Application Report

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Antenna Matching for the TRF7960 RFID Reader

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1 Introduction

This paper describes the design method for determining an antenna matching circuit. While there are an infinite number of possible impedance matching networks, this application example focuses on a 50-Ω three element match. A three element match is recommended as it allows the designer to select the required antenna quality factor, Q, for the application.

The PCB design used in this application is based on FR4 material, Er = 4.5, with a material thickness of 0.062 inches. The board design is 2 layer design (layer 1 top, & layer 2 bottom), with 2 oz copper.

2 Antenna Fabrication

A schematic of a typical antenna circuit is given in Figure 1. The antenna trace width together with the trace spacing, will determine the antenna impedance and Q respectively.

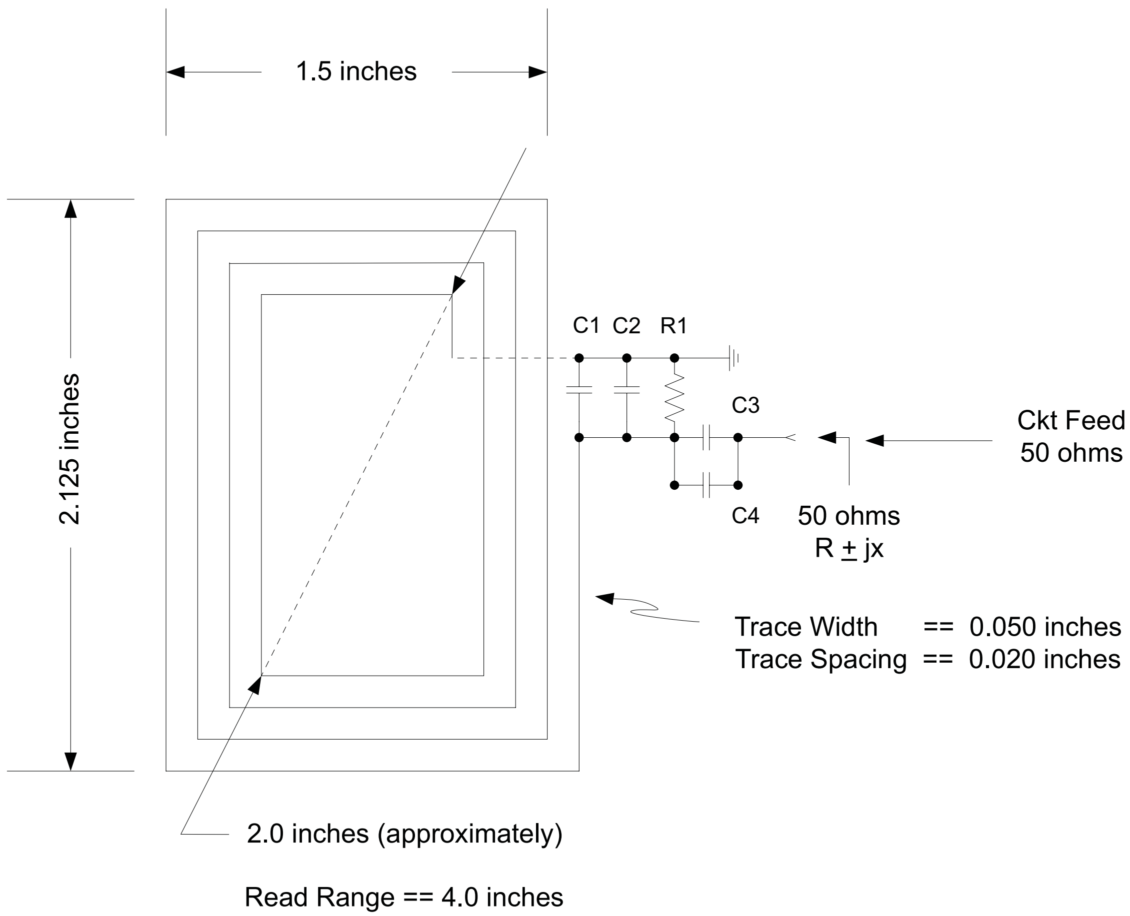

Figure 1. RFID Antenna (Typical)

In this application, the antenna is fabricated on the top side of PCB. Some antenna designs will have antenna traces on both top and bottom layers. In either case, it is important to keep ground planes away from antenna traces or elements.

Notice that the antenna drawing (Figure 1) shows a diagonal measurement of approximately 2.0 inches. A rule of thumb is that the expected read range is twice the antenna diagonal measurement.

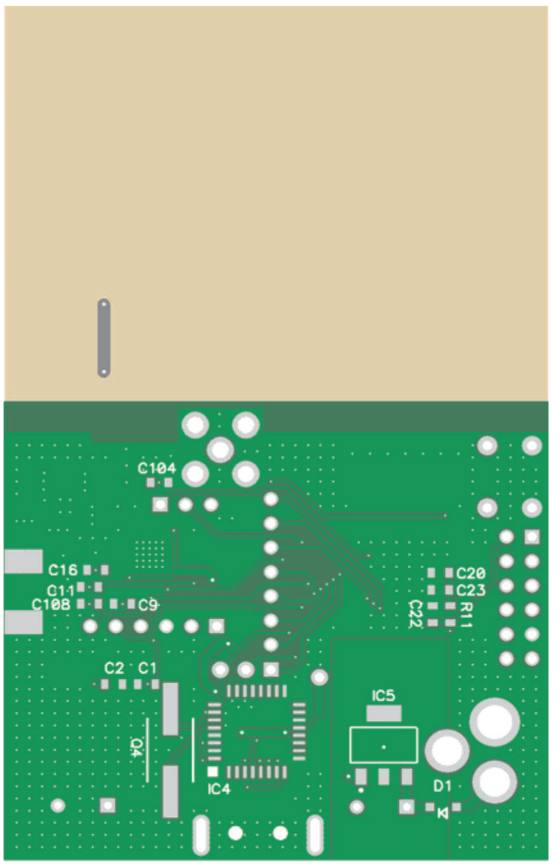

Figure 2. Antenna Bottom Layer

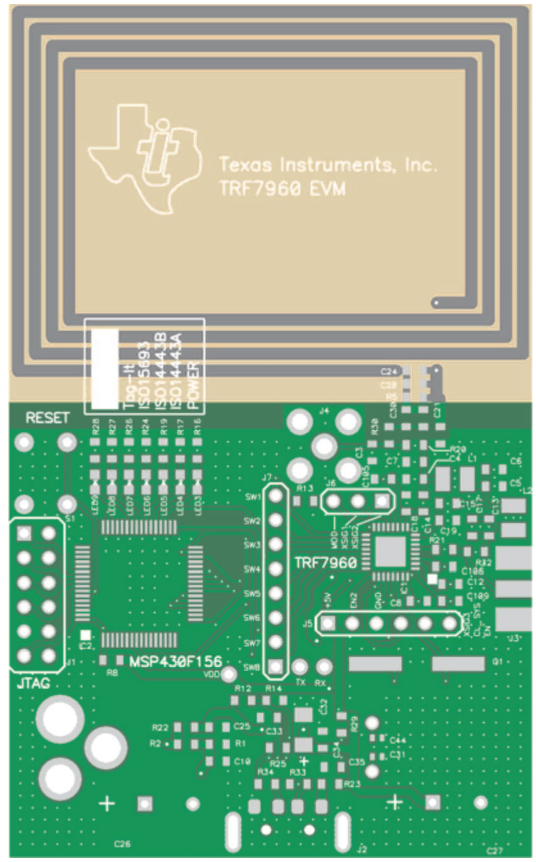

Figure 3. Antenna Top Layer

3 Antenna Impedance Matching

A three element match is used as it has the added advantage of allowing the circuit Q to be a chosen value.

$$Q = F_O/BW = 13.56\ MHz/2\ MHz = 6.78 \quad (1)$$

Where the required operating bandwidth is chosen at 2 MHz.

The first step in impedance matching is calibrating the network analyzer. This is done by connecting a RF test connector on three blank circuit boards, one with a 50 load, second with a short (0-Ω resistor), and third with an open. By using the application board in the calibration, PCB parasitic effects are accounted for.

Following the calibration step, the antenna trace is connected to the test connector as required by 0-Ω resistors. The antenna trace is measured as shown in Figure 4; the resulting measurement is the starting impedance which will be matched to 50 Ω.

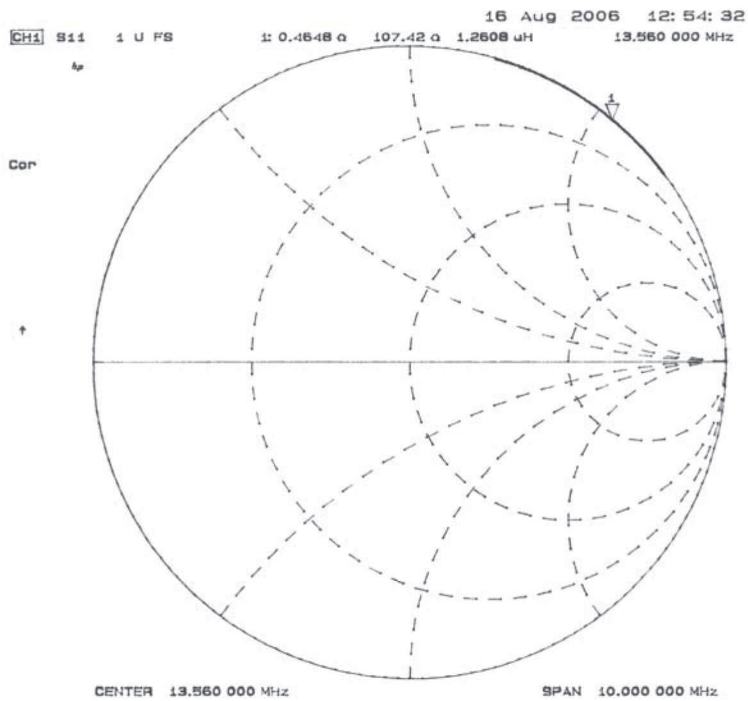

Figure 4. Antenna Impedance = = (0.4648 Ω + j107.42) = = 1.2608 µH

The measured antenna impedance (0.4648 + j107.42) at 13.56 MHz is shown in Figure 4. Note that in this application the antenna impedance is at the Smith Chart's outer limit; or other wise stated the starting impedance is up against the rail. This makes the impedance matching a little more difficult.

A minimum bandwidth (BW) of 2 MHz is chosen in order to accommodate the upper and lower RFID sidebands for various data rates given in ISO15693 & ISO14443 A/B. Hence the approximate resistor value needed is determined as follows:

$$Q = F_O/BW = 13.56\ MHz/2\ MHz = 6.78 \quad (2)$$

$$Q = R_P/X_L = R/2 \times \pi \times 13.56\ MHz \times 1.2608\ \mu H = R/107.42 \quad (3)$$

Note that the X_L value is the same as the measured Smith Chart value (107.42) from Figure 4.

$$R_P = Q \times X_L = 6.78 \times 107.42 = 728\ \Omega \quad (4)$$

Figure 5 is a Smith Chart impedance matching simulation.

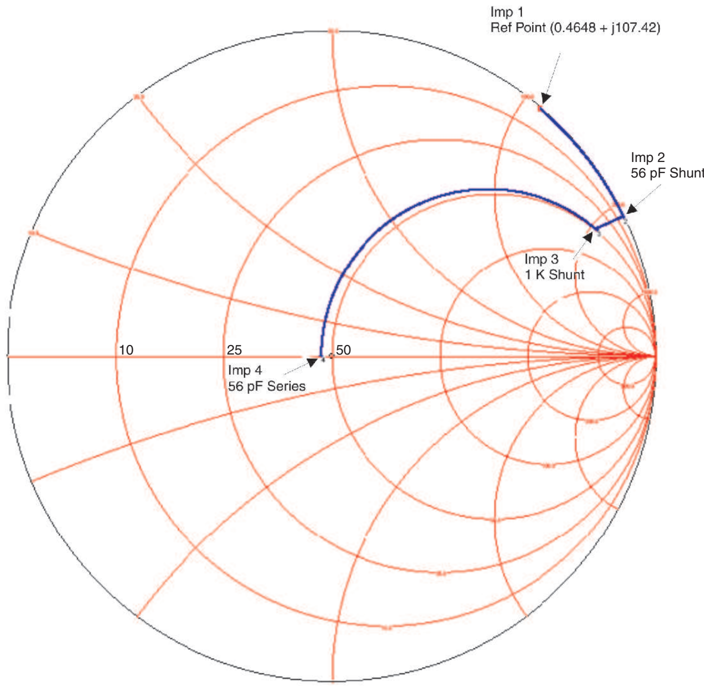

Figure 5. Smith Chart Impedance Match Simulation

The measured impedance from Figure 4 is shown in Figure 5 as Imp 1. A shunt 56-pF capacitor rotates the impedance to Imp 2. Next a shut resistor (which sets the antenna Q or BW), rotates the impedance from Imp 2 to Imp 3; where the impedance is now on the 50-Ω circle. The final matching element is a 56-pF capacitor, which rotates the impedance from Imp 3 to Imp 4 (46.6 + j0.3). This capacitor is split into two parallel caps (47 pF + 10 pF) to allow fine tuning of the antenna frequency while also reducing component parasites.

Note earlier the shut resistor was calculated to be 728 Ω whereby it is now rounded to up to 1.0 KΩ in order to yield a match with standard capacitor values.

Final circuit values for the antenna circuit given in Figure 1 are as follows:

C1 = = 56 pF

C2 = = DNP (Do Not Place)

R1 = = 1 .0 KΩ

C3 = = 47 pF

C4 = = 10 pF

4 Antenna Performace

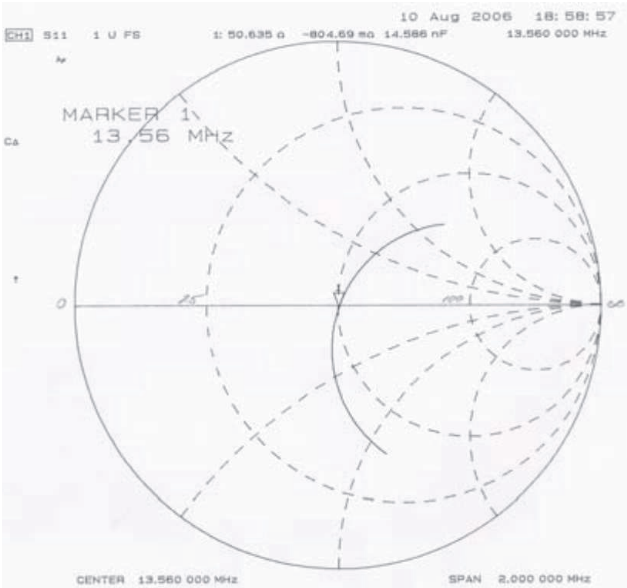

Figure 6. Smith Chart
(50.635 - j804.67) = = 14.586 nF

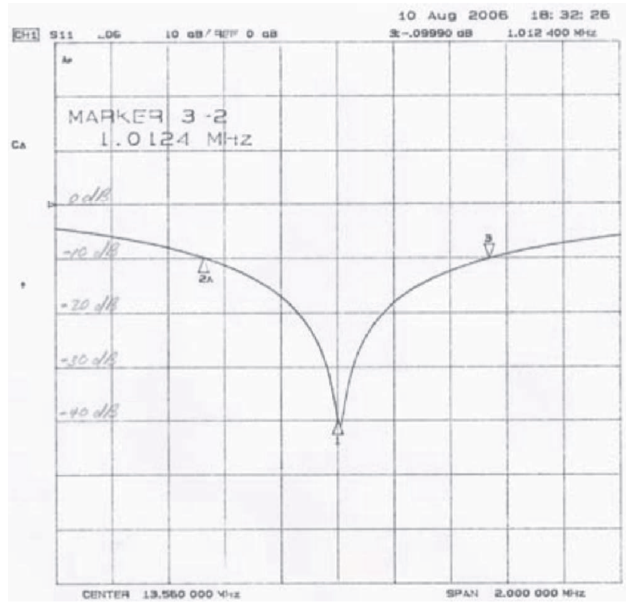

Figure 7. Return Loss
(RL = 40 dB at 13.56 MHz)

Note that Figure 7 shows a 10 dB return loss over a 1.0124-MHz BW (Mkr 3-2). A rule of thumb is that the antenna 3-dB BW is twice the 10-dB return loss bandwidth. Applying the rule to this application would yield an antenna bandwidth of 2.248 MHz.

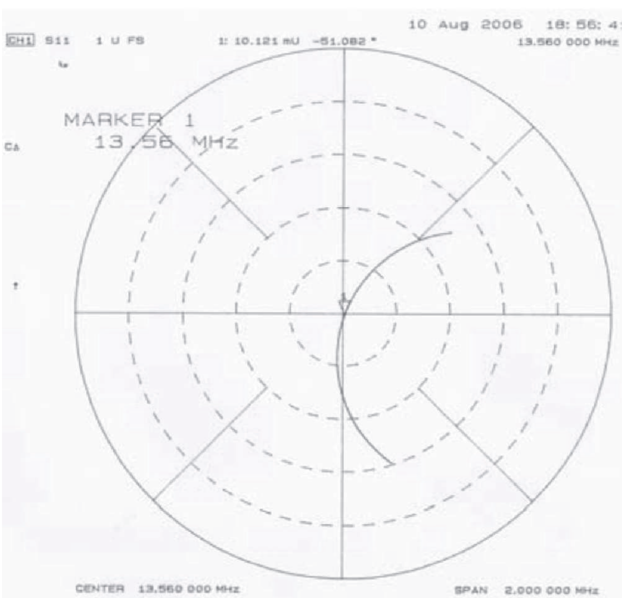

Figure 8. Polar Plot

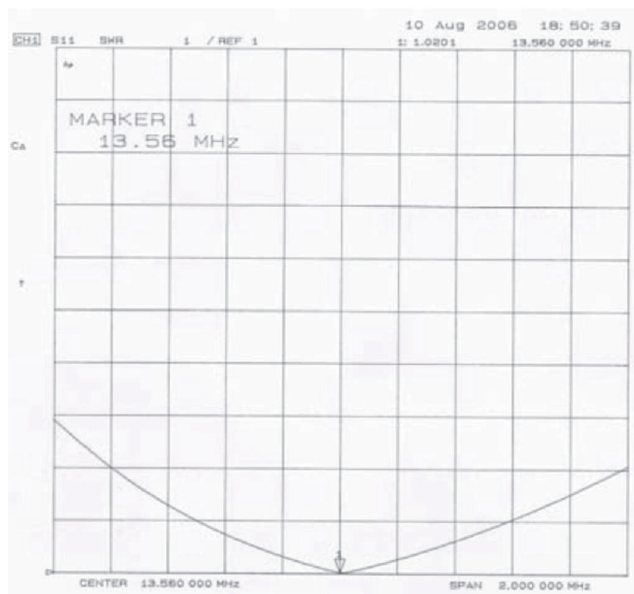

Figure 9. VSWR Plot

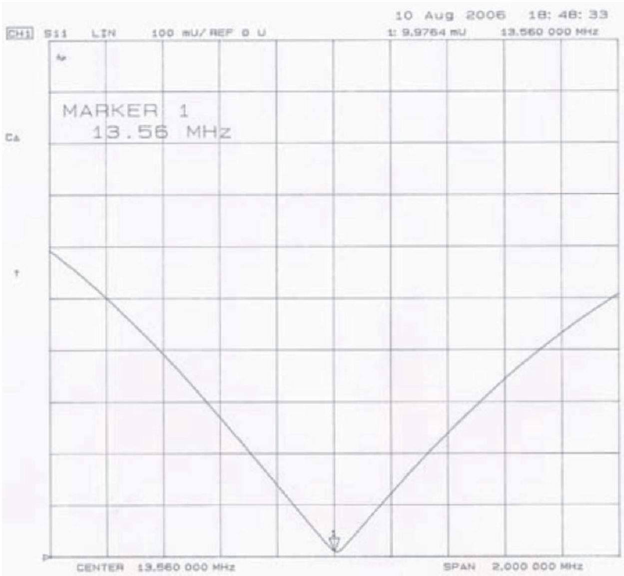

Figure 10. Linear Plot

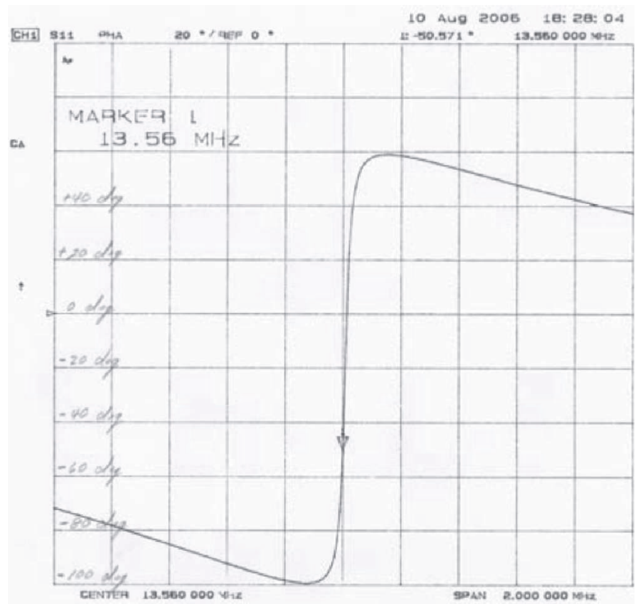

Figure 11. Phase Plot

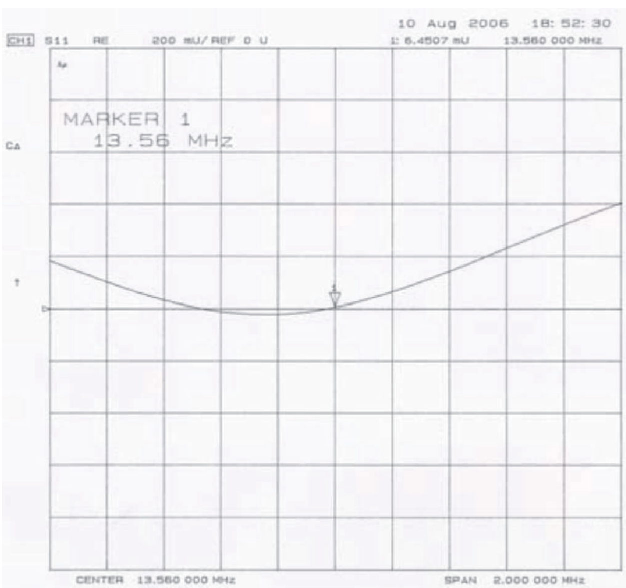

Figure 12. Real Part

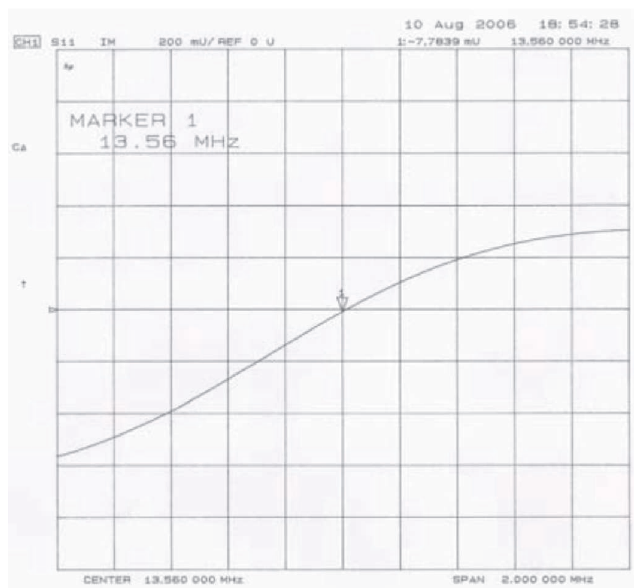

Figure 13. Imaginary Part

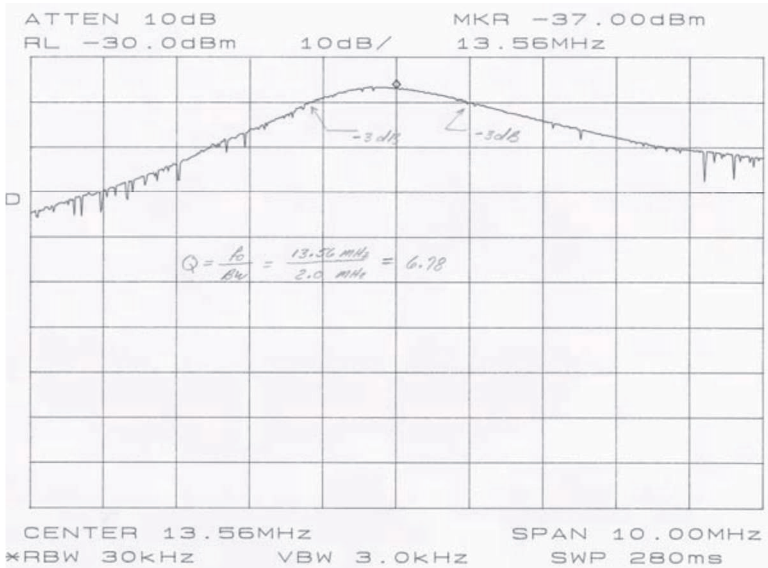

Figure 14. Measured Antenna Bandwidth and Q

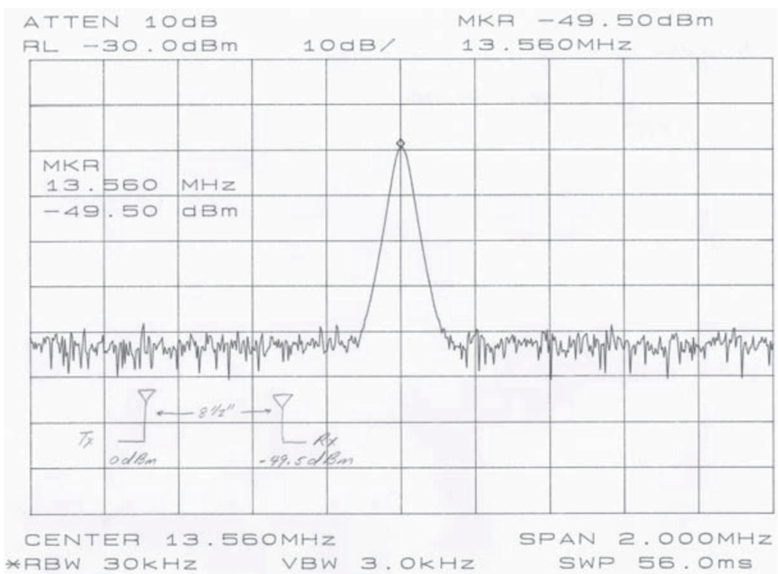

Figure 15. Antenna Transmission Test

As a final test to ensure the antenna elements will radiate, a test set up was established. A 0-dBm CW signal is applied to the Tx antenna; the Rx antenna is placed 8.5 inches from the Tx antenna (the width of a standard piece of office paper). The output from the Rx antenna is measured on a spectrum analyzer which shows a –49.5-dBm signal level. Both Tx & Rx antenna are PCB RFID reader antennas.

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