A Review of the CW-Ambient Technique for Measuring G/T in a Planar Near-Field Antenna Range

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***Abstract*— Techniques for measuring G/T have been previously presented at AMTA; however, there are very few papers that discuss how to measure G/T in a near-field antenna range. One recent paper discussed such a method and gave a brief description within the larger context of satellite payload testing [1]. The paper's treatment of G/T was necessarily brief and gives rise to several questions in relation to the proposed method. Other papers that treated this topic required the antenna aperture to be separable from the back-end electronics, which may not be possible in all cases [2-3]. In this paper, we discuss in great detail a slightly modified version of the G/T measurement method presented in [1]. A signal and noise power diagram is presented that can be useful for understanding how system signal-to-noise ratio (SNR) relates to G/T, and a few common misconceptions concerning the topic of G/T are addressed. The CW-Ambient technique for computing G/T of a Unit Under Test (UUT) from measurements in a planar near-field system is described in detail, and a list of assumptions inherent to the CW-Ambient technique is presented. Finally, the validity of the CW-Ambient technique is assessed by analyzing measured data collected from a separable UUT.**

I. Introduction

Antenna designers and systems engineers are often tasked to understand the antenna (i.e., aperture) gain, electronics gain, and noise figure of interconnected antenna systems. One parameter used to quantify the sensitivity of a receiving antenna system is referred to as gain (G) over noise temperature (T), typically denoted G/T. By using a known value of G/T along with other parameters like operating frequency, power density of an impinging plane wave, and receiver bandwidth, a systems engineer can obtain the signal-to-noise ratio (SNR) that will be present at the output of the antenna system. When the passive aperture of an antenna is inseparable from the system's active devices, such as amplifiers or mixers, then the antenna gain, electronics gain, and noise figure of the system cannot be measured independently, and G/T becomes an important parameter used to quantify the performance of the antenna system.

Techniques for measuring G/T inside an anechoic chamber with a far-field or compact range have been previously presented [4-9]; however, there are very few papers that discuss how to measure G/T in a near-field antenna range. A few papers that discuss antenna noise temperature measurements in a planar near-field antenna range using a Y-factor method (i.e., a method that uses a ratio of received noise powers when transmitting the energy emitted from a calibrated noise source) require the antenna aperture to be separable from the back-end electronics in order to compute G/T, and this separation may not be possible in all cases [2-3]. One recent paper discussed a method that can be used to compute G/T for both separable and inseparable systems using planar near-field measurements, and gave a brief description within the larger context of satellite payload testing [1]. The paper's treatment of G/T was necessarily brief and gives rise to several questions in relation to the proposed method. In this paper, we discuss this particular G/T measurement method in greater detail and attempt to answer those questions. In contrast to [1], this paper assumes that the noise contribution of the measurement device is negligible; consequently, our final G/T formulation differs slightly from the formulation originally reported in [1].

We begin our treatment by discussing a few of the common misconceptions regarding G/T; for example, what the G represents in the G/T metric, how antenna noise temperature is defined, and why the combined G/T term is measurable for inseparable RF front-ends while the individual terms G and T are not. Next, we will describe the "CW-Ambient" technique for measuring G/T, originally proposed in [1], and the associated expression for computing G/T from near-field measurements. We will also describe the assumptions that are inherent to this technique. Finally, we will present a comparison of calculated and measured G/T values for a system where the aperture can be separated from the receive electronics, which will demonstrate the validity of the CW-Ambient technique.

II. Deriving the Relationship between SNR and G/T

To inform the following discussions on G/T misconceptions and on measuring G/T using the CW-Ambient technique, we will first derive the signal-to-noise ratio (SNR) at the output of an antenna system. This derivation will be accompanied by a power flow diagram, shown in Figure 1, which we will refer to during the discussion on G/T measurements.

To begin, we assume that the system is composed of two major parts:

1) A passive antenna (abbreviated as *Ant*)
2) A collection of active electronics connected to the output of the passive antenna (abbreviated as *Elex*)

To clarify, the passive antenna need not be a single aperture. The antenna may be a single aperture, or it may be an array of antenna elements. Also, the active electronics may be a series of active devices, such as amplifiers, phase shifters, and mixers. In the subsequent analysis, all of the active electronics are grouped into a single device when modeling the SNR of the system.

A. Signal Power

To determine the signal power available at the output of the system, we must assign a value to the power density of a plane wave incident upon the antenna. This power density shall be written as S. The units on S are typically written in Watts/m^2. Therefore, the signal power that is available an infinitesimal distance behind the aperture of the antenna is

$$P_{signal}^{in} = S \cdot D \cdot A_{iso} \, , \tag{1}$$

where D is the directivity of the antenna relative to an isotropic radiator, and where $A_{iso} = \lambda^2/4\pi$ is the effective aperture area of an isotropic radiator.

If the units on S are Watts/m^2 and the units on A_{iso} are m^2, then the units on P_{signal}^{in} are Watts, since the value of D is dimensionless. It should be noted that in writing the expression for P_{signal}^{in} in this manner, we've assumed that no power is lost due to polarization mismatch.

Since we've defined the antenna as a passive device, the antenna will have some amount of loss. The efficiency of the antenna can be written as

$$\eta_{Ant} = 1/L \, , \tag{2}$$

where L is a linear dimensionless loss term and may take any value between 1 and ∞. In this manner, the value of η_{Ant} may take any value between 0 and 1. Therefore, the amount of power available at the terminals of the antenna is

$$P_{signal}^{Ant} = S \cdot \eta_{Ant} \cdot D \cdot A_{iso} = S \cdot G_{Ant} \cdot A_{iso} \, , \tag{3}$$

noting that antenna gain can be written as $G_{Ant} = \eta_{Ant} D$.

Finally, assuming that the antenna is perfectly matched to the active electronics (i.e., no power is lost through impedance mismatch), then the power available at the output terminals of the system is

$$P_{signal}^{out} = S \cdot G_{Ant} \cdot A_{iso} \cdot G_{Elex} \, . \tag{4}$$

The power flow for the signal is described graphically in the top-half of the diagram in Figure 1.

B. Noise Power

To determine the noise power present at the output of the system, the noise power contribution from the passive antenna must first be determined. As described in [10] and [11], the antenna sees a spatially-dependent noise power due to the effective brightness temperature of the environment, $T_B(\theta, \phi)$. This noise temperature, weighted by the directivity of the antenna and integrated over all space, produces a radiation noise temperature T_r, given as

$$T_r = \frac{1}{4\pi} \int_0^{2\pi} \int_0^{\pi} T_B(\theta, \phi) D(\theta, \phi) \sin\theta \, d\theta \, d\phi \, . \tag{5}$$

Therefore, the amount of noise power seen by the antenna (the radiation noise power) can be computed as kT_rB, where k is Boltzmann's constant, and B is the bandwidth of the receiver.

Since the antenna will have some amount of loss, the antenna will add noise power to the system and attenuate the radiation noise power. It has been shown in [10] that the amount of noise power generated by a lossy device at a physical temperature of T_o is given by $k(L-1)T_oB$. Since $\eta_{Ant} = 1/L$, the amount of noise power generated by the antenna structure can be written as $k\left(\frac{1}{\eta_{Ant}} - 1\right)T_oB$. By convention, the contributing noise power is added to the total noise power before passing through the attenuation or gain stage of the device. Therefore, we add the radiation noise power to the noise power generated by the antenna structure, and then multiply this quantity by the efficiency of the antenna to obtain the total noise power present at the antenna terminals, thus obtaining

$$\begin{aligned} P_{noise}^{Ant} &= \eta_{Ant}\left[kT_rB + k\left(\frac{1}{\eta_{Ant}} - 1\right)T_oB\right] \\ &= k[\eta_{Ant}T_r + (1-\eta_{Ant})T_o]B \\ &= kT_{Ant}B \, , \end{aligned} \tag{6}$$

where $T_{Ant} = \eta_{Ant}T_r + (1-\eta_{Ant})T_o$. If the antenna efficiency is 100%, then no noise power is contributed by the antenna itself, and $T_{Ant} = T_r$, as expected. If the antenna efficiency is 0%, then no noise power will be contributed by the environment, and the antenna will appear as a load to the system, resulting in $T_{Ant} = T_o$.

Furthermore, if the brightness temperature is a constant T_o in all directions, as might be expected in an indoor anechoic chamber, then the radiation noise temperture simplifies to $T_r = T_o$, and thus $T_{Ant} = \eta_{Ant}T_0 + (1-\eta_{ANT})T_0 = T_0$.

Finally, the active electronics will contribute noise power, and this contribution plus the noise power generated by the antenna will be increased by the gain of the electronics, resulting in a system noise power output of

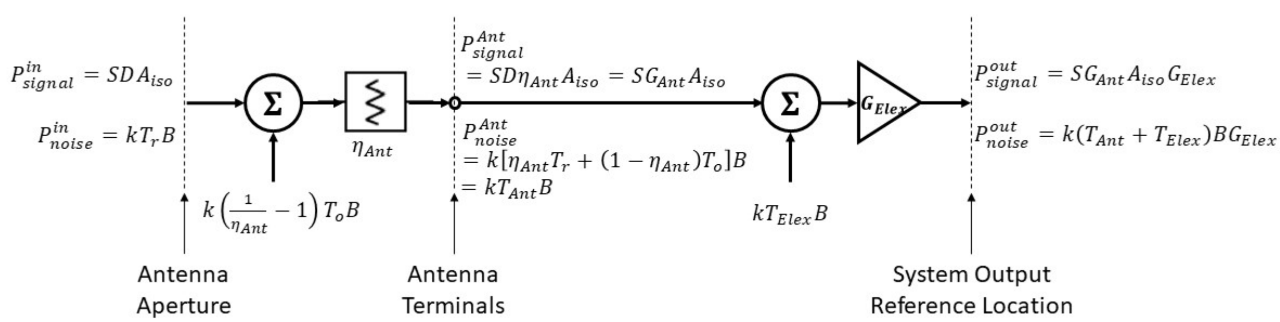

Figure 1. Signal and noise power diagram for a system composed of a passive antenna and active electronics.

$$P_{noise}^{out} = (kT_{Ant}B + kT_{Elex}B)G_{Elex} = k(T_{Ant} + T_{Elex})BG_{Elex} = kT_{sys}BG_{Elex}\ , \quad (7)$$

where $T_{sys} = T_{Ant} + T_{Elex}$. The power flow for the noise is described graphically in the bottom-half of the diagram in Figure 1.

C. Signal-to-Noise Ratio

The signal-to-noise ratio (SNR) at the output of the system is the ratio of (4) and (7), resulting in

$$SNR^{out} = P_{signal}^{out}/P_{noise}^{out} = \frac{SG_{Ant}A_{iso}G_{Elex}}{kT_{sys}BG_{Elex}} = S\frac{\lambda^2}{4\pi kB}\cdot\frac{G_{Ant}}{T_{sys}}. \quad (8)$$

Therefore, the SNR at the output of the system is a function of G_{Ant}/T_{sys}, which is often written as G/T.

III. G/T Misconceptions

Based on the results obtained from the derivations carried out in Section II, we can now discuss a few common misconceptions concerning the G/T parameter.

A. Misconception #1: The Definition of "G" in G/T

The first misconception is the definition of the "G" parameter in G/T. It would be easy to assume that the definition of "G" refers to total system gain, e.g., $G_{Ant}G_{Elex}$. However, as shown in the derivation of the system SNR, the "G" parameter in G/T refers to antenna gain (sometimes referred to as aperture gain) G_{Ant} alone. This is because the gain of the electronics G_{Elex} will be applied both to the signal power received by the antenna and to the noise power generated by the antenna, and therefore the value of G_{Elex} is cancelled when the signal power is divided by the noise power. Of course, electronics gain is important in the system design to minimize the total noise figure of the back-end electronics, which thus will minimize the noise power contributed by the active electronic components.

B. Misconception #2: G/T for Inseparable Systems

Another misconception relates to the measurement of G/T for inseparable systems. For a separable system, i.e., a system where the passive antenna can be removed from the active electronics, the gain of the antenna can be measured using standard methods, like the gain substitution method. Also, for a separable system, the noise power contributions of the antenna and the active electronics can be measured independently.

However, for an inseparable system that contains frequency down-conversion electronics, measurement of the gain of the system becomes difficult. A custom calibration standard would need to be constructed that contains built-in down-conversion electronics that mimic the down-conversion scheme of the system to be measured. Even so, the measurement would yield the combined quantity of $G_{Ant}G_{Elex}$, and further assumptions would need to be applied to solve for the quantity of G_{Ant}.

For these reasons, it is simpler to measure the quantity of G/T directly when measuring an inseparable system. By doing so, custom calibration standards and assumptions about the gain of the active electronics are not required.

C. Misconception #3: The Influence of Brightness Temperature

The last misconception that we will discuss involves the influence of brightness temperature on the reported value of G/T. It is sometimes assumed that the G/T value reported from a measurement system located inside of an anechoic chamber will be the same as the G/T value experienced when the system is deployed in the field. However, recall that $T_{sys} = T_{Ant} + T_{Elex}$. The noise contribution of the system's electronics (T_{Elex}) may be expected to be largely stable, but T_{Ant} is a function of the environment. When G/T is measured in an anechoic chamber, T_{Ant} is likely to equal the physical temperature of the absorber in the chamber. An operational environment has the potential to be quite different. Thus, the G/T value has the potential to change, perhaps significantly, when the system is moved from the test environment to an operational environment.

Measurements of G/T, while different from the operational G/T value, can still be used to validate system models. If the model can accurately predict the G/T of the system in an anechoic environment, then the same model could be used to predict the G/T of the system when the system is deployed in an environment with a different brightness temperature distribution. An example of this type of analysis is available in [12].

IV. CW-Ambient Technique for Measuring G/T in a Planar Near-Field Measurement System

In this section, we will derive the procedure for computing G/T in a planar near-field measurement system using the technique that we refer to as the "CW-Ambient" measurement technique. The "CW-Ambient" technique involves four measurements:

1) Measure the noise power output by the Unit Under Test (UUT) when subjected to an ambient environment in the anechoic chamber with no active sources present.
2) Measure the signal power output by the UUT when a CW source is applied to the input of the probe.
3) At the probe's reference plane, measure the transmit power of the signal source used in measurement #2.
4) Make a complete near-field scan of the UUT using a standard planar near-field measurement technique.

We will demonstrate how the values collected during these four measurements can be used to determine the G/T of the UUT. Note: The CW-Ambient technique requires that the same near-field probe is installed during all four measurements.

This measurement technique has many similarities to the "cold source" method of measuring noise figure for a device (for a description of the "cold source" method, see [13]). However, we feel that connecting the term "cold source" to an antenna system measurement would cause confusion, and thus we propose the term "CW-Ambient" to describe this technique.

A. Derivation of the Near-Field Gain Parameter

In our analysis, we will use a parameter that we refer to as "near-field gain". This parameter will be used to help us model the power transfer that occurs in a planar near-field system.

We will define the "near-field gain" of the system as the scalar multiplicative term that must be applied to the power supplied to the probe in order to obtain the power output by the passive antenna portion of the UUT when the probe is located at a position $\boldsymbol{P_o}$. As such,

$$\frac{1}{2}|b_o'(\boldsymbol{P_o})|^2 = \frac{1}{2}|a_o|^2 G_{Near-Field}(\boldsymbol{P_o}) \,, \quad \text{therefore} \quad G_{Near-Field}(\boldsymbol{P_o}) = \frac{|b_o'(\boldsymbol{P_o})|^2}{|a_o|^2} \,. \tag{9}$$

where b_o' and a_o are defined within [14]. It is important to note that $G_{Near-Field}$ is not the same as the "near-field correction factor", described in [1] and [14].

Assuming that the probe and the UUT are polarization matched when the propagation vector $\boldsymbol{K} = \boldsymbol{K_o}$ and when the probe is oriented in the prime orientation (e.g., when collecting the $b_o'(\boldsymbol{P_i})$ values), and assuming that mismatch is negligible, we can re-organize equation (17a) within [14] to obtain a definition of near-field gain for a planar near-field system, G_{PNF}:

$$G_{PNF}(\boldsymbol{P_o}) = \left(\frac{\lambda^2}{4\pi}\right)^2 \frac{G_{Ant}(\boldsymbol{K_o}) G_{Probe}(\boldsymbol{K_o})}{\left|\delta_x \delta_y \sum_i B_o'(\boldsymbol{P}_i)\, e^{-j\boldsymbol{K_o}\cdot\boldsymbol{P_i}}\right|^2} \,, \tag{10}$$

where $B_o'(\boldsymbol{P}_i) = b_o'(\boldsymbol{P}_i)/b_o'(\boldsymbol{P_o})$, and where $\boldsymbol{P_i}$ indicates the x,y location of the probe during the i^{th} measurement.

Using the definition of the near-field gain parameter, we can model the power flow of a CW signal incident upon the probe's reference plane. This model is illustrated in Figure 2.

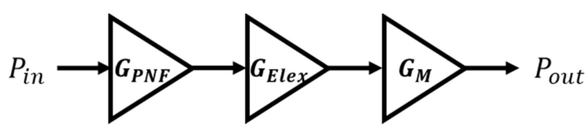

Figure 2. Signal power diagram of a planar near-field system, including the gain of the measurement device.

Therefore, in equation form, we can write the following transfer function for the signal power:

$$P_{out}(\boldsymbol{P_o}) = P_{in} G_{PNF}(\boldsymbol{P_o}) G_{Elex} G_M \tag{11}$$

where G_M is the gain of the device that is used during the measurement of P_{out}. However, for the remainder of this analysis, we assume the use of a measurement device that is calibrated to report the power referenced to its input port, so G_M can be effectively ignored.

B. Measurement #1: Power Output from the UUT when Subjected to the Ambient Environment

The first required measurement is the power that is output from the UUT when no active sources are present. In this case, the only "signal" available to the UUT is the brightness temperature of the ambient environment of the anechoic chamber. For this scenario, we can use the diagram presented in Figure 1 and set $S = 0$, thus determining that this measurement will yield

$$P_1 = kT_{sys} B G_{Elex} + kT_M B \,, \tag{12}$$

where T_M is the effective noise temperature of the measurement device. This measurement should be performed with the measurement device's bandwidth centered at the expected output frequency of the UUT, which may be at an Intermediate Frequency (IF) if the UUT contains down-conversion electronics. From initial experimental data, the value of this measurement does not seem to vary as a function of where the probe is located within the scan plane during the measurement.

C. Measurement #2: Power Output from the UUT when Subjected to the CW Signal

The second required measurement is the power that is output from the UUT when a CW source is applied to the input of the probe located at a position $\boldsymbol{P_o}$. The signal power flow diagram for this case is shown in Figure 2, remembering that we can neglect G_M since we are using a calibrated device to measure power values. By including the noise power that will be present in this measurement, we obtain

$$\begin{aligned} P_2(\boldsymbol{P_o}) &= P_{in} G_{PNF}(\boldsymbol{P_o}) G_{Elex} + kT_{sys} B G_{Elex} + kT_M B \\ &= P_{in} G_{PNF}(\boldsymbol{P_o}) G_{Elex} + P_1 \,. \end{aligned} \tag{13}$$

Identical to Measurement #1, this measurement should be performed with the measurement device's bandwidth centered at the expected output frequency of the UUT, which may be at a different frequency than the CW signal incident upon the input of the probe.

D. Measurement #3: Power Incident upon the Probe

The third required measurement is the power of the CW signal that is incident upon the reference plane of the probe. This reference plane must be the same as the reference plane used when defining the gain of the probe. This becomes

$$P_3 = P_{in} + kT_M B \,. \tag{14}$$

Here, we have assumed that the noise power generated by the CW source is negligible compared to the power of the CW tone.

Assuming also that the noise power generated by the measurement device is negligible compared to the signal power generated by the CW source, this measurement will yield

$$P_3 \approx P_{in} \,. \tag{15}$$

E. Measurement #4: Planar Near-Field Scan

The final measurement is actually a series of measurements, by which we mean a planar near-field scan with the typical requirements: sampling at steps of no greater than $\lambda/2$, ensuring that the scan plane is sufficiently large to avoid truncation errors, etc. After completing the planar near-field scan, a set of complex values will have been obtained, referred to as $b_o'(\boldsymbol{P_i})$. From these measurements, the value $\left|\delta_x \delta_y \sum_i B_o'(\boldsymbol{P}_i) e^{-j\boldsymbol{K_o}\cdot\boldsymbol{P_i}}\right|^2$ can be obtained, since $B_o'(\boldsymbol{P}_i) = b_o'(\boldsymbol{P}_i)/b_o'(\boldsymbol{P_o})$.

F. *Computation of G/T using the CW-Ambient Technique*

Armed with these four measurements, we are now prepared to compute G/T for the UUT. Let's define a parameter X, where

$$X(\boldsymbol{P_o}) = \frac{P_2(\boldsymbol{P_o})}{P_1}. \tag{16}$$

In this manner, we obtain the following:

$$X(\boldsymbol{P_o}) - 1 = \frac{P_2(\boldsymbol{P_o}) - P_1}{P_1} = \frac{P_3 G_{PNF}(\boldsymbol{P_o}) G_{Elex}}{kT_{sys}BG_{Elex} + kT_M B}. \tag{17}$$

If we assume that the noise power contributed by the measurement device is very small compared to the noise power generated by the UUT, then we obtain

$$X(\boldsymbol{P_o}) - 1 \approx \frac{P_3 G_{PNF}(\boldsymbol{P_o})}{kT_{sys}B}. \tag{18}$$

Substituting the previously derived equation for $G_{PNF}(\boldsymbol{P_o})$ in (10), we obtain

$$X(\boldsymbol{P_o}) - 1 \approx \frac{P_3}{kT_{sys}B}\left(\frac{\lambda^2}{4\pi}\right)^2 \frac{G_{Ant}(\boldsymbol{K_o})G_{Probe}(\boldsymbol{K_o})}{\left|\delta_x\delta_y \sum_i B_o'(\boldsymbol{P_i})e^{-j\boldsymbol{K_o}\cdot\boldsymbol{P_i}}\right|^2}. \tag{19}$$

Then, solving the equation for G_{Ant}/T_{sys} , we obtain

$$\frac{G_{Ant}(\boldsymbol{K_o})}{T_{sys}} = \frac{G}{T}(\boldsymbol{K_o}) \approx \left(\frac{4\pi}{\lambda^2}\right)^2 \frac{kB[X(\boldsymbol{P_o}) - 1]}{P_3 G_{Probe}(\boldsymbol{K_o})}\left|\delta_x\delta_y \sum_i B_o'(\boldsymbol{P}_i)e^{-j\boldsymbol{K_o}\cdot\boldsymbol{P_i}}\right|^2, \tag{20}$$

recalling that $B_o'(\boldsymbol{P}_i) = b_o'(\boldsymbol{P}_i)/b_o'(\boldsymbol{P_o})$.

At this point, it is important to remember that this equation was previously published in [1]. We performed a more involved derivation of the equation to understand the assumptions that are made when obtaining this result. We also made the assumption that the noise power contributed by the measurement device is small compared to the noise power of the UUT, thus (20) differs slightly from the expression reported in [1].

G. *Assumptions Inherent to the CW-Ambient Technique*

The attentive reader will have noticed that a few assumptions were required in order to derive the expression given in (20). A list of these assumptions is compiled here for convenience. A few additional assumptions that were not mentioned explicitly are also included in this list. A few of these assumptions were compiled from [13].

- The bandwidth is known for the measurement device used to measure signal and noise power levels. Therefore, a spectrum analyzer could be used for these power measurements, where the resolution bandwidth of the device can be set by a user. A power meter with a well-characterized in-line filter could also be used, as long as the measurement properly accounts for the additional loss of the filter.
- All impedance mismatch terms are negligible.
- The UUT and the probe are polarization matched when the propagation vector $\boldsymbol{K} = \boldsymbol{K_o}$ and when the probe is oriented in the prime orientation.
- The noise power generated by the CW source and the noise power generated by the measurement device are negligible when compared to the signal power generated by the CW source at the input of the probe.
- The noise power contributed by the measurement device is negligible compared to the noise power of the UUT. This assumption becomes less valid as the gain of the electronics within the UUT decreases.
- The measurement device is calibrated to report the power incident upon the device. To validate this assumption, the power reported by a spectrum analyzer could be compared to the power reported by a power meter.
- Losses from additional cables, adapters, switches, and/or test fixtures are all properly accounted for.
- The trace jitter encountered on the power measurement device during the noise power measurement (i.e., the Ambient measurement) has been decreased to an acceptable level by increasing the non-coherent integration time.
- The brightness temperature of the environment is stable between the P_1 and P_2 power measurements; therefore, this assumes that the environmental conditions of the anechoic chamber are stable over time.
- All errors inherent to the planar near-field scan have been reduced to an acceptable level.

The above list of assumptions could be used as a starting point for an uncertainty analysis on a G/T measurement performed using the CW-Ambient technique.

V. Measuring G/T of a Separable UUT in a Planar Near-Field System

To confirm that the expression for computing G/T using planar near-field measurements is accurate, a separable UUT was measured on a bench-top and on a planar near-field range. The block diagram of the separable UUT is shown in Figure 3.

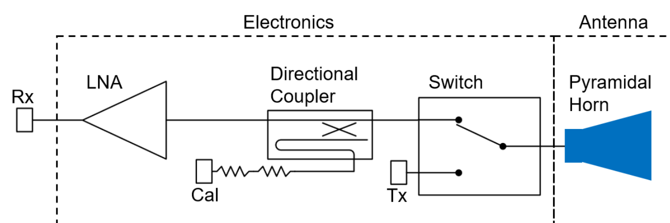

Figure 3. Block diagram of the separable UUT.

The pyramidal horn is a standard gain horn (SGH), for which a gain table is available. Bench-top and planar near-field range measurements were then used to compute G/T of the UUT operating in Rx mode using two methods.

The first method uses three parameters to compute the G/T of the UUT:

1) Gain of the pyramidal horn, as provided by the gain table

2) Equivalent noise temperature of the electronics, measured using the “cold source” technique, as described in [13]

3) Antenna noise temperature, obtained by using the assumption that the antenna noise temperature of the pyramidal horn could be approximated as the physical temperature of the chamber

With these three parameters, G/T of the UUT is computed as

$$\frac{G}{T} = \frac{G_{Horn}}{T_{Ant} + T_{Elex}}. \quad (21)$$

The values obtained using the first method are summarized in Table I.

TABLE I. COMPUTATION OF G/T USING METHOD #1.

Parameter	Value	Method to Obtain
Gain of horn	24.7 dBi	From the SGH gain table
$\boldsymbol{T_{Elex}}$	4376 K	Cold source method
$\boldsymbol{T_{Ant}}$	295 K	Assumed equal to T_o
G/T	**-12.0 dB/K**	Computed using (21)

The second method uses the expression shown in (20) to compute the value of G/T. The PNF probe gain was available from a calibration report. The values obtained using the second method are summarized in Table II.

TABLE II. COMPUTATION OF G/T USING METHOD #2.

Parameter	Value	Method to Obtain
$\boldsymbol{B/\lambda^4}$	1.86 Hz·cm^{-4}	From spectrum analyzer RBW and center frequency
$\boldsymbol{P_1}$	-131.6 dBm	Measured on spectrum analyzer with noise floor of -142.5 dBm at chosen RBW
$\boldsymbol{P_2}$	2.1 dBm	Measured
$\boldsymbol{P_3}$	-5.5 dBm	Measured
$\boldsymbol{G_{probe}}$	8.6 dBi	From calibration table
$\left\lvert \delta_x \delta_y \sum_i B_o'(P_i) e^{-jK_o \cdot P_i} \right\rvert^2$	778.6 cm^4	From planar near-field scan, setting $\boldsymbol{K_o = 0}$
G/T	**-14.4 dB/K**	Computed using (20)

When comparing the results of Method #1 to Method #2, the results are within 2.4 dB/K. Although a rigorous uncertainty evaluation has not yet been performed, these results are likely to be shown to agree within their respective uncertainty bounds.

VI. CONCLUSIONS

Within this paper, we have derived the expression to compute G/T of a UUT using the “CW-Ambient” technique, and we have summarized a number of the assumptions that are inherent to this technique. We speculate that this list of assumptions could be used as a starting point for a rigorous uncertainty analysis of a G/T measurement that employs the CW-Ambient technique.

We have also presented measured data for a separable UUT. The measured data strongly suggests that the CW-Ambient technique is a valid method for computing G/T of a UUT from measurements taken with a planar near-field measurement system.

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