POS2-17

Free space Antenna Gain Measurements by way of Tracing the Reflected Waves in Time Domain

#Jungkuy Park [1], Woo-Nyun Kim [2]
[1] National Research Agency of Korea Communication Commissions
370-9, Sinpil, Sulsung, Icheon, Guunggi, 461-881, Republic of Korea, niehaner@gmail.com
[2]wnkim@naver.com

1. Introduction

There exist reflected waves which obstruct measuring the free space antenna gains or factors in open area test site (OATS). The various methods to measure them with properly treating the reflected wave keep being tried [1,2,3]. Generally, the methods are given in the frequency domain. It was possible to measure the insertion loss S_{21} between two antennas in the frequency domain and mathematically calculate Inverse Fourier Transform of the data to give the time domain response [4]. There is a gap of the reaching time from Tx to Rx due to a path difference between the direct and reflected signal. If resolution is sufficient to distinguish between them, time domain analysis continues to be an effective tool which selectively removes unwanted responses like a reflected wave on open area test site. The time domain technology using a network analyzer and computer for antenna calibration is proposed for the first time [5]. It is applied to measuring the antenna factors of a dual ridged horn(1 ~ 9 GHz) and a biconical dipole(30 ~ 300 MHz).

This document gives tracing a reflected wave on metal ground plane in open area test site and estimating a response time of a double ridged horn(1 ~ 18 GHz) during the tracing it and measuring the free space gains. And the results are also compared with Standard Site Method.

2. Measurement Range

In time domain, the measurement range is defined as the length of time that a measurement can be made without aliasing. According to sampling theorem, if the time length T in time domain is greater than $1/\Delta f$, then the aliasing will result. Therefore the maximum measurement length without aliasing equal to $1/\Delta f$. For network analyzer, the measurement time T is expressed as [4]

$$T = \frac{1}{\Delta f} = \frac{1}{(f_N - f_0)/N} = \frac{N}{f_N - f_0} \quad (1)$$

where the frequency span is f_N-f_0 and the number of points is N+1. The measurement range in m is given by

$$D(m) = T \times c \quad (2)$$

where c is speed of light. In figure 1, both the direct path d_1 and reflected path d_2 of the signal have to be within the measurement range D. The responses of the signals in time domain also have to be resolved sufficiently in order to remove the reflected wave due to the gating. They have not to overlap within the path time difference $(d_2-d_1)/c$ like shown in figure 2

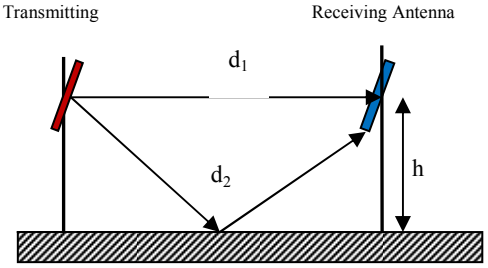

Figure 1. Geometry of S_{21} Measurement between Antennas in OATS

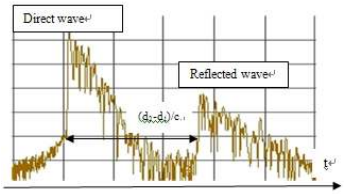

Figure 2. Resolution of the direct and reflected wave

3. Measurement

3.1 Open Area Test Site and Facility

National Radio Research Agency has the open area test site with metal ground 50m×40m mounted 10m height mast for antenna calibration shown in figure 3. The network analyzer is Agilent 8362B. Double ridged horn antennas including AUC are two Schwarzbeck BBHA9120D and EMCO 3115 ranging 1 GHz ~ 18GHz.

Figure 3. Open area test site with metal and mesh 50m×40m

3.2 Tracing of Reflected Wave

The configuration to trace the reflected wave in OATS is shown in figure 1. The separation between the two antennas is d_1 and the antenna height from the ground is h, which the transmitting and receiving antennas have same height. The path of the reflected signal is given by

$$d_2 = 2 \times \sqrt{(d_1/2)^2 + h^2} \quad (3)$$

TABLE 1

FREQUENCY SPAN, NUMBER OF POINTS AND MEASUREMENT RANGES

Frequency span (0.01 ~ 18 GHz)	17.99
Number of points	1801
Time measurement range(ns)	100.02
Distance measurement range(m)	30.02

The reflected waves are traced from 1m height to 9m height. The signals begin to be split up into two in second of figure 4. The signal in square is the reflected wave due to the metal ground. It shows that the signal in square has a shift to the right but the signal in circle stays at the same location from third 3m height to ninth 9m height. The signals in circle remain stationary and the levels is hardly any change no matter how the height of antennas changes. It says that the signals are the components of the direct wave in time domain.The bi-directional arrow in ninth of the figure 4 is analysed with the width of antenna response time. The width is about 9.61ns.Converting it into distance, it is about 2.88m. It means that the path difference between the direct and the reflected wave has to be larger than 2.88m. Figure 5 shows frequency domain response before and after gating. There are many ripples before gating more than after gating. The difference is nearly 1dB.

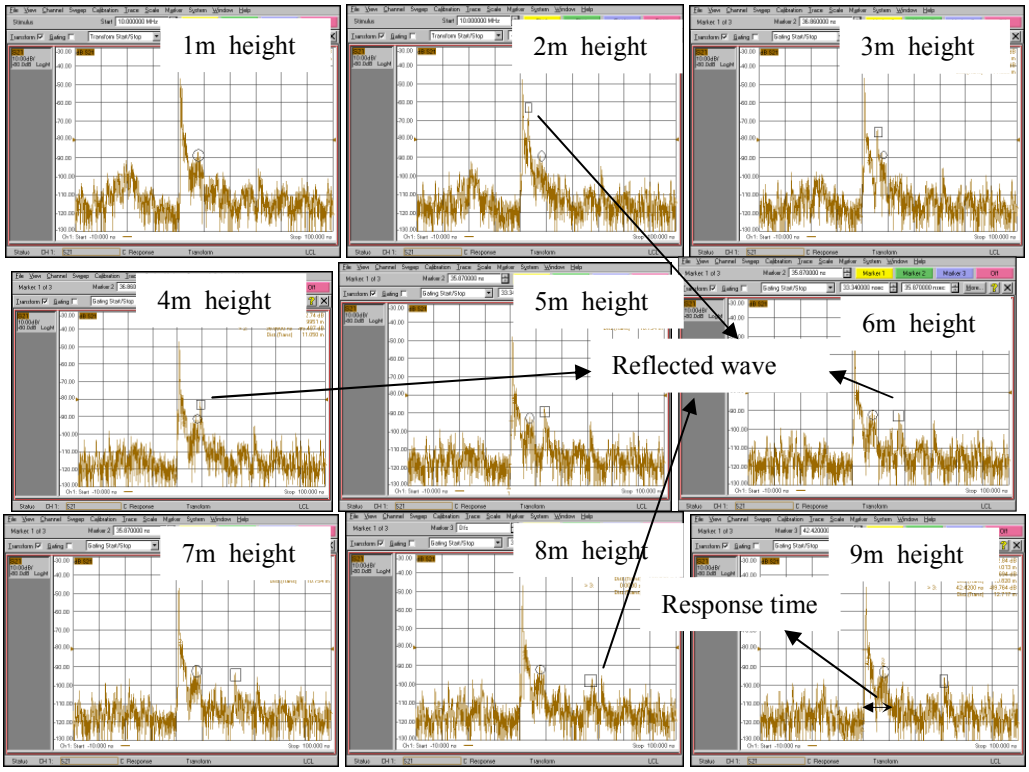

Figure 4. Tracing of Reflected Wave due to changing from 1m to 9m in Time domain

TABLE 2

COMPARISON TO CALCULATED AND MEASURED PATH DIFFERENCES

Antenna height	Antenna distance	Peak signal	Calculated Path	Measured Path
2	10	10.38	0.77	0.72
3	10	10.38	1.66	1.60
4	10	10.38	2.81	2.80
5	10	10.38	4.14	4.17
6	10	10.38	5.62	5.53
7	10	10.38	7.20	7.21
8	10	10.38	8.87	8.89
9	10	10.38	10.59	10.57

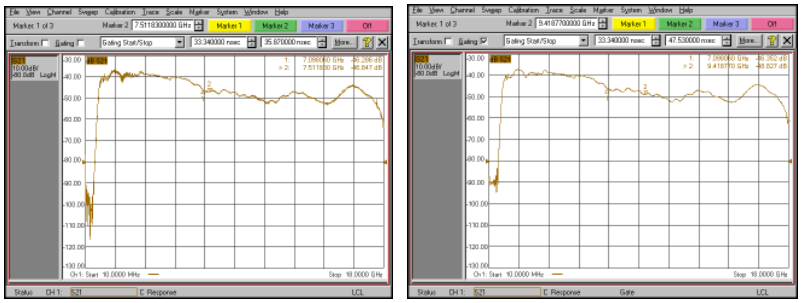

Figure 5. frequency domain S_{21} before (left) and after (right) time gating at 5m height

3.3 3-Antenna Method

The free space antenna gains are given by Friis equation[6].

$$G_T G_R = \frac{4\pi d}{\lambda} \frac{P_R}{P_T} \quad (4)$$

The antenna gains of Schwarzbeck horn BBHA 9120D are shown in table 3.

TABLE 3
HORN ANTENNA GAINS OBTAINED BY TIME DOMAIN MEASUREMENT AT 5M, 6M AND 7M HEIGHT

Freq (GHz)	Gain(dB)_ 5m	Gain(dB)_ 6m	Gain(dB)_5m	Δ(5-6)	Δ(6-7)	Δ(7-5)
1	5.72	5.87	5.65	-0.15	0.22	-0.07
2	10.19	10.16	10.18	0.02	-0.02	-0.01
3	11.50	11.56	11.56	-0.06	0.00	0.05
4	12.72	12.69	12.68	0.03	0.00	-0.04
5	12.89	12.94	12.94	-0.05	0.00	0.05
6	13.76	13.76	13.78	0.00	-0.02	0.02
7	12.38	12.38	12.42	-0.01	-0.04	0.05
8	11.57	11.54	11.57	0.02	-0.03	0.01
9	12.04	12.03	12.10	0.01	-0.07	0.06
10	11.43	11.36	11.42	0.07	-0.06	-0.01
11	10.29	10.33	10.34	-0.04	-0.01	0.05
12	12.63	12.56	12.58	0.06	-0.02	-0.04
13	13.77	13.73	13.74	0.04	-0.01	-0.03
14	12.49	12.56	12.53	-0.07	0.03	0.04
15	12.18	12.29	12.25	-0.11	0.04	0.07
16	15.76	15.79	15.70	-0.03	0.09	-0.07
17	14.50	14.51	14.54	-0.01	-0.03	0.04
18	8.95	9.12	9.17	-0.17	-0.05	0.21

3.3 4 Check

ANSI C63.5 calculates the antenna factors with the following expression[1].

$$AF_T AF_R = \frac{f_M E_D^{\max}}{279.1} A_{RT} \qquad (5)$$

The results for 5m height are compared to as shown in figure 6.

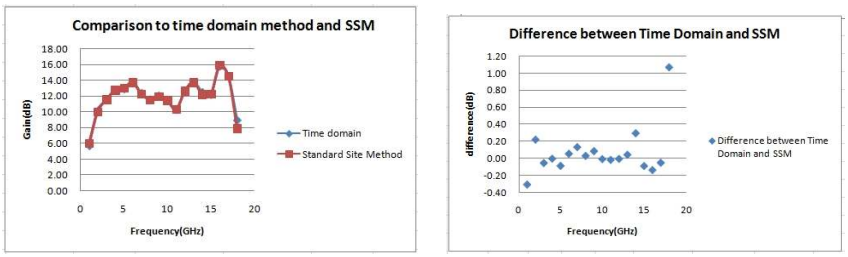

Figure 6. Comparing Time Domain Method with SSM (left) and the deviation (right)

4. Discussion

In this paper, we discussed antenna measurement method using time domain in open area test site we traced the reflected wave by the antennas going up from 1m to 9m for horn antenna. we found the response time of horn about 9.61ns. the path difference is larger than it when the antenna height for 10m distance is higher than 4m. After gating of the time domain data at 5m, 6m and 7m, the frequency responses of the direct signal gives the free space antenna gains due to 3-Antenna Method. The antenna gain values showed very good agreement each other. The method are also checked using Standard Site Method(ANSI C63.5). The results showed mostly good agreement except for 18GHz.

References

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