Preliminary Drive Noise Measurements

David D. Brandt

Rockwell Automation

Purpose

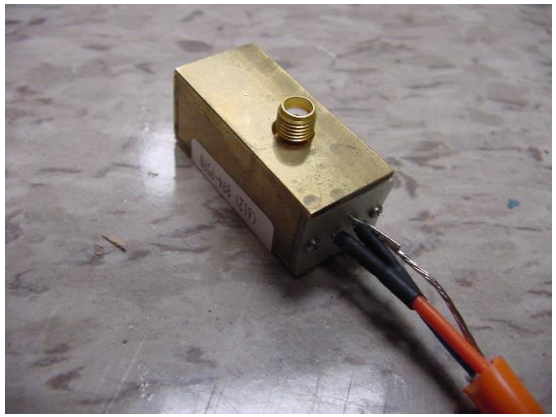
- The purpose of this presentation is to:
  - Present “first pass” measurements of Drive noise induced in a communication cable typical of the 1000 m link segment
  - Consider whether a more extensive evaluation is warranted

Drives

- Drives operate motors at variable speed from a fixed frequency (60 Hz) line
  - VFD = Variable Frequency Drive
- Typically 3Φ line voltage is rectified to DC (480 Vac -> 678 Vdc)
- The DC is switched in pulses via PWM to a 3Φ Motor cable, where the inductance in the motor integrates the current into a sinusoid
  - Typical PWM rate is 2-4 kHz, sometimes higher

- Drive cables, grounding, and proximity are significant and common sources of interference in industrial facilities

Communication link

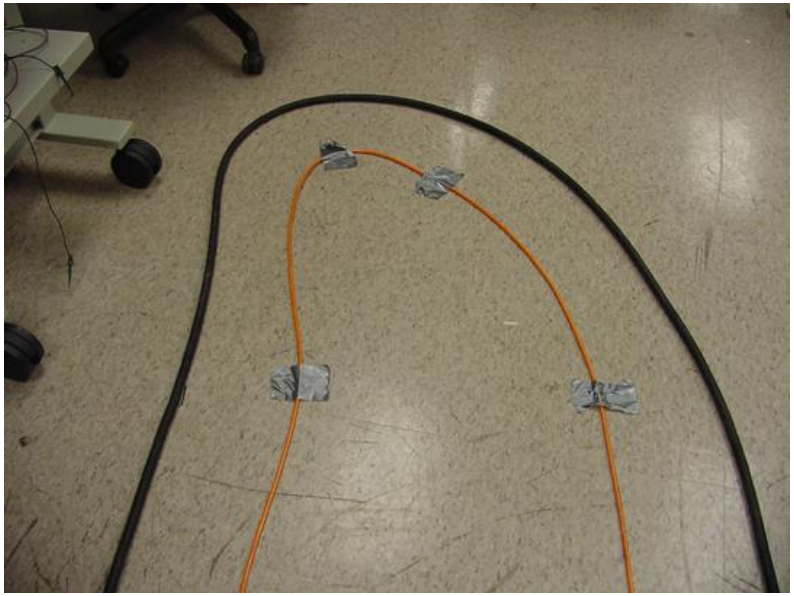


- Belden 3076F cable (10 m)
  - ISA/SP-50, FOUNDATION Fieldbus or PROFIBUS
  - 18 AWG stranded (7x26), twisted balanced pair, foil shield, drain wire, polyolefin insulation
- BH Electronics 040-0055 BALUN on each end
  - 100 Ω differential termination for cable pair
  - 50 Ω SMAs for measurement of CM and DM
  - Optional shield termination via case
  - 2.4 dB maximum insertion loss

Interference source

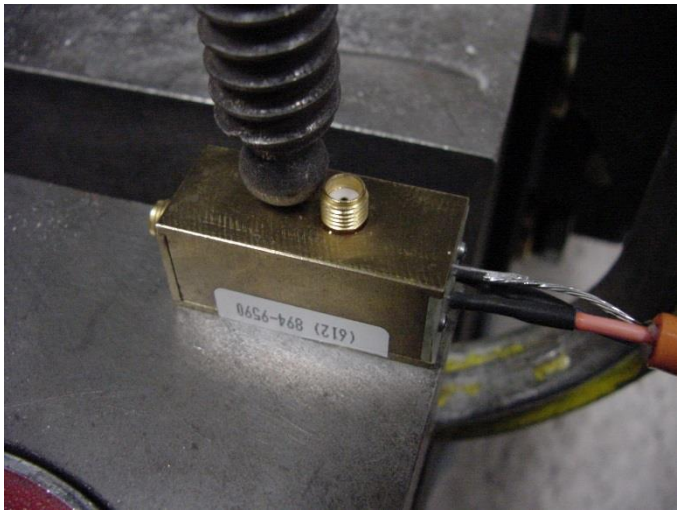
- Drive: PowerFlex 755, 7.5 hp
  - PWM configured to 12 kHz
- Motor: Reliance Electric Duty Master, 10 hp
  - No load
- Cable: Carol 4C 10 AWG
  - No Shield (systems below 10 hp are often unshielded)

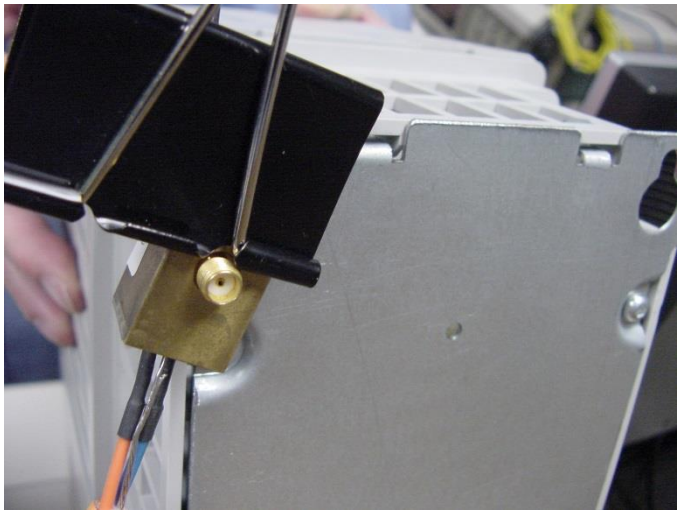
Cable placements



- The communication cable was placed in parallel to the motor control cable
- Two variations
  - Adjacent
  - Approximately 20 cm separation

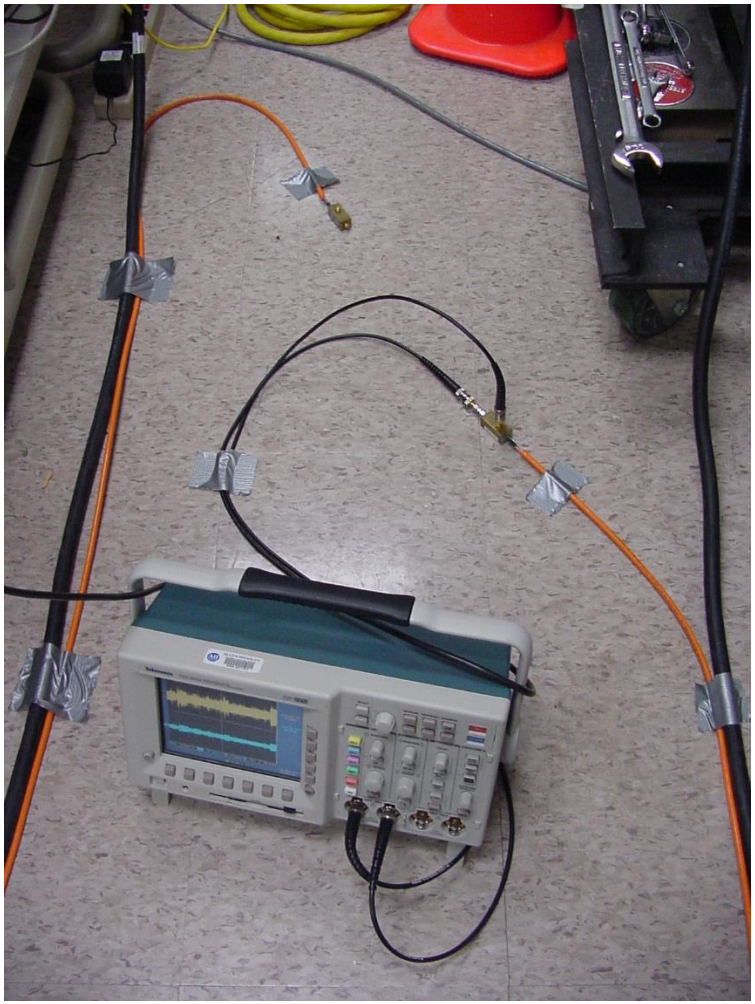
Communication shield termination





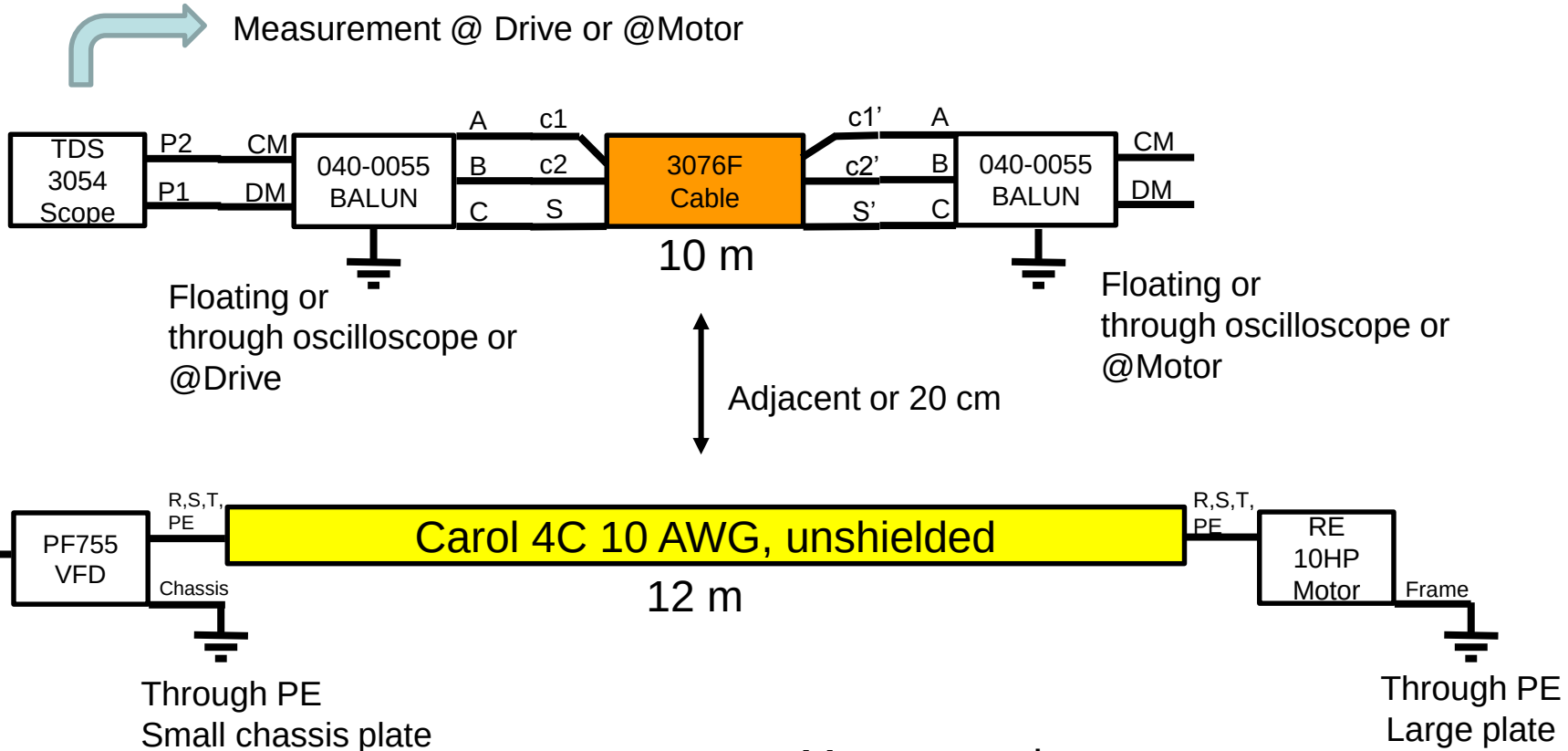
- The shield GND was through the BALUN
  - On the measurement, GND included the oscilloscope
  - On the other end in one of 3 ways:
    - Isolated from Drive and Motor
    - Tied to the Motor's frame ground via metal plate
    - Tied to the Drive's metal mounting plate

Measurements



- Tektronix TDS 3054, 500 MHz, 5 GS/s
- 2 channels attached to BALUN
  - Ch1 to BALUN CM
    - 50 Ω
  - Ch2 to BALUN DM
    - 50 Ω
    - 20 MHz BW limit
- FFT calculation

Setup summary



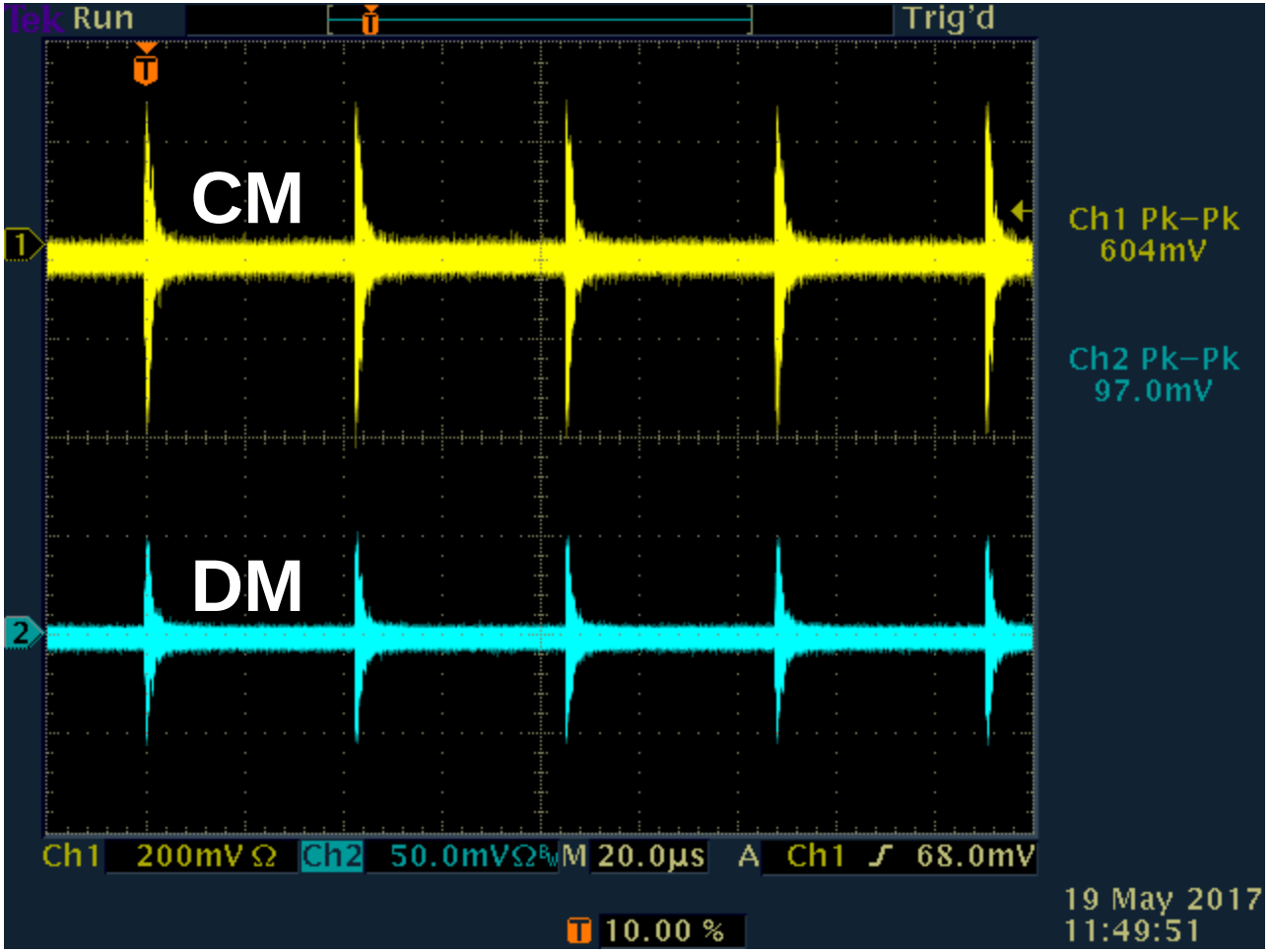
Motor speed

0 Hz is held in position

60 Hz is run at full speed

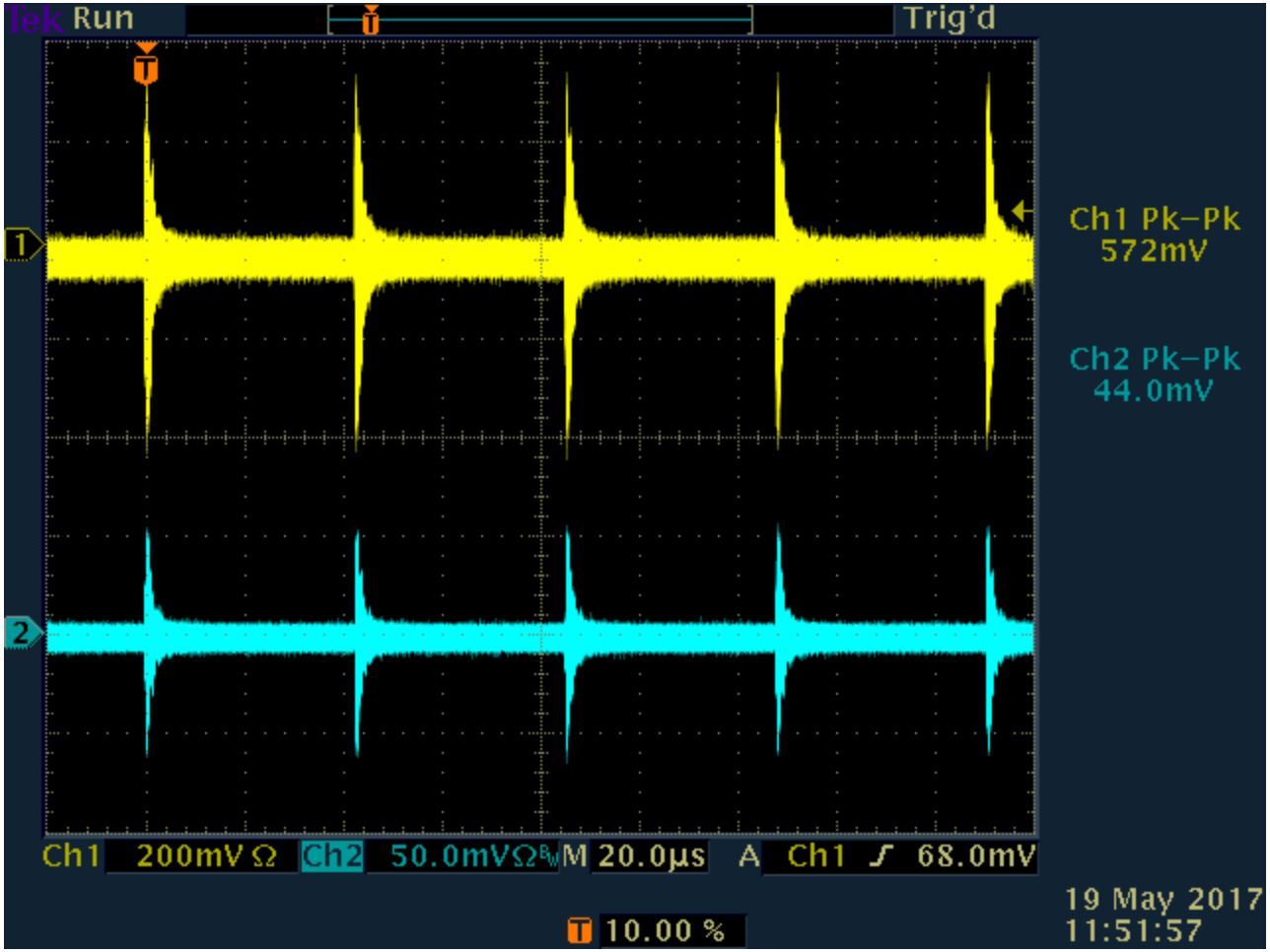
Testing with adjacent cables

Setup: Adjacent cables, Isolated GNDs, 0 Hz
Measurements: Drive end



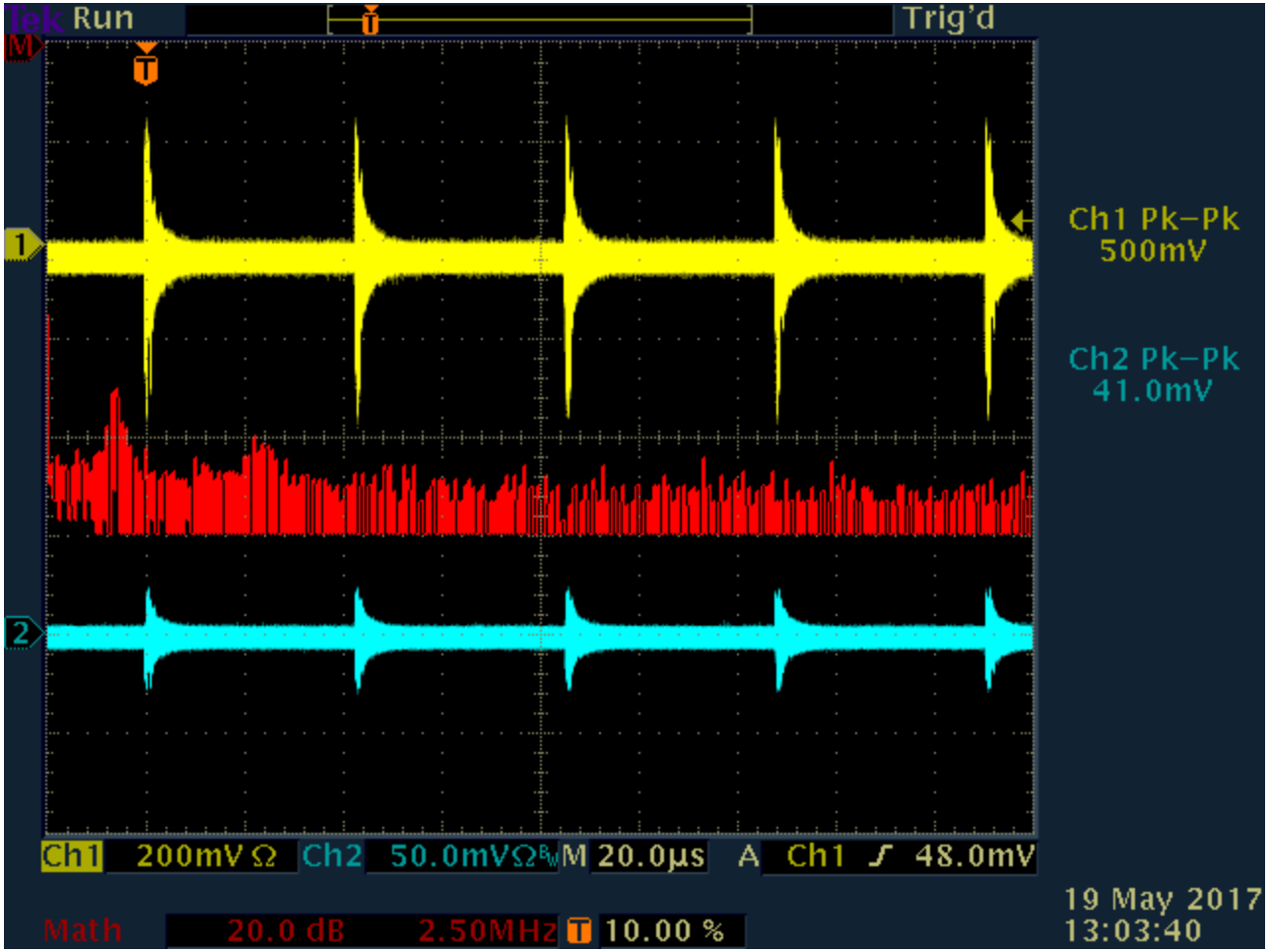
- ~6x voltage reduction
- ~24 kHz

Setup: Adjacent cables, Isolated GNDs, 0 Hz
Measurements: Motor end



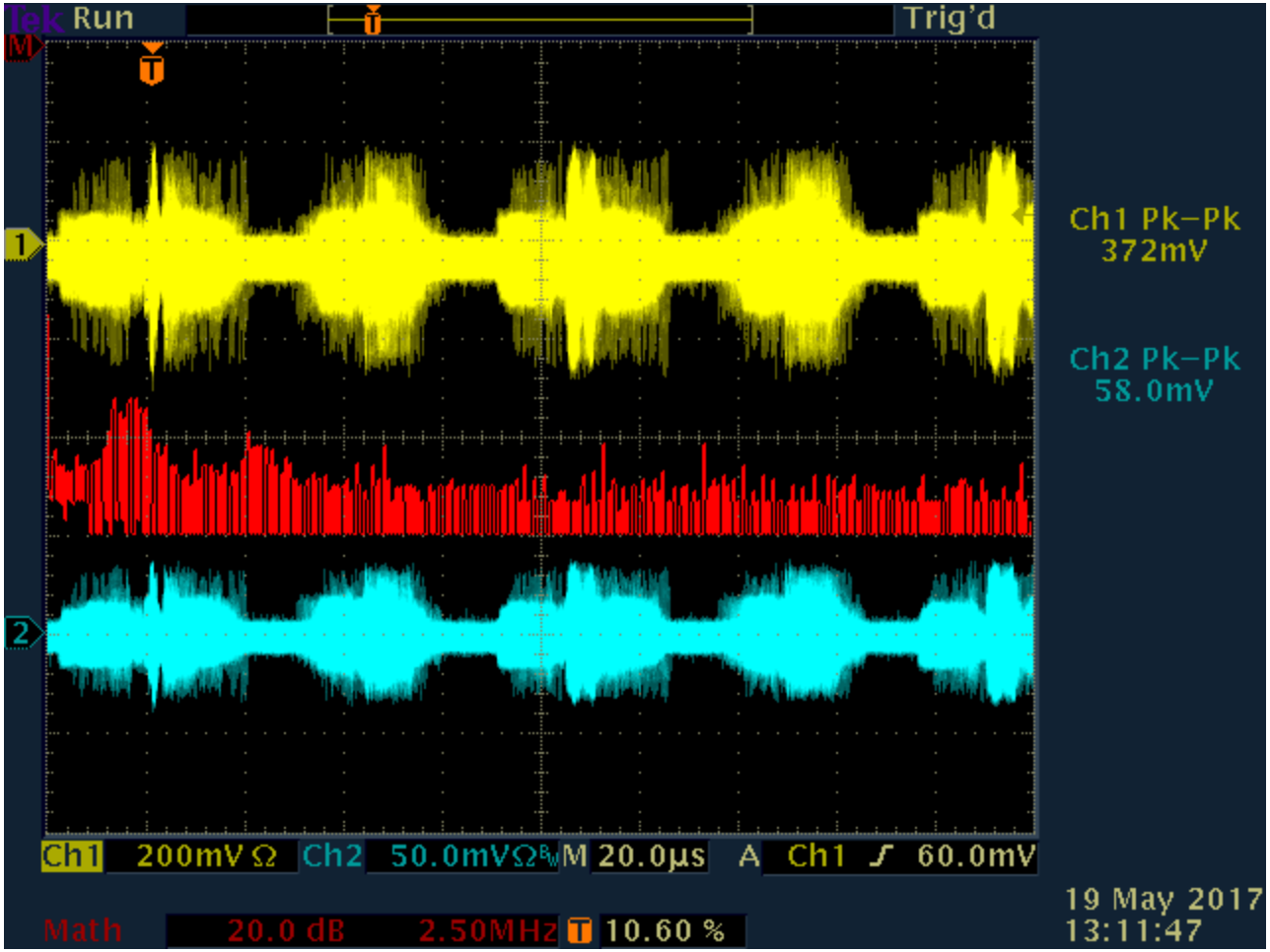
- CH2 visually appears to be 100 mV Pk-Pk
  - 50 mV differential
- Pk-Pk does not appear accurate

Setup: Adjacent cables, Isolated GNDs, 0 Hz
Measurements: Motor end



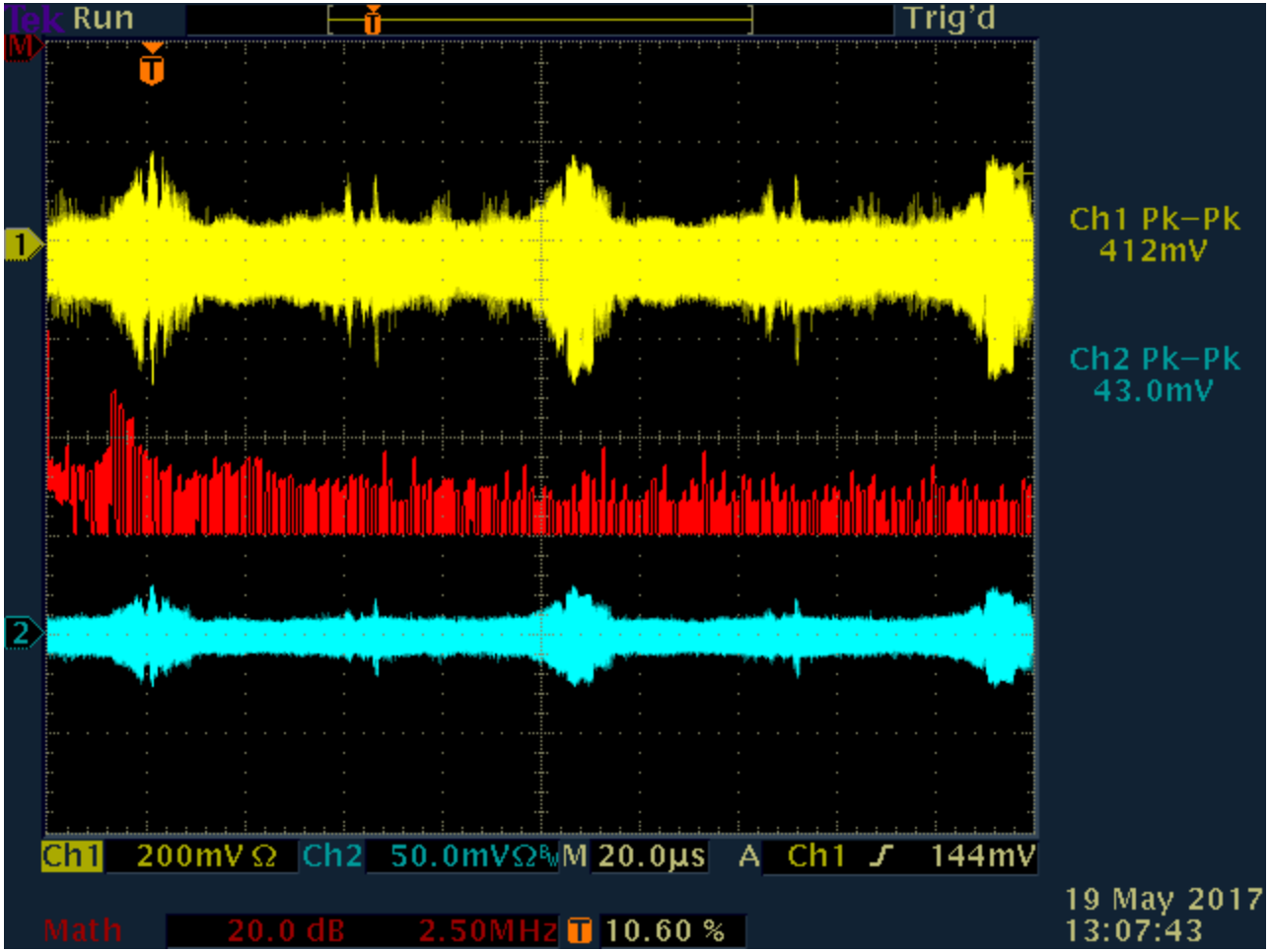
- Add FFT
  - Rectangular window
  - dBV
- 25 MHz span
- Pk between 1.5 - 2 MHz

Setup: Adjacent cables, Isolated GNDs, 60 Hz
Measurements: Drive end



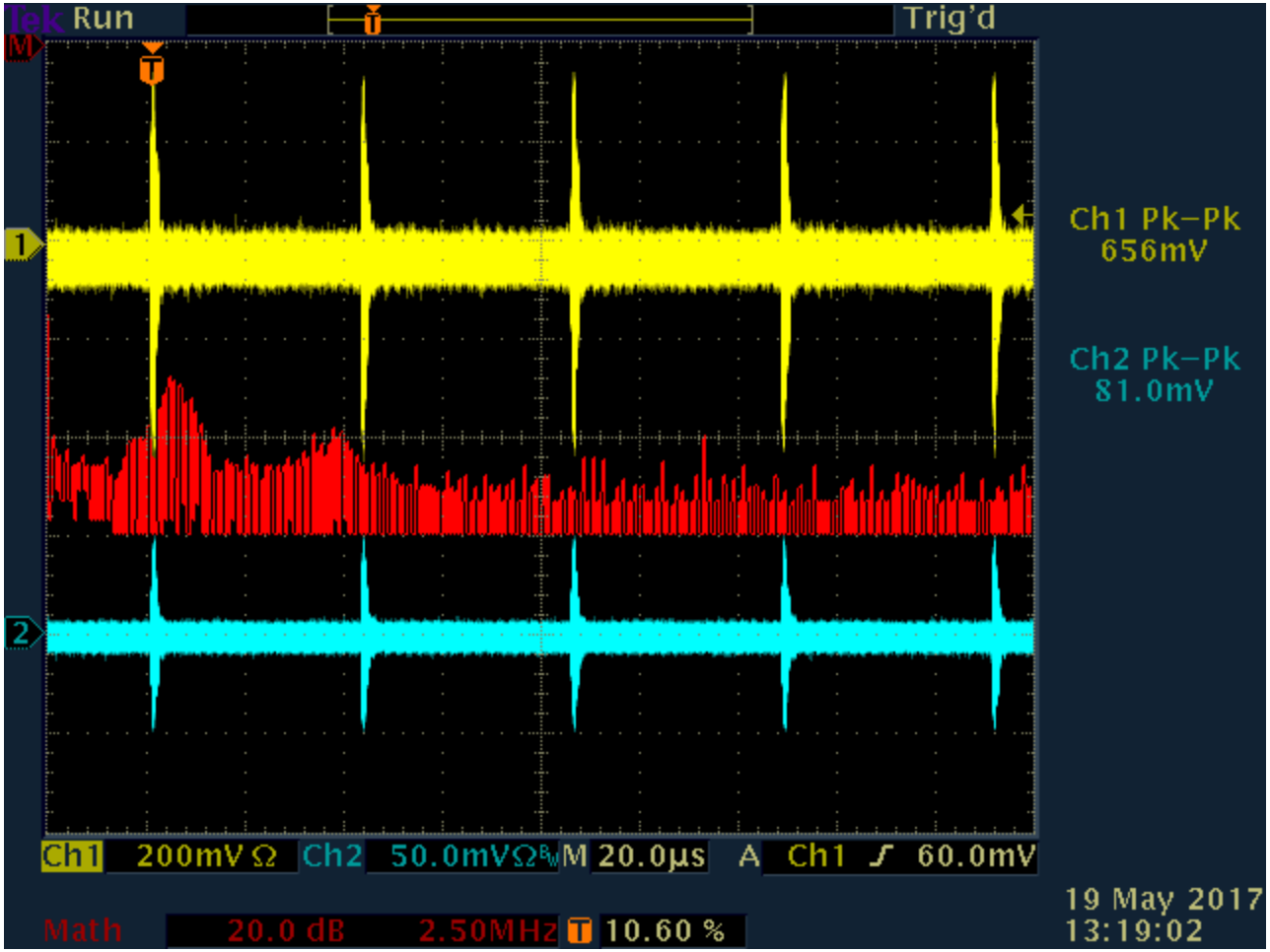
- Motor “at speed”
- Reduced peaks
- More noise between peaks

Setup: Adjacent cables, Isolated GNDs, 60 Hz
Measurements: Motor end



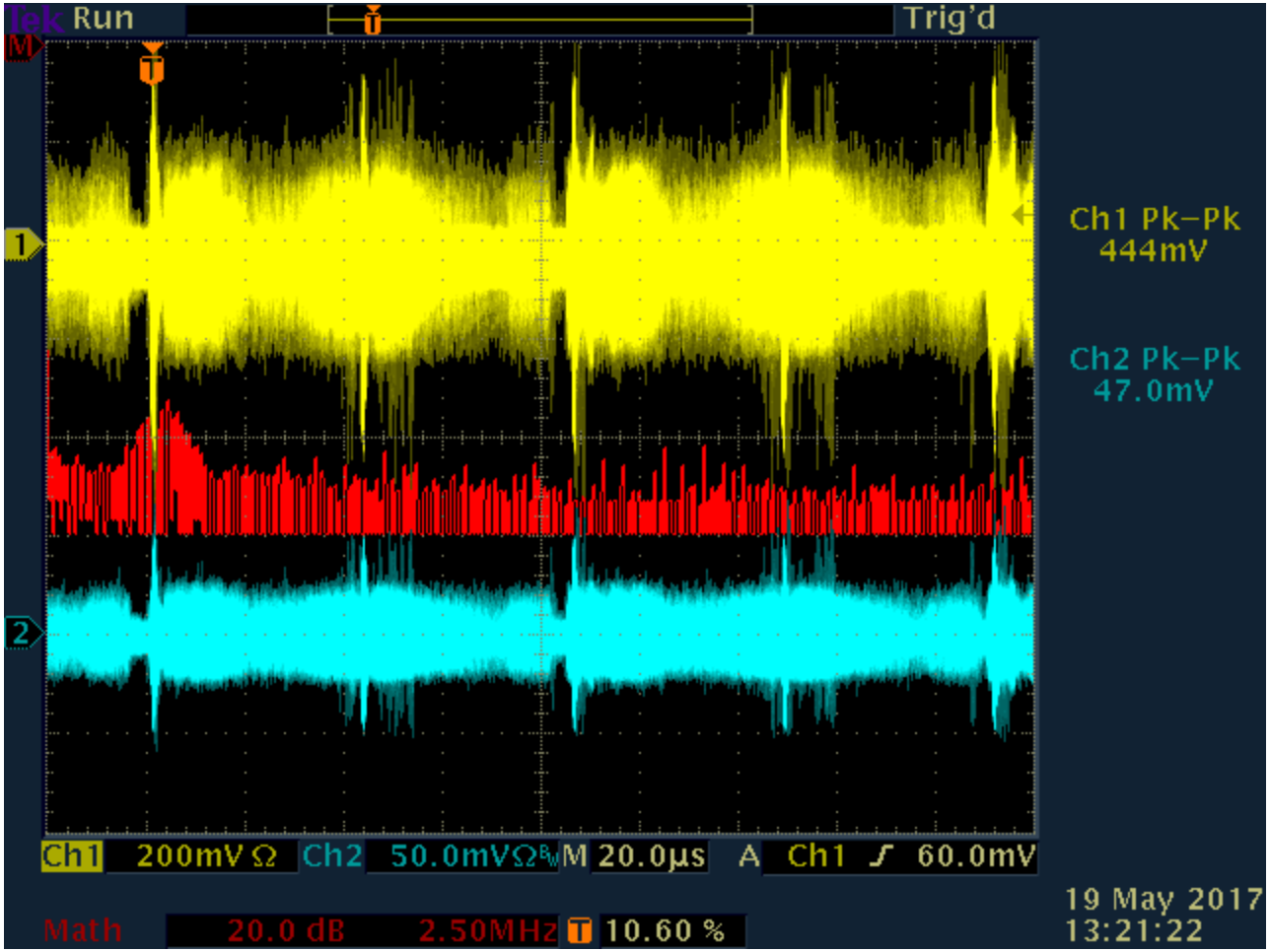
- Motor “at speed”

Setup: Adjacent cables, GND BALUN at motor, 0 Hz
Measurements: Drive end

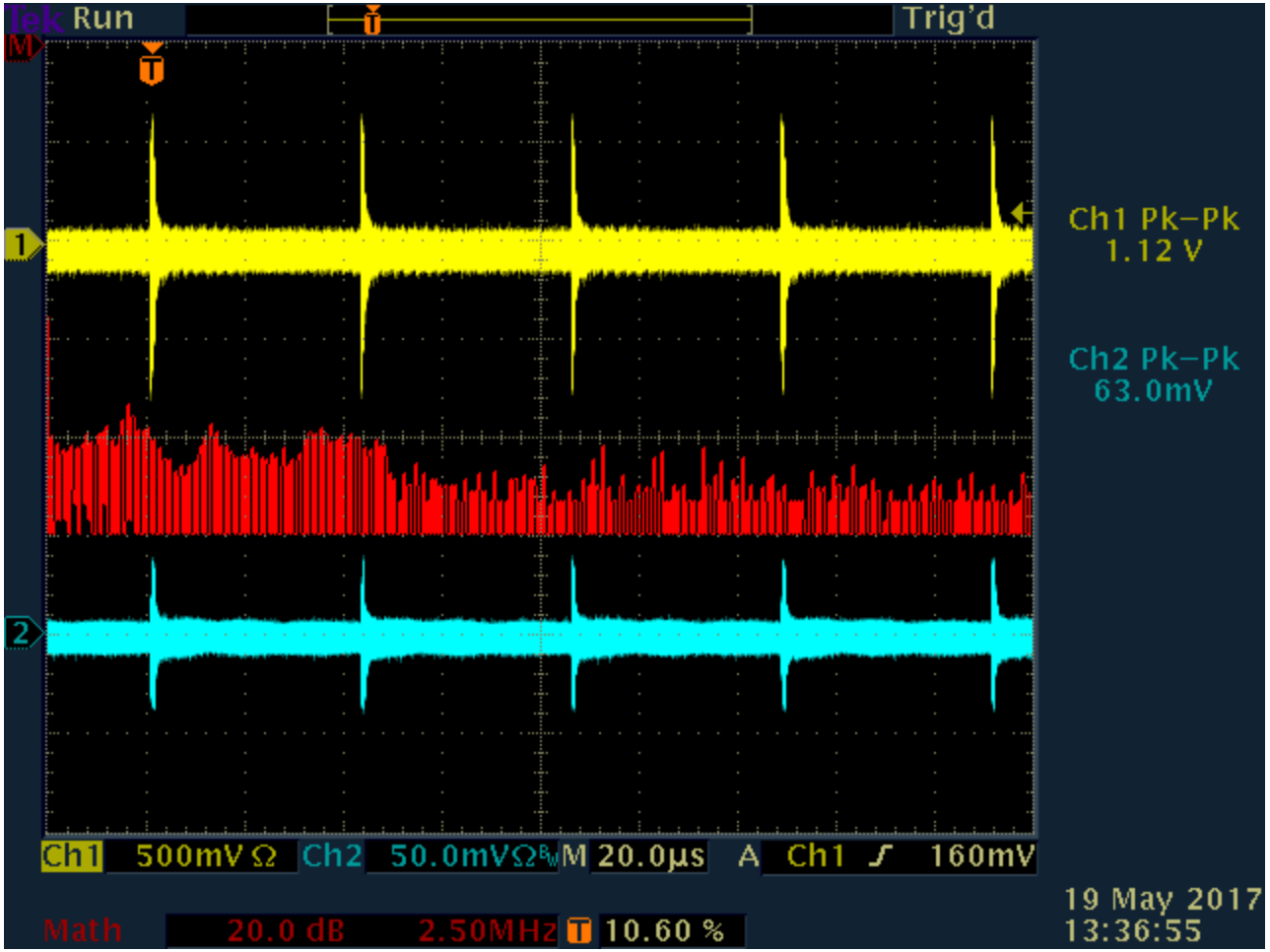


- Motor GND appears to add little to Pk noise
- ~8x voltage reduction
- FFT Pk about 3 MHz (shifted)

Setup: Adjacent cables, GND BALUN at motor, 60 Hz
Measurements: Drive end

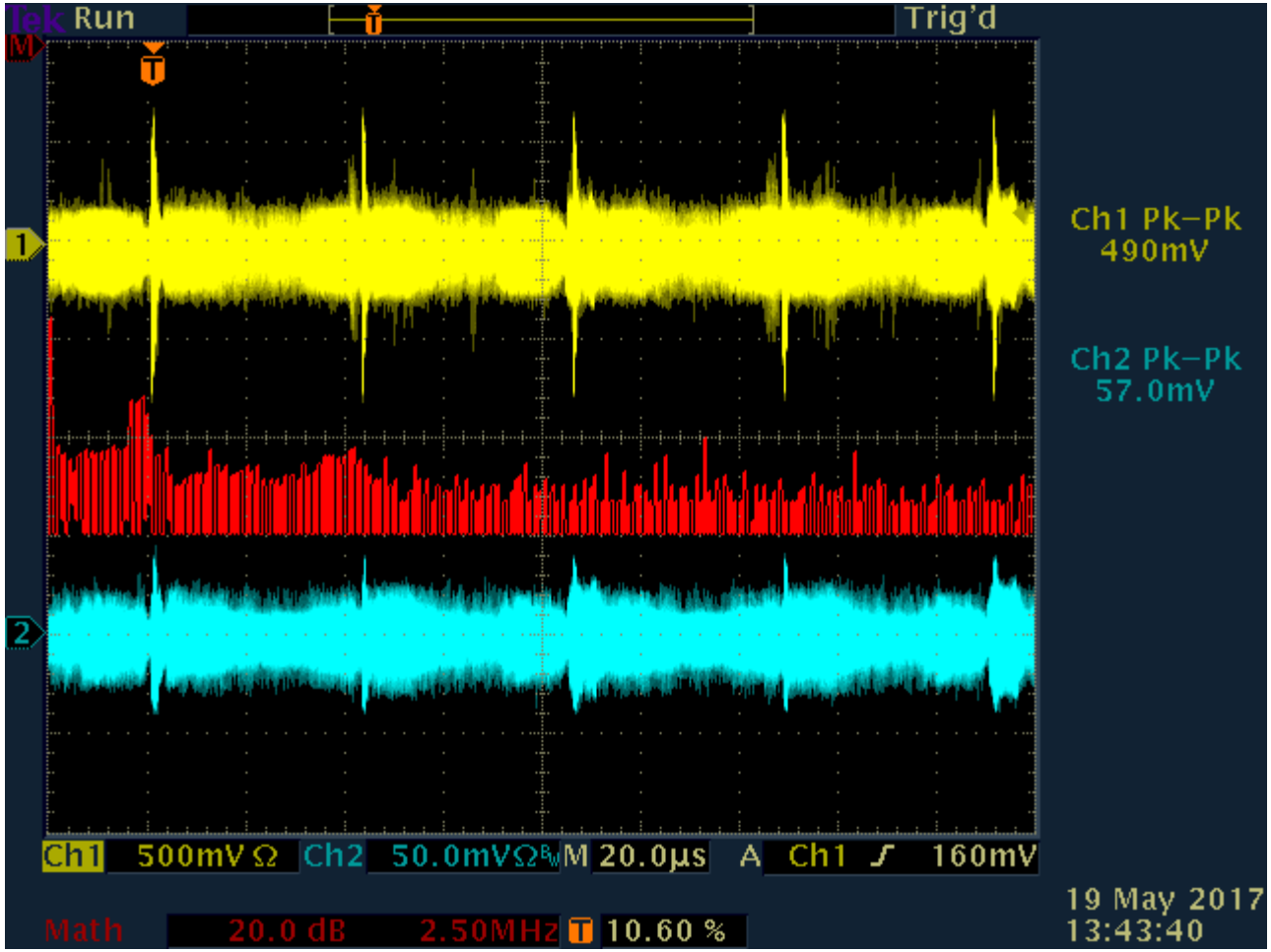


Setup: Adjacent cables, GND BALUN at Drive, 0 Hz
Measurements: Motor end



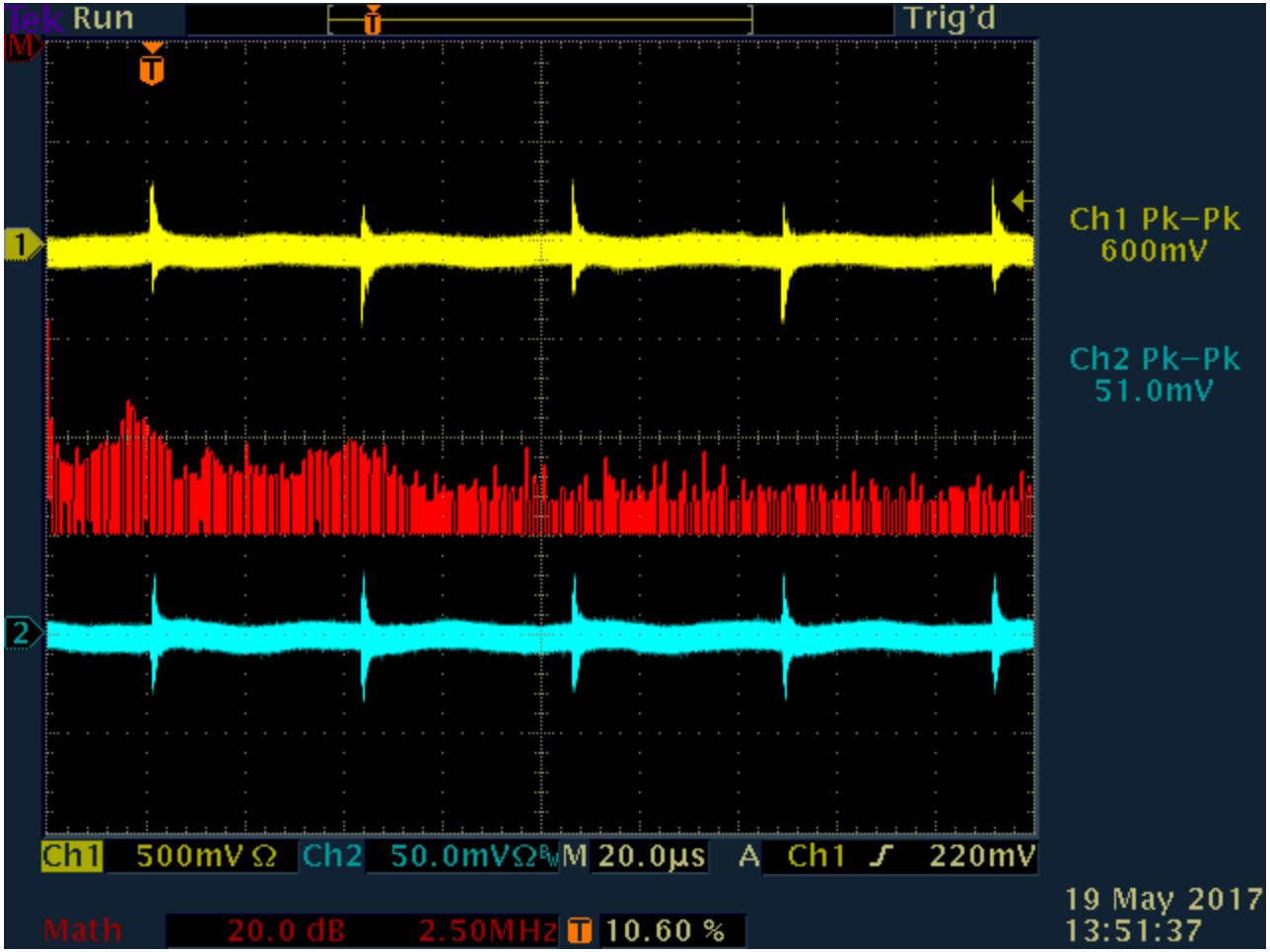
- Drive GND appears to add little Pk noise
- ~20x voltage reduction

Setup: Adjacent cables, GND BALUN at Drive, 60 Hz
Measurements: Motor end



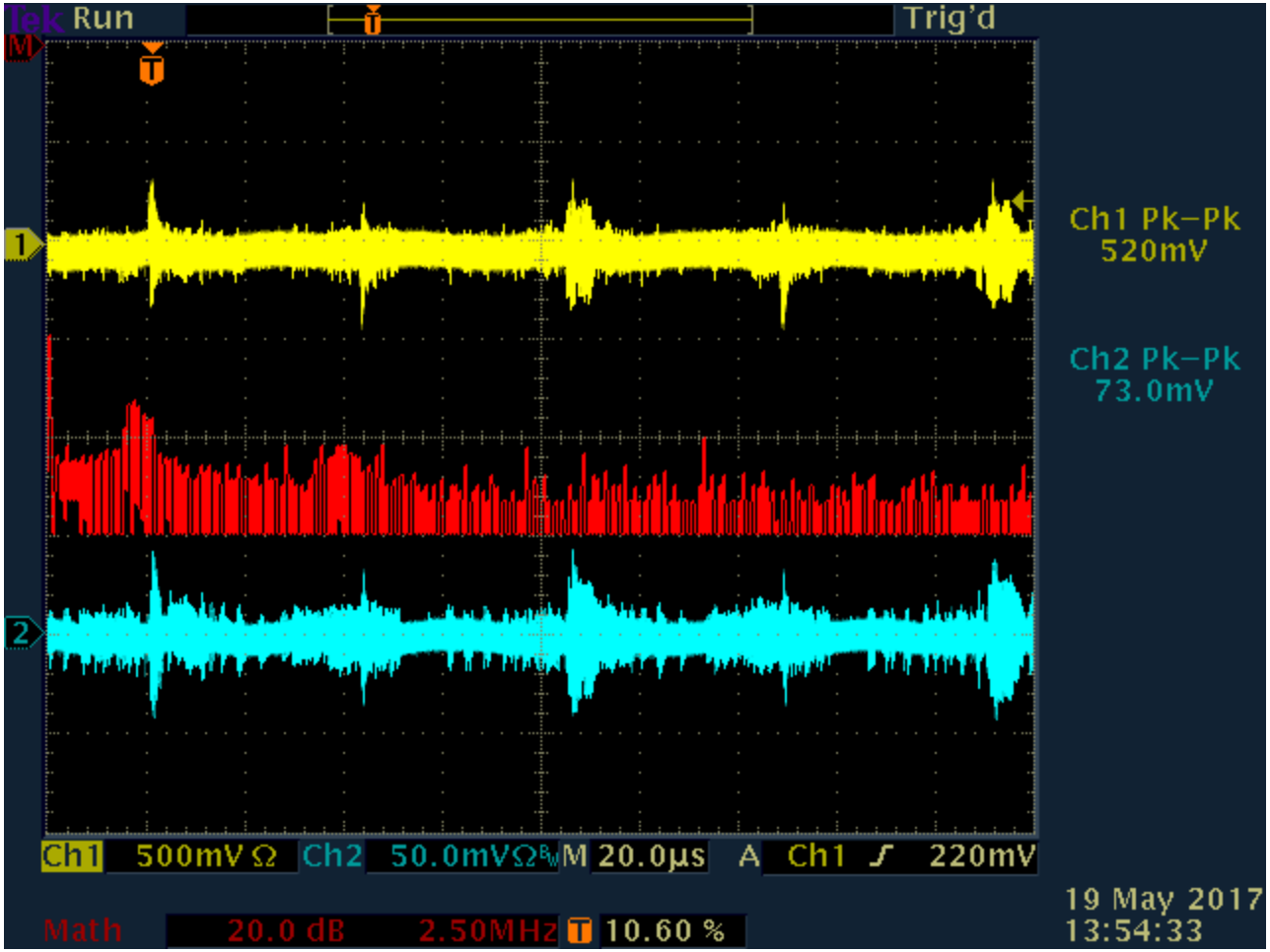
Testing with 20 cm cable separation

Setup: 20 cm cable separation, GND BALUN at Drive, 0 Hz
Measurements: Motor end



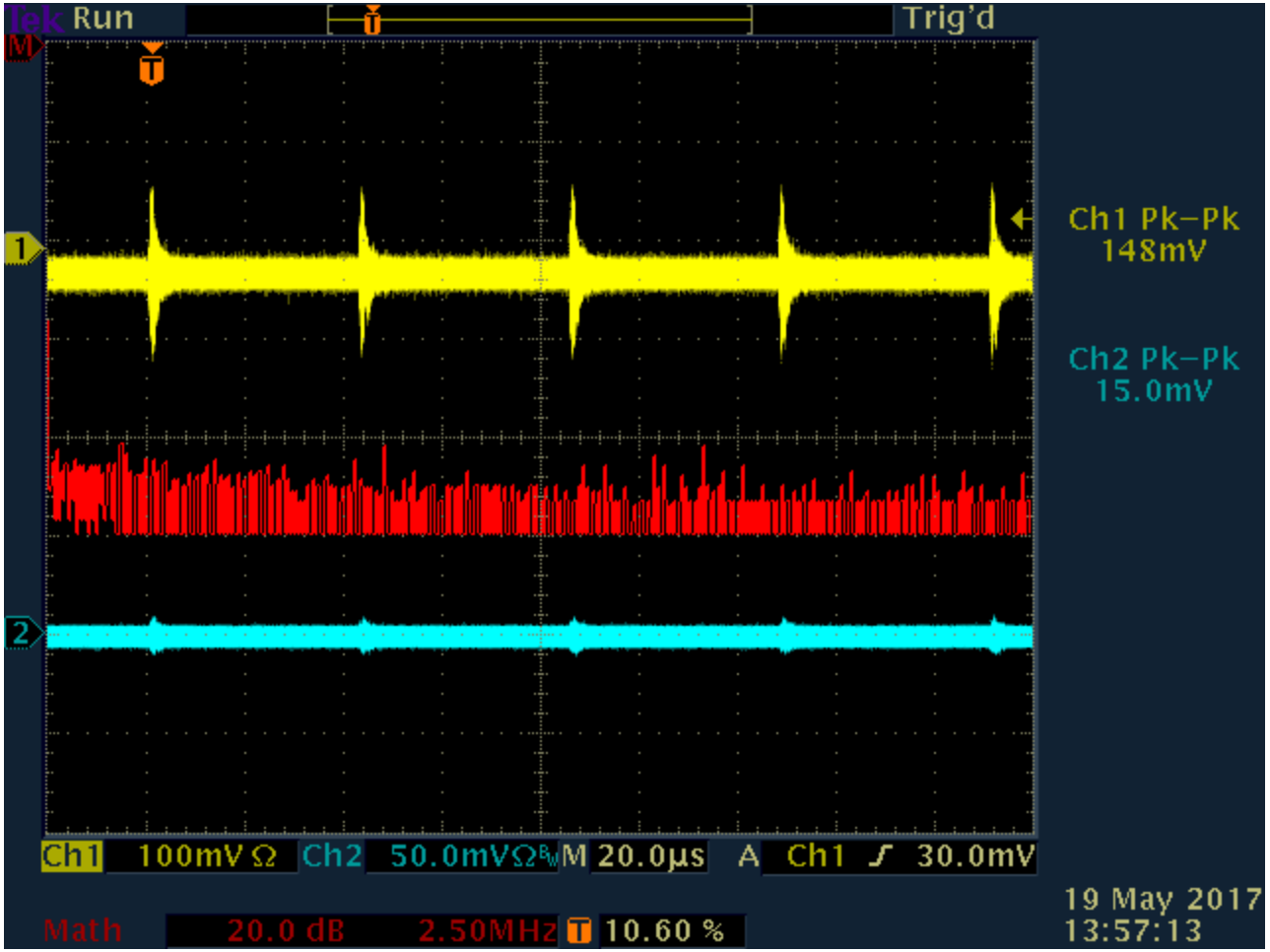
- ~10x voltage reduction
- Cable separation reduces Pk noise
- Visually appears to be 60 mV Pk-Pk

Setup: 20 cm cable separation, GND BALUN at Drive, 60 Hz
Measurements: Motor end



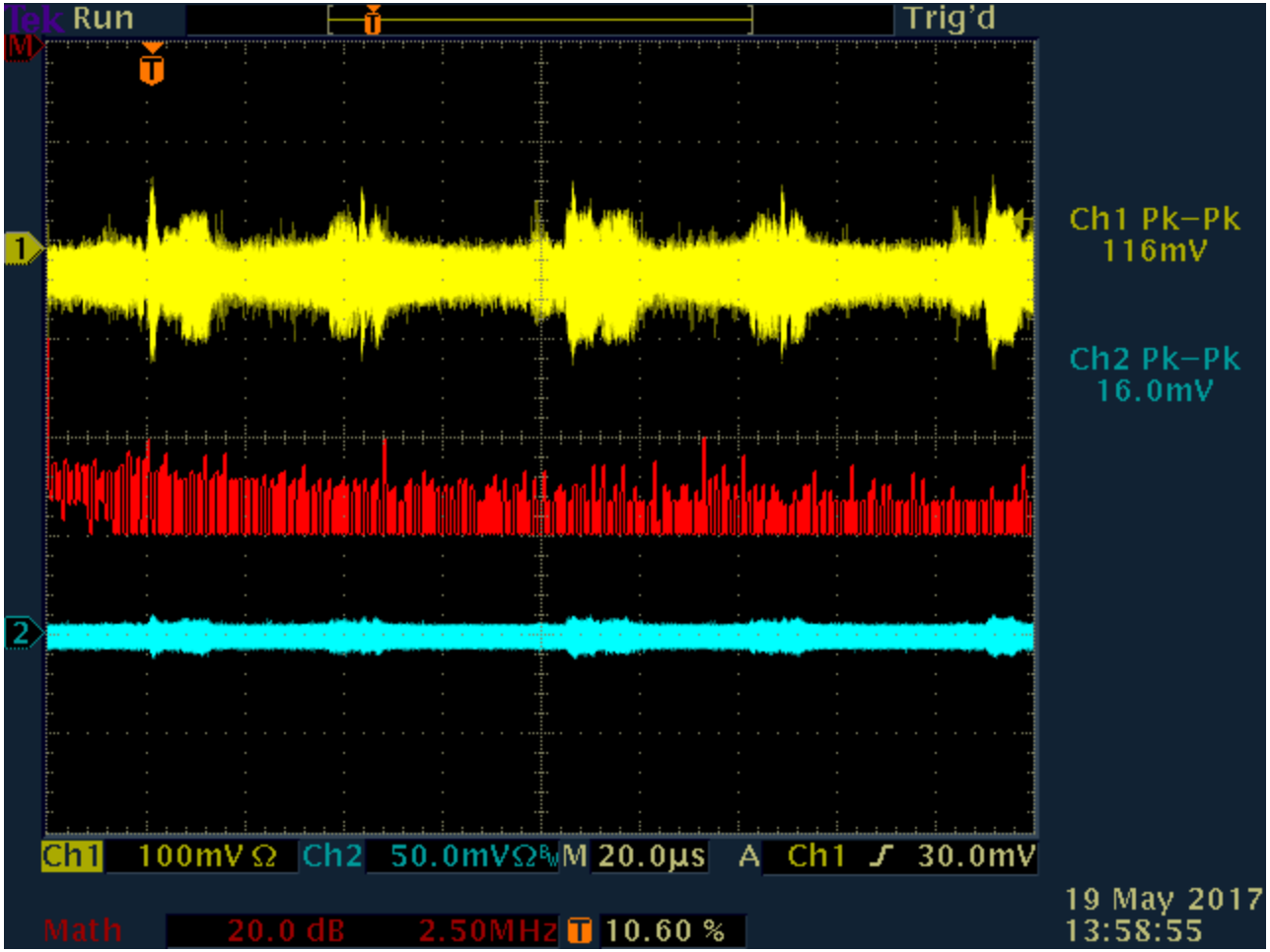
- Visually appears to be 90 mV Pk-Pk

Setup: 20 cm cable separation, Isolated GNDs, 0 Hz
Measurements: Motor end



- GND coupling was dominating over capacitive coupling between cables
- Visually appears to be 20 mV Pk-Pk

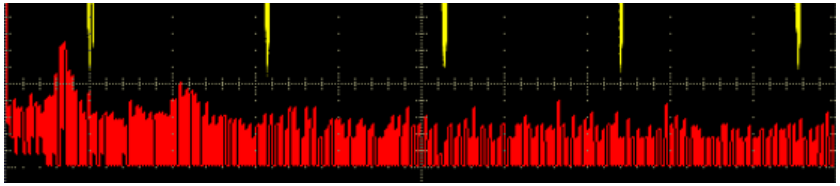
Setup: 20 cm cable separation, Isolated GNDs, 60 Hz
Measurements: Motor end



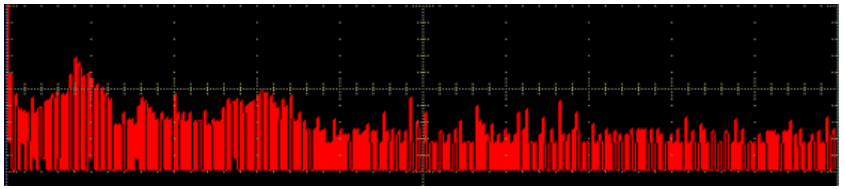
- Visually appears to be 25 mV Pk-Pk

FFT comparisons (partial)

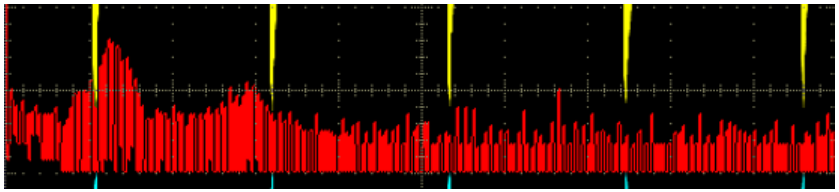
Adjacent cables, Isolated GND



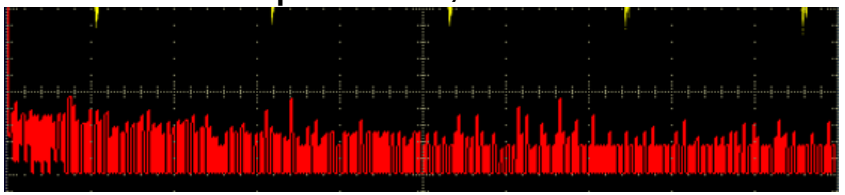
20 cm separation, Drive GND



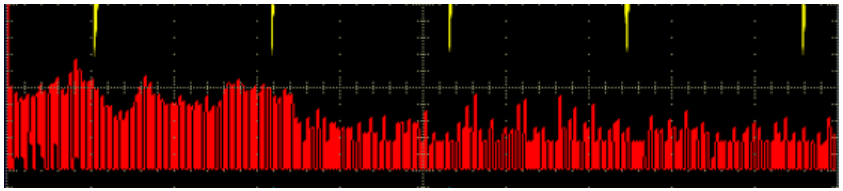
Adjacent cables, Motor GND



20 cm separation, Isolated GND



Adjacent cables, Drive GND



- Noise below 10 MHz
- Noise may come through capacitive coupling or shield grounding

Rise time “rule of thumb”

- BW (GHz) = 0.35 / Rise_Time (ns)
- IGBT (typical)
  - Rise = 30 ns
    - BW = 11.6 MHz
  - Fall = 70 ns
    - BW = 5 MHz

Conclusions

- Drive noise can enter differential pair:
  - By capacitive coupling of parallel cables
  - Through shield sharing common GND with Drive
- Both causes must be addressed to limit noise
- Peak noise relates to 2x the PWM frequency
- A lower level of noise *appears* continuous
- Good installation practice *may* reduce noise well below the 75 mV fieldbus rule of thumb
  - This is just <u>one</u> configuration

Next Steps

- Some additional scrutiny on this configuration
- Characterize the communication cable
- Test with a longer run of cable
- Test with a larger Drive and Motor