

Improved use of the UK waveguide noise standards

Stephen Protheroe

1. Abstract

Historically, the development of the UK waveguide standards at the same time as the development of the radiometer in each frequency band has meant that the standard and the radiometer have developed as a single unit. In particular, the standard is operated and controlled by the same system and software as the radiometer. This means that each standard can only be used with its associated radiometer.

Advances in the characterisation of adaptors and tapers has led to a situation where this is no longer the ideal solution and a new approach where the standard is used and controlled separately is described here. The new approach means that it is now possible to perform a waveguide calibration using a coaxial radiometer with minimal increase of uncertainty. Furthermore, it has also been demonstrated that with the use of calibrated adaptors, this method can produce a lower uncertainty for coaxial noise source calibrations.

2. Introduction

The ability to use a waveguide standard on more systems than originally intended has several possible benefits. These include:

1. The use of a standard covering the frequency band 8.2 GHz to 12.4 GHz (for example) on the adjoining bands to allow the frequencies at the band edges to be compared across systems without the use of an intermediate calibration.
2. The use of a waveguide standard on the coaxial radiometer with a waveguide to coaxial adaptor allows the system to be calibrated directly at the waveguide flange and used to perform waveguide calibrations on the coaxial radiometer as an alternative to the range of Dicke radiometers used by NPL below 18 GHz.
3. The use of a waveguide standard on the coaxial radiometer using a calibrated waveguide to coaxial adaptor allows the coaxial radiometer to be calibrated at the coaxial input port (a figure referred to as the 'working standard' temperature) in terms of the waveguide standard directly. This should improve the uncertainty of calibrations carried out on the coaxial radiometer.

Objective 2 above was the original motivation of this work but objective 3 is likely to offer the greatest benefit. At present, the coaxial radiometer is calibrated in terms of a coaxial primary standard to 2 GHz and by use of a hot transfer standard calibrated through adaptors on the waveguide systems above this. This means that the uncertainty of a coaxial calibration is made up of the following components:

1. the uncertainty of the waveguide system working standard calibration
2. the uncertainty of the waveguide system unknown calibration (the transfer device)
3. the uncertainty associated with the adaptor characterisation
4. the uncertainty of the calibration of the coaxial working standard
5. the uncertainty of the final calibration of the coaxial unknown device.

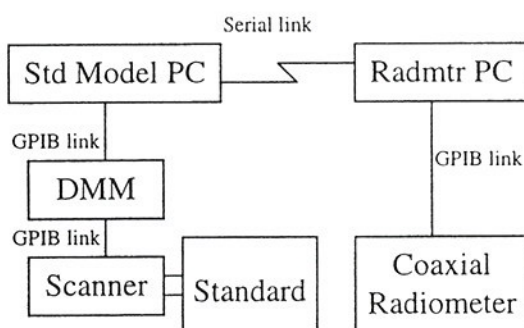
The use of the waveguide standard directly on the coaxial radiometer eliminates components 1 and 2 in this list and so can be expected to give lower overall uncertainties.

National Physical Laboratory, Queens Road, Teddington, Middlesex, TW11 0LW

Objective 1 above is worthy of some consideration. At present, it is only possible to compare two waveguide standards by use of an intermediate device which is calibrated on two systems. The uncertainty associated with this calibration means that agreement can only be shown to within wider limits than would be desirable. If the working standard on one waveguide radiometer can be carried out directly using one standard and nearly directly, using only a calibrated waveguide taper with another standard then a better intercomparison can be achieved. In some cases it may be possible and desirable to broaden the range of overlap between the standards for the purpose of performing intercomparisons of this sort. This could be done by extending the range of operation of the waveguide standards below the normal operating range for that waveguide size. To do this would require re-characterisation of the standards which is not a trivial task but it could be considered for the future.

3. Description of the method

The proposed method is quite simple in principle. The standard requires a number of platinum resistance thermometers (PRTs) to be read, a noise temperature calculated and then supplied to the radiometer control program. In the existing systems, the radiometer control and the calculation of the standard values are performed sequentially in the same program but this is not actually necessary. The new approach is to separate the process into two concurrent operations which has the additional benefit of reducing measurement time and hence the period over which we must assume the radiometer is stable.



The primary standards program consists of code to calculate the noise temperature of the standard by controlling a scanner and reading the value of the PRTs using a DMM. The noise temperature can then be calculated in one of two ways. Historically, a 'simple' model derived from the rigorous 'full' model has been used since the full model was too computationally intensive for real time operation on the computers available until recently. The simple model consists of a correction factor to a calculated noise temperature based on the deviation of temperatures in the standard from those used in the full model. The advent of more powerful computers has meant that it is possible to implement the full model in real time and this is a task which is desirable. The work described here does not, however, implement the full model although the software contains the option to use it.

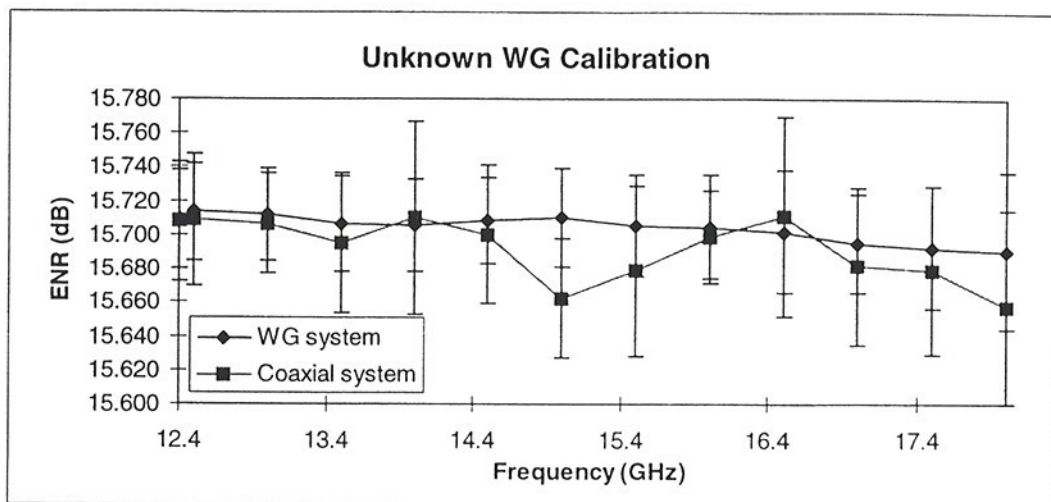
The standard operation is controlled by a separate computer with associated scanner and DMM. The communication with the radiometer system is performed using a serial link. In operation, the radiometer program requests a value of noise temperature and uncertainty at a particular frequency and the standard program takes the necessary PRT readings, calculates the noise temperature and uncertainty and sends the values along the serial link. The whole of the standard part of this operation mode has been implemented using the 12.4 GHz to 18.0 GHz standard although the lower frequency standards may be used when mechanical modifications to the bench are made.

4. Results.

4.1. Waveguide calibrations

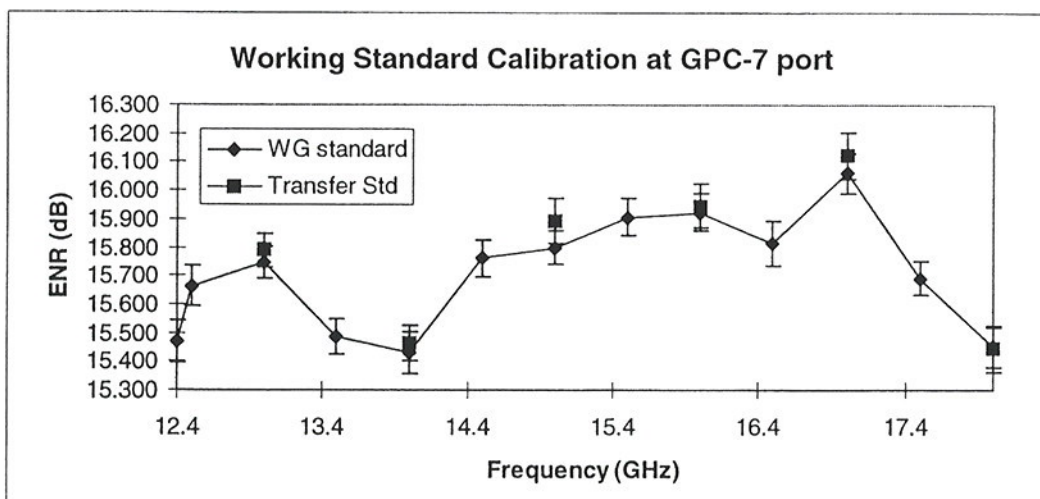
The GPC-7 input port of NPL's Total Power coaxial radiometer was adapted to WG18 and calibrated using the primary standard as described previously. A gas discharge reference device was then measured. The graph below shows the historical average for the device as measured on NPL's waveguide Dicke radiometer which contains not less than six sets of measurements at each frequency and the coaxial results which is the average of two sets. As can be seen, the results

agree to within the 95% confidence level uncertainty with the worst case at 15 GHz where there is still a good overlap in the uncertainties. The level of uncertainty is on average 0.015 dB higher using the adapted coaxial system because of the relatively poor match of the adaptor compared to the input of the waveguide radiometer.



4.2. Coaxial Calibration

The efficiency of the adaptor used in 4.1 was found which enables the system (working standard) to be calibrated at the input connector of the radiometer. Since this value has been previously determined with a transfer device, we are able to compare this value directly and do not require the addition reference device measurement.



Freq (GHz)	ENR uncertainty (95% CL)	
	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.