VNA Accuracy Test

Raul Monsalve

SESE, Arizona State University

July 18, 2013

Description

- There is a new VNA available in our lab, an AGILENT E5072A, and it was compared to the R&S ZVL3 we have been using until now.
- The comparison consisted of the accuracy of the measurement of three 10-dB attenuators (SA18H, 2W), after correction using the expectations for the *open*, *short*, and *match*. The temperature at all moments was $23.5 \pm 0.5^{\circ}$C.
- Three power settings were used, in principle, to compare the noise levels: 0 dBm, 10 dBm, and 20 dBm. The other settings, common to both, are:
  - frequency range: 1 to 300 MHz
  - frequency resolution: 1 MHz
  - bandwidth: 100 Hz
  - averaging: 20 traces
- The steps in the testing at each power level are:
  1. calibrate the VNA at its SMA port (with *open*, *short*, & *match*).
  2. measure the *open*, *short*, & *match*, AGAIN after calibration.
  3. measure the three attenuators.
  4. correct the measurements.
  5. compare corrected measurements to expectations at DC.

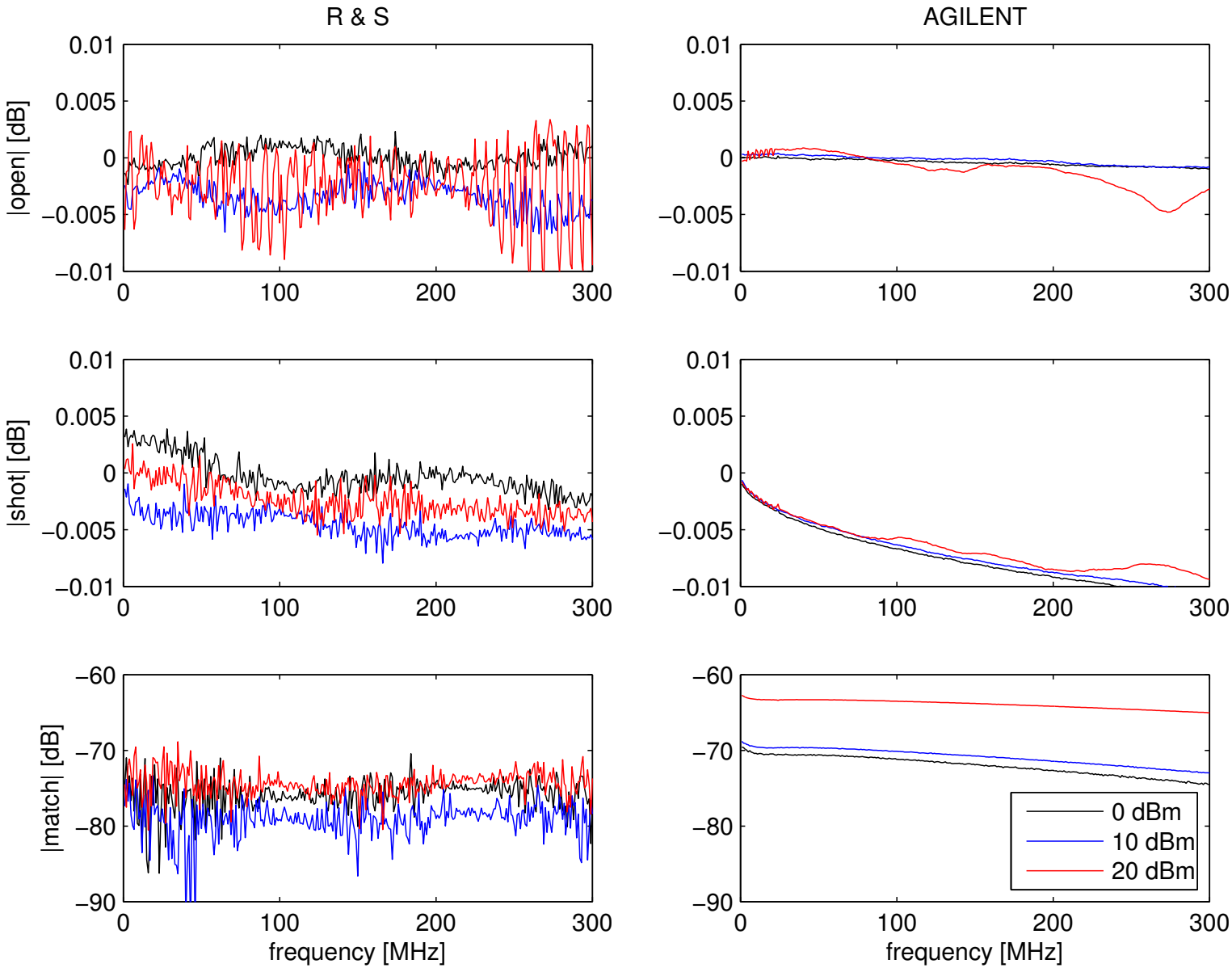

Figure: Magnitude of the *open*, *short*, and *match*, after calibration. R & S on the left and AGILENT on the right, and three power levels. The difference in trace noise between the two VNAs with the same settings is significant. On the other hand, the expectation for the match at 23.5°C is -73 dB, and therefore the R & S is closer at all power levels, at least as we approach DC.

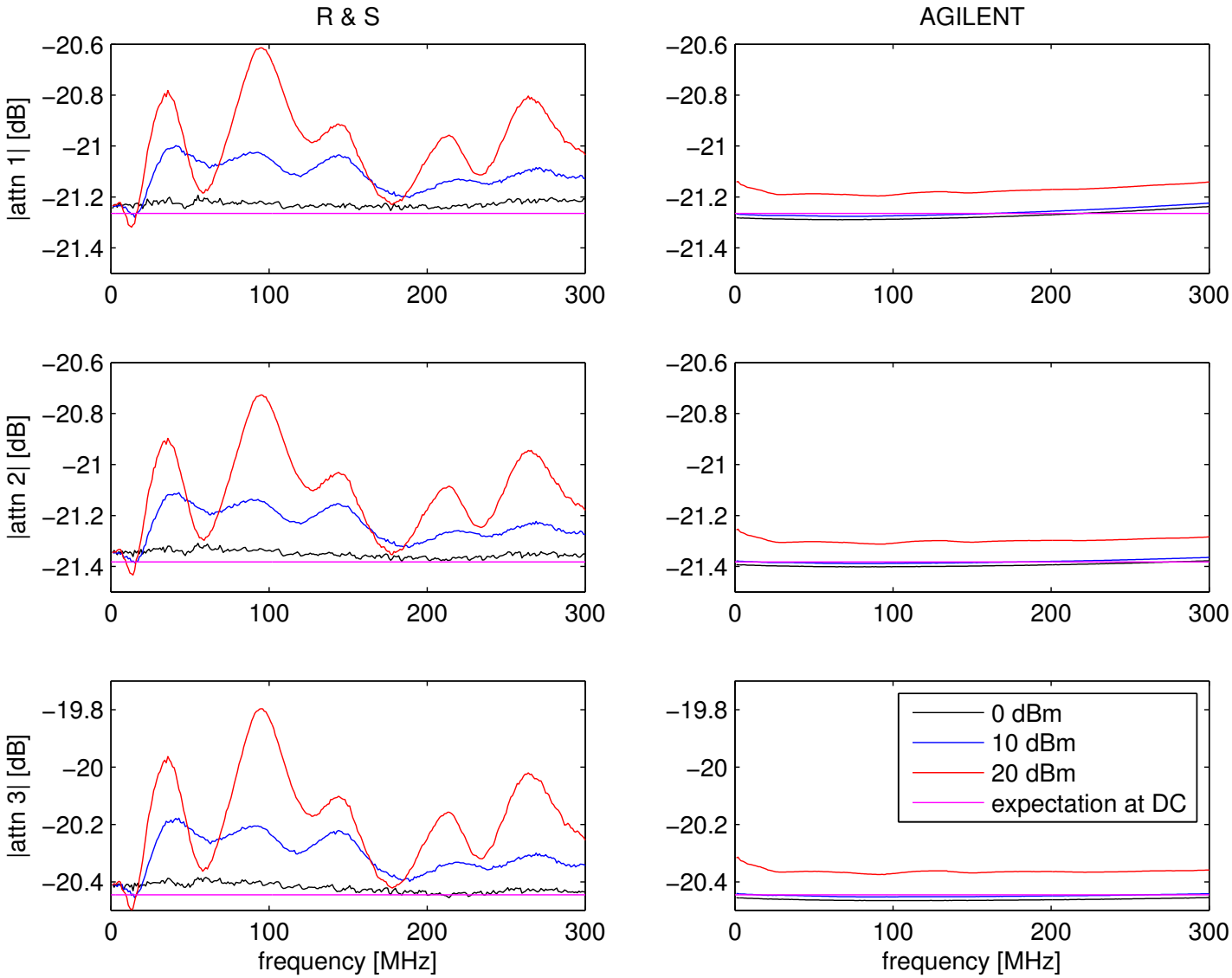

Figure: MEASURED magnitude of the three attenuators, along with expectations for the attenuators at DC (magenta line). The vertical scales are the same for both VNAs. The most evident feature in both cases consists of the change of the traces as the power level increases. The changes occur not only in offset (primarily AGILENT), but also in shape (primarily R & S). The shape of the measured traces are put into question, even at 0 dBm, due to the difference between the two VNAs.

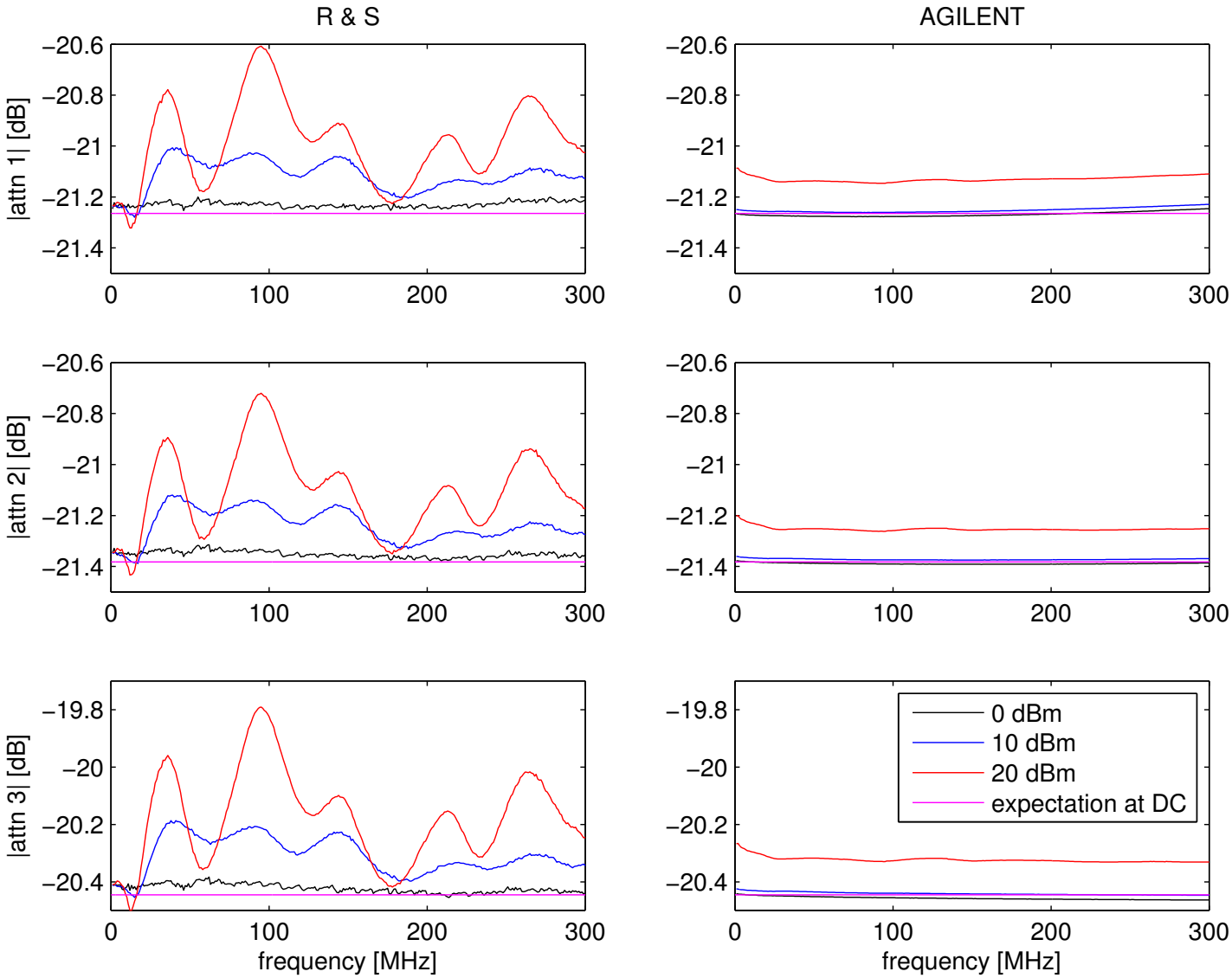

Figure: CORRECTED magnitude of the three attenuators, along with expectations for the attenuators at DC (magenta line). Compare them with previous figure. FOR R & S: It is evident that the departure of the standards from expectations (Figure on page 3) is not responsible for the shapes of the traces. The overall level of the traces does not change much after correction (see previous Figure) and it is interesting that they converge at DC. FOR AGILENT: The offset changes more than for R & S, due to the departure of the *match* from expectation (Figure on page 3). After correction, the traces for 0 dBm get very close to the expectation as we approach DC. The traces at 20 dBm show some ripples, although small compared to R & S.

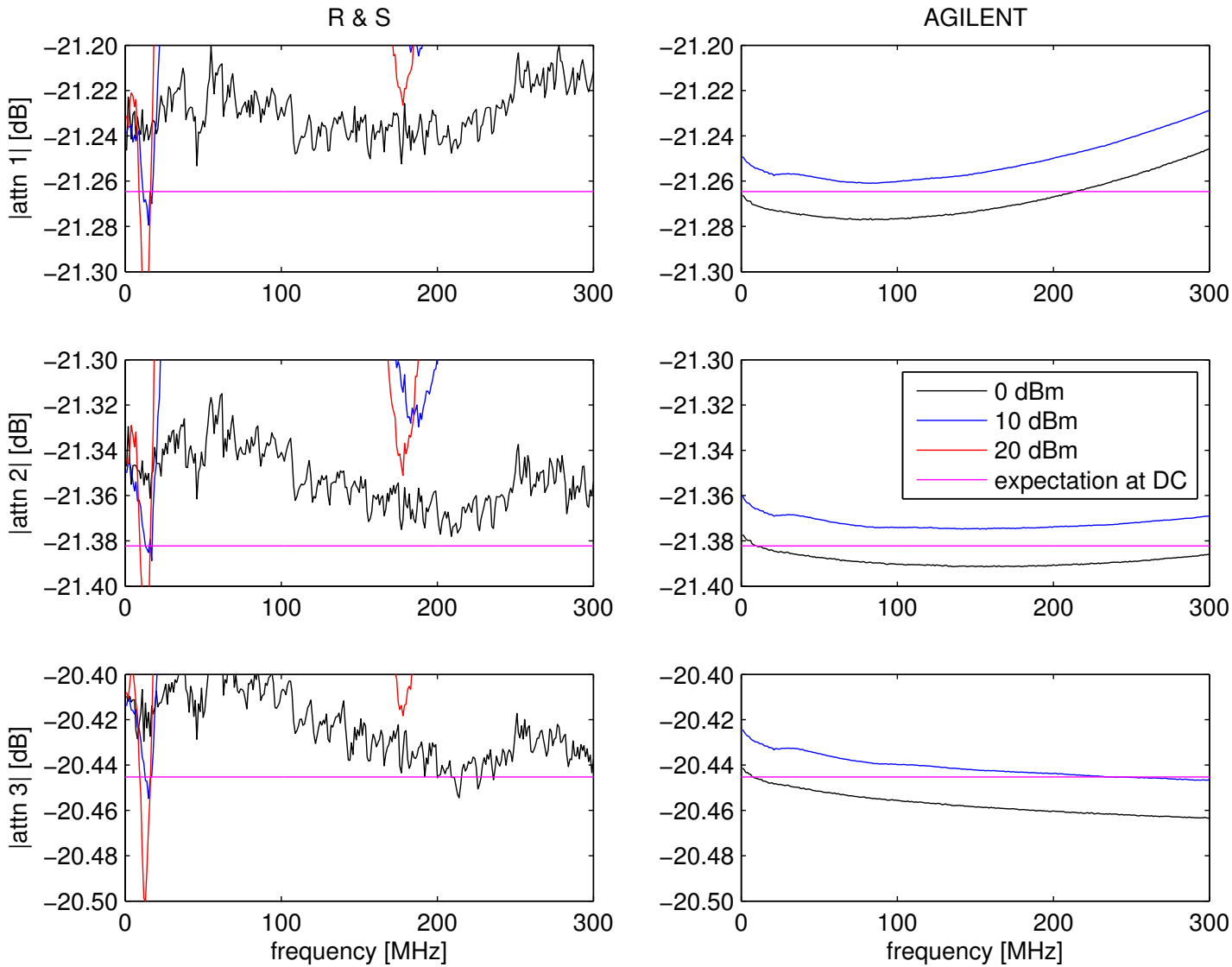

Figure: SAME AS PREVIOUS FIGURE, BUT smaller vertical range. FOR R & S: At DC, the corrected measurements are $\sim$ 0.04 dB from expectations. The trace noise is very high when compared to AGILENT. It is clear that the traces get flatter as the power decreases. However, even at 0 dBm they are not that flat. Maybe the optimal power level for this VNA/load combination is lower than 0 dBm. Also, some features are common to the three attenuators, at $\sim$ 50 MHz and $\sim$ 270 MHz. FOR AGILENT: Accuracy at DC is 0.005 dB or better, at 0 dBm. Shape of traces is smooth, but given the context, it is not certain if they are the true shape. More testing is needed.

Discussion

- Standards were measured at the VNA just after calibration at the three power levels. Departure from expectations was small, but trace noise is significantly higher for R & S, especially at 20 dBm.
- Even after correction, the measurements of the three attenuators obtained with the same VNA differ largely at different power levels. Although attributing this to changes in the attenuators seems tempting, it does not explain the difference between VNAs. The attenuators (SA18H) can withstand 2W, and show these shapes right after connecting them to the VNA. If the shape were due to changes in the attenuators as they heat up, it should manifest itself as a shape that varies in time. However, the shape is constant since they are connected.
- This suggests that the VNAs have a '*non-linear*' mapping of reflection coefficient, accentuated at high power levels. Under this hypothesis, in the case of the R & S the power output does not seem constant across the frequency range, converging to the same value at DC. Also for the R & S, even a power level of 0 dBm does not seem low enough considering the significant structure common to the three attenuators, and different to that measured with the AGILENT.
- Under these conditions, the accuracy at DC is of order 0.04 dB for the R & S, and 0.005 dB for the AGILENT.
- More testing is needed, with different loads and different power levels.