Freq	ENR uncertainty (95% CL)	
(GHz)	Transfer std	Primary std
12.4		0.074
12.5		0.070
13.0	0.059	0.056
13.5		0.060
14.0	0.063	0.074
14.5		0.065
15.0	0.080	0.062
15.5		0.066
16.0	0.078	0.065
16.5		0.078
17.0	0.083	0.072
17.5		0.060
18.0	0.083	0.069

Again we see that the results agree to within the uncertainties shown at the 95% confidence level. As hoped, the level of uncertainty is generally lower using the primary standard directly on the coaxial radiometer by 0.01 dB with the dominant uncertainty component being the adaptor.

5. Conclusion

The flexibility of the use of the UK waveguide standards has been considerably increased. The main benefits to the end users of these standards is improved uncertainty of calibration for coaxial devices. Additional benefits include greater flexibility in the provision of waveguide calibrations and improved confidence in the waveguide standards through direct comparison between them on the same radiometers.

Further investigation into phase-noise uncertainties

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1. Abstract

The question of the uncertainty of a phase noise measurement is a vexed question which is difficult to answer well. This is partly because the measurement depends on so many parameters and some of these change with every measurement. A consequence of this is that the uncertainty of the measurement depends to a great extent on the device being measured.

The work reported here describes some investigations into the effect of variation of some of the parameters with the particular intention of investigating the uncertainty of noise measurements made close to the carrier. Throughout this paper the method of making the phase noise measurements discussed is the phase detector method using a phase locked loop. This means that measurements close to carrier are inside the phase locked loop and that it is necessary to correct the noise measurement for the effect of the phase locked loop. The uncertainty of performing this correction is the main uncertainty which is investigated here.

2. Introduction

The phase detector method using a phase locked loop is the most common phase noise measurement technique used and a block diagram is given in Figure 1 below.

Schematic of Phase Detector Measurement Set-up

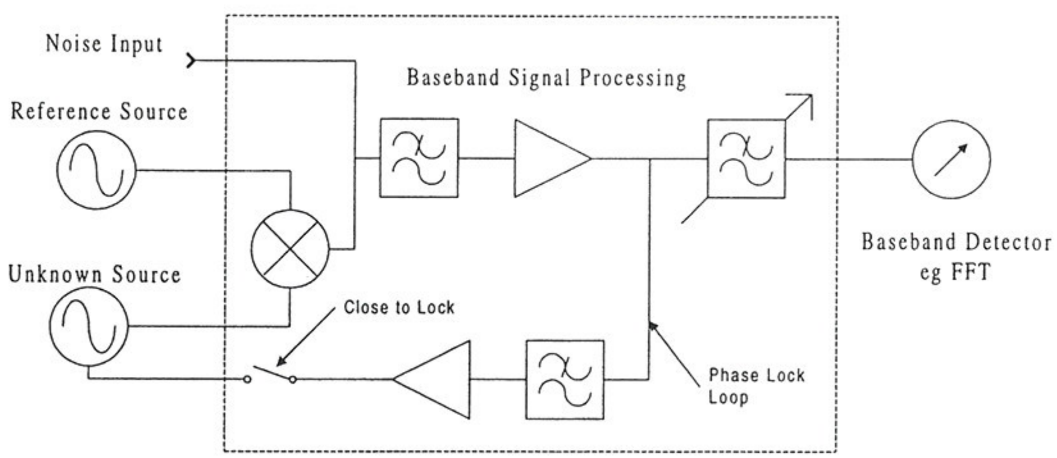

Figure 1 : Phase detector method block diagram

The use of a phase locked loop to establish quadrature suppresses the close in noise and the effect of this must be measured and a compensation applied. Establishing traceability for this correction has not previously been addressed. For close to carrier noise this correction will be very large and any errors in the correction could result in highly erroneous measurements

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2.1. Previous work on traceability

Work on the traceability of this method has been presented previously [reference 1]. This work does not address any issues associated with the phase lock loop itself and so can only be considered to be valid outside the loop bandwidth at least until the treatment is extended. The discussion here draws heavily on that work and this discussion would not have been possible without it.

Several contributions to the overall uncertainty are considered and are given in the table below which is reproduced from reference 1:

Uncertainty Component	Contribution [dB]
Type A Contribution per Measurement	$\frac{10}{\ln 10} \cdot \frac{1}{\sqrt{N}}$
V_{rms}.	= 0.19 (N=500)
Type B Contributions per Measurement	
Linearity, G_{Lin}.	0.07
Power Spectral Density, K_{PSD}.	0.92
Frequency Response, G(f).	0.013
Phase Detector Constant, K_ϕ.	0.08
Measurement Environment Contributions	
AM Noise Rejection	*measure level and rejection*
Noise Floor	*measure or calculate*
Reference Source	*measure or calculate*
Multiple Source Measurement	*combine uncertainties*
Total, as RSS [dB]	**0.95**

Table 1 : Uncertainty for phase detector method

There are several terms which must be considered, the dominant term being that due to the deviation from unity of the power spectral density response of the spectrum analyser. The uncertainty due to the phase detector constant is small and there is no term for the VCO tune constant. This is correct for measurements made outside the phase locked loop and for measurements made inside the phase locked loop where the loop suppression is measured. However, the loop suppression can also be predicted from the values of the phase detector constant and the VCO tune constant and it is this approach which is investigated here.

3. Correction for the phase locked loop

The method of correcting for the phase locked loop is based on that used in the HP 3048A phase noise measurement system. In this system a polynomial curve is derived which is used to correct the measured phase noise. The coefficients of this curve are derived by one of two methods, fitting to measured data or fitting to values calculated from the measured loop constants. In normal circumstances it would be reasonable to assume that one would use measured data when seeking the most accurate value but for the purposes of this investigation it is valid to use values calculated from the measured loop constants since this makes it straightforward to alter the correction coefficients in a realistic manner.

The response of the phase locked loop is described in terms of its poles and zeros, some of which are fixed by the interface and some of which are dependant on the oscillators under test. Two parameters vary depending on the phase locked loop configuration. One of these is an assumed pole which can be calculated from measured phase locked loop suppression data to allow for any peaking in the PLL or which can be derived from previously measured data. The other parameter is the open loop bandwidth, B_{op} defined by $B_{op}=|K_\phi.K_{VCO}.A_1.A_2.10^{(G1+G2+6)/20}|$ where K_ϕ is the

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