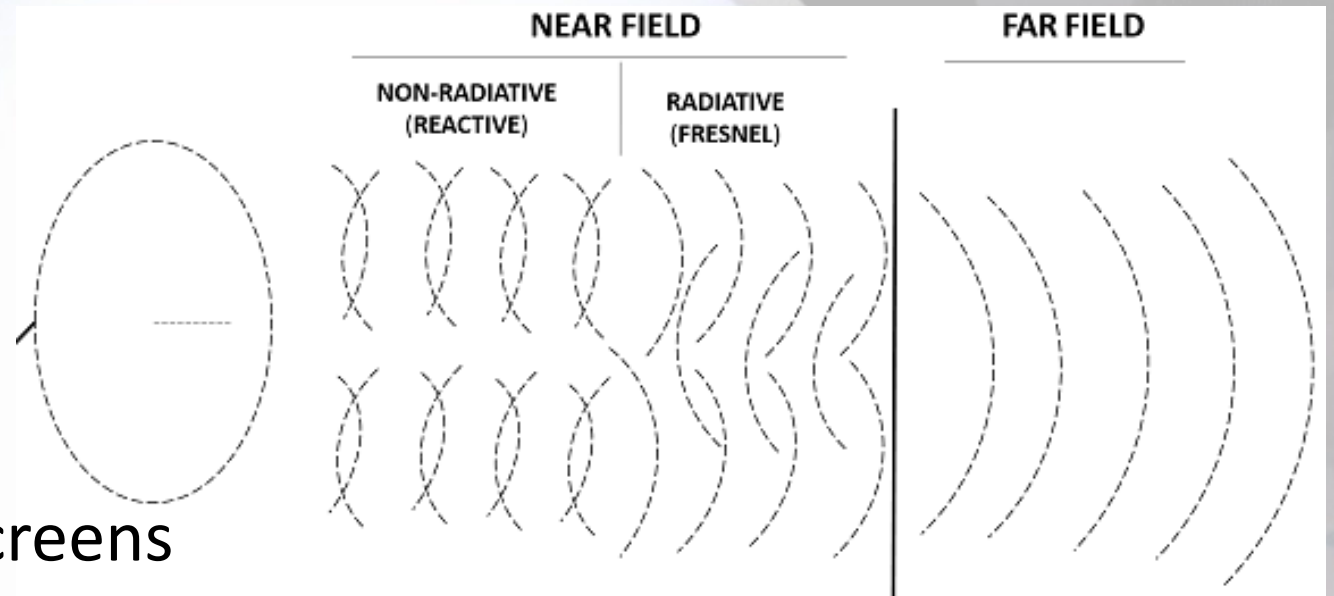
What is an antenna?

- A wire designed to be resonant at a named frequency.



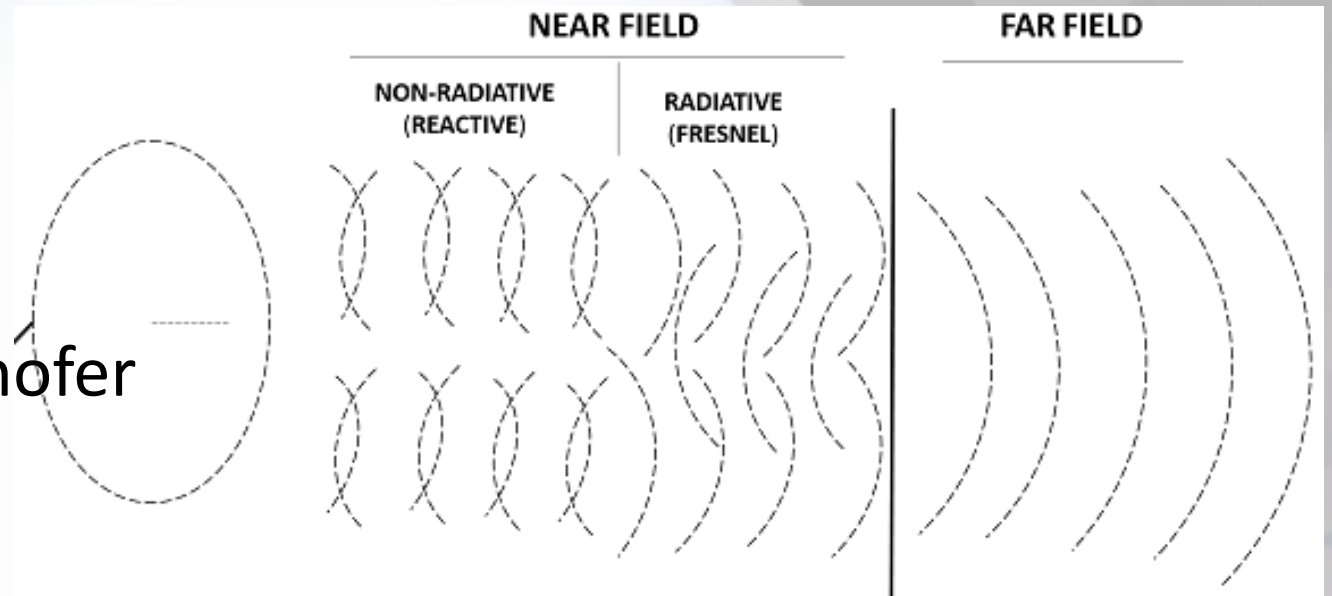
Radiating Antenna Fields—the Near-Field

- Reactive
 - Inductive
 - stores energy
- Does not radiate
- Working element of touch screens
- Completely vanish in a few wavelengths.
- Sometimes called the Fresnel region
- Density function: $1/d^3$

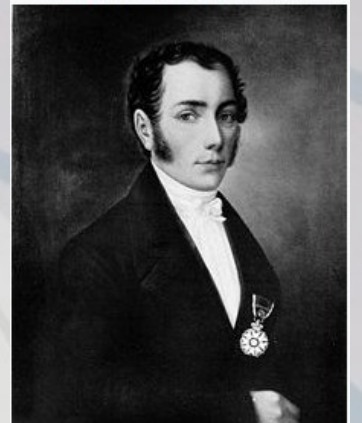


Radiating Antenna Fields—the Far-Field

- Energy Escapes, not stored
- Can circumvent the globe
- Sometimes called the Fraunhofer region
- Density $1/d^2$



Joseph von Fraunhofer



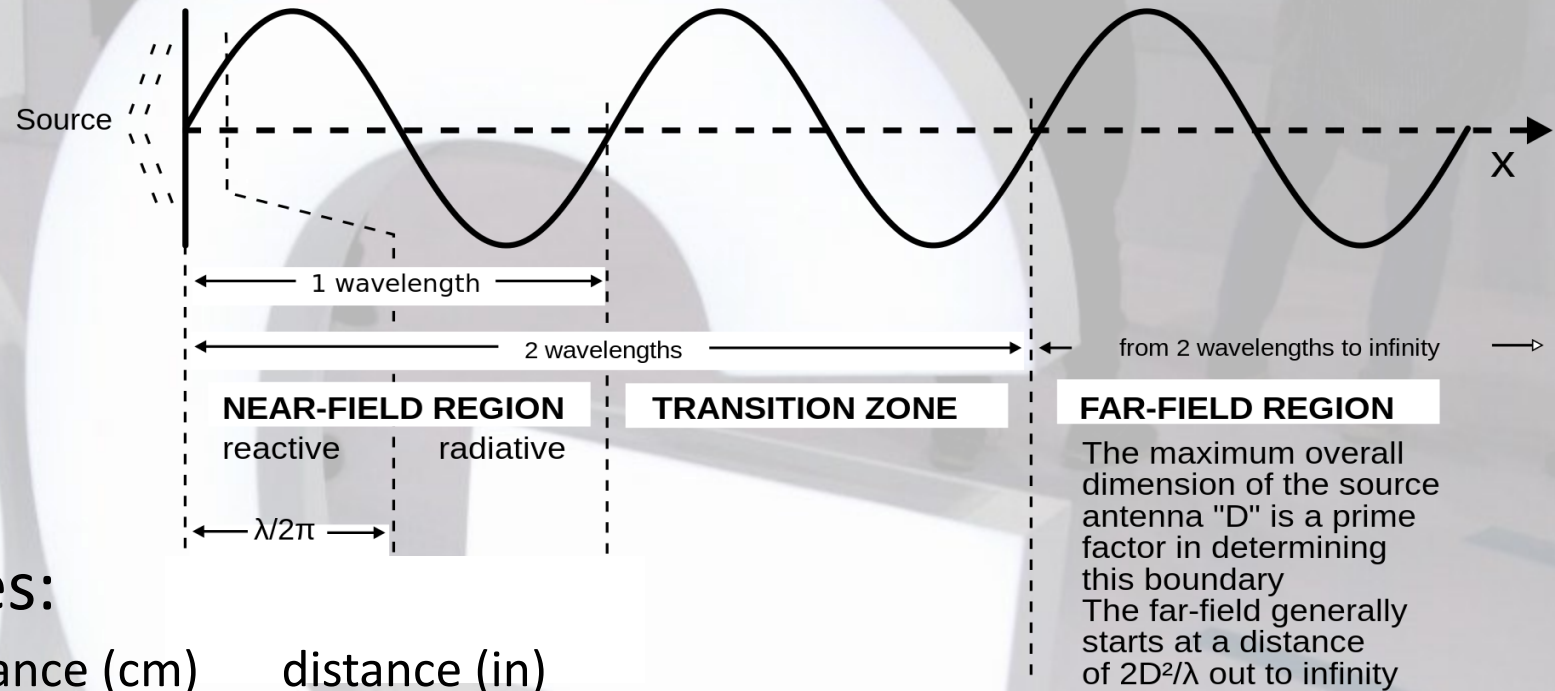
Near-Field Radiation

- Near-field is inductive reactive
 - E-field and H-field out of phase by 90°
 - E/H fields must be perpendicular to radiate
 - Remember the right-hand rule.
 - Because no radiation, no spending of energy, only storage
- There is a transition region

Far-Field Radiation

- E/H fields
 - orthogonal or perpendicular allowing radiation
 - In phase
- Transmitter energy can be spent

Quantification of How Far a Near-Field



- Region limits for λ values:

Freq (Lambda)	distance (cm)	distance (in)
• 2 meters	= 32.7	= 13
• 430 MHz (70 cm)	= 11.1	= 4
• 900 MHz (33.3cm)	= 5.3	= 2
• 2.4 GHz (12.5cm)	= 2	= $\frac{3}{4}$

Interference with Medical Implants

- Is the implant designed to protect (hardened) against general RFI and solar flares?
- Sources of RFI
 - Cell phones
 - The sun
 - Handheld transceivers
 - Mobile transceivers
 - Electric vehicle DC-DC converters, inverters
- International standard for RF immunity:
 - 1993 rev of IEC Standard 60601-1-2
- It falls on manufacturers to design according RFI standards.

Pop Quiz

- Someone says to you:
 - Because 5G networks are new, the FCC should update regulations for 5G.
- How do you respond?
 - Using logic
 - Circumventing controversy
 - Putting the question into perspective.

High School Physics

- What did we learn in high school physics about WORK?
 - Done on an object
 - When a force
 - Accomplishes
 - Moves an object a distance
 - Generating heat
 - Units of measure
 - Joules per second → $1 \text{ Joule/sec} = 1 \text{ Watt} = i*i*r = e*e/r$
 - Therefore, $1 \text{ Joule} = (1 \text{ Ampere})^2 * 1 \text{ Ohm} * 1 \text{ second}$
- Power?
 - A rate of doing work
 - Is Work / time

Why Is Work of Importance?

- In order to injure a mammal's body what must be done?
 - Answer: work
 - It doesn't happen because somebody waves a hand.
- Work = Thermal Energy
- Conclusion
 - Thermal energy can be a source of ill-health to mammals.

Thermal Resistance

- Any mass has an ability to “drop” and “conduct” heat.
- Thus, the commonly known “heat sink” for transistors.

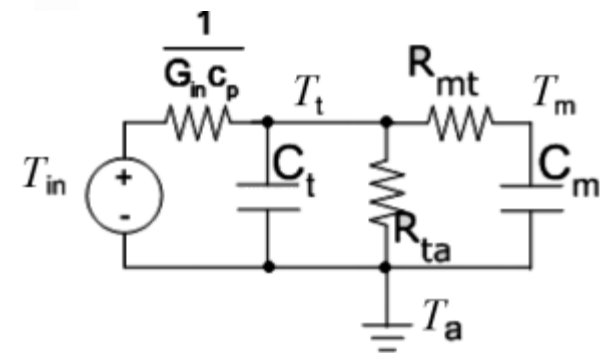
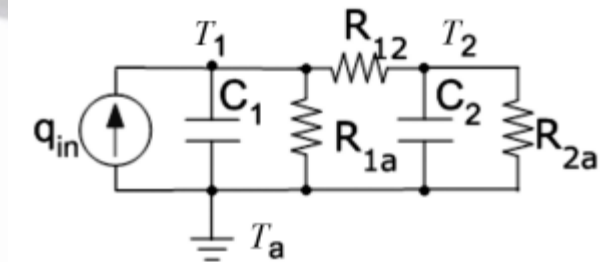


Thermal Reactance--Capacitance

- Any mass has an ability to store heat.
- Thermal capacitance is a measure of how much heat a mass can store.
- SPECIAL NOTE: There is no thermal inductance in the real world.

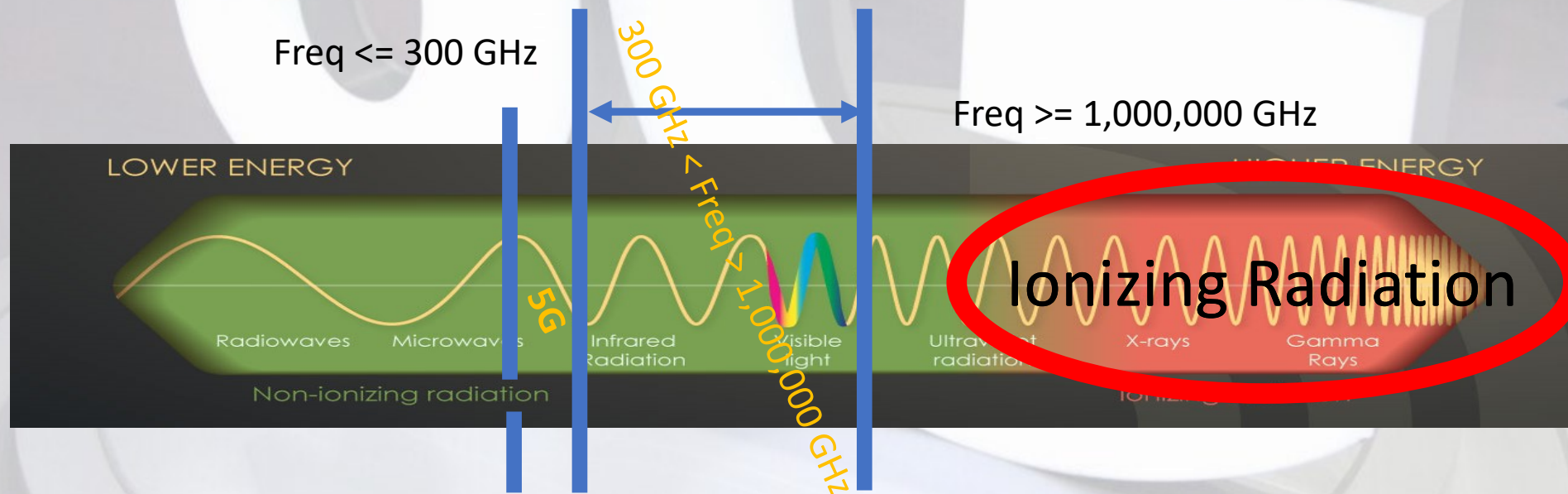
Thermal-electrical analogy: thermal network

Q_t Heat (Joule)	q_t Heat flow rate (J/s)		$1/C_t$ C_t :Thermal capacitance	R_t Thermal resistance	T Temp. (°C)
q	i	L	1/C	R	V
Charge (Coulomb)	Current (Amper)	Induc. (Henry)	C:Capac. (Farad)	Resistance (Ohm)	Voltage (Volt)



Should we Consider Ionizing Radiation?

- CDC Statement (abbreviated):
 - Ionizing radiation removes electrons from atoms including living tissue.
- Conclusion:
 - 5G frequencies lie well outside of the ionizing region and may be excluded from further consideration.



Here Are the Questions

- How do Near and Far fields affect a mammal's flesh?
 - Near-Field?
 - Far-Field?
- Any effects on a mammal must be a result of spent energy
- Means of acquiring energy
 - From a far-field
 - Mammal must be resonant
 - From a near-field
 - Mammal must physically enter the field and carry a box of Band-Aids.

The Near-Field

- Near-Field is STORED energy
- If you enter a near field, it will spend its energy on you.
- Owing to thermal capacitance, some number of seconds or hours may be required.
- If you are an arm's length or more from the antenna, the near-field is powerless to touch you.

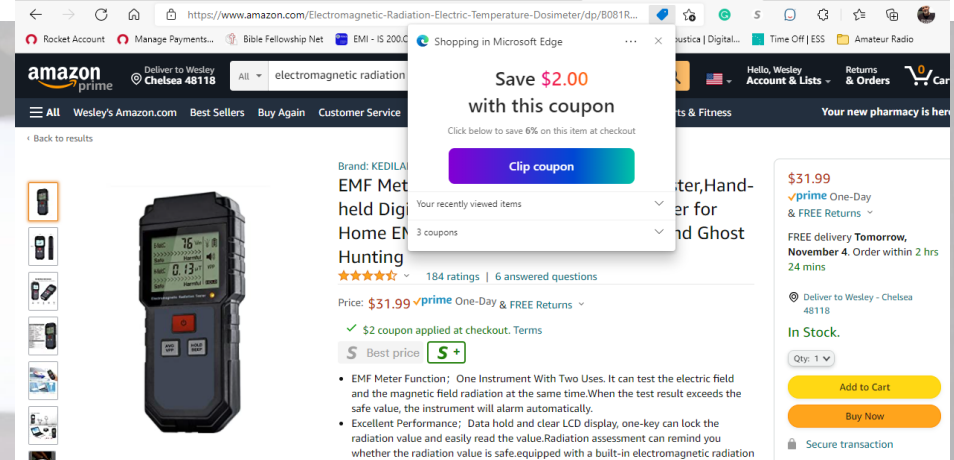


The Far-Field

- The far-field has energy that falls off as a reciprocal of the distance from the antenna squared.
- You can capture some of its energy...if, and ONLY if, you are resonant.
- How much can you capture?
 - Suppose an S9 signal at your transceiver's antenna:
 - input represents 50uV.
 - Your transceiver's Z_{in} is 50 Ohms.
 - Power is therefore $50e-12/50 = 1$ pico Watt at the antenna input
 - Suppose a resonant mammal's input resistance is 1 Ohm (EXTREMELY unrealistic)
 - Power into the mammal is $50e-12/1 = 50$ pico Watts

EMF Meter

- Hand-held meter for well under a hundred bucks.
- Nearly 5-stars



Brand: KEDILAKE
EMF Meter, Electromagnetic Radiation Tester, Hand-held Digital LCD EMF Detector, Great Tester for Home EMF Inspections, Office, Outdoor and Ghost Hunting

★★★★★ 184 ratings | 6 answered questions

Price: **\$31.99** ✓prime One-Day & FREE Returns

✓ \$2 coupon applied at checkout. Terms

Best price **S+**


- EMF Meter Function; One Instrument With Two Uses. It can test the electric field and the magnetic field radiation at the same time. When the test result exceeds the safe value, the instrument will alarm automatically.
- Excellent Performance; Data hold and clear LCD display, one-key can lock the radiation value and easily read the value. Radiation assessment can remind you whether the radiation value is safe. Equipped with a built-in electromagnetic radiation

E/H Field Measurement



EMF Meter, Improved

• X



10:52:53
1.6 | 205
mV/m | V/m
RF | EF
73.7
mG | High
PEAK: 85.1 mG
WiFi/Phone

6 VIDEOS

Roll over image to zoom in

Visit the GQ Store

EMF Meter, Advanced GQ EMF-390 Multi-Field Electromagnetic Radiation 3-in-1 EMF ELF RF meter, 5G Cell Tower Smart meter Wifi Signal Detector RF up to 10GHz with Data Logger and 2.5Ghz Spectrum Analyzer

★★★★★ 1,527 ratings | 214 answered questions

List Price: ~~\$158.00~~ Details
Price: **\$119.80** ✓prime One-Day & FREE Returns

You Save: **\$38.20 (24%)**

S Best price **S+**

May be available at a lower price from [other sellers](#), potentially without free Prime shipping.

- Multiple high sensitivity sensors installed for detecting Power line, Smart meter, Cell phone, Microwave etc.
- Identify/recognize the common possible sources, such as Power line, Cell Tower, Microwave, Static etc.
- Safety suggestion lets you understand current situation instantly.
- Detects 5G network signal and RF up to 10Ghz
- Built-in RF Spectrum analyzer and GQ RF Browser for real time RF monitoring.

\$119.80
✓prime One-Day & FREE Returns

FREE delivery **Tomorrow, November 5.** Order within 8 hrs 46 mins

📍 Deliver to Wesley - Chelsea 48118

In Stock.

Qty: 1

Add to Cart

Buy Now

🔒 **Secure transaction**

Ships from Amazon
Sold by GQ Electronics LLC

Return policy: Returnable until Jan 31, 2022

RF Exposure Rules Effective May 3, 2021

- There have been no changes to the existing RF exposure (RFE) limits
- Amateur stations are now no longer exempted on the basis of power.
- Amateur stations must now
 - Determine if they qualify for an exemption (most will qualify)
 - Or must perform a routine environmental evaluation
- There is a 2-year grace period
 - Amateurs have until May 3, 2023, to perform these (if they have to)
- ARRL publishes a guide “RF Exposure and You.” (316 pages)
 - www.arrl.org/files/file/Technology/RFsafetyCommittee/RF+Exposure+and+You.pdf

Worksheet:

Use this worksheet for each band you operate to determine if you need to do a station evaluation on that band.

(A) Station Call Sign: N8QM (B) Station Licensee: Yours truly

(C) Station Location: 10626 Coopersfield Rd.
Chelsea, Michigan 48118

(D) Frequency Band: _____

(E) Maximum Transmitter PEP used on this band: _____ W PEP

Refer to Table 1.1 — If the power on line (E) of this worksheet is less than or equal to the power limits given in the table for this band, you do not need to do an evaluation on this band. If the power exceeds the limits, continue with this worksheet.

Calculate Feed Line Loss in dB:

(F) Feed Line Type: _____ (G) Feed Line Length: _____ ft

(H) Enter Feed Line Loss in dB per 100 ft: _____ dB

(From Chapter 5 or manufacturers specification. You can use 0 dB for a conservative estimate. If you use 0 dB, skip to step J and enter 0%.)

Summary of What Discussed

- The frequencies 5G uses are nothing new.
- We looked at the implementation of 5G from an electromagnetics perspective.
- There are three modes of health issues to consider
 - Everyday EMI and effect on other electronic devices (already regulated)
 - Ionizing radiation (not relevant)
 - Near and Far-Fields energy displacement
- Cheap instrumentation for the consumer.
- This discussion is unique in that it is from an amateur radio perspective.