Class 5
Ham Radio Technician Course

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Review

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Keywords

- Automatic Control
- Remote Control
- CTCSS
- DCS
- DTMF
- Third Party Agreement
- Club Station
- Repeater Offset
- Offset Direction
- Band Plan
- Call Sign
- Tactical Call Sign
- Indicator

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More Keywords

- Control point
- Control operator
- Station Licensee
- ITU, FCC
- VE, VEC
- RMS
- NVIS
- Broadcasting
- One-Way Communication
- Repeater
- RACES, ARES
- PEP
- SID, MUF, LUF

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Yes, Even More Keywords

- Meteor scatter
- Auroral backscatter
- VFO
- RIT / Clarifier
- DMR, D-STAR
- Knife-edge Diffraction
- D, E, F1, F2
- AM, FM, SSB
- Volts, Amps, Ohms
- Hertz
- PEP
- Henry
- Tropospheric Ducting
- Farad

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Keywords Reloaded

- PTT
- FSK31
- Grid Square
- Rule of 3s
- ISS
- Duty cycle
- Rectifier
- FT8
- Relay
- WSJT
- APRS
- SDR
- Beacon
- IRLP, VOIP, DMR

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OMG, Make it Stop!

- Simplex
- Duplex
- “Reverse” function
- QRM, QRN, QRP
- QSO, QSL, QSY
- Net Control Station
- “Traffic”
- ”Check”
- Picket Fencing
- Flat topping
- Wavelength
- Frequency
- RF
- EMF

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Magic Numbers

- Speed of light
- 2m National Calling Frequency
- 2m repeater offset
- 70cm repeater offset
- 219-220 MHz
- Our ITU region
- 3dB
- 6dB
- 10dB
- -43dB
- License Term
- License Grace Period

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Bandwidths

- CW?
- SSB?
- FM?
- Fast Scan TV?
- Slow Scan TV?

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3+1 Related Topics

- Interference & Distortion
- Coax
- Safety (Mostly about RF)

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Distortion

- A problem with your transmitted signal
- Low battery might cause audio dropouts when you speak
- Microphone gain too high or speaking too loud can cause clipping / flat-topping
  - Overmodulation / Over-deviation
- Narrow filters in the receiver will cause over-deviated parts of your transmission to be cut off

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Interference

All AC/RF Interferes With Everything All the Time

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Your Base Station is Powered by Wall AC

- Can the 60Hz A/C leak into your RF Output?
- Can your RF find its way into your house wiring?
- Can your RF influence other electronics in your house?
- Can other electronics in your house affect your radio?
- Is interference isolated to just your own house?
- What if a (non-HAM) neighbor is interfering with your radio?
- What about that nearby FM broadcast station?

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Powering Your Mobile Station

- Let's start with the engine off – all good?
- With the engine running, what does the power look like?
- Alternator output is AC and gets only partially filtered
- What happens to that unfiltered power in your radio?
- Can your RF affect the electronics in your car?

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How Do We Fix All This!

- Should we just not use Radios? Are they a societal menace?
- No, we fix all of this with two tools
  - Your new understanding of EM radiation
  - Impedance
  - Shielding
- With impedance we can make filters
  - Low pass
  - High pass
  - Notch
- Shielding is an enclosing, grounded, antenna

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Filters Can Fix Most Interference

- High pass ("Noise blanker" and "power line noise filter")
  - Keeps wall current and alternator noise out of your radio
  - Protect your neighbor's (analog? Really?) TV from your transmitter
- Low pass ("choke")
  - Keeps RF out of power wires and mic cables
  - RF filters will fix landline phones if you happen to find one!
  - Keep nearby military radar from overloading your receiver
- Notch
  - Keep the big FM broadcaster from overloading your receiver
  - Keep your transmitter from overloading badly designed consumer gear
- What about just looping the wire a few turns?

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The One Filter to Rule Them All

Shielding!

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Grounded Metal Boxes for Devices

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Coax is Shielding for Wires

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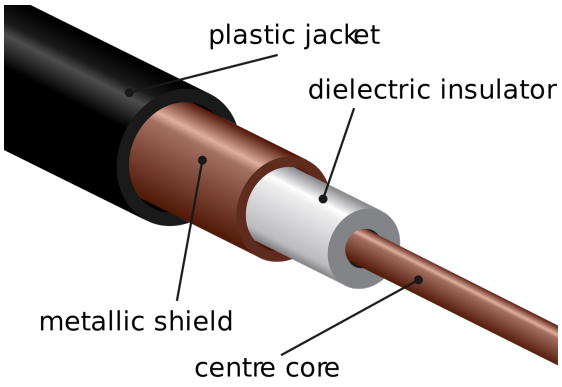

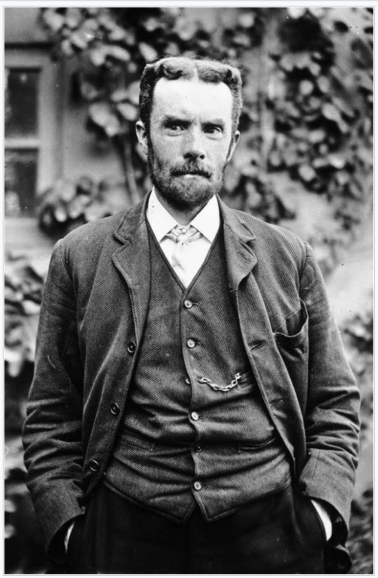

In his 1880 British patent, Oliver Heaviside showed how coaxial cable could eliminate signal interference between parallel cables.

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Characteristics of Coax

- Impedance
- Loss vs. Cost
- Connector Types
- Loose connectors are bad!
- Water is even more bad!!

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Ladder Line – the Coax Alternative

- Much better performance
- Really not convenient!
- Pretty much the reason everyone uses coax

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SWR [more correctly VSWR]

The RF version of “failure to communicate”

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SWR

- Standing Wave Ratio
- The measure of “Reflected Power” in a transmission line
- Caused by Impedance Difference Between Source and Sink
- Power reflects from the sink back to the source… recursively!
- Reflected Power Turns into Heat
- Reflected Power Can Damage Your Radio

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SWR Cheat Sheet

- 1:1 means no reflected power
  - A perfect match!
  - Pretty much doesn't happen
- 1.5:1 is a typical "good" match
- 2:1 is "fair" but marginal (IMHO)
- Anything more and you should fix it
- Modern commercial radios protect you
  - I *never* rely on that because they will not give me a new radio!

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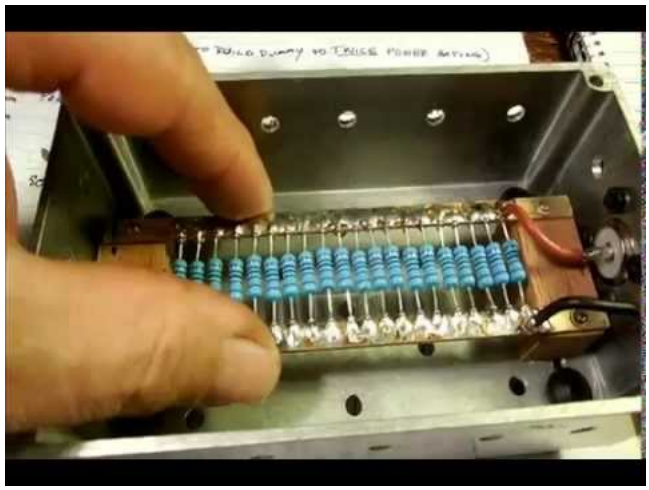
Dummy Load – a standard test tool



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Safety

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Physical Safety

- Summary: Don't be Dumb!
- Hard hat
- Assistant
- Proper climbing gear
- Distance to power wires
  - OMG! Imagine how that got on the test!
- Local codes control
  - There is no “interstate commerce” argument to make this federal

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Safety Regulations are LOCAL

- Federal Law Does Not Reach Your Antenna Tower
- State and City Laws Control

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Electrical Power Safety

- Fuses and Circuit Breakers
- Careful Around High Voltages
- Careful of Stored Charge
- Always Have Good Grounds
- Don't Be a Good Ground!
- Yes, Batteries Can and Do Explode

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Lightning Loves Your Good Ground!

- Best Grounds are
  - Short
  - Wide
  - Bare
- Short gives less total resistance
- Wide gives more surface area to carry high frequency RF
- Bare gives nothing to heat up and catch fire!

- Your radio is also a good (but very expensive!) ground so make your lightning ground better

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Radio Exposure

- Your Body is a Tuned Circuit
- Different Parts are Tuned Differently
- 50 MHz is the Most Dangerous "Whole Body" Frequency
- Various small parts are sensitive to higher frequencies

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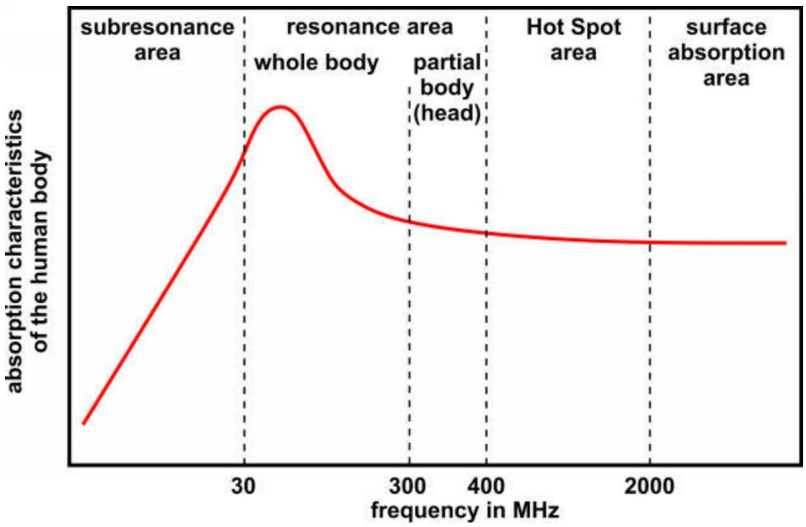
The "Fine Print"



Absorption of radiofrequency fields in the human body depending on the frequency.

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Controlled vs. Uncontrolled

- This is pretty simple
  - You are in control
  - Your neighbor is not in control
- A theoretical (and theatrical) scenario
  - Suppose Officer Kelly is writing me a speeding ticket
  - I key up my mobile to complain to Director Foster
  - I'm inside my big metal truck with an antenna on top
  - The guy with the ticket book is 4 feet away from a 5/8 whip transmitting 25 watts on 2 meters

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Total Exposure

- More Power => More Exposure
- Antenna Gain => More Exposure
- Lower Duty Cycle => Less Exposure
- More Distance => Less Exposure

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Total Exposure

$$\frac{\text{Power x Gain x Duty Cycle}}{\text{Distance Squared}}$$

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Yagi Gain

APPROXIMATE YAGI-UDA ANTENNA GAIN LEVELS

NUMBER OF ELEMENTS	APPROX ANTICIPATED GAIN DB OVER DIPOLE
2	5
3	7.5
4	8.5
5	9.5
6	10.5
7	11.5

dbd = 2.15 dbi

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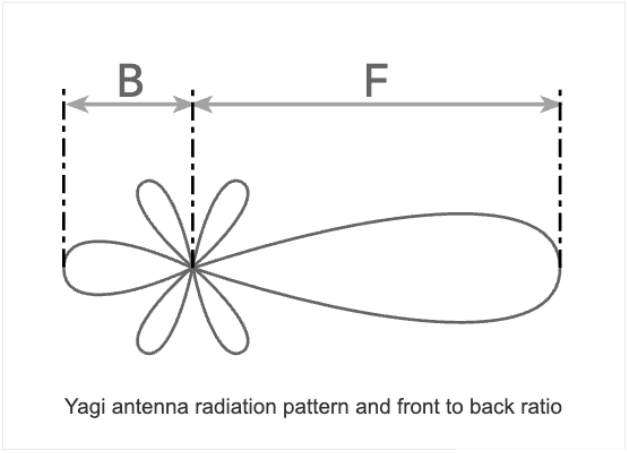
Yagi Front to Back Ratio



Yagi antenna radiation pattern and front to back ratio

$$\text{Front to back ratio (dB)} = \log\left(\frac{F}{B}\right)$$

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Yagi

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Three Ways to be Safe

- FCC OET Bulletin 65
- Computer modeling
- Measure with a field strength meter

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When is an "RF Exposure Evaluation" Required?

- At VHF and Above
- 50 watts PEP at the antenna

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Three Ways to Comply

- Measure it with a field strength meter
- Module it in software
- Use FCC OET Bulletin 65

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The "Even Finer Print"

Table 1
You must perform an RF environmental evaluation if the peak-envelope-power (PEP) input *to the antenna* exceeds these limits.

Band	*Power (W)*
160 meters	500
80	500
40	500
30	425
20	225
17	125
15	100
12	75
10	50
6	50
2	50
1.25	50
70 cm	70
33	150
23	200
13	250
SHF (all bands)	250
EHF (all bands)	250

Repeaters: **Non-building-mounted antennas:** If the distance between ground level and the lowest point of the antenna is less than 10 meters *and* the power is greater than 500 W ERP.
Building-mounted antennas: If the power exceeds 500 W ERP.

Table 2
Operating Duty Factors by Mode

Mode	*Duty Factor*	*Notes*
Conversational SSB	20%	Note 1
Conversational SSB	40%	Note 2
Voice FM	100%	
FSK/RTTY	100%	
AFSK	100%	
Conversational CW	40%	
Carrier	100%	Note 3

Note 1: Includes voice characteristics and syllabic duty factor. No speech processing.
Note 2: Moderate speech processing employed.
Note 3: A full carrier is commonly used for tune-up purposes.

Table 3
Typical Antenna Gains in Free Space

Antenna	*Gain*	
	dBi	*dBd*
Quarter-wave ground plane or vertical	1.0	-1.1
Half-wavelength dipole	2.15	0.0
2-element Yagi array	6.0	3.9
3-element Yagi array	7.2	5.1
5-element Yagi array	9.4	7.3
8-element Yagi array	13.2	11.1
10-element Yagi array	14.8	12.7
17-element Yagi array	16.8	14.7

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Ionizing vs. Non-Ionizing Radiation

Radio waves Do Not Have Enough Energy
"to cause genetic damage"

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