Power, Grounding, Bonding, and Audio for Ham Radio

Safety, Hum, Buzz, and RFI

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Don’t Bother Taking Notes

- These slides are on my webpage k9yc.com/publish.htm

Why An Earth Connection?

- **Lightning Safety**
  - **That's all!**
- **Does not help with RFI**
- **Does not make an antenna work better**

Bonding Is Critical

- Lightning Safety
- Life Safety – Electrical shock
- Minimizes hum, buzz, and RFI

What is Bonding?

- A Robust, Low Impedance connection between grounds, and between equipment enclosures
  - Low impedance => short, fat
  - Fat => low resistance
  - Short +> low inductance

Lightning is NOT a DC Event

- Lightning is an impulse, with most of its energy concentrated in a very broad spectrum roughly centered around 1 MHz
  - Mostly from 100 kHz – 10 MHz
- Above 1 kHz, impedance is dominated by inductance, not resistance

What Must We Bond?

EVERYTHING!

What Must We Bond?

- Power Service Entry
- Telephone Entry
- Cable TV Entry
- Antenna Entry
- Operating Desk
- All ground rods
- Towers near the building
- Building structural steel
- Grounded metallic plumbing

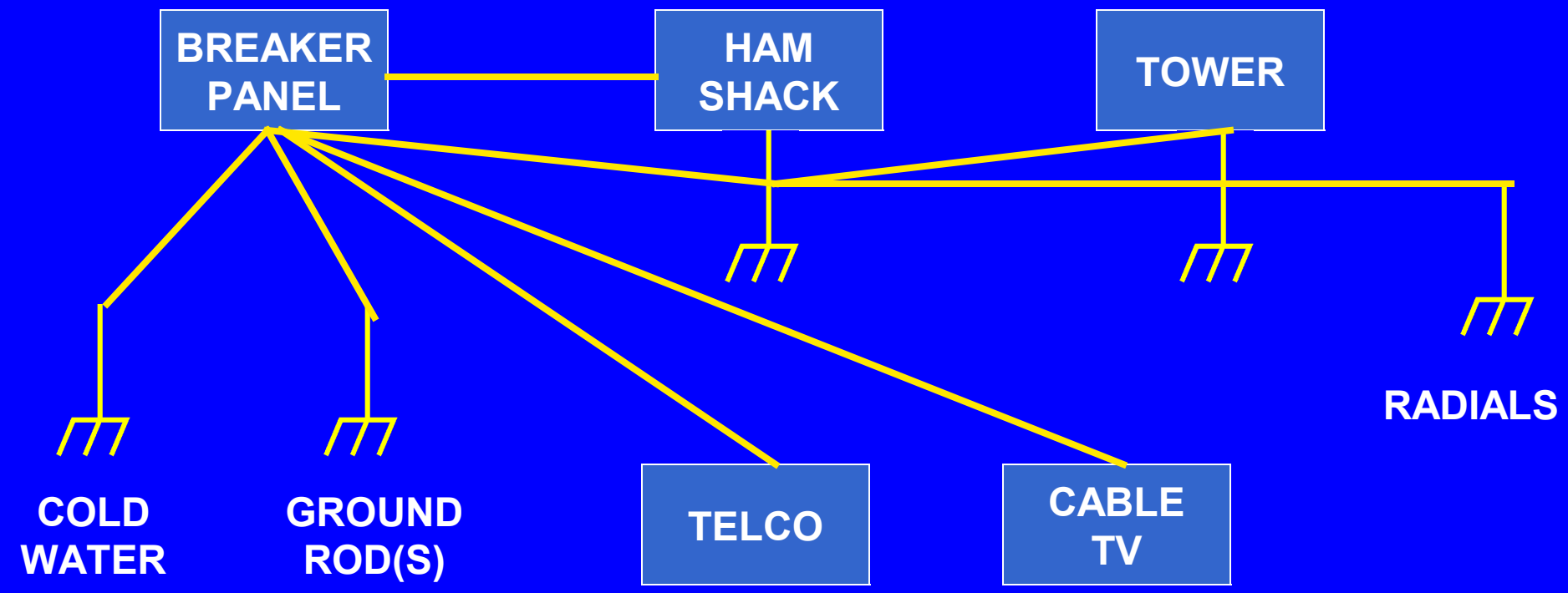
Everything Must Be Bonded Together

- Separate grounds are illegal and unsafe!

Station Grounding

ALL GROUNDS MUST BE BONDED TOGETHER FOR SAFETY

Bonding All Building Grounds



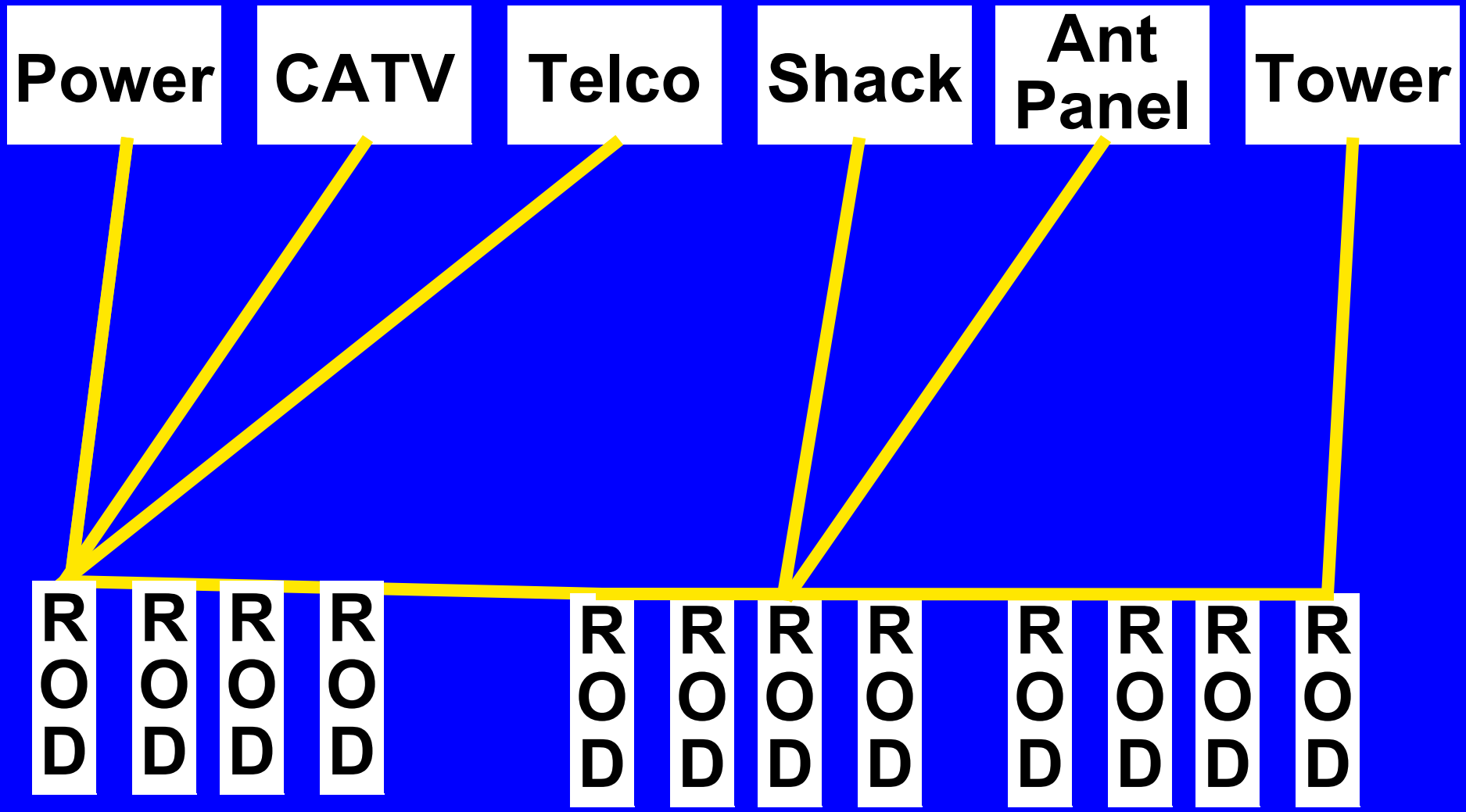
Grounding is for SAFETY

Lightning protection

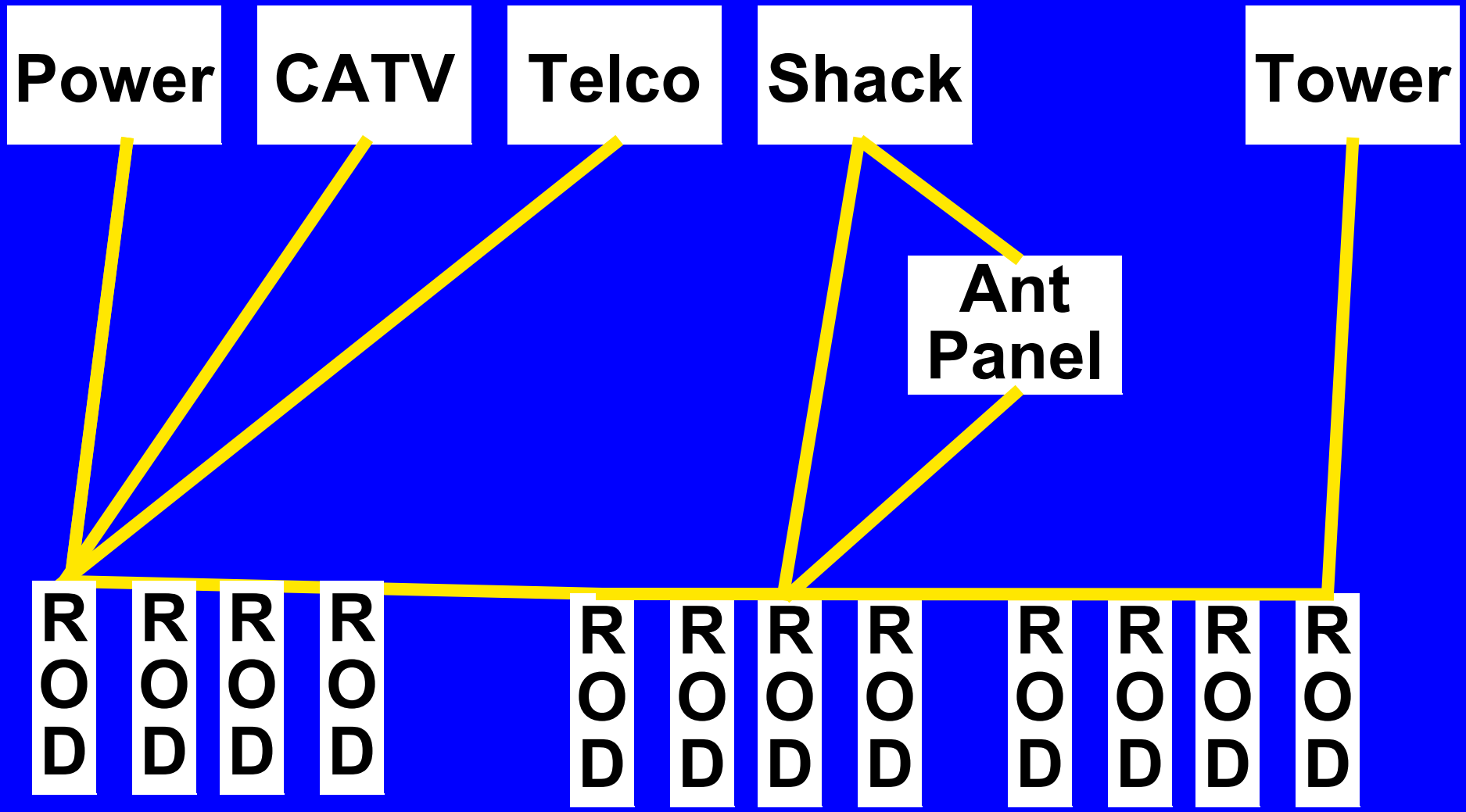
Blows a breaker if a power system short

Connections should be big copper and short

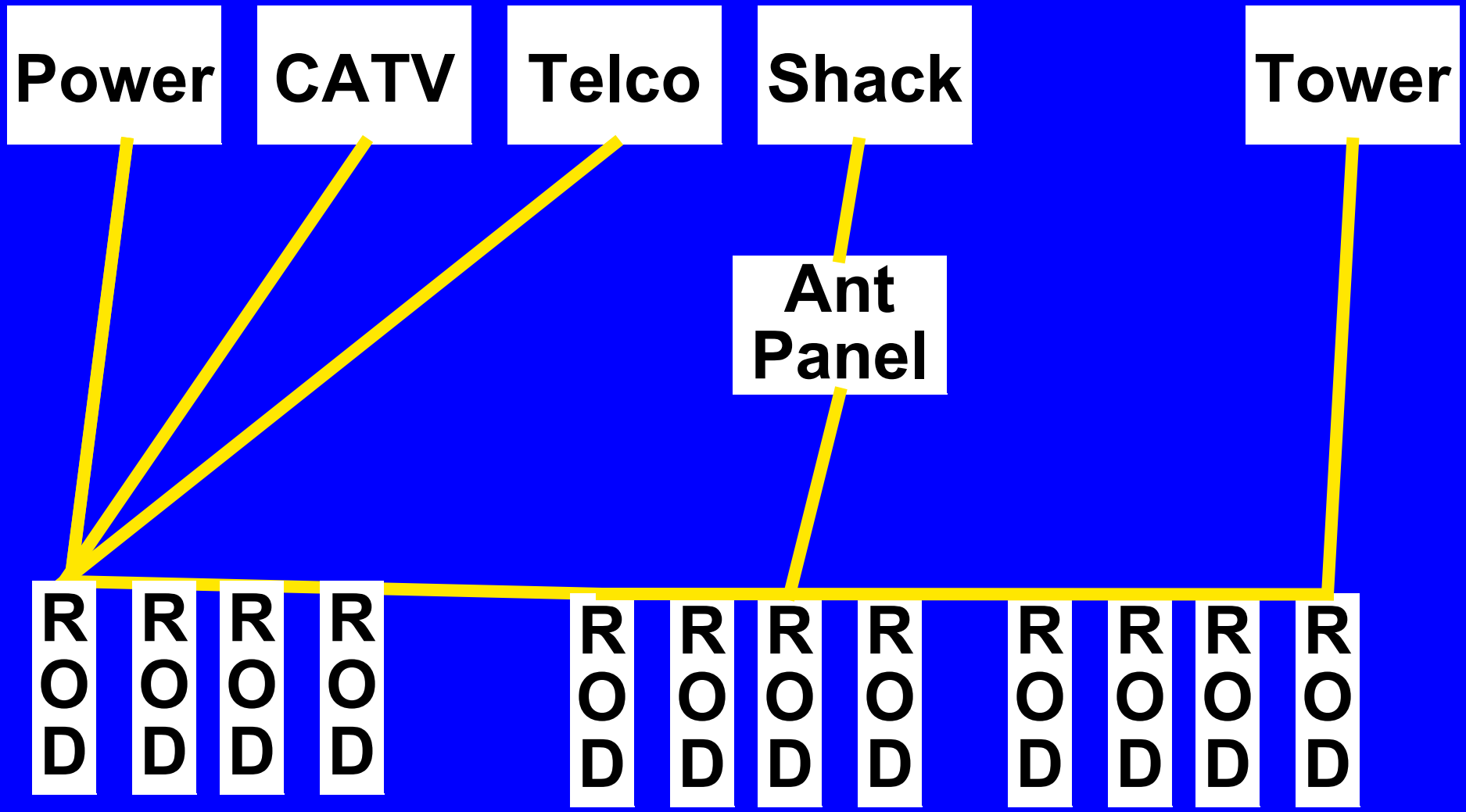
Bonding All Building Grounds



Bonding All Building Grounds



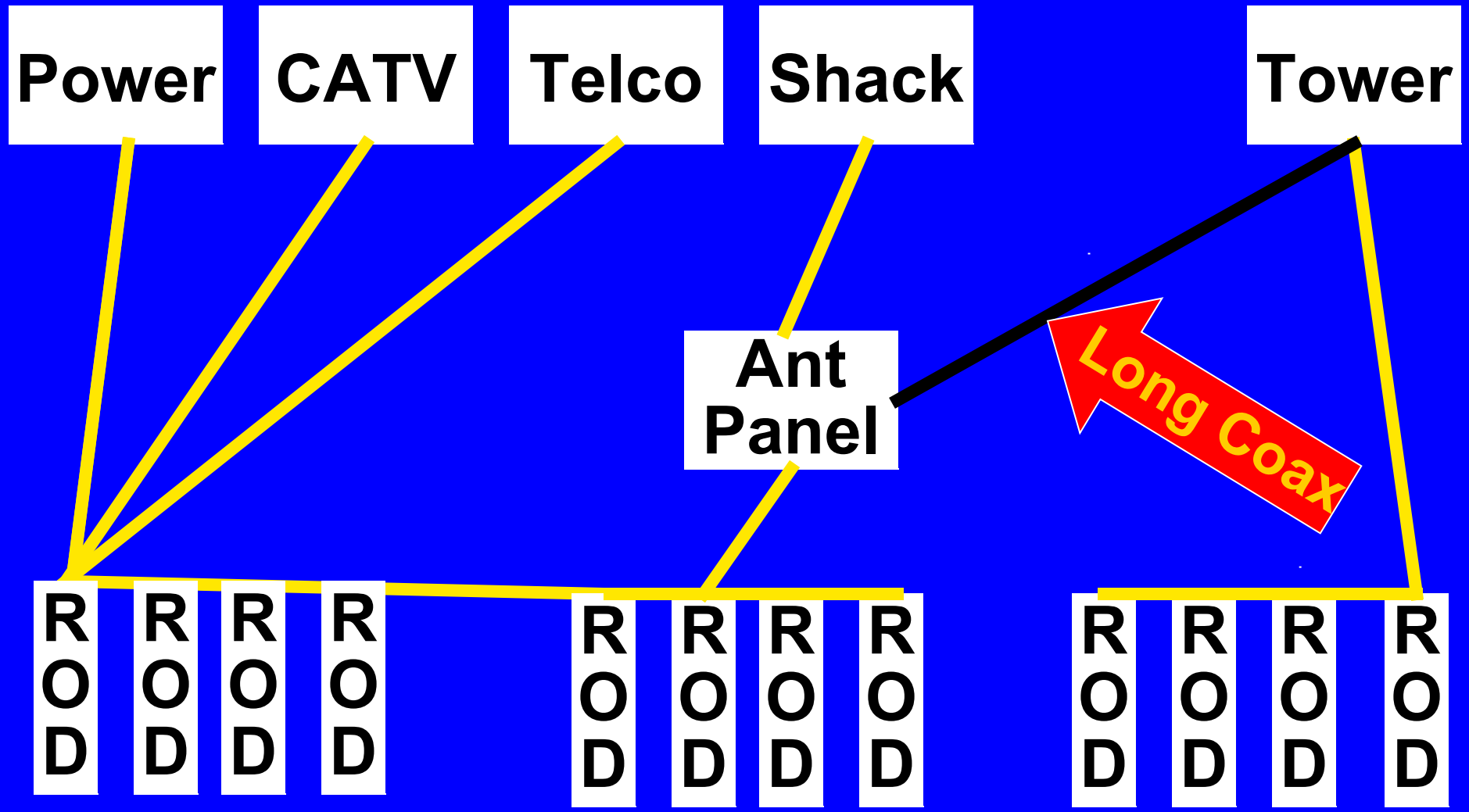
Bonding All Building Grounds



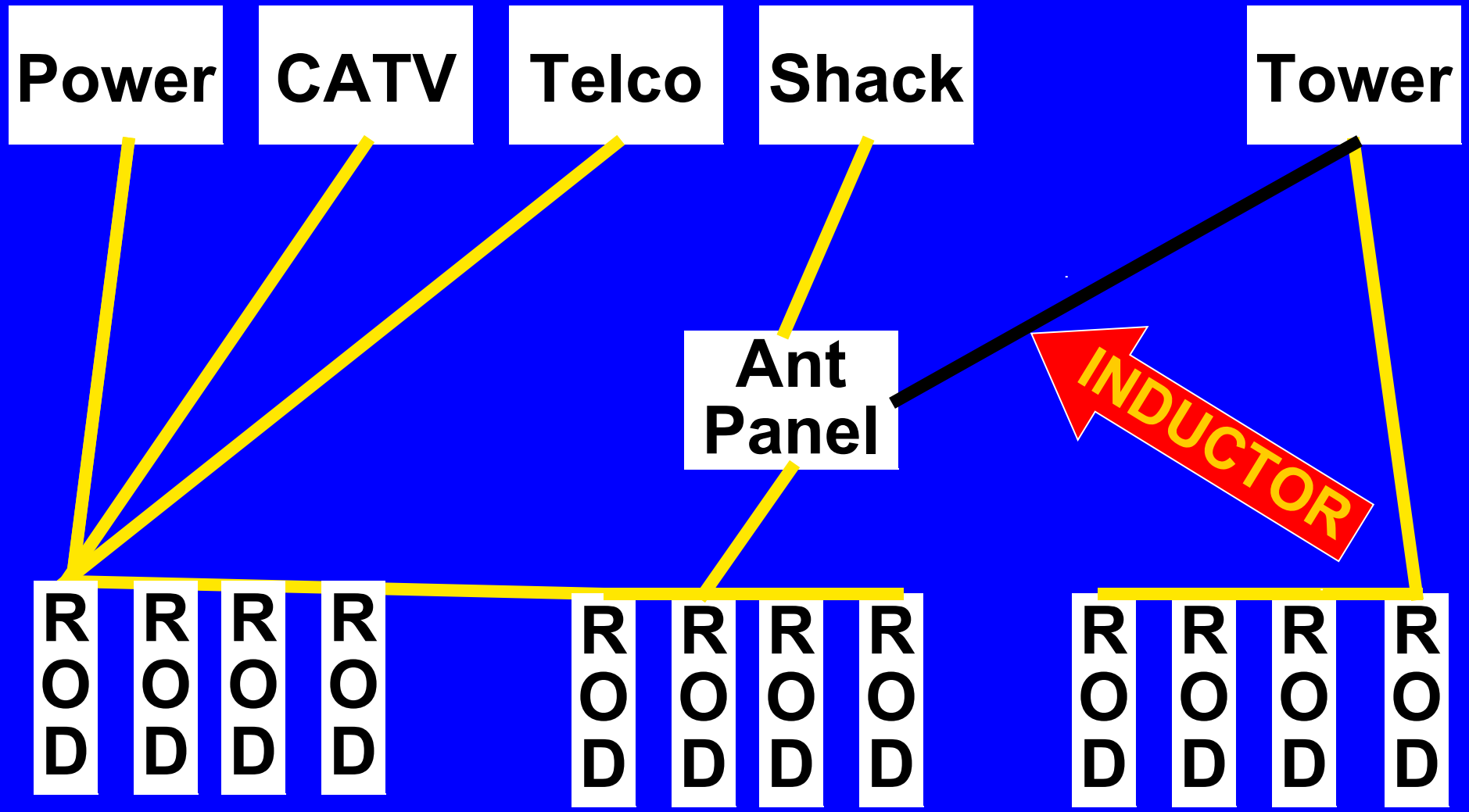
Bonding Tower To House

- If close to the house, it must be bonded to house ground
- If distant from house, it should not be bonded to house ground
  - Coax shield will provide inductive connection, so most lightning current will go to tower grounds
  - "Distant" >200 ft cable run from base to house

If Tower is Widely Separated



If Tower is Widely Separated



Tower Grounding

- Bury copper strap in concrete
- Bond copper strap to rebar cage
- Bond copper strap to tower legs
- Bond each tower leg to at least two buried rods spaced radially
  - Rods at least 8 ft long
  - Spacing at least equal to their length
- Concrete forms Ufer ground

Tower Grounding

- Bond coax shield to the tower at top and bottom
  - Keeps coax at the same potential as the tower
  - Prevents arc-over between coax and tower from lightning
  - Arc-over fries the coax (or hard line) at points where it occurs
- Run coax and other cables inside the tower

Bonding Conductors

- Bigger is better
  - At least #4 around tower, to all rods, between rods, rods to building
  - At least #10 between equipment in the shack
  - Steel conduit is great if properly installed
- Shorter is better
  - Minimizes both R and L

Bonding Conductors

- Braid is bad outdoors
  - Corrodes quickly with moisture unless very well sealed
- Be careful with dissimilar metals
- DX Engineering sells a fixture for bonding copper to steel tower

Bonding Inside The Shack

Why Bond Equipment?

- Lightning Safety
- Kill hum, buzz, and RFI
  - Shields of unbalanced connections carry power system leakage currents that are added to the signal
  - Shields act as antennas, pick up our transmitted RF
  - Pin One Problems couple RF inside the box, where it is detected

Interconnections in our Shacks

- Audio from the computer
  - Playback voice messages to radio
  - Transmit RTTY, PSK31, WSJT
- Audio to the computer
  - Decode RTTY, PSK31, WSJT
- Mic to computer
  - Record messages for contests

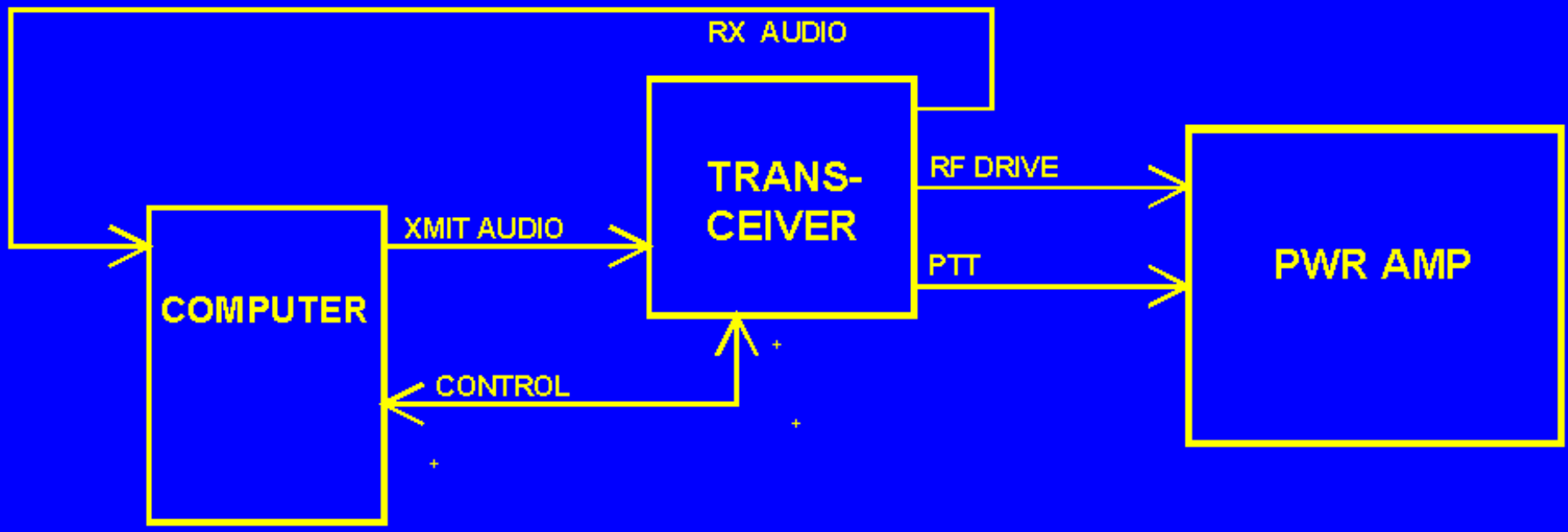
Interconnections In Our Shacks

- Sending CW
  - Computer to radio
  - Paddle and keyer to radio
- PTT from computer to radio
  - Or use VOX

Interconnections In Our Shacks

- Rig control and data for logging software
  - Frequency and mode readout, band changes
- Rig control for MMTTY (RTTY software)
  - Needed only if you're not using VOX
- RS232, USB, Ethernet to most rigs
  - Use WiFi when possible

Simple RTTY Setup w / VOX



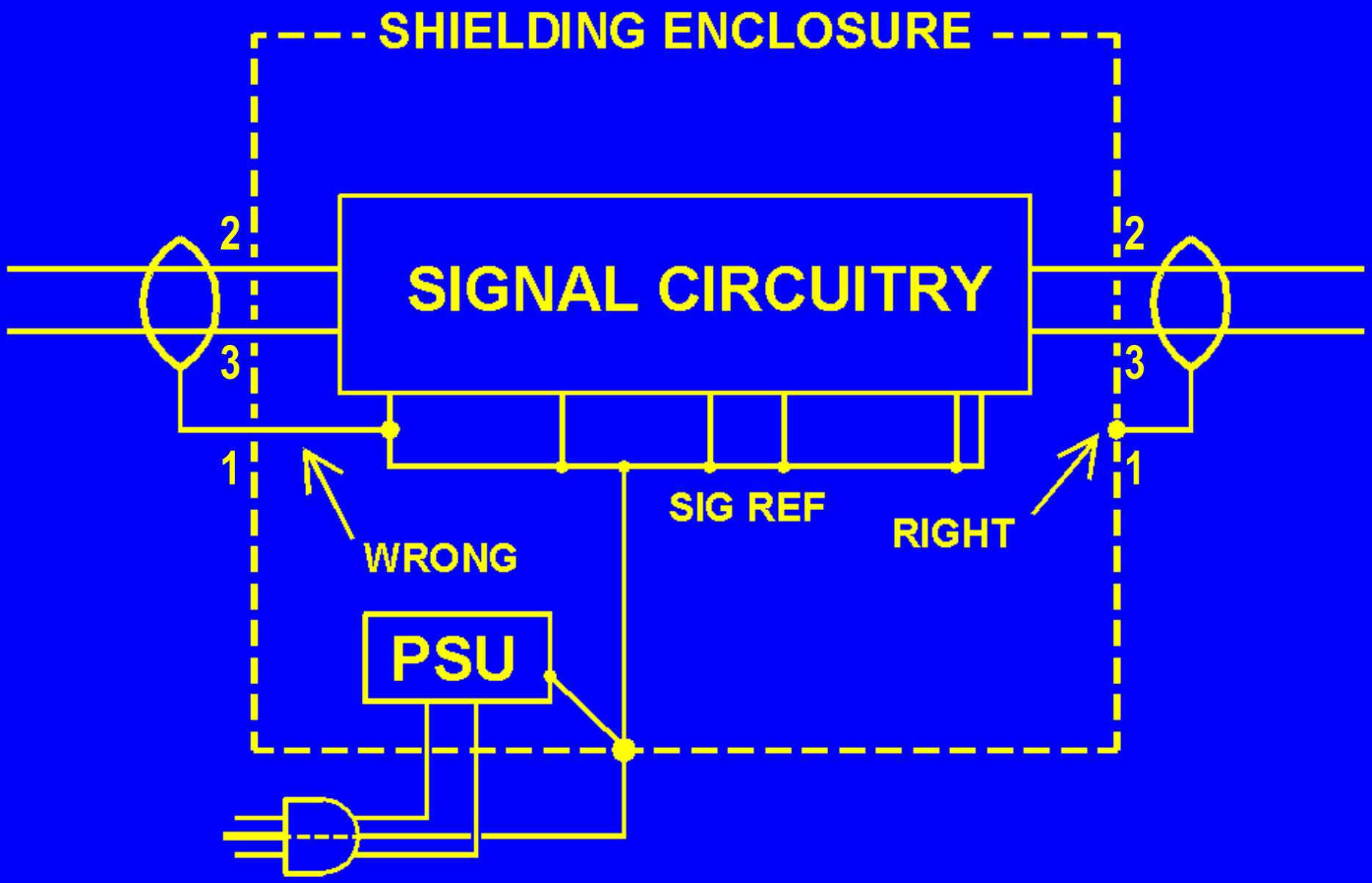
- Computer generates AFSK RTTY signal, sends to rig
- Rig sends received RTTY signal to computer, which decodes it
- This setup works for PSK31, JT65, etc.

Unbalanced Interconnections

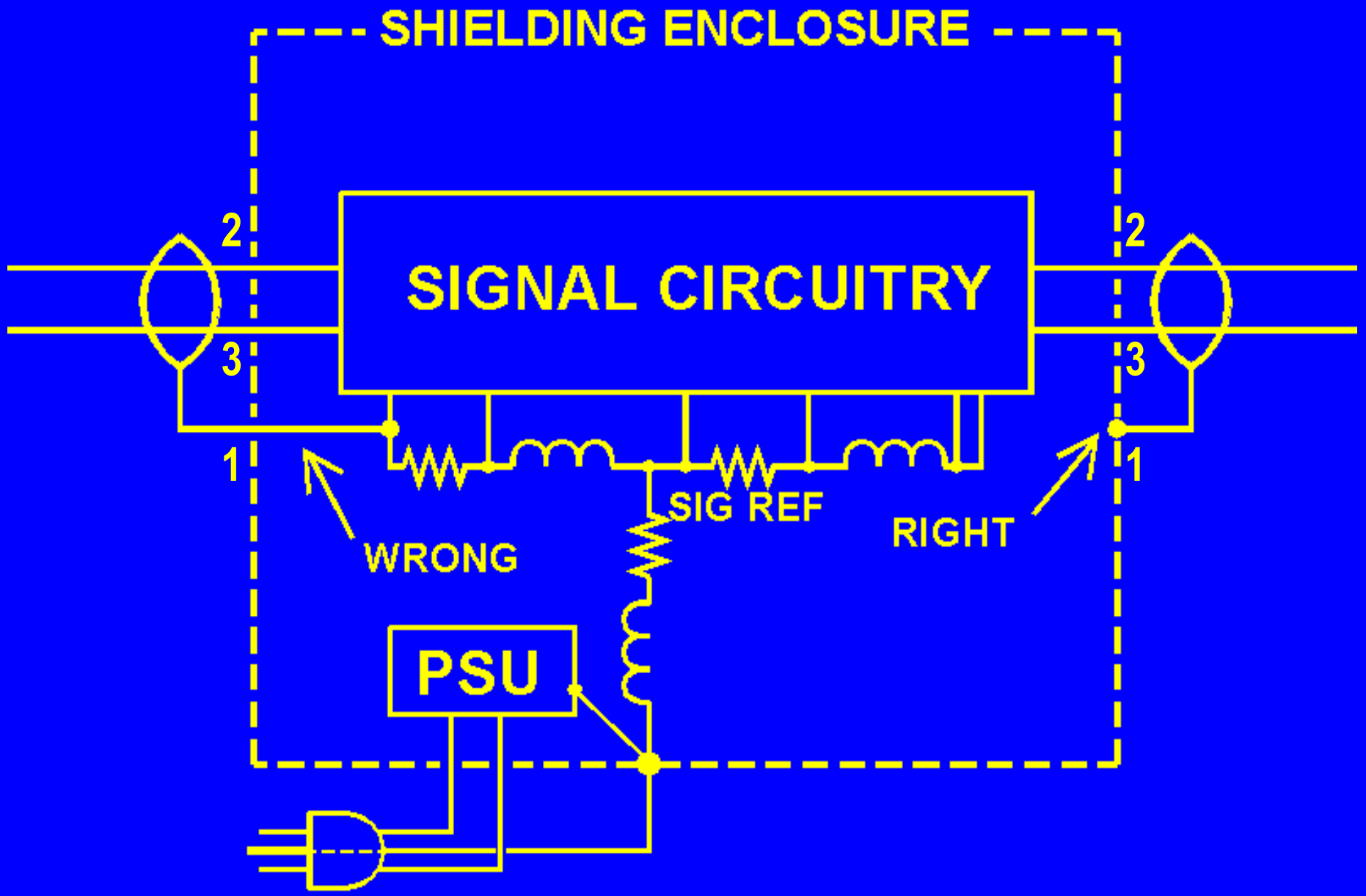
- All of our interconnections are unbalanced
  - Shields of unbalanced connections carry power system leakage currents that are added to the signal
  - Shields act as antennas, pick up our transmitted RF
  - Pin One Problems couple RF inside the box, where it is detected

What's A Pin One Problem?

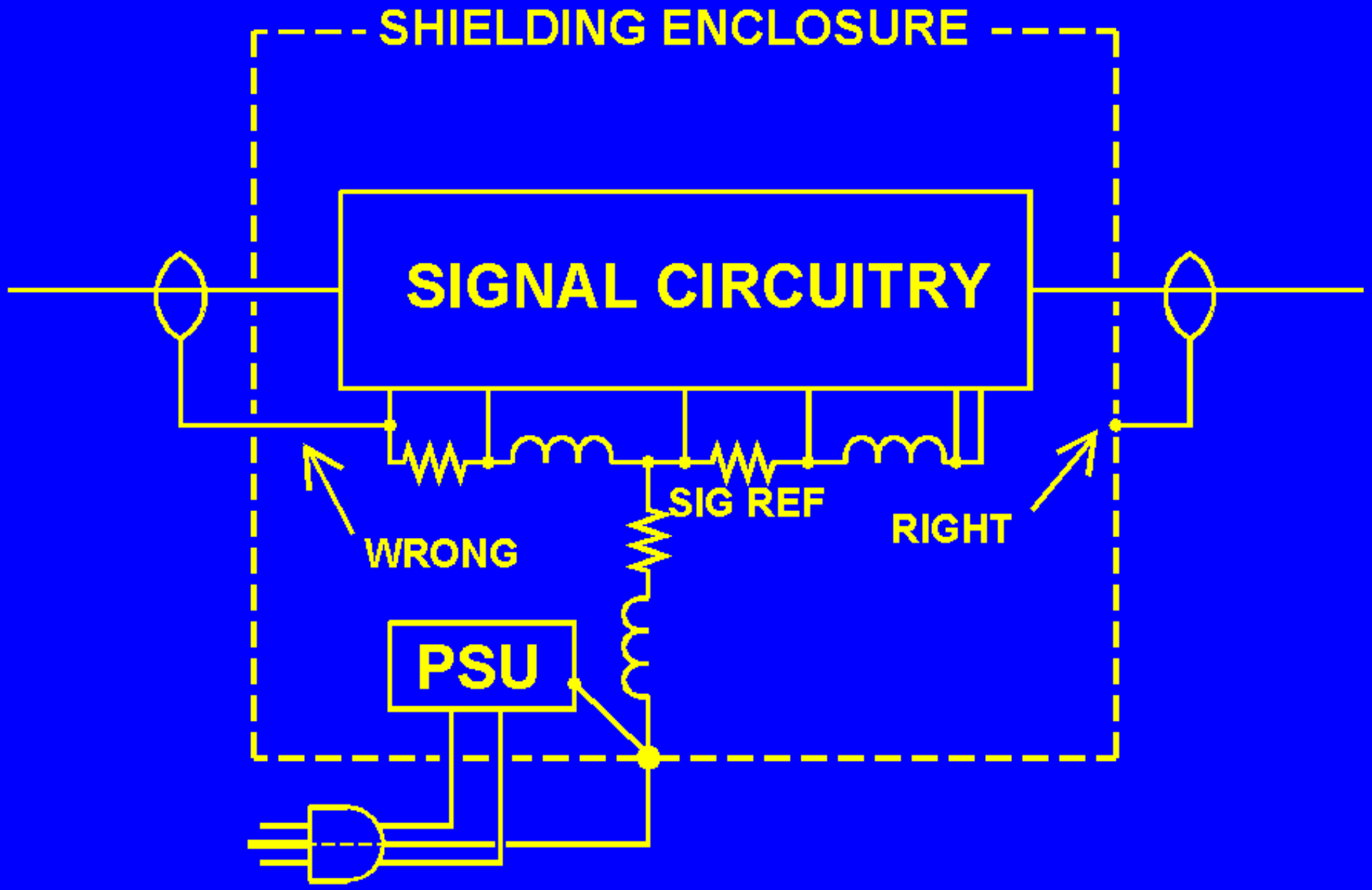
Pin 1 Problem in Balanced Interfaces



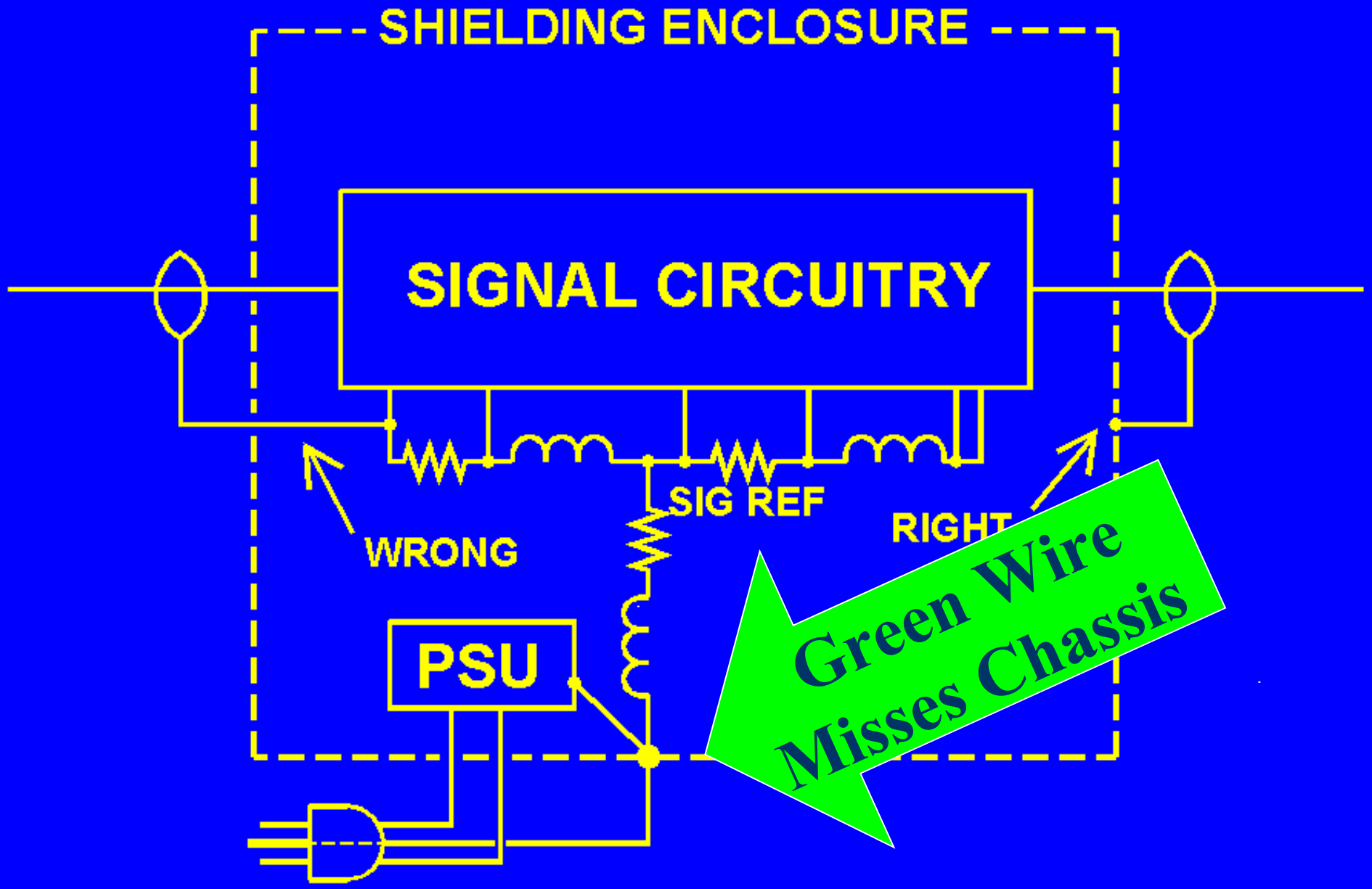
Pin 1 Problem in Balanced Interfaces



Pin 1 in Unbalanced Interfaces



"*Green Wire*" Pin One Problem



Most RFI is caused by Pin 1 Problems!

That Includes “RF in the Shack,” AKA “RF Feedback!”

Nearly All Equipment Is Built With Pin 1 Problems

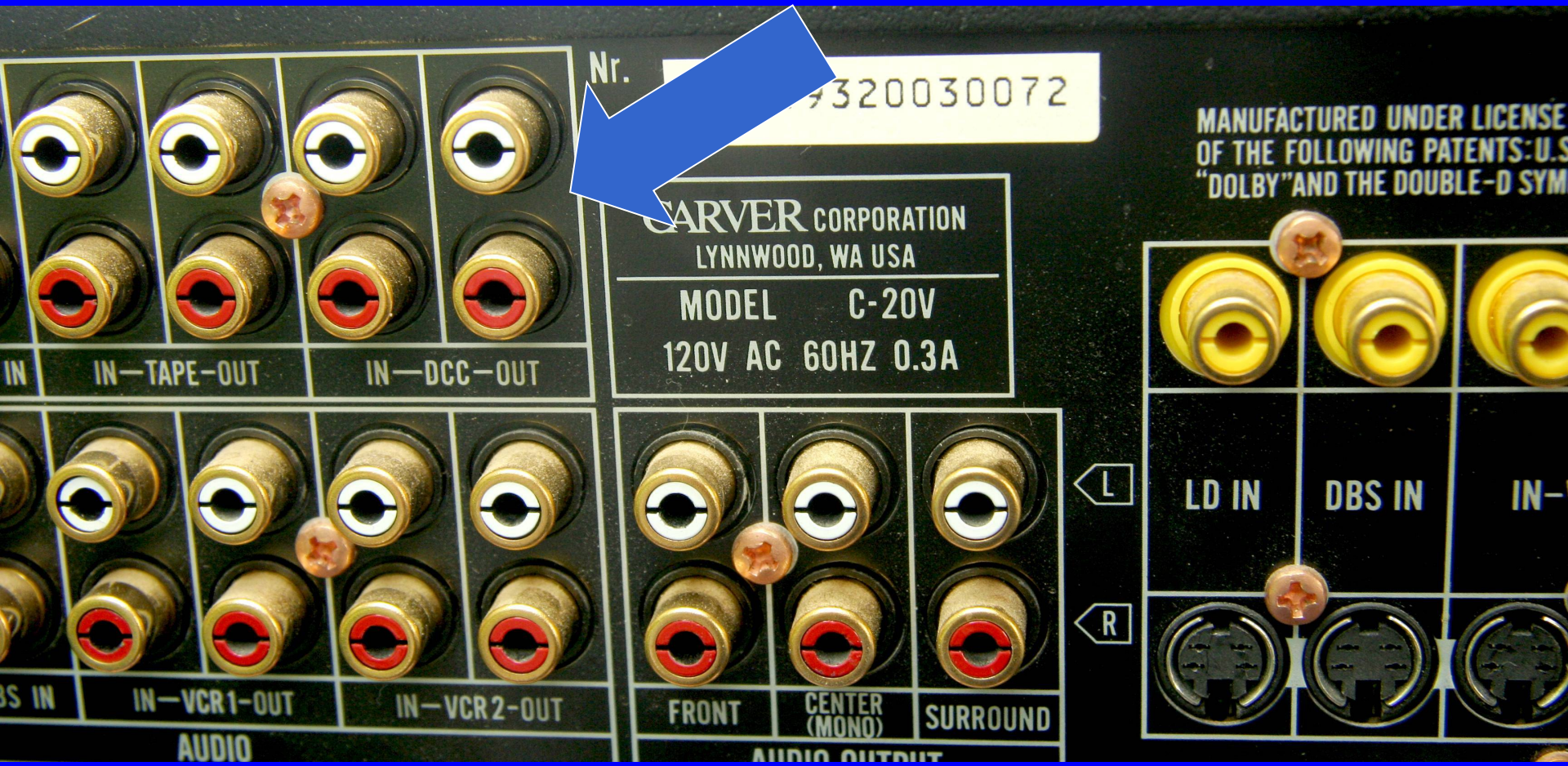
- Audio and Video Gear
  - Home and Pro Audio Systems
  - TV Sets, Video Recorders, Cable Boxes
- Computers and Accessories
- Ham Rigs and Accessories
- Telephone Equipment

How Do Pin 1 Problems Happen?

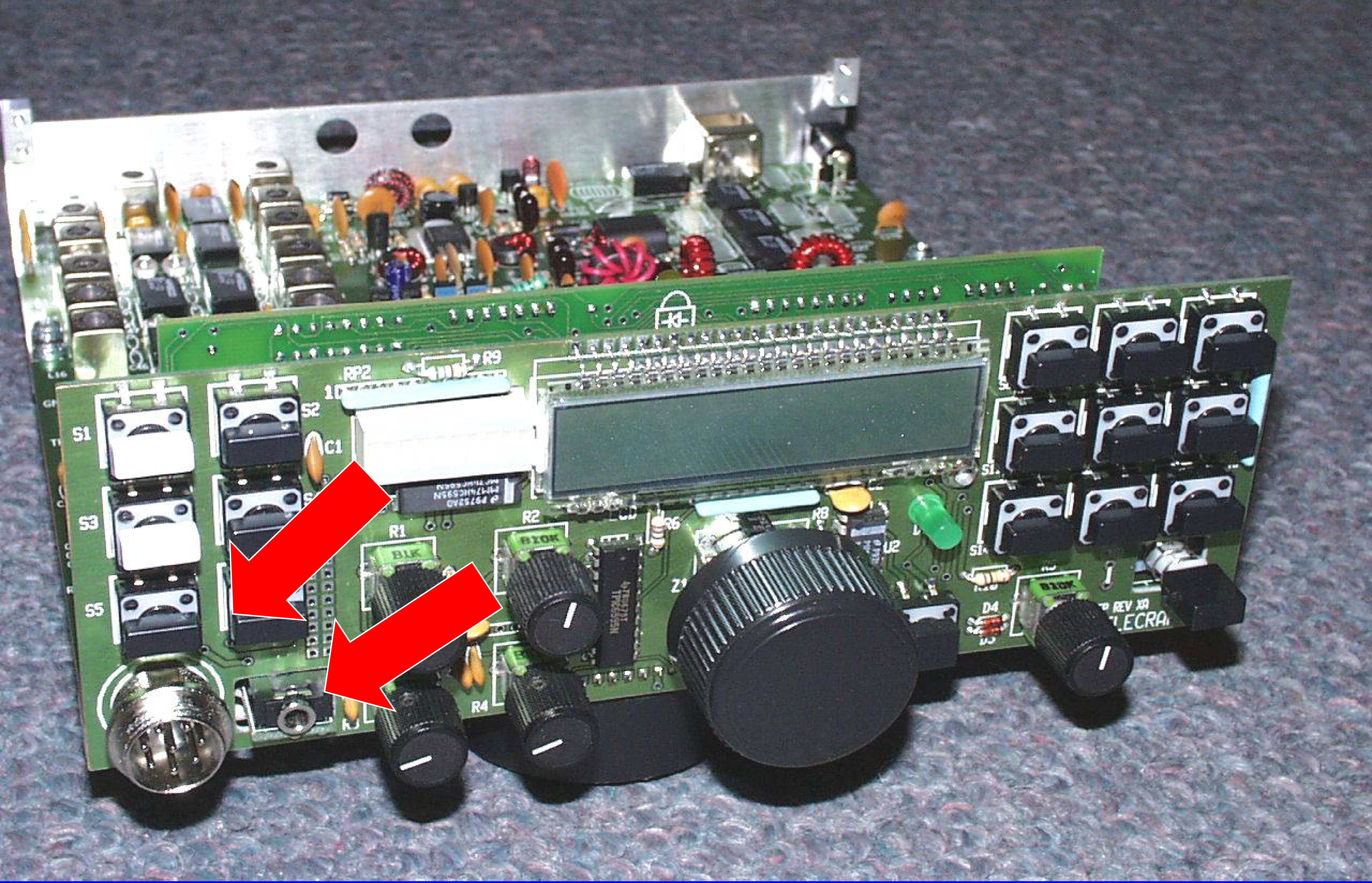
- Connectors mounted to PC board
- Shell not bonded to chassis
  - Should be, but is not – that costs more!
- Often very difficult to fix
- All inputs and outputs are usually wrong
  - Audio and video
  - Serial and USB interfaces
  - Control wiring

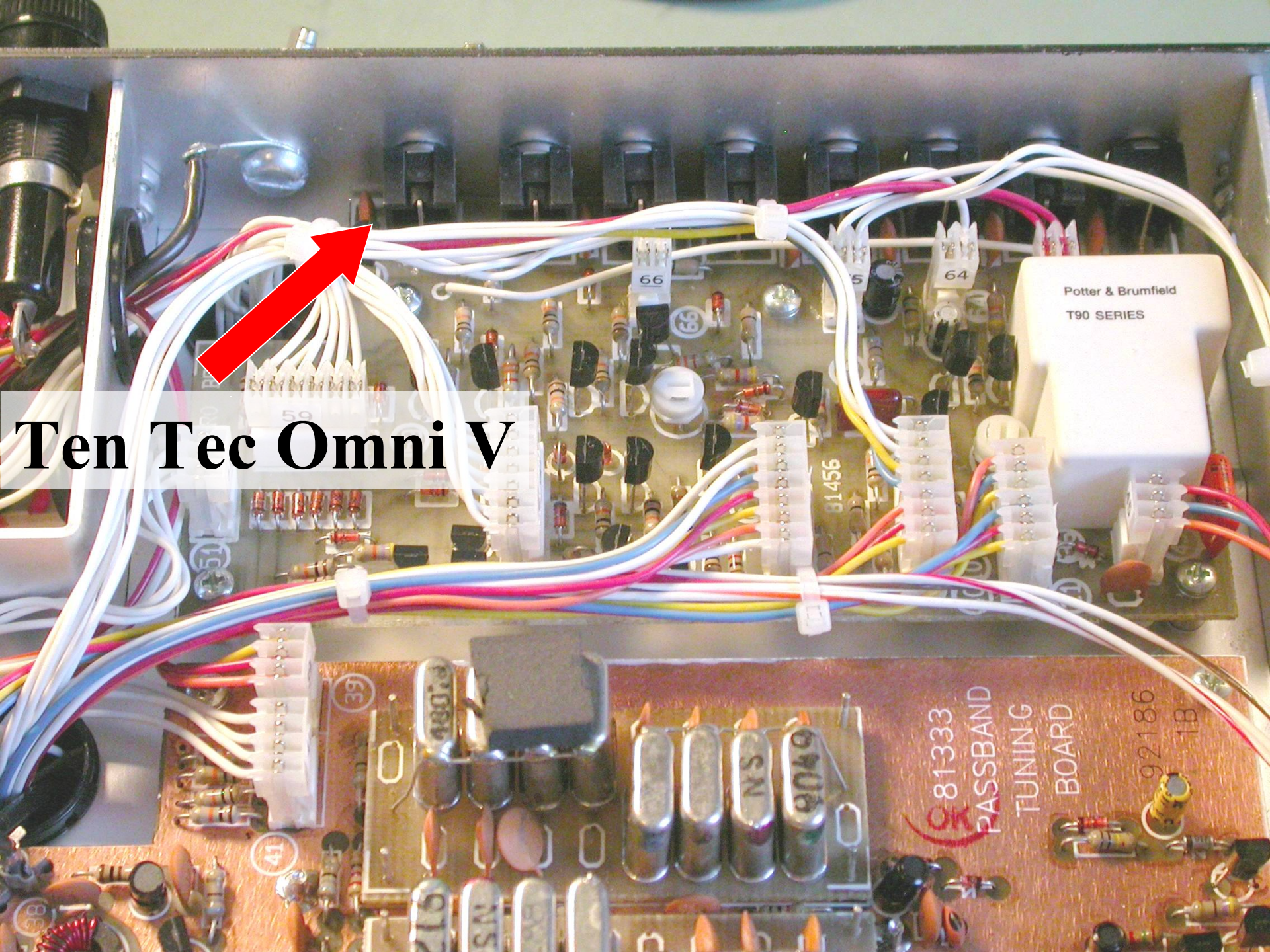
How Do Pin 1 Problems Happen?

Insulating rings around connectors prevents chassis contact!



Nice Radio, Has Pin 1 Problems


S1
S2
S3
S5
C1
RP2
R9
R1
R2
R4
R8
U2
Z1
D4
BLK
REV XA



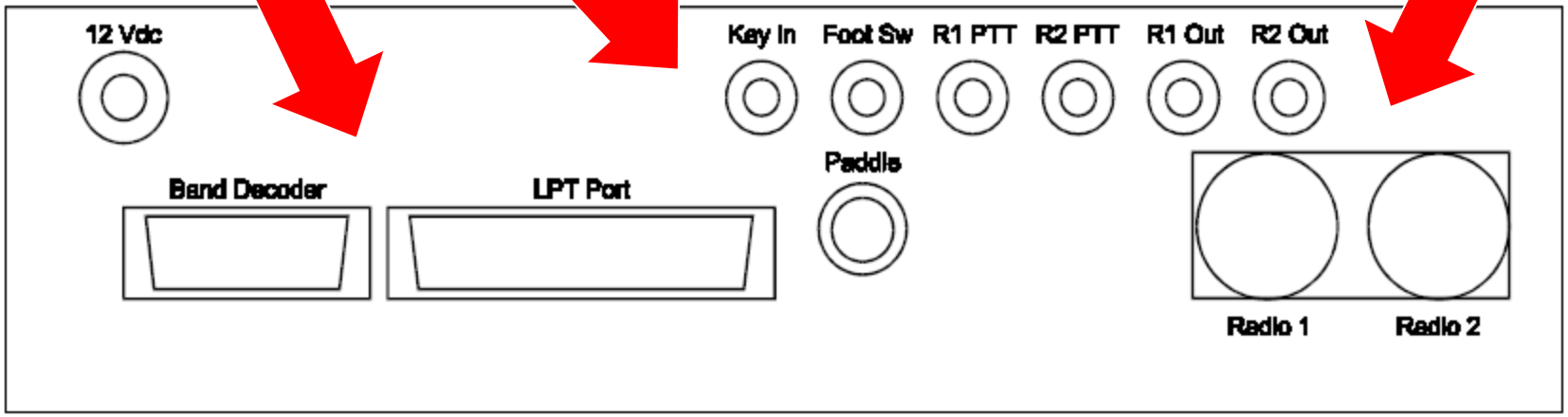
Ten Tec Omni V

A Pin 1 Problem in FT-1000MP

RF Feedback on 75 and 15 Meters

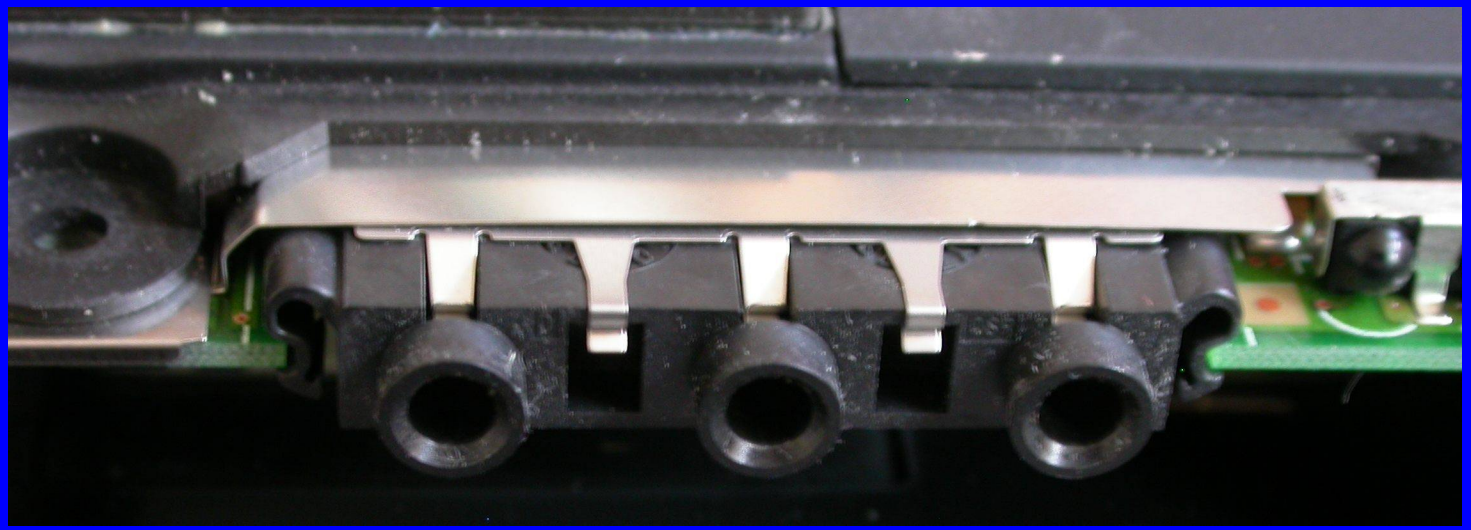
Multiple Pin 1 problems cause hum, buzz, and probably RF feedback

Rear Panel C ections



Where are the Chassis Connections for this laptop's sound card?

- Hint: It isn't an audio connector shell!
  - They should be, but they are not!



Where are the Chassis Connections for this laptop's sound card?

Yes, it's the DB9, DB15, and DB25 shells!

Pin One Problems in Elecraft KX3

- Only the mic and BNC connectors are bonded to the chassis

Dayton 2014 Booth Survey

- Rigs With Apparent Pin One Problems
  - Yaesu (all I could look at)
  - Kenwood (all I could look at)
  - ICOM (all I could look at)
  - Ten Tec (all I could look at)
  - Elecraft (K3, KX3)
  - Many (most?) other booths
  - Flex (most models)
  - ANAN Radios

Green Wire Pin One Problems

- Astron Power Supplies
  - Green Wire goes to Terminal Strip insulated from chassis by paint
  - More about Astron later

Killing Pin One Hum, Buzz, RFI

- Rewire/rebuild the connector
  - Wire shield to the chassis, not to PC board
  - Bond connector to chassis, not to PC board
- Can cause other problems because it changes the return circuit
- Can be a real can of worms
- NOT recommended unless you want to own any of those problems

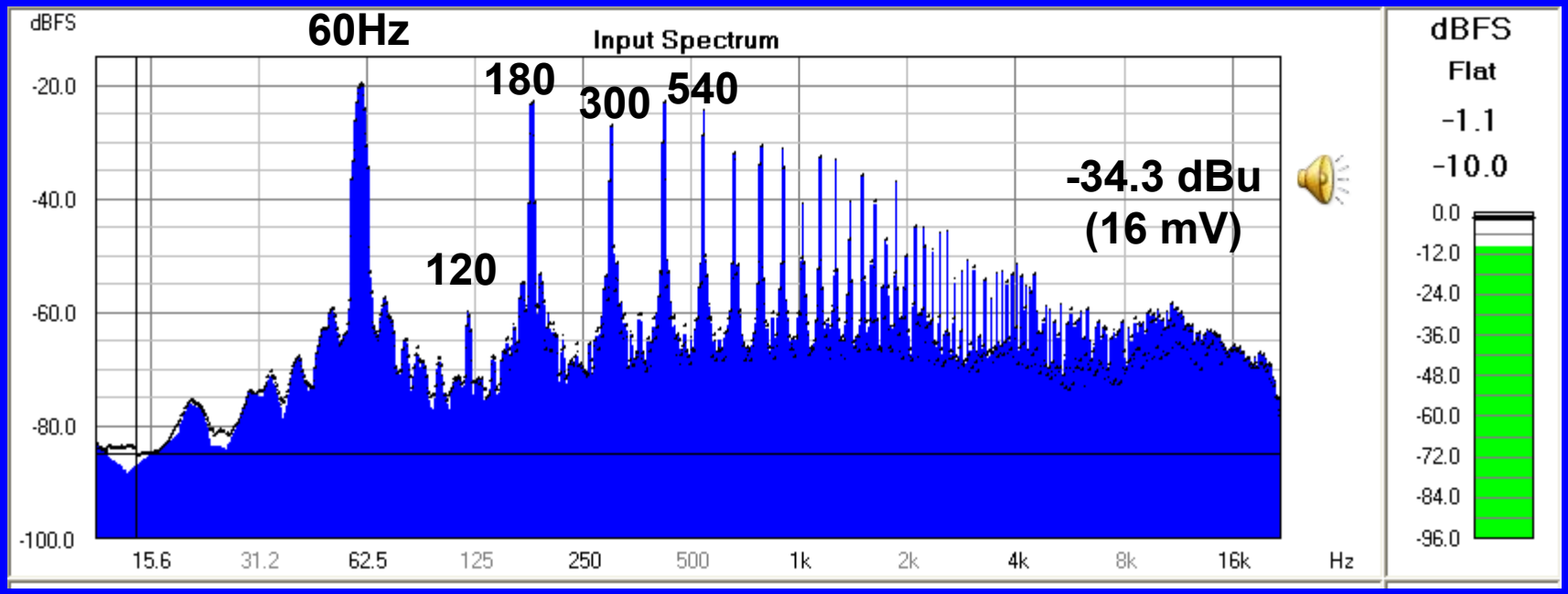
Killing Pin One Hum, Buzz, RFI

- Kill the current
  - Add a common mode choke to make the wiring a lousy antenna
  - Short out the current (chassis bonds)
  - Kills voltage that causes current flow
- This the best approach by far
- My rule with hum, buzz, and RFI is ALWAYS STAY OUTSIDE THE BOX

The Unbalanced Interface

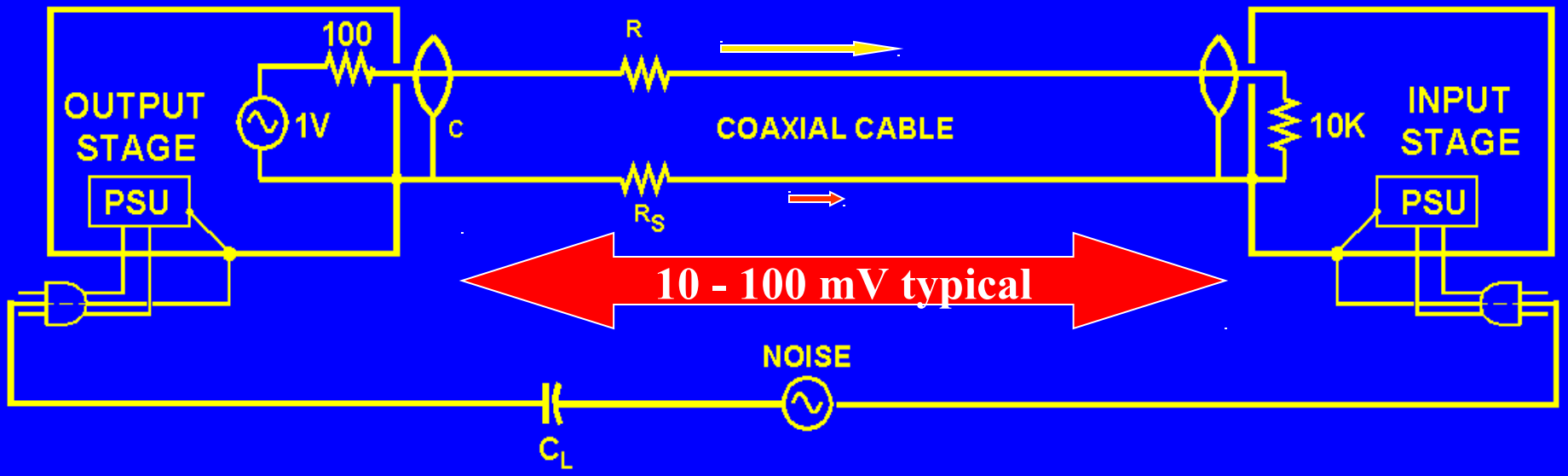
Preventing Hum and Buzz

Typical Noise Spectrum on “Ground”



Measured between two outlets on opposite walls of my ham shack, into a high impedance

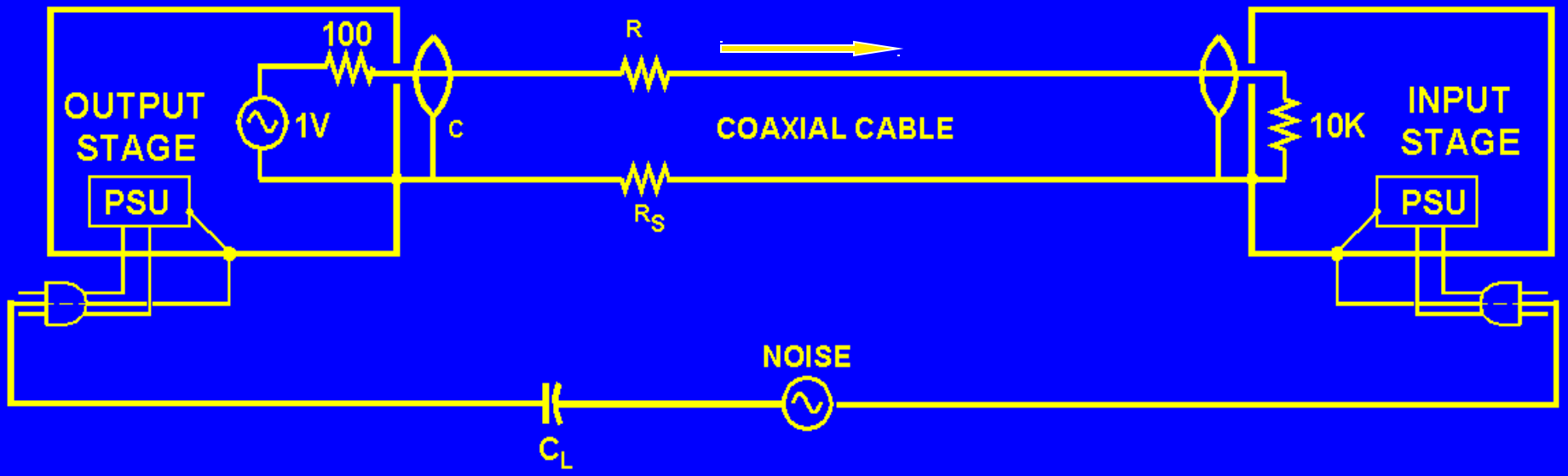
The Problem with Unbalanced Interfaces



Noise current flows on the shield, and the IR drop is added to the signal.

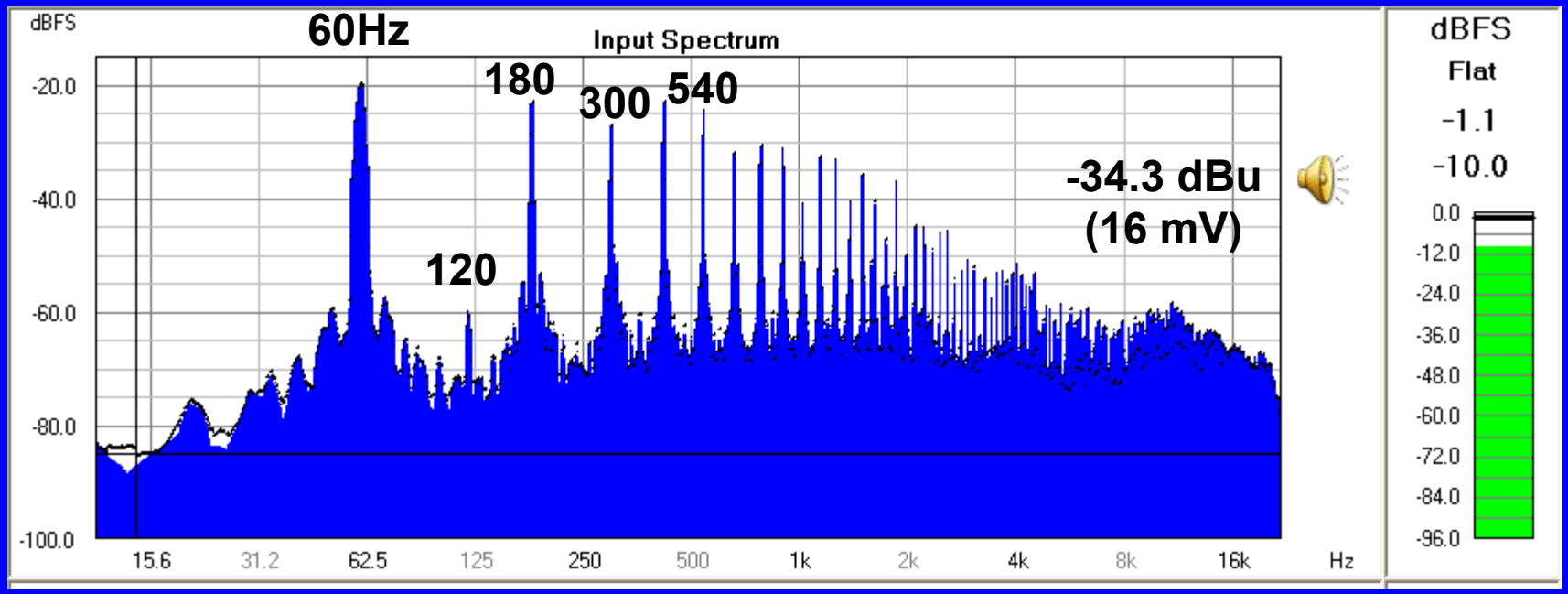
Any voltage between the two chassis is added to the signal.

The Problem with Unbalanced Interfaces



- Input stage is high impedance, so very little signal current through R, R_S, and 10K
- Resistance of center conductor doesn't matter
- Noise current flows on the shield
  - Resistance of the shield is very important
  - Hi-fi cables have lousy shields

Typical Noise Spectrum on “Ground”



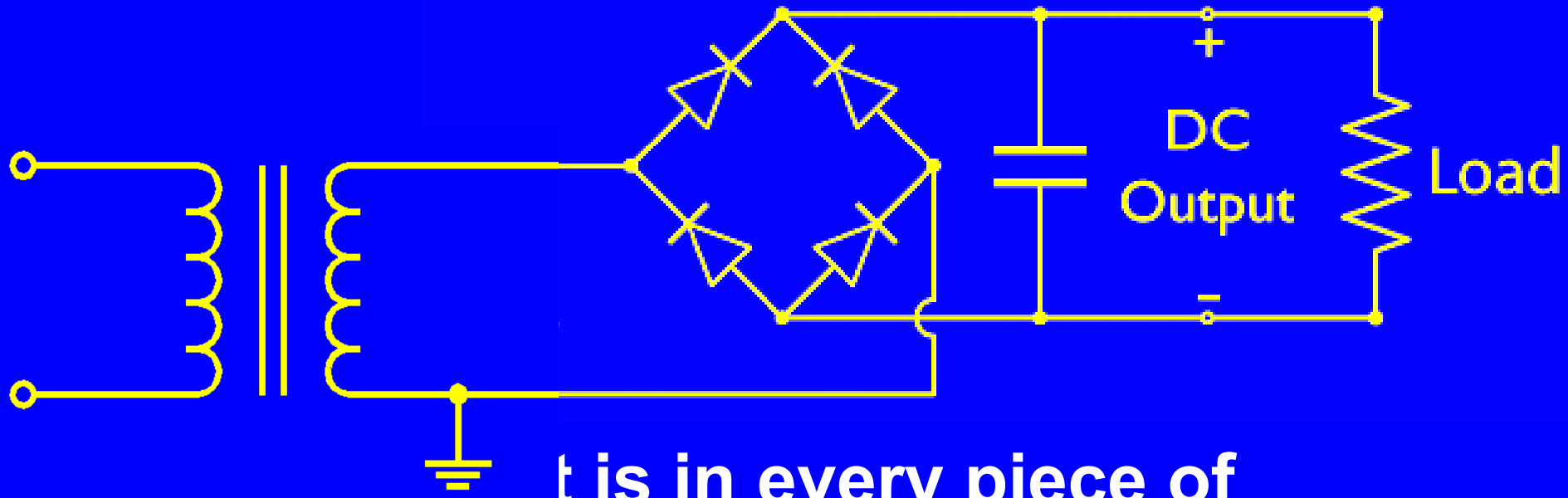
Measured between two outlets on opposite walls of my ham shack, into a high impedance

That’s Not 60 Hz!

- Where did all those harmonics come from?

The Harmonic Problem

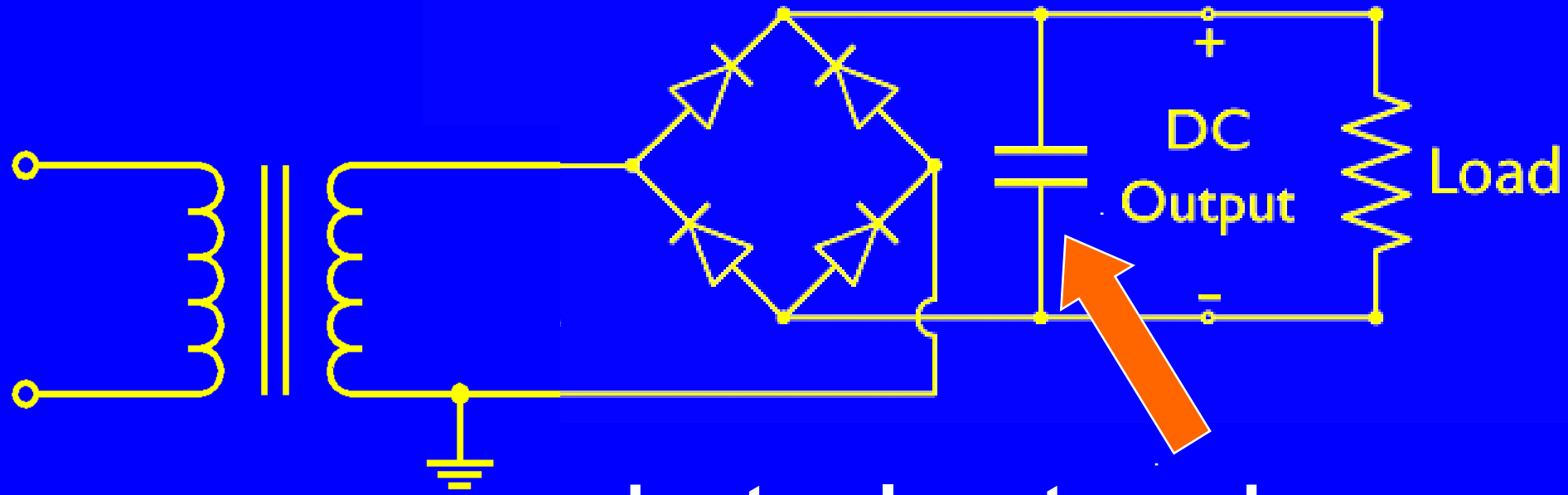
Recognize this power supply?



t is in <u>every</u> piece of electronic gear – computers, audio, video, printers, copiers (even switching power supplies)

The Harmonic Problem

Recognize this power supply?



Current flows in short pulses to recharge the filter cap on each half cycle

Current is not even close to a sine wave

The Harmonic Problem

- Nearly all electronic loads have power supplies with capacitor-input filters

so:

- Load current is drawn in short pulses at peaks of the input sine wave

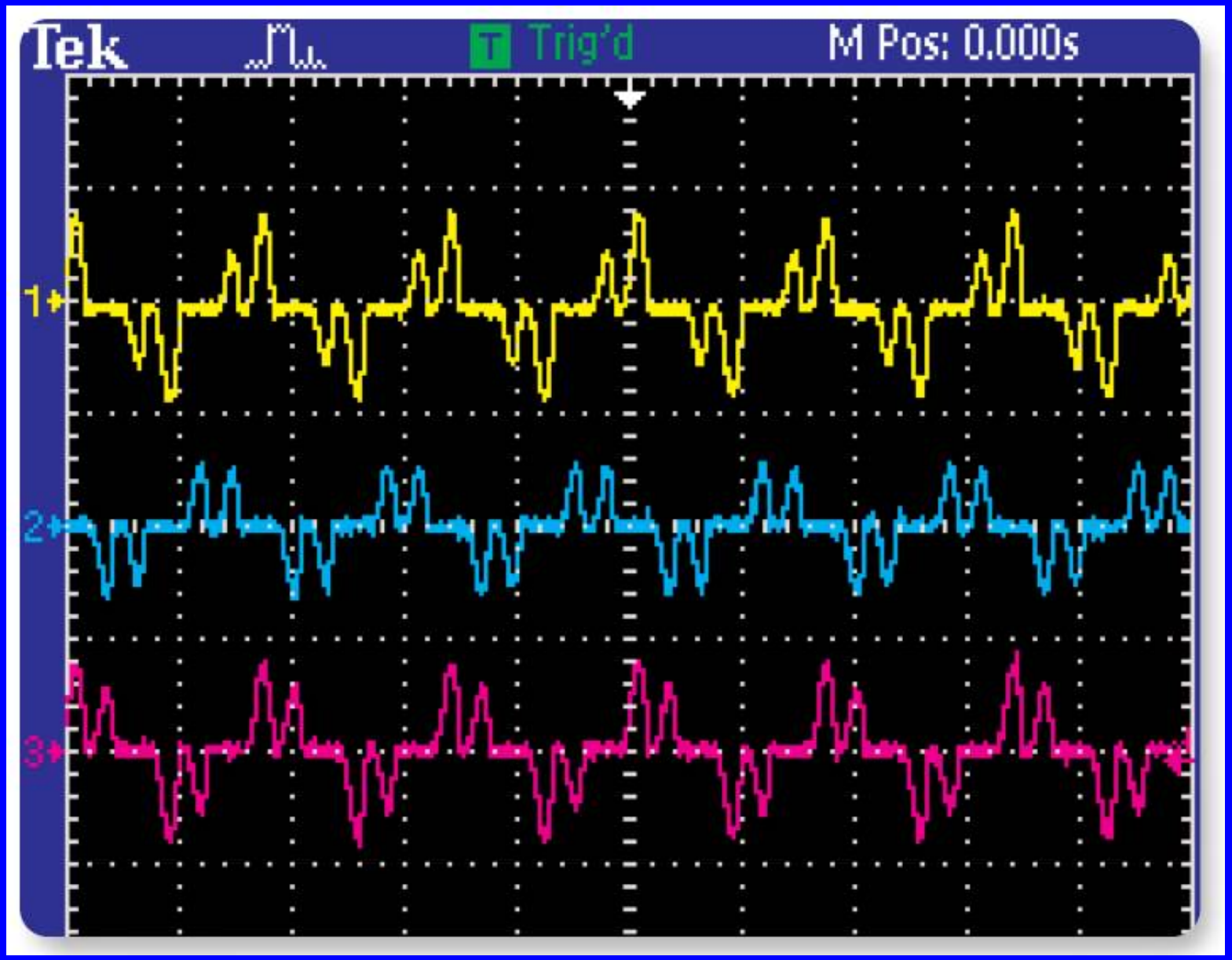
thus:

- Phase, neutral, and leakage currents are highly distorted
- Distortion => harmonics

Problems With Pulse Currents

- Because current flows in short pulses, the IR drop at the peak of the current waveform can be much greater than for a sine wave
  - Greater I^2R losses
  - Voltage waveform is distorted
  - Lower voltage delivered to equipment
  - Increased dissipation in phase and neutral conductors
  - Increased dissipation in transformers

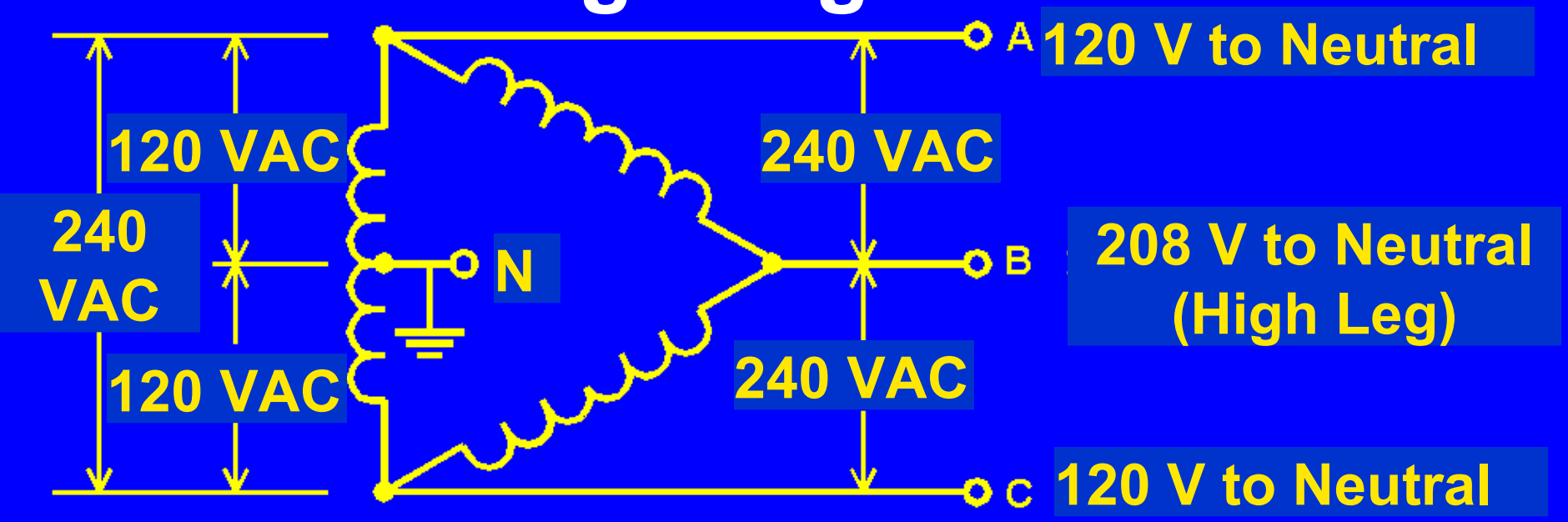
Load Currents in a 3-Phase System



But I Don't Have 3-Phase at Home!

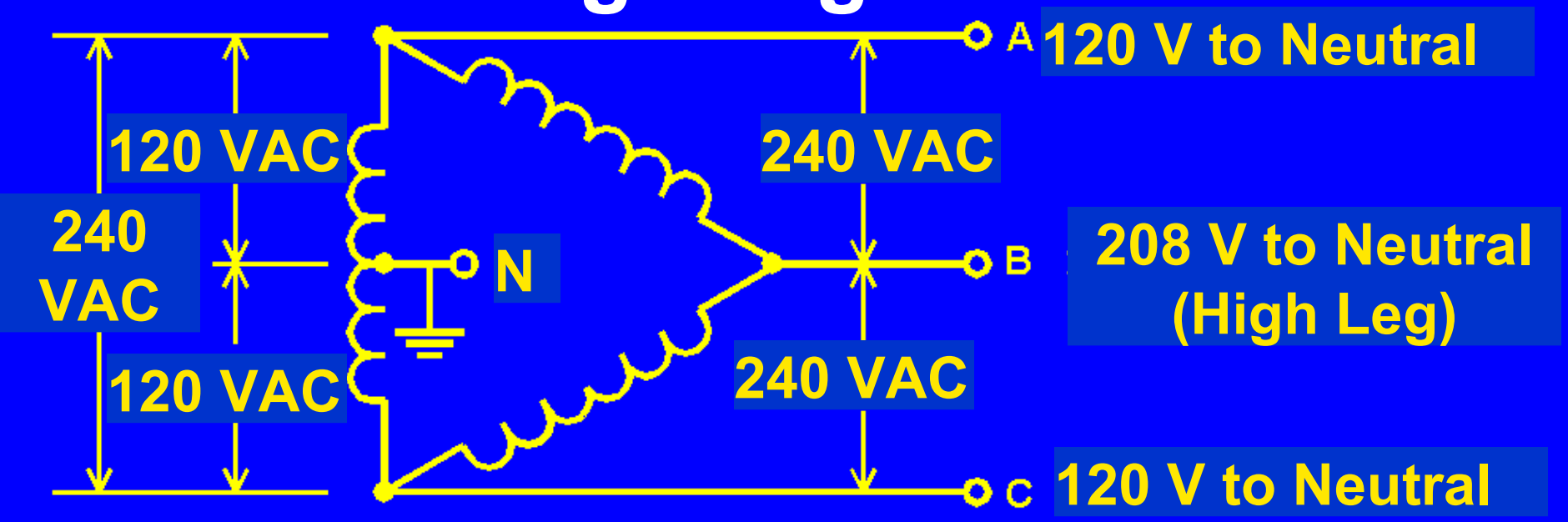
- No, but a factory or business down the street does, so you get your 120V-0-120V service from a "High Leg Delta" service in your alley!
- Much of the factory's neutral current may flow through your neutral to ground.
- High Leg Delta feeds my home in the Santa Cruz Mountains.

“High Leg” Delta



- Common in mixed industrial/residential areas where both single phase and 3-phase power are needed
  - A-N-C feeds residences (120-0-120)
  - A-B-C feeds industrial users (240-240-240)

“High Leg” Delta

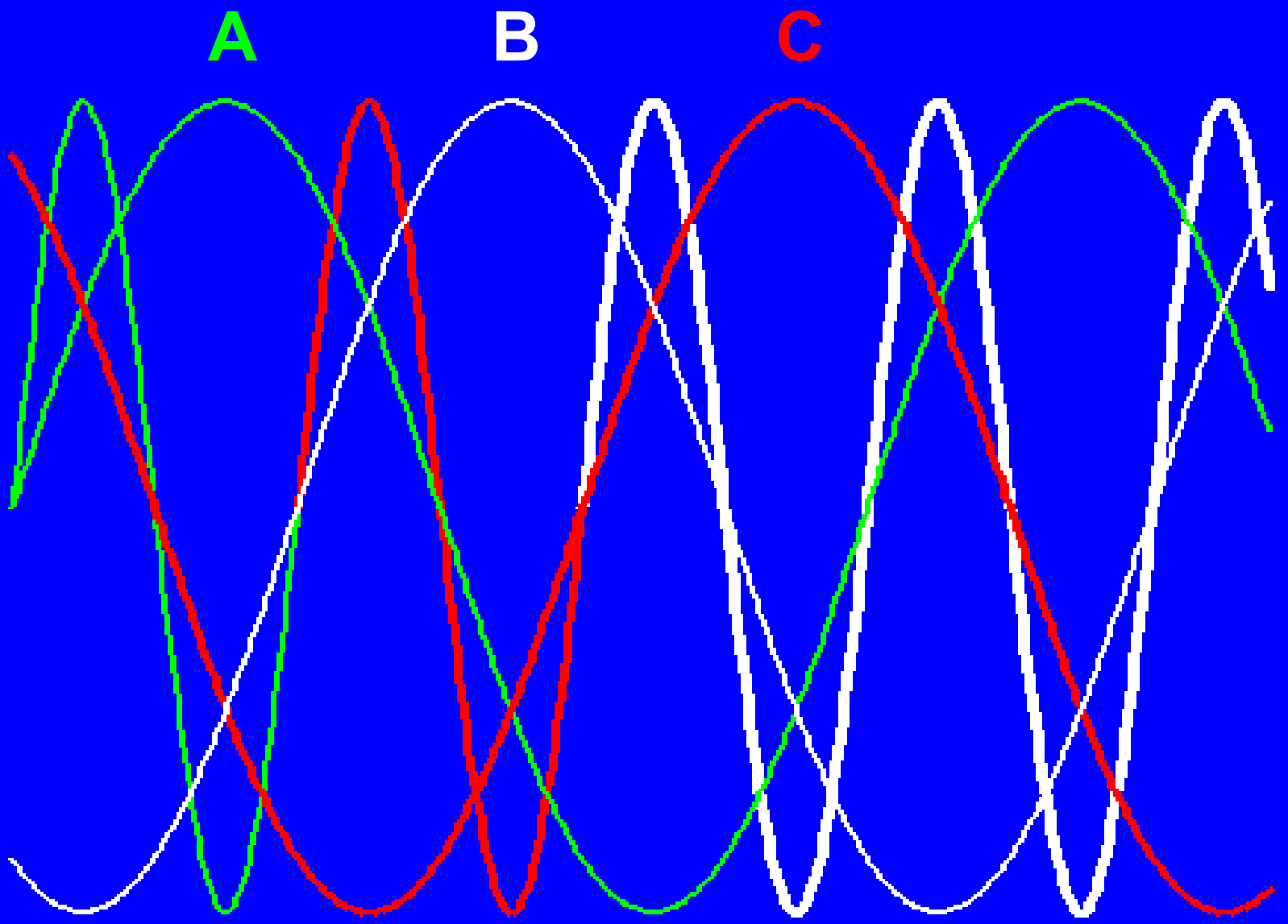


- Part of Neutral current from 3-phase customers goes to ground through single-phase residential ground connection!

Sources of Noise on "Ground"

- Capacitance from AC "hot" to ground
  - Leakage capacitance in transformers
  - AC line filters
- Magnetic induction
  - Leakage fields from power transformers
  - Wiring errors in buildings and homes
    - Double bonded neutrals
  - Leakage fields from motors and controllers
  - Variable speed drives
- 3-Phase noise current from neighbors

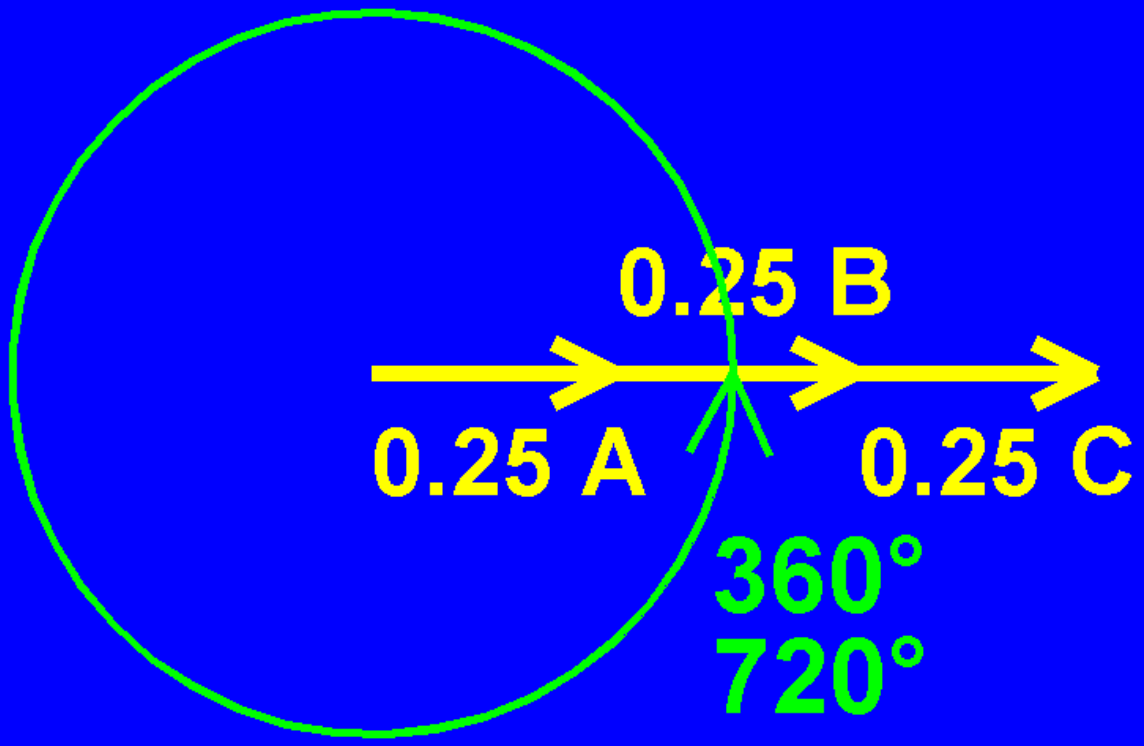
Phase Currents – Fundamentals and Third Harmonics



What Happens in the Neutral?

- Triplen harmonics ADD!
  - Third, sixth, ninth, etc
- Neutral current up to 1.7X the phase currents, even in a perfectly balanced system!
- Potentially dangerous overheating
  - Neutral conductors (and contacts)
  - Transformers
- Use bigger copper in neutrals
- Use *harmonic-rated* transformers

25% 3rd Harmonic on the Phases becomes 75% 3rd Harmonic on Neutral



In Single Phase Systems

- 120V – 0V – 120V
- If leg currents are equal (they rarely are), they cancel in the neutral

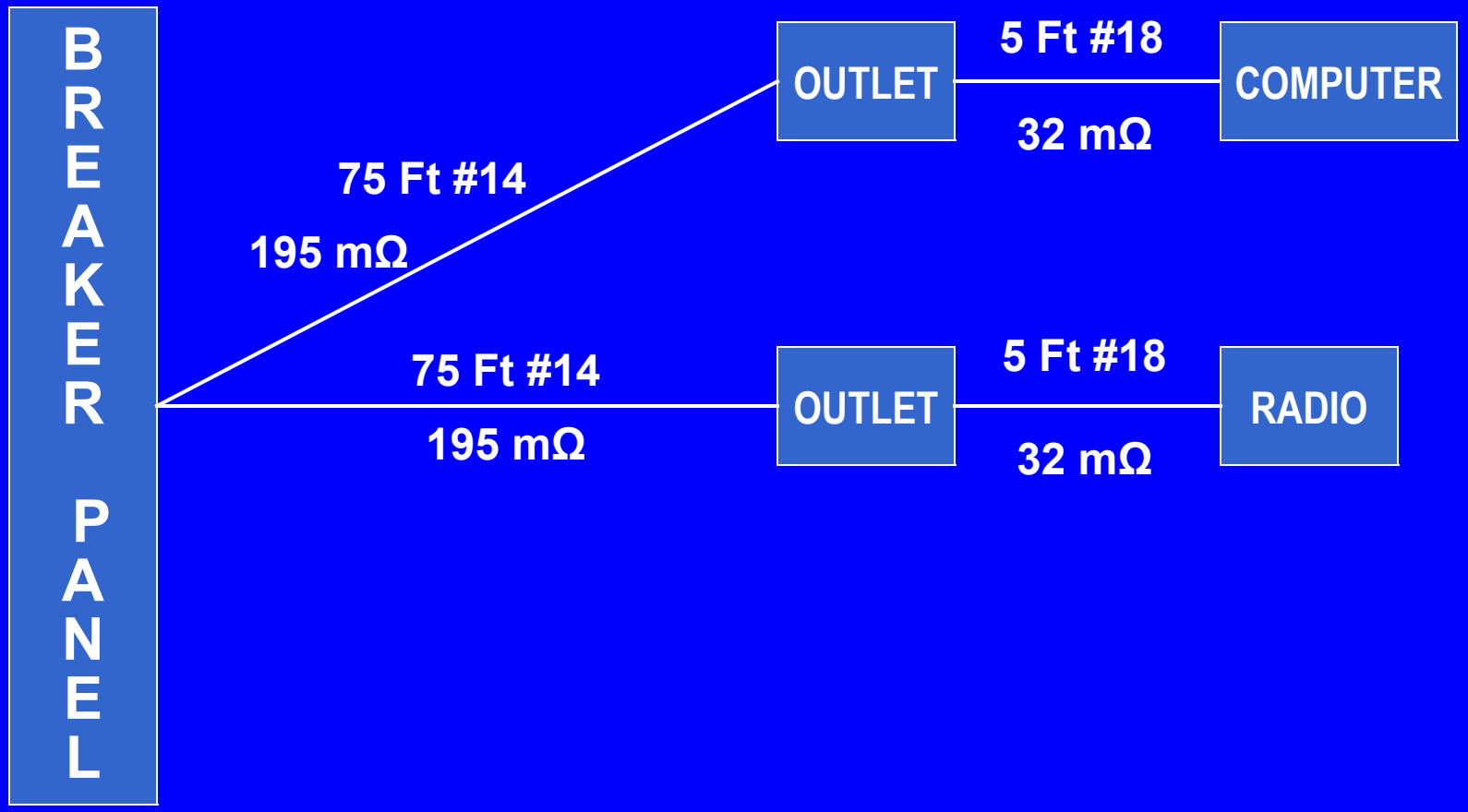
In Three Phase Systems

- If leg currents are equal, the *fundamental* and most harmonics cancel in the neutral and in the ground

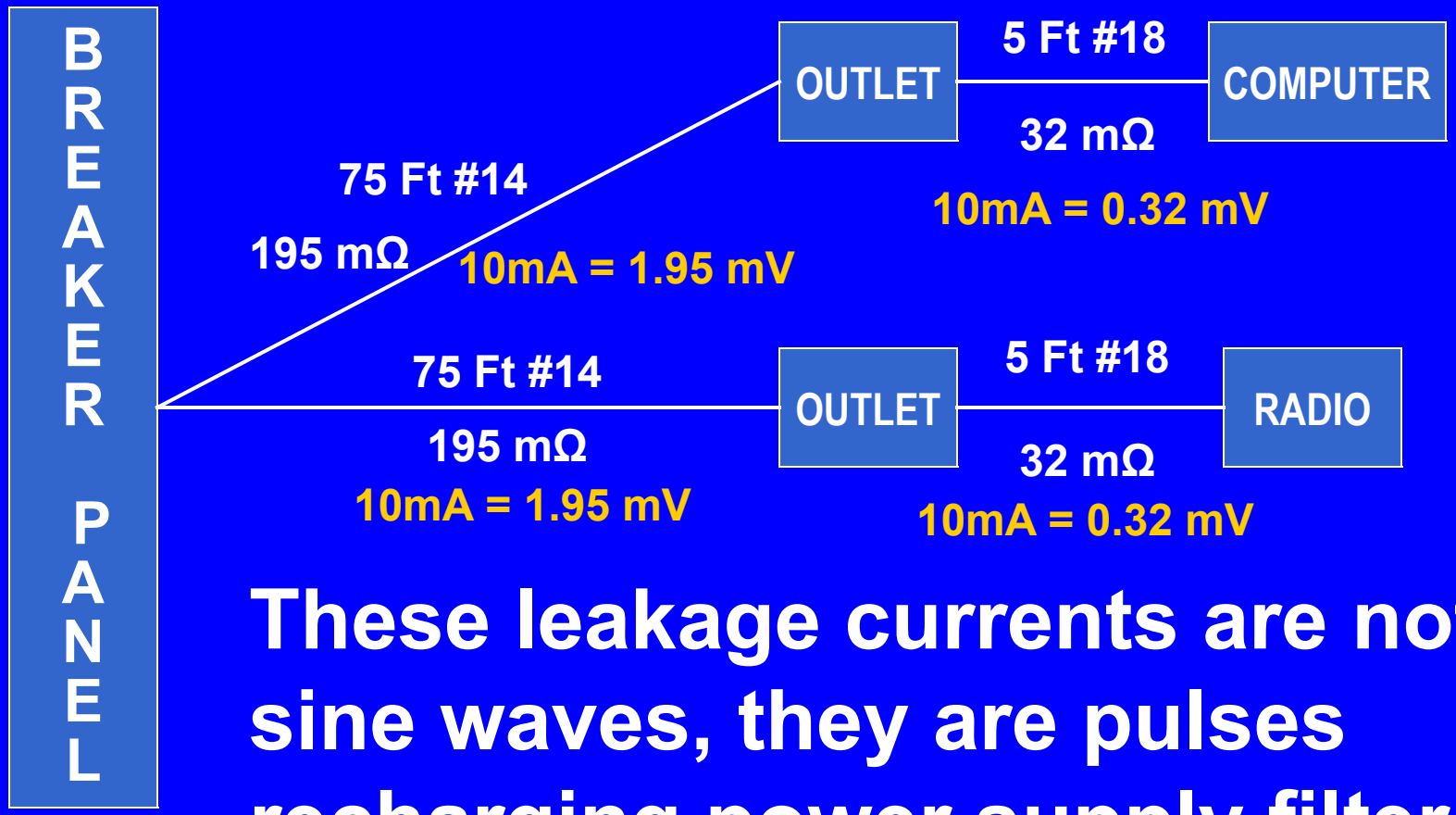
BUT:

- Triplen harmonics (3rd, 6th, 9th, etc.) ADD in the neutral and in the ground
- This tends to make 180 Hz, 360 Hz, 540 Hz, etc. dominant buzz frequencies

Our Power System Ground Wiring (The "Green Wire")

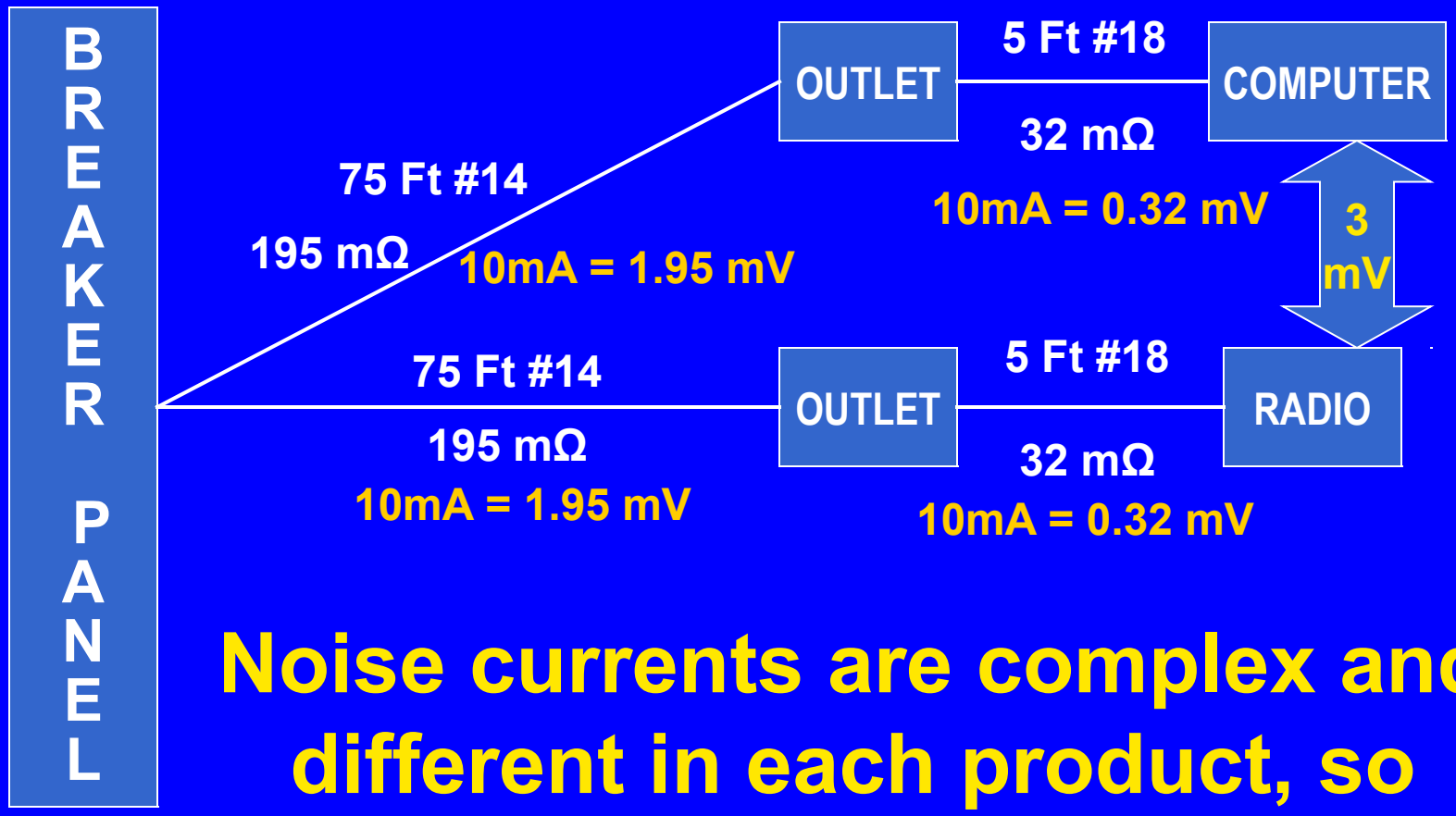


Leakage Currents On the Green Wire



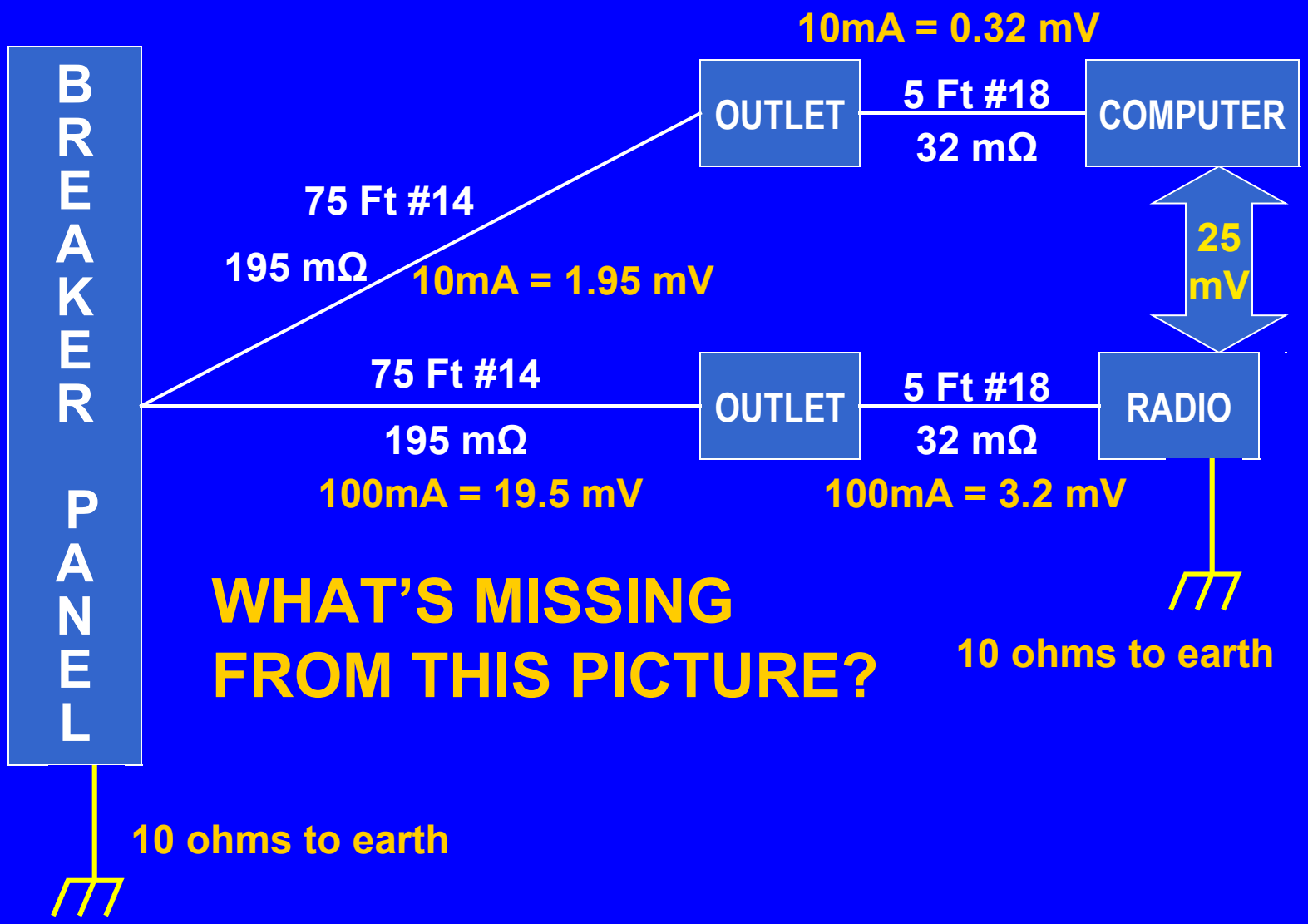
These leakage currents are not sine waves, they are pulses recharging power supply filter capacitors!

Leakage Currents On the Green Wire



Noise currents are complex and different in each product, so how they add is unpredictable

Home Power Ground Wiring (The "Green Wire")



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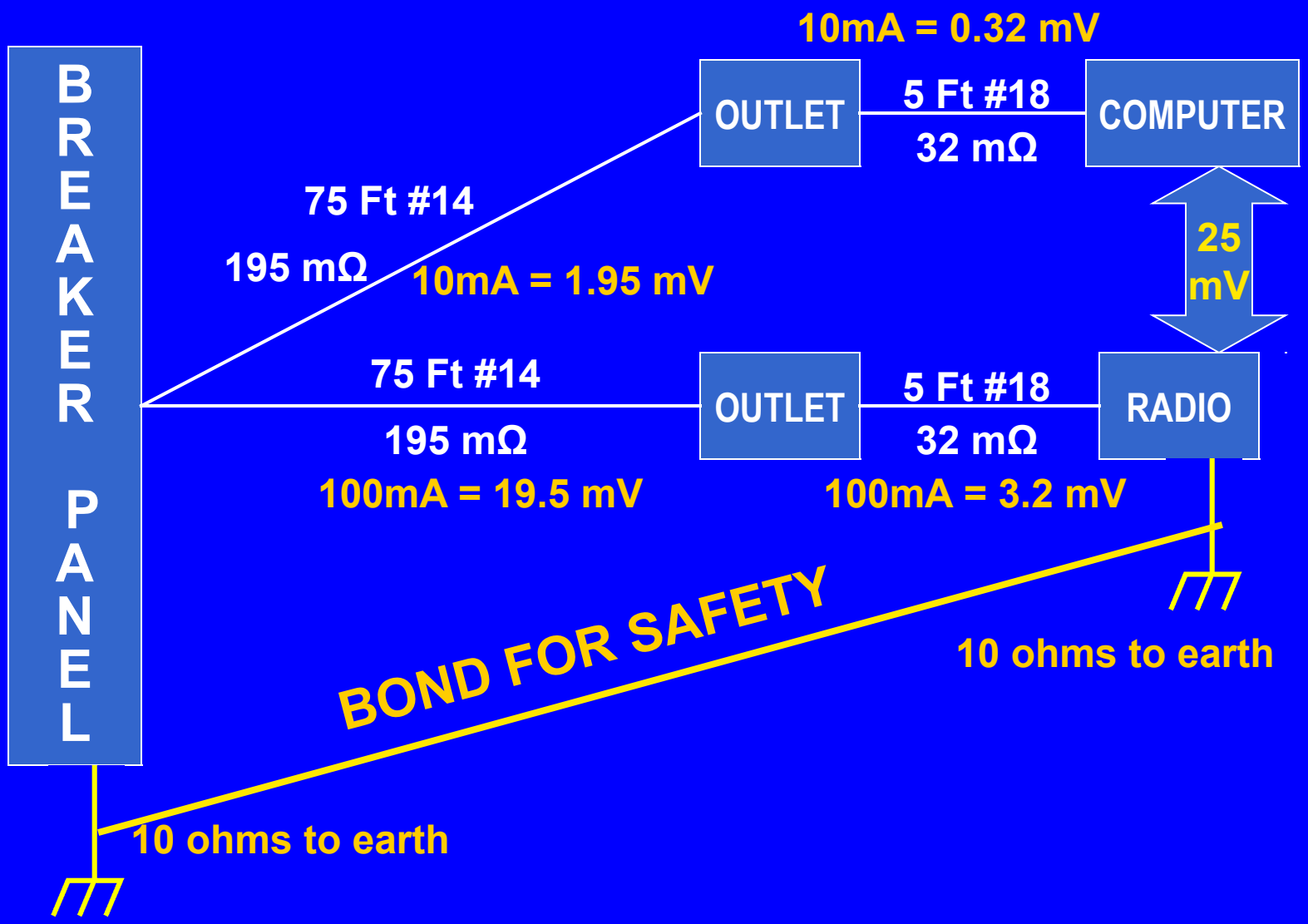

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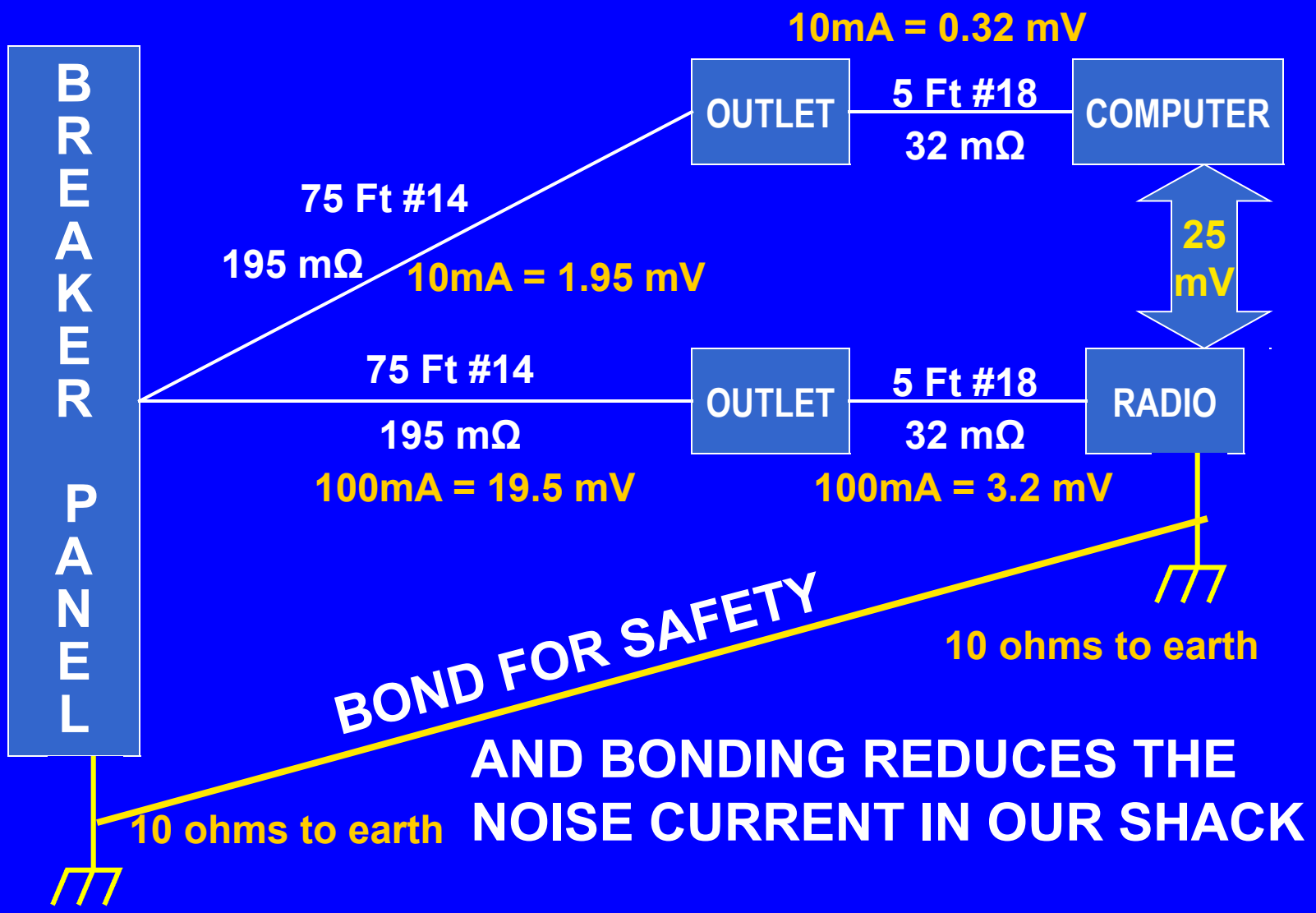
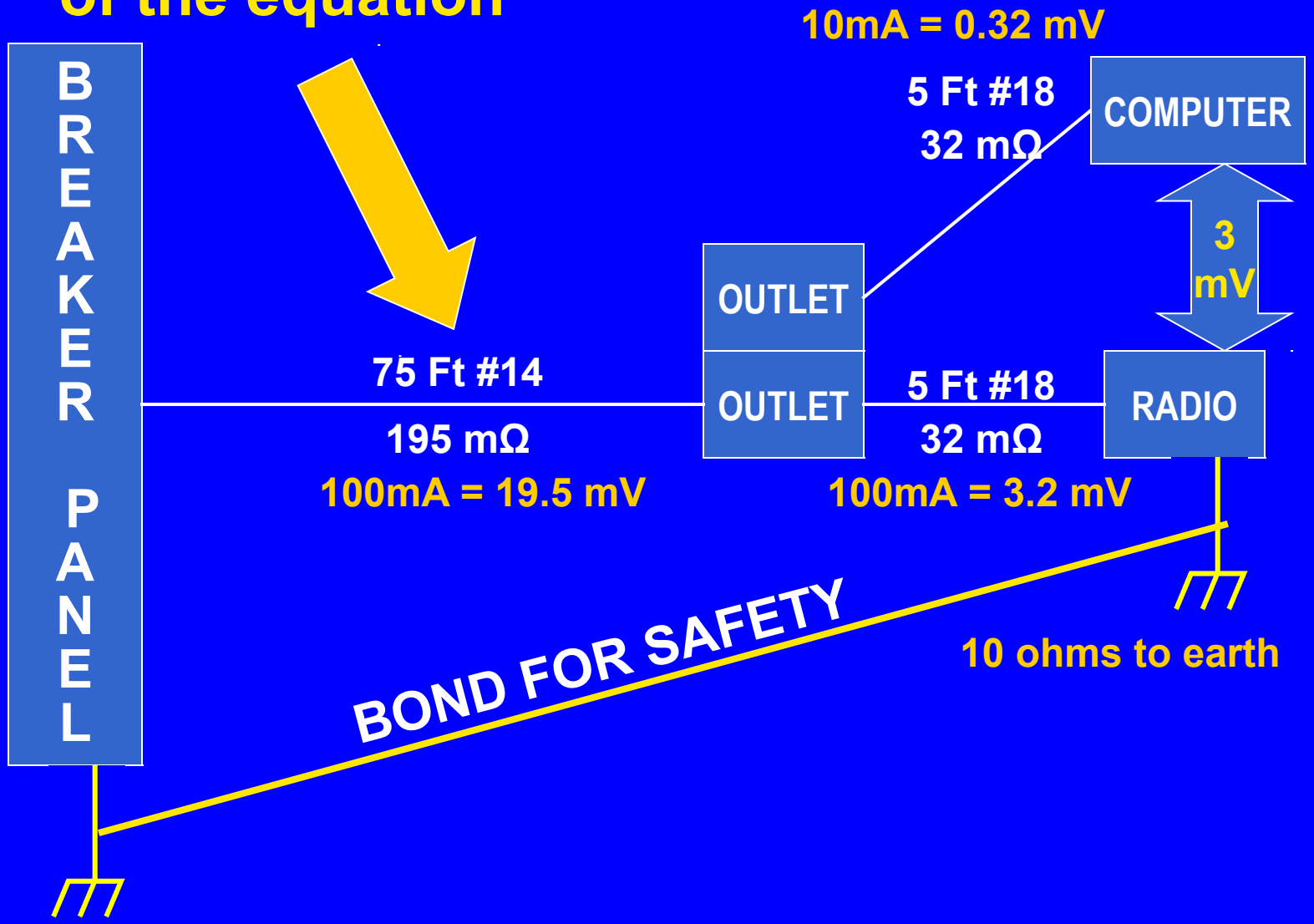


Hum/Buzz Step #1

Take this large component out of the equation

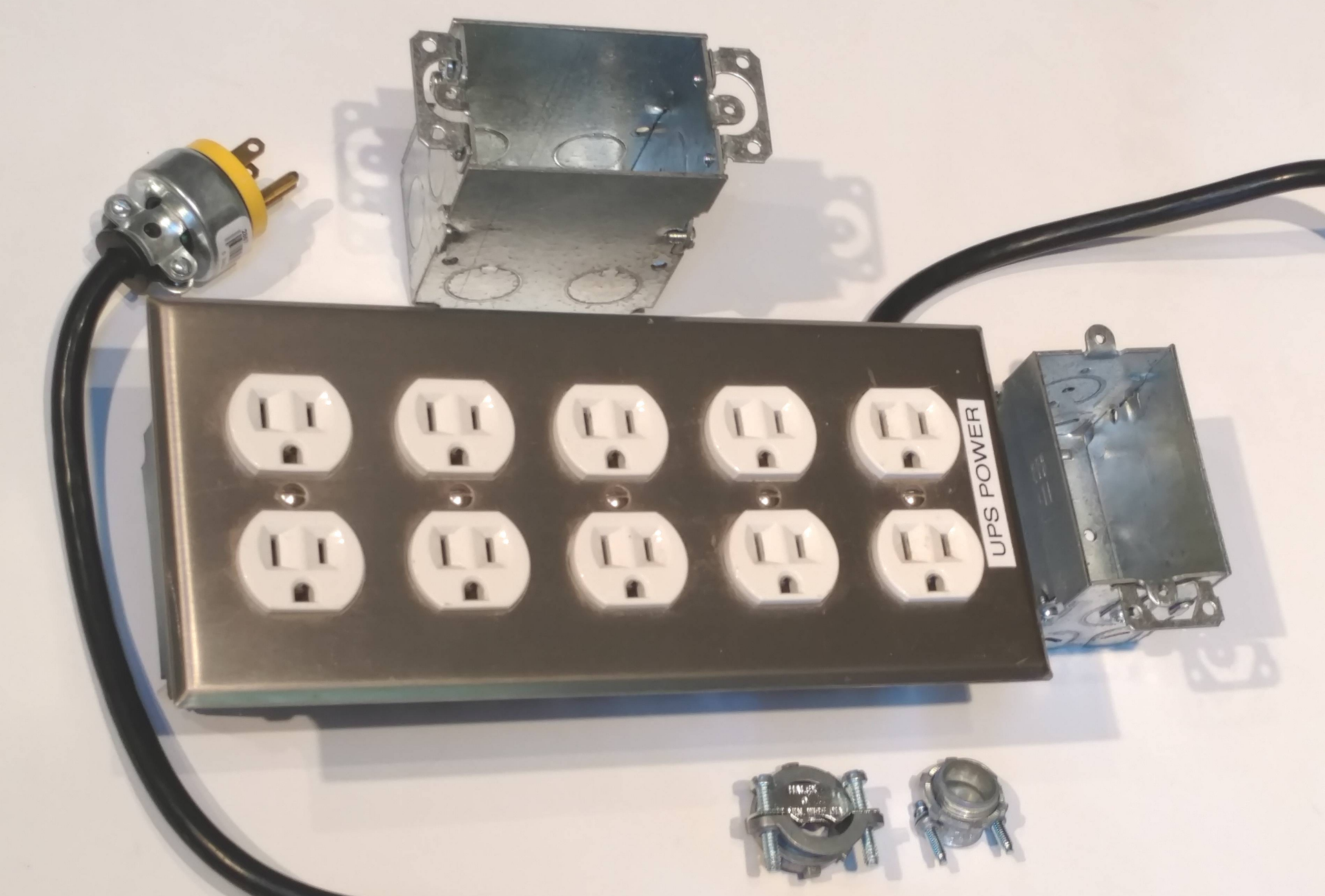


Hum/Buzz Step #1

- Get all the power for your ham station from outlets connected to the same “green wire”
  - A 15A circuit can run three 100W radios (transmitting simultaneously) and two computers
  - If you need more outlets, bolt multiple quad boxes together
  - If installing new wiring, always run #12 (or even #10) for 20A circuits
- Put 240V outlet in a backbox bolted to the 120V box(es)

A Contractor-Installed Quad Box in My Shack with 20A Outlets

Use Gangable Boxes for More Outlets



Use Gangable Boxes for More Outlets

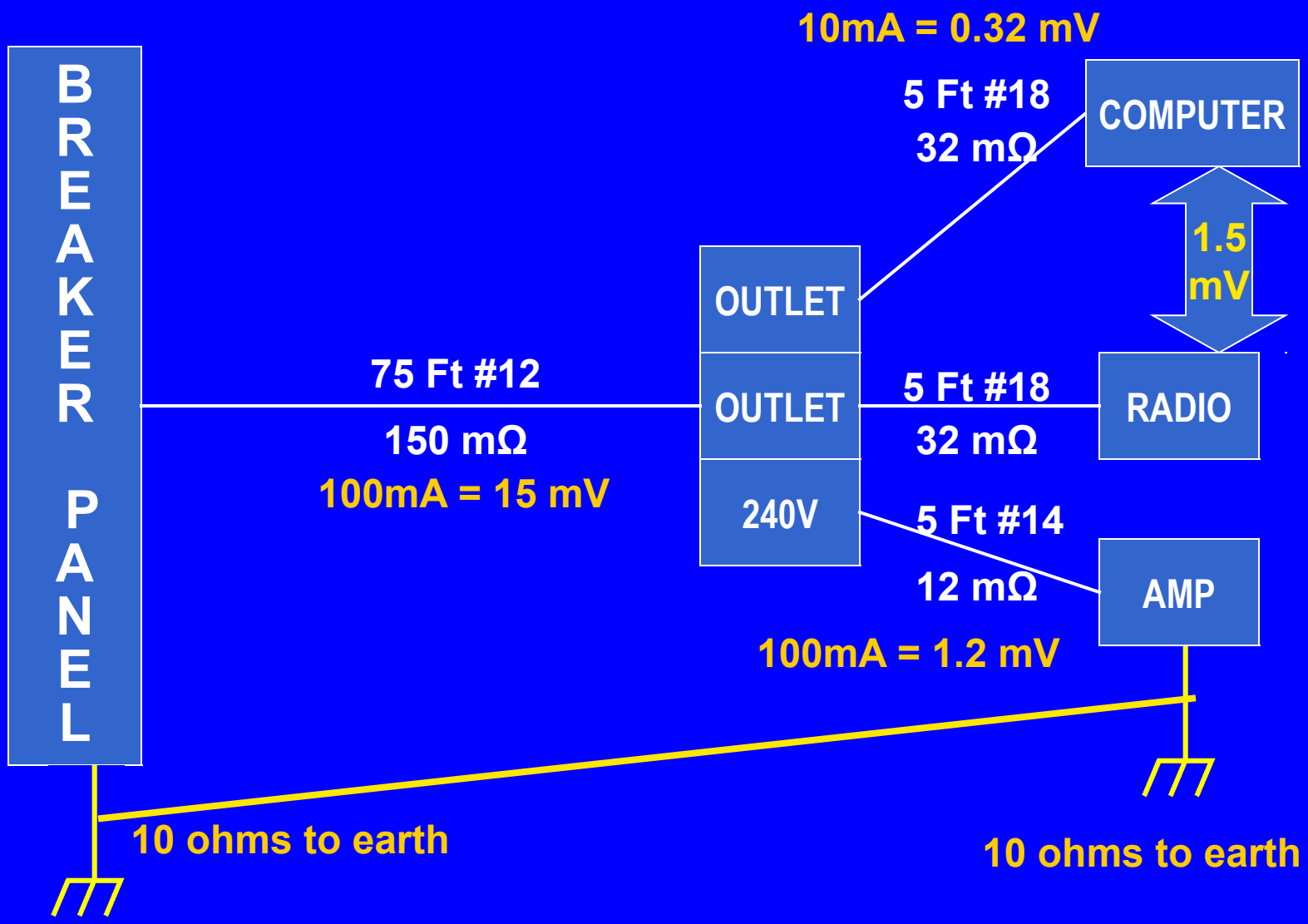
Building Multi-Outlet Boxes

- Buy gang-able boxes from the local big box store
- Remove mounting ears
- Remove side panels for interior boxes
- Screw boxes together using mounting screws removed from side panels
- Buy high quality duplex outlets
- Pre-wire them with short lengths of #12
- Feed power cable through strain relief mounted in one of the knockouts

Building Multi-Outlet Boxes

- Wire power cable to one of the outlets
- Mount outlets to the box, carefully centering each of them
- It may be necessary to tweak outlet centering when mounting the cover plate
- Large cover plates like this can be found from internet vendors
- Power cable should be #14 or larger

Home Power Ground Wiring (The "Green Wire")



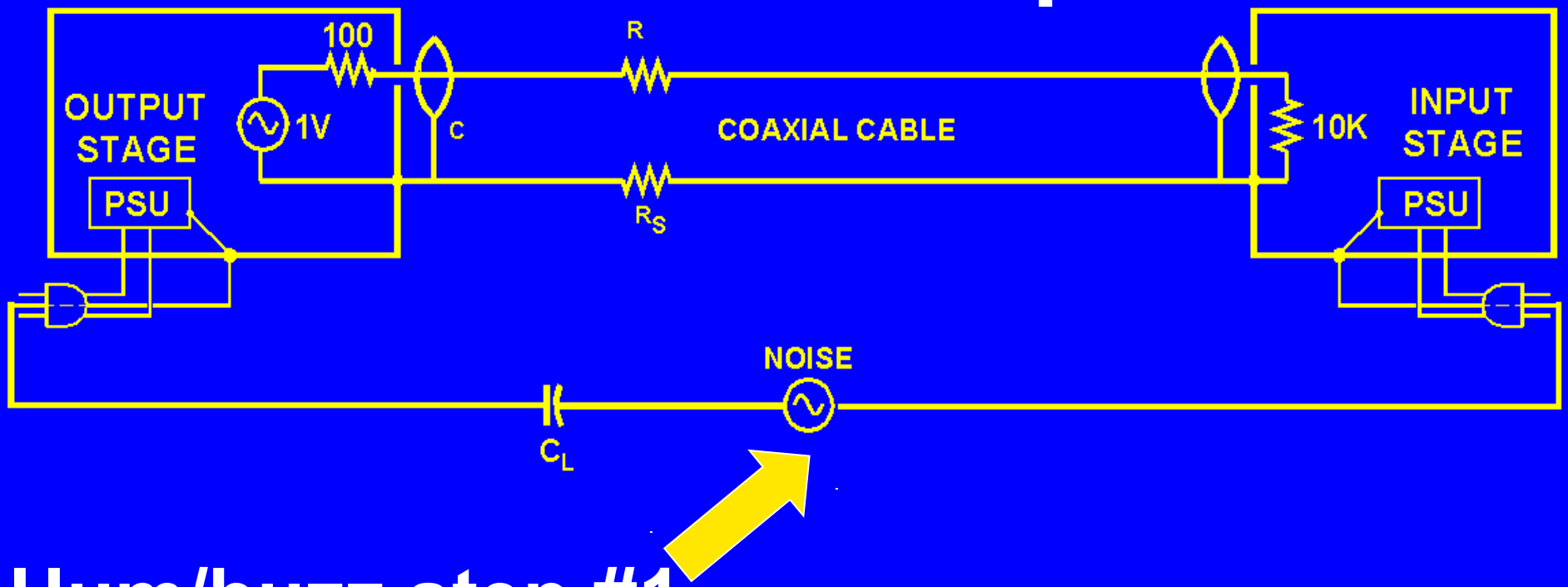
Hum/Buzz Step #1

- This reduces the voltage between outlets to a few millivolts or less
- What's left are the IR drops on line cords within your station
- Step #1 typically reduces buzz by 20 dB

Hum/Buzz Step #1 for Multi-Multi

- Get all the power for as many stations as possible from outlets connected to the same “green wire”
  - Add boxes, bolted together as needed
  - When outlets can’t be bolted, bond them together with steel conduit or heavy braid
  - When different green wires, bond together all outlets for all stations

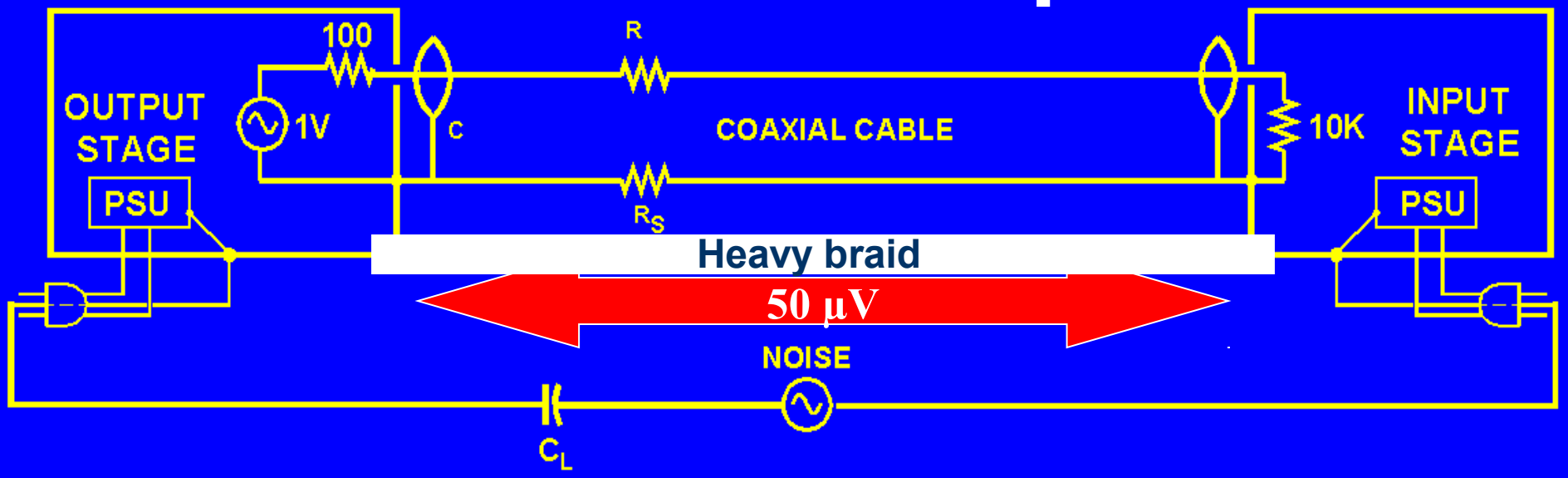
Hum/Buzz Step #1



Hum/buzz step #1 reduces this voltage, but often not enough

So we need step #2

Hum/Buzz Step #2



- Short out the remaining noise (reduce the IR drop) by adding a short, fat conductor between the two chassis
- 50µV would yield 76 dB audio S/N ratio

Hum/Buzz Step #2

- Bond all interconnected equipment together with short, heavy copper braid
  - Radio to power supply
  - Radio to computer
  - Radio(s) to SO2R box
  - Radio to band decoder, etc.

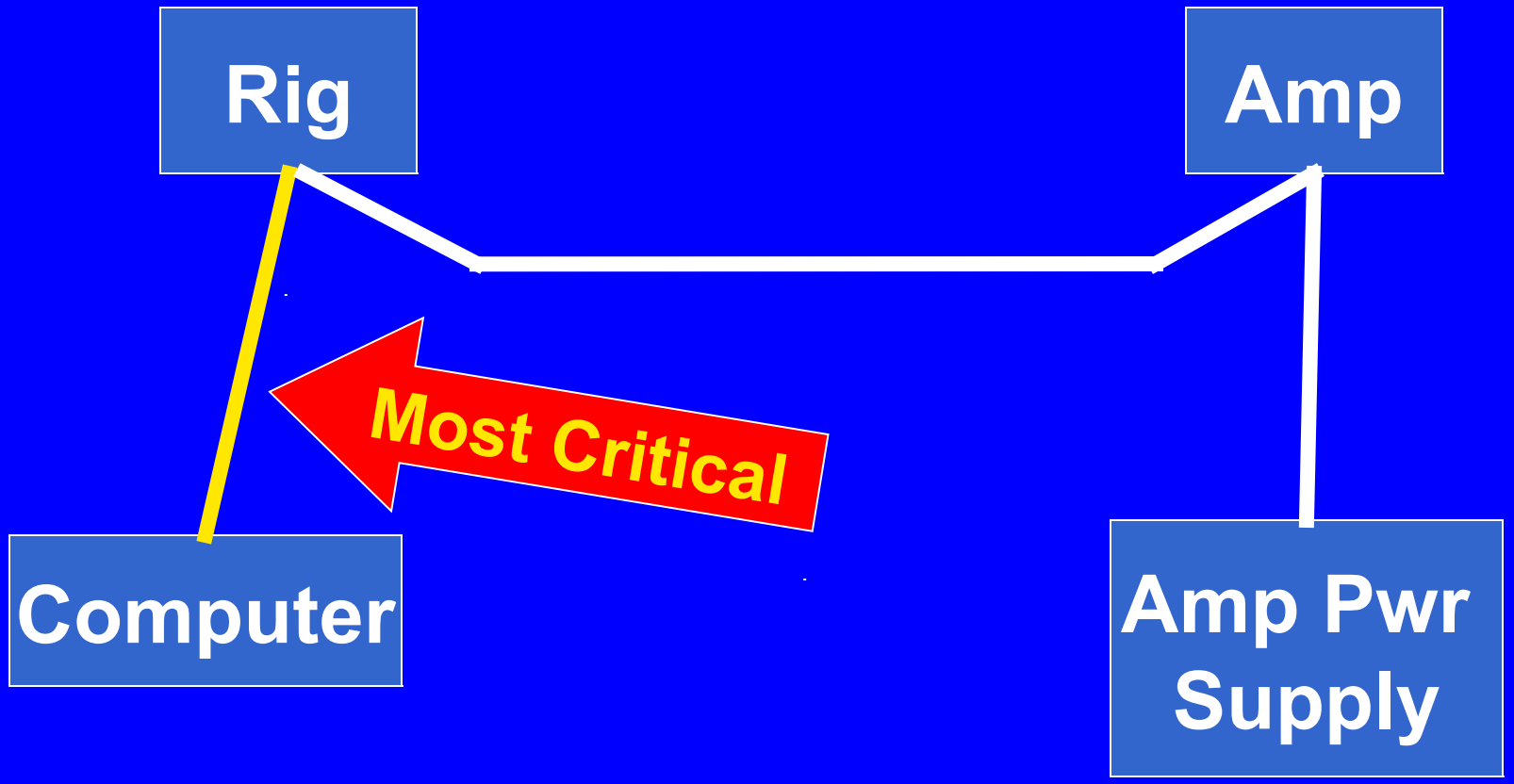
Guidelines For Bonding

- Add bonding in parallel with every unbalanced audio and data path
- Use #10 copper or larger
  - Strip braid from transmitting RG8, RG11
  - Or buy braid if you see it cheap enough
  - #10 THHN stranded is fine, but stiffer
- Bond to chassis of rigs and computers
- Always as short as possible

Guidelines For Bonding

- Noise (buzz) is proportional to resistance of the bonding path
- Make conductor BIG
  - Double the size = 6 dB less buzz
  - Two conductors in parallel = 6 dB less buzz
  - Four conductors in parallel = 12 dB less
- Make bonding conductor SHORT
  - Half the length = 6 dB less buzz

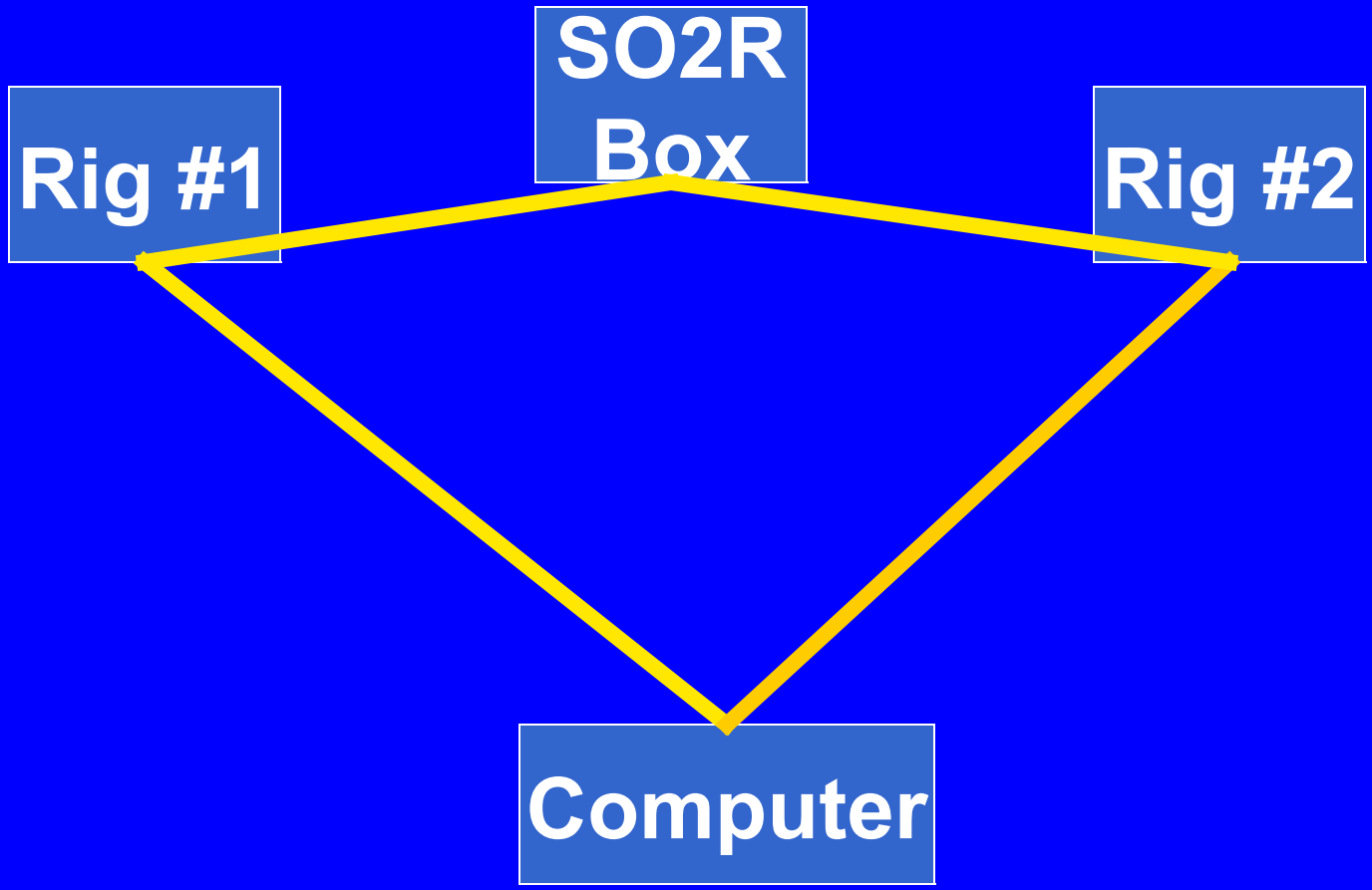
Equipment Bonding – A Basic High Power Station



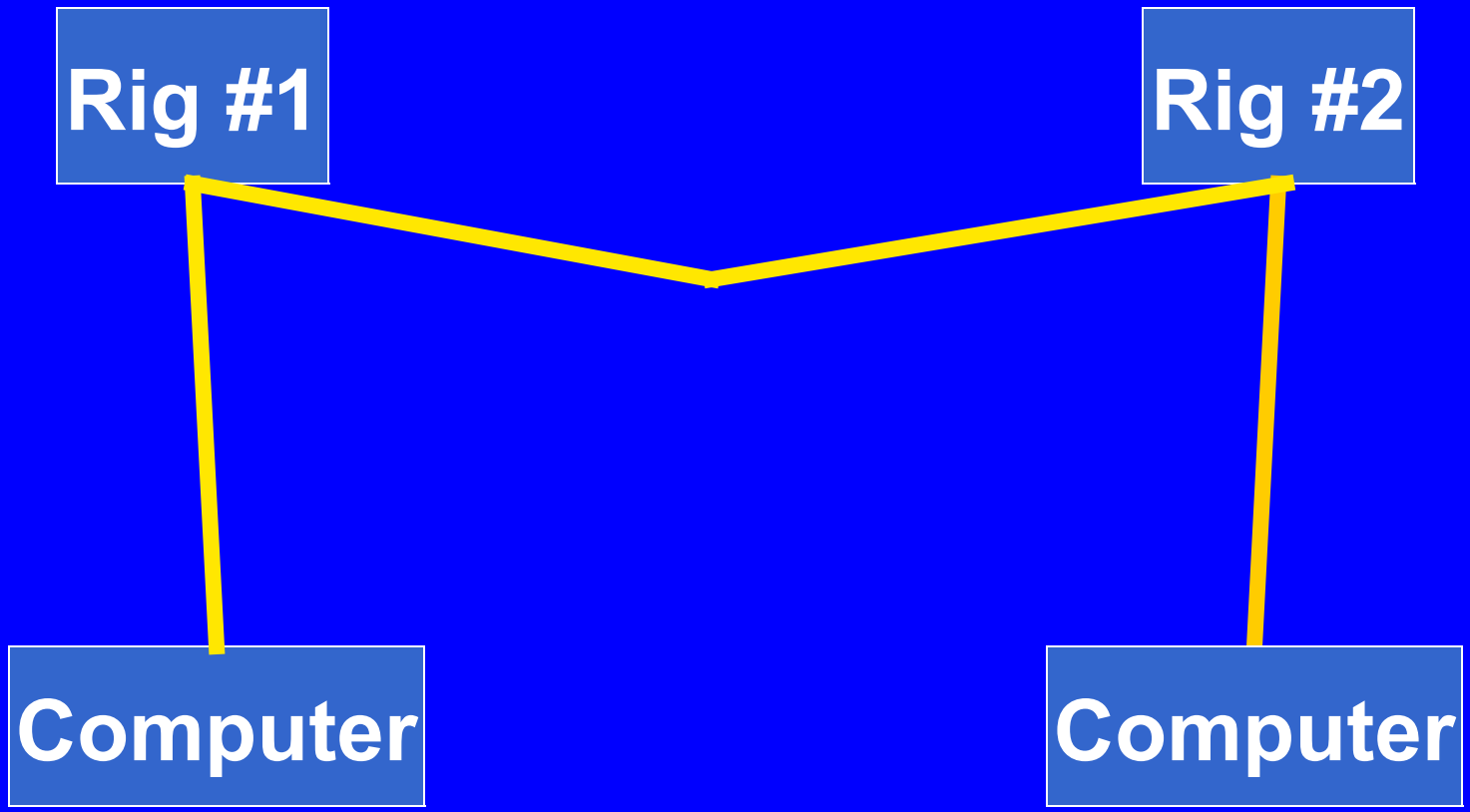
Multi-Transmitter Bonding

- Bond all transmitters together
- Bond all power outlet green wires together
- Use bigger copper for longer runs
  - Multiple RG8/RG11 braids in parallel
  - Multiple #10 stranded in parallel

Equipment Bonding – SO2R Station



Equipment Bonding – Two Rigs, Two Computers



SO2R Box Bonding

- Bond transmitters together
- Bond computer(s) to transmitters
- Bond SO2R box to computer(s) and tranceivers
  - This can be difficult – many SO2R boxes are poorly built
    - Chassis and connectors insulated by paint
  - Bonding all equipment connected to the SO2R box will usually kill the buzz

When There's No Metal to Bond To

- Power that unit from a good DC power supply and bond the chassis of the supply
- Bond to a D-connector retaining screw

Or

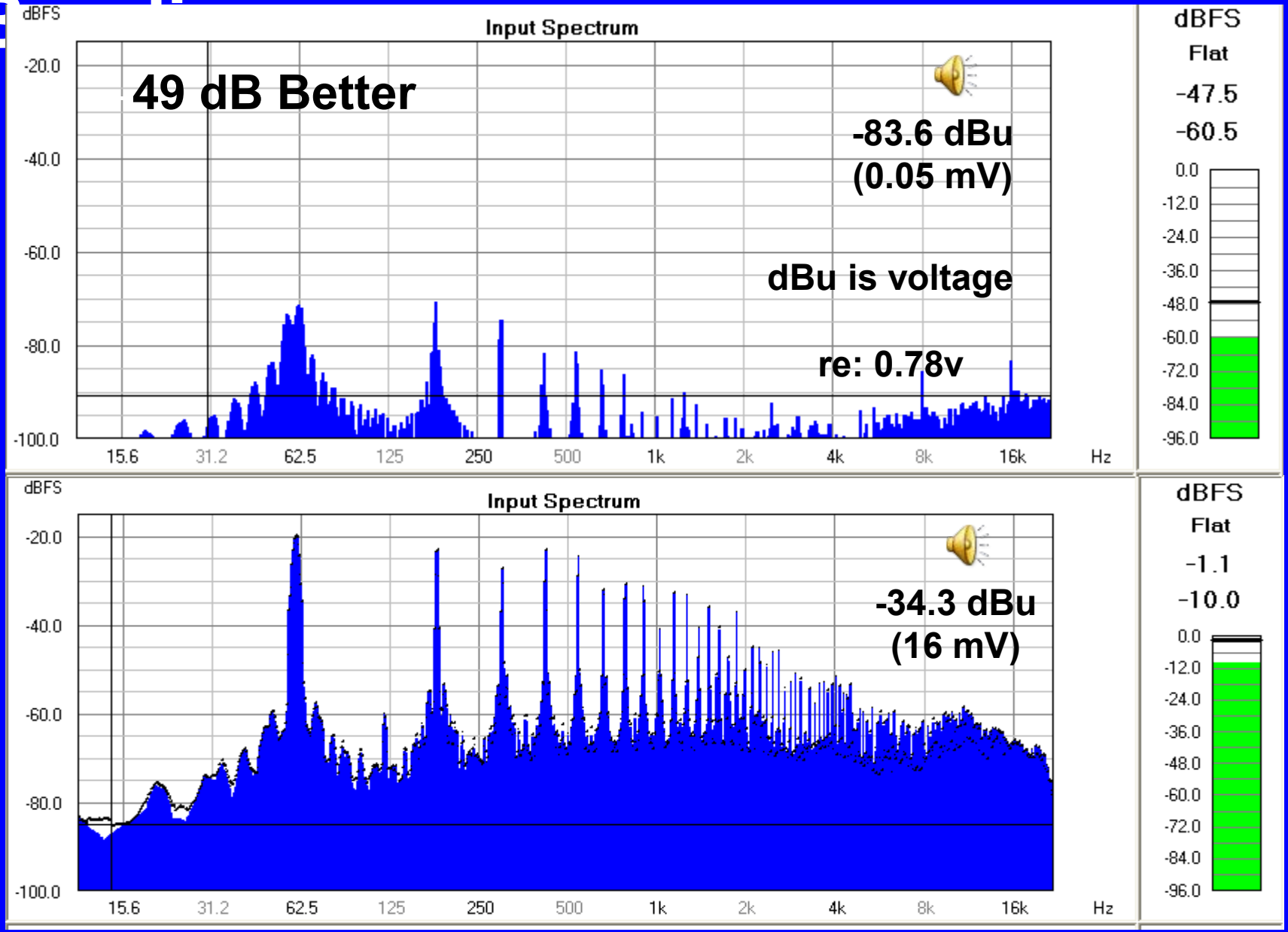
- Use a double-insulated power supply (legal 2-wire power cord) for the SO2R box and bond only the rig, amp, and computer(s)

Hum/Buzz Steps #1 & #2

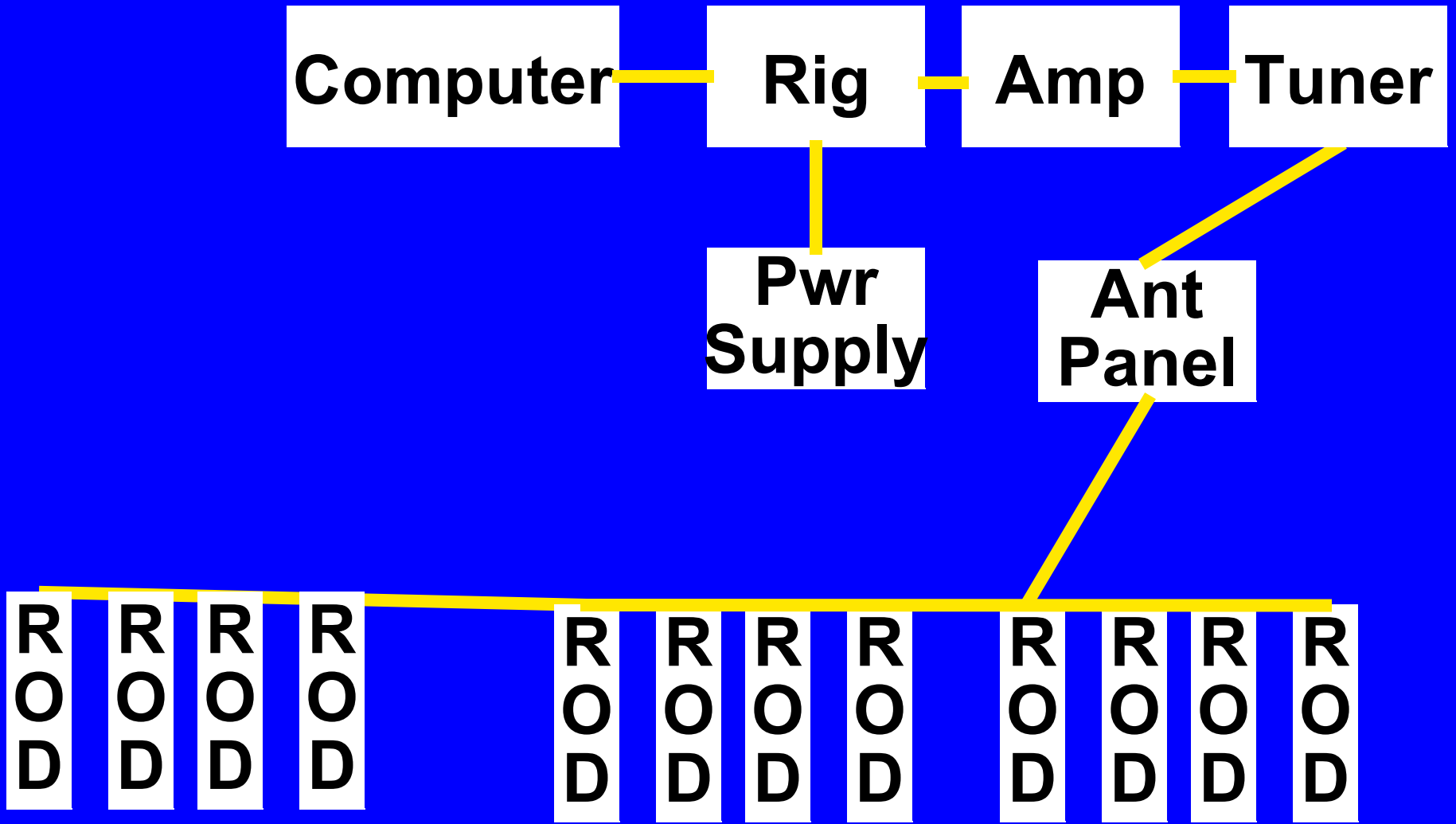
- Should eliminate most hum and buzz
- No need to replace crummy cables
- AND it puts a band-aid on power-related pin 1 problems!
  - No shield current, no pin 1 problem
  - RF pin 1 problems still possible

How Well Does This Work?

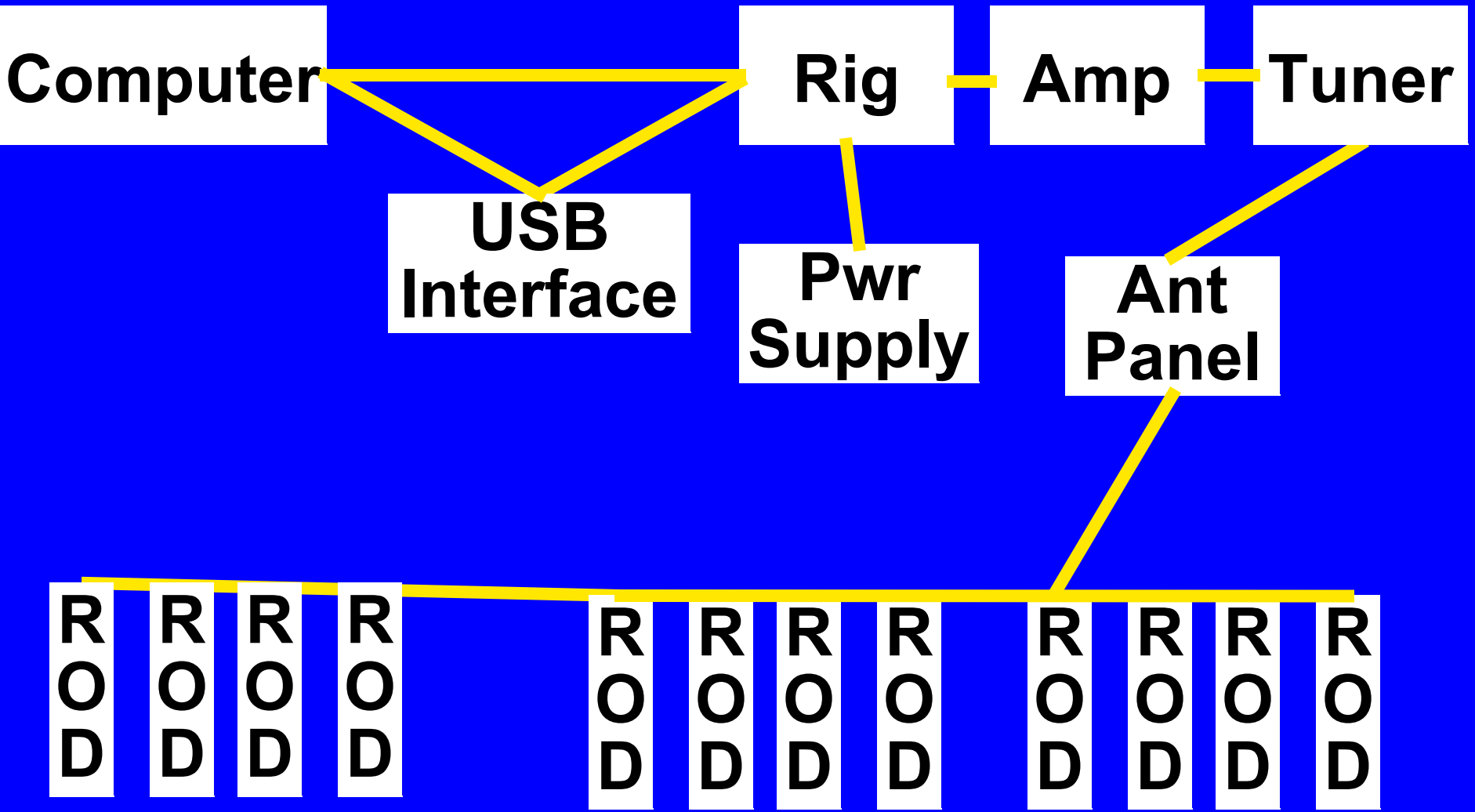
Noise Reduction From Simple B



Proper Bonding For The Shack



Proper Bonding For The Shack

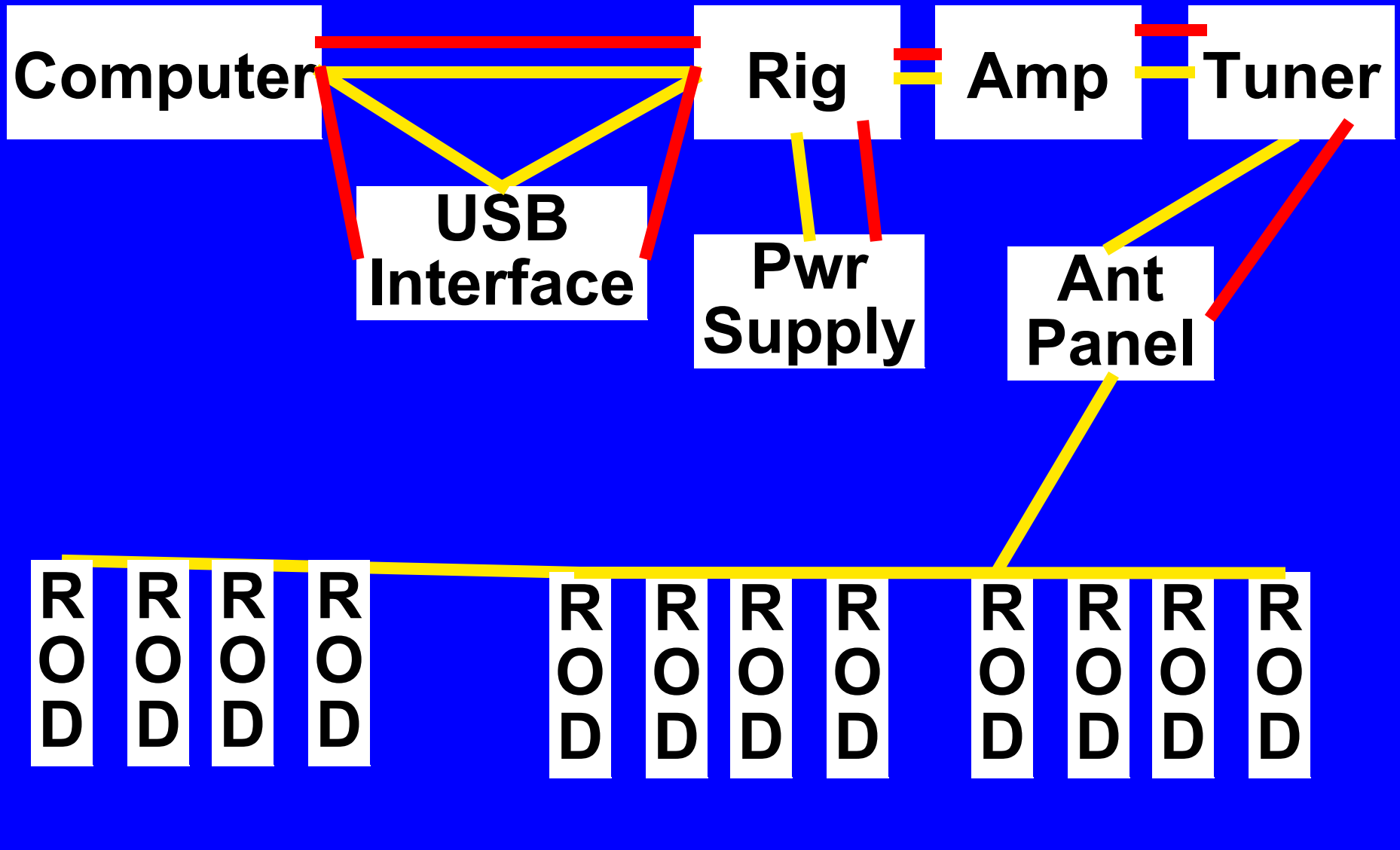


And It's Right for Lightning Safety and RFI

- Step One eliminates voltage between power outlets
- Both steps minimize voltage between our gear
- Both steps minimizes the area of loops for magnetic coupling
- Magnetic coupling is proportional to loop area

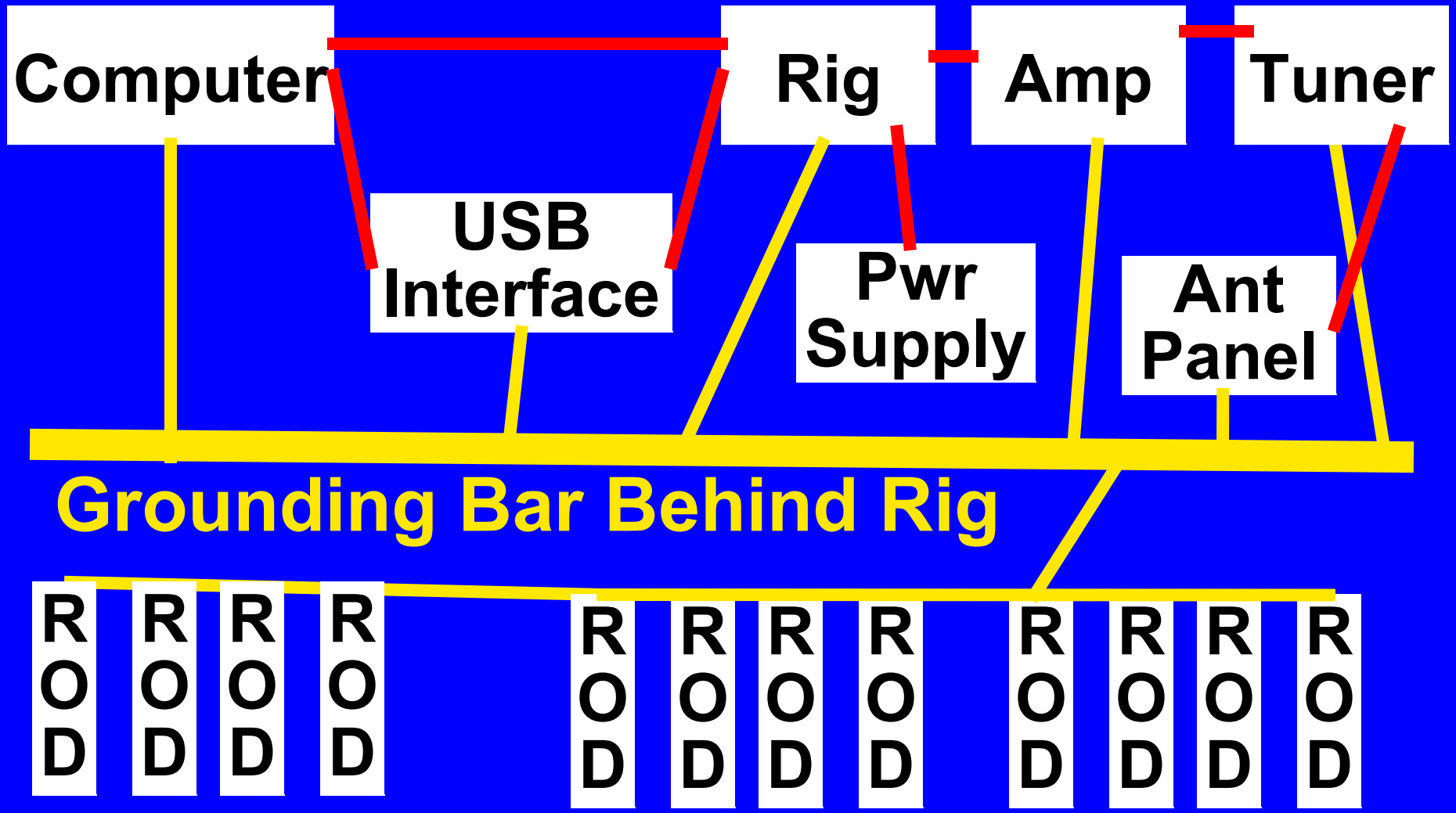
Thinking About Loops

Red Lines are Unbalanced Cables



Single Point Creates Loops

Red Lines are Unbalanced Cables

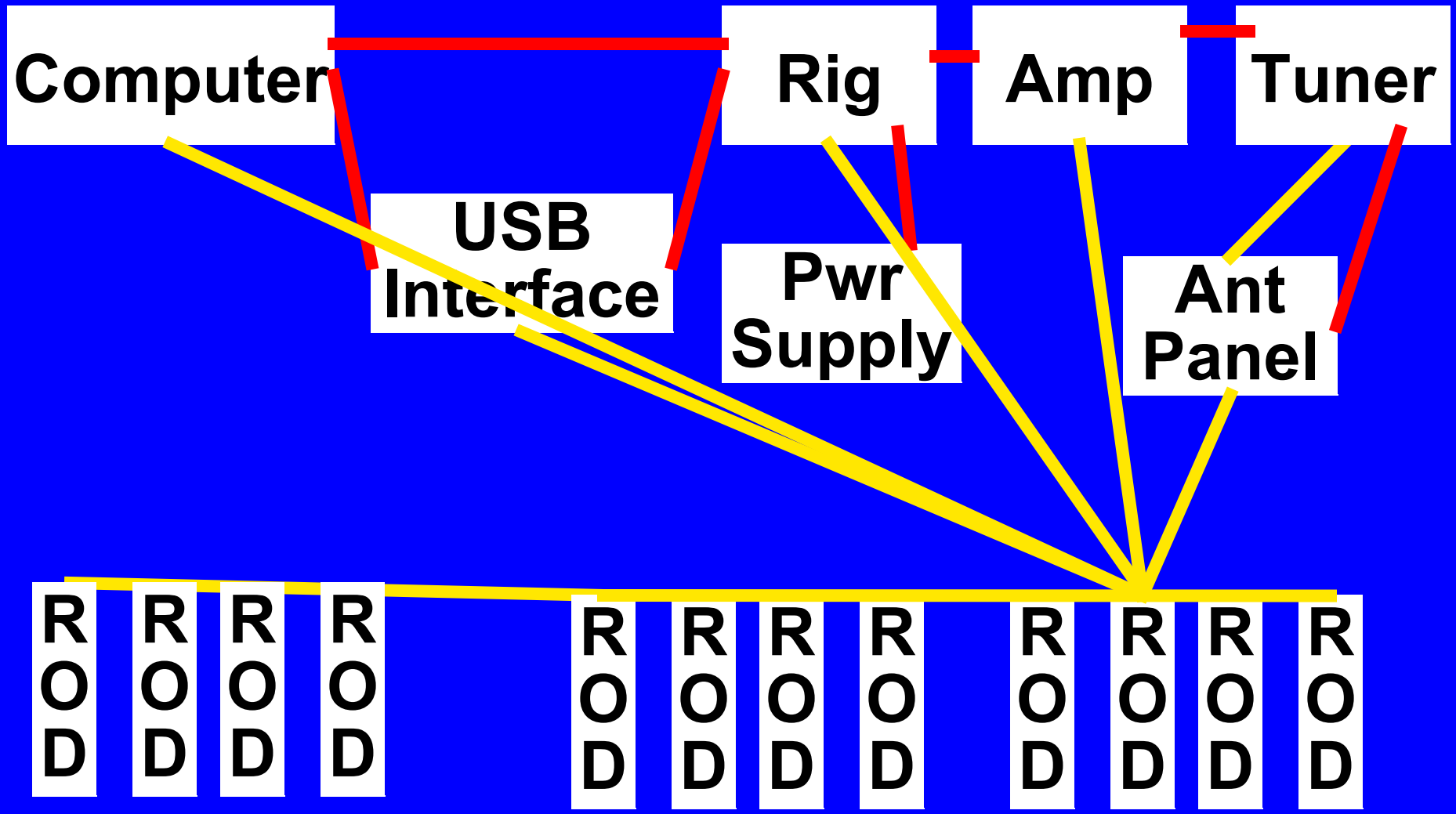


Ground Bar At Back of Desk

- We have unbalanced connections (cable shields) between gear, so bonding to the bar creates a loop
- Magnetic coupling to the loop
  - Leakage flux from transformer
  - Lightning
- Bonding path between gear is longer, so more resistance, more hum, buzz, and RFI

Single Point Creates Loops

Red Lines are Unbalanced Cables

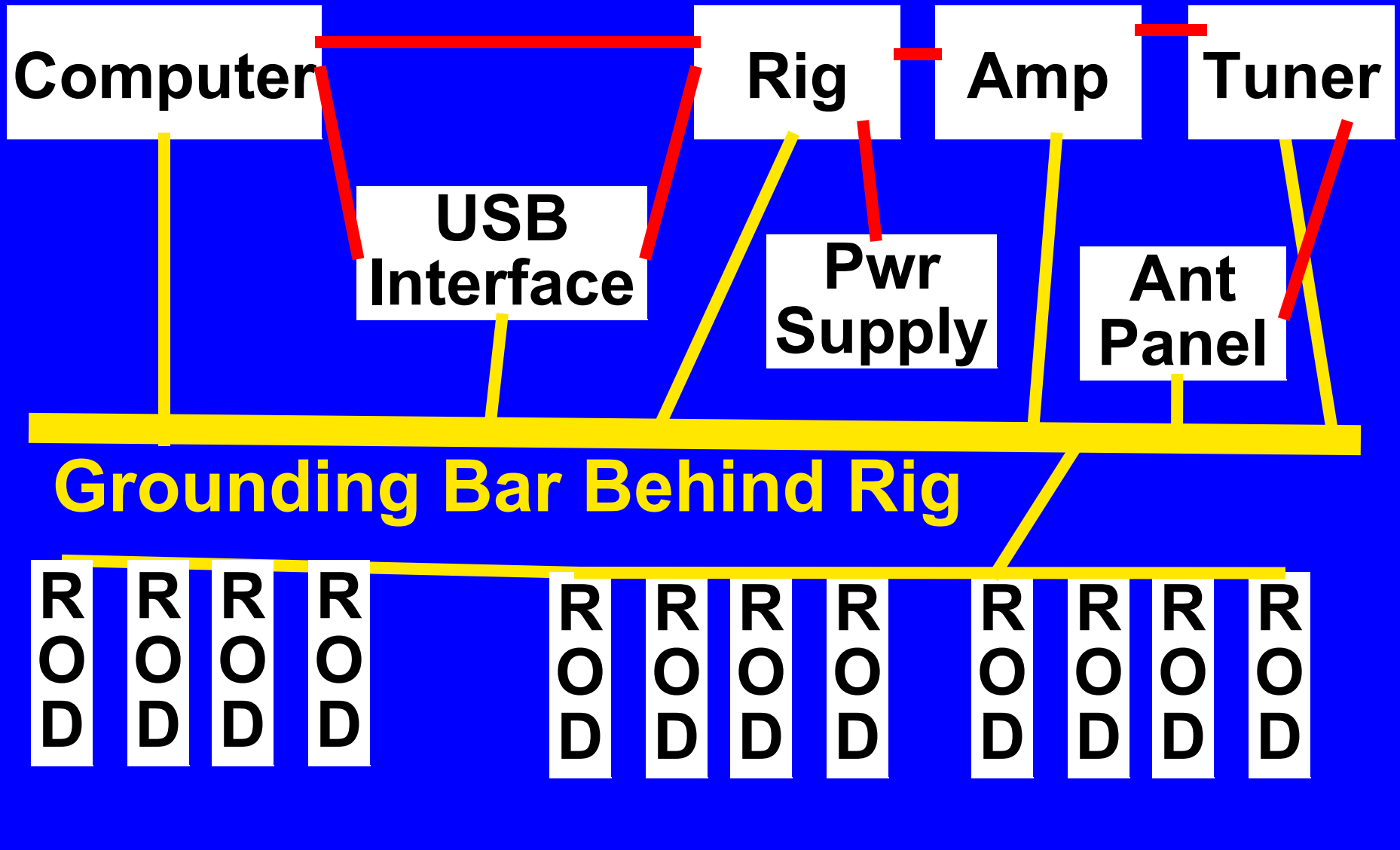


Single Point at Ground Rod

- The much longer path creates a much larger loop
- Magnetic coupling is proportional to the loop area
- Bonding path between gear is much longer, so more resistance, more hum, buzz, and RFI

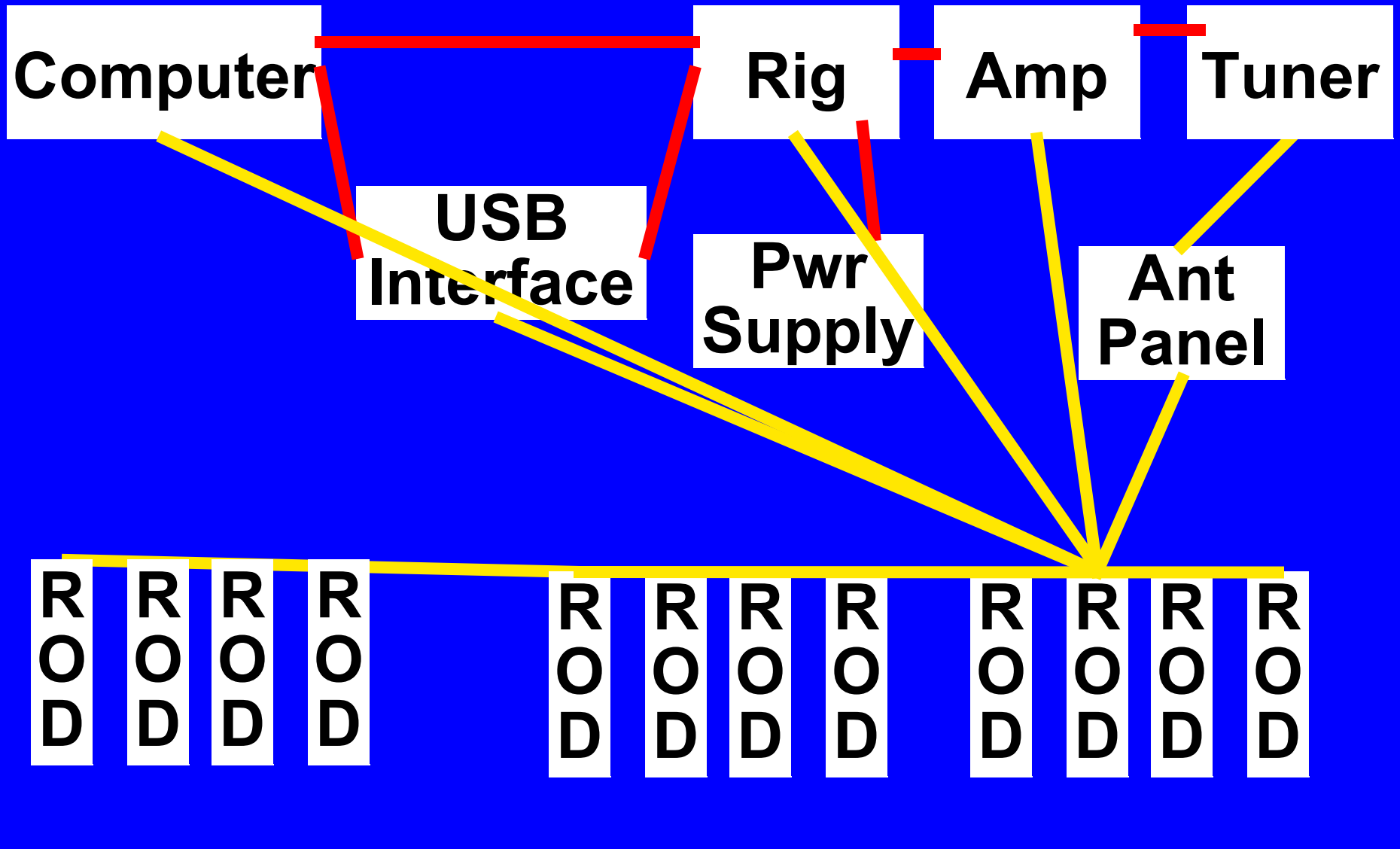
This is NOT Better!

Red Lines are Unbalanced Cables



This is NOT Better!

Red Lines are Unbalanced Cables



Single-Point Madness

- Virtually all interconnects are unbalanced, tie chassis to chassis
- We may call them an audio cable or computer cable or "coax between rig and amp," but Mother Nature sees their shields as part of a big loop with star bonding conductors
- Most equipment has a Pin One Problem
  - Current in the loop gets inside our gear
  - Hum, buzz, RFI, lightning damage

Single-Point Madness

- Ground bar at back of desk is a bad idea
- Individual bonds from each piece of gear to a common ground inside or outside the shack is a bad idea
- Greatly increases resistance between interconnected equipment
  - More power line buzz
  - Creates loops for magnetic coupling

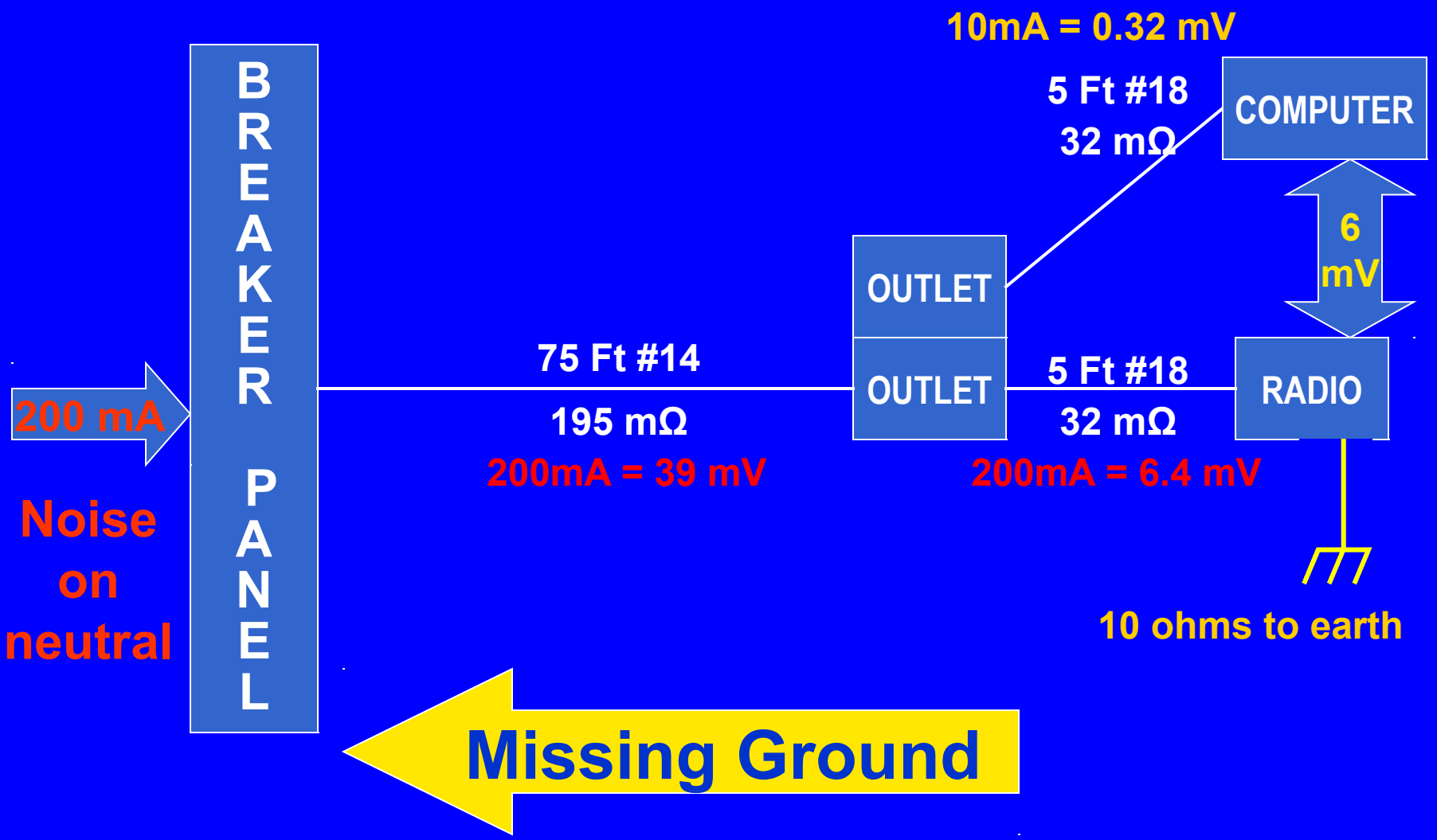
Killing Pin 1 Hum, Buzz, RFI

- Use Step 1 and Step 2 Bonding
  - Ohm's Law causes most audio current to flow on low impedance bonding conductors rather than much smaller interconnect cables
  - Forces most RF currents to bonding conductors
- Add ferrite choke(s) to interconnect cables if still some RFI
  - k9yc.com/RFI-Ham.pdf

Still Have Hum/Buzz?

- Carefully Investigate Building Grounds

Another Cause of Buzz



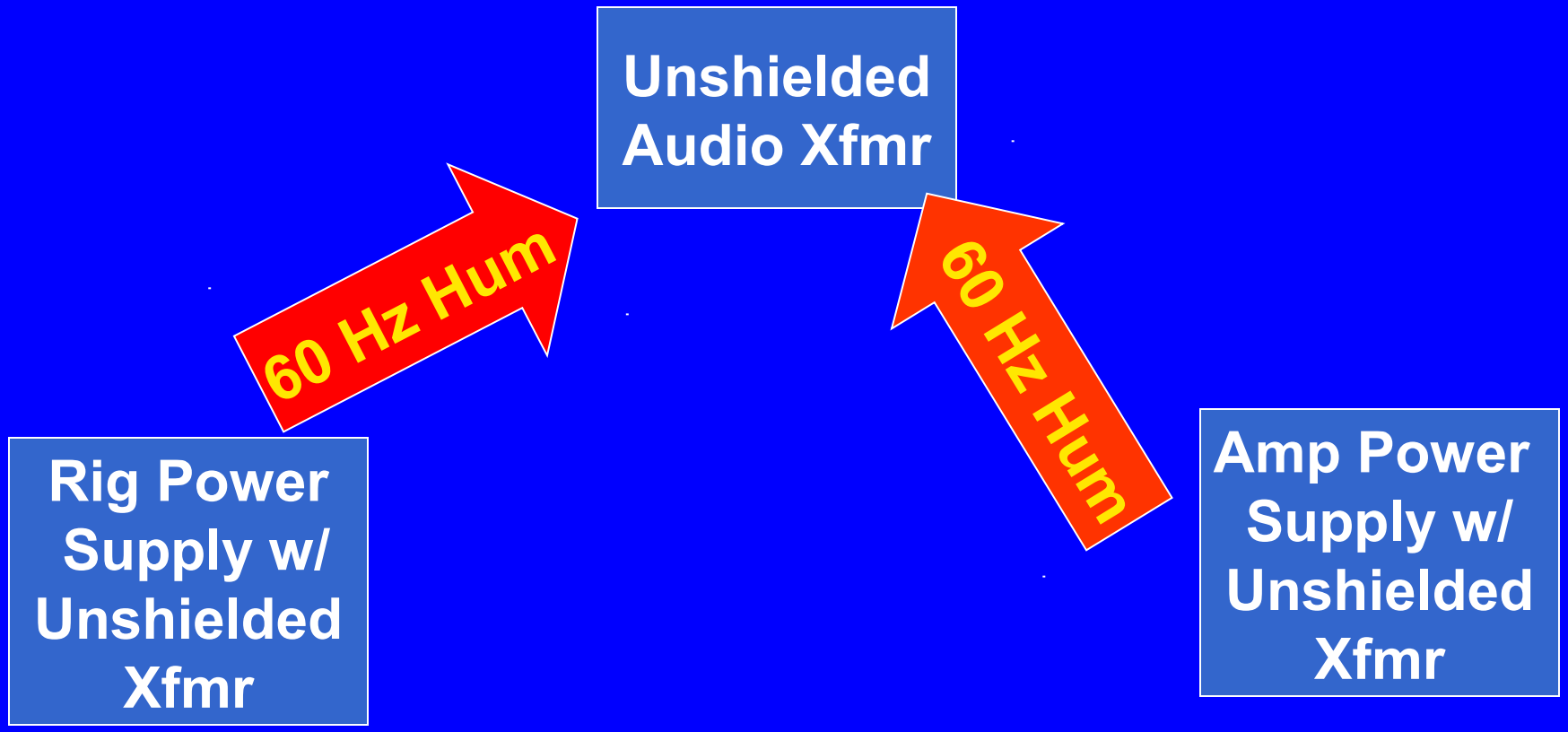
Still Have Hum/Buzz?

- Suspect Magnetic Fields
- Move on to Step #3

Hum/Buzz Step #3

- Fix magnetic field problems
  - Big transformers in power supplies couple hum into audio transformers
  - Move power xfmr away from audio xfmr
  - Rotate the power supply to put the field at 90° to the audio transformer's field
  - Rotate the audio transformer
  - Get rid of the audio transformer (you don't need it!)
  - Shield the audio transformer

The Problem with Cheap Audio Transformers



An unshielded audio transformer can cause a hum problem!

Audio Transformers

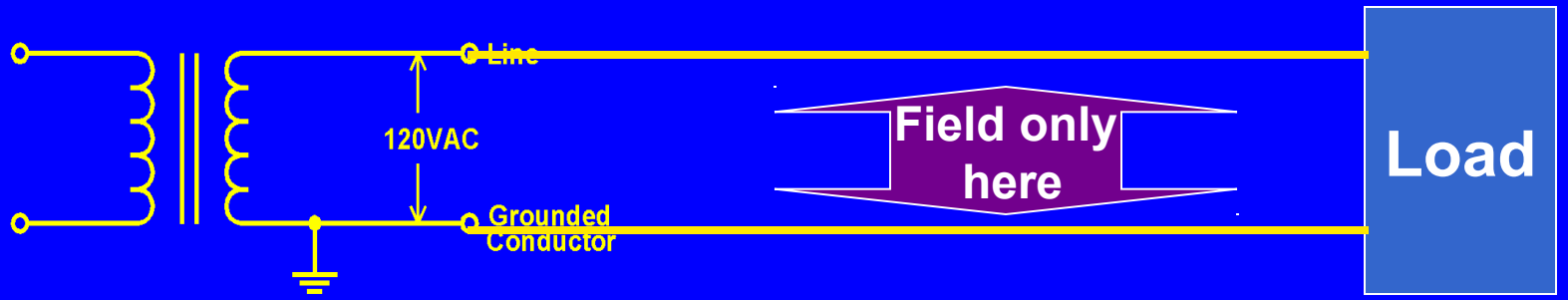
- An expensive fix for “ground loops”
- Sitting duck for magnetic fields
  - Must be well shielded!
  - Shielding is expensive (typically $50-$70)
- With Hum/Buzz steps #1 and #2
  - You don’t need a transformer!
  - You don’t need an opto-isolator!
- An ***unshielded*** audio transformer can cause more problems than it solves!

Audio Transformers

- We do need a transformer to bring audio in from another building on wires
  - Remote operation, etc.
  - Need *mu-metal shield* to reject magnetic fields
  - Need *dual Faraday shields* to reject RFI
- Lundahl – http://lundahl.se
  - Sweden, good, better, best
- Jensen – http://jensen-transformers.com
  - SoCal, better, best, super best

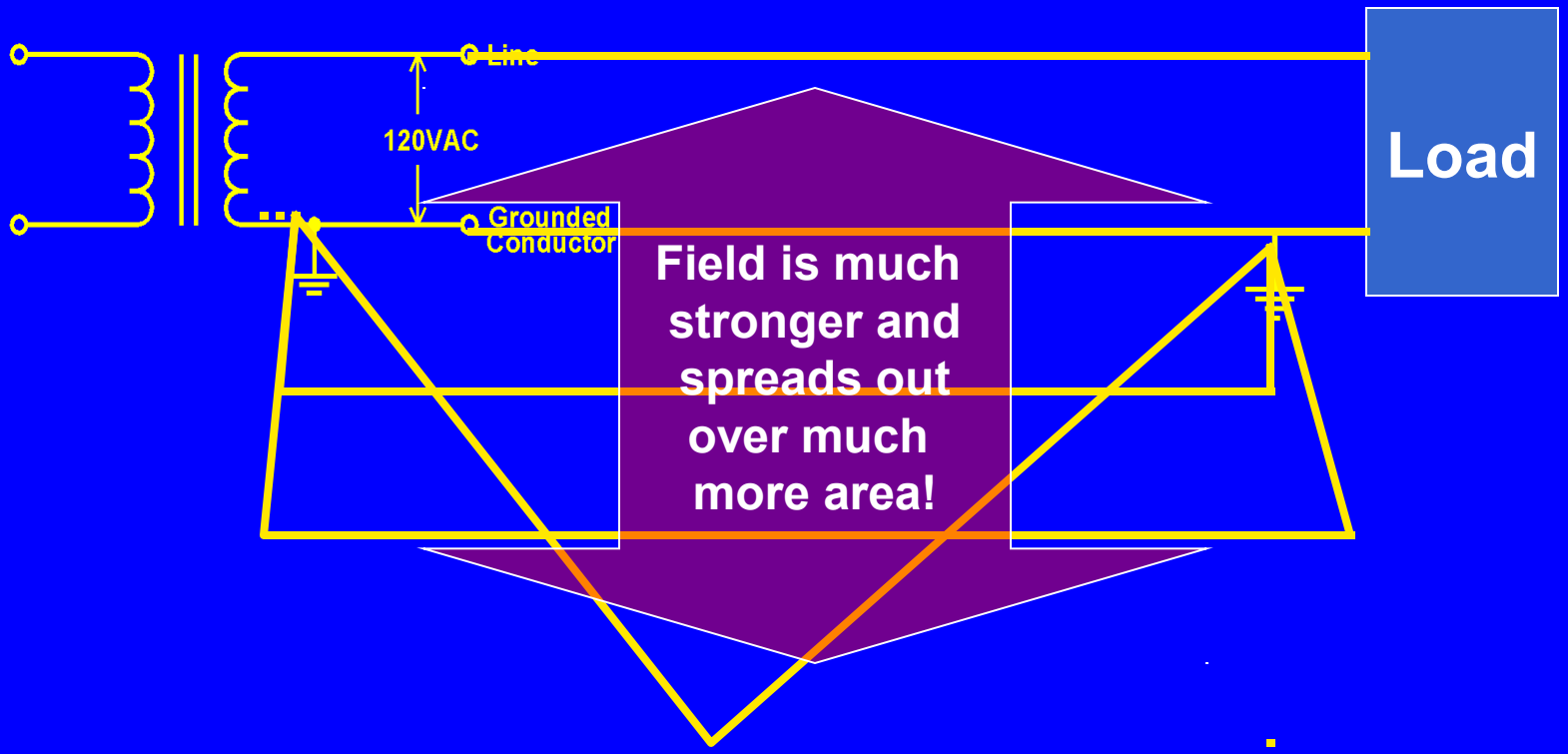
A Double-Bonded Neutral Creates An Interfering Magnetic Field

Field with Single-Bonded Neutral (Right)



- Field mostly confined to the very small area between conductors – that is, between the wires

Field With Double-Bonded Neutral (Wrong)

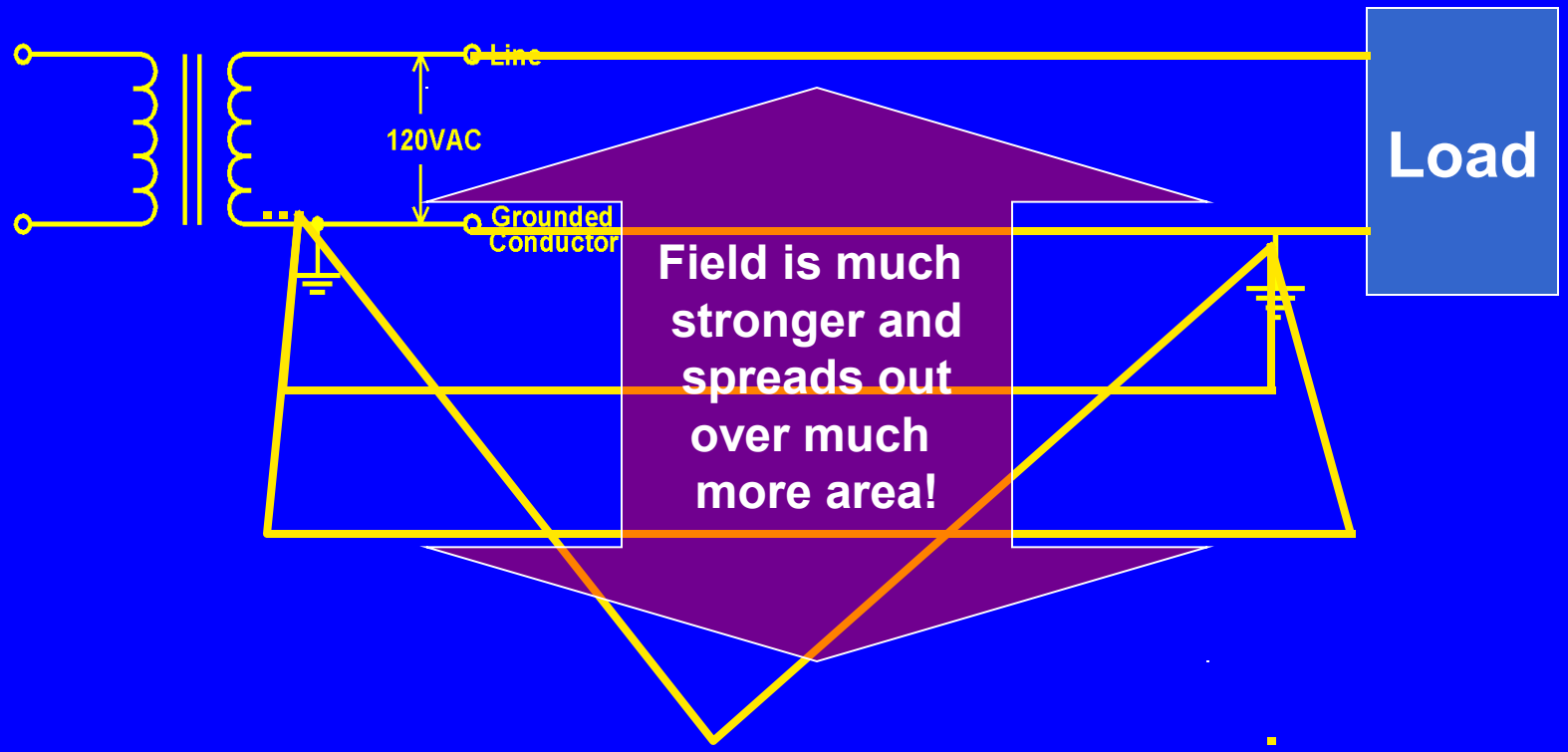


- Field may engulf large areas of a building!

Hum/Buzz Step #3

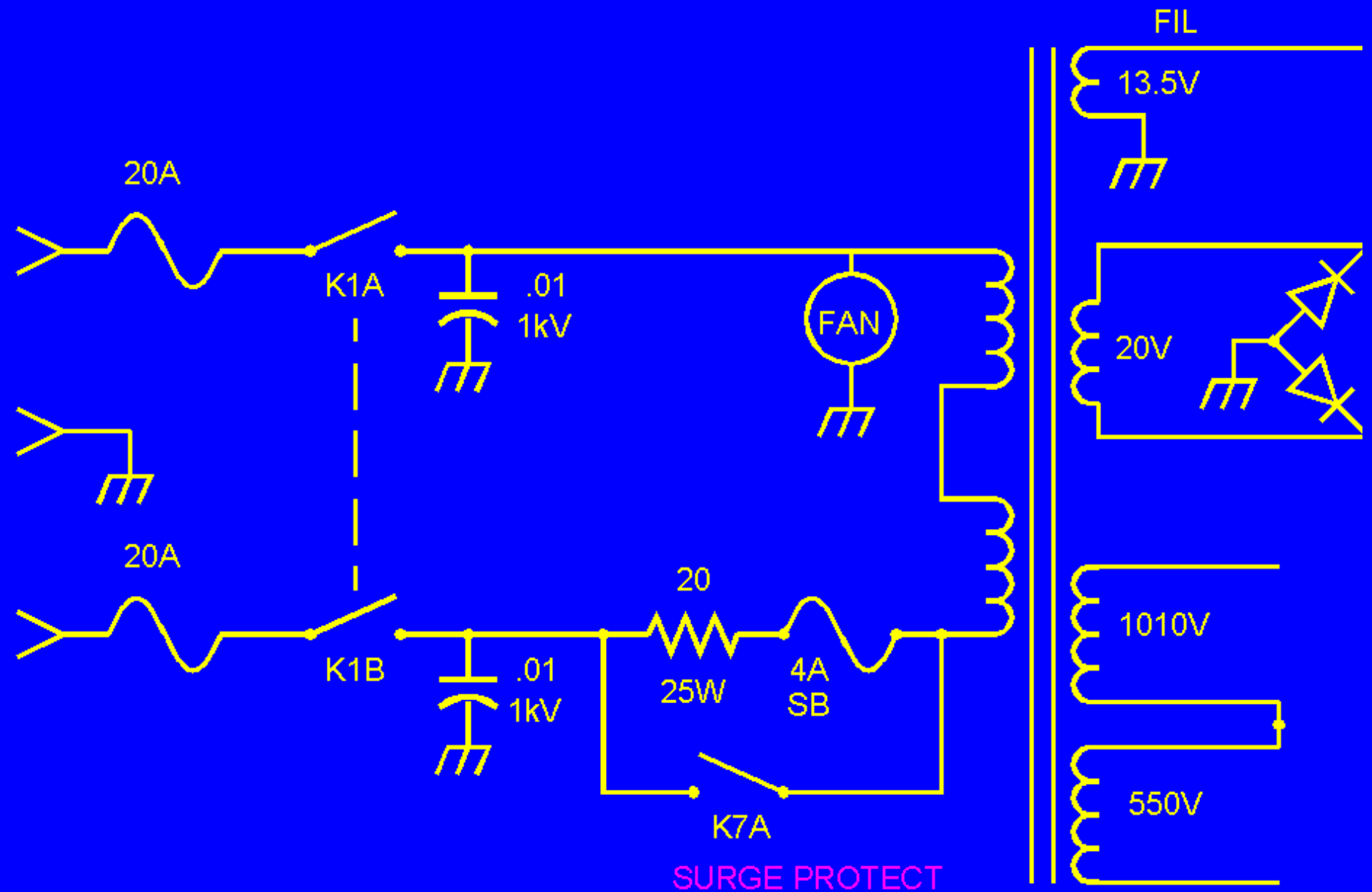
- Fix magnetic field problems
  - Double-bonded neutral
    - Neutral must be bonded to ground ONLY at the breaker panel, NEVER anywhere else
    - Use AC voltmeter to look for zero volts between neutral and ground (that's bad – it indicates an extra bond)
    - "Normal" is 20mV – 2 volts
    - This will be ***buzz***, not ***hum***

Load Connected Hot to Ground (Also Wrong)

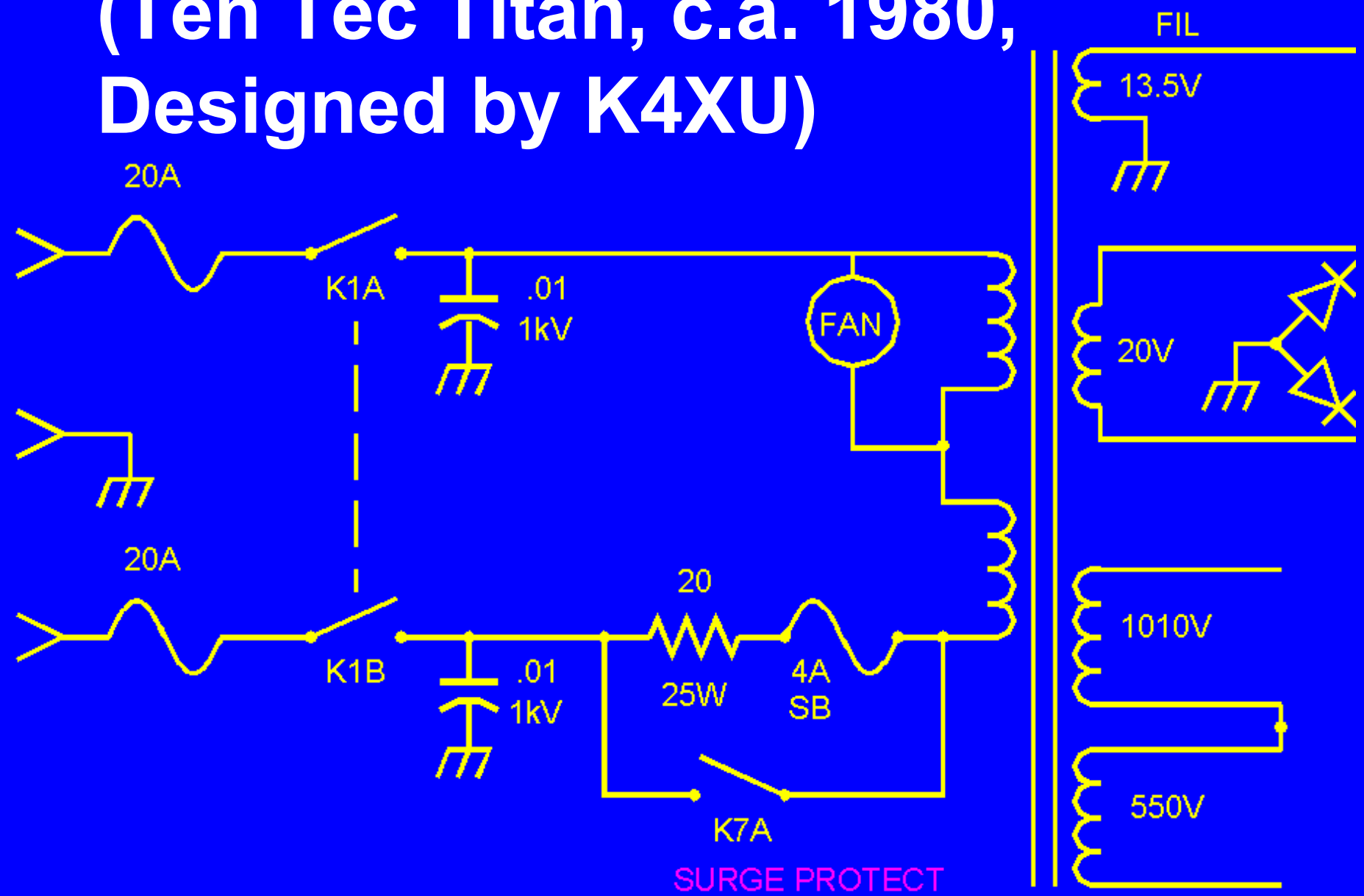


- Field may engulf large areas of a building!
- Puts hum voltage on green wire (chassis)
- Fans in some older power amps

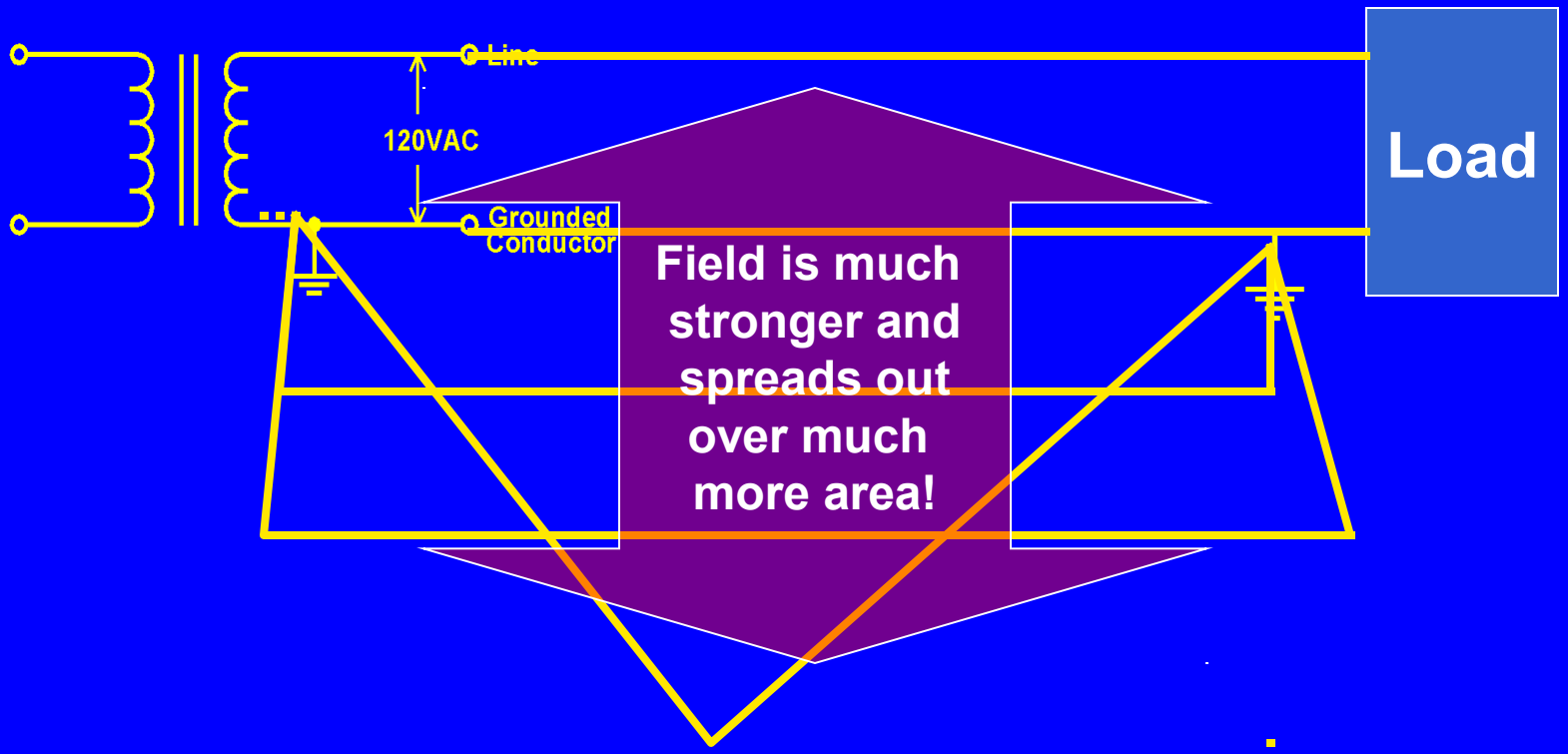
120V Fan in Power Amp - Wrong



120V Fan in Power Amp – Right (Ten Tec Titan, c.a. 1980, Designed by K4XU)



Load Connected Hot to Ground In Alpha 77, 500 mA



- Field may engulf large areas of a building!
- Puts hum voltage on green wire (chassis)

Measuring Ground Currents

- Use AC voltmeter to measure voltage drop on green wire between outlet and the chassis
- Use Ohm's law and the wire resistance to find the current
- (measure the length – 5-6 ft typical)
  - 5 ft of #18 = 0.032 Ω (most IEC line cords)
  - 5 ft of #16 = 0.020 Ω (a few heavier IEC line cords)
  - 5 ft of #14 = 0.0126 Ω (maybe on your power amp)

Measuring Ground Currents

- This method won't work if equipment is bonded, so measure before bonding and connections to other gear
- 6 mA is maximum leakage permitted by NEC; more is illegal, and should trip a GFCI

Hum/Buzz Step #3

- Fix magnetic field problems
  - Hot to ground loads
    - NEVER do this – causes current to flow on ground
  - Current on green wire to station ground
    - Station ground better than power system ground?
    - Power system ground not bonded to station ground?
    - Power system not properly grounded?

Power For A New Shack

- One 20A 240V circuit
- Bring 4 wires to the shack
  - Both sides of 120V (Black, Red)
  - Neutral (White)
  - Ground (Green)
- One or two 240V outlets (for SO2R)
  - Both sides of 240 plus ground (green)
- Use #10 for reduced IR drop

Power For A New Shack

- Add 120V quad boxes, at least two per leg (wired 120, neutral, green)
  - Feed from the same 20A-240V circuit
  - More than enough power for all the radio (and computer) equipment in any single-op legal limit station
- Mount all outlets in steel backboxes
  - Backboxes must be bonded together
  - Steel conduit between boxes (EMT is fine) provides excellent bonding

Power For A New Shack

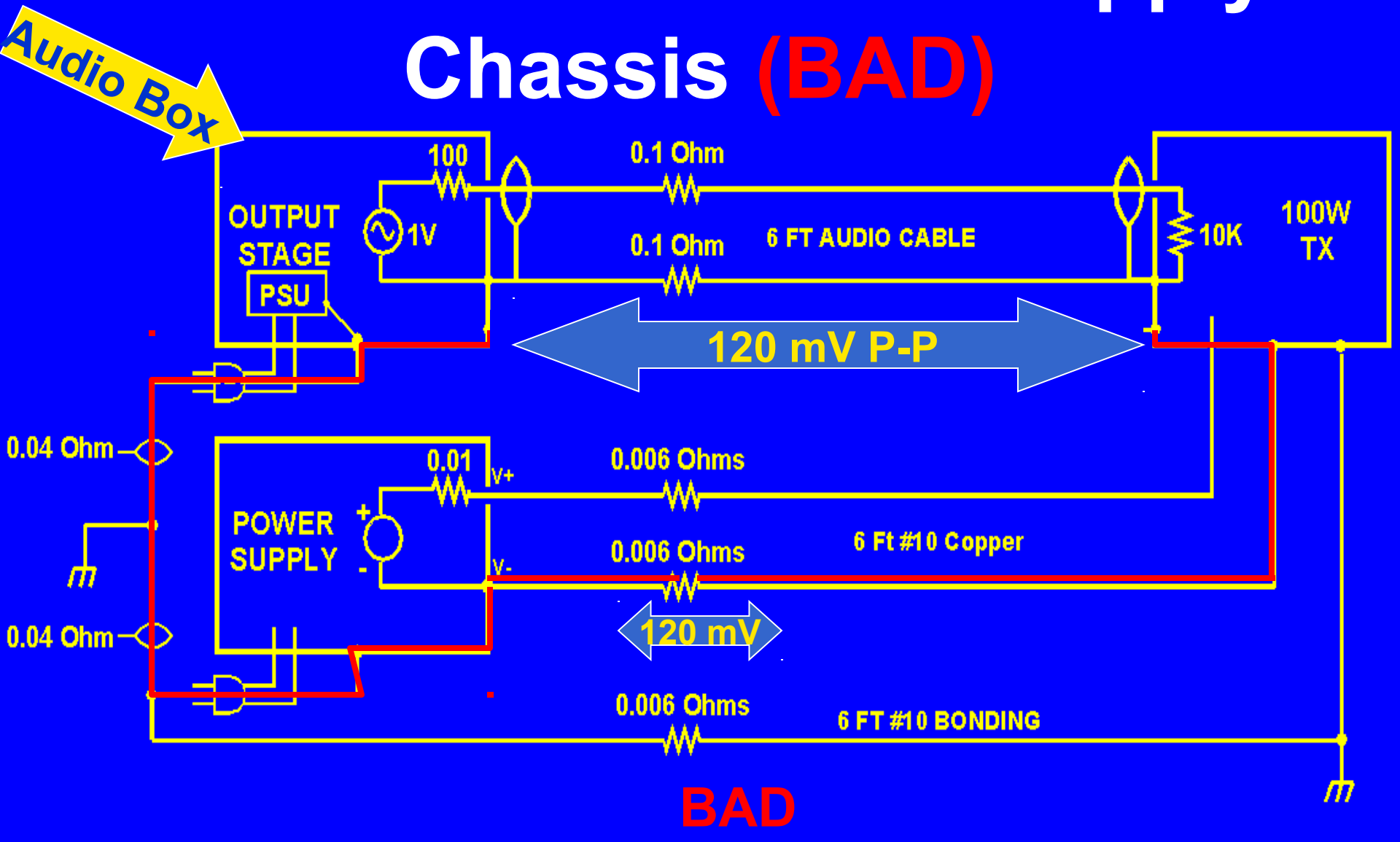
- Lowest cost alternative
  - Only one run from breaker panel to shack
  - Most of the cost is labor
  - Wire, outlets, backboxes are cheap
  - Use good quality 20A outlets
  - Use #10 copper for everything
    - 30A circuit will run two legal limit amps TX at the same time (Multi-2)

Power For A New Shack

- A 30A 240V circuit split to 120V 20A outlets will require a small sub-panel in (or near) the shack
  - Will run two legal limit amps, rigs, and computers at the same time (Multi-2)
  - #10 AWG is legal for 30A, but #8 would be better

Power Supply Bonding

V– Bonded to Power Supply Chassis (BAD)



BAD

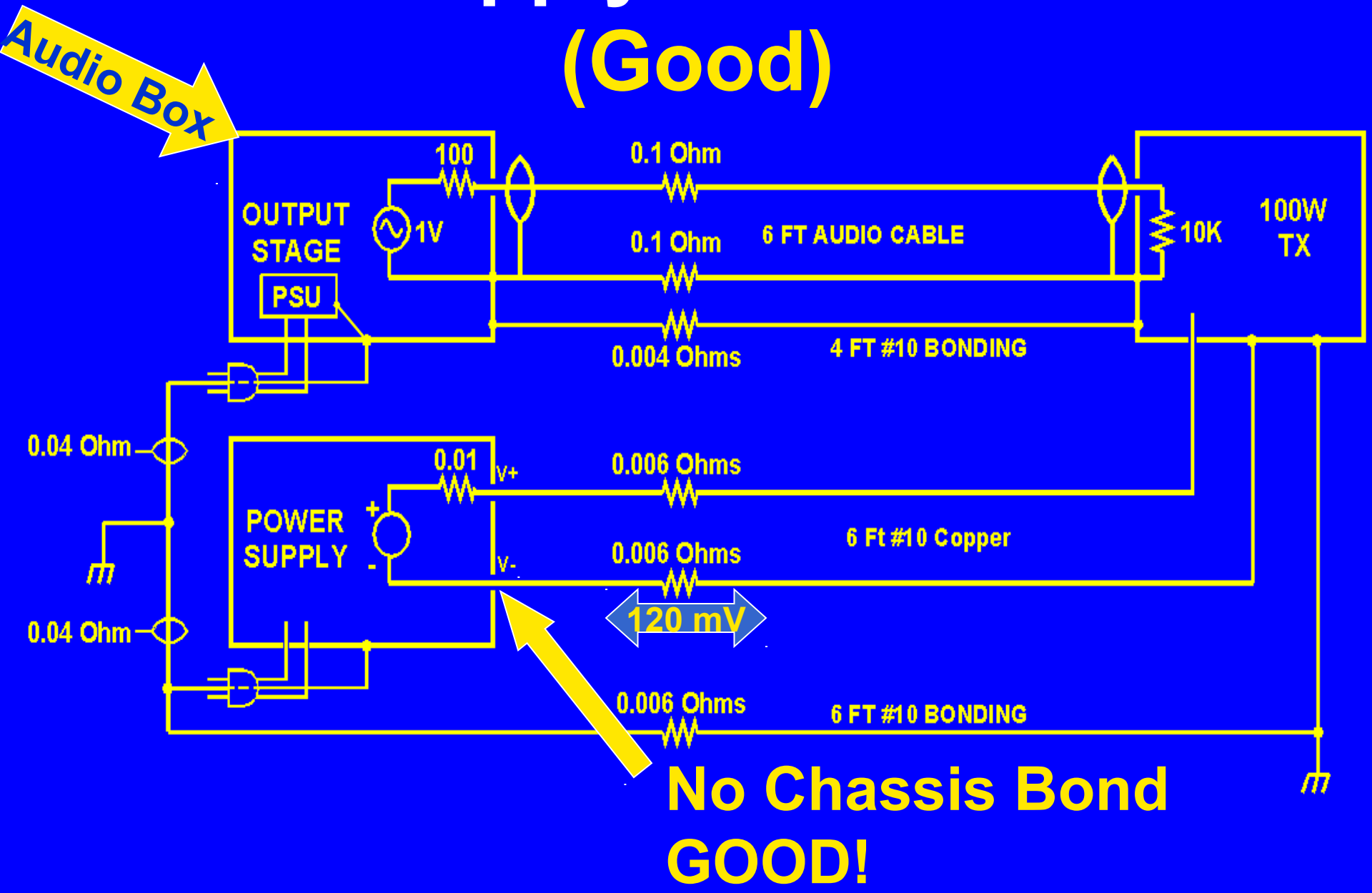
The Power Supply V– Bonding Problem

- If V– is bonded to the power supply chassis, the IR drop in the V– lead between the radio and the power supply appears on the shield of audio wiring to an accessory also fed by that power supply
- On SSB or RTTY, that current, and the IR drop, vary with the envelope of the transmitted audio

The Power Supply V– Bonding Problem

- With SSB, the modulated IR drop sounds like SSB in an AM radio
- It will appear in the unbalanced audio feed from the accessory to the rig, and will sound like RF feedback

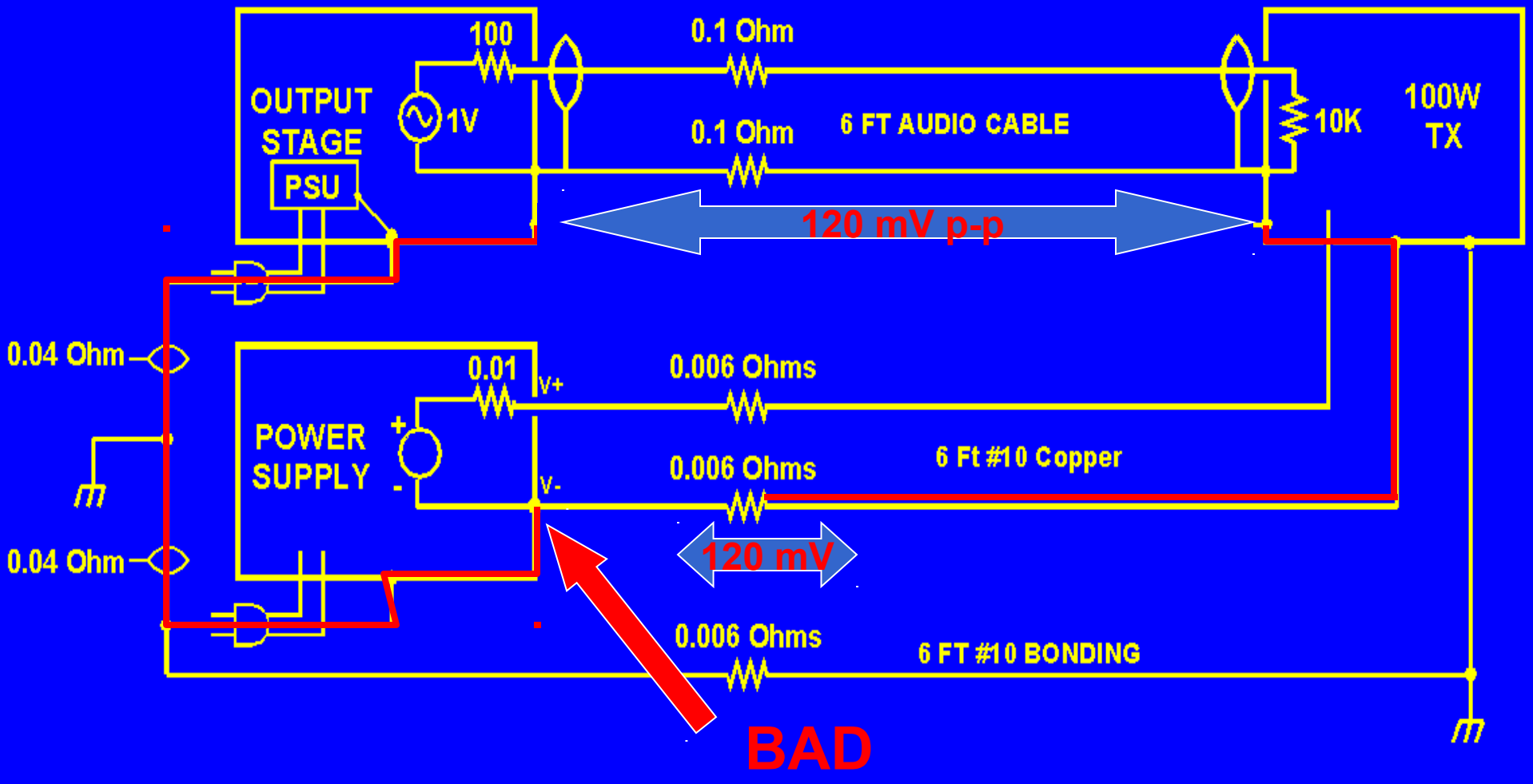
Power Supply V – Not Bonded (Good)



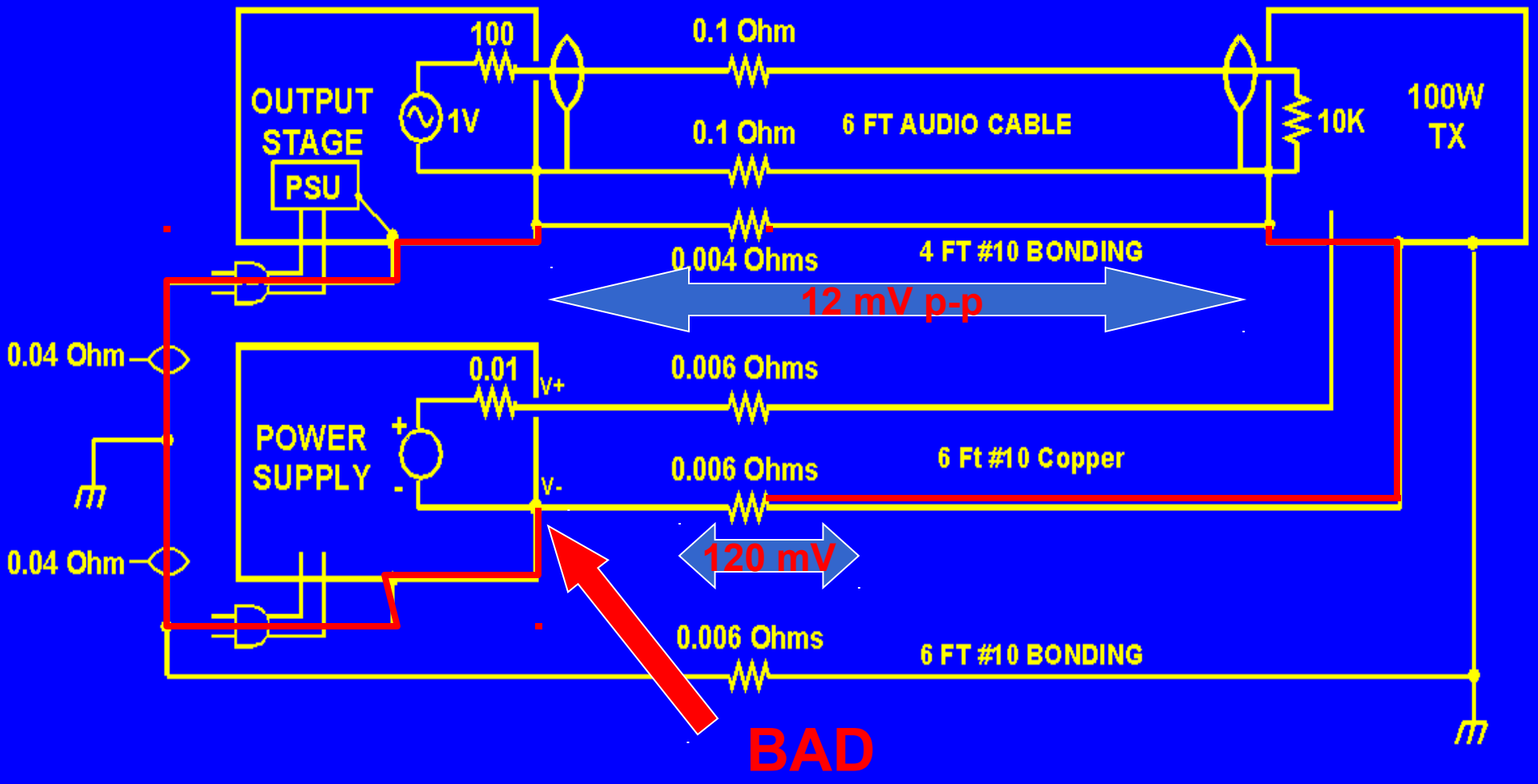
Solving The Power Supply V– Bonding Problem

- Always do Step 1 & 2 bonding recommended to kill hum and buzz
  - This will often be enough
- Open the power supply and remove the bond (most good power supplies are not bonded, and most with bonds are designed so that the bond can be removed with no problems created)
  - This is a complete solution

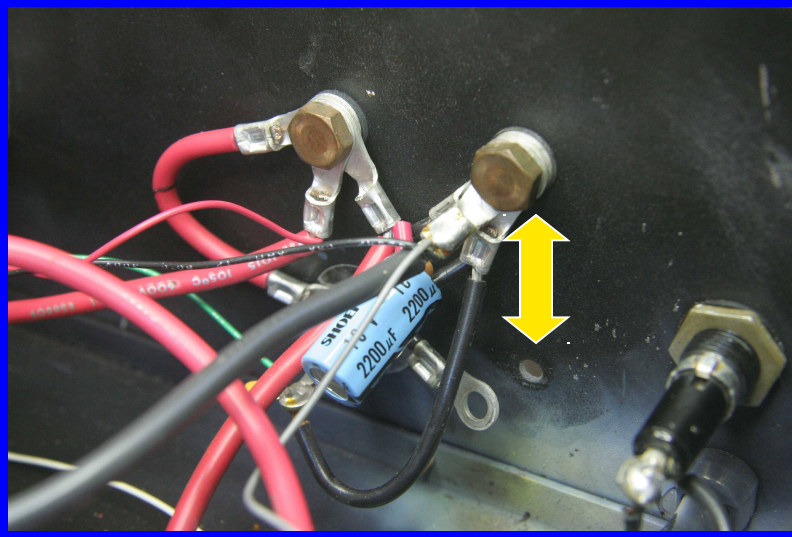
V– Bonded to Power Supply Chassis (BAD)



Bonding Rig to Audio Box Shorts Out Noise Voltage (– 20 dB)



Removing The Power Supply V– Bond



- In Astrons, the bond is at the V– terminal to the chassis ground screw near it
- In many Astrons (like this one), paint gets in the way of the bond, so many Astrons that appear to be bonded are not!

Fix The Astron

- Unscrew the terminal strip, scrape the paint
- Remove the V– bond
- Leave the green wire from the 120V plug connected
- Re-mount the terminal strip

Other Solutions

- Get power for the accessory from
  - A split of the power connector where it plugs into the radio (zero length lead between the split and the radio)
  - The accessory jack of the radio (if it can provide enough current)
  - A separate power supply dedicated to the accessory

USB Audio Interfaces

Outboard USB Interfaces

- Decoders for digital modes work best with better quality A/D converters
  - Good linearity around the noise floor helps weak signal decoding
    - PSK31, JT65, JT9, FSK441, ISCAT, WSPR
  - Lower distortion, flat response improves RTTY decoding
- Inexpensive USB interfaces for DJs and small home studios work very well

Semi-Pro USB Audio Interfaces

- Features in common
  - Two channels of A/D and D/A
  - 16-bit, 48 kHz
  - RCA connectors for line level ins and outs
  - Output level control
  - Powered from USB port
  - Use standard Windows drivers

Semi-Pro USB Audio Interfaces

- Numark Stereo I/O USB (~ $50)
  - Lowest cost “good” product
  - Bare bones unit, decodes as well as more expensive (and fancier)Tascam
  - Lacks input gain control
  - Lacks signal level indicators
  - Discontinued, check eBay

Semi-Pro USB Audio Interfaces

- Tascam US100, 122, 125, 144 (~ $100)
  - More inputs (mic, guitar) provide more flexibility of signal level, ¼-in and XLR
  - Input and output level controls
  - Input signal presence indicator (green LED) and Input clip light (red LED) allow positive setting of good input gain
  - Most discontinued, check eBay

ASUS Xonar U5, U7

- More bits and data rate than we need, but cheap and works great
- N8LP recommends for LP-Pan
- U5 about $70, U7 about $85 @ B&H

Semi-Pro USB Audio Interfaces

- Models change every few years
  - Some are discontinued but may be found used
  - Quality and features remain good
- Tascam is old line audio manufacturer
- Numark is reliable low cost DJ gear
- ASUS makes good computer stuff

Some Good Vendors

- B&H Photo (NYC)
- Full Compass (Madison, WI)
- Sweetwater (Fort Wayne, IN)

How I Tested

- First test – compare each unit to the internal sound card of a T43 Thinkpad
  - JT65A
  - Two computers, each running JT65-HF
  - K3 fed both to mic input of computer #1 and to computer #2 via the USB interface
  - Hundreds of decode cycles
- Results – both decoders “twice as good” as T43 sound card
  - Twice as many decodes on a cycle
  - Decoded signals 10-12 dB lower into the noise

How I Tested

- Second test – Numark vs. Tascam
  - Two computers, each running JT65-HF
  - K3 fed to both USB interfaces, each to its own T43 computer
  - Many hundreds of decode cycles
- Results – equally good decoding
  - With 6-8 decodes per pass, one might miss one signal the other copied, but which decoded better was statistically random

Recommendations

- If money is tight, buy the Numark
- The Tascam units provide more flexibility at about twice the cost
- The Tascam US100 is on my primary radio and primary computer
- I use the Numark with WSJT and WSJT-X on 2M, and with my second radio and a second computer for RTTY SO2R contesting

SignalLink USB – A Poor Choice

- Only one channel
- Support info suggests a Pin One Problem
- Voltage regulation problem
- QST noted problem below 600 Hz, published a fix
- Each radio needs a custom interface cable
- I have not tested this unit – I bought other products for my own use, and my research made it clear that I didn't want to own one

Audio Interconnections

The Elements of the Problem

- We must connect the right pins of the right connectors to each other
- We must match audio levels properly
  - Avoid overload of transmitter input stage
  - Optimize operation of sound card
  - Avoid distortion in sound card
- We do not need to match impedances
- All these interconnects are unbalanced
  - Noise voltage between equipment grounds adds hum and buzz

Audio Levels and Impedance

600 Ohm Circuits are a Myth!

- 600 ohm circuits have not been used in pro audio for nearly 50 years!
- In the olden days, telephone circuits loaded and equalized for up to 20kHz bandwidth were used as broadcast studio-to-transmitter links, and for other special uses. These were 600 ohm lines, but they have been very rare for nearly 40 years!

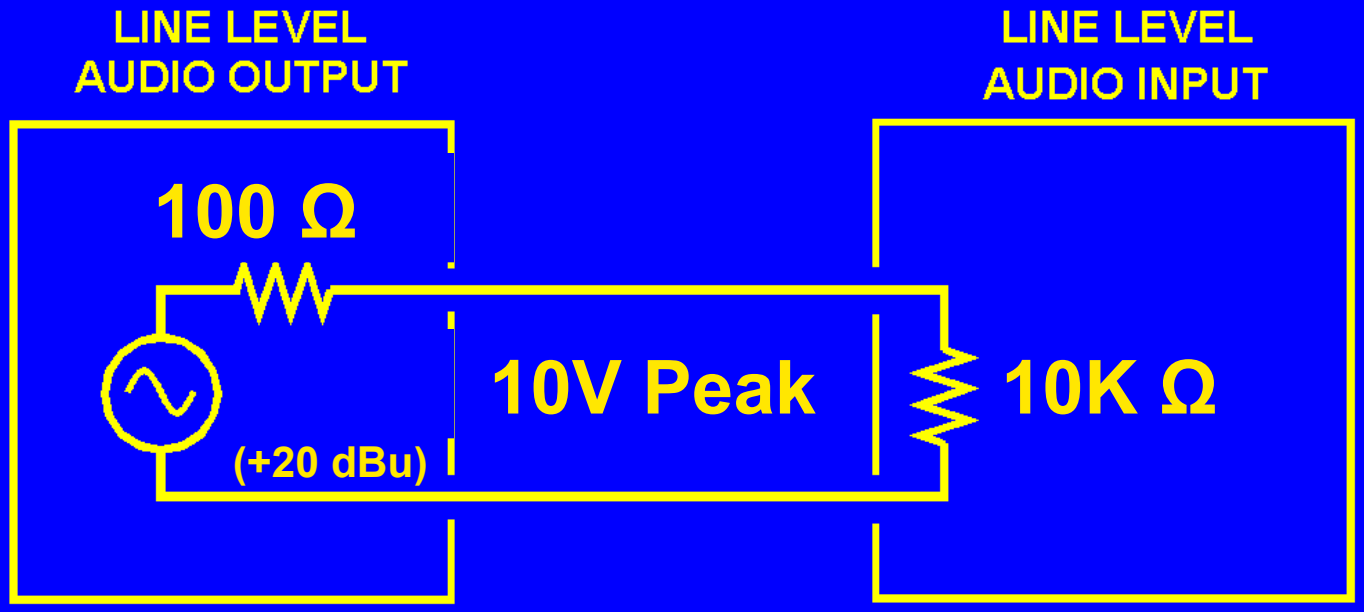
600 Ohm Circuits are a Myth!

- Those who talks about 600 ohms for audio circuits must have slept through the last 50 years!
  - Video people
  - Marketing people (product literature)
  - Hams

In the World of Audio

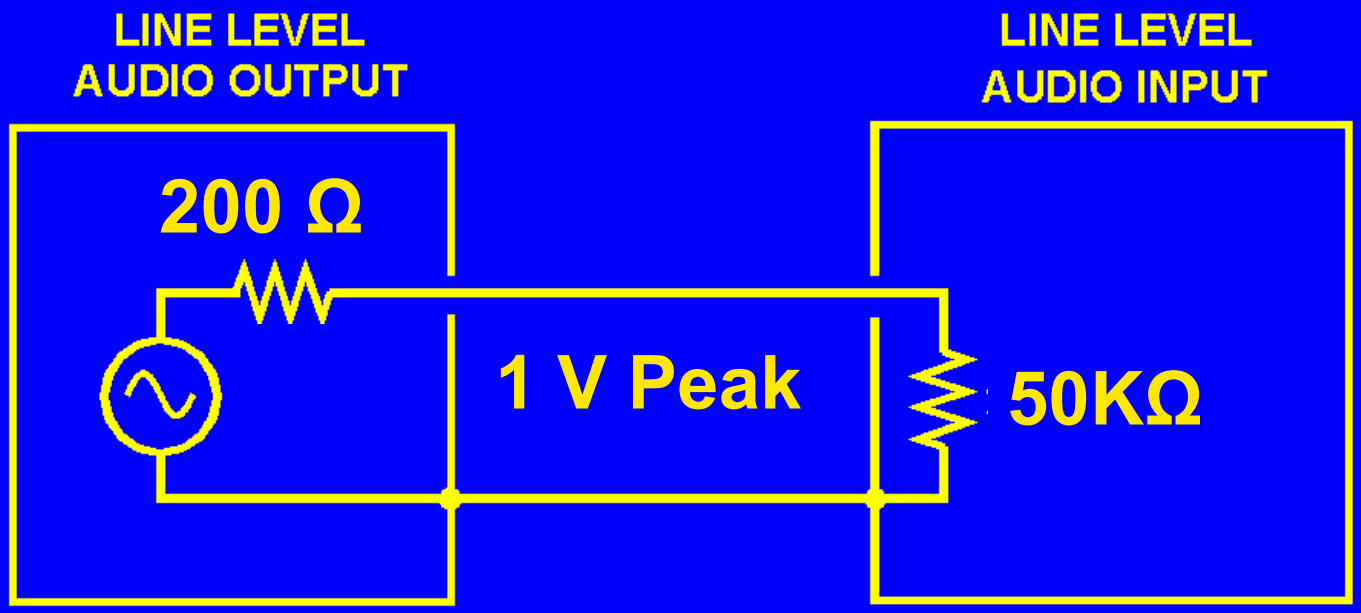
- We never match impedances
- We must match levels!

Pro Balanced Line Level



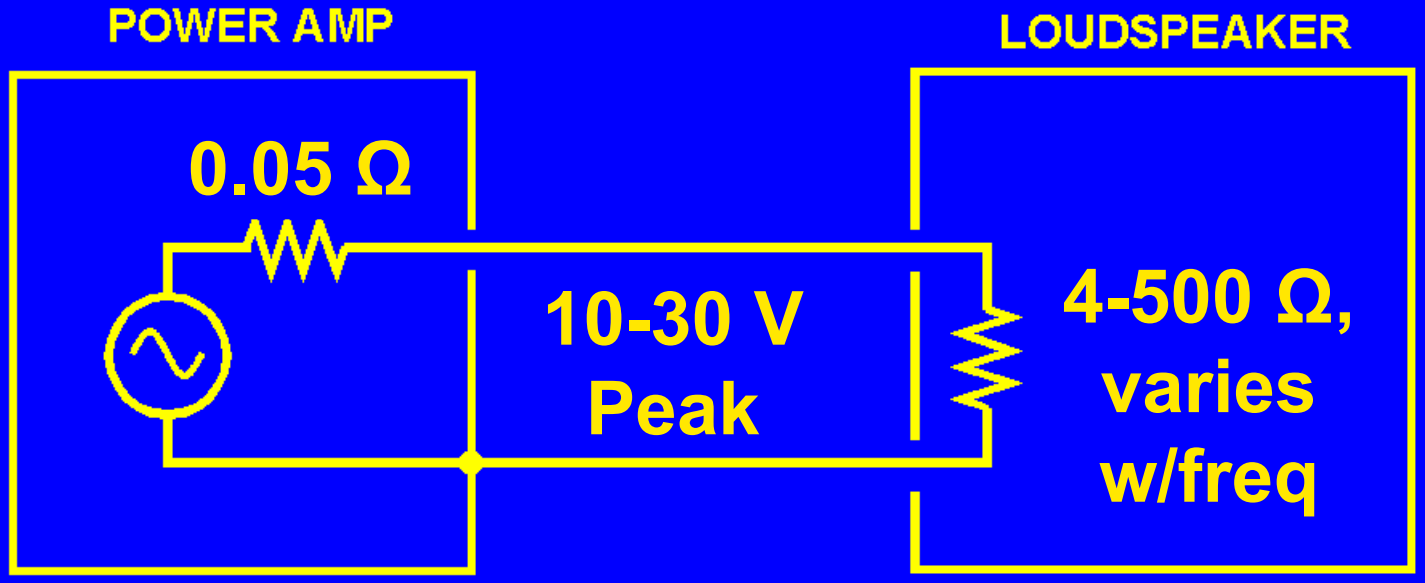
- Almost no audio current flows
- Wire size doesn't matter
- Twisting critical for hum/buzz/RFI rejection
- Shield is not necessary!
- Some pro stages are 6 dB hotter (20V peak)

Consumer Unbalanced Line Level



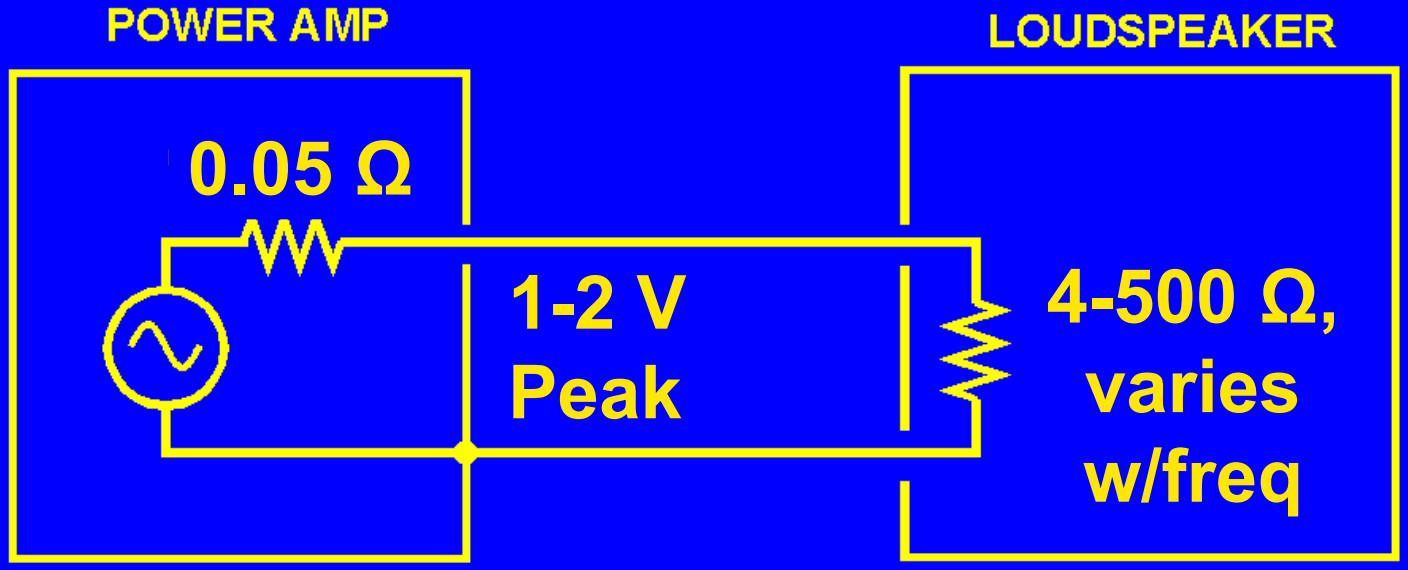
- Almost no audio current flows
- Center conductor wire size doesn't matter
- Shield resistance increases hum/buzz

Speaker Level (Medium)



- For a power amp:
  - 8 volts = 8 watts @ 8Ω, 16W @ 4Ω
  - 15 volts = 28 watts @ 8Ω, 56W @ 4Ω
- 8-15 volts is pro line level (+20 to +26 dBu)
  - It drives headphones just fine – just don't turn it up!

Speaker Levels (Low)



- For a typical computer sound card:
  - 1.4 volt = ¼ watt @ 8 ohms, ½ watt @ 4 ohms
  - 1 volt = ¼ watt to 4 ohm speaker
  - 1 – 1.4 volt is consumer line level!
  - It drives headphones just fine too!

Audio Level Matching

- Maximum Level is just before audio clips
- Clipping causes distortion
  - Harmonics, intermodulation
  - Muddy sound
  - Splatter!
- Consumer Line Ins and Outs clip at about 1 volt sine wave
- Mic Inputs may Clip at 100-200 mV
- Good output stages work best near their maximum output

Computer Output Level

- Computer sound cards usually produce less distortion about 6dB below clip
  - Poor quality analog output stage
- VERY important for digital modes
  - PSK31
  - AFSK RTTY
  - Distortion produces sidebands (extra copies of your signal)
- Run the computer about 6 dB below clip

Audio in the Digital Domain

- Analog audio is converted to a digital signal by an Analog to Digital (A/D) converter
- Massive distortion occurs at “digital clip,” when the signal is so strong that the A/D has filled all the bits and tries to go higher
- Mild distortion occurs near the noise floor

Setting Digital Levels

- Always set levels so that
  - there is never clipping on peaks

  and
  - The weakest signals are well above the noise floor
- With the Tascam USB interfaces
  - The green signal presence is always on
  - The red clip light never flashes, even on static crashes

Finding Computer Level Controls

- Click the Speaker Symbol in the TaskBar
  - You should see some volume controls
  - Or Accessories, *Entertainment, Volume Control*
  - Click On *Options*
- Select *Playback* to set levels to the radio
  - Use the WAV control for Voice Playback and RTTY tones
  - If you have a mic plugged into the computer, use the Mic control to set its level when fed to the radio by your logging program
- Select *Record* to set input gain for the RTTY or PSK signal from the radio

Mic Settings to Record Messages

- Feed Mic into the Computer Mic Input
- Click the Speaker Symbol in the TaskBar
  - You should see some volume controls
  - Or Accessories, *Entertainment, Volume Control*
  - Click On *Options*
- Select *Record* to set input gain for the mic
  - Most computers will have a mic preamp
  - Called “mic boost”

Recording Voice Messages

- A webinar I did a few years ago
- http://nccc.cc/misc/RecordingVoiceMessages-K9YC.wmv
- The editing software I showed may no longer be free
  - Other editing software works fine, some commands are different, all the principles are the same
  - Audacity

Setting Computer Output Level

- Three ways to do it
  - Scope (Best)
  - AC Voltmeter with good low volts scale (very good)
  - Your ears (better than you think!)

Setting Computer Output

- Before connecting to radio, set the computer to transmit PSK31 or AFSK RTTY and watch audio on a scope
  - Set sweep to see sine waves of audio
  - Increase output level until you see clip
  - Turn down computer output by 6 dB (half the voltage)
- This should optimize the computer
- The same computer settings should work for SSB message playback

Setting Computer Output

- If no scope, use AC voltmeter at computer output while it's sending PSK or RTTY tones, and increase the output level control until voltage stops increasing. That's clipping.
- Now reduce the level to one half of the measured voltage at clip.
- This is the right setting for the computer, both for tones (RTTY, PSK) and SSB.

Setting Computer Output

- If no voltmeter or scope, listen to the computer output while it's sending PSK or RTTY tones, and increase the output level until you hear the sound change (get harsh, raspy). That's clipping
- Now reduce the level until harshness is gone and it sounds about half as loud
- This is the right setting for the computer, both for tones (RTTY, PSK) and SSB.

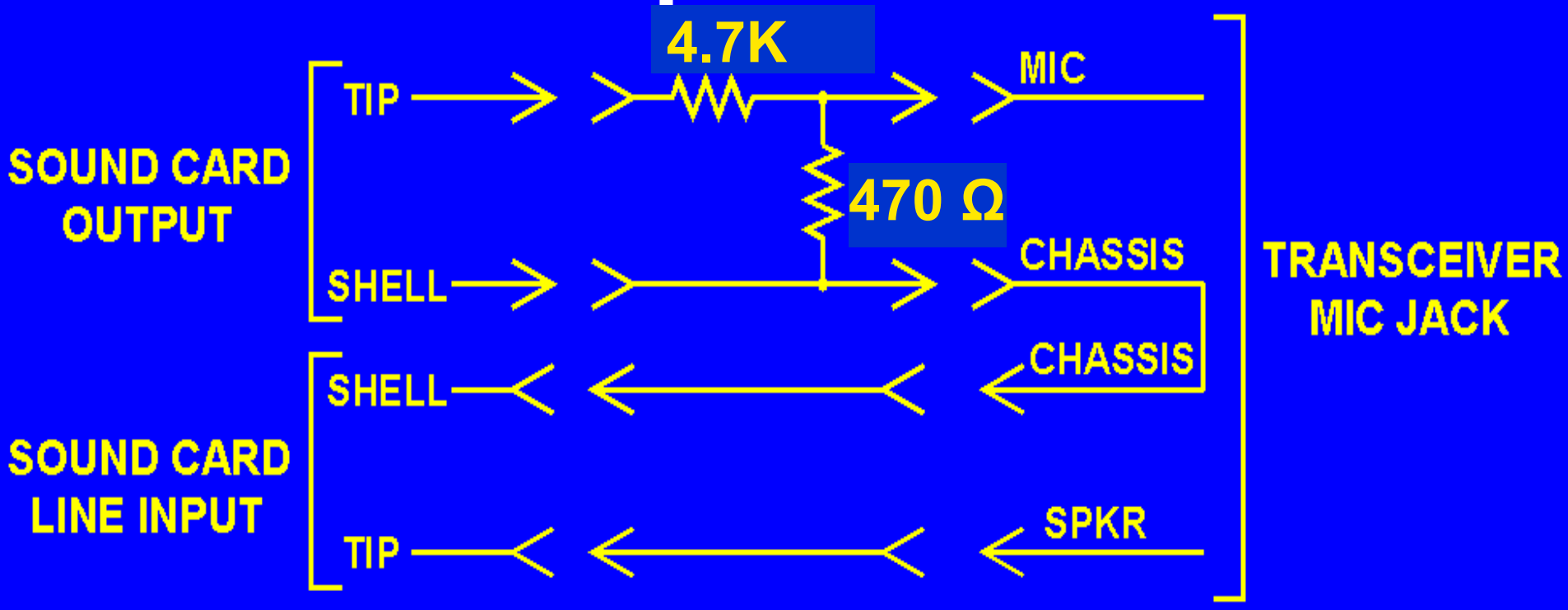
Feeding Audio to the Radio

- Every radio is different
- Study the reference section of the manual for your rig
- Line Inputs and Line Outputs are best
  - Phone Patch connections
  - RTTY/PSK connections
  - Often on accessory DIN connectors
- Mic Inputs can work fine
  - More about that later

Setting Levels in the Radio

- The mic gain should be set about the same as it is for your mic
- Use a 10dB or 15dB pad on the line input if needed to put mic gain in "normal" range
- Always use the 20dB pad if computer feeds the mic input
- Resistive pads
  - 2.2K in series, 1K across line input (10 dB)
  - 4.7K in series, 1K across line input (15 dB)
  - 4.7K in series, 470Ω across line input (20 dB)

K6DGW Simple RTTY Interface



- Set rig for SSB, VOX operation
- No PTT required
- Follow Hum/Buzz steps 1 & 2

Now Lets Talk About Mics

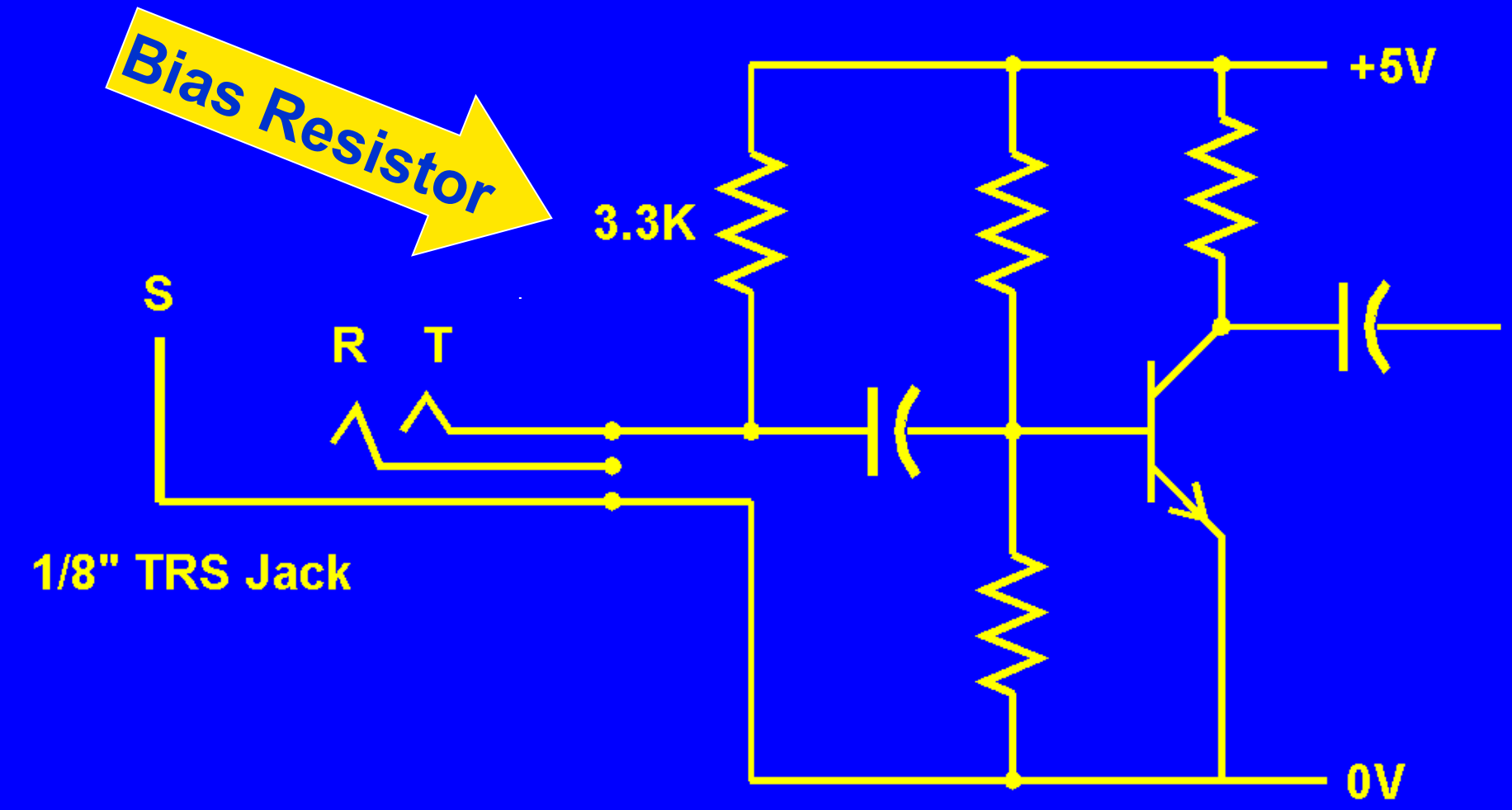
Mic Levels and Impedances

- Audio circuits operate on voltage
- Unbalanced line level is 1 volt sine wave on peaks
- Audio is quite dynamic. A low impedance mic may produce less than 1 mV with soft sounds, but 2 volts with very loud music
- Low impedance mic outputs are 150-250Ω
- Low impedance mic input stages are typically 1,000 – 4,000Ω
- Most ham mics are low impedance mics

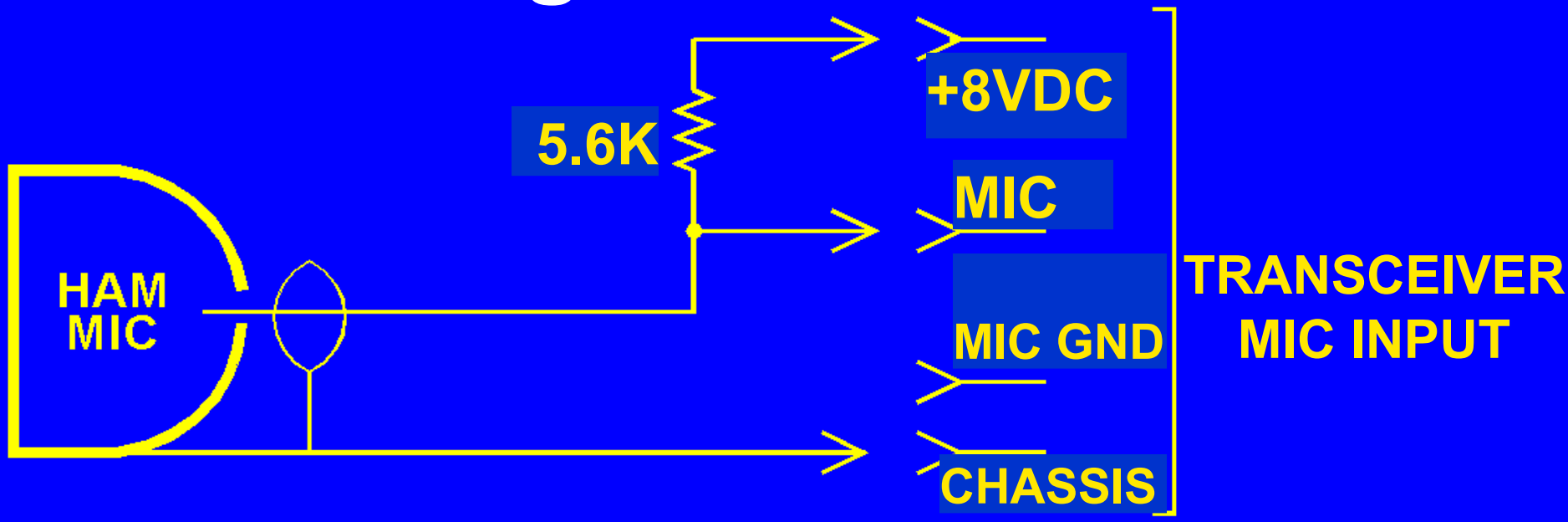
Dynamic and Electret Mics

- Mics convert sound vibrations to voltage
- *Electret* mics have a polarized capacitive diaphragm connected to a FET "follower" impedance converter. The FET needs a small DC voltage (bias) to operate.
- *Dynamic* mics have a diaphragm attached to a coil that vibrates in a magnetic field.
  - Do not need bias, but they can tolerate bias from a high resistance source (5K)
- Many modern ham mics are electrets, but dynamic mics work fine with ham gear too

Laptop Mic Input (Typical)



Biasing an Electret Mic



- DC voltage not critical (5-12VDC)
- Resistor value not critical (4.7K-6.8K)
  - Use less resistance for low voltage, more for high voltage
  - Can often fit inside ham mic connector
- Built into K3, KX3, turn it on and off from setup menu

Ham Mic to Laptop

- Many ham mics are electrets
  - Need power for the FET
- If a 1/8-inch connector
  - Wire mic audio to Tip (audio input)
  - Wire mic audio ground to Shell
  - Wire mic shield to Shell
- In laptop, turn on mic pre-amp
  - Called “mic boost” in my Thinkpad
  - Not all sound cards have a mic pre-amp!
  - If no preamp, it may not be loud enough

Yamaha CM500

- About $60
- Great response for ham radio
- Electret mic
- Plugs into rear panel of K3 (turn on bias)
- 1/8-in plug, so needs cable adapter for other rigs, get bias from mic connector
- Plugs straight in to most laptops
- Headphones are very comfortable, good isolation, and sound very good

Wearing a Headset Mic

- Not too close
- Prevent breath pops
- Prevent bass buildup
- Space to munch, drink coffee

CM500 Mic to Icom, Kenwood, Yaesu

- Much nicer than Heil headsets
  - Mic sounds much better
  - Headphones more comfortable
  - Much less expensive!
- Build cable adapter
  - Tip of 1/8-in connector to mic in
  - Tip of 1/8-in connector thru 5K to +8VDC
  - Shell to mic connector ground
  - No connection to ring

Make Your Own Audio Cables

- Much better than you can buy
- Cables that work well
  - Small coax with braid shield
    - RG58, RG174, etc.
  - Miniature shielded twisted pair
    - Gepco XB401, Belden 1901A

Cable-Mount Audio Connectors

Description	Switchcraft	Neutrik
3-ckt male 1/8” plug	35HDNN	NYS231BG
2-ckt male 1/8” plug		NYS226BG
3-ckt female 1/8” jack		NYS240BG
Phono (RCA) male plug	3502	NYS352
Phono female jack	3503	

Buying Good Audio Connectors

- Stick to Switchcraft, Neutrik
- Full Compass Systems (Madison, WI)
- Sweetwater (Ft Wayne, IN)
- Buy in quantity, share with friends – much of the cost is shipping
- Avoid Radio Shack, Fry's, Best Buy, etc.
  - Cheesy construction, dissimilar metals

Junk DIN Connectors

- Virtually all DIN connectors sold to hams are JUNK (but they're CHEAP – about $1)
  - Contact metal doesn't take solder
  - Dielectric melts with heat
- Some guilty parties (Hams are cheap)
  - RF Connection, Digikey, HSC
- The good ones cost $5-$7 each
  - Switchcraft, Tuchel
  - Buy from Allied, Newark, etc.

DIN Connectors

- An acceptable low cost alternative
  - Kobiconn
  - 8-pin male plug is Mouser 171-0278
  - About $0.75
- Takes solder well, doesn't melt
- "Clamshell" pieces don't mate very well
  - OK for very light duty use
  - OK if connector goes in once and stays there
  - Bad if connector will be plugged in and out

Good DIN Connectors

buy from Newark, Allied, $5 - $7 each

Configuration		Switchcraft Part Nr
4 pins at 210°	Yaesu FSK	09BL4M, 09GM4M
5 pins at 180°	Icom, Yaesu	05BL5M, 05GM5M
5 pins at 240°		12BL5M, 12GM5MX
6 pins at 240°	Icom, Kenwood, Yaesu	12BL8M, 15GM6MX
7 pins at 270°	Icom, Yaesu	15GM7MX
8 pins at 262°	Kenwood	20BL8M, 20GM8M
8 pins at 270°	Icom, Yaesu	15BL8MX, 15GM8MX

Rig Control Interfaces

- Most modern rigs use RS232
  - Kenwood, Yaesu, Elecraft, Ten Tec
  - New ICOM, some Flex use USB
  - Each radio needs its own port
  -
- Older Icom had unique CI-V interface
  - Icom adapter was needed $$$
  - Converts one RS232 port to two wire 1/8” plug
  - One RS232 port can control four radios

USB / RS232 Control Functions

- Radio control
  - Read frequency, mode for logging
  - Remote control – change frequency, radio settings, filters, etc.
  - Elecraft, Kenwood, Yaesu have serial port
  - Icom is proprietary, needs special adapter
- CW, PTT (from contest logger)
  - Can be on same serial port used for control
  - Can be on a parallel port
  - Require a simple NPN inverter/level shifter

RS232 Control Wiring

- Interconnects are unbalanced
  - We must eliminate the noise voltage on equipment grounds (solved by bonding)
  - Only two circuits for radio control
  - TXD and RXD (pin 2, pin 3, return)
  - Twisted pair (CAT5) has best RFI rejection
- Send CW on COM DTR (pin 4)
  - Need simple NPN inverter/level shifter
- Send PTT on COM RTS (pin 7)
  - Same simple NPN inverter/level shifter
- Can also use parallel port for CW and PTT

The K9YC Serial Cable

- Eliminates RFI, minimizes hum and buzz
- Use ordinary CAT5, CAT6 (4 twisted pairs), one pair per circuit
  - Pin 2 Brown
  - Pin 3 Orange
  - Pin 4 Green (DTR, used to send CW)
  - Pin 7 Blue (RTS, used for PTT)
  - Connector shell – Brown/White, Orange/White, Green/White, Blue/White
- Don’t use pin 5 – it’s a pin 1 problem!
  - RFI, hum, buzz, noise interferes with RS232

Computers Without Serial Ports – What are the Options?

- Older Desktop Computers
  - Real RS232 Ports on a PCI Card
  - USB to RS232 Emulators
- Older Laptop Computers
  - Real RS232 Ports on a PCMCIA or PC Card
  - Real RS232 Port on Port Replicator
  - USB to RS232 Emulators
- A Used Computer with real RS232 ports

Serial Ports For Older Laptops

- Real Serial Ports are best
  - Look for 16550 or 16750 UART
- PCMCIA (PC Card) Adapter for laptop
  - Quatech – Buy at B&B Electronics $150 2-ports
- Buy a port replicator for your laptop

PC-Card to Two RS232 Serial Ports

About $150

USB Serial Ports

- Buy only adapters using FTDI chipset
- Emulate (pretend to be) a serial port
- Compatibility with hardware and software can be a problem
- May work with some programs and not others
- More processor overhead than a real serial port
- Cheap

USB to Four RS232 Serial Ports

A New (Used) Computer

- Use a modern computer for Windows
  - Windows XP Pro, Windows 7
  - Avoid Vista
- Use enough RAM (1 GB min, 2 GB better)
- Thinkpads work well for ham radio
  - OK (not great) sound card, with mic preamp
  - T40-series and later have serial port in port replicator
- Off-lease IBM desktop $125 - $250
  - Real serial ports, XP Pro
  - Tiger Direct and other sources

References

- *A Ham's Guide to RFI, Ferrites, Baluns, and Audio Interfacing*
  http://k9yc.com/RFI-Ham.pdf
  - *Chapter 8 – Solving Problems in the Shack*
  - *Appendix 6 – Audio For Ham Radio*
- *Power, Grounding, Bonding, and Audio for Ham Radio* **(this presentation)**
  http://k9yc.com/HamPowerGroundAudio.pdf
- *Power and Grounding for Audio and Video Systems – A White Paper for the Real World*
  http://k9yc.com/SurgeXPowerGround.pdf

See the Appendix for Slides that wouldn't fit in an hour

- More about mics for ham radio
- More about serial port adapters for CW and PTT

Power, Grounding, Bonding, and Audio for Ham Radio

Safety, Hum, Buzz, and RFI

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Appendix
–
Slides and Topics That Don't Fit in an Hour

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Where Does All That Buzz Come From?

Noise on “Ground” from Power

- Leakage currents to green wire
  - Power transformer stray capacitances
- Intentional currents to green wire
  - Line filter capacitors
- Power wiring faults
- Shunt mode surge suppressors
- Magnetic coupling from mains power
  - Harmonic current in neutral
  - Motors, transformers

Sources of Noise on “Ground”

- Capacitance from AC “hot” to ground
  - Leakage capacitance in transformers
  - AC line filters
- Magnetic induction
  - Leakage fields from power transformers
  - Wiring errors in buildings and homes
    - Double bonded neutrals
  - Leakage fields from motors and controllers
    - Variable speed drives
- 3-Phase noise current from neighborhood

Leakage Current to Green Wire

- Capacitance from phase (“hot”) to equipment ground (green wire)
- $I = E/X_C = 120/X_C$
- $X_C = 1/(2\pi f C)$
- Maximum permitted leakage current is 5 mA with 110% of rated line voltage
- $X_C = E / I = 1.1 \times 120 / .005 = 26.4\ k\Omega$
- $C = 1/(2\pi f X_C) = 0.1\ \mu F$ is the largest capacitance that can exist from line to ground within equipment

Leakage Current to Green Wire

- 0.1 μF is the largest capacitance that is permitted from line to ground within equipment
  - This includes stray capacitance within the power transformer
- We often have many pieces of equipment connected to the same branch circuit
  - All capacitances (and leakage currents) are in parallel, so they add
  - More noise

The Harmonic Problem

- Nearly all electronic loads have power supplies with capacitor-input filters

so:

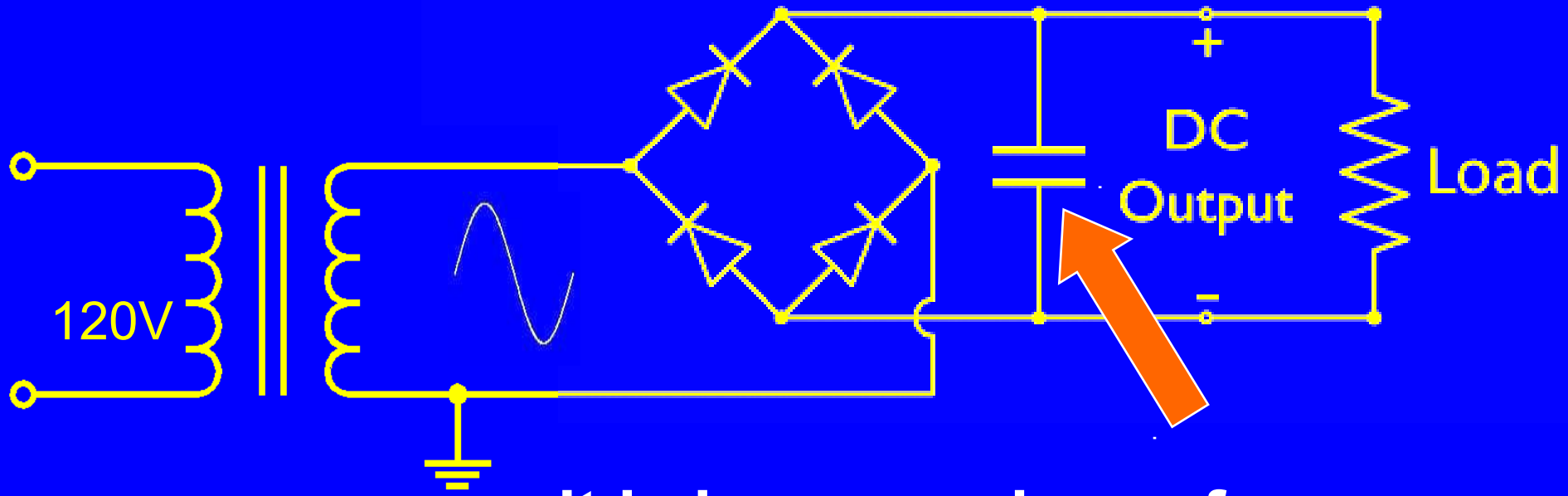
- Load current is drawn in short pulses at peaks of the input sine wave

thus:

- **Phase, neutral, and leakage currents are highly distorted**

The Harmonic Problem

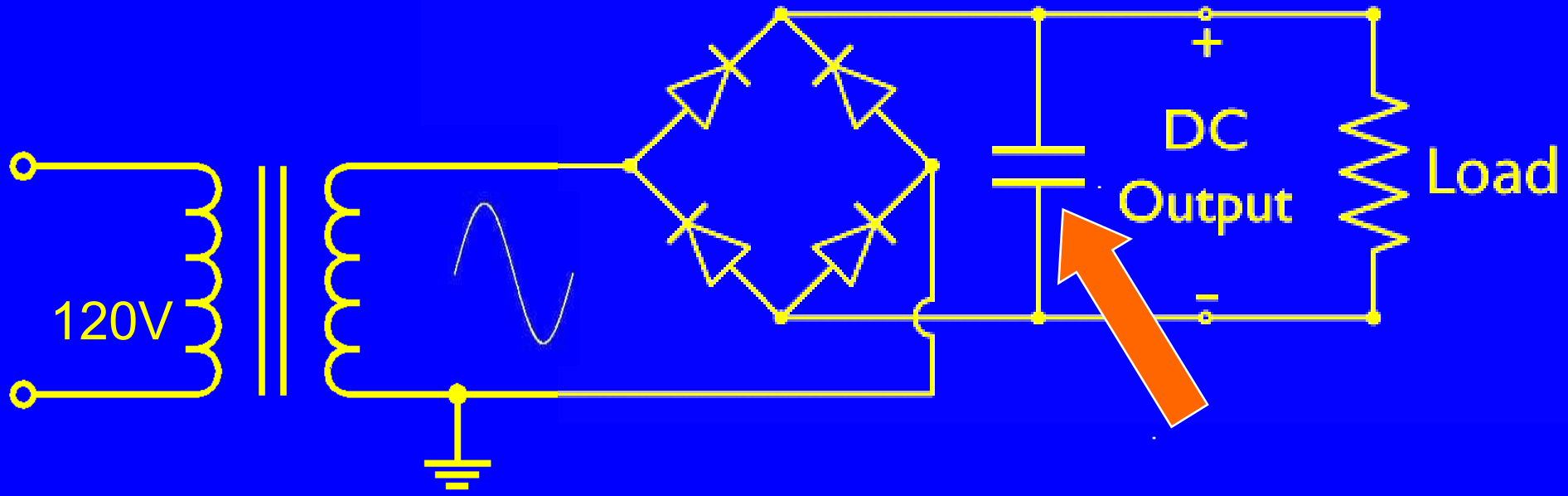
Recognize this power supply?



Something like it is in <u>every</u> piece of electronic gear – audio, video, computers, printers, copiers (even switching power supplies)

The Harmonic Problem

Recognize this power supply?



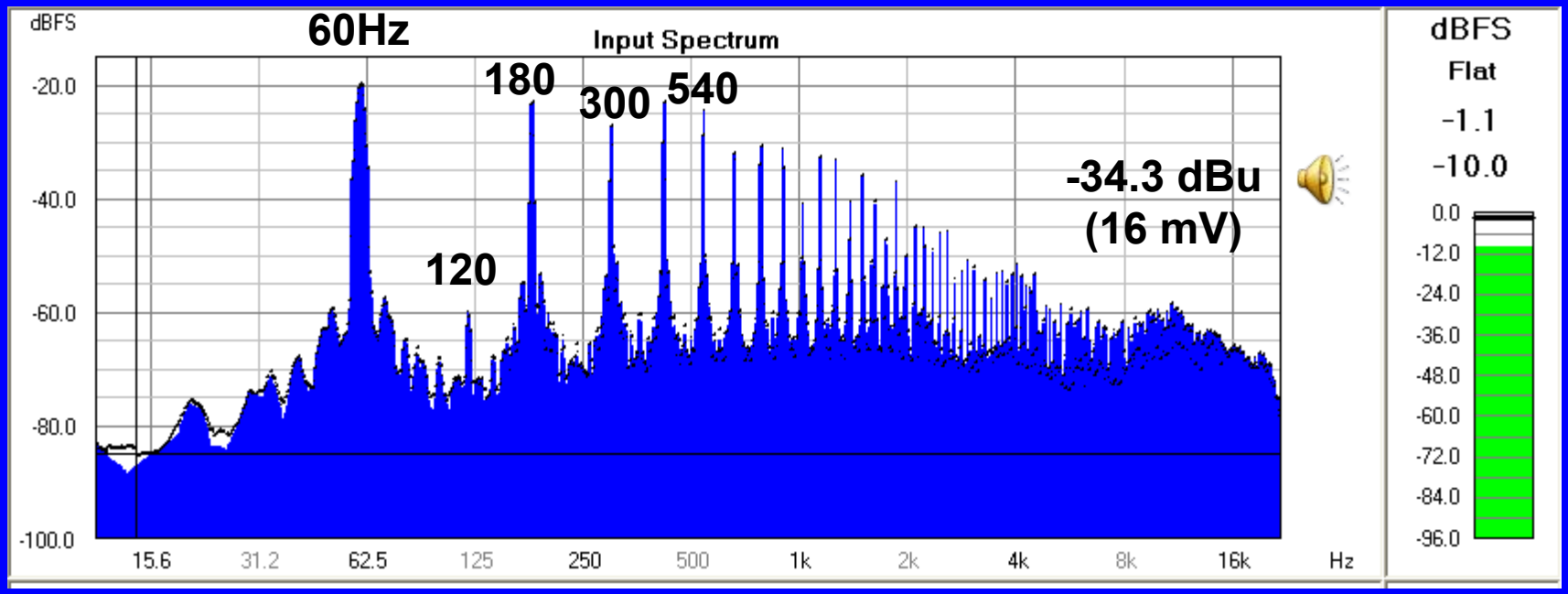
Current flows in short pulses that recharge the filter caps on each half cycle

Current is not even close to a sine wave

Problems With Pulse Currents

- Because current flows in short pulses, the IR drop at the peak of the current waveform can be much greater than for a sine wave
  - Greater I^2R losses
  - Voltage waveform is distorted
  - Lower voltage delivered to equipment
  - Increased dissipation in phase and neutral conductors
  - Increased dissipation in transformers

3-Phase Noise in Santa Cruz Mountains!



Measured between two outlets on opposite walls of my ham shack and office

Triplen Harmonics and Leakage

- 3-phase equipment has stray capacitance to ground too
- Triplen harmonics contribute to leakage current, and ADD, just like in the neutral!
  - Third, sixth, ninth, etc
- Adds to noise current on cable shields
- Fundamental (50/60 Hz) and low harmonics (150/180 Hz, 450/540 Hz) are perceived as “hum”
- Higher harmonics are heard as “buzz”

The Hum/Buzz Problem

- Ham Interfaces are Unbalanced
  - One Conductor goes to chassis at each end
- There is noise voltage between chassis #1 and chassis #2
- “Ground” isn’t a single point!
  - “Grounds” are connected by resistors (wires)
  - Capacitance from 120V to chassis causes current in those resistors (wires)
  - There are other sources of ground current
  - There’s a voltage drop from that current

For Unbalanced interconnections, shield resistance can be important!

- Shield current (noise) creates IR drop that is added to the signal
- $E_{NOISE} = 20 \log (I_{SHIELD} * R_{SHIELD})$
- Coaxial cables differ widely
  - Heavy copper braid (8241F) 2.6 Ω /1000 ft
  - Double copper braid (8281) 1.1 Ω /1000 ft
  - Foil/drain shield #22 gauge 16 Ω /1000 ft
- Audio dynamic range 100 dB
  - For 1 volt signal, 10 µV noise floor

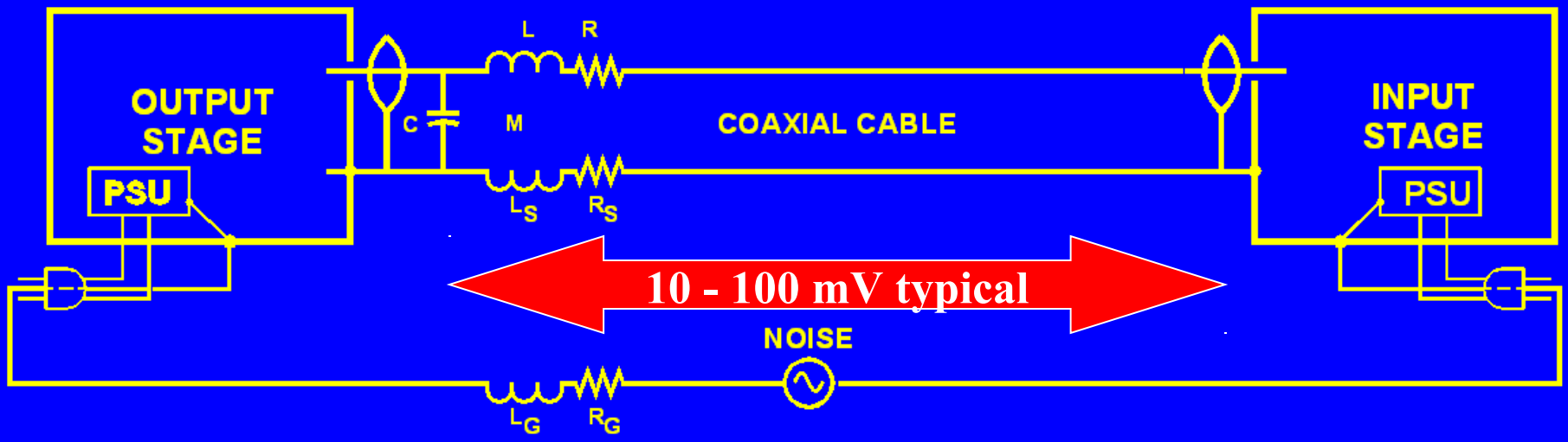
A Calculated Example

- 25-foot cable, foil shield and #26 AWG drain with resistance of 1 Ω
- Leakage current between two pieces of equipment is measured at 100 µA
- From Ohm's law, noise voltage =100 µV
- Consumer reference level = 316 mV
- Signal to noise ratio = 316 mV ÷ 100 µV = 3160:1 = 70 dB = not very good!
- Belden #8241F cable, shield resistance of 0.065 Ω, would reduce noise ≈ 24 dB!

Audio Noise Coupling Mechanisms

- IR drop on shields of unbalanced signal wiring
- Pin 1 problems – current on shields
  - Improper shield termination within equipment
- Magnetic field coupling to wiring
  - POWER TRANSFORMERS
  - Audio Transformers

The Problem with Unbalanced Interfaces

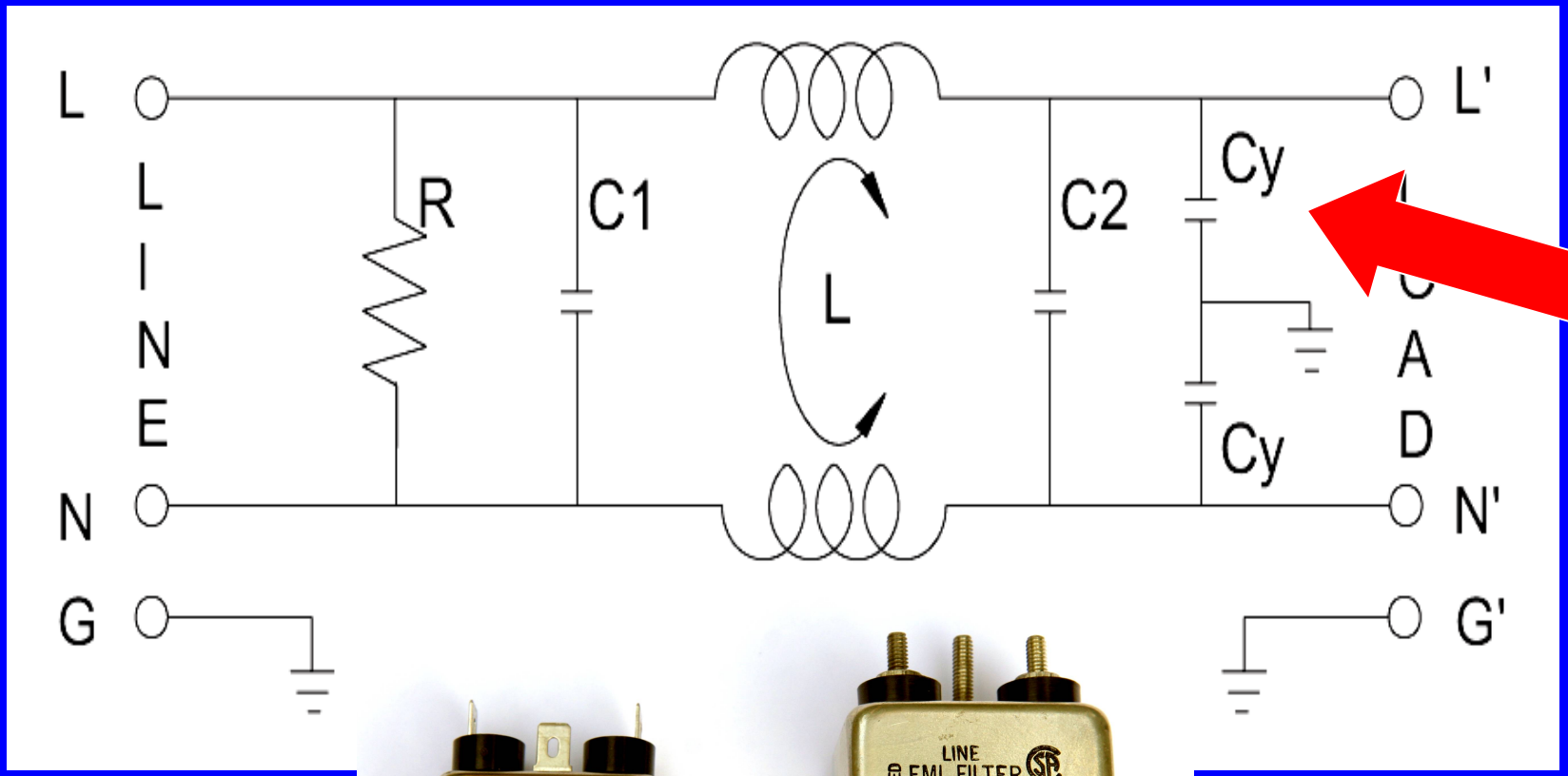


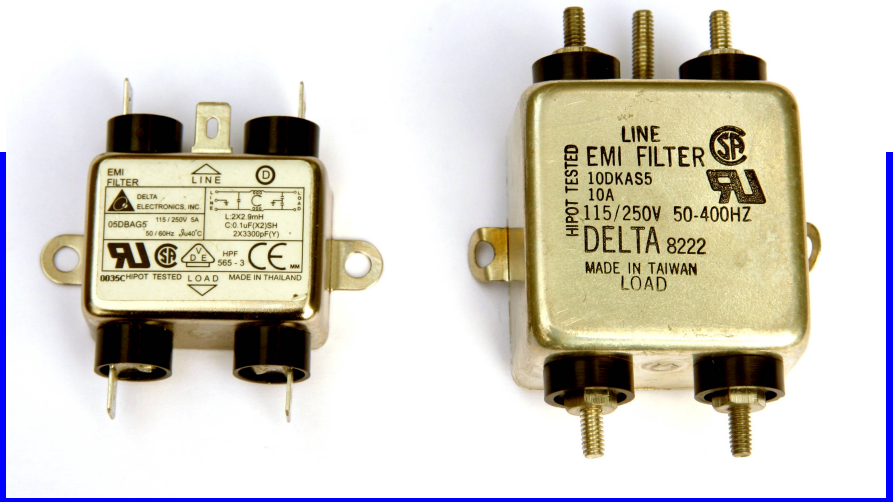
Noise current flows on the shield, and the IR drop is added to the signal.

- Mu doesn't help at audio frequencies

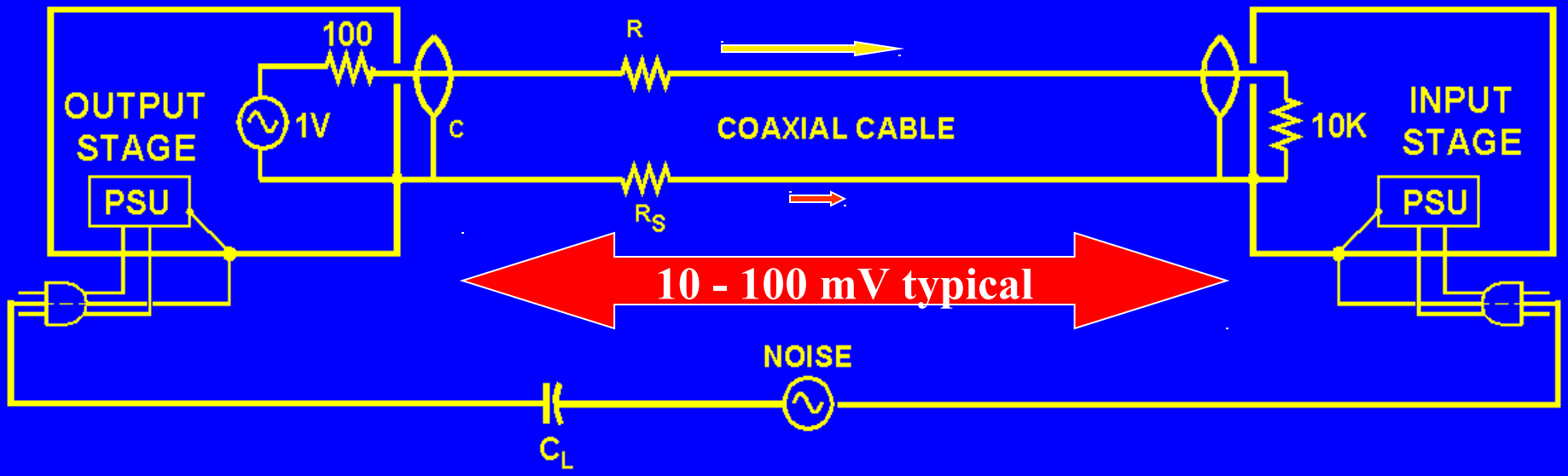
  $R_S >> X_L$

Line Filters Contribute Noise to the Green Wire





The Problem with Unbalanced Interfaces

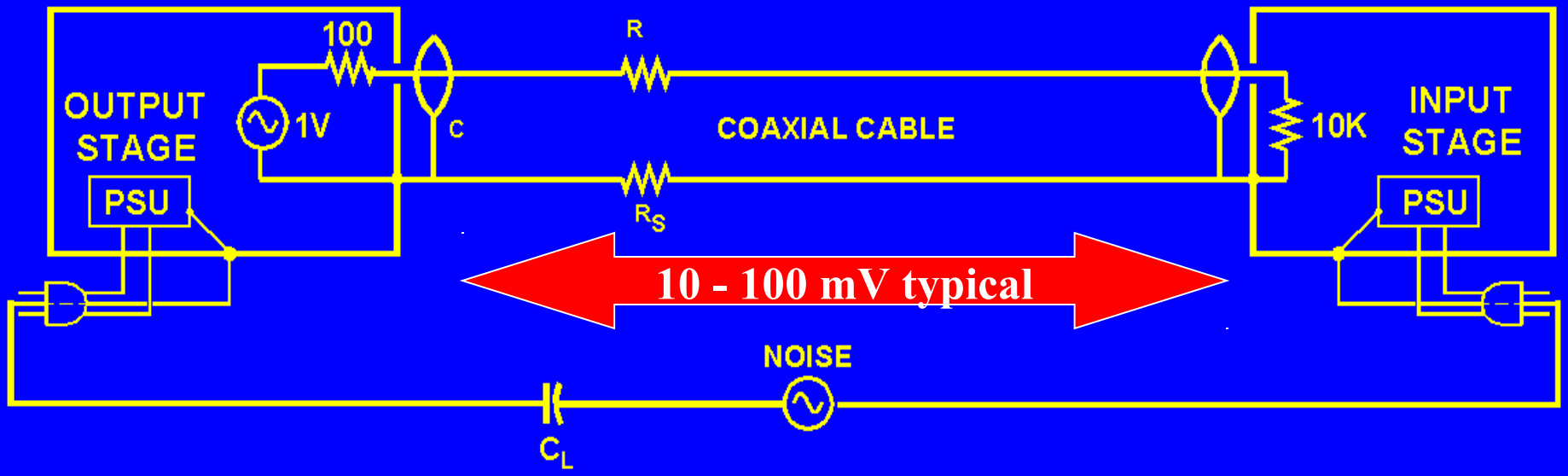


Noise voltage between the two chassis is added to the signal.

- **So we have 1v signal (on peaks) and 10mV – 100 mV of noise**
- **Average value of speech is 10 dB below peak**

  So only 10dB - 30 dB S/N ratio!

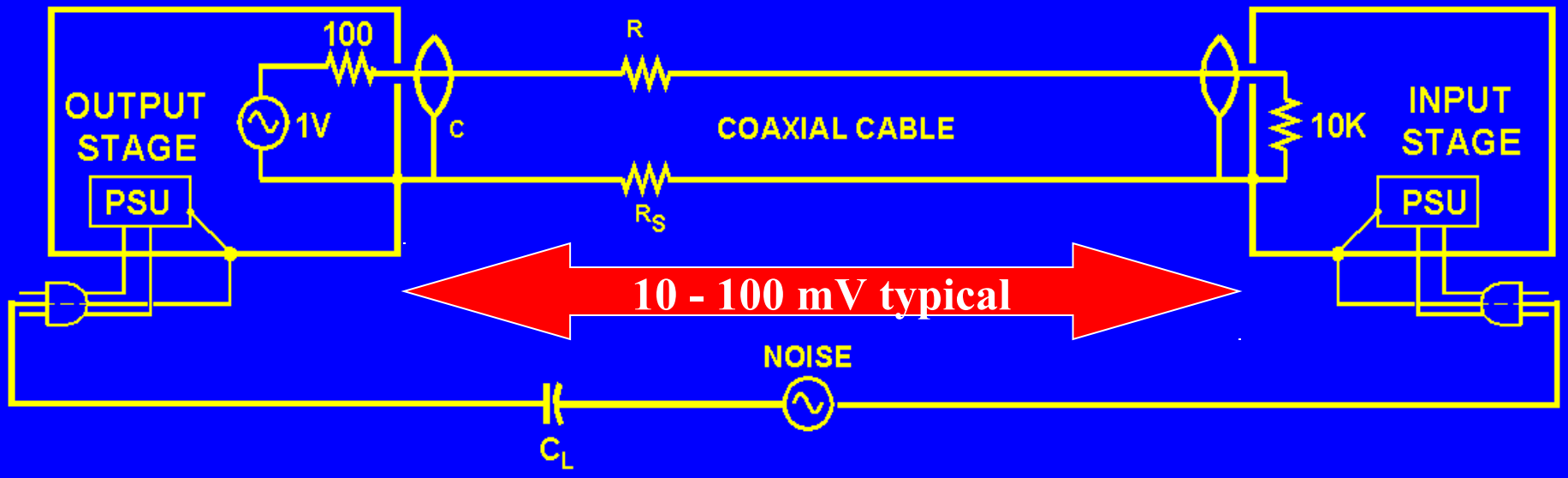
The Problem with Unbalanced Interfaces



Noise current flows on the shield, and the IR drop is added to the signal.

- **Re ends of the cable**
- **Use a "beefy" cable shield**
  - **Minimizes the drop**

The Problem with Unbalanced Interfaces



- **Why we hear more buzz than hum**
  - **Noise is leakage through capacitance, so it's a voltage divider between C_L and R_S**
  - **The noise is dominated by harmonics**

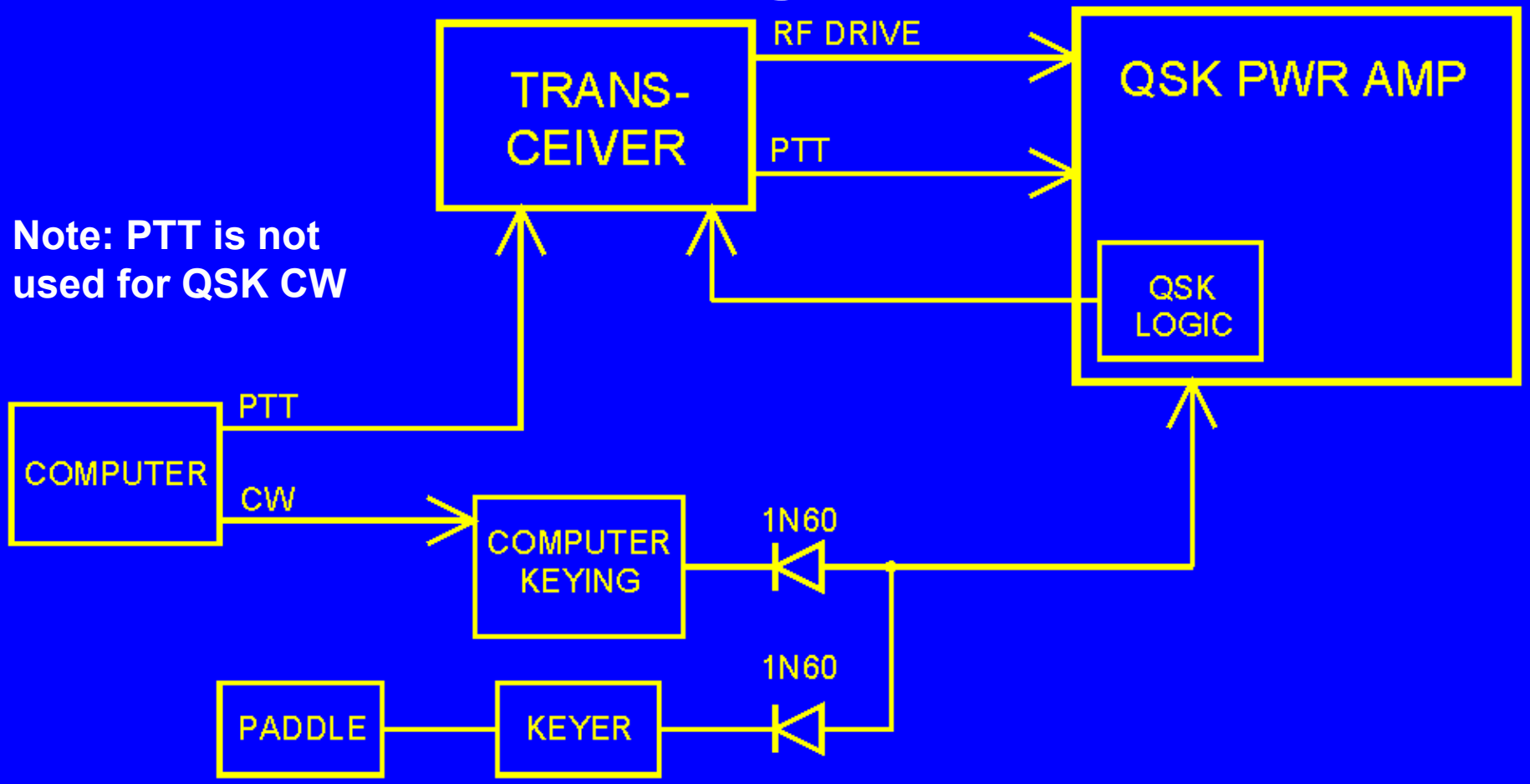
Audio Levels and Impedances

- Audio line outputs have low impedance
  - 100 ohms for pro circuits
  - 300 ohms for consumer gear
  - 0.1 ohms for loudspeaker power amps
- Audio line inputs have high impedance
  - 10K for pro circuits
  - 50K for consumer gear

Audio Level Matching

- Line level circuits are not designed to provide current
  - That is, they want to see a 10K or 50K load
  - If you load them with 600 ohms, distortion increases!
- Mic level circuits are not designed to provide current
  - Loading them with 600 ohms reduces their output and can increase distortion
- Loudspeaker and headphone outputs are designed to supply power (current)

Interface Logic – QSK CW

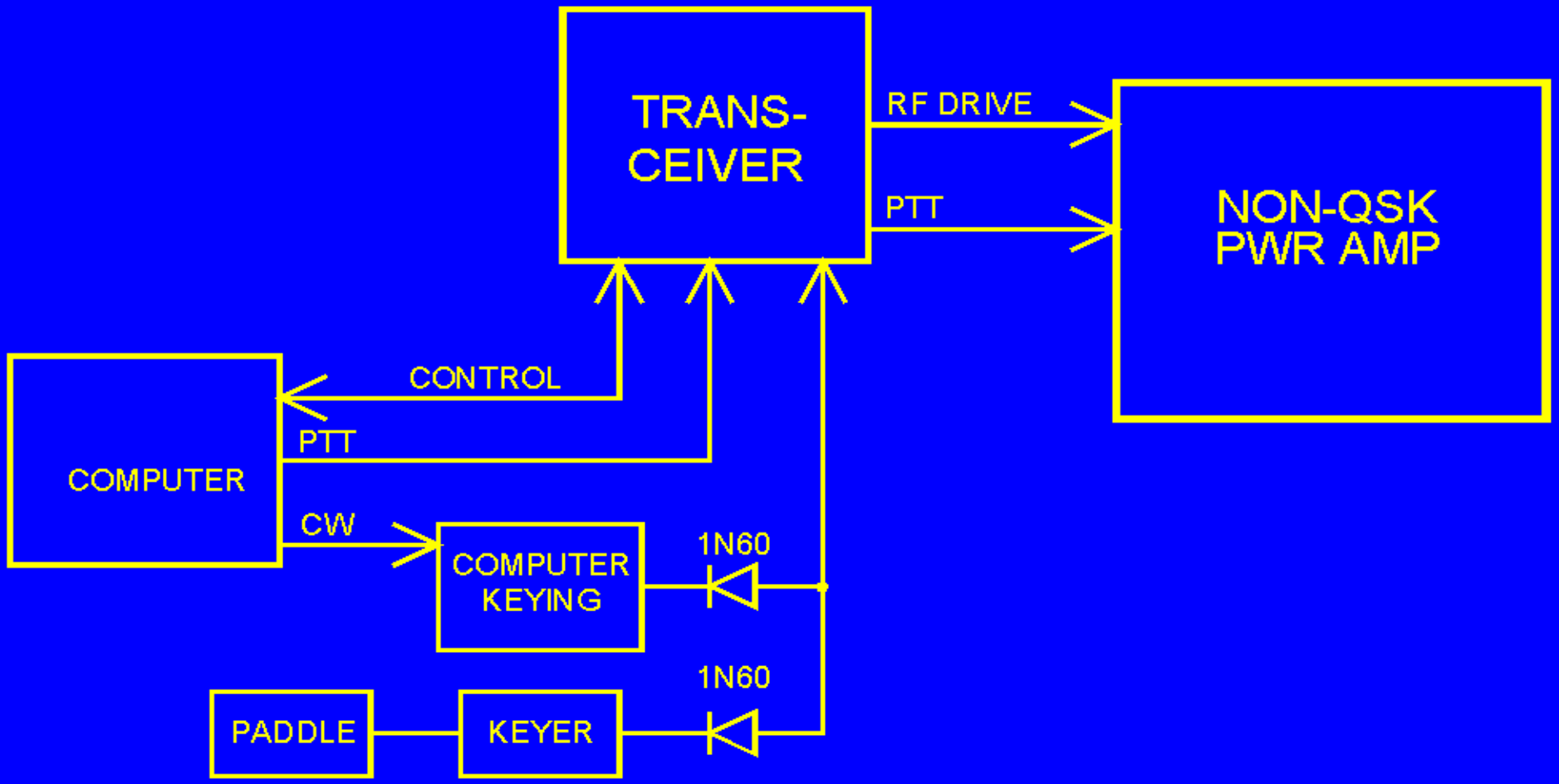


QSK logic in power amp prevents hot switching of T/R relay

Amp has fast-switching vacuum T/R relay, follows fast CW

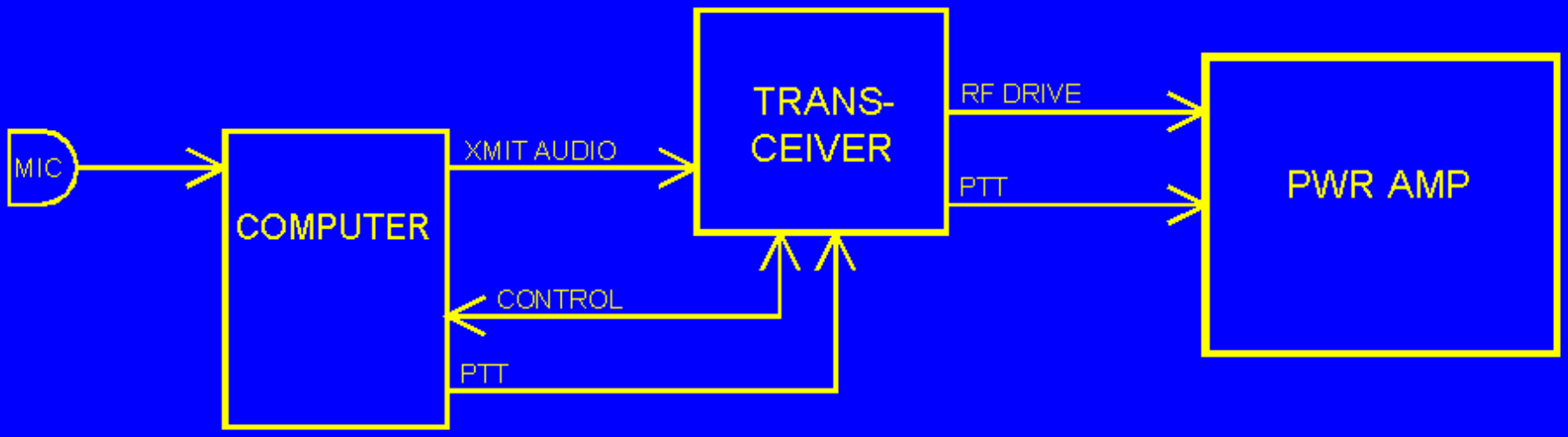
Keying pulls in T/R relay, senses relay position, then keys transceiver

Interface Logic – Non-QSK CW



Hot-switch protection in some power amplifiers may chop the first character

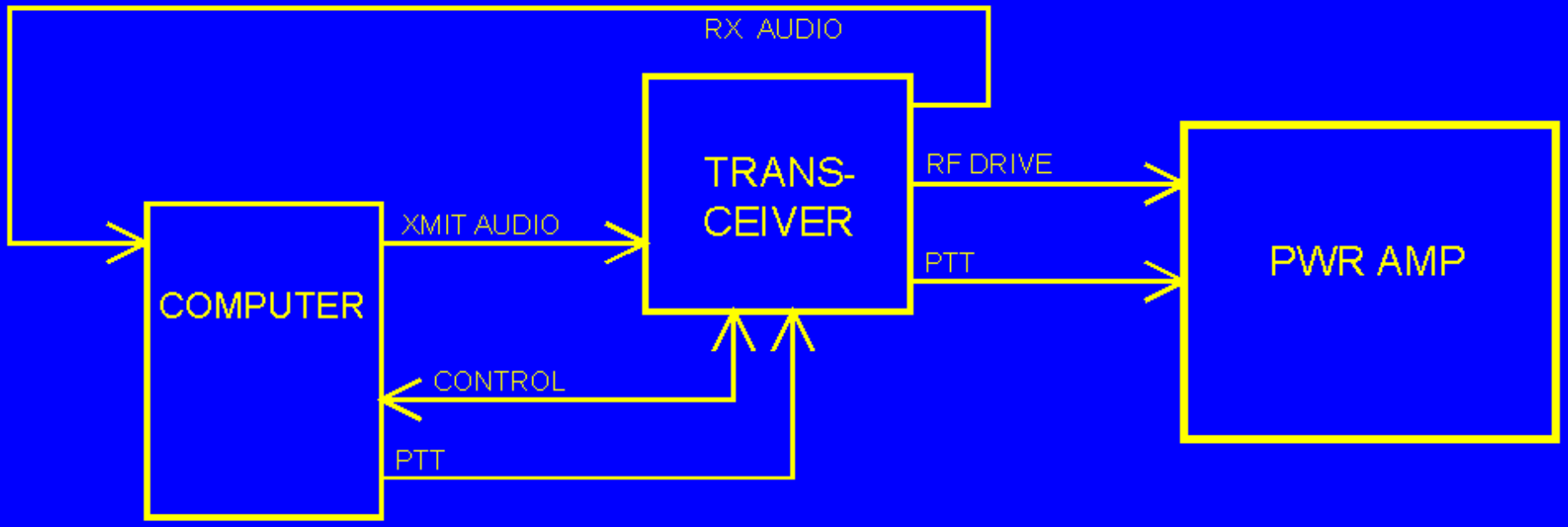
Interface Logic – SSB



Note: Assumes VOX operation

This setup allows direct recording of new voice messages "on the fly" (for example, "CQ contest, listening this frequency and 7065")

Interface Logic – RTTY, PSK



No RTTY software I know of works with “control” and PTT sharing a COM port

PTT can be on parallel port or second COM port

Pro Dynamic Mic to Laptop

- No power required
- Pro mics use XLR connector
  - Wire mic audio to Tip (audio input) (XLR pin 2)
  - Wire mic audio return to sleeve (XLR pin 3)
  - Wire shield to sleeve (XLR pin 1)
- In laptop, turn on mic pre-amp
  - Called “mic boost” in my Thinkpad
  - Not all sound cards have a mic pre-amp!
  - If no preamp, it may not be loud enough

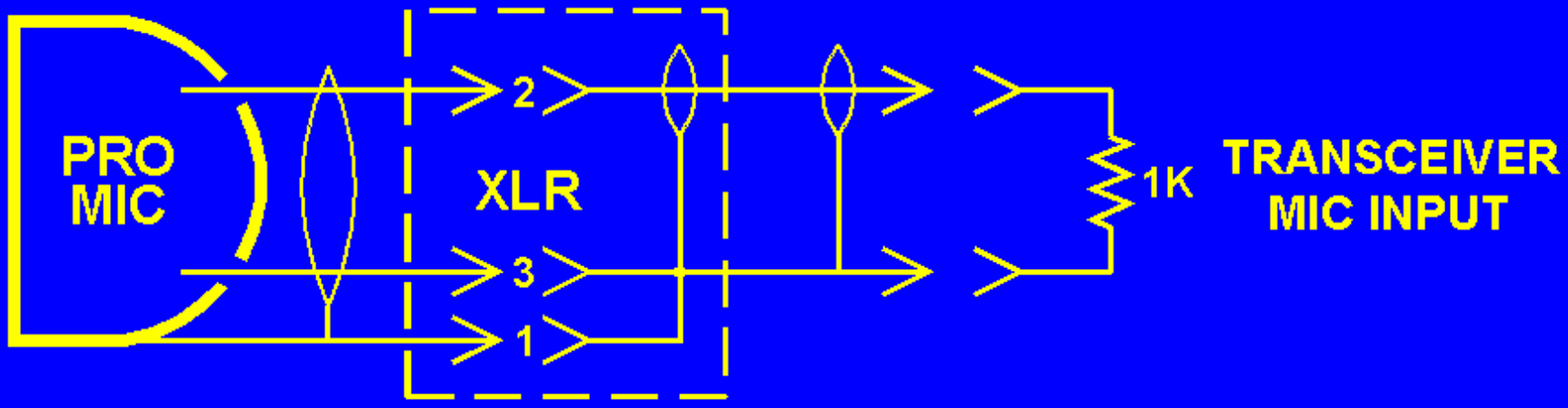
Pro Balanced Electret Mic to Laptop

- Balanced *Phantom power* is required
  - Cannot plug directly into computer
  - External phantom power supply and transformer are needed
  - Wire transformer output like a dynamic mic

Pro Pigtail Electret Mic to Laptop

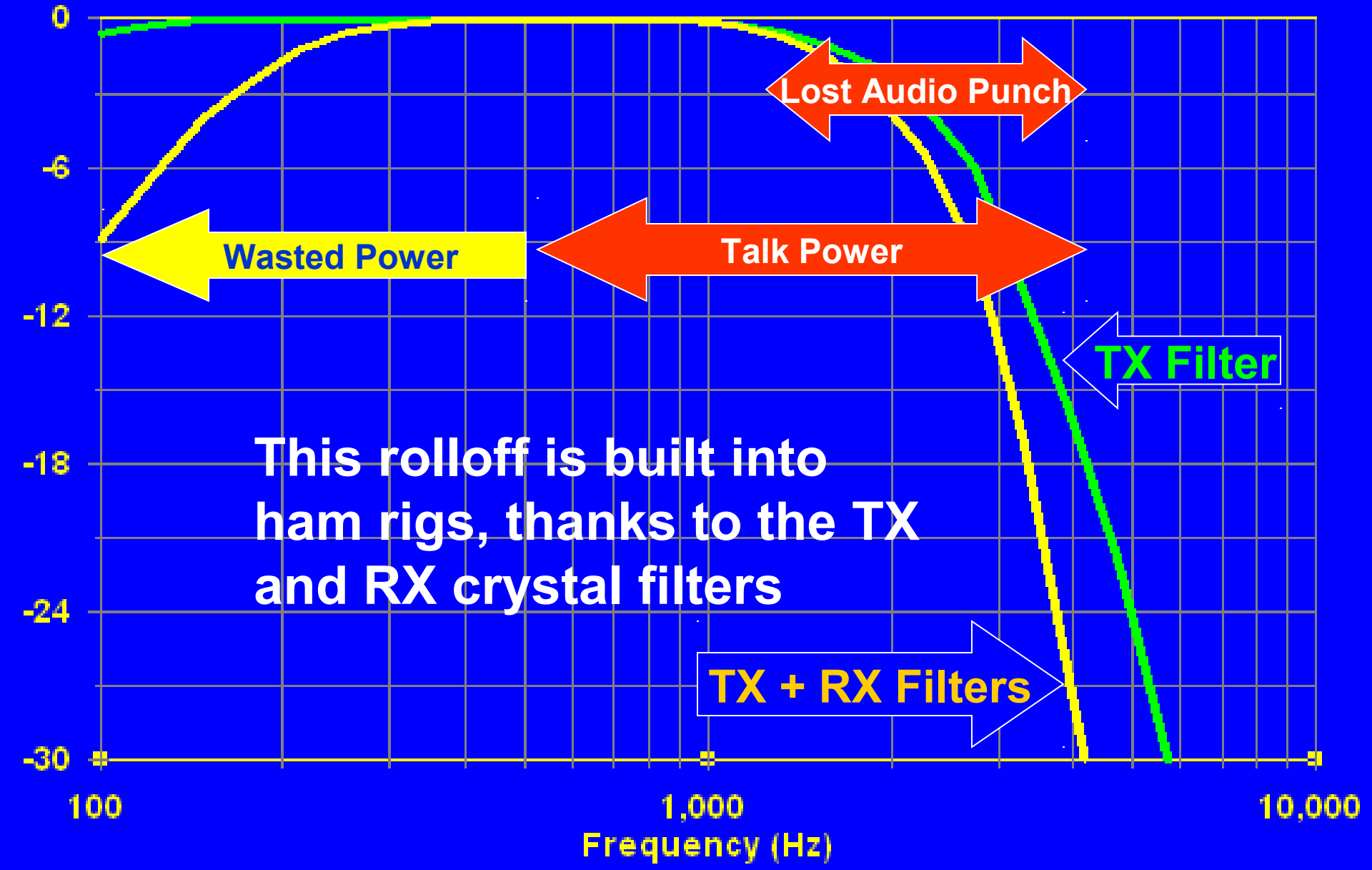
- Unbalanced electret mics with pigtail leads are built for use with wireless mics
  - Can work fine with a laptop
- On 1/8-inch TRS plug
  - Wire audio to Tip
  - Wire power to Ring (resistor may be needed)
  - Wire shield (audio return) to Shell

Pro Dynamic Mic to Ham Gear

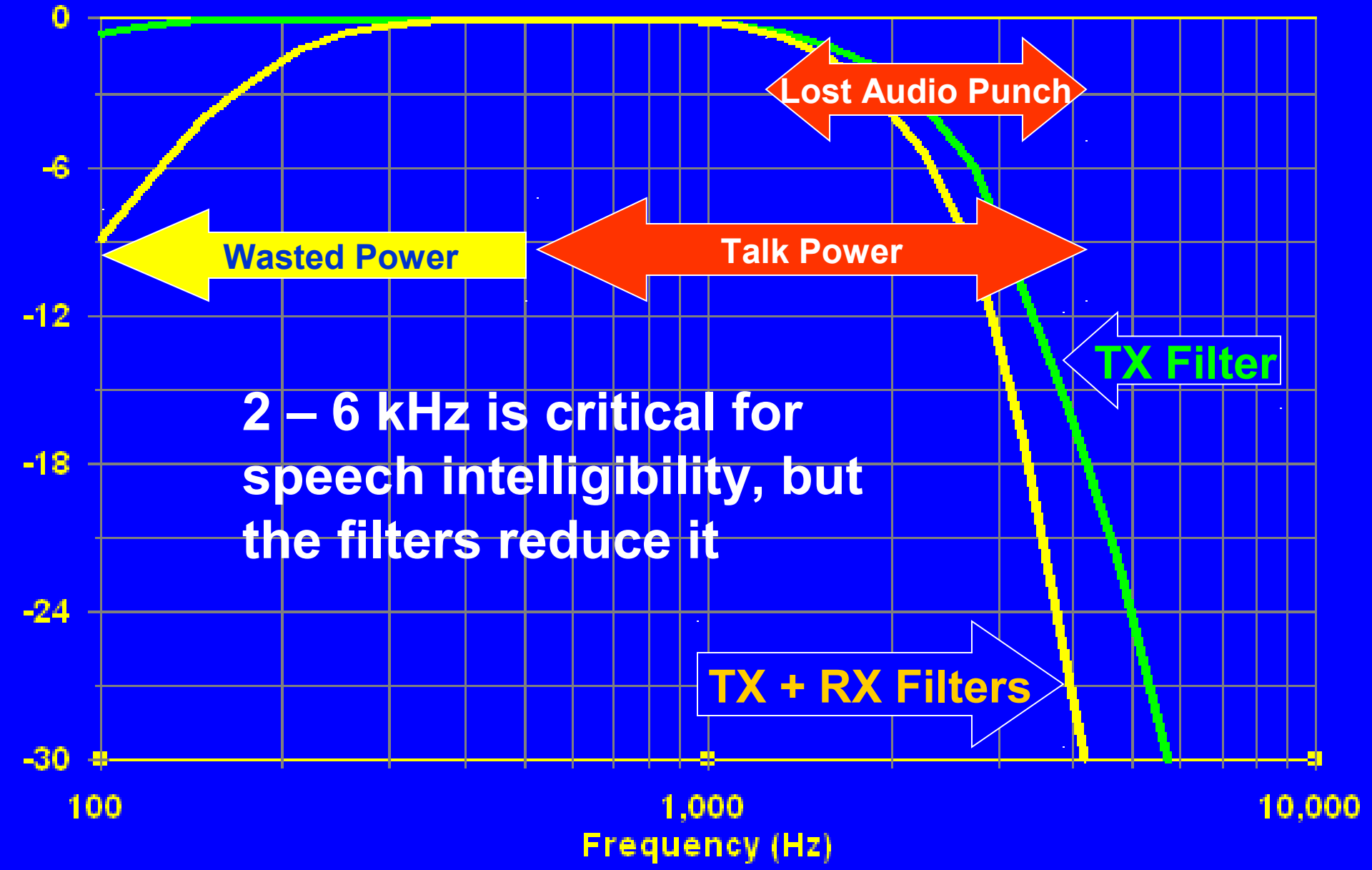


- Plenty of good clean audio
- But also a lot of low end we don't need!

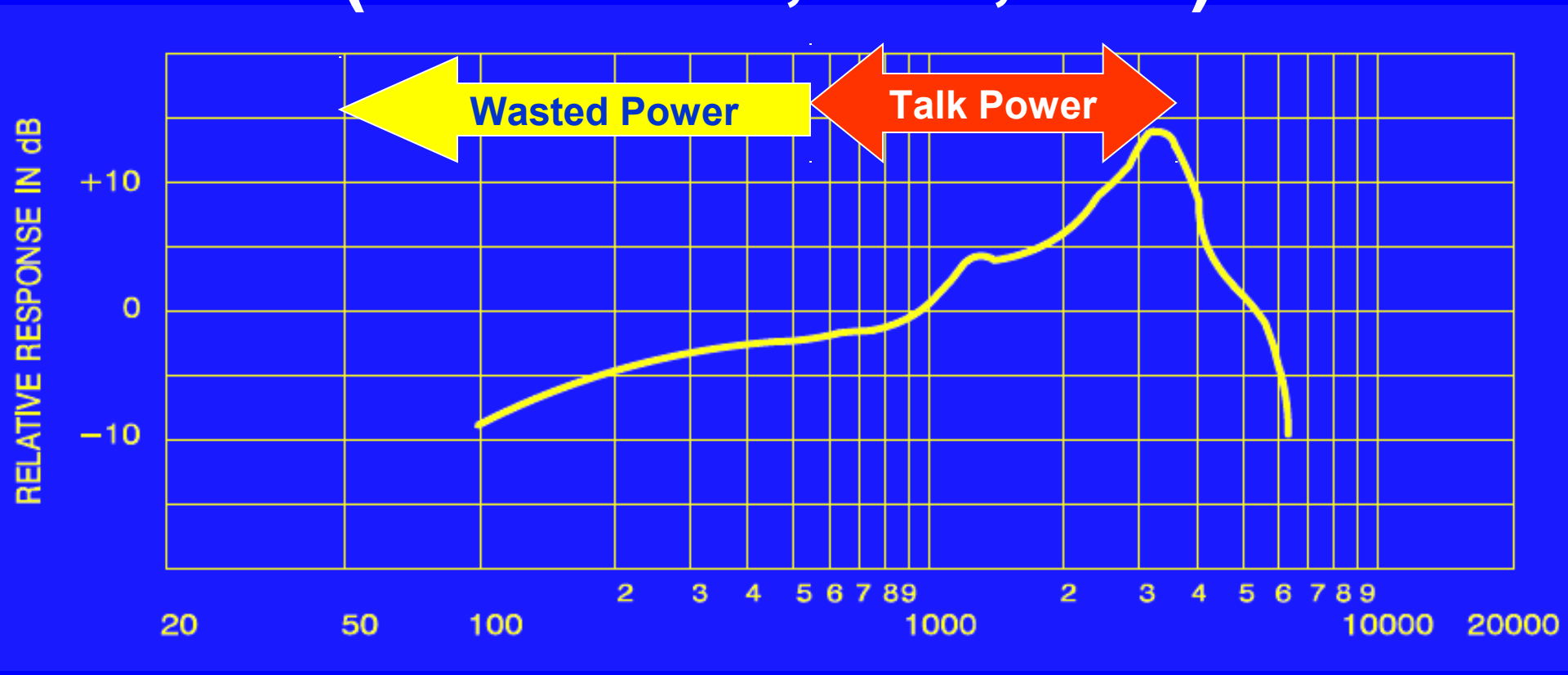
The Frequency Response Problem



The Frequency Response Problem

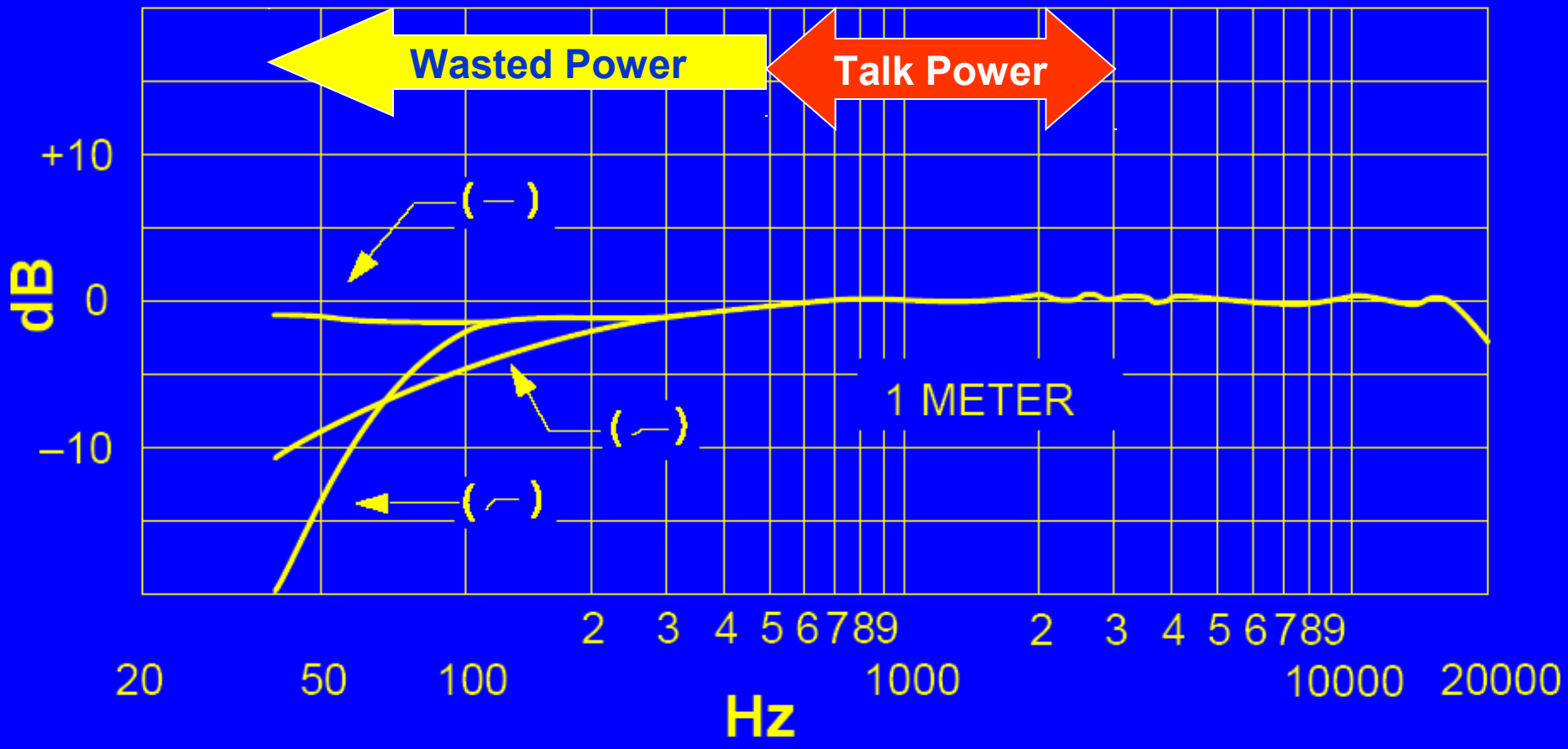


Typical Communications Mic (Shure 450, Heil, etc.)



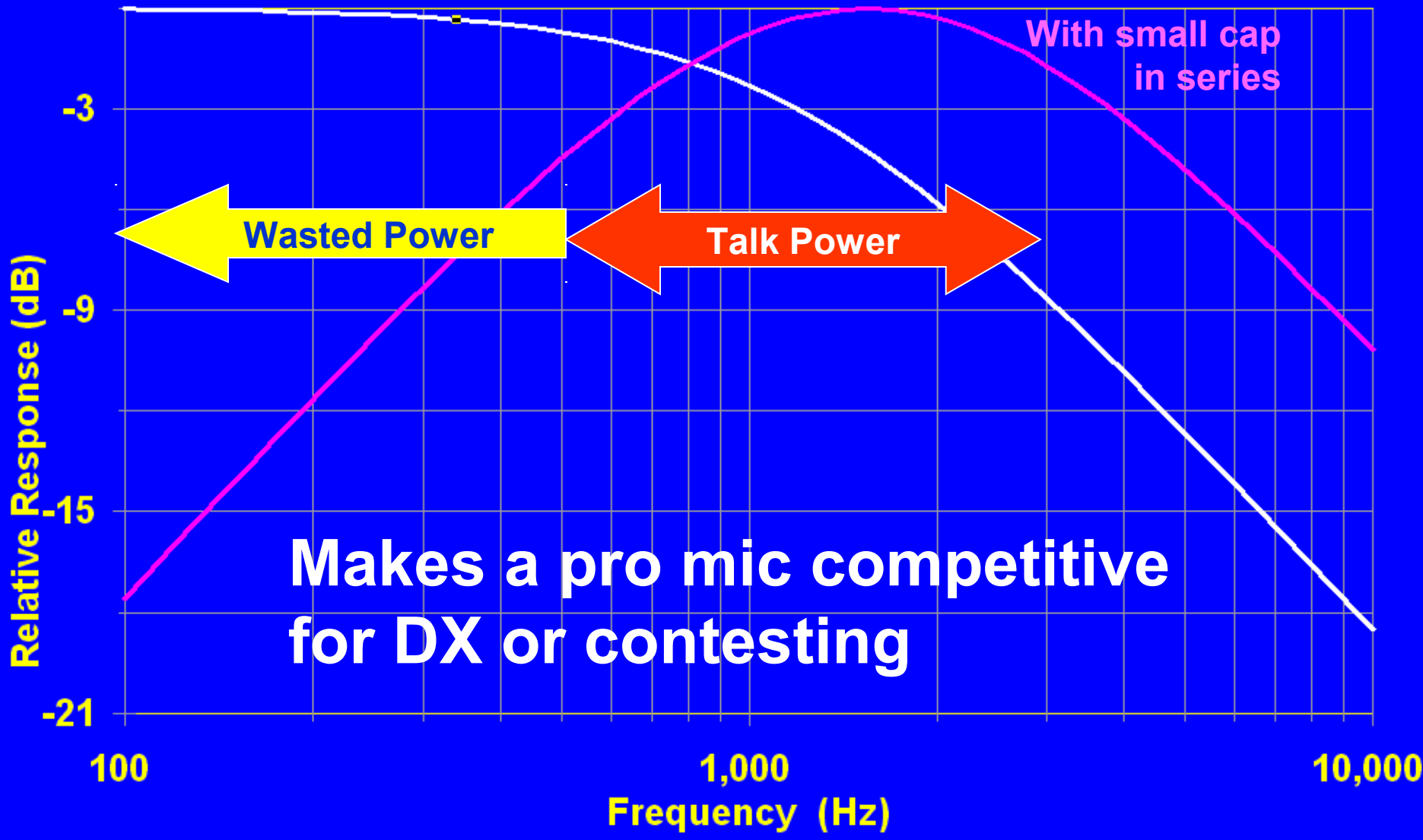
The response of the mic is tailored to correct for the TX and RX filter response

High Quality Professional Mic



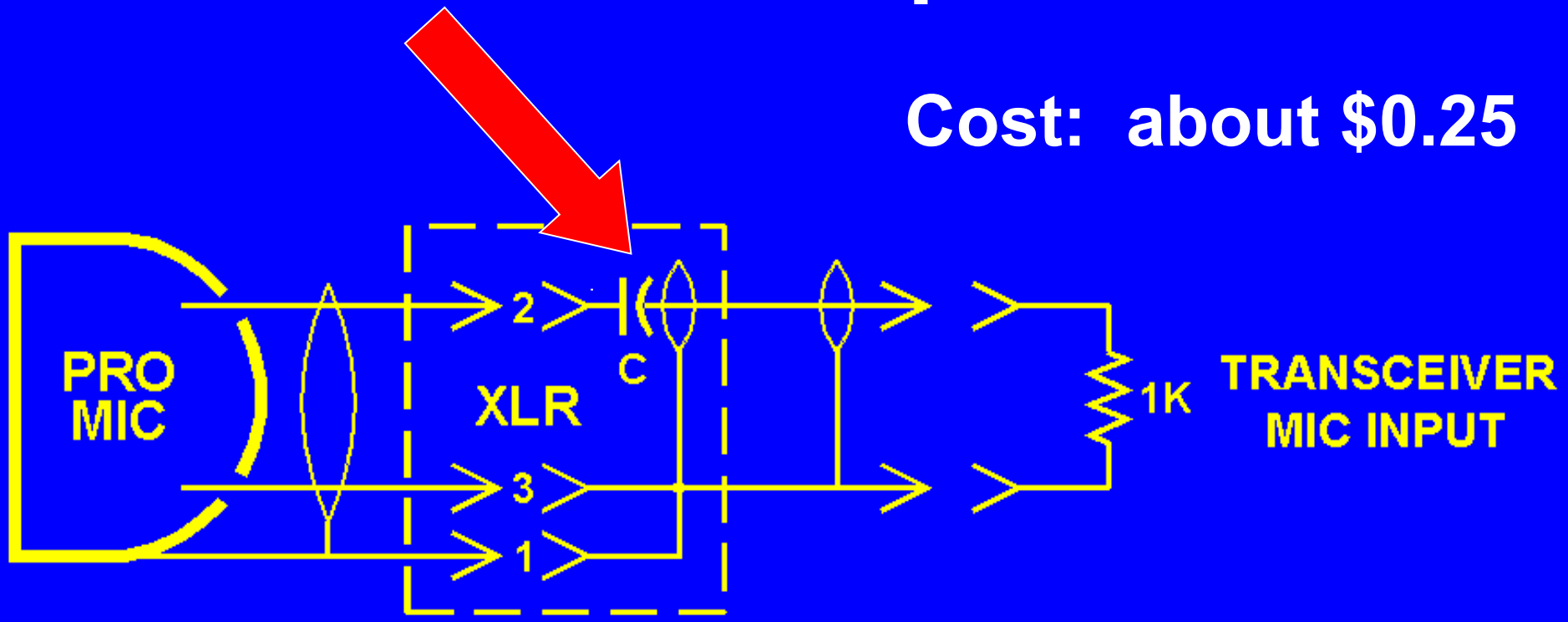
Broad, flat response to sound great on music and voices

The K9YC Mic Equalizer



The K9YC Equalizer

Cost: about $0.25

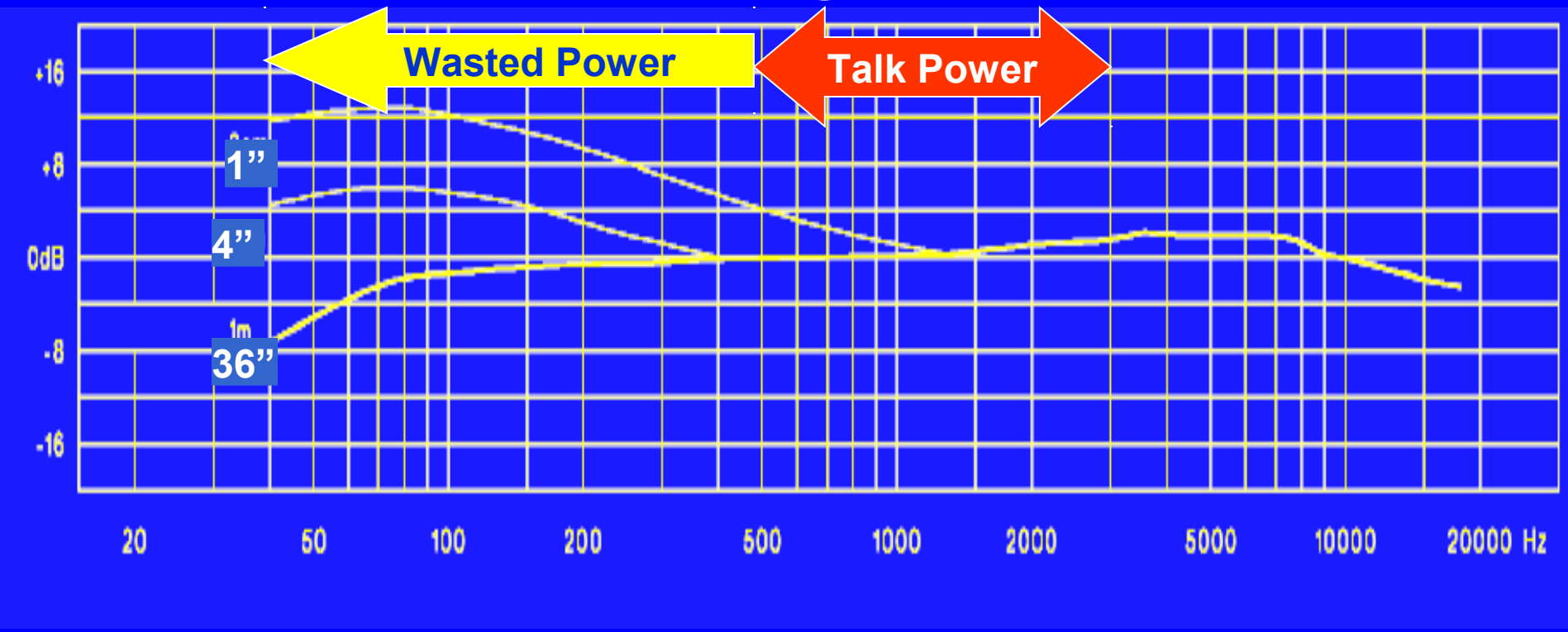


- Add capacitor in series with audio
  - C = 1 / (2πf R)
    - f is 3,000 Hz
    - R = (input Z of input stage) + (Z of mic)
    - In this example, C = 0.047μF

Directional Mics

- Most ham mics are omni-directional – they pick up sound from all directions
- Most performance mics are unidirectional
  - Pick up best from the front, reject room noise
- Most directional mics have proximity effect – bass is boosted for sounds very close to the mic
  - Breath pops
  - Very “bassy” sounding
  - Not good for communications!

Proximity Effect

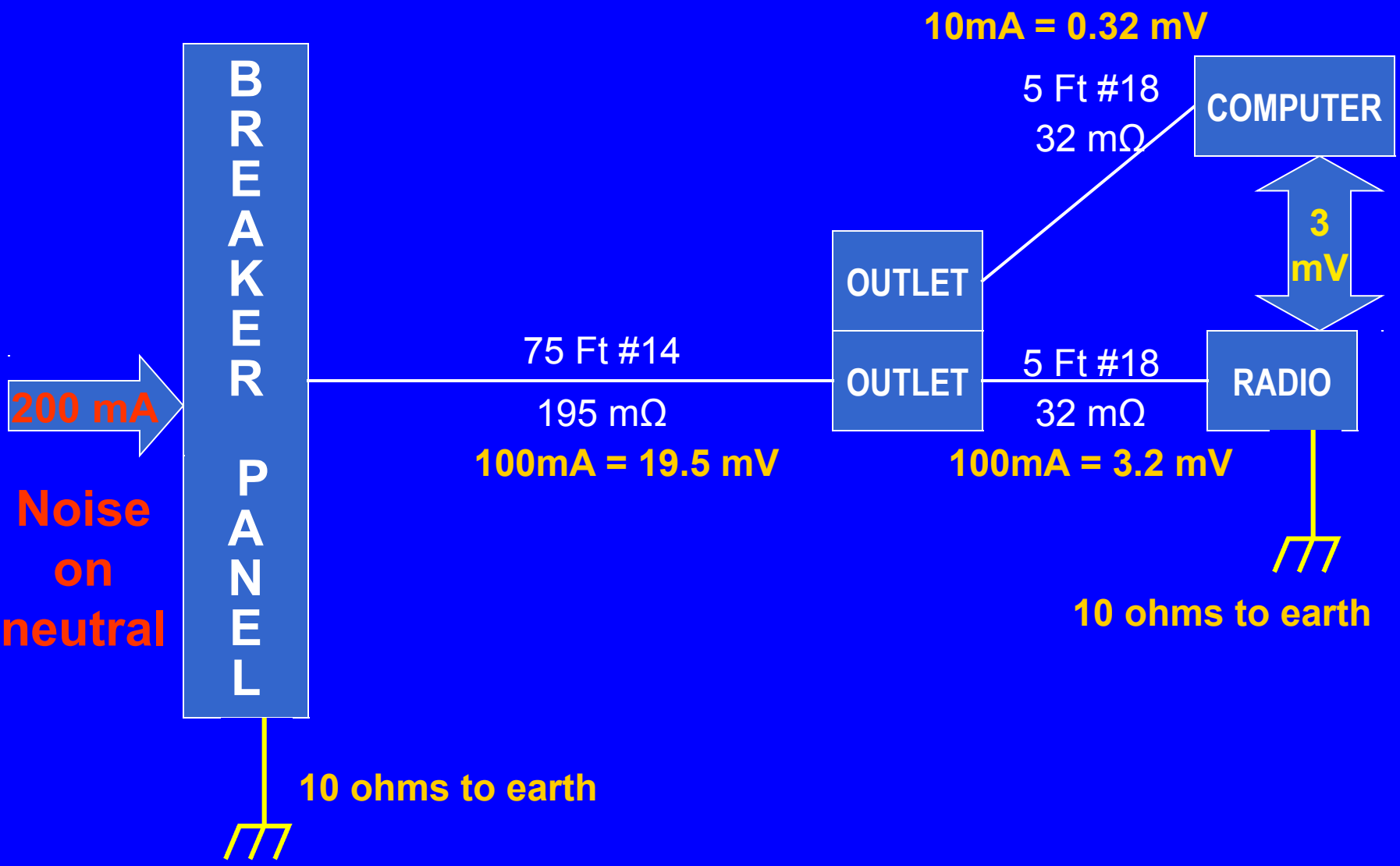


- Bass boost when you talk very close to it
- Present in almost all directional mics
- K9YC equalizer will reduce it!
- Most pro mics have some low cut built-in

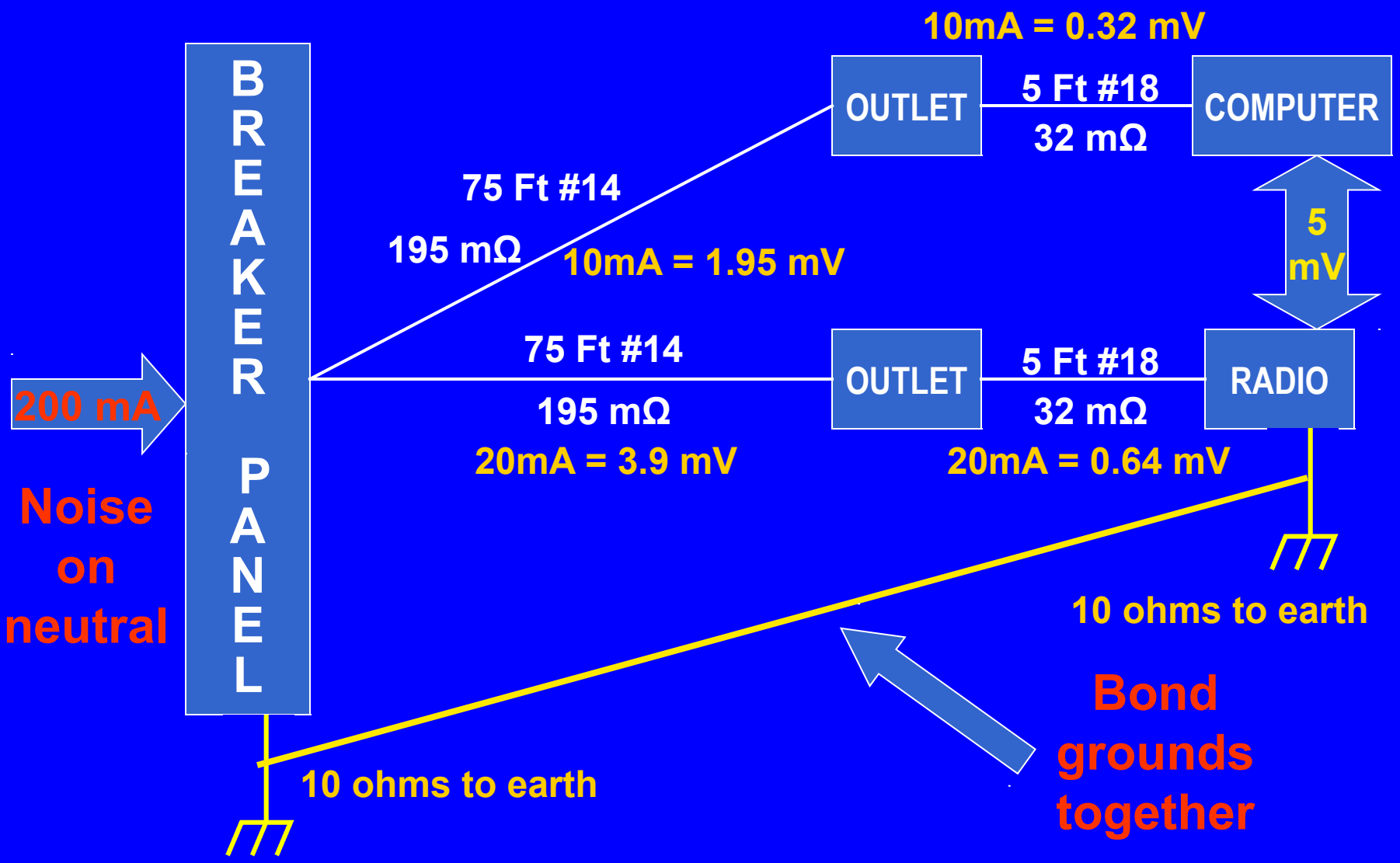
Directional Mics without Proximity Effect

Good Low-Cost Headset Mics

Home Power Ground Wiring (The "Green Wire")



Home Power Ground Wiring (The "Green Wire")

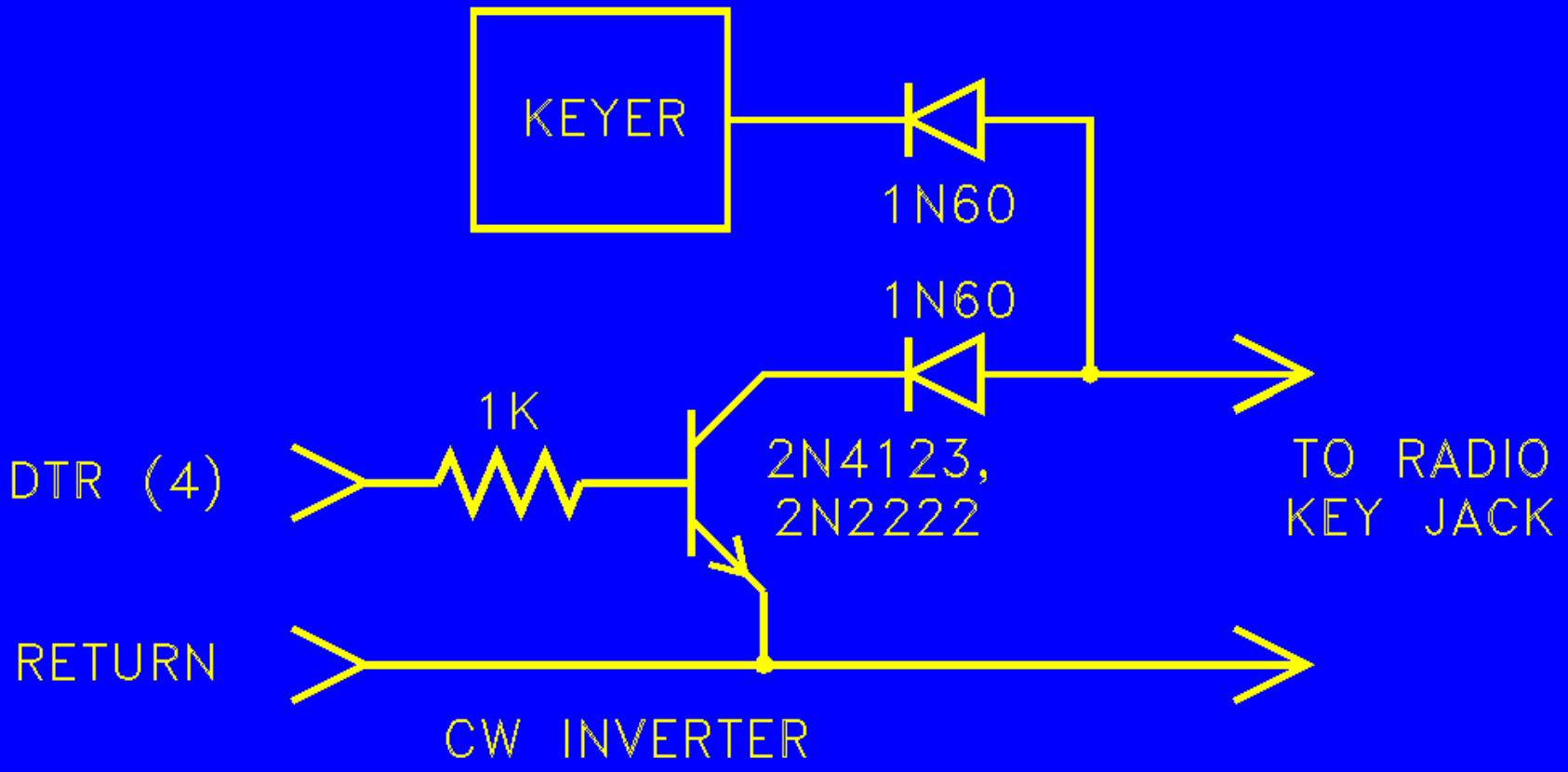


Hot Switching in Amplifiers

- It takes a few msec for a T/R relay to pull in
- Keying transmitter before T/R pulls in is called “hot switching”
  - Amplifier transmits briefly without loading, can damage output stage
  - Contacts arc, causing relay failure
- Methods to prevent hot switching
  - Amp locks out input until relay has pulled in

  or:
  - Key amplifier, amp senses relay operation and keys exciter when relay has pulled in

Diodes Add a Keyer to DTR Keying

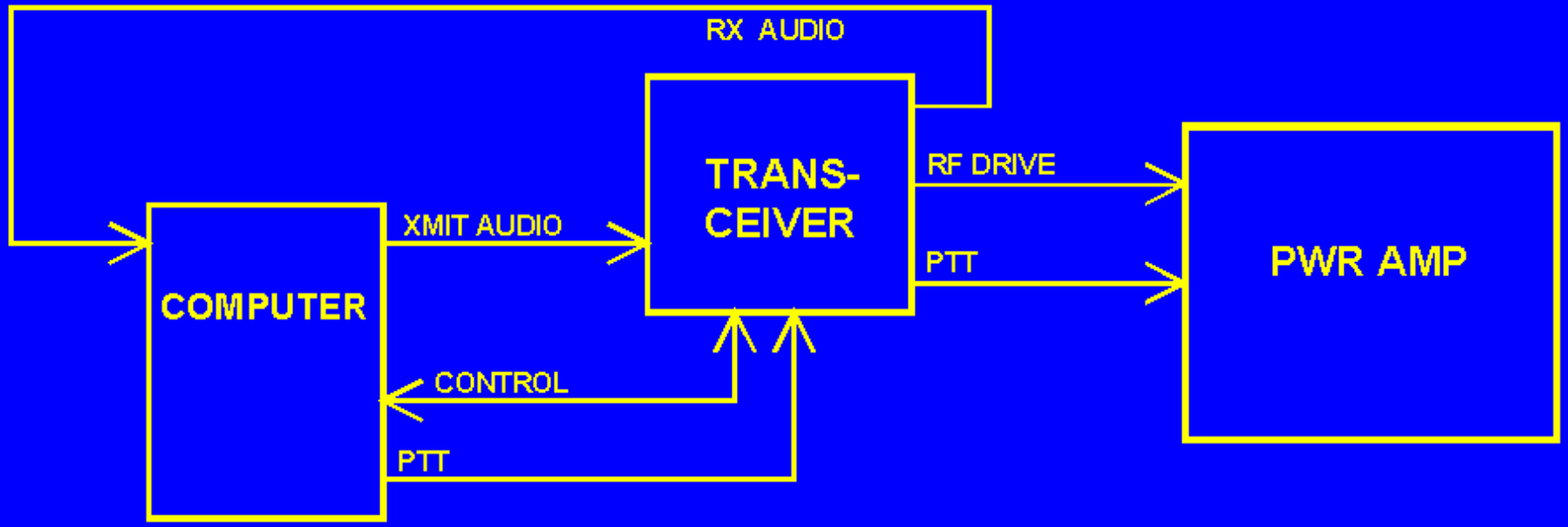


- **Works with almost any keyer**
- **Si diode works with most radios, but for a few, lower voltage of Ge diode may be needed**

In a Contest, Pre-Recorded CQs are Crucial!

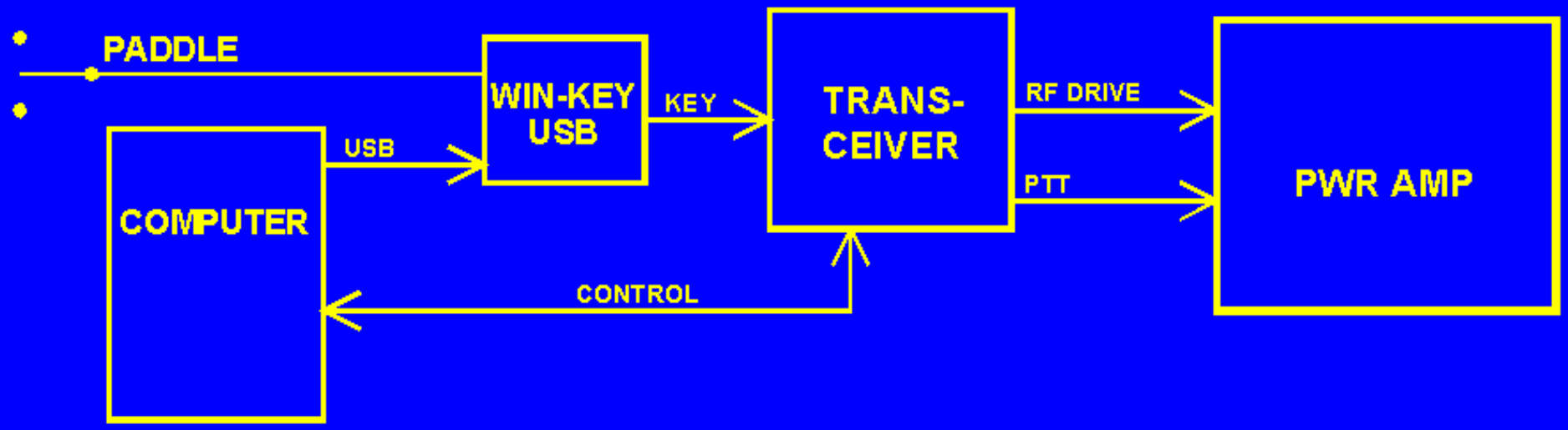
- Without them, you can't
  - Munch or drink coffee!
  - Rest your voice
  - Think about what you're going to do next
  - Listen on another radio to find QSOs on another band

Simple RTTY Setup with PTT



- This is the same as the first setup, but it uses PTT rather than VOX
  - PTT for RTTY requires a second serial port
  - No good reason for PTT – VOX works fine!

Simple CW Setup



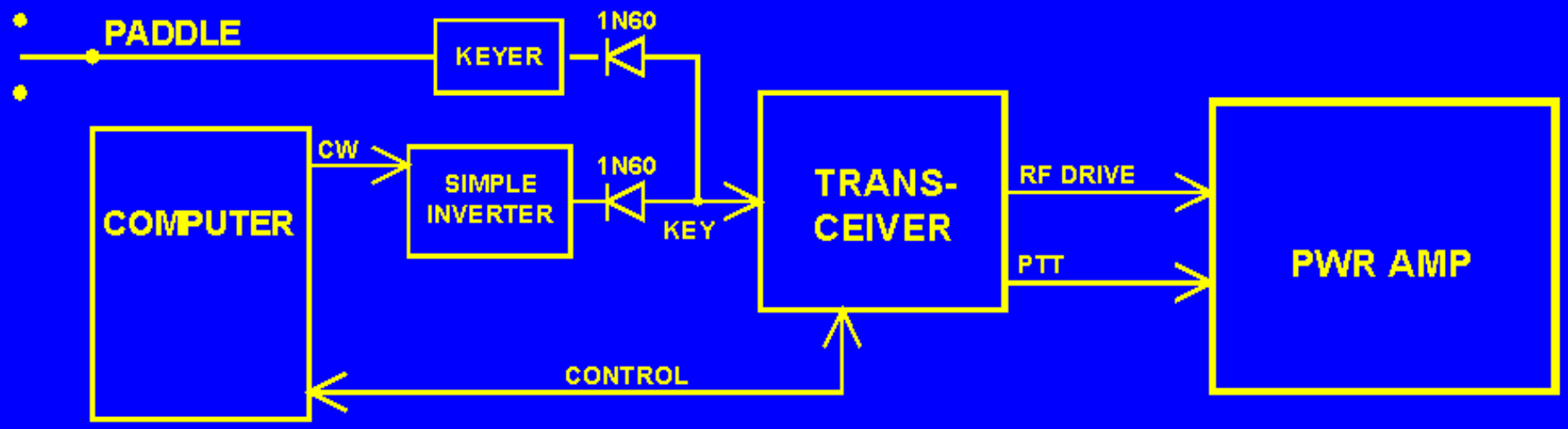
- **Buy WinKey as a kit ($78)**
  - **Build it in two hours**
  - **Use your paddle with it for things that aren't programmed in your Logger**
  - **It's a nice stand-alone keyer too**
  - **Buy the USB version**

What's a WinKey?

Why WinKey?

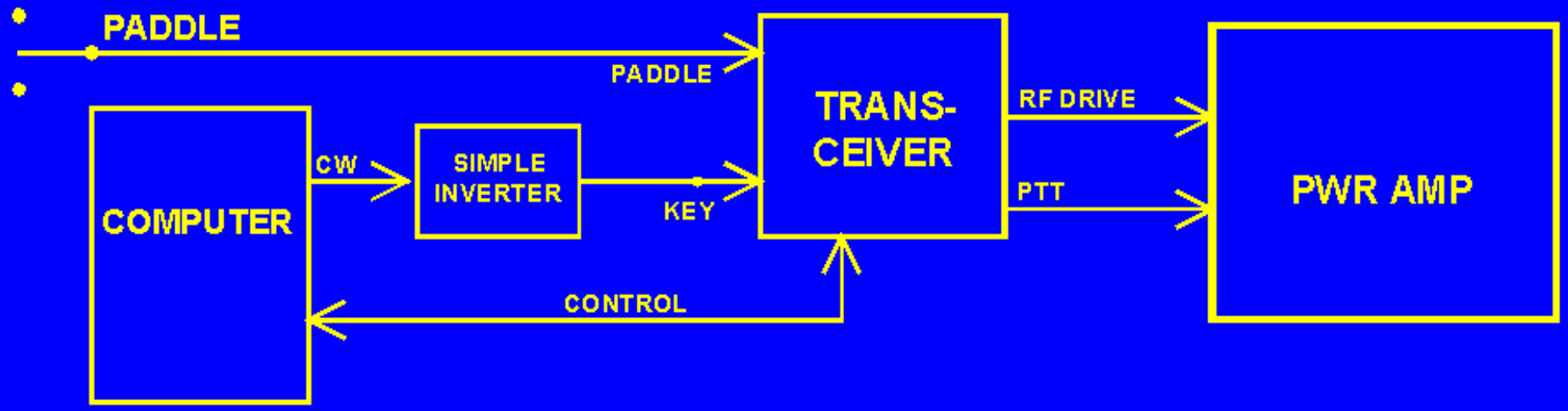
- Logging programs aren't very good at sending CW on serial port or printer port
  - It's a byproduct of Windows multi-tasking
  - Sending CW hogs the processor
  - Putting spots on a bandmap also uses a lot of processing cycles
  - CW can get choppy if the processor is too busy
- Sending CW to WinKey uses much less of the processor
- WinKey has two outputs, so it can key two radios for SO2R (Single Operator 2 Radios)

Another Simple CW Setup



- If you already own an outboard keyer
  - I've used this with an AEA MM-1 keyer on Elecraft, TenTec, Icom, and Kenwood rigs

This Works With A Few Rigs



- Most rigs with built-in keyers let you use the “key” input or the built-in keyer, but not both a the same time
- Some rigs can be modified to work
- An outboard keyer is usually easier

Stuttering CW?

- Use a modern computer for Windows
- Use enough RAM (at least 512MB)
- My 10 year old IBM XP Pro T22 with 512MB simultaneously ran
  - N1MM or WriteLog
  - DXKeeper
  - DXView (map)
  - Browser with Propagation
  - VE7CC Cluster software
  - Zone Alarm
  - Quattro Pro Spreadsheet

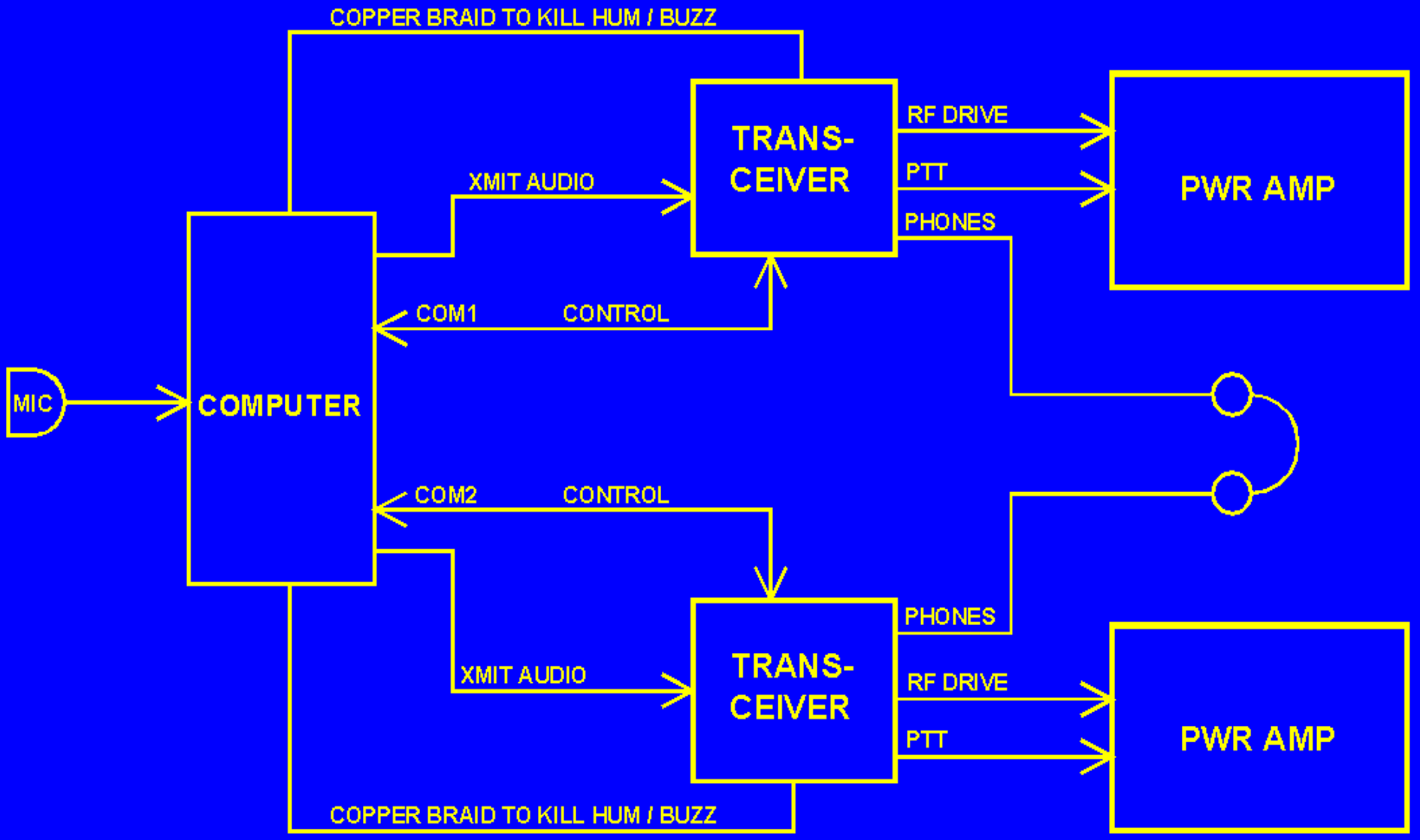
Stuttering CW?

- Another cause is a lot of spots from a DX cluster to your logging program
- No good fix for this except a more powerful processor

or

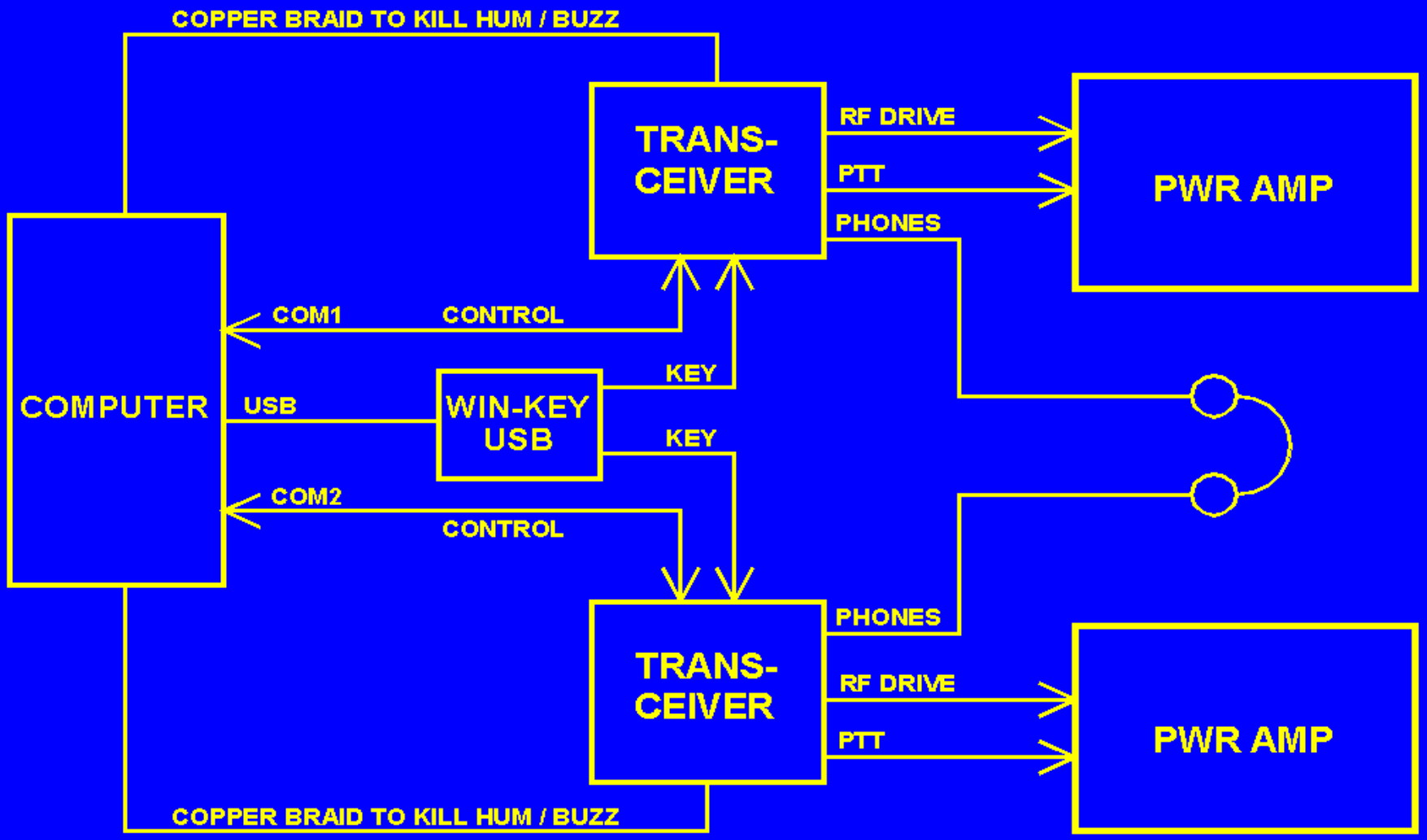
- Buy a WinKey USB (about $78)

Simple SSB SO2R with N1MM



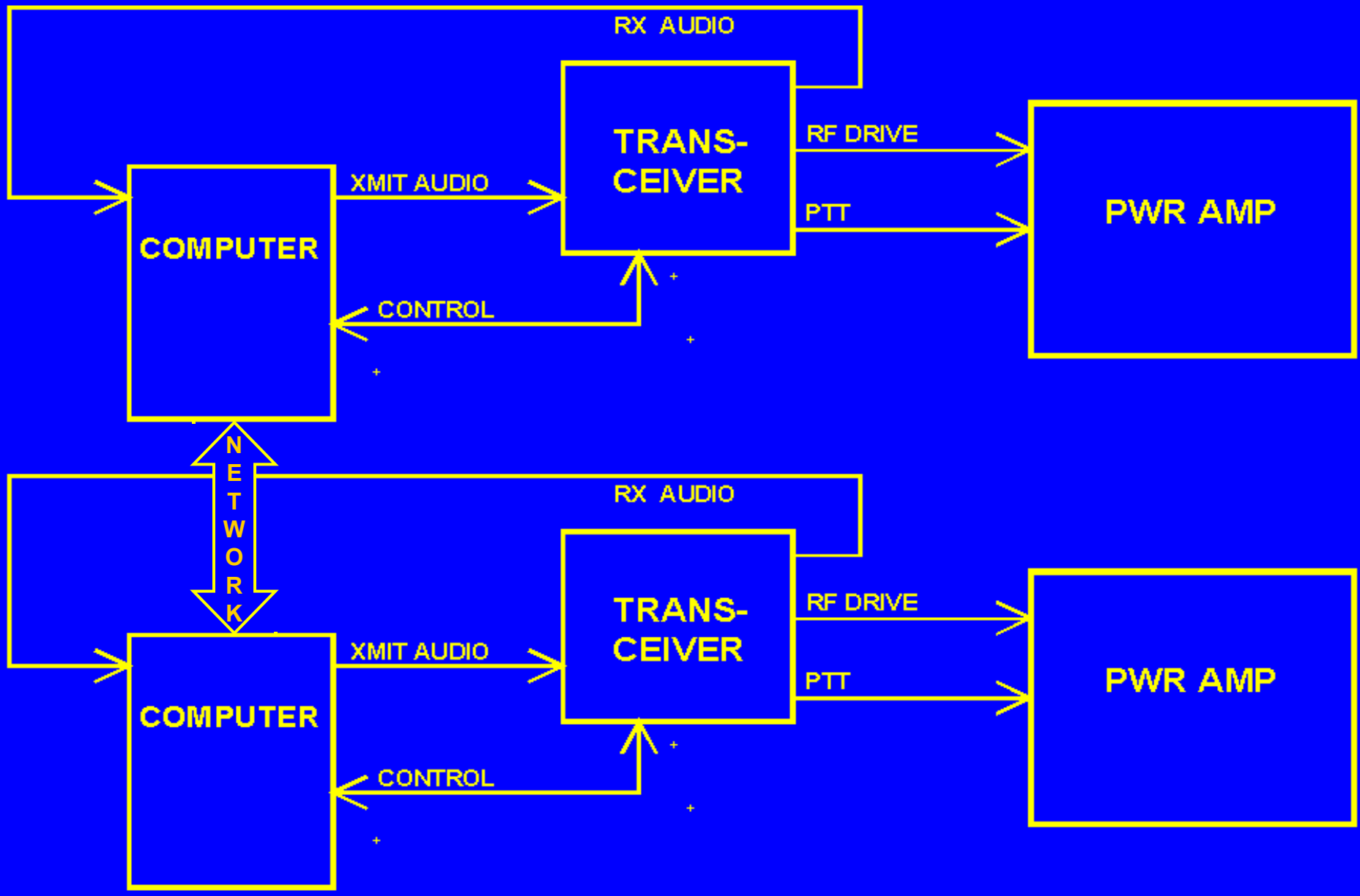
Use VOX to key radio

Simple CW SO2R with N1MM

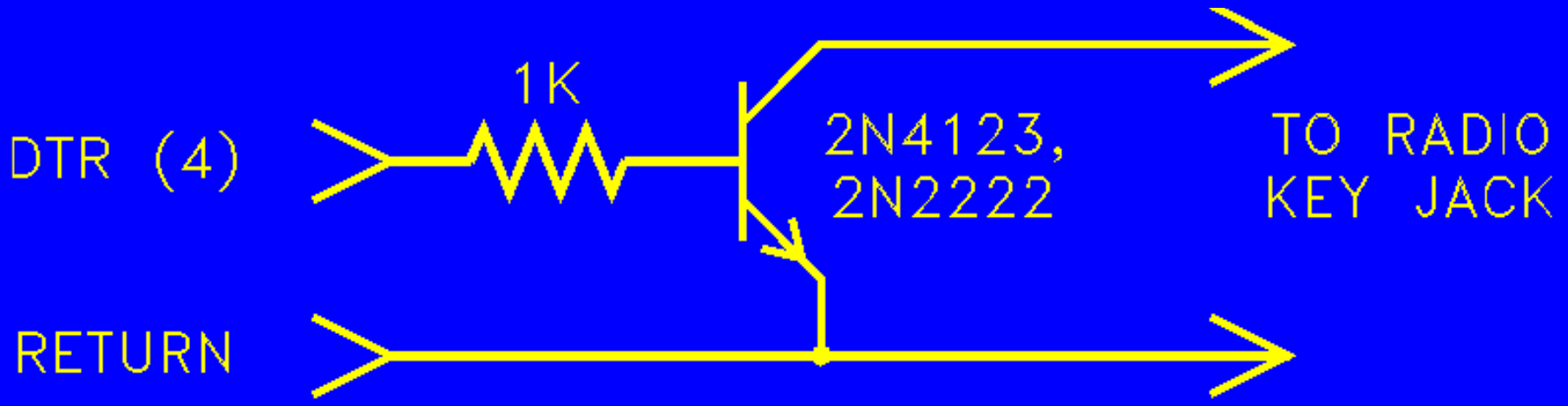


- **Buy WinKey as a kit (about $90, two hours)**
  - **Good standalone keyer, use with your paddle**

Simple RTTY SO2R with N1MM

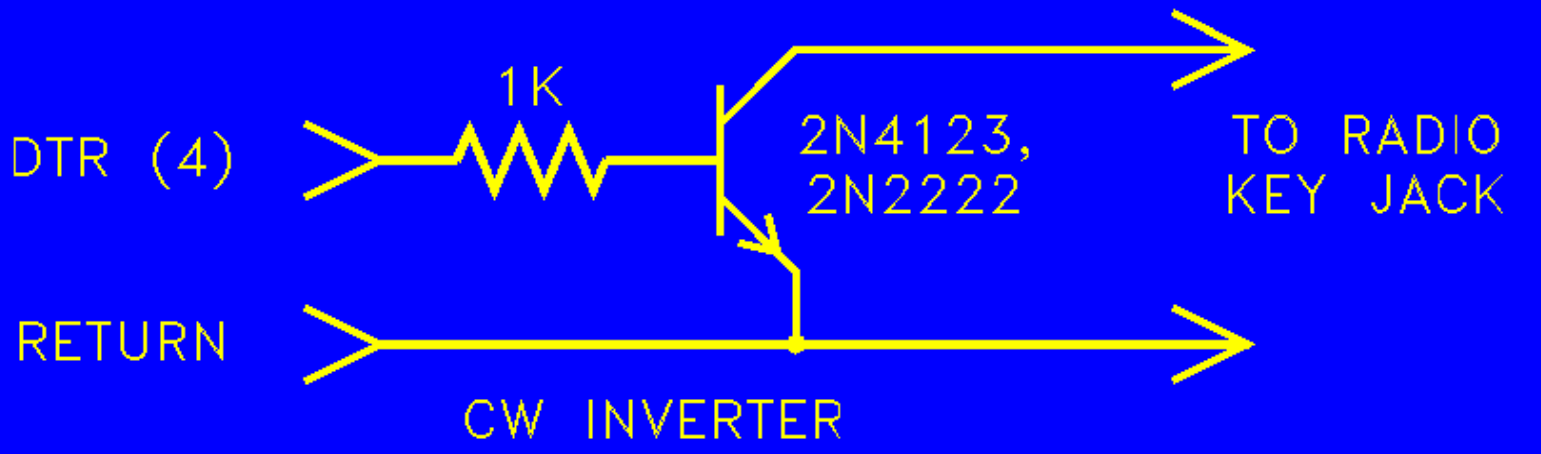


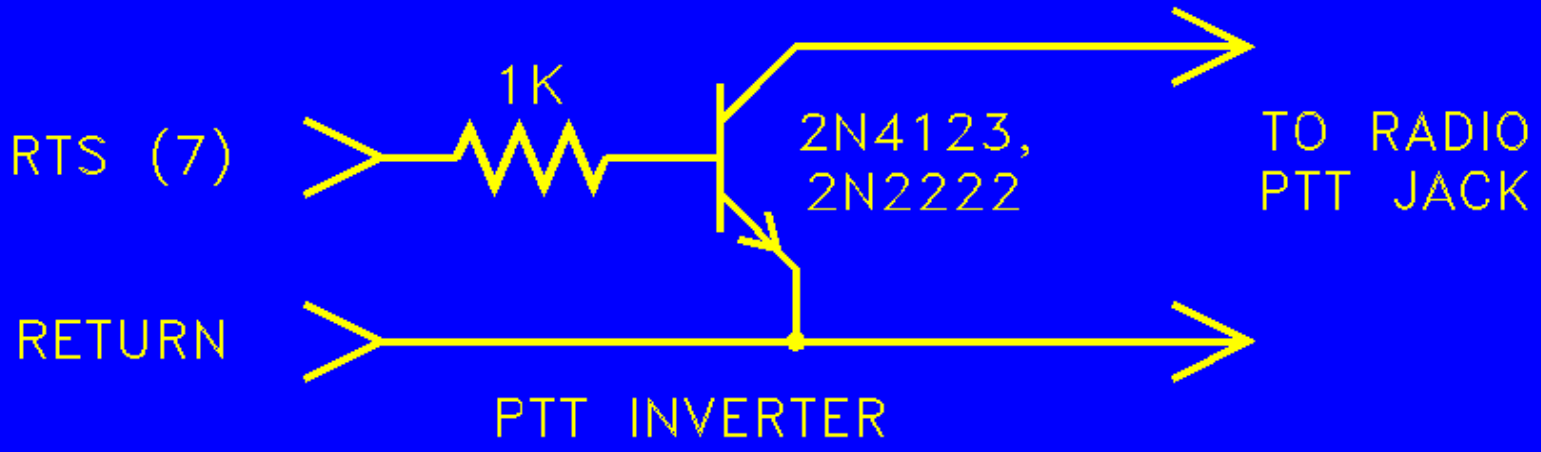
The CW Inverter



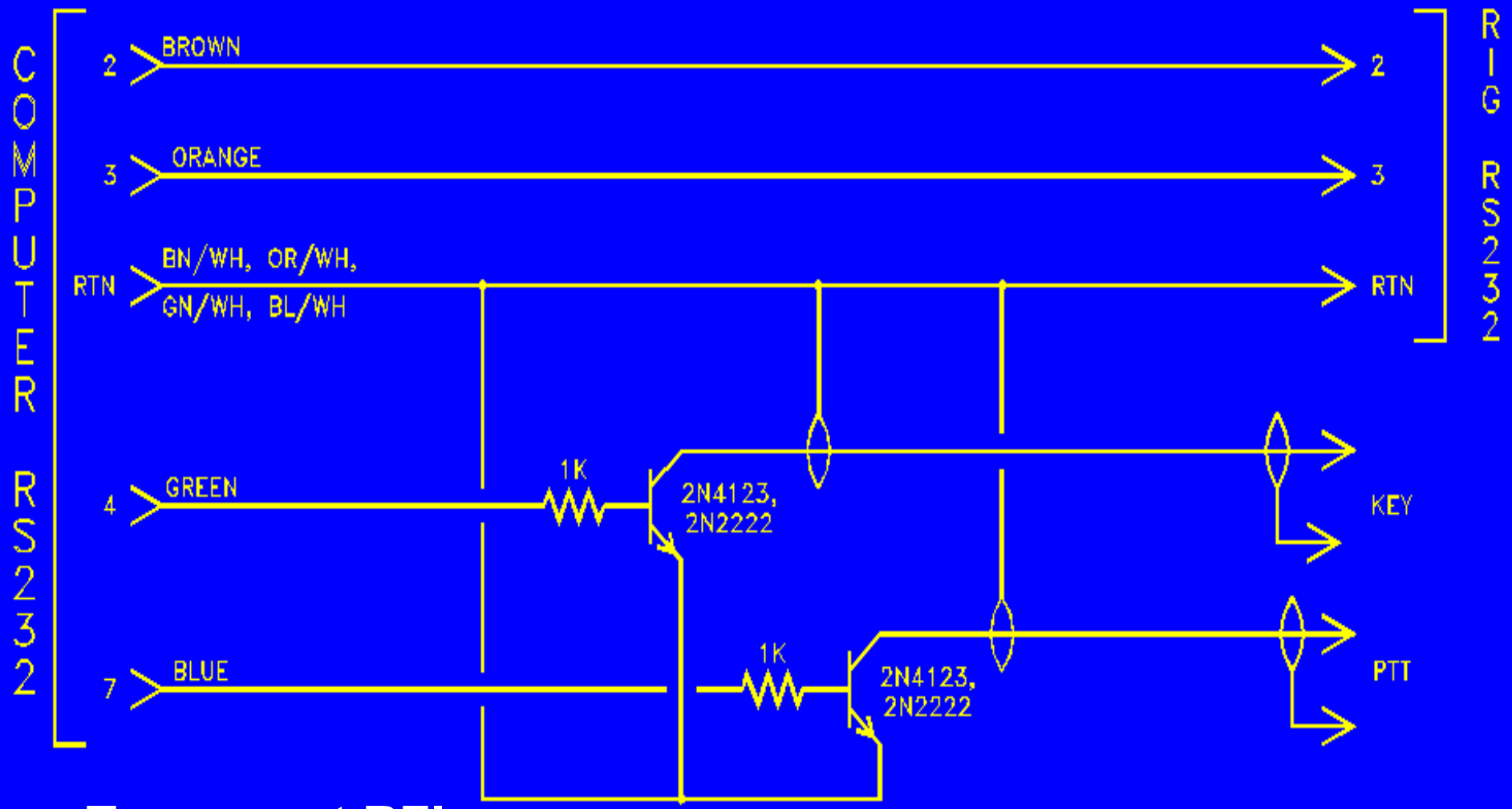
- Almost any small signal NPN works
- Can fit inside a DB9 M/F adapter
- Build a “thru” adapter to work with any radio
  - Carry control signals through it (pins 2, 3, common)
  - Break out CW and PTT (4, 7, common)

PTT Inverter is the Same





Serial Port Connections

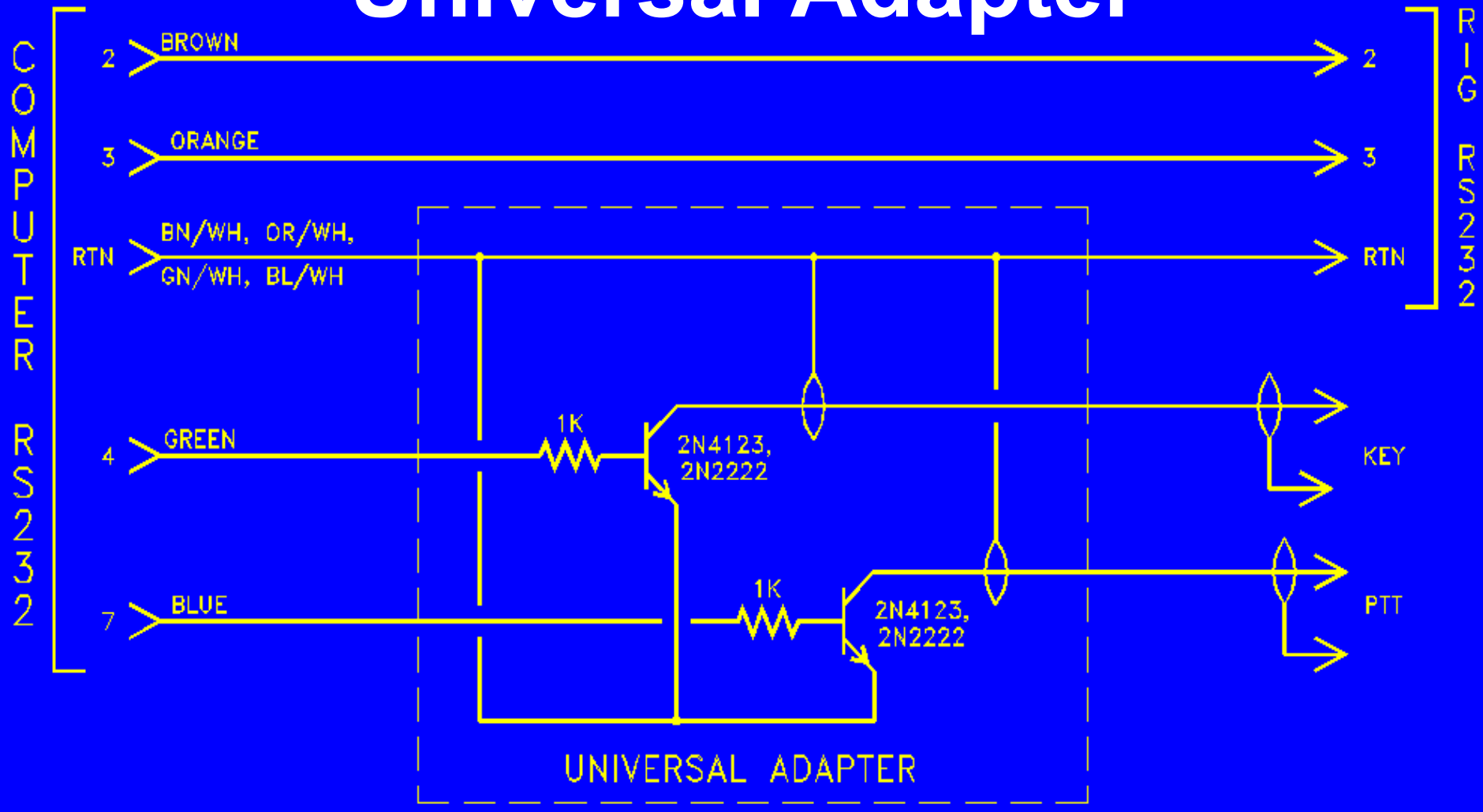


To prevent RFI:

Use CAT5 for computer to radio interface

Use chassis (DB9 shell) as return, not pin 5

Universal Adapter

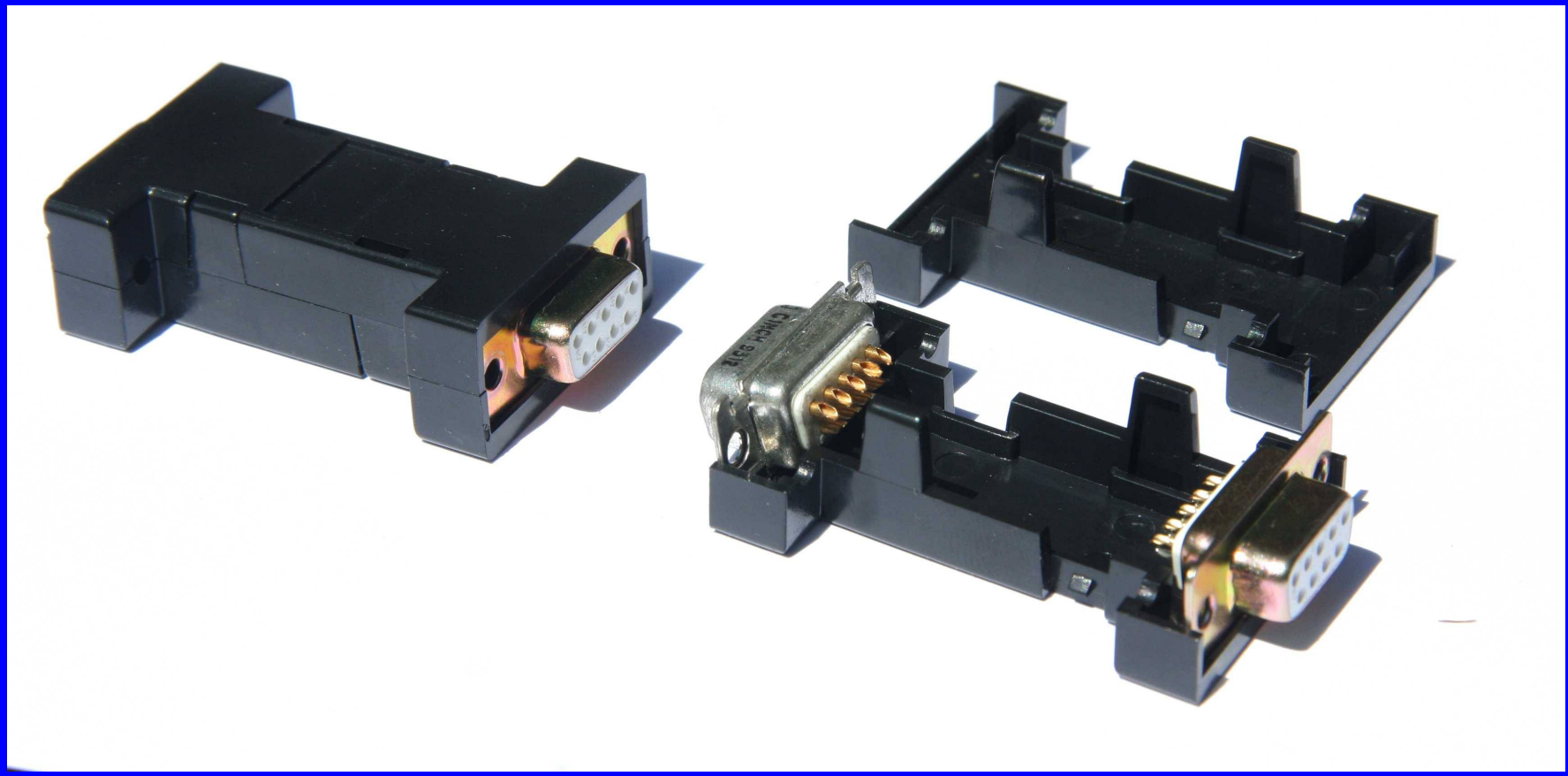


To prevent RFI:

Use CAT5 for computer to radio interface

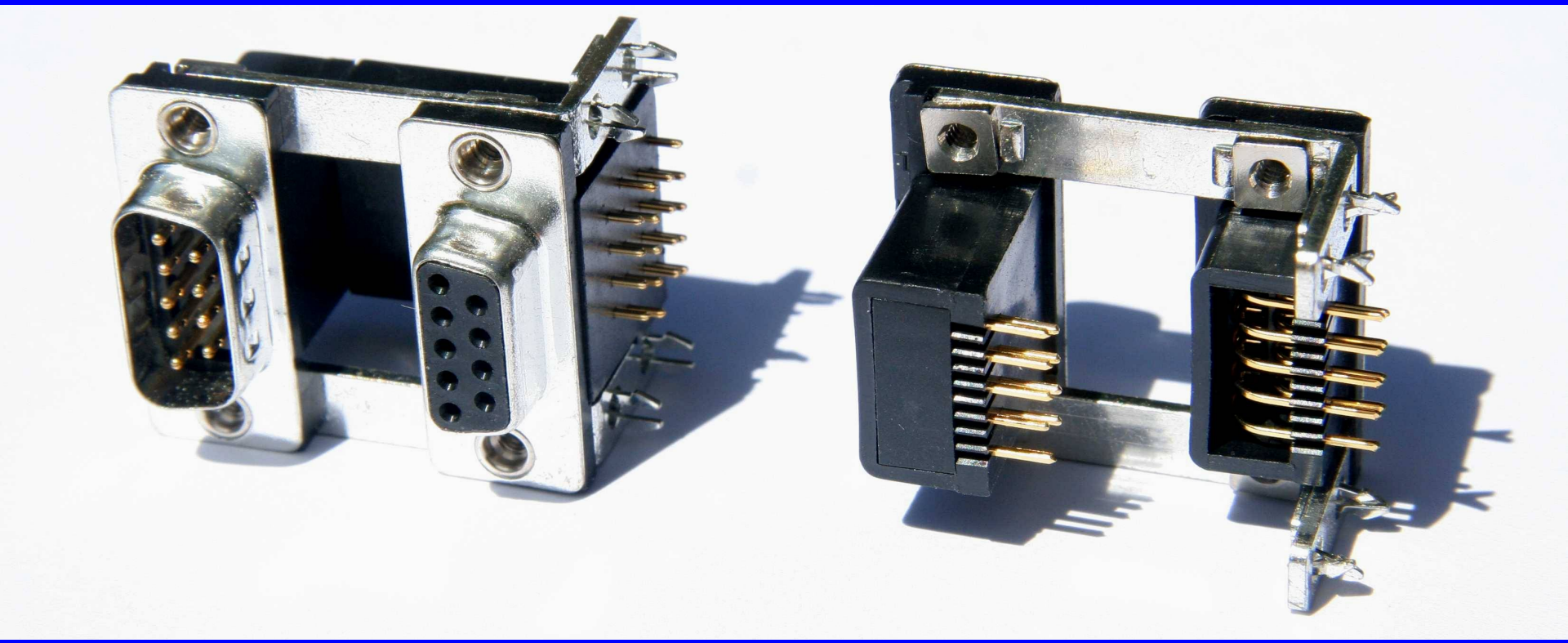
Use chassis (DB9 shell) as return, not pin 5

Building a Universal Adapter



Jumper pins 2, 3, and 5
Add transistors, resistors for Key, PTT
Drill hole(s) for Key and PTT cables to exit

Building a Universal Adapter

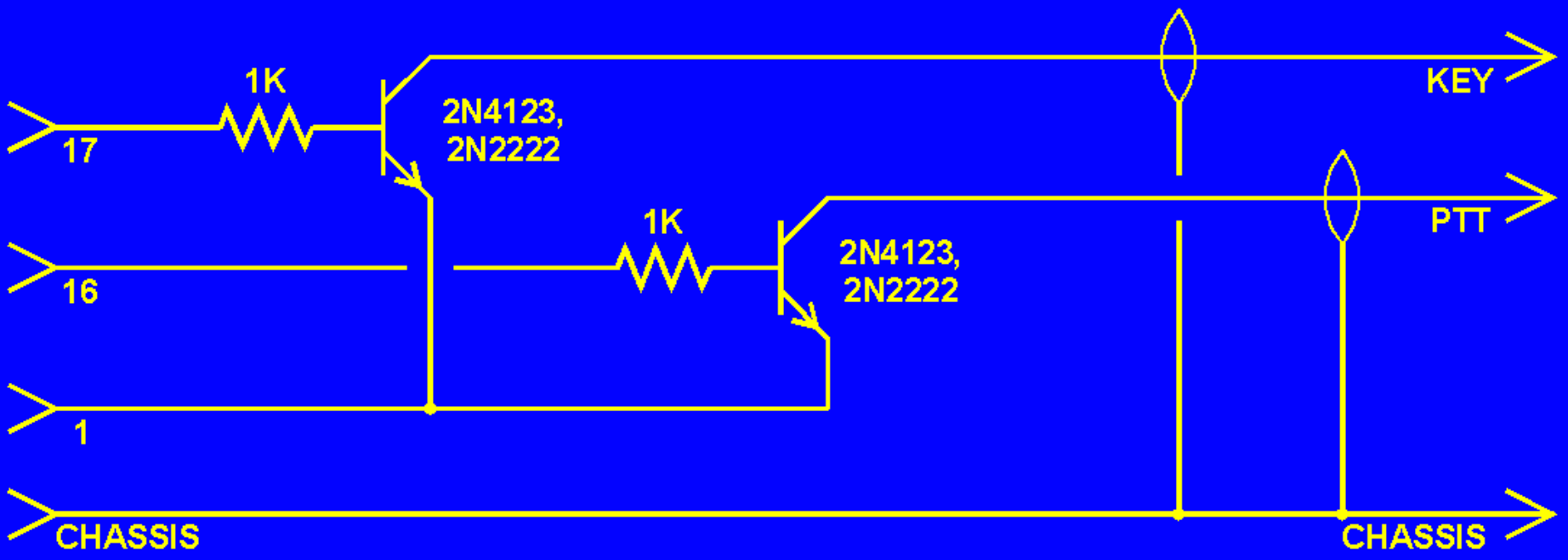


This costs about $1 at HSC (Halted)
Remove jumper block between connectors
Add transistors, resistors, and jumps for 2, 3, 5

Adapter – Cost of Parts

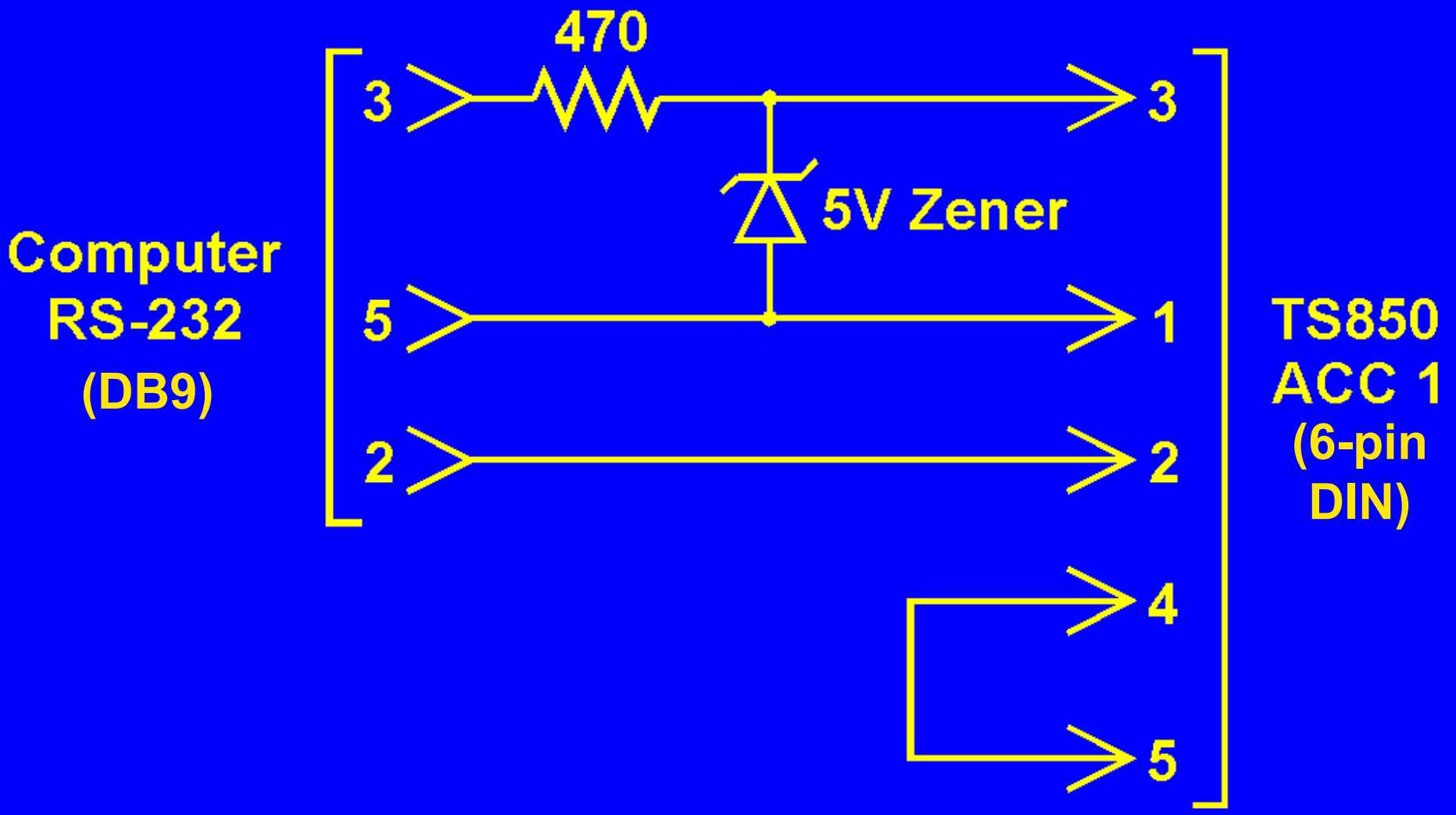
- Enclosure to hold adapter $1 - $2
- Transistors $0.20 at HSC
- Diodes $0.05 at HSC
- Resistors $0.01 at HSC
- DB9 Connector for Computer $1 at HSC
- DIN connector for radio $7 for a good one
- Plug for key input
  - RCA phono male $1
  - 1/4-inch stereo plug $2

LPT1: Keying and PTT



- Same inverters as for serial port keying
- Almost any small signal NPN works
- Can fit inside a DB25 shell or M/F adapter

Interface for Older Kenwood

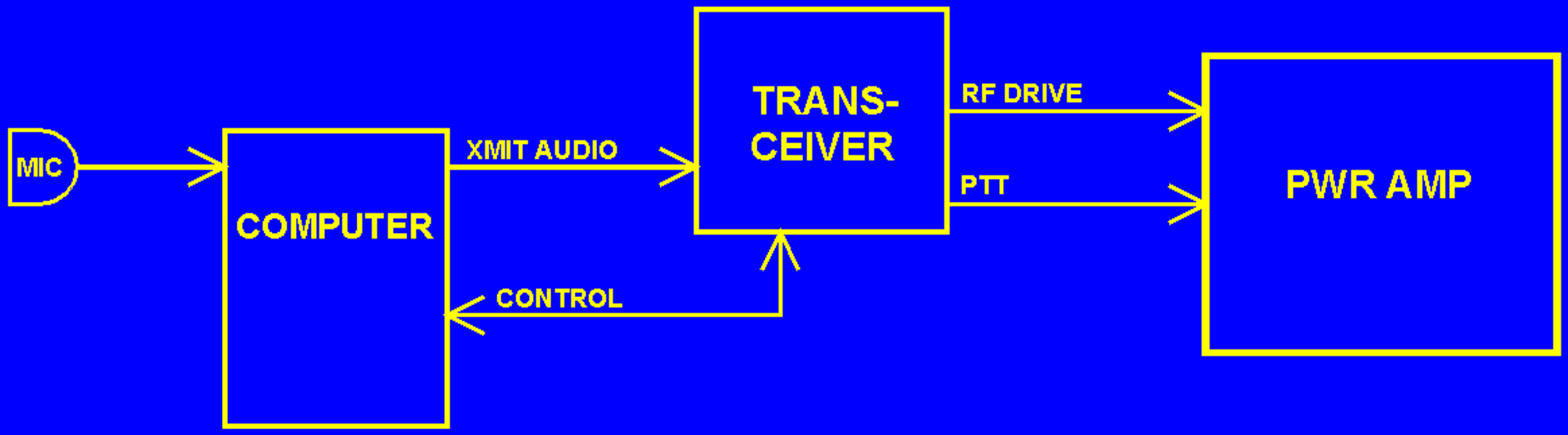


Can fit inside a DB9 or DIN

Low Cost Icom CI-V Interface

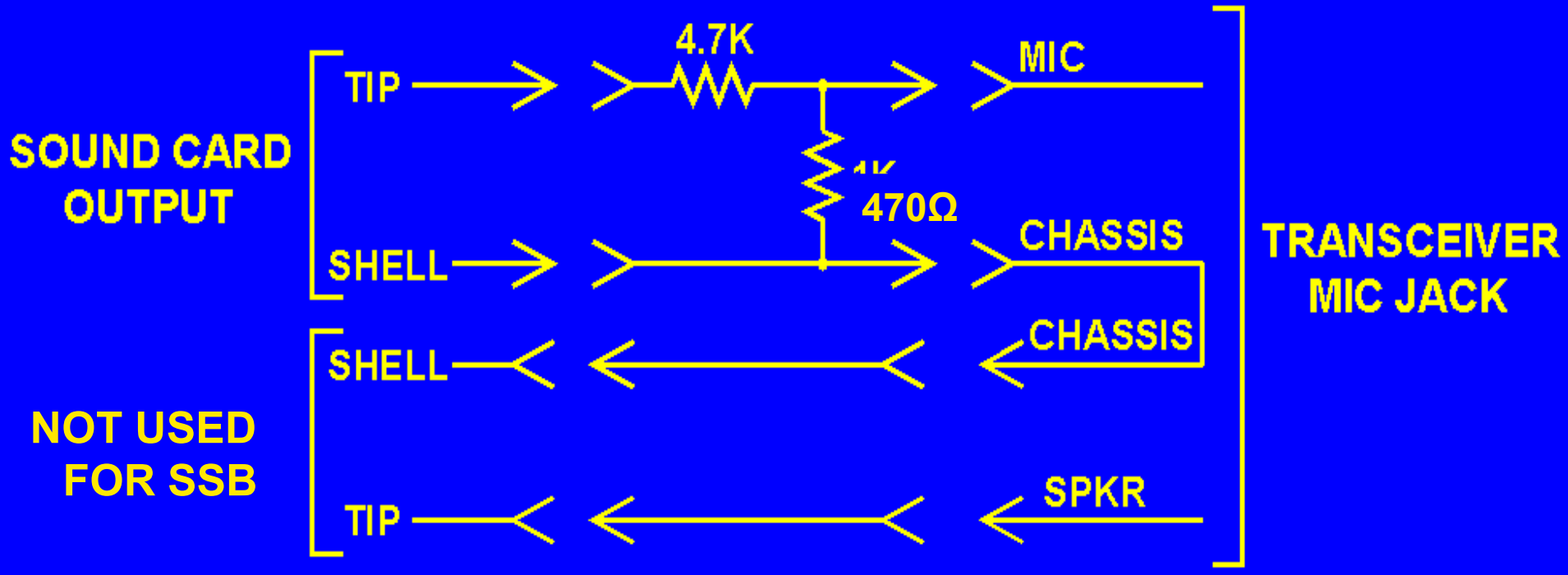
- By KG7SG, in July 1992 QST
  - Get circuit board from Far Circuits $5
- 4-transistors, 2 diodes, easy to build
- W1GEE builds them and N3FJP sells them ($50)
- Self-powered from RTS line
  - Must modify circuit if you want to use RTS for PTT
  - Get power from a 12V source instead

Simple SSB Setup



- The logging program feeds your mic to the rig
  - Allows you to record new messages during the contest
  - This setup uses VOX to key rig

K6DGW Simple SSB Interface



- This works for SSB too!
- Plug your mic into the computer
  - Most contest logging programs will mute it when playing messages

Common Mode Coupling

- So How does RF get inside the box?

Pin One Problems!

How Do Pin Problems Happen?

- Pin 1 of XL's go to chassis via circuit board and ¼" connectors (it's cheaper)
- XLR shell not connected to anything!
- RCA connectors not connected to