

Radio Frequency Interference (RFI) and Electromagnetic Interference (EMI) Causes and Control

de VE1FA



Industry Canada says:

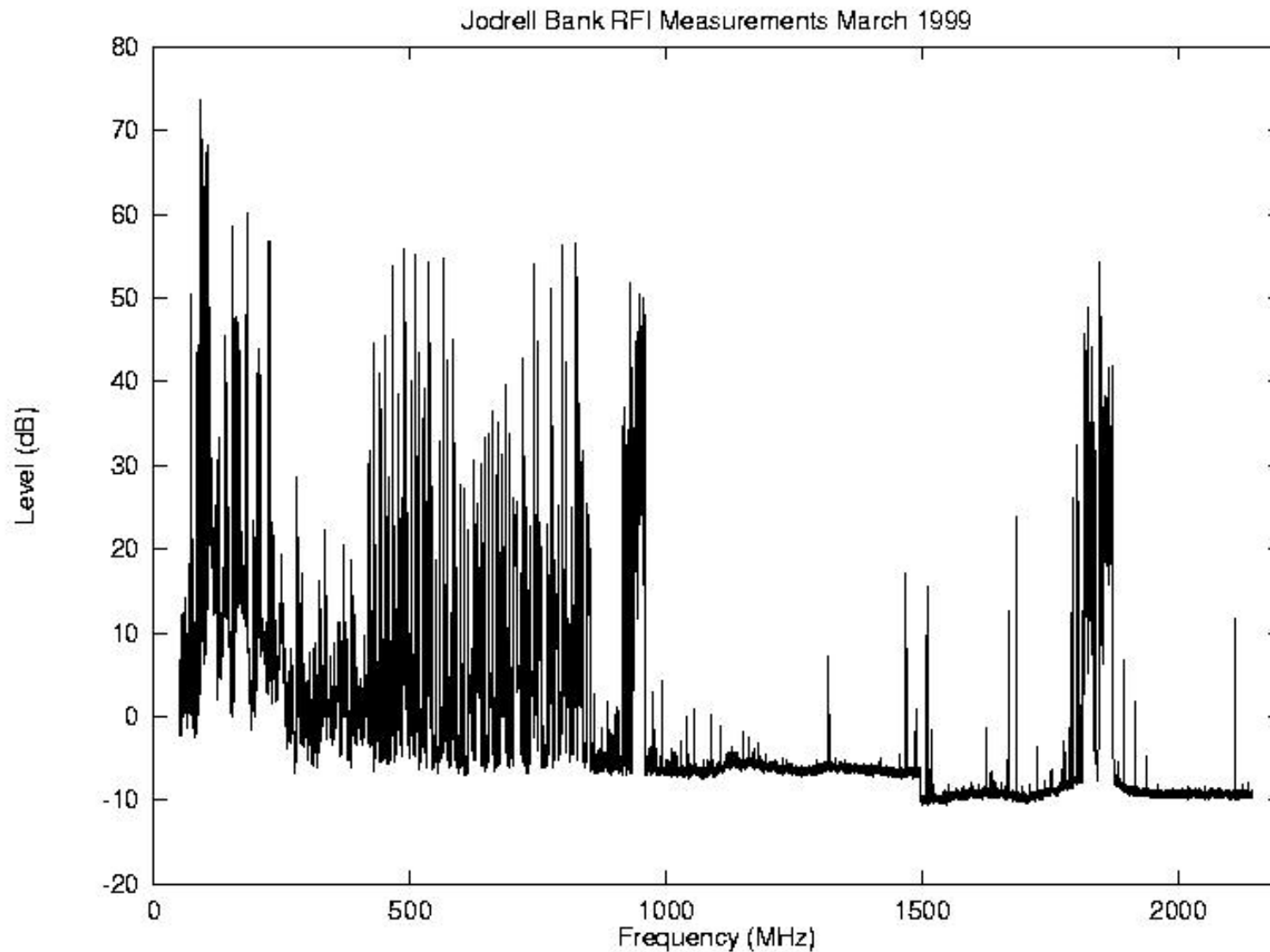
- “Transmissions from an amateur station shall not cause harmful interference to a station operating in another service nor be protected from interference caused by a station operating in another service in the same frequency band as set out in Column III of Schedule I in accordance with the provisions of sections 52 and 53 of the Regulations.”
- The amateur should have two concerns:
- 1. Don't interfere with other services, fellow hams, or your neighbors!
- 2. Minimize RFI/EMI production in your station + home, so you can communicate well and enjoy amateur radio.

Electromagnetic interference (EMI) => affects: (A) non-radio electronics + electrics (e.g. stereos, washing machines, computers, thermostats; and (B) radio devices (eg phones, garage door openers) not designed to receive the EMI frequencies

Radio Frequency Interference (RFI) => produced in radios/TVs on frequencies the radio or TV is designed to receive

EMI/RFI Susceptibility: varies greatly with design of affected device

RFI seen in spectrum scan at Jodrell Bank Radio-telescope, UK



RFI Effects

Cross Modulation: strong off frequency AM/SSB signal overloads AM radio, and is heard over the desired signal

Harmonics: TX is radiating on multiples of intended transmit frequency, eg: 7020 intended, harmonics on 14040, 21060, 28080 kHz

Intermodulation (distortion) (IMD): mixing of strong unwanted signals in “front end” of RX (RF amp or mixer, usually) to produce audible interference

Receiver desense (front end overload): strong unwanted signal activates AGC or saturates amplifier to reduce radio gain and obscure desired signal

Splatter: overmodulation of a signal causes audio harmonics up and down the band

Spurious emissions: any radiation from a TX outside it's intended frequency

Transmitter Signal Flaws

Click: Spark at Morse (CW) key causes sharp rise (spike) at leading edge of each dit and dah transmitted. Heard up and down the band being used. **(RFI)**

Chirp: CW key down causes slight shift in master oscillator frequency due to altered supply voltage or oscillator load. Heard as audio chirp

Hum: carrier or voice signal modulated by 60 or 120 Hz ripple.

Drift: slow change in master oscillator frequency over time.

Excessive speech compression/processing → splatter (RFI)
(OR poor adjacent signal rejection by your RX!)

RFI/EMI Regulations

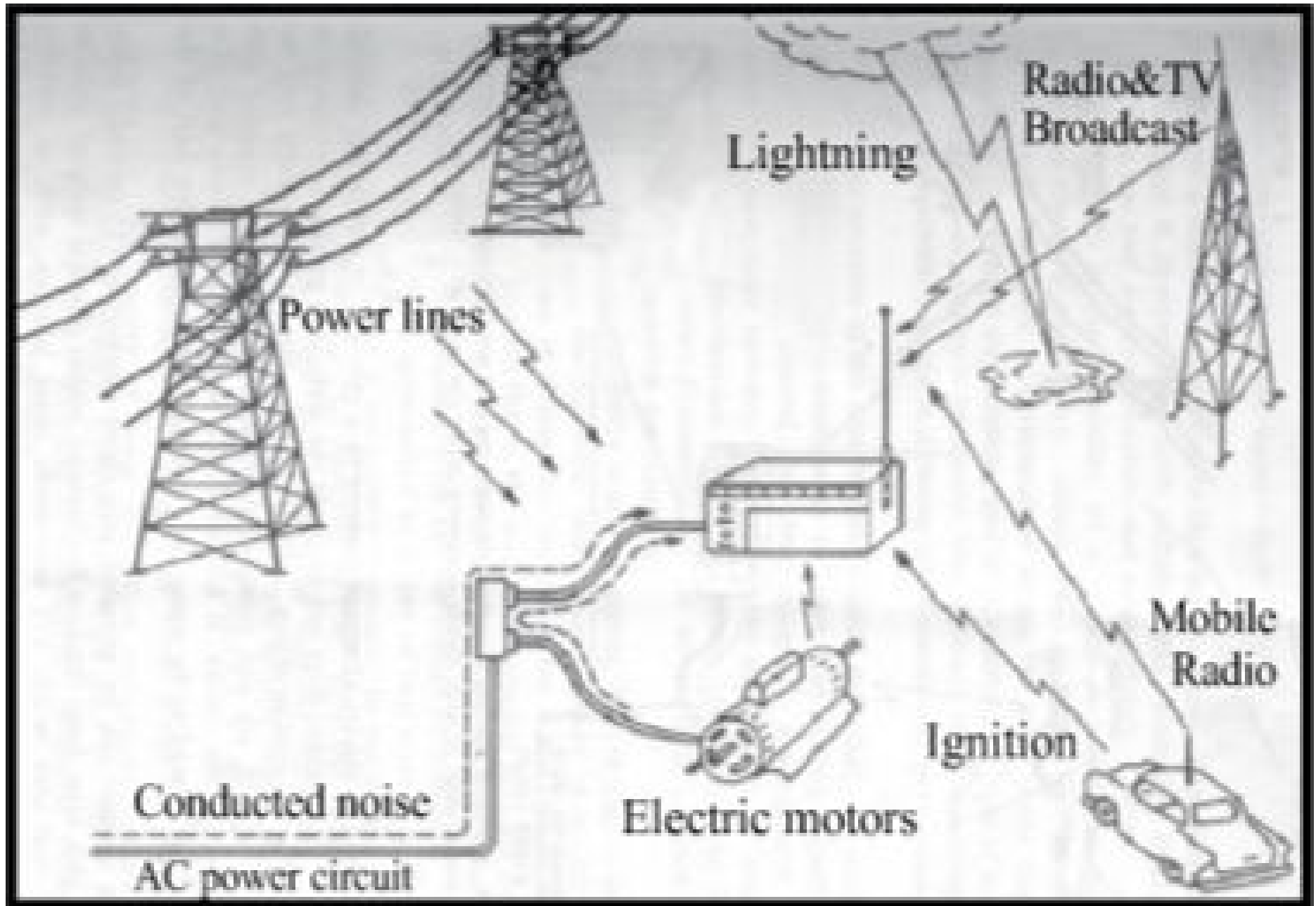
US Federal Communications Commission (FCC):

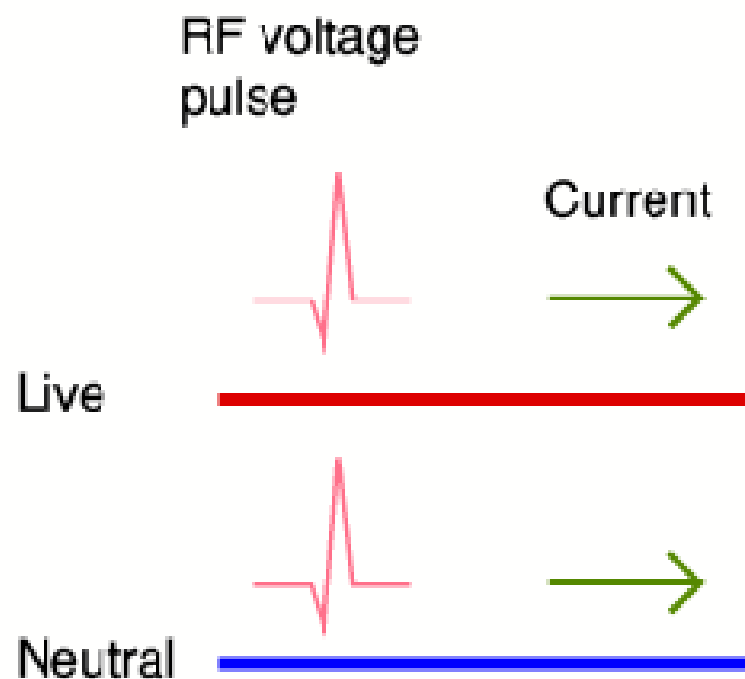
“part 15” regulations: EMI/RFI susceptibility/emission standards for all electronics sold

Industry Canada: read EMCAB-2, (Radio Act, Section 5(1) (1) available on Coax Publications site

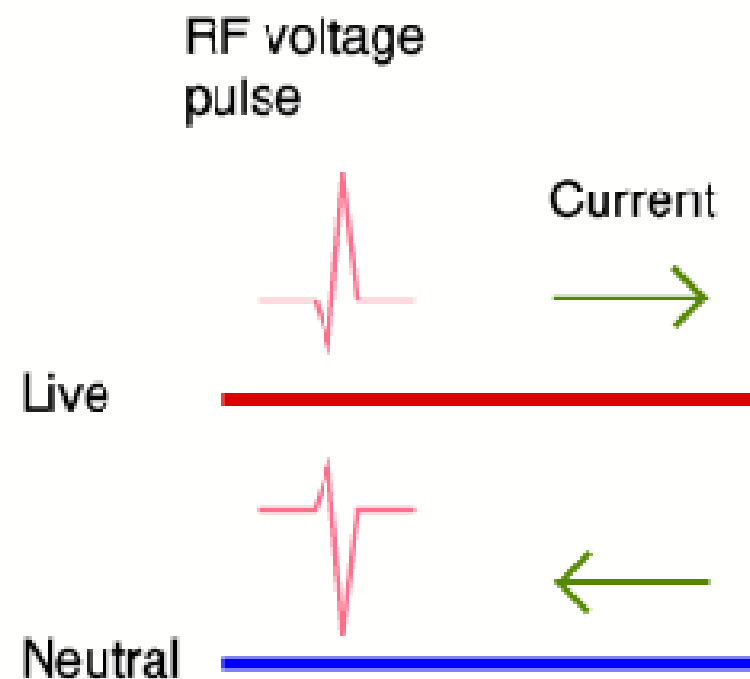
“Criteria for Resolution of Immunity Complaints Involving Fundamental Emissions of Radiocommunications Transmitters”

Main noise paths into your Rx: conducted and received





Common Mode
Voltages and currents the same on both wires.



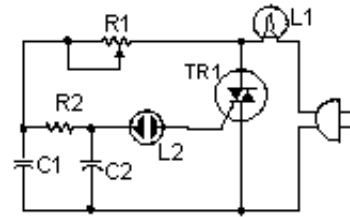
Differential Mode
Voltages have the same size but opposite signs.

RFI

Figure 1 Two ways EM energy can flow along the wires.

Common domestic noise (RFI/EMI) sources (worst at lower MF/HF frequencies)

- Power lines, their hardware (hum, arc, spark, corona buzz,
- AC light dimmers
- Electric fences
- Computers + all microprocessors with digital clocks (oscillator)
- Brush-type motors (vacuum, sewing machine, power tools)
- Thermostats, power controllers, motor controllers (washer, dryer, fridge, etc.)
- Fluorescent lights, touch lights, neon lights
- Bug zappers, electric fences, ignition pulses
- Cordless phones, baby monitor
- Weird stuff: doorbell transformer, electric blanket, fish tank thermostat

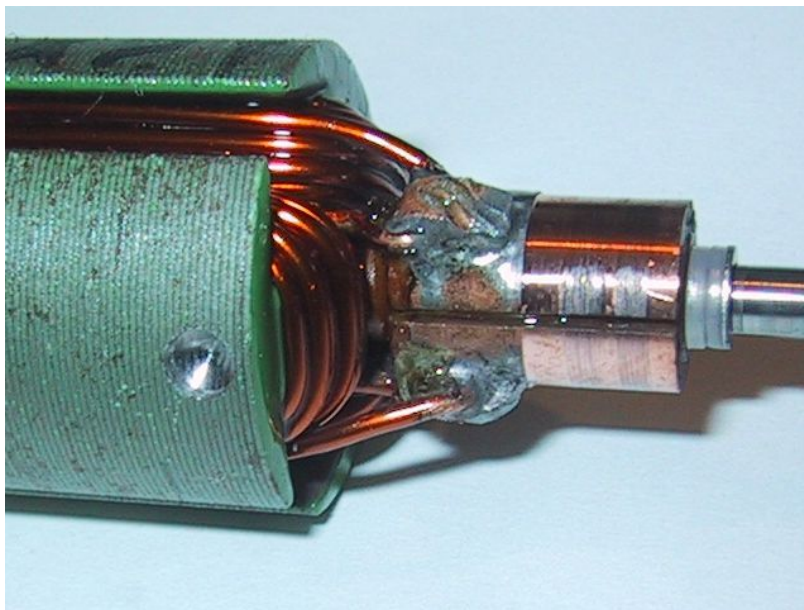
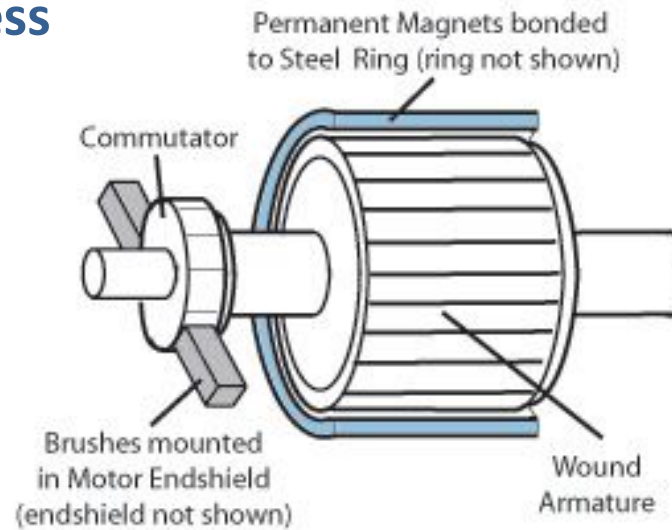


“Modern” devices often producing MF-HF interference

- **1. DVD + Blu-Ray players**
- **2. In-line or “wall-wart”-type laptop power supplies (especially switcher-type)**
- **3. Newer front-loading washing machines**
- **4. Computers, tablets, smart phones (some good, some BAD!)**
- **5. Plasma flat-screen TVs (most BAD)**
- **6. Automotive engine computers (some)**
- **7. ADSL box/desktop computer combination**
- **8. “Touch” –controlled lights, faucets, etc.**
- **9. “Coil”-type fluorescent bulbs –some quiet, some bad**
- **10. Wireless modem jacks, digital cable converters**
- **11. LED light assemblies for house lighting (120 VAC) and DC flashlights**

Common AC + DC brush-type motors: always produce sparks and EMI!

Series L, shunt C can suppress
EMI from sparking brushes



The rusty bolt effect

Junctions between different corroded metals can act as diodes.

When two or more strong RF signals “received” by metal structure or objects MIXING can occur.



Result: many mixer sums/differences => => more mixing => => lots of spurious signals!!

Common in : old plumbing, rain gutters, rusty masts, rusty towers, especially when ferrous metals were originally galvanized.

Minimizing RFI/EMI into and out of your station

- Ensure Tx is not defective

Do you get good signal reports? (Good voice quality; pure tone with no key clicks on CW). Do all transmit functions work correctly? Output matched to 50 ohms?

- Ensure your TX is properly adjusted / know your radio!

Correct RF output, mic gain and audio boost/response; compression/RF processing; proper ALC (automatic level control) setting; low SWR. Check TX signal with “internal monitor” if transceiver has one. Ensure balanced modulators balanced.

- Good shielding of Tx/Rx signal paths in station.

- Use properly grounded AC line filters.

- Well-designed antenna + station ground systems.

- Low-pass (TVI) filter for HF radios

- Use minimum power level necessary for good communication!

Amateur Radio Station Grounding

Safety grounding:

- (1) green (neutral) wire in AC wiring always connected to all station units.
- (2) Ensure building AC wiring system has good ground.
- (3) Desirable to have and use “AC polarity tester”.

Lightning grounding:

- (1) More complex, especially for antenna. Have way to quickly disconnect antenna when lightning may be approaching.
- (2) Never operate when lightning is near!!

RF grounding: Very important for:

- (1) proper operation of station + antenna;
- (2) Minimizing RFI/EMI emission and reception.

Station (RF) Grounding

- Important at MF/HF to have a good RF ground.
- Minimizes RFI and EMI in/out, importance varies with type of antenna
- Makes grounded electronics cases and coax shields into effective RFI/EMI shields.
- All boxes grounded to a common buss: NOT a daisy chain!
- Ground lead should be $<1/4 \lambda$.
- Heavy copper wire to heavy copper pipe or stake (iron/steel not good).
- Multiple ground stakes connected with heavy wire best.
- Water pipe ground...often no good.
- Copper water pipe: makes good buss, makes good ground stakes (with “re-rod” inside).
- Third AC outlet pin (green): NOT a good RF ground!

Typical ham transmitter interference with TV/VCR

(Basic problem is often poor TV/VCR design)

Normal

Tx QRM



Frequency selective filters: can solve many EMI + RFI problems

- :effective at both noise source and at transceiver
- : most effective when used at both
- :available for both RF and AC (50 or 60 Hz) frequencies

FILTER TYPES:

High-pass

Low-pass

Band-pass

Band reject

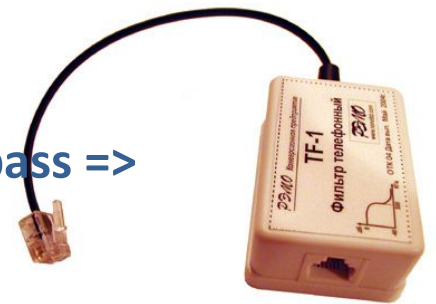
Notch/Peak



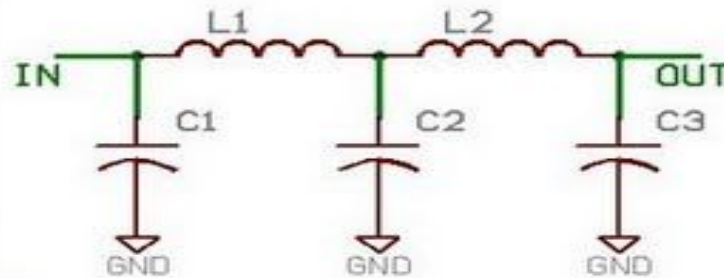
TVI: how to infuriate your neighbors!

Low and high-pass filters for received (antenna) interference

Telephone low-pass =>



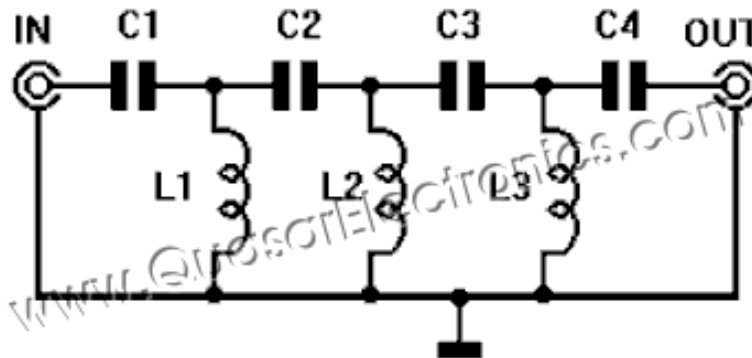
HF Tx low pass
(<40 MHz)



Part	Part Values		
	Butterworth	Chebyshev 0.1 DB	Bessel
L1	0.131 uH	0.126 uH	0.041 uH
L2	0.131 uH	0.126 uH	0.090 uH
C1	20.07 pF	42.27 pF	5.66 pF
C2	64.96 pF	72.79 pF	26.11 pF
C3	20.07 pF	42.27 pF	73.35 pF



TV high pass
(>50 MHz) =>



2 meter 100W band-pass filter (DCI)



-passive filter for 2m transceivers

-greatly decreases intermod in high signal environment

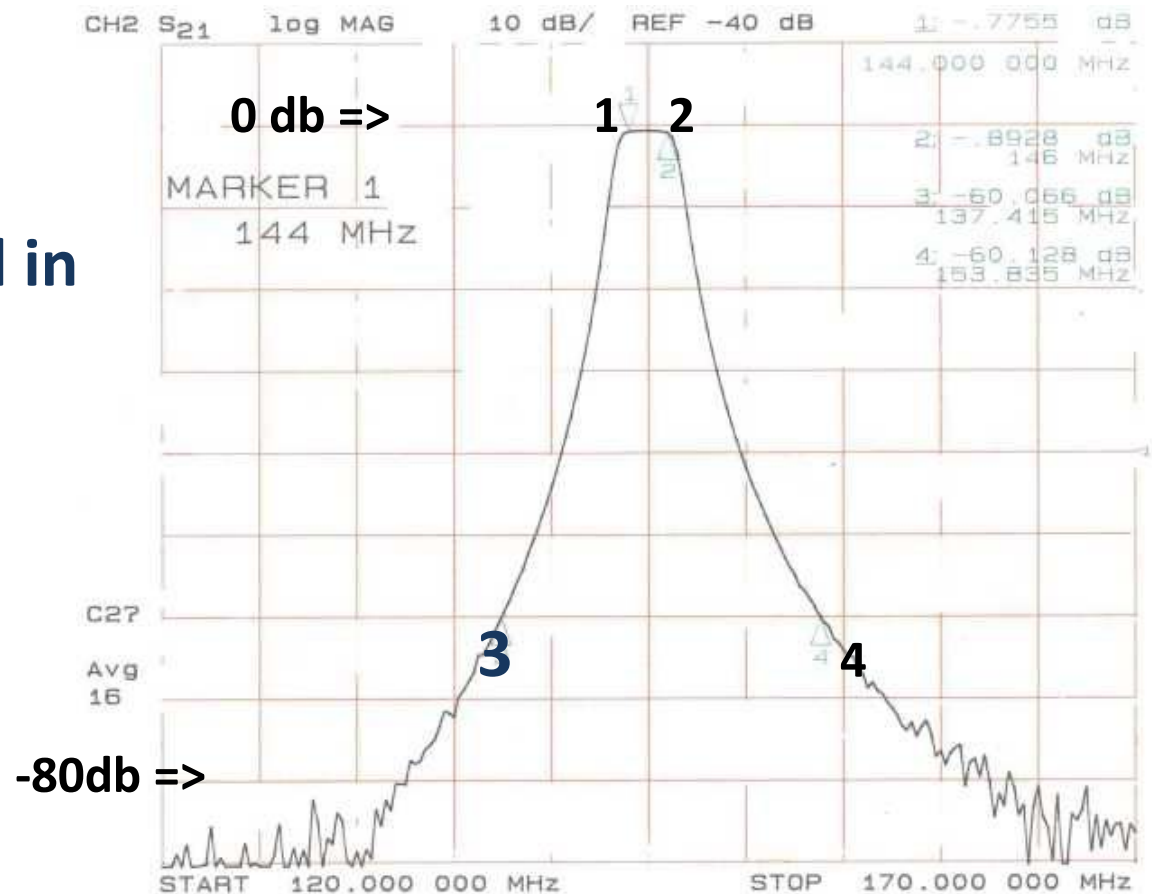
- $Z_{in} + Z_{out} = 50 \Omega$

-3 = 137 MHz

-4 = 154 MHz

-1 = 144 MHz

-2 = 146 MHz



Finding and fixing RFI/EMI sources at home and locally

- Listen on RX: (1) is it entering via antenna or power cord?
(2) disconnect appliances/circuits one at a time
- Is noisy device defective?
- Try AC power line filter on noisy appliance.
- Try chokes, capacitive bypasses on long leads from noise source.
- Check ground of source (if appropriate)
- Nova Scotia Power grid/pole: locate noise source, phone company with details.
- Noise from neighbor's house/possessions... Diplomacy comes first!
- **Modifying or repairing neighbors' electronics is risky!**
- **Big antenna = interference with neighbors' stuff!**
- **Keep log!**

RFI/EMI complaints from your neighbors

Keep an operating log to correlate operation with times of interference

Be nice! Be helpful!

Investigate and determine:

Is your station responsible?

Is your grounding good?

Problems with your equipment?

Filters on your equipment?

Does reducing your power help?

Filters on the neighbor's equipment (be careful here)

If problem not located/solved, find more experienced ham to help

Ferrite and powdered iron toroids and beads: keep RFI/EMI off wires and cables

Many “mixes”!

Mix #43 good for general RFI



LC Line Filters-The Way to Go!



“Potted” chassis mount filter



“Potted” filter on rear of IEC chassis plug

Power line filters

Many styles + applications

Protects equipment from power line surge/spike damage

Keeps RFI + EMI off AC power lines

Nearly all electronic equipment running on 120/240 VAC benefits from having a good power-line RFI/EMI filter!

Example: imagine serious RFI/EMI problems in an Intensive Care Unit...

For Wide Performance Range	
Power Entry Module with high performance Filter <i>LA-Series</i> Page 23	IEC Connector Filters <i>EC-Series, ED-Series</i> Page 38 / 36 Faston- or Wire Terminals
IEC Connector Filters with Fuses <i>EGG-Series</i> Page 28 Faston- or Wire Terminals	Chassis-mount Filters <i>G/N-Series</i> Page 45
IEC Connector Filters <i>EBF-Series</i> Page 30 Faston- or Wire Terminals	Chassis-mount Filters <i>VS-, VV-, VW-Series</i> <i>NEW : MV-Series for medical applications up to 20A/250VAC</i> Page 54
IEC Connector Filters with Fuses <i>EHG-Series</i> Page 28 For medical applications	Chassis/Back Panel Mount Filters with/without IEC Connector <i>SK-Series</i> Page 56
2-Phase Filters <i>IK-Series</i> Page 66	3-Phase Filters (With neutral) <i>AYA6-Series</i> Page 74
IEC Connector Filters with double Pole Switch <i>C-Series</i> Page 26	High Current Filters <i>CFN-Series</i> <i>NEW</i> Page 84

What's in a good “potted” line filter?

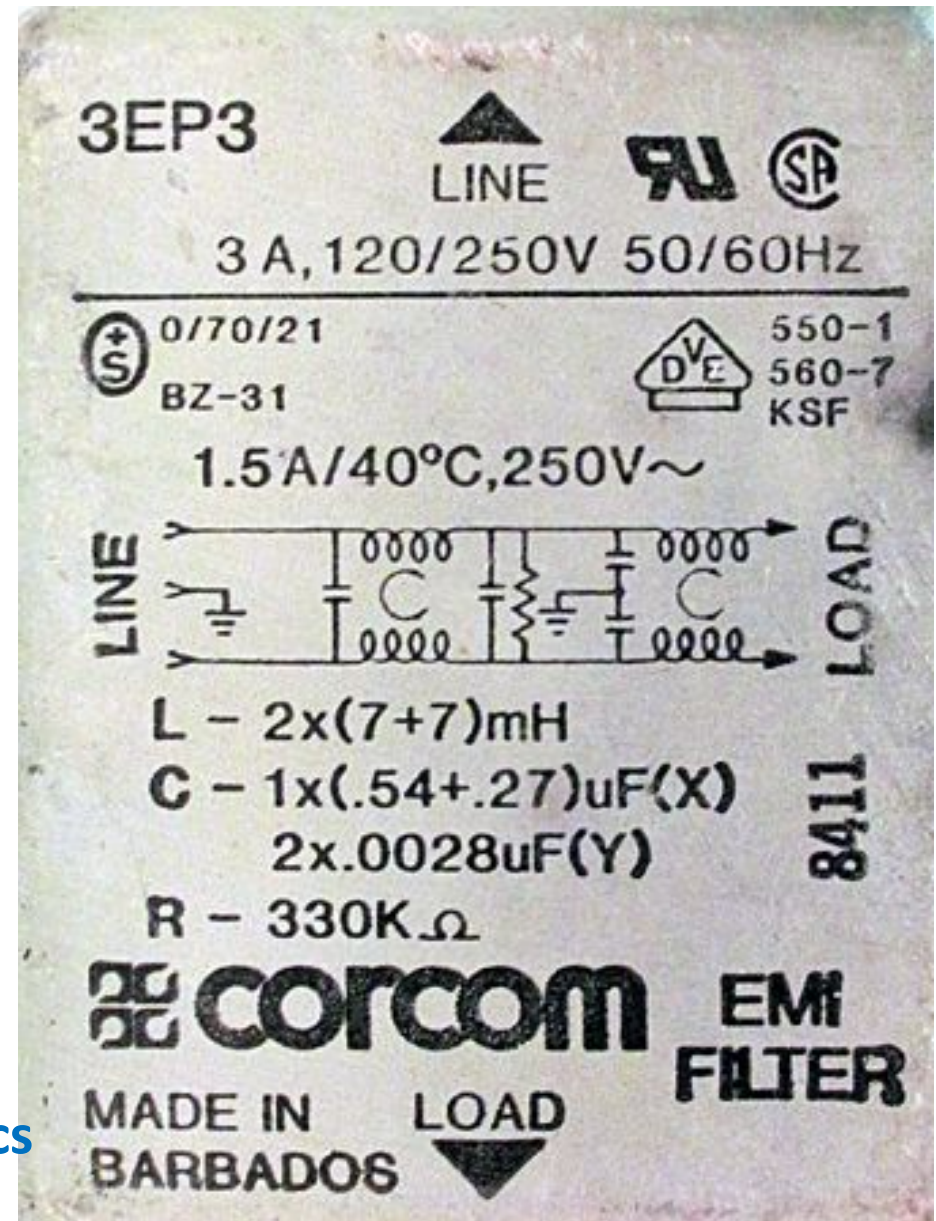
“LINE” = AC wiring of building (to wall plug)

Filter ratings →

Schematic →
(CM + DM capacitors)

Component values →

“LOAD” = To protected or noisy electronics



Common vs. differential mode RMI/RFI filtering and suppression

Common mode (CM): in-phase interference on both AC wires

Differential mode (DM): interference on 1 line only, or different on each wire.

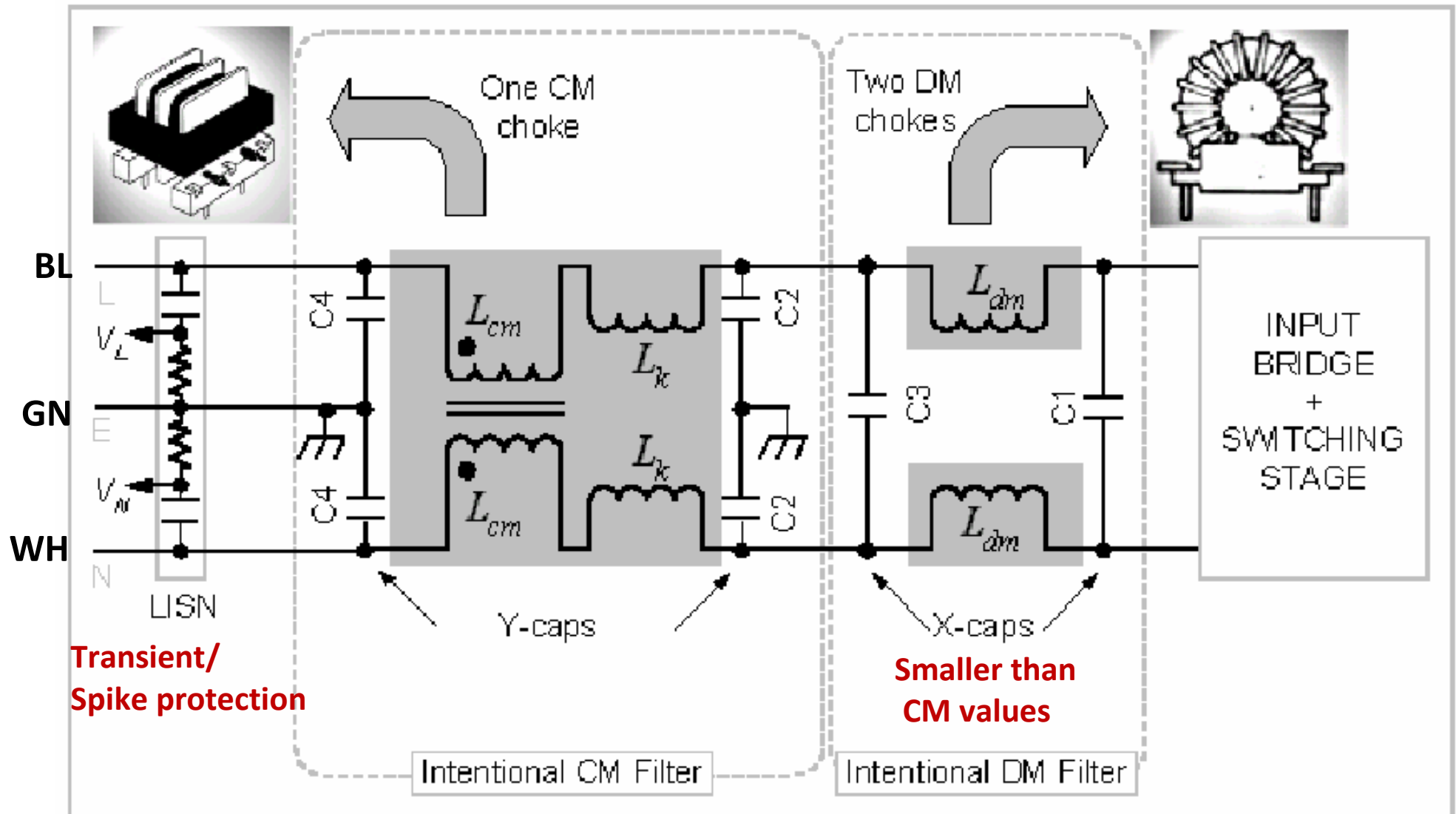
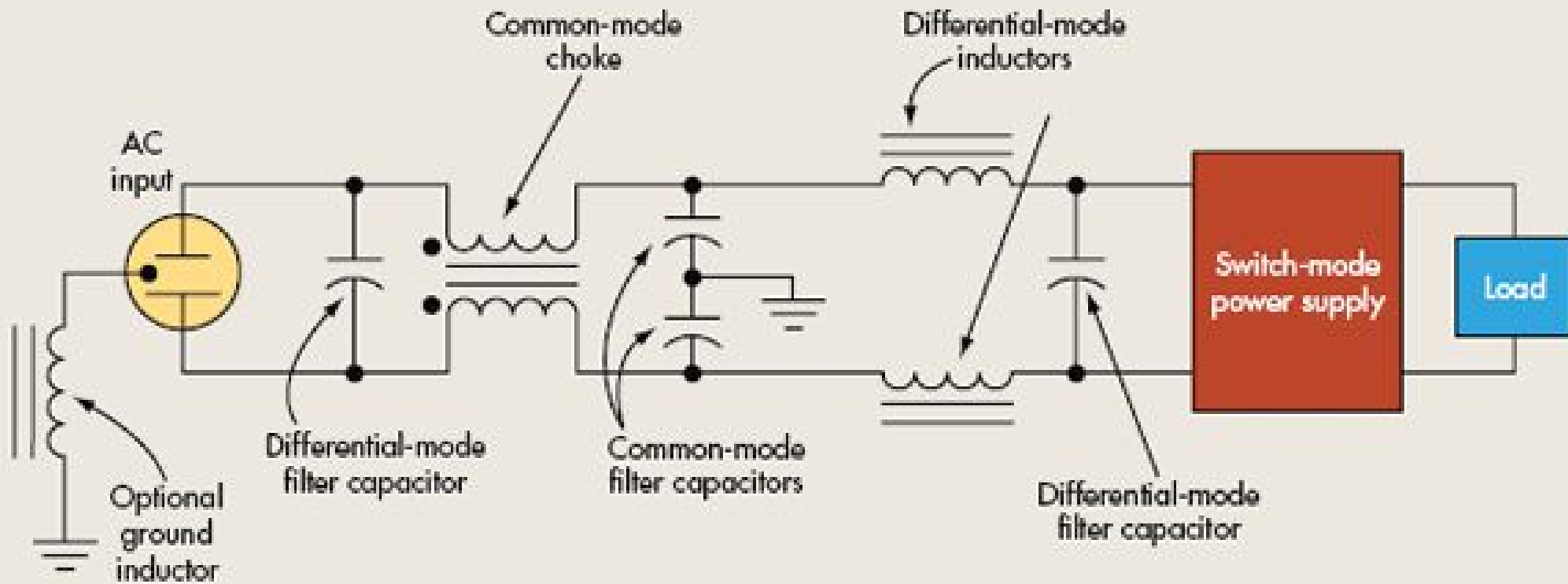


Figure 1: A typical off-line Input Filter

A good line filter uses both common-mode and differential mode filtering



1. To minimize both types of EMI that routinely occur in most electronic products, ac power lines require common-mode and differential-mode filtering.

Metal Oxide Varistor (MOV): shorts out rapid (microsecond) transients

Direct short across device at clamping voltage

8 μ sec rise-20 μ sec fall times

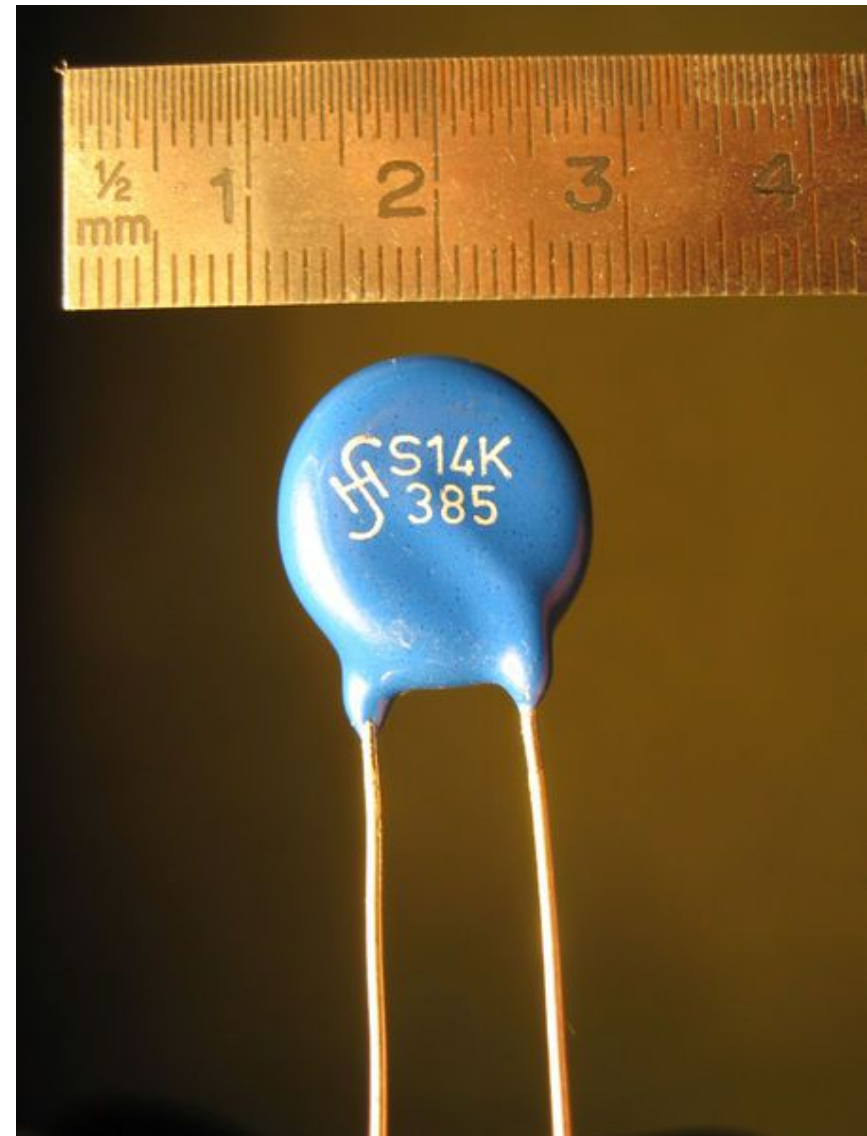
Tolerates short duration spikes only

Good for lightning, inductive spikes

Ceramic + zinc oxide

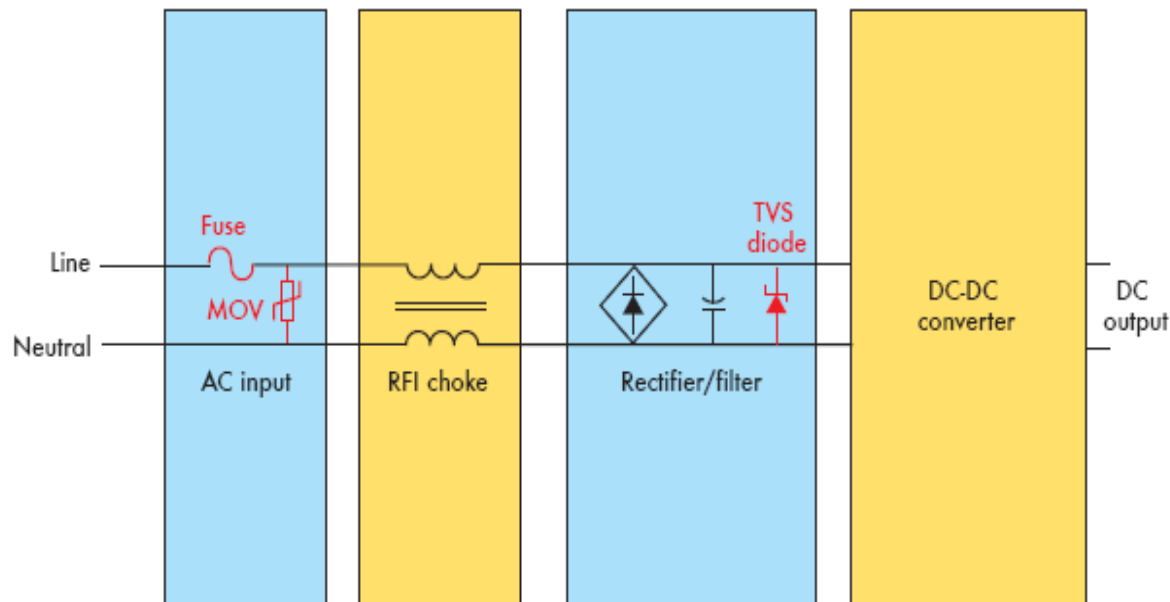
This one: 385 V “clamping voltage”

Lifetime dependent on number and size of spikes absorbed



Input protection and RFI/EMI suppression

Metal oxide varistors (MOV)



1. To protect the dc-dc converter stage, a fuse in line with the ac input of a switch-mode power supply (SMPS) will open should a short-circuit condition occur within the rectifier stage or across the RFI inductor.



Stereo system QRM from amateur Tx

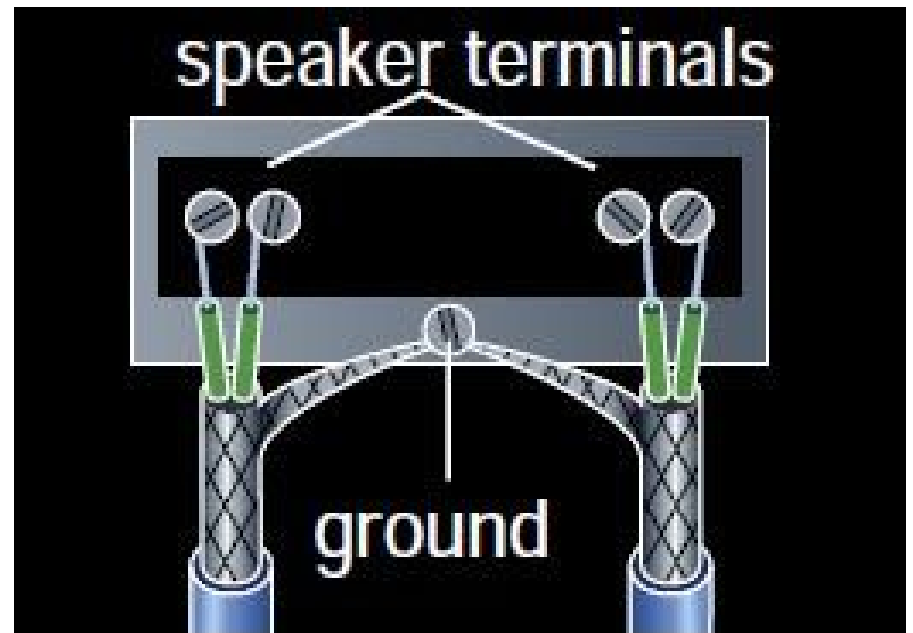
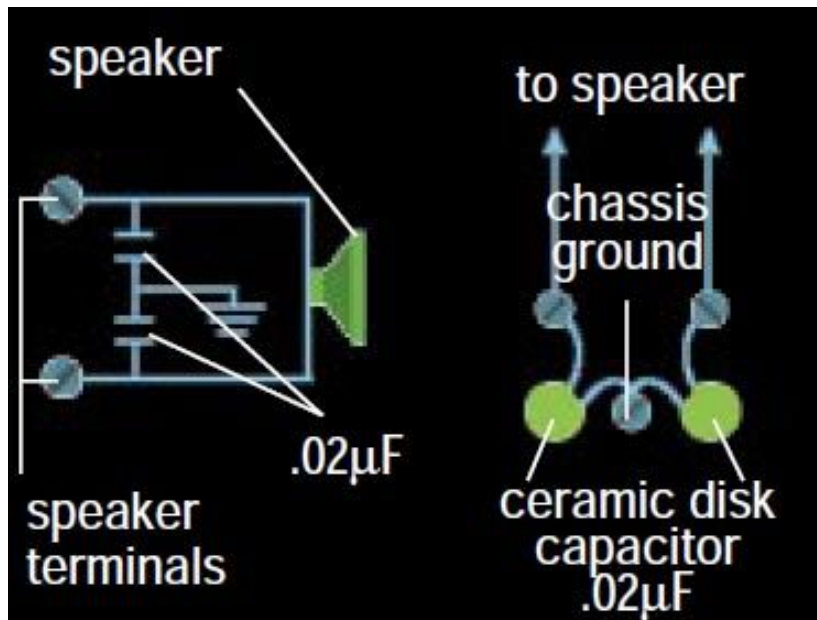
Often speaker leads acting as antenna

Assume both speaker leads are NOT DC grounded!

Shielded wire often best solution.

Ferrite inductors with speaker leads wound around them usually help (chokes)

Sometimes AC power line filter helps too.



Miscellaneous

- **Operating log:** keep one to correlate complaints with operation
- **Parasitics:** unintended oscillations in a circuit, often at VHF frequencies in HF power amplifiers
- **Stub trap:** single frequency notch filter made from $\lambda/4$ length of transmission line
- **Rectification:** EMI/RFI can produce DC in affected circuits, altering their performance
- **RFI/EMI Book from the ARRL:** Elimination of Electrical Noise
- by Don Pinnock G3HVA \$13.95 USD