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Development of a Wave Propagation model in a Lossy Transmission Line

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ABSTRACT

Technology has developed in several ways to improve the way of life, one of them is by being able to transmit information from one point to another. This is no easy task as different problems may arise in transmitting information through a transmission line. One of the problems that may be encountered in transmission lines is the standing waves. Standing waves may damage transmission lines when very high maximum amplitudes pass through. Simulations in MATLAB can be performed by determining the behavior of the standing wave in a transmission line and observing what are the factors that may affect how it travels concerning distance. It can also be observed that when a certain variable is changed, there is a specific part of the output value or the waveform that will also change. Understanding these waveforms are important as transmission lines are a vital part of transporting information to distant places or around the country or internationally.

Key words: Transmission line, Standing wave, Standing wave ratio, Attenuation constant, Impedance, Impedance matching.

1. INTRODUCTION

In a world where information has become the center of life, an engineer must figure out how to transmit this information or data from one point to another. The key to understanding this is to first understand how transmission lines work [1].

A transmission line is a very long wire that is used to connect to devices that can transmit information such as an antenna. Since we are dealing with both electricity and information that it carries, it is important to know what are some interferences or noise that may occur as well. In a transmission line, it is possible that some of the power delivered may be reflected in a transmission line. [2,3,4] Although not necessarily a bad thing, it may sometimes pose as a hazard or as a liability to have big amplitudes of these signals coming back, at some points along the transmission line, it may be dangerous as it may cause damage to the line or overloading of the source [5].

As one can see, although standing waves are not a bad thing, it is important to limit the standing waves to not have spikes of peak maximum values to protect the circuit from being damaged. This is important because it would not be ideal of efficient to have a system always being under repair because of something that can be avoided. Therefore, understanding how transmission lines work and how standing waves have an effect on how signals are sent is important especially in the world we live in today because these transmissions would now be data-heavy and it is a requirement that these lines are always working in their best condition to be able to propagate important information to various places [6].

The development for these transmission lines is now being implemented using integrated circuit technology, and since the integrated circuit is continually being developed; there are improvements for the transmission of signals, and for different modes, there are equivalent ways on how to study the behaviors of a certain transmission mode depending on the line used [7,8].

2. BACKGROUND OF THE STUDY

Standing waves are caused when the impedance of the line does not match the impedance of the load, this means that not all power is consumed by the load at the end of the circuit. Some of the signals that are sent through the transmission line reflect the source, although standing waves are not exactly harmful, some spikes in the amplitude in either current or voltage in the circuit may cause overloading for some loads if not properly managed. Therefore, impedance matching is a big part of understanding how transmission lines should be designed, as well as how to operate and troubleshoot the circuits if needed [9].

Impedance matching is important for transmission lines as it can determine how much power will be used by the circuit, and how much will be wasted or reflected the source. It can also be seen that standing waves are affected by different frequencies, the higher the frequencies the more it will occur, it can later be seen that the frequency is proportional to the standing waves present in the transmission lines. This is because the behavior of the signal that goes through a transmission line is affected by frequency. Standing waves are also affected by how much power you apply to the transmission line, the power applied to the transmission line will be proportional to the reflected waves in the transmission line [10].

Standing wave ratio (SWR) is also a part of this transmission line study as SWR relates the characteristics and the load impedance. The value that will be acquired from the SWR will tell the programmer how matched the load and line impedance will be. The lower the SWR the better the performance since this would mean that the impedance of both the line and load is closely matched with each other. Therefore, it is important to match the load and line impedance as often as possible to refrain from having standing waves that may damage the equipment connected to the transmission line [11].

3. STATEMENT OF THE PROBLEM

Standing waves may cause problems to a circuit if not properly managed, and this is only that the impedance of the line does not meet or match the impedance at the load. The problem with having standing waves present in a transmission line circuit is that there are peaks of voltages that are present due to the reflection of the signals sent through an unmatched transmission line [12].

As stated, before in this paper, standing waves are not that problematic in a more general case, however, there may be instances wherein standing waves may cause damage to the load in the form of overloading. This happens because of the peak values of the reflected waves. Impedance matching is one of the factors to look at because it affects how much power will be taken in by the receiving end, and how much power will be reflected in the transmitting end. This can be seen in the equation of a standing wave ratio wherein the line impedance and characteristic impedances are both taken into account [13].

4. SIGNIFICANCE OF THE STUDY

The significance of this study is to further understand how transmission lines behave, in this case, lossy transmission lines. The study will allow further understanding of how standing waves behave through a lossy transmission line which changing factors like what happens when the attenuation constant is changed, what will be the estimated response of the transmission line.

This will also help understand how the changes in the load impedance and attenuation constant can also affect the input impedance present in the line. These are important to understand to be able to improve the maintenance, design, and troubleshooting of certain transmission lines. The basic concepts of these are helpful in practical applications to have a rough idea of how actual transmission lines should behave, and what are the expected output waveforms and standing waves that should be present.

Simulations using MATLAB is very useful for this study and tests are done by the researcher can be improved by future researchers who would want to improve the research's scope to help future generations in further enhancing the way we shape the world. Since this is a rather old technology, there are still improvements that can be done and can be further progressed to develop more efficient systems that will lessen any disturbances or interferences that are being experienced.

5. DESCRIPTION OF THE SYSTEM

The system is an open-circuited unbalanced transmission line. This would mean that all the signals from the transmitting side will be reflected from the receiver side back to the transmitting end where the standing waves will occur.
The code will be comprised of the time for the analysis to take place, the range of which the data will be analyzed, the attenuation constant that will affect the waveform produced, the impedances of the load and line. Other variables in the code are also there wherein one can change the frequency, voltage, and others within the code to understand the behavior of the standing waves in a transmission line.

The scope of this study will only differ the load impedance, attenuation constant, and the frequency given in a lossy transmission line. This is to further understand the behaviors or data that will be produced once a certain variable has been changed. These were selected because it was observed by the researcher that significant changes in the data occurred when these variables are being changed. The other variables are not as impactful on the data that is being observed by the researcher.

6. METHODOLOGY

MATLAB will be used as the programming medium because it is easy to code and understand, and all the required data can be acquired with just a press of a button. The code can also be easily altered to produce different results depending on what the researcher needs [14].

The code used composes of the input voltage, the chosen inductance, and capacitance per unit length, the phase and propagation constant, the desired frequency, time, and range for the analysis to be performed. The computations for the reflection constant and the standing wave ratio is also implemented into the code, this is for the researcher to understand the differences that may occur inside the circuit that is not necessarily seen on the waveform that will be produced by the program.

The characteristic impedance and load impedance can also be altered to determine the differences in how unmatched the transmission line is, or what will happen to the output when the line is matched. However, since the focus on this study is lossy transmission lines, the researcher did not match the line and load impedance to be able to observe the different outcomes present in the data [15].

7. THEORETICAL CONSIDERATIONS

The theoretical conditions that were considered were that the signal is being sent through a lossy transmission line and that it is an open circuit system. This is to ensure that standing waves will be present in the experiment that will be conducted. If the circuit is not an open circuit, then the standing waves will not be there, and the experiment will be pointless.

Another theoretical consideration here is that the load and line impedance should not be matched, this is to also provide a means of seeing how this changes the input impedance is being changed. This is because the lossy transmission line occurs if the load and line are unmatched.

The matching of the impedance is what allows the efficiency of the system because the matching of the line and load impedance is also a factor for knowing whether the power transmitted is being fully consumed and nothing is being returned to the transmitting end.

8. DATA AND RESULTS

8.1. Program Output

Figures 1 to 6 show the waveforms at different frequencies.

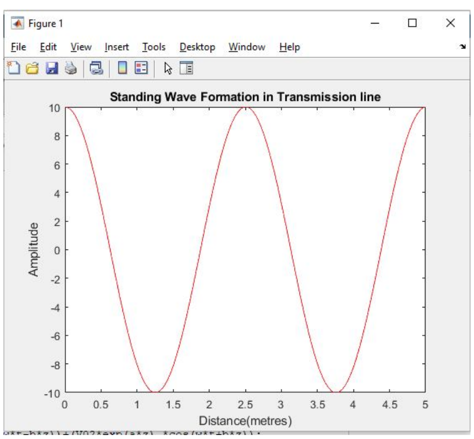

Figure 1: Waveform of 80MHz, ZL=0, a=0

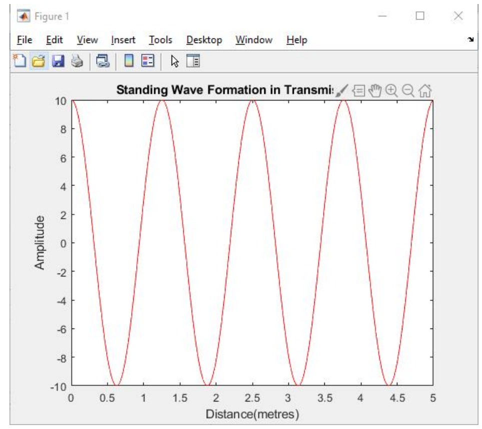

Figure 2: Waveform of 160MHz, ZL=0, a=0

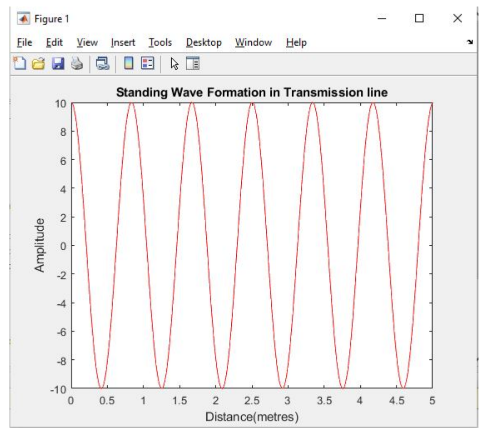

Figure 3: Waveform of 240Mhz, ZL=0, a=0

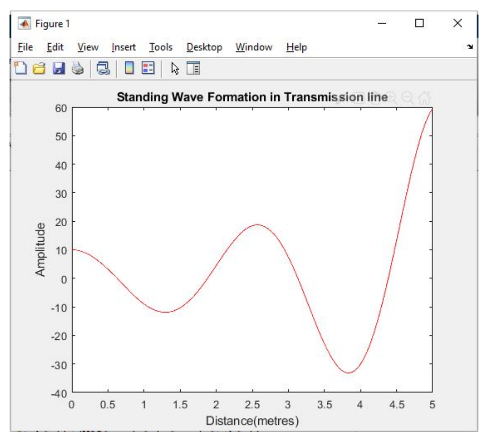

Figure 4: Waveform of 80MHz, ZL=75, a=0.5

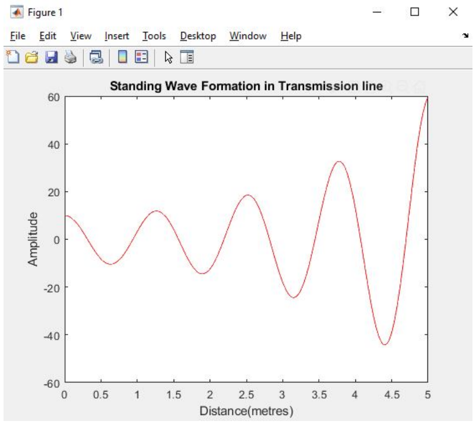

Figure 5: Waveform of 160MHz, ZL=75, a=0.5

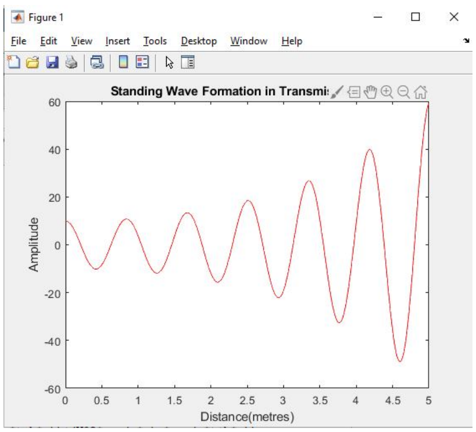

Figure 6: Waveform of 240MHz, ZL=75, a=0.5

Figures 7 to 15 show the data of the system at different frequencies.

```
Refection_Coeficient =

     1


Standing_Wave_Ratio =

   Inf


Input_Impedance =

   0.0000 - 5.7039i
```

Figure 7: Data of 80MHz, ZL=0, a=0

```
Refection_Coeficient =

     1


Standing_Wave_Ratio =

   Inf


Input_Impedance =

   2.9671e+02 + 1.5778e+01i
```

Figure 8: Data of 80MHz,ZL=0,a=0.5

```
Refection_Coeficient =

    0.6000


Standing_Wave_Ratio =

     4


Input_Impedance =

   3.1421e+02 + 9.3380e+00i
```

Figure 9: Data of 80MHz,ZL=75, a=0.5

```
>> Project_1

Refection_Coeficient =

     1


Standing_Wave_Ratio =

   Inf


Input_Impedance =

   0.0000 -11.3008i
```

Figure 10: Data of 160MHz, ZL=0, a=0

```
>> Project_1

Refection_Coeficient =

     1


Standing_Wave_Ratio =

   Inf


Input_Impedance =

   2.9905e+02 + 8.1216e+00i
```

Figure 11: Data of 160MHz,ZL=0, a=0

```
Refection_Coeficient =

    0.6000


Standing_Wave_Ratio =

     4


Input_Impedance =

   3.2415e+02 + 4.7452e+00i
```

Figure 12: Data of 160MHz,ZL=75,a=0.5

```
Refection_Coeficient =

     1


Standing_Wave_Ratio =

   Inf


Input_Impedance =

   0.0000 - 5.6605i
```

Figure 13: Data of 240MHz,ZL=0, a=0

```
Refection_Coeficient =

     1


Standing_Wave_Ratio =

   Inf


Input_Impedance =

   2.9949e+02 + 5.4438e+00i
```

Figure 14: Data of 240MHz,ZL=0, a=0.5

```
Refection_Coeficient =

    0.6000


Standing_Wave_Ratio =

     4


Input_Impedance =

   3.2970e+02 + 3.1596e+00i
```

Figure 15: Data of 240MHz, ZL=75, a=0.5

9. ANALYSIS OF DATA

It can be seen in the data that was acquired, that the standing wave formation is constant when the attenuation constant is at zero. It was observed that the load impedance had no bearing in the output waveform would be. It was, however, observed that as the frequency increases the standing wave formation would also increase with distance.

It was also observed that the theory holds wherein the signal that is produced and sent through a transmission line, there will be a reflected signal going back to it if it is an open-ended circuit. This is very evident in the data produced because as the waveforms present the amplitude of the standing wave is equivalent to the input voltage which is ten volts.

It can also be seen through the formula for the reflection coefficient that it is dependent on the matching of the circuit's impedance. The more matched it is, the more the value approaches zero. Initially, the code was used with a load impedance of 0 ohms, it was noticed that the reflection coefficient was one, it means that all the power was reflected in the transmitting end of the transmission line. However, as different values were used, it can be seen that the reflection coefficient was being reduced to decimal and approaching 0.

It can also be seen that the impedance of the circuit changes phases for every change in the impedance load. It was noticed that sometimes there is a positive phrase or a negative phase shift. This was noticed that it was changing with differing values of the impedance of the load.

This paper helped the researcher to further understand standing waves and how each parameter in the code was able to affect the output data and results. One should be aware of how transmission lines work and should understand how standing waves occur to further be able to understand if the data being produced by the application is accurate, or close to what is being expected of the circuit application.

10. CONCLUSION

The researcher concludes that this study was able to help him comprehend behaviors of transmission lines better for conditions that it is a lossy transmission line, it is treated as an open circuit, and the impedances are not matched. These are important considerations to remember because standing waves will occur on open circuit systems and if the impedances do not match.

It was observed that standing waves are also affected by frequency because the reflected waves are coming from signals that are not consumed by the receiving end of the transmission line, therefore as frequency increases, the presence of standing waves also increases.

The attenuation constant affects the output by minimizing the peak values of the waves that are present from the point of origin and gradually increases as the length of the transmission line being observed increases. It can be said that the attenuation constant can be used to protect equipment for a certain distance from the point of origin of the standing waves to avoid overloading the equipment along the transmission line. Since standing waves are potentially dangerous for equipment since peak values may cause overloading therefore attenuation constants can be used to minimize the occurrence.

The code used by the researcher can compute for the reflection coefficient by the given line and load impedance and from there the reflection coefficient and the standing wave ratio can be computed efficiently. It can be seen that when the load impedance is zero, it can be seen that the standing wave ratio is computed as infinity and as the load impedance is being increased the standing wave ratio now has a finite rational value. This can be said that the lower the standing wave ratio the better because there is more power that is being consumed at the receiving end of the circuit and there are fewer power losses that may occur.

11. RECOMMENDATIONS

The researcher recommends for future research to be conducted using this to delve deeper into a comparison of the transmitted signal and the reflected signal to be better represented and understood for people who will pursue and search for this topic. After presenting proper waveforms of both transmitted and reflected waves, it is also recommended to show the waveform of the resultant waveform of the incident and reflected wave to better understand what is happening in the circuit.

Since this technology is still growing and only differs in the application, it is also advised to compare this transmission line to fiber optic transmission lines if possible. To measure and compare the efficiency and transmitted signal through the line to be able to understand better as to why they go to transmission lines now are fiber optics instead of the traditional copper wire transmission lines. In fiber optics, if the experiment is to be conducted, the researchers to experiment could try and vary the different parameters that make up a fiber optic line and compare it with the traditional transmission line's parameters being changed and observe the results as to whether which is significantly better to use, if any, or what would be the changes or similarities that the researcher has observed while experimenting.

It is also important to take note on the algorithm used for future researches that the code implemented above is a lossy transmission line, it would also be better if future research could present code and output on ideal transmission lines where losses do not occur to be able to make clear comparisons on why standing waves would need to be minimized on practical applications. Further research on how standing wave peak values can overload equipment can also be suggested as a continuation of this research to be able to help future learners to visualize how overloading may occur due to the presence of standing waves at specific distances from the source.

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