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MARCONI INSTRUMENTATION

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ELECTRONIC INSTRUMENTS FOR TELECOMMUNICATIONS AND INDUSTRY

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VOL. 8 NO. 3

SEPTEMBER, 1961

MARCONI INSTRUMENTATION

issued with

the compliments of

MARCONI INSTRUMENTS LIMITED

ST. ALBANS

ENGLAND

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Limited by Noise

FROM THE TIME physicists put forward their thermodynamical theory of the Properties of Matter, it has been clear that the ultimate sensitivity of any radio communication system must be determined in the limit by the random motion of the electrons themselves. In practical terms this means that in such a system there is always present a residual signal, whose amplitude is a function of absolute temperature. Known in common parlance as Johnson or Thermal Noise, this signal has been used for many years to define what may be called the 'ideal' radio receiver.

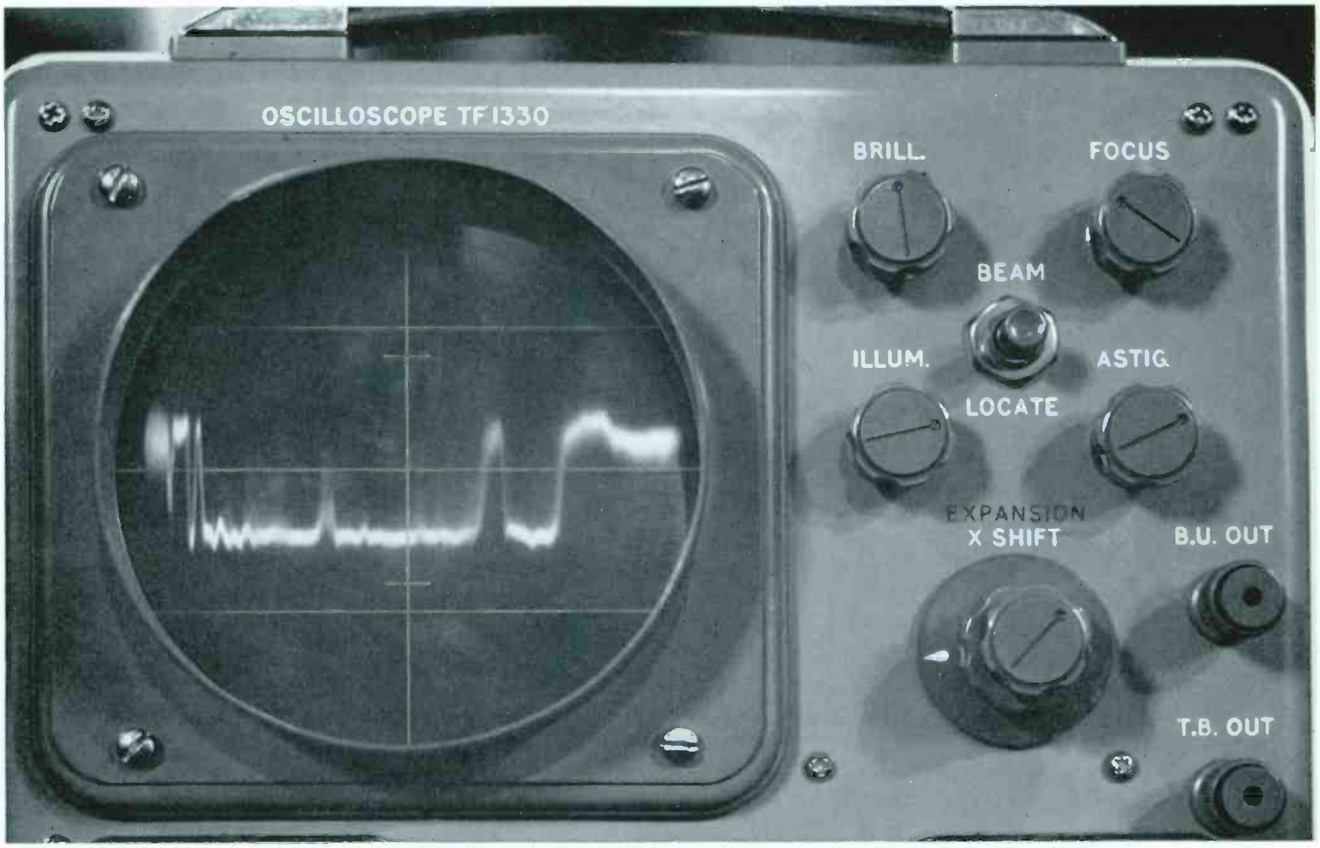
The 'ideal' receiver, however, can never quite be realised in practice, although much time and effort has in fact been expended in approaching the 'ideal' performance. As the main source of additional noise is usually found in the frequency changer this has meant providing some pre-mixing amplification at r.f.

From the use of the thermionic valve, a triode used in grounded grid configuration, new and more sophisticated devices have now come into being. For example, use has been made in the so-called parametric amplifier of loss free amplification using a reactive element. This is based upon the principle that when a capacitance is reduced in value in sympathy with the size of the charge upon it, work is done by the mechanism causing the change which may then be transferred as increased energy into an associated resonant circuit. The non-linear reactance of the capacitance of a back-biassed junction diode has been found suitable for this purpose; as it is purely reactive it is non-dissipative and does not introduce additional Johnson Noise.

The Maser (an abbreviation for Microwave Amplification by Stimulated Emission of Radiation) has also contributed much to low noise r.f. amplification. The maser is based upon the fact that under certain conditions molecules may exist in two energy states simultaneously. Amplification is achieved by separating out the two components and providing means for extracting the excess energy released as the higher energy molecules fall back into their lower energy state. Here the only source of noise is actually in the thermal fluctuations in the components of the maser itself and this can be reduced to a minimum by reducing the temperature of the active components to a few degrees absolute.

Whether in a receiver one ought to use a grounded grid triode, a parametric amplifier, or maser, will depend very much on the circumstances of the case—and may well, in the final instance, be decided upon economic grounds. Sometimes, however, as for example in extremely long distance communication from space probes, the nearness of approach to the ideal receiver may well make the difference between the success or failure of the whole venture.

For most applications the performance of radio receivers is specified in terms of Noise Factor—that is, simply by how many times it is worse than the 'ideal'. As is well known, this can most readily and simply be determined by using a calibrated source of noise, namely a Noise Generator. Various devices have been used from time to time to produce such a signal, ranging from the temperature limited diode to the gas discharge tube. The Company's activities in this field are outlined in an article on page 67 and it can now be seen that a range of Noise Generators are now available which give continuous frequency cover to over 2,000 Mc/s



One of the many cases where reduction of receiver noise enhances the performance of an installation. A typical Radar A-Scan as seen on an M.I. Oscilloscope, TF 1330
(Photograph by Marconi's Wireless Telegraph Co. Ltd.)

So far noise has been considered solely in the context of the limitation it imposes on receiver sensitivity. However, in many communication systems, one is not so much concerned with this aspect as with the quality of transmission in which noise, defined as the sum total of all unwanted spurious signals, is the degrading factor. It may be met as inter-modulation and cross-talk on a telephone circuit, hum modulation in a transmitter, or microphony in a high gain amplifier. Whatever form it takes, the aim of the designer is naturally to eliminate it.

In modern communication systems requirements in this context are becoming more stringent as each year passes by. Nowadays even the conventional a.m. transmitter is not considered good enough unless unwanted hum and noise are of the order of −70 dB relative to 30% modulation depth. When it comes to the use of f.m. for narrow band mobile systems, 50 c/s spurious deviation is considered a maximum; a similar figure applies to the high fidelity f.m. broadcast transmissions. By international agreement high standards too are set for telephone link systems, cross-talk on any one circuit having to be reduced to the order of 60 dB down on the wanted signal.

It naturally follows that if capital equipment manufacturers are to be in a position not only to test but also maintain their apparatus to such rigid specifications, they need extremely high performance test gear. In this connection it should be remembered that an increased onus is placed upon the test gear manufacturer as he is obliged to maintain the performance of his equipment over a wide band of frequencies whilst the capital equipment itself can often be optimized for best performance at one operating frequency.

To keep abreast of requirements Marconi Instruments are always seeking to improve the performance of their test apparatus and this has involved, amongst many other things, practically continuous development of instruments like the Signal Generators TF 995, TF 1064 and TF 1066. Some measure of what is involved can be gleaned from the article on the TF 1064 to be found on page 57. The TF 144H, the mechanics of which are also described in this issue, is an example of a new design replacing an old established line in which particular attention has been paid to obtaining a highly stable c.w. signal free from spurious hum, microphony and noise.

To sum up then, we at Marconi Instruments are involved in the never-ending battle against Noise. Whether we seek to produce it under controlled conditions, as in our Noise Generators, or whether we endeavour to eliminate it from our other test apparatus, the final objective is the same—to enable our customers to produce a better, noise-free product.

A.G.W.

MARCONI INSTRUMENTS

621.396.615.12

Standard Signal Generator . . . TYPE TF 144H

by J. BALDING

This article is complementary to the one by J. M. Parkyn which appeared in Instrumentation *Vol. 7 No. 8. It describes in greater detail some of the mechanical design features of this new instrument, and also some general aspects of the mechanical engineering of signal generators.*

DESIGN CONSIDERATIONS

From the very beginning of the design stage of TF 144H it was obvious that the new instrument would have to incorporate all the desirable features of its predecessors, which had made them so popular. The extent of this popularity can perhaps best be judged by the fact that the original design, created some 26 years ago, had been in continuous production ever since, with only very minor modifications.

The outstanding feature of the previous instruments in this series was the rugged simplicity of the overall design which imparted the high order of reliability proved under arduous conditions of service with the armed forces.

Other good features were accessibility and consequent ease of servicing, good frequency discrimination and simplicity of operation.

DESIGN DETAILS

The R.F. Unit

Once a broad overall specification of the new signal generator had been decided upon, the starting point of the design was the heart of the instrument, the r.f. unit.

Frequency stability was a prime requirement, and this was approached primarily from two angles. Firstly, the provision of a rigid base or plate to maintain the correct relationship between the various components, and secondly, the prevention of a large temperature rise, or variations, inside the r.f. unit.

Instead of the more usual box or frame type of R.F. Box casting, a simple cast plate of aluminium alloy was decided upon. This requires much less machining and is easier to drill as all the holes lie in the same plane. This plate is mounted vertically behind the front panel, and is spaced off from it by substantial steel pillars to give clearance for the various drives, etc., mounted on the front face. All the larger components are mounted on the rear of this plate, *i.e.* the tuning gang, attenuators, filter box and the fixed contacts which engage with the coil turret.

The three valves — r.f. oscillator, a.l.c. and crystal oscillator — together with their associated components are mounted on a separate chassis secured to the top of the cast plate at right-angles to it. Thus the r.f. unit is divided into two separate units for assembly purposes, one being of a mainly mechanical nature, and the other, the valve deck, consisting mainly of wiring and small

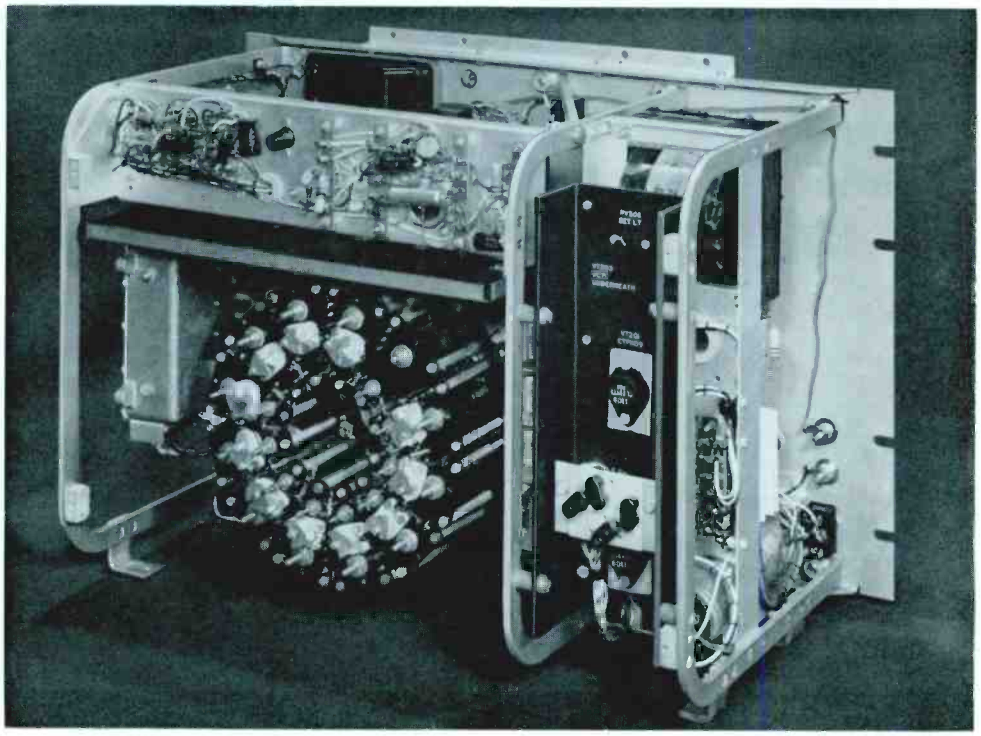
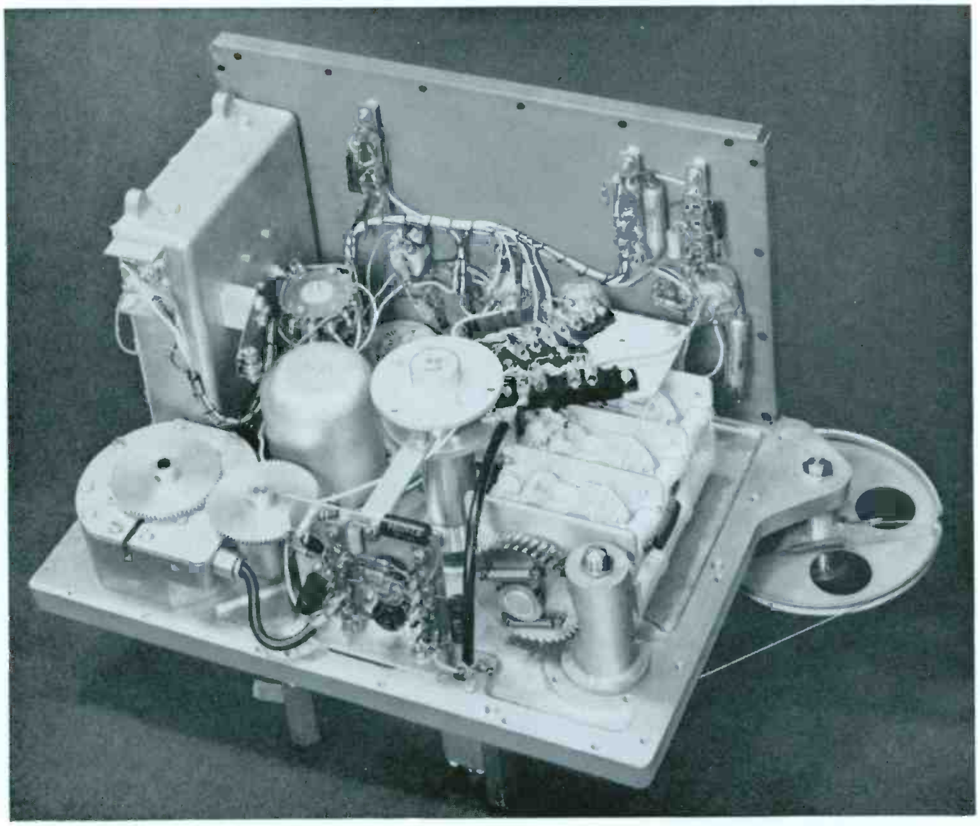
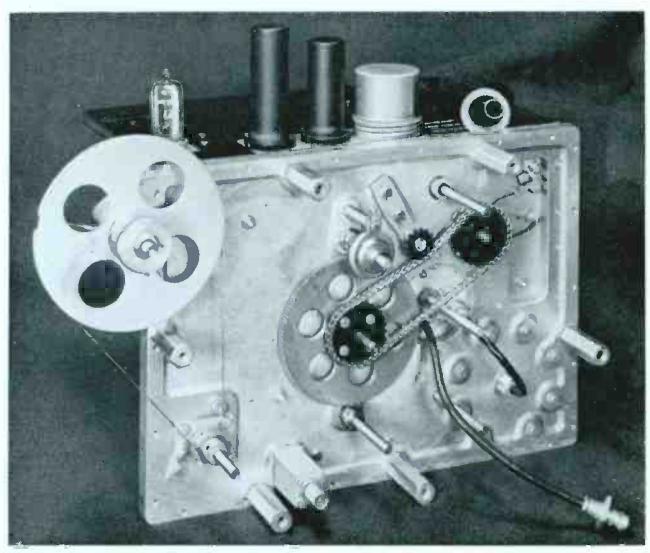


Fig. 1
Rear view of TF 144H, with R.F. Box cover removed, showing the open, accessible layout of the various sub-units



Figs. 2 and 3
Rear and front views of R.F. Box, with coil turret removed. The basic construction and simple drive spindle arrangements can be clearly seen



soldered components. This means that specialized operators can not only work on the two units independently but also at the same time.

In order to keep the temperature in the R.F. Box within reasonable limits the valves are mounted externally in special heat dissipating screening cans, only the pins of the valve holders projecting into the inside of the unit. These special cans consist of a copper tube, closed at the top end, inside which there is a stocking of tinned copper braid designed to fit closely around the glass envelope of the valve. This braid is secured at the base of the tube by a spinning operation, and a threaded bush is forced in to enable the can to be screwed onto the valve holder. Thus the heat is conducted away from the valve by the braid, and radiated partly by the outer copper tube, and partly by the chassis, which is in intimate contact with the tube adjacent to the valve holder, and acts as an effective heat sink.

The relative positioning of the main tuning capacitor, oscillator valve and coil turret contacts was given considerable thought, not only from the usual angle of endeavouring to keep the length of the inter-connecting leads to a minimum but also in trying to bring out the various control spindles in logical positions on the front panel without resorting to complicated drive mechanisms. Both these aims have been met. The coil for the highest frequency range (30-72 Mc/s) consists of three turns, showing that most of the inductance is where it can be closely controlled—on the turret mounted coil former—and not in the connecting leads.

The tuning capacitor driving spindle projects directly through to the front panel, the only gearing being on the turret driving spindle. This was included to give a lighter action to the range change control, which is geared down 6:1, giving half a turn of the control knob between ranges.

Coil Turret

In the interests of frequency stability the coil formers for the tuned windings have been made as large as possible—$\frac{3}{4}$ inch diameter—consistent with accommodating twelve complete units on the $7\frac{1}{4}$ inch diameter turret disc.

The turret disc is a bakelite moulding $\frac{3}{8}$ inch thick and is mounted in a vertical plane directly behind the tuning capacitor with the contacts facing forwards. These contacts are elliptical in section to mate easily with the butterfly type fixed contacts secured to the cast plate. They are made of a solid silver alloy and are held in correct alignment by moulded recesses in the turret disc. The outer periphery of the disc has twelve vee notches moulded in to act as locations for the roller indexing mechanism.

The individual coils are placed axially around the turret and are mounted on twelve segment-shaped plates each supported parallel to the disc by three aluminium alloy pillars which are slightly longer than the coil formers. The plates are also of bakelite with soldering pins moulded in. These serve to terminate the coil windings, and support associated components on one side, and provide anchoring points for the short leads which connect with the turret contacts on the other.

This arrangement allows the individual coil units to be easily removed as complete assemblies, a feature which greatly facilitates production, testing and servicing.

Tuning Capacitor

The main tuning capacitor is a specially designed three-gang unit with a ceramic spindle running in large-diameter ball races, and ceramic side bars and stator supports. All the metal parts are of brass heavily silver plated, and the temperature coefficient is very low.

This capacitor is mounted with its spindle vertical, and is secured firmly to the base casting by short steel pillars adjacent to the driving gear at the lower end, the upper end being flexibly mounted to allow for the differing expansion coefficients of the aluminium alloy base casting and the ceramic parts of the capacitor. Rotation of the capacitor is effected by a rigidly mounted stainless steel worm gear, driven directly by the front panel tuning knob, which meshes with a bronze wheel mounted on the rotor spindle close to the lower bearing.

The worm wheel is a fully throated design of generous proportions (20 diametral pitch) and is split laterally across its centre, the two halves being spring-loaded together to reduce the backlash to a low figure.

The comparatively low ratio of 8:1 for this main tuning drive was chosen to give rapid travel from end to end of a range without undue loss of discrimination. Each range is divided into approximately 400 divisions by the four-turn 100-division dial secured to the tuning knob, the total backlash in the system amounting to less than 1 part in 3000. The main frequency dial is driven directly from the worm spindle by a simple wire drive, each range covering 180° of the $7\frac{1}{2}$ inch diameter dial.

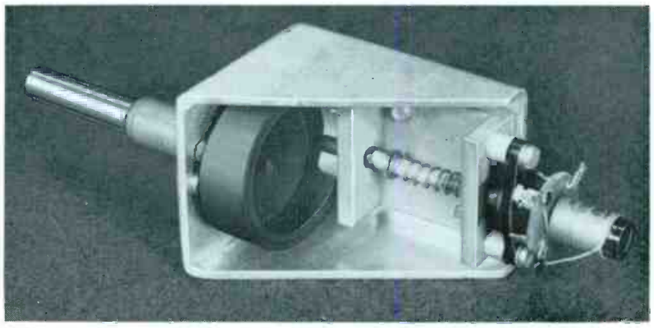


Fig. 5. The incremental frequency control unit

Fine Tuning

For the greater frequency discrimination required by modern narrow bandwidth receivers an improved type of incremental frequency control* was developed for this instrument. This consists of a small permeability tuned inductor coupled via a special auto transformer across part of the main tuned winding of the oscillator coil.

The front panel control operates a face cam via a 6:1 ratio ball drive. Spring-loaded against this cam is a

* Prov. Patent 6806/60

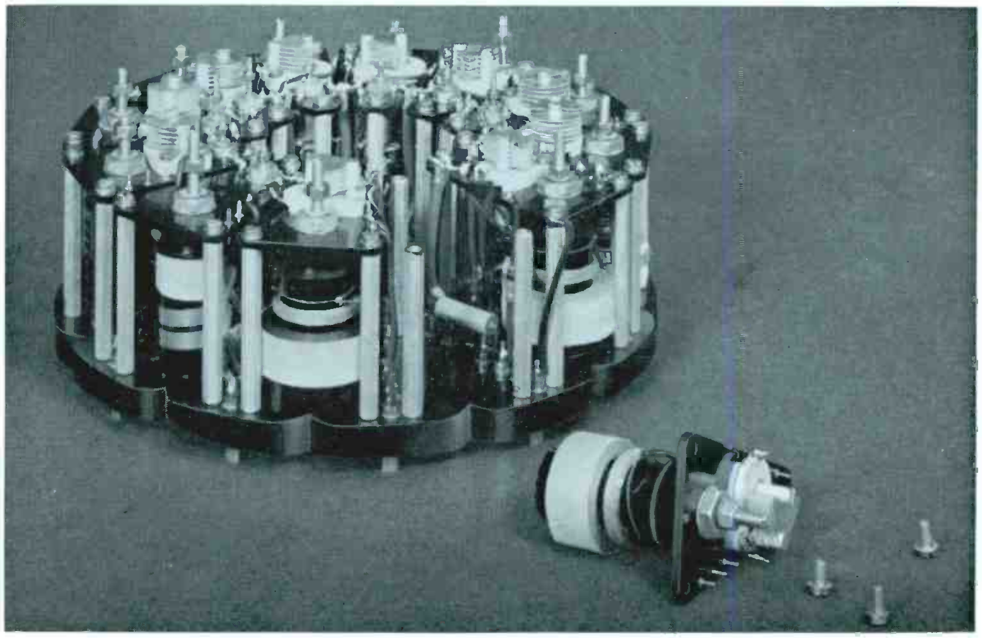


Fig. 4
The coil turret assembly, showing how individual coil units are easily removed

ceramic spindle which carries the iron dust core at the opposite end. The spindle is ground to very fine limits, and slides in two accurately reamed holes to ensure that very small reversals of the face cam result in purely axial and not lateral movements of the spindle. For 320° rotation of the incremental dial, the core has $\frac{1}{4}$ inch of linear motion which, in conjunction with the ratios of the various inductors and transformer, gives a total cover of 1% of the frequency indicated on the main tuning dial.

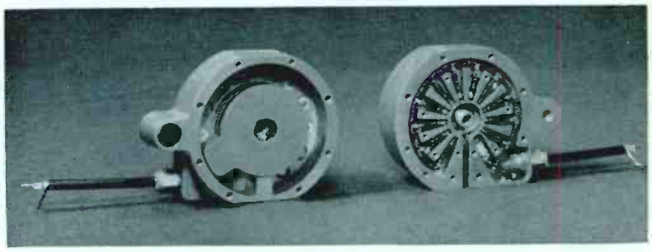


Fig. 7. Front and rear views of the coarse step attenuator

Filters

The various supplies to the R.F. Box pass through a series of r.f. filters which are housed in an aluminium alloy filter box. The box, together with the coarse attenuator body and index head, are pressure die castings. This process was chosen in preference to sand or gravity die methods because the vast saving in machining costs more than offsets the increased cost of the dies. It is also possible to reduce the wall thickness of the castings, resulting in lighter components and maximum use of available space. Pressure die castings can also be produced with much greater accuracy, and the nature of the process ensures that the metal is homogeneous and free from blow holes and concealed cavities.

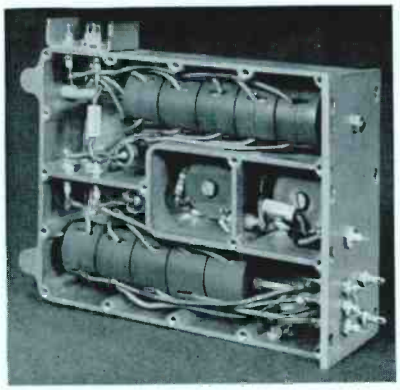


Fig. 6
The filter box assembly. This unit houses six double-section filters and associated components in a space only $5\frac{1}{2} \times 4\frac{1}{2} \times 1$ in.

Attenuators

Both the coarse and fine attenuators are part of the R.F. Box assembly. This is a new departure in signal generator design and overcomes one of the major difficulties usually encountered when the attenuators are separated from the main r.f. unit, namely that of obtaining a low resistance earth bond between them.

The output from the oscillator valve is fed first into the coarse attenuator by a lead inside the R.F. Box. The output from the wiper arm is then transferred via a double screened coaxial lead external to the R.F. Box to the fine attenuator which is mounted inside the R.F. Box with its connecting sockets accessible from the front of the base plate. The output from the fine attenuator is then taken via another double screened lead to the output socket on the front panel

As previously mentioned, the coarse attenuator body is an aluminium alloy pressure die casting, and careful attention has been paid to the screening of the resistors forming the individual π sections, and the provision of separate earth points for each 'rung' resistor of the ladder network. A $\frac{1}{8}$ inch wide radial slot, $\frac{3}{8}$ inch deep, runs outwards from the centre of the attenuator, and serves to reduce the flow of earth currents between the high potential and low potential ends of the ladder. The contacts are of solid silver alloy fitted in P.T.F.E. inserts recessed into the centre wall which separates the resistors from the wiper arm assembly. These contacts have a very low capacitance to earth, in the order of 0·3 $\mu\mu$F.

The rotor arm is screened by an aluminium alloy cover, the outside of which is formed with axial grooves, to provide an index location in conjunction with a spring-loaded ball fitted into the main body casting.

The rotor assembly is mounted on the centre spindle which is moulded in an insulating material to prevent coupling between the rotor section and the stray fields inside the R.F. Box. The output lead is secured firmly to the base casting as it passes through and picks up with the rotor arm via a pin which fits into a specially formed plunged hole in the centre of the rotor.

Since the fine attenuator deals with much smaller differences in power levels, an orthodox wafer switch was found adequate for switching the series and parallel resistors of the ladder network. Nevertheless, great care has been taken to keep all lead lengths as short and direct as possible, and the main earth path is a $\frac{3}{16}$ inch thick aluminium disc, which also carries the wafer switch, and is secured to the attenuator case as close as possible to the R.F. Box base casting

Power Supplies, L.T. Stabilizer and Modulator Oscillator

The rest of the instrument is composed mechanically of three units, the power supply, l.t. stabilizer and modulator oscillator chassis. These are mounted on three rectangular section steel support rails of U formation, the open ends being secured to the top and bottom of the front panel. These rails also carry the eight fixing blocks to which the case is attached.

Power Supplies

The power supply chassis is mounted vertically on the left-hand side of the instrument at the side of the R.F. Box between two of the supporting rails, and carries the mains transformer, l.t. and h.t. rectifiers and smoothing capacitors. It is arranged with the open side towards the rear of the instrument, for ease of access.

L.T. Stabilizer
The l.t. stabilizer unit is mounted directly behind the power unit, and consists simply of a U-section aluminium alloy strip $\frac{1}{8}$ inch thick to form a suitable heat sink for the transistors. It also carries the mains voltage selector panel which is accessible by removing a cover plate on the rear of the case. The unit is arranged so that by removing the top pair of the four fixing pillars, it can be swung downwards to allow access to the power unit chassis.

Modulator Oscillator
The modulator oscillator and h.t. stabilizer components are mounted on a horizontal chassis above the R.F. Box. Here again the open side faces rearwards and all components are readily accessible. Great care was taken in the layout of all these units to ensure that the majority of the components were placed on the same side of the various chassis for ease of assembly and servicing. The use of grommets was also kept to a minimum, and in the few places they are used are of generous size to enable the cable forms to pass through easily.

Front Panel Layout
The basic arrangement of the controls presented on the front panel follows the now familiar pattern, with the main frequency dial, tuning controls and input arrangements to the left, and the attenuators and output sockets to the right, with the carrier and modulation level controls and monitoring meter above them.

The main tuning control is placed low down on the panel so that the operator's wrist may rest on the bench to give a steadying effect to the hand when making fine adjustments. The range change control is conveniently situated adjacent to the tuning control, and operates the R.F. Box coil turret via a 6:1 reduction gear for ease of operation. The turret is continuously rotatable, *i.e.* there are no stops at the extreme ends of the frequency coverage.

The main frequency dial is protected by a shallow Perspex cover, which also houses the cursor. A small knob near the centre of this cover enables the cursor to be adjusted accurately with respect to the dial by using the crystal check points, the locations of which are conveniently indicated on the centre of the dial cover.

To make the fullest use of the available front panel area, two dials, the range indicator and coarse attenuator, have been placed behind the panel and are viewed through small moulded escutcheons.

Rack Mounting Facilities
The overall size of the front panel is 19 inches wide by $12\frac{3}{16}$ inches deep, and is provided with slots at the edges, of suitable size and spacing to enable mounting in a standard rack frame. When specified for rack mounting, a dust cover is provided in place of the case, and panel handles are fitted to protect the controls and enable convenient handling.

Battery Operation
It was decided to retain the battery operation facility of the previous instrument in this series, to maintain the versatility under field conditions.

This has been achieved very simply. Both the power supply leads, battery and mains, for the proprietary versions terminate at the front panel with 12-way sockets,

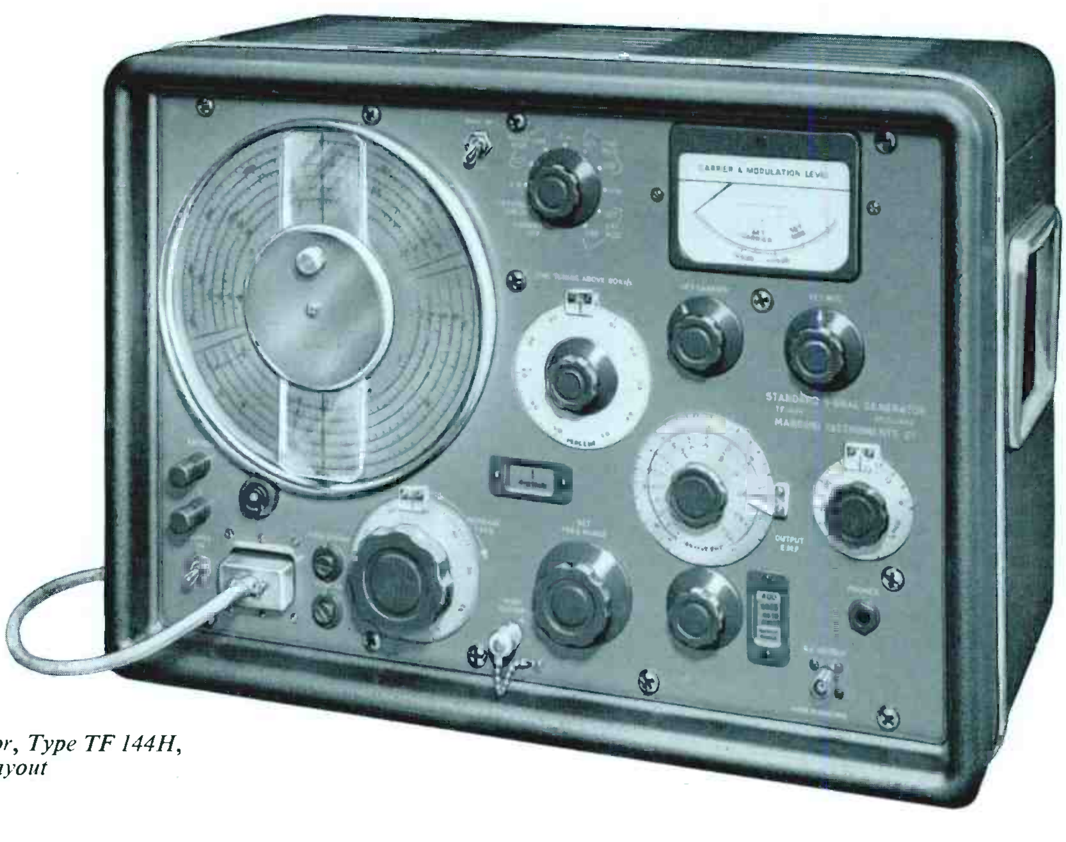


Fig. 8
Standard Signal Generator, Type TF 144H, showing the front panel layout

which mate with a 12-way plug recessed behind the panel. The wiring of this plug and the battery lead socket is so arranged that the internal stabilizing and power supply circuits are disconnected, and the battery h.t. and l.t. supplies are fed in via the same switch as the mains supply.

Proprietary and Service Versions

Either the cased or rack mounting versions are available to proprietary or service specifications. In all instances the component construction and finishes of the basic instruments are identical, the only differences being in the meter, power supply leads and the accessories provided

Meters

To meet the stringent Services specification, the standard 3×4 inch rectangular meter is replaced by a round hermetically sealed unit. This is mounted behind a plate which fits exactly into the panel cut-out provided for the standard meter and the two units are directly interchangeable.

Mains Supply

For the Services versions a supply adaptor, TM 6263, is screwed to the front panel. This converts the recessed 12-way plug into a Plessey Mk. IV socket suitable for the standard Services mains lead. It may be easily removed to enable the battery lead to be used.

Protection

The Services cased versions are also fitted with a lid which completely covers the front panel to protect the controls during transit and storage

These features have all been arranged so that any instrument can be converted to a particular type quickly and simply.

The extent to which the outstanding features of the previous instruments in this series have been included and improved upon in this new version can be seen by comparing the relative specifications. Although designed primarily as a proprietary instrument, TF 144H has passed the Services acceptance tests and has been designated GENERATOR, SIGNAL CT 452.

STANDARDIZATION OF CRYSTAL CALIBRATORS TF 1374 & TF 1374/1

An alternative method suggested by a reader—

Sir,—In *Marconi Instrumentation* for June, Mr. E. Isaacs describes the method of standardization of Crystal Calibrators using a CR.100 receiver and a separate a.g.c. voltmeter.

I would like to point out that a war surplus receiver of Marconi manufacture is, from my experience, probably the ideal for this. This is the R.1155A which is equipped with 'magic eye' tuning indication. By adjusting the signal from the crystal to be approximately equal to that from Droitwich, the eye can be made to open and close in accordance with the beats. The advantage is that the magic eye will respond to a note below audibility but still of a considerably higher frequency than any pointer type meter can follow, thus the crystal can be trimmed through a stage in which the eye is fluttering to one in which the opening and closing takes place over a period of several seconds.

I felt that after reading Mr. Isaacs' article, I could not resist pointing out the advantages of this old type receiver.

H. O. BRADSHAW

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621.396.615.12

MARCONI INSTRUMENTS

V.H.F. Signal Generator . . . TYPE TF 1064 Series

by J. H. DEICHEN, A.M.I.E.E.

The continually expanding instrumentation requirements of the electronic industry are satisfied by Marconi Instruments in two ways: by introducing new designs, and by progressive development and adaptation of established designs. Typical of the latter policy is the evolution of the V.H.F. Signal Generator TF 1064; this composite r.f., i.f. and a.f. source was originally designed as part of a test set for mobile f.m. and a.m. equipment, and has been developed into an independent signal generator for field or laboratory use.

Introduction

When an instrument is modified it is also necessary to modify its type number for indentification purposes. This is done by adding a letter or a stroke number after the basic type number. In general, with a major redesign involving, say, valve changes, the type number is followed by a letter; the previous models become obsolete. Minor modifications which give the instrument added features or an alternative function are usually designated by the addition of a stroke number; this implies that the modified version does not supersede the basic version but is an alternative to it.

A good example of these type designations is the TF 1064 series. This V.H.F. Signal Generator, by the nature of its design, is a narrow range instrument; therefore, to meet the full frequency requirements, a number of alternative models designated by different stroke numbers are available. This article attempts to give the reader a complete picture of the whole series of these instruments by describing each different feature.

The models to be described are as follows:

Model	*Features*	*Remarks*
TF 1064	Original model	Superseded by TF 1064A
TF 1064/2	Alternative bottom r.f. range	Superseded by TF 1064A/2
'A' SERIES: *Fitted with new stabilized h.t. and l.t. supply for testing close-channel systems*		
TF 1064A	Basic model	Superseded by TF 1064B
TF 1064A/2	Alternative bottom r.f. range Indirectly heated valves	Superseded by TF 1064B/2
TF 1064A/3	Alternative top r.f. range	Superseded by TF 1064B/3
TF 1064A/4	Alternative top r.f. range	Superseded by TF 1064B/4
'B' SERIES: *Preset calibrating controls instead of selected components*		
TF 1064B	Basic model	Current version
TF 1064B/2	Alternative bottom r.f. range Indirectly heated valves	Current version
TF 1064B/3	Alternative top r.f. range	Current version
TF 1064B/4	Alternative top r.f. range	Current version

TF 1064

The V.H.F. Signal Generator, TF 1064, was first designed in 1956 and this original model was described in *Instrumentation* in December of that year.[1] The instrument and subsequent models were designed primarily as a portable unit to be used in conjunction with the Transmitter and Receiver Output Test Set, TF 1065, for making most measurements on mobile equipment. Although intended for field use, the TF 1064s have found their way into many laboratories throughout the world.

The instrument has three r.f. ranges: 68 to 108 Mc/s, 118 to 185 Mc/s, and 450 to 470 Mc/s. The first two ranges are obtained from fundamental oscillators and the top range from a trebler following a narrow range oscillator. Each oscillator has its own valve, coil and variable capacitor so that the range change is obtained by simple switching of the h.t. supply to the valve of the wanted range. This method eliminates the need for r.f. contacts in the tuned circuit. The three launching coils and a monitor pick-up loop are all located in a small area at the opening of the cylinder for the piston attenuator. Thus the space limits the number of ranges permissible

Fig. 1
The Marconi Instruments V.H.F. Signal Generator, Type TF 1064B

in an instrument. The range cover on the two lower ranges is purposely limited to about 1·6 to 1 to prevent harmonic relationships existing between the ranges at a common point on the calibrated frequency dial. The top range, which is a narrow band range, is positioned on the frequency dial so that the fundamental oscillator from which the signal is derived is not harmonically related to either of the other two ranges.

This instrument and all subsequent models are particularly stable in respect of warm-up frequency drift; this is due to the construction of the r.f. unit being such that the valves are not located in the r.f. box which contains the associated circuit components. The valves are screened by special screw-on cans which also serve the purpose of heat sinks.

The frequency modulation was originally designed for fixed deviations of 5 kc/s and 25 kc/s, at two switch positions, but these were later changed to 3·5 kc/s and 10 kc/s. The modulating signal is derived from a 1000 c/s oscillator built into the instrument. An electronically obtained incremental frequency produces a controlled frequency shift from 0 to ± 100 kc/s on all ranges. However, the shift was later limited on the lower two ranges to ± 25 kc/s on range A and ± 50 kc/s on range B. Both the frequency modulation and the incremental frequency are produced on the two lower ranges by a magnetic reactor. On the top range these functions are obtained by varying the h.t. supply to the fundamental oscillator and using the inherent frequency shift produced. This system gives negligible spurious a.m. or level variation on the output due to the class 'C' operation of the trebler stage.

Deviation tracking is not necessary on the top range because of the narrow frequency band involved. However, on the two lower ranges the tracking is obtained by a variable resistor ganged to the variable capacitor and by an impedance network to track between the ranges.

A fixed amplitude modulation of nominal 30% modulation depth is provided by a unique method*, using two germanium diodes in the head of the piston attenuator. These diodes are connected so that the pick-up impedance is altered in sympathy with the modulating signal but the impedance looking in at the output end of the attenuator remains constant at 50 ohms. The system has an important advantage of little or no spurious f.m. on a.m.

All the TF 1064 series of instruments have a calibrated signal output level which is variable by a piston attenuator between 0·5 μV and 10 mV e.m.f., with a higher uncalibrated output up to at least 200 mV.

Besides the r.f. output as described above, the instrument gives an i.f. output at five frequencies derived from an oscillator with plug-in crystals switched by a front panel control. The crystal circuit is set to 30 $\mu\mu$F input capacitance, so that the frequency accuracy of the oscillator is equal to the accuracy of the crystal, providing it is one that is suitable for the 30 $\mu\mu$F circuit. The crystals are plugged in at the back of the instrument and a label is attached to the front panel so that the crystal frequencies can be tabulated according to the switch positions. The oscillator will accept crystals in the range 290 kc/s

* British Patent No. 806,291

to 16 Mc/s; however, at the extremes of the range low activity crystals may prove to be unsuccessful. The crystal holders are the standard seven-pin base type suitable for B7G glass envelope crystals. The i.f. output is uncontrolled and the level depends on crystal activity and frequency; but an external control, TM 5570, is available as an optional accessory.

By switching on the a.f. oscillator, the i.f. signal becomes amplitude modulated. The depth of modulation is uncalibrated and depends on the crystal activity and frequency.

The a.f. oscillator output is brought to a front panel terminal and is controlled by a front panel control. The maximum level is at least 1·2 volts uncalibrated. However, an external Monitor and Attenuator, TM 5567, is available. This unit and the I.F. Level Control are described under Accessories.

The oscillator valves are of the directly heated type and are fed from a rectified supply. The h.t. supply is rectified and regulated by a neon stabilizer.

TF 1064/1

The TF 1064/1 was introduced at the same time as the TF 1064 and differed only in that the fixed f.m. deviations were 3·5 and 10 kc/s. When the standard TF 1064 model was later changed to have the same deviations, the -/1 version was no longer required.

TF 1064/2

Closely following the marketing of the TF 1064 instrument it became apparent that, for some customers, a 30 to 50 Mc/s frequency range was more useful than the 68 to 108 Mc/s range. Thus a new model was introduced incorporating a change in the bottom range and stroke number '2' was given to it for identification. This lower frequency range presented somewhat more difficulty in design than the previous model and involved added mechanical structure for supporting the range coil.

The use of this model was for f.m. equipment only, therefore the a.m. facility was deleted. The f.m. and incremental frequency facilities were similar to the original model. The crystal holders used for this model are the two-pin type suitable for 'D' type crystals.

TF 1064A and TF 1064A/2

Following the design of the TF 1064 and TF 1064/2, very narrow bandwidths for mobile equipment were introduced. Also the Signal Generators were being required for use under adverse conditions where the mains voltage supplies were continually varying. Thus it became apparent that better stability of the frequency against mains voltage changes was required. This called for re-engineering of the power supply for the instruments.

A conventional electronic h.t. stabilizer using a series control element was considered necessary. However this was found to be only partly sufficient as the valve heater voltage change also causes frequency change, which is an inherent feature of oscillators. After various types of low voltage, high current stabilizers were investigated, a transistorized l.t. stabilizer[2] was incorporated. In fact, this was the beginning of the use of this type of heater stabilizer which is now used on many Marconi equipments. As these features represented major re-design, producing models that would supersede the original models, the letter 'A' was added to the type numbers. Thus the new models were TF 1064A and TF 1064A/2, corresponding in other respects to the TF 1064 and the TF 1064/2.

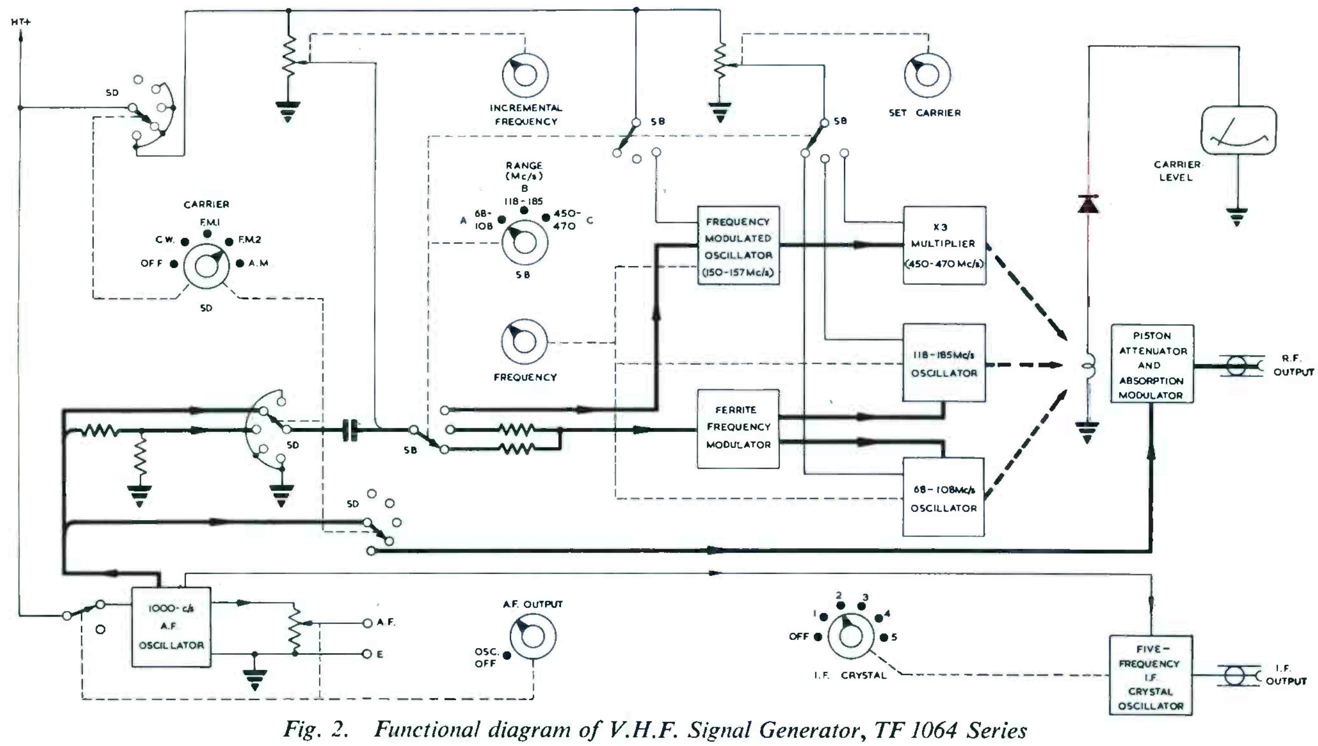


Fig. 2. Functional diagram of V.H.F. Signal Generator, TF 1064 Series

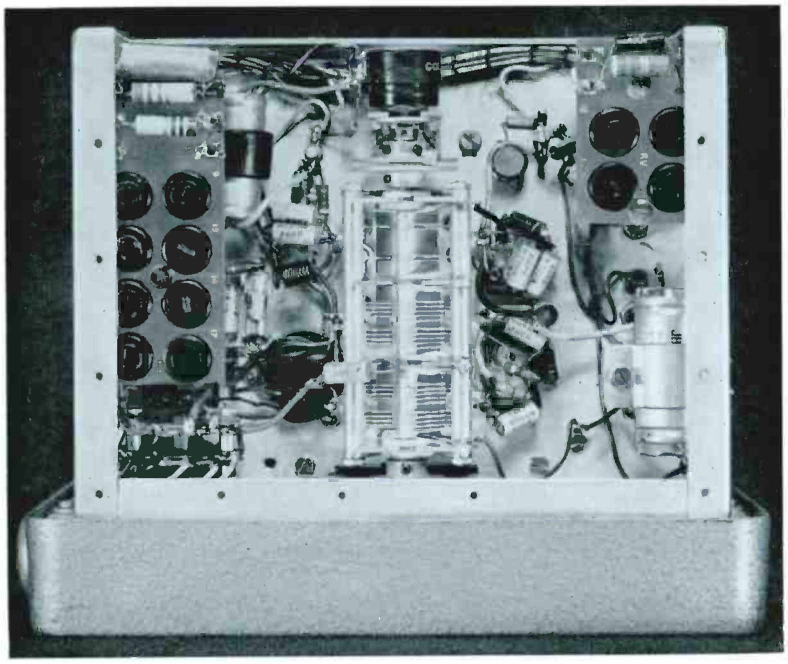


Fig. 3. The R.F. Box, cover removed, of the TF 1064B, showing the variable resistors for calibrating the modulation level and signal level monitor

Further work was carried out on the TF 1064A/2 to replace the directly heated valves with indirectly heated valves. This was because the instrument catered mostly for the American market where indirectly heated valves are more readily obtainable for replacement. The valves chosen require a higher heater current; therefore, to eliminate the need for a higher power l.t. stabilizer it was necessary to switch the heater supply to the valve for the range oscillator in use. During the unused period of a particular oscillator the heater of the valve receives an a.c. supply to maintain thermal stability. The switching was possible by using the positions which are normally used for amplitude modulation on the TF 1064A model.

On the TF 1064A/2 it was not possible to frequency modulate on the top range by varying the h.t. supply because of the lower interelectrode capacitance of the valves; a variable capacitance diode was used instead. The incremental frequency shift was produced by varying the h.t. to the oscillator valve, but as the instrument is used for narrow band operation the shift on all ranges was limited to ± 25 kc/s.

A request was received to supply a facility for using an external signal for frequency modulating. The facility was designed into the TF 1064A/2 by a switch arrangement and by using the existing a.f. output terminal as the input terminal for modulating. However, the external modulation is uncalibrated and the input required is dependent upon the modulating frequency. A further facility added was a variable f.m. deviation from 0 to 15 kc/s, monitored on a calibrated dial attached to the variable resistance control. This function is obtained on one position of the function switch; on a further position a fixed deviation of 10 kc/s is obtained.

TF 1064A/3

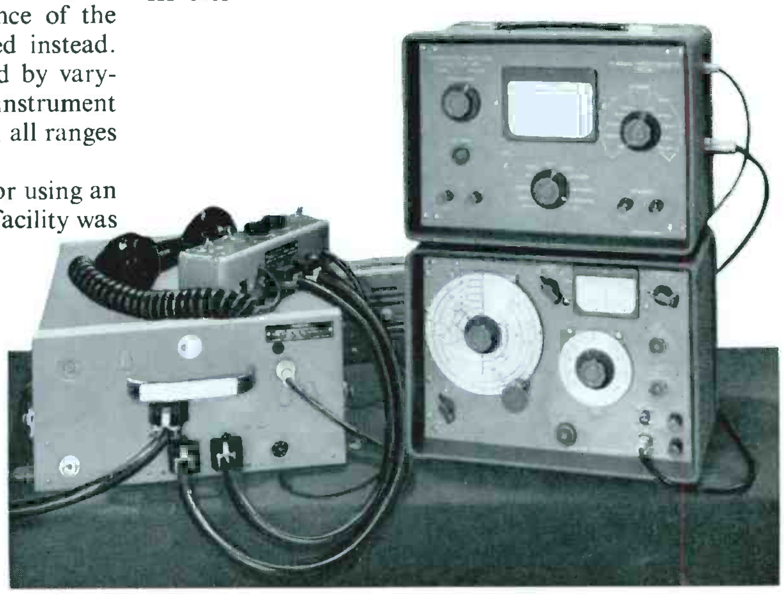
A new model, TF 1064A/3, was designed to meet the requirements for mobile equipment using frequencies up to 500 Mc/s. The instrument is identical to the TF 1064A for performance except that the top range is 470 to 500 Mc/s.

This top range is somewhat wider than the 450 to 470 Mc/s range of the TF 1064A and presented more difficulty in respect to frequency modulation. It was found to be unsatisfactory to use the same method of modulation because of the large variation of f.m. sensitivity. Therefore, two variable capacitance diodes are used, one for the f.m. function and one for the incremental frequency shift function. The two diodes are used independently for the two functions so that f.m. deviation is not influenced by the incremental frequency control position.

TF 1064A/4

It became necessary to introduce a still further model, the TF 1064A/4, to cater for the frequency requirements between 440 and 460 Mc/s. This instrument is identical in every way to the TF 1064A except for the different frequency cover on the top range.

Fig. 4. The TF 1064, with its companion Transmitter and Receiver Output Test Set, Type TF 1065, being used as a test rig for the Marconi V.H.F. F.M. Telephone Equipment, Type HP 81A



As these two latter instruments did not supersede the previous models but were supplied concurrently, they were identified by the stroke numbers.

TF 1064B Series

With the introduction, by component manufacturers, of miniature variable resistors it became possible to replace the usual selected fixed resistors in the TF 1064A series by these. Variable resistor presets have the obvious advantage of saving in production time and cost, but there are two other important advantages. (1) the accuracy of calibration can be set to a closer limit due to the fact that a resistor is not being selected to a near value within a certain tolerance; (2) the instrument lends itself to easy recalibration during the standardization procedure. A further advantage is that for a spot frequency the accuracy of, say, the f.m. deviation can easily be set to a particularly close tolerance if required, although at a sacrifice to the accuracy at other frequencies.

These variable resistors are mounted on an insulated board in a position normally occupied by tag boards. Two such boards are used inside the r.f. box. These can be seen in the picture of Fig. 3, which is a picture of the inside of an r.f. box for the TF 1064B.

All the four instruments in the TF 1064A series were superseded by the TF 1064B series which use the variable resistors. The stroke numbers used on the A and B series are identical.

Accessories

There is a comprehensive range of accessories available for use with the TF 1064 series of V.H.F. Signal Generators. These include the following items:

50 to 75 ohm Matching Unit, TM 5569, which is contained in a small screened case with BNC input socket and a Belling Lee output plug.

20 dB Attenuator Pad, TM 5573, housed in a fully screened case with a BNC plug at one end and a BNC socket at the other end. With this pad the v.s.w.r. of the instrument output is less than 1·15 to 1.

6 dB Attenuator Pad, TM 5573/1, which is similar in construction to the 20 dB Pad. This unit is intended for use where a loss of 20 dB cannot be tolerated.

I.F. Level Control Unit, TM 5570, uses an uncalibrated control to adjust the i.f. signal level from zero to maximum value, continuously variable.

A.F. Monitor and Attenuator, TM 5567, is housed in a small case with a hinged lid. This unit has a level meter which gives direct indication up to 1·5 volts when the output is taken from the high level output terminal, and a divide-by-10 indication when on the low level output terminal. As the unit has a low input impedance it is not suitable for use with the TF 1064A/2 or the TF 1064B/2 models.

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1. Parkyn, J. M.; New Test Equipment for V.H.F. Mobile Radio, *Marconi Instrumentation*. 5, 201 (December 1956).
2. Deichen, J. H.; A Transistorized L.T. Regulator. *Electronic Engineering* 31, 688 (November 1959).

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Extended Q-Meter Measurement and Measurement Accuracy

by J. M. PARKYN

This article discusses some of the more common queries that Q meter users have referred to the author. A simple, practical method is given for assessing the need for corrections. This shows the inadvisability of using standard Q coils for setting up Q meters. An advanced method of obtaining the highest accuracy from corrected readings is considered. A substitution method of measurement which is described avoiding Q meter loss corrections, can be extended to give zero or negative capacitance for resonating external circuits.

A Q METER is perhaps the most versatile of all electronic measuring instruments yet, due to an inadequate appreciation of the need for corrections, doubt is often cast upon the accuracy of measurement when different figures for Q are obtained from several different instruments for the same identical coil–this may occur to some degree even when all the instruments concerned are manufactured by the same Company. The doubt will most certainly be greater if the measurement is in the upper audio range where a comparison can be made between a direct Q meter reading on a high inductance coil and a non-resonant inductance bridge measurement at the same frequency.

A practical guide to corrections, which could act as a supplement to the complex treatment generally included in comprehensive Q meter instruction books and technical papers, is included in this article. An outline of a precise correction technique is given for those who wish to obtain a higher order of accuracy which is not generally within the scope of most instruction books. A method of measurement is described which avoids corrections for the most significant Q meter residuals which are generally the series and shunt losses.

Versatility

The use of a Q meter for the direct measurement of the Q factor of a coil is perhaps the most obvious and general use of the instrument, but as an impedance measuring device a Q meter is a valuable complementary instrument to extend measurements beyond the range of h.f. bridges. Measurements of impedance made on a Q meter are of greatest accuracy when they involve halving the complete test circuit Q factor. This will occur with high impedances of, say, a megohm at 1 Mc/s for parallel measurements and a few ohms for series measurements at the same frequency. Usable measurements can be made several orders of magnitude above and below these figures. Non-resonant bridges, however, give their greatest accuracy when measuring medium impedances of, say, 10 to 1,000 ohms. A similar distinction exists at all other frequencies in the high frequency range covered by both types of instrument; the extreme range of Q meter measurements is more restricted at the highest frequencies but this is of no practical significance since many megohms at hundreds of megacycles is not a realisable impedance, and the same applies to extremely low impedances. It will be seen that as the accuracy and discrimination of a non-resonant h.f. bridge falls at high and low impedance values a Q meter passes into its region of greatest accuracy, permitting measurements to be made well beyond the attainable limits of bridge systems.

Another aspect of impedance measurement using a Q meter is the ease with which the absolute value of reactance and resistance of the component under test can be evaluated from the Q meter indications even when the loss factors involved are extremely small to the extent of being less than those of the Q meter test circuit itself. This results from the fact that two measurements are made, one with the component under test disconnected and the other with the unknown in circuit. It is therefore the change, negative or positive, in the setting of the capacitor dial that gives the magnitude and sign of the unknown reactance and the fall (or rise!) in Q indication which gives the resistance value (and sign) of the unknown.

Fig. 1
Marconi Instruments Circuit Magnification Meter, Type TF 1245, and Oscillator TF 1247

(Q meter measurements are not restricted to passive circuits, active circuits exhibiting negative resistance can be measured.)

Apparent Errors

It is when comparing the direct indication of coil Q factor that the performance of Q meters is sometimes criticized for small apparent errors. For example, different Q meters may give slightly different direct readings for the same high Q coil because of differences in conductance of the test circuits in the instruments. The instruments are. however, correctly indicating the combined Q of the coil and the test circuit, and the pitfall must be avoided of using a set of standard-Q coils for setting up all Q meters to indicate the same uncorrected Q figure. The true Q of the coil can be found by use of corrections or substitution methods, both of which will be described. As an extension of a substitution method of measurement which avoids conductance and series resistance corrections, a simple method of resonating a coil requiring less capacitance than the minimum figure for the instrument in use will be described. Taken to the extreme this allows measurements at resonance of complete tuned circuits, for example, i.f. coils with the tuning capacitor already fitted.

Assessing the Need for Corrections

A simple general rule in assessing the need for applying corrections to an indicated Q reading is to correlate the resonant impedance of the component under test with the Q meter residuals and the accuracy required. The setting of the Q meter capacitor and the oscillator frequency will enable the operatoı to calculate the capacitive (or inductive) reactance at resonance. The product of the indicated Q and the reactance will give a dynamic impedance figure which should be less than one tenth of the shunt loss of the test instrument to avoid a 10% error from this cause. Marconi Instruments Circuit Magnification Meter TF 1245, has a loss figure of approximately 50 megohms at 1 kc/s 12 megohms at 1 Mc/s, 300 kilohms at 100 Mc/s and 50 kilohms at 300 Mc/s. From these figures it will be seen that under extreme conditions, and in spite of the very small losses within the instrument, heavy corrections will occasionally be necessary. A 1 kc/s measurement on a 50 henry coil of 150 Q factor — a practical component using ferrites — will yield an indicated figure of just under 75 because the coil loss alone would give a dynamic impedance of over 50 megohms, the Q meter valve voltmeter accounting for the other half of the loss.

The series impedance of a circuit at resonance is smaller than the parallel impedance by a factor of Q^2. The series loss of TF 1245 is almost exclusively in the resistive injection system of the 1 kc/s to 50 Mc/s test circuit and has a value of 20 milliohms. Similar considerations exist when the series impedance of the circuit under test is only 10 times greater than the injection resistance of the Q meter when a 10% correction will be necessary. It is very uncommon to produce such a high Q that the parallel impedance is very high and the series impedance is very low so that both corrections are necessary. It is, however, necessary to appreciate that very low and very high L/C ratio circuits will generally need one or other correction, the commonly used L/C ratio circuits having medium values of effective series and parallel impedance will not need either correction.

Avoiding Corrections

A factor which is not always appreciated when seeking the greater Q accuracy that correction can give is that, although a comprehensive list of correction formulae and residual constants is generally included in a Q meter instruction book, still greater accuracy can be obtained by measuring the precise constants for the particular instrument in use since these may differ slightly from the average correction constants quoted for that instrument type. The conductance of one Q meter can be measured by using another Q meter, which need not be similar, to give the loss factor of the test capacitor by the usual substitution method. In the absence of another instrument the conductance of the standard capacitor in a Q meter can be deduced from series measurements on a fixed capacitor at one frequency with different settings of the Q meter variable. From the slight difference in the readings can be calculated the shunt conductance of the Q meter variable capacitor. Parallel substitution methods yield figures for the Q meter series residuals of inductance and resistance.[1]

However, as the conductance does not affect the accuracy of parallel substitution measurements, and series injection resistance will appear as part of the loss of the subsidiary coil, a direct measurement can be made on this basis which needs no corrections for series resistance or shunt conductance and hence no precise knowledge of the loss figures. The Q meter is brought to resonance at the required frequency by using a subsidiary screened coil to give a Q figure Q_1 with indicated capacitance C_1. A second measurement is made at the same frequency with the coil to be tested across the capacitor terminals of the Q meter, the subsidiary coil still in circuit in the normal coil position. The capacitor is reset to restore resonance at capacitance setting C_2 and new Q figure Q_2. Then the absolute Q (Q_A) of the coil under test is given very closely in equation 1.

$$Q_A = \frac{Q_1 Q_2}{Q_1 - Q_2} \cdot \left(\frac{C_2 - C_1}{C_1}\right) \qquad \ldots (1)$$

Strictly a C_0 correction should be used but there is some degree of cancellation of this error since both coils may have a similar C_0.

In a case where negative capacitance is needed to effect resonance of a particular circuit under test a substitution test is made by taking a first measurement at the required frequency with the Q meter test circuit resonating a subsidiary test coil. A second condition of resonance at the same frequency with the circuit under test across the capacitor terminals of the Q meter may be obtained with a lower capacitance setting of the Q meter capacitor, the reduction in the capacitor setting being the negative capacitance needed by the external circuit to establish resonance.

Measuring Q of Complete Circuits

Extending this type of measurement a complete parallel resonant L/C circuit can be measured. A subsidiary coil is brought to resonance on the Q meter at the frequency where the complete circuit to be tested will resonate. A small adjustment to the frequency and/or capacitance setting of the Q meter is made until no readjustment is necessary to restore resonance when the complete circuit under test is placed across the Q meter capacitor terminals. Let the two Q readings be Q_1 in the first case and Q_2 for the composite measurements and the capacitance C_1 in both cases. A third measurement is taken, for ease of calculation, at half the final frequency in the above test in order to determine the capacitance of the circuit under test; in this measurement the subsidiary coil is out of circuit and the parallel L/C circuit under test is connected at the coil terminals of the Q meter. The Q meter is brought to resonance by use of its variable capacitor to give a capacitor reading of C_2. The total tuning capacitance C_x of the unknown circuit under test is then given by,

$$C_X = \frac{C_2}{3} \qquad \ldots (2)$$

and the Q of the circuit under test, Q_{LC}, at its self resonant frequency, is given by

$$Q_{LC} = \frac{Q_1 Q_2}{Q_1 - Q_2} \cdot \frac{C_2}{3C_1} \qquad \ldots (3)$$

1. Field, R. F., and Sinclair, D. B. 'A method for determining the residual inductance and resistance of a variable air condenser at radio frequencies.' *Proc. I.R.E* February 1936.

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MARCONI INSTRUMENTS

Low Frequency Generator . . . TYPE TF 1382

by G. PETERS, B.Sc.
and G. HARRIS, B.Sc.

The Low Frequency Generator provides sine, square and ramp waveforms in the frequency range 0·0033 c/s to 1 kc/s. A single cycle of each waveform can be obtained. The output available is at least 15 volts peak-to-peak into a 2,500 ohm load. Other facilities provided are marker pulses with definite phase relationships to the output waveform and a built-in relay with heavy-duty contacts which can be used to drive external circuits. The instrument is largely transistorized.

THE HEART of the instrument is a circuit producing a ramp waveform. A capacitor is charged by a constant current circuit and is rapidly discharged through a low impedance path whenever the voltage across it reaches a certain fixed value. The ramp waveform is passed, via a valve buffer stage to a transistor amplifier and thence to the output terminals via a power output stage.

The sine waveform is produced by first rectifying the ramp waveform by means of a bridge circuit and then clipping the resultant triangular waveform at two voltage levels at the amplifier output, by means of Zener diodes. The resultant sine wave is then fed to the power output stage. The distortion of the signal generated in this way is less than 5%.

Square waves are obtained by using the ramp waveform to operate a bistable squaring circuit.

APPLICATIONS

The Low Frequency Generator is a small, easily portable instrument with low power requirements. The internal temperature rise above ambient is very low, enabling the instrument to be used in comparatively high ambient temperatures despite the use of semiconductors. All outputs are isolated from chassis so the instrument can be connected to give outputs of either polarity.

The generator should have many applications falling into three main categories.

In the laboratory the instrument will have application as a general-purpose, very low frequency generator. One particular application for the ramp waveform is as an external time-base for oscilloscopes to permit low frequency waveforms to be displayed.

Among the industrial applications are the testing of servo-mechanisms, flight-simulators and nuclear-reactor simulators, for which the low frequencies obtainable from the TF 1382 make it particularly suitable. The built-in relay may be used to switch external circuits so that the instrument has application as a timer and for the life testing of mechanical equipment.

In the medical field the instrument can be used for testing the very low frequency amplifiers and pen-recorders used in electro-encephalographs, electro-cardiographs, etc. Other medical applications are as a treatment timer and for the cyclic control of electro-stimulation equipment.

DESIGN DETAILS

A. Ramp Generator

The operating principle of the ramp generator is shown in Fig. 2(*a*), a simplified circuit in Fig. 2(*b*), and the waveform produced in Fig. 2(*c*).

A sawtooth waveform is produced by charging the capacitor, C_T, at substantially constant current, then

Fig. 1. The Marconi Instruments Low Frequency Generator, Type TF 1382

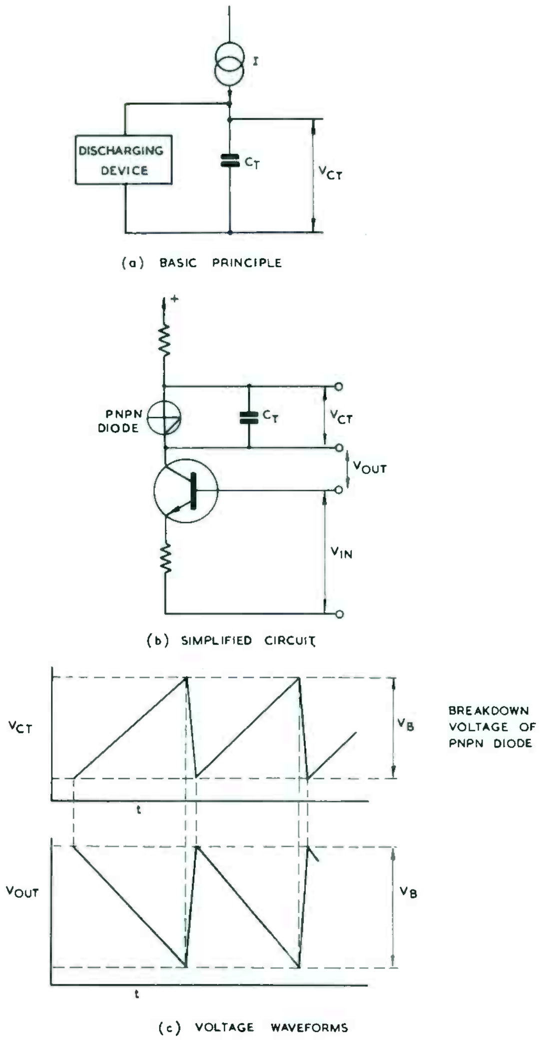

Fig. 2

rapidly discharging it through a low impedance path when the voltage reaches a certain level.

In practice, the constant current, I, is the collector current of a silicon n-p-n transistor. The discharging device is a four-layer pnpn diode which has a resistance of several megohms until the voltage across it exceeds a definite breakdown voltage, V_B, in this case approximately 20 volts. The diode then conducts heavily with a low resistance of the order of a few ohms and continues to do so until the current flowing through it drops below a certain level, the holding current, I_h. A ramp waveform is thus produced with a slow rise due to the steady charging of the capacitor, followed by a rapid fly-back as the capacitor discharges through the pnpn diode.

The frequency of operation is controlled in two ways:- to produce the five frequency ranges of the instrument, different values of timing capacitor, C_T, are switched in; to achieve continuous frequency variation over each range the charging current is varied by altering the bias on the transistor.

The output from the primary circuit is taken across the collector-base junction of the transistor and has the form shown in Fig. 2(*c*); the output level is independent of frequency.

B. Buffer Stage

The output from the ramp circuit is fed to a buffer cathode follower, a valve stage being used rather than a transistor to avoid loading of the primary circuit. The output from the buffer stage is taken from between the two cathodes.

C. Shaping Circuits

The output from the buffer stage is treated in three ways to produce the three output waveforms.

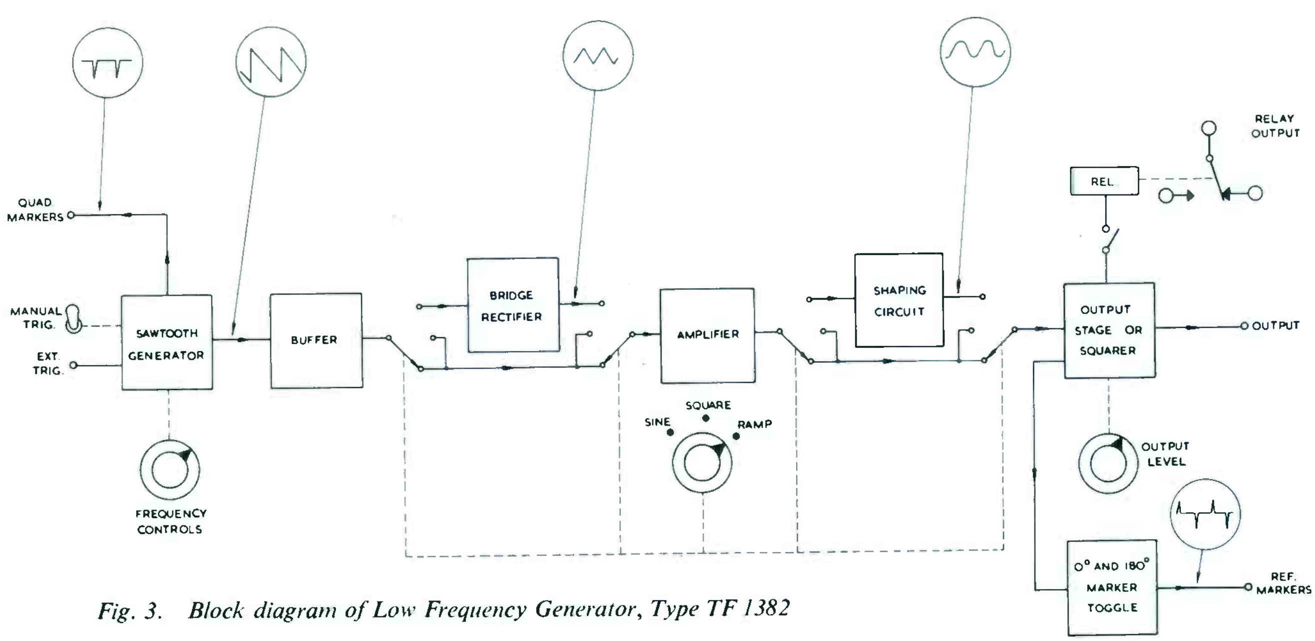

Fig. 3. Block diagram of Low Frequency Generator, Type TF 1382

For the ramp output a portion of the buffer stage output, taken from a potentiometer across the two cathodes, is applied to the bases of two silicon p-n-p transistors arranged as an emitter-coupled differential amplifier. The amplified output is then taken to two germanium power transistors connected in the common collector mode. The instrument output is taken from the two emitters of this stage via an output level control.

In the sine wave connection the output from the buffer stage is applied to a germanium diode bridge circuit giving a triangular output waveform with a d.c. component. This waveform is suitably attenuated and the d.c. component removed before it is passed to the differential amplifier. The sine wave is produced by a Zener diode clipping circuit connected between the collectors of the two amplifier transistors. The triangular wave is clipped at two voltage levels to produce a good approximation to a sine wave. This waveform is then passed through the same output circuit as that used for ramp waveforms.

For square waves the buffer stage output is amplified by the differential amplifier, the clipping circuit being switched out. The amplified output is fed to the two power transistors which in this case are connected to form a bistable squaring circuit. The instrument output is taken from the collectors of these transistors via the output level control. With this bistable circuit rise times of the order of 5 μsec are obtained.

D. Relay Operation

A built-in relay with heavy-duty changeover contacts wired to front panel terminals can be switched to operate on square waves at frequencies up to 1 c/s. This is achieved by switching the relay coil in place of one collector load in the power transistor output stage.

E. Single Shot Operation

By switching in a silicon diode clamping circuit, the primary generator can be prevented from free-running. A single cycle of ramp, cosine or square wave can then be initiated either manually, by means of a front panel switch, or by shorting external contacts.

F. Marker Circuits

'Quadrature Markers' with a phase angle of 90° relative to the sine output can be obtained from front panel terminals. These markers are obtained from the flyback voltage across a resistor in series with the pnpn diode in the primary generator and are coupled to the 'Markers Quadrature' output terminals by means of a transformer. These markers have an amplitude of 5 volts, a rise time of 2 μsec and a duration of 4 μsec.

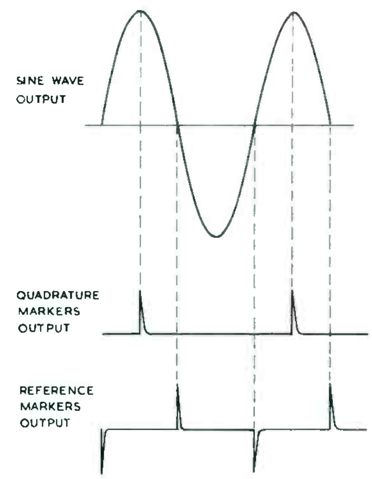

Fig. 4
Showing phase relationship of markers to signal

'Reference Markers' with phases of 0° and 180° relative to the sine output can also be obtained from front panel terminals. These markers are produced by applying part of the output from the power transistor stage to a bistable squaring circuit, consisting of two germanium transistors, and differentiating the output by means of a C-R network. These markers have an amplitude of 5 volts.

The phase relationships between these two sets of markers and the main output are shown in Fig. 4.

ABRIDGED SPECIFICATION

Frequency

RANGE: 0·0033 c/s to 1 kc/s in five overlapping ranges; 5 minutes to 0.001 second/cycle in five overlapping ranges.

ACCURACY: ±5%.

STABILITY: ±2½% including normal mains fluctuations.

Output

LEVEL: Output continuously adjustable from 0 to 15 volts peak-to-peak into a 2·5-kΩ load.

AMPLITUDE STABILITY: ±5%.

OUTPUT IMPEDANCE: *Sine and ramp:* less than 500Ω.

Square: less than 1,000Ω.

Distortion

RAMP: Departure from linearity less than 5%.

SINE: Distortion less than 5%.

SQUARE: Mark to space ratio variable by preset control from about 0·5:1 to 2:1.

Markers

QUADRATURE MARKERS: Amplitude: 5 volts.

REFERENCE MARKERS: Amplitude: 5 volts.

CORRECTION

In the Specification for the TF 1299 Gamma Radiation Monitor, on page 39 of Vol. 8 No. 2, June 1961, the stability figure of 4%/°C should have read 0·4%/°C.

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MARCONI
INSTRUMENTS

A New Helical Coupled Noise Source

by H. C. GRIBBEN

The sensitivity of a radio receiver is limited by internally generated noise, and is most realistically expressed in terms of noise factor. The article describes the requirements of a noise source for measuring noise factor. The spectrum covered by noise diodes and waveguide-mounted gas discharge tubes leaves a gap between about 500 and 2500 Mc/s which can be filled by a helical coupled discharge tube, such as is used in the TF 1301 Noise Generator.

THE RANDOM FLUCTUATIONS of electrons in a resistance generate noise voltages across it (Johnson Noise). The resistance may be considered as a source of noise power of magnitude kTB watts, where k = Boltzmann's constant = $1{\cdot}38 \times 10^{-23}$ joules per degree Kelvin, T = absolute temperature of the resistance in degrees Kelvin, B = bandwidth of the resistance in cycles per second.

The uneven emission of electrons from valve cathodes (shot noise) is an additional source of noise in radio receivers and, with Johnson or thermal noise, limits the minimum amplitude of signal detectable by a radio receiver. Receiver sensitivity is therefore most realistically expressed by its noise factor which is defined as the ratio of the signal/noise power input of the receiver to its signal/noise power output. It may be shown that this leads to a simplified definition which states that noise factor is the ratio of the actual noise power output of the receiver to the noise power output which would exist if the receiver were noiseless.

Shot noise, like Johnson Noise, occupies a wide frequency band. Consequently, the magnitude of the noise power appearing at the output of a receiver is dependent upon the bandwidth of the receiver. Because of this, if noise factor measurements are to be made with a conventional c.w. signal generator, it is first of all necessary to establish the gain/bandwidth characteristic of the receiver.

A more convenient method is to use a noise generator to supply the signal input. Noise input from the noise generator and noise originating in the receiver are equally affected by receiver gain and bandwidth, and a separate bandwidth measurement is unnecessary.

The source of noise power must have certain characteristics. Noise power must be accurately known. The

Fig. 1
Marconi Instruments
Noise Generator, Type TF 1301

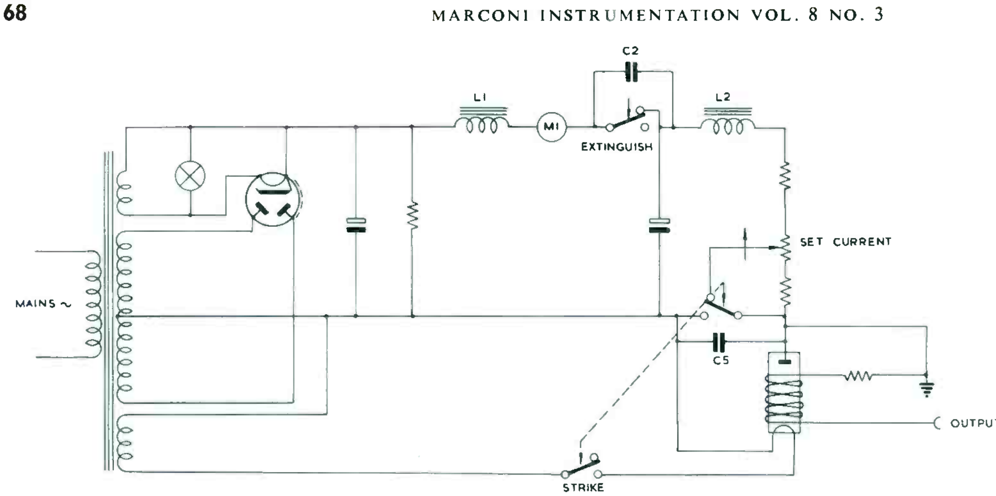

Fig. 2
Functional diagram of Noise Generator, Type TF 1301

source must have a frequency band wide compared with the response of the receiver under test and it must be a good match to the receiver input impedance.

A resistance heated to a high temperature is a simple noise source. Unfortunately, the noise power obtainable is insufficient for practical purposes due to the limited maximum possible temperature.

A conventional thermionic diode operated under temperature limited conditions constitutes a noise source of sufficient power whose output is calculable. With careful design it is satisfactory for measurements up to approximately 200 Mc/s. Transit time effects and reactance associated with the conductors coupling the diode to its output circuit introduce inaccuracies which make it unsuitable for use above the frequency mentioned.

By constructing the diode in the form of a coaxial transmission line its upper frequency limit can be increased to several hundred megacycles. Close spacing between cathode and anode reduce transit time effects and the coaxial construction reduces the difficulties associated with the output coupling.

An instrument using a coaxial diode noise source covering a frequency range from 100 Mc/s to 600 Mc/s was described in *Instrumentation*, Vol. 4, No. 8, December 1954.

At frequencies above about 600 Mc/s the same limitations apply to the coaxial diode as was the case with the conventional diode at 200 Mc/s.

Gas Discharge Tube Noise Source

W. W. Mumford[1] and others found that a gas discharge tube provided a reliable source of wide-band noise. This type of noise source, mounted in waveguide, has been used for some years for noise factor measurements at microwave frequencies. Below about 2500 Mc/s waveguide size becomes large and coaxial transmission systems are more generally used.

It is possible to couple the noise produced by a gas discharge tube into the coaxial system, however, by means of a suitably dimensioned helix wound around the gas tube.[2] The helix may be regarded as the inner conductor of a transmission line and the hollow metal tube into which it is inserted forms the outer conductor (see Fig. 3). The helix and gas tube are centred and supported by nylon screws screwed into tapped holes in the wall of the outer conductor.

A noise generator of this type, TF 1237, covering the frequency range 1700 to 2300 Mc/s, was described in *Instrumentation*, Vol. 6, No. 7, September 1958.

A similar type of noise source has now been designed to cover the range 200 Mc/s to 1700 Mc/s. Like its predecessor, it is suitable for the measurement of noise factors from 0 to 20 dB with an accuracy of 0·2 dB.

The new instrument, TF 1301, uses the commercially available gas tube CV 1881. One end of the helix surrounding the tube is terminated by a 50 ohm coaxial resistance. The other end is brought to a 50 ohm type N socket mounted on the outer conductor of the gas tube assembly. This unit is mounted inside the instrument in such a way that the type N output socket protrudes through a hole in the front panel.

In addition to the type N output socket, the front panel carries a mains on/off switch, two biassed toggle switches, a SET CURRENT control and a meter to indicate the tube discharge current. One of the biassed switches is labelled STRIKE and the other one EXTINGUISH.

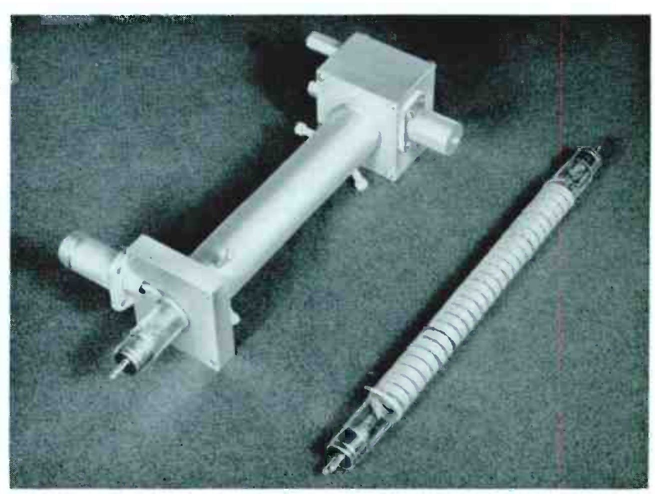

Fig. 3. Showing the way in which the gas discharge tube is mounted into the coaxial system

When the mains supply is switched on, the h.t. rectifier produces a no-load d.c. voltage of approximately 400 volts. The directly heated cathode of the gas tube has no heater voltage applied to it until the STRIKE switch is depressed. This operation also short-circuits the discharge tube and current flows in chokes L_1 and L_2 (Fig. 2). When the switch is released the collapse of the magnetic field, due to the fall of current in the chokes, generates a high voltage sufficient to ignite the tube. The discharge current should be adjusted by means of the set current control to be within the recommended limits, indicated by two red lines on the meter scale.

To extinguish the discharge, the h.t. circuit is broken by depressing the EXTINGUISH switch.

Measurement of Noise Factor using TF 1301

Noise factor is given by

$$F = \frac{\frac{T_D}{T} - 1}{\frac{P_{on}}{P_{off}} - 1}$$

where T_D = Electron noise temperature of discharge, °K

T = 290°K (17°C)

P_{on} = Receiver power output with the noise tube switched on

P_{off} = Receiver power output with the noise tube switched off.

The ratio T_D/T for the CV 1881 has been found to be 35·5 (15·5 dB).

The most convenient method of finding the ratio P_{on}/P_{off} is to connect a square law indicator, calibrated in arbitrary units, to the receiver output.

For good noise factors, where the P_{on}/P_{off} is large, it may be necessary to insert a known value of attenuation (N) between the noise source and the receiver input so that P_{on}/P_{off} may be read more accurately on the output meter. The expression for noise factor then becomes

$$F = \frac{\frac{34{\cdot}5}{N}}{\frac{P_{on}}{P_{off}} - 1}$$

where N is the attenuation ratio.

If a variable attenuator is used, the ratio P_{on}/P_{off} can be made equal to 2 and the expression becomes

$$F = \frac{34{\cdot}5}{N}$$

Factors affecting the accuracy of the equipment

Any function of the equipment which prevents its noise power output from being 15·5 dB relative to thermal noise at 290°K is, of course, a source of error. Glass losses may be neglected in the frequency range 200 Mc/s to 1700 Mc/s. The remaining possible sources of error are:

1. Coupling.
2. Matching.

Coupling

The coupling between the helical line and the noise produced by the gas discharge is not perfect due to the limited length of the helix. A measure of the loss of power due to this cause may be made by injecting a signal into one end of the helical line and measuring its attenuated value at the other end when the discharge is switched on; a second measurement is made with the discharge switched off. The difference between the two ratios is a measure of the coupling between the gas discharge and helix.

It may be shown that the effective noise output of the source is:

$$P_{off} = P\left(1 - \frac{1}{A}\right)$$

where $P = \frac{T_D}{T} = 35{\cdot}5$

A = Attenuation ratio.

If $A = 40$ (16 dB), the effective power output is reduced by 2·5% or 0·1 dB. Fig. 4 gives the attenuation introduced by the helical coupled noise source used in TF 1301 over the frequency range 200 Mc/s to 1700 Mc/s.

FREQUENCY	INSERTION LOSS		V.S.W.R.	
	DISCHARGE ON	DISCHARGE OFF	DISCHARGE ON	DISCHARGE OFF
200 Mc/s	27 dB	—	1·07	1·45
300 ,,	30 ,,	—	1·05	1·32
500 ,,	30 ,,	0·3 dB	1·13	1·34
700 ,,	30 ,,	0·5 ,,	1·11	1·23
900 ,,	31 ,,	0·5 ,,	1·12	1·5
1100 ,,	30 ,,	1 ,,	1·09	1·45
1300 ,,	25 ,,	1·5 ,,	1·09	1·38
1500 ,,	21 ,,	2 ,,	1·07	1·50
1700 ,,	18 ,,	2 ,,	1·04	1·24

Fig. 4. Insertion loss and v.s.w.r. figures taken on a prototype model of TF 1301.

Matching

The transitions between helix and coaxial transmission line, and the geometry of the helix, can produce errors due to reflections. The v.s.w.r. of the noise source in the ignited condition does not exceed 1·3, therefore the error will not be greater than 0·1 dB.

With the tube extinguished, v.s.w.r. is affected by the 50 ohm termination of the helix, in addition to the other factors. The magnitude of the error is dependent upon the noise factor being measured and may be found from:

$$E = log_{10} \frac{F}{F - \rho^2} \text{ dB}$$

where E = Error in dB

F = Noise factor (ratio)

ρ = Reflection coefficient of the extinguished noise source

$$= \frac{(VSWR) - 1}{(VSWR) + 1}$$

The v.s.w.r. of TF 1301 is not worse than 1·5 with the discharge tube extinguished. The error is, therefore, insignificant for normal values of noise factor. If necessary a matched load may be connected to the receiver in place of the extinguished noise source if very good noise factors are to be measured.

Typical 'Struck' and 'Extinguished' v.s.w.r. values are given in Fig. 4.

TF 1301 takes over where the accuracy of the conventional temperature limited diode begins to decline and covers the hitherto difficult band of frequencies up to 1700 Mc/s. (With its introduction Marconi Instruments are now able to offer Noise Generators for use at any frequency between 1 Mc/s and 2,300 Mc/s.)

This is a simple instrument to use. The ease with which a measurement may be made is shown by the following summary of operations.

1. Replace the aerial by the noise generator.
2. With the noise power tube extinguished, note the reading of the square law output meter.
3. Switch the noise power on by depressing the strike switch. Again note the meter reading.
4. Substitute the ratio of the two readings P_{on}/P_{off} in the formula for noise factor.

1. Mumford. W. W. A Broad-Band Microwave Source. *B.S.T.J.*, October, 1949
2. Steward, K. W. F. Helix Coupled Gas Tube Noise Sources. *The Marconi Review*. 2nd Quarter, 1958.

Summaries of Articles appearing in this issue

RESUME D'ARTICLES PUBLIES DANS LE PRESENT NUMERO

GENERATEUR STANDARD TYPE TF 144 H

Cet article complète celui de J. W. Parkyn qui est paru dans "Instrumentation", Vol. 7, No. 8.

L'article décrit avec plus de détails quelques unes des caractéristiques mécaniques de ce nouvel instrument, et quelques aspects généraux de la réalisation mécanique des générateurs.

Page 51

GENERATEUR DE SIGNAL VHF SERIE TYPE TF 1064

La demande d'instruments dans l'industrie électronique qui croît continuellement, est satisfaite par la Compagnie "Marconi Instruments" de deux façons – par l'introduction de nouvelles réalisations et par le développement et l'adaptation de réalisations bien établies.

L'évolution du générateur de signal VHF TF 1064 est un exemple typique de cette dernière ligne de conduite. Cette source composite de H.F., M.F. et B.F. fut originairement conçue comme faisant partie d'un appareil de dépannage pour équipement portatif f.m. et a.m., et a été realisée en un générateur pour usage pratique et de laboratoire.

Page 57

MESURE PAR Q-METRE ETENDUE, ET PRECISION DE MESURE

Cet exposé discute quelques unes des questions les plus habituelles que les personnes qui se servent de Q-mètres ont posé à l'auteur. Une méthode simple et pratique pour évaluer le besoin de corrections y est donné. Cette méthode montre qu'il est inopportun d'utiliser des bobines étalonnées pour le réglage des Q-mètres. On considère une méthode plus avancée pour obtenir la plus grande précision avec les valeurs corrigées. Une mesure par méthode de substitution, évitant les corrections pour les pertes des Q-mètres, qui est décrite peut être étendue pour donner des capacités nulles ou négatives pour des circuits extérieurs accordés.

Page 61

GENERATEUR TBF TYPE TF 1382

Le générateur de basse fréquence fournit des ondes sinusoïdales, rectangulaires et en rampe dans la gamme de fréquence 0,0033 Hz à 1 kHz. On peut obtenir un seul cycle de chaque forme d'onde. La tension de sortie est au moins 15 volts crête a crête avec une impedance de charge de 2500 ohms. Le générateur peut aussi fournit des impulsions de marquage ayant des rapports de phase définis avec l'onde de sortie, et comprend un relais aux contacts robustes qui peut être employé à actionner des circuits extérieurs. L'appareil est équipé en grande partie de transistors.

Page 64

UNE NOUVELLE SOURCE DE BRUIT A COUPLAGE HELICOIDAL

La sensibilité d'un récepteur radio est limitée par le bruit produit intérieurement, et s'exprimé d'une façon extrêmement réaliste par le facteur de bruit. Cet exposé décrit les conditions requises d'une source de bruit pour mesurer le facteur de bruit.

Le spectre couvert par les diodes de bruit et par les tubes à décharge montés en guides d'ondes laisse un intervalle entre 500 et 2500 MHz qui peut être comblé par un tube à décharge à couplage helicoidal, tel que l'on utilise dans le générateur de bruit TF 1301.

Page 67

ZUSAMMENFASSUNG DER IN DIESER NUMMER ERSCHEINENDEN BEITRÄGE

MESS-SENDER TYP TF 144H

Dieser Aufsatz ergänzt den von J. M. Parkyn, welcher in *Instrumentation* Vol. 7 No. 8 erschienen ist. Er beschreibt eingehender einige der mechanischen Konstruktionsmerkmale dieses neuen Gerätes, und auch einige allgemeine Fragen der mechanischen Konstruktion von Mess-Sendern.

Seite 51

UKW MESS-SENDER DER TYPENSERIE TF 1064

Die beständig wachsenden Geräteanforderungen der Industrie für Elektronik werden von Marconi Instruments auf zweifache Weise erfüllt: Durch die Einführung neuer– und durch die fortschreitende Entwickelung und Umarbeitung bestehender Konstruktionen. Typisch für letzteres ist die Entwickelung des UKW Mess-Senders TF 1064; dieser Allwellen– (HF, ZF und NF) –Generator wurde ursprünglich als Teil eines Messgerätes für bewegliche FM– und AM–Anlagen entwickelt und ist zu einem selbständigen Mess-Sender für den Gebrauch im Ausseneinsatz und im Labor entwickelt wurden.

Seite 57

VERBESSERUNGEN VON GÜTEMESSUNGEN UND DEREN MESSGENAUIGKEIT

Dieser Aufsatz erörtert einige der häufiger auftretenden Fragen, die Benutzer von Güte-Messgeräten an den Verfasser gerichtet haben. Ein einfaches, praktisches Verfahren für die Abschätzung der Notwendigkeit von Verbesserungen– wird angegeben. Dieses zeigt die Unratsamkeit der Verwendung von Normalspulen für die Einstellung von Güte-Messgeräten. Ein fortschrittliches Verfahren zur Erzielung der höchsten Genauigkeit bei verbesserten Messungen wird mit einbezogen. Ein beschriebenes Vergleichsmessverfahren, unter Vermeidung von Verlustkorrekturen am Gütemessgerät, kann erweitert werden um Kapazitätsfreiheit oder negative Kapazität für mitschwingende äussere Schaltungen zu liefern.

Seite 61

TIEFSTFREQUENZGENERATOR TYP TF 1382

Der Tiefstfrequenzgenerator liefert Sinus– Rechteck– und Sägezahnschwingungen mit einer Wiederholungsfrequenz zwischen 0,0033 Hz und 1 kHz. Die zur Verfügung stehende Ausgangsspannung beträgt mindestens 15 V_{ss} bei einer Belastung von 2500 Ohm. Einzelschwingungen aller Schwingungsformen können abgegeben werden. Weitere eingebaute Einrichtungen liefern einen Markierungsimpuls mit einem bestimmten Phasenverhältnis zu der Ausgangsschwingung. Ein eingebautes Relais mit Kontakten für hohe Stromstärken kann für die Steuerung äusserer Stromkreise benutzt werden. Das Gerät ist weitgehend mit Transistoren bestückt.

Seite 64

EIN RAUSCHNORMAL MIT WENDELKOPPLUNG

Die Empfindlichkeit eines Funkempfängers wird durch das innerhalb des Empfängers erzeugte Rauschen beschränkt und auf die praktischste Weise durch den Rauschfaktor angegeben. Dieser Aufsatz beschreibt die Anforderungen die an ein Rauschnormal für die Messung des Rauschfaktors gestellt werden. Das von Rauschdioden und von in Hohlleitern eingebauten Gasentladungsröhren überdeckte Spektrum weist zwischen etwa 500 bis 2500 MHz eine Lücke auf, die sich durch eine Gasentladungsröhre mit Wendelkopplung, wie im Rauschgenerator TF 1301 ausfüllen lässt.

Seite 67

SOMMARIO DEGLI ARTICOLI PUBBLICATI IN QUESTO NUMERO

GENERATORE DI SEGNALI CAMPIONE TIPO TF 144H

Quest'articolo è di complemento a quello di J. M. Parkyn apparso in *Instrumentation* Vol. 7, No. 8. Contiene una desrizione più dettaglata di alcuni elementi del progetto meccanico di questo nuovo strumento e affronta, allo stesso tempo, aspetti generali della realizzazione meccanica di generatori di segnali.

Pagina 51

GENERATORE DI SEGNALI VHF TIPO TF 1064 (SERIE)

Le esigenze, sempre crescenti, da parte dell'industria elettronica nel campo della strumentazione vengono soddisfatte dalla Marconi Instruments sia con l'introduzione di nuovi modelli, sia con il continuo perfezionamento e adeguamento di modelli già affermati. Un esempio tipico di questo secondo modo di affrontare il problema viene offerto dalla evoluzione del generatore di segnali VHF TF 1064. Questa sorgente multipla di segnali a frequenza radio media e audio, progettata in origine come parte di un complesso di prova per apperecchiature mobili a modulazione di frequenza e di ampiezza, ha, nella sua versione più recente, tutti i tratti di un generatore di segnali a sè stante per uso all'aperto o in laboratorio.

Pagina 57

UN PIU'LARGO INTERVALLO DI MISURA E LA PRECISIONE DI UN MISURATORE DEL Q

Quest'articolo discute alcuni dei quesiti posti più di frequente all'autore sull'uso di misuratori del fattore di qualità. Un metodo semplice e pratico per accertare la necessità di eventuali correzioni viene presentato. Ne segue che l'uso di bobine standard per la taratura di misuratori del fattore di qualità va sconsigliato. Viene considerato un metodo perfezionato per ottenere la massima precisione partendo da misure opportunamente corrette. Un metodo per sostituzione, che viene descritto, evita la necessità di correzioni per tener conto delle perdite del misuratore, e può venire esteso a capacità nulle o negative per circuiti esterni risonanti.

Pagina 61

GENERATORE A BASSISSIMA FREQUENZA TIPO TF 1382

Questo generatore di bassa frequenza genera forme d'onda sinusoidali, quadre e a rampa in un intervallo di frequenze fra 0,0033 Hz e 1 kHz. Un ciclo singolo di ognuna di queste forme d'onda può essere ottenuto. La tensione d'uscita è di almeno 15 Volt da cresta a cresta con un carico di 2500 Ohm. Un marcatore, che genera impulsi in una relazione di fase ben determinata con le forme d'onda d'uscita ed un relè internamente connesso e provvisto di robusti contatti per alimentare circuiti esterni, costituiscono ulteriori pregi dello strumento. Lo strumento è largamente transistorizzato.

Pagina 64

UNA NUOVA SORGENTE DI RUMORE CON ACCOPPIAMENTO AD ELICA

La sensibilità di un ricevitore radio è limitata dal rumore generato all'interno di esso e viene caratterizzata nel modo più realistico dal fattore di rumore del ricevitore. L'articolo descrive i requisiti di una sorgente di rumore adoperata per la misura del fattore di rumore. Lo spettro delle frequenze generate da diodi di rumore e da tubi a scarica gassosa con montaggio a guida d'onda lascia scoperto un intervallo tra 500 e 2500 MHz, che può essere colmato da un tubo a scarica gassosa con accoppiamento ad elica, come quello adoperato nel generatore di rumore TF 1301.

Pagina 67

RESUMENES DE ARTICULOS QUE APARECEN EN ESTE NUMERO

GENERADOR DE SEÑALES PATRON TIPO TF 144 H

Este artículo es complementario al artículo por J. M. Parkyn que se publicó en *Instrumentation* Vol. 7 No. 8.

Describe con más detalle algunos de los aspectos del diseño mecánico de este instrumento, además de los aspectos generales de la parte mecánica de los generadores de señales.

Página 51

GENERADOR DE SEÑALES EN F.M.A. SERIE TF 1064

Los requerimientos que contínuamente pide la industria electrónica, son satisfechos por Marconi Instruments de dos maneras: con la introducción de nuevos diseños, y con la adaptación de desarrollos progresivos de diseños corrientes.

Típico de ésto es el desarrollo del generador de señales en VHF TF 1064. Este instrumento se desarrolló orginalmente para proveer frecuencias altas, intermedias y bajas para equipos móviles de modulación de amplitud y frecuencia, y ha sido desarrollado para ser un generador de señales independiente para uso en el campo o en el laboratorio.

Página 57

MEDICION EXTENDIDA DE Q Y EXACTITUD DE MEDICION

Este artículo discute algunas preguntas que se le han hecho al autor sobre el uso del medidor Q. Se da un método simple y práctico para tasar la necesidad de correcciones. Esto muestra lo inconveniente que es el uso de bobinas standard de Q para el ajuste del medidor Q.

Se considera un método avanzado para obtener el máximo de exactitud de mediciones corregidas. Se describe un método de sustitución que evita las correciones de las pérdidas del medidor Q y esto puede ser extendido para dar zero ó capacitancia negativa que se puede usar para sintonizar circuitos externos.

Página 61

GENERADOR DE BAJA FRECUENCIA TIPO TF 1382

Este generador de baja frecuencia proporciona formas de onda senoidales, cuadradas y rampa, en la gama de frecuencias desde 0,0033 c/s hasta 1 kc/s. Se puede obtener únicamente un ciclo de cada onda. La salida es por lo menos de 15 voltios pico a pico en una carga de 2500 ohmios. Otras facilidades son impulsos de calibración con relaciones de fase definitivas a la onda de salida y un relé interior con contactos de gran duranza que se usa para controlar circuitos externos. El instrumento en gran parte está transistorizado.

Página 64

UNA FUENTE NUEVA DE RUIDO CON ACOPLAMIENTO HELIOCOIDAL

La sensibilidad de un receptor de radio está limitada por el ruido que se genera internamente, y ésto se expresa con más realidad en términos de ruido de fondo.

Este artículo describe los requerimientos de una fuente de ruido para la medición del ruido de fondo. El espectro cubierto por diodos de ruido y por tubos de descarga de gas de guía de ondas, deja un intervalo desde 500 hasta 2500 Mc/s que se puede cubrir con un tubo de descarga, con acoplamiento helicoidal, tal como se usa en el generador de ruido TF 1301.

Página 67

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