All About Coax

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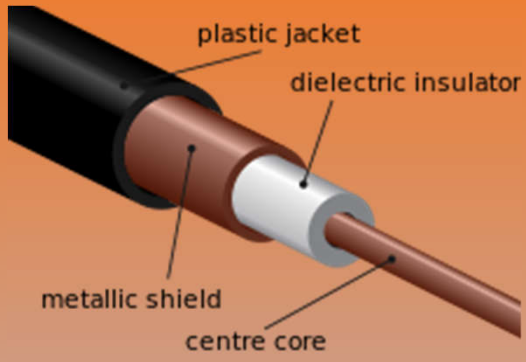
Your First Station

What's the most important part of your station? **THE ANTENNA!**

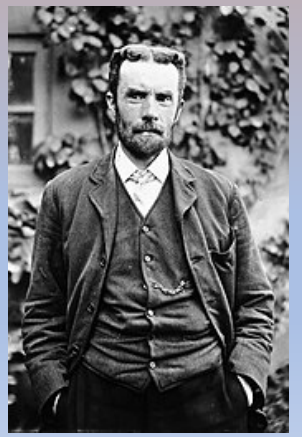
What's the 2nd most important part of your station? **THE COAX**

What is Coax?

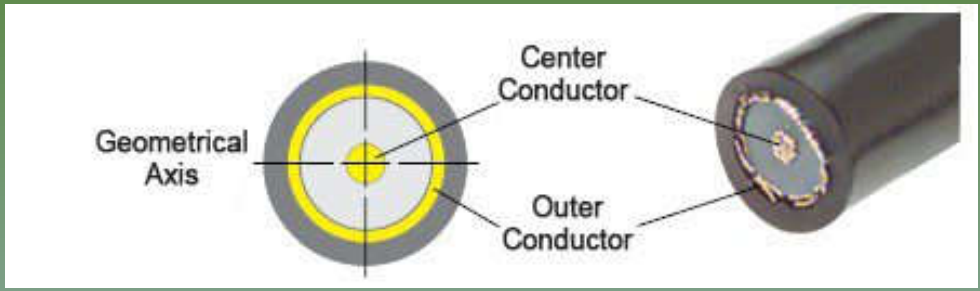


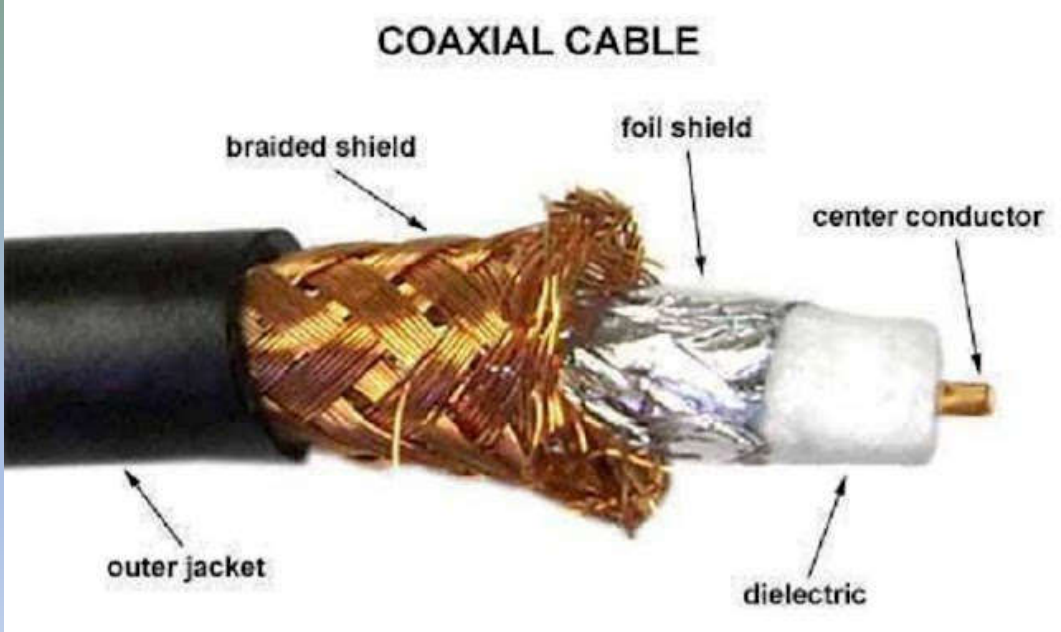
- Coaxial Cable
  - That black cable that hooks up your radio to your antenna
  - A type of electrical cable consisting of an inner conductor surrounded by a concentric conducting shield, with the two separated by a dielectric (insulator)
  - A type of transmission line, used to carry high-frequency electrical signals with low losses

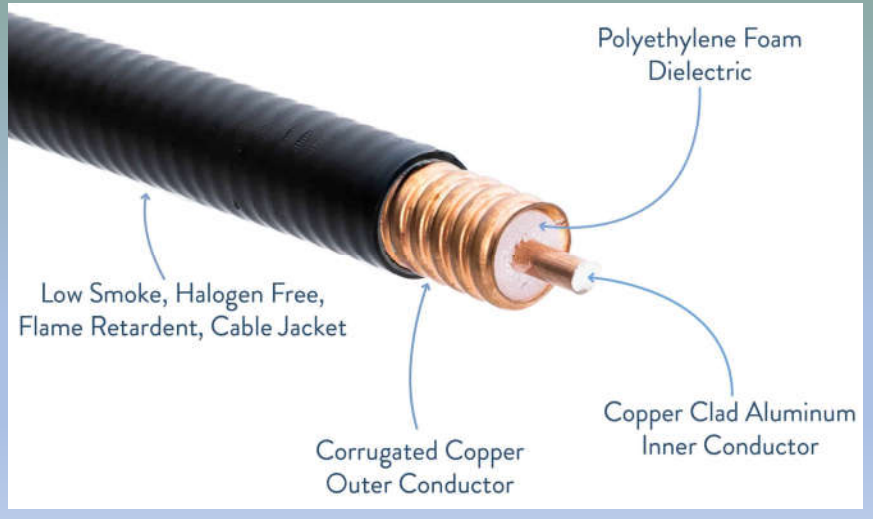
- Where did it come from?
  - First patent for coax issued in 1880 to Oliver Heavyside
  - First use was in 1858 in transatlantic cables
  - Designed to eliminate interference between parallel cables



Construction

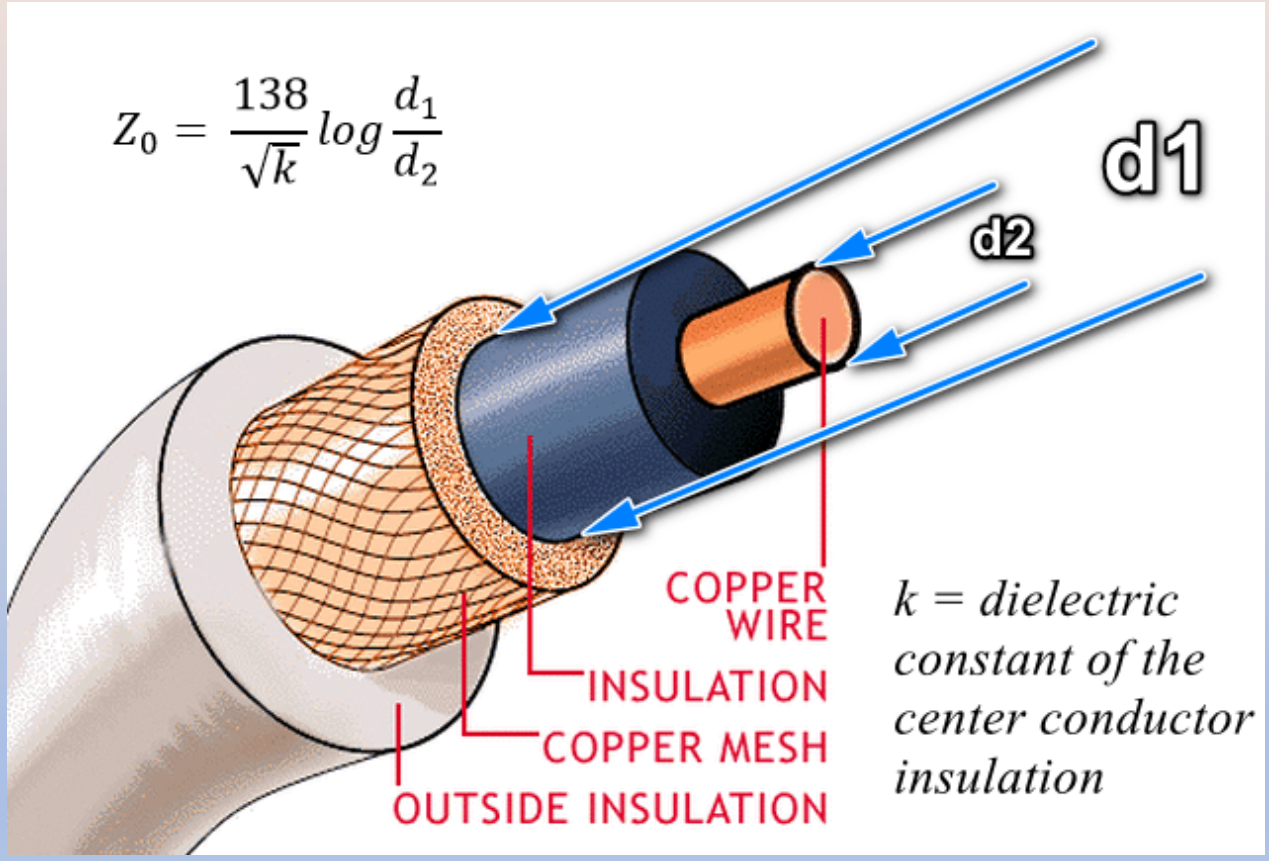






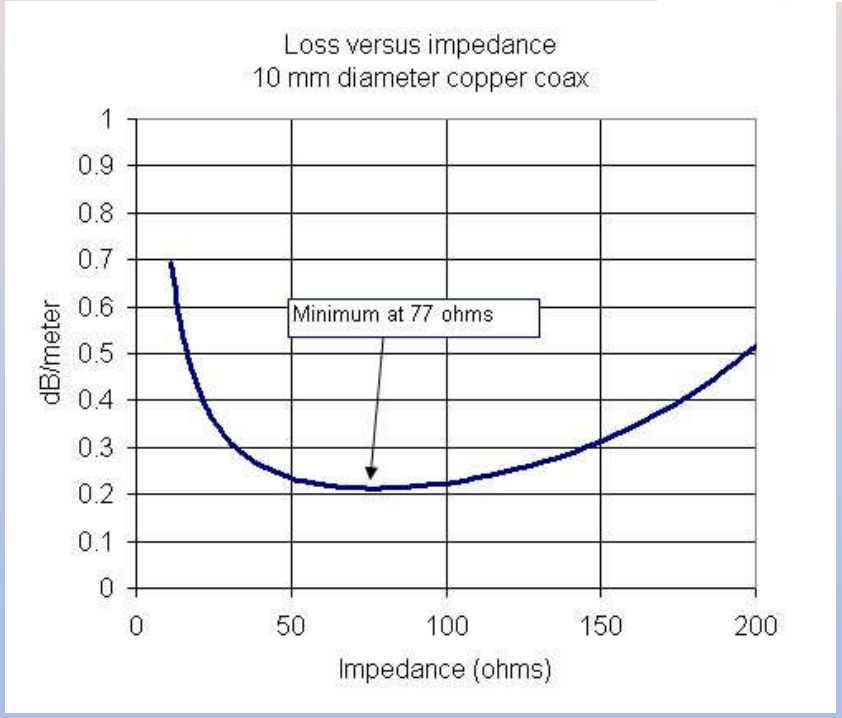
Impedance

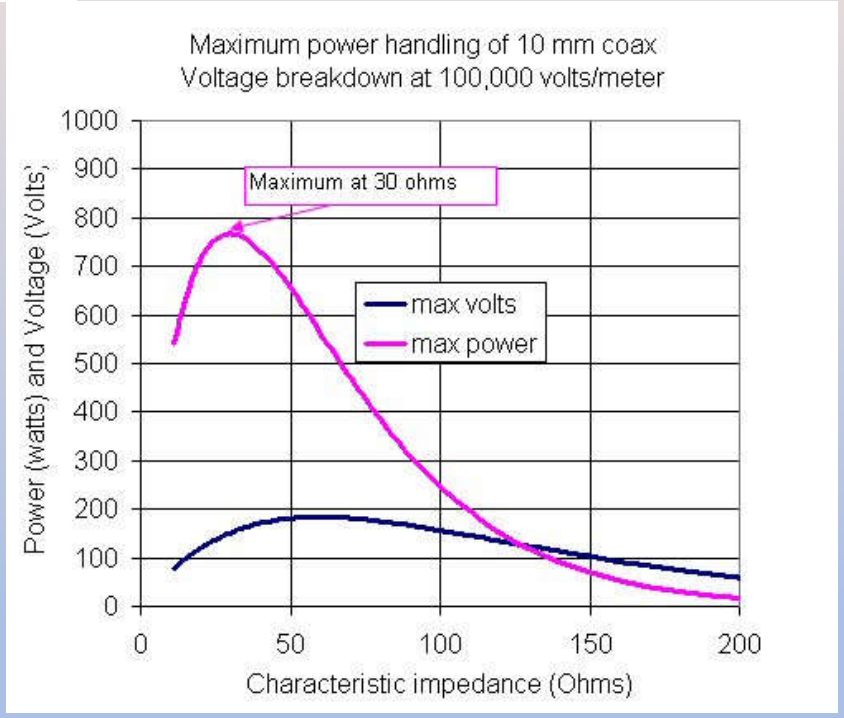
$$Z_0 = \frac{138}{\sqrt{k}} log \frac{d_1}{d_2}$$



Why 50Ω?

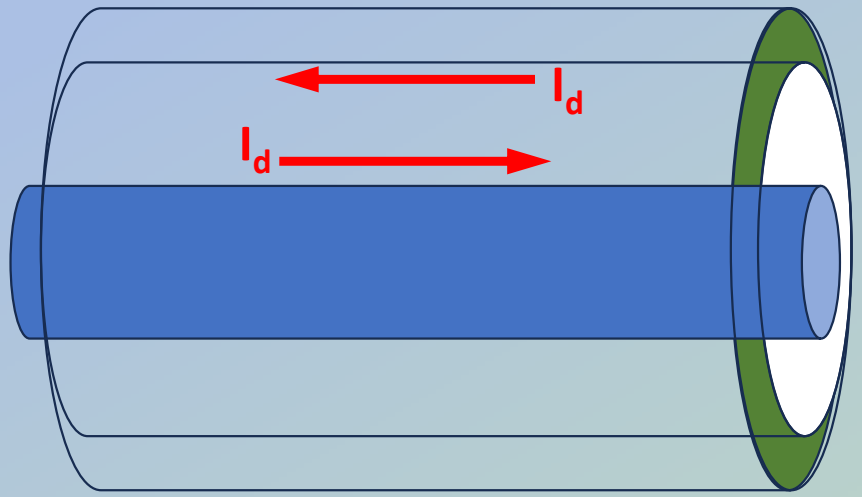
$$Z_0 = \frac{138}{\sqrt{\varepsilon_R}} \log\left(\frac{D}{d}\right) (ohms)$$





50Ω is compromise between loss and power handling capacity

Currents on Coax

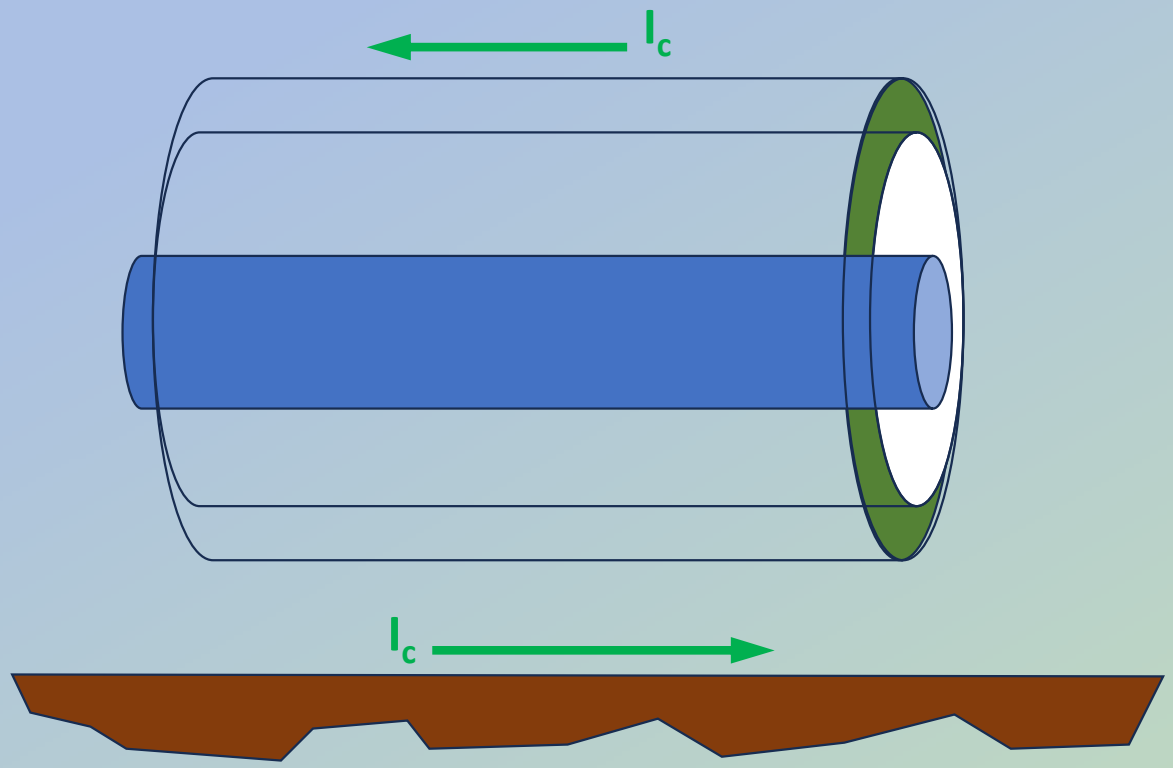


Currents stay on inside of coax due two factors:

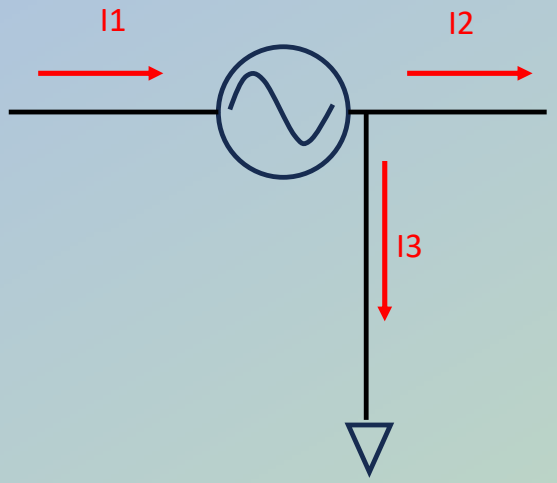
- Skin effect
- Proximity effect

Currents on Coax

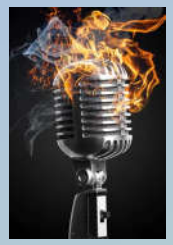
Currents on Coax



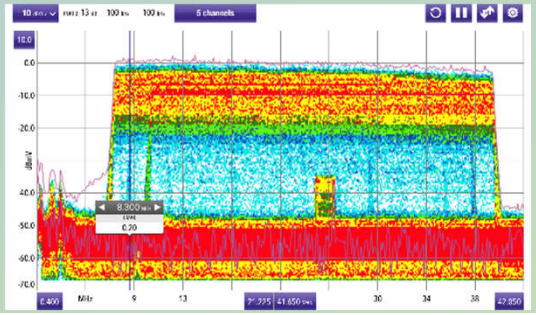
Common Mode Currents



- Your coax is part of your antenna system
  - My dipole has three legs!
  - “Weird” tuning
- RF in the shack (TX)
  - hot microphone
  - Rig issues
  - Computer upsets



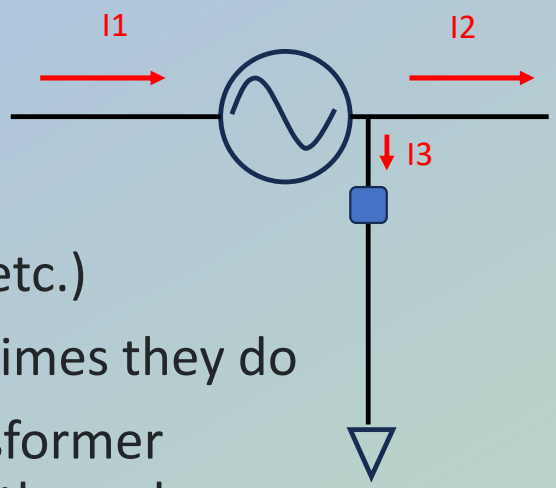
- Ingress path for noise sources (RX)
  - Does your noise floor go up more than 1-2 S-units when you connect the antenna?



Combating Common Mode Currents

- http://www.k9yc.com/RFI-Ham.pdf
- Chokes
  - Not just for transmit but also for receive
- Balun (transformer)

Choke vs Balun



- Baluns are designed to be transformers (like 1:1 4:1, 6:1, etc.)
- They do not always perform the same function but sometimes they do
- A regular current balun internally is very much like a transformer where as a choke balun usually focuses on multiple turns through toroids to provide high-impedance to common mode currents
- A choke is an inductor which is used to block high frequencies while allowing DC to pass. All chokes are inductors but not all inductors are chokes
- A balun is any device designed to connect a balanced source to an unbalanced load or vice-versa.

Popular Coax for Amateur Use

Coax	Diameter	Delectric	Bend radius	Loss dB/100' @10 MHz	Loss dB/100' @200 MHz	Power @200 MHz	$/ft
RG-174	0.11"	PE	1.1"	3.3 dB	11.9 dB	80W	$0.16
RG-58	0.159"	Teflon	1.5"	1.4 dB	7.3 dB	200W	$0.26
RG-8X	0.242"	FPE	2.5"	1.0 dB	5.4 dB	360W	$0.40
RG-8	0.405"	PE	4"	0.6 dB	2.8 dB	685W	$0.90
RG-213	0.405"	PE	4"	0.6 dB	3.3 dB	685W	$1.12
9913	0.405"	PE*	4"	0.4 dB	1.8 dB	685W	$0.81
LMR400	0.405"	Foam PE	1"/4"	0.6 dB	1.9 dB	1200W	$1.29
LMR600	0.565"	LD Teflon	1.5"/6"	0.35 dB	1.2 dB	2000W	$2.33
1/2" Hardline	1/2" nom	Foam PE	5"	0.21 dB	0.95 dB	1310W	$2.85
7/8" Hardline	7/8" nom	Foam PE	10"	0.11 dB	0.53 dB	5380W	$8.00
RG-400	0.195"	Solid PTFE	1.18"	1.2 dB	5.5 dB	1500W	$3.14
RG-6 (75Ω)	0.18"	Foam PE	3"	0.6 dB	2.8 dB	*	$0.20
RG-11 (75Ω)	0.28"	Foam PE	3.9"	0.4 dB	2.3 dB	*	$0.50

Coax Connectors

- Your connection to the “World”
  - Radio
  - Antenna
- Mechanical requirements
  - Rugged – may be supporting the weight of the cable
  - Protects its mating connector
  - Keep water (and other things) out
- Electrical
  - Keeps the RF in
  - Ideally maintains the impedance of the coax through the connector

Popular(?) Coax Connectors

- RCA
  - DC-?

- PL-259 (UHF)
  - DC-?

- BNC
  - DC-4 GHz

- TNC
  - DC-11 GHz

- N
  - DC-11(18) GHz

- SMA
  - DC-18 GHz

Putting Connectors on Coax (PL-259)

Solder vs Crimp

What's the goal?

Reliable, consistent connection both **electrically** and **mechanically**

Soldering

- Go to YouTube and watch any of a gazillion videos
- Use sharp tools for cutting
- Use a “Big Enuf” soldering iron
- This is very much a learned skill
- Practice, practice, practice
- Cons
  - Every “practice” costs $$
  - Melting the dielectric is very easy, especially while soldering the shield
- At HF & low power you can get away with a lot (i.e. poor soldering)
- High power will let you know when your connectors are not “good enough”

Crimping

- YouTube is your friend for learning; but don’t watch just one
- Crimp connectors are the standard in commercial RF
- Much easier to make consistent, reliable connectors
  - Stronger mechanically
- Cons
  - You **have** to have a crimp tool $$
  - Need different crimping dies for different size coax
  - Connectors *might* be a little more expensive
  - You still have to solder the center conductor

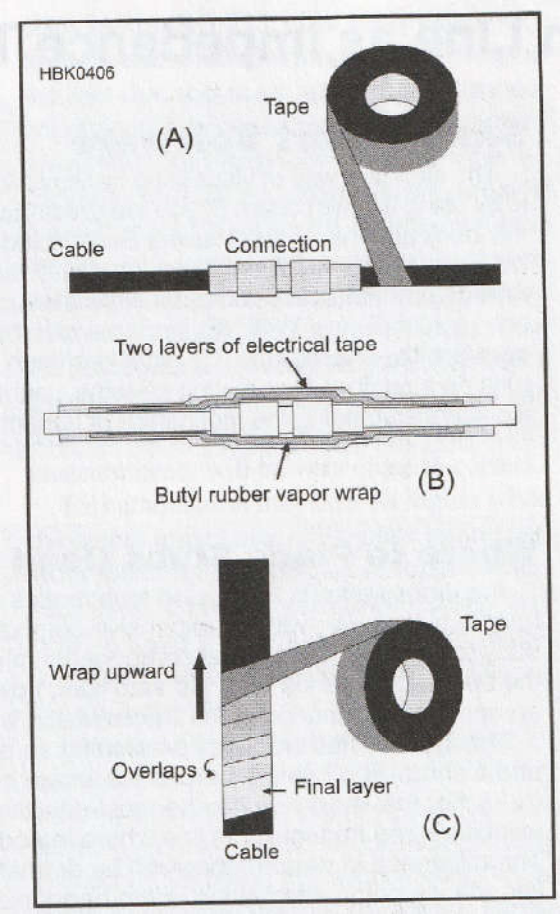
Tightening Connectors

- Every *threaded* connector needs proper tightening
  - Mechanical reasons
  - Electrical reasons
- Step 1: Tighten by hand
- Step 2: Use pliers to tighten ¼ turn more (no more!)
  - Exception – SMA connectors

"Franking" tool
(ala W3LPL)

Protecting from the weather

- AFTER making sure the connections are tight
- Protect against moisture ingress
  - 1-2 Layers of electrical tape
    - Use quality tape (3M Scotch Super 33+ - top of the line)
    - Wrap with edges overlapping
  - Layer of mastic tape
    - 3M Scotch 2228
    - Overlap edges
  - Layer of electrical tape
- Moisture will increase the loss of the coax
  - May result in connector/coax failure (arcing, rust)



Testing Coax

- Why?
  - Check condition before installing
  - “Something” goes wrong with antenna (SWR change)
- You SWR meter is useless
  - Can’t differentiate between load and coax
  - Can’t measure loss

Testing Coax – Loss measurement

- Measure loss through coax
- Equipment required
  - Signal source
  - Dummy load
  - Power meter

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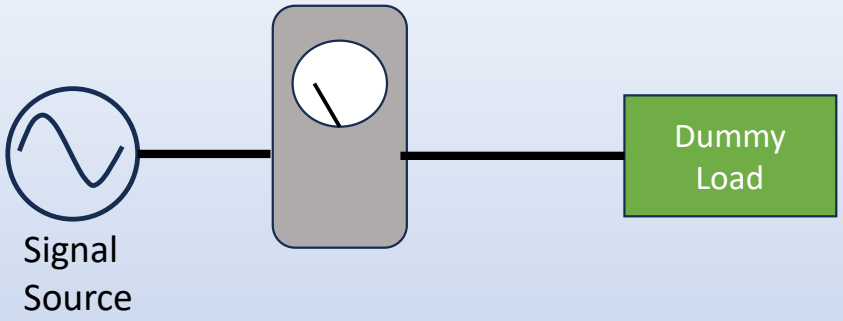
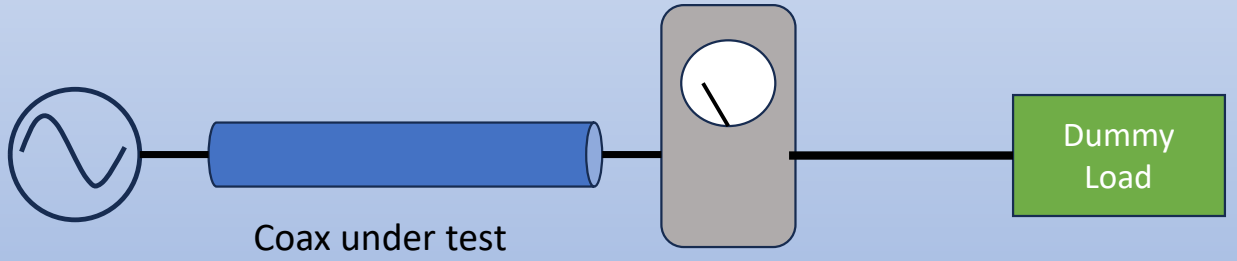


Step 1. Measure power output of signal source into dummy load (P_{source})

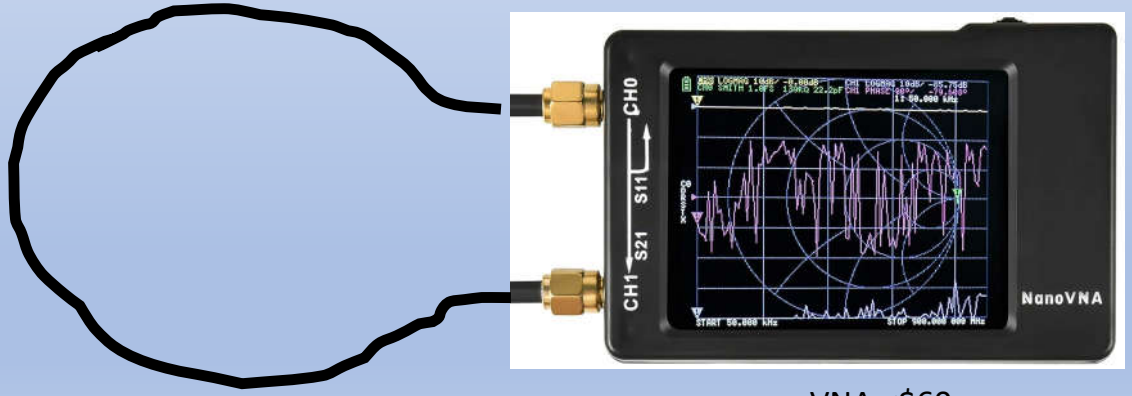


Step 2. Measure power output through coax into dummy load (P_{load})

$$Loss(dB) = 10*\log10 (P_{load}/P_{source})$$

Testing Coax – Loss measurement

- VNA – Vector Network Analyzer
  - Measure loss of cable (S21)
    - Port 2 to Port 1 (CH1 to CH0 on nanoVNA)
  - More accurate than wattmeter method
  - Can measure across a wide bandwidth



nanoVNA <$60

Testing Coax – TDR

- Time Domain Reflectometry (TDR)
  - Concept: send a narrow pulse down the coax and watch the reflections that come back
  - Can see imperfections along the coax
  - Find location of the faults

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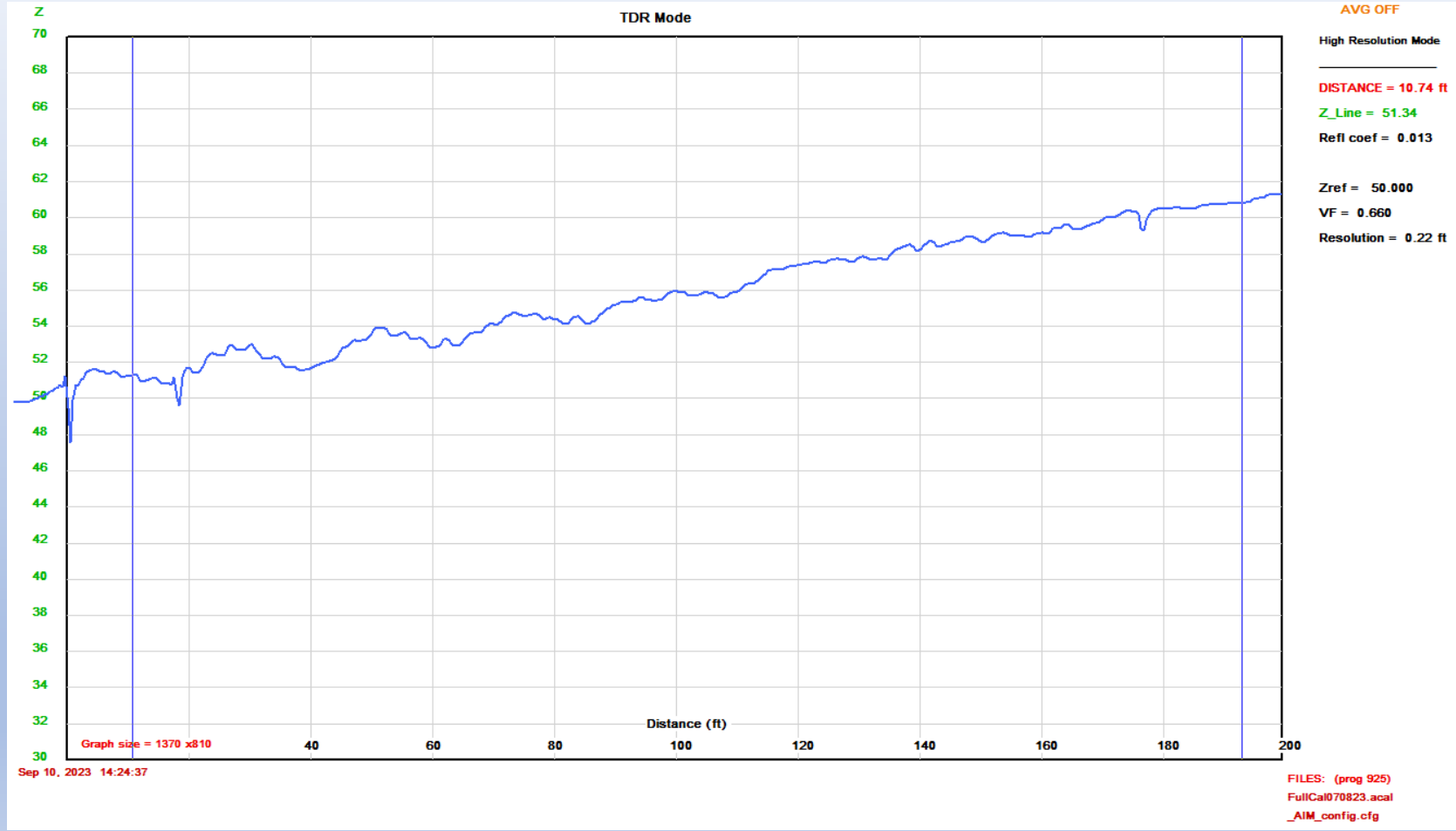
  - Can see imperfections along the coax
  - Find location of the faults
- Devices
  - VNA – nanoVNA is capable
  - AIM antenna analyzer

TDR for 20m Yagi @AG4TT



SUMMARY

- Use good quality coax
  - Consider length/loss
- Use good quality connectors
- Protect your coax
  - Mechanically –
    - Don’t let it get crushed
    - Don’t exceed the bend radius
  - Electrically – make good electrical connections
  - Environmentally – seal the connectors and any adapters