Amateur Radio - Wet Ladderline

By S E Hunt G3TXQ

Introduction

A doublet antenna fed via ladderline from a tuner is a popular solution to the requirement for a low-cost, multiband, HF antenna system. However, a question sometimes arises about losses in the ladderline, and how they change when the line is wet.

Wes Stewart, N7WS, carried out measurements on commercial 450Ω line and reported quite large increases in loss when the line was wet; his work was published in the ARRL Antenna Compendium Volume 6. In the November 2009 edition of QST magazine Joel Hallas W1ZR and Bob Allison WB1CGM published the results of related experiments and reported much smaller losses. Intrigued by the differences, I set out to conduct some experiments of my own!

Experimental method

I tried various methods to measure changes in loss, including driving the line with a known power and measuring changes in the current delivered to a load resistor. **However, I found that the most repeatable method was to measure the line loss directly as an S21 measurement in a 50Ω system using a VNA2180 2-port Vector Network Analyser;** then, having measured the input impedance of the line, to correct the S21 figure for the source mismatch loss. I believe this method was very similar to that used by N7WS, although his measurements were made between 50MHz and 150MHz whilst mine were made between 1MHz and 30MHz.

Of course using this method the line is not matched, but is operating with an SWR of 6:1 (300Ω) or 9:1 (450Ω); however it avoids the need for 6:1 and 9:1 baluns, and arguably is more representative of real world applications where ladderline is often operated at a high SWR.

Net losses and Velocity Factor were calculated at frequences where the electrical line length was a multiple of a half-wavelength and the input resistance was a nominal 50Ω; an estimate was also made of Zo, using line input resistances measured at adjacent frequences where the electrical line length was an odd multiple of a half-wavelength.

A 1:1 current balun was used at each end of the line; each balun had a choking impedance of >4kΩ above 3.5MHz, and >8kΩ from 10MHz thru 30MHz. The baluns and the coax leads connecting them to the analyser were included as elements within the VNA2180 calibration process.

For tests where the line was elevated it was suspended in a straight line between two plastic garden chairs, with a third chair providing support at the centre to reduce the sag. At its lowest point the line was 24" above ground.

Results (300Ω line)

My initial work was carried out on a 60ft length of commercial 300Ω line which I had to hand; I reasoned that the large changes that N7WS reported on his 450Ω line - if real - would likely also show up on my 300Ω line. The US manufactured line consisted of two 20AWG stranded copper conductors with black PE insulation spaced 0.275” apart. The “windows” occupied about 47% of the length.

Test 1

60ft of new 300Ω line (SWR=6:1) suspended 24" above ground:

Freq	6.68MHz	13.48MHz	20.24MHz	27.00MHz
Net loss (60ft)	0.46dB	0.57dB	0.69dB	0.71dB
Velocity Factor	0.814	0.822	0.823	0.823
Estimated Zo	289Ω	294Ω	295Ω	297Ω

Test 2

60ft of 300Ω line (SWR=6:1) suspended 24" above ground and dowsed with rain water from a butt using a hand sprayer:

Freq	6.56MHz	13.16MHz	19.84MHz	26.44MHz
Net loss (60ft)	0.62dB	0.78dB	0.88dB	0.93dB
Velocity Factor	0.800	0.802	0.806	0.806
Estimated Zo	279Ω	286Ω	286Ω	287Ω

Note: a small increase in loss; a 2% drop in Velocity Factor.

Test 3

N7WS noted that "water tended to bead up and run off, making it difficult to make meaningful measurements." I observed something similar - see Test 2 photo - although my measurements were repeatable. N7WS reckoned that a typical line used outdoors would quickly lose its water shedding ability as it degrades from sunlight and accumulates dust and other pollutants; to simulate this, he added a wetting agent to the water to create a water film on the surface. I tried to replicate what N7WS did by adding a few drops of washing-up liquid to the rain water and running the measurements again:

Freq	5.84MHz	12.44MHz	19.04MHz	25.52MHz
Net loss (60ft)	6.22dB	7.32dB	7.52dB	8.10dB
Velocity Factor	0.712	0.758	0.774	0.778

Estimated Zo	265Ω	279Ω	282Ω	280Ω

Note: large increases in loss; 5.5% drop in Velocity Factor.

Test 4

For comparison with W1ZR's experiments, I dried the 300Ω line and laid it directly in contact with the dry paving that it had been suspended above in Tests 1-3:

Freq	6.20MHz	12.56MHz	18.96MHz	24.92MHz
Net loss (60ft)	0.95dB	1.63dB	2.34dB	2.56dB
Velocity Factor	0.756	0.766	0.771	0.760
Estimated Zo	266Ω	252Ω	248Ω	262Ω

Note: large increase in losses compared to elevated line; 7.7% drop in Velocity Factor.

Test 5

60ft of 300Ω line (SWR=6:1) laid directly on the damp soil of a flower border:

Freq	6.48MHz	13.00MHz	19.56MHz	26.16MHz
Net loss (60ft)	0.97dB	1.69dB	2.27dB	2.91dB
Velocity Factor	0.790	0.792	0.795	0.797
Estimated Zo	269Ω	270Ω	265Ω	279Ω

Note: similar losses to lying on paving, but higher Zo and higher Velocity Factor.

Test 6

Out of curiosity, and spurred by the claim of a QRZ.COM forum “expert” that ladderline can be buried with impunity, I buried the line in the flower border soil at a depth of about 1":

Freq	4.88MHz	9.80MHz	15.08MHz	20.24MHz	25.96MHz
Net loss (60ft)	2.71dB	4.43dB	5.50dB	6.91dB	7.25dB
Velocity Factor	0.595	0.597	0.613	0.617	0.633
Estimated Zo	196Ω	198Ω	208Ω	212Ω	259Ω

Note: very high losses; very low Velocity Factor; low and variable Zo.

Results (450Ω line)

For a more direct comparison with the work of N7WS and W1ZR, a 60ft length of 450Ω line was purchased from a UK supplier. This US manufactured line consisted of two 18AWG (1mm) copper-clad-steel conductors with black insulation spaced 0.85" apart - similar to Wireman 551. The “windows” occupied about 40% of the length.

Test 7

60ft of new 450Ω line (SWR=9:1) suspended 24" above ground:

Freq	7.38MHz	14.73MHz	22.12MHz	29.51MHz
Net loss (60ft)	0.42dB	0.53dB	0.71dB	0.73dB
Velocity Factor	0.900	0.898	0.899	0.899
Estimated Zo	374Ω	365Ω	351Ω	347Ω

Note: Zo much lower than the nominal 450Ω.

Test 8

60ft of 450Ω line (SWR=9:1) suspended 24" above ground and dowsed with rain water from a butt using a hand sprayer:

Freq	7.19MHz	14.44MHz	21.69MHz	28.98MHz
Net loss (60ft)	0.48dB	0.60dB	0.80dB	0.82dB
Velocity Factor	0.877	0.880	0.881	0.883
Estimated Zo	372Ω	362Ω	356Ω	344Ω

Note: small increase in loss; 2% decrease in Velocity Factor; no change in Zo.

Test 9

As Test 8, but a few drops of washing-up liquid added to the rain water to aid water retention:

Freq	7.05MHz	14.10MHz	21.30MHz	28.45MHz
Net loss (60ft)	4.24dB	4.74dB	5.06dB	5.19dB
Velocity Factor	0.860	0.860	0.866	0.867
Estimated Zo	390Ω	387Ω	386Ω	382Ω

Note: high losses; 4% drop in Velocity Factor; increase in Zo.

Test 10

60ft of dry 450Ω line (SWR=9:1) lying on dry paving:

Freq	6.38MHz	12.76MHz	19.48MHz	25.96MHz	32.68MHz
Net loss (60ft)	1.27dB	2.33dB	3.17dB	3.61dB	3.89dB
Velocity Factor	0.778	0.778	0.792	0.791	0.797
Estimated Zo	327Ω	352Ω	355Ω	340Ω	290Ω

Note: significant increase in losses, and changes in Velocity Factor.

Test 11

60ft of dry 450Ω line (SWR=9:1) suspended 24" above ground, with middle 11ft lying against aluminium ladder:

Freq	7.16MHz	14.28MHz	21.72MHz	28.92MHz
Net loss (60ft)	0.49dB	0.53dB	0.92dB	0.98dB
Velocity Factor	See note	See note	See note	See note
Estimated Zo	See note	See note	See note	See note

Note: small increase in losses at higher frequencies; TDR measurement confirmed that the 11ft section of line in contact with the aluminium ladder has a different Zo and Velocity Factor - overall figures for the whole 60ft are therefore a little meaningless.

Test 12

60ft of 450Ω line (SWR=9:1) suspended 24" above ground, during heavy rain:

Freq	6.72MHz	13.40MHz	20.12MHz	27.16MHz
Net loss (60ft)	1.08dB	1.12dB	1.66dB	1.27dB
Velocity Factor	0.819	0.817	0.818	0.828
Estimated Zo	362Ω	422Ω	373Ω	296Ω

Note: some inconsistency in the results, probably caused by the variation in rainfall during the period of the test.
Results closer to those of Test 8 than Test 9

Discussion

- Spraying the lines with rain water caused a small increase in loss that would probably be unnoticeable in normal operation. However, the change in Velocity Factor is sufficient that a tuner connected to a ladderline/doublet system would likely need some re-adjustment because of the difference in transformed impedance.

- Adding a wetting agent to the rain water caused a large increase in loss - comparable to the losses observed by N7WS. However, these losses recovered to dry levels over a relatively short period of time, as follows at the frequency where line is 2λ long:

  0 mins: 5.2dB
  +10 mins: 1.83dB
  +30 mins: 0.73dB
  +60 mins: 0.72dB

  Interestingly the 300Ω line losses recovered more slowly, and they never fully recovered to dry levels until the line was throughly cleaned; this implies that some residue was left on the line after the water had evaporated.

- It is not clear whether the high losses associated with using the wetting agent were due to the more complete wetting of the line or to some electrical properties of the agent. Nor is it clear how well this test represents conditions that will be experienced in the "real world". N7WS' view was that the results: "are probably worst case and not something that would necessarily be encountered in a typical installation."

- Laying the ladderline in contact with the ground produced high losses and large reductions in the Velocity Factor - results similar to those reported by W1ZR.

- Clearly, ladderline cannot be buried with impunity despite the claims of one forum "expert"!

- A section of ladderline in contact with aluminium exhibited a different Zo and Velocity Factor from the remainder of the line; there was a small increase in overall losses at higher frequencies.

- The 450Ω line has been left in position so that further testing can be carried out across a range of UK weather conditions.