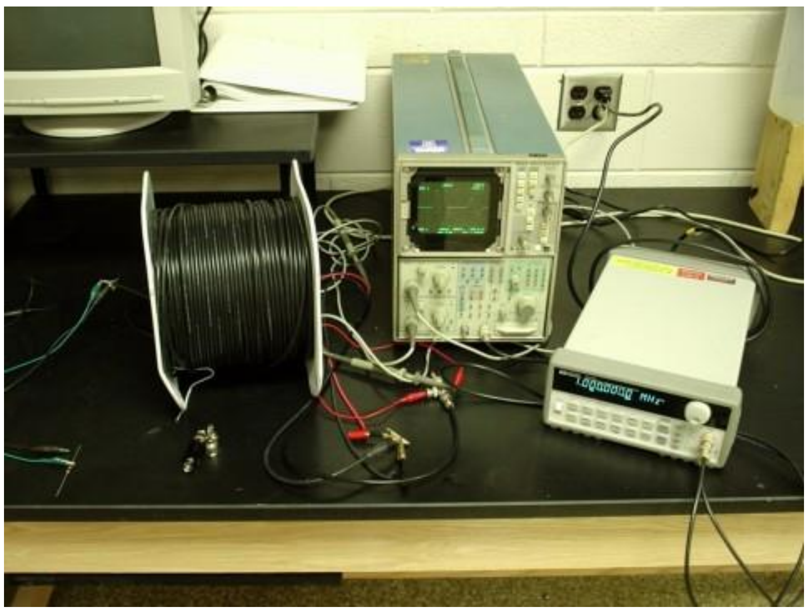
Wave Reflection within Coax

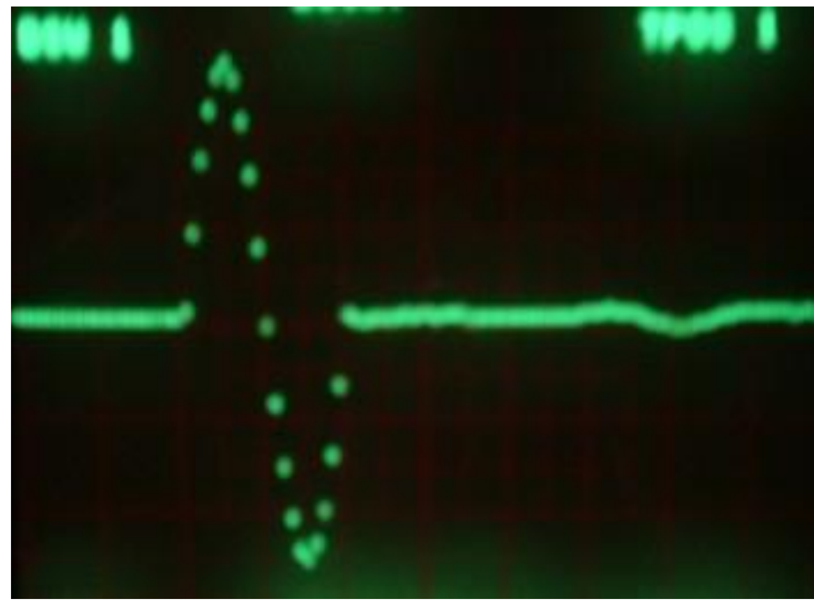
Coax Reflection Measurement

Signal generator, scope with 180 m. spool of 50 Ω coax @ VF = 0.66 = 1.8 μs. to return



Coax, end matched @ 50 Ω

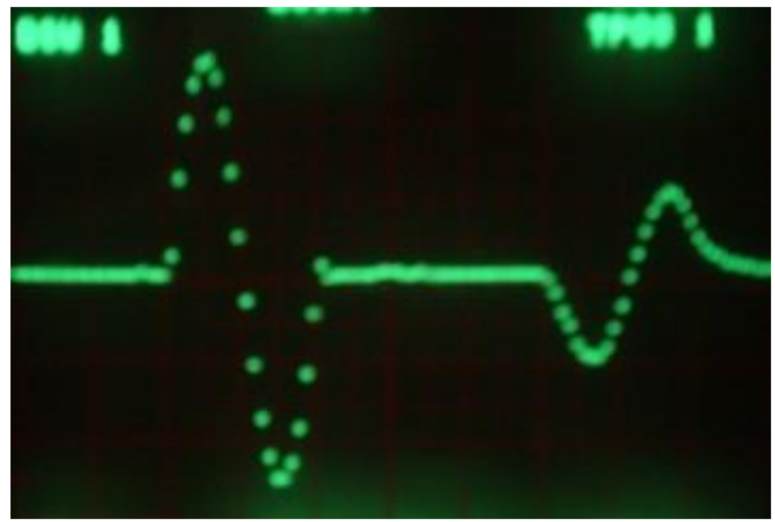
Pulse almost fully absorbed



Reflection from end of coax

Coax, end open, reflection pulse is in phase

Coax, end shorted, reflection pulse is 180^0 out of phase



Our Test Set-up

- 290 feet (88.4 m) of 75 Ω RG-59U (VF ≈ 0.8)
  - Matched loss ≈ 0.3 to 0.6 dB/100 ft. @ 1 MHz.
- Signal reflection time should be
  - (88.4 m X 2) / (3 X 10^8 m/s X 0.8) ≈ 0.74 µs.
- Frequency equivalent to this reflection time
  - = 1 / (0.74 X 10^{-6}) = 1.36 MHz.
- Therefore, at ≈1.36 MHz the reflection should be in phase and superimposed on each square wave (depending upon accuracy of VF figure).

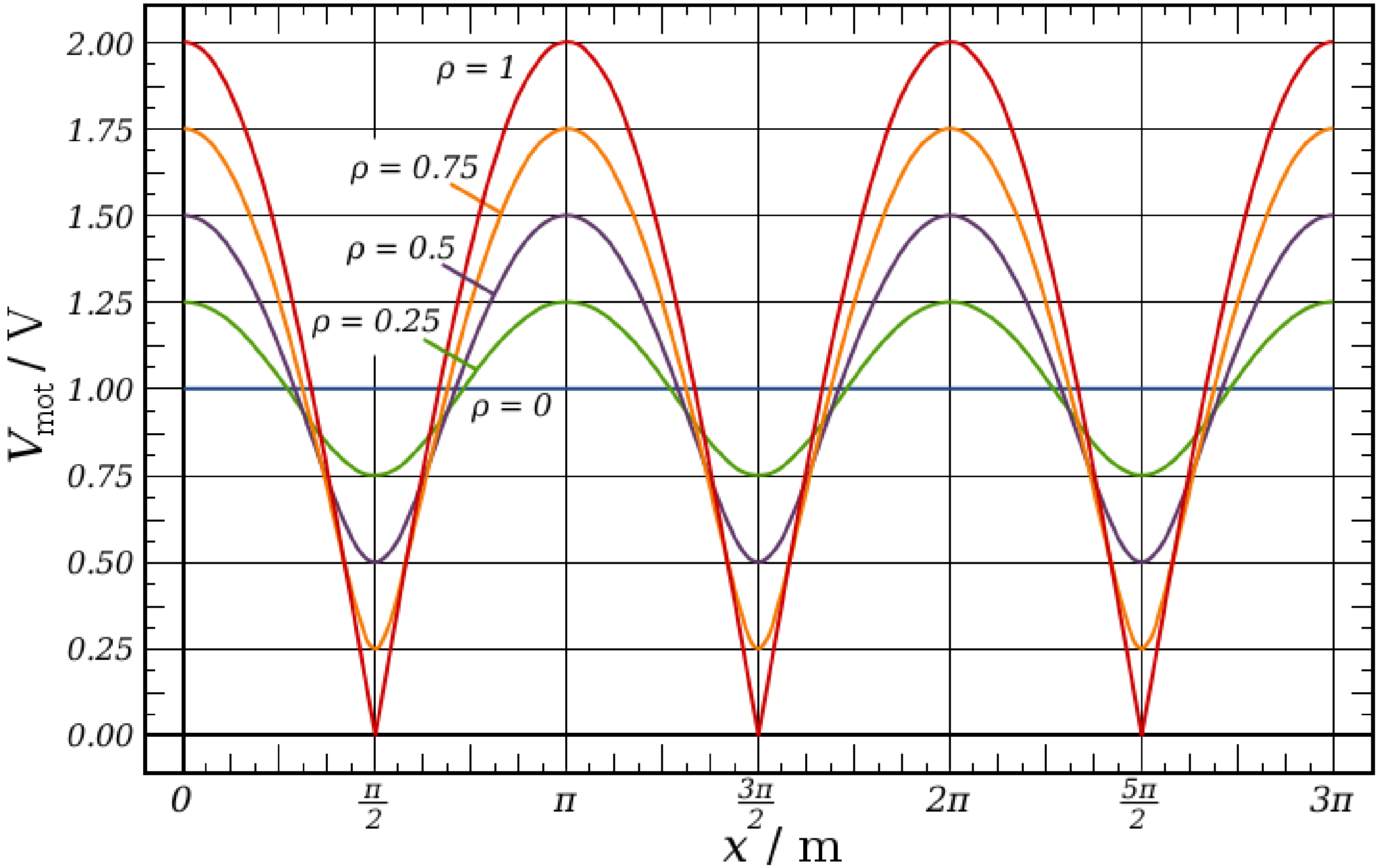
Reflected Power using 75 Ω Coax

- VSWR = $|Z_L|/Z_0$ or = $Z_0/|Z_L|$, whichever is ≥ 1
  - So the transceiver sees a VSWR of 75/50 = 1.5
- $|\rho|$ = the reflection coefficient
  - = (VSWR -1) / (VSWR + 1) = 0.5/2.5 = 0.2
- $|\rho|$ = positive sq.rt. $(P_R/P_F) \leq 1$, where
  - P_R is the reflected power back into the tansceiver, and
  - P_F is the forward power
- So $P_R = 0.04\ P_F$ using 75 Ω coax

Reflected Voltage using 75 Ω Coax

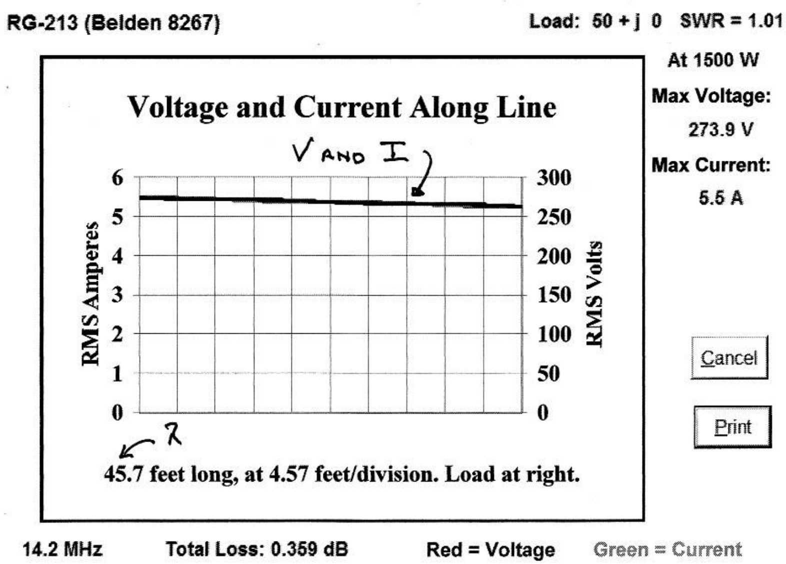
- $\rho = (V_R / V_T) = (Z_0 - Z_L) / (Z_0 + Z_L)$
  - where V_R and V_T are the reflected and transmitted voltages, and
  - $Z_0 = 75\ \Omega$ for the coax and $Z_L = 50\ \Omega$ for the load.
- If Z_0 and Z_L are close to pure resistances, then
  - $\rho = |\rho| = 25 / 125 = 0.2$, and
  - $V_R = 0.2\ V_T$
- 0.3 dB/100 ft. matched loss over 290 ft.= 11 % voltage drop. A 0.6 dB/100 ft loss = 22% drop

Standing Waves "ρ" should be |ρ|

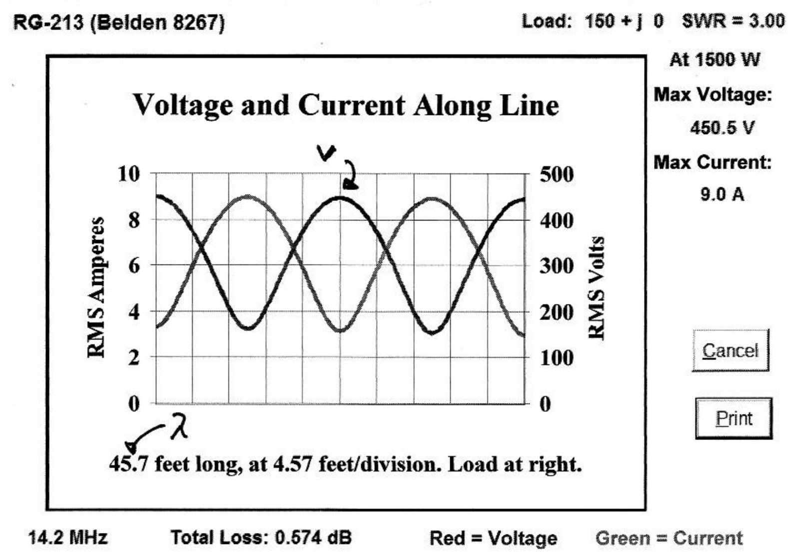


Standing Wave Along Coax (1)

VSWR =1, Length = λ



VSWR = 3, Length = λ



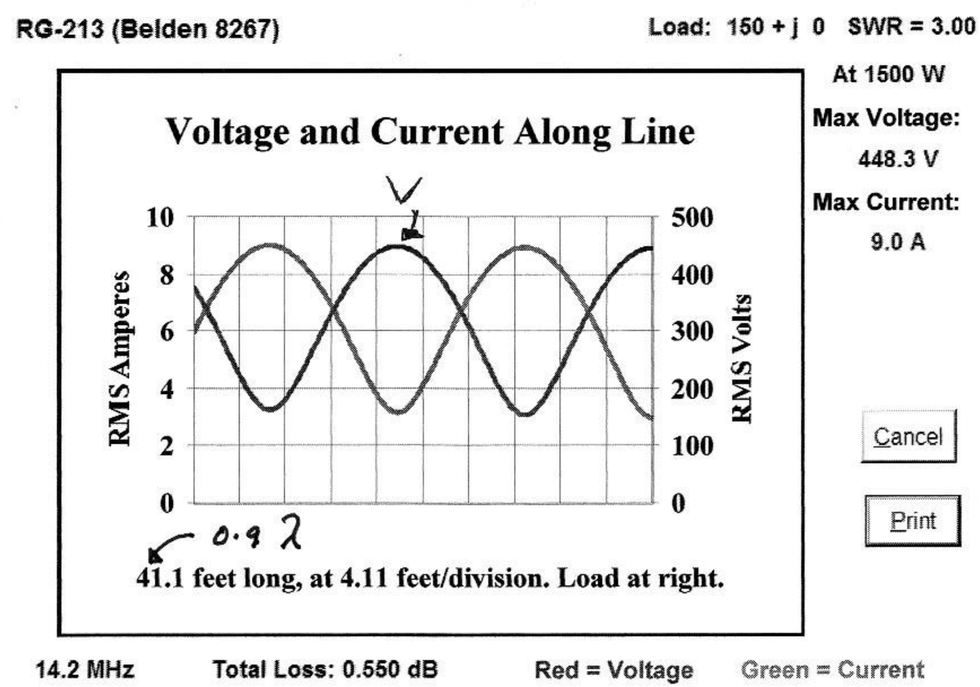
Standing Wave Along Coax

VSWR = 3, Length = 0.9 λ

These are maximum voltages and currents due to the standing waves established along the coax.

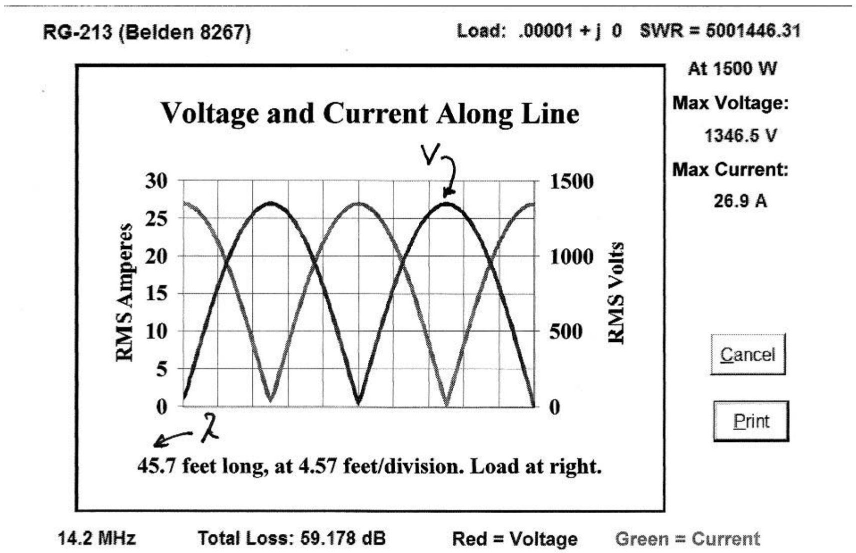
Note that when coax length is not an exact multiple of half-wavelengths, the voltage and current at the load is not equal to that at the source.

VSWR is less at the source than at the load and increases smoothly as the length of the coax is progressively shortened.

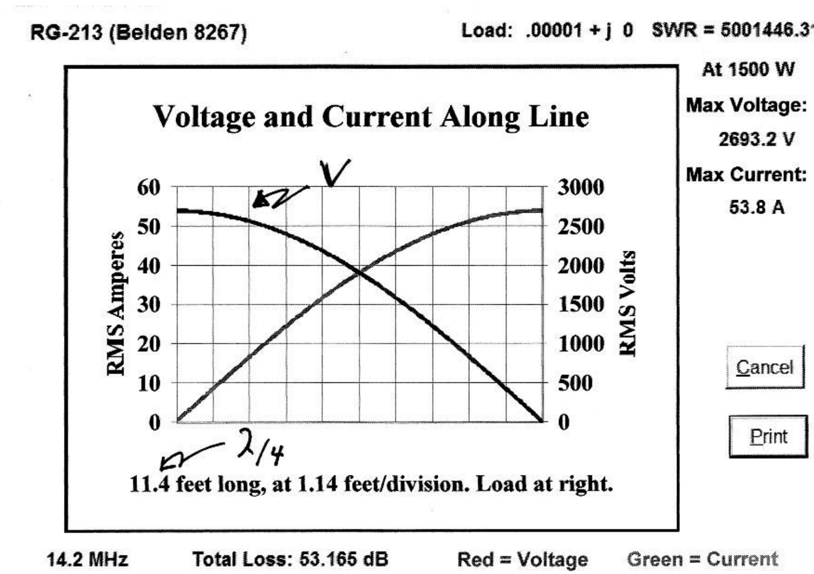


Standing Wave Along Coax

End Shorted, Length = λ



End Shorted, Length = 0.25 λ

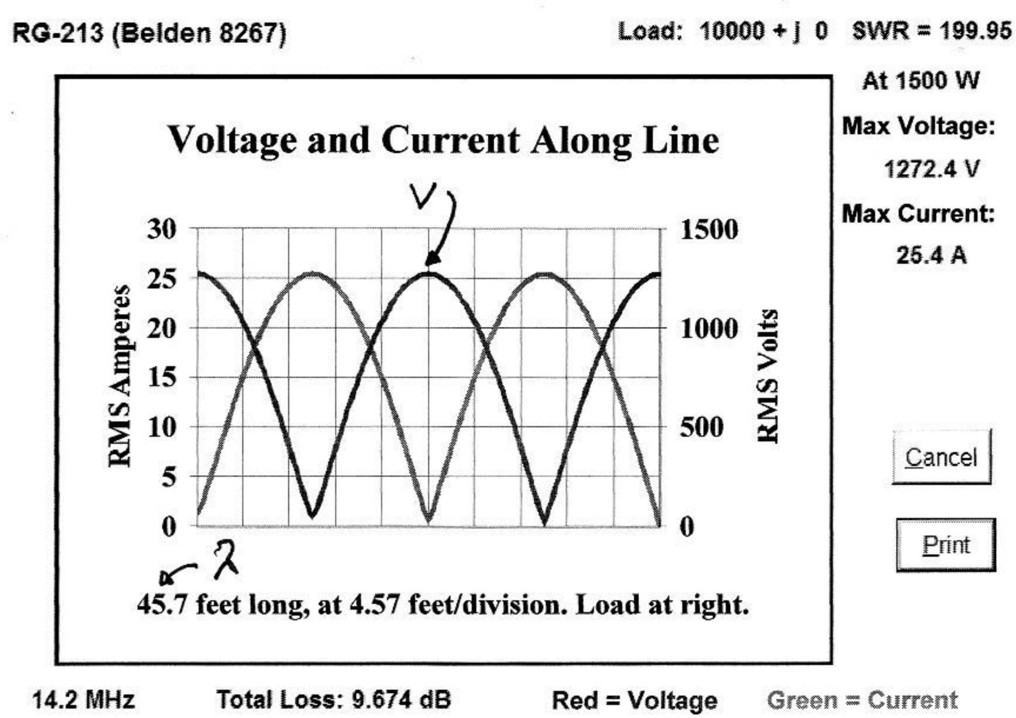


Standing Wave Along Coax

End Open, Length = λ

Note that voltage = maximum and current =0 at the load.

Note that if coax length = λ/2 or any multiple of λ/2, then voltages and currents at source and load will be equal even though VSWR's will not be equal.



Measurements (1)

- When the 75 Ω coax end has a 75 Ω load
  - the VSWR is 1.0
  - All of the forward power is absorbed by the load.
  - No return wave is generated because there is no mis-match.
  - Note the waveform at source and the signal travel time.

Measurements (2)

- The square wave has a rise time of ≈ 27 ns./V
  - If P-P voltage is 4 volts then rise time ≈ 108 ns.
  - At 1 MHz. the positive half of a “square” wave has a width of 500 ns.
  - Therefore the waveforms are far from being square
  - This rise time is also significant compared to one-way signal travel time ≈ 368 ns., over 290 ft.

Measurements (3)

- When the coax end is open, the return signal is in-phase with the forward signal and augments it .
  - Return time for the wave = 230 ns., so
    - VF = (290 X 2)/(3.28 X 0.74 X 10^{-6} X 3 X 10^{8}) = 0.80
  - If initial positive voltage = 2.0 V @ 1 MHz.
    - At open end (in phase) voltage should be ≈ 3.5 V
  - Note the superimposed waveform at source, the result of signal travel time.

Measurements (4)

- When the coax end is shorted, the return signal is 180 degrees out-of-phase with the forward signal.
  - Note that the voltage at the shorted end is zero, a horizontal line on the oscilloscope.
  - Note the superimposed waveform at source, the result of signal travel time and the phase difference.