COMS SOC 13M ANTENNA G/T MEASUREMENT

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ABSTRACT: At COMS SOC, 13m antenna system will serve to transmit command and receive telemetry in S-Band for COMS operation. In addition, Sensor Data and LRIT/HRIT in L-Band will be received and LRIT/HRIT in S-Band will be transmitted through this antenna system. In many cases, G/T is used as barometer to estimate the receiving capability of antenna system. To estimate G/T, this paper presents two approaches, one is analysis based on the specification of antenna and RF equipment while the other is measurement by using Sun. From the results, G/T was proven as more than 20dB/K and it means that the required G/T, 19dB/K is verified successfully.

KEY WORDS: COMS, SOC, DATS, G/T

1. INTRODUCTION

The first Korean geostationary satellite, COMS (Communication, Ocean, and Meteorological Satellite), is supposed to transmit its observed data in L-Band frequency to ground station. In addition, the satellite is designed to receive pre-processed meteorological data, so-called LRIT (Low Rate Information Transmission) and HRIT (High Rate Information Transmission) in S-Band and return them with changing frequency to L-Band to user station. For the satellite operation, command and telemetry need to be exchanged in S-Band between COMS and ground station. Ground station consists of three different centers, namely, MSC (Meteorological Satellite Center), KOSC (Korea Ocean Satellite Center) and SOC (Satellite Operation Center) to interface with satellite in L-, S-Band. When it comes to the receiving of observed data, MSC and KOSC is primary station to receive SD (Sensor Data) in L-Band and process meteorological data observed by MI (Meteorological Imager) and ocean data monitored by GOCI (Geostationary Ocean Color Imager), respectively. Both MI and GOCI are payloads mounted on the COMS. For the broadcasting service, MSC is supposed to transmit LRIT and HRIT in S-Band after conducting radiometric correction and geometric correction, so-called pre-processing on the meteorological data. In the case of SOC, its primary function is the satellite operation. Therefore, command and telemetry in S-Band are exchanged between SOC and COMS. However, SOC is designed to receive SD and conduct a pre-processing on both meteorological data and ocean data, meaning that SOC acts as a backup of MSC and KOSC regarding the receiving and pre-processing function. In addition, SOC has a capability of transmitting LRIT and HRIT like MSC. To communicate with satellite in L-, S-Band, single antenna has been developed and installed at KARI site, Deajeon. Both L-, S-Band is commonly designed by single feed, meaning that one of two polarizations, linear and circular, should be determined. Considering the seasonal Faraday rotation, circular polarization was determined in the preliminary stage of antenna development. To cope with 3dB loss occurred when linear-polarized SD in L-Band is received by circular-polarized antenna, it has been already designed to combine two SD received through two orthogonal circular polarizations, RHCP (Right-Hand Circular Polarization) and LHCP (Left-Hand Circular Polarization). When it comes to the receiving performance of antenna, G/T is usually used as a barometer. Thanks to the link analysis performed in the preliminary state of ground station development, the required G/T was specified as 19dB/K for receiving SD in L-Band [1]. When the necessary G/T is determined, the specification of receiving equipment implemented into ground station can be specified.

Figure 1 shows the hardware configuration for SD receiving at SOC.

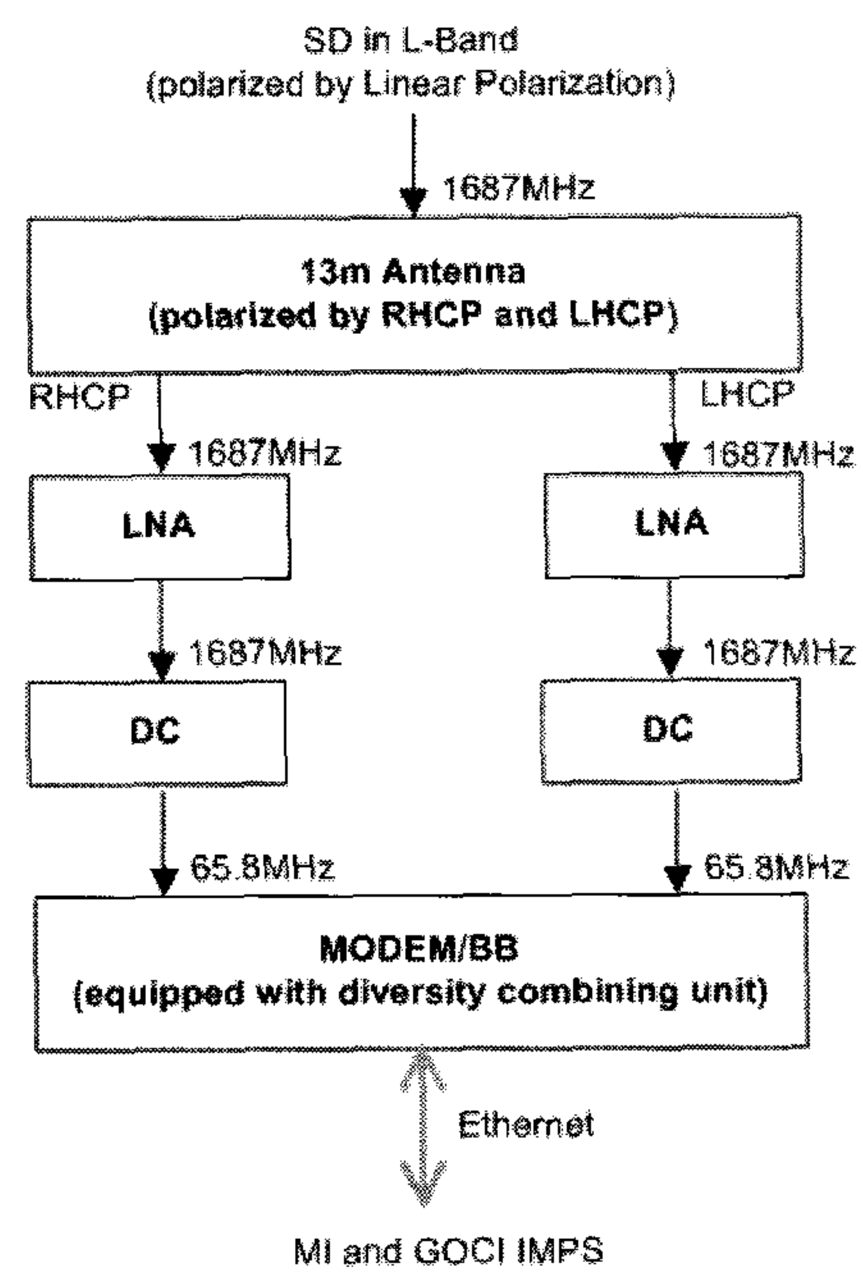

Figure 1 Hardware configuration for SD receiving at SOC

Two SD in L-Band received through two orthogonal circular polarizations are inputted into two identical LNA (Low Noise Amplifier) which provides amplifying the inputted signal level with specific gain. At DC (Down-Converter), the frequency of two SD is converted as IF-Band which is available at the input port of MODEM/BB. Eventually, two SD is combined by the diversity combining unit in MODEM/BB. After conducting demodulation and decoding, MODEM/BB delivers MI and GOCI VCDU (Virtual Channel Data Unit) into MI IMPS and GOCI IMPS, respectively. This paper presents two approaches to estimate G/T, one is analysis based on the specification of receiving equipment and the other is measurement by using solar flux density generated by Sun.

2. G/T ANALYSIS

G/T is the ratio of gain to noise temperature at specific point in the hardware configuration shown in Figure 1. It is commonly considered the LNA input as the specific point. In that case, gain is calculated by subtracting loss caused by passive element between antenna feed and LNA input by antenna gain. Noise temperature is also estimated by adding antenna noise temperature into receiver noise temperature. The receiver noise temperature is indicating the noise temperature generated by the cascaded LNA, DC and MODEM/BB.

2.1 Antenna Noise Temperature

Antenna noise temperature means the noise temperature captured by antenna. The contribution to antenna noise temperature is divided as two parts, one is sky noise temperature and the other is ground noise temperature. When antenna is pointing to satellite, sky noise temperature (T_{SKY}) can be assimilated with the brightness temperature for the elevation angle of the antenna [2]. According to the description in CCIR Report 720-2, the brightness temperature is about 4K when elevation angle of antenna is laid between 40 and 60 degrees. The other contribution, ground noise temperature (T_{GROUND}) is corresponding to the noise temperature captured by side lobe of antenna.

In the directional antenna, the ground noise temperature can be negligible. Considering the conditions of rain and cloud, the antenna noise temperature is estimated as followings

$$T_A = \frac{T_{SKY}}{A_{RAIN}} + T_m\left(1 - \frac{1}{A_{RAIN}}\right) + T_{GROUND}$$

Where, A_{RAIN} is the attenuation caused by the condition of rain and cloud, which is usually 0.576dB in L-Band. T_m is the mean thermodynamic temperature, which can be assured as 275K based on the CCIR Report 564.

2.2 Receiver Noise Temperature

Noise Figure (NF) is a parameter that expresses the noise characteristic of two-ports unit such as LNA, DC, even cable, compared with a reference noise source at the input port. Noise figure is expressed as followings,

$$NF = \frac{(SNR)_{in}}{(SNR)_{out}} = \frac{S_i / N_i}{GS_i / G(N_i + N_{ai})}$$

Where, S_i is signal power at the related unit input port, N_i is noise power at the related unit input port, N_{ai} is related unit's noise referred to the input port, and G is the gain. When n devices are connected in series, the composite noise figure can be expressed as followings,

$$F_{comp} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \cdots + \frac{F_n - 1}{G_1 G_2 \cdots G_{n-1}}$$

Using the relation between noise figure and noise temperature, the composite noise temperature can be expressed as followings,

$$T_{comp} = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2} + \cdots + \frac{T_n}{G_1 G_2 \cdots G_{n-1}}$$

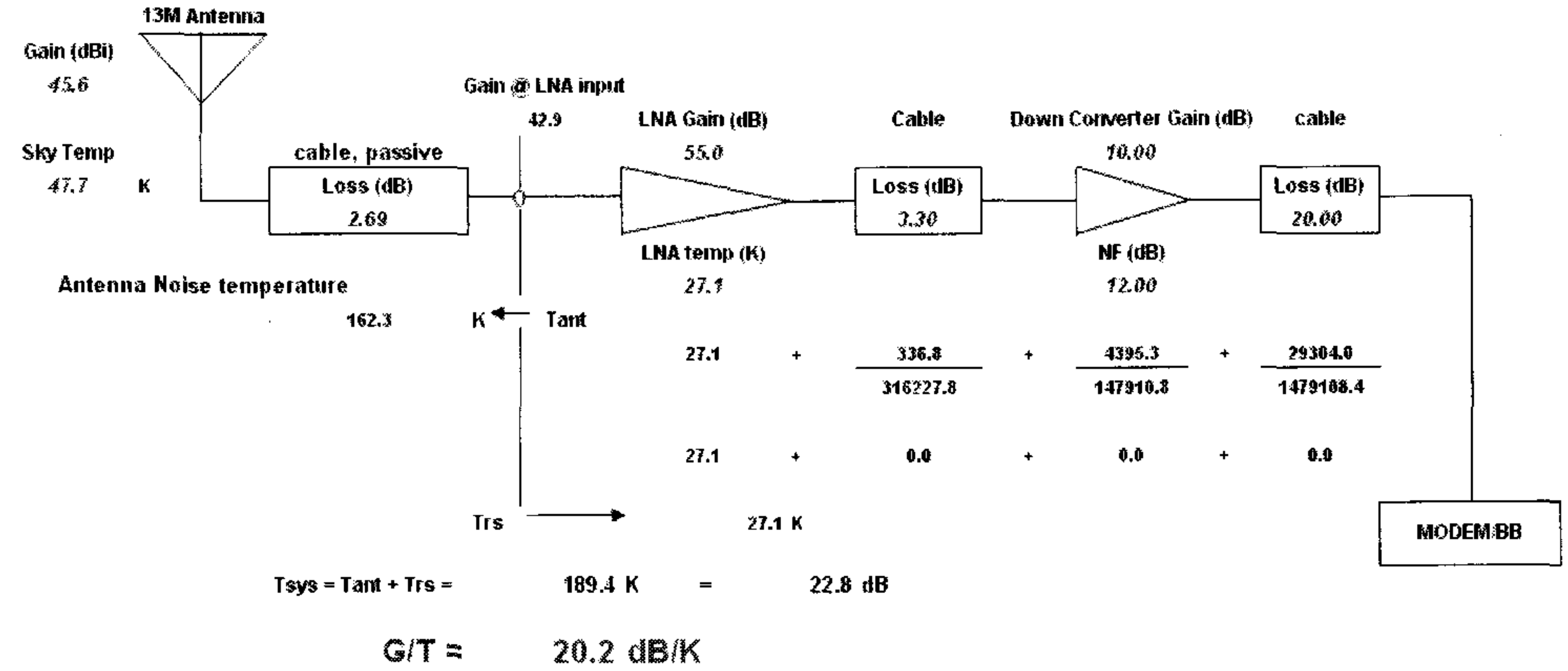

Figure 2 G/T Estimation of SOC 13m Antenna System

From the equation on the composite noise temperature, it can be found that the noise temperature of first-end unit plays a major role to determine the whole receiver noise temperature.

2.3 G/T Estimation

Figure 2 shows the G/T estimation based on the hardware configuration shown in previous figure. Antenna gain is assumed as 45.6dBi based on the design value at SGCS (Satellite Ground Control System) CDR (Critical Design Review). Since the loss of passive element between antenna feed and LNA input is estimated as 2.69dB, the antenna gain is 42.9dB at LNA input. When the gain and noise temperature of LNA is considered as 55dB and about 27K, the receiver noise temperature is calculated as 27.1K. Eventually, G/T is estimated as 20.2dB/K, meaning that 19dB/K of requirement is satisfied.

3. G/T MEASUREMENT

To verify that G/T of implemented SOC 13m antenna system is over 19dB/K, G/T measurement was conducted with using solar flux density. In a fact, the contribution of LNA noise temperature is major factor to estimate G/T. That is why G/T measurement is possible even though only LNA was connected with antenna. Figure 3 shows the test configuration for G/T measurement.

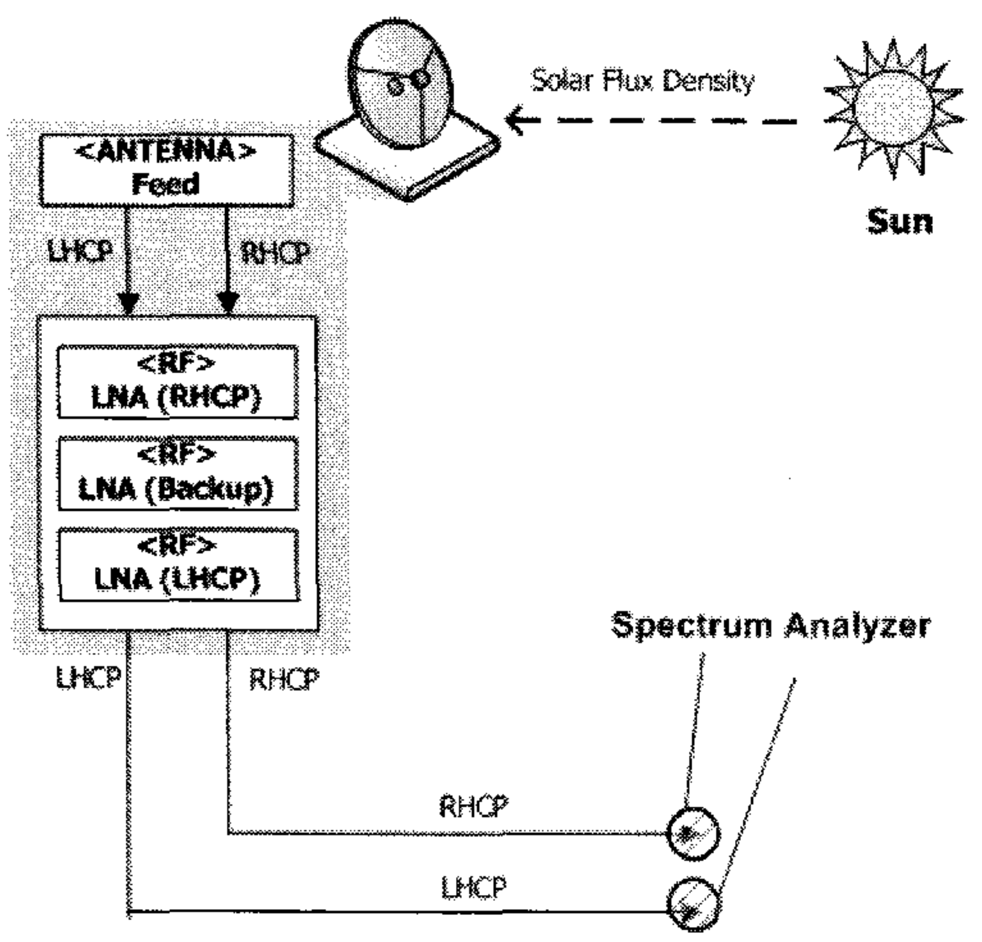

Figure 3 Test configuration for G/T measurement

The summarized test procedure is as followings,

○ Step1: Measuring Y-factor by using spectrum analyzer. Y-factor is the noise floor difference when antenna is pointing to Sun and cold sky. Namely, $Y = P_{SUN}/P_{COLD\text{-}SKY}$

○Step2: Calculating G/T with following equation.

$G/T = (Y-1) \times 8 \times \pi \times k \times L / (F \times Lambda^2)$

Where,

k = Boltzmann's constant, 1.38E-23 joules/degK

L = beamwidth correction factor

F = solar flux at 1697MHz in watts/meter^2/Hz

Lambda = wavelength in meters at 1687 MHz,

Beamwidth correction factor (L) can be estimated as followings; $L = 1 + 0.38\ (Ws/Wa)^2$

Where, Ws = diameter of radio sun, 0.5 degree at 3000 MHz, 0.6 degree at 1420 MHz, 0.7 degree at 400MHz

Ws = antenna 3 dB beamwidth, 0.8 degree.

Regarding solar flux density (F), USAF Space Command runs a worldwide solar radio monitoring network with station in Massachusetts, Hawaii, Australia, and Italy. These stations measure solar flux density at 245, 410, 610, 1415, 2696, 4995, 8800, and 15400 MHz. Since the SD frequency is 1687MHz, corresponding solar flux density needs to be searched by means of interpolation.

All solar flux density during 45 days are available at http:www.sec.noaa.gov/ftpdir/lists/radio/45day_rad.txt

Figure 4 and 5 are Y-factor measured at the output of LNA on RHCP and LHCP path, respectively.

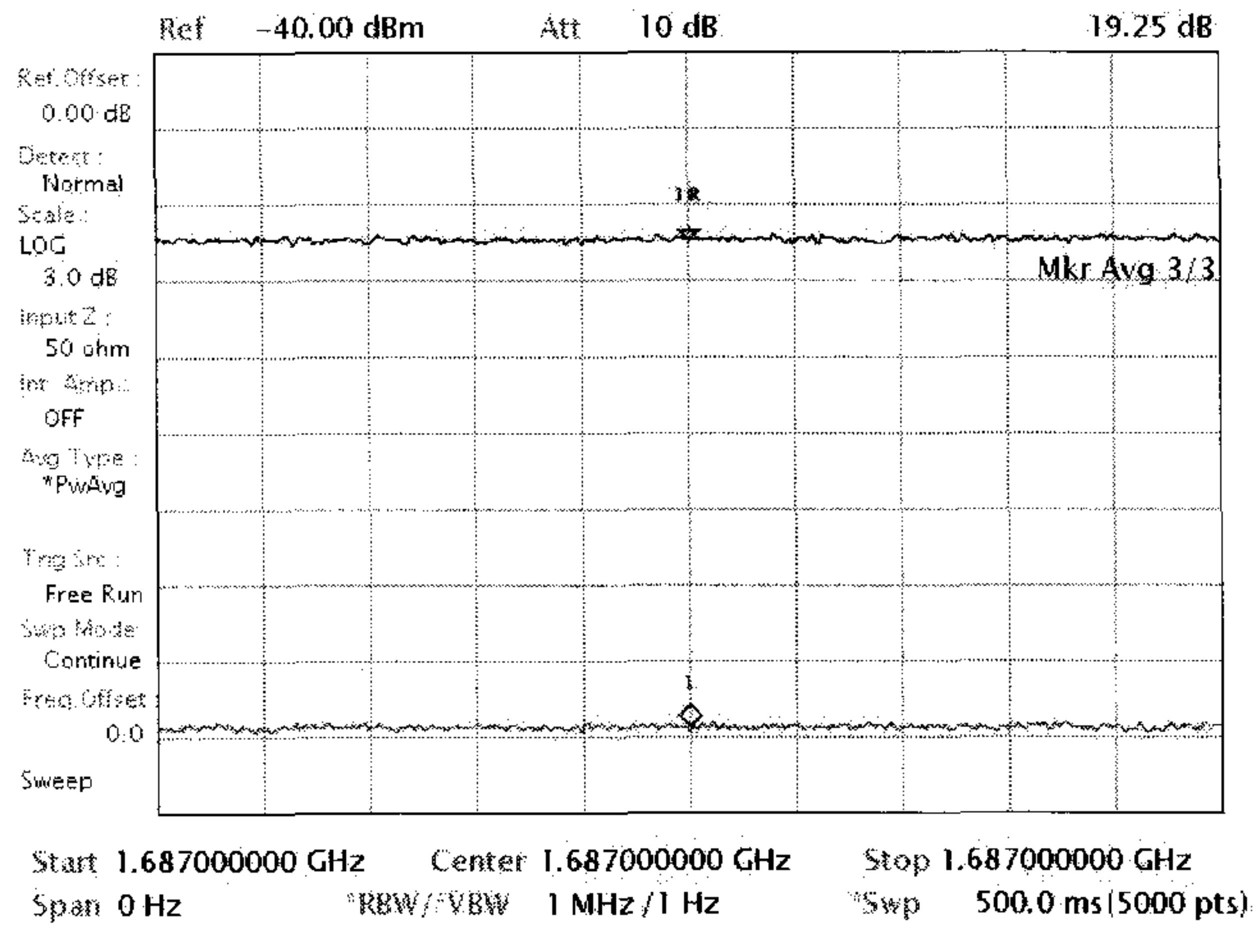

Figure 4 Y-factor measured on RHCP path

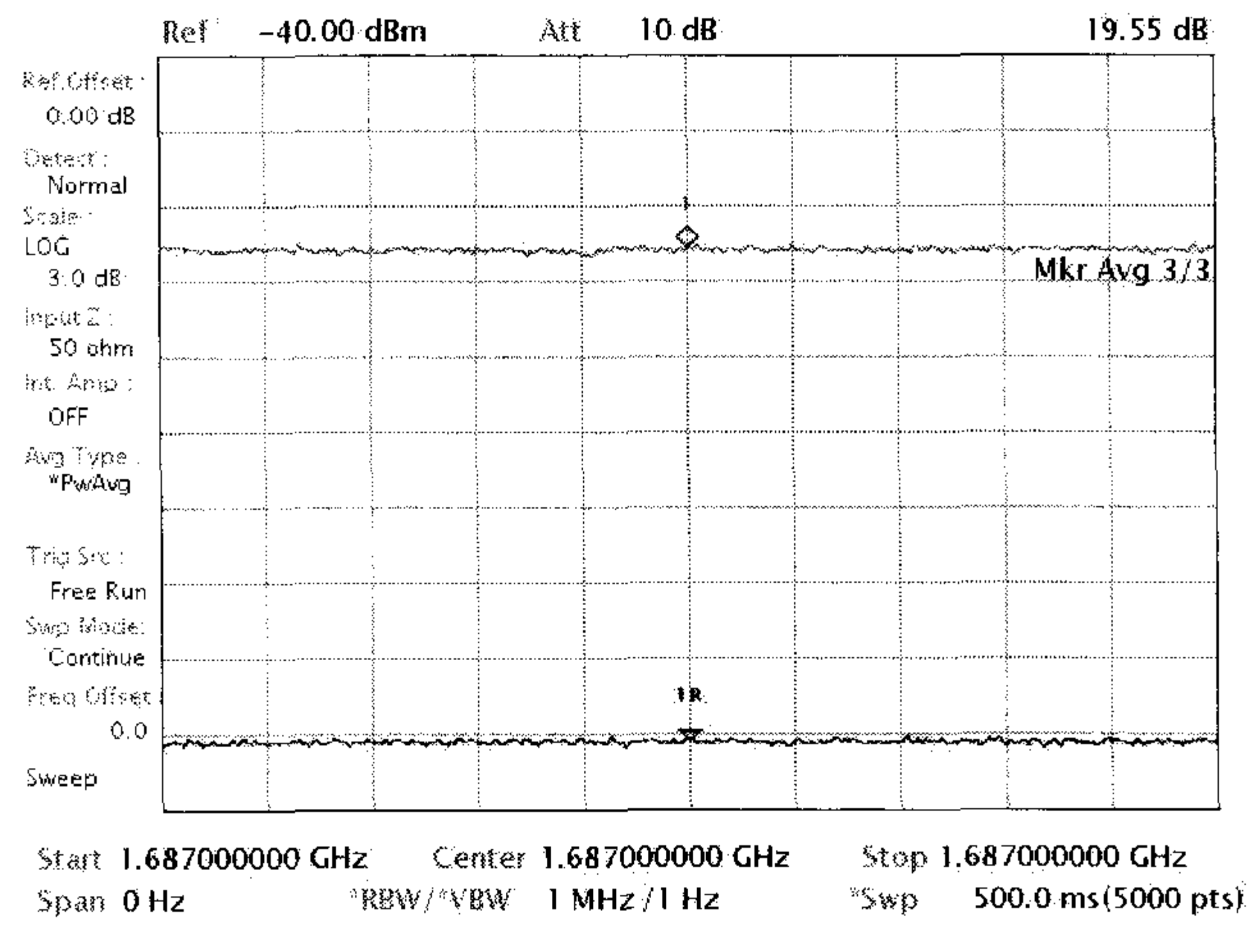

Figure 5 Y-factor measured on LHCP path

Considering solar flux density in the mentioned website, G/T was estimated as 22.64dB/K for RHCP path and 22.94dB/K for LHCP path, meaning that required G/T, 19dB/K is satisfied. However, there is about 2dB of difference between analyzed G/T and measured G/T. Regarding the G/T analysis, major parameters such as antenna gain, loss of passive elements placed between antenna and LNA input was referred to worst case design value. Therefore, there is possibility of improving the G/T features while integration was conducted with increasing antenna gain and decreasing the loss of passive elements.

4. CONCLUSIONS

G/T is a barometer to estimate the receiving performance of SOC 13m antenna system. For the stable operation, 19dB/K of G/T has been required. This paper presents the way to verify that G/T of implemented antenna system meets to the requirement by using two different methods, one is analysis with design value and the other is measurement by using solar flux density. As a result, the analyzed G/T is 20.2dB/K while the G/T measurement is about 22dB/K, meaning that the required 19dB/K is satisfied.

5. REFERENCE

[1] EADS Astrium 2007, MODCS to Ground ICD (Interface Control Document), *COMS critical design review meeting*, Issue 3, Revision 1, Toulouse, France

[2] Gerard Maral and Michel Bousguet, 2003. *Satellite Communications Systems*. Wiley, England, pp. 210-214.