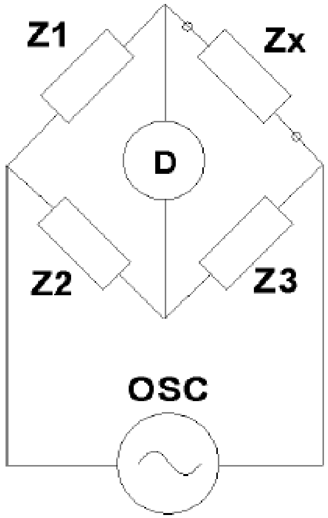
Radiofrequency Measurements

Impedance Measurements

Low-frequency Methods

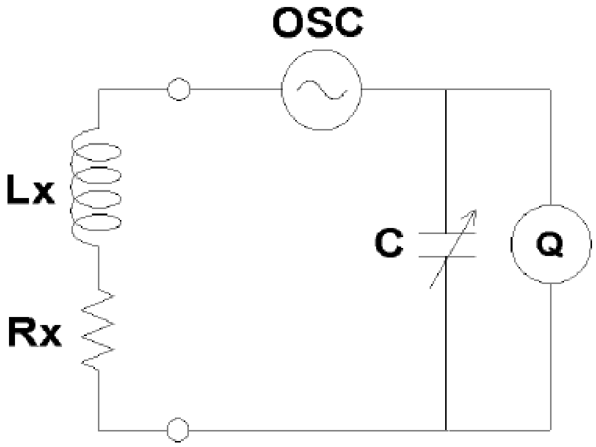
Bridge method



$$Zx = \frac{Z1}{Z2} Z3$$

When no current flows through the detector (D), the value of the unknown impedance Zx can be obtained by the relationship of the other bridge elements. Various types of bridge circuits, employing combinations of L, C, and R components as the bridge elements, are used for various applications.

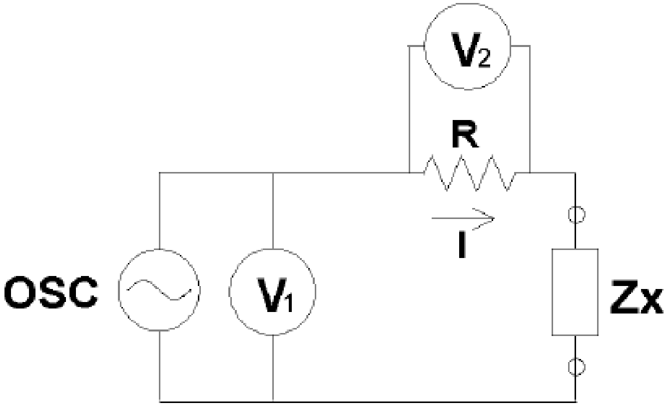
Resonant method



When a circuit is adjusted to resonance by adjusting a tuning capacitor C, the unknown impedance Lx and Rx values are obtained from the test frequency, C value, and Q value. Q is measured directly using a voltmeter placed across the tuning capacitor. Because the loss of the measurement circuit is very low, Q values as high as 1000 can be measured. Other than the direct connection shown here, series and parallel connections are available for a wide range of impedance measurements.

Low-frequency Methods

I-V method

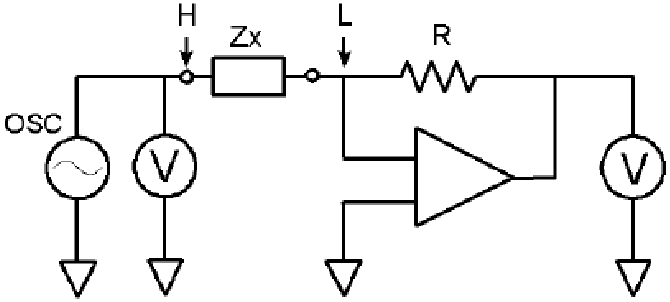


$$Zx = \frac{V_1}{I} = \frac{V_1}{V_2} R$$

An unknown impedance Zx can be calculated from measured voltage and current values. Current is calculated using the voltage measurement across an accurately known low value resistor, R. In practice a low-loss transformer is used in place of R to prevent the effects caused by placing a low value resistor in the circuit. The transformer, however, limits the low end of the applicable frequency range.

Low-frequency Methods

Auto balancing bridge method



The current, flowing through the DUT, also flows through resistor R. The potential at the "L" point is maintained at zero volts (thus called a "virtual ground"), because the current through R balances with the DUT current by operation of the I-V converter amplifier. The DUT impedance is calculated using voltage measurement at High terminal and that across R.

Note: In practice, the configuration of the auto balancing bridge differs for each type of instrument.
Generally LCR meters, in a low frequency range typically below 100 kHz, employ a simple operational amplifier for its I-V converter. This type of instrument has a disadvantage in accuracy, at high frequencies, because of performance limits of the amplifier. Wideband LCR meters and impedance analyzers employ the I-V converter consisting of sophisticated null detector, phase detector, integrator (loop filter) and vector modulator to ensure a high accuracy for a broad frequency range over 1 MHz. This type of instrument can attain to a maximum frequency of 110 MHz.

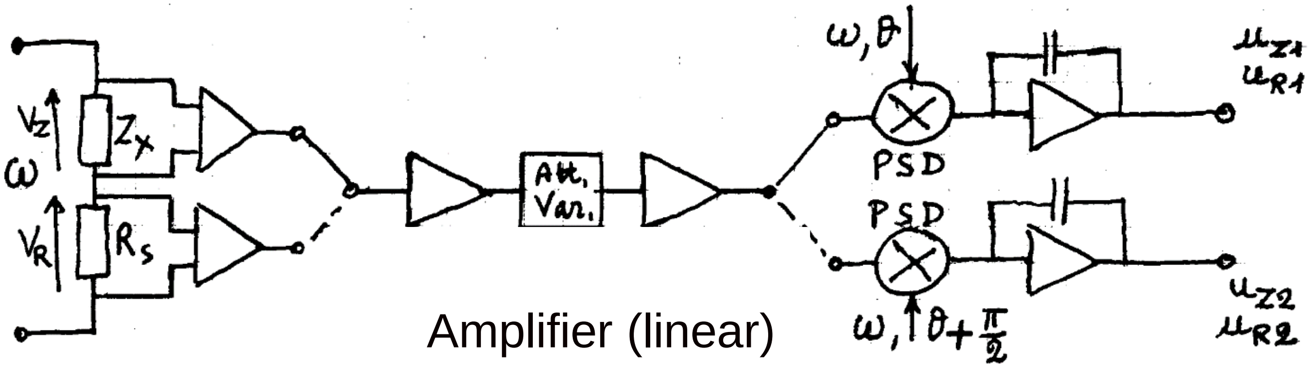
RF-IV

$$Z_X = |Z_X|\, e^{j\varphi}$$

$$V_Z = A\cos(\omega t + \varphi)$$

$$V_R = B\cos\omega t$$

$$\left|\frac{Z_X}{R_S}\right| = \frac{A}{B}$$



C cos (ωt + θ)

Amplifier (linear)

C cos (ωt + θ + π/2)

$$V = V_0\cos(\omega t + \varphi)\cos(\omega t + \theta) = (V_0/2)\,[\cos(\varphi - \theta) + \cos(2\omega t + \varphi + \theta) +]$$

$$\langle V\rangle = (V_0/2)\cos(\varphi - \theta)$$

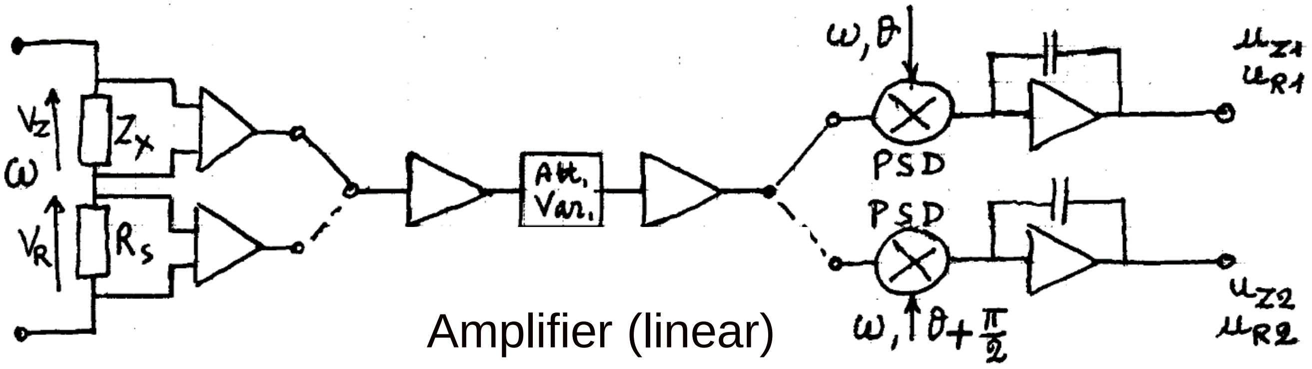
$$u_{Z1} = kA\cos(\varphi - \theta)$$

$$u_{Z2} = kA\cos(\varphi - \theta - \pi/2) = kA\,\mathrm{sen}(\varphi - \theta)$$

$$u_{R1} = kB\cos(-\theta)$$

$$u_{R2} = kB\cos(-\theta - \pi/2) = kB\,\mathrm{sen}(-\theta)$$

RF-IV



C cos (ωt + θ)

Amplifier (linear)

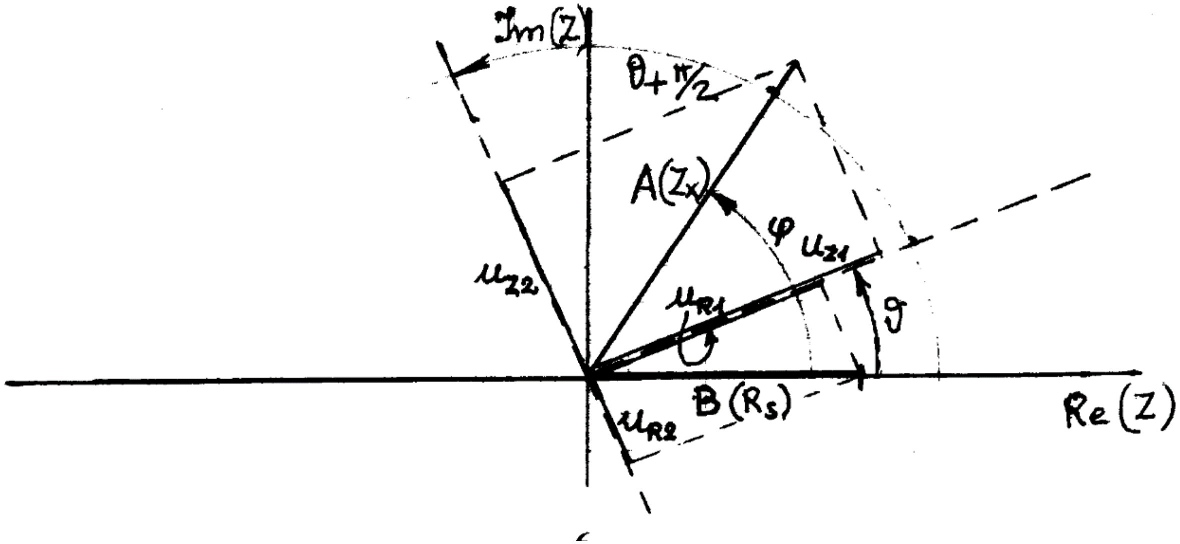
C cos (ωt + θ + π/2)

$$Z_X = |Z_X| e^{j\varphi}$$

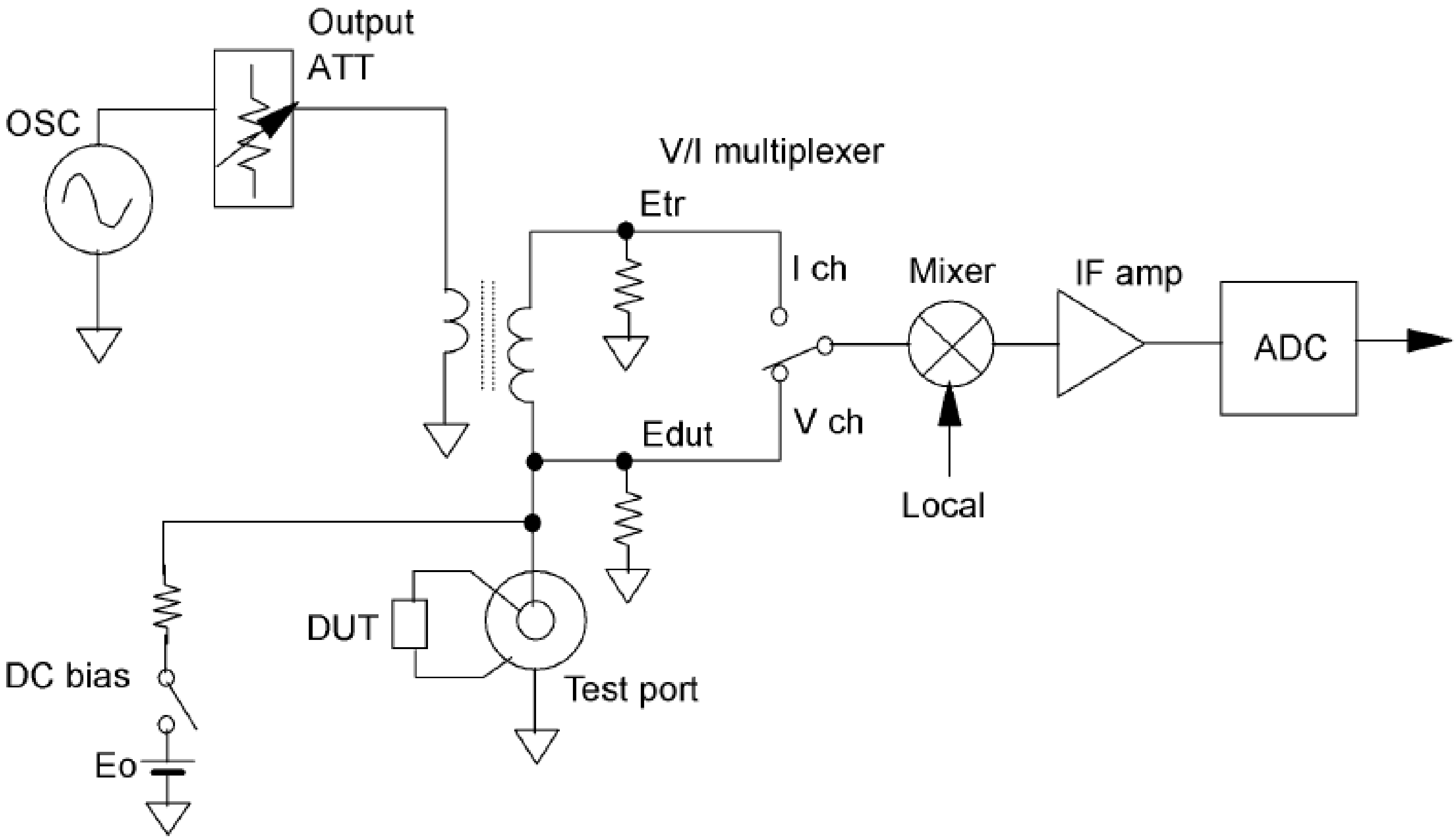
$$\left|\frac{Z_X}{R_S}\right| = \sqrt{\frac{u_{Z1}^2 + u_{Z2}^2}{u_{R1}^2 + u_{R2}^2}} = \frac{A}{B}$$

$$\cos\varphi = \frac{B}{A}\,\frac{u_{R1}u_{Z1} + u_{R2}u_{Z2}}{u_{R1}^2 + u_{R2}^2}$$

$$sen\varphi = \frac{B}{A}\,\frac{u_{R1}u_{Z2} - u_{R2}u_{Z1}}{u_{R1}^2 + u_{R2}^2}$$

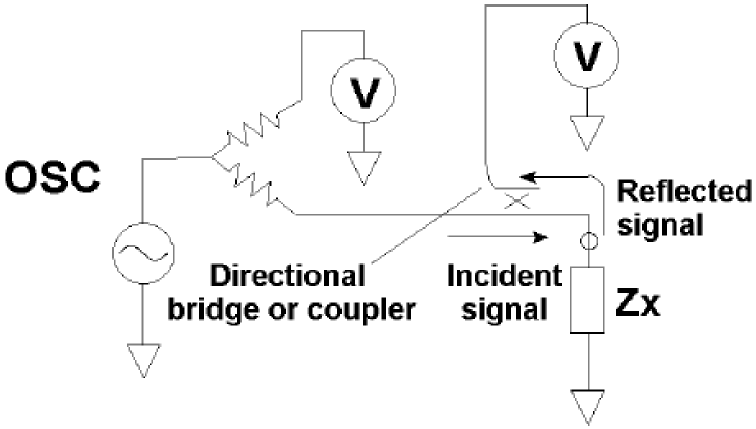


RF-IV (for GHz)


Output
ATT
OSC
V/I multiplexer
Etr
I ch
Mixer
IF amp
ADC
V ch
Edut
Local
DUT
DC bias
Test port
Eo

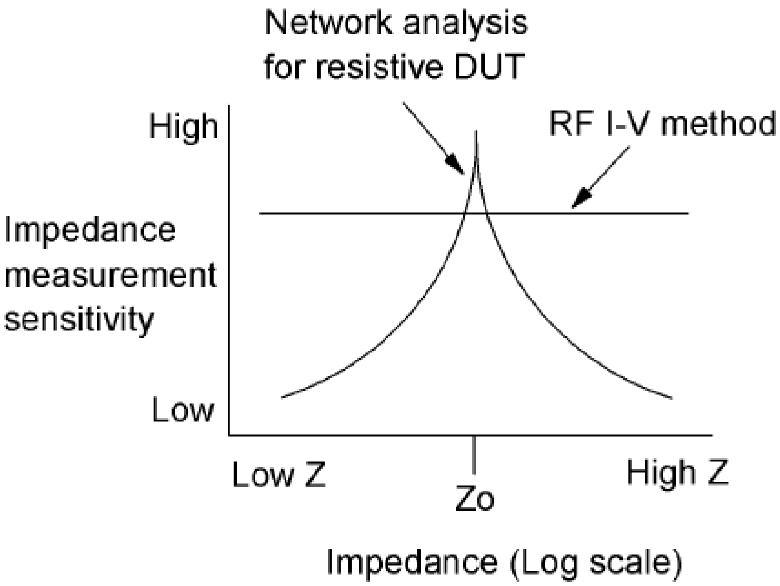
High-frequency Methods

Network analysis method

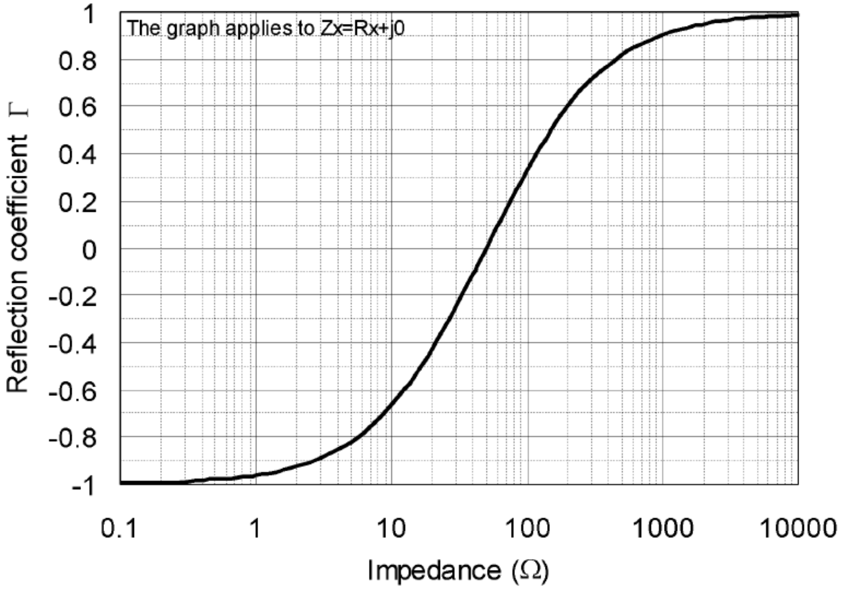


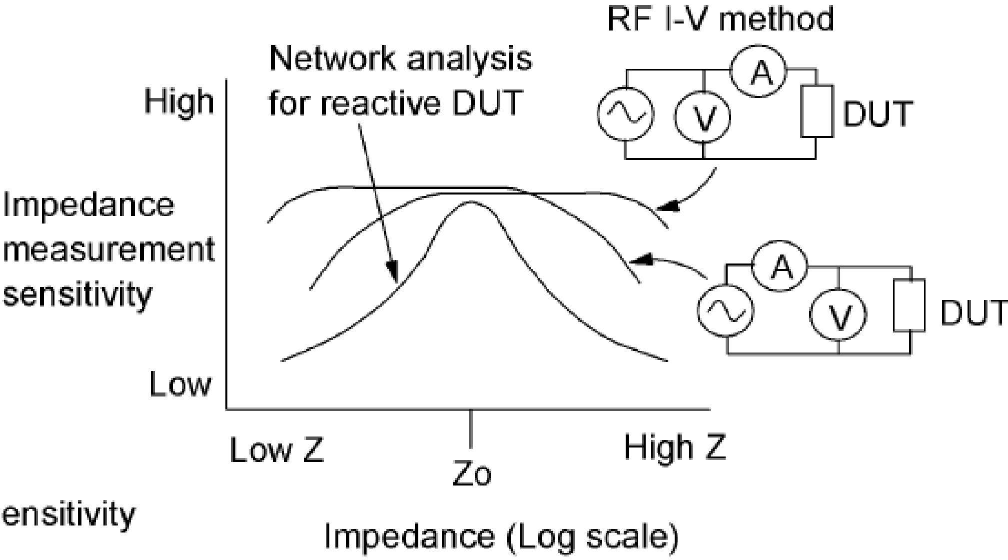
The reflection coefficient is obtained by measuring the ratio of an incident signal to the reflected signal. A directional coupler or bridge is used to detect the reflected signal and a network analyzer is used to supply and measure the signals. Since this method measures reflection at the DUT, it is usable in the higher frequency range.

High-frequency Methods



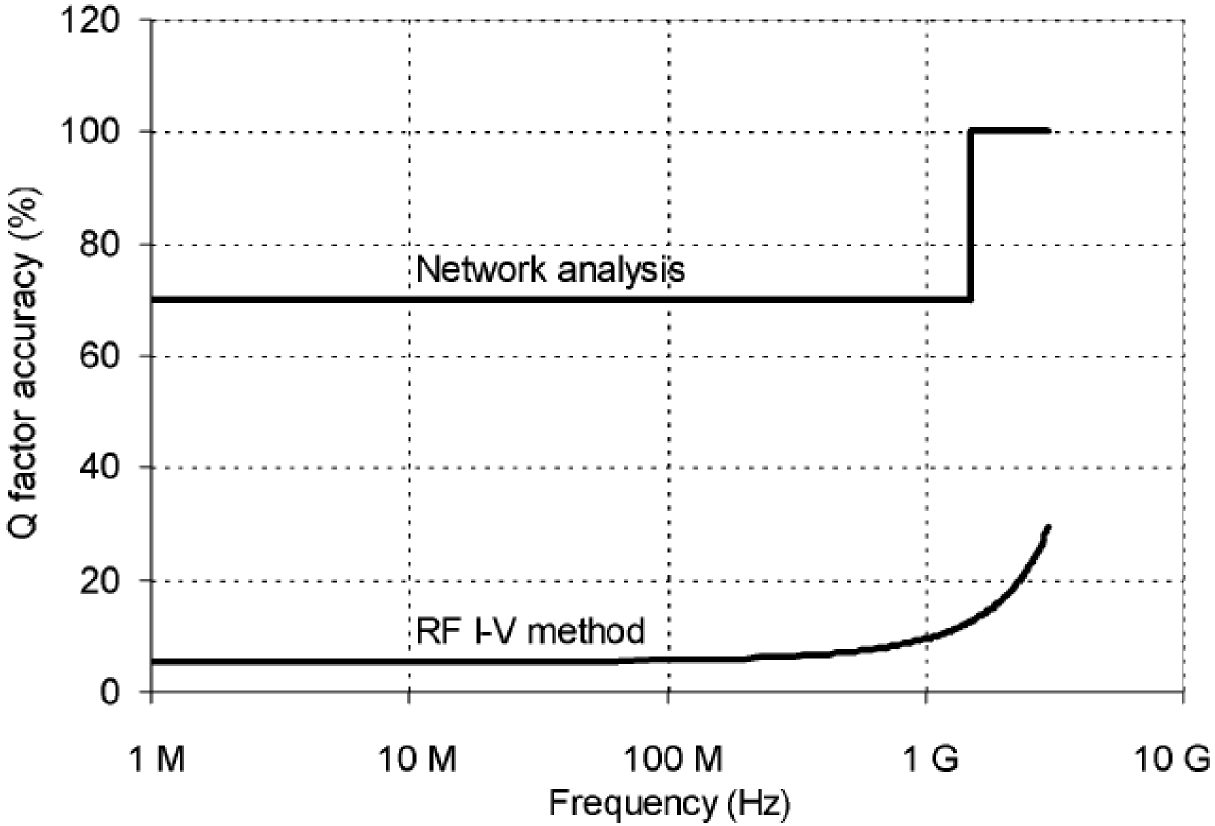
(a) Theoretical measurement sensitivity





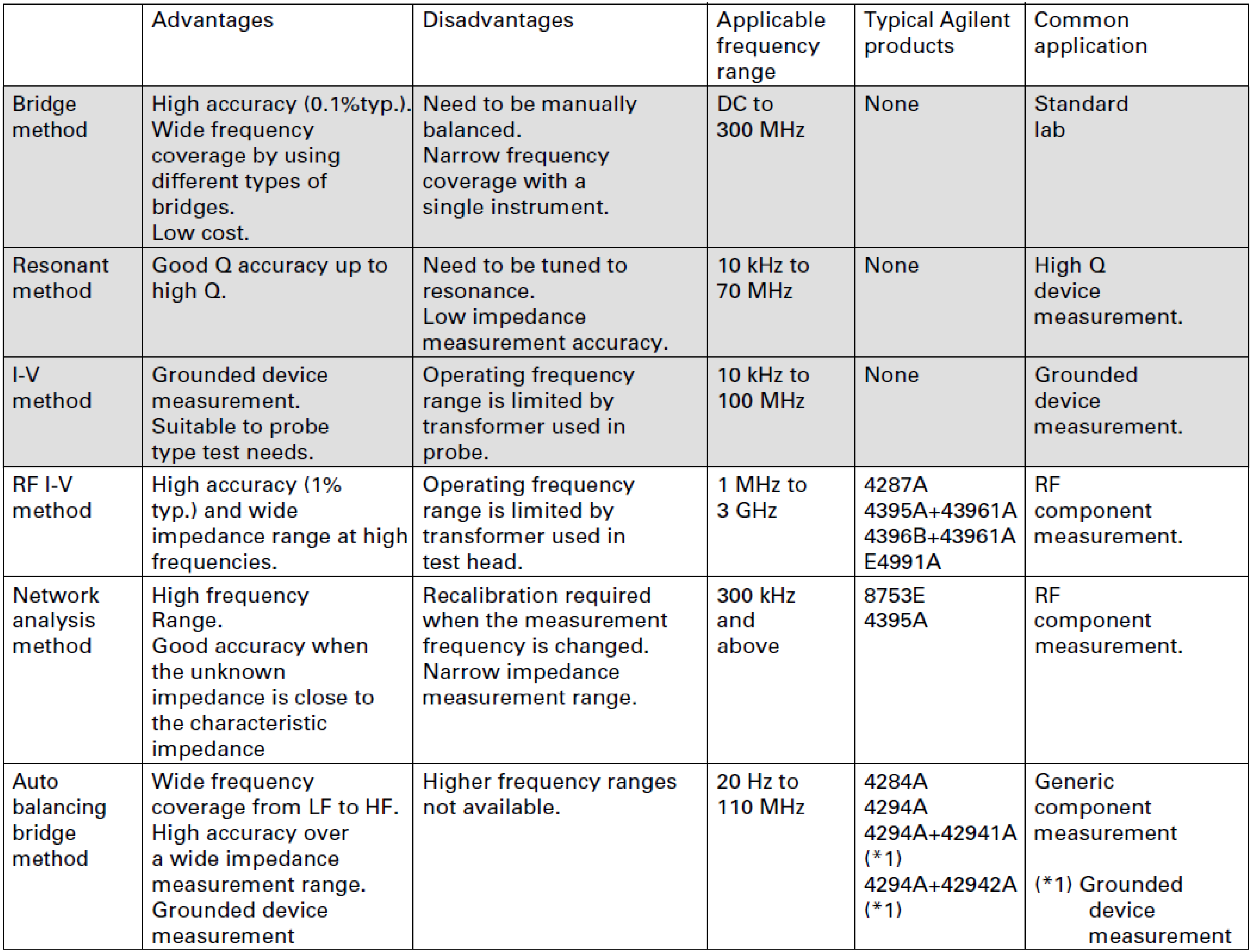
(b) Practical measurement sensitivity

High-frequency Methods



Note: The Q accuracy is compared at Q factor of 100 at 50Ω impedance.

Measurement Methods



	Advantages	Disadvantages	Applicable frequency range	Typical Agilent products	Common application
Bridge method	High accuracy (0.1%typ.). Wide frequency coverage by using different types of bridges. Low cost.	Need to be manually balanced. Narrow frequency coverage with a single instrument.	DC to 300 MHz	None	Standard lab
Resonant method	Good Q accuracy up to high Q.	Need to be tuned to resonance. Low impedance measurement accuracy.	10 kHz to 70 MHz	None	High Q device measurement.
I-V method	Grounded device measurement. Suitable to probe type test needs.	Operating frequency range is limited by transformer used in probe.	10 kHz to 100 MHz	None	Grounded device measurement.
RF I-V method	High accuracy (1% typ.) and wide impedance range at high frequencies.	Operating frequency range is limited by transformer used in test head.	1 MHz to 3 GHz	4287A 4395A+43961A 4396B+43961A E4991A	RF component measurement.
Network analysis method	High frequency Range. Good accuracy when the unknown impedance is close to the characteristic impedance	Recalibration required when the measurement frequency is changed. Narrow impedance measurement range.	300 kHz and above	8753E 4395A	RF component measurement.
Auto balancing bridge method	Wide frequency coverage from LF to HF. High accuracy over a wide impedance measurement range. Grounded device measurement	Higher frequency ranges not available.	20 Hz to 110 MHz	4284A 4294A 4294A+42941A (*1) 4294A+42942A (*1)	Generic component measurement (*1) Grounded device measurement