

RADIOMETER

Type FRA1e

Wave Analyzer

Electrical
measuring instruments for
industrial and scientific work



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Wave Analyzer

$$I_a = f(V_{osc})$$

$$S = f(V_{osc})$$

Type FRA1 Wave Analyzer

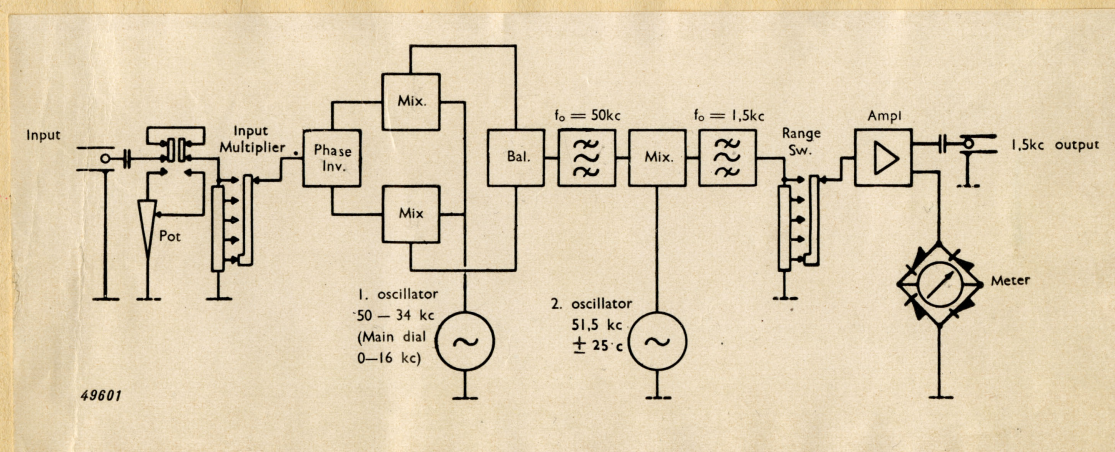
The type FRA1 Wave Analyzer is designed for measuring the separate frequency components in a complex a-c voltage. It is essentially a sensitive and selective vacuum-tube voltmeter that can be tuned to any frequency from 0 to 16,000 cycles. The voltage range is 100 microvolts (full-scale deflection) to 400 volts.

In the laboratory the instrument is especially used for analyzing the separate harmonics at harmonic distortion when measuring the various components of frequency and amplitude modulation, when measuring intermodulation distortion, and when examining noise and hum voltages of any kind.

The high sensitivity of the instrument provides for direct connection to a microphone or vibration pickup, so that sound analysis or analysis of mechanical oscillations can be made without employing an extra amplifier.

When coupling the Wave Analyzer to a mechanical recorder (logarithmic recorder) there is amongst others a possibility of recording curves of noise voltages as a function of the frequency of the noise voltage.

The Wave Analyzer operates on the heterodyne principle, and two different intermediate frequencies are employed (double transposition) so as to obtain high selectivity in conjunction with adjustable bandwidth.



Description

The voltage to be examined is fed to a phase inverter tube, either through a continuously variable potentiometer and a voltage divider (attenuator) with steps of 20 db (position "Pot. on") or through the voltage divider only (position "Pot. off"). In the former position the input impedance is about 0.2 megohm in parallel with 30 pF, in the latter position it is 2 megohms in parallel with 15 pF. A series condenser that blocks d-c voltages, if any, is coupled in both positions.

The input voltage can be damped with the switch "Input Multiplier" in the positions x1, x10, x100, x1000, and x10,000. If the instrument is to be adjusted the "Input Multiplier" is set to "Adjustment".

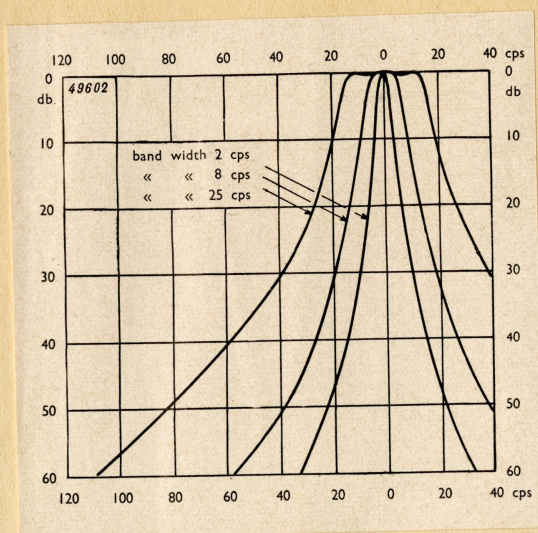
A series of multiplication figures ("Multiply by") are stated on the "Input Multiplier" switch. The figures indicate how many times the applied voltage is higher than the value read on the meter. Each position of the voltage divider is also marked by a voltage ("Max. Voltage") indicating the maximum voltage that may be fed to the input jack when the "Input Multiplier" switch is set to the position in question. A transitory connection of a considerably higher voltage (maximum 400 volts), however, will not damage the instrument, but may cause errors in measurement because the input tubes are overloaded.

The db figures stated on the "Input Multiplier" switch indicate the number of db that is going to be added to the db figures of the "Range Switch" and the meter in order to make the voltage measured exceed 1 millivolt.

From the phase inverter tube the input voltage or part of it is carried to the grids of the push-pull coupled mixer tubes that constitute the "l. converter". Here the input voltage is mixed with the voltage from the "l. oscillator" whose frequency is set by means of the big frequency dial which is calibrated from 0 to 16,000 cycles. When the "l. oscillator" is set to e.g. 1 kilocycle, its frequency is virtually $50 - 1 = 49$ kilocycles so that when mixed with an input voltage of the frequency 1 kilocycle, it gives a sum frequency of 50 kilocycles. The sum frequency is filtered in the l. band filter which is tuned to 50 kilocycles. In conjunction with the l. converter stage there is also a balancing device which is set when the l. oscillator operates at 50 kilocycles, i.e. when the main dial is set to 0 cycle. Its fre-

quency here is 50 kilocycles so that the 1. band filter would allow it to pass. The 50 kilocycle voltage can be damped by means of the balancing device, so that it will only cause disturbance when measuring frequencies lower than approximately 10 cycles.

Having passed the 1. band filter the signal voltage of 50 kilocycles is passed to the 2. converter stage where it is mixed with a voltage from the 2. oscillator which operates at 51.5 kilocycles. The difference frequency of $51.5 - 50 = 1.5$ kilocycles is filtered in the 2. band filter which is tuned to 1.5 kilocycles.



This filter has adjustable band-width (see fig. 2) and determines the selectivity of the Wave Analyzer, as the selectivity of the 1. band filter only serves to eliminate image frequency signals and high heterodyne frequencies, if any. By means of the dial for fine adjustment the 2. oscillator can be mistuned by

approximately 25 cycles on either side of the 51.5 kilocycles. The frequency variation thus obtained is independent of the setting of the big frequency dial (1. oscillator), so the fine adjustment can be calibrated directly in cycles.

From the 2. band filter the signal voltage of 1500 cycles is passed to a vacuum-tube voltmeter consisting of a voltage divider ("Range Switch"), an amplifier, and a copper-oxide rectifier meter. Adjustment of the Wave Analyzer as regards frequency and amplification is made by means of a 50 cycle adjusting voltage, which is fed from the built-in line transformer. After a filtering a small part of the adjusting voltage is passed to the input tube of the Wave Analyzer so that the meter gives a certain deflection when

the frequency dial has been set to 50 cycles. The frequency adjustment is then made by setting to maximum deflection by means of the knob "Frequency Adj. Fine". By means of the push button "Amplifier Adjustment" the copper-oxide voltmeter is coupled to direct measurement of the whole adjusting voltage and the amplification is then controlled by means of the knob "Amplifier Adjustment" until the meter gives the same deflection, no matter whether the calibrating voltage is measured directly by the copper-oxide rectifier voltmeter or part of it is measured by the Wave Analyzer. The operation of the calibrating device is simple and it operates independently of the magnitude of the line voltage.

The instrument is operated from a-c voltage, 50 cycles, and can be set to the voltages 110, 127, 150, 200, 220, and 240 volts. The consumption is about 50 VA. The anode voltage is stabilized by means of amplifier tubes, and the filament current for the first 3 tubes is rectified and filtered.

Operating instructions

Connect the Wave Analyzer to the power line, preferably 10 to 20 minutes before it is taken into use.

Ordinary adjustment is made with the instrument set to the smallest bandwidth (2 cycles), i.e. with the switch "Band Width in c/s" in position 2). Set the "Input Multiplier" switch to position "Adjustment", the frequency dial to 50 cycles, the fine adjustment to 0, and the "Range Switch" to position "Adjustment". Set to maximum deflection by means of the knob "Frequency Adjustment Fine" and vary the amplification with the knob "Amplitude Adjustment" until the meter gives the same deflection as when the push button "Amplifier Adjustment" is pressed.

Adjustment of "Balance" is only necessary when measuring at low frequencies with the "Range Switch" set to the most sensitive ranges. Adjustment of the balance is made after the adjustment with the frequency dial set to 0 cycle. Set to minimum deflection (which it during a short period should be possible to bring down below about 1 mV) by means of the slotted shaft "Amplitude Balance Coarse", the knob "Amplitude Balance Fine", (and the slotted shaft "Phase Balance")

After adjustment and possible setting of the balance the Wave Analyzer is ready for use. The accuracy of a voltage measure-

ment is 0.5 db, and the accuracy of the frequency is $1\% + 1$ cycle. When maximum accuracy is required a re-adjustment during the operation may be necessary as the tubes and other components are heating.

Comments on the adjustment: If the Analyzer has not been used for some time or has been heavily mistuned the best way to make a coarse setting of adjustment and balance is as follows: Set the "Band Width" switch to 2 cycles, the "Input Multiplier" switch and the "Range Switch" to position "Adjustment". Set the fine adjustment to 0 and the knob "Frequency Adjustment Fine" to center position (the white spot upwards). Set the balance controls to approximately center position (this applies to both "Amplitude Fine", "Amplitude Coarse", and "Phase Balance". Turn the frequency dial slowly downwards from approximately 500 cycles until the meter deflects to about 3 to 7 mV.

Now "move" this deflection by means of the slotted shaft "Frequency Adj. Coarse" so that it will lie at 50 cycles. If the deflection does not appear when the frequency dial is turned down to 0 cycle, set the dial to 0 cycle while turning the slotted shaft until the deflection appears, and then "move" it up to 50 cycles by alternately rotating the frequency dial and the slotted shaft for frequency adjustment.

Coarse adjustment of the balance is most conveniently made with the "Range Switch" set to 100 mV. Turn the frequency dial towards 0 until the meter deflects. Then set the slotted shaft "Amplitude Balance Coarse" so that minimum deflection is obtained with the frequency dial set to 0 cycle. Make the fine adjustment and adjustment of balance in normal way as mentioned under ordinary adjustment.

Connect the input voltage to the jack "Input" when measuring voltage, and set the "Input Multiplier" switch to such a position that no component of the input voltage exceeds the maximum voltage stated on the switch, corresponding to full-scale deflection on the meter when the "Range Switch" is set to the 100 mV range.

When using the POSITION "Pot. on" the potentiometer is also so set that no voltage component gives more than full-scale deflection on the 100 millivolt range. A voltage causing a deflection exceeding 100 millivolts will not damage the instrument.

but may give rise to overloading the converter tubes and consequently to errors in measurement. If several high voltages are applied simultaneously (as when measuring intermodulation distortion) the sum of the applied voltages should not exceed what corresponds to a 100 millivolt deflection. When using the input potentiometer, the "Input Multiplier", or the knob "Potentiometer" are set with a view to the largest voltage component available, all other changes of the measuring range are made by means of the "Range Switch".

The frequency adjustment is made by the frequency dial and the corresponding fine tuning which can be employed to advantage when narrow bandwidth is employed at higher frequencies.

The "Band Width" control is set to the highest value permissible with regard to the selectivity. When measuring harmonics (distortion factor) the widest bandwidth (25 cycles) can thus be employed if only the fundamental is higher than approximately 100 cycles. The employment of wide bandwidth facilitates the frequency adjustment considerably and reduces the risk of overlooking small voltage components.

Reading of the voltage on meter and "Range Switch" is made as on an ordinary voltmeter and is direct when the "Input Multiplier" is in another position, the voltage must be multiplied by the factor in question (10, 100, etc.). The sum of the db readings on the "Input Multiplier", "Range Switch" and the meter gives the input voltage in db over 1 millivolt.

At measurements where the ratio between various voltage components is examined (e.g. distortion factor measurements) it is convenient to employ the position "Pot. on" and set the potentiometer so that the greatest voltage component (the fundamental) causes a deflection to 100 millivolts. The voltage of the other components (that of the harmonics) in millivolts will then indicate the voltage direct in per cent of the fundamental, as 1 mV corresponds to 1%.

An a-c voltage of maximum approximately 10 volts can be fed from the jack "1500 cycles Amplifier Output" at a load of 50 kilohms.

The output impedance is 50 kilohms in parallel with 4000 μ f.

The frequency range of the Wave Analyzer is about 5 to 16,000 cycles. However, when measuring at frequencies below 30 cycles the voltage read must be corrected by adding a number of db, as appears from the curve below.

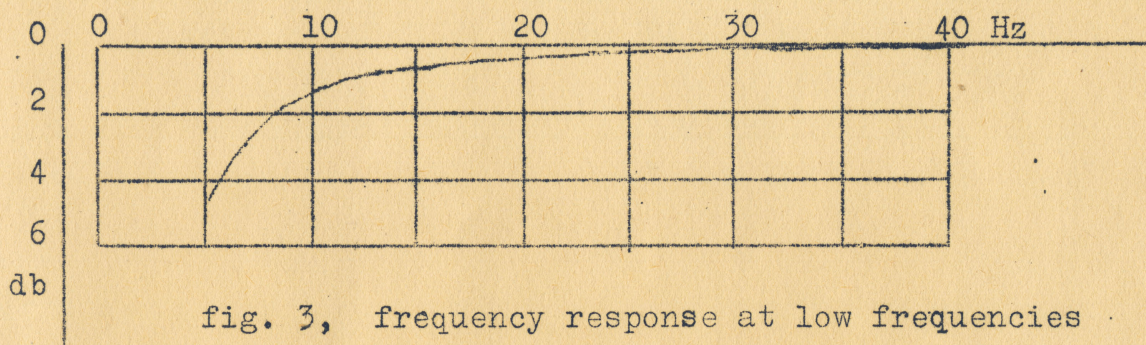


fig. 3, frequency response at low frequencies

When the Wave Analyzer is tuned to e.g. 1 kilocycle (1. oscillator to 49 kilocycles) an input voltage of the frequency 99 kilocycles will be able to give deflection, as 99 minus 49 kilocycles makes 50 kilocycles, which is equal to the 1. band filter frequency. However, this "image frequency range" from 100 to 84 kilocycles can only be utilized for comparative measurements, as the "Input Multiplier" switch is only independent of the frequency up to about 16 kilocycles. The "Range Switch", however, operates quite normally so that it is possible to measure direct the ratio between various voltage components within a small frequency range (2 to 5 kilocycles) between 84 and 100 kilocycles. Thus if a modulated transmitter can be set within this frequency range the separate side frequencies can be measured in proportion to the carrier wave, so that both modulation percentage and modulation distortion can be measured directly without any preceeding demodulation.

When measuring on the ordinary frequency range from 0 to 16 kilocycles the image frequencies may sometimes cause disturbance, if frequency components occur on the range 84 to 100 kilocycles or at about 50 kilocycles. This may be the case in certain heterodyne oscillators. This nuisance can be removed by connecting a filter at the input of the Analyzer.

The Wave Analyzer can be mechanically coupled to a type NS3 Logarithmic Recorder by means of a cardan drive, and electrically by connecting the jack "1500 cycles Amplifier Output" to the input jack of the NS3 by means of a shielded cable. By inserting a plug in the jack "1500 cycles Amplifier Output" the meter is switched off. The motor of the NS3 rotates the

dial of FRA1 from 16.000 cycles to 0 cycle in 135 seconds. The selectivity (note: 25 cycle bandwidth) does not provide for a more rapid scanning of the frequency range. The chart speed is 75 cm in 135 seconds.

An input voltage of 10 μ V is recorded with ± 2 db noise superimposed, owing to the noise of the Wave Analyzer itself. On the frequency range below 150 cycles the minimum voltage that can be recorded increases as the frequency decreases, owing to the drift of the zero balance.

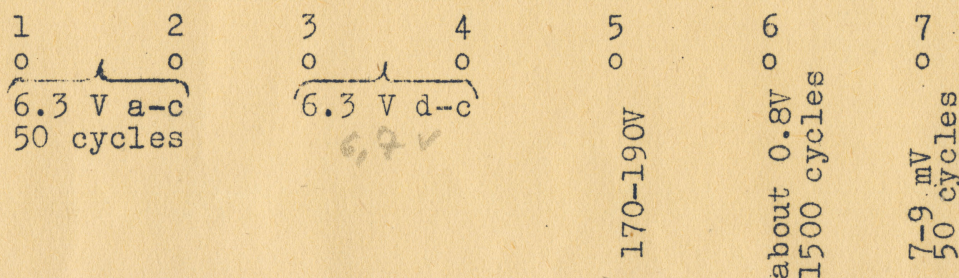
Specifications

Frequency range:	5 to 16.000 cycles		
Bandwidth:	2, 8 or 25 cycles within 1 db, 40 db damping at 15, 28 or 55 cycles mistuning		
Voltage ranges:	100 μ V, 300 μ V, 1 mV...300 V, 1000 V. Lowest measurable voltage about 4 μ V		
Input impedance:	2 megohms in parallel with 10 to 20 μ F when employing the voltage divider. 0.2 megohms in parallel with 15 to 40 μ F when employing the potentiometer and the voltage divider		
Accuracy:	Frequency: 1% + 1 cycle Voltage: 0.5 db on the frequency range 30 to 16.000 cycles. A correction chart may be employed below 30 cycles		
Spurious formation of frequency: (harmonics, image frequencies, etc.	75 db lower, when the fundamental frequency is over 100 cycles. Below 100 cycles the suppression decreases gradually to about 60 db.		
Hum voltage:	10 to 20 μ V at 50 cycles. Below 10 μ V at 100 and 150 cycles		
Power supply:	operation from 110, 127, 150, 200, 220, or 240 volts a-c. Consumption about 50 VA		
Weight:	33 kilos		
Over-all dimensions:	Height 420 mm	Width 555 mm	Depth 305 mm

Maintenance

The easiest way to remove the instrument from the case is by putting it down with the front panel upwards. When all the screws along the edge of the front panel have been removed the instrument is lifted right out by means of the two handles on the front panel.

The various operating voltages are measured by means of the connecting leads on the back panel. The sketch below shows the connecting leads seen from behind and states the approximate voltages that are to be present when the instrument is switched on and set to adjustment (deflection to about 8 mV). The voltages at 5, 6, and 7 are measured with respect to chassis.



The rectified filament voltage (6.3 V d-c) can be controlled by moving the output of the line transformer which can furnish 13, 14, 15, or 16 volts to the filament current rectifier.

The anode voltage (170-190 V) can be adjusted by the potentiometer on the upper shelf. It should be about 180 volts. The neon tube 11 should burn with an even light. The voltage on lead No. 6 is to be measured by a vacuum-tube voltmeter.

The easiest way to trim the 1500 cycle filters is as follows Set the knob "Band Width in c/s" to 2, damp circuit 10 by about 10 kilohms, set (with a frequency stable input voltage) the F dial and the \pm cycle dial until maximum deflection is obtained on a vacuum-tube voltmeter connected to the jack of C_9 and to chassis. Then connect the vacuum-tube voltmeter to the jack of C_{10} . Remove the damping resistor and adjust to maximum deflection on the slotted shaft C_{10} . Finally connect the vacuum-tube voltmeter to the jack of C_{11} and set to maximum deflection once more by means of the slotted shaft C_{11} . A fine control for establishing that the 1500 cycle filter is correctly trimmed is obtained by examining the band filter curve for "Band Width in c/s" set to 25. If on this examination the two outer tops (cf. fig. 2) differ in height, this can be corrected either by

rotating the slotted shaft C_9 or C_{10} once. Uniform amplification of "Band Width in c/s" in positions 2, 8, and 25 is obtained by adjusting the two slotted shafts marked "2 c/s Band Width" and "25 c/s Band Width" on the back panel of the instrument.

The tuning circuits (5 altogether) of the 50 kilocycle filter (1. band filter) are located in the low coil boxes on the lower chassis, at tube 1-2, and at tube 4. Only very seldom will it be necessary to trim 1. band filter and 2. oscillator. It can be done as follows: Apply a voltage of a few millivolts of the frequency 50.0 kilocycles ($\pm 1\%$) to the input jack. Turn the frequency dial to 5-10 kilocycles, and set the fine tuning to 0. Now set 2. oscillator and the 5 tuning circuits in 1. band filter until maximum deflection is obtained.

The trimmer condenser is coupled in parallel with the condensers for "Frequency Adj." and can be employed for correction if the variation range of the "Frequency Adjustment" does not suffice.

If the meter of the Wave Analyzer deflects even if no input voltage is applied, the best way to locate the cause of the disturbance is by connecting the grid of tube 4 to the chassis. With the controls set to maximum bandwidth and sensitivity (25 cycles and 0.1 mV), the disturbance must be particularly visible here, i.e. 1 to 2 μV . If the disturbance exceeds that, it is probably due to errors in one of the tubes 4 or 10.

If the disturbance does not appear when the ground connection at tube 4 is disconnected it must be 2-5 μV at maximum bandwidth (the balancing must be adjusted) and 1-2 μV at minimum bandwidth when setting to 225 cycles. (Apart from a few greater deflections which may be due to sudden line voltage variations or disturbance due to neon tube 11). If the disturbance exceeds these values essentially the error is probably located in one of the tubes 1, 2, or 3.

When setting the frequency dial to 50, 100, and 150 cycles the corresponding hum voltages must be about 25, 10, and 10 μV with empty input jack and the chassis of the instrument grounded. If the latter values are exceeded this may generally also be due to errors in one of the tubes 1, 2, or 3 or to errors in the filter of the rectified filament voltage. Normally the a-c voltage on the rectified and filtered filament voltage should be about 40 mV.

All tubes except tube 2, 3, and 4, can be replaced right away.

After replacement of tube 4 it may be necessary to re-adjust 2. oscillator according to the method previously mentioned. After replacement or interchange of the tubes 2 or 3 the potentiometer marked "Min. 2. Harm." must be re-adjusted.

During this adjustment a very pure sinusoidal a-c voltage must be fed to the input jack. The frequency may be 400 to 2000 cycles, and the voltage must be at least 50 to 100 mV. The a-c voltage must be especially filtered for 2. harmonics, which may not exceed 0.1% of the fundamental. Make the setting with the Wave Analyzer tuned to the 2nd harmonic of the applied voltage. Turn the slotted shaft "Min. 2. Harm." until minimum of 2. harmonics is obtained. This minimum should be less than 0.2% of the fundamental of the voltage applied.

