

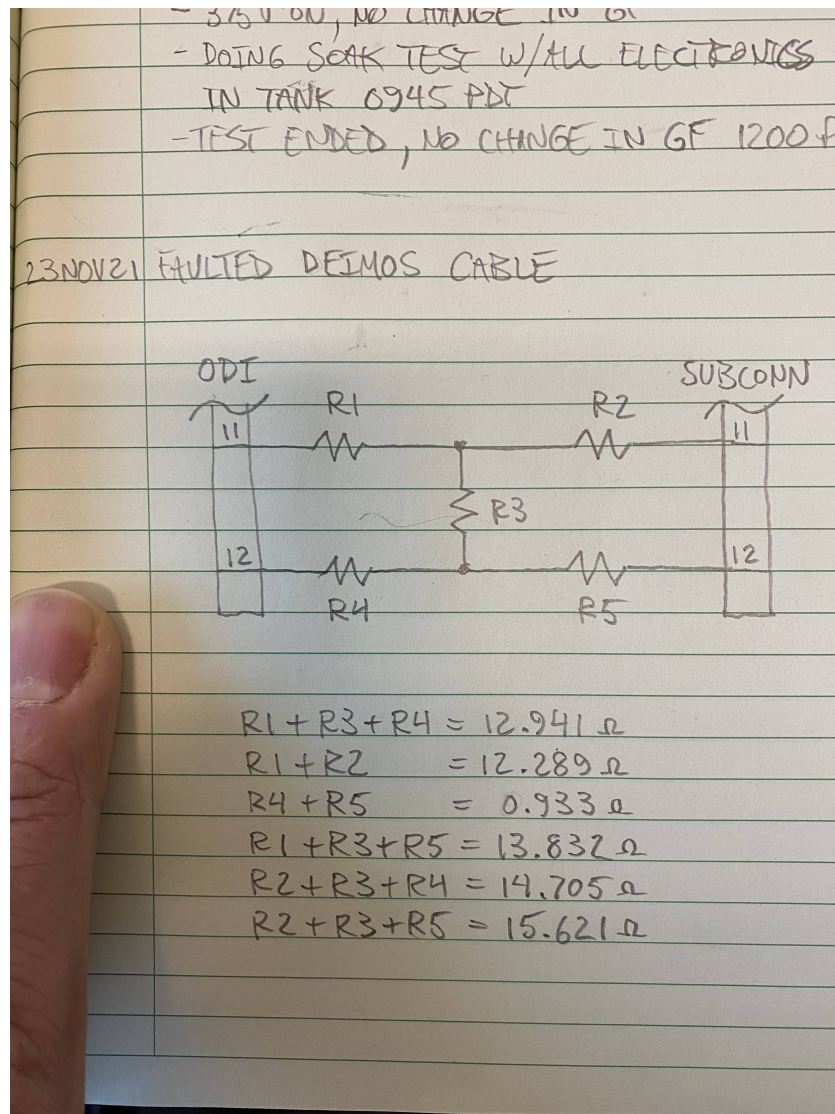
Deimos Cable Fault Analysis

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23Nov21

The cable connecting the Deimos echosounder to MARS failed with an overcurrent fault. We'd like to know how the cable failed and where along the cable the fault lies. The cable is Falmat Xtreme Cat FMXCAT51806K12, with six 18 AWG power conductors. Each conductor should have a resistance of 20 mΩ/meter.

Resistance Measurements

Here are the data from my lab notebook, as measured by a BK Precision model 894 LCR meter.



There are six possible ohmmeter measurements that can be made on the four free ends of the two faulted conductors. Here we form one equation from each measurement.

$$\text{eq1} = R1 + R2 = 12.289 \, \text{ohms}$$

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$$\text{eq2} = R4 + R5 == 0.933 \text{ ohms}$$

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$$\text{eq3} = R1 + R3 + R4 == 12.941 \text{ ohms}$$

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$$\text{eq4} = R2 + R3 + R5 == 15.621 \text{ ohms}$$

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$$\text{eq5} = R2 + R3 + R4 == 14.705 \text{ ohms}$$

$$R2 + R3 + R4 == 14.705 \text{ ohms}$$

$$\text{eq6} = R1 + R3 + R5 == 13.832 \text{ ohms}$$

$$\text{Out}[27] = R1 + R3 + R5 == 13.832 \text{ ohms}$$

Since there are six equations but only five unknowns, we have more information than we need. We'll always use the measurements that go end to end on each conductor (eq1 and eq2), but we'll use only three of the four equations that involve the fault, since those measurements are less reliable. We'll solve for all possible combinations of using three out of the four equations eq3, eq4, eq5, and eq6.

$$\text{sol1} = \text{Solve}[\{\text{eq1}, \text{eq2}, \text{eq3}, \text{eq4}, \text{eq5}\}, \{R1, R2, R3, R4, R5\}]$$

$$\{\{R1 \rightarrow 5.2625 \text{ ohms}, R2 \rightarrow 7.0265 \text{ ohms}, R3 \rightarrow 7.67 \text{ ohms}, R4 \rightarrow 0.0085 \text{ ohms}, R5 \rightarrow 0.9245 \text{ ohms}\}\}$$

$$\text{sol2} = \text{Solve}[\{\text{eq1}, \text{eq2}, \text{eq3}, \text{eq4}, \text{eq6}\}, \{R1, R2, R3, R4, R5\}]$$

$$\{\{R1 \rightarrow 5.25 \text{ ohms}, R2 \rightarrow 7.039 \text{ ohms}, R3 \rightarrow 7.67 \text{ ohms}, R4 \rightarrow 0.021 \text{ ohms}, R5 \rightarrow 0.912 \text{ ohms}\}\}$$

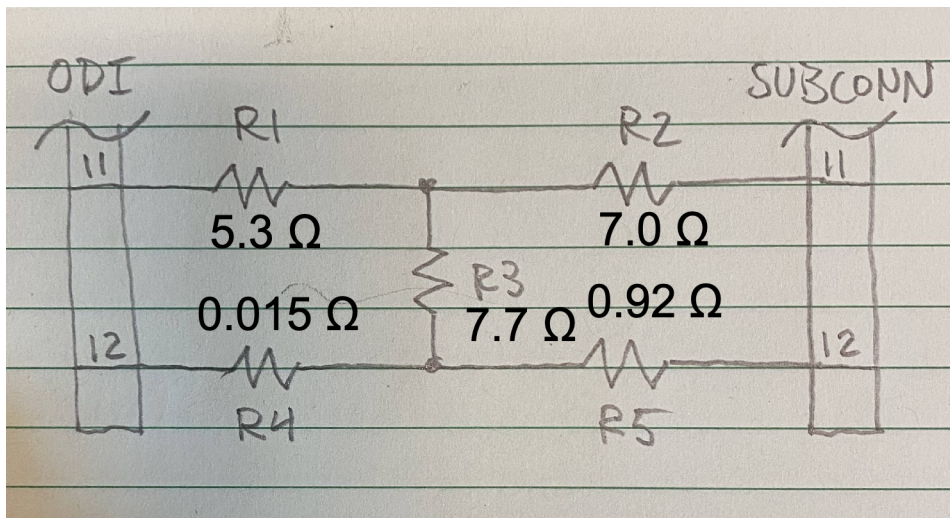
$$\text{sol3} = \text{Solve}[\{\text{eq1}, \text{eq2}, \text{eq3}, \text{eq5}, \text{eq6}\}, \{R1, R2, R3, R4, R5\}]$$

$$\{\{R1 \rightarrow 5.2625 \text{ ohms}, R2 \rightarrow 7.0265 \text{ ohms}, R3 \rightarrow 7.6575 \text{ ohms}, R4 \rightarrow 0.021 \text{ ohms}, R5 \rightarrow 0.912 \text{ ohms}\}\}$$

$$\text{sol4} = \text{Solve}[\{\text{eq1}, \text{eq2}, \text{eq4}, \text{eq5}, \text{eq6}\}, \{R1, R2, R3, R4, R5\}] // N$$

$$\{\{R1 \rightarrow 5.25 \text{ ohms}, R2 \rightarrow 7.039 \text{ ohms}, R3 \rightarrow 7.6575 \text{ ohms}, R4 \rightarrow 0.0085 \text{ ohms}, R5 \rightarrow 0.9245 \text{ ohms}\}\}$$

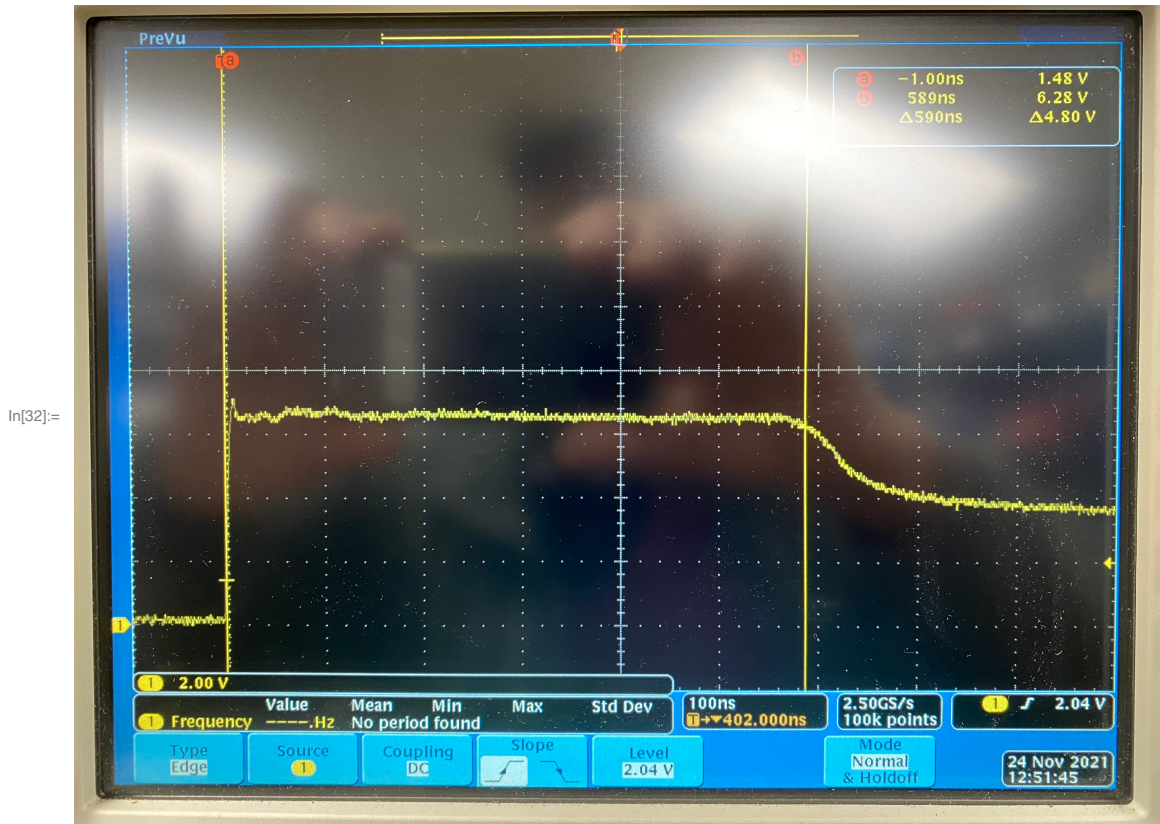
This makes the circuit values approximately as follows:



In an unfaulted cable, the value of $R1+R2$ and $R4+R5$ should be about 1Ω and $R3$ should be infinite. The most likely location of the fault is inside or very close to the ODI connector with the fault causing a low-resistance connection between the two lines and adding resistance to either side of the fault in the pin 11 line.

Time Delay Measurements

In an attempt to verify the location of the fault, I connected a 9 V battery in series with a 50 Ω resistor and applied the voltage across the two conductors on the SubConn end of the cable. I attached an oscilloscope across the same two conductors at the same end and triggered the scope on the rising edge of the voltage.



The reflection returns after 590 ns. If multiply the delay by the speed of light and we assume a velocity factor of 0.6, then the distance to the fault is

$$\text{In}[33]:= d = \frac{590 \times 10^{-9} \times 2.998 \times 10^8 \times 0.6}{2}$$

Out[33]= 53.0646

The measured length of the cable (without uncoiling it) is about 50 m, so the fault appears to be in the ODI connector. The Falmat Xtreme Cat cable is only rated to 300 m and was deployed to 900 m in this application, but I don't believe that the cable failed. There are no visible signs of damage to the cable near the ODI connector.

Craig Dawe reports that he has seen failures in this type of ODI connector and has found voids in the urethane potting that seals the connector. Fortunately the new MARS Echosounder will use a PBOF (pressure-balanced, oil-filled) ODI connector and it should not be vulnerable to this type of failure.