Introduction to Transmission Lines
(& SWR)

Mark N4BCD
January 18, 2013

Purpose of Transmission Line

The desirability of installing an antenna in a clear space, not too near buildings or power and telephone lines, cannot be stressed too strongly. On the other hand, the transmitter that generates the RF power for driving the antenna is usually, as a matter of necessity, located some distance from the antenna terminals. **The connecting link between the two is the RF transmission line, feeder or feed line. Its sole purpose is to carry RF power from one place to another, and to do it as efficiently as possible.**

Efficiency

- Efficiency = (Power Out / Power In) x 100%
- Efficiency = (65 watts / 100 watts) x 100%
  = 65%

Efficiency / Loss

- **dB = 10 • $\log_{10}$ (Power 1 / Power 2)**
- **= 10 x log (65 / 100)**
- **= -1.87 dB**

Q: What's a dB among friends?

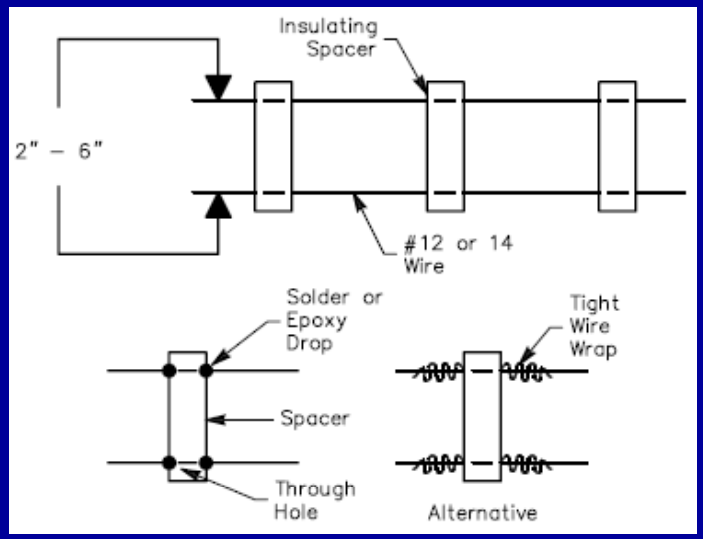
IARU Region 1 Technical Recommendation R.1-Brighton 1981, Torremolinos 1990 defined that on frequencies below 30 MHz, a S-9 signal is equivalent to a power of -73 dBm (continuous wave on receive).

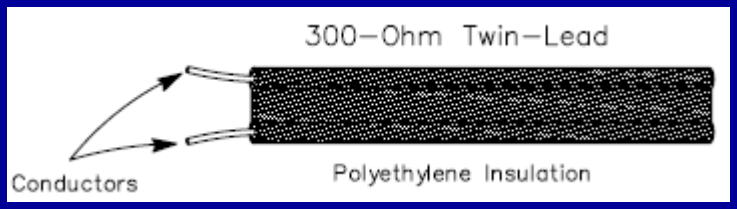
Note that on frequencies higher than 30 MHz a S-9 signal is equivalent to a power of -93 dBm (continuous wave on receive). The 20 dB difference between HF and VHF is due to the less noise temperature as frequencies increase and the use of transverters in front of HF transceivers calibrated for S9 = - 73 dBm showing usually a gain over 20 dB.

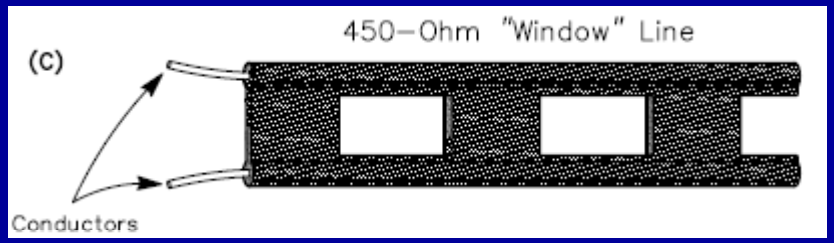
S-point	Microvolt	dBm
S9+10	= 160.00 µV	= - 63 dBm
S9	= 50.15 µV	= - 73 dBm
S8	= 25.13 µV	= - 79 dBm
S7	= 12.60 µV	= - 85 dBm
S6	= 6.31 µV	= - 91 dBm
S5	= 3.16 µV	= - 97 dBm
S4	= 1.59 µV	= - 103 dBm
S3	= 0.79 µV	= - 109 dBm
S2	= 0.40 µV	= - 115 dBm
S1	= 0.20 µV	= - 121 dBm

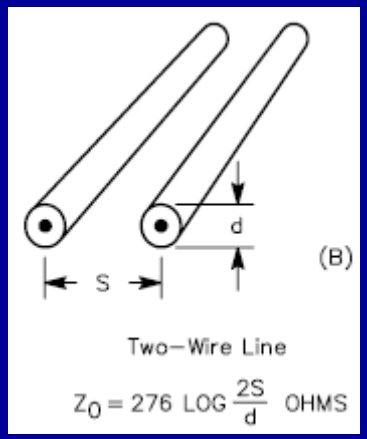
A: a dB represents 1/6 of an S Unit.

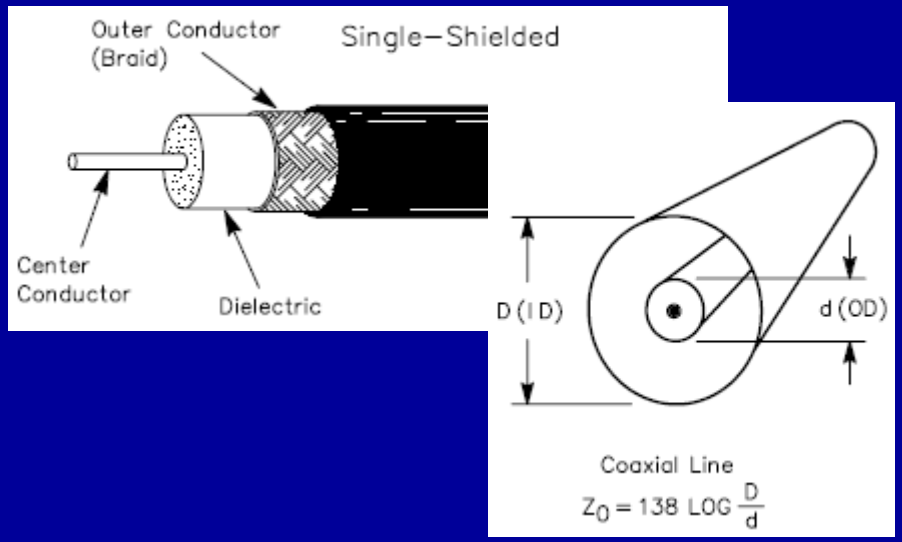
Typical Transmission Lines





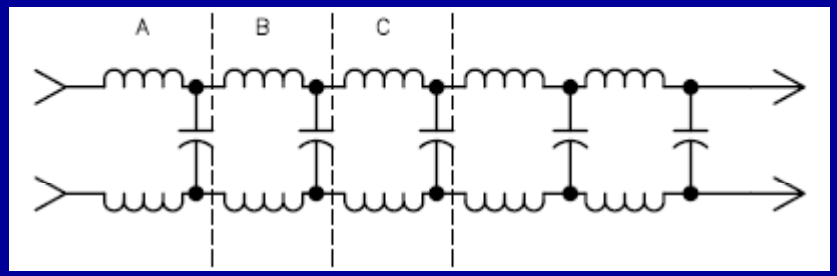






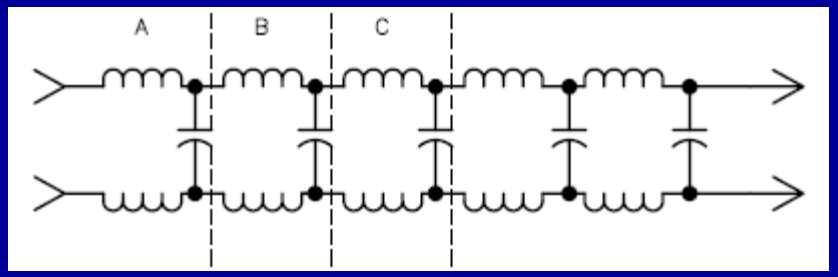
Transmission Line

Characteristics



Losses

- I^2 x R (resistive or ohmic loss)
- Dielectric Loss



Conductor and dielectric loss both increase as the operating frequency is increased, but not in the same way.

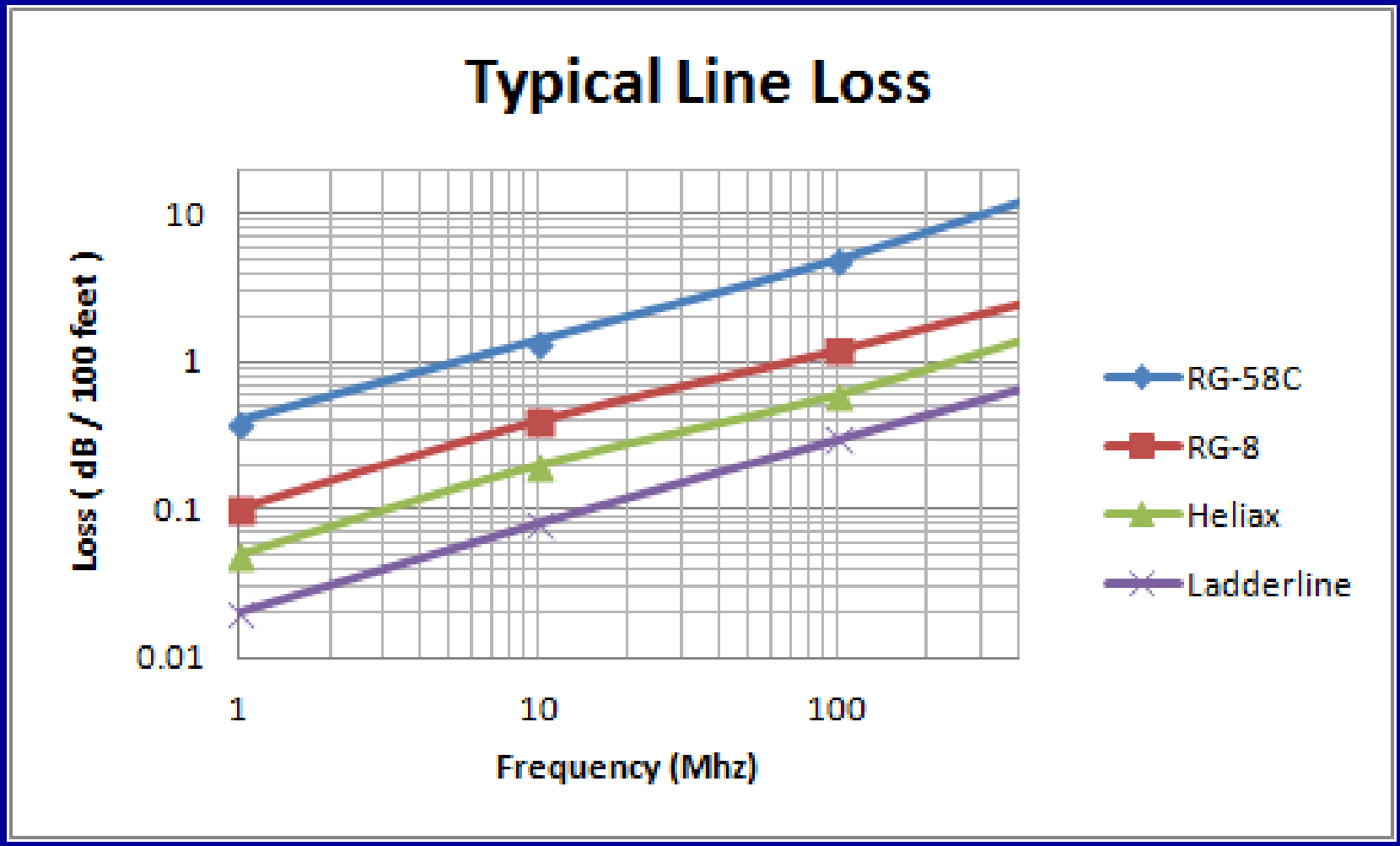
This, together with the fact that the relative amount of each type of loss depends on the actual construction of the line, makes it impossible to give a specific relationship between loss and frequency that will apply to all types of lines. Each line must be considered individually.

Actual loss values for practical lines are given in a later section of this chapter.

Matched Line Loss

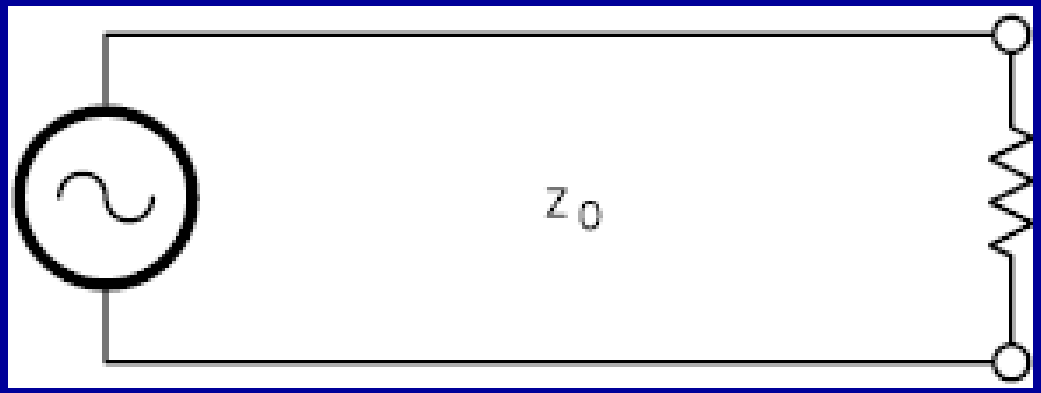
i.e SWR = 1:1

	Freq (Mhz)			
	1	10	100	1000
RG-58C	0.4	1.4	4.9	21.5
RG-8	0.1	0.4	1.2	4
Heliax	0.05	0.2	0.6	2.4
Ladderline	0.02	0.08	0.3	1.1


Typical Line Loss
10
1
0.1
0.01
Loss (dB / 100 feet)
1
10
100
Frequency (Mhz)
RG-58C
RG-8
Heliax
Ladderline

Mis-Matched Line Loss

i.e SWR > 1:1



Z not equal z_line

RG-8 Coax what is it?

- RG-8 was a Mil-Spec cable
  - Diameter = 0.405”
  - 52 ohms
  - Specification is Obsolete
  - RG-8 types still made but most cables are now 50 ohm.

Other Coax Characteristics

- Direct Bury
- Flexibility
- Lifetime – 10 ~ 20 years ???
- Waterproof – NOT!

- Cost

SWR

What is it? How do we measure it?
How bad is having it?

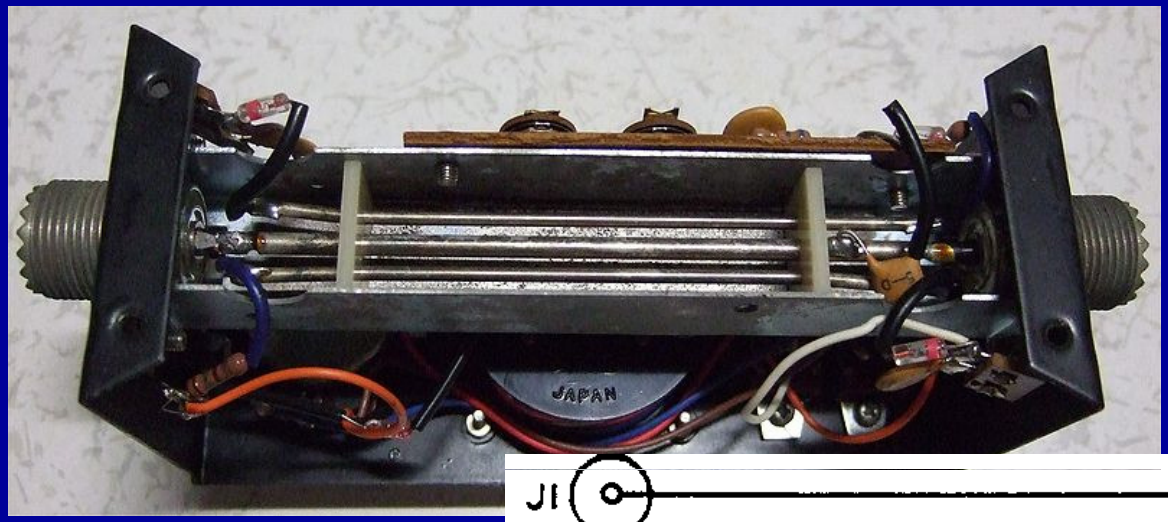
The ratio of the maximum voltage (resulting from the interaction of incident and reflected voltages along the line) to the minimum voltage, is defined as the voltage standing-wave ratio (VSWR) or simply standing-wave ratio (SWR).

$$SWR = \frac{E_{max}}{E_{min}} = \frac{I_{max}}{I_{min}}$$

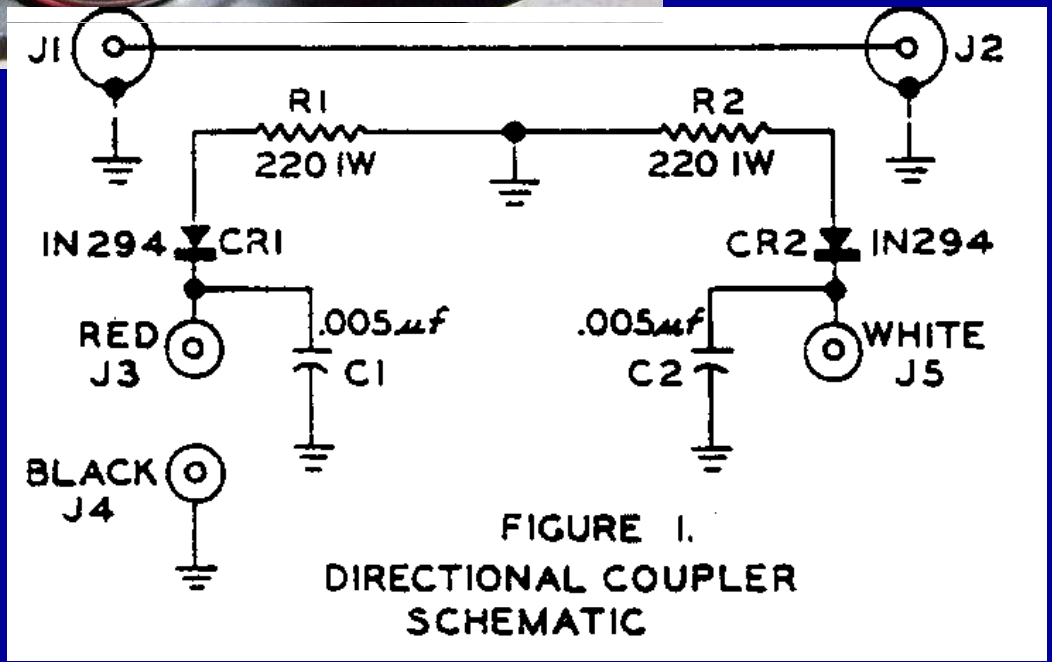
$$\rho = \sqrt{\frac{P_r}{P_f}}$$

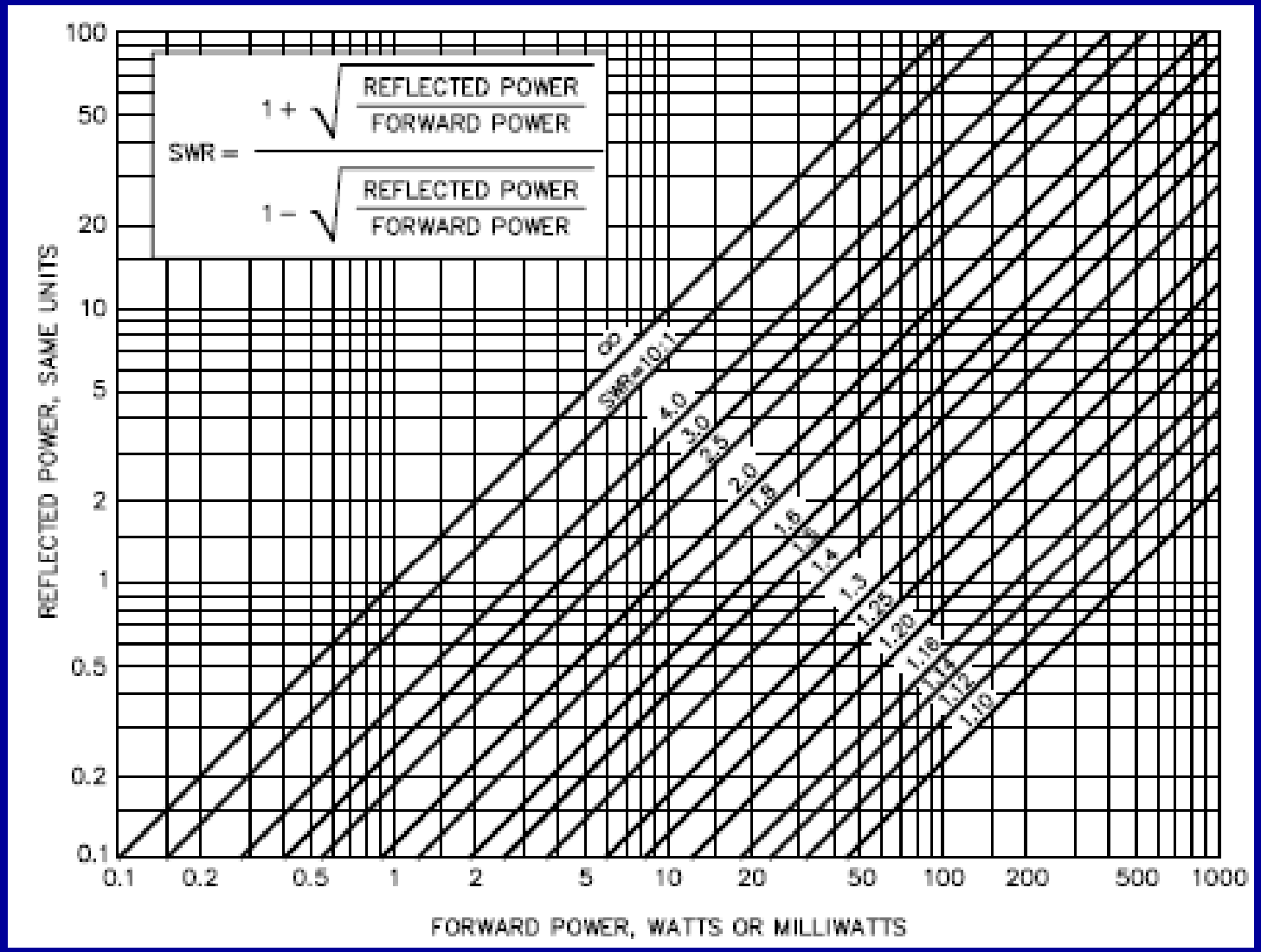
$$SWR = \frac{1 + |\rho|}{1 - |\rho|}$$

Directional Coupler

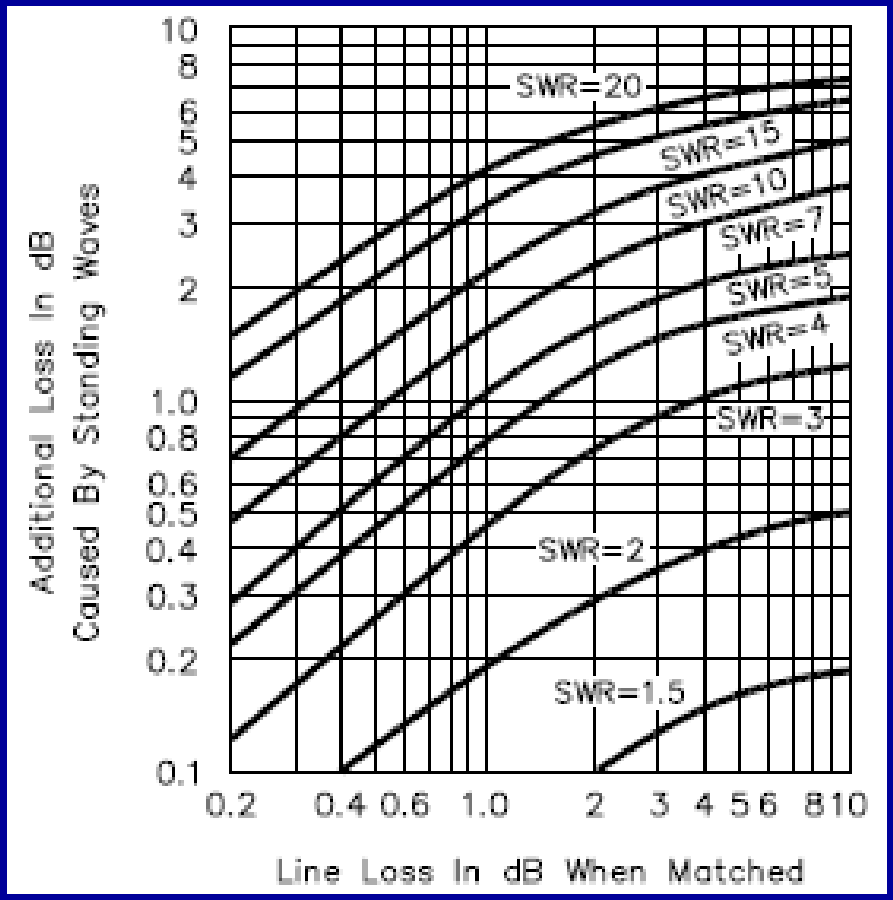


Simplified Schematic





SWR as a function of forward and reflected power.

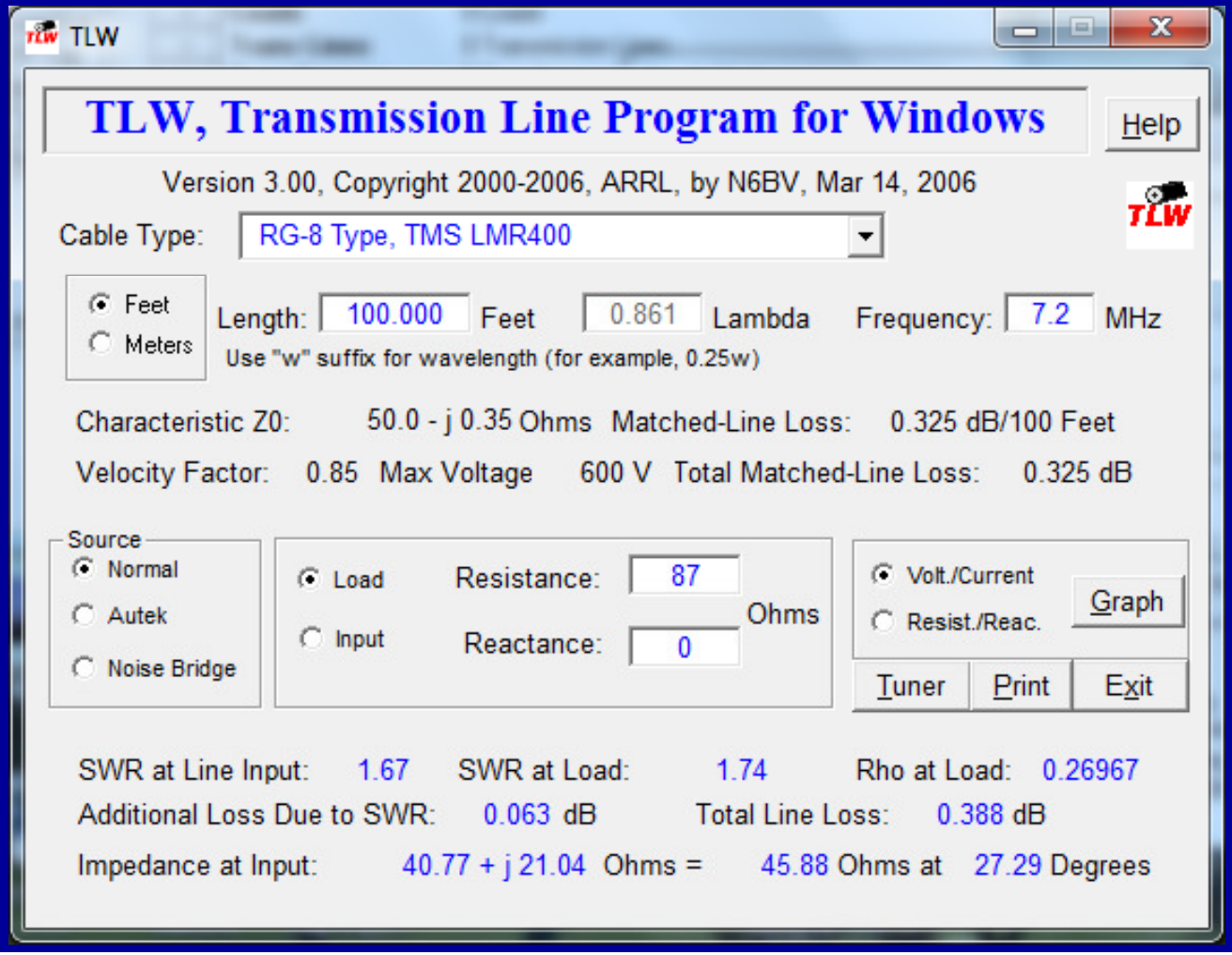


Additional line loss due to standing waves (SWR, measured at the load). To determine the total loss in dB, add the matched-line loss to the value from this graph.

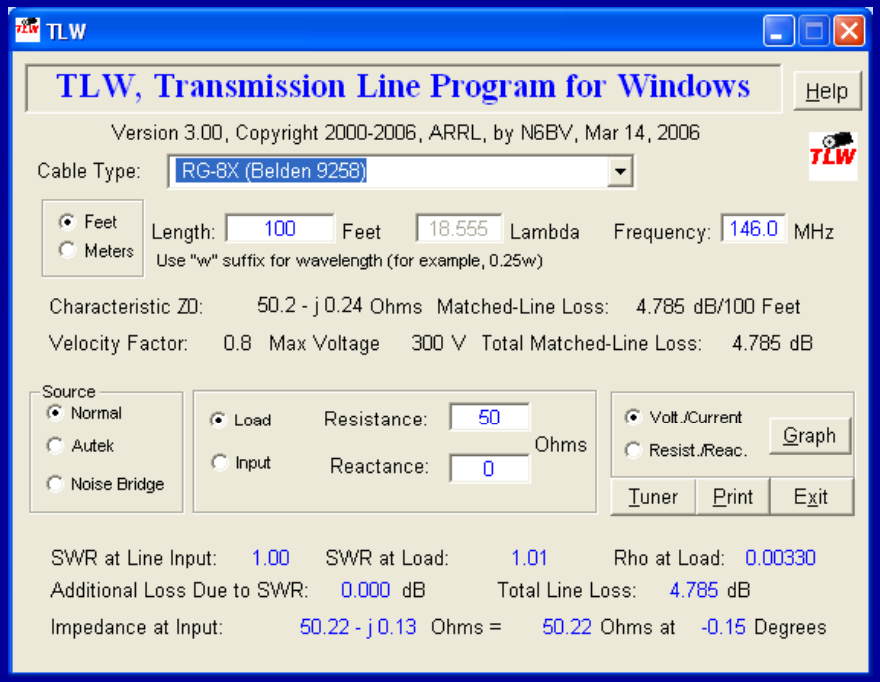
Example

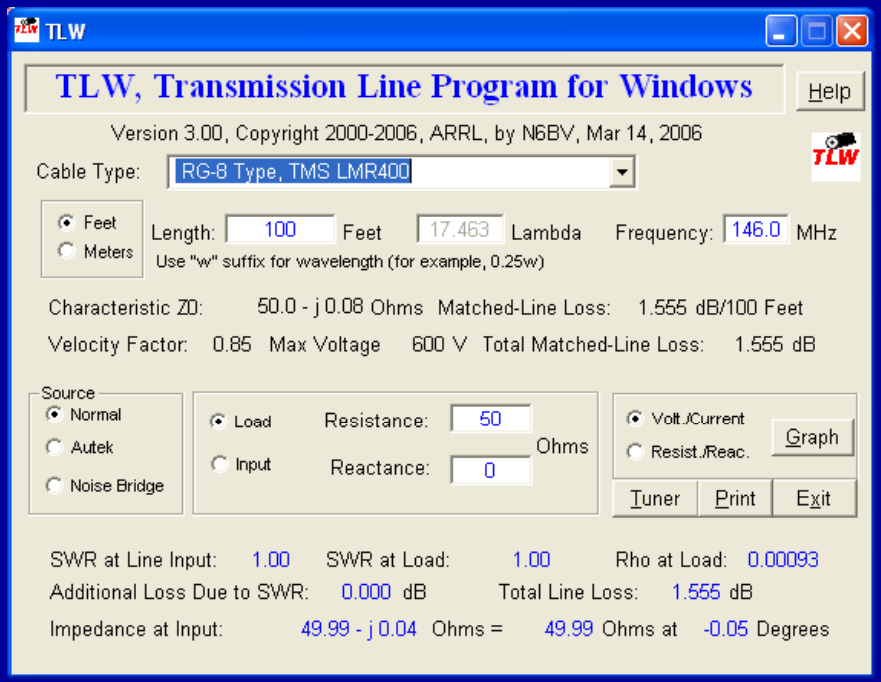
A 40m dipole at 40 feet. FP impedance = 87 ohms

SWR with 50 ohm cable =



Example





Matched Antenna For 2m

RG-8X vs LMR-400

SYSTEM Efficiency

- **What's your Antenna SYSTEM efficiency?**
  - **Classic dipole approaches 90% ~ 0.3dB**
  - **Short for their frequency antennas – 8 to 50%**
    - **8% is -11dB**
    - **50% is -3dB**
  - **Gain antennas would be + dB**
  - **System Losses (in dB) add up.**

Fact or Fiction
Truism / BS ?

- Coax going up the tower is lossless.
- Coax traveling horizontally has loss.

Conclusion

- Buy the best coax you can afford – especially for VHF.

Recommendation

- Buy the ARRL Antenna Book.
  - New $46 at Gigaparts
  - Often available used @ Amazon.com

See you in the pile-ups…

73,

Mark – N4BCD