FACTA UNIVERSITATIS (NIŠ)
Series: Electronics and Energetics vol. 1(1995), 97–102

NOISE FACTOR MEASUREMENT OF TVRO LOW NOISE CONVERTER

Bratislav D. Milovanović, Branko M. Narančić, Sladjana T.Ivković and Vladan D. Stanković

Abstract. A new, simple method for precise TVRO LNC (Television Receive Only Low Noise Converter) noise factor measurement is proposed in this paper. In this manner, the systematic measuring error due to the presence of coaxial/waveguide adapter is eliminated. The measurement procedure is developed using microwave measuring system for noise factor measurement based on the noise figure meter HP 8970B, opt. H18.

1. Introduction

Noise factor measuring characteristics of RF and microwave devices with standard coaxial connectors at input and output ports is well known and simply made in practice [1].

With devices of the waveguide ports, appropriate coaxial/waveguide adapter must be used. The adapter presence at input port of low noise devices significantly influences noise factor measurement. For eliminating systematic error caused by presence of the adapter, there should be previously done the characterization of the adapter in the frequency band of interest. Therefore, correction of the measurement results (de-embedded) is usually done by the attenuation of the adapter [2]. Adapter's attenuation vs. frequency, in this case, must be constant but it is usually not satisfied. This problem specially occurs with measurement noise factor of the low noise SATV SHF (Satellite Television Super High Frequency) converter which is essentially part of the receiving satellite system. Sensitivity and quality of SATV equipment primarily depends of the converter noise factor characteristic. Commercially available SATV SHF converters used in amplifying and

Manuscript received April 23, 1994.
Prof. dr B. Milovanović, S. Ivković and V. Stanković are with the Faculty of Electronic Engineering , University of Niš, Beogradska 14, 18000 Niš, Yugoslavia. B. Narančić is with the Ei EKOS-Niš, bul. Cara Konstantina 80-84, 18000 Niš, Yugoslavia.

conversion of the satellite TV signal from $(10.9 - 11.7)GHz$ band into a IF band have waveguide input port type R120 and extremely low noise factor (low level approximately $0.7dB$). The frequency characteristic of adapters is not constant in the band of the interest. These adapters are not widely extended in the SATV laboratory and also selfmade increases the problem. Insufficiently precise tools for production, despite carefully operation, cause variation of the attenuation vs. frequency from $0.05dB$ to $0.25dB$. Standard noise factor measurement procedure is the cascade connection adapter - converter measuring and it results higher noise factor for adapter's attenuation. Error correction results which are established by supposition of the constant attenuation are not applied here. For this reason, development of the new method which will be efficient and correct for noise factor measuring is needed.

In this paper, a new measurement noise factor procedure which successfully eliminates systematic error in the complete band of the interest, despite using adapter of unknown characteristics, is evaluated. The measurement is supported by standard available microwave measurement system which consists of noise source, microwave oscillator, mixer, noise figure meter and additional equipment such as cables, adapters etc. It is important to note that basic frequency band of the noise figure meter (directly measurement without external mixing) must cover IF band. The evaluation of this method is performed in the Laboratory for microwave techniques and satellite television of the Faculty of Electronic Engineering of Niš by using the Noise Figure Meter HP 8970B option H18 with higher frequency limit baseband $1.8GHz$.

2. Basic Theory

The simplest characterization of the coaxial/waveguide adapters is done with two identical adapters. Therefore, in the common case, there are differences between the same type adapters which accomplished this measurement. The measurement method, proposed in this paper, is based on the noise factor measuring of different combination two-cascade elements (adapter-converter). Denote with F_1, G_1 and F_2, G_2 the noise factor and available gain 1st and 2nd adapters, respectively. Therefore, the amplifying of the passive devices in dB is negative, and equation which related to the noise factor and noise figure is $F(dB) = 10 \log F$ [1].

Denote noise factor converter with F_D (index D for Device Under Test).

For two-elements cascade combination (Figure 1a,1b,1c) overall noise

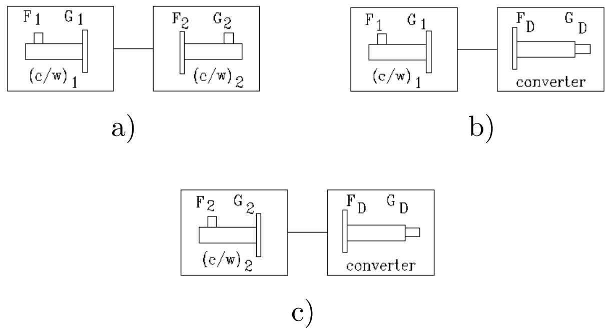

Fig. 1. The two elements combination of adapters and converter

figure may be presented by following equations:

$$F_{12} = F_1 + \frac{F_2 - 1}{G_1}, \tag{1}$$

$$F_{1D} = F_1 + \frac{F_D - 1}{G_1}, \tag{2}$$

$$F_{2D} = F_2 + \frac{F_D - 1}{G_2}, \tag{3}$$

respectively.

The results for F_1, F_2 and F_D are obtained by solving of equations. For F_D we have the relation

$$\begin{aligned} F_D =& \frac{1 + G_2 F_{2D} - G_1 G_2 (F_{12} - F_{1D})}{1 + G_2} \\ =& \frac{1 + G_2 (F_{2D} + G_1 F_{1D}) - G_1 G_2 F_{12}}{1 + G_2}. \end{aligned} \tag{4}$$

Adapters are passive devices that following relation may be obtained:

$$F_1 = \frac{1}{G_1}, \quad F_2 = \frac{1}{G_2}, \quad F_{12} = \frac{1}{G_1 G_2} \tag{5}$$

and equation (4) simplifies,

$$F_D = \sqrt{\frac{F_{1D} F_{2D}}{F_{12}}}. \tag{6}$$

For decibel representation, relation above is

$$F_D(dB) = \frac{F_{1D}(dB) + F_{2D}(dB) - F_{12}(dB)}{2}. \tag{7}$$

In the special case, when adapters are identical, relation (6) and (7) further simplify

$$F_D = \frac{F_{1D}}{\sqrt{F_{12}}}, \tag{8}$$

$$F_D(dB) = F_{1D}(dB) - \frac{F_{12}(dB)}{2}, \tag{9}$$

that results with decreasing number of the measurements. According to this results may be concluded that, in the common case, are needed three measurements. First measurement is part of the calibration, and another measurement is cascade connection adapter-converter.

3. Measurement Procedure

Following by equations given above, measurement procedure consists of the next parts

1. the noise factor measurement of cascade connection two adapters,
2. the noise factor measurement of cascade connection adapter 1 - converter,
3. the noise factor measurement of cascade connection adapter 2 - converter.

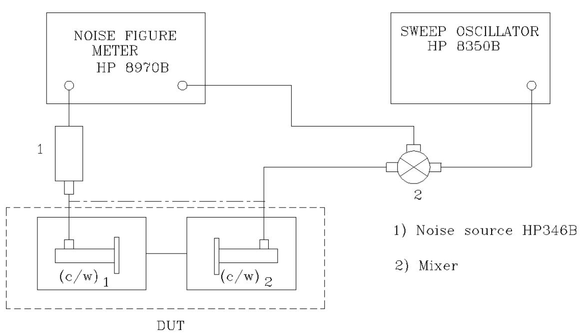

Fig. 2. Measurement configuration for cascade connection of two adapters

Noise factor measurement is preceded by the calibration of the measuring system with "through" connection. The measurement configuration of two adapters cascade connection is shown on Fig. 2. Basically, from the point of view of converter, this is extended calibration. Measurement is done once, and result does not depend on converter and is used for eliminating the effect of adapter presence. Since adapter is connected at input of the converter, it should be done its characterization in the frequency band $(10.9 - 11.7) GHz$. According to measuring configuration (Fig. 2), measurement mode 1.2 is used and allows frequency conversion outside of DUT. The mixer and external oscillator are used for conversion. Converted band is $(0.9 - 1.7) GHz$ which corresponds to satellite IF band. From the Figure 2 may be seen that mixer is the part of calibration routine which improves measurement results. This measurement begins with the following choices:

- measurement mode (1.2 SP),
- type of conversion (2.2 SP),
- L.O. frequency (3.1 SP 10000),
- start frequency (START 10900),
- stop frequency (STOP 11700),
- step frequency (STEP 20).

After that external oscillator HP 8350B should be turn on (48.0 SP, 46.0 SP, 41.0 SP). When all settings have been done, measurement configuration of DUT measuring (adapter1+adapter2) is done. The results are obtained on display of the HP 8970B.

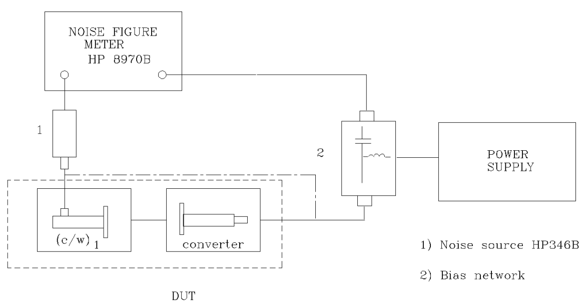

Fig. 3. Measurement configuration for the cascade connection adapter + converter

Second part of measuring is related to noise factor of cascade connection adapter1+converter. For the standard operation, DC voltage must be applied to the converter. Separating between DC and RF signal is done by so-called "bias network". Proposed measurement configuration is given in Fig. 3. It is obviously that "bias network" is taken into account during calibration which is another advantage. This measurement part begins by entering of data (L.O. frequency, start, stop and step frequencies). After calibration, the noise factor measurement of cascade connection adapter-converter is allowed. The third phase of the measurement is optional, and is done only if available adapters are different. In that case, procedure from second part with another adapter is repeated. Measurement consists of two phases in the case of identical adapters. Although the procedure of calculating noise factor converter is based on equation (4) and (6) it is very simply and usefully obtain complete measuring automatically. In this way measuring and processing error possibility is significantly decreased.

4. Conclusion

A new simply and satisfied correct method for noise figure measurement of the low noise SATV SHF converter supported by standard measurement microwave system is established. Proposed method eliminates the systematic measurement error caused by coaxial/waveguide (in the measurement procedure) whose characterization has not been done previously. In this manner, measurement error is reduced to the measurement error of the noise source. It is important to note that the valid characterization of the converter from the point of view noise has great importance and results in this paper it should be seen in that way. Beside that, proposed method may be applied without limitation for the noise figure measurement of the another RF and microwave devices with waveguide ports or with non-standard connectors.

REFERENCES

1. Fundamentals of RF and Microwave Noise Figure Measurements: *Application Note 57-1.*, Hewlett Packard, 1983.
2. Application and Operation of the HP 8970B Noise Figure Meter and HP 8970S Microwave Noise Figure Measurement System: *Product Note 8970B/S-2.*, Hewlett Packard, 1987.
3. HP 8970S, 8970T, 8970B, 346 A/B/C Noise Figure Measurement Product: *Hewlett Packard.*, 1987.
4. Applications and Operation of the HP 8350B Sweep Oscillator: *Hewlett Packard.*, 1987.
5. David E. Meer: *Noise Figures.* IEEE Transactions on Education, Vol.32, No.2, May 1989.
6. Jonathan Bird: *An Introduction to Noise Figure.* RF Design, March 1993.
7. Recommended methods of measurement on receivers for satellite broadcast transmissions in the 12 GHz band: *(Part 1: Radio frequency measurements on the outdoor unit).* Working group 8 of SC12A Technical Committee No.12: Radiocommunications (Sub-Committee 12A: Receiving Equipment), IEC, February 1988.