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## Introduction

Electronic devices comprising transmission lines coupled with antennas have many applications in modern society. Such devices are configured to transmit and receive electromagnetic (EM) waves. This facilitates microwave communications (e.g., global positioning systems used for navigation), wireless communications (e.g., cell phones, remote controls, keyless entries into automobiles) and many other applications.

Implantable devices need the ability to communicate with other devices for maintenance, repair, and gathering of statistical information such as heart beat and blood pressure. Wireless transmission through the body is more convenient and a more reasonable method for gathering information, improving the mobility and the peace of mind of the implanted individual. In this lab, a network analyzer was used to gather information about the characteristics of an antenna. Later this information can be adapted to an implantable device to allow for wireless communication to take place.

The main purpose of this experiment was to understand how to: 1) gain a working knowledge of using a network analyzer to measure the impedances of a line(s) and load(s); 2) design an antenna; and 3) build a matching network, comprising: a source, multiple transmission lines, and an antenna.

## Method

A HP8720C Network Analyzer with a 50Ω coax was calibrated and employed to measure the impedance of a monopole antenna coupled to one end of a microstrip line at a frequency of 440MHz. Calibrating the network analyzer is important so that the network analyzer knows what kind of transmission line is connected and can give more accurate measurements about its load.

After calibrating the analyzer, a very narrow copper adhesive strip was attached to build a quarter-wave monopole antenna. Then, the "port extensions" option in the analyzer was activated. This enabled the power to be delivered through the 50Ω coax and microstrip lines to the antenna.

More, a microstrip stub having an optimal length was built and placed substantially normal to the line coupled to the antenna to aid in designing a matched network. The objective was to tune the antenna at 440MHz by reducing the length of the antenna such that any reactive impedances of the antenna would be ideally eliminated. This ensured a successful design of a matching antenna network.

A graphical user interface, in the form of a desktop computer application program, was used to capture the impedance measurements and plot them on a graph, as shown in the Figure (see next page).

Despite trimming the antenna (~ 17.5 cm) to eliminate the reactive part of the load impedance, the impedance of the antenna still had a small imaginary component. Possible sources for error in these results may be attributed to: the antenna being bent in various points thereon, taking measurements close to the analyzer, internal impedances of the equipment, and electromagnetic interference.

Don't forget main objective to minimize $S_{11}$

## Results

Table 1.1 shows the measured distance of stub from antenna and stub length vs. calculated.

**Table 1.1 - Measured Distance and Length vs. Calculated**

| | Measured (cm) | Calculated (cm) | Delta (%) |
|---|---|---|---|
| Distance of Stub from Load | 6.5 | 7.5 | 15.0% |
| Stub Length | 2.1 | 3.4 | 62.0% |

As shown in Table 1.1, our Smith Chart calculations of the distance and stub length varied from the values we measured. Using our calculated values, the impedance mismatch was not eliminated completely. A match was successfully obtained with a 2.1cm stub positioned approximately 6.5cm from the antenna, positioned normal to the TL. A reason for the variances may be attributed to potential errors with using the Smith Chart and with imprecise width measurements of the copper strip.

Table 1.2 shows a Magnitude of S11 vs. frequency.

**Table 1.2 - Magnitude of Reflection Coefficient (S11) vs. Frequency**

| Frequency (MHz) | 420 | 440 | 460 |
|---|---|---|---|
| Magnitude of S11 | 0.216 | 0.101 | 0.396 |

Table 1.2 shows a measurement of the amount of an electric signal is being reflected back from the antenna at 420MHz, 440MHz, and 460MHz, respectively. The fact that S11 was measured close to zero at 440 MHz indicates that the match is almost perfect, but not quite.

The figure below depicts a plot of the antenna's normalized impedance at 440MHz. Its value of 50*[0.843 + j0.099]Ω = 42.1+j4.95Ω varied from an expected value of 36.5 +j0Ω.

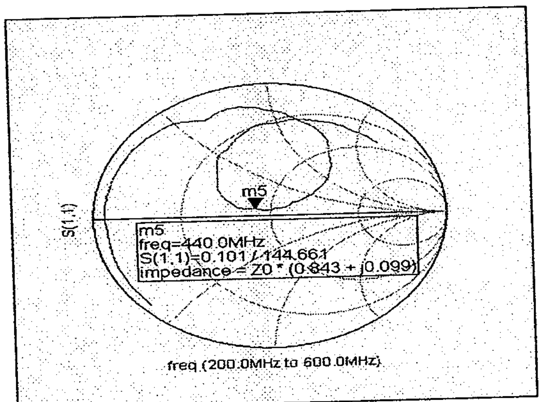


Figure – Plot of Normalized Voltage vs. Time

This slight variation may have occurred due to the following factors causing the analyzer's reflection coefficient (Γ = S11) to be mismatched with the 50Ω line. This mismatch may be caused by the following factors: the internal source impedance of the analyzer; the sensitivity of the network analyzer associated with measurements being taken too close to the analyzer; and imperfect properties of the 50Ω line itself.

In addition to the measurements documented in this report, the following measurements were recorded in lab notebooks: dimensions of the 50Ω line; power reflected at 420MHz, 440MHz, and 460MHz, and magnitude of S11 at 420MHz, 440MHz, and 460MHz.

## Conclusion

In this lab, impedances and reflection coefficients were measured after calibrating a HP8720C Network Analyzer. The measurements were crucial in the design of a single stub matching network.

It was observed that the calculated stub length of 3.4cm was approximately 62% larger than the measured length of 2.1cm. In addition, the stub was calculated to be approximately a distance of 7.5cm from the antenna. This distance calculation was 15% larger that the measured distance of 6.5cm. The differences between the calculated and measured values may be attributed to the use of an imperfect Smith Chart to calculate the values and there may have been wrap-around since the impedance of the lines is described as an arctan, it is repetitive. It is likely that the length of the stub used was longer than necessary and a shorter stub length could have been found, time permitting.

Units

More, it may be inferred that the magnitude S11 increased with frequency with the exception of 440MHz. The S11 values measured 0.216, 0.101, and 0.396 at 420MHz, 440MHz, and 460MHz respectfully. Given the fact that only three measurement values were recorded in the experiment, more experimentation is needed to support a conclusion a trend.

Impedance matching a system involves the use of a network analyzer to measure and graphically depict the impedance characteristics of lines and loads. This enables engineers to employ techniques to eliminate reactive load impedances, allowing impedance matching using a stub with real impedance.

Using the network analyzer to match impedances of the source(s), line(s), and load(s) can virtually eliminate wave reflections and standing waves that minimize the magnitude of power that may be delivered by a source, through a transmission line, to a load. Employing the network analyzer to measure impedances can help in the optimal design of matching networks and other electronic systems.

An impedance matching network will be needed for wireless communication with the cardiac pacemaker circuit. This network will need to allow maximum power transfer from the pacemaker to an external device and from the external device to the pacemaker. The skills learned in this lab will enable all of its participants to develop the required impedance matching networks for the circuit.