Testing the PIFA on the Irene mote

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Setup:

I used an HP 8753E network analyzer to perform the following tests.

The PIFA was attached to a semi-rigid coax cable assembly with an SMA connector on the opposite end. The RF feed on the PIFA was soldered to the coax's center conductor and the RF ground was soldered to the outer shell of the coax.

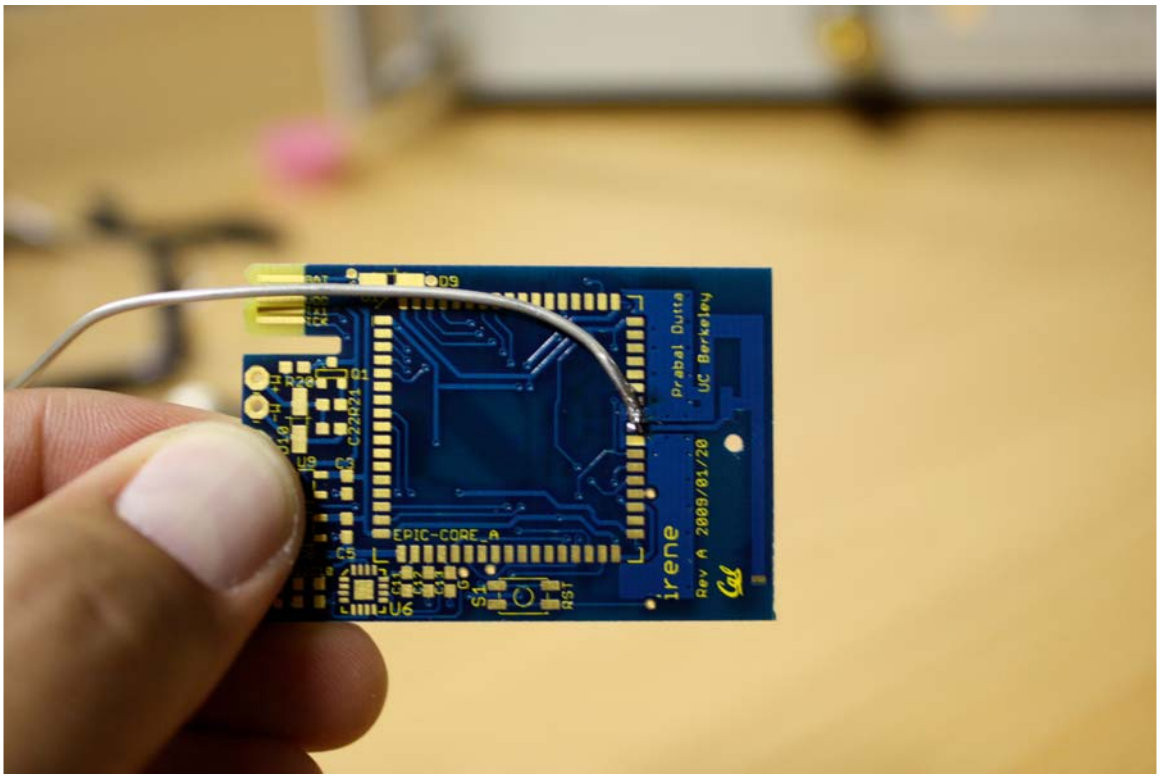

Figure 1 - Semi-rigid coax test harness with SMA termination

The network analyzer injects a signal into the PIFA and measures the reflected power. In an ideal world all energy emitted from the analyzer would pass un-attenuated through the coax and be radiated by the antenna. I calibrated the analyzer with the coax attached so as to remove any negative effects due to the test harness. (Figure 2)

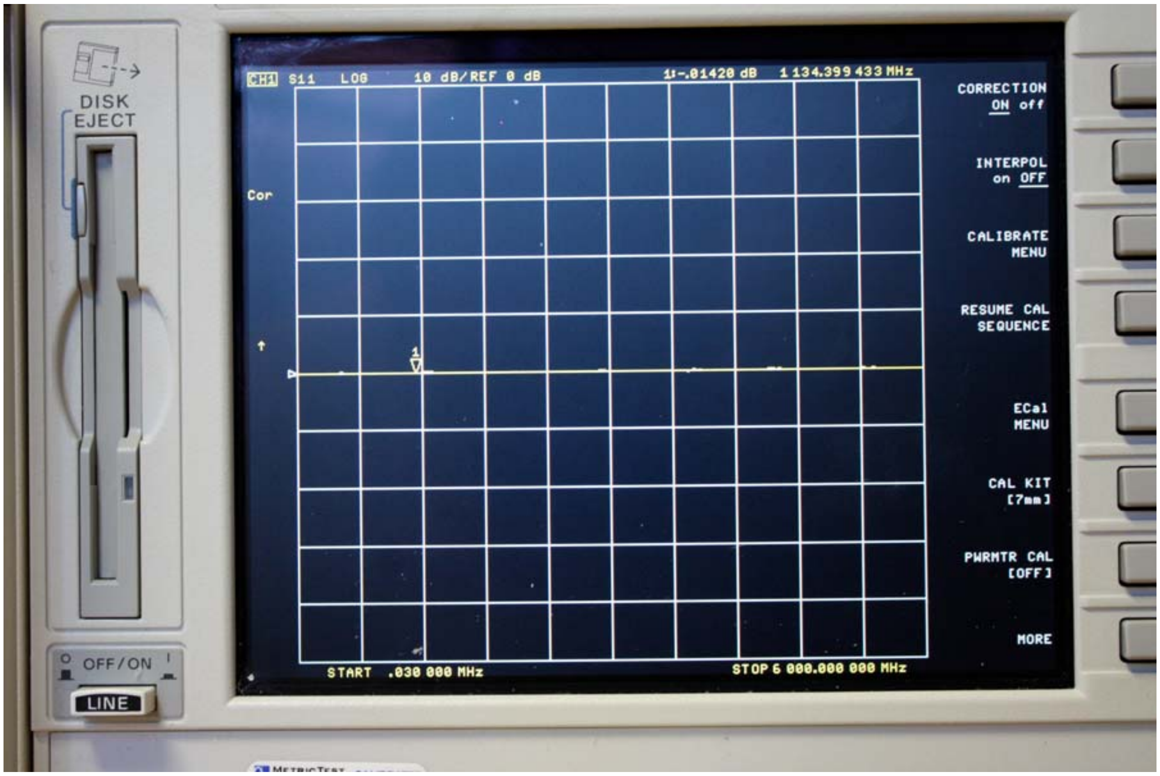

Figure 2 - Calibrated Analyzer

I tested the performance of both Irene boards (rev A & B):

(A) 1mm thick
(B) 0.062" thick

In this write-up, I'm really concentrating on the log magnitude plots because they provide a really easy to understand visual indicator of the tuning of the antenna across a broad range of frequencies. However, there are other metrics such as smith charts and VSWR plots which provide more insight when considering the impedance and reflection characteristics of the antenna. I took pictures of those plots, but omitted them from this write-up to keep things concise.

Test 1: Board (A) (1mm thick)

I hooked the first board up to the analyzer and plotted the reflected power in a log magnitude plot. I had the analyzer track the minimum, which turned out to be at 2.49 GHz (Figure 3).

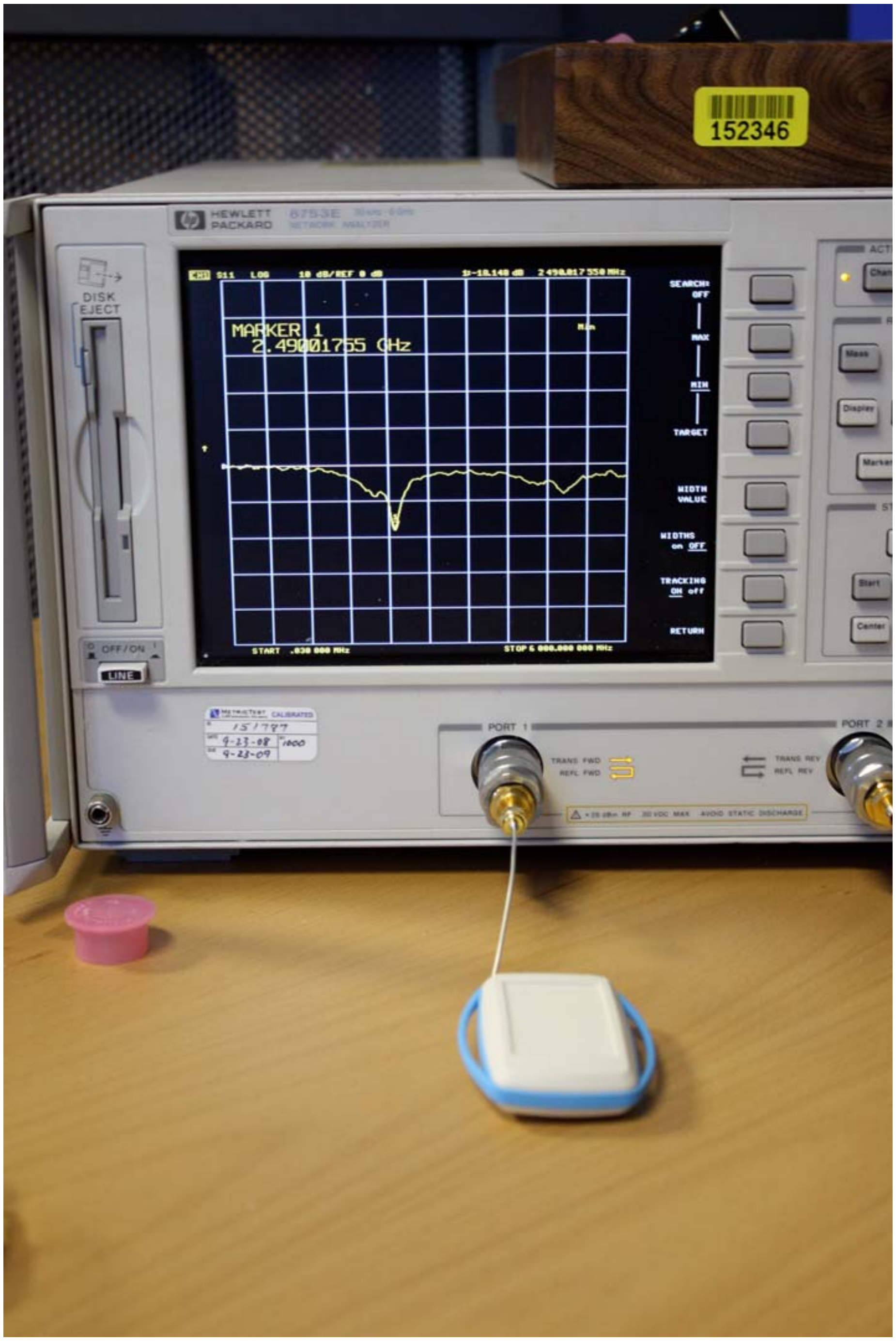

Figure 3 - (A)'s reflected power tracking minimum (log mag)

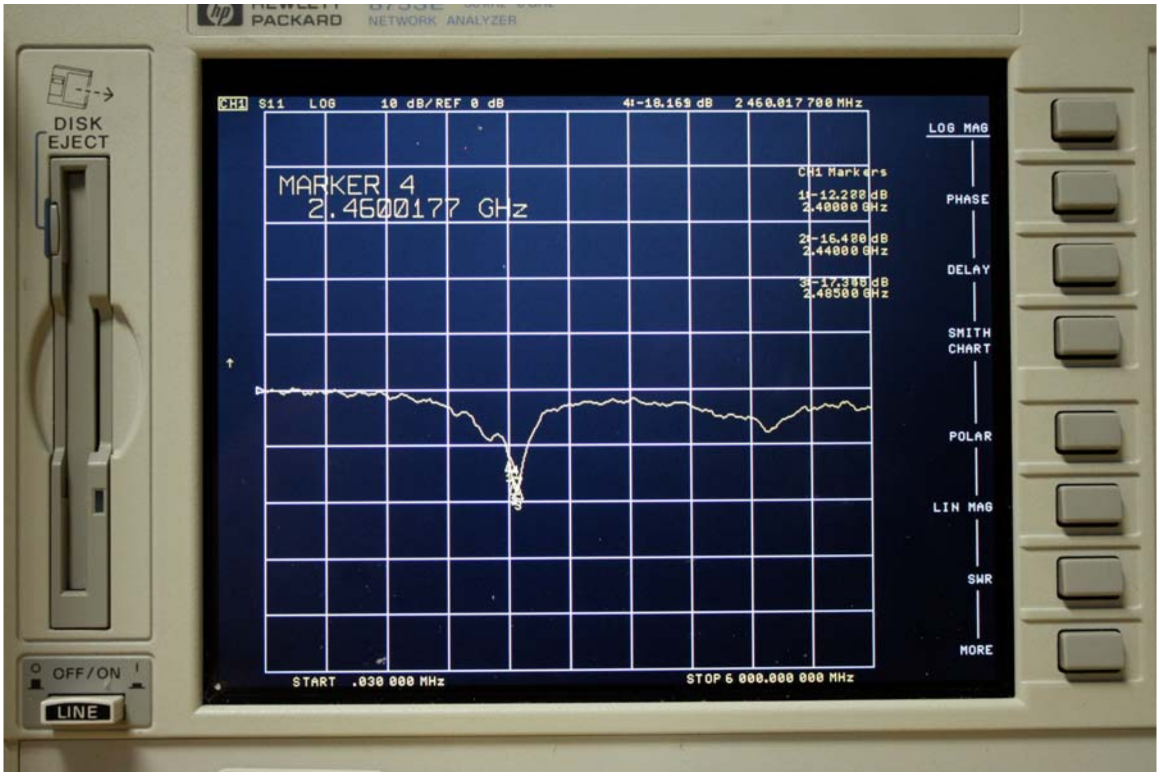

Figure 4 - (A)'s reflected power tracking minimum, markers at 2.40, 2.44, 2.48 GHz (log mag)

Summary for board (A):

It looks like the antenna is tuned pretty well for the 2.4 GHz band (-12dB at 2.40 GHz, -16dB at 2.44 GHz, and -17dB at 2.48 GHz), but it's not ideal. Since I couldn't lengthen the antenna, I couldn't try to improve performance by tuning it.

Test 2: Board (B) (0.062" thick)

Now on to the second board… I had the analyzer track the minimum on this board too, which turned out to be at 2.25 GHz (Figure 5).

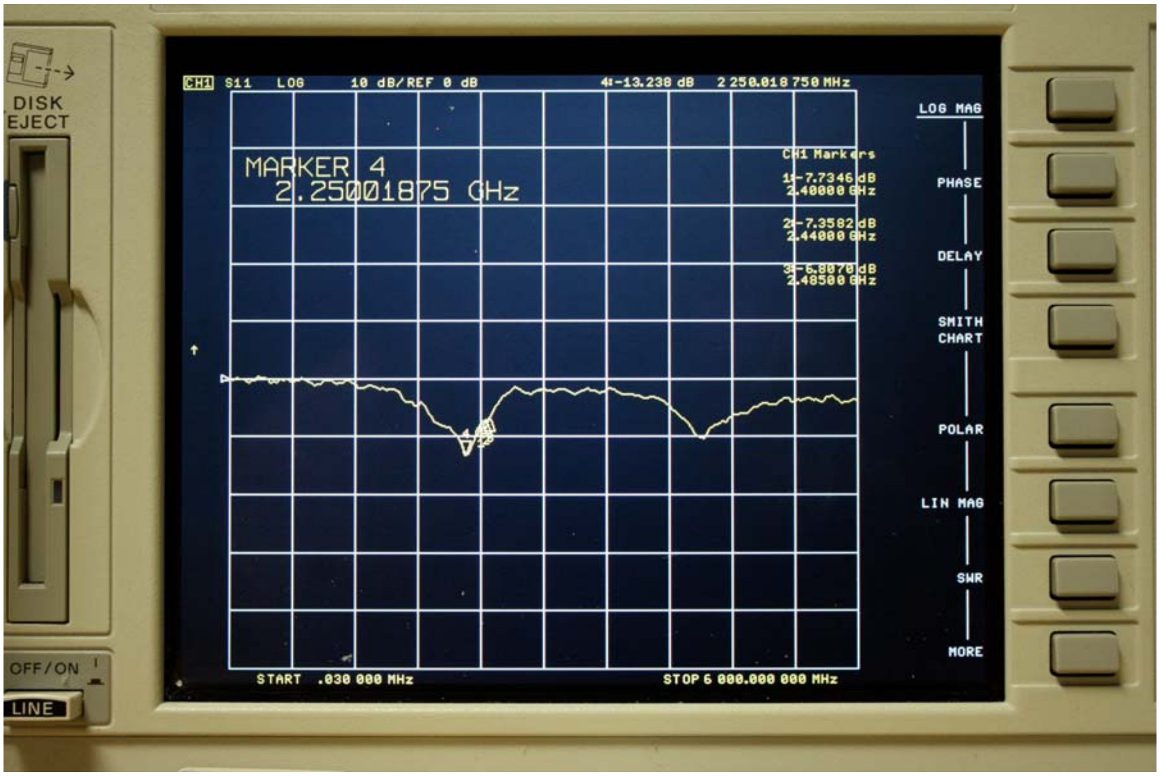

Figure 5 - (B)'s reflected power tracking minimum, markers at 2.40, 2.44, 2.48 GHz (log mag)

As you can see in Figure 5, the 2.4 GHz band begins about half way up the right side of the first valley from the valley's minimum point, and continues to get worse as the frequency increases.

Test 3: Board (B) without the enclosure

Interestingly, by taking (B) OUT of its enclosure and letting it float in the air, the antenna performance changed significantly. The valley minimum shifted up to about 2.45 GHz, with reflected power about -11 dB at that point (Figure 7).

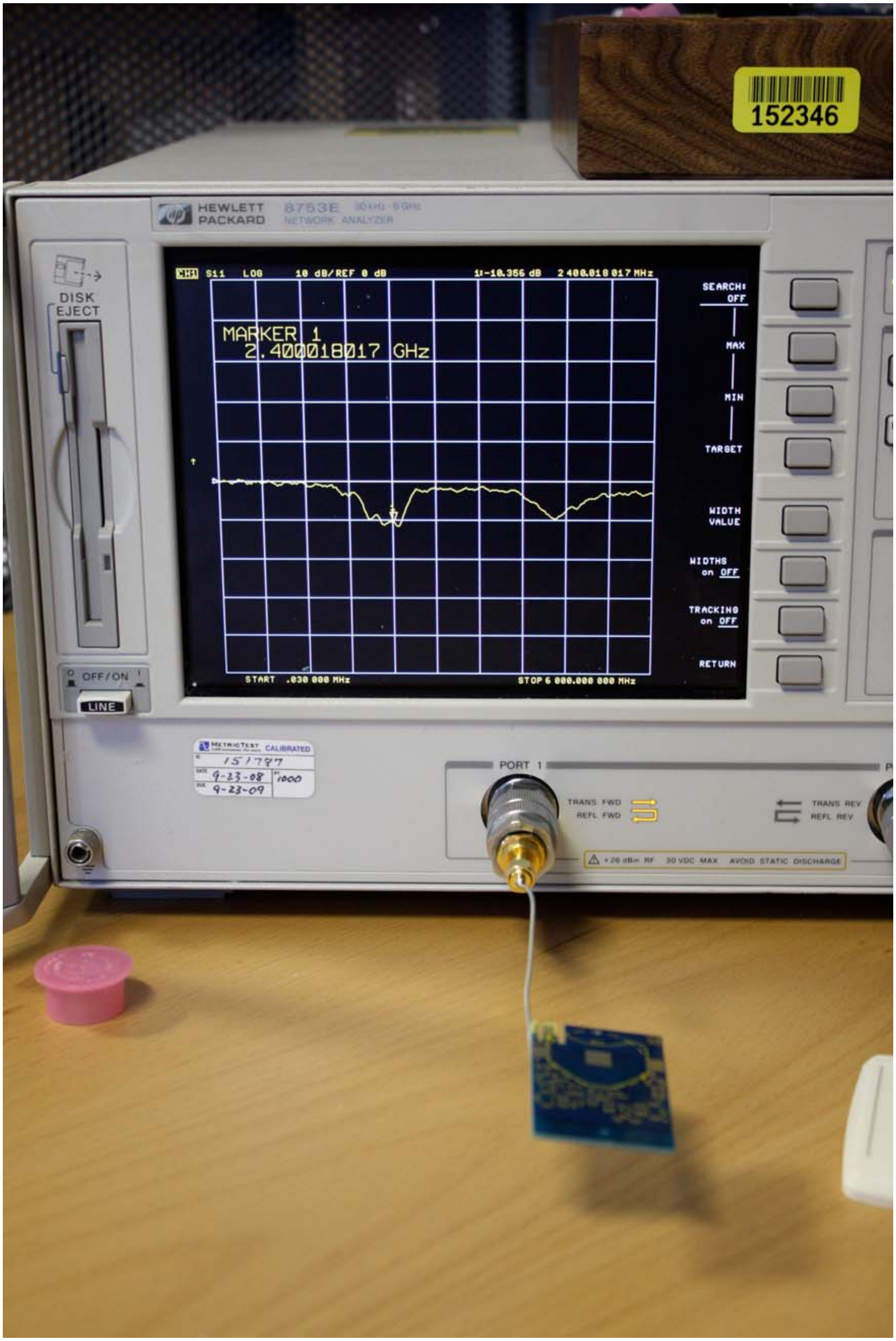

Figure 6 - (B)'s reflected power at 2.40 GHz (removed from enclosure, log mag)

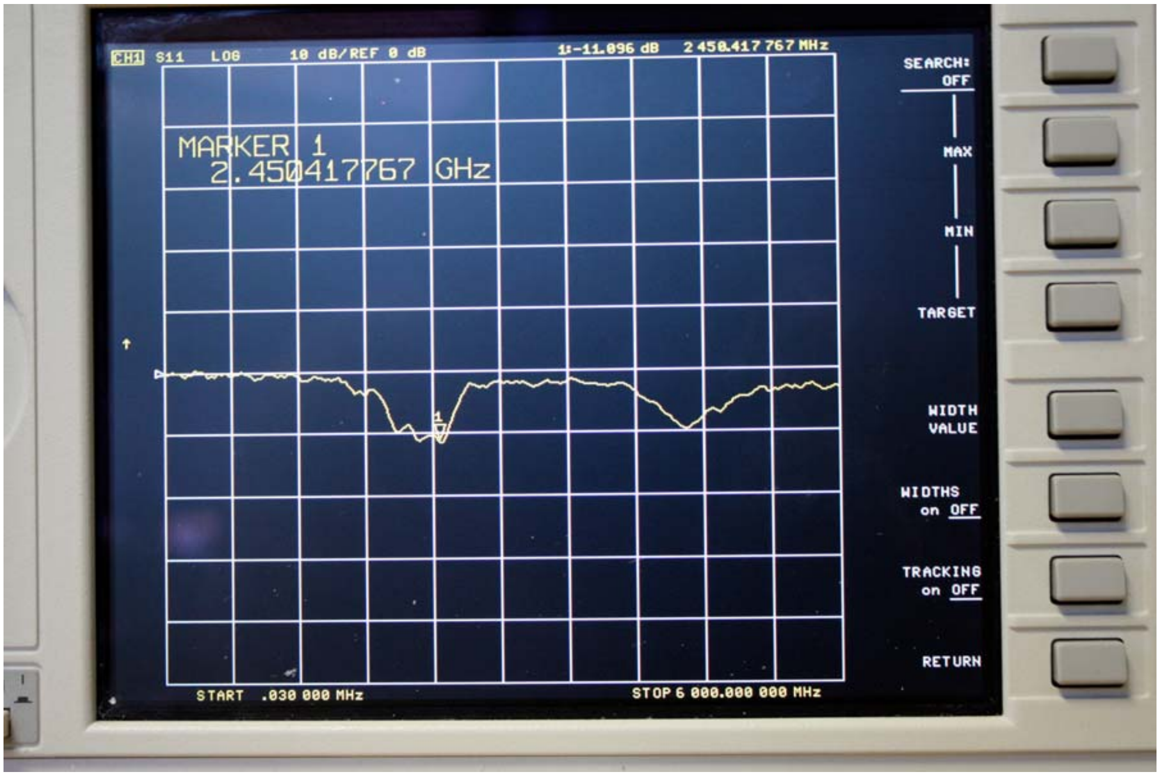

Figure 7 - (B)'s reflected power at 2.45 GHz (removed from enclosure, log mag)

Summary for board (B):

When seated within the enclosure, it appears that the antenna is actually a bit too long. At 2.40 GHz it's -7.5 dB, at 2.45 GHz it's -7 dB, and at 2.48 GHz it's at -6.5 dB. When taken out of the enclosure, the valley shifts up and reflected power decreases to -11 dB.

Test 4: Board (B) with reduced antenna length (~25mm), in its enclosure

By trimming off a bit of the antenna tip on board (B), I was able to shift the valley "up" by a couple tenths of a GHz to center around 2.46 GHz, improving the performance in the 2.4 GHz range.

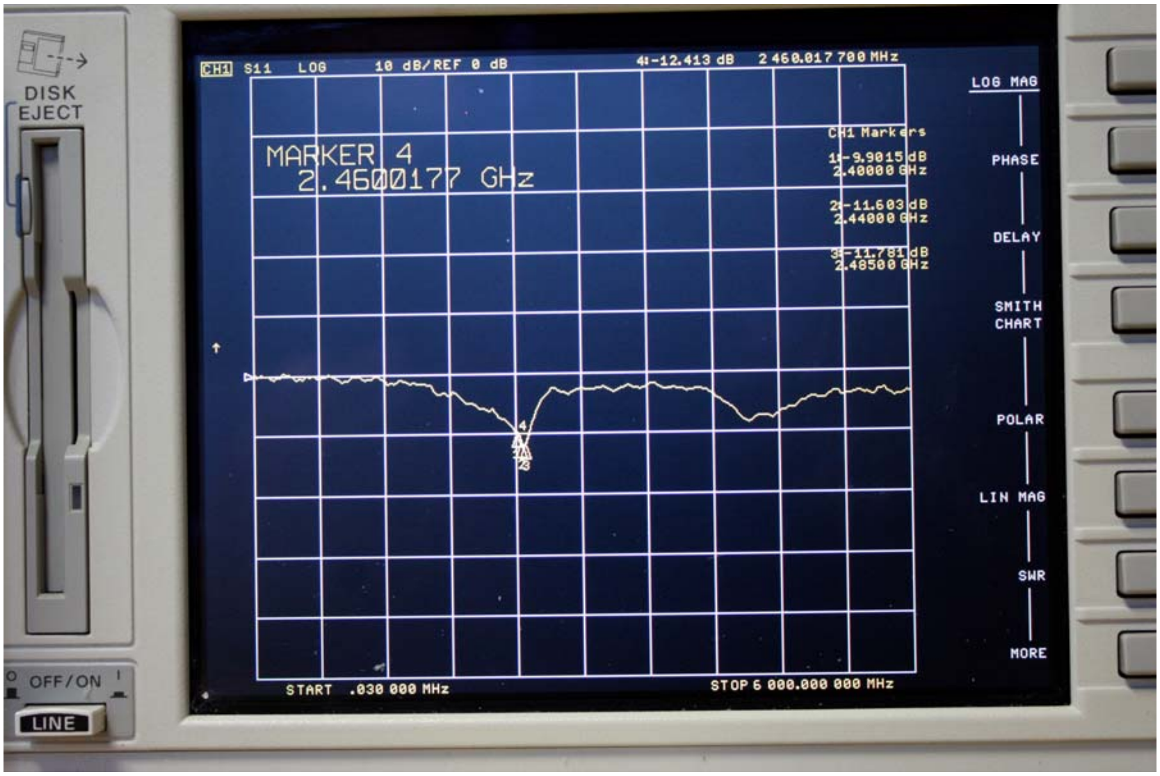

Figure 8 - (B)'s reflected power tracking min, markers at 2.40, 2.45, 2.48 GHz (log mag)

As you can see in Figure 8, reducing the antenna length shifted the valley minimum “up” to 2.46 GHz. The reflected power at 2.40 GHz is -10 dB, at 2.44 GHz is -11.6 dB, and at 2.48 GHz is -11.8 dB. This is about a 4 dB reduction in reflected power back into the analyzer from the default Irene rev B within an enclosure.

Test 5: Board (B) with reduced antenna length (~25mm) in its enclosure on a human wrist

Since Irene can be strapped to a human, I was curious to see what affect my wrist had on the antenna performance (using my modified Irene B with a shorter antenna). Turns out it works great! At 2.40 GHz it was -20 dB, at 2.44 GHz -30 dB, and at 2.48 GHz -20 dB (see Figure 9).

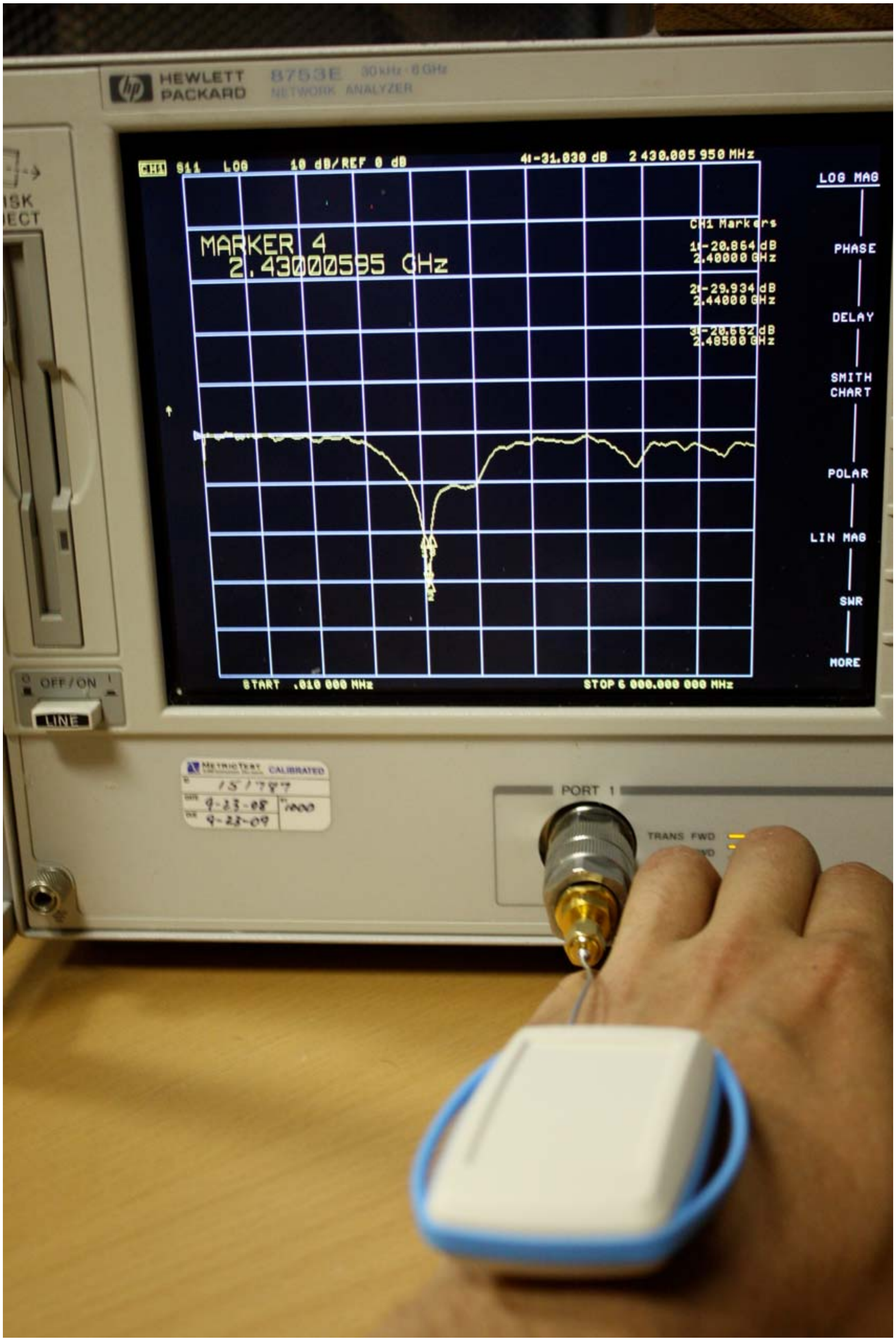

Figure 9 - reflected power board (B) with shorter antenna strapped to my wrist

Summary:

It appears that the Irene rev A performs significantly better in the 2.4GHz band than Irene rev B. The Irene rev A requires almost no tuning to achieve great performance. In fact, in testing a second Irene rev A board, I got even better results than in “Test 1” (-13 dB at 2.40 GHz, -21 dB at 2.44 GHz, and -25 dB at 2.48 GHz). By shortening the Irene rev B antenna to ~25mm, I was able to increase performance by 4 dB. However, I only tried to tune a single Irene B board (by hand), so there is still room for improvement by more precisely tuning the antenna length and the width of the antenna’s RF feed.