A 0.01-18 GHz WIDE DYNAMIC RANGE PRECISION VECTOR RATIO METER

by

Fritz K. Weinert, Senior Member, IEEE
Weinschel Engineering Co., Inc.
Gaithersburg, Maryland

Summary

A dual channel complex vector ratio meter has a greatly improved dynamic range and higher accuracy than presently available Attenuator Calibrators[1] or Network Analyzers[5]. State-of-the-art performance is achieved through the application of a new Parallel IF Vector Substitution principle. It produces measurements in digital form over a 100 dB single step dynamic and display range, has 0.001 dB and 0.01° resolutions for a frequency range 10 MHz to 18 GHz.

It is operated manually or under internal or external program control in stepped or swept frequency modes, without the need for equalized cables. It performs insertion loss measurements.

Signal to noise ratios are adaptively enhanced by control of the closed loop bandwidth of the vector substitution balancing loops. Adaptive digital averaging provides shortest measurement times consistent with the selected resolutions.

Digital data processing, local oscillator tuning and tracking, internal programming and self test functions are provided by two internal micro-processors.

Local Oscillators

Two yig-tuned local oscillators (LO) are employed for the conversion of the microwave signal to the intermediate frequency (IF). One covers the range 10 MHz to 2.2 GHz, the other 1.9 to 18 GHz.

LO frequencies below 500 MHz are generated by digital frequency divider circuits. This gives superior performance over heterodyne LO's because of improved carrier to noise ratio and better tuning accuracy. LO frequencies in the range 1-2.2 GHz are obtained by use of frequency doublers. The 1.9 to 18 GHz range is covered by one LO with a frequency range of 1.9 to 4.6 GHz and through the use of second and fourth harmonic mixing.

Phase coherence between the microwave signal and the LO is obtained by phase locking to the channel 1 IF. A low noise digital to analog converter tunes the LO's in coarse steps and achieves high spectral purity of the LO signals. Fine tuning is provided by the phase locked loop.

Tuning, searching, sideband determination, locking and signal tracking are under control of one micro-processor. Search width is nominal 2% of center frequency and is selectable between 1 and 20%.

An IF frequency of 1.25 MHz provides a spurious free locking range down to 10 MHz.

Mixers

Broadband mixer/IF-preamplifier/LO-isolation amplifier combinations are contained in RF-probes on 3 ft. long cables. One set covers the 10 MHz to 2.2 GHz range, the other the 1.9 to 18 GHz band.

Greater than 160 dB of attenuation is provided for the coherent leakage path between both channels by the LO-isolation amplifiers and by good signal to LO port isolation of the mixers. The frequency range of the high band LO and its isolation amplifiers covers only 1.9 to 4.6 GHz. The latter provide increasing attenuation above this band where it is otherwise difficult to achieve high reverse isolation in a broadband microwave amplifier.

High coherent leakage attenuation assures high measurement accuracies particularly for the measurement of high attenuations. For the measurement of a 100 dB device and by using RF levels of -70 dBm at the input of the reference channel 1 and 0 dBm at the device under test (DUT) insertion point one obtains maximum errors of 0.00027 dB and 0.0018°. Errors due to coherent leakage are therefore negligible.

Double balanced mixers are employed in the 10 MHz to 2 GHz probes. Stability of conversion loss is obtained by the use of leveling loops which keep the LO power input into the mixers constant.

A five diode wideband balanced mixer is used in the high band probes. It employs fundamental mixing from 2-4.6 GHz and second harmonic mixing from 4-9.2 GHz without increase of conversion loss due to an anti-parallel diode pair construction[6]. Fourth harmonic mixing is used from 8-18 GHz with an 8 dB increase in conversion loss. Closed loop feedback bias circuits are employed which control the rectified diode currents and diode bias voltages and the local oscillator power level. High stability of conversion loss is provided by these circuits as well as by a fifth diode which is used for temperature tracking.

The IF preamplifiers used in the probes have low noise FET front ends. Extraordinary gain stability and linearity are achieved through heavy negative feedback. A gain compression of less than 0.001 dB is obtained.

Parallel IF Vector Substitution

The parallel IF vector substitution employed is a refined technique of known basic principles[4,1]. It combines the high accuracy of the parallel IF substitution method with the wide dynamic range of coherent detection. The high accuracy of the former is obtained by substituting the unknown IF signal for a precisely known signal which is generated by means of an accurate IF reference attenuator[7]. In the parallel IF vector substitution principle a high gain closed loop control circuit uses a precision step attenuator as feedback element which entirely determines the closed loop gain.
The wider dynamic range of coherent detection over envelop detection is due to the fact that former does not suffer from signal compression by noise which yield an effective square law characteristic for the latter.

The advantages of the parallel IF vector substitution principle as implemented in the model VM-4A are:
1. High measurement accuracy
2. Wide dynamic range
3. Phase measurement capability
4. No signal modulation required
5. Optimized measurement times

The performance of the instrument relating accuracy, dynamic range and measurement times is pictured in figure 1.

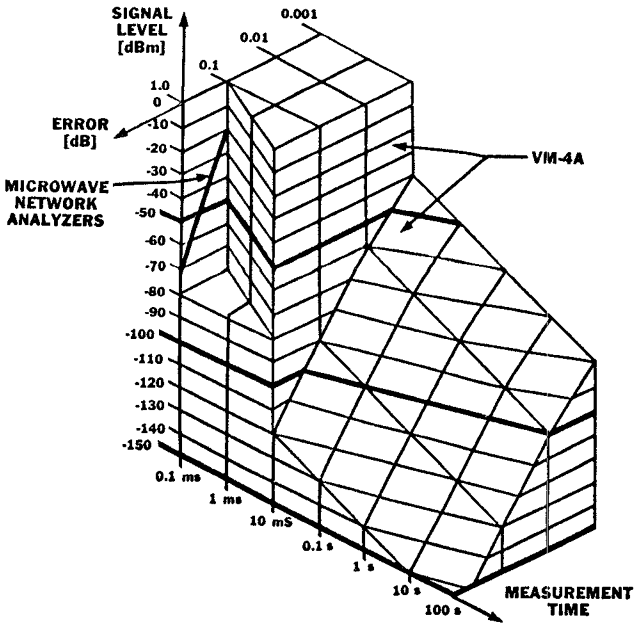

Figure 1. Performance of Model VM-4A Precision Vector Ratio Meter.

The conditions under which the performances of figure 1 are obtained are as follows: 3σ noise error equals accuracy. System is calibrated by Weinschel Model PA-4 Laser Piston Attenuator. Source and load mismatch errors have been eliminated by self calibration[2] (time of which is not included). Precision masking attenuator ahead of measurement channel 2 as follows: 20 dB for accuracies 0.001 dB and 0.01 dB; 10 dB for 0.1 dB accuracy and 0 dB for 1 dB accuracy.

A high level complex vector of known amplitude and phase is generated automatically by a high gain negative feedback balancing circuit and is attenuated by a precision step attenuator of 130 dB in 10 dB steps. This accurately known substitution vector is summed with the IF signal from the mixer (figure 2). The feedback control loops keep the sum voltage at zero and therefore the substituted vector equal in amplitude an opposite in phase to the IF vector.

Quadrature synchronous detection is employed and used to generate error signals for controlling the phase and amplitude of the 1.25 MHz high level substitution vector. Its amplitude is accurately measured by a combination of a precision 15 dB (in 1 dB steps) attenuator, followed by a linear detector, a lin/log shaper and a 12 bit analog to digital converter. The phase is measured by a zero crossing triggered digital counter with selectable resolution.

The noise error in the displayed measurement result is reduced by adaptive control of the closed loop bandwidth of vector substitution loops and by adaptive digital signal averaging. The 3σ noise error equals one least significant count of the chosen resolution, i.e. 0.001 dB/0.01°, 0.01 dB/0.1°, 0.1 dB/1° respectively.

The combination of adaptive analog filtering and digital averaging provides for shortest measurement times. Measurements of level differences in dB, the phase in degrees between the channels and of frequency are updated every 5 milliseconds.

Signal Source

The Weinschel Model 4312 Phase Locked Multiband system 0.01-18 GHz is used as signal source for the internal program mode. The signal source is digitally tuned over the IEEE-std-488 general purpose interface bus and the measured data is stored in the instrument for later display or printout through a RS-232 port.

References

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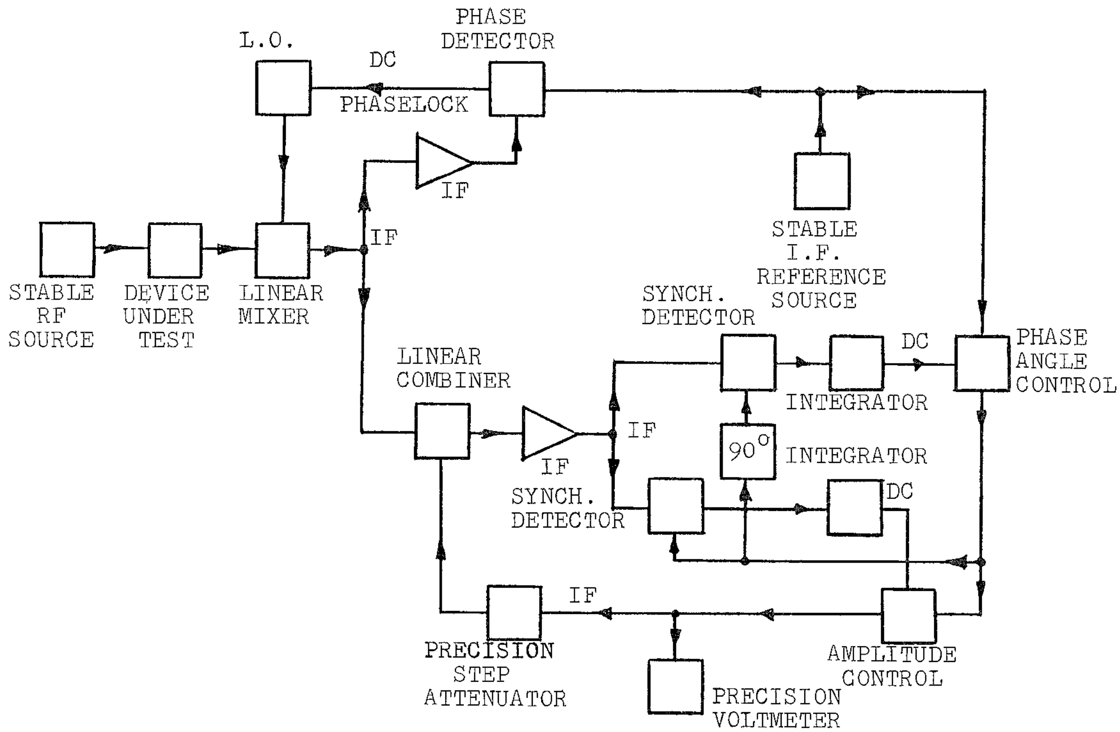

Figure 2.
Parallel IF Vector Substitution