Antenna Feedline Friend or Foe

Athens Amateur Radio Club

September 19, 2026

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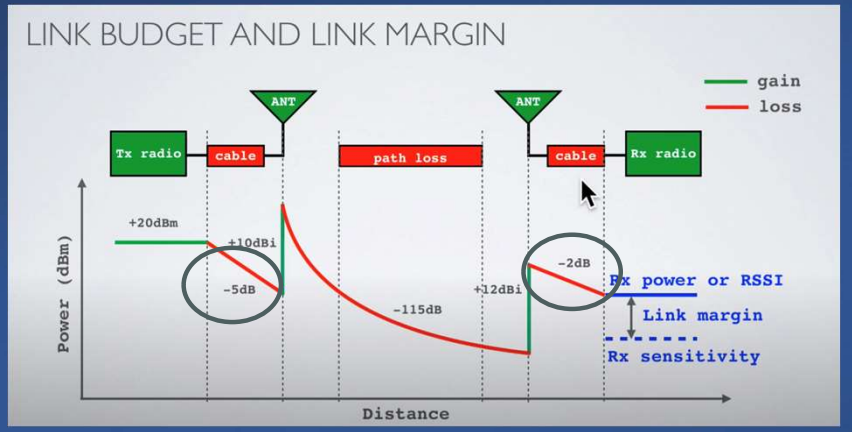
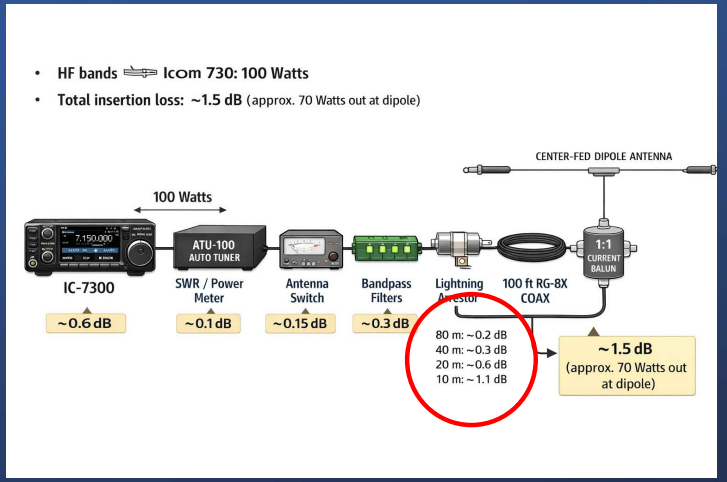
ARRL The national association for AMATEUR RADIO

Introduction

Recently, we've had a couple presentations about losses between your radio and the antenna.

Today, we're going to dig a bit deeper into possibly the biggest area of losses in the radio system, the choice of antenna feedline.





How Well Do You Know Feedlines?

There are 23 questions in the current Technician License Test Pool.
Let's try a few to see how we do!

T9B02 What is the most common impedance of coaxial cables used in amateur radio?
A. 8 ohms
B. 50 ohms
C. 600 ohms
D. 12 ohms

T9B03 Why is coaxial cable the most common feed line for amateur radio antenna systems?
A. It is easy to use and requires few special installation considerations
B. It has less loss than any other type of feed line
C. It can handle more power than any other type of feed line
D. It is less expensive than any other type of feed line

T7C07 What happens to power lost in a feed line?
A. It increases the SWR
B. It is radiated as harmonics
C. It is converted into heat
D. It distorts the signal

How Well Do You Know Feedlines?

T9B05 What happens as the frequency of a signal in coaxial cable is increased?
A. The characteristic impedance decreases
B. The loss decreases
C. The characteristic impedance increases
D. The loss increases

T7C11 What is an advantage of foam-dielectric versus solid-dielectric coaxial cable?
A. It is more resistant to moisture contamination
B. It has higher voltage breakdown
C. It has less loss per foot
D. It has a better impedance match to 50 ohms

T9B08 Which of the following is a source of loss in coaxial feed line?
A. Water intrusion into coaxial connectors
B. High SWR
C. Multiple connectors in the line
D. All these choices are correct

T7C09 Which of the following causes failure of coaxial cables?
A. Moisture contamination
B. Solder flux contamination
C. Rapid fluctuation in transmitter output power
D. Operation at 100% duty cycle for an extended period

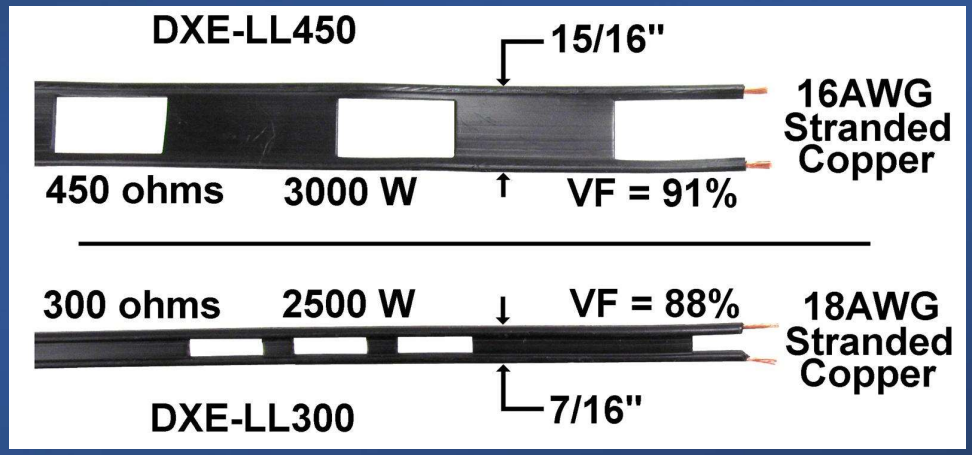
T9B11 Which of the following types of feed line has the lowest loss?
A. 50-ohm flexible coax
B. Multi-conductor unbalanced cable
C. Air-insulated hardline
D. 75-ohm flexible coax

Objectives

- Explain characteristic impedance, velocity factor, shielding and power handling.
- Identify common balanced and unbalanced antenna feedlines.
- Predict how attenuation changes with frequency and feedline length.
- Convert feedline loss in dB to power delivered at the antenna.
- Recognize how SWR increases real feedline loss.
- Select practical feedline types for HF, VHF, and UHF.

Balanced Feedlines

- Two conductors carry equal and opposite RF currents.
- Common impedances: 300 Ω twin lead and ~450 Ω window/ladder line.
- Very low matched loss (higher impedance, lower current) compared with many coaxial cables.
- Can remain efficient with high SWR when used with a suitable tuner.
- Performance is affected by nearby metal, wet surfaces and routing.
- Must be impedance matched to radio

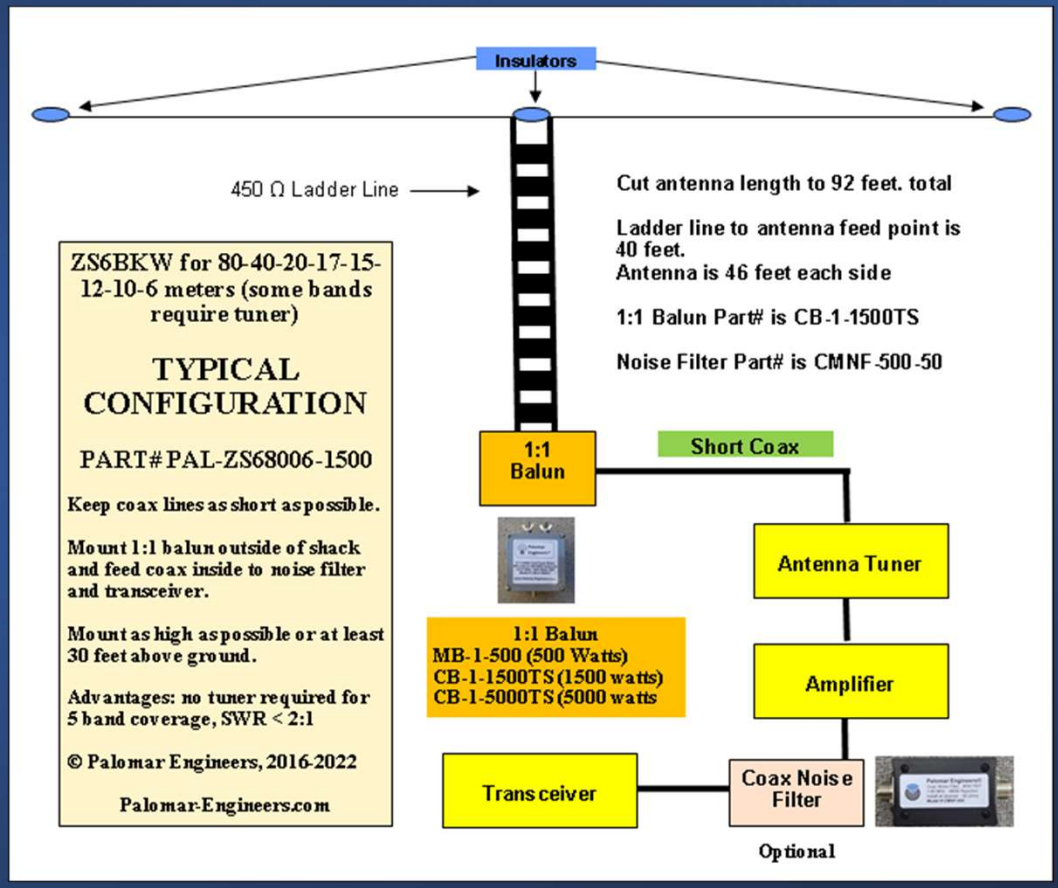


DX Engineering

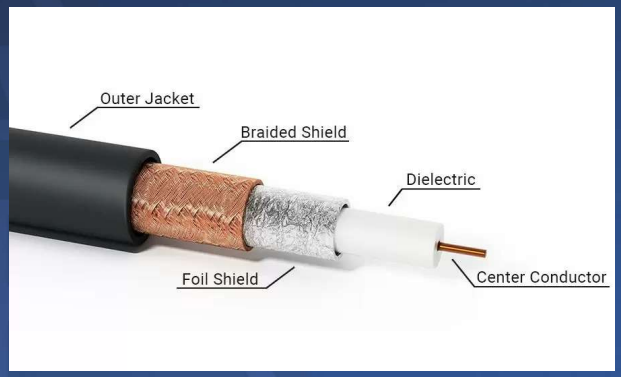
Balanced (Ladder Line) Antenna System

This is an example of a balanced line antenna installation that can be purchased.

Note the band coverage of this antenna and that it needs no tuner for 5 of the bands.



Unbalanced Feedlines (Coax)



- 50 Ω coax is standard for most amateur-radio transmitter systems.
- Shielding reduces radiation from the line and pickup of external noise.
- Easy to route near structures compared with open-wire line.
- Loss rises substantially as frequency increases.

Cable Layers

- **Center Conductor**: A solid or stranded copper wire that carries the primary electrical or data signal.
- **Dielectric Insulator**: A plastic or foam non-conductive layer surrounding the core that keeps spacing fixed and prevents short circuits.
- **Metallic Shield**: A woven metal braid and/or foil wrap that blocks electromagnetic interference (EMI) and acts as the current return path.
- **Outer Jacket**: A tough plastic exterior sheath that protects the internal components from weather, moisture, and physical damage.

I'm going to focus on coax in this presentation

Unbalanced Dipole Antenna Example

Coax connected directly to antenna elements

Coax connected to antenna elements through balun.

Coax Types

Feedline	Nominal Z_o	Diameter class	Typical role	Relative loss
RG-58	50 Ω	Small	Short HF / portable	High
RG-8X	50 Ω	Small/medium	HF stations	Med-high
RG-213/U	50 Ω	Large	HF / VHF	Medium
LMR-240	50 Ω	Medium	Portable / VHF	Medium
LMR-400	50 Ω	Large	HF / VHF / UHF	Low
LMR-600	50 Ω	Very large	Long VHF/UHF runs	Very low
1/2 in Heliax	50 Ω	Hardline	Repeater / tower	Very low

Rule of thumb: as frequency and distance increase, larger/lower-loss cable becomes more valuable.

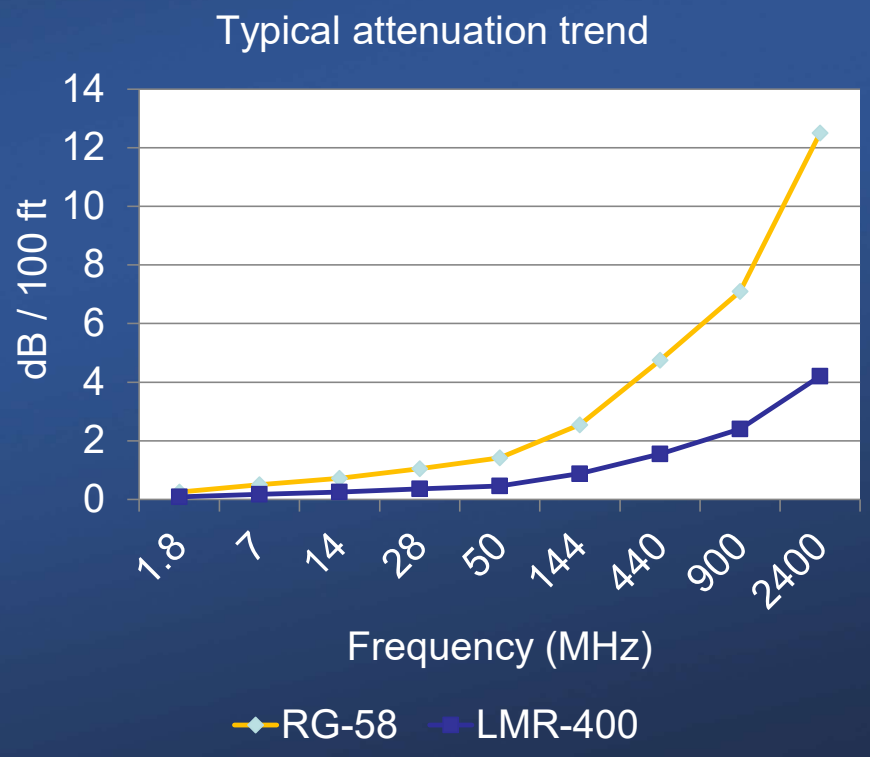
Why Feedline Loss Increases With Frequency

Skin effect confines RF current to a thinner region near the conductor surface.

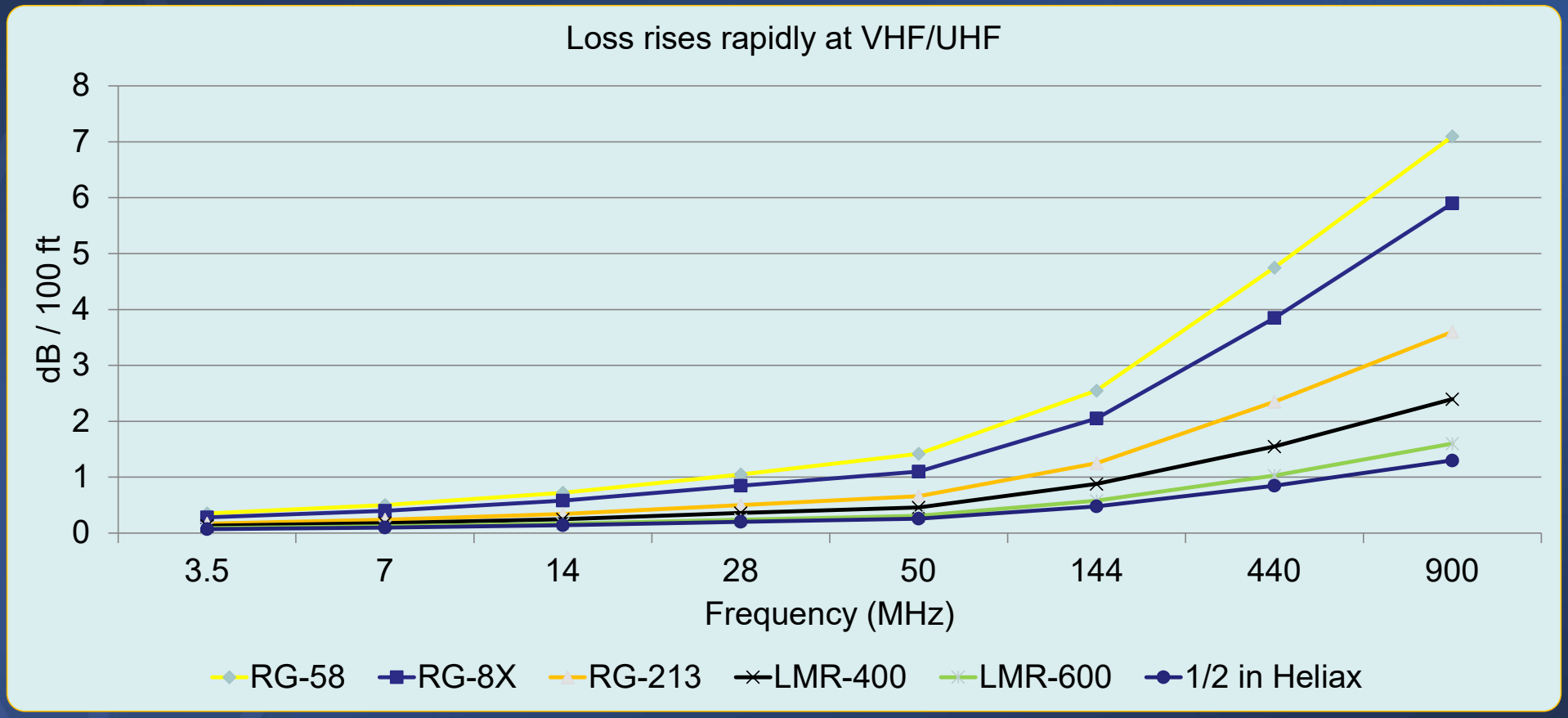
Conductor resistance therefore rises with frequency.

Dielectric losses also increase as the electric field reverses more rapidly.

Shield construction and connector quality become increasingly important at VHF/UHF.



Effect of Frequency Loss



Coax Line Length Considerations

- Minimizing the length of the coax will result in the least amount of loss due to cable length.
- If 100 ft has 2.0 dB loss, 50 ft is approximately 1.0 dB.
- Doubling line length approximately doubles loss in dB.
- Loss in dB is additive; power percentage is not linear.
- Shortening a high-frequency feedline is often the cheapest performance improvement.

HF Approximate Loss Per 100 Ft Length

Cable	3.5 MHz	7 MHz	14 MHz	28 MHz
RG-58	0.35 dB	0.50 dB	0.72 dB	1.05 dB
RG-8X	0.28 dB	0.40 dB	0.58 dB	0.85 dB
RG-213	0.17 dB	0.24 dB	0.34 dB	0.50 dB
LMR-400	0.13 dB	0.18 dB	0.25 dB	0.36 dB
LMR-600	0.09 dB	0.12 dB	0.17 dB	0.24 dB
1/2 in Heliax	0.07 dB	0.10 dB	0.14 dB	0.20 dB

On HF, even modest coax may be acceptable for short runs. Length still matters.

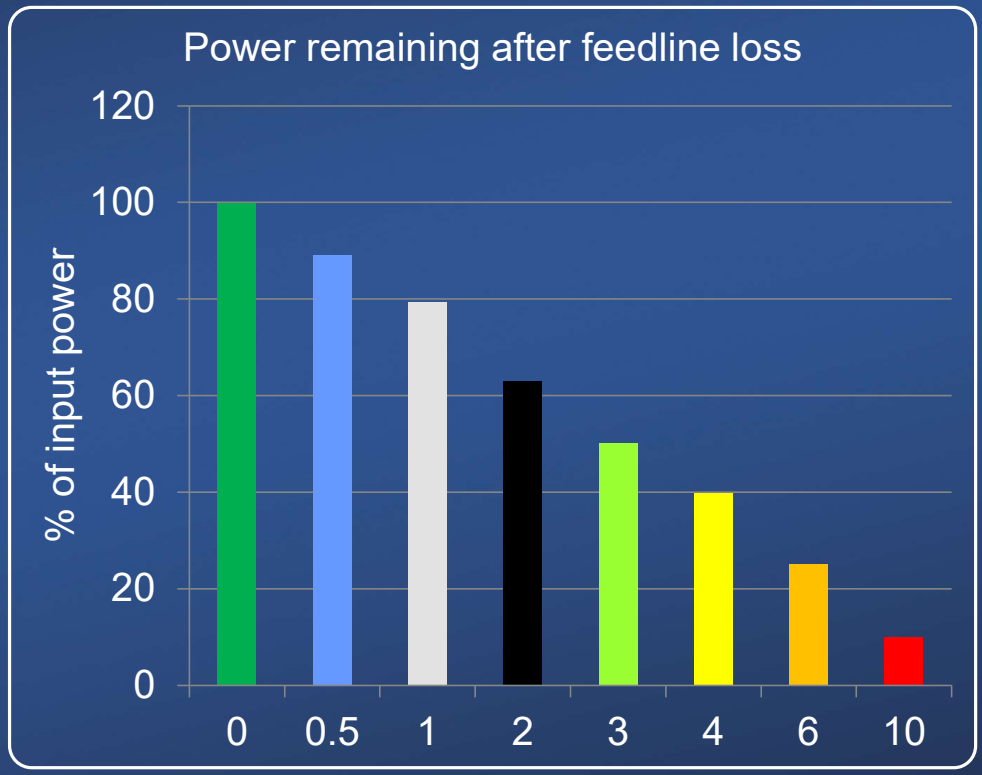
VHF/UHF Losses Per 100 Ft Length

Cable	50 MHz	144 MHz	440 MHz	900 MHz	1200 MHz
RG-58	1.42 dB	2.55 dB	4.75 dB	7.10 dB	8.40 dB
RG-8X	1.10 dB	2.05 dB	3.85 dB	5.90 dB	7.00 dB
RG-213	0.66 dB	1.25 dB	2.35 dB	3.60 dB	4.30 dB
LMR-400	0.46 dB	0.88 dB	1.55 dB	2.40 dB	2.80 dB
LMR-600	0.31 dB	0.58 dB	1.03 dB	1.60 dB	1.90 dB
1/2 in Heliax	0.26 dB	0.48 dB	0.85 dB	1.30 dB	1.55 dB

At 440 MHz and above, feedline choice can determine whether much of the transmitter power reaches the antenna.

Converting dB Loss to Power Delivered

Loss	Power remaining	100 W input → antenna
0 dB	100.0%	100.0 W
0.5 dB	89.1%	89.1 W
1 dB	79.4%	79.4 W
2 dB	63.1%	63.1 W
3 dB	50.1%	50.1 W
4 dB	39.8%	39.8 W
6 dB	25.1%	25.1 W
10 dB	10.0%	10.0 W

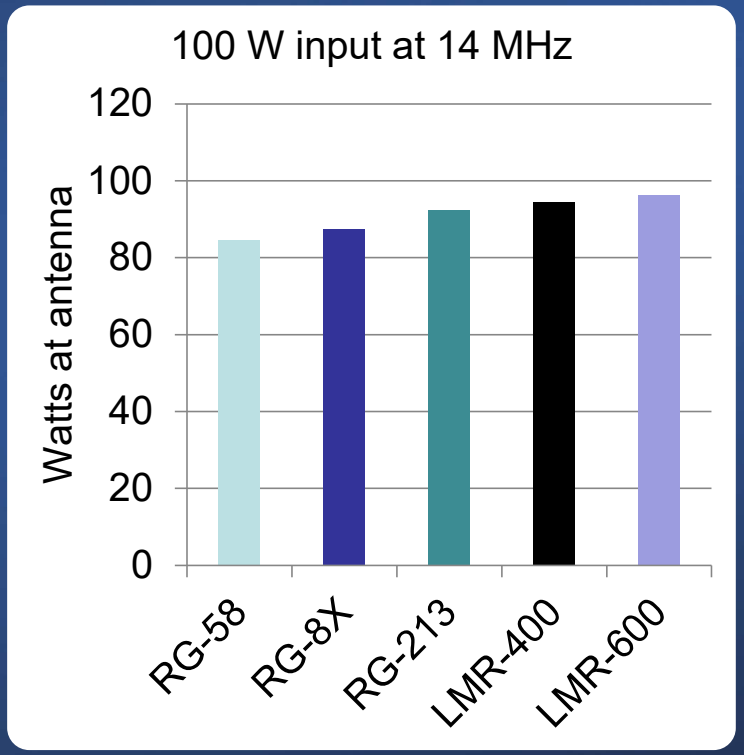


Coax Suppliers

#	Manufacturer / cable	Origin	14.25 MHz loss / 100 ft	100 W	1500 W	Shield	Center conductor	VF	Approx. 100-ft price	My rating
1	DX Engineering DXE-8X	USA	≈1.0 dB	✓	✓	95% Cu braid	16 AWG stranded Cu	81%	~$65	★★★★★
2	ABR ABR240-UF	USA	≈1.1 dB	✓	✓	Foil + 95% tinned Cu	16 AWG tinned Cu	84%	~$100–120	★★★★★
3	Times Microwave LMR-240	USA	≈0.9–1.0 dB	✓	~✓	Bonded Al foil + Cu braid	Solid bare Cu	84%	~$110–137	★★★★★
4	Messi & Paoloni Ultraflex 7	Italy	0.6 dB	✓	✓	100% foil + Cu braid	19-strand Cu	~87%	~premium	★★★★★
5	Davis RF RG-8X	USA	≈1.0–1.1 dB	✓	~✓	95% Cu braid / foil+braid version	16 AWG stranded Cu	78%	~$59–65	★★★★★
6	Belden 9258	USA	≈1.15 dB	✓	No — 1000 W @ 10 MHz	95% bare Cu braid	16 AWG bare Cu	82%	~$varies	★★★★½
7	Wireman CQ118	USA seller / cable varies	≈0.9–1.0 dB	✓	No — 800 W HF	100% foil + tinned Cu braid	16 AWG tinned Cu	80%	$70–85	★★★★½
8	Ancor 151510 RG-8X	USA	≈1.5–1.6 dB*	✓	Not specified	96% tinned Cu braid	16 AWG tinned Cu	78%	~$100–145	★★★½
9	Times LMR-240-UF	USA	≈1.1 dB	✓	~✓	Al foil + tinned Cu braid	Solid bare Cu	80%	~$165/100 ft	★★★★½
10	RF Connection 9092 Plus RG-8X/IIA	USA supplier	≈1.5 dB*	✓	Not clearly published	100% foil + 98% Cu braid	16 AWG stranded Cu	78%	~$45–60	★★★★

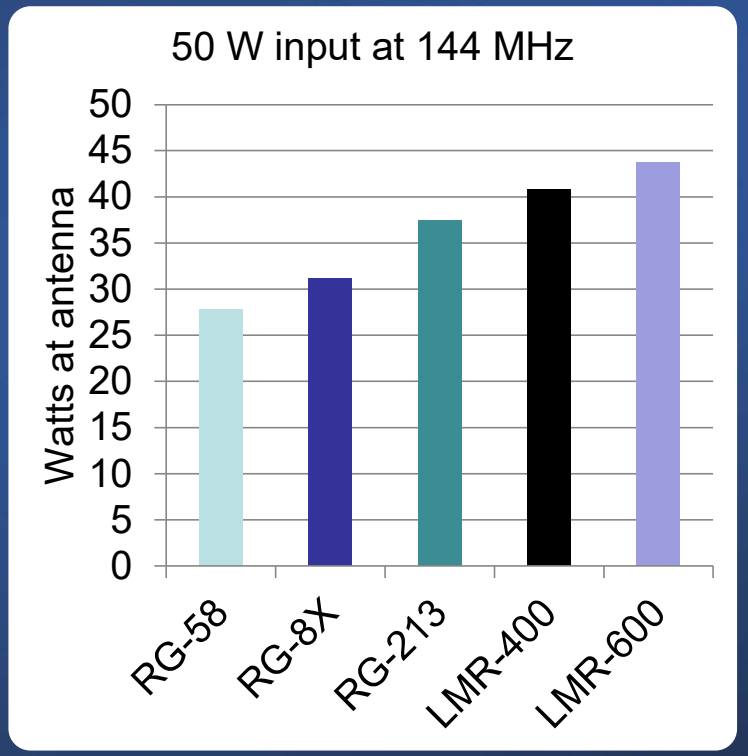
Example: 100 W on 20m, 100-ft Feedline

Cable	Loss	Power at antenna	Efficiency
RG-58	0.72 dB	84.7 W	84.7%
RG-8X	0.58 dB	87.5 W	87.5%
RG-213	0.34 dB	92.5 W	92.5%
LMR-400	0.25 dB	94.4 W	94.4%
LMR-600	0.17 dB	96.2 W	96.2%



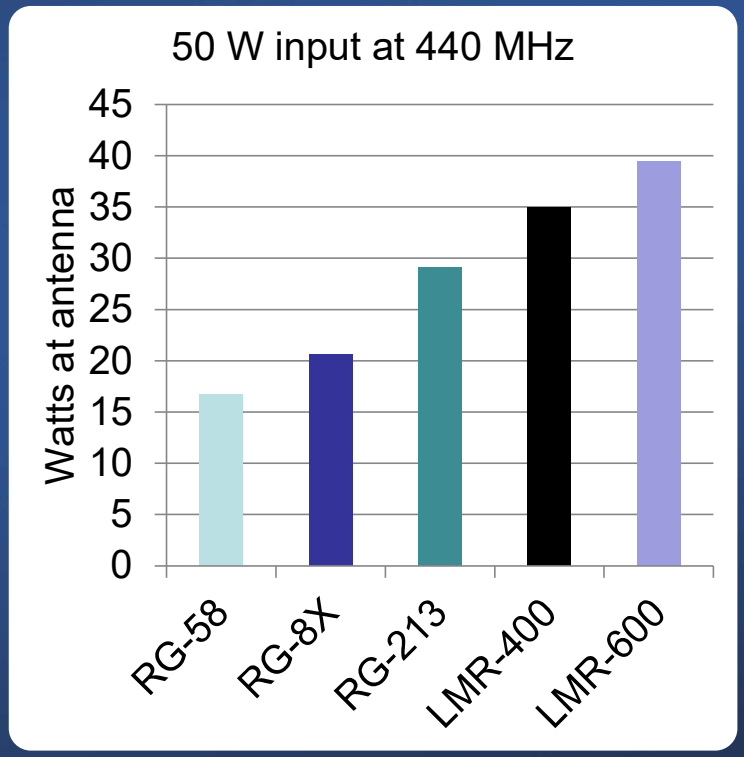
Example: 50 W on 2m, 100-ft Feedline

Cable	Loss	Power at antenna	Efficiency
RG-58	2.55 dB	27.8 W	55.6%
RG-8X	2.05 dB	31.2 W	62.4%
RG-213	1.25 dB	37.5 W	75.0%
LMR-400	0.88 dB	40.8 W	81.7%
LMR-600	0.58 dB	43.7 W	87.5%



Example: 50 W on 70 cm, 100-ft Feedline

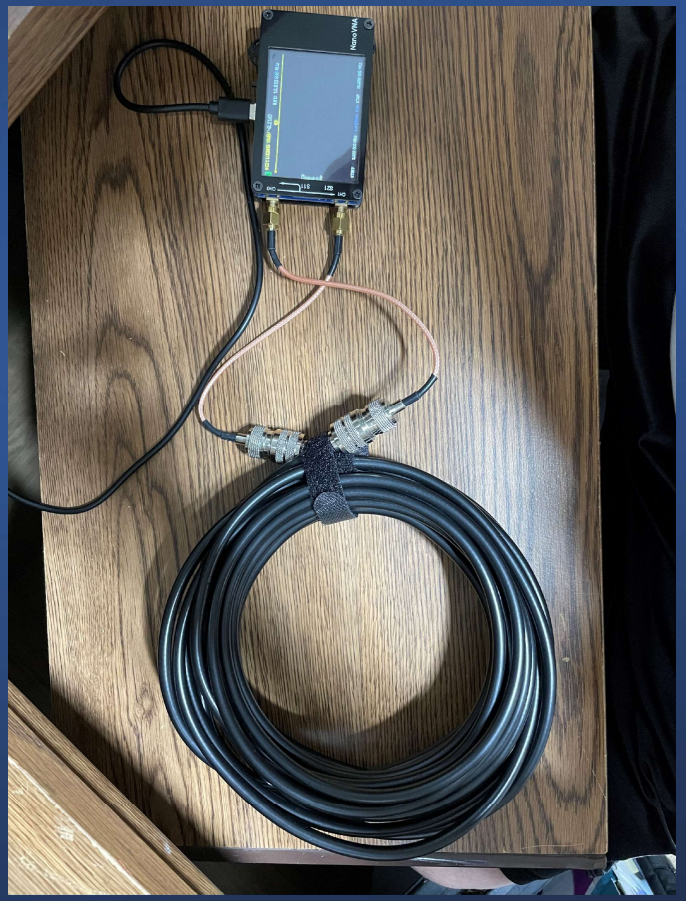
Cable	Loss	Power at antenna	Efficiency
RG-58	4.75 dB	16.7 W	33.5%
RG-8X	3.85 dB	20.6 W	41.2%
RG-213	2.35 dB	29.1 W	58.2%
LMR-400	1.55 dB	35.0 W	70.0%
LMR-600	1.03 dB	39.4 W	78.9%



Measuring Feedline Performance

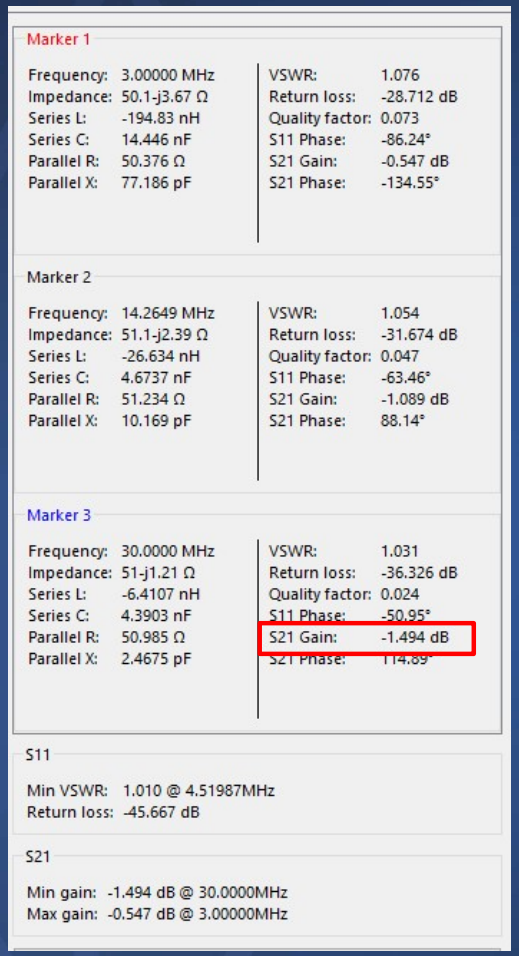
- NanoVNA / VNA: measure return loss, SWR, cable length and insertion loss.
- SWR/power meter: confirms match and forward/reflected power under transmit conditions.
- Dummy load: provides a known 50 Ω termination for troubleshooting.
- TDR or VNA time-domain functions: locate discontinuities, damaged sections and connectors.
- Two-port VNA measurement is the most direct way to measure cable insertion loss.

Let’s look at some real numbers using a Chinese 100’ coax cable.



Real 100Ft RG8X Scan Results

Frequency Effect of 100Ft RG8X



Marker 1

Frequency:	3.00000 MHz	VSWR:	1.076
Impedance:	50.1-j3.67 Ω	Return loss:	-28.712 dB
Series L:	-194.83 nH	Quality factor:	0.073
Series C:	14.446 nF	S11 Phase:	-86.24°
Parallel R:	50.376 Ω	S21 Gain:	-0.547 dB
Parallel X:	77.186 pF	S21 Phase:	-134.55°

Marker 2

Frequency:	14.2649 MHz	VSWR:	1.054
Impedance:	51.1-j2.39 Ω	Return loss:	-31.674 dB
Series L:	-26.634 nH	Quality factor:	0.047
Series C:	4.6737 nF	S11 Phase:	-63.46°
Parallel R:	51.234 Ω	S21 Gain:	-1.089 dB
Parallel X:	10.169 pF	S21 Phase:	88.14°

Marker 3

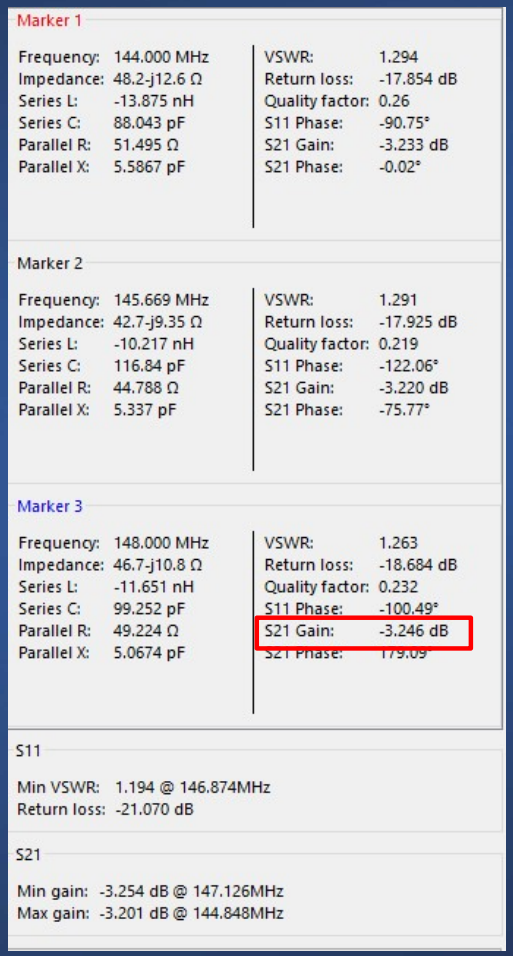
Frequency:	30.0000 MHz	VSWR:	1.031
Impedance:	51-j1.21 Ω	Return loss:	-36.326 dB
Series L:	-6.4107 nH	Quality factor:	0.024
Series C:	4.3903 nF	S11 Phase:	-50.95°
Parallel R:	50.985 Ω	S21 Gain:	-1.494 dB
Parallel X:	2.4675 pF	S21 Phase:	114.89°

S11

Min VSWR: 1.010 @ 4.51987MHz
Return loss: -45.667 dB

S21

Min gain: -1.494 dB @ 30.0000MHz
Max gain: -0.547 dB @ 3.00000MHz



Marker 1

Frequency:	144.000 MHz	VSWR:	1.294
Impedance:	48.2-j12.6 Ω	Return loss:	-17.854 dB
Series L:	-13.875 nH	Quality factor:	0.26
Series C:	88.043 pF	S11 Phase:	-90.75°
Parallel R:	51.495 Ω	S21 Gain:	-3.233 dB
Parallel X:	5.5867 pF	S21 Phase:	-0.02°

Marker 2

Frequency:	145.669 MHz	VSWR:	1.291
Impedance:	42.7-j9.35 Ω	Return loss:	-17.925 dB
Series L:	-10.217 nH	Quality factor:	0.219
Series C:	116.84 pF	S11 Phase:	-122.06°
Parallel R:	44.788 Ω	S21 Gain:	-3.220 dB
Parallel X:	5.337 pF	S21 Phase:	-75.77°

Marker 3

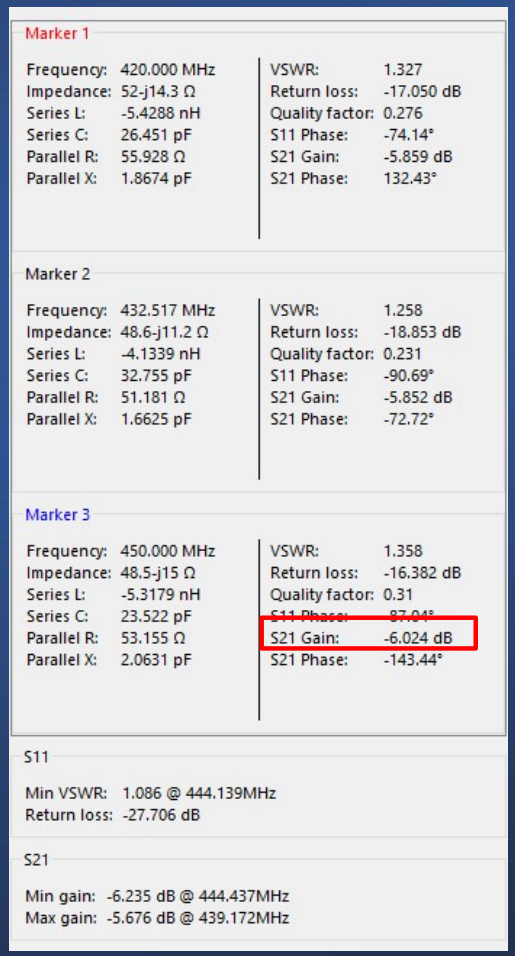
Frequency:	148.000 MHz	VSWR:	1.263
Impedance:	46.7-j10.8 Ω	Return loss:	-18.684 dB
Series L:	-11.651 nH	Quality factor:	0.232
Series C:	99.252 pF	S11 Phase:	-100.49°
Parallel R:	49.224 Ω	S21 Gain:	-3.246 dB
Parallel X:	5.0674 pF	S21 Phase:	179.09°

S11

Min VSWR: 1.194 @ 146.874MHz
Return loss: -21.070 dB

S21

Min gain: -3.254 dB @ 147.126MHz
Max gain: -3.201 dB @ 144.848MHz



Marker 1

Frequency:	420.000 MHz	VSWR:	1.327
Impedance:	52-j14.3 Ω	Return loss:	-17.050 dB
Series L:	-5.4288 nH	Quality factor:	0.276
Series C:	26.451 pF	S11 Phase:	-74.14°
Parallel R:	55.928 Ω	S21 Gain:	-5.859 dB
Parallel X:	1.8674 pF	S21 Phase:	132.43°

Marker 2

Frequency:	432.517 MHz	VSWR:	1.258
Impedance:	48.6-j11.2 Ω	Return loss:	-18.853 dB
Series L:	-4.1339 nH	Quality factor:	0.231
Series C:	32.755 pF	S11 Phase:	-90.69°
Parallel R:	51.181 Ω	S21 Gain:	-5.852 dB
Parallel X:	1.6625 pF	S21 Phase:	-72.72°

Marker 3

Frequency:	450.000 MHz	VSWR:	1.358
Impedance:	48.5-j15 Ω	Return loss:	-16.382 dB
Series L:	-5.3179 nH	Quality factor:	0.31
Series C:	23.522 pF	S11 Phase:	-87.04°
Parallel R:	53.155 Ω	S21 Gain:	-6.024 dB
Parallel X:	2.0631 pF	S21 Phase:	-143.44°

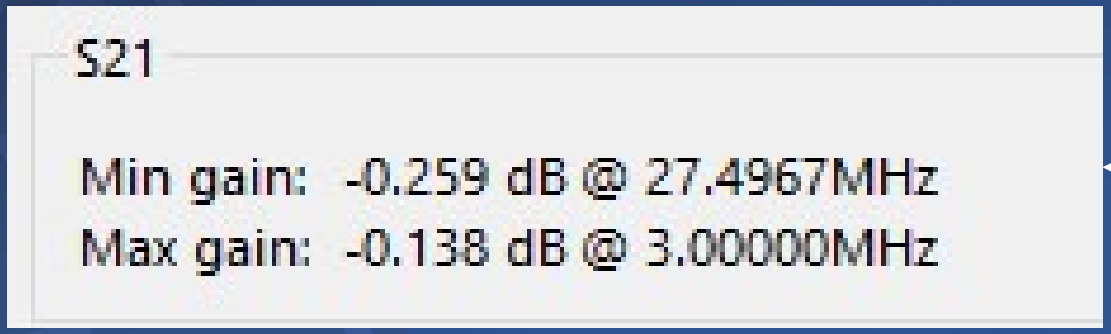
S11

Min VSWR: 1.086 @ 444.139MHz
Return loss: -27.706 dB

S21

Min gain: -6.235 dB @ 444.437MHz
Max gain: -5.676 dB @ 439.172MHz

RG8X Loss VS Length and Frequency



HF 25 ft RG8x

HF 100 ft RG8x

Effect of SWR on Feedline

- Published attenuation normally assumes a matched load.
- When SWR is greater than 1:1, forward and reflected waves cause additional conductor and dielectric loss.
- A tuner at the transmitter can make the radio see 1:1 SWR, but it does not remove high SWR on the coax beyond the tuner.
- Low-loss line is especially valuable when the antenna presents a large mismatch.
- Open-wire/ladder line is often chosen for multiband antennas because its loss under high SWR can remain relatively low.

Velocity Factor Considerations

Dielectric / line type	Typical VF range	What it means
Solid polyethylene coax	~0.66	Electrical length is much longer than physical length
Foam polyethylene coax	~0.78–0.88	Common in low-loss coax
Air-spaced/open-wire line	~0.90–0.98	Propagation approaches free-space speed

Normally velocity factor is not a concern unless you're cutting phasing lines, quarter-wave transformers, stubs and resonant feedline sections.

Practical Feedline Selection Matrix

Application	Short run	Medium run	Long run / priority
HF fixed station	RG-8X / RG-213	RG-213 / LMR-400	LMR-400 or balanced line
6 m / 50 MHz	RG-213	LMR-400	LMR-600 / hardline
2 m / 144 MHz	RG-213 / LMR-400	LMR-400	LMR-600 / hardline
70 cm / 440 MHz	LMR-400	LMR-600	Hardline / Heliax
900 MHz–2.4 GHz	Low-loss coax	Very low-loss coax	Hardline; minimize run length
Multiband nonresonant HF	—	450 Ω ladder line	450 Ω ladder/open-wire line

Choose by actual loss at your frequency and length—not simply by cable diameter or name.

Key Takeaways

- Feedline loss increases with both frequency and length.
- dB loss converts directly into less transmitter power reaching the antenna—and less received signal reaching the receiver.
- At HF, short runs of common coax often perform adequately; at VHF/UHF, low-loss cable becomes much more important.
- High SWR causes additional feedline loss; a shack tuner does not eliminate mismatch loss in the coax.
- Balanced line can be extremely efficient for multiband HF systems when installed and matched correctly.
- Always use manufacturer data for final engineering decisions.

Thank You

Feedline Fundamentals

- Balanced vs unbalanced: determines matching and common-mode-current considerations.
- Characteristic impedance (Z_0): impedance of a uniform transmission line.
- Attenuation: RF power converted to heat and other losses, normally stated in dB per 100 ft.
- Velocity factor (VF): propagation speed relative to the speed of light.
- Electrical length: physical length scaled by velocity factor.
- Power handling: limited by conductor heating, dielectric voltage and SWR.