International Journal of Physical Sciences Vol. 4 (11), pp. 651-656, November, 2009
Available online at http://www.academicjournals.org/ijps
ISSN 1992 - 1950 © 2009 Academic Journals

Full Length Research Paper

Voltage standing wave ratio measurement and prediction

P. O. Otasowie* and E. A. Ogujor

Department of Electrical/Electronic Engineering University of Benin, Benin City, Nigeria.

Accepted 8 September, 2009

In this work, Voltage Standing Wave Ratio (VSWR) was measured in a Global System for Mobile communication base station (GSM) located in Evbotubu district of Benin City, Edo State, Nigeria. The measurement was carried out with the aid of the Anritsu site master instrument model S332C. This Anritsu site master instrument is capable of determining the voltage standing wave ratio in a transmission line. It was produced by Anritsu company, microwave measurements division 490 Jarvis drive Morgan hill United States of America. This instrument works in the frequency range of 25MHz to 4GHz. The result obtained from this Anritsu site master instrument model S332C shows that the base station have low voltage standing wave ratio meaning that signals were not reflected from the load to the generator. A model equation was developed to predict the VSWR values in the base station. The result of the comparism of the developed and measured values showed a mean deviation of 0.932 which indicates that the model can be used to accurately predict the voltage standing wave ratio in the base station.

Key words: Voltage standing wave ratio, GSM base station, impedance matching, losses, reflection coefficient.

INTRODUCTION

Justification for the work

In microwave radio planning, it is absolutely necessary to measure the voltage standing wave ratio of a base station to know the level of mismatch in the transmission line. This measurement is expected to be carried out before a base station is commissioned. Also when the base station has been operational for many years, it is also necessary to carry out the measurement.

Hence, Evbotubu base station which has just been built and awaiting commissioning was chosen among all the base station in Benin City for the investigation.

Voltage standing wave ratio

The ratio of the maximum voltage to the minimum voltage amplitude in a transmission line is called the Voltage Standing Wave Ratio (VSWR). In many practical circumstances this parameter can be readily measured and then used as indication of the transmission line performance (Stanniforth, 1999; Otasowie, 2005).

The voltage standing wave ratio can be related to the modulus (magnitude) of the reflection coefficient. If we designate the amplitude of the reflected wave as (Vr) and the incident voltage as (V_i) then the maximum voltage in the standing wave is (Otasowie, 2005; Motorola Ltd, 2000; http://.www.anritsu.com, www.us.anritsu.com, 2008). $V_{\max} = V_i + V_r$ and at the minimum voltage $V_{\min} = V_i - V_r$, Therefore;

$$VSWR = \frac{V_{\max}}{V_{\min}} = \frac{V_i + V_r}{V_i - V_r}. \quad (1)$$

Hence,

$$VSWR = \frac{1 + \frac{V_r}{V_i}}{1 - \frac{V_r}{V_i}} \quad (2)$$

*Corresponding author. E-mail: potasowie@yahoo.co.uk.

Abbreviations: GSM; Global System for Mobile Communication, **VSWR;** Voltage Standing Wave Ratio, **I;** Current, **V;** Voltage, λ**;** Reflection coefficient, $\mathbf{V_r}$; Reflected voltage, $\mathbf{V_i}$; Incident voltage, $\mathbf{V_{max}}$; Maximum voltage, $\mathbf{V_{min}}$; Minimum voltage.

$\frac{V_r}{V_i}$ is the modulus of the phasor ratio. At the termination $\frac{V_r}{V_i}$ is the modulus of the reflection coefficient $|\lambda|$ hence:

$$VSWR = \frac{1+|\lambda|}{1-|\lambda|} \ldots \quad (3)$$

Since usually the standing wave ratio is easier to measure than the reflection coefficient, then equation (3) gives a way of deducing $|\lambda|$. The formula can be manipulated to give (Otasowie, 2005).

$$|\lambda| = \frac{VSWR-1}{VSWR+1} \quad (4)$$

A standard applied to high frequency transmission line terminators is that VSWR should not exceed 1.5:1.

The two numbers 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 in the signal path (CWNA manual on "Radio frequency fundamentals", 2002; Ericsson "Radio systems antenna installation test manual", (2006).

Measurement of VSWR

The VSWR measurements per distance were determined with the aid of an Anritsu site master instrument model No. S332C which was produced by the Anritsu Company, microwave measurement division 490 Jarvis drives Morgan Hill CA 95037 – 2509 United States of America. (http://www.anritsu.com, www.us.anritsu.com, 2008).

The VSWR measurements per distance in meters were taken regularly once a week. This gives a total of four readings in a given month as shown in Table 1. These measurements were performed for the months of August, September, October, November, December 2007 and January 2008. The average of the four readings per distance was recorded in Table 1 as the reading for August, September, October, November, December 2007 and January 2008. The VSWR measurements per distance of all the six months were averaged to get the final VSWR readings as shown in Table 1, the Evbutubu GSM base station is own by CELTEL communication Limited in Nigeria. In using the Anritsu site master instrument, the measurement process is done in such away that the Anritsu site master is connected to the transmission line which in this case was 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 measurement setup is shown in Figure 1. 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 is 900 MHz and 1800 MHz. The following steps were taken in selecting the frequency range.

i) Turn on the site master by pressing the on button.
ii) Press the FREQ soft key from the main menu.
iii) Press F1 Soft key from the main menu.
iv) Enter the lower frequency limit in MHz for the antenna system by using the up/down arrow and press ENTER.
iv) Press the F2 soft key from frequency menu.
v) Enter the higher frequency limit in MHZ for the antenna system by using the UP/down arrow and press ENTER.
vi) Check that the FREQ (MHz) scale in the display area indicates the new frequency start and stop values.
The next stage in calibration is to perform the following.
vii) Press the start key.
viii) Choose calibration type and press ENTER.
ix) Follow the instruction on the screen.

After the calibration, connect the site master to the transmission line as shown in Figure 1.

ANALYSIS OF RESULT

From the graph of Figure 2, the upper limit value is 1.175 and the lower limit is 1.0. The measured value is therefore 1.175:1.0. The VSWR of the GSM base station falls within the standard range of 1.5:1.0. This implies that the mismatch on the transmission line is at minimum level as a result of this, there is no Voltage Standing Wave in the transmission line. From Figure 2, the upper limit value indicates the highest point where mismatch occurs in the transmission line.

VSWR model

The key issue in microwave radio planning is the prediction of received signal strength in the link investigated. Propagation model is a set of mathematical expression and algorithms used to represent the radio characteristics of a typical link (Dons, 2003; Landstorfer, 1999; Aleksandra, 2000).

The VSWR model was developed using Matlab version 7.5 software programs. The data obtained were curve fitted with polynominal of the 10^{th} order degree as illustrated in Figure 3. The relevance of the VSWR model is that it gives the prediction of VSWR per distance in a typical base station. This prediction is necessary for network planning purposes.

Table 1. Average VSWR readings in Ebvotubu district GSM base station in Benin City. For August, 2007 to January, 2008.

Distance (m)	Months / VSWR Measurement						
	August 2007	September 2007	October 2007	November 2007	December 2007	January 2008	Average
1.0	1.025	1.026	1.025	1.026	1.024	1.025	1.025
2.0	1.051	1.052	1.050	1.051	1.050	1.048	1.050
3.0	1.058	1.060	1.062	1.060	1.059	1.061	1.060
4.0	1.040	1.042	1.040	1.040	1.039	1.039	1.040
5.0	1.045	1.045	1.045	1.044	1.046	1.045	1.045
6.0	1.045	1.044	1.045	1.045	1.046	1.045	1.045
7.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8.0	1.023	1.024	1.026	1.023	1.022	1.024	1.024
9.0	1.024	1.022	1.023	1.022	1.024	1.023	1.023
10.0	1.012	1.010	1.011	1.012	1.011	1.011	1.011
11.0	1.011	1.011	1.012	1.011	1.010	1.012	1.011
12.0	1.011	1.011	1.012	1.011	1.010	1.012	1.011
13.0	1.011	1.011	1.012	1.011	1.010	1.012	1.011
14.0	1.011	1.011	1.012	1.011	1.010	1.012	1.011
15.0	1.013	1.012	1.012	1.011	1.011	1.014	1.012
16.0	1.014	1.011	1.011	1.012	1.012	1.013	1.012
17.0	1.012	1.013	1.012	1.015	1.014	1.013	1.013
18.0	1.013	1.012	1.015	1.012	1.013	1.014	1.013
19.0	1.022	1.021	1.020	1.019	1.020	1.018	1.020
20.0	1.022	1.021	1.020	1.018	1.020	1.019	1.020
21.0	1.022	1.021	1.020	1.018	1.020	1.019	1.020
22.0	1.019	1.020	1.018	1.020	1.021	1.022	1.020
23.0	1.022	1.021	1.020	1.018	1.020	1.019	1.020
24.0	1.023	1.025	1.020	1.020	1.022	1.023	1.022
25.0	1.026	1.026	1.023	1.027	1.026	1.025	1.026
26.0	1.024	1.025	1.024	1.026	1.025	1.025	1.025
27.0	1.024	1.022	1.023	1.026	1.023	1.024	1.024
28.0	1.075	1.075	1.075	1.075	1.075	1.075	1.075
29.0	1.100	1.100	1.100	1.100	1.100	1.100	1.100
30.0	1.175	1.175	1.175	1.176	1.174	1.175	1.175
31.0	1.172	1.174	1.173	1.173	1.172	1.174	1.173
32.0	1.170	1.171	1.172	1.170	1.170	1.168	1.170
33.0	1.150	1.148	1.150	1.151	1.152	1.150	1.150
34.0	1.145	1.145	1.145	1.145	1.145	1.145	1.145
35.0	1.130	1.128	1.129	1.130	1.132	1.131	1.130
36.0	1.026	1.024	1.025	1.025	1.026	1.025	1.025
37.0	1.023	1.025	1.022	1.020	1.020	1.023	1.022
38.0	1.025	1.022	1.023	1.020	1.023	1.020	1.022
39.0	1.022	1.022	1.022	1.022	1.022	1.022	1.022
40.0	1.020	1.019	1.018	1.020	1.022	1.021	1.020

Comparism of VSWR measured and predicted values

The measured VSWR data were compared with the predicted VSWR data. This was achieved in the M – file environment of Matlab version 7.5 software program (William, 1998). The result of the comparism showed that

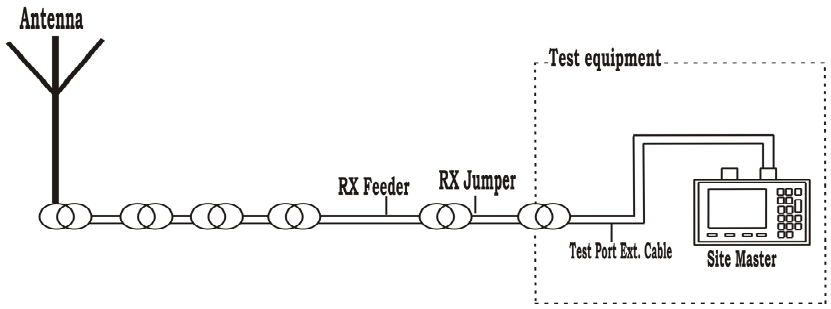

Figure 1. Measurement setup of Anritsu site master instrument.

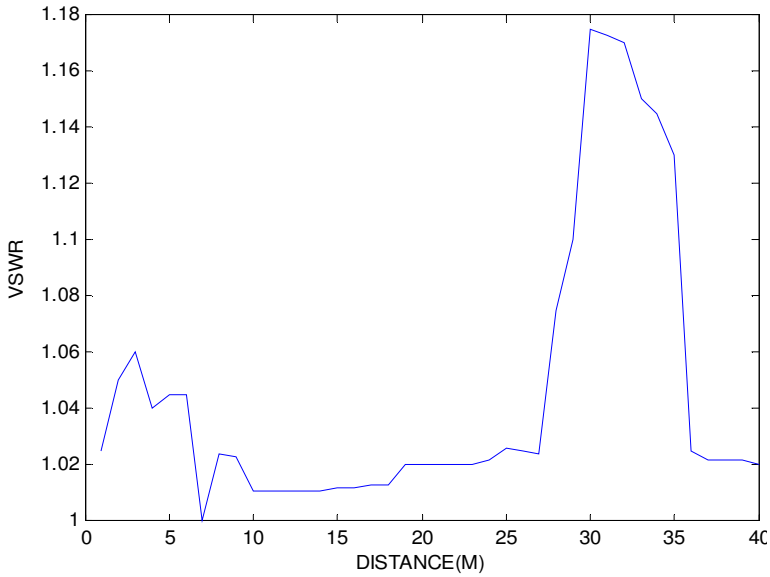

Figure 2. A graph of VSWR versus distance in Evbotubu district base station in Benin City.

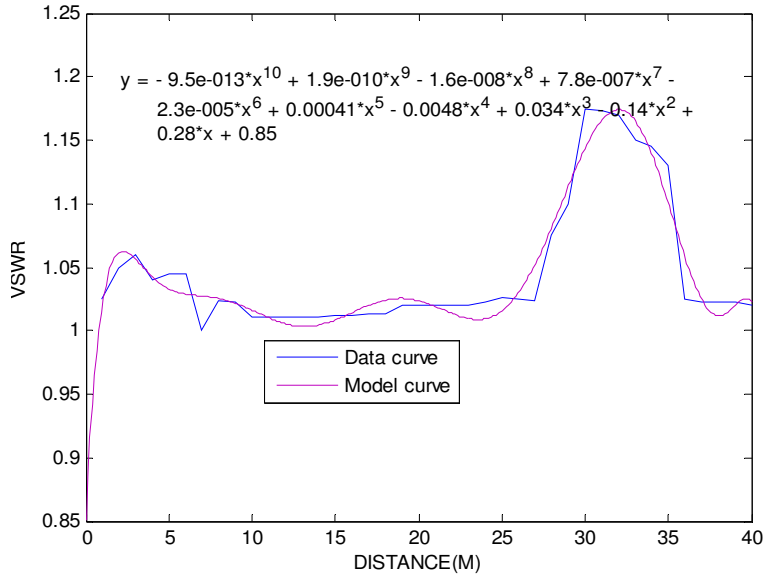

Figure 3. A Model graph of VSWR versus distance.

Table 2. VSWR Measured and predicted values for August, 2007 to January, 2008.

Distance (m)	VSWR measured	VSWR predicted	Deviation	% Deviation
1.0	1.025	1.020	0.005	0.50
2.0	1.050	1.020	0.003	0.30
3.0	1.060	1.020	0.004	0.40
4.0	1.040	1.020	0.002	0.20
5.0	1.045	1.020	0.025	2.50
6.0	1.045	1.020	0.025	2.50
7.0	1.000	1.020	-0.020	-2.00
8.0	1.024	1.020	0.004	0.40
9.0	1.023	1.020	0.003	0.30
10.0	1.011	1.020	-0.009	-0.90
11.0	1.011	1.020	-0.009	-0.90
12.0	1.011	1.020	-0.009	-0.90
13.0	1.011	1.020	-0.009	-0.90
14.0	1.011	1.020	-0.009	-0.90
15.0	1.012	1.020	-0.008	-0.80
16.0	1.012	1.020	-0.008	-0.80
17.0	1.013	1.020	-0.007	-0.70
18.0	1.013	1.020	-0.007	-0.70
19.0	1.020	1.020	0.000	0.00
20.0	1.020	1.020	0.000	0.00
21.0	1.020	1.020	0.000	0.00
22.0	1.020	1.020	0.000	0.00
23.0	1.020	1.020	0.000	0.00
24.0	1.022	1.020	0.002	0.20
25.0	1.026	1.020	0.006	0.60
26.0	1.025	1.020	0.005	0.50
27.0	1.024	1.020	0.004	0.40
28.0	1.075	1.030	0.045	4.50
29.0	1.100	1.020	0.080	8.00
30.0	1.175	1.030	0.145	14.5
31.0	1.173	1.030	0.143	14.3
32.0	1.170	1.030	0.150	15.0
33.0	1.150	1.030	0.130	13.0
34.0	1.145	1.020	0.125	12.5
35.0	1.130	1.020	0.110	11.0
36.0	1.025	1.020	0.005	0.50
37.0	1.022	1.020	0.002	0.20
38.0	1.022	1.020	0.002	0.20
39.0	1.022	1.020	0.002	0.20
40.0	1.020	1.020	0.0000	0.00

the model is sufficiently accurate considering the mean deviation of 0.932 between the measured and predicted VSWR values as shown in Table 2.

The VSWR model is:

$$y = -9.5\times10^{-13}x^{10} + 1.9\times10^{-10}x^{9} - 1.6\times10^{-8}x^{8} + 7.8\times10^{-7}x^{7} - 2.3\times10^{-5}x^{6} + 0.00041x^{5} - 0.0048x^{4} + 0.034x^{3} - 0.14x^{2} + 0.28x + 0.85.. \quad (5)$$

The equation is valid for x > 0 boundary condition. If x is VSWR measured in equation 5, then y = predicted value. The substitution of x gives y as illustrated in Table 2.

Conclusion

In this work, VSWR values were measured in the investigated base station and the result of the study showed that the VSWR values are within the acceptable range as at the time of the research. This implies that the levels of mismatch in the antenna systems are at minimum level. The model equations that have been developed to predict VSWR in the link investigated is sufficiently accurate.

REFERENCES

Aleksandra N (2000). "Modern Approaches in modeling of Radio propagation environment" IEEE communication surveys USA.
CWNA manual on "Radio frequency fundamentals" (2002).
Dons G (2003). "Model system overview cosmo newsletter No 3 Deutcher wetterdienst offenbach Germany.
Ericsson "Radio systems antenna installation test manual" (2006). http://.www.anritsu.com, www.us.anritsu.com "Operation of the site master instrument" May 4th, 2008.
Landstorfer FM (1999). "Wave propagation models for planning of mobile communications networks Proceedings of the 29th European microwave conference (EUMC) Munich.
Motorola Ltd (2000). "Introduction to GSM Cellular GSM Manual.
Otasowie PO (2005). "Understanding Telecommunication Principles" Abiodun publishers Benin City Nigeria.
Stanniforth JA (1999). "Microwave Transmission" Eagle wood publishers London.
William JP (1998). "Introduction to Matab for Engineers" Mc Graw – Hill publishers company New York.