Communications Receivers

An examination of the extent to which circuit design and cost are being influenced by increasingly stringent performance requirements

by Pat Hawker, G3VA*

Many of the basic features of m.f./h.f. communications receivers originated 35 to 40 years ago, initially in large part to meet the requirements of amateur radio operators. In the early 'thirties, single-conversion superhets were developed, with adequate signal-frequency amplification to overcome the high noise of the early multi-electrode frequency-changer valves. The application by Lamb of the Robinson "stenode" crystal filter to provide "single-signal" reception of c.w. signals, coupled with electrical and mechanical band-spreading, resulted in a new class of radio receiver designed for communications purposes. Costs were not excessively above those of good domestic receivers. By the mid-thirties, the National HRO, the Hammarlund Comet-pro and Super-pro, several Hallicrafters' models, some early professional-user models by RCA had all appeared, and were soon followed in the U.K. by receivers for similar applications by Peto-Scott and Eddystone.

With the outbreak of war in 1939, receivers of this category were soon found useful for many communications applications: the HRO was even paid the compliment of being closely copied by both the Germans and the Japanese. Since then, increasing emphasis on the professional users has resulted in a succession of designs of increasing complexity, and the blurring of the former distinction between 'communications' and the more complex 'commercial' receivers used on point-to-point circuits.

While, in some respects, the requirements of the h.f. amateur remain every bit as rigorous as those of other communications services, the professional user has demanded ever-higher standards of stability, dynamic range, adjacent channel selectivity, accuracy of tuning and frequency read-out, resulting in receivers at prices well beyond the reach of most amateurs. There has thus been a marked tendency for communications receiver designs to split into several categories: simple and relatively cheap general purpose receivers primarily intended for the keen "short-wave-listener"; more advanced amateur-bands-only receivers in which high-performance at medium cost can be achieved by limiting the total frequency coverage; and higher-cost general-purpose l.f./m.f./h.f. receivers for professional users at prices ranging up to well over £1000. A further professional category is the v.h.f./u.h.f. receiver for monitoring and surveillance, with Eddystone as the main U.K. firm in this field.

The merging of 'communications' and 'commercial' receivers is still continuing with modern techniques making it possible to build receivers of the highest attainable performance in quite compact units. For example, the recently announced Marconi 2900-series, intended for the most demanding commercial circuits, is packaged virtually in the style and size of a general purpose communications receiver. It can be tuned in steps as small as 0.1 Hz.

It might be thought that, after some 35 years of continuous development, the design of each of these classes of receiver would by now have reached the ultimate either in performance or in cost-effectiveness, and that few significant improvements can be expected. In reality, this is far from the case. Each advance in receiver design has been accompanied (or preceded) by increasingly stringent user demands in terms of stability, ease of tuning, dynamic range, and absence of spurious responses and reliability under arduous conditions.

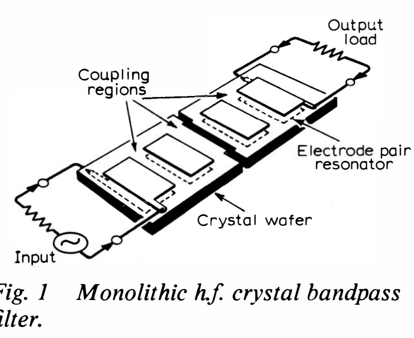

Fig. 1 Monolithic h.f. crystal bandpass filter.

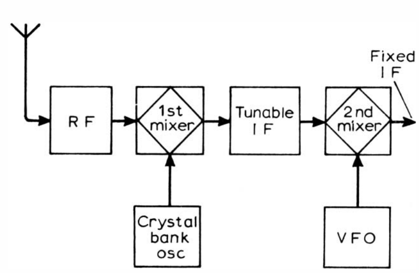

Fig. 2. Multi-conversion superhet having crystal-controlled first oscillator.

Not all design changes have been uniformly beneficial. Although the development of h.f. semiconductors (and more recently integrated circuits) has opened the way to compact receivers of extremely high stability and impressive "mean time between failures", these devices have posed serious "front-end" problems. These include limitations to dynamic range due to increased susceptibility to cross-modulation and inter-modulation, and damage from static charges and local transmitters. Other drawbacks are increased loading of tuned circuits, lower stage isolation and greater spread of characteristics. The availability, during the past few years, of single- and dual-gate field effect transistors, with near square-law transfer characteristics, and the increasing impact of hot-carrier (Schottky) diodes in wideband, double-balanced mixers are reducing these problems.

In some respects, the concentration on all-semiconductor designs came at an unfortunate time, when, for example, the availability of beam-deflection valves (7360, 6JH8 etc) for use as low-noise mixers made possible the elimination of signal-frequency amplification and offered a useful improvement in dynamic range; factors which have been exploited in only a very few designs. An exception was the Squires-Sanders SSR1 receiver for the amateur market.

Even today, in the lowest price ranges, it is usually possible to achieve a higher standard of front-end performance with valves than with semiconductor devices. The continuing demand for low-cost valve or "hybrid" designs of sufficient stability and low-enough tuning rate for s.s.b. reception has increasingly been met by Japanese firms. British, European and American firms tend to concentrate more on the professional user.

A marketing problem in all these fields is that, to achieve financial viability, the receiver design needs to remain basically unchanged for a time-span approaching a decade (often spawning many variations on the basic chassis). More complex

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receivers may take several years to reach production. This means that, at the initial planning stage, the needs of users for at least a decade ahead must be taken into account. No easy matter when device, filter and component developments continue to follow in rapid succession.

In the past, impressive operational lifetimes have been achieved: models dating from the early 'forties (RCA AR88 National HRO etc) continue in use in vast numbers; the G.E.C. BRT400 series, introduced in 1947, were marketed for 20 years. The Racal RA17-series, which pioneered the 1950 Wadley triple-mix, drift-cancelling loop, came out in 1954 and remained in production for more than 10 years. Several current amateur designs (for example the Collins 75S series) date back 10 years.

Long operational lifetimes often depend as much on the mechanical as on the circuit design. It was no accident that James Millen, designer of the original HRO, had studied mechanical rather than electrical engineering. The need to combine good mechanical with good electrical characteristics, to achieve a receiver which is ergonomically pleasant to operate, is still not always appreciated. One of the more successful basic designs of recent years—the Plessey PR155 series—resulted from extensive investigation into control features required by operators.

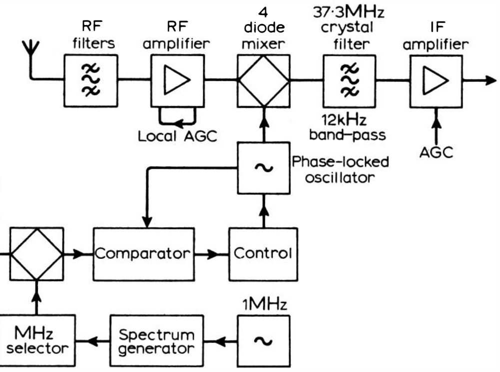
Choice of intermediate frequencies

The continuously-tunable superhet receiver, whether single- or multi-conversion, must have its first i.f. outside its tuning range. For a typical receiver covering say 2 to 30MHz, this limits choice to below 2 or above 30MHz. On the other hand, models with a non-continuous tuning range (such as amateur-bands-only designs) have a far more flexible choice, and often adopt frequencies between 3 and 9MHz. To reduce image response, without increasing pre-mixer selectivity, the professional designs are increasingly using a first i.f. above 30MHz, resulting in up-conversion in the first mixer.

This trend has been encouraged by the development of h.f. and v.h.f. crystal filters having good selectivity characteristics and suitable for use as 'roofing filters' (filters included early in a receiver to reject out-of-band signals but with final selectivity characteristics usually determined by a subsequent filter). Several current designs use initial crystal filters above 30 MHz—as high as 40.5 and 73 MHz in some Rohde & Schwarz models.

Recent filter developments have included multi-section ceramic filters having good "shape factor" (ratio of bandwidths at -60dB to that at -6dB) and the introduction of monolithic crystal filters. The monolithic crystal filter (MXF) promises to reduce size and cost of high-frequency s.s.b. filters by a significant factor. It consists of a quartz wafer on which pairs of metal electrodes are deposited on opposite sides of the plate.

Fig. 3. Synthesis of 1MHz signals in Plessey PR155 series.



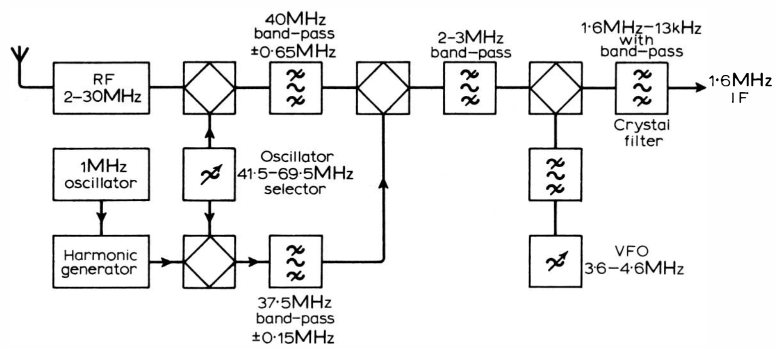


Fig. 4. Wadley drift-cancelling loop technique as used in many Racal receivers.

The quartz acts as a piezo-electric transducer, converting input signals into mechanical vibrations, and vice versa. The quartz also provides the coupling medium between the pairs. The metal electrodes lower the resonant frequency of the transverse shear-wave in the plated regions only, so that this resonance does not extend into the areas without electrodes, but remains "trapped" under the thin metal film electrodes. Filters having 12 coupled resonators may have a shape factor of about 1.5 to 1 in the upper h.f. region, and the technique can be applied to filters up to u.h.f.

Stability

The resolution of s.s.b. speech requires that a receiver should be capable of being set. and remain, within about 30Hz of the nominal frequency: about one part in 10^6 at 30MHz. For commercial applications both long- and short-term stability are important; for amateur use good short-term stability is the main requirement.

It has been the need for stability of this order which has brought about many of the receiver developments of the past decade or so. It led initially to much greater use of the form of multi-conversion superhet having switched crystal-controlled first oscillator and tunable first i.f., a form of receiver popularized by Collins and Drake and now widely used. The tuning rate remains the same on all frequencies, with a degree of electrical bandspreading determined by the tuning range of the i.f. which may be 1MHz, 200kHz or even 100kHz. The reduction of the tuning range requires progressively the use of more crystals, until—at least for general coverage models—it becomes

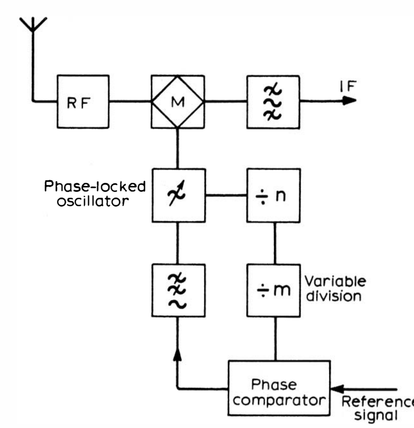


Fig. 5. Phase-locked synthesizer using digital techniques.

more economical (and offering potentially higher stability) to replace the individual crystals with some form of frequency synthesizer to provide the spaced first-oscillator frequencies.

With this type of arrangement, the second local oscillator providing the tuning span, remains a simple *LC* oscillator. Such a system is often called "partial synthesis". One of the first all-semiconductor general-purpose receivers of this type, using a phased-locked synthesizer, was the National HRO-500 although this was soon followed by many alternative designs using synthesis based on phase-locked oscillators (often including a variable digital divider) or variations of the Wadley drift-cancelling loop as in the Racal RA217 and subsequent all-semiconductor designs.

A rather different simple partial-synthesis technique, providing a stable variable-frequency oscillator for the first (and sometimes only) frequency changer has been used in several amateur-bands-only receivers, including the Hallicrafters SX146 and Drake R4 series. This synthesizes the injection frequency from a relatively low-frequency tunable oscillator combined with a series of crystal-oscillator frequencies chosen for the band in use, forming what is often termed a heterodyne-type v.f.o. with equal tuning rate on all wavebands.

The stability of a partial-synthesis receiver is usually adequate for conventional s.s.b. reception. However, increasing use is being made of narrow-band frequency shift keying, phase-coded data transmissions and signal-processing techniques such as Lincompex and Piccolo. Several of these systems demand a frequency stability in the receiver of from 1 to 3Hz, or at 30MHz, a few parts in 10^8. Long-term stability of this order cannot normally be achieved with partial synthesis although techniques for stabilizing a v.f.o. to within one part in 10^7 have been developed (e.g. Racalok). A Racalok unit forms a built-in facility in the latest Racal RA1220 receiver and frequency locking to within $\pm$2Hz is also provided in the Plessey PR1551 and PR1553.

The more conventional method of achieving stability beyond that available with partial-synthesis is by means of full synthesis, in which all high-frequency oscillator frequencies are derived from a single temperature-compensated crystal standard. Until recently, such synthesizers have usually been built as separate units to the receiver proper, but G.E.C. achieved the distinction of developing the first general purpose h.f. receiver (type RC410) to use full frequency synthesis in such a manner that the tuning has much the same 'feel' as a normal continuously tuned receiver. The synthesizer, of the variable ratio divider type, is controlled by mechanical gearing of the synthesizer 'switches' in conjunction with servo-motor control of the signal-frequency tuned circuits. A similar facility is provided in the Collins 651-S, which can also be remote-tuned by computer techniques.

Tuning in steps of only 1Hz, and with a stability of 0.5Hz, has been achieved in the Marconi H2900 series, in which a

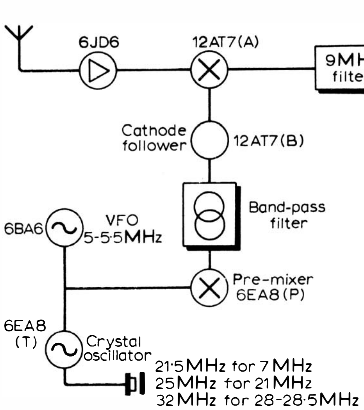


Fig. 6. Pre-mixer arrangements of the Hallicrafters SX146.

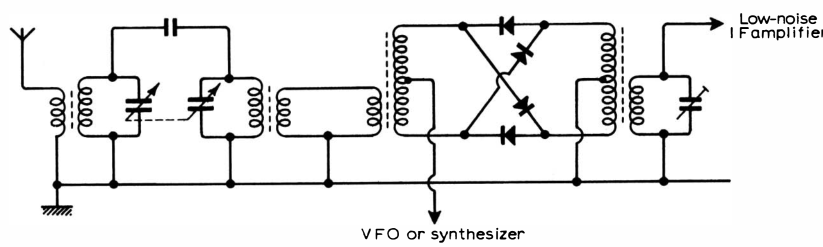


Fig. 7. Even without an r.f. amplifier, diode-ring mixers using Schottky (hot-carrier) diodes can give low-noise performance with wide dynamic range.

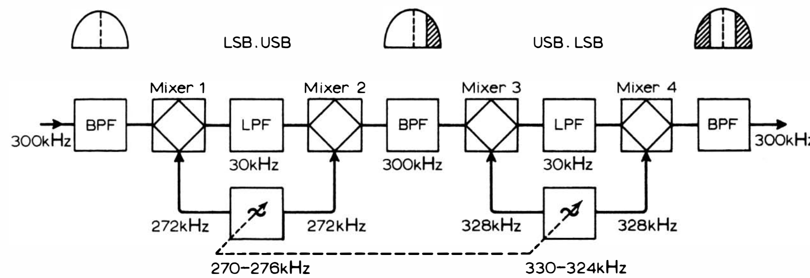


Fig. 8. Rohde & Schwarz variable-bandwidth i.f. filter shown set for ± 2kHz bandwidth.

highly stable *LC* oscillator is controlled by means of assembly and subtraction of pulses.

A possible limitation on adjacent channel operation of any receiver is oscillator 'noise' or 'jitter', although, in practice, this characteristic becomes important only after a large dynamic range and high order of frequency stability have been achieved. In general terms, the noise sidebands associated with low-power oscillators appear to be about 6dB higher for bipolar transistors than for valves, which in turn appear to be about 6dB more noisy than field-effect transistors. For these and other reasons increasing use is likely to be made in future of f.e.t. devices for oscillators as well as in the signal path. The phase-locked oscillator has an inherent jitter which can impose limitations, and digital synthesizers also involve high-frequency pulses which must be carefully screened from the signal path. Noise, jitter and spurious response levels of synthesized oscillators are likely to be of increasing importance in the coming decade.

Frequency read-out

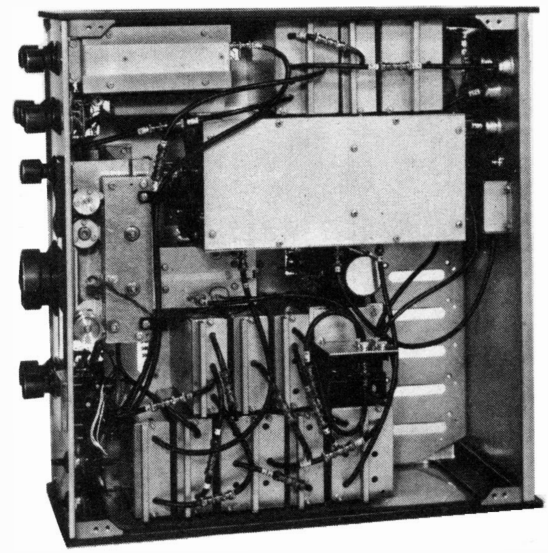
Accurate setting and read-out of frequency has always been a problem on h.f. Traditionally, the slow-motion dial, using mechanisms of varying degrees of ingenuity, often in association with a considerable degree of electrical band-spreading, has been the solution. The practical problems have included limitations of scale length of the dial and the backlash and discontinuities associated with reduction gearing. The film strip, or—as in the recent Eddystone 958—a finely printed film disc optically projected and magnified, can provide a film scale the equivalent of several feet in length. Veeder Root and other counter-type read-out mechanisms have been used, for example by Racal and Collins. A significant advance, however, has come with the widespread introduction of built-in or add-on digital frequency counters providing direct read-out of frequency on numerical display (Nixie-type) tubes, even though this approach adds appreciably to the cost of a receiver.

Dynamic range

The extremely wide range of signals—from fractions of a microvolt up to volts from a local transmitter—demands good cross-modulation and inter-modulation characteristics particularly where broadband input filters are used. This calls for an extremely high degree of linearity in all signal-path stages up to the final selectivity shaping filter (for extreme narrow-band reception using a.f. filters this implies the need for a detector with extremely good linearity). Unless the selective filter can be placed early in the receiver (usually possible only with single-conversion designs), this means careful distribution of gain, keeping signal levels low at least as far as the roofing filter. The limiting factor is often the signal handling capabilities of the first mixer, although where extremely strong signals are present, the linearity of the signal-frequency stages, if any, become important.

The limited performance of the bipolar transistor as mixer and amplifier has led to a determined search for alternative techniques (for valve receivers the beam deflection valve and balanced triode mixers have good dynamic performance). Bipolar mixer performance is improved by using a high level of local oscillator injection, so that the device operates in the switching mode.

One means of dispensing with signal-frequency amplification and achieving a mixer dynamic range of over 130dB is the use of parametric diode up-conversion: this technique has been used in American designs by National, Avco, RCA, etc. The parametric up-converter can be likened to a cross between a balanced modulator and a



Sub-unit constructional techniques used in Plessey PR155 series.

coupled pair of circuits. This approach is limited to up-conversion; and to achieve maximum linearity requires substantial pump power. The parametric up-converter can pass up to a few volts of input signal. A possible future alternative for both up- and down-conversion, with low-power oscillator injection, is the square-law resistor (space-charge-limited diode) which follows an accurate square law characteristic.

At present, a more practical approach consists of using a special f.e.t. amplifier in conjunction with a wideband double-balanced diode ring mixer using hot-carrier diodes. Amplifiers of this type, capable of handling linearily signals up to over a volt, have been introduced by Comdel. Several current receivers use field-effect r.f. amplifiers employing the cascode arrangement, either with dual-gate m.o.s.f.e.t. devices or with two separate f.e.t. devices, since the junction f.e.t. appears to be less susceptible to static puncture than the dual-gate m.o.s.f.e.t.

Where bipolar transistors are used in r.f. amplifiers a useful extension of dynamic range can often be achieved by the use of r.f. overlay power transistors, an approach found in some recent Redifon receivers, which also make use of voltage-controlled diode attenuators in the input circuits. Manual attenuators are fitted in many semiconductor designs.

Front-ends

The protection of front-end devices remains a difficult problem, since the widely adopted solution of incorporating back-to-back diodes across the tuned circuit can introduce cross-modulation on strong local signals. Silicon diodes are much better in this respect than germanium diodes, but a more satisfactory solution may be the use of neon tubes in the receiver, or gas-filled surge arrestors in the feeder lines.

Electronic tuning diodes represent another possible source of non-linearity, and this is one reason why mechanical tuning remains popular, except for receivers for frequency-hopping and similar military techniques.

Little need be said about the basic noise performance of receiver front-ends. In practice, for many years, there has been no difficulty in achieving the lowest usable noise factor, since over most of the l.f./m.f./h.f. spectrum galactic and site noise makes it pointless to strive for a noise factor of less than about 10dB (where emphasis is on performance between 20 and 30MHz this can be usefully reduced to about 8dB).

Since any improvement in the noise performance of an amplifier usually involves a reduction of dynamic range, most receivers have a noise figure of about 10dB. For the reception of extremely weak signals, it is better to limit the noise bandwidth to the minimum appropriate to the information rate. Correlation detection and integrating techniques can result in recovery of information from below the noise level.

A valid reason for including r.f. amplification in front of a low-noise mixer is to facilitate the provision of pre-mixer selectivity. Several designs now use double-tuned input circuits with a cascode f.e.t. amplifier.

Spurious responses

The susceptibility of the superhet to various spurious responses, of which image response is the best known, to direct i.f. breakthrough and to internally generated 'birdies' calls for careful choice of intermediate and oscillator frequencies, effective pre-mixer selectivity and generous use of screening within the receiver. Recent years have seen increasing use of wideband and sub-octave filters in the input circuits; this approach imposes even more stringent linearity requirements. Screening, however, has been facilitated by the wider adoption of modular sub-unit construction with low-impedance coaxial interconnections.

While image, direct i.f. breakthrough and other forms of spurious response should ideally be better than 120dB down on the desired signal, most users would be happy with 80 to 100dB of protection. In practice, even for high-performance receivers, image may be only 50 or 60dB down at 30MHz, and on the lower cost models may be restricted to about 35 to 50dB.

Especially severe conditions exist on board naval vessels where several transmitters may be operating in close proximity to the receiver. It is worth recalling that a G.E.C. h.f. receiver developed for the Navy in the early 'sixties achieved an image and spurious response better than 130dB down by using six signal-frequency tuned circuits with single conversion (i.f. 1600kHz). This had two low-gain cascode valve amplifiers and a double-triode balanced mixer. It seems doubtful whether this performance has yet been bettered with conventional forms of all-semiconductor front-end, despite the benefit of up-conversion to v.h.f.: special selectivity units are offered by some firms for use near powerful transmitters.

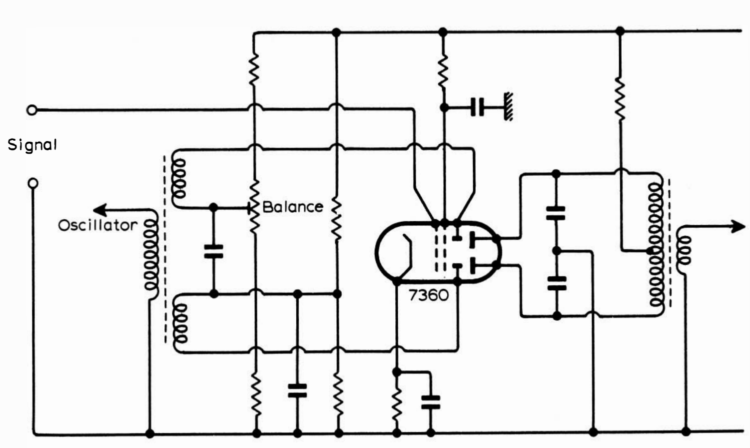


Fig. 9. Balanced mixer using 7360 beam deflection valve can provide low-noise and extremely wide dynamic range.

Variable i.f. filters

The final selectivity characteristics of most modern receivers are determined by one or more crystal or mechanical i.f. filters (although some lower-cost models still depend on a final i.f. of about 50kHz). High-grade s.s.b. filters have a shape

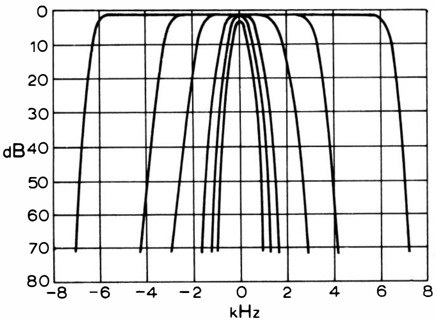


Fig. 10. Claimed selectivity curves for one of the Rohde & Schwarz filters.

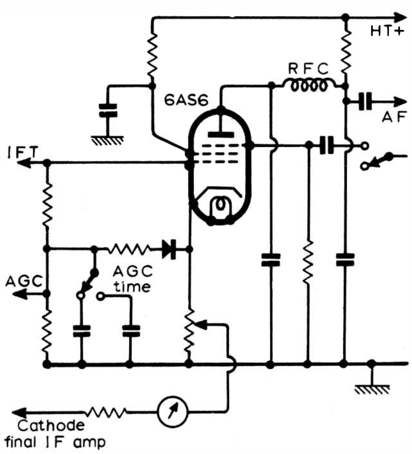


Fig. 11. Philco combined a.m./s.s.b. demodulator.

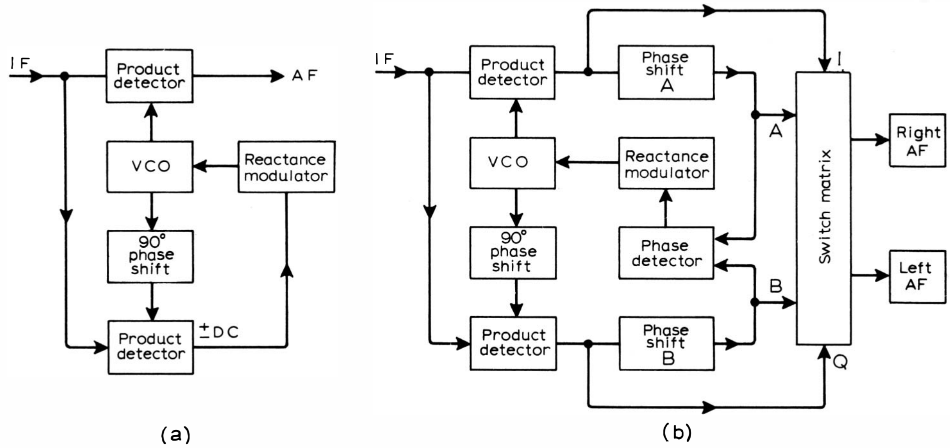


Fig. 12. Block diagram (a) of phase-lock loop synchronous demodulator; (b) bi-aural demodulator. Matrix switch positions; a.m./d.s.b. right A.F.I., left A.F.I.; u.s.b. both A + B; both sidebands right A + B, left A − B; l.s.b. both A − B. f.m. both Q.

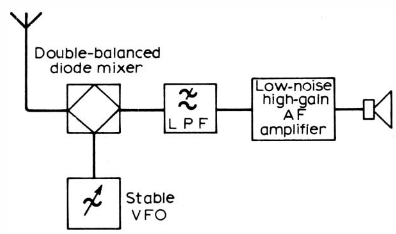


Fig. 13. Basic outline of simple homodyne (direct conversion) receiver for s.s.b./c.w. reception.

factor approaching unity with low pass-band ripple; even with such filters it is important that there is no signal leakage around the filter, or any sudden fall-off below the 60dB level. Typically, however, an overall s.s.b. shape factor below about 4 must be considered good.

There are still attractions in a continuously variable bandwidth filter, and several techniques to achieve this have been developed, mostly involving some form of pass-band i.f. tuning to stagger the relative position of successive bandpass filters, for example in the Redifon R408 marine receiver.

An arrangement capable of providing almost ideal selectivity characteristics is used in several Rohde & Schwarz receivers, based on a dual-mix system in conjunction with high-grade 30kHz low-pass filters. The incoming i.f. signals can be shifted away from or towards the sharp cut-off edges of the two filters, using sideband inversion to permit the slicing action to occur on the upper and lower sideband: see Fig. 8. At ±6 kHz a shape factor of 1.07 is claimed.

Demodulation and a.g.c.

Almost all recent designs have incorporated heterodyne (product) detectors for s.s.b. and c.w. reception, although envelope detection must usually also be provided for a.m. Fig. 11 shows a combined s.s.b./a.m. detector developed by Philco for valve receivers. High-performance product detectors have also used 7360 beam-deflection valves and hot-carrier diodes.

Considerably greater flexibility and improved performance on some modes is possible, though at an increase in complexity, by the use of lock-loop synchronous demodulation (or preferably by bi-aural demodulation comprising a lock-loop demodulator with independent presentation and selection of the two sidebands). Such demodulation can be highly effective not only on s.s.b., c.w. and a.m. but also on narrow-band f.m. and double-sideband-suppressed-carrier modes. Synchronous demodulation is incorporated in the recent Marconi H2900 series.

The coming of integrated circuits has almost certainly opened the way to much greater use of synchronous detection, since almost all components for a phase-lock loop can be provided on a single chip.

Synchronous demodulation also makes possible an extension of interest in homodyne (direct-conversion) and synchrodyne type of receivers as an alternative to the superhet. Already simple forms of direct conversion receivers (including some which phase-out the audio image) have been developed for s.s.b. and c.w. reception by amateurs, providing reasonably good performance at relatively low-cost. Many have used hot-carrier diode ring mixers to heterodyne the incoming signal directly to audio frequency.

Another receiver function which lends itself to the use of integrated circuits is audio-derived a.g.c. with 'pedestal' or 'hang' characteristics. Hang a.g.c. systems using discrete components have been widely used, but the development of integrated-circuit generators, such as the Plessey SL621, makes possible sophisticated systems with a minimum of contructional problems. Timing characteristics are governed by the values of the few external components.

Microelectronics

Digital integrated circuits are widely used in frequency synthesizers and in frequency locking and digital readout counters. The development of linear integrated circuits, monolithic and thin-film, has resulted in high-performance 'pocket' communications receivers (prototype models of this type have been described by MEL Equipment and by Avco).

Recent price reductions in linear integrated circuits, however, now make this form of construction increasingly attractive for almost all classes of receiver. There are still a few functions where the advantages remain with discrete devices, so that a hybrid discrete/integrated approach can be anticipated. One practical problem has been the rapid development in this field, often making it necessary to reconsider ideas during the development of new models. A major advantage, now that linear integrated circuits are becoming standardized, will be the appreciable reduction in design and development time, since many receivers will be variations of discrete components fashioned around a set of linear modules.

For example, the Plessey SL600 series of linear integrated circuits make possible receivers using SL610 r.f. amplifier; SL641 diode-ring frequency changer; block crystal filter; untuned SL612 i.f. amplifier; SL641 product detector; SL621 a.g.c. system and SL630 a.f. amplifier. By utilising such combinations a great deal of the detail design work is eliminated. Indeed, this factor could well encourage, in the coming decade, more home-construction of high-performance receivers, meeting individual requirements with a minimum of design problems.

Communications Receivers

Abridged specifications of some of the equipment on the British market

It being several years since we published a survey of communications receivers we recently sent a questionnaire to some 60 manufacturers and importers. From the replies received we have compiled the following tables showing the main features of over 50 receivers. This information, together with the survey article by Pat Hawker on p. 256 will, we hope, assist readers in the choice of suitable equipment. The list includes only those receivers which are complete in one unit (except for power supplies, in some cases) and which can be continuously tuned. Further details may be obtained by direct application to the appropriate supplier.

Name, Brand and Model	Type of Circuit	Frequency Coverage	Receiving Modes	Input and Output Impedance	Sensitivity and S/N Ratio	Number of Valves and/or Semi-conductors	Gain Controls	Country of Origin	Additional Information
ASTRO COMMUNICATION LABORATORY (U.K.)									
SR–209B (Standard) from £900 or SR–250B (Ruggedized version) from £1,100	Single, double or triple superheat	2MHz–12GHz using plug-in tuning heads	A.M. F.M. C.W. Pulse	50Ω (I/P) 600Ω audio, 93Ω video (O/P)	0·3μV at 1kHz bandwidth to 60μV at 8MHz A.M. 10dB F.M. 21dB	Typically 75 transistors 20 diodes dependent on modules used	R.F. A.F. Video	U.K.	Image rejection 60dB. Built-in power supply. Signal strength and tuning meters. Modular construction. Battery Pack.
SR–502 from £1,000	Double superhet	10–500kHz 0·5–30 MHz	A.M. F.M. C.W. S.S.B. Search	As for SR–209B	1μV A.M. and F.M. 0·3μV S.S.B. 0·1μV C.W. A.M. 10dB F.M. 20dB	← As for SR-209B →		U.K.	As for SR-209B. Plus frequency synthesizer with digital readout.
AVELEY ELECTRIC LTD.									
Rohde & Schwarz EK 47 (Price on request)	Double superhet	10kHz–30MHz	A.M. C.W.	50Ω (I/P) 600Ω (O/P line) 5Ω (O/P L.S.)	— 10dB			Germany	B.F.O. "S" meter. Battery/mains supply. Image rej. > 80dB. I.F. rej. > 80dB.
EK 56 (Price on request)	Double superhet	10kHz–30MHz	A.M. F.M. C.W.	As for EK 47	2·6–8μV 20dB			Germany	Aerial E.M.F. meter. Variable I.F. bandwidth. A.G.C. <2dB change from 1μV–100mV aerial E.M.F. Image rej- > 80dB. I.F. rej. > 80dB. Battery/mains supply.

Name, Brand and Model	Type of Circuit	Frequency Coverage	Receiving Modes	Input and Output Impedance	Sensitivity and S/N Ratio	Number of Valves and/or Semi-conductors	Gain Controls	Country of Origin	Additional Information
Aveley Electric Ltd. cont.									
HFH (Price on request)	Double superhet	100kHz–30MHz	A.M.	60 Ω (I/P) 4k Ω (phone) 15 Ω (L/S) 500k Ω (recorder)	0·1μV	13 Valves 10 Transistors		Germany	B.F.O. Crystal cal. 500kHz. Battery/mains supply. Variable I.F. bandwidth. Meter. I.F. rej. > 50dB.
ESUM (Price on request)	Double superhet Triple superhet	25–1,300MHz (plug-in units)	A.M. F.M.	50 Ω (I/P) 4k Ω (phone) 15 Ω (L/S) 250k Ω (recorder)	1μV > 6dB	32 Valves 36 Semiconductors		Germany	Crystal freq. cal. 10MHz. Meter 0–20dB and 0–80dB. Battery/mains supply. Variable I.F. bandwidth. Image rej. > 50dB. I.F. rej. > 90dB. Built-in L.S.
BARNET FACTORS LTD.									
Unica UNR 30 £13 13s.	Superhet	550kHz–30MHz	A.M.	75 Ω (I/P) 8 Ω (O/P)		4 Valves		Japan	Built-in P.U. Built-in L.S.
UR 1A £24	Superhet	550kHz–30MHz	A.M. S.S.B.	75 Ω (I/P) 8 Ω (O/P)				Japan	Built-in P.U. or 12V battery operated. Built-in L.S. "S" meter. Telescopic aerial. Bandspread tuning.
Lafayette HA 600 £45	Superhet	150–400kHz 550kHz–30MHz	A.M. C.W. S.S.B.	50–400 Ω (I/P) 4,8 or 500 Ω (O/P)	1μV 10dB	19 Semiconductors	A.F. R.F.	Japan	Built-in P.U. or 12V battery operated. "S" meter. Mechanical filter. Noise limiter. Bandspread tuning.
HA 800 £57 10s.	Double superhet	3·5–4MHz 7–7·3 MHz 14–14·35MHz 21–21·45MHz 28–29·7MHz 50–54MHz	A.M. C.W. S.S.B.	50 Ω (I/P)	1μV 10dB	24 Semiconductors	A.F. R.F.	Japan	Built-in P.U. or 12V battery operated. "S" meter. Mechanical filters. Noise limiter. Crystal cal. Bandspread tuning.
PF 60 £37 10s.	Superhet	152–174MHz	F.M.	50 Ω (I/P)	0·7μV 20dB	27 Semiconductors		Japan	Built-in P.U. or 12V battery operated. Built-in L.S. Squelch control. Facilities for crystal control.
B. H. MORRIS & CO. (RADIO) LTD.									
Trio 9R59DE £41 10s.	Superhet	550kHz–30Mhz (4 ranges)	C.W. S.S.B.	4–8 Ω (O/P)	6–18dB for 10dB S/N ratio	8 Valves	A.F. R.F.	Japan	Built-in P.U. "S" meter. Noise limiter Bandspread tuning.
JR500SE £69 10s.	Double superhet	Amateur bands between 3·5 and 30MHz (600kHz width)	A.M. C.W. S.S.B.	8 Ω 500 Ω } (O/P)	1·5μV for 10dB	7 Valves 2 Transistors	A.F. R.F.	Japan	Built-in P.U. "S" meter. Crystal osc. Crystal B.F.O. Bandspread tuning.
JR 310	Double superhet	<—— As for JR 500SE ——>				6 Valves 5 Transistors	A.F. R.F.	Japan	Built-in P.U. "S" meter. Crystal osc. Crystal B.F.O. Mechanical filter.
BROOKES & GATEHOUSE LTD.									
Homer Model K Mk2 (Navigation receiver) £84	Superhet	160–415kHz (1) 600–1,650kHz (2) 1,600–4,150kHz (3)	A.M. C.W.	3,000 Ω 1,000 Ω } (I/P)	3μV (Band 1) 40μV (Bands 2 & 3)	14 Transistors	A.F.	U.K.	Battery operated. Crystal B.F.O. Expanded scale for radio beacons (250–350kHz). A.G.C. < 6dB O/P for 40dB I/P.
COLLINS RADIO COMPANY OF ENGLAND									
51S–1 £1,250	Double superhet Triple superhet	2–30MHz, 200kHz–30MHz with 55G–1 preselector	A.M. C.W. S.S.B. R.T.T.Y.	50 Ω (I/P) 4 Ω 600 Ω } (O/P)	0·6μV (S.S.B. and (C.W.) 3μV (A.M.) 10dB	Valve		U.S.A.	

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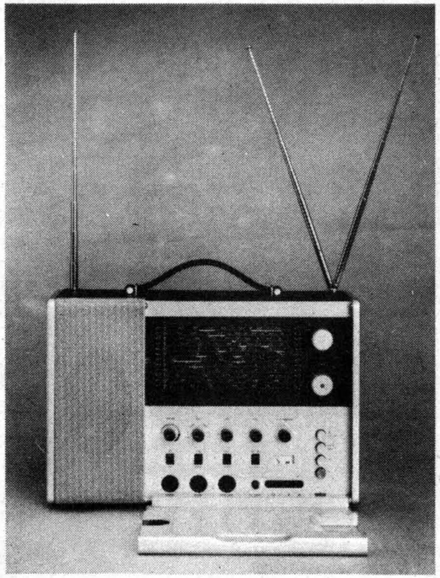
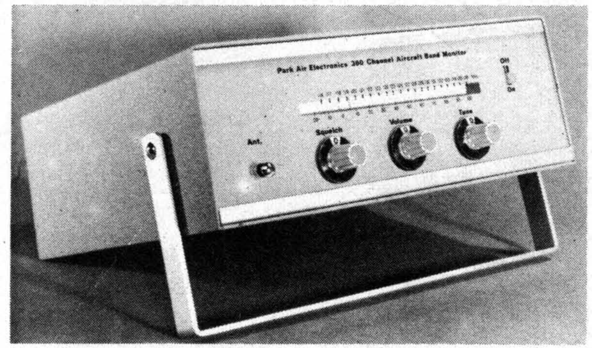


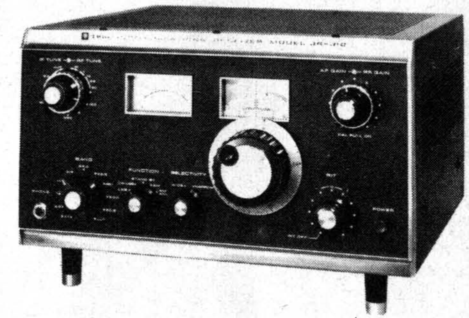
Braun T1000CD (portable)

Eddystone EC958

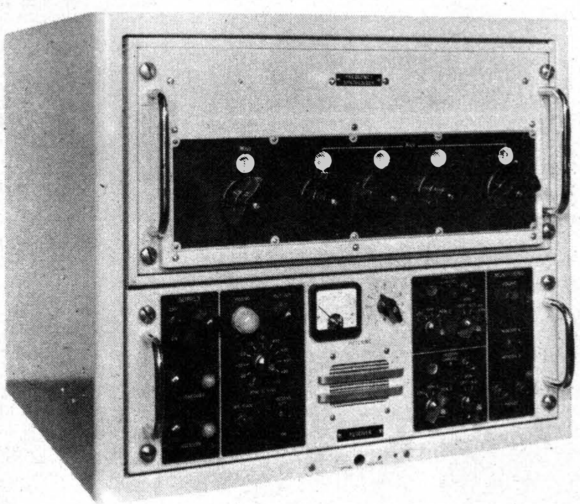
Plessey PR1553



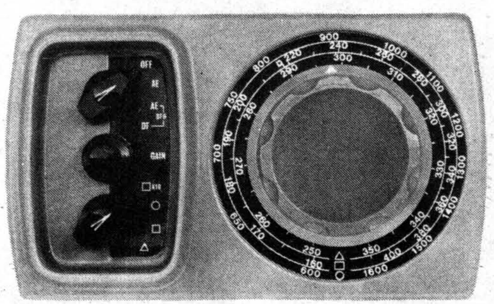
Park Air S Line aircraft monitor



Trio JR-310



Marconi N2020



Brookes & Gatehouse Homer K Mk2

Heathkit GC-1U "Mohican"

Name, Brand and Model	Type of Circuit	Frequency Coverage	Receiving Modes	Input and Output Impedance	Sensitivity and S/N Ratio	Number of Valves and/or Semi-conductors	Gain Controls	Country of Origin	Additional Information
Collins Radio Co. of England cont.									
651S–1 £2,300	Triple superhet	400kHz–30MHz	A.M./C.W. S.S.B. R.T.T.Y. N.B.S.V.	50Ω (I/P) 8–600Ω unbalanced and 600Ω balanced (O/P)	0·7µV (S.S.B. and C.W.) 3·5µV (A.M.) 10dB	Semiconductor		U.S.A.	
DAYSTROM LTD. **Heathkit** SB–301 £163 6s. (kit)	Double superhet (tunable I.F.)	3·5–4MHz 7–7·5MHz 14–14·5MHz 15–15·3MHz 21–21·5MHz 28–30MHz	A.M. S.S.B. C.W.	50Ω (I/P) 8Ω (O/P) High Z (phone)	< 0·25µV 10dB on S.S.B.	10 Valves 8 Diodes	A.F. R.F.	U.S.A.	Built-in power unit. "S" meter. Crystal filter. Crystal cal. Image rej. 60dB.
SB–310 £156 14s. (kit)	Double superhet (tunable 1st I.F.)	3·5–4MHz 5·7–6·2MHz 7–7·5MHz 9·5–10MHz 11·5–12MHz 14–14·5MHz 15–15·5MHz 17·5–18MHz 26·9–27·4MHz	A.M. S.S.B. C.W.	50Ω (I/P) 8Ω (O/P) High Z (phone)	0·3µV 10dB on S.S.B.	10 Valves 8 Diodes	A.F. R.F.	U.S.A.	Built-in power unit. "S" meter. Crystal filter. Crystal cal. Linear master osc. freq. 5–5·5MHz. Image rej. 60dB.
GR–54 £48 16s. (kit)	Superhet	180–420kHz 550–1,550kHz 2–30MHz	A.M. S.S.B. C.W.	50Ω (I/P) 8Ω (O/P) High Z (phone)	Various from 1–8µV (A.M.) to 0·4–4µV (S.S.B.) 10dB	6 Valves 8 Diodes	A.F. R.F.	U.K.	Built-in power unit. Switched B.F.O. Bandspread. "S" meter. Crystal filter. Image rej. 50dB (average).
GR–64 £24 16s. (kit)	Superhet	550kHz–30MHz	A.M. S.S.B. C.W.	High Z (I/P) 8Ω (O/P) 50Ω–10kΩ (phone)		4 Valves 2 Diodes		U.K.	Built-in power unit. Built-in L.S. tuning indicator meter.
GR–78 £68 18s. (kit)	Superhet Double superhet	200–400kHz 550kHz–30MHz	A.M. S.S.B. C.W.	High Z (I/P) 16Ω (O/P) High Z (phone)	15µV and 4µV 10dB	17 Transistors 7 Diodes	A.F. R.F.	U.S.A.	Rechargeable battery supply. "S" meter. Crystal cal. Image rej. 45dB. Band-spread.
GC–IU £39 16s. (kit)	Superhet	580–1,550kHz 1·69–30MHz	A.M. S.S.B. C.W.	50Ω, High Z } (I/P) 25Ω (O/P) High Z (phone)	10µV and 2µV 10dB	10 Transistors 4 Diodes	A.F. R.F.	U.K.	Battery operated. "S" meter. B.F.O. Bandspread. Image rej. 30dB.
EDDYSTONE RADIO LTD. 830/7 (Price on request)	Superhet Double superhet	300kHz–30MHz (9 ranges)	A.M. C.W. S.S.B.	75Ω (I/P) 250Ω I.F., 3Ω A.F., 600Ω line, Med. Z phone } (O/P)	3µV for 15dB 3kHz bandwidth	15 Valves 4 Semiconductors	A.F. I.F. R.F.	U.K.	Built-in P.U. Built-in L.S. "S" meter Crystal cal. Crystal filter. Noise limiter. Image rej. >70dB and >50dB. Provision for crystal control.
850/4 (Price on request)	Superhet	10–600kHz (6 ranges)	A.M. C.W.	75Ω, 300Ω } (I/P)	< 5µV for 15dB above 100kHz (A.M.) < 5µV for 15dB (all frequencies C.W.)	11 Valves	A.F. I.F. R.F.	U.K.	Built-in P.U. Built-in L.S. Crystal filter. Provision for crystal control. Image rej. >75dB at 600kHz.
940 (Price on request)	Superhet	480kHz–30MHz (5 ranges)	A.M. C.W. S.S.B.	75Ω (I/P) 100kΩ A.F., 2·5Ω A.F., 600Ω line, 200Ω phone } (O/P)	< 3µV for 15dB	13 Valves	A.F. R.F./I.F.	U.K.	Built-in P.U. Built-in L.S. "S" meter. Crystal cal. Image rej. 90dB at 1MHz, 40dB at 20MHz.
958 (Price on request)	Superhet Double superhet Triple superhet	10kHz–30MHz (10 ranges)	A.M. F.M. C.W. S.S.B. F.S.K.(optional)	75Ω, 600Ω, Ext. synth. } (I/P) 3Ω A.F., 150Ω line, 600Ω line, 75Ω I.F., Low Z phone } (O/P)	3µV for 10dB at 3kHz bandwidth (A.M.) 1µV for 10dB at 3kHz bandwidth (C.W./S.S.B.)	97 Semiconductors	A.F. I.F. R.F.	U.K.	Built-in P.U. Built-in L.S. "S" meter. Crystal cal. Crystal filter. Ranges 1–4, local oscillator has drift cancelling loop locked to harmonics derived from oven-controlled crystal oscillator. Image rej. >60dB below 1·6MHz, >70dB up to 18MHz, >50dB to 30MHz.

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Name, Brand and Model	Type of Circuit	Frequency Coverage	Receiving Modes	Input and Output Impedance	Sensitivity and S/N Ratio	Number of Valves and/or Semi-conductors	Gain Controls	Country of Origin	Additional Information
Eddystone Radio Ltd continued									
990S (Price on request)	Superhet	230–510MHz 470–870MHz	A.M. F.M.	75Ω Low Z I.F. } (I/P) 3Ω A.F. 150Ω line 600Ω line 1kΩ video Low Z I.F. Low Z phone } (O/P)	< 5µV for 10dB at 1MHz bandwidth (A.M.) < 4µV for 10dB at 1MHz bandwidth (F.M.)	42 Semiconductors	A.F. I.F. R.F.	U.K.	Built-in P.U. or 12V battery operated. "S" meter with log or linear scale. Image rej. > 50dB. A.G.C. characteristic, < 12dB variation of O/P for I/P variation of 70dB above 10µV.
990R (Price on request)	Superhet	27–240MHz (4 ranges)	A.M. F.M. C.W.	75Ω (I/P) Low Z I.F. 1kΩ video 3Ω A.F. 150Ω line 600Ω line Low Z phone } (O/P)	< 5µV for 10dB at 30kHz bandwidth	52 Semiconductors	A.F. I.F. R.F.	U.K.	Built-in P.U. or 12V battery operated. "S" meter. Built-in L.S. Crystal cal. Crystal filter to suit 12·5, 25 or 50kHz spacing. I/P for ext. osc. Provision for crystal control. Image rej. 50dB up to 200MHz, 45dB above 200MHz.
1830/1 (Price on request)	Superhet Double superhet	120kHz–30·3MHz (9 ranges)	A.M. C.W. S.S.B.	75Ω (I/P) 3Ω A.F. 150Ω line 600Ω line Low Z phone } (O/P)	3µV for 15dB at 3kHz bandwidth	53 Semiconductors	A.F. I.F. R.F.	U.K.	Built-in P.U. or 12V d.c. supply. Built-in L.S. "S" meter. Crystal cal. Provision for crystal-controlled channels. Image rej. 50dB–70dB.
EC 10 Mk 1 (Price on request)	Superhet	550kHz–30MHz (5 ranges)	A.M. C.W.	75Ω 400Ω } (I/P) Low Z phone (O/P)	5µV for 15dB above 1·5 MHz 15µV for 15dB below 1·5MHz	13 Semiconductors	A.F. R.F.	U.K.	Battery operated, mains P.U. optional. Built-in L.S. Image rej. 50dB at 2MHz, 20dB at 18MHz.
EC 10 Mk 2 (Price on request)	Superhet	As Mk 1	As Mk 1	75Ω 400Ω } (I/P) 5kΩ record Low Z phone } (O/P)	As Mk 1	15 Semiconductors	A.F. R.F.	U.K.	EC 10 Mk 2 and EC 10 A Series differ from the Mk 1 by the addition of (a) fine tuning control, (b) carrier level meter, (c) standby switch.
EC 10 A Series (Price on request)	Superhet	330–550kHz 1·5–30MHz (5 ranges)	A.M. C.W.	As Mk 1	As Mk 1	15 Semiconductors	A.F. R.F.	U.K.	EC 10/A/2 RM has two additional speakers for ship intercom system. Additional information otherwise as for Mk 1.
MARCONI COMMUNICATION SYSTEMS LTD.									
H 2310 "Argo" (Price on request)	Superhet Double superhet Triple superhet	10kHz–30MHz	A.M. C.W. S.S.B.	75Ω (I/P) 3 or 600Ω (O/P)	1µV 10dB			U.K.	
H 2001 "Hydrus" (Price on request)	Triple superhet	1·5–30MHz	C.W. S.S.B D.S.B. I.S.B. F.S.K.	50 or 75Ω (I/P) 600Ω (O/P)	1µV 17dB			U.K.	
N 2020 (Price on request)	Double superhet	240–525kHz 1·5–28MHz	C.W. S.S.B. D.S.B. F.S.T.	75Ω (I/P) 200 or 600Ω (O/P)	1µV 15dB			U.K.	
RC 410/R (Price on request)	Double superhet	2–30MHz	A.M. C.W. S.S.B.	50Ω (I/P) 3 or 600Ω (O/P)	0·6µV 10dB			U.K.	
RC 411/R (Price on request)	Double superhet	15kHz–30MHz	<——— As for RC 410/R	———>	30µV (L.F.) 10µV (M.F.) 0·6µV (H.F.)			U.K.	
PARK AIR ELECTRONICS LTD.									
Double S Line (Aircraft monitor) £52 16s to £95 16s.	Superhet	118–136MHz	A.M.	50Ω (I/P) 8Ω 600Ω } (O/P)	1µV > 15dB at 2µV	16–28 Semiconductors		U.K.	Comprises 6 models, 3 mains operated (15 Series) and 3 battery operated (10 Series). Models W/SS have 6 additional positions for crystal-controlled osc. Models A/SS use 50kHz crystal filters.

Name, Brand and Model	Type of Circuit	Frequency Coverage	Receiving Modes	Input and Output Impedance	Sensitivity and S/N Ratio	Number of Valves and/or Semi-conductors	Gain Controls	Country of Origin	Additional Information
THE PLESSEY COMPANY LTD.									
PR 155 Series (Price on request)	Triple superhet	15kHz–30MHz	A.M. C.W. S.S.B.	75 Ω (I/P) 600 Ω line, 600 Ω phone, 150 Ω } O/P	0·5μV for 10dB (S.S.B.) 0·5μV for 20dB (C.W.) 2·5μV for 10dB (A.M.)	118 Transistors	A.F. R.F./I.F.	U.K.	Built-in P.U. Built-in L.S. "S" meter. Crystal cal. Crystal filter. Phase lock loop circuits. Analogue/digital readout Image rej. 100dB up to 20MHz, 80dB up to 30MHz.
RACAL-BCC LTD.									
RA 17 (Price on request)	Triple superhet	1–30MHz	A.M. C.W.	75 Ω (I/P) 3 Ω, 600 Ω } (O/P)	1 μV for 18dB (A.M.) 3μV for 18dB (M.C.W.)		A.F. R.F.	U.K.	Built-in P.U. Built-in L.S. "S" meter. Crystal cal. A.G.C. short/long.
RA 117 (Price on request)	← As for RA17 →		A.M. C.W. S.S.B.	← As for RA17 →			A.F. R.F.	U.K.	Built-in P.U. Built-in L.S. "S" meter. Crystal cal. A.G.C. short/med/long.
RA 1217 (Price on request)	← As for RA 117 →			75 Ω (I/P) 600 Ω (O/P)	3μV for 15dB (A.M.) 1 μV for 15dB (S.S.B.)		A.F. R.F.	U.K.	Built-in P.U. "S" meter. Crystal cal. A.G.C. short/med/long.
RA 1218 (Price on request	← As for RA 1217 →								Built-in P.U. "S" meter. A.G.C. short/med/ long. Frequency digital readout.
RA 1220 (Price on request)	← As for RA 1217 →								As for RA1218 with additionally the "Racalock" frequency stabilizer with one part in 10 per day stability.
RA 329B (Price on request)	Triple superhet	1–30MHz	A.M. C.W. S.S.B. F.S.K. Ph.M. F.M.	← As for RA1217 →				U.K.	Built-in P.U. Built-in L.S. "S" meter. Crystal cal. A.G.C. short/med/long. Military receiver in waterproof carrying case. Integral F.S.K. demodulator.
RA 6217 (Price on request)	Triple superhet	1–30MHz	A.M. C.W. F.M. S.S.B.	50–70 Ω (I/P) 600 Ω (O/P)	0·5μV for 15dB (C.W. and S.S.B.) 1·5μV for 15dB (A.M.)		A.F. R.F.	U.K.	Built-in P.U. Crystal cal. A.G.C. short/med/long.
REDIFON LTD.									
R408 (Price on request)	Superhet Double superhet	13kHz–28MHz (14 ranges)	C.W. D.S.B. S.S.B.	Below 4MHz, 10 Ω in series with 200–600pF. Above 4MHz, 75 Ω (I/P) 3 Ω, 10 Ω, 600 Ω } (O/P)	Above 650kHz 1 μV, 100–250kHz 3μV, 36–100kHz 30μV for 10dB S/N ratio	90 Semiconductors		U.K.	
R475 (Price on request)	Superhet	250–538kHz 625kHz–24MHz (6 ranges)	C.W. D.S.B.		3–30μV on M.C.W. for 50mW O/P	6 Valves 9 Semiconductors		U.K.	
R550 (Price on request)	Double superhet	200kHz–30MHz	C.W. S.S.B. D.S.B. I.S.B. with add-on unit	Below 1MHz, 10 Ω in series with 200–700pF. Above 1MHz, 50 Ω (I/P) 3 Ω, 600 Ω } (O/P)	Above 1MHz, 0·5μV. Below 1 MHz 10μV (C.W.), for 0·5W O/P Above 1MHz > 21dB, below 1MHz > 24dB (C.W.)	140 Semiconductors		U.K.	ARU10 I.S.B. add-on unit and ARU11 frequency synthesis add-on unit available. ARU10: provides duplicate I.F. channel. 50 Ω (I/P), 3 Ω and 600 Ω O/P. S/N ratio typically 7dB. Contains 30 semiconductors.
R551 Marine version of R550 (Price on request)	Double superhet	60kHz–30MHz	← As for R550 →					U.K.	ARU11: frequency synthesizer for R550. Covers 200kHz–30MHz. Contains 11 semiconductors.
WINTER TRADING CO. LTD.									
Braun T1000CD (Portable) 229 gn	Superhet	130kHz–30MHz 87–108MHz	A.M. F.M.	Built-in aerials 240 Ω (I/P) on F.M. 5 Ω, High Z phone } (O/P)	2–9μV for 10dB (A.M.) 1·7μV for 30dB (F.M.)	21 Transistors	A.F. R.F.	Germany	Dry battery operated. Adaptor available for A.C. or 6, 12 and 24 V.D.C. operation. Built-in L.S. B.F.O. "S" meter. Variable bandwidth. Bandspread tuning.