Impedance matching system design using non uniform transmission line for 2.4 Ghz antenna system

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Abstract. The Matching Impedance (MI) design method using Non-Uniform Transmission Line (N.U.T.L.) is a design method that offers more advantages over the 1/4 transformer method, the 1/4 multisection method, and the stub method. In this study, the Matching Impedance system is designed to match the WLAN antenna load with a line impedance of 50 Ohm at the 2.4 GHz. The Matching Impedance system is designed using a transmission line with a Characteristic Impedance (Zo) value that is triangular (Triangular Taper) distributed. This study also examines the effect of the number of cutting sections on a transmission line if the line with the Triangle distribution is implemented on a Microstrip. From the test results, it is found that the number of sections used to form the Non Uniform transmission line has a significant effect on the bandwidth of the system working frequency for the required value of the Reflection Coefficient.

1. Introduction

Impedance Adjuster is an important circuit in the radio communication especially in the high frequency and microwave. Although the Impedance Adjustment field is not a new issue, its development is continuously being made to obtain an efficient and highly efficient system. One of the methods developed is by arranging a Matching Impedance using a Non Uniform Transmission Line (NUTL). Non Uniform Transmission Line is a transmission line which has a Non-Monotonous Characteristic Impedance value or changes as a function of distance (Zo (l)).

The use of matching impedance using a non-uniform transmission line is expected to improve the performance of similar devices developed from a quarter-wavelength uniform transmission line, where to widen the working area of the device, more sections are needed [1].

2. Non uniform transmission line

The Characteristic Impedance Distribution of a Non Uniform Transmission Line is illustrated as follows [1,2].
If $Z_2$ is the Load Impedance, $Z_I$ is the Input Impedance and $Z(x)$ is the line’s characteristics impedance as a function of distance ($x$), then the Reflection Coefficient on the Input side is expressed as [1]:

$$\Gamma_i = \int_0^L \exp(-j2\beta x) \left\{ \frac{d \ln(Z(x))}{dx} \right\} dx$$

(1)

where

$$\bar{Z}(x) = \frac{Z(x)}{Z_i}$$

For transmission lines with a $Z(x)/Z_i$ distributed Triangular (Triangular Taper) with a mathematical model of the form [1]:

$$\frac{d}{dx} \ln(\bar{Z}(x)) = \begin{cases} \frac{4x}{L^2} \ln(\bar{Z}_L) & 0 \leq x \leq \frac{L}{2} \\ \frac{4}{L^2}(L-x) \ln(\bar{Z}_L) & \frac{L}{2} \leq 0 \leq L \end{cases}$$

(2)

where:

$$\bar{Z}_L = \frac{Z_L}{Z_i}$$

(3)

then the Reflection Coefficient on the Input side can be expressed as:

$$\Gamma_i = \frac{1}{2} \exp(-j\beta L) \ln(\bar{Z}_L) \left[ \frac{\sin(\beta L/2)}{\beta L/2} \right]^2$$

(4)

To get the value of $\beta L$ as a function of $\Gamma_i$ in a closed manner is something difficult to do so that the easiest method to design Matching Impedance using Non Uniform Channels with Triangular distribution can be used the Graph method as follows [2]:

$$\left| \frac{2\Gamma_i}{\ln(\bar{Z}_L)} \right| = |\rho| = \left[ \frac{\sin(\beta L/2)}{\beta L/2} \right]^2$$

(5)

or in graphic form as stated in Figure 2. below
3. Impedance adjustment system design
The design procedure for the Impedance Adjustment System using a Non-Uniform Transmission Line with a Triangular distribution can be stated as follows:
- Determine first the load impedance ratio (ZL) and the desired input impedance to obtain Equation 5.
- Determine the maximum value of the reflection coefficient ρ desired and with Graph 2 determine the value of βL.
- Find β with the equation \( \beta = \frac{2\pi f\sqrt{\varepsilon_r}}{c} \). By determining β and βL, the value of L (channel length) can be determined.

If the system is implemented on a microstrip or stripline board, then the value of Z(x) or the Line Characteristics Impedance needs to be expressed in the form of width (w) and strip length (l).

In this study, the length line is divided into 3 (three) different specimens to obtain information on the effect of the number of division segments on the designed performance of the Matching Impedance. The number of segments divided is 4 (four) segments, 8 (eight) segments and 16 (sixteen) segments.

4. System testing
From the test results on 3 (three) specimens, namely: 4, 8 and 16 segments for the value \( \overline{Z_L} = 2 \), the working frequency is 2.4GHz, βL = 4.6 rad, the following results are obtained:

![Figure 3. Segment division 4th for βL = 4.6 rad.](image-url)
From Figure 3, Figure 4 and Figure 5, the width of the Matching Impedance system use can be shown as follows:

**Table 1. Number of segment over working area comparison table**

| No | Segment | Bandwidth $\rho < 0.1$ |
|----|---------|------------------------|
| 1  | 4       | 3 GHz                  |
| 2  | 8       | 4.6 GHz                |
| 3  | 16      | 5.5 GHz                |

In the Table 1 above, it can be seen that the more segments are divided for a fixed length $L$, the wider the area below the value $\rho = 0.1$ will be. This means that the smoother the $Z(x)$ distribution, the wider the working area of the system.

5. **Conclusion**

- Impedance adjustment system using Non-Uniform Transmission Line with Triangular Distribution offers a wide range of system usage compared to a quarter-wave transformer system.
• The greater the segment division for a fixed $\beta L$ value (the gradation level of the Characteristic Impedance distribution is getting smoother), the Matching Impedance system is designed to show a wider range of use.

References
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