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Determination of Transmission Line Impedance Matching Parameters

Otasowie P.O

Department of Electrical and Electronic Engineering University of Benin, Benin City.

Abstract

In this work, transmission line impedance matching parameters were determined in Ugbowo ED0024GI Global System for Mobile Communication (GSM) base station in Benin City, Edo State, Nigeria.

The transmission line impedance matching parameter viz voltage standing wave ratio was measured with the aid of the Anritsu site master instrument model No S332C. the other transmission line impedance matching parameters such as voltage reflection co-efficient and return loss were computed using the voltage standing wave ratio measurement.

The analysis of measured and computed matching parameters show that the values obtained are within the acceptable standard threshold values of Voltage Standing Wave Ratio ≤ 1.50 and Return loss ≥ +14dB used by telecommunication transmission designers worldwide.

Keywords: : Impedance matching, voltage standing wave ratio, return loss, voltage reflection coefficient.

1.0 Justification For The Work

In microwave network transmission, it is absolutely necessary to determine the transmission line impedance matching parameters in a transmission line as a means to determine the line performance before it is commissioned and after it has been operation for two to four years, it is necessary to carry out the measurement. If the measurement deviates from the acceptable standard threshold of voltage standing wave ratio (VSWR) ≤ 1.50 and return loss (RL) ≥ 14d B then there will be severe losses of signal power on the transmission line.

In this work, the Ugbowo base station ED 0024GI was chosen because it is very near to the University of Benin and also it has been in operation for three years now and as such, there is need for this research, to determine the transmission line performance.

2.0 Introduction

Transmission line can be defined as any means used to transfer energy from one point to another. In a transmission line when power is applied by a generator, a voltage and current appear on the line and the value of voltage and current depend on the characteristic impedance of the line and the magnitude of the applied power[1].

The voltage and current waves travel to the load at a speed slightly less than the speed of light depending on the velocity factor. The velocity factor of a transmission line is given by [2].

$$V_f = \frac{1}{\sqrt{k}} \quad (1)$$

Where k is the dielectric constant which range from about 1.2 to 2.8.

When a line is terminated by its characteristic impedance (Z_0) then the line behaves as an infinite line in which there is no reflected wave. Such a line is said to be correctly terminated and in such situation, the incidence wave is totally absorbed in the load and there is no reflected wave. Thus, the line is loss less. If a transmission line is loss less it means the conductors of the line are perfect. For such a line Resistance (R) = 0, Conductance (G) = 0. [3]

If ,

$$P = \text{Propagation constant} = \sqrt{(R+jwL)(R+jwC)} \quad (2)$$

Then,

$$R = 0,\ G = 0,\ P = \sqrt{jwL.jwC} \quad (3)$$

Corresponding authors: E-mail: -, Tel. +2348037921371

Hence ,

$$P\sqrt{jwL.jwC} = jw\sqrt{jwC} = \propto + j\beta \text{ -} \quad (4)$$

and

$$\alpha = 0 \text{ and } P = jw\sqrt{LC} \quad (5)$$

However, if the terminating load impedance (Z_L) is not equal to the characteristic impedance then discontinuity of the medium appears. In such a situation some of the incidence wave is not absorbed in the load and is reflected back towards the source. These reflected waves are mismatched signal power losses on the transmission line [4]. These losses can be obtained by voltage reflection coefficient, voltage standing wave ratio and return los determination.

3.0 VOLTAGE REFLECTION COEFFICIENT

The voltage reflection coefficient of the load impedance can be represented by (Γ) and it is equal to the ratio of the reflected voltage to the incident voltage, that is [5].

$$\Gamma = \frac{V_r}{V_i} \quad (6)$$

Where V_r = reflected voltage, V_i = incident voltage. Since specific reflected and incident voltage are difficult to separate and measure, we can solve for (Γ) much more easily by using known impedance. Therefore

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} \quad (7)$$

Where Z_L = Load impedance, Z_O = characteristic impedance of the line.

The symbol (ℓ) can also be used to indicate the voltage reflection coefficient but it represents only the magnitude without phase association [5].

4.0 VOLTAGE STANDING WAVE RATIO (VSWR)

This is a measure of the mismatch between the load and the line. It refers to the maximum voltage to minimum voltage along a transmission line. The higher the standing wave ratio, the greater the mismatch between line and load. In many practical circumstances this parameter can be readily measured and used as an indication of the transmission line performance. If we designate the amplitude of the incident wave as V_i and that of the reflected wave as V_r than the maximum voltage on the line $V_{max} = V_i + V_r$ and the minimum voltage $V_{min} = V_i - V_r$ [6]

Therefore,

$$\text{VSWR} = \frac{V_{max}}{V_{min}} = \frac{V_i + V_r}{V_i - V_r} \quad (8)$$

Hence,

$$\text{VSWR} = \frac{1 + \frac{V_r}{V_i}}{1 - \frac{V_r}{V_i}} \quad (9)$$

$\frac{V_r}{V_i}$ is the modulus of the phasor ratio

At the termination $\frac{V_r}{V_i}$ is the modulus of the voltage reflection coefficient /ℓ/

Hence,

$$\text{VSWR} = \frac{1 + /\ell/}{1 - /\ell/} \quad (10)$$

and

$$\ell = \frac{VSWR - 1}{VSWR + 1} \quad (11)$$

5.0 RETURN LOSS

This is the loss of signal power resulting from the reflection caused by a discontinuity in a transmission line. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. It is usually expressed in decibels. Two lines or devices are well matched if the return loss is high. A high return loss is therefore desirable as it results in a lower insertion loss. Return loss (RL)is given by [7].

$$RL = -20 log\ /\ell/ dB \quad (12)$$

$$RL = 20 log \left| \frac{VSWR + 1}{VSWR - 1} \right| dB \quad (13)$$

The standard threshold values, worldwide applied to high frequency transmission line terminator is that VSWR should not exceed 1.5:1 while the return loss should not be below +14 dB [7]. In VSWR measurement, the two numbers 1.5 and 1 represents perfect impedance match. The second number is always 1 representing the perfect match whereas the first number varies. The lower the first number (closer to 1) the better impedance matching the system has. For example a VSWR of 1.1:1 is better than 1.4:1. A VSWR measurement of 1:1 would denote a perfect impedance match and no voltage standing wave would be present on the signal path.

6.0 Voltage Standing Wave Ratio (Vswr) Measurement

In this work VSWR measurements per distance were determined with the aid of an Anritsu site master instrument model No S3326 which was produced by the Anritsu Company, microwave measurement division 490 Jarvis drives Morgan Hill CA 95037-2509 United States of America [8].

The VSWR measurements per distance in meters were taken regularly once a week for four weeks in November, 2009 at the Ugbowo GSM Base Station No ED0024GI owned by Airtel Communication Limited in Nigeria. In using the Anritsu site master instrument, the measurement process was done in such a way that the Anritsu site master is connected to the transmission line which in this case was a coaxial cable. The measurement was done per distance in order to ascertain at what point on the transmission line where reflection of voltage occurs. The Anritsu site master instrument was calibrated before measurements were taken. The first process in calibration is to select the desire frequency range which in this case was 900MHz and 1800MHz.

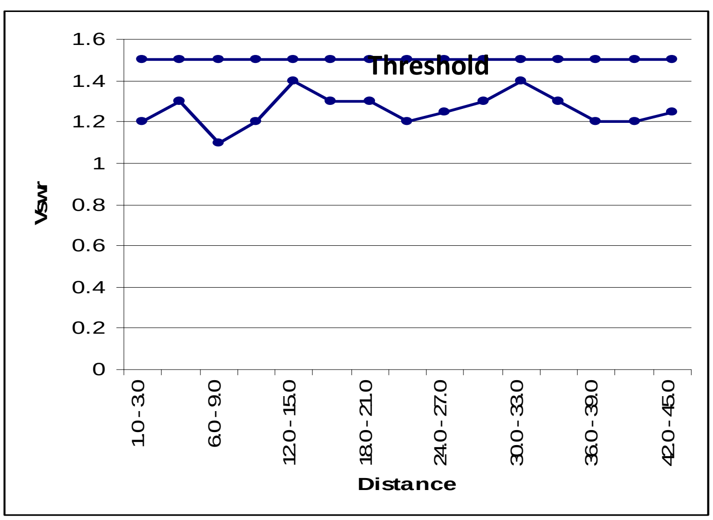
The average of the four readings for four weeks taken per distance was averaged to get the final VSWR measurements per distance for the month of November, 2009. This is shown in Table 1.0.

7.0 Computation of Voltage Reflection Coefficient (E) and Return Loss (Rl)

The voltage reflection coefficient (ℓ) was computed from equation (11) while the return loss was computed from equation (13). The computed values of voltage reflection coefficient and return loss are shown in Table 1.0.

Table 1.0: The average measured VSWR readings per distance and the computed voltage reflection coefficient and Return Loss in Ugbowo Base station (ED0024GI) for November, 2009

Distance (meters)	VSWR	ℓ	RL dB
1.0-3.0	1.20	0.0909	20.83
3.0-6.0	1.30	0.1304	17.69
6.0-9.0	1.10	0.0476	26.45
9.0-12.0	1.20	0.0909	20.83
12.0-15.0	1.40	0.1667	15.56
15.0-18.0	1.30	0.1304	17.69
18.0-21.0	1.30	0.1304	17.69
21.0-24.0	1.20	0.0909	20.83
24.0-27.0	1.25	0.1111	19.09
27.0-30.0	1.30	0.1304	17.69
30.0-33.0	1.40	0.1667	15.56
33.0-36.0	1.30	0.1304	17.69
36.0-39.0	1.20	0.0909	20.83
39.0-42.0	1.20	0.0909	20.83
42.0-45.0	1.25	0.1111	19.09



(M)

Fig. 1.0: A graph of VSWR versus distance in Ugbowo Base station in Benin City

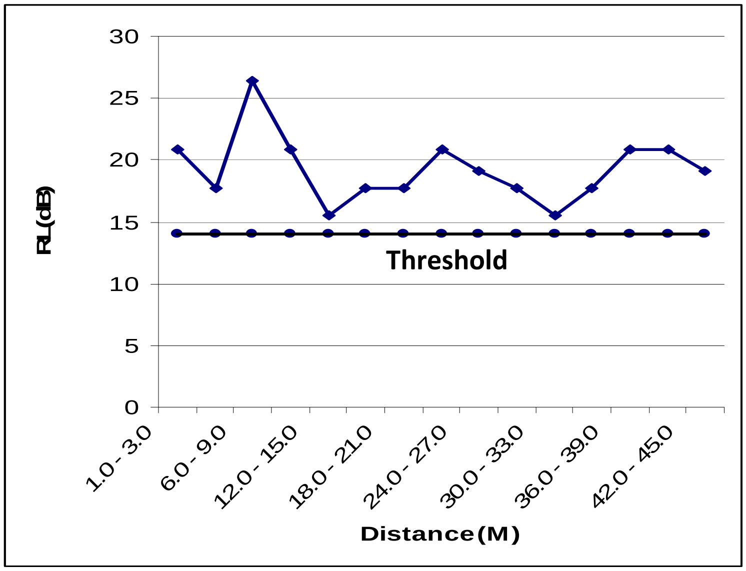


Fig. 2.0: A graph of RL dB versus distance in Ugbowo Base station in Benin City

8.0 Analysis of Result

From the graph of Fig. 1.0, the upper limit is 1.40 and the lower limit is 1.10. The VSWR of the base station transmission line is 1.40:1.0. The VSWR of the base station transmission line lies within the standard threshold of 1.50:1.0. The upper limit value indicates the highest point where mismatch occurs in the base station transmission.

From the graph of Fig. 2.0, the upper limit is 26.45 dB and the lower limit is 15.56 dB. The upper limit value indicates the point where the base station is well matched. All the points on the line lies within the acceptable threshold value of RL ≥ +14 dB.

9.0 Conclusion and Recommendation

The transmission line impedance matching parameters were determined in this work and found to conform to the acceptable standard threshold values. The transmission line performance of the Ugbowo Base station are good, it is recommended that this work should be carried out after two years as transmission line performance deviates from its earlier value with time due to usage.

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