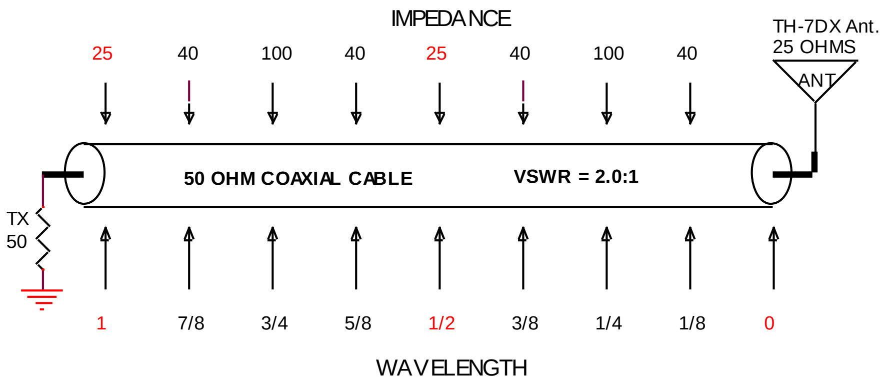
RF CONNECTORS & IMPEDANCE

(For Amateur Radio)

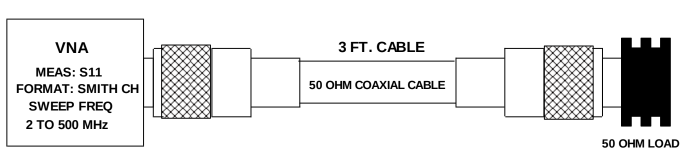
Introduction Amateur radio equipment is designed to operate at its maximum efficiency when the antenna port is terminated with an impedance of 50 ohms. If you stray very far from this impedance value, it can destroy your radio transmitter amplifier stage. RF connectors terminate the coaxial cable ends and play an important role in maintaining impedance. To understand how impedance is affected by the RF connectors and other components that are connected to the radios antenna port, I will explain the following subjects:

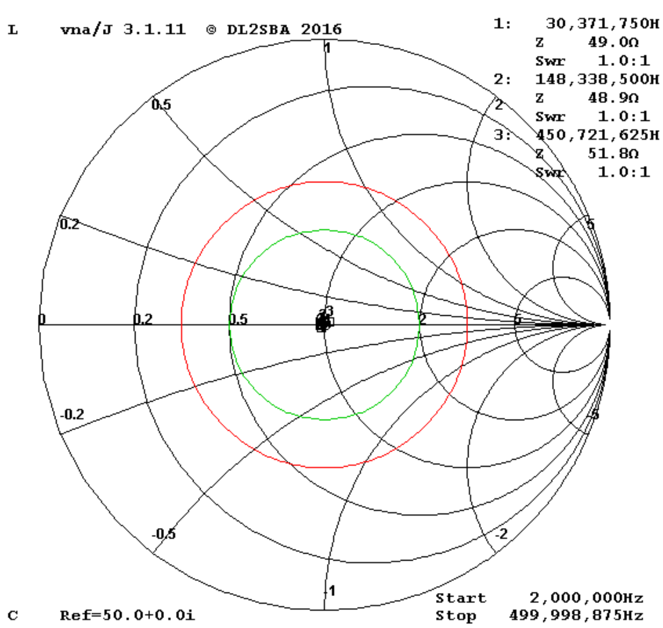
- RF Reflected Power
- Can reflected power or impedance destroy your transmitter's output stage?
- RF connector specifications
- Connector test results

RF Reflected Power Reflected power is encountered anytime there is discontinuity in the flow of RF energy. Amateur radio operators are familiar with the reflected power that occurs when the antenna impedance does not match the coaxial cable 50 ohms impedance. Reflected power is usually measured with a SWR meter. SWR values are a common specification used to signify an antenna's performance. RF connector specifications **do not** include SWR values, but do specify "Return Loss". Return loss is just another way of measuring reflected power and can be converted to SWR. Example: A Return Loss of -9.542 dB equals to a SWR of 2.0:1. Can a SWR meter reading be converted to an impedance value? The answer is **No.** The diagram below shows what happens to the impedance value at different wavelengths along a coaxial cable when the far end is terminated with an impedance of 25 ohms. Notice that the 2:1 SWR value does not change as the impedance changes. The Hy-Gain TH-7DX Tri-Band antenna has a maximum SWR of 2.0:1 (50÷2=25 ohms).

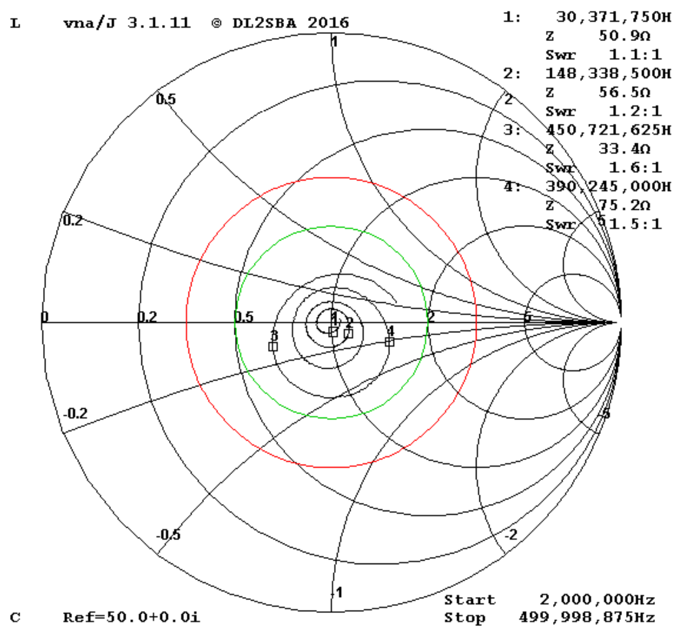


To illustrate how a poorly designed RF connector can cause the same problem as an antenna, I used Vector Network Analyzer to test two **3 foot** cables, one with N type connectors and one with PL259's. A VNA was used to test the cable characteristics because this instrument can measure impedance and SWR across a 2 to 500 MHz frequency range. The antenna is replaced with a non-reactive 50 ohm load.





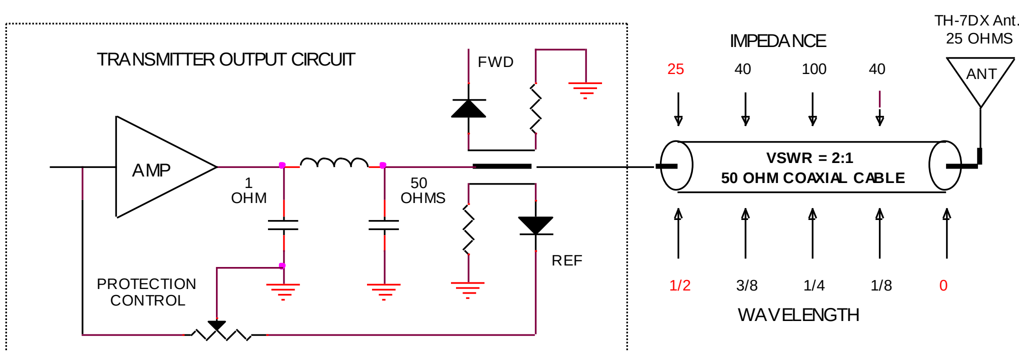
N Type Test Results



PL-259 Test Results

The Smith Chart markers show impedance (Z) and SWR values at the HF, 2M and 70CM frequencies. Note: A 4th marker was added to the PL-259 to show at what frequency maximum impedance occurred. It's obvious that the PL-259 connectors did not perform very well in the UHF frequency range. Remember, the cable was terminated with 50 ohms. Imagine what the test results would look like if the cable was terminated with an antenna.

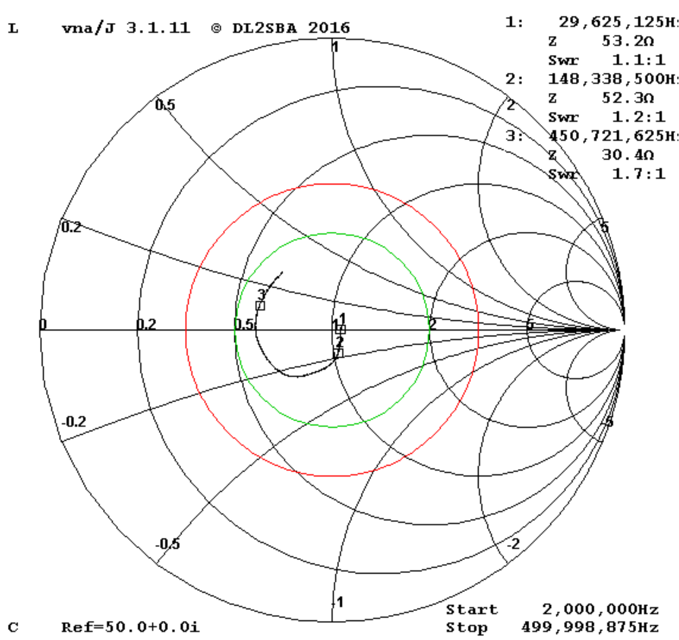
Can reflected power or impedance destroy your transmitter's output stage? The answer to this question is hidden in the "Transmission Line" section of the ARRL handbook. (2001 Handbook, page 19.4) [What actually happens to the energy reflected back down the line? This energy will encounter another impedance discontinuity, this time at the generator. Reflected energy flows back and forth between the mismatches at the source and load. After a few such journeys, the reflected wave diminishes to nothing, partly as a result of finite loses in the line and by absorption at the load.] The transmitter's output stage is never subjected to reflected energy. Most transceivers incorporate a circuit that monitors SWR and reduces the amplifier output power at some predetermine level. **Impedance** is the major opponent that destroys the transmitter's amplifier output stage. If the impedance applied to the radios antenna port is not 50 ohms, this impedance mismatch **detunes** the matching circuit which causes a mismatch to the amplifiers output. If this mismatch exceeds the amplifiers design limit it will destroy the device.



RF connector specifications Connector manufacturers use special test equipment to characterize their connector designs. Most of the connectors I tested where manufactured by Amphenol and the following list of specifications is published in their documents.

1. Impedance
2. Frequency Range
3. Return Loss
4. Peak Power
5. Average Power
6. 3rd Order IM.
7. Durability

Connector test results Impedance (Z), frequency and SWR are the only test specs shown in Smith Chart test plots because most amateurs are familiar with these characteristics. Return Loss, Peak Power, 3rd Order Intermodulation and Durability will not be included in this document. The photo below shows the test cables that were tested. To prevent any impedance anomalies that would be created by the coaxial cable, the cable length was kept very short between the connectors. Two PL-259 cables were tested to see if RG-58 connector adapters change the impedance characteristics.



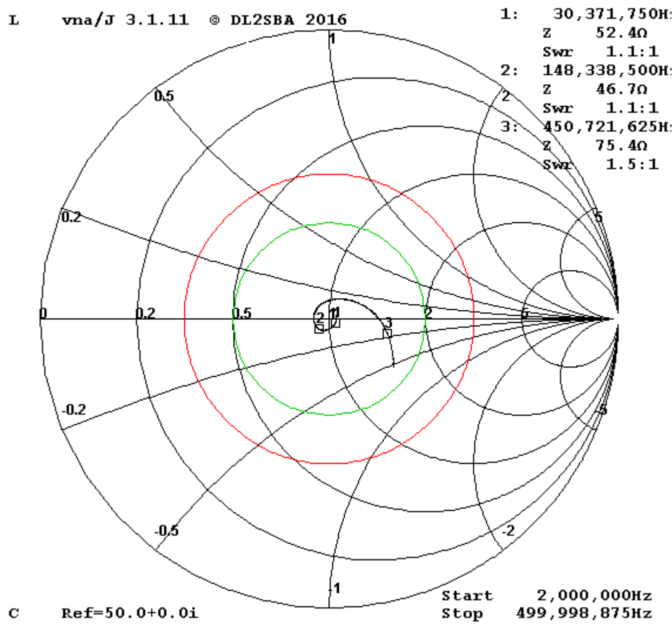
PL-259 (RG-8)

PL-259 (RG-8)

Impedance: Non-Constant

HF: Z = 53.2Ω, SWR = 1.1:1
2m: Z = 52.3Ω, SWR = 1.2:1
70cm: Z = 30.4Ω, SWR = 1.7:1
Frequency Range: .6 to 300 MHz
Average Power: 1 kw

Note: Non-Constant impedance means that the connector's impedance changes with any change in frequency.



PL-259 (RG-58)

PL-259 (RG-58)

Impedance: Non-Constant

HF: Z = 52.4Ω, SWR = 1.1:1
2m: Z = 46.7Ω, SWR = 1.1:1
70cm: Z = 75.4Ω, SWR = 1.5:1
Frequency Range: .6 to 300 MHz
Average Power: 1 kw @ 30 mhz

Note: Non-Constant impedance means that the connector's impedance changes with any change in frequency.

The **PL-259** connector was designed by Amphenol in the 1930's and was originally used as a video connector. Amphenol's frequency range (.6 to 300 MHz) has not changed since its original design, but most design engineers of commercial equipment will not use this connector if the frequency is above 100 MHz. This connector has two major problems. Its impedance changes with frequency and their intermodulation characteristics is not very good. Manufacturers use PL-259 connectors because they are cheap. Andrew makes a replacement for the PL-259 that has an impedance of 50 ohms, but the cost is $26.50 each. The Andrew's part number is 41SP in case you want to buy a couple for your next project.

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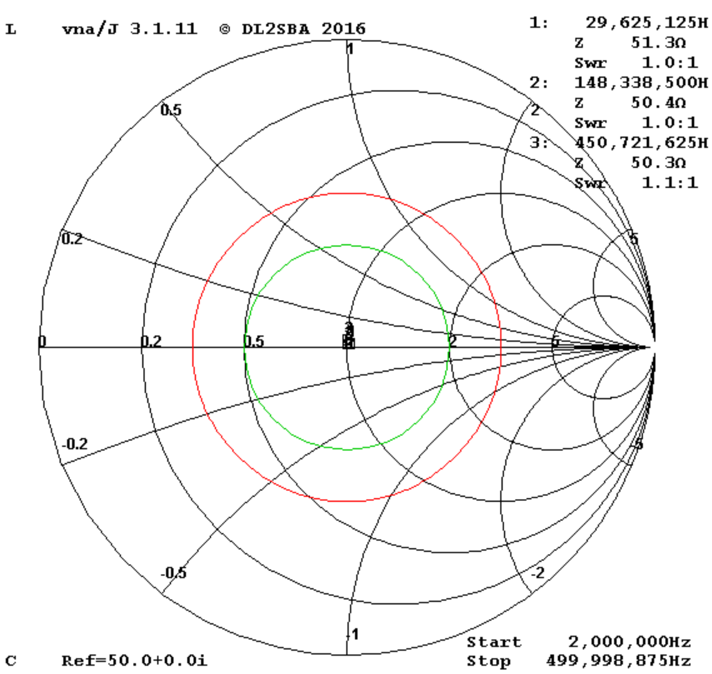


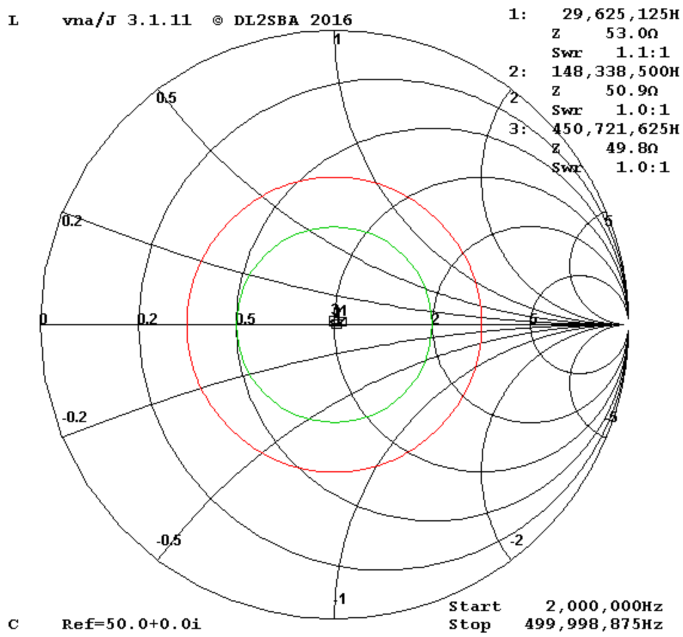
N Type (RG-223)

N Type (RG-223)

Impedance: 50 ohms

HF: Z = 51.3Ω, SWR = 1.0:1
2m: Z = 50.4Ω, SWR = 1.0:1
70cm: Z = 50.3Ω, SWR = 1.1:1

Frequency Range: DC to 11 GHz
Average Power: 1.6 kw



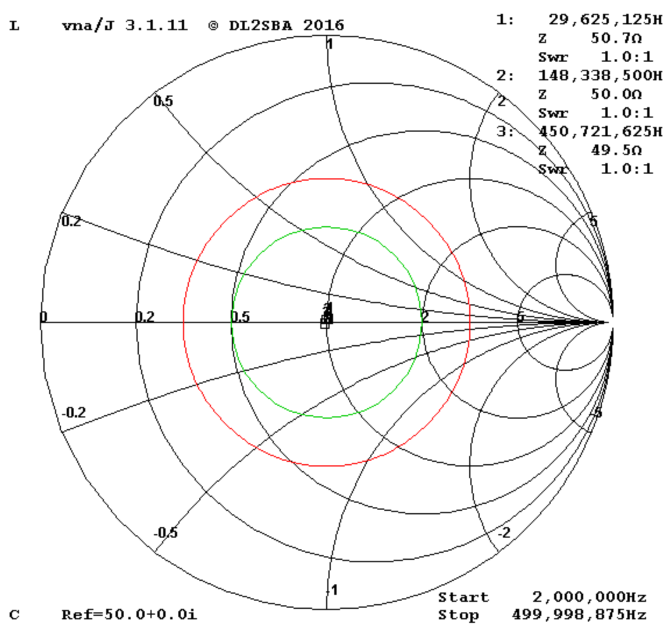
BNC (RG-58)

BNC (RG-58)

Impedance: 50 ohms

HF: Z = 53.0Ω, SWR = 1.1:1
2m: Z = 50.9Ω, SWR = 1.0:1
70cm: Z = 49.8Ω, SWR = 1.0:1

Frequency Range: DC to 4 GHz
Average Power: 100 W



SMA (RG-142)

SMA (RG-142)

Impedance: 50 ohms

HF: Z = 50.7Ω, SWR = 1.0:1
2m: Z = 50.0Ω, SWR = 1.0:1
70cm: Z = 49.5Ω, SWR = 1.0:1

Frequency Range: DC to 12.4 GHz
Average Power: 500 W

Summary Page 1 demonstrates what happens to the impedance along a coax cable went it is attached to an impedance other than 50 ohms. Page 2 of this document shows how even a short section (3 ft.) of coax cable can react to a connector that doesn't have an impedance of 50 ohms. Most amateurs use a SWR meter to determine the health of their antenna, but a SWR reading **cannot** be converted to impedance. Look at the PL-259 test results; the SWR = 1.5:1/Z = 75.4Ω and SWR = 1.7:1/Z = 30.4Ω. Connecting a 50 ohm impedance antenna to cable end that has 35 ohm impedance connector is a bad decision. I wouldn't change all of the SO-239's on my HF rig, but I choose to invest in better connectors when designing equipment for the VHF/UHF frequencies.

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