COAXIAL CABLE AND RF CONNECTORS FOR HAM RADIO

PRESENTATION TO THE DESERT RATS

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SEARCHING FOR "DESSERT" RATS

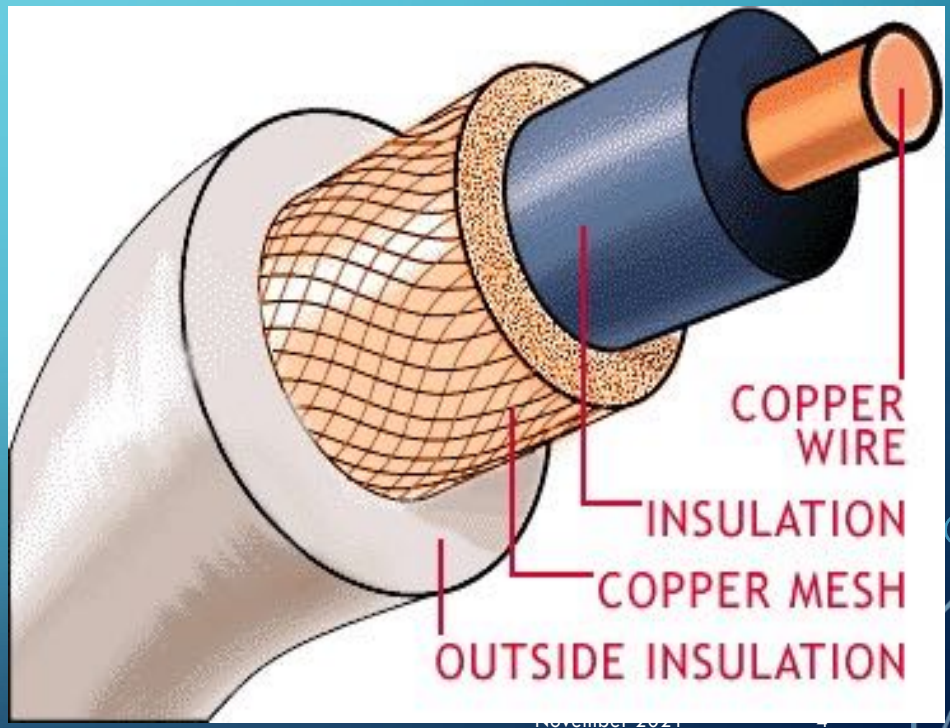
- Here is what came up!

OVERVIEW

- Briefly review coaxial cables, why they are necessary, various types
- The reasons we need RF connectors
- The various types of connectors
- The reason for the various names given to connectors
- The reasons why connectors do not work for all ham radio bands
- Various performance characteristics of cables and connectors
- Adapter cables for various radios to extend antenna

ENTER COAXIAL CABLES

- Coaxial cable was invented by the English engineer **Oliver Heaviside** in 1880.
- AT&T invents modern coax cable in 1929 to send telephone calls between major cities
- RG stands for Radio Guide; it was the early US standards group



COAXIAL CABLE PHYSICS

- RF frequencies travel on the surface of a conductor
- If you surround the conductor with a tubular conductor, the energy propagates without radiating
- To do this efficiently, the coaxial cable "impedance" needs to be matched to the equipment at each end

The Math: Coaxial cable

$$Z_O = \frac{138}{\sqrt{\epsilon_r}} \times \log\left(\frac{a}{b}\right)$$

- Z_0 = characteristic impedance in ohms
- a = outside radius of inner conductor
- b = inside radius of the outer conductor
- ε_r = dielectric constant of the insulating material between inner and outer conductors

IMPEDANCE

- The measure of the opposition that a circuit presents to a current when a voltage is applied.
- Measure in ohms
- It depends upon the frequency of the sinusoidal voltage.
- *Best Practice: Make sure you match impedance of interconnected equipment as closely as possible*

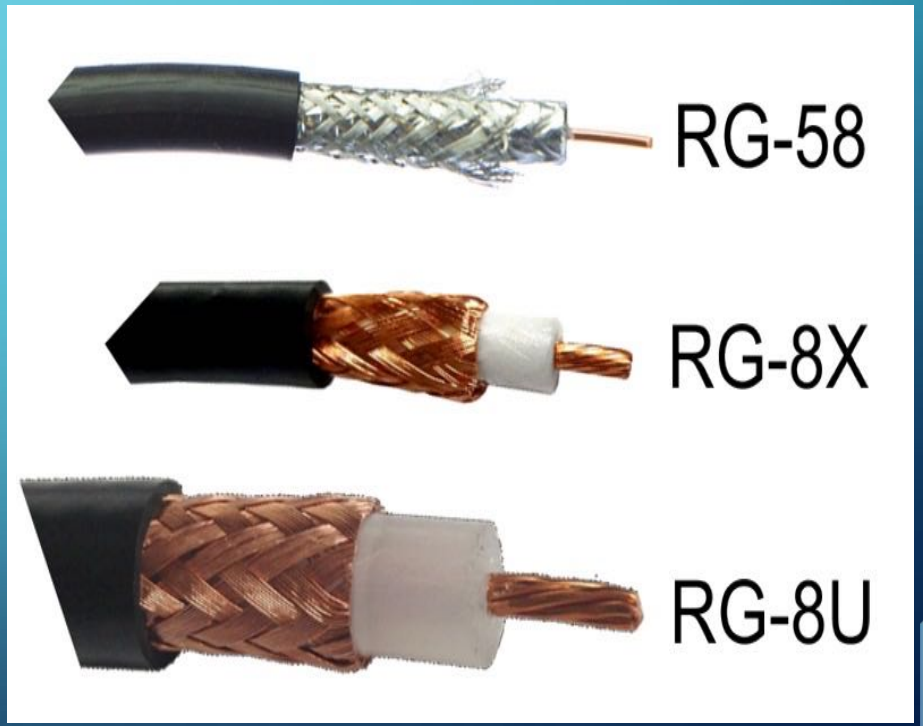
COAXIAL (OR COAX) CABLE

In general:

- Hams usually use 50 ohm cable but 75 ohm has a place in HF
- The larger the diameter of the coax, the lower the loss
- The smaller the diameter of the coax, the higher the useful frequency
- Air cable has the lowest loss, but is really only suitable for permanent uses
- Modern low loss foam cables are a great compromise between loss and flexibility

COAXIAL 50 OHM CABLES IN COMMON HAM USE

- Medium loss, very flexible, handles about 250 watts on HF
- Medium loss, very flexible, handles more power than RG-58
- Lower loss, less flexible, easily handles up to 1,000 watts on HF



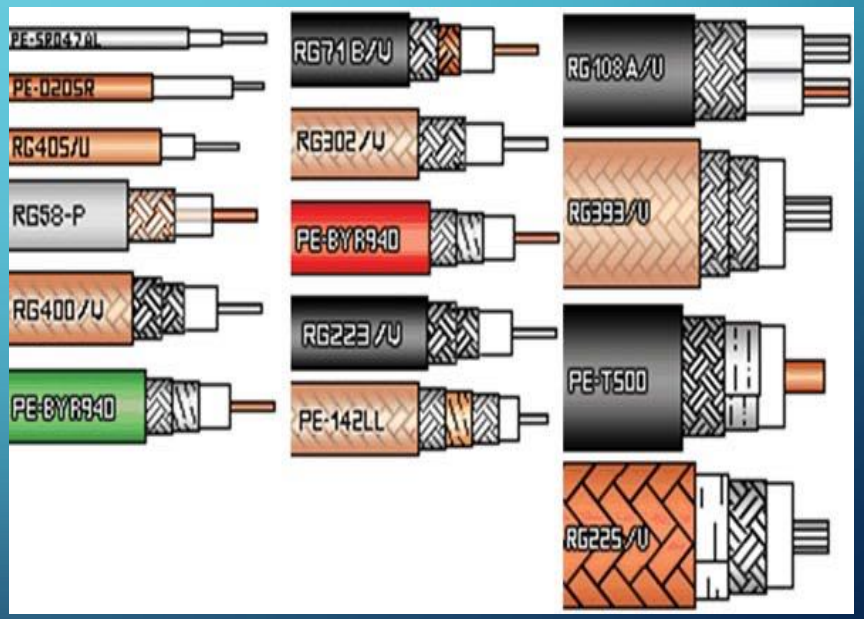
IN REALITY, THERE ARE HUNDREDS OF CABLE TYPES

RG Coax Cable Applications

Cable Type	Impedance	Typical Application	Best feature	Trade Off
RG174/U	50 Ohm	Transmission of data signals in applications such as LAN/WAN or GPS	Small diameter, flexible	Higher signal loss than larger diameter cable such as RG58
RG188A/U	50 Ohm	Transmission of data signals in applications such as LAN/WAN or GPS in situations where high temperature performance is needed	Small diameter, flexible, High temperature rating of taped TFE outer jacket	Higher signal loss than larger diameter cable such as RG58 and higher cost than standard RG174
RG316/U	50 Ohm	Transmission of data signals in applications such as LAN/WAN or GPS in situations where high temperature performance is needed	Small diameter, flexible, High temperature rating of extruded FEP outer jacket	Higher signal loss than larger diameter cable such as RG58 and higher cost than standard RG174
RG58C/U	50 Ohm	Transmission of data signals in applications such as antenna feed cables or Ethernet backbones	Lower signal loss than smaller diameter cable such as RG174	Less flexible than smaller diameter cable such as RG174
RG142B/U	50 Ohm	Transmission of data signals in applications such as antenna feed cables or Ethernet backbones in situations where high temperature performance is needed	Lower signal loss than smaller diameter cable such as RG174. High temperature rating of extruded FEP jacket	Less flexible than smaller diameter cable such as RG174 and higher cost than RG58C cable.
RG59A/U	75 Ohm	Transmission of a video or audio signal in applications such as security systems or CATV	Lower signal loss than smaller diameter cable such as RG179. Flexibility of stranded center conductor cable	Higher signal loss than solid center conductor RG59B/U cable
RG59B/U	75 Ohm	Transmission of a video or audio signal in applications such as security systems or CATV	Lower signal loss than smaller diameter cable such as RG179 and RG59A/U stranded center conductor cable	Less flexible than smaller diameter cable such as RG179 or stranded center conductor RG59A/U
RG6/U	75 Ohm	Transmission of a video or audio signal in applications such as security systems or CATV	Lower signal loss than smaller diameter cable such as RG179 and both RG59A/U or RG59B/U cable	Less flexible than smaller diameter cable such as RG179 and both RG59A/U or RG59B/U
RG223/U	50 Ohm	Transmission of data signals in applications such as LAN/WAN or GPS in situations where low signal loss and high shielding performance is needed	Lower signal loss and better shielding than smaller diameter cable such as RG174 or RG58C/U cables	Less flexible than smaller diameter cable such as RG174 and higher cost than single shielded RG58C cable
RG213/U	50 Ohm	Transmission of data signals in applications such as antenna feed cables in situations where low signal loss and high operating voltage performance is needed	Lower signal loss and higher operating voltage than RG58C/U cable	Larger diameter and less flexible than RG58C/U cable
RG179B/U	75 Ohm	Transmission of a video signal in applications such as security systems where high temperature performance is needed	Small diameter, flexible, High temperature rating of extruded FEP outer jacket	Higher signal loss and cost than larger diameter cable such as RG59
RG187/U	75 Ohm	Transmission of a video signal in applications such as security systems where high temperature performance is needed	Small diameter, flexible, High temperature rating of TFE taped outer jacket	Higher signal loss and cost than larger diameter cable such as RG59

L-com Global Connectivity

For more information, visit us at www.L-com.com or call 1-800-343-1455



BENEFITS OF COAXIAL CABLE

- Coax is not supposed to radiate your signal (some are better than others) and transfers most of the signal to the antenna depending on the length and loss
- Coax has a wide frequency range
  - In Ham Radio Terms, HF to Microwave
- Coax is flexible, it can be reused, and is generally water tight
- Coax is very easy to install and most cables can connect to a variety of connectors

COAX ATTENUATION

- Attenuation is the loss of signal over a give length of transmission line
- Low loss is always better, but always a cost vs. performance decision

Cable Xperts

Attenuation Chart

Nom. Attenuation. Frequency in Mhz db/100ft									
Cable Type	10Mhz	30Mhz	50Mhz	150Mhz	220Mhz	450Mhz	900Mhz	1.2Ghz	2.4Ghz
100 Series	2.3	3.9	5.1	8.9	10.9	15.8	22.8	26.7	38.9
195 Series	1.1	2.0	2.5	4.4	5.4	7.8	11.1	12.9	18.6
240 Series	0.8	1.3	1.7	3.0	3.7	5.3	7.6	8.8	12.7
400 Series	0.4	0.7	0.9	1.5	1.9	2.7	3.9	4.5	6.6
600 Series	0.2	0.4	0.5	1.0	1.2	1.7	2.5	2.9	4.3
LMR-400-UF	0.5	0.8	1.1	1.8	2.2	3.3	4.7	5.5	7.9
RG142/U									
RG213/U	0.6	1.2	1.5	2.8	x	5.2	7.3	x	x
RG214/U	0.6	0.9	1.3	2.3	x	4.5	7.3	x	x
RG223/U	1.2	2.0	2.8	5.0	x	9.8	13.4	x	x
RG316/U									
RG393/U									
RG58A/U	1.5	2.6	3.3	6.8	x	12.6	21.0	x	x
RG8/U (CXP1318FX)	0.5	0.8	1.1	1.8	2.2	3.3	4.7	5.5	7.9
RG8X-Mini	1.0	2.0	2.3	4.7	x	8.6	13.0	x	x

www.cableexperts.com

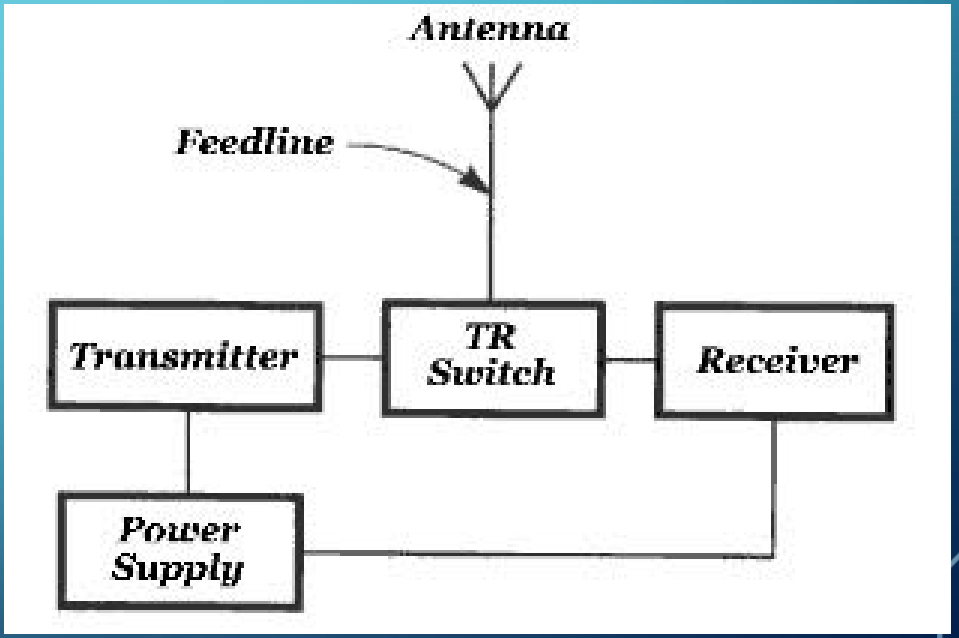
WHY DO WE NEED RF CONNECTORS?

- Originally, coax was just soldered or bolted in place at each end of the coax
- We need a convenient way to get the RF in or out of a transmitter or receiver
- We need a properly designed coaxial connector to match the coax type
- These connectors make radio systems more flexible and easy to reconfigure
- Connectors allow for portable operation
- And there are hundreds of connector types to choose from! (Ugh)

TYPICAL RADIO SYSTEM

All ham radio systems have these things in common:

- A transceiver (or transmitter and receiver)
- A transmission line or feedline
- An antenna



TRANSMISSION LINE?

Where is the transmission line on your portable?

What is the output impedance of your radio?

COMMON CONNECTORS IN THE HAM WORLD

- Screw terminals
- UHF
- BNC
- N
- SMA
- Reverse SMA
- 7/16 DIN (for critical repeater system)

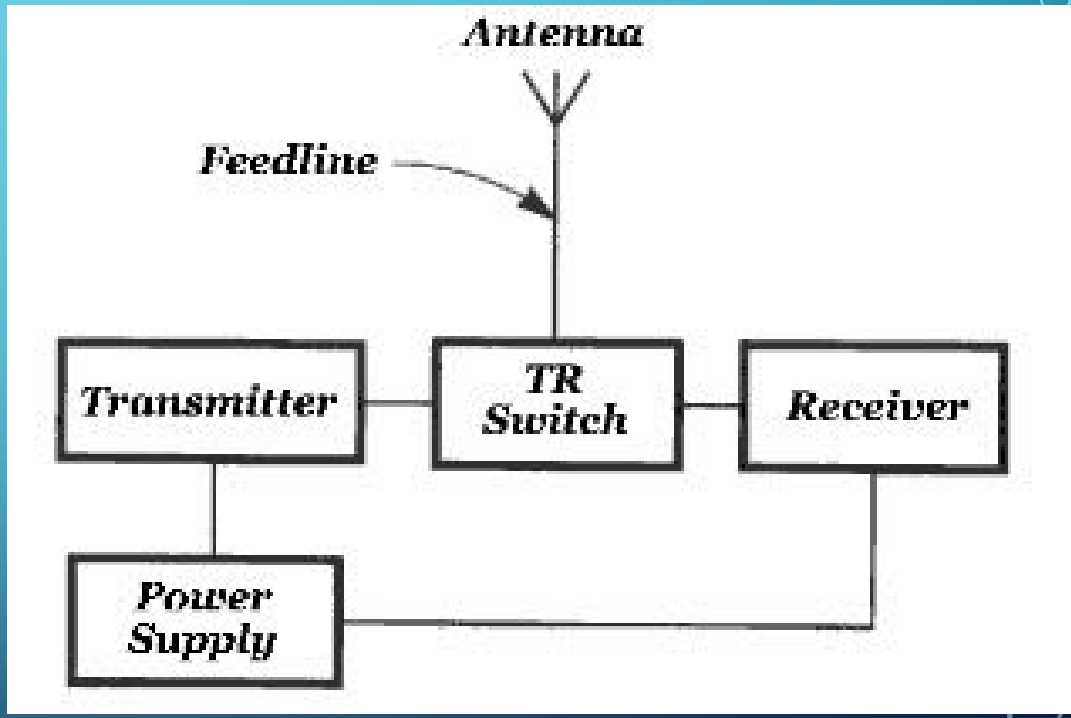
WHERE DO THESE NAMES COME FROM?

- Various manufactures over the last 75 years have come up with names.
- For example, the “N” connector was invented at Bell Labs in the 1930’s by Paul Neill. They named it after his last name.
- The SMA connector is an abbreviation for: “Sub Miniature version A”

CASE STUDY—
ROOFTOP ANTENNA FOR 144 AND 440 MHZ BANDS

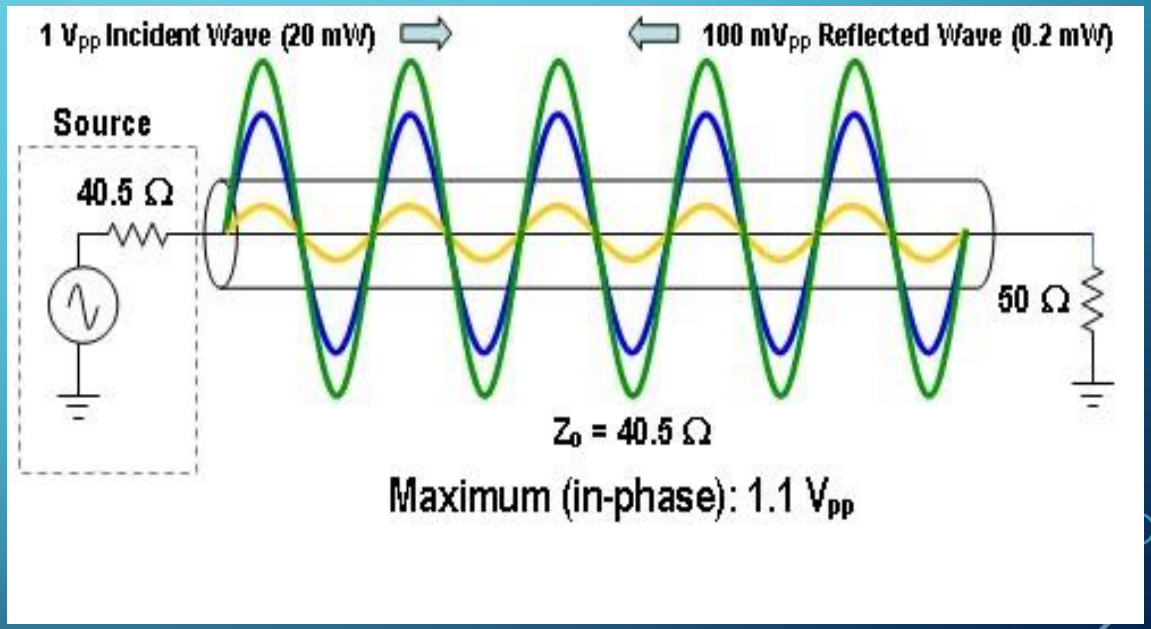
<u>You want to obtain:</u>

- A transmitter that has a 50 ohm output impedance
- A low loss coax with a 50 ohm impedance
- And an dual band antenna with a 50 ohm impedance
- *<u>If you do, it will all work fine</u>*



ENTER IMPEDANCE MISMATCH

- Matching impedance of the transmitter, line, connectors, and antenna is important
- Mismatched impedance causes reflections and creates standing waves
- Reflections add loss, standing waves cause higher voltages!



SCREW TERMINALS

- The first connector was a screw or bolted connection
- These are still in use today on HF systems

SCREW TERMINALS

- Very useful for VLF (300 kHz to 3 MHz) and HF (3 MHz to 30 MHz)
- At these frequencies the wavelengths are so long, small changes in wire spacing makes insignificant difference to the performance of the system
- You can use coax *without* connectors up to 30 MHz with few performance problems as long as the impedance is matched
- Most HF antenna tuners have screw terminals in addition to UHF connectors

UHF CONNECTORS--MALE AND FEMALE

UHF CONNECTOR

- The most popular connector in the Amateur radio world.
- Invented in the 30's as one of the first coaxial connectors
- Standardized during WWII by the Signal Corps as the PL-259 (plug) and the SO-239 (socket)
- Useful at 150 MHz and beyond with reduced performance
- UHF is a bad name as it is not really good at UHF frequencies as the impedance is not constant and causes loss
- Found on nearly all HF equipment and a lot of VHF equipment
- Can handle 1000 watts of power on HF
- Made for a lot of different cables and usually cheap (as low as $1 each)

MINI UHF—MALE AND FEMALE

MINI UHF CONNECTOR

- Introduced in the 1970's for the original in car cell phones
- Popular on VHF and UHF mobile radios
- A good constant impedance connector
- Useful to 2.5 GHz but only with small sized cables
- It has a 500 volt rating, but power is limited by the small diameter cables it is designed for

BNC—MALE AND FEMALE

BNC CONNECTOR

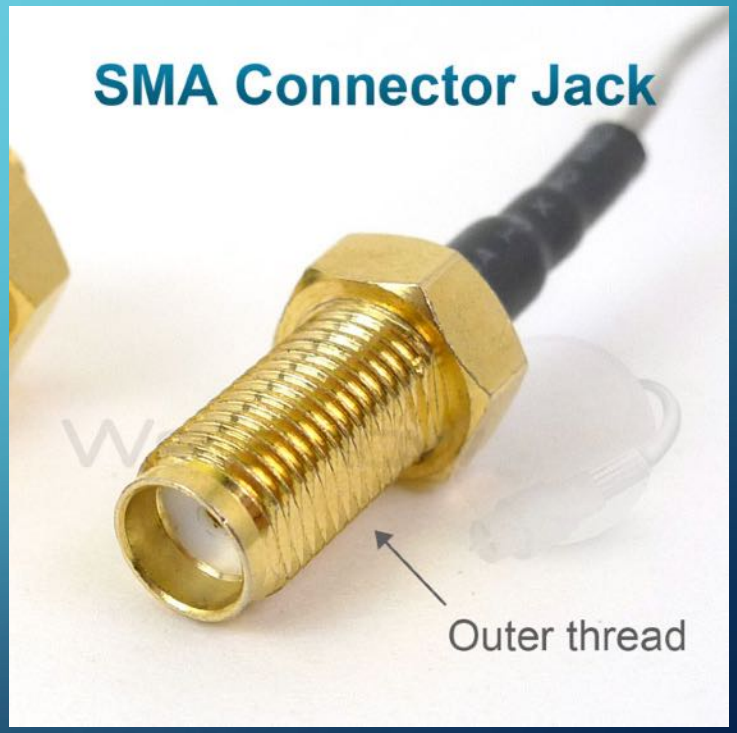
- This connector was invented around 1945
- The idea is to have high quality connector with quick connect/disconnect
- Very good constant impedance up to at least 2 GHz
- Made for most types of cables
- Power handling mostly depends on cable type
- Available in both 50 and 75 ohm types

N—MALE AND FEMALE

N CONNECTOR

- Invented in the 1940's as a constant impedance connector useful to 1 GHz
- Later improvements allow it to pass signals up to 18 GHz
- It is one of the primary connectors for Ham Radio on UHF and above
- Most commercial transmitters and base station antennas designed for 150 MHz and above come with N connectors
- Typically, about 5-10 times the cost of a "UHF" connector

SMA—MALE AND FEMALE



SMA CONNECTOR

- Named “Subminiature Version A (yes there is a Version B)
- Developed in the 1960’s as a miniature connector for the aerospace industry
- Has excellent impedance characteristics and is useful to 18 GHz
- Became very popular on hand held radios after 2000
- Not high power due to small size

REVERSE SMA—MALE AND FEMALE
CONNECTORS WITH AN IDENTITY PROBLEM?

REVERSE SMA

- Developed to meet the FCC requirements systems with integral antenna
- Theoretically, you could not change the antenna as typical SMA connector would not mate
- That lasted about 6 months and the industry started making all the mating connectors and adapters!
- A good connector useful up through the UHF range

7/16 DIN—MALE AND FEMALE

7/16 DIN CONNECTOR

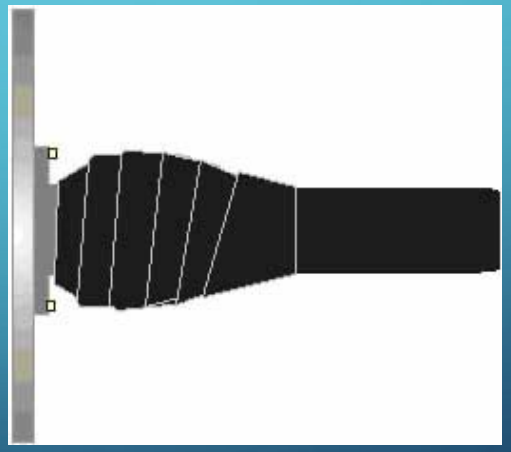
- Developed in Europe as a high power connector
- DIN is a German standards organization
- Now very popular in the US for cellular and wireless systems
- A very well designed high quality connector that can handle high power, typically over 1,000 watts, at UHF frequencies to 3 GHz
- Useful to frequencies in the microwave range

RIGHT CONNECTOR FOR THE CABLE

- Since there are hundreds of cables, there are hundreds of connectors
- The connector has to match the cable exactly to mount correctly and perform correctly and many require special tools
- If you want to build your own cables, ask for help the first few times to insure success
- *Best Practice: Premade cables are the way to go for those Amateurs who are "amateurs" at installing connectors or lack the tools*

OUTDOOR CONSIDERATIONS

- Connectors are not weatherproof
- *Another best practice: Always weatherproof outdoor connections!*



GENDERLESS CONNECTORS?

- Yes. There are a few. These are made by General Radio, and they were very popular on their post war test equipment

ADAPTERS

- Since there are so many connectors, there are many more adapters to interconnect cables and equipment
- What adapters do you have?

ADAPTER KIT

- These are great kits to have
- They are useful for connecting nearly anything you find in Ham Radio
- Basic kits start around $80

ADAPTER CABLES

- A cable assembly with different connectors at each end
- Used to jumper from one piece of equipment to another
- Useful to hook up a mag mount or roof antenna to our portables

TYPICAL ADAPTER CABLES FOR YOUR RADIOS

- Wouxun and Baofeng—SMA(M) to UHF(F)
  - https://www.amazon.com/DHT-Electronics-Kenwood-Handheld-Connector/dp/B00M5Z9N8I/ref=sr_1_6?s=electronics&ie=UTF8&qid=1515966497&sr=1-6&keywords=sma+male+to+uhf+cable
- Wouxun and Baofeng—Reverse SMA to UHF(F)
  - https://www.amazon.com/Handheld-handitalk-Antenna-Quasheng-Antennas/dp/B00IA9655M/ref=sr_1_15?s=electronics&ie=UTF8&qid=1515966155&sr=1-15&keywords=reverse+sma+cable

ADAPTER CABLES FOR YOUR RADIO

- *Best Practice: Use a cable made with a small diameter coax. Do not use an adapter. The weight of a heavy cable can break the solder connection on your antenna connector.*

WRAP UP

- There are lots of coax cable types used by Amateurs
- There are lots of connector types used by Amateurs
- Bigger diameter cable typically has less loss, but costs more
- Smaller diameter cables typically cost less, but have more loss
- Choose connectors based on the frequency range and VSWR you can tolerate
- Always match the connector to the cable to the cable type

WRAP UP

- Choose the right adapter cable for your radio if needed
- Adapters can be very useful to interconnect equipment

- Questions?

CONTACT INFORMATION

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