A TYPICAL RECEIVER DESIGN

It will be of value to discuss the main features of a typical modern double-conversion communication receiver, though it should be appreciated that considerable variations may be met in practice.

A skeleton circuit is shown in Fig. 12, and it will be noted that it is a double superheterodyne. The first intermediate frequency is centred at 1·2 Mc/s to give a high value of image signal protection, and the second intermediate frequency is 100 kc/s and provides the main adjacent channel selectivity. Continuous tuning is provided by ganging the signal-frequency circuits to that of the variable first oscillator, but up to a maximum of six preset frequencies are available by substituting a crystal oscillator for the variable oscillator.

Radio-frequency Circuit Design

It is advantageous to cover the whole frequency range in as many bands as is practical, for the following reasons :

(1) The circuit impedances are subject to less variation and are higher than when fewer bands are used. This is of particular value at the higher frequencies, where it is normally difficult to make the first-circuit noise high in comparison with the first-valve noise. It is also easier to obtain the stage gain necessary so that the relatively high mixer noise does not degrade the signal-to-noise ratio.

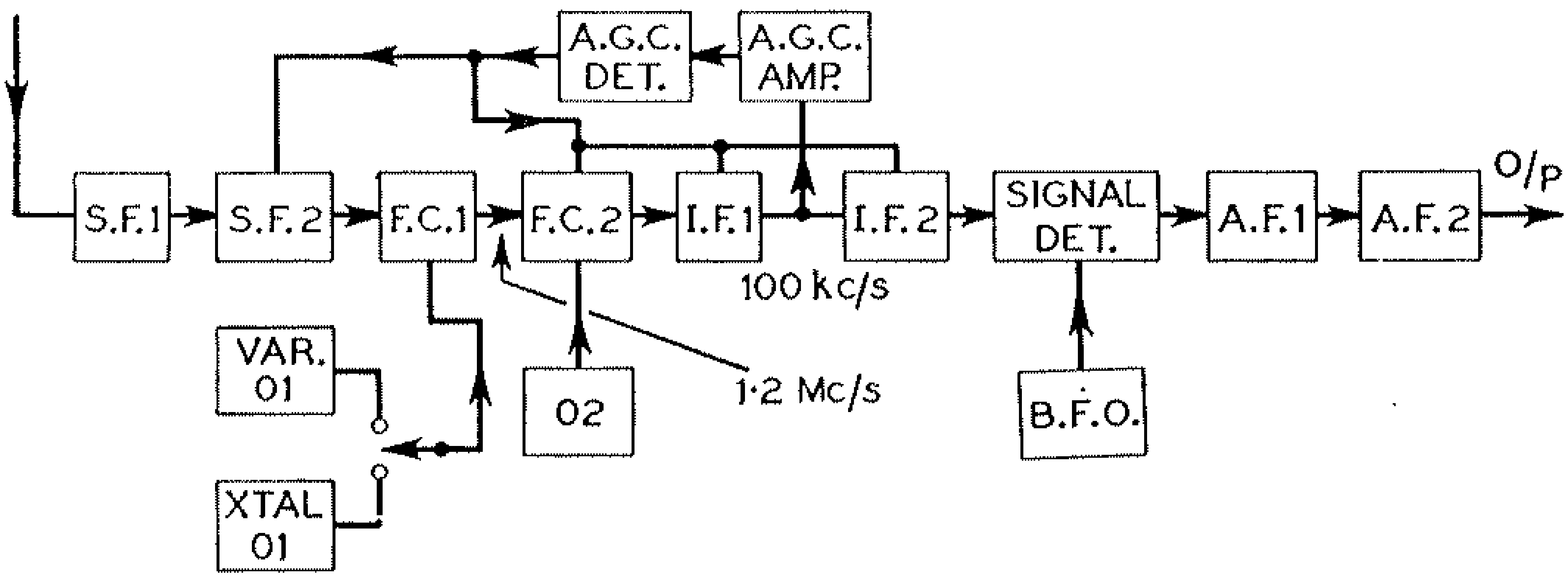

Fig. 12.—Block Diagram of a Typical Double Superheterodyne Communication Receiver.

(2) Misganging errors are minimized.

(3) The calibration scale is more open, and can be read to a greater degree of accuracy.

It follows, of course, that the stray circuit capacitance should be kept as low as possible. This involves detailed attention to the mechanical layout and run of wiring, but it should not be difficult to attain a figure of 40 pF for the stray capacitances, so that using a variable capacitor of 164 pF sweep, a range factor of 2 to 1 can be obtained. Allowance must be made for the parallel trimming capacitors and for adequate overlaps between ranges.

The coils used have adjustable dust-iron cores to facilitate ganging, and should have a high-Q value so as to maintain a high circuit impedance and to provide the minimum response to the image signal. A free coil may have a Q value of 100, but the effect of the wiring, switches, etc., can reduce the Q to 50, and in the case of the input circuit this can be further reduced to 25 by the aerial damping. There is little point, then, in devoting effort to the design of a high-Q coil unless attention is paid also to the associated circuitry.

For best performance, two radio-frequency stages of amplification are normally used; this has the effect of ensuring that the gain is sufficient to mask the mixer noise and that the number of tuned circuits provides a good value of image-signal protection. If the circuit impedances are high, two radio-frequency stages may not show much improvement over one radio-frequency stage in the matter of sensitivity, the only gain being in image-signal protection. It is possible, of course, to couple two tuned circuits together without the aid of a valve, but it is difficult to maintain the correct coupling over a frequency band, and valve coupling is much easier.

A four-gang capacitor tunes the two radio-frequency stages, the mixer and the oscillator, circuits simultaneously. The coils not in use are shorted out, so that unwanted resonance effects are avoided. Automatic gain control is applied to the second radio-frequency amplifier stage, which is a variable-mu type valve. The first stage has a short-grid-base valve of low noise equivalent.

The variable first oscillator uses a tuned-anode circuit, and is coupled through a small capacitor (C26) to the pentagrid mixer; alternatively, a triode hexode could, of course, be used as a mixer. When using the crystal oscillator, the variable oscillator stage is used as an amplifier or as a multiplier at the higher frequencies.

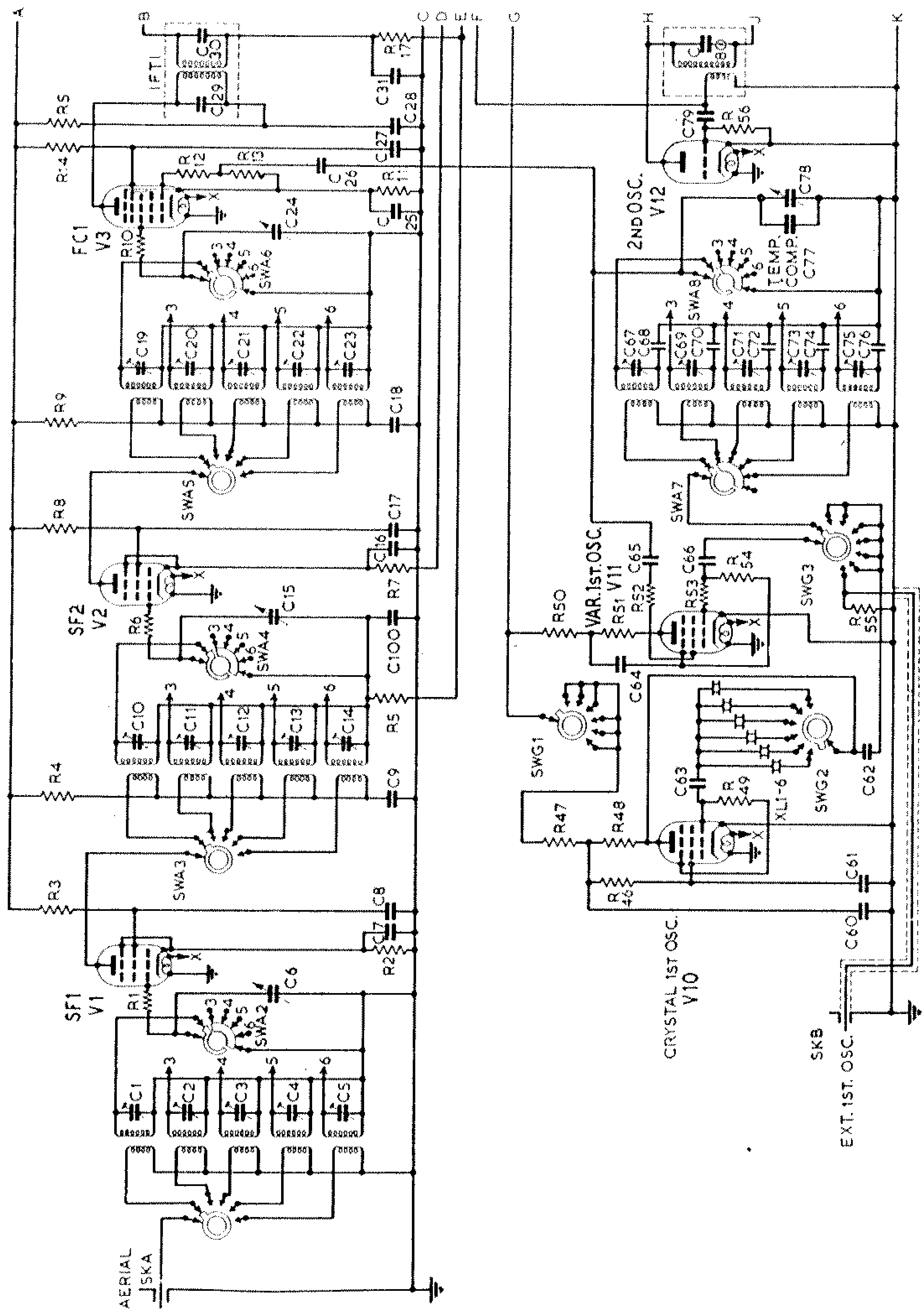

Fig. 13 (a).—R.F. Amplifiers and Frequency Changers of Typical Double-conversion Communication Receiver.

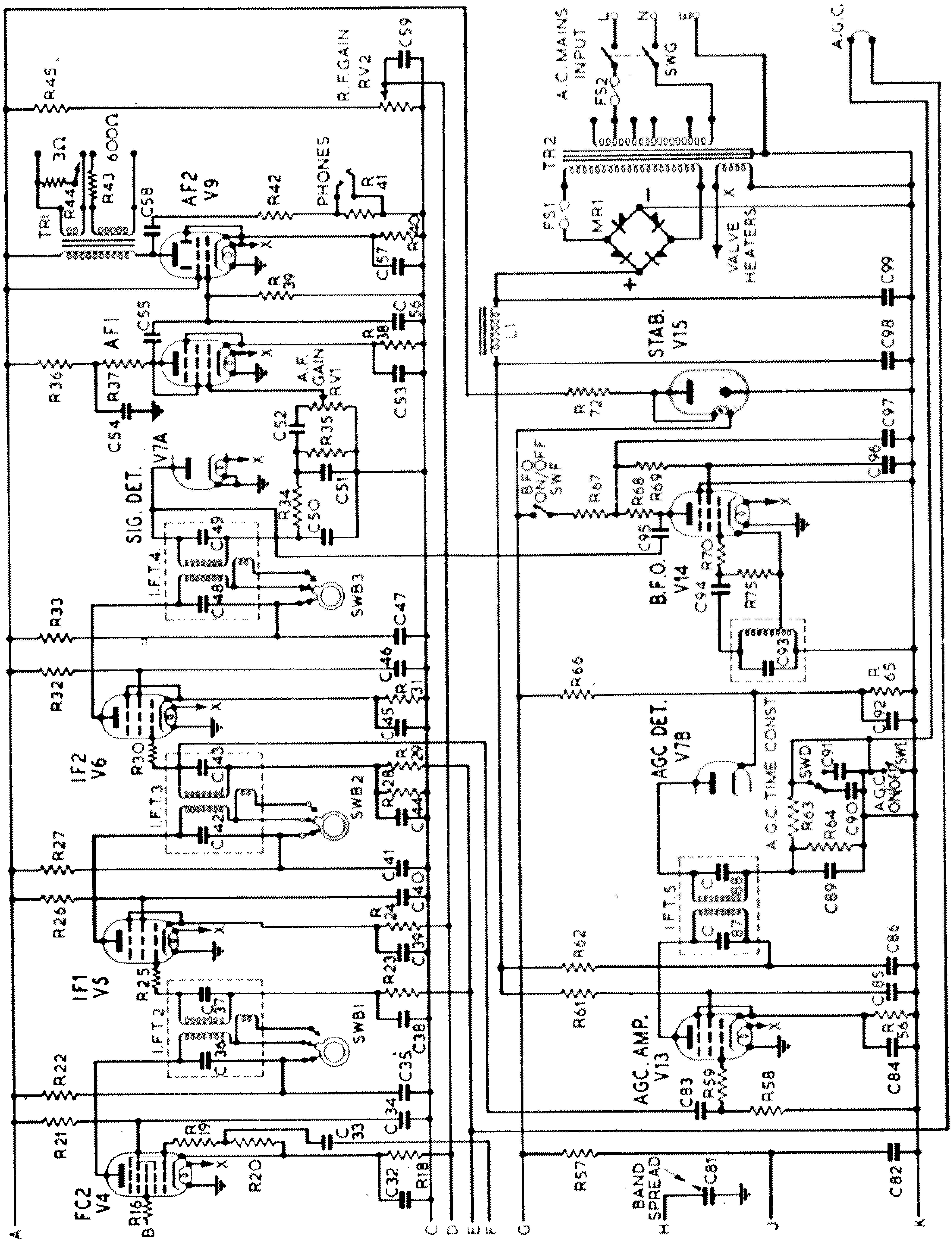

FIG. 13 (b).—INTERMEDIATE-FREQUENCY AND AUDIO-FREQUENCY SECTION OF TYPICAL DOUBLE-CONVERSION COMMUNICATION RECEIVER.

TABLE 2.—FREQUENCY COVERAGE OF TYPICAL RECEIVER

Band	*Nominal (Mc/s)*	*Actual including Overlaps (Mc/s)*
1	1·5–2·75	1·425–2·89
2	2·75–5·0	2·61–5·25
3	5·0–9·0	4·75–9·45
4	9·0–16·5	8·55–17·3
5	16·5–30	15·7–31·5

VALVE AND COMPONENT DATA, SEE FIG. 13.

Valve Types.

V1	CV138	V5	CV131	V9	CV2136	V13	CV131
V2	CV131	V6	CV131	V10	CV138	V14	CV131
V3	CV453	V7	CV140	V11	CV138	V15	CV216
V4	CV453	V8	CV138	V12	CV133		

Resistors.

R1	22	R19	100	R37	47k	R55	75
R2	330	R20	22k	R38	1k	R56	100k
R3	47k	R21	33k	R39	470k	R57	150k
R4	10k	R22	10k	R40	270	R58	470k
R5	47k	R23	47k	R41	4·7k	R59	100
R6	22	R24	1k	R42	47k	R60	330
R7	330	R25	100	R43	560	R61	47k
R8	47k	R26	47k	R44	3·3	R62	10k
R9	10k	R27	10k	R45	68k	R63	1M
R10	22	R28	2·2M	R46	47k	R64	100k
R11	330	R29	3·3M	R47	68k	R65	10k
R12	22	R30	100	R48	22k	R66	150k
R13	22k	R31	330	R49	47k	R67	33k
R14	33k	R32	47k	R50	1k	R68	22k
R15	10k	R33	10k	R51	10k	R69	33k
R16	100	R34	47k	R52	22	R70	100
R17	47k	R35	220k	R53	22	R71	47k
R18	330	R36	47k	R54	10k	R72	3·9k

Capacitors.

C1–C5	3–30 pF
C6	164 pF sweep
C7	0·01
C8	0·01
C9	0·01
C10–C14	3–30 pF
C15	164 pF sweep
C16	0·01
C17	0·01
C18	0·01
C19–C23	3–30 pF
C24	164 pF sweep
C25	0·01
C26	10 pF
C27	0·01
C28	0·1
C29	560 pF
C30	560 pF
C31	0·01

C32	0·1
C33	100 pF
C34	0·1
C35	0·1
C36	330 pF
C37	330 pF
C38	0·01
C39	0·1
C40	0·1
C41	0·1
C42	330 pF
C43	330 pF
C44	0·01
C45	0·1
C46	0·1
C47	0·1
C48	330 pF
C49	330 pF
C50	220 pF
C51	220 pF
C52	0·01
C53	2
C54	2
C55	0·01

C56	470 pF
C57	2
C58	0·1
C59	0·1
C60	0·1
C61	0·1
C62	47 pF
C63	22 pF
C64	0·01
C65	100 pF
C66	100 pF
C67	3–30 pF
C68	2,700 pF
C69	3–30 pF
C70	1,500 pF
C71	3–30 pF
C72	876 pF
C73	3–30 pF
C74	485 pF
C75	3–30 pF
C76	270 pF
C77	Temperature compensator

C78	164 pF sweep
C79	100 pF
C80	270 pF
C81	3–10 pF
C82	0·1
C83	100 pF
C84	0·1
C85	0·1
C86	0·1
C87	330 pF
C88	330 pF
C89	470 pF
C90	0·2
C91	0·5
C92	0·1
C93	1,000 pF
C94	100 pF
C95	22 pF
C96	0·1
C97	0·1
C98	8
C99	8
C100	0·01

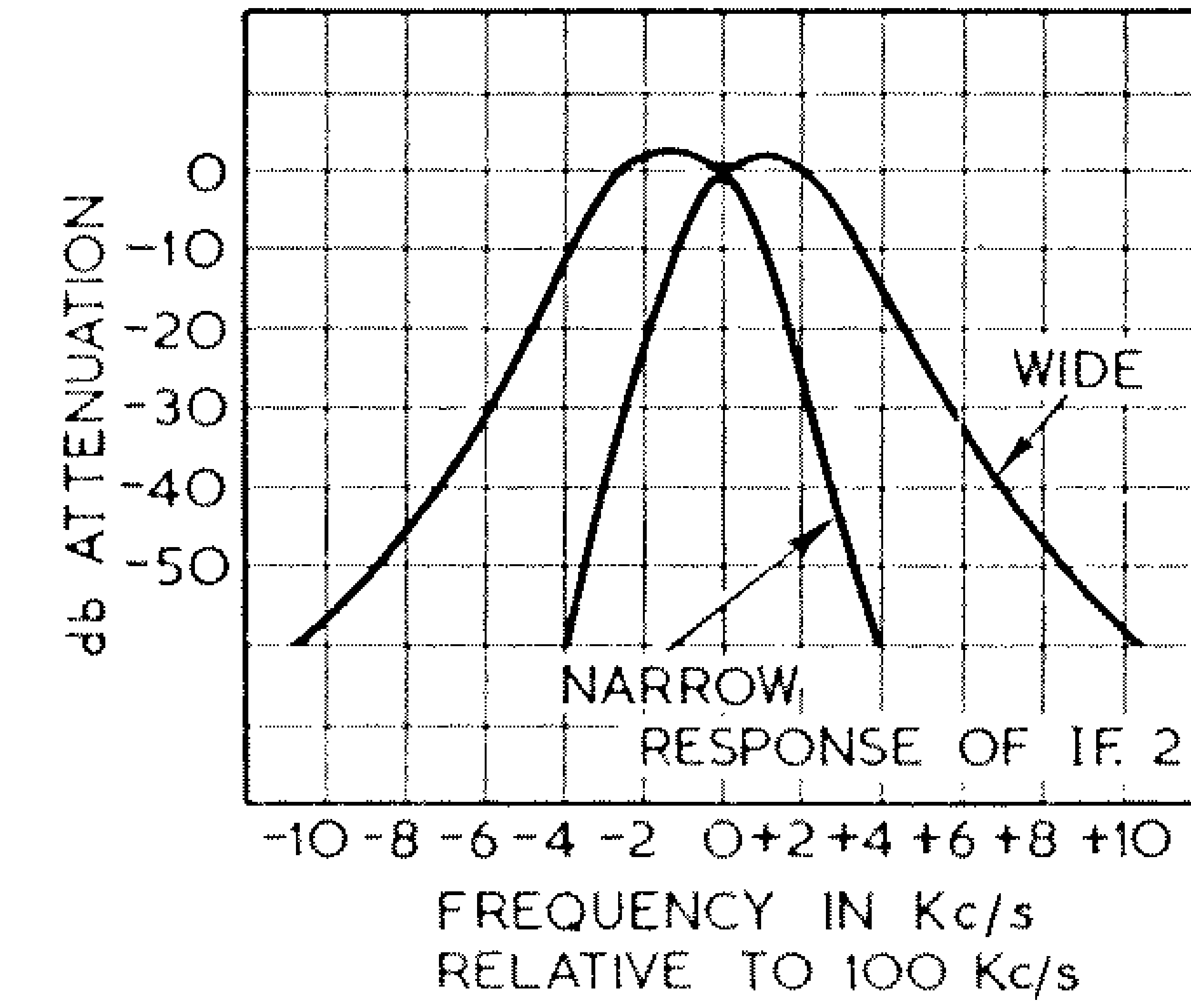

FIG. 14.—SECOND INTERMEDIATE-FREQUENCY RESPONSE CURVE.

The intermediate-frequency output from the first mixer at 1·2 Mc/s is taken to the second mixer via the double-tuned circuits (IFT1). The second oscillator is variable to the extent of ±5 kc/s, and this provides the band-spread control.

The second intermediate-frequency amplifier employs two variable-mu valve stages and a total of six tuned circuits. Two degrees of coupling provide band-widths of 1·5 kc/s for telegraphy and 6 kc/s for telephony. The mid-frequency is 100 kc/s, and is sufficiently low to enable good selectivity to be obtained without the use of a crystal-gate.

Audio-frequency Stages

Diode detection is used, the load being provided by R35, and the intermediate-frequency filter by R34, together with capacitors C50 and C51. The degree of intermediate-frequency filtering must not be so high as to affect the modulation frequencies. The output from the signal diode is taken to the first audio-frequency stage via the audio-frequency gain control (RV1) and thence to the output stage. Three audio-frequency outputs are shown, these being for loudspeaker, 600-ohm line and headphone monitoring. The line output is normally limited to about 10 mW, as the maximum line level permitted by the G.P.O. is about 5 mW.

A separate beat-frequency oscillator is coupled to the signal detector for continuous-wave reception, and is pre-set to give a beat note of 1 kc/s.

An automatic-gain-control amplifier feeds the automatic-gain-control detector, the delay voltage being supplied by the potentiometer formed by R65 and R66, and the time-constant being selected by the switch SWD. The time-constants chosen are 0·2 seconds for telephony and 0·5 seconds for telegraphy. Resistance values for R63 and R64 are 1 MΩ and 100 kΩ respectively, so that there is no appreciable difference between the "on" and the "off" time-constants. If a short "on" time-constant is used, a strong noise element can operate the automatic-gain-control system, so that several telegraph characters may be rendered inaudible, even though the duration of the noise element may be so short that the noise itself cannot be heard.

The manual gain control operates on both the radio-frequency and intermediate-frequency amplifiers simultaneously. A separate radio-frequency gain control is sometimes adopted, and is particularly useful in preventing cross-modulation due to strong signals; such a control is frequently misused, however, and causes degradation of the signal-to-noise ratio, so that on balance it is probably best omitted.

The power supply is conventional; it uses a metal rectifier on the score of economy of maintenance as compared with a valve rectifier. The smoothed H.T. is about 250 volts, and is stabilized for supply to the oscillators and automatic-gain-control delay potential.

In common-frequency, spaced-aerial diversity working, it is usual to common the automatic-gain-control systems, so that the receiver with the strongest signal controls the gain of the other receiver, or receivers, and reduces the unwanted noise. It is also advantageous to use a common first-frequency-change oscillator, as this simplifies the location of the signal and subsequent monitoring.

The receiver circuit as given in Fig. 13 is intentionally simple for ease of presentation, obviously it can be elaborated by the addition of more intermediate-frequency pass-bands, a distortionless audio-frequency amplifier, valve-feed metering and the like.

Estimated Performance

The following information gives guidance as to the standard of performance that could be expected in practice with this receiver:

(1) *Noise Factor.*—Band 1, 4 db; Band 2, 4 db; Band 3, 5 db; Band 4, 6·5 db; Band 5, 9 db.

(2) *Signal-to-noise Ratio.*—(*a*) Signals modulated 30 per cent at 400 c/s to give 10 db signal-to-noise ratio with a pass-band of 6 kc/s. (*b*) Continuous-wave signals to give 20 db signal-to-noise ratio with a pass-band of 1·5 Kc/s.

Band	*Signals as* (a)	*Signals as* (b)
1	1·45 μV	0·7 μV
2	1·45 μV	0·7 μV
3	1·6 μV	0·8 μV
4	1·9 μV	0·9 μV
5	2·6 μV	1·2 μV

(3) *Image Protection.*—Band 1, 100 db; Band 2, 100 db at 2·75 Mc/s, 85 db at 5 Mc/s; Band 3, 95 db at 5 Mc/s, 72 db at 9 Mc/s; Band 4, 80 db at 9 Mc/s, 50 db at 16·5 Mc/s; Band 5, 50 db at 16·5 Mc/s, 35 db at 30 Mc/s.

(4) *Automatic-gain-control.*—Two time constants—0·2 and 0·5 seconds. The action of the automatic-gain-control is such that if the inputs given in (2) above are increased by 60 db the outout will increase by approximately 7 db.

(5) *Input Impedance.*—75-ohms, unbalanced.

(6) *Audio Output.*—1-watt into 3 ohms; 10 mW into 600 ohms.

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