A FULLY AUTOMATED AF SERIES SUBSTITUTION RF ATTENUATION MEASUREMENT SYSTEM

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Abstract

The series substitution technique is one of the most accurate methods for measuring RF and Microwave attenuation and is capable of making measurements exceeding 150 dB at RF frequencies with uncertainties of the order of ± 0.001 dB per 20 dB. This paper details such a system incorporating an automatic inductive voltage divider as its attenuation reference.

Introduction

The National Standards of Attenuation have been provided by a variety of different techniques depending on frequency and dynamic range requirements. The current 'low frequency' system [1, 2] employs a mixture of techniques to cover the measurement range of 150 dB at frequencies between 0.5 and 100 MHz. Up to 100 dB the fully automated Voltage Ratio method is employed but at higher attenuations this method suffers from noise. To overcome this limitation the system can also be configured for series substitution employing phase sensitive detection which is comparatively unaffected by the noise generated by the mixer. As the Voltage Ratio method requires the calibration of a detector (which can be considered as a transfer device) the uncertainty of this method will generally be inferior to 'pure' series substitution.

While the Voltage Ratio system (once calibrated) is fully automatic, the reliance on a manual Inductive Voltage Divider (IVD) as the reference device in the series system makes the system slow and labour-intensive to use. The development by NPL of electrically isolated automated IVDs enables the full automation of such a system.

This paper will discuss the development of an automated series substitution system (figure 1), which combines the operational convenience of the current Voltage Ratio systems together with the higher dynamic range and lower uncertainties of the series substitution technique.

Design Considerations

The operation of series substitution attenuation systems together with the IVD standard is discussed in reference [3]. In common with other NPL developed systems, the device being measured is inserted into the system between impedance matching elements so that the change in power level is (by definition) the actual attenuation value and no correction for impedance mis-match is required. The system described here has RF isolation and impedance matching circuits optimised for operation around 30 MHz. However there is no reason why the techniques developed here cannot be applied to the other NPL systems operating between 0.5 MHz and 50 GHz. Additionally, the automated IVDs can be incorporated into the existing Voltage Ratio systems to reduce the manual intervention needed to characterise the detector. While designed for 10 kHz operation one of the IVDs was successfully adapted to operate at 50 kHz for operation with the higher frequency Voltage Ratio systems.

Generally the practical limitations on the dynamic range of an attenuation measurement are set by the system noise and by signal leakage. Good engineering practice regarding system layout and screening can reduce the leakage to the 180-190 dB level. The phase sensitive detector requires a reference that is locked to, or derived from, the RF source. Here, rather than introduce a second mixer and 'AF' channel to generate the reference, a third synthesiser is locked to the RF source and the local oscillator. Unwanted signals are further reduced by generating the reference signal at half the IVD operating frequency and using the PSD to detect the second harmonic of the reference. Employing optical fibre interfaces for controlling the IVD (which is itself battery powered) and also for the frequency reference links between the RF and AF signal generators will minimise earth loops and spurious RF paths.

Unlike other primary systems developed at NPL, wherever possible, commercial equipment has been used to facilitate the wider adoption of primary level attenuation capability in other laboratories. In the current design only the RF matching and isolation components plus the IVD and 10 kHz amplifiers are NPL designed and manufactured.

System Verification and Testing

At the time of writing the testing of the system is incomplete, however the initial results are encouraging with resolution and stability of 0.0001 dB being demonstrated for a 100 dB insertion.

It is important that the IVDs are used correctly in order to extract their full potential accuracy. Normally these devices are used in bridge circuits, here they are connected between high input / low output impedance unity gain buffer amplifiers. The buffer amplifier linearity, together with the IVD performance, can be evaluated by multiple substitutions and by comparison with the existing IVDs used with other attenuation systems. At normal working signal levels the amplifier pairs have departures from linearity of ± 0.0001 dB in 20 dB. It is interesting to note that during these trials an apparent discrepancy between the new automated and old manual IVDs of 0.0002 dB was observed. This is in exact agreement with the calibration data supplied by NPL's Applied Electrical and Magnetic (AEM) group. Such resolution and agreement is better than expected and bodes well for the overall design targets for the system performance.

Full results, including comparison with other attenuation systems will be presented at the conference.

Acknowledgement

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References

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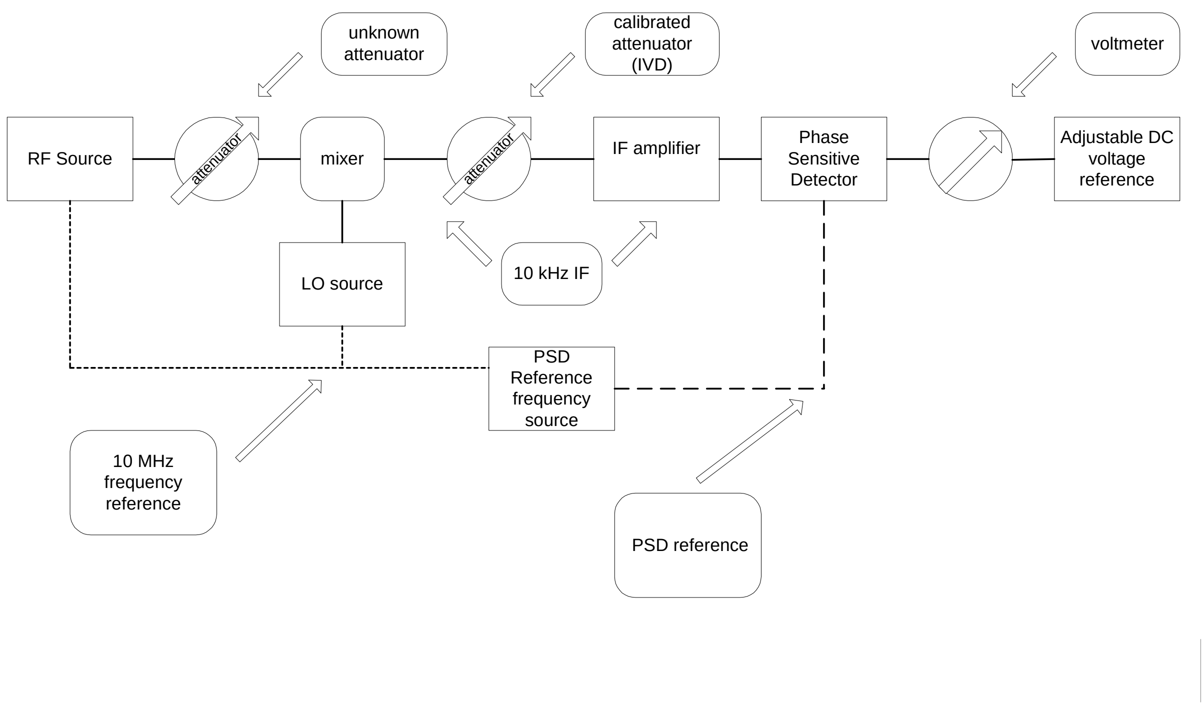

Figure 1: AF Series Substitution System
For clarity, impedance matching and RF isolation components have been omitted from the diagram.