A PORTABLE VHF TRACING AND MEASURING SET

(Eddystone Model 31A)

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A portable v.h.f tracing and measuring set

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SUMMARY

The main use of radio-frequency noise-measuring sets is in connection with radio-interference problems. Noise Measuring Set 31A is a portable equipment for the frequency range 31–250MHz intended primarily for field use where weight and cost are important considerations. The receiver, which has a CISPR-type quasi-peak detector and a bandwidth of 120kHz, is suitable for measurement of c.w signals and of impulsive noise at pulse repetition frequencies down to 20 per second. Telescopic antennas are included in the equipment for field-strength measurements. The total range of measurement of 110dB and measuring accuracies of 4dB on noise and 3dB on sine-wave signals are adequate for most practical purposes.

EQUIPO PORTATIL TRAZADOR Y MEDIDOR DE LA M.A.F: Sumario

Los equipos medidores de ruido a radio-frecuencia se usan principalmente en relación a los problemas de interferencia en radio. El Equipo Medidor de Ruido 31A es portátil, para la gama de 31-250MHz y ha sido proyectado principalmente para empleo en campaña, toda vez que el peso y el costo de la unidad son factores importantes. El receptor cuenta con un detector tipo CISPR de cuasi-crestas y un ancho de banda de 120kHz y es apto para la medición de señales de onda contínua y de ruidos impulsivos a frecuencias de repetición de impulsos que bajan hasta los 20 ciclos. El equipo incluye antenas telescópicas que sirven para medir intensidades de campo. Su gama total de 110db y la precisión de medición de 4db en ruido y 3db en señales sinusoidales lo hacen adecuado a casi todas las aplicaciones de la práctica.

EIN TRANSPORTABELES UKW-SUCH-UND MESSGERÄT: Zusammenfassung

Hochfrequenz-Störmeßgeräte werden hauptsächlich im Zusammenhang mit Radiointerferenzproblemen eingesetzt. Störmeßgerät 31A ist eine transportable Ausrüstung für den Frequenzbereich 31–250MHz, in erster Linie für Feldeinsatz gedacht, wo Gewicht und Kosten eine wichtige Rolle spielen. Der Empfänger, der einen Quasispitzendetektor vom Typ CISPR und eine Bandbreite von 120kHz besitzt, eignet sich zur Messung von Dauerwellensignalen und Störimpulsen mit einer Wiederholungsfrequenz bis hinunter zu 20 Impulsen pro Sekunde. Teleskop-Antennen gehören zur Ausrüstung für Feldstärkenmessung. Der Gesamtmeßbereich von 110dB und Meßgenauigkeit von 4dB für Störsignale und 3dB für harmonische Sinuswellen ist ausreichend für die meisten praktischen Anwendungsfälle.

APPAREIL PORTATIF DE DETECTION ET DE MESURE A TRES HAUTE FREQUENCE: Résumé

L'emploi des appareils haute fréquence de mesure de bruit concerne les problèmes des parasites L'appareil de mesure de bruit 31A est portatif pour la gamme des fréquences 31-250MHz, destiné en premier lieu à être utilisé sur les terrains où le poids et le prix sont d'une importance capitale.

Le récepteur, avec un détecteur des quasi-crêtes du type CISPR et une largeur de bande de 120kHz, convient pour mesurer des signaux d'onde porteuse et des bruits impulsifs á des fréquences de répétition d'impulsions allant jusqu'à 20 par seconde.

Les antennes téléscopiques sont comprises dans le matériel pour la mesure des intensités de champ. La limite de mesure de 110dB et une précision de 4dB pour les bruits et de 3dB pour les signaux d'onde sinusoidale satisfont la plupart des conditions normales.

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INTRODUCTION

A radio-frequency noise measuring set is a tuned radio-frequency voltmeter consisting essentially of a receiver, which has special characteristics and facilities that make it suitable for the purpose, and one or more variable attenuators. The most general use of such a set is in the investigation of interference caused to radio systems by man-made radio-frequency noise of various types and the Noise Measuring Set 31A has been designed primarily for use by field staff investigating interference to v.h.f broadcast sound radio and television services. The specification has been based on the relevant British Standard,[1] which conforms closely to the specifications for radio-interference measuring apparatus published by the International Special Committee on Radio Interference (CISPR).

National authorities in many countries lay down limits for the permitted radio noise output from various types of electrical equipment, in order to protect existing radio services and as a factor in the planning of new services. In the United Kingdom, Statutory Regulations have been made which specify limits for several types of apparatus, and limits are also specified in British Standards in the series concerned with the abatement of radio-interference. A statement of limits necessarily includes a specification of the method of measurement and of the measuring equipment to be used, and the U.K Regulations specify the use of a quasi-peak measuring set conforming to BS 727: 1967. Measuring sets to other specifications are prescribed elsewhere for other purposes. A brief description is given later of the use of Measuring Set 31A in conjunction with standard auxiliary apparatus which is specified for measurements of radio-frequency noise voltages and fields.

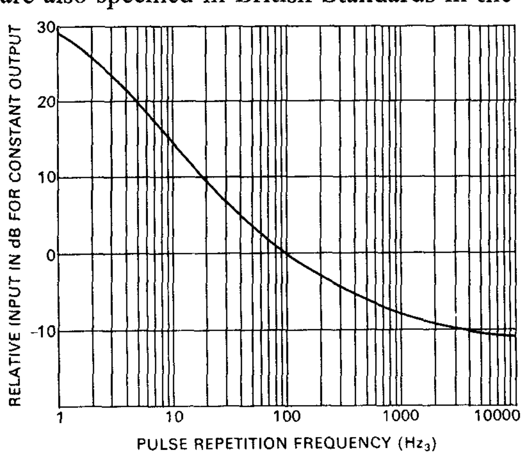

Fig. 1. Pulse response of CISPR quasi-peak detector

RESPONSE OF A MEASURING SET TO IMPULSIVE NOISE

A radio-frequency noise measuring set has two prime functions, the first being to relate the measured value to the subjective effect of the noise on the service to be protected, so that the measurement becomes, in effect, a measurement of interference. The second function is to ensure standardization of measurement so that measurements made by different observers at different times and places can be related. Interference waveforms range from continuous wave (c.w), to single steep-fronted pulses, and may consist of a mixture of a number of different waveforms. An example of a source of interference having a complex waveform is the small commutator motor which generates noise consisting of a sine-wave component, a smooth noise component and random spikes of large amplitude. For such a wide range of noise it is impossible to design a single measuring receiver that will accurately relate the measured value to the subjective effects on the various types of services to be protected and it has been necessary to arrive at a satisfactory compromise.

For all broadcast services the subjective effect of impulsive interference reduces as the

TABLE 1
Performance specification

Frequency Range	31 to 250MHz
Detector	
Charge time constant	1ms
Discharge time constant	550ms
Mechanical time constant of meter	100ms
Overload Factor	20dB
Bandwidth at ±6dB points	120kHz ± 10kHz
Screening Factor at 31MHz	$\nless$ 55dB
at 250MHz	$\nless$ 40dB
Image Frequency Rejection at 31MHz	$\nless$ 30dB
at 250MHz	$\nless$ 20dB
I.F. Rejection	$\nless$ 40dB
Spurious Responses at least 30dB below level of tuned signal	
Measuring Range	110dB
Input Impedance less than 20% reactive	75ohms ± 40%

pulse repetition rate decreases, and the standard measuring receiver is designed to act as a weighting network which requires a larger input for the same output as the pulse repetition rate decreases. This causes the radio-frequency and intermediate-frequency stages to be subjected to high voltages at low pulse-repetition rates and places a restriction on the bandwidth that can be employed. The necessity for standardization makes it essential to specify bandwidth and detector time constants to obtain the required weighting factor in a receiver covering a particular frequency range. The dynamic response of the r.f and i.f circuits must be linear over the large voltage range which the receiver must handle. The design in this respect is made more difficult because at low pulse repetition rates the nature of the noise makes it impossible to employ automatic gain control.

The pulse response of the standard quasi-peak interference measuring set for the frequency range 25 to 300MHz[1,2] is shown in figure 1. This response is obtained with an overall bandwidth of 120kHz, detector charge and discharge time-constants of 1ms and 550ms respectively, and a mechanical time-constant of 100ms for the critically-damped meter. The logarithmic ratio of the input at 10,000 p.p.s to the input at 1 p.p.s for the same output is a measure of the voltage range over which the dynamic response of the receiver must be linear and is known as the overload factor of the receiver. For complete compliance with the specification the overload factor required for a receiver for the frequency range 25 to 300MHz is 43·5dB.

NOISE MEASURING SET 31A

PERFORMANCE SPECIFICATION

The Noise Measuring Set 31A is the commercial version of the Post Office Receiver Radio 31A, which was designed at the Post Office Research Station. The design specification was for a portable v.h.f tracing and measuring receiver that could be produced at moderate cost, intended mainly for use by staff engaged in investigating radio-interference problems in the field. Considerations of weight and cost imposed some limitations on the performance compared with the CISPR and BS 727: 1967 specifications but these limitations were acceptable in a receiver for this type of work. The original specification required the receiver to be capable of measurement of pulses at repetition rates down to 50 per second for the investigation of interference from power lines. In this respect the design is better than the original requirement and measurements may be made at pulse repetition rates down to 20 per second. An input impedance of 75ohms was chosen to enable voltage measurements to be made on coaxial television and radio aerial feeders and r.f distribution feeders. The principal performance characteristics are given in Table 1.

Fig. 2. Eddystone noise measuring set type 31A

DESCRIPTION

The equipment is illustrated in figure 2 from which it can be seen that the receiver is housed in a stiffened aluminium case with a removable lid and a substantial carrying handle which may be locked in any of three positions. Excluding the handle the dimensions of the case are 302 × 206 × 256mm, and the total weight 8·6kg. The accessories provided, including telescopic rod and dipole antennas, coaxial connecting cables and a mains lead, are housed in the removable lid which may be clipped under the base of the receiver when the receiver is in use. Power is provided by an internal 12V nickel-cadmium battery which may be recharged from a 240V a.c mains supply by means of a built-in rectifier. The battery has a capacity of 2Ah giving some twelve hours continuous use. Charging current and battery voltage may be monitored on the meter and because the nickel-cadmium battery requires protection against over-discharge a circuit is provided which disconnects the battery from the load when the voltage falls to 10·5V. The receiver may be used while the battery is being charged. The internal assembly comprises a number of separate units enclosed in 'ALOCHROME' treated aluminium boxes, which effectively provide double screening, with the tuners and slow-motion drives mounted together on a sub-panel to provide a very rigid assembly. The dipole antenna unit comprises two telescopic elements screwed into sockets in the sides of a diecast box which houses a balun transformer. Figure 3 shows the dipole assembly fitted on the receiver handle by means of the sectional mounting provided. The rod antenna, also shown in figure 3, may be mounted on the handle in a similar manner when the receiver is used for tracing, but is mounted directly on the receiver input socket when the field-strength of vertically polarized radiations is being measured.

CIRCUIT ARRANGEMENT

As may be seen from the block schematic diagram in figure 4, double frequency-conversion is employed in the receiver, with intermediate frequencies of 25MHz and 3MHz. Conventional fixed-inductance/variable-capacity tuning is used in the r.f tuners and the difficulties associated with the switching of tuned circuits, especially at the higher frequencies where the inductance and capacity values are very small, are avoided by the use of three separate tuners covering frequency ranges 31–68MHz, 68–135MHz and 135–250MHz.

In field work the receiver is liable to be used in areas where strong signals exist, for instance from nearby broadcast transmitters, so that good image rejection is necessary. With the frequency coverages chosen the image frequencies lie outside the range of the lowest frequency tuner and partly outside the range of the 68–135MHz tuner, but low-pass input filters have been provided to give additional image frequency rejection. In the 135–250MHz tuner, adequate image rejection is ensured by the use of tuned band-pass coupling between the two r.f stages.

The tuners are preceded by a switched r.f attenuator having a range of 50dB in 10dB steps, and a fixed 30dB r.f attenuator may also be connected in circuit if required. Between the tuner outputs and the input to the first (25MHz) i.f amplifier there are two attenuators, one having a range of 10dB in 1dB steps and the other a range of 20dB in 10dB steps. The second attenuator is ganged to the switched r.f attenuator in such a way that this part of the i.f attenuation is brought into circuit before any r.f attenuation. The purpose of this arrangement will be explained in the later section on measurement. The total attenuation available, and therefore the measuring range, is 110dB. Output from the 3MHz second i.f amplifier feeds the quasi-peak detector used for measurements and also a.m and f.m detectors for monitoring purposes. The output meter is fed via a d.c amplifier and is connected in a bridge circuit for which a balance control is provided. Output from the first i.f amplifier (25MHz) and d.c output from the meter circuit are available on the receiver panel, and all operating functions of the receiver are controlled by a single switch.

CALIBRATION

The primary voltage calibration is made against the r.m.s output of a standard c.w signal source at frequencies throughout the range of the receiver and a calibration chart is supplied with each receiver. This requires laboratory or calibration centre facilities but for normal purposes it is not necessary to repeat the full calibration at intervals of less

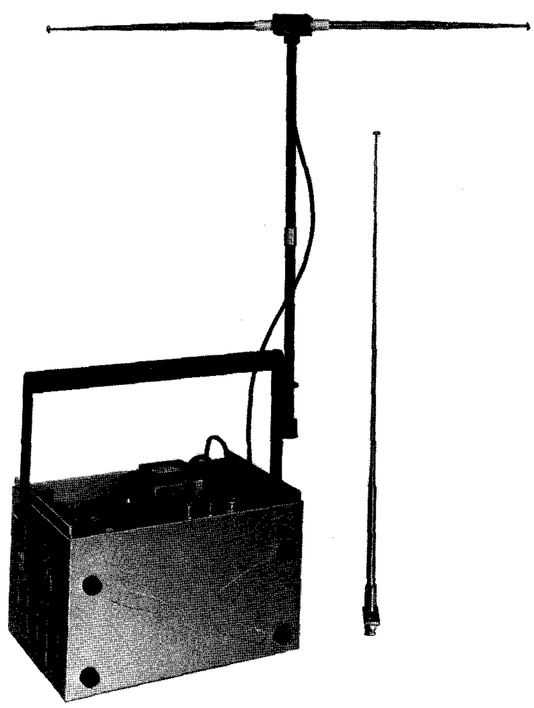

Fig. 3. Method of mounting antennas

than six months. For subsequent use the receiver is calibrated prior to each measurement by resetting the gain to the standard used in the c.w calibration, using noise from the first stage. With no input signal and with all attenuation switched out, the meter deflection due to noise is brought to the calibration mark by adjustment of the 3 MHz i.f gain control (CAL control). The predominance of first stage noise over other noise may be checked by switching off the power supply to the first transistor. The procedure for standardization of gain is simple but the calibration is adequately stable, typically remaining within 1dB of the original calibration over a period of 6 months of normal use.

MEASUREMENTS

When the gain has been standardized as described above, an input signal is measured by adjusting the attenuators to bring the meter needle to the calibration mark. The measured value is then given by the sum of the attenuation inserted and any appropriate correction factor. Radio-frequency attenuation at the input affects only the input signal whereas i.f attenuation affects both signal and noise from the tuner. By introducing i.f attenuation before r.f attenuation, as described earlier, the signal/noise ratio at the input to the first i.f amplifier is effectively improved for low-level input signals. For very low-level signals, below about 10dB(μV), the measurements are affected by noise, and additional correction factors have to be applied.

OPERATION

VOLTAGE MEASUREMENTS ON FEEDERS

In the course of radio-interference investigations, and for some other purposes, it may be necessary to make *in-situ* measurements at the receiving end of antenna or distribution feeders. For this purpose coaxial feeders of 75ohms impedance may be connected directly to the receiver but for feeders of other types or impedance some form of matching network may be necessary.

MAINS TERMINAL VOLTAGE

At very high frequencies, conducted noise is considerably attenuated in mains wiring and is therefore less significant as a cause of interference than noise radiated from the first few feet of the main wiring. A method of measure-

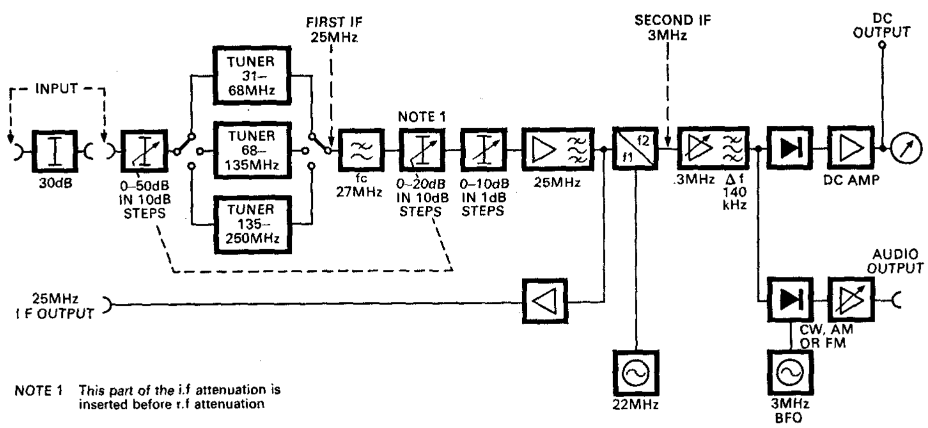

Fig. 4. Schematic diagram of receiver

ment of terminal noise voltage has however been specified by the CISPR and in BS 727: 1967, using a resistive network of V configuration. The noise voltage is measured across a resistance of 50ohms between each line and earth, and a filter is inserted between the network and the mains supply to stabilize the mains impedance and to isolate the network from noise on the mains. A method of using the Measuring Set 31A with such a network is to connect it so that the input impedance forms part of a high resistance shunt across the 50ohms measuring resistance. If the shunt resistance is more than 500ohms the inaccuracy introduced is not more than 1dB. With such an arrangement the voltage measured is only a part of the line voltage and an appropriate correction should be made.

FIELD STRENGTH MEASUREMENTS

As a source of interference in the v.h.f range, radiated noise is of considerable importance and limits of radiation are specified for a number of types of apparatus. In most cases the limits are stated in respect of measurements made on a calibrated test site with the receiving antenna positioned at a specified distance from the source and at a specified height above ground, but in some cases radiation may be measured with the equipment *in situ*. In the frequency range 30–300MHz the specified antenna is invariably a dipole and usually of half wavelength but for practical convenience a 50MHz antenna is often used for the 30–50MHz band, with an appropriate correction factor. The general practice is to adjust the height and orientation of the antenna to obtain a maximum response in the measuring set. Field strength measurements, however, may sometimes be required not for comparison with limits but to establish what conditions exist at a particular location. In these circumstances it may not be necessary or advisable to maximize the response. Field strength measurement consists of measuring the output from the antenna and applying the appropriate ANTENNA CONSTANT to convert the voltage measurement in dB(μV) to field-strength measurement in dB(μV) per metre.

Telescopic rod and dipole antennas are provided with the Measuring Set 31A and calibrations (ANTENNA CONSTANTS) for both are given in the operating manual. For most practical purposes the dipole is more convenient for measuring horizontal fields and the rod for vertical fields. The dipole is mounted on the receiver handle as shown in figure 3, the receiver is placed so that the antenna is in the position where measurement is required, and the response is maximised if this is called for. If the measurement is made on a test site the antenna should preferably be separated from the receiver and mounted a little distance away to allow greater flexibility in positioning, but in this event due allowance should be made for any additional loss in the antenna feeder. When the dipole antenna is mounted separately in this way it may be practicable to use it for vertical field-strength measurements, but for many purposes, and especially for *in-situ* measurements, the rod antenna is usually more convenient. When the rod antenna is used the receiver is placed with the panel upwards and the handle lowered, and the rod, which is adjusted to a quarter wavelength, is plugged directly into the BNC input socket so that the body of the receiver forms an earth plane.

MEASUREMENTS USING THE FERRITE ABSORBENT CLAMP

Radiation in the v.h.f range from small mains operated appliances occurs predominantly from the mains lead itself, and for measurements on appliances which contain small commutator motors the CISPR has specified a method which may be used indoors, thus avoiding the problems associated with outdoor measurements. This method, which is coming into use in the U.K and other countries, involves the use of a ferrite absorbent clamp surrounding the mains lead to measure r.f energy in the frequency range 30–300MHz radiated from the mains lead. The device consists of a number of ferrite rings, through which the mains lead is passed, assembled together as a tubular unit. A single turn of screened conductor is also passed through two or three of the rings nearest to the appliance, forming a coupling transformer the output of which is connected to a measuring set. The remaining rings form a stable, mainly resistive, load in which the r.f energy is absorbed. They also effectively isolate the coupling transformer from noise on the mains. A standing-wave pattern is set up on the mains lead and measurement is made with the transformer positioned at a maximum point, as indicated by the measuring set.

TRACING

Although the Measuring Set 31A has many applications in noise voltage and field strength measurement, its suitability as a field instrument for tracing sources of interference is also important. Tracing usually involves a mixture of direction finding, for which the dipole antenna may be used, and location by field intensity for which either the rod or dipole antenna may be used as convenient. When measurement is not required the rod antenna is mounted on the receiver handle in a similar manner to the dipole and connected to the receiver via a short coaxial feeder. For tracing purposes it is not necessary to calibrate the receiver gain, and the length of the antenna rods is not critical. Figure 5 shows the equipment being used to trace a noise source in a typical situation.

ACCURACY OF MEASUREMENTS

It is generally recognized that because of a number of factors, including the variable nature of the noise itself, measurements of radio noise voltage using a CISPR receiver are liable to inaccuracy of ± 2dB, and that field strength measurements of noise are liable to somewhat greater error. For the purposes for which it was intended the Measuring Set 31A was not required to meet the full CISPR specification, and noise measurements with this receiver may be subject to errors up to ± 4dB. In particular it is not suitable for measurement of pulses at repetition frequencies below 20 per second. Overall accuracy of measurement of sine-wave signals, however, is better than ± 3dB.

Measurements on a number of motorized appliances, and c.w and pulse sources, have been made in the Radio Interference Laboratory of the Ministry of Posts and Telecom-

Fig. 5. The measuring set being used to trace a noise source

munications using the production version of the Post Office Receiver Radio 31A in comparison with a CISPR type receiver. The two receivers gave results generally within 2dB, which is less than the range of variation within which noise measurements are usually repeatable. This indicates that the Measuring Set 31A may be used to make measurements with acceptable accuracy in many circumstances where a measuring set of higher specification is not prescribed. For instance it could be usefully employed for production testing on many types of appliances.

ACKNOWLEDGEMENTS

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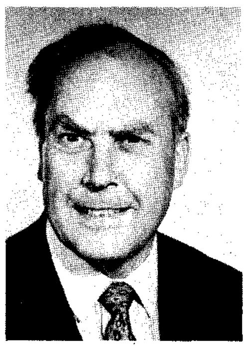
References

[1]BS 727: 1967 'Specification for Radio-Interference Measuring Apparatus for the Frequency Range 0·015MHz to 1000MHz'.

[2]CISPR Publication 2. 'Specification for CISPR radio interference measuring apparatus for the frequency range 25MHz to 300MHz'.



J. H. AINLEY

joined the Post Office in 1936 after leaving Manchester Grammar School. His early experience was in automatic telephony but this was followed by a considerable period of work in the h.f radio field, mainly in the development of high-power single-sideband transmitters. In 1964 he transferred to radio-interference work and is at present at the radio-interference laboratory which has become part of the Ministry of Posts and Telecommunications. He represents the Ministry on BSI committees concerned with radio-interference and for the past three years has been a U.K. delegate to meetings of the CISPR.

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