WS No. 19 Mark III

Note: This Issue 3 supersedes Pages 1-4 and 7-18 Issue 1, dated 30 Apr 47 and Pages 5-6, Issue 2, dated 28 Jan 52. The regulation has been revised.

# V.F. TELEGRAPHY

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VF TELEGRAPHY

## General

### Advantages of v.f. telegraphy

1. The method of telegraphy described in EMER Tels A 170 (d.c. telegraphy) suffers from the following limitations when long distances are to be covered:-

a. D.C. connection (metallic circuit) must be maintained between transmitting and receiving stations, eg radio links etc may not be used.

b. The maximum number of channels on each metallic circuit is very limited.

c. The distortion introduced by a transmission line carrying initially rectangular pulses limits signalling speeds.

d. Serious interference may be given to telephone circuits on the same route.

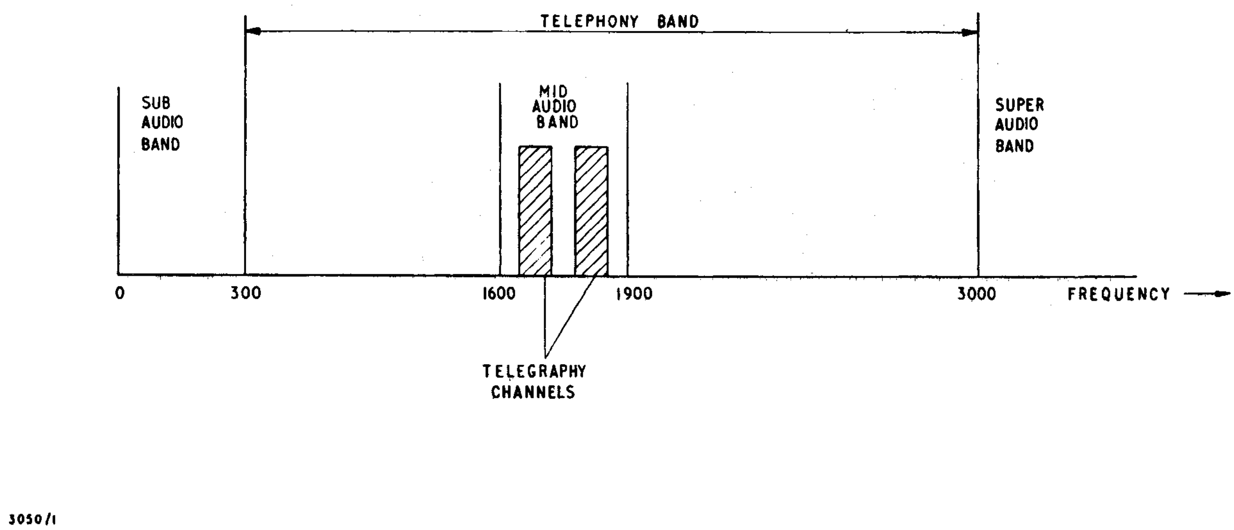



Fig 1 - Telegraphy spectrum

2. The general use of carrier telephone (voice) channels particularly on radio links has necessitated the introduction of a telegraph system which could be transmitted over these voice channels. Voice frequency telegraphy uses, as the name implies, tones in the normal telephony spectrum which therefore meets this requirement.

3. The tones may be either on or off (corresponding to single current d.c. signalling) or may change frequency for mark and space, corresponding to double current signalling.

4. Where only one telegraph channel is required, the speech channel may be retainined as it has been found that the frequency band 1600 to 1900Hz can be removed from the speech channel with little effect on intelligibility and in one system this band is used as a v.f. telegraph path on an existing telephone line.

5. A v.f. system requires more terminal equipment and introduces its own type of distortion. Both of these aspects are covered later in this EMER. The limitations of a d.c. system which were outlined in para 1 are overcome by the use of v.f. telegraphy:-

a. D.C. connection is no longer necessary because a.c. signalling is used.

b. By using different tones for each station, many channels may be transmitted along the same pair of lines, or over a non-metallic circuit.

c. The receiver has only a single tone to detect, so the need to transmit a square pulse no longer exists.

d. Intereference problems are reduced to those encountered between normal telephone channels.

V.F. telegraphy systems - general principles

Tone systems

6. The simplest v.f. system employs a tone to indicate mark and no tone to indicate space, or vice versa, (Fig 2.a.) but on a long or difficult path, noise will fill the space intervals causing mis-operation of the receiving circuits.

7. Two-tone v.f. is an improved system utilising one tone for space and another for mark and is therefore, inherently less liable to mutilations. The mark and space tones may be obtained either from separate oscillators or by frequency modulation of a single oscillator.

8. Single-tone working is applicable to short links and can be either tone-off (tone on for space) or tone-on (tone off for space), the latter is preferred for the following reason: The A.G.C. circuit must have a long time constant to prevent operation between characters which would increase received noise. Thus when using a tone-off system, the first character received will be amplified by the receiver at full gain, the A.G.C. will not come into full operation until after several characters have been received and spacing bias will result (Fig 3). If a tone-on system is used the A.G.C. is operating when the first character is received and the amplifier is at its correct gain. Bias distortion should not occur.

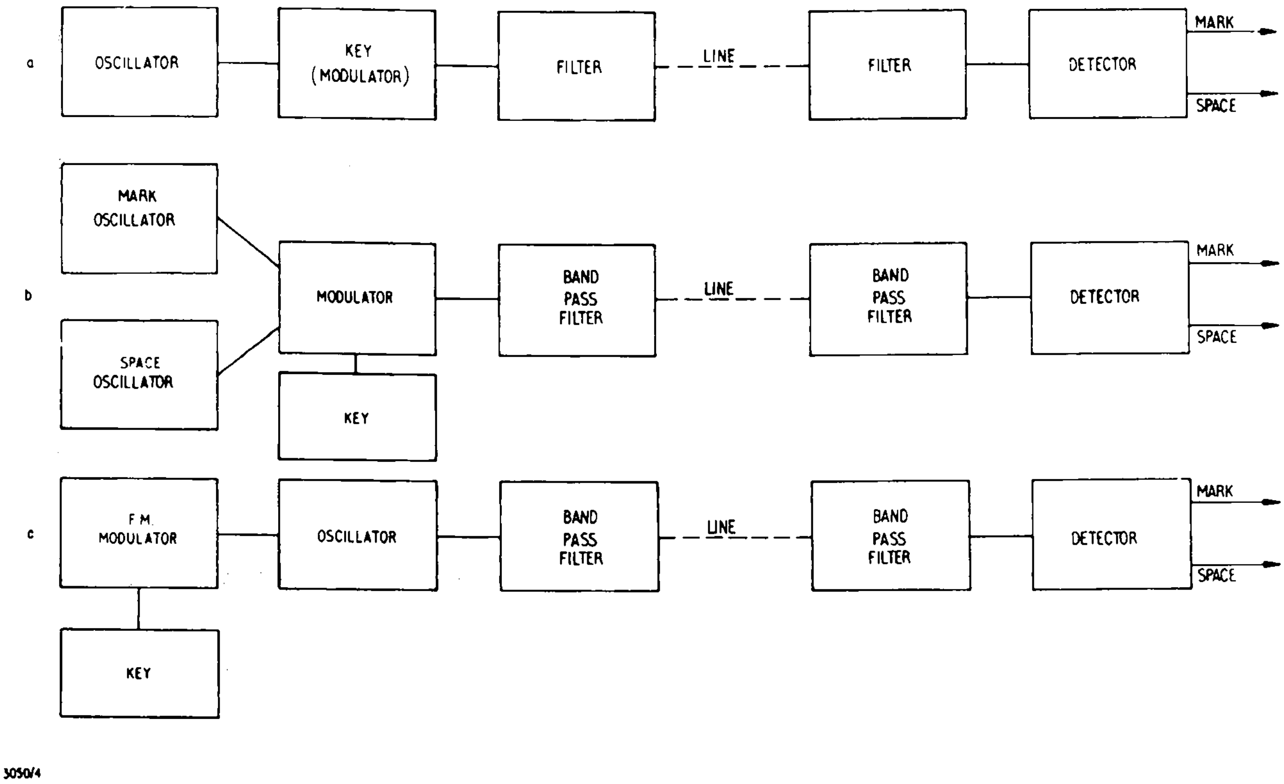



Fig 2 - Block diagrams of modulation systems

## Frequencies of operation

Table 1 - List of standard tone frequencies for multi-channel v.f. telegraph systems

| Channel No | Carrier frequency | Channel No | Carrier frequency |
|---|---|---|---|
| 1 | 420 | 13 | 1860 |
| 2 | 540 | 14 | 1980 |
| 3 | 660 | 15 | 2100 |
| 4 | 780 | 16 | 2220 |
| 5 | 900 | 17 | 2340 |
| 6 | 1020 | 18 | 2460 |
| 7 | 1140 | 19 | 2580 |
| 8 | 1260 | 20 | 2700 |
| 9 | 1380 | 21 | 2820 |
| 10 | 1500 | 22 | 2940 |
| 11 | 1620 | 23 | 3060 |
| 12 | 1740 | 24 | 3180 |

It should be noted that the frequencies are odd harmonics of 60Hz, consequently beating of one channel with another will result in an output frequency not in any channel, ie at an even harmonic of 60Hz.

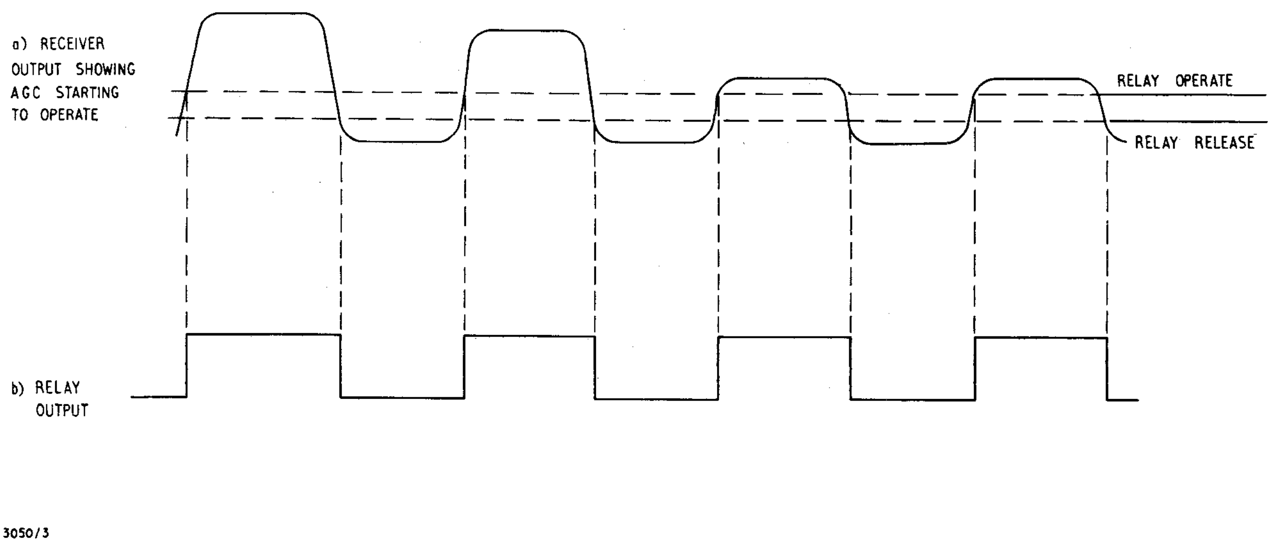



Fig 3 - Bias distortion caused by amplitude variation

Phone Systems

9. An alternative method of v.f. transmission is used in Skynet. This system uses phase modulation to achieve a narrow bandwidth and some measure of security; rate of handling traffic is fixed at 2.4 kilobaud, so therefore, only data, digital speech or time division multiplexed telegraph signals ie synchronous traffic is acceptable to the equipment.

10. The receiver in this system is first phase-locked to the transmitter carrier; when phase lock is established, the carrier is modulated by changing its phase in accordance with the 2.4 kilobit information stream. The receiver demodulates this signal and re-produces the digit stream, the timing of the digits being closely controlled in order not to mislead the T.D.M. equipment by offering it randomly spaced pulses. (Time Division Multiplexing (T.D.M.) is described in EMER Tels A 172).

11. Whilst phase modulation has a narrower bandwidth than frequency modulation, the bandwidth is further halved by a diplex technique (see para 28), whereby the modulator views the incoming bits in pairs. The carrier is changed in phase according to the following table and is thus modulated at a 1.2 kilobit rate.

Table 2 - Phase modulation

| Digit | Phase change (normal) | Phase change (alternative) |
|---|---|---|
| 00 | 0° | -270° |
| 01 | -90° | 0° |
| 11 | -180° | -90° |
| 10 | -270° | -180° |

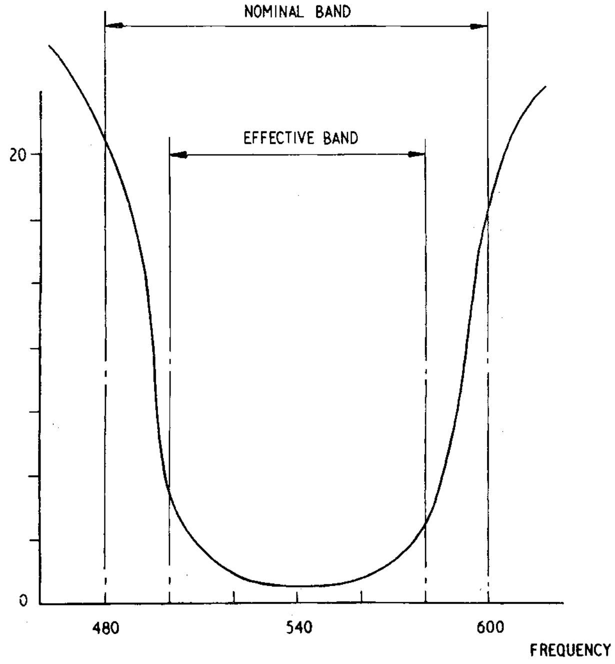



Fig 4 - Typical filter characteristic

Bandwidth

12. The bandwidth required to transmit signals is a function of the speed of working and, as can be seen from EMER Tels A 170, the minimum bandwidth of a 50 baud transmission is 50Hz whilst an 80 baud transmission has a minimum bandwidth of 80Hz. Using the standard carrier frequencies listed in Table 1, an 80 baud speed is the maximum possible if crosstalk is to be avoided, because the filters require a finite bandwidth to cut off (Fig 4). It must be appreciated that if a teleprinter is working through four or five channels in series eg through switchboard routing, the effective bandwidth will be narrower because of the cumulative effect of bias distortion, and the maximum speed will be unattainable. Under these conditions two tones must be used to indicate mark and space as previously indicated.

Oscillators

13. Because several v.f. channels are normally working on the same path, filters must be used at transmitter and receiver to ensure correct routing of traffic. Stability of frequency and output voltage are essential to ensure the passage of information through the filters.

14. Adequate stability is achieved by using a well designed valve oscillator in a tuned-feedback configuration.

15. New equipments now in service use LC transistor oscillators with a crystal controlled group oscillator/modulators (see Tels A 151 for explanation of group modulation) when more than four channels are required.

Modulators

16. Fig 5 shows a simple single tone on-off modulator circuit; modulators which do not use mechanical switching relays are sometimes referred to as static relays.

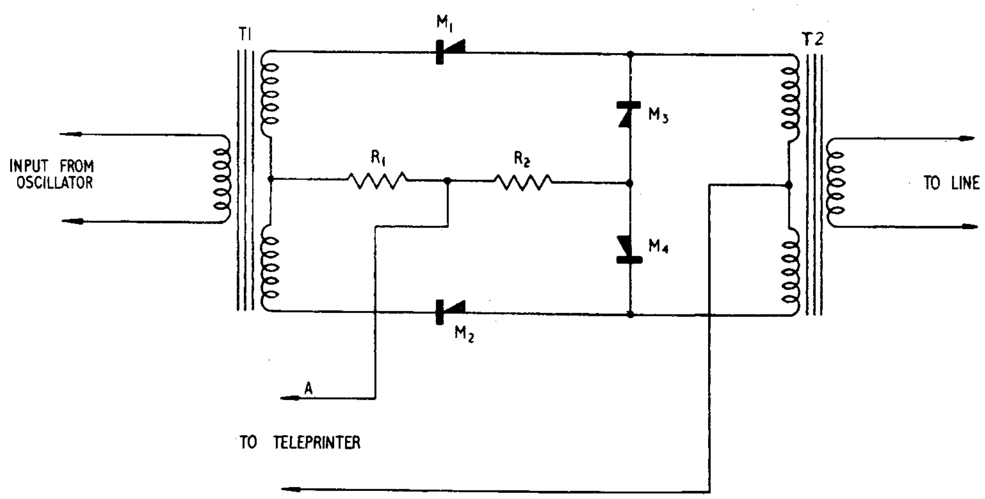



Fig 5 - Typical modulator

17. The operation of the circuit of Fig 5 is as follows: A marking signal from the teleprinter, line A -ve, causes current to flow through R1, divide through T1, then re-combine via M1 and M2 at T2. This current will bias M1 and M2 on, M3 and M4 off; so oscillator output is transmitted to line. A spacing signal causes current to flow through R2, divide through M3 and M4, re-combining in T2; M3 and M4 therefore conduct, short-circuiting oscillator tone across T2.

18. Two of these modulators may be combined so that different tones for mark and space are transmitted.

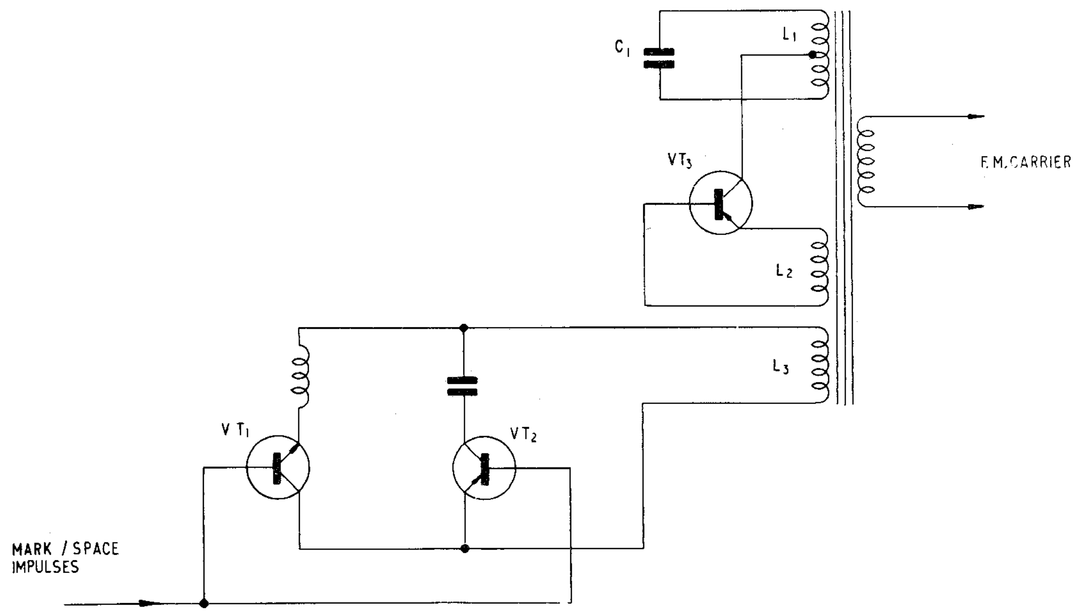



Fig 6 - Skeleton circuit of a f.m. modulator

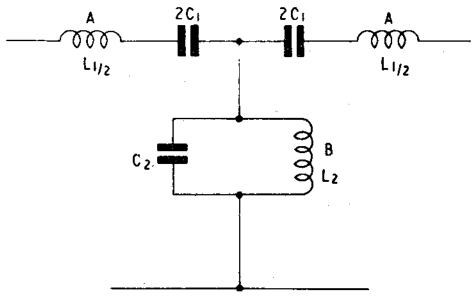
Frequency modulation

19. Various FM modulators are in use, but all work on the principle of changing the reactance of an oscillatory circuit in accordance with (eg teleprinter) keying. A skeleton circuit is shown in Fig 6 where VT3 is the oscillator and L1, C1 form the tuned circuit with L2 for feedback. Inductive or capacitive reactance is added to winding L3 by switching either VT1 or VT2 into full conduction by a negative or a positive pulse. This changed reactance is reflected into L1 and the output frequency is (eg) increased for mark and decreased space.

Filters

20. The filters used chiefly are band-pass, band-stop and low-pass types. Each teleprinter channel must transmit only frequencies within its allowed band to avoid interaction with other channels from the harmonics generated by modulation (see EMER Tels A 013) also the outputs from other channels must not affect it. For this reason band-pass filters are placed in the output of each transmitter and on the input of each receiver.

21. Band-stop filters are used (eg) in speech-plus-duplex equipments to exclude the mid-band telephone signals from a telephone line so that it may be used by a telegraph channel. Low-pass filters may be used after modulators to exclude higher order modulation products. Examples will be found in Tels A 151.



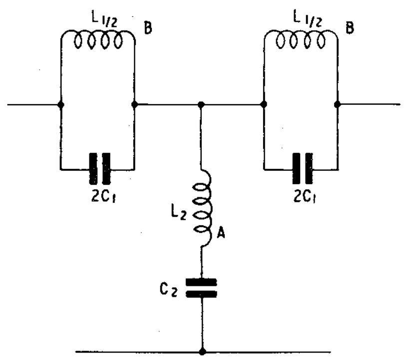




Fig 7 - Band-pass filter

Fig 8 - Band-stop filter

RECEIVER

The detector with a.g.c.

22. The circuit of Fig 9 is of a two-tone detector and comprises two single-tone detectors, with common electro-mechanical output relay. A detailed description can be found in EMER Tels R 250.

23. Signals are applied to the input of the circuit of Fig 9 as mark and space tones to the appropriate input transformer; the potentiometer R1 balances the input to the amplifiers by loading the transformers differentially as necessary. The appropriate V1 amplifies an incoming signal and applies it to V2 where it is rectified and applies positive bias to the appropriate V3 valve across R1. The current flowing through the relay moves the armature in accordance with whichever valve is conducting. One valve always conducts because either a mark or a space signal is always applied to the input.

24. If the signal applied to V3 is greater than the bias produced by Rk, V3 grid current will flow and negative bias will be developed across Rg. This limits the anode current of both V3 valves to a value which will not saturate the relay.

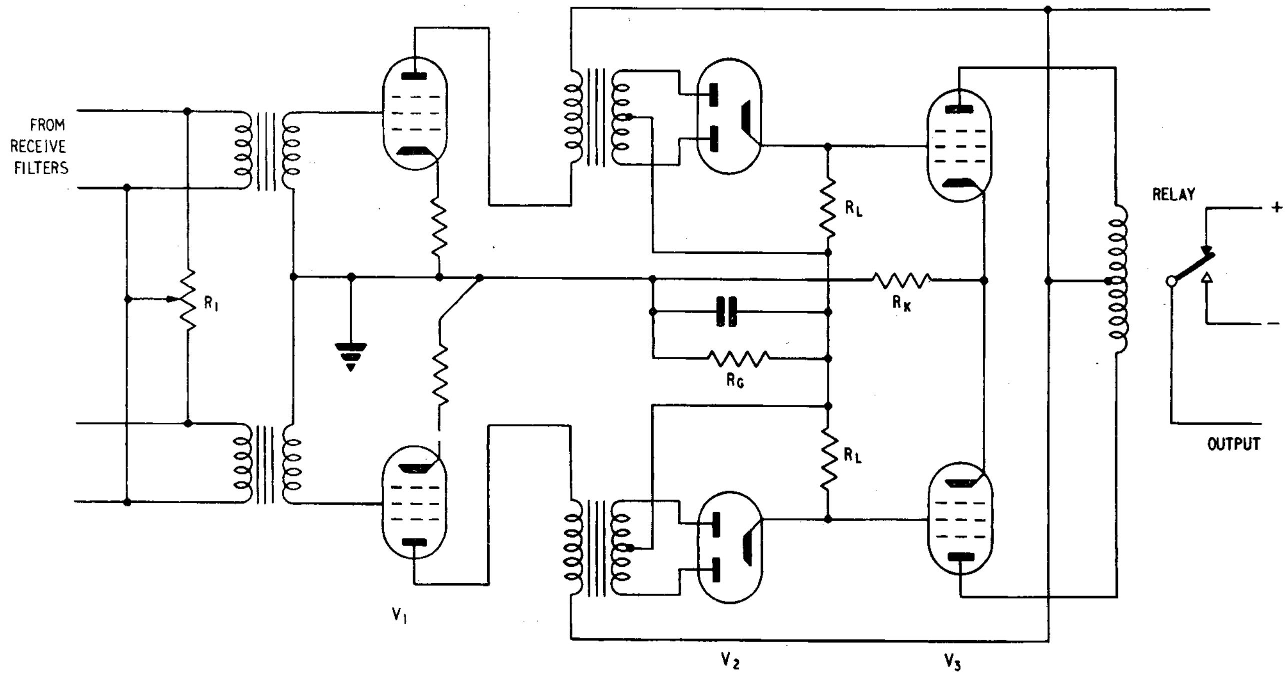



Fig 9 - A two-tone detector

F.M. detector

25. Detection of f.m. signals is achieved by a discriminator. The detailed action of a current used in the TTV F4/12 is given in EMER Tels R 342. A short description of its operation is given below. (Fig 10). The transformers T1 and T2 are tuned to frequencies respectively above and below the nominal mean channel mark and space frequency thus working on a substantially linear portion of their resonance curves; this ensures linear frequency response over the normal deviation range. When (eg) a space frequency is received, the output is almost entirely from T1, so a voltage appears at A which is positive w.r.t. point C. Similarly, a mark frequency produces a voltage at B negative w.r.t. point C. RV1 is used to balance these voltages which trigger a bi-stable whose output drives an electronic relay.

Complete systems

Speech plus-duplex

26. This system uses a 'slot', accommodating two frequencies in the usual audio band as mentioned in para 4, (see also block diagram, Fig 11). An arrangement of this sort provides a speech channel and a duplex teleprinter link using two v.f. tones, one for each direction within the slot, (which in the S & DX No 2 extends from 1540-2030Hz) (see EMER Tels R 312). The 17 or 20Hz ringing current from the

telephone or switchboard is converted to 500 or 500/20 v.f. tone so that signalling also may be carried out within the audio band.

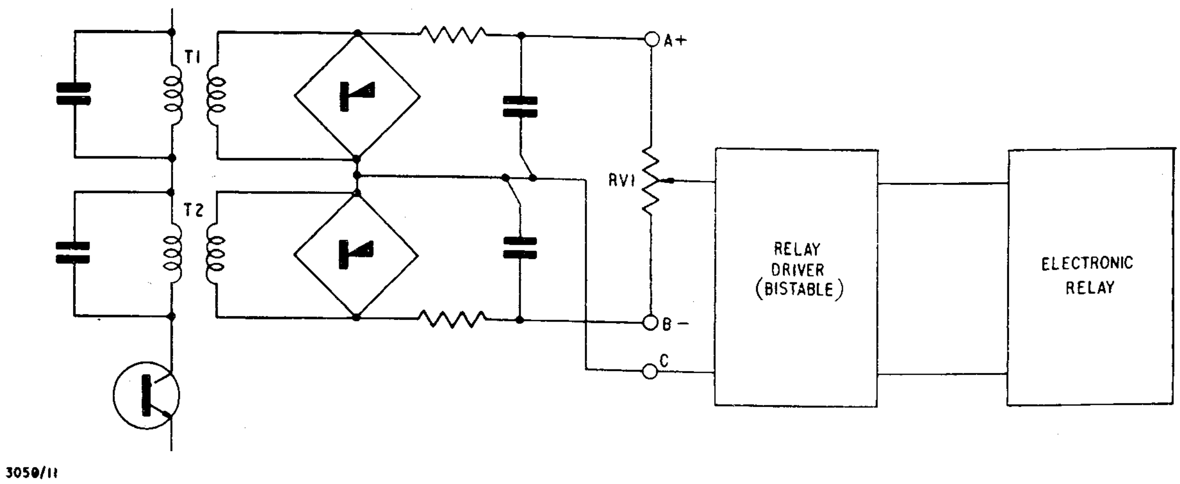



Fig 10 - Typical discriminator (f.m. detector)

Working over difficult radio paths

27. When v.f. telegraph channels are transmitted over a h.f. radio link where serious fading is experienced it may be found that even two-tone working is unstable. This can be offset to some extent by four or six tone working, where a mark is represented for instance, by tones on channels 1, 3 and 5 and space by tone on channels 2, 4 and 6, the reception from the strongest channel taking preference. Alternatively, levels may be raised on send, with receiver sensitivity correspondingly reduced, all the available send power being concentrated in one channel. This method is suited to a very noisy path. Improved working can be obtained only by reducing the number of channels (see EMER Tels A 172 for further information).

28. Multiple frequency shift working is sometimes used to overcome multipath distortion and has the advantage that the peak power of the radio transmitter is continually used. In this system a tone (or no-tone) on a given channel represents a given combination of signalling conditions. For N communication channels $2^N$ links are required and the system is normally used only for two channels using four carriers and is known as twinplex or frequency-shift diplex. When the twinplex is synchronised, up to four time-division multiplexed systems can be impressed on each twinplex channel. Two common twinplex codes are given in Table 3.

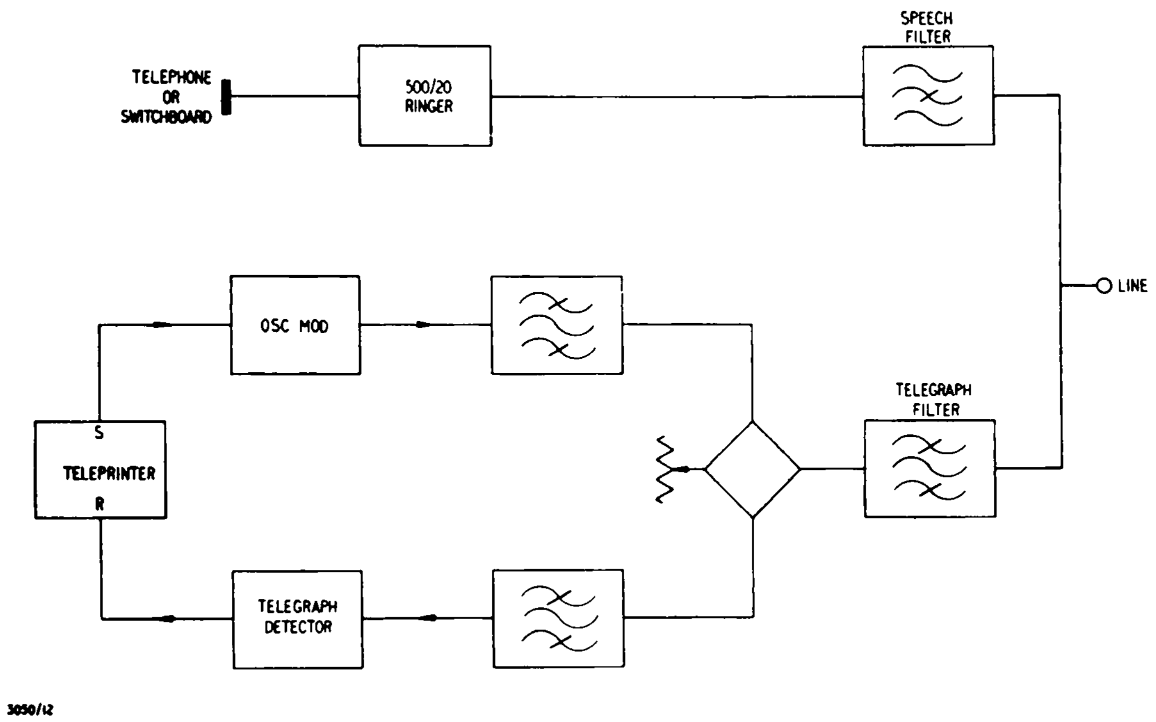



Fig 11 - Block diagram of speech plus duplex

Table 3 - Twinplex codes

| Tone frequency | Code 1 | | Code 2 | |
|---|---|---|---|---|
| | Channel A | Channel B | Channel A | Channel B |
| f1 | Space | Mark | Space | Space |
| f2 = f1+400 | Space | Space | Space | Mark |
| f3 = f1+800 | Mark | Space | Mark | Space |
| f4 = f1+1200 | Mark | Mark | Mark | Mark |

Distortion in v.f. telegraphy

29. The distortion caused by a.g.c. has been outlined in para 8. Another type of distortion is inherent in the system because of the use of filters. It can be shown that the time (t) of build-up of a filter mid-frequency input to a steady value is inversely proportional to the filter bandwidth, consequently any character shorter than this time may not pass the filter and traffic speed is therefore limited. It will be seen from Fig 13 that some delay is introduced and bias distortion may occur.

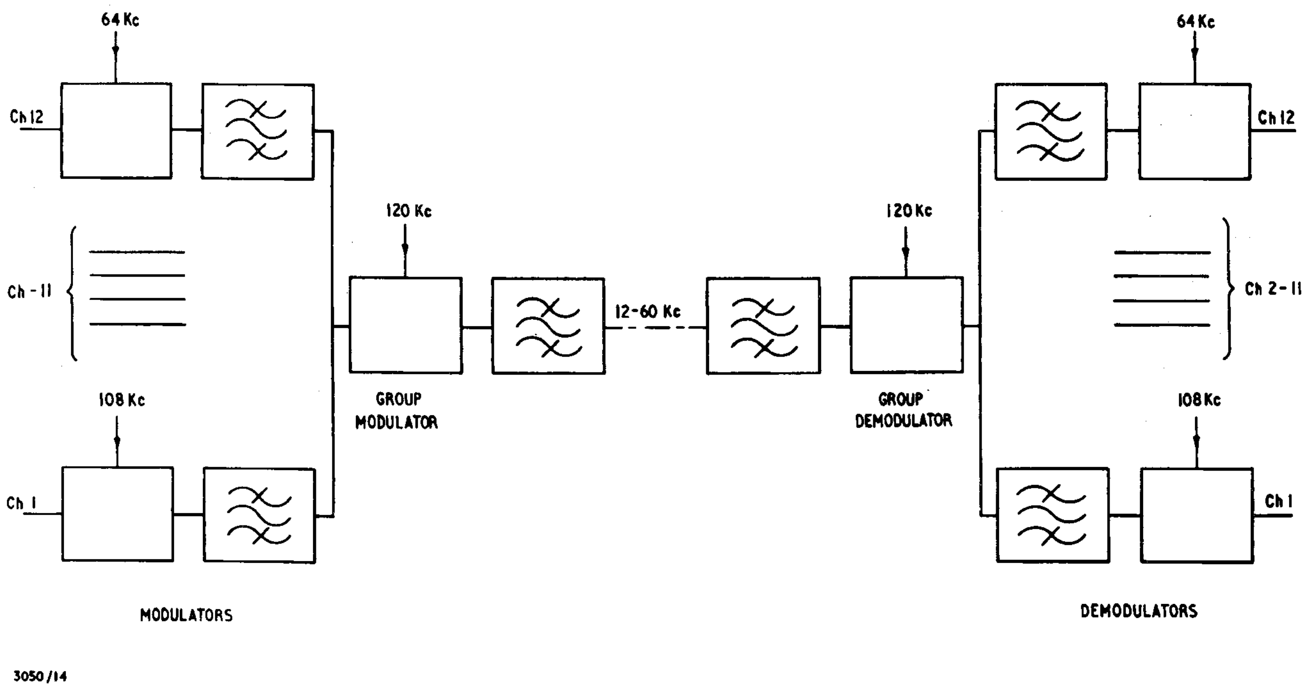



Fig 12 - Simplified 12-circuit MCVF system

30. Intermodulation effects can cause amplitude changes in a.m. signals and spurious signals can be generated by the mixing effect of any non-linear impedances in the equipment. These are minimised in design by arranging that spurious frequencies lie outside channel and filter ranges.

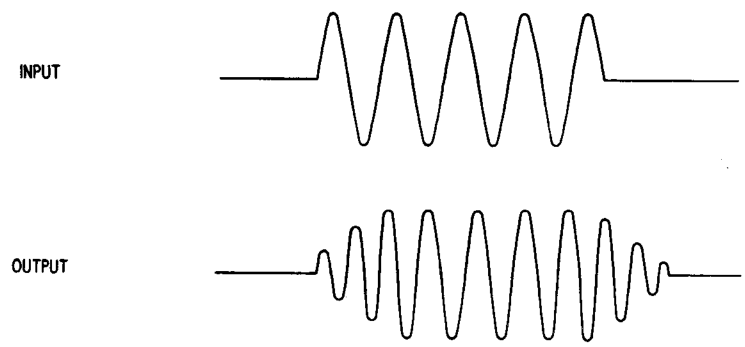



Fig 13 - Distortion introduced by a filter

EME/8/3050/Tels

END